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Assessment and Conceptualization of Groundwater Flow in the Edwards Aquifer Through the Knippa Gap in Uvalde County, Texas

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Assessment and Conceptualization of Groundwater Flow in the Edwards Aquifer Through the Knippa Gap in Uvalde County, Texas

Assessment and Conceptualization of Groundwater Flow in the Edwards Aquifer Through the Knippa Gap in Uvalde County, Texas

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Geology

By

Jennifer Adkins
University of Arkansas
Bachelor of Science in Geology, 2011

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University of Arkansas

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ABSTRACT

The Edwards aquifer is one of the major regional karst aquifers in the United States, with an average withdrawal of 950 million liters per day (L/d). This investigation focuses on the connection between the Uvalde pool and the San Antonio pool of the Edwards aquifer, known as the Knippa Gap, west of the San Antonio metropolitan area in Uvalde County. This is a major zone of recharge to the Edwards aquifer and is approximately 6.4 km wide. The Knippa Gap is bounded by northeast trending faults of the Balcones Fault Zone (BFZ) on the north (specifically the Cooks and Trio Faults), and uplift from the Uvalde salient and igneous intrusive plugs to the south. Aspects of the hydrogeology in the Knippa Gap have been a topic of major interest among researchers in this area for numerous years, however, the exact location and nature of boundaries are undefined, and the discharge through this area is not accurately known. The input data from this investigation will allow for assessments of discharge, better water budget approximations for the San Antonio pool, and determination of accurate flow boundaries and budgets for Uvalde County. This investigation was limited to the transmissive (karstified) portion of the Edwards aquifer within the study area, and is based on previous studies, and newly collected data. The newly collected data include: 1) compilation of a complete table of wells within the study area; 2) redefined placement of flow boundaries (faults) most of which appear to be structurally controlled; 3) hydrostratigraphic analysis of the Knippa Gap area based on drilling and wireline logs; 4) characterization of the depth of karstification within the Knippa Gap; and 5) analyses of water quality within and contiguous to the study area. These data constrain a revised conceptual model of the flow and karstification in this critical area of recharge to the Edwards aquifer, and provide specific lateral boundaries and vertical karstification zones which can be tested quantitatively. Although current interpretations are tentative, it appears this conceptual model

will be readily convertible into a digital model that can test hypotheses relating to water levels and spring discharges.

ACKNOWLEDGEMENTS

This study would not have been possible without the aid and consideration of several individuals whose assistance in the preparation and completion of this study were invaluable.

I would like to extend a special thanks to my advisor Dr. John Van Brahana. His mentorship, dedication, commitment, and tireless belief in me have made this project possible. I am honored to work with a man that is such a prominent figure in the field of Karst hydrogeology. His compassion and enthusiasm make him a joy to work with and an invaluable friend and mentor.

Geary Schindel, Chief Technical Officer for the Edwards Aquifer Authority, for providing me with one of the internships that allowed me to complete this research, and providing invaluable hydrogeologic insight into the Edwards Aquifer. I also want to extend my gratitude toward him for making resources and personnel available to assist in this endeavor. In addition I would like to extend my thanks to Mrs. Sue Schindel, thank you for making me feel at home. Your kindness and generosity astound me.

Thanks to Dr. Ron Green and Paul Bertetti of the Southwest Research Institute for providing me with an internship, guidance, and encouragement throughout the summer. This research is based off work previously conducted by Dr. Ron Green in 2006, and would not have been possible without his knowledge and expertise.

I would like to thank Mr. Vic Hilderbran, general manager for the Uvalde County Underground Water Conservation District, for all the help he gave me throughout this project. The depth and breadth of his knowledge about the groundwater in Uvalde County was unparalleled, and he shared his knowledge with me freely. I am truly grateful to him for his assistance and effort.

I would like to send a special thank you to all of the well owners in Uvalde County who allowed me access to their property and facilitated the sampling and measuring of hydrogeologic parameters within their wells. I know their water is precious to them, as it is to all of us, and I thank them for trusting me and facilitating my study.

Thank you to the staff of the Edwards Aquifer Authority, especially Rob Esquilin for his tireless efforts to improve my computer skills and his determination to train me in the art of the steel tape. Thank you to Mark Hamilton, Markus Gary, Anastacio Moncada, Gizel Luevano, and Steve Johnson who were incredibly generous in sharing their knowledge and data about the Edwards aquifer.

Thank you to Allan Clark at the USGS for taking the time to meet with me as well as providing essential data and research that made this study possible.

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Thank you to Zachary Schudrowitz for his inexhaustible patience, encouragement, support, and his invaluable formatting skills. In his words "She blinded me with Science!"

DEDICATION

This work is dedicated to my parents, Mark and Tammy Adkins. I cannot express how deeply grateful I have been for their unconditional support and dedication, both financially and emotionally. This thesis and the completion of my degrees would not have been possible without them. Their support has been the rock upon which all of my work was founded. To my parents, thank you.

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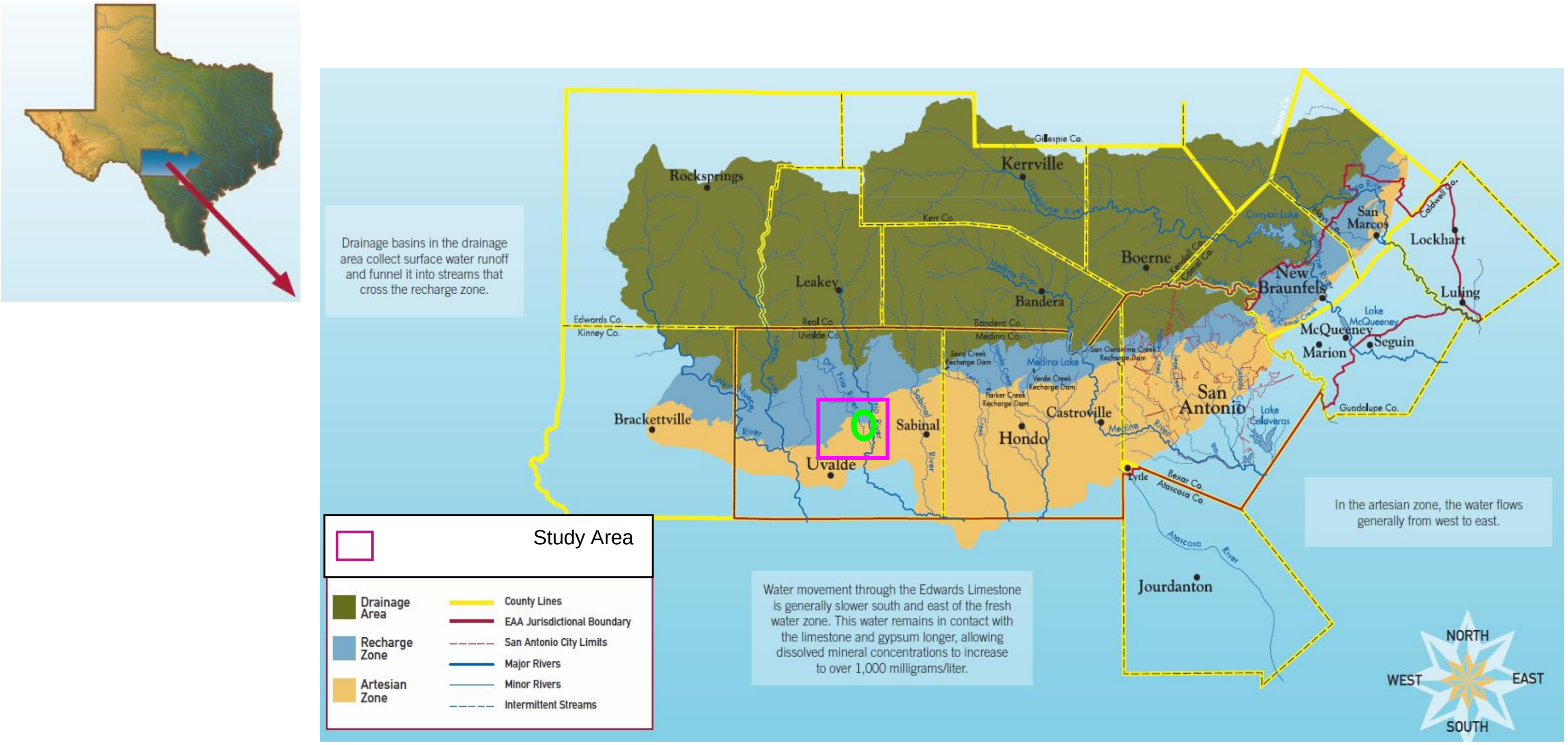
INTRODUCTION

The Edwards aquifer, located in south-central Texas (Figure 1), is one of the most prolific and important karst aquifers in the world. For the city of San Antonio alone, the aquifer provides an average of more than 950 million liters of water to more than 2 million people a day. In addition, its ecological role is significant; it is home to more than 40 aquatic subterranean species, several of which are endangered, and one that is threatened (http://www.edwardsaquifer.org/). The Edwards aquifer is exceedingly prolific; west and north of San Antonio the Edwards provides most of the agricultural, industrial, recreational, and domestic water needs, making it the largest sole groundwater supply in the United States (Welden and Reeves, 1962; Maclay, 1995; Hamilton et al., 2012).

The Edwards aquifer is interconnected with the Balcones Fault Zone (BFZ) a series of normal en echelon strike faults (Maclay, 1995). This zone separates the Edwards Plateau from the Gulf Coastal Plain in south central Texas. The aquifer is composed of extensively faulted and fractured Early Cretaceous age limestones and dolomite. The thickness of the aquifer is often affected by vertical displacement along fault segments in the BFZ, which often act as barriers to down gradient groundwater flow (Maclay, 1995). There are several prominent structural features present throughout the study area (Uvalde County, Figure 1). One such feature, the Uvalde salient, a north trending ridge that is wider in the north and narrows and plunges to the south, results from crustal uplift and faulting (Green et al., 2006). Activity associated with the Uvalde Salient and intrusive igneous plugs throughout the study area elevates the Edwards aquifer to the surface across the central region of the county. The structural feature being assessed within this study, for boundary determination and hydrogeologic properties is the hydrogeologic constriction referred to as the Knippa Gap (Figure 2).

Edwards Aquifer Authority, (2005) Green et al., (2006) and Hamilton et al., (2011) estimated that approximately 46% of total average recharge to the San Antonio pool segment that flows through or is captured by stream-flow, can be attributed to recharge occurring in Uvalde County. Further understanding of water resources in Uvalde County will aid development of a refined conceptual model for groundwater flow, thereby producing more precise estimates for water budgets, model calibrations, and overall resource management.



Drainage basins in the drainage area collect surface water runoff and funnel it into streams that cross the recharge zone.

Water movement through the Edwards Limestone is generally slower south and east of the fresh water zone. This water remains in contact with the limestone and gypsum longer, allowing dissolved mineral concentrations to increase to over 1,000 milligrams/liter.

In the artesian zone, the water flows generally from west to east.

Figure 1. *Location of the major hydrogeologic zones of the Edwards aquifer in south-central Texas, by county. Expanded study area in Uvalde County, outlined in pink and the focused study area of the Knippa Gap outlined in Green. [Modified from Edwards Aquifer Authority webpage].*

Problem Statement

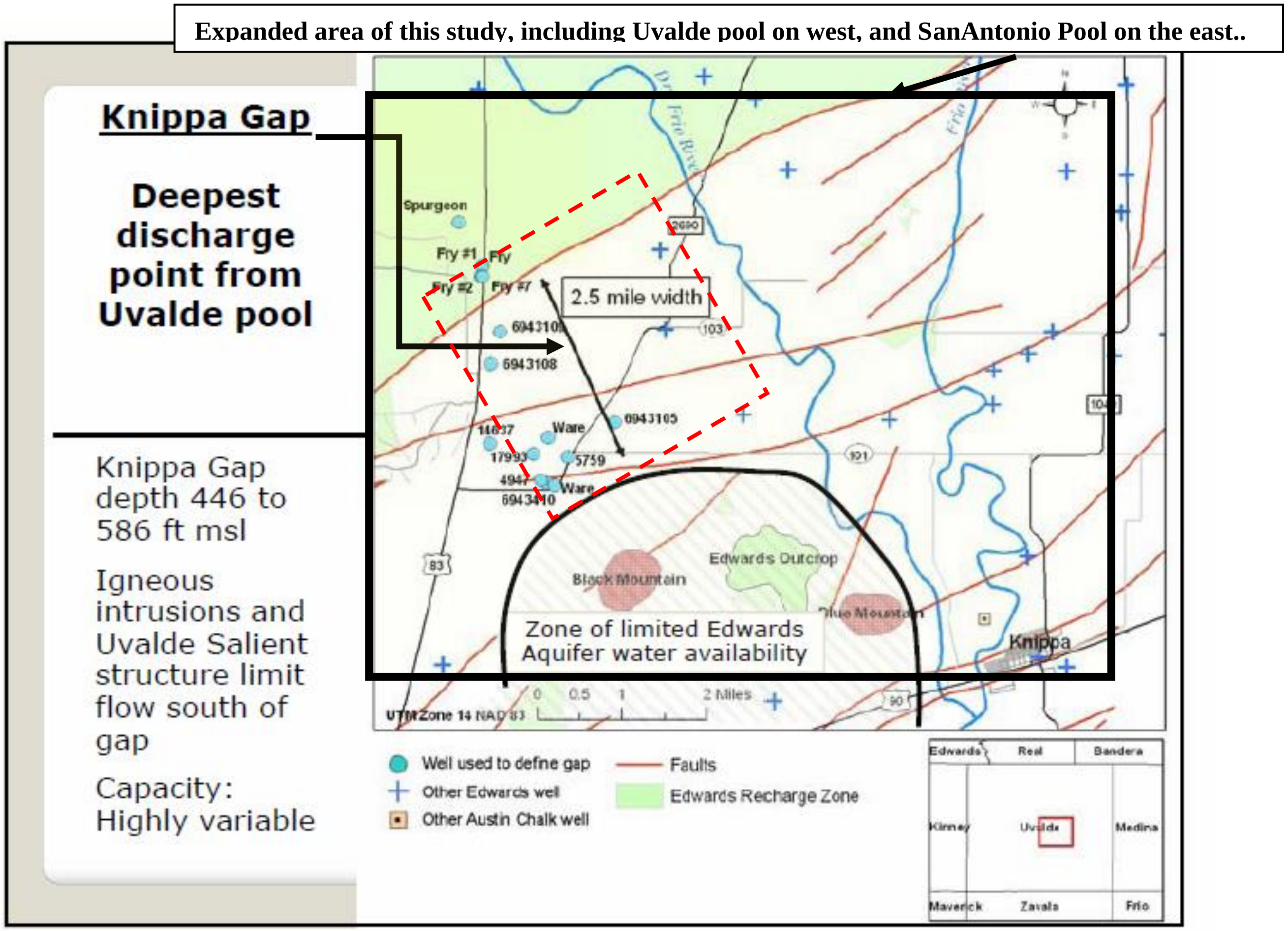
The hydrogeology of the Knippa Gap is central to understanding the hydrologic budget of the overall Edwards aquifer, specifically the inflow to the pools (regions surrounded by low-permeability zones that restrict dynamic flow out of the region). The hydrologic budget is critical to hydrogeologic model calibration, which is essential for optimum aquifer management and maintenance of sustainable use. This budget term is currently poorly constrained, and the hydrogeology of the Knippa Gap is only generally known.

The Knippa Gap in the Edwards aquifer (Figures 2 and 5) represents one of two major overflow zones. Water discharges from the Uvalde Pool in the west into the San Antonio Pool in the east. A pool within an aquifer is a region surrounded by low-permeability zones that form a bowl that restricts dynamic flow out of the region. Input exceeds output until water level in the pool (bowl) overflows the low points. In the study area, most water escapes through the Knippa Gap, and from springs along the Leona River in the city of Uvalde (Green et al., 2006). The southeastern margin of the Knippa Gap is caused by structural uplift from underlying igneous intrusions and the formation of the Uvalde Salient, resulting in little or no-flow and minimal well yields. This part of the aquifer essentially creates "a zone of no flow along the southeastern edge of the Uvalde Pool" (Green, 2006).

Green et al., (2006), Maclay and Land (1988) provide a refinement of the original structural geology, determining "the underlying structural premise to the Knippa Gap is . . . faulting associated with the Balcones Fault Zone and uplift along the Uvalde Salient have developed a constriction in flow through the Edwards aquifer near the City of Knippa" (Figure 5) (Green et al, 2006). The amount of groundwater flow that discharges through the Knippa Gap is not well constrained, in part because a significant portion of outflow from the Uvalde pool discharges to the south through subcrops to the Leona gravels. More refined flow estimates, along with a better understanding of how the Knippa Gap functions, would greatly refine the water budget for the San Antonio Pool and more accurately determine flow boundaries and budgets for the regional Edwards aquifer.

Purpose and Scope

The overarching purpose of this study is to refine hydrogeologic understanding of flow in the Edwards aquifer in the vicinity of the Knippa Gap between the Uvalde Pool and the San Antonio Pool through the assessment of structural geology, hydrology, geochemistry, and stratigraphy. This study incorporates the integrated results of previous studies with recently conducted field sampling and measurements. Secondary purposes of the study include 1) compilation of a complete table of wells within the study area (Appendix A); 2) redefined placement of flow boundaries (faults), most of which appear to be structurally controlled, based on (Maclay, 1988; Clark, 2003; Green et al., 2006); 3) hydrostratigraphic analysis of the Knippa Gap area based on water levels, wireline logs interpretation, cross-sectional interpretations, and water quality records; 4) characterization of the depth of karstification within the Knippa Gap based on well yields and wireline logs; 5) generation of water-quality analyses within and contiguous to the study area; and 6) construction of a conceptual model of the hydrogeology of the area, based hydrostratigraphy and geochemical analyses. The project is limited to the transmissive (karstified) portion of the Edwards aquifer within the study area, and the scope is essentially limited to the subsurface and to reaches of streams that flow across the surface. Although, it is important to note that significant quantities of surface recharge and discharge are present within the study area. Supplemental studies outside hydrologic boundaries are included to test the veracity of the conceptual model. This study focuses primarily on groundwater resources relating to the Knippa Gap, however the study area has been expanded to include hydrologic boundaries and areas that contributed to the overall understanding and interpretation of the hydrogeology and structural geology within the study area (Green et al., 2006; Clark, 2003).



Expanded area of this study, including Uvalde pool on west, and SanAntonio Pool on the east..

Knippa Gap

Deepest discharge point from Uvalde pool

Knippa Gap depth 446 to 586 ft msl

Igneous intrusions and Uvalde Salient structure limit flow south of gap

Capacity: Highly variable

Figure 2. *Location of key components and structural interpretation of the Knippa Gap, the major study area, the expanded study area, and other relevant hydrogeologic features in Uvalde County. [Modified from Green, 2010].*

Study Area

The primary study area for this research is depicted by the red-dashed rectangle in (Figure 2). An expanded but secondary area of interest surrounds the primary study area, encompassing contiguous portions of the integrated Edwards aquifer flow system. The primary study area (Figure 3) is approximately 13.25 kilometers [Km] north to south and 14.38 Km east to west whereas the expanded study area is approximately 58.4 Km north to south and 67.8 Km east to west [measurements extracted from location points in Google Earth software]. Uvalde County is described as having a semi-arid climate, and like most of the Edwards aquifer region suffers highly variable precipitation levels. In the Edwards aquifer region, precipitation ranges from 55.88 cm in the west, to approximately 86.36 cm in the east. The average precipitation for Uvalde County is 58.06 cm. Table 5 (modified from the Edwards Aquifer Authority Hydrologic Data Report 2011) synthesizes the annual precipitation from 1934-2011 for Uvalde County and the remaining Edwards Aquifer region (Edwards Aquifer Authority, 2011). There are several drainage basins present throughout the region. Uvalde County lies within the Nueces River-West Nueces River drainage basin (western portion), the Frio River-Dry Frio River basin (central), the Sabinal River drainage basin (eastern portion), and a small un-named basin somewhere between the Sabinal River and Medina River basins (northeast) (Green et al., 2006). The Edwards Group (Figure 8) in Uvalde County is predominantly composed of Lower Cretaceous carbonate (dolomitic limestone) of the Devils River Formation within the Devils River trend in the northeast, transitioning into the West Nueces, McKnight, and Salmon Peak Formations in the Maverick Basin in the southwest (Figure 3,4, and 5). These carbonate rocks were formed in evolving environments that ranged across a variety of tectonic and depositional conditions.

The Edwards Aquifer in Uvalde County is known to support high-volume irrigation wells, and is thus interpreted to have the capacity to transmit significant volumes of water (Green et al., 2006). The focus of this study, the Knippa Gap is a high-volume capacity channel of the Edwards aquifer in central Uvalde County. Preliminary interpretations of the Knippa Gap, indicate that it is a structural feature that acts as a barrier, separating the Uvalde pool from the San Antonio pool under Medina, Bexar, and Comal Counties. Previous investigations determined that the Knippa Gap was restricted to an east-trending narrow band or channel in the middle of Uvalde County approximately (i.e., 4–5-mi wide). The Methods and Approach section of this report in combination with the results and discussion sections explain determinations for the increased boundaries of the Knippa Gap estimating it to be approximately 6.41km wide. The northern and southern limits of the Edwards aquifer far exceed the limited width of the channel. The contributing and recharge zones of the Edwards aquifer (where the saturated thickness is insufficient to transmit large volumes of groundwater) extend north of the channel. According to Green et al., 2006 the southern boundary of the Knippa Gap or the high-capacity flow channel of the Edwards aquifer is bound by either the saline-water (bad water) portion of the Edwards aquifer, or igneous intrusions (where permeability is reduced), geologic structure, localized zones of reduced permeability, or some combination of these factors (Green et al., 2006)

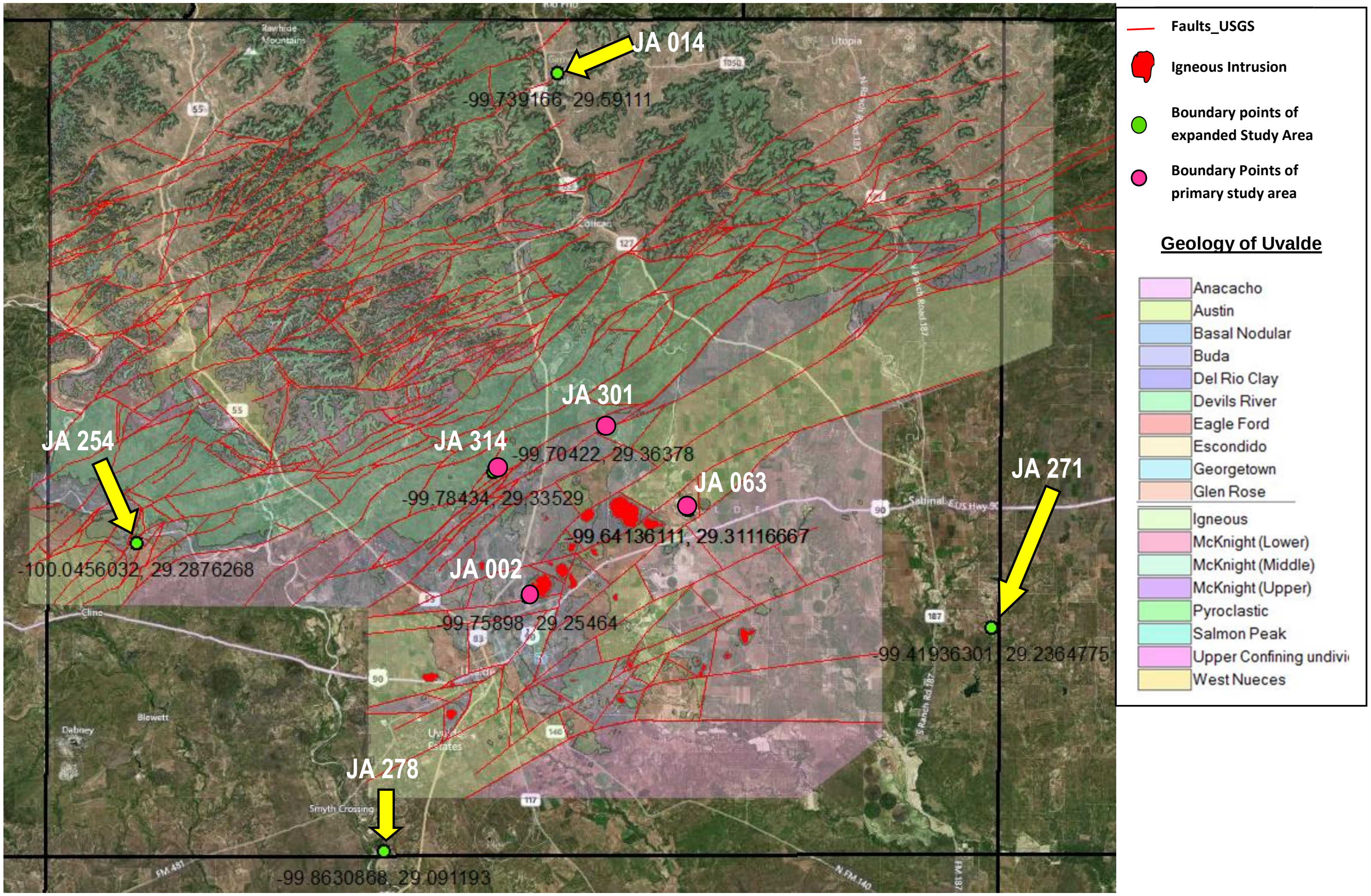


Figure 3. *GIS image displaying the study area with point boundaries of expanded and Primary study areas, JA identification referenced to Appendix A.*

The Knippa Gap is located directly north of the city of Knippa, and forms the southern boundary of the Uvalde Salient, and has been described as being a narrow opening in an extensive system of barrier faults (Green et al., 2006; Maclay and Land, 1988). The BFZ is thought to delineate the northwestern boundary of the Knippa Gap as a series of faults that have been plugged by low-permeability, fine-grained sediments, and therefore act as no-flow boundaries (Mclay and Land, 1988), while igneous intrusions in conjunction with the Uvalde salient (structural uplift) define the southern boundaries for the Knippa Gap. Although 2.4×10^{11} liters (200,000 acre-feet) are estimated to flow through the Knippa Gap annually, the constriction still contributes to water level build up in the Uvalde pool. Green et al. (2006; 2009a; 2009b) conclude that the Uvalde salient has several prominent structural high points that constrict the groundwater flow through "topographic saddles," low troughs between higher elevation points that are bounded by lower permeability boundaries that form the rim of the Uvalde pool. The Frio and Dry Frio Rivers contribute large amounts of recharge to the groundwater flow regime within the study area. The incoming captured surface stream-flow associated with these recharge features in combination with the constricted flow path of the Knippa Gap, cause a damming effect of the groundwater up-gradient and west of the Knippa Gap (Green et al., 2006).

Previous Investigations

Several studies have been undertaken to aid in the understanding and management of the Edwards aquifer, all of which provide a foundation for the investigations of this study. These studies can be assessed and grouped based on interpretations relating to hydrogeology, structural geology, geochemistry, stratigraphy, and other pertinent areas of interest relating to this investigation. Several of these studies are described below, and the majority have been synthesized in (Table 1) with short descriptions of their work. Table 1 and the discussions of previous work below, were completed based on interpretations by Green et al., (2006) “Evaluation of the Edwards Aquifer in Kinney and Uvalde Counties, Texas”; which provides an excellent summary of the previous research conducted in and or relating to the study area. Dr. Green’s extensive research expands on the knowledge of these previous studies relating to the study area as well as future studies. The majority of the investigations pertaining to the study area were initiated in the 1950’s by the U. S. Geological Survey; few were conducted and or recorded prior to this.

In the 1950's, the U.S. Geological Survey collected samples for Uvalde County that were later used in studies by Sayre (1962), Welder and Reeves (1962), and Holt (1956). These studies provided brief descriptions of water quality pertaining to potential irrigation and human consumption. Welder and Reeves (1962) constructed a groundwater elevation map for Uvalde County for December 1957. Maclay and Small (1984) addressed the initial storage and flow concepts in the Edwards aquifer and the influences controlling these systems, as they relate to the study area. These discussions produced a map of the regional groundwater flow pattern relating to the study area, which was later reproduced in reports by (Maclay and Land 1988). Maclay and Land (1988) presented a groundwater contour map for the winter of 1973 that is "commonly cited as representative elevations for "normal precipitation" periods in the San Antonio segment of the Edwards aquifer" (Green et al., 2006).

Discussions by Ferril et. al (2004) constructed a three-dimensional digital geologic framework model using part of the recharge and confined zone of the Edwards aquifer. The model represents the segmented faulting of the Edwards aquifer and confining strata, and expands on potential structural controls relating to recharge, groundwater flow, and transmissivity within the aquifer. Hovorka (2004) utilized existing data from water-levels, structural information, cave maps, water-chemistry, and well hydrographs to better characterize the conduit system within the subsurface of the Edwards aquifer.

Green (2006) evaluates the groundwater systems in Uvalde County and defines the hydraulic and hydrogeologic relationship between the Uvalde pool and the San Antonio pool of the Edwards Aquifer. (Green, 2009) discusses the minor groundwater resources, or secondary aquifers, that are present within the study area, and their effect on the regional groundwater flow. Green (2010) presents a definition of the Uvalde pool, and he estimates approximately 55% of pumping from the Edwards Aquifer in Uvalde County is from the Uvalde Pool. These and other studies serve as the foundation of this research.

Rose (1972) provides the structural framework for the geology of the Edwards Aquifer, and suggests that the igneous intrusions present in the study area may affect groundwater flow. Interpretations relating to the igneous intrusions were reassessed in Green et al., (2006). Later studies by Clark (2003), Clark and Small (1997), Small (1986), and Hovorka (2004) improved upon the understanding of the geologic structure and lithology within the study area. Rose (1972) also provides a regional compilation of the stratigraphy, and the depositional environment of strata within the study area. This combined with later studies conducted by Hovorka et al. (1993, 1996) determine the effects of depositional environment on the hydraulic properties of the Edwards Aquifer. Mosher et al., (2006) describes the major regional tectonic activity that occurred within the study area, detailing how the events bowed the overlying sediments, uplifting the formations to far shallower depths, and resulting in the structural features that are currently present in the study area such as the Uvalde salient of the Devils River Trend structural uplift.

Table 1 *Selected studies previously completed that are directly relevant to this research. [TWC (Texas Water Commission); USGS (U.S. Geological Survey; Journal of Hydrology; TWDB (Texas Water Development Board);San Antonio City Water Board; Texas Board of Water Engineers; BEG (Bureau of Economic Geology); Edwards Underground Water District or Edwards Aquifer Authority (EAA), Geology; Rotterdam, Netherlands, A.A. Balkema; Journal, Groundwater; Society of Petroleum Engineers Annual Conference; Proceedings of Aquifers of the Edwards Plateau Conference; SWRI (Southwest Research Institute); GSA (Geological Society of America); United States Department of the Interior, Geological Survey]*

Author/Date	Major Topics Covered	Publication Outlet
Anaya and Jones, (2004)	Groundwater availability model of the Edwards-Trinity (Plateau) and the Cenozoic alluvium aquifer systems, Texas.	TWDB
Bush et al., (1992)	Historical piezometric surface of the Edwards-Trinity aquifer system and contiguous hydraulically connected units, west-central Texas	USGS
Clark and Journey, (2005)	Hydrological and geochemical identification of flow paths in the Edwards aquifer, northeastern Uvalde and northern Medina County	USGS
Clark and Small, (1997)	Geologic framework and hydrogeologic characteristics of the Edwards Aquifer, Uvalde County, Texas	USGS
Clark, (2003)	Geologic framework and hydrogeologic characteristics of the Edwards Aquifer, Uvalde County, Texas	USGS
Clement and Sharp, (1988)	Hydrochemical facies of the bad-water zone of the Edwards aquifer, Central Texas	National Water Well Association
Edwards Aquifer Authority, (2006)	Synoptic Water Level Program - 1999-2004: Final Report May 2006	EAA
Esquilin et al., (2012)	Edwards Aquifer Authority Synoptic Water Level Program 2005″2009 Water Level Data	EAA
Garza (1962,1996)	Groundwater resources of the Edwards and associated Limestones	Texas Water Engineers
Green et al., (2006)	Evaluation of the Edwards Aquifer in Kinney and Uvalde Counties, Texas	SWRI
Green et al., (2012)	Measure Floodplain Hydraulics of Seco Creek and Medina River where They Overlie the Edwards Aquifer	SWRI
Green et al., (2009)	Analysis of the Water Resources of or Near Uvalde and Zavala Counties	SWRI

Green et al., (2009)	Investigating the Secondary Aquifers of the Uvalde County	SWRI
Green et al., (2009)	Measuring Floodplain Hydraulics of the Frio River where it Overlies the Edwards Aquifer	SWRI
Groschen, (1996)	Hydrogeologic factors that affect the flow path of water in selected zones of the Edwards Aquifer in the San Antonio region, Texas	USGS
Hamilton et al. (2010)	Edwards Aquifer Authority Hydrologic Data Report for 2010	EAA
Hamilton et al. (2012)	Edwards Aquifer Authority Hydrologic Data Report for 2011	EAA
Holt, 1956, 1959	6212 Bulletin: Geology and Ground-Water Resources in Medina County, Texas	TWC-USGS
Hovorka et al. (1993)	Structural Geology and depositional environment in relation to hydraulic properties of the Edwards Aquifer	Edwards Underground Water District; Bureau of Economic Geology
Hovorka et al. (1995)	Regional distribution of permeability in the Edwards Aquifer	Edwards Underground Water District (EAA)
Hovorka et al. (1996)	Geologic controls on porosity development in platform carbonates, South Texas	Bureau of Economic Geology
Hovorka et al. (1997)	Interplay of karst, fractures, and permeability in the Cretaceous Edwards aquifer: analogs for fractured carbonate reservoirs	Society of Petroleum Engineers Annual Conference
Hovorka et al. (1998)	Permeability structure of the Edwards Aquifer	Bureau of Economic Geology
Hovorka et al. (2004)	Analysis of conduit development in the Edwards Aquifer	Bureau of Economic Geology: contracted to the EAA
Klemt et al., 1979	Ground-water resources and model applications for the Edwards (BFZ) Aquifer in the San Antonio Regions	Texas Department of Water Resources
Kuniansky et al.(1994)	Simulations of flow in the Edwards-Trinity Aquifer system and contiguous hydraulically connected units, west-central Texas	USGS
Lindgren et al., 2004	Conceptualization and simulation of the Edwards Aquifer, San Antonio Region, Texas	USGS

Livingston et. al, 1936	Water Resources of the Edwards Limestone in the San Antonio Area, Texas	United States Department of the Interior, Geological Survey
Livingston, 1947	Relationship of ground water to the discharge of the Leona River in Uvalde and Zavala Counties, Texas	Texas Board of Water Engineers
Lowry, 1955	Recharge to the Edwards Aquifer	San Antonio City Water Board
Mace and Anya, 2004	Estimate of recharge to the Edwards (Blacones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County, Texas	Proceedings of Aquifers of the Edwards Plateau Conference
Mace and Hovorka, 2000	Estimating porosity and permeability in a karst aquifer	Rotterdam, Netherlands: A.A. Balkema
Mace, 2000	Transmissivity from specific capacity tests in a Karst aquifer	Journal: Groundwater
Maclay and Land, 1988	Assesment of flow and refinement of flow concepts in the Edwards Aquifer; Provides Groundwater elevation maps for Winter 1973	USGS
Maclay and Small, 1983	Hydrostratigraphic subdivisions and fault barriers of the Edwards Aquifer, south-central Texas	Journal of Hydrology
Maclay and Small, 1986	Carbonate geology and hydrology of the Edwards Aquifer in the San Antonio area	TWDB
Mclay et al. 1980	Hydrochemical data for the Edwards Aquifer	Texas Department of Water Resources
Mclay, 1995	Geology and hydrogeology of the Edwards Aquifer in the San Antonio area, Texas	USGS
Mosher, (2007)	Mesoproterozoic plate tectonics: A collisional model for the Grenville-aged orogenic belt in the Llano uplift, central Texas	Geological Society of America
Painter et al. (2002)	Geostatistical assessment of the transmissivity of the San Antonio segment of the Edwards Aquifer	South West Research Institute
Pearson and Rettman, 1976	Geochemical and isotopic analyses of waters associated with the Edwards Limestone aquifer	Edwards Underground Water District (EAA)
Petite and George, 1956	Recharge to the Edwards Aquifer	Texas Board of Water Engineers
Puente (1975, 1976, 1978)	Groundwater Recharge in the Edwards Aquifer	USGS

Raye et al., (2011)	Composition of the mantle lithosphere beneath south-central Laurentia, Evidence from peridotite xenoliths, Knippa, Texas	Geological Society of America
Rose,1972	Structural Geology, Stratigraphy and depositional environment in relation to hydraulic properties of the Edwards Aquifer	Bureau of Economic Geology
Sayre, 1936; Sayre and Bennet,1942 ;Bennet and Sayre, 1962	6212 Bulletin: Geology and Ground-Water Resources in Kinny County, Texas; 1962 Provide maps of Groundwater elevation Contours (1930-1940, January 1952, and August 1956)	TWC-USGS
Schindel et al., (2002)	Groundwater chemistry changes during a recharge event in the karstic Edwards Aquifer, San Antonio, TX	Geological Society of America
Small, 1986	Hydrogeologic sections of the Edwards aquifer and its confining units in the San Antonio area, Texas	USGS
Smith et al., 2002	Aeromagnetic survey of Medina and Uvalde counties, Texas	USGS
TWDB, 2005	Well Information/Groundwater Data	TWDB
Welder and Reeves, 1962	6212 Bulletin: Geology and Ground-Water Resources in Uvalde County, Texas; Provides Groundwater Contour map for December, 1957	TWC-USGS
Worthington (2004)	Analysis of conduit development in the Edwards Aquifer	EAA

SETTING

Tectonics and Regional Structural Characteristics

Uvalde County is described as having a semi-arid climate, and like most of the region underlain by the Edwards aquifer experiences highly variable precipitation levels. In the Edwards aquifer region, precipitation ranges from 56 cm in the west, to approximately 86 cm in the east. The average annual precipitation for Uvalde County is 58 cm. [Table 5 (modified from the Edwards Aquifer Authority Hydrologic Data Report, 2011)] which synthesizes the annual precipitation from 1934-2011 for Uvalde County and the remaining Edwards aquifer region (Edwards Aquifer Authority, 2011). There are several drainage basins present throughout the region; Uvalde County lies within the Nueces River-West Nueces River drainage basin (western portion), the Frio River-Dry Frio River basin (central), the Sabinal River drainage basin (eastern portion). A small unnamed basin also sits between the Sabinal River and Medina River basins northeast of the study area (Green et al., 2006). The Edwards Group Formation (Figure 8) in Uvalde County is predominantly composed of Lower Cretaceous carbonate (dolomitic limestone) of the Devils River Formation within the Devils River trend in the northeast, transitioning into the West Nueces, McKnight, and Salmon Peak Formations in the Maverick Basin in the southwest (Figures 5, 7, and 8). These carbonate rocks were formed in evolving environments that ranged across a variety of tectonic and depositional conditions. As indicated by Clark, (2003), the lower Cretaceous rocks in this region were deposited onto a continental shelf-margin platform. The platform was sheltered from storm waves and deep ocean currents associated with the ancestral Gulf of Mexico by the Stuart City reef. The transgression and regression periods occurring across the tectonic hinge line (located near the southern margin of this carbonate shelf) kept parts of Kinney, Uvalde, and Medina counties submerged in a semicircular depression previously referred to as the Maverick Basin (Figure 5).

Increased subsidence rates south of the tectonic hinge line led to different facies of rocks deposited along the hinge line and those deposited elsewhere on the Comanche Shelf. Superseding zones of reef growth, known as the Devils River Trend (Figures 5) isolated the depositional environments inside the basin, and bound the basin on three sides; north, east, and west, composing the Devils River Formation seen today. The Devils River Formation (Figure 8) was deposited in an open, shallow-marine environment of high current energy, whereas the West Nueces, McKnight, and Salmon Peak Formations were restricted to open marine, deep-basinal environments (Rose, 1973; Clark, 2003). Regionally, several noteworthy structural features have been studied throughout Uvalde County, such as the Uvalde salient, a north trending ridge that is wider in the north and narrows, plunging to the south, ensuing from crustal uplift, faulting, and igneous activity that elevates the Edwards aquifer to the surface across the central region of county. The BFZ a tensional area of faulting aligned southwest to northeast across the study area is also a structurally significant feature impacting the study area (Green et al., 2006). The BFZ has an escarpment rising from an altitude of 182m to 274m along the sloping lowlands of the Gulf Coastal Plain to approximately 426m to 701m in the uplands of the Edwards Plateau (Maclay and Land, 1988). As a result of the structural features and there impacts, particularly the extensive faulting associated with the BFZ, within the Edwards aquifer the structure of the aquifer itself is exceedingly complex.

Most researchers attribute the BFZ to the long and varied sequence of continent-arc-continent collision, subduction, uplift, and extension associated with the history of the southern margin of Laurentia, (the North American Craton) (Mosher et al., 2008; Mosher, 1998). Much of the BFZ in Uvalde, as well as Medina and Bexar counties is covered by widespread flat alluvial fans and terraces. The faulting in the BFZ is predominantly down to the southeast with primarily northeast-southwest trending *en echelon* normal faulting (Maclay, 1995; Clark, 2003; Barker and Ardis, 1996; Hovorka et al., 2004). The BFZ, specifically Cook's Fault, delineates the northwestern boundary of the Knippa Gap. The series of faults having been plugged by low-permeability, fine-grained sediments, act as "no-flow boundaries" (Maclay and Land, 1988). South and east of the Knippa Gap, major regional tectonic activity occurred, including but not limited to igneous intrusions, uplift and folding. This event bowed the overlying sediments, including the Edwards Group, uplifting the formations to much shallower depths (Mosher et al., 2006), and resulted in the formation of the structural feature known as the Uvalde salient associated with the Devils River Trend. The Uvalde Salient (Figure 5) dips toward the southwest, into the Maverick Basin.

The tectonic map for the state of Texas (Figure 4) provided by the Bureau of Economic Geology (BEG), summarizes the regional deformation history (plate tectonic processes) of Texas. The map documents the movement history throughout the state, indicating structural relationships among the crust, and showing crustal patterns that indicate the sequence of tectonic events (Laubach, 1997). Tectonics maps differ drastically from the more common Geologic maps, (Figure 7) that display the surface strata of the study area. Geologic maps are generally used to identify outcrop symmetry in distinct rock formations, whereas tectonic maps such as (Figure 4) have a more simplified color pattern and identify the more basic map elements (tectonostratigraphic units), "sequences of sedimentary rock strata or groups of metamorphic and igneous rocks that share a common history of deformation" (Laubach, 1997). This lumping or combing effect of formations is depicted in Figure 4, in the Paleozoic formations between

Midland, Dallas, and Amarillo; which in combination with a thin veneer of younger Cretaceous, Tertiary, and Quaternary deposits at the surface were combined or lumped together (Laubach, 1997). Figure 4 also shows several tectonic fronts, indicated by crosscutting relations which distinguish relative ages. These tectonic fronts mark the edges of major basins and former orogenic belts. The tectonic Map of Texas (Figure 4), clearly displays the three principal tectonic cycles within the region as described by Laubach, (1997): (1) Precambrian cycles recorded in the ancient rocks of the Llano region, and near Van Horn and El Paso. (2) The Paleozoic Ouachitan cycle; beginning with continental rifting around 550 mya, followed by the inundation of most of Texas by shallow seas, ending with the collision of the South and North American plates leading to the Ouachita mountain-building event, ending about 245 mya. The tectonic map (Figure 4) indicates that there are two primary features recorded in Texas during the Ouachita Orogeny; the foreland area of West Texas, seen in shades of blue, and the partially buried and eroded mountain belt to the southeast of the Ouachita tectonic front seen in shades of purple. (3) The Gulf Coast cycle (current tectonic cycle in Texas), beginning with continental rifting in the Late Triassic approximately 220 mya, led to the creation of oceanic crust in the Gulf of Mexico (Laubach, 1997). The tectonic map of Texas (Figure 4) also specifies rocks in green and brown (Gulf Coast Cretaceous and Tertiary strata), east of Dallas, Austin, and San Antonio, deposited during the creation of the Gulf of Mexico and Atlantic Ocean, and indicates byproducts of basin formation, such as normal faults and salt diapirs. In relation to the study area, between Del Rio and Dallas, the edge of the Gulf Coast Basin follows the older Ouachitan tectonic front, illustrating tendencies for localized deformation through time along preexisting fault zones (Laubach, 1997).

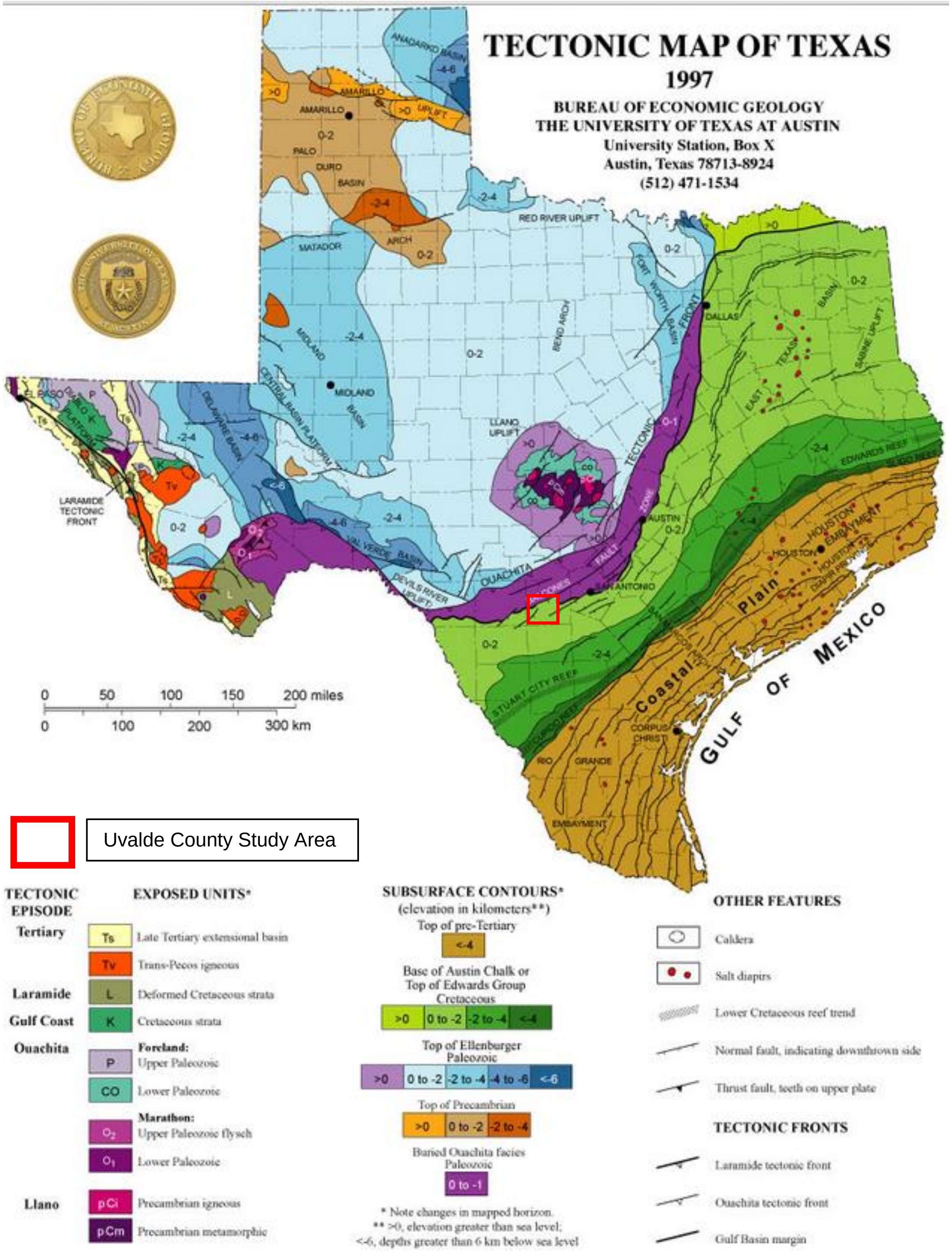


Figure 4. *Tectonic map of Texas with the approximate location of the Knippa Gap, study area indicated by the small black rectangle. (Adapted from the Bureau of Economic Geology, University of Texas). (http://www.lib.utexas.edu/geo/geologic_maps.html)*

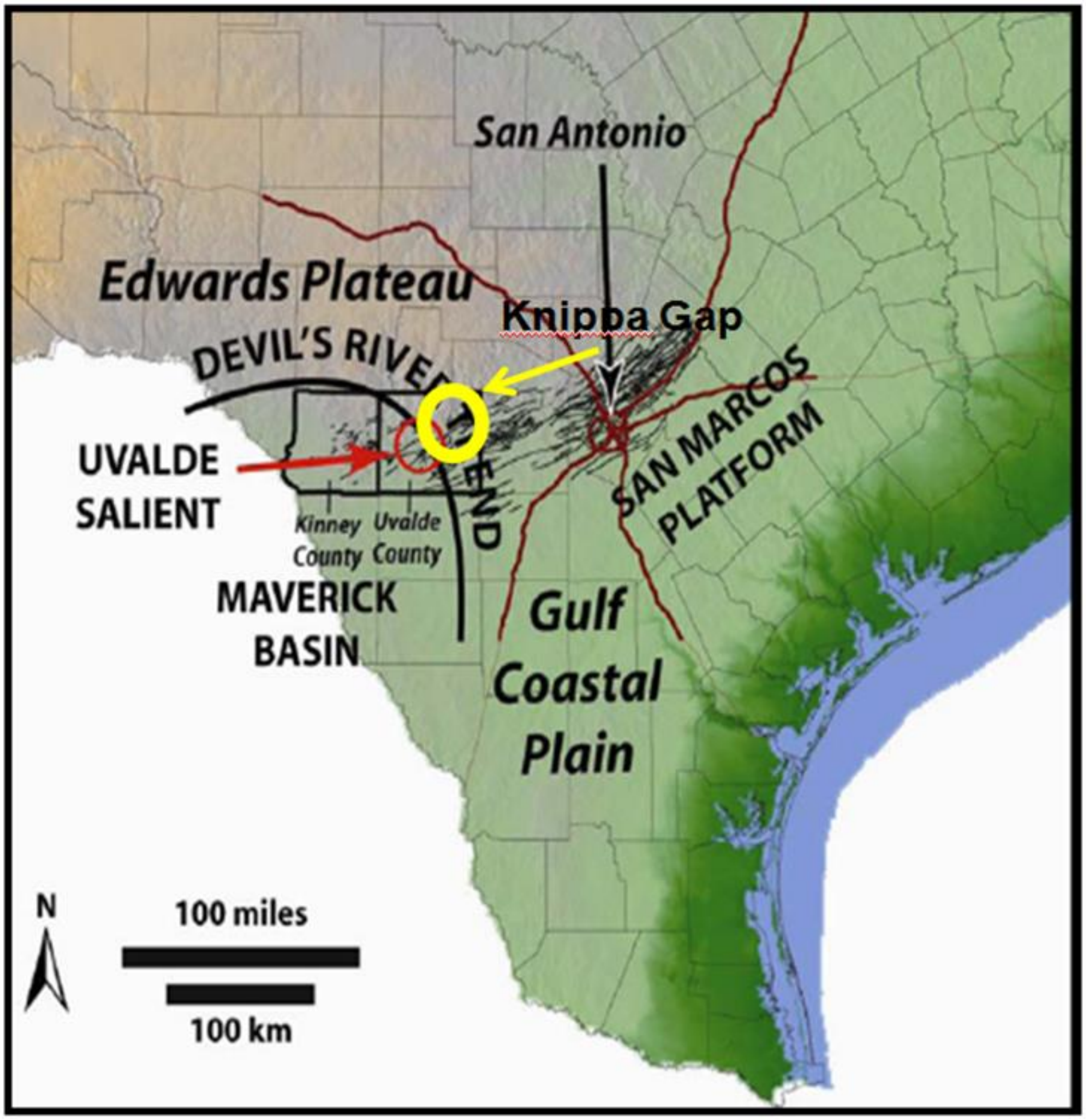


Figure 5. *Location of the Devils River Trend, Maverick Basin, Uvalde Salient, the San Marcos Platform and the Knippa Gap study area (Indicated by yellow circle and arrow) [Adapted from Green et a., 2006].*

Peridotite xenolith samples, collected by Raye and others in 2011, relative to the study area in the Knippa quarry, Knippa County, Texas, are among the few samples collected, that represent the southern margin of Laurentia. The xenoliths are hosted by Cretaceous (~83 Ma) basinites that erupted along the lithospheric discontinuity separating Mesoproterozoic lithosphere of the Texas craton and the Jurassic transitional lithosphere of the NW Gulf of Mexico passive margin. Basinites are extrusive igneous rocks with aphanitic to porphyritic texture having common augite and olivine pheocrysts in the matrix and little or no silica generally associated with continental rifting and ocean island magmatism (Buchwald, 2003). Raye and others (2011) were able to utilize petrographic, mineral, and major element data from 29 mantle xenoliths relative to the study area, specifically Knippa County Texas, to characterize and constrain the nature of the lithospheric mantle beneath south central Texas. These sample localities are in the Balcones Igneous province (BIP) (Figure 4). The BIP is described by the authors as "an association of Mesoproterozoic and transitional lithosphere of the Gulf Coastal plain, having been affected by the Mesoproterozoic accretion and subsequent Paleozoic tectonism representing the boundary between the Mesoproterozoic continental lithosphere and the transitional Gulf of Mexico Passive margin" (Raye et al., 2011).

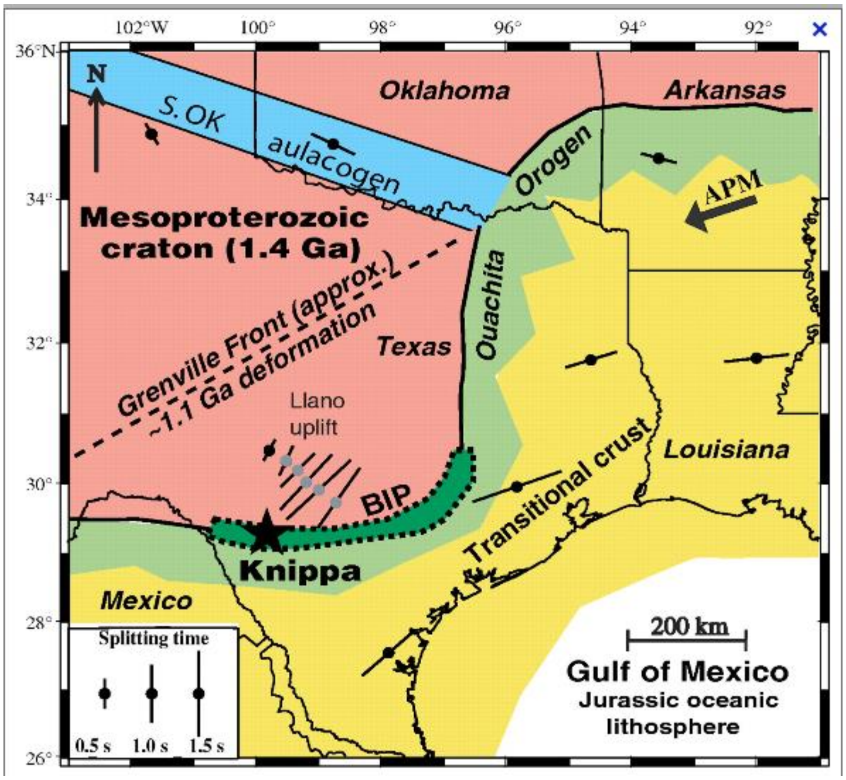


Figure 6. *Location of Knippa mantle xenolith locality in south-central Texas, relative to the study area showing simplified crustal provinces. The Ouachita orogeny approximates the boundary between the North American craton to the north and west and transitional crust to the east and south. APM—apparent plate motion; BIP—Balcones Igneous Province. According to the Raye (2011) Geophysical studies indicate that orientation and magnitude of splits correlate to crustal provinces (Gao et al.,2008). The rapid variation in splitting delay times from Llano uplift to southeastward might be either due to different degree of alignment of the crystals' fast axes or to difference in thickness of the anisotropic layer (Satsukawa et al., 2010). APM—apparent plate motion; BIP—Balcones Igneous Province. (Adapted from Raye, 2011)*

Lithology and Stratigraphy

The Edwards aquifer in the area of the San Antonio pool comprises as many as 8 members and formations of the Edwards Group (Figure 8), predominantly carbonates and evaporates that were deposited in the latter part of the Early Cretaceous. Original sediments were composed of aragonite, calcite, dolomite, and gypsum, which have since been replaced by calcite to form the exceedingly porous and strongly heterogeneous limestone rock seen today (Clark, 2003; Hvorka et al., 2004). At the surface along the Balcones Escarpment the Edwards Group dips toward the southeast occurring in an irregular band, exposing older rocks north and younger rocks south (Maclay and Land, 1988). Work by Hovorka et al., (2004) observes that lateral and vertical variability in response to Cretaceous depositional processes within fabrics of the rock has led to "distinct variations of depositional facies." (Hovorka et al., 2004) These variations led to the formation of beds with irregular solubility and mechanical properties, creating the regionally extensive stratigraphic intervals that are mapped as formations and hydrostratigraphic members within the study area (Figure 8) (Hovorka et al., 2004). The Major stratigraphic units referred to in this study include the Devils River Formation of the San Marcos Platform margin, and West Nueces, McKnight, and Salmon Peak Formations of the Maverick Basin; utilizing stratigraphic nomenclature and lithologic descriptions of Lozo and Smith (1964) and Clark, 2003) (Figures 5 and 8). The upper units of the Devils River Trend along with the upper unit of the Salmon Peak Formation are the most prolific water bearing units in the study area. As previously discussed, the Devils River Formation was an open, shallow-marine environment of high current energy; it is also described as having subtidal and supratidal facies (Clark, 2003; Hovorka et al., 2004). According to despriptions in Clark, (2003) the West Nueces Formation is nodular, and contains burrows (in-filled with dark insoluble material) and possesses low porisity and permeability. Similarly these descriptions from Clark, (2003) indicate that the McKnight Formation has low porosity and permeability, is dark, fine-grained, laminated, and argillaceous carbonate containing massive anhydrite beds. The Salmon Peak Formation (the most prolific formation within the Edwards group) has a high porosity and permeability and consists of light colored, homogeneous wackestone, packstone, and grainstone [Clark, 2003; Hovorka et al., (1993, 19964); Green et al., 2006].

The permeable strata are hydraulically interconnected by open inclined fractures associated with the BFZ. These high-angle normal faults often displace the entire thickness of the Edwards Limestone creating discontinuity, within the "lateral continuity of the strata" (Maclay and Land, 1988). According to reports by Green (2009) and Hovorka et al., (2004) voids within the Edwards Group (Figure8) vary in size, shape, and degree of interconnectivity relating to the textural and diagenetic history of the rock. Primary porosity within the Edwards Group results from small voids within and between the particle material compiling the rock matrix. Secondary porosity is attributed to solutioning and dedolomitization processes taking place below the substantial cover of confining rock (Green, 2009; Hovorka et al., 2004). Pools within the Edwards aquifer are regions surrounded by low-permeability zones that restrict dynamic flow out of the region. Most water escapes from the pool by overflowing at low points, such as the Knippa Gap (Figures 2 and 5), and springs along the Leona River (Green et al., 2006). In this area of transition in the Knippa Gap, that number decreases from 8 to 3 formations in the Maverick Basin, or 1 formation in the Devils River Trend of the Uvalde salient (Figures 5 and 8) (Green, 2009). Hovorka et al., (2004) concludes that the widespread faulting in the region, associated with the BFZ, "has significantly increased hydrologic gradient" (Hovorka et al., 2004) and that uplift at the base of the Edwards Group level in the western portion of the aquifer is occurring at elevations greater than 457.2 m above sea level, while the "maximum downdip extent of the freshwater aquifer" is at approximately 1036.32 m below sea level (Hovorka et al., 2004).

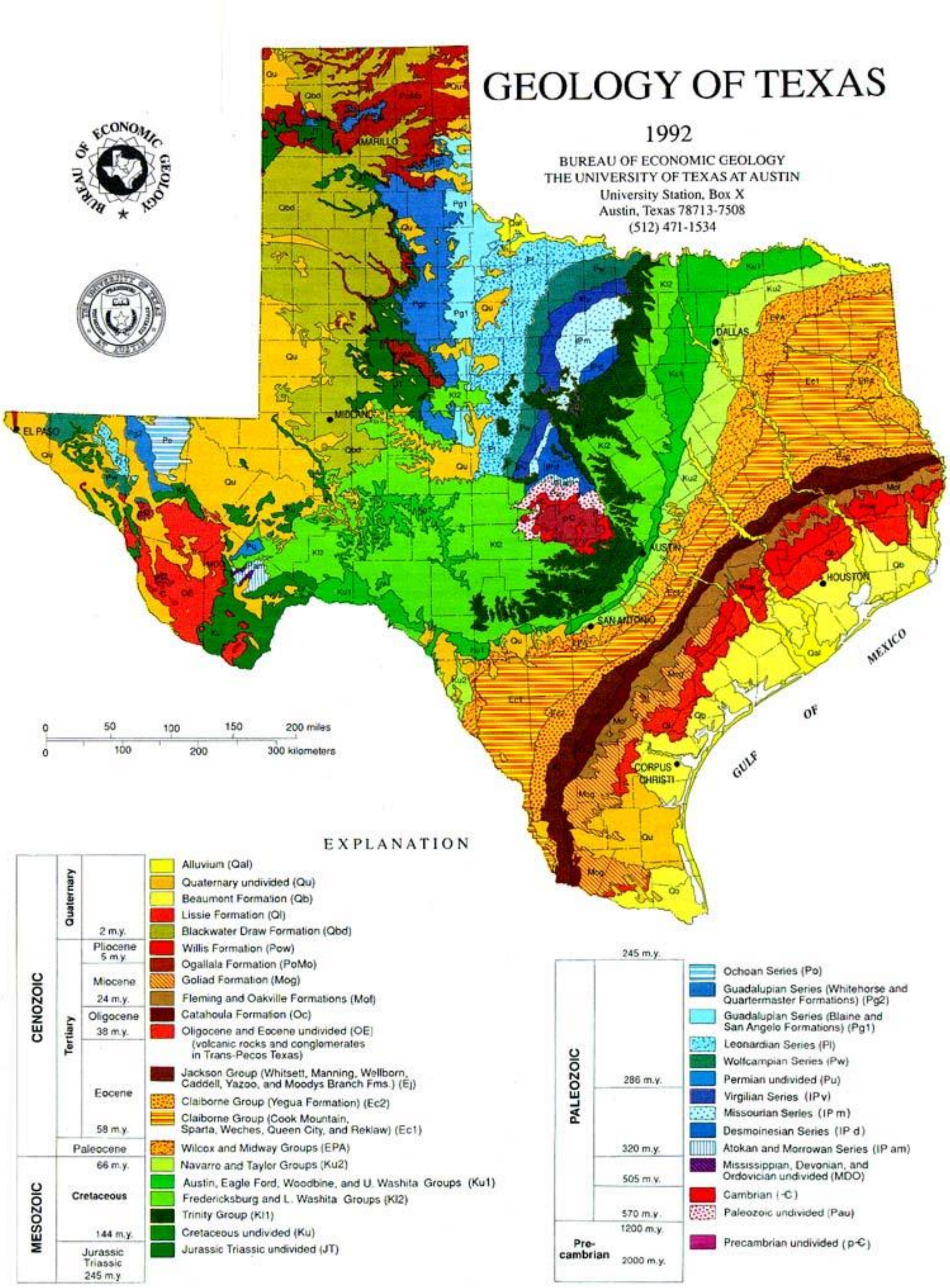


Figure 7. *Geologic Map of Texas, Modified from the University of Texas Libraries of the University of Texas at Austin.*

Stratigraphic Units of the Study Area in South Central Texas

	Stratigraphic Unit		**Hydrologic Unit**	**Approx. Max Thickness (ft)**	**Character of Rock**	**Porosity-Permeability**	**Cavern Development**
	Maverick Basin	**Devils River Trend**					
Upper Cretaceous	Escondido Formation	Escondido Formation	CU	285	Fine-grained sandstone, with interbedded shale, clay, and pyroclastic material locally fossiliferous	Low porosity/low permeability	None
	Anacho Limestone	Anacho Limestone	CU	Greater than 470	Massive mudstone to packstone, with interbedded bentonitic clay	Low porosity/low permeability	None
	Austin Group	Austin Group	CU; AQ where connected to Edwards by faults/fractures	300	Massive, chalky to marly, fossiliferous mudstone	Low to moderate porosity and permeability	Minor along fracture/faults
	Eagle Ford Group	Eagle Ford Group	CU	130–150	Brown, flaggy, sandy shale and argillaceous limestone	Primary porosity lost/low permeability	None
	Buda Limestone	Buda Limestone	CU	70-90	Buff to light-gray, dense mudstone Porcelaneous limestone, nodular	Low porosity/low permeability	Minor surface karst
	Del Rio Clay	Del Rio Clay	CU	50-110	Blue-green to yellow-brown clay; Fossiliferous	Negligible; primary upper confining unit	None

Lower Cretaceous	**Salmon Peak Formation**	**Upper Unit**	**Devils River Formation**	AQ	75	Mudstone that grades upward into grainstone; Light-gray mudstone, with abundant fossil fragments	Both fabric and non-fabric selective, low to high porosity/low to high permeability	Minor karst, associated with solutioningmalong fractures
		Lower Unit		AQ	310	Thick, massive lime mudstone, grainstone, and chert; Massive, gray mudstone	Mostly non-fabric selective; low porosity/ low permeability	Minor karst, associated with solutioning along fractures
	McKnight Formation	**Upper nit**		AQ	100-160	Brownish, thin-bedded, pelleted, mudstone, wackestone, packstone, and grainstone;	Mostly fabric selective; high porosity and permeability where evaporite dissolution has occurred	Negligible
		Middle Unit		CU	40	Dark, laminated mudstone, fissile Mudstone; Petroliferous odor; vegetative band on aerial	Mostly non-fabric selective; low porosity/ low permeability	None
		Lower Unit		Cu; AQ in evaporates	60-80	Thin-bedded mudstone to grainstone	Mostly fabric selective; low to high porosity/low permeability	Negligible
	West Nueces Formation	**Undivided**		CU	120-260	Gray, thick-bedded, burrowed, shell-fragment wackestone, packstone, and grainstone;	Mostly non-fabric selective; low porosity/ low permeability	Minor, associated with fracture solutioning
		Basal nodular unit		CU; AQ Where solutionally enhanced	20-60	Nodular, burrowed mudstone to wackestone *miliolids*, gastropods, and *Exogyra texana*	Mostly non-fabric selective; low porosity/ low permeability	Minor, primarily near contact with Glen Rose Limestone
	Glen Rose Formation	**Upper member of Glen Rose Limestone**		CU; evaporite beds AQ	350-500	Lower confing unit for Edwards aquifer; Yellowish-tan, thinly bedded limestone and marl	Mostly non-fabric selective porosity, with generally low permeability	Minor, associated with fracture solutioning

Figure 8. *Summary of the lithologic and hydrologic properties of the stratigraphic units of the Devils River Trend and the Maverick basin, Uvalde County, Texas; [Groups, formations and table modified from Clark (2003), Gary (2013), Welder and Reeves (1962), Lozo and Smith (1964), Rose (1972), Humphreys (1984), Miller (1984), and Ewing and Barker (1986); lithology modified from Dunham (1962); and porosity type modified from Choquette and Pray (1970). CU, confining unit; AQ, Edwards aquifer.*

Hydrogeology

Water use in the San Antonio pool of the aquifer is significant, owing to close proximity to the cities of San Antonio, New Braunfels, and San Marcos. Recharge of the eastern part of the aquifer is greatly impacted by periodic droughts. Water in the aquifer is primarily recharged by entryways stemming predominantly from the faults of the BFZ, and major inputs are point and line sources where streams and rivers cut across this zone of faulting. Water flow in the subsurface of the aquifer is generally from west to east through the artesian (confined) zone of the aquifer. Potentiometric contour maps from previous studies relating to the study area such as Hovorka et al., 2004; Green et al., 2006; Maclay and Land, 1988; and others, illustrate the general paths and patterns of groundwater flow within the study area. Uvalde County contains multiple minor groundwater resources from a thick sequence of sedimentary rocks. The Edwards is by far the most significant of these aquifers, spanning the central portion of the county from west to east. The Buda, Austin Chalk, gravels of the Leona River, and the Trinity aquifers are the major secondary aquifers that are present in Uvalde County (Green et al., 2006). Throughout the study area there are several Upper Cretaceous or Lower Tertiary igneous rocks that intrude through the stratigraphic units (Figures 2, 3, 8, and 23) composing the Edwards aquifer (Rose, 1973, Clark, 2003). Green et al., 2006 (Table 1) investigated the previous hypothesis (Rose, 1972), suggesting that the concentration of igneous intrusions in the study area could affect the groundwater flow in the area. After assessing the aeromagnetic survey map of Uvalde county (Smith et al., 2002), inspection of well logs, and the synoptic water-elevation survey for Kinney and Uvalde counties; the authors found no indication that the igneous intrusions affect the groundwater flow regime in the study area. The authors do concede that it is probable that the individual intrusions could affect local flow paths by either direct effect, or through indirect contact metamorphism relating to aquifer properties, in correlation primarily with the decreased number of drilled wells, and lower well yields associated with these intrusions (Green et al., 2006). These interpretations and their affects relating to the boundaries of the Knippa Gap are discussed further in the results section of this report.

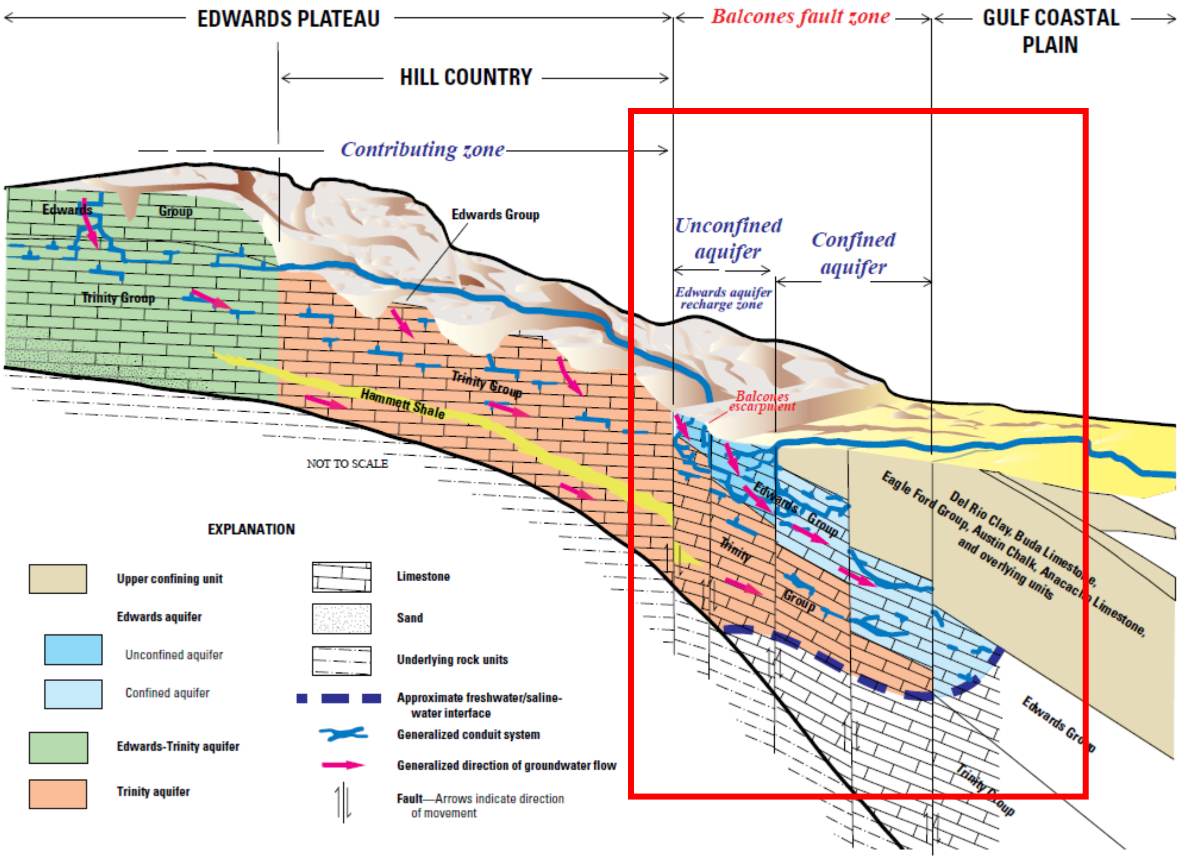


Figure 9. *Diagrammatic north-northwest-to-south-southeast section showing hydrogeologic framework and generalized groundwater flow directions, Edwards Plateau to Gulf Coastal Plain, San Antonio region, Texas. Approximate study area outlined in red. (modified from Musgrove et al., 2011; Barker and Ardis, 1996, plates 1 and 3).*

The Edwards aquifer is made up of three zones, the recharge zone, the contributing (catchment) zone, and the artesian zone (Figures1, 9, and 10). The contributing zone lies between two physiographic provinces-the Edwards Plateau and the Gulf coastal plain (Figure 9) (Maclay and Land, 1988). The contributing zone captures infiltrated precipitation and allows run off into streams or infiltration to the water-table aquifer to occur. This zone is also where contamination of the aquifer is most likely to occur, primarily as a result of shallow water tables, intense karstification, and thin to no soil cover. The recharge zone is dominated by vertical faulting associated with the BFZ, and is the part of the aquifer where major recharge occurs to the artesian zone (Figures 1 and 9). Entryways for the aquifer are predominantly faults of the BFZ, and major inputs are point and line sources where streams and rivers cut across this zone of faulting (Maclay and Land, 1988). The artesian zone occurs in the southern and easternmost part of the aquifer, where water is confined. The confining layers for the Edwards are the Glen Rose Formation below and the Del Rio Clay above (Figure 8). Reports by the Edwards Aquifer Authority (2005, 2006, 2010, 2011) determine that the artesian zone (confined) of the Edwards aquifer typically occurs at depths ranging from 150 to 300 m, with potable (non-saline) water at depths extending up to 1,000 m.

The north – south extent of the aquifer ranges between 10 to 60 kilometers, and the east – west extent is approximately 240 kilometers (Figures 1, 9, and 10). Down towards the southern end of the of the artesian zone, the aquifer makes a transition from freshwater to saline water (Edwards Aquifer Authority 2005, 2006, 2011, 2012). Reports by the Edwards Aquifer Authority (2005, 2006, 2011, 2012) also indicate the transition is abrupt on the order of a mile or less; this is known as the "bad-water line." The freshwater zone within the aquifer occurs at shallower depths, has high permeability from more intensified dissolution, and increased transmissivity allows the water to move through relatively quickly. In comparison the saline–water zone of the aquifer occurs at greater depths and gradient, has lower permeability, less dissolution, and less flow. These conditions, plus the chemically-closed nature of the system result in higher residence time, decreased transmissivity, and increased salinity (Edwards Aquifer Authority; 2005, 2006, 2011, 2012).

The ability of the aquifer to supply water during extended droughts depends upon aquifer storage, transmissivity, and relation of the recharge zone to the overall extent of the unconfined zones of the aquifer. The unconfined zone of the aquifer (Figures 1,9, and 10 recharge, and discharge zones) has a storage coefficient, about four orders of magnitude greater than the confined zone. The high transmissivity of the confined zone aids in the distribution of the water movement between the confined and unconfined zones of the aquifer (Maclay and Land, 1988; Edwards Aquifer Authority 2012). Recharge to the Edwards aquifer (Table 2) originates as precipitation within the outcrop of the Edwards and associated limestones, occurring from the capture of surface water on the contributing zone (allogenic recharge), as direct precipitation into the recharge zone (autogenic recharge), and inter-formational flow from adjoining formations, both above and below the Edwards aquifer (Edwards Aquifer Authority 2005, 2006, 2011, 2012). Recharge measurements compiled by the Edwards Aquifer Authority (Table 2) show the estimated annual recharge by drainage basin from 1934 through 2011 are based on United States Geological Survey (USGS) calculations and are estimated using a water-balance method that relies on precipitation records and stream-flow measurements across the region (Maclay and Land, 1988; Edwards Aquifer Authority 2012).

The Edwards Aquifer Authority, in conjunction with the USGS, provides recharge estimates by drainage basin (Figure 10). According to the hydrologic data report (Edwards

Aquifer Authority, 2012), the USGS estimates that annual recharge for the period of record (1934–2011) in Table 2 ranged from a minimum of 43,700 acre-feet in 1956 during the drought of record to 2,486,000 acre-feet in 1992, during a very wet year. Recharge was estimated to be 112,000 acre-feet in 2011well below the maximum. The median annual recharge was estimated to be 559,400 acre-feet (Table 2, most recent published calculation), these estimates exclude flow from the Guadalupe River, (Edwards Aquifer Authority, 2011)

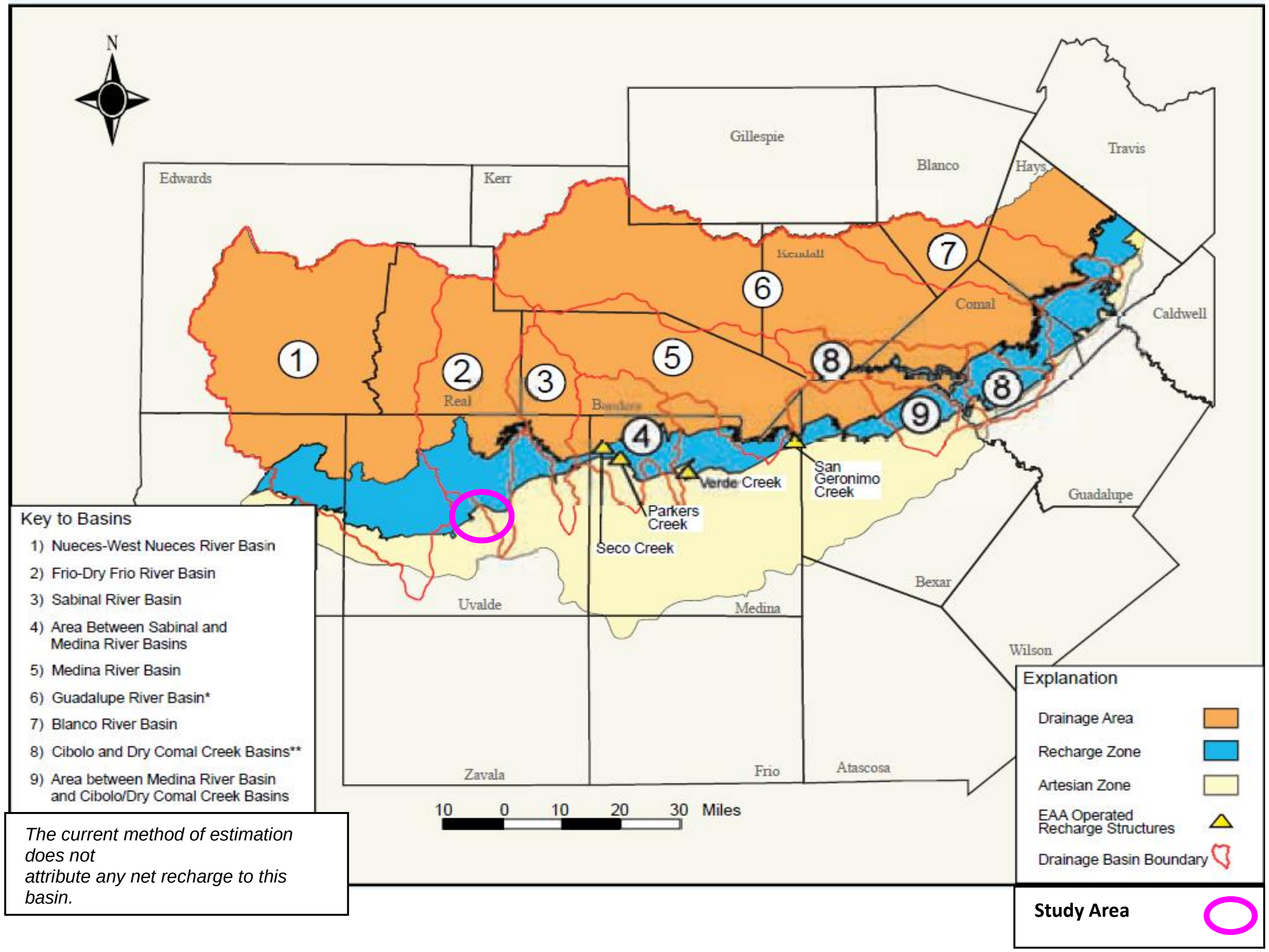


Figure 10. *Major drainage basins in the Edwards aquifer.* *(Modified From Edwards Aquifer Authority, 2011)*

Table 2. *Estimated annual groundwater recharge to the Edwards aquifer by drainage basin, 1934-2011 (in units of thousands of acre-feet), Modified from Edwards Aquifer Authority, 2011.*

Year	Nueces River/ West Nueces River Basin (acre-ft /year)	Frio River/ Dry Frio River Basin (acre-ft /year)	Sabinal River Basin (acre-ft /year)	Area Between Sabinal River and Medina River Basins (acre-ft /year)	Medina River Basin (acre-ft /year)	Area Between Medina River and Cibolo Creek/ Dry Comal Creek Basins (acre-ft /year)	Cibolo Creek/ Dry Comal Creek Basin (acre-ft /year)	Blanco River Basin (acre-ft /year)	Total* (acre-ft /year)
1934	8.6	27.9	7.5	19.9	46.5	21.0	28.4	19.8	179.6
1935	411.3	192.3	56.6	166.2	71.1	138.2	182.7	39.8	1258.2
1936	176.5	157.4	43.5	142.9	91.6	108.9	146.1	42.7	909.6
1937	28.8	75.7	21.5	61.3	80.5	47.8	63.9	21.2	400.7
1938	63.5	69.3	20.9	54.1	65.5	46.2	76.8	36.4	432.7
1939	227.0	49.5	17.0	33.1	42.4	9.3	9.6	11.1	399.0
1940	50.4	60.3	23.8	56.6	38.8	29.3	30.8	18.8	308.8
1941	89.9	151.8	50.6	139.0	54.1	116.3	191.2	57.8	850.7
1942	103.5	95.1	34.0	84.4	51.7	66.9	93.6	28.6	557.8
1943	36.5	42.3	11.1	33.8	41.5	29.5	58.3	20.1	273.1
1944	64.1	76.0	24.8	74.3	50.5	72.5	152.5	46.2	560.9
1945	47.3	71.1	30.8	78.6	54.8	79.6	129.9	35.7	527.8
1946	80.9	54.2	16.5	52.0	51.4	105.1	155.3	40.7	556.1
1947	72.4	77.7	16.7	45.2	44.0	55.5	79.5	31.6	422.6
1948	41.1	25.6	26.0	20.2	14.8	17.5	19.9	13.2	178.3
1949	166.0	86.1	31.5	70.3	33.0	41.8	55.9	23.5	508.1
1950	41.5	35.5	13.3	27.0	23.6	17.3	24.6	17.4	200.2
1951	18.3	28.4	7.3	26.4	21.1	15.3	12.5	10.6	139.9
1952	27.9	15.7	3.2	30.2	25.4	50.1	102.3	20.7	275.5
1953	21.4	15.1	3.2	4.4	36.2	20.1	42.3	24.9	167.6
1954	61.3	31.6	7.1	11.9	25.3	4.2	10.0	10.7	162.1
1955	128.0	22.1	0.6	7.7	16.5	4.3	3.3	9.5	192.0
1956	15.6	4.2	1.6	3.6	6.3	2.0	2.2	8.2	43.7
1957	108.6	133.6	65.4	129.5	55.6	175.6	397.9	76.4	1142.6
1958	266.7	300.0	223.8	294.9	95.5	190.9	268.7	70.7	1711.2
1959	109.6	158.9	61.6	96.7	94.7	57.4	77.9	33.6	690.4
1960	88.7	128.1	64.9	127.0	104.0	89.7	160.0	62.4	824.8
1961	85.2	151.3	57.4	105.4	88.3	69.3	110.8	49.4	717.1
1962	47.4	46.6	4.3	23.5	57.3	16.7	24.7	18.9	239.4
1963	39.7	27.0	5.0	10.3	41.9	9.3	21.3	16.2	170.7
1964	126.1	57.1	16.3	61.3	43.3	35.8	51.1	22.2	413.2
1965	97.9	83.0	23.2	104.0	54.6	78.8	115.3	66.7	623.5
1966	169.2	134.0	37.7	78.2	50.5	44.5	66.5	34.6	615.2
1967	82.2	137.9	30.4	64.8	44.7	30.2	57.3	19.0	466.5
1968	130.8	176.0	66.4	198.7	59.9	83.1	120.5	49.3	884.7
1969	119.7	113.8	30.7	84.2	55.4	60.2	99.9	46.6	610.5
1970	112.6	141.9	35.4	81.6	68.0	68.8	113.8	39.5	661.6
1971	263.4	212.4	39.2	155.6	68.7	81.4	82.4	22.2	925.3

1972	108.4	144.6	49.0	154.6	87.9	74.3	104.2	33.4	756.4
1973	190.6	256.9	123.9	286.4	97.6	237.2	211.7	82.2	1486.5
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	658.5
1975	71.8	143.6	47.9	195.9	93.4	138.8	195.7	85.9	973.0
1976	150.7	238.6	68.2	182.0	94.5	47.9	54.3	57.9	894.1
1977	102.9	193.0	62.7	159.5	77.7	97.9	191.6	66.7	952.0
1978	69.8	73.1	30.9	103.7	76.7	49.6	72.4	26.3	502.5
1979	128.4	201.4	68.6	203.1	89.4	85.4	266.3	75.2	1117.8
1980	58.6	85.6	42.6	25.3	88.3	18.8	55.4	31.8	406.4
1981	205.0	365.2	105.6	252.1	91.3	165.0	196.8	67.3	1448.3
1982	19.4	123.4	21.0	90.9	76.8	22.6	44.8	23.5	422.4
1983	79.2	85.9	20.1	42.9	74.4	31.9	62.5	23.2	420.1
1984	32.4	40.4	8.8	18.1	43.9	11.3	16.9	25.9	197.7
1985	105.9	186.9	50.7	148.5	64.7	136.7	259.2	50.7	1003.3
1986	188.4	192.8	42.2	173.6	74.7	170.2	267.4	44.5	1153.8
1987	308.5	473.3	110.7	405.5	90.4	229.3	270.9	114.9	2003.5
1988	59.2	117.9	17.0	24.9	69.9	12.6	28.5	25.5	355.5
1989	52.6	52.6	8.4	13.5	46.9	4.6	12.3	23.6	214.5
1990	479.3	255.0	54.6	131.2	54.0	35.9	71.8	41.3	1123.1
1991	325.2	421.0	103.1	315.2	52.8	84.5	109.7	96.9	1508.4
1992	234.1	586.9	201.1	566.1	91.4	290.6	286.6	226.9	2483.7
1993	32.6	78.5	29.6	60.8	78.5	38.9	90.9	37.8	447.6
1994	124.6	151.5	29.5	45.1	61.1	34.1	55.6	36.6	538.1
1995	107.1	147.6	34.7	62.4	61.7	36.2	51.1	30.6	531.4
1996	130.0	92.0	11.4	9.4	42.3	10.6	14.7	13.9	324.3
1997	176.9	209.1	57.0	208.4	63.3	193.4	144.2	82.3	1134.6
1998	141.5	214.8	72.5	201.4	80.3	86.2	240.9	104.7	1142.3
1999	101.4	136.8	30.8	57.2	77.1	21.2	27.9	21.0	473.4
2000	238.4	123.0	33.1	55.2	53.4	28.6	48.6	34.1	614.4
2001	297.5	126.7	66.2	124.1	90.0	101.5	173.7	89.7	1069.4
2002	83.6	207.3	70.6	345.2	93.7	175.5	447.8	150.0	1573.7
2003	149.8	112.2	31.7	67.4	86.6	56.2	105.0	59.9	668.8
2004	481.9	424.5	116.0	343.9	95.5	213.4	315.0	185.8	2176.0
2005	105.5	147.2	50.1	79.1	82.8	84.8	140.4	74.1	764.0
2006	45.5	60.2	9.0	5.0	47.7	5.1	11.2	17.9	201.6
2007	471.8	474.4	104.0	406.4	75.2	227.6	306.1	96.9	2162.4
2008	48.2	44.5	5.9	9.8	53.6	9.6	22.8	18.5	212.9
2009	58.5	30.3	1.8	13.5	45.6	7.3	26.4	27.5	210.9
2010	135.4	104.9	31.5	186.3	68.2	81.4	148.2	57.5	813.4
2011	15.3	13.7	1.0	2.0	43.3	3.0	15.3	18.3	111.9
Recharge for the Period of Record 1934-2011:									
Median	102.2	120.5	31.5	78.4	61.4	52.8	78.7	35.2	559.4
Mean	126.1	136.0	42.2	112.2	62.8	72.0	110.0	46.6	711
Recharge for the Period of Record 2001-2011:									
Median	94.6	108.6	31.6	73.3	71.7	68.8	122.7	58.7	716.5
Mean	159.6	161.9	42.2	145.9	69.2	86.4	153.8	70.6	889.6
Data Source Used by Edwards Aquifer Authority: USGS Unpublished Report (April 2012)									

Green et al., (2006) determined the calculations for recharge in Uvalde County based on assumptions that the two major sources of recharge to the Edwards aquifer are from the Nueces River-West Nueces River basin and the Frio River-Dry Frio River basin (Edwards Aquifer Authority, 2005). This report estimates the average and median annual recharge for the Nueces River-West Nueces River basin is approximately 119,594 and 106,000 acre-ft/yr (predicted values assume all recharge from the West Nueces River recharges the Uvalde pool of the Edwards aquifer). Section nine of Green et al., (2006) also determines that most of the recharge from the West Nueces River basin primarily recharges the Kinney County pool of the aquifer not the Uvalde pool, however recharge from the Nueces River and the Frio River-Dry Frio River basins do in fact recharge the Uvalde pool of the Edwards aquifer. The Sabinal River basin also recharges the Edwards aquifer in Uvalde County, however based on these reports it is believed to recharge the aquifer only to the east of the Knippa Gap into the San Antonio pool of the Edwards Aquifer (Green et al., 2006).

Discharge in the Edwards aquifer most often occurs by spring-flow, pumping, and inter-formational flow to down-gradient aquifers. Numerous wells are drilled throughout the Edwards aquifer to provide water for uses such as irrigation, municipal water supplies, industrial applications, as well as domestic and/or livestock consumption. However, even with the substantial number of wells drilled within the aquifer, the amount of groundwater discharge from spring-flow has historically been greater than that through wells. Estimates of annual total groundwater discharge from spring-flow and pumping for the Edwards aquifer are depicted by county in Table 3, for the period of record (1934–2011). The 2011 Hydrologic Report provided by the Edwards Aquifer Authority, estimates ranges from a low of 388,800 acre-feet in 1955 to a high of 1,130,000 acre-feet in 1992. The total groundwater discharged from the Edwards aquifer from wells and springs for 2011, was estimated to be approximately 692,870 acre-feet, (well discharge 427,653 acre-feet, and spring discharge 265,217 acre-feet) (Edwards Aquifer Authority, 2012). Table 3 indicates spring-flow from 1934 through 2011 has varied from a 1956 low of 69,800 acre-feet to a high of 802,800 acre-feet in 1992. Regional flow systems in the Edwards aquifer resurge as large springs where groundwater is returned to the surface from depth, such as the Leona Springs in Uvalde County, and San Marcos Springs in Hays county (Esquilin 2012; Hamiltion, 2006,2012; Green et al, 2012). These springs issue from faults forming in open cracks and solution channels (Maclay and Land, 1988). The aquifer within the study area exhibits variable hydraulic properties that have been attributed to a variety of regional and local activities, including but not limited to lithofacies, faulting, karst features, and igneous intrusions (Green et al., 2006; Hovorka et al., 2004; Rose 1972; Worthington, 1999, 2004).

Table 3. *Estimated annual groundwater discharge to the Edwards aquifer by county, 1934-2011 (In units of thousands of acre-feet), Modified from Edwards Aquifer Authority, 2011.*

Year	Uvalde County	Medina County	Bexar County	Comal County	Hays County	Total Wells	Total Springs	Total
1934	12.6	1.3	109.3	229.1	85.6	101.9	336.0	437.9
1935	12.2	1.5	171.8	237.2	96.9	103.7	415.9	519.6
1936	26.6	1.5	215.2	261.7	93.2	112.7	485.5	598.2
1937	28.3	1.5	201.8	252.5	87.1	120.2	451.0	571.2
1938	25.2	1.6	187.6	250.0	93.4	120.1	437.7	557.8
1939	18.2	1.6	122.5	219.4	71.1	118.9	313.9	432.8
1940	16.1	1.6	116.7	203.8	78.4	120.1	296.5	416.6
1941	17.9	1.6	197.4	250.0	134.3	136.8	464.4	601.2
1942	22.5	1.7	203.2	255.1	112.2	144.6	450.1	594.7
1943	19.2	1.7	172.0	249.2	97.2	149.1	390.2	539.3
1944	11.6	1.7	166.3	252.5	135.3	147.3	420.1	567.4
1945	12.4	1.7	199.8	263.1	137.8	153.3	461.5	614.8
1946	6.2	1.7	180.1	261.9	134.0	155.0	428.9	583.9
1947	13.8	2.0	193.3	256.8	127.6	167.0	426.5	593.5
1948	9.2	1.9	159.2	203.0	77.3	168.7	281.9	450.6
1949	13.2	2.0	165.3	209.5	89.8	179.4	300.4	479.8
1950	17.8	2.2	177.3	191.1	78.3	193.8	272.9	466.7
1951	16.9	2.2	186.9	150.5	69.1	209.7	215.9	425.6
1952	22.7	3.1	187.1	133.2	78.8	215.4	209.5	424.9
1953	27.5	4.0	193.7	141.7	101.4	229.8	238.5	468.3
1954	26.6	6.3	208.9	101.0	81.5	246.2	178.1	424.3
1955	28.3	11.1	215.2	70.1	64.1	261.0	127.8	388.8
1956	59.6	17.7	229.6	33.6	50.4	321.1	69.8	390.9
1957	29.0	11.9	189.4	113.2	113.0	237.3	219.2	456.5
1958	23.7	6.6	199.5	231.8	155.9	219.3	398.2	617.5
1959	43.0	8.3	217.5	231.7	118.5	234.5	384.5	619.0
1960	53.7	7.6	215.4	235.2	143.5	227.1	428.3	655.4
1961	56.5	6.4	230.3	249.5	140.8	228.2	455.3	683.5
1962	64.6	8.1	220.0	197.5	98.8	267.9	321.1	589.0
1963	51.4	9.7	217.3	155.7	81.9	276.4	239.6	516.0
1964	49.3	8.6	201.0	141.8	73.3	260.2	213.8	474.0
1965	46.8	10.0	201.1	194.7	126.3	256.1	322.8	578.9
1966	48.5	10.4	198.0	198.9	115.4	255.9	315.3	571.2
1967	81.1	15.2	239.7	139.1	82.3	341.3	216.1	557.4
1968	58.0	9.9	207.1	238.2	146.8	251.7	408.3	660.0
1969	88.5	13.6	216.3	218.2	122.1	307.5	351.2	658.7
1970	100.9	16.5	230.6	229.2	149.9	329.4	397.7	727.1
1971	117.0	32.4	262.8	168.2	99.1	406.8	272.7	679.5
1972	112.6	28.8	247.7	234.3	123.7	371.3	375.8	747.1
1973	96.5	14.9	273.0	289.3	164.3	310.4	527.6	838.0
1974	133.3	28.6	272.1	286.1	141.1	377.4	483.8	861.2
1975	112.0	22.6	259.0	296.0	178.6	327.8	540.4	868.2
1976	136.4	19.4	253.2	279.7	164.7	349.5	503.9	853.4
1977	156.5	19.9	317.5	295.0	172.0	380.6	580.3	960.9
1978	154.3	38.7	269.5	245.7	99.1	431.8	375.5	807.3
1979	130.1	32.9	294.5	300.0	157.0	391.5	523.0	914.5
1980	151.0	39.9	300.3	220.3	107.9	491.1	328.3	819.4

Year	Uvalde County	Medina County	Bexar County	Comal County	Hays County	Total Wells	Total Springs	Total
1981	104.2	26.1	280.7	241.8	141.6	387.1	407.3	794.4
1982	129.2	33.4	305.1	213.2	105.5	453.1	333.3	786.4
1983	107.7	29.7	277.6	186.6	118.5	418.5	301.6	720.1
1984	156.9	46.9	309.7	108.9	85.7	529.8	178.3	708.1
1985	156.9	59.2	295.5	200.0	144.9	522.5	334.0	856.5
1986	91.7	41.9	294.0	229.3	160.4	429.3	388.0	817.3
1987	94.9	15.9	326.6	286.2	198.4	364.1	557.9	922.0
1988	156.7	82.2	317.4	236.5	116.9	540.0	369.7	909.7
1989	156.9	70.5	305.6	147.9	85.6	542.4	224.1	766.5
1990	118.1	69.7	276.8	171.3	94.1	489.4	240.6	730.0
1991	76.6	25.6	315.5	221.9	151.0	436.0	354.6	790.6
1992	76.5	9.3	370.5	412.4	261.3	327.2	802.8	1130.0
1993	107.5	17.8	371.0	349.5	151.0	407.3	589.4	996.7
1994	95.5	41.1	297.7	269.8	110.6	424.6	390.2	814.8
1995	90.8	35.2	272.1	235.0	127.8	399.6	361.3	760.9
1996	117.6	66.3	286.8	150.2	84.7	493.6	212.0	705.6
1997	77.0	31.4	260.2	243.3	149.2	377.1	383.9	761.0
1998	113.1	51.3	312.4	271.8	168.8	453.5	464.1	917.6
1999	104.0	49.2	307.1	295.5	143.0	442.7	456.1	898.8
2000	89.1	45.1	283.6	226.1	108.4	414.8	337.5	752.3
2001	68.6	33.9	291.6	327.7	175.4	367.7	529.6	897.3
2002	76.2	40.6	311.9	350.4	202.1	371.3	609.9	981.2
2003	89.4	34.8	331.7	344.7	176.3	362.1	621.5	976.9
2004	91.3	22.5	331.9	341.4	153.1	317.4	622.9	940.3
2005	107.4	37.3	366.1	349.3	175.6	388.5	647.1	1035.6
2006	107.5	64.9	289.5	216.7	87.9	454.5	312.0	766.5
2007	64.1	18.4	330.2	331.7	196.0	319.9	621.0	940.9
2008	102.0	48.8	320.4	266.6	108.0	428.6	417.1	845.7
2009	76.9	47.3	265.2	206.6	87.8	395.7	287.9	683.6
2010	53.1	36.6	298.5	312.1	162.5	372.8	490.0	862.8
2011	79.6	57.4	277.2	187.7	91.0	427.7	265.2	692.9
For period of record 1934-2011:								
Median	76.6	17.1	256.1	234.7	117.7	327.5	384.2	699.2
Mean	73.1	22.9	248.4	230.7	123.1	313.7	384.2	697.7
For period of record 2001-2011 (last ten years):								
Median	84.5	39.0	316.2	321.9	164.4	380.7	550.0	901.6
Mean	85.0	40.9	312.3	290.7	147.0	383.8	489.5	872.7

Data source: USGS and Edwards Aquifer Authority files (2012).

A = As of 2008, no longer includes Kinney County discharge; perio years include 1,900 acre-feet of discharge for Kinney County

B = Includes reports of Edwards aquifer irrigators in Alascosa County

C = Includes reports of Edwards aquifer industrial and municipal users in Guadalupe County

Differences in totals may occur as a result of rounding

Since deposition, rocks of the Edwards Group have experienced a complex history, including surface exposure to earth's atmosphere, burial (middle Cretaceous), faulting, uplift, erosion, and intense karstification (Rose, 1973). Karstification within the region has produced sinkholes, caves, sinking streams, and an extensive subsurface drainage system, characterizing the Edwards aquifer as a “karst aquifer” (Esquilin 2012; Hamiltion, 2006,2012).. Dedolomitization and solutioning processses within the Edwards Group are "often accelerated by intermittenet movement along active faults" (Maclay, 1988) associated with the BFZ. Movement along these faults increases the amount of contact between the permeable dolomites and circulating groundwater having increased ratios of dissolved calcium to magnesium concentrations (Maclay, 1988; Maclay and Small, 1984). In the catchment area of the aquifer (Figures 1, 9, and 10), dominant karst processes are epigenic, meaning dissolution is produced primarily by descending recharge and horizontal groundwater movement (Schindel et al., 2008). However, based on the cave structure and morphological forms such as vertical shafts, scallops, and cupolas, many researchers conclude that hypogenic speleogenesis (deep regional upward flow) has played an essential role in the karst development of the Edwards aquifer (Klimchouk, 2007; Schindel et al., 2008). Schindel et al., (2008) concluded that the permeability derived by this upward water flow plays an integral part in the aquifer development as well as hydrocarbon storage within the rock units (Schindel et al., 2008). My Jennay Sinkhole (Figures 11, 12, 20, 23; and Table 4) is a karst feature (a paleo-hypogenic spring) located within the study area during karst inventory (Figure 13 and Table 4), resulting from deep regional upward flow such as that discussed in Schindel et al., (2008) and Klimchouk et al., (2007). Syndepositional karst developed on top and within the Edwards Group (Figures 8 and 22) throughout the study area, creating zones of high permeability at the top of the aquifer, particularly the Salmon Peak

Formation of the Edwards Group (Figures 8 and 22). According to Palmer, (1991) the incorporation of freshwater into these permeable carbonate rocks formed an “extensive aquifer”, and led to the formation of interconnected dissolved conduits. During investigations regarding the simulation of flow in the Edwards aquifer, authors Maclay and Land, (1988) noted the presence of "live blind catfish." These catfish were netted from the surface discharge of flowing wells near the "bad-water line", from wells reaching depths of approximately 1,500 feet. These catfish differ significantly from the "cave fish" located in other aquifers and cave systems throughout the world. Maclay and Land, (1988) also infer that the "presence of these catfish suggests there are interconnected cavernous openings occurring at great depths within the buried carbonate aquifer." These conduits are thought to be associated with paleokarst (ancient karst features having been fossilized or preserved) developed during the Cretaceous Period (Palmer, 1991, 2007; Maclay and Land, 1988). Paleo subsurface flow-paths such as these, with significantly increased hydraulic conductivities within the study area are also associated with karst development, and are the foundation for the large volumes of groundwater associated with the Knippa Gap (Green et al., 2006).

Figure 11. *Google Earth image location of My Jennay (sinkhole) located during the karst inventory of the study area.*

Figure 12. *Field images of My Jennay Sinkhole located during the karst inventory of the study area. This feature is thought to have formed hypogenically (upwelling of water pressure from below), representing a paleo-abandoned spring outflow. If this is the case, My Jennay sinkhole represents an excellent site for dye injection to determine flow rates and direction.*

99^{0} 52' 30"	99^{0} 45'	99^{0} 37' 30"	99^{0} 30'
Deep Creek	Concan	Trio	29^{0} 30'
Seven Mile Hill	Knippa	Blanco Lake	29^{0} 22'30"
Uvalde	Garner Field	Garner Field NE	29^{0} 15'
			29^{0} 7' 30"

Figure 13. *Index of U.S. Geological Survey 7.5 minute topographic quadrangles. The study area is approximately in the northwest quadrant of the Knippa 7.5 minute topographic quadrangle. Quadrangle maps are referenced to Table 4.*

Table 4. *Karst-Hydrogeologic Inventory of study area, Keyed to (Figure 13).*

Feature Number	Karst Feature	Topographic Map	Lat (Decimal Degrees)	Long (Decimal Degrees)	Comments
1	My Jennay sinkhole	Knippa 7.5	29.32325	-99.702111	On Salt Creek- Hypogenic- near flow line, good location for dye injection
2	Un-named sinkhole	Knippa 7.5	29.349278	-99.706861	Head of Salt Creek ID from topo_20ft relief
3	Un-named sinkhole	Knippa 7.5	29.360472	-99.704611	20 ft total relief no surface water nearby: ID from topo-map
4	Un- named sinkhole	Knippa 7.5	29.337444	-99.723583	Small, near road, discharge point taylor slough: ID from topo- Map
5	Frio River Down-stream flow lost	Concan 7.5	29.430167	-99.655778	ID from topo-Map
6	Un-named cave	Concan 7.5	29.429611	-99.658306	ID from topo-map
7	Eight Mile waterhole	Sevenmile Hill 7.5	29.295360	-99.769611	WL estimated 985 in (1971) ID from topo-Map
8	Resurgence of Leona River	Uvalde 7.5	29.194889	-99.771944	Major Flow belt estimated at 890 (1971) ID from topo-Map
9	Two Mile waterhole on Leona River	Uvalde 7.5	29.233967	-99.784090	WL estimated at 905 (1971) outside of flow zone ID from topo-Map
10	Resurgence of cooks slough	Uvalde 7.5	29.185612	-99.794413	WL estimate at 875 (1971) ID from topo-Map
11	Dry Frio River loses flow up-gradient	Deep Creek 7.5	29.469306	-99.7735	WL estimated (1971) 1330_outside study area ID from topo-Map
12	Gauging station flow loss from Leona River	Garner Field 7.5	29.154467	-99.743202	WL estimated 845 ID from topo-Map
13	Resurgence Leona River	Garner Field7.5	29.148959	-99.733486	WL estimated 827 ID from topo-Map
14	Resurgence of Frio River	Garner Field 7.5	29.173554	-99.628937	WL estimated 793 ID from topo-Map
15	Toadstool water hole on Frio River	Garner Field 7.5	29.194926	-99.669265	WL estimated at 835 (1971) ID from topo-Map
16	Cypress Waterhole or Frio River	Garner Field 7.5	29.216738	-99.677601	WL estimated at 807 (1971) ID from topo-Map
17	Blanco River goes dry downstream	Garner Field NE 7.5	29.115668	-99.518353	WL estimated at 769 (1971) ID from topo-Map

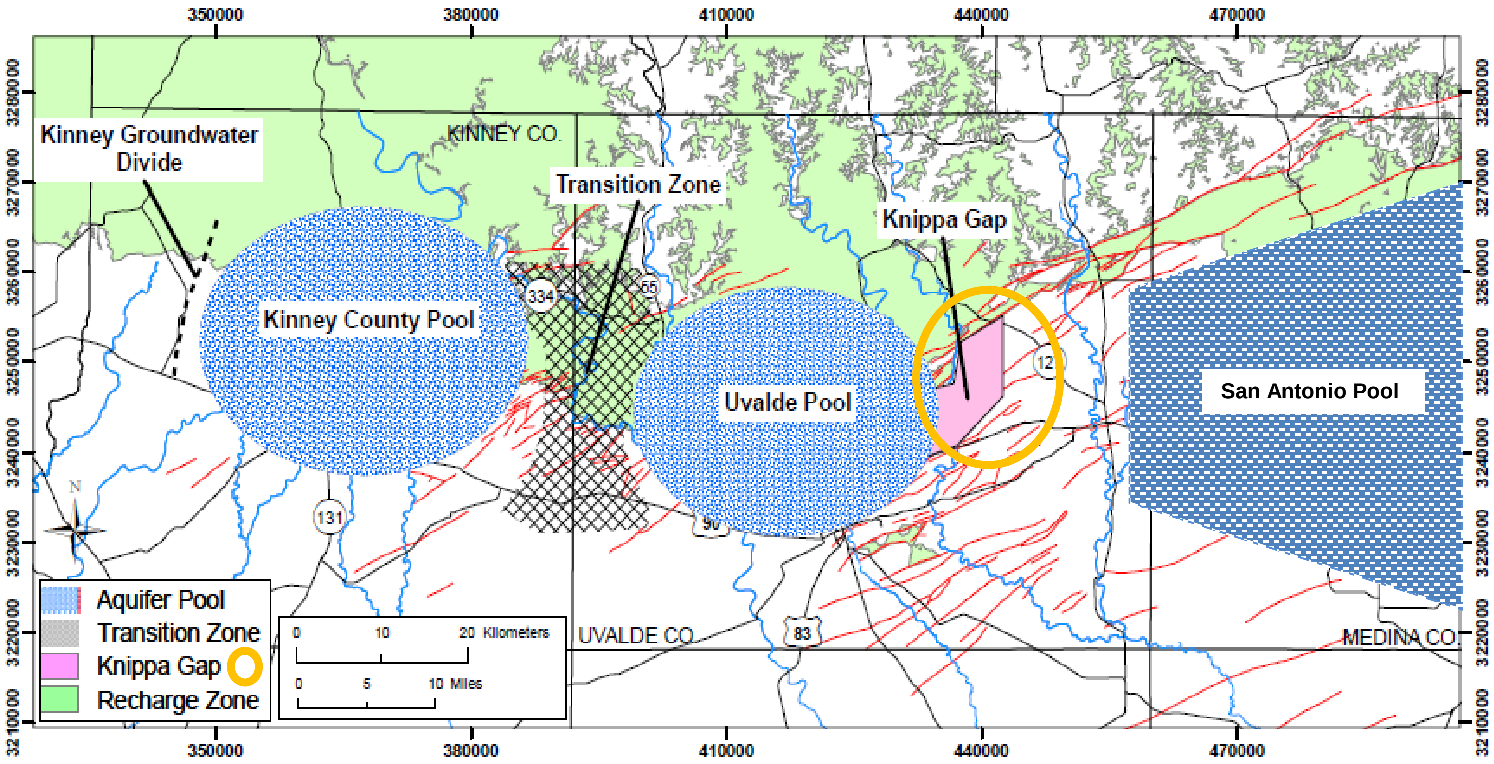


Figure 14. *Map of the Kinney County, Uvalde, and San Antonio pools of the Edwards aquifer. The Kinney County and Uvalde pools are separated by a transition zone of low permeability. The Uvalde and San Antonio pools are separated by the Knippa Gap(Shown in Pink, with extended boundaries outlined in yellow, a constriction in the Edwards Aquifer. A groundwater divide defines the western limit of the Kinney County pool. Map projection is UTM Zone 14, NAD83. Modified from (Green et al., 2006).*

Table 5. *Index of Previous Synoptic Water-Level Maps relative to the study area and the BFZ Edwards Aquifer [Modified From (Edwards Aquifer Authority, 2010)]*

Date of Map	Area Covered	Source of Information
1930	Uvalde and Medina Counties	Sayer (1936)
October 1934	Bexar County and portions of Medina and Comal Counties	Livingston et al. (1936)
January 1947	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Klemt et al. (1975)
January 1951	Medina County	Holt (1959)
January 1952	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Petitt and George (1956)
August 1952	Medina, Bexar, and Comal Counties	Lang(1954)
August 1954	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Petitt and George (1956)
August 1956	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Garza (1962)
March 1958	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Garza (1962)
January 1961	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Garza (1966)
January 1972	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	Klemt et al. (1975)
February 1972	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
June 1972	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
February 1973	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
July 1973	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
February 1974	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict

Date of Map	Area Covered	Source of Information
July 1974	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
July 1975	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
February 1976	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
August 1976	Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties	USGS Files_San Antonio Subdistrict
July 17-July 25, 2000	Groundwater Elevation at Uvalde County Index Well J-27	Edwards Aquifer Authority SWLP 1999-2004 Report
October 29-November 2, 2001	Groundwater Elevation at Uvalde County Index Well J-27	Edwards Aquifer Authority SWLP 1999-2004 Report
November 12-19, 2002	Groundwater Elevation at Uvalde County Index Well J-27	Edwards Aquifer Authority SWLP 1999-2004 Report
July 19-30, 2004	Groundwater Elevation at Uvalde County Index Well J-27	Edwards Aquifer Authority SWLP 1999-2004 Report
December 6 -13, 2004	Groundwater Elevation at Uvalde County Index Well J-27	Edwards Aquifer Authority SWLP 1999-2004 Report

METHODS AND APPROACH

It has been estimated that approximately 46% of the total average recharge to the San Antonio pool segment that flows through or is captured by stream-flow, can be attributed to the recharge occurring in Uvalde County (Esquilin, 2012; Hamilton et al., 2008; Green et al., 2006). Reports by Green et al., (2006) conclude that in order to interpret accurate groundwater flow regimes in the Uvalde pool analyses using the integrated results of the water chemistry, geologic structure, stratigraphy, and hydrogeological investigations had to be interpreted and assessed. Well information was included with those data collected for the study, and were used to identify the Knippa Gap, a high-volume capacity channel of the Edwards Aquifer in central Uvalde County (Green et al.,2006). The compilation of wells relating to this study was limited and required further interpretation. Previous investigations leading into this project are numerous including a complex conceptual model that has been through several iterations, and the assessment of the existing literature on geologic structure, water chemistry, and hydrogeologic properties of the study area. The methodology for this study is based on the utilization of existing data from the Edwards aquifer, as well as the integration of newly collected data. The newly collected data sets include water levels, hydrostratigraphic analysis (geophysical logs), and water chemistry. These data were used to fill in the gaps of understanding and improve the resolution and scope of the study (Green et al., 2006), drawing specifically from the following sources: The Texas Water Development Board online well database for Uvalde County; USGS files for Uvalde County; Edwards Aquifer Authority geophysical logs and files for Uvalde County; South West Research Institute; Published sources include (Collins and Hovorka, 1997), Welder and Reeves (1962), and the Uvalde County Underground Water Conservation District well records.

Water-Level Collection

The Edwards aquifer is a karst aquifer, containing a highly permeable and porous subsurface accompanied by the presence of sinkholes, caves, sinking streams, springs, and well integrated subsurface drainage (Esquilin 2012; Hamiltion, 2006,2012). The aquifer supplies extremely productive water wells and increasingly high spring discharges, and transmits large volumes of water, allowing groundwater to rapidly respond to recharge events (Esquilin 2012; Hamiltion, 2006,2012). The synoptic water level interpretations for this study took place in both the recharge (unconfined) and artesian (confined) zones of the Edwards aquifer; the contributing well locations are indicated in (Figures 15 and 16). Synoptic groundwater-levels (in wells) such as those used for this study are measured over a short period of time under similar or nearly identical hydrologic conditions. Water levels were taken through manual measurements using a steel tape/tape down (graduated in feet, tenths and hundredths of feet), or electronic tapes (whistler) and recorded in feet above mean sea level (ftamsl) (Appendix F). Each well was measured during the designated survey period (July 17-23, 2012). Many of the wells used for this study have partial historical records dating back to the 1930s (Esquilin 2012; Hamiltion, 2006,2012).

In order to increase the accuracy of the synoptic water-level study, survey-grade global positioning system (GPS) coordinate and elevation data were collected during August 2012 for twenty-eight wells, utilizing resources from both the Edwards Aquifer Authority and the University of Arkansas (U of A). This survey improves the quality of the data set by providing sub-centimeter-scale location data and plus or minus 7 cm elevation accuracy with respect to both location and groundwater elevation. Twenty-eight wells were surveyed using the survey-grade GPS, a Leica model provided by the U of A, and operated by the Edwards Aquifer

Authority. Anastacio Mondaca with the Edwards Aquifer Authority was the project professional in charge of aiding in these GPS surveys. The location data are reported in Appendix F, with results reported in decimal-degrees in the WGS84 or NAD83 horizontal coordinate system, and the WGS84 vertical coordinate system. Each of the wells for the synoptic water-level study is identified in Appendix F with coordinating information for each well found in the complete well inventory Appendices A-C relating to coordinating JA ID, but may also be identified within the well inventory by one or more aliases including; Well Owner, Texas Water Development Board (TWDB) well numbering identification system (state-ID, or tracking number), or Edwards Aquifer Authority pseudo-number ((Esquilin 2012; Hamiltion, 2006,2012).

Water Quality (QW) Sample Collection

The hydrologic properties of eleven wells from the study area (Table 6 and Figures 18, 19, and 20) were sampled for field parameters of water quality: temperature, conductivity, pH, dissolved oxygen (DO), and turbidity. Calibration of conductivity meters was performed using standards of known concentrations appropriate to the anticipated range of conductivity of the sampled water, and major-element geochemistry to evaluate areal distribution of water quality and indicate flow path geometry within the aquifer. PH was calibrated according to the manufacturer’s requirements, using a two or three point calibration with buffers of known concentration. DO is the amount of dissolved oxygen in a sample and varies with depth, temperature, and biological demand. DO measurements are accurately obtained by placing the probe within a "closed flow cell", excluding atmospheric contact with the water. Turbidity measures the quantity of suspended material in a water body.

The sampled wells were selected to incorporate their close proximity to the igneous intrusions within the study area, and their ability to reflect the potential flow-path of the Knippa Gap as determined by Green, 2006. The geochemical samples for this study were collected and analyzed by the Edwards Aquifer Authority, following their observed protocols and sampling standards. To ensure the reliability and interpretability of the collected data and locations, appropriate documentation was incorporated. Appropriate chain-of-custody information for collected samples was followed as stipulated by the Edwards Aquifer Authority, with the completion of the sampling report. Initial sampling reports contained the following information: location (and name) of well with coordinates, date and time of sampling, sampler name, and other relevant information pertaining to the well, such as depth, screened interval, casing condition, volume of water purged from the well, and duration and rate of pumping prior to sampling. Once collected, samples were stored and transported properly so as to prevent damage to containers or labels, minimize or eliminate degradation of the sample, and prevent contamination of the sample. Upon delivery to the analytical laboratory, information relating to the time between sample receipt and analysis, storage and preservation methodology employed at the laboratory, and analytical techniques used were documented (Department of Mines and Energy, 2009). The collected QW data were plotted and interpreted using both Stiff and Piper diagrams (Figures 18 and 19), which were then used to construct a conceptual model (Figure 19). This refined conceptual model allows the visualization of flow and karstification in the Knippa Gap area of the Edwards aquifer, and describes the dominant water chemistry which can be used to qualitatively assess the overall understanding of the system.

Hydrostratigraphic Methodology

Refined structural interpretation of the study area was assessed through the utilization of wireline and drilling logs, fault locations (shape file USGS), and previous structural interpretations. Digital images of geophysical logs were obtained from John Meyer (Texas Water Development Board Personal Contact), and "hard-copy" geophysical logs were provided by the Edwards Aquifer Authority. These logs were utilized to create "Top-Picks", for the top of the stratigraphic Edwards Group Formation (Figure 8) in the study area. The primary geophysical log types utilized were gamma ray, spontaneous potential, and resistivity; secondary log types used for comparison include porosity, neutron density, and caliper. The determination of the elevation of the top of the formations of the Edwards Group was synthesized into Appendix B, for easy access and incorporation between software. The geophysical logs in the table were also supplemented with drillers reports from the TWDB website (http://wiid.twdb.texas.gov/). These data were used to construct cross-sections within the Knippa Gap area, which will aid in a refined assessment of structural and stratigraphic controls on permeability, constrain a revised conceptual model (Figure 10) of the flow and karstification in this critical area of recharge to the Edwards aquifer, provide specific lateral boundaries, and vertical karstification zones which can be tested quantitatively.

RESULTS AND DISCUSSION

Water Level Interpretation

Synoptic groundwater-levels (in wells) are measured within a short period of time (hours or days) under near-identical hydrologic conditions. Groundwater level measurements are exceedingly important in assessing groundwater flow, as they describe the hydraulic head (energy distribution) of the water in the aquifer in three dimensions. The water-level data for this study was measured during the interval of July 17-July 23, 2012; a period of little precipitation and low water levels. In conjunction with previous water-level maps, the data (Appendix F) was used to assess the elevation of the potentiometric surface, determine hydraulic gradients, assess flow directions within the study area, and aid in delineation of aquifer boundaries (Esquilin 2012; Hamiltion, 2006,2012).

The water levels that were measured for the July 2012 synoptic study are included in database (Appendix F) containing location information and well data, and were plotted in ArcGIS (ArcMap 10.1) (Figures 15 and 16). These figures were overlain on a base map showing county lines, aquifer boundaries, faults, and surface geology to interpret the general potentiometric surface at the time of the synoptic-data collection. Interpretation of the water levels (Figures 15 and 16) was difficult, owing to the highly variable areal distribution of hydraulic heads. Even with supporting historical data (Hovorka et al., 2004; Esquilin 2012; Hamiltion, 2006, 2012), attempted contouring of the water level elevations for the wells in this area by hand and through computerization techniques using ArcMap 10.1 proved to be inconsistent. In a dominantly two-dimensional flow field down gradient, water-levels should be consistently lower however, the wells for this study showed no such pattern. The computer generated potentiometric surfaces did not show a consistent two-dimensional trend in flow directions, nor did the hand-contoured surfaces, honoring faults and surface geology. All maps had "dimples" and "peaks", consistent with a complex flow system, and can be explained by the following factors, or most likely a combination that varies aerially within the Knippa Gap study area: 1) vertical flow (three dimensional) along major faults, fractures, or karst conduits; 2) intense pumping from nearby irrigation wells; 3) well completion in different zones of varying secondary karstification; 4) variation in vertical recharge from linear line sources such as the Frio and Dry Frio Rivers; 5) variation in vertical recharge from overlying or underlying formations, and well-developed secondary karst flow zones near faults and fractures. These suggest point- and line-source flow (both confined and unconfined) in three dimensions with high variability within the system. Although these data were collected during the "off" season for farming there is still significant water withdrawal within the region creating unsteady three dimensional flow, and the variation of fault impacts in close proximity to wells (some faults act as short circuit pathways and allow water movement, while others act as barriers). These variances within the water-levels resulted in a non-planar surface and a highly un-reliable map from which to generalize regional flow trends, but were extremely beneficial in assessments of the overall system. These data in combination with the geochemistry, hydrostratigraphy, structural data, well yields, and water-levels from the synoptic study, indicate the uplifted area to the south of the Knippa Gap (Figures 3, 5, 15, and 16)are consistent with much less flow (and dissolution of the highly soluble evaporites). High well yields in the Knippa Gap area indicate increased flow through the region (Dr. Van Brahana Written and Verbal communication, 2013).

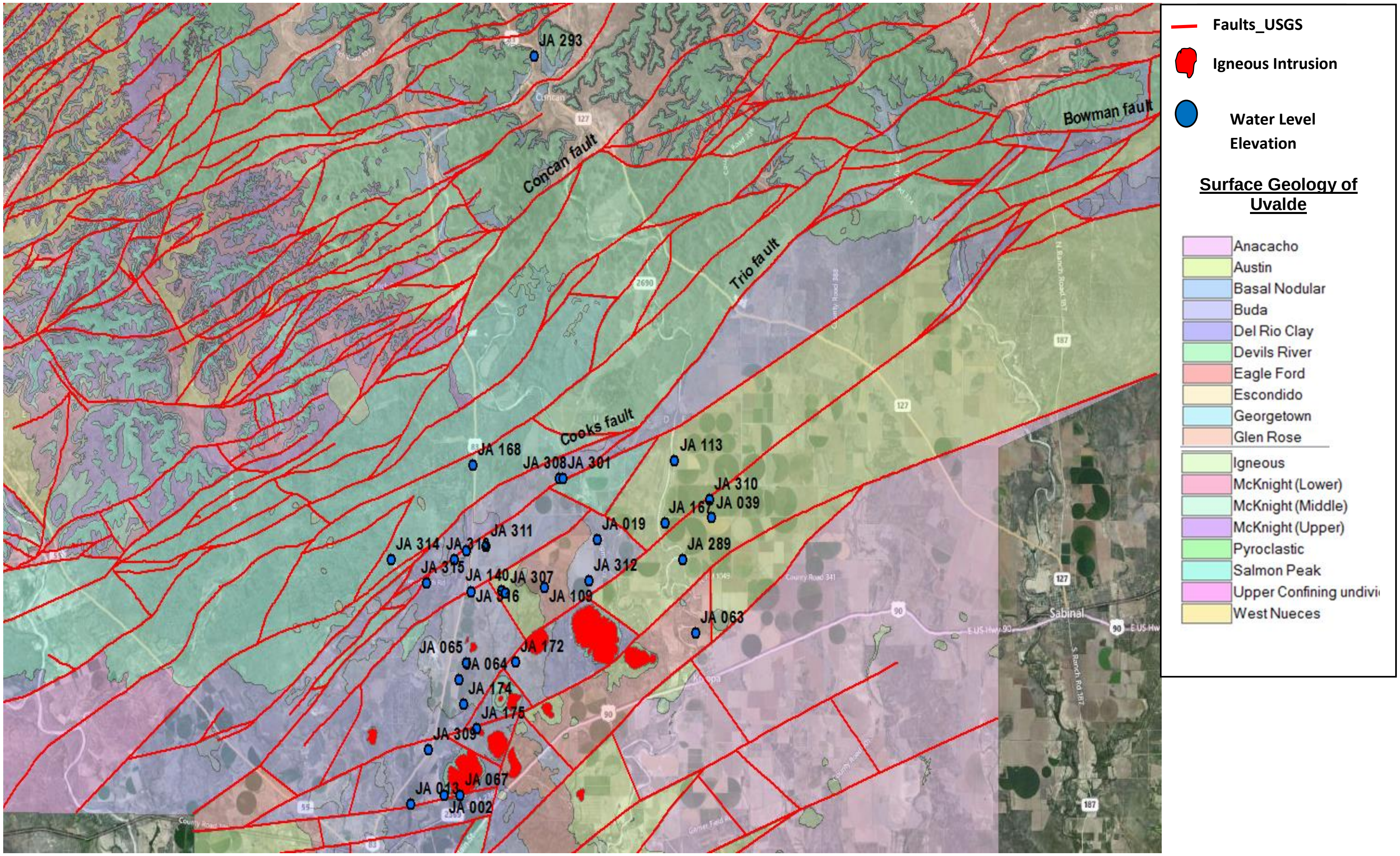


Figure 15. Data points for synoptic water level survey July 2012, and plotted water level elevation (low period), Referenced to Appendices A, B, C and F. Shape file data Provided by Edwards Aquifer Authority.

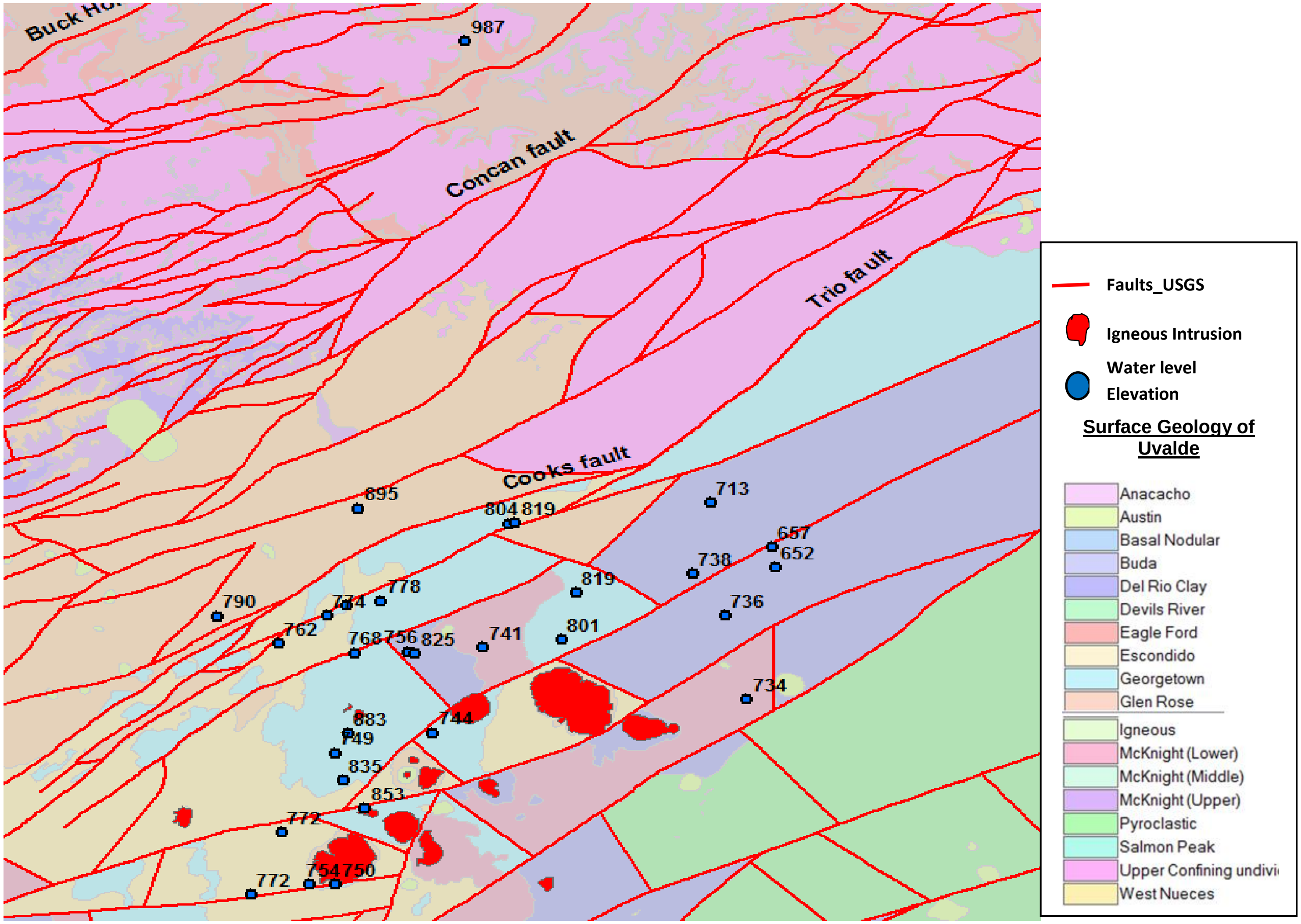


Figure 16 *Close view of synoptic water level results for study area, showing varying water-levels and the resulting complex potentiometic surface and plotted water level elevation. Locations are referenced in Figure 16 and data for each well are provided in Appendix F . Shape file data provided by Edwards Aquifer Authority.*

***Table 6.** Highest and Lowest recorded water levels for Uvalde County monitoring well (J27-YP69-50-302), 1934-2011: Modified from Edwards Aquifer Authority Hydrologic Data Report 2011.*

Year	High	Low		Year	High	Low		Year	High	Low
1934	-	-		**1962**	878.3	867.7		**1990**	872.9	861.6
1935	-	-		**1963**	869.7	860.9		**1991**	873.8	865.4
1936	876.6	876.5		**1964**	860.9	849.0		**1992**	885.2	872.9
1937	878.1	877.1		**1965**	865.8	860.3		**1993**	884.9	877.3
1938	875.8	874.0		**1966**	867.2	860.2		**1994**	-	-
1939	873.4	869.6		**1967**	867.4	856.4		**1995**	877.2	871.1
1940	872.3	868.5		**1968**	873.3	864.8		**1996**	874.2	859.0
1941	875.7	867.7		**1969**	875.0	866.5		**1997**	882.3	868.2
1942	875.8	871.9		**1970**	876.1	871.3		**1998**	880.6	868.7
1943	874.4	868.0		**1971**	877.7	864.0		**1999**	880.7	876.8
1944	869.3	866.8		**1972**	877.8	874.6		**2000**	878.3	868.0
1945	870.1	865.2		**1973**	881.6	874.5		**2001**	877.2	872.7
1946	867.1	862.9		**1974**	881.4	876.0		**2002**	883.2	876.3
1947	870.7	867.1		**1975**	882.1	879.4		**2003**	883.3	877.9
1948	868.4	860.5		**1976**	884.9	876.0		**2004**	884.9	879.2
1949	871.2	859.1		**1977**	886.2	881.3		**2005**	885.6	880.2
1950	871.2	861.8		**1978**	882.6	875.6		**2006**	879.3	868.6
1951	861.8	846.8		**1979**	882.0	876.1		**2007**	882.7	867.8
1952	846.8	834.9		**1980**	879.1	868.0		**2008**	882.6	873.4
1953	835.2	817.8		**1981**	881.8	867.9		**2009**	873.3	860.1
1954	836.7	823.1		**1982**	881.8	876.4		**2010**	867.0	862.2
1955	834.3	824.1		**1983**	877.1	871.3		**2011**	864.3	847.4
1956	834.2	814.2		**1984**	873.3	856.9				
1957	840.9	811.0		**1985**	876.9	862.2				
1958	866.1	840.8		**1986**	877.8	872.2				
1959	876.1	866.2		**1987**	889.1	877.9				
1960	876.9	873.1		**1988**	887.0	878.0				
1961	878.5	875.6		**1989**	879.0	866.6				
									High	**Low**
								Mean	**873.4**	**864.4**
								Median	**876.6**	**868**
								Record Level	**889.1**	**811**
								Month	**June**	**April**
								Year	**1987**	**1957**

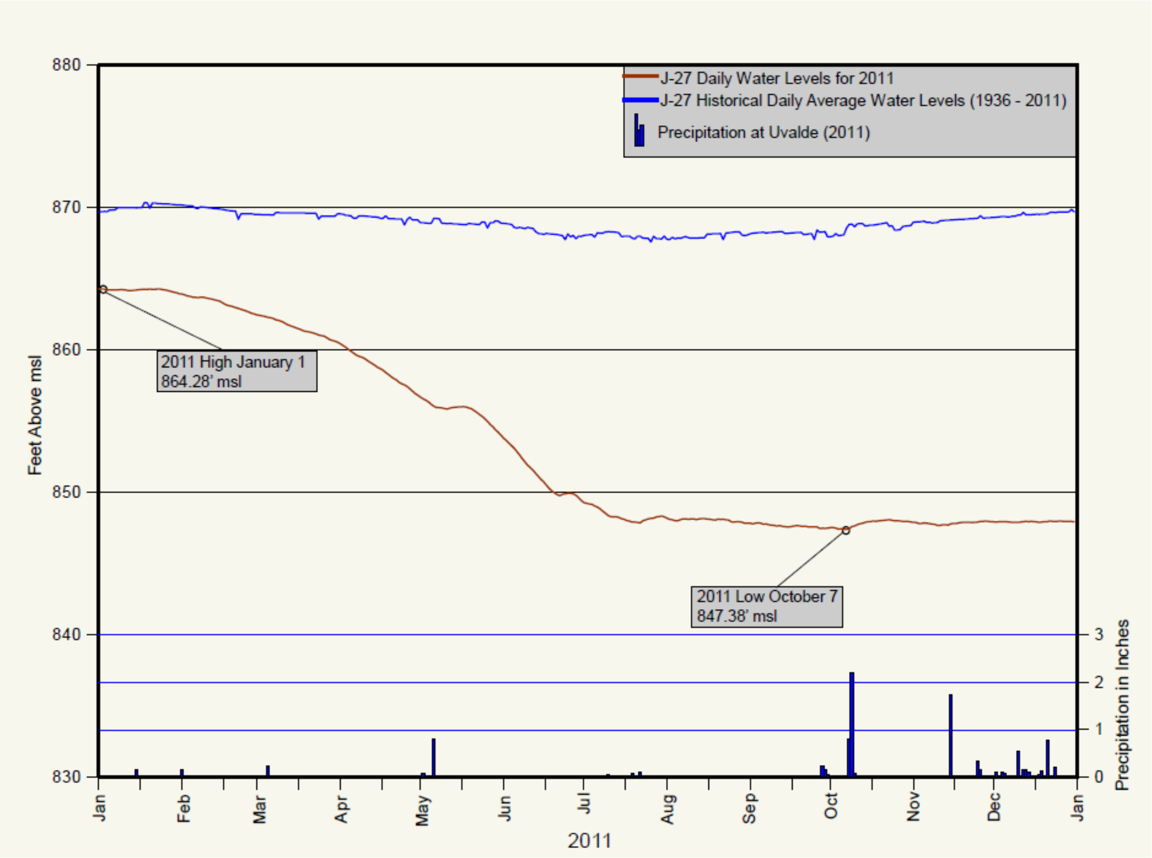


Figure 17. *Comparison of historical daily mean water level for the period of record 1936 –2011 and the daily high water level at the uvalde county index well, J-27 YP-69-50-302, JA 144 referenced in Appendix A, B, C, and D: (Modified from Edwards Aquifer Authority Hydrologic data Report for 2011)*

Geochemical Analyses

The hydrogeologic properties of eleven wells sampled for this research (Table 7, Figures 18, 19 and 20) were analyzed for field parameters and major-element geochemistry to evaluate areal distribution of water quality and to redefine flow boundaries in the conceptual model. The conceptual model (Figure 19) incorporates samples contiguous to the study area, displaying the major ion compositions of these samples. These data allow visualization of geochemically related waters and the determination of flow paths within the Knippa Gap. The location of high-capacity flow channels in the Edwards aquifer is consistent with other data describing the fresh-water channel identified using water-chemistry data. "Karst dominated flow systems are likely to have a complex variation in calcite saturation depending on the location of conduits and the scale of conduit flow" (Palmer, 1991). These data also facilitate an understanding of the geochemical processes acting in the flow system, and help to characterize evolution of water type in the aquifer. These should not be used alone to delineate the gap, but they are a good conceptual start to test alternative hypotheses.

Considering the complex faulting in the immediate area, they are consistent with structural and hydrostratigraphic basis for constructing the boundaries of the Knippa Gap. The resulting geochemical analyses from the study area indicate an increasingly high-flow zone of fresh water flowing through the Knippa Gap constriction. These analyses are consistent with observations from previous investigations regarding hydrochemical studies of the aquifer (e.g., Green et al., 2006; Maclay et al., 1980; Groschen, 1996). Table 7 shows the water quality and dissolved constituents in water from wells sampled within the study area. The Well ID in Table 7 is referenced to the QW Sites in Figure 20. Figure 20 includes 2 sample sites (QW site JA 293, and JA 003) that were excluded from the study owing to cation/anion imbalances outside the range of 5% error, these wells are also listed in Table 7 with NA representing excluded variables. Table 7 and Figures 18 and 19 indicate the presence of high sulfate and high chloride waters with higher specific conductance (701 to 1605 µS/cm) and higher temperatures (26.6 to 24.7 ^{o}C) that occur in wells within the Uvalde salient (QW Sites JA 288, JA 002, JA 290). Waters west (QW Sites JA 001, JA 317, JA 291, JA 064, JA 292, and JA 003) and east (QW Sites JA 289 and JA 063) of the salient are calcium-magnesium bicarbonate waters with lower dissolved solids (428 to 601 µS/cm) and slightly lower temperatures (23.5 to 25.1 ^{o}C). QW Site JA 291 represents the least mineralized of all wells sampled, not only in terms of specific conductance, but also in terms of the lowest concentrations of dissolved chloride and dissolved sulfate. Various degrees of mixing of waters from different sources are present in these latter wells, reflecting variations in lithologies along the flow path.

The average total dissolved solids (TDS) for Edwards water lies in the range of 200 to 500 mg/L (Hovorka et al., 2004), and are generally indicative of longer residence time and a longer flow-path, both of which result in increased dissolution. The TDS in the sample water can be calculated to an accuracy of plus or minus 2% from the electrical conductivity (EC) using the following formula: 0.70 * EC = TDS (Personal Communication Dr. Brahana, 2013). Groundwater geochemistry can be affected by a variety of geochemical processes including mineral-solution reactions, mixing with saline waters from other hydrostratigraphic units, and interaction with overlying soils and sediment (Musgrove et al., 2011). Data from the QW sites designated as Knippa Gap wells have Stiff diagrams representing the fresh fast-flow zones with dissolution acting as the main geochemical process. Knippa Gap QW sites plot within the carbonate dissolution field of the Piper diagram, and have calculated TDS values less than 400mg/L, supporting the high flow of the constricted flow path of the Knippa Gap. The QW sites with high specific-conductance, and higher concentrations of chloride and sulfate do not contain rapid groundwater flow zones and major karst development. Wells with these attributes overlie the Uvalde salient and or igneous intrusive region of the study area, suggesting greatly restricted flow. Well yields in this uplifted area are consistent with much less flow (and dissolution of the highly soluble evaporites) through this part of the aquifer, while high well yields in the Knippa Gap area indicate increased flow.

Table 7. *Selected water quality and dissolved constituents in water from wells in the study area. QW Site number is referenced to Figure 4. Chemical parameters are in mg/L. [QW, water quality; TDS, total dissolved solids, in mg/L; Cond, specific conductance, in µs/cm]*

Water Quality Used To Assess the Knippa Gap within the Study Area

JA ID	**TDS**	**Temp C**	**Cond**	**pH**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**ALK**	**HCO3^{-}**	**Cl^{-}**	**So^{4-}**	**Cations**	**Anions**	**%error**
JA 001	340	23.9	477	7.49	86.8	9.28	11.1	1.1	203	248	20.2	11.7	5.60	4.87	1.37
JA 002	877	24.7	1274	7.24	168	21.9	77.8	5.62	241	294	158	196	10.44	13.34	2.63
JA 003	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.44	4.88	1.09
JA 063	303	23.5	481	7.20	82.1	10.4	10.8	1.07	203	248	19.9	12.3	5.21	5.14	.078
JA 064	303	23.6	502	7.21	80.3	8.22	11.7	0.973	199	243	33.5	10.6	6.51	5.75	1.22
JA 110	365	23.8	448	7.19	93.2	9.57	24	1.09	215	262	51.1	19.2	17.33	18.54	-2.05
JA 288	1210	26.6	1605	6.98	277	27	28.1	2.91	169	206	72.9	630	5.29	4.56	1.47
JA 289	260	24.6 23.2 23.6	485 465 471	7.23 7.30 7.27 **(7.25)**	79.9	10.3	9.93	0.974	188	229	20.6	11	7.28	7.55	-.09
JA 290	376	24.7	701	7.16	93.1	17.8	25.6	2.36	200	244	555	55.9	4.58	4.20	4.8
JA 291	238	25.1	428	7.36	63.9	13	6.9	0.0971	179	218	14.1	11.5	6.14	5.82	.515
JA 292	344	23.2	601	7.37	88.8	9.19	21.3	0.962	212	259	42.8	18	5.48	5.03	.830
JA 293	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.60	4.87	1.37
JA 317	353	24	502	7.27	85.3	8.33	11.7	1.03	206	251	23.8	12	10.44	13.34	2.63

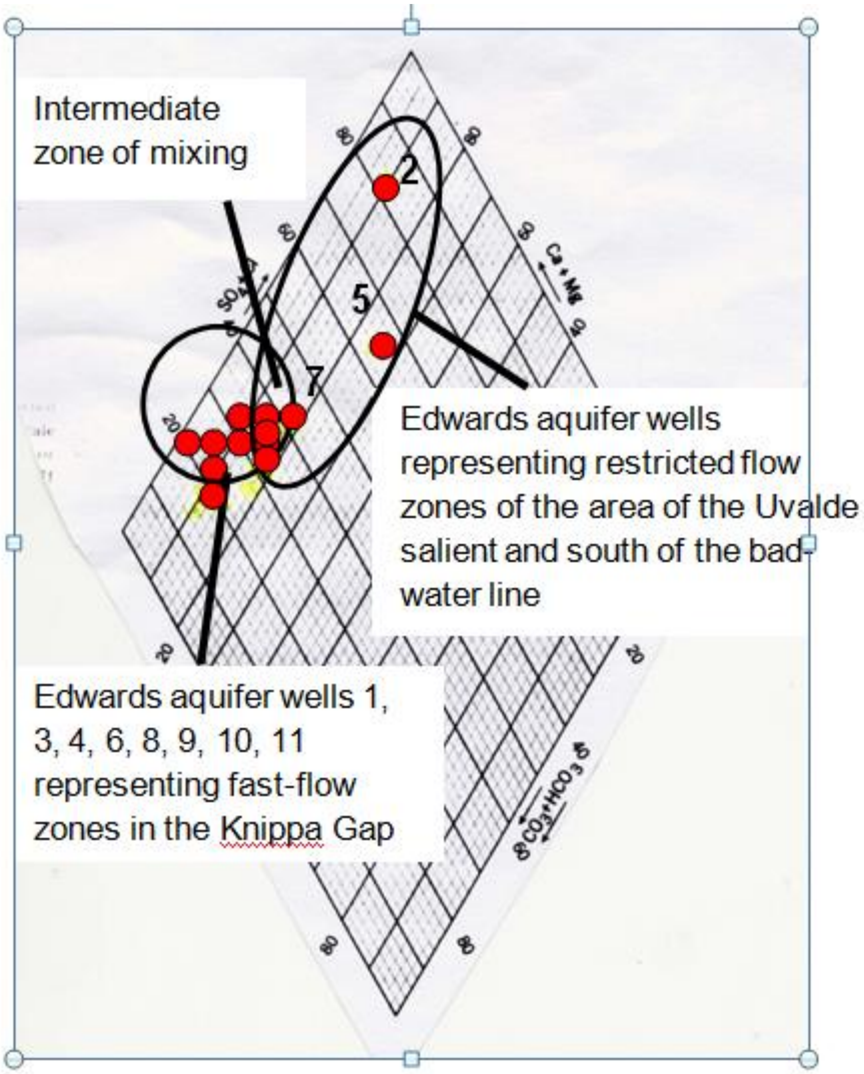


Figure 18. *Piper diagram of groundwater in the study area. The diagram shows quality types ranging from waters within the Knippa Gap (within black circle) to waters derived from mixing of high sulfate and chloride waters associated with residual evaporites in less dynamic flow zones (see wells 2, 5, and 7 in Table 3).*

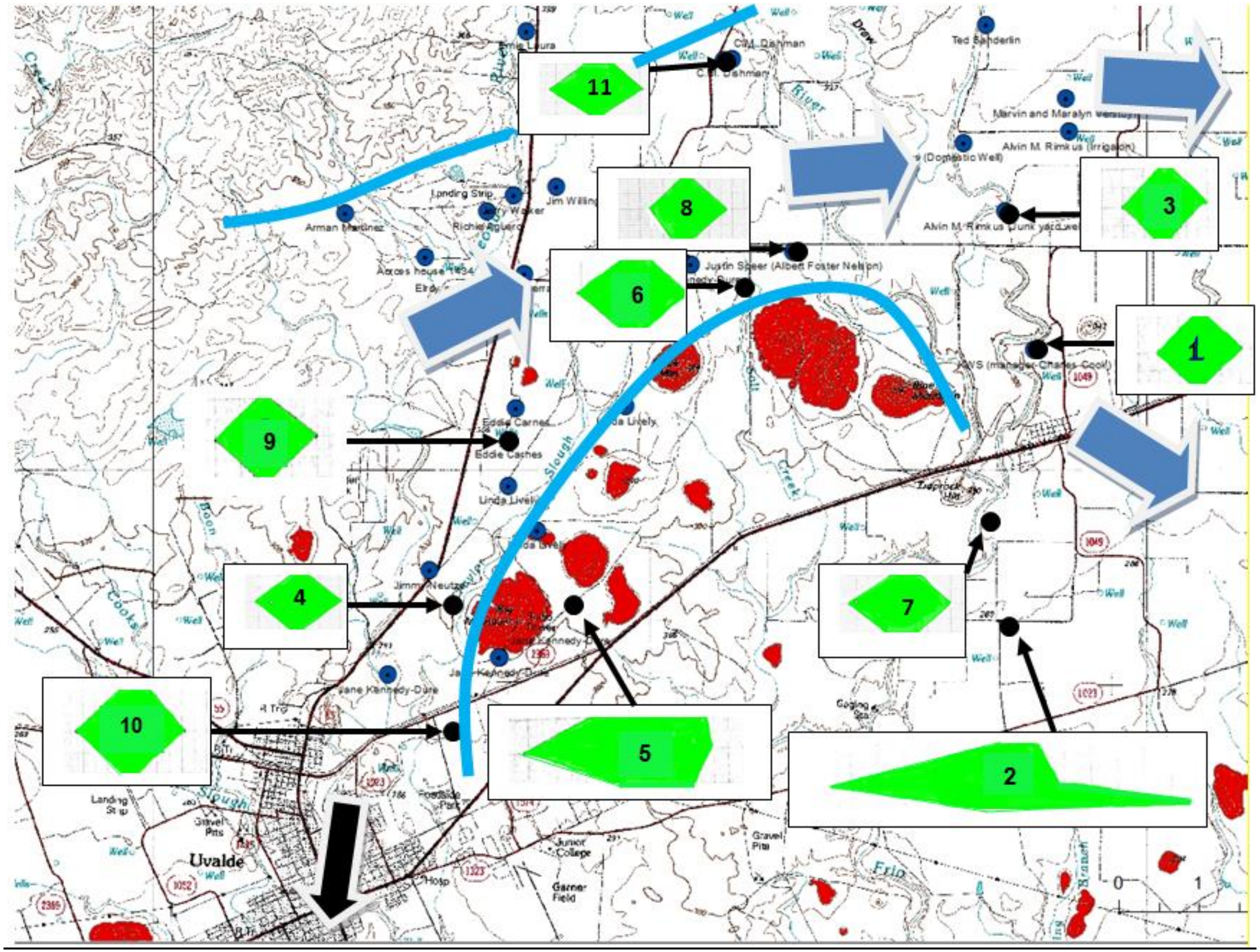


Figure 19. **Figure 19.** *Conceptual model of Edwards aquifer in the study area with Stiff diagrams. Stiff diagrams reflecting major element concentrations dissolved in groundwater (in green), approximate locations of boundaries of flow through the Knippa Gap (curved blue lines), major flow directions through the Knippa Gap constriction (blue arrows), subsurface overflow from the Uvalde Pool to the Leona gravels (black arrow), and exposures of igneous intrusives associated with the Devils River Trend of the Uvalde salient (in red). Sampling sites of wells for which chemical analyses are reported are shown by black dots: the numbers refer to the sampled wells discussed in table 3. [JA 063-QW 1, JA 288-QW 2, JA 289-QW 3, JA 001-QW 4, JA 002-QW 5, JA 317-QW 6, JA 290-QW 7, JA 291-QW 8, JA 064-QW 9, JA 292-QW 10, JA 003-QW 11]*

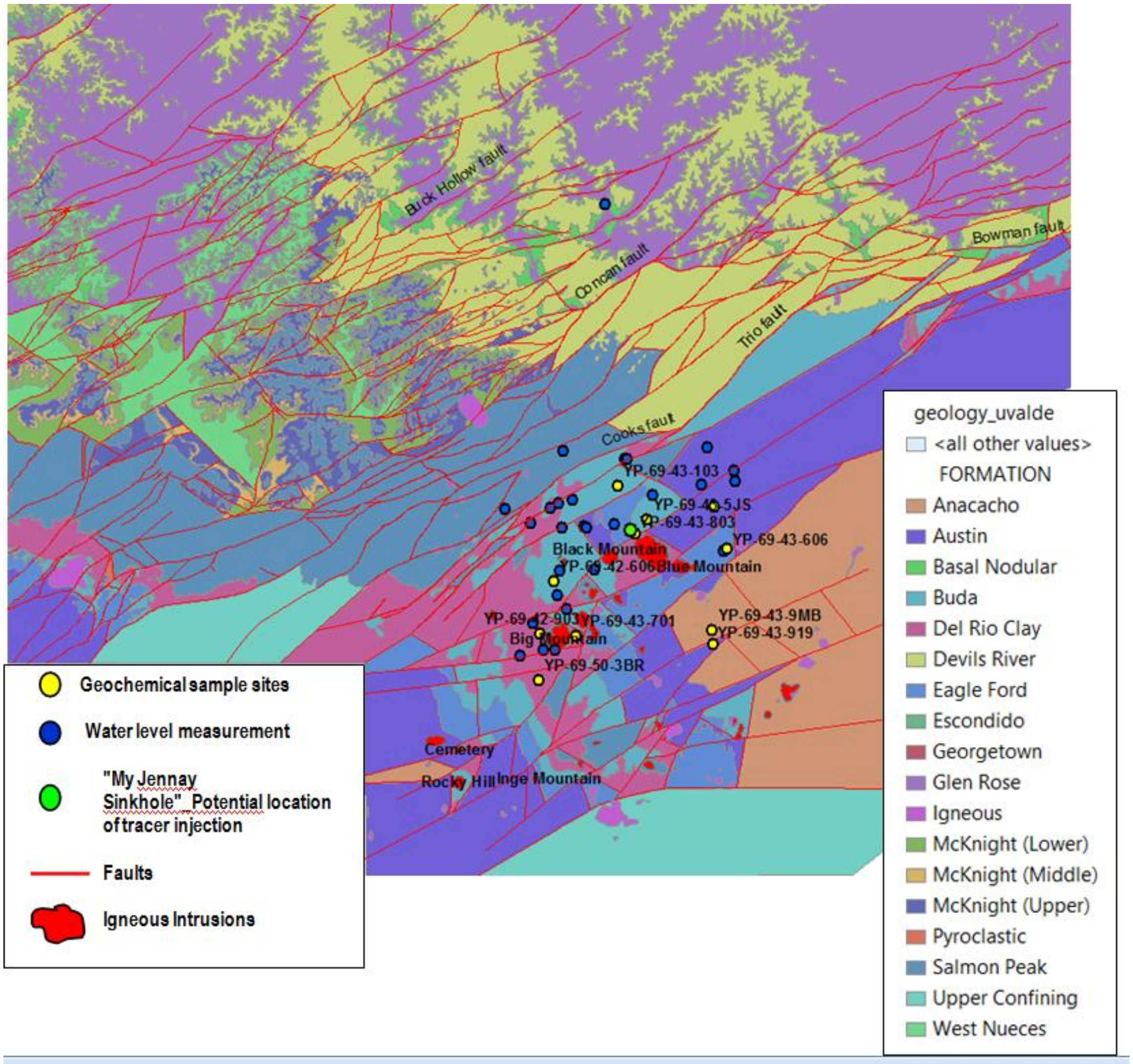


Figure 20. *Geology of the Edwards aquifer in the study area. The geology includes areal geology, faulting associated with the BFZ (red lines), exposures of igneous intrusives associated with the Devils River Trend of the Uvalde salient (in red), and sampling sites of wells used to measure water levels and collect groundwater samples. The numbers refer to the sampled wells discussed in Appendix A. [Map modified from multiple sources, including Clark, 2003; Green, 2006, and personal communications with Vic Hilderbran, Uvalde County Water Conservation District and Rob Esquilin, Edwards Aquifer Authority].Shape file Data provided by Edwards Aquifer Authority.*

Hydrostratigraphic Analysis.

As Maclay and Land (1988), Maclay (1995), and Green et al. (2006) have previously indicated, the Knippa Gap is the most dominant geologic feature that affects groundwater flow in the study area between the Uvalde pool and the San Antonio pool of the Edwards aquifer. This study reinforces that interpretation. The combination of structural deformation and karstification has juxtaposed soluble rocks in a dynamic flow system such that secondary permeability has been greatly enhanced in the rocks of the Salmon Peak Formation to intervals as deep as the McKnight Formation (Figures 22 and 23).

Figure 22 summarizes a suite of wireline logs of well JA-289, which reflects the vertical complexity of eight identifiable flow zones aligned along bedding planes within rocks of the Edwards aquifer. It is thought that these flow zones and the faults contribute to three-dimensional flow that is extremely complex, as reflected by the water-level measurements determined during the synoptic potentiometric run discussed previously. Based on flowmeter results (Figure 22), the Salmon Peak Formation has a well-developed flow zone from 342 to 350 feet depth (immediately below the base of the casing) that receives flow under conditions at well JA-289 during the time period January 27-28, 2012. Sequentially downward, the next high-permeability zone yields water to the well from 366 to 374 feet depth, the third zone loses water to the aquifer from 391 to 395 feet below land surface, the fourth zone gains water from the interval 412 to 422 feet below land surface, the fifth zone yields water to the well from 450 to 458 feet below land surface, the sixth zone loses water from the well to the aquifer at a depth of 504 to 512 feet below land surface, the seventh zone provides water from the aquifer to the well at a depth of 814 to 818 feet below land surface, and the final zone gains significant water from the aquifer to the well at a depth of 824 to 833 feet below land surface. It should be mentioned that these high-permeability flow zones can reverse flow directions based on stresses in the immediate vicinity of the high-permeability zone and the proximity to and hydraulic characteristics of nearby faults. Other factors that affect flow and interconnection of high-permeability within this stratigraphic sequence (Figure 8) are; degree of hydraulic sealing, nearby pumping, and nearby point- and line-sources of recharge from surface streams.

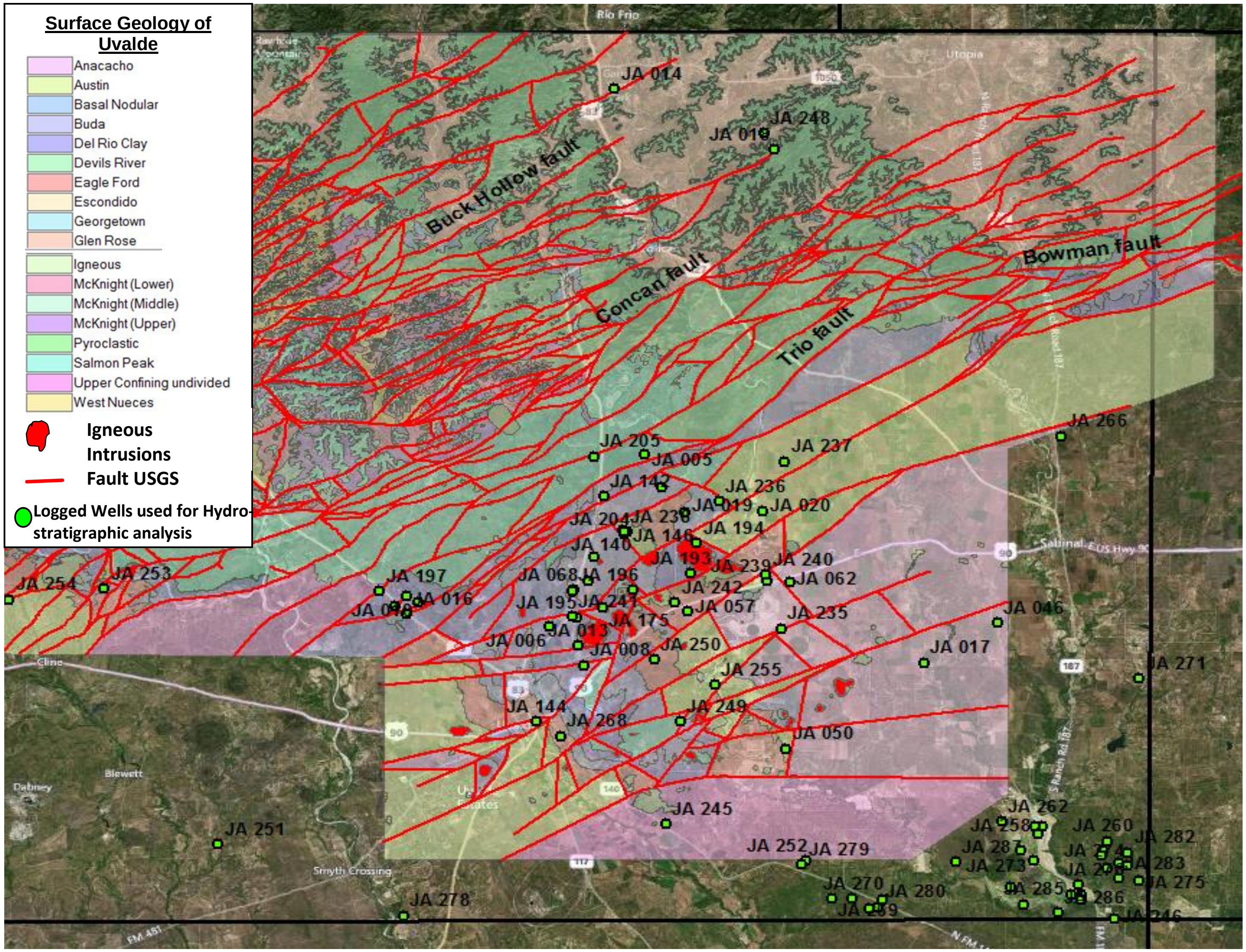


Figure 21. *Location of Wells used for hydrostratigraphic analyses within the Knippa Gap, labled with JA ID*

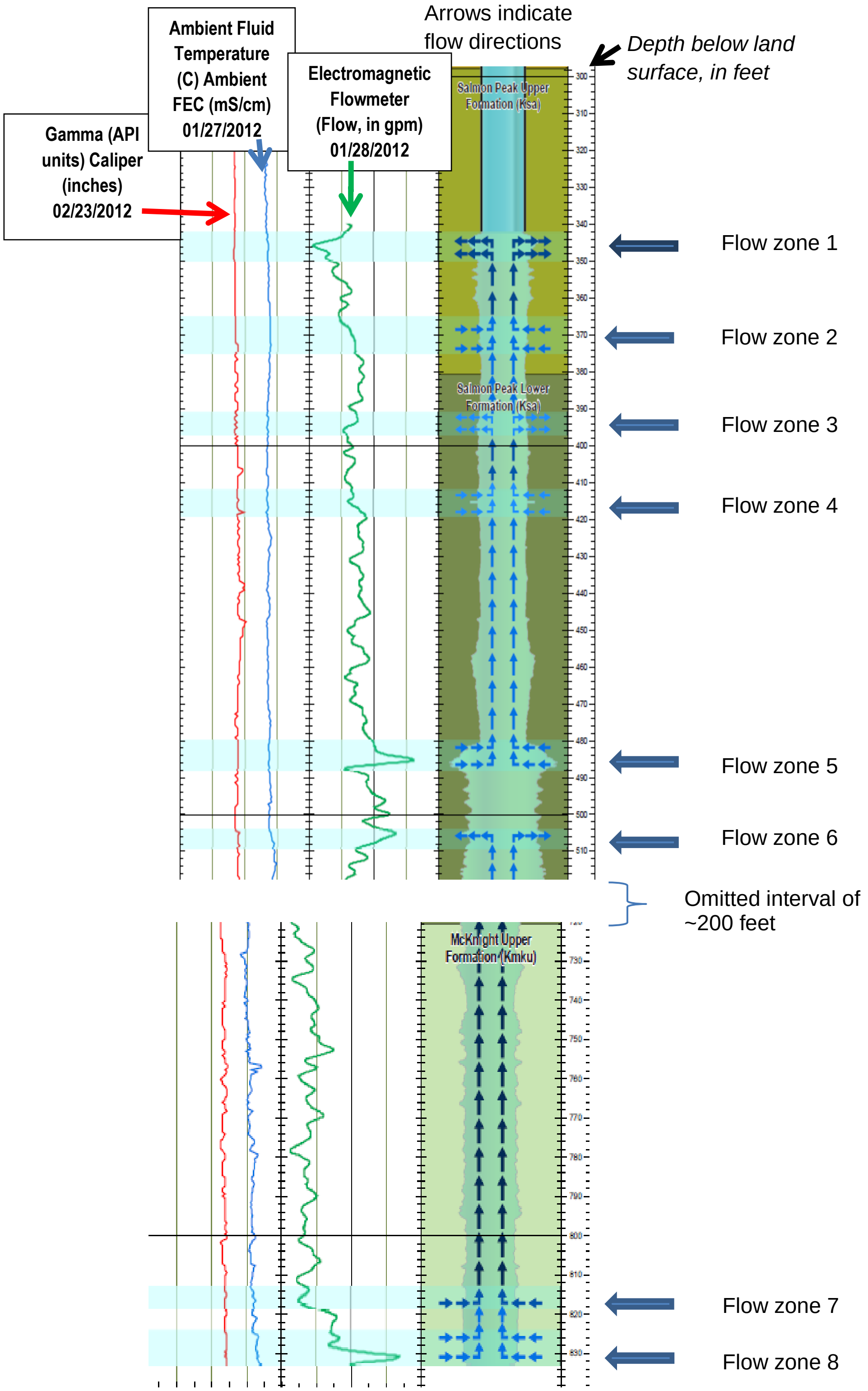


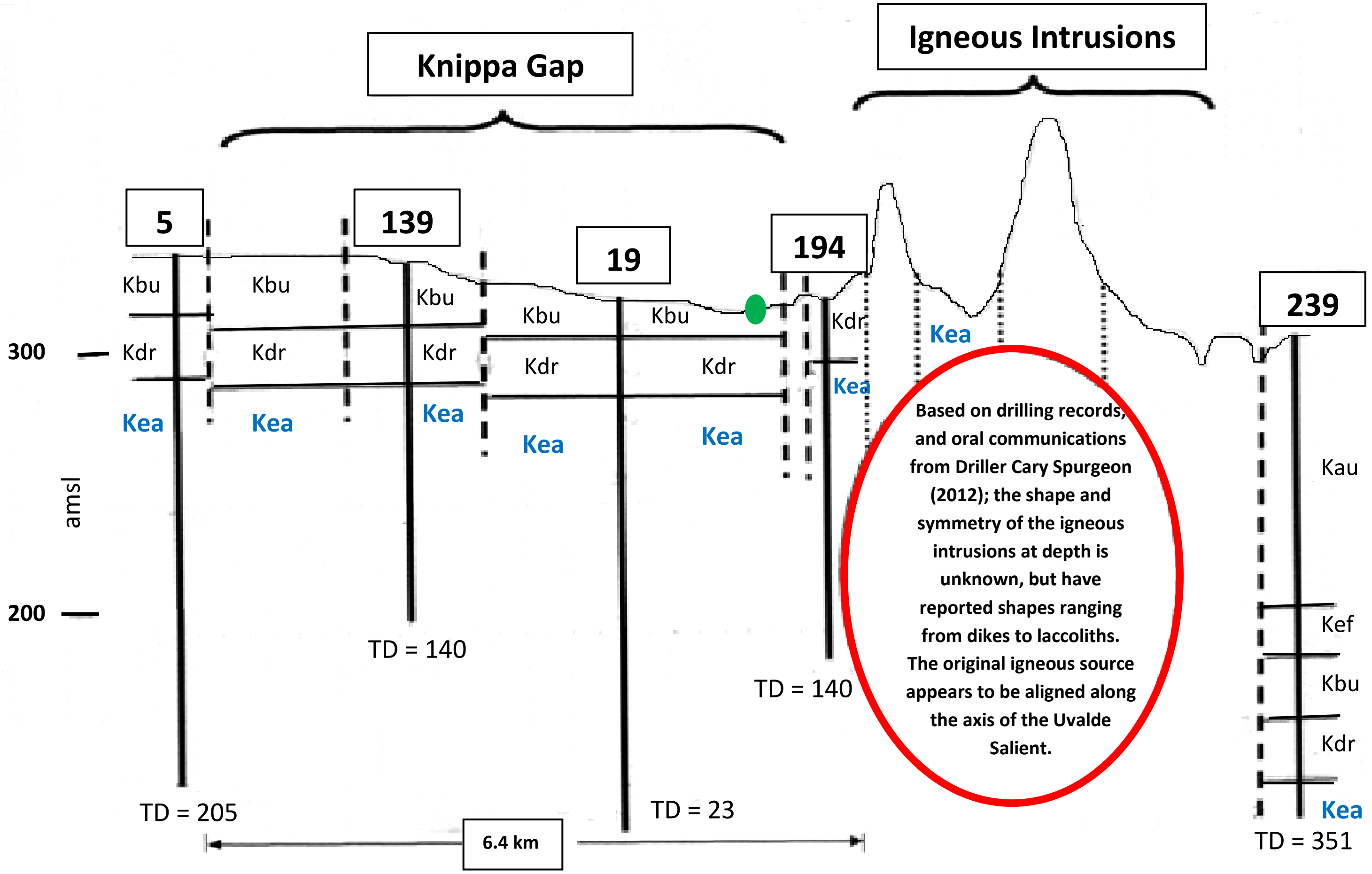
Figure 22. *Wireline logs of caliper, ambient fluid temperature, and electromagnetic flowmeter from well JA 289 showing eight separate flow zones and directions of flow in open borehole in the study area. In general, flow is hypogenic in this part of the Knippa Gap, from deeper to shallower flow zones*

Most of the flow through the Knippa Gap is in the Salmon Peak (the upper unit of the Edwards Formation), although deeper flow zones are present as indicated in Figure 22. The stratigraphy is significantly simpler in Uvalde County with only three distinct formations, while the area of Bexar County and San Antonio, has as many as eight individual zones reported for the Edwards aquifer (Hauwert, 2009; Maclay and Small, 1988; Hvorka et al., 2004). In the Knippa Gap study area, there is significant flow being contributed to the Edwards aquifer from the Frio and Dry Frio Rivers. Utilizing the existing models of the aquifer, in conjunction with the pumping data and water levels for the aquifer, and flow loss studies from the surface streams, one should be able to gain an approximate stage/discharge relation of the aquifer in the Knippa Gap constriction.

According to Green et al. (2006), the high-capacity zone of the Edwards aquifer is restricted to “an east-trending, narrow (i.e., 4–5-mi wide) band or channel in the middle of Uvalde County.” The location of this high-capacity flow channel is consistent with the fresh-water channel identified using water-chemistry data. "The northern and southern limits of the Edwards aquifer extend over a much broader area than the limited width of the channel. The contributing and recharge zones of the Edwards aquifer extend north of the channel where the saturated thickness of the Edwards aquifer is insufficient to transmit significant volumes of groundwater. To the south, the high-capacity flow channel of the Edwards aquifer is bordered either by the saline-water portion of the Edwards aquifer, where permeability is reduced by igneous intrusions, geologic structure, localized zones of reduced permeability, or some combination of these factors.” An analysis of geologic structure establishes the foundation for the interpretation of the high-capacity flow channels in Uvalde County. Maclay and Land (1988) identified geologic barriers that restrict groundwater flow, and geologic gaps and channels that convey groundwater flow in Uvalde County. The most notable of these geologic features affecting the groundwater flow regime in Uvalde County is the Knippa Gap (Maclay and Land, 1988; Maclay, 1995). Maclay and Land (1988) describe the Knippa Gap as "a narrow opening within an extensive, complex barrier system" that includes the combination of the Uvalde and Sabinal horsts and the Medina Lake Fault.

Green et al. (2006) also concludes that examination of the more detailed geological structure maps provided refinement to the structural geologic interpretation inherent in the Maclay and Land (1988) conceptual model. Geologic structural features that define the Knippa Gap and the associated high-capacity flow channel in Uvalde County are the Uvalde salient, Cooks Fault, a graben located due east of Knippa, and a deepening of the Edwards aquifer to the east of Knippa. This list of geologic features differs somewhat from the list by Maclay and Land (1988), but the underlying structural premise to the Knippa Gap is the same. That is, faulting associated with the BFZ and uplift identified as the Uvalde salient have developed a constriction in flow through the Edwards aquifer near the City of Knippa. The constriction is bounded to the north by Cooks Fault, north of which is the recharge zone. The east-northeast trending Cooks Fault is located approximately 4 miles north of the City of Uvalde and about 6 miles north of the City of Knippa. Cooks Fault effectively defines the northern limit of high-capacity Edwards aquifer irrigation wells, which in turn define the high capacity flow channel (the Knippa Gap) in Uvalde County. A continuation of Cooks Fault to the east where it crosses the Frio River is referred to as the Trio Fault by Blome et al. (2005). The northern boundary of the constriction and the high-capacity flow channel is referred to in this report as Cooks Fault for simplicity and because of uncertainty in the precise northern location of these features. Irrigation wells are not prevalent north of Cooks Fault (or Trio Fault), mostly because of the limited saturated thickness of the Edwards aquifer in the recharge zone (Green et al., 2006).

Final structural interpretation of the study area was assessed using wireline logs, drilling logs, fault locations based on shape files provided by the USGS (Allen Clark, written communication., 2012), and previous structural interpretations (Maclay, 1995; Clark, 2003; Hvorka et al., 2004, Green et al., 2006). Utilizing these interpretations, it was determined that the previous boundary dimensions as assessed in Green et al., (2006) approximating 4.02 km wide (2.5 mi) can be expanded to 6.4 km wide (3.98 mi). All information, especially Maclay (1995) and Clark (2003), led to the conclusion that the northwest boundary for the Knippa Gap is the Cooks Fault and Trio Faults, while the southeast boundary is determined by the uplifted zone associated with the igneous intrusions of the Uvalde salient (Figure 20).



Based on drilling records, and oral communications from Driller Cary Spurgeon (2012); the shape and symmetry of the igneous intrusions at depth is unknown, but have reported shapes ranging from dikes to laccoliths. The original igneous source appears to be aligned along the axis of the Uvalde Salient.

Figure 23. *Refined hydrostratigraphic model and cross-section, using wells JA 5, 139, 19, 194, and 239 (Appendix E) picks from geophysical and drillers report logs. Indicating the Edwards Group Formations in blue, karst feature (My Jennay Sinkhole) in green, and Igneous intrusive plugs outlined in red below. [**Kau** – Austin Chalk Formation; **Kef** – Eagle Ford Shale Formation; **Kbu** – Buda Formation; **Kdr** – Del Rio Clay (upper confining unit); **Kea** – Top of Edwards Formation; My Jennay Sinkhole - ● ; Igneous Inrusive plugs ○.]*

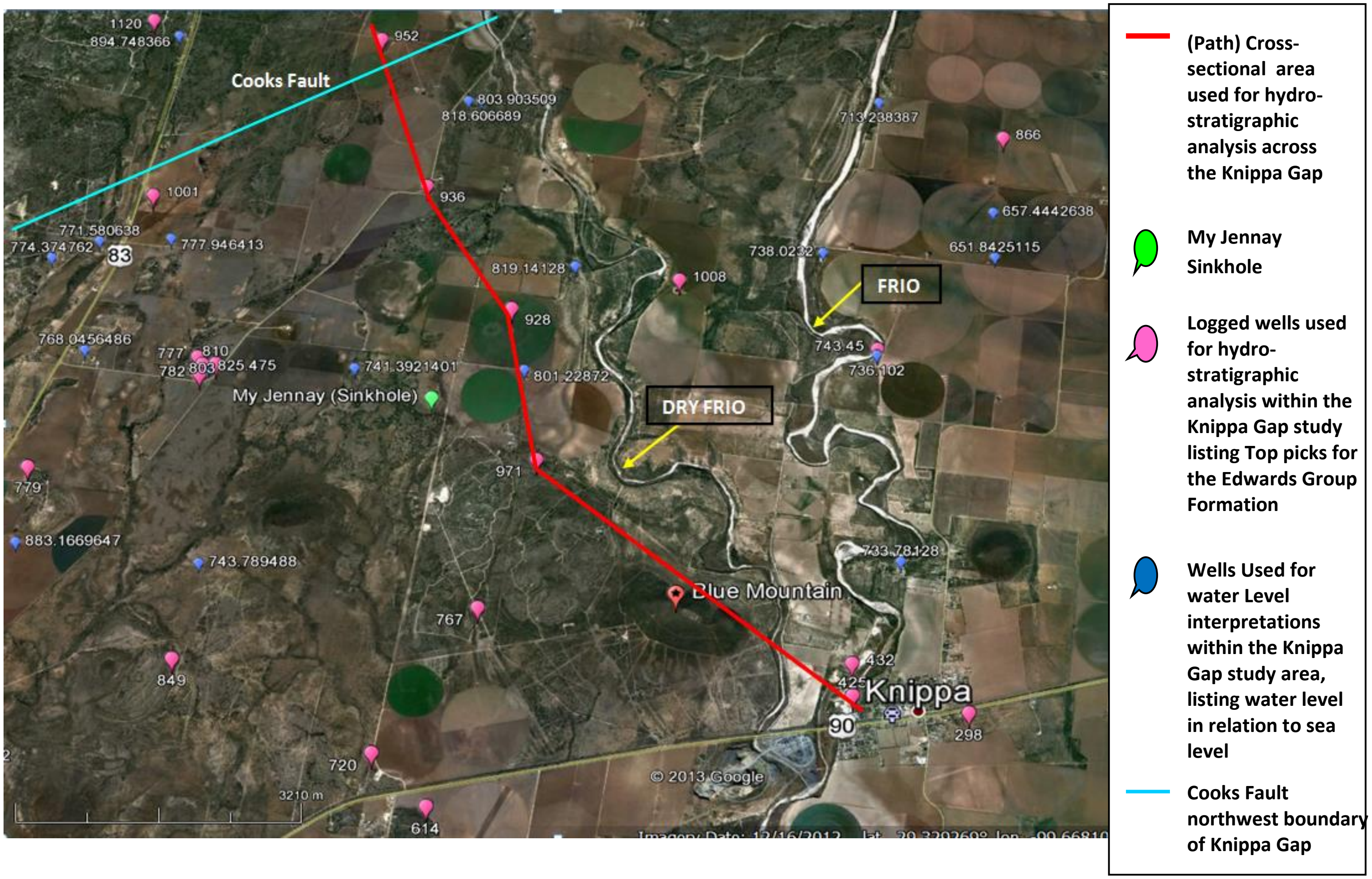


Figure 24 *Google Earth image displaying well locations for cross-sectional area used to create the refined hydrostratigraphic model and cross-section (Figure 23), wells included in cross section are as follows: JA 5, 139, 19, 194, and 239 as referenced in (Appendix A). These wells as well as the other logged wells used for the hydrostratigraphic assessments of the Knippa Gap are indicated in pink, and refer to (Appendix E). The associated water-levels for this study collected during July, 2012 are also indicated in blue with associated water-levels listed, referenced in (Appendix F).*

CONCLUSIONS

The objective of this report was to expand understanding of groundwater storage, structural constraints, and flow concepts of the Edwards aquifer in the area of the Knippa Gap, in Uvalde County Texas. Optimization of use of this heavily subscribed aquifer requires accurate quantification and realistic mapping of the relationships between the limestone matrix which stores most of the water, and the conduit system which transmits water into, through, and out of the aquifer. This balance between storage and drainage is a key variable needed for predicting sustainability of flow during periods of low recharge and heavy use (Hovorka, 2004). Because aquifers transmit water from sources of input to outflow (pipeline function), a water budget is essential in quantitatively understanding the amount of water that is available, including all additions, all losses, and change in storage (Fetter, 2001). It has been estimated that approximately 46% of the total average recharge to the San Antonio pool segment that flows through or is captured by stream-flow, can be attributed to recharge occurring in Uvalde County (Esquilin, 2012; Hamilton et al., 2008; Green et al., 2006). Further understanding of the water resources in Uvalde County will aid in the development of a refined conceptual model for groundwater flow, thereby producing more precise estimates for the water budget, for model calibrations, and for overall resource management. Aspects of the hydrogeology in the Knippa Gap have been a topic of major interest among researchers in this area for numerous years, however, the exact location and nature of boundaries are undefined, and the discharge through this area is not accurately known. The input data from this investigation will allow for these assessments to be made, as well as aid in the approximation of a water budget for the San Antonio Pool of the Edwards aquifer, and in the determination of accurate flow boundaries and budgets for Uvalde County. Construction of refined conceptual models of the flow-path and karstification in the Knippa Gap area of the Edwards aquifer (Figures 19 and 23) provide specific lateral boundaries and vertical karstification zones, and depict dominant water chemistry which can be used to qualitatively assess our overall understanding of the system. The results of this study were able to expand on previous interpretations and assumptions relating to the Knippa Gap. Determining Cooks fault and the Trio fault combine to create the northwest boundary of the Knippa Gap, while the southern boundary is determined by the uplifted zone of igneous intrusive plugs and the Uvalde salient to the southeast. Based on hydrostratigraphic analysis and log interpretations associated with this study and other previous interpretations by the Edwards Aquifer Authority, it can be concluded that although the majority of the flow through the Knippa Gap is in the Salmon Peak (upper Edwards formation), there are deeper flow zones present (Figures 22 and 23).

Water quality analysis within the Knippa Gap indicate water that is fresh and dominantly calcium bicarbonate. The conceptual modeling of the QW (Figure 19) allows visualization of water type, major flow directions, and defines flow boundaries for the Knippa Gap. Stiff diagrams within the Knippa Gap indicate fresh fast-flow zones with dissolution as the primary geochemical process. The Knippa Gap QW sites also plot within the carbonate dissolution field of the Piper diagram, with calculated TDS values less than 400 mg/L. Both of these methods are demonstrated within the geochemical conceptual model (Figure 19) and are supporting evidence for the constricted flow path of the Knippa Gap. The resulting hydrostratigraphic data, water-quality data, and water-level data collected for this study constrain revised conceptual models that interpret the flow and water-quality in this critical area of recharge to the San Antonio pool, and provide specific lateral boundaries and vertical karstification zones. Well yields in this uplifted portion of the study area associated with igneous intrusive plugs and the Uvalde Salient are consistent. Whereas much less flow (and dissolution of the highly soluble evaporites) through the southern portion of the aquifer, and high well yields in the Knippa Gap area indicate increased flow and less mineralized fresh water. In order to determine accurate stage discharge relations within the Knippa Gap an accurate velocity must be obtained via dye trace injection and analysis. Hopefully this type of study will be undertaken as the next step in ascertaining a complete understanding of the of the Knippa Gap constriction.

SELECTED REFERENCES

Al-Rashidy, Said M., 1999, Hydrogeologic Controls of Groundwater in the Shallow Mantled Karst aquifer, Copperhead Springs, Savoy Experimental Watershed, Northwest Arkansas: unpublished M.S. thesis, University of Arkansas, Fayetteville.

Barker, R.A., and Ardis, A.F., 1996, Hydrogeologic framework of the Edwards-Trinity aquifer system, West-Central Texas: U.S. Geological Survey Professional Paper 1421-B, 61 p.

Blome, C.D., J.R. Faith, D.E. Pedraza, G.B. Ozuna, J.C. Cole, A.K. Clark,. T.A. Small, and R.R. Morris. 2005. Geologic map of the Edwards Aquifer recharge zone south-central Texas. U.S. Geological Survey. 1:200,000 sheet.

Clark, A.K., and Small, T.A. 1997. Geologic framework of the Edwards Aquifer and upper confining unit, and hydrogeologic characteristics of the Edwards Aquifer, south central Uvalde County, Texas: U.S. Geological Survey Water-Resource Investigations Report 97-4094. 11 p.

Clark, A. K., 2000,Vulnerability of ground water to contamination, Edwards aquiferrecharge zone, Bexar County, Texas, 1998: U.S. Geological Survey WaterResources Investigations Report 00-4149.

Clark, A. K., 2003, Geologic framework and hydrogeologic characteristics of the Edwards aquifer, Uvalde County, Texas: U.S. Geological Survey, Water Resources Investigations Report 2003-4010, 17 p.

Clark, S.K. and C.A. Journey. 2005. Hydrological and geochemical identification of flow paths in the Edwards Aquifer, northeastern Uvalde and northern Medina County, Texas. U.S. Geological Survey. Presentation to the Edwards Aquifer Technical Advisory Group. July 2, 2005.

Deike, R. G., 1990, Dolomite dissolution rates and possible Holocene dedolomitization of water-bearing units in the Edwards aquifer, south-central Texas: Journal of Hydrology, v. 112, no. 3-4, p. 335-373.

Dickinson, William R., Gehrels George E., Stern, Robert J., 2010, Late Triassic Texas uplift preceding Jurassic opening of the Gulf of Mexico: Evidence from U-Pb ages of detrital zircons. Geological Society of America

Department of Mines. 2009. Methodology for the Sampling of Ground Water. Minerals and Energy Advisory #: AA7-024.

Esquilin, Roberto., Hamilton, Mark J., Schindel, Geary M. 2012. Edwards Aquifer Synoptic Water Level Program 2005-2009 Walter Level Data. http://www.edwardsaquifer.org

Ferrill, D.A., Morris, A.P., Stamatakos, J.A., and Sims, D.W. 2000. Crossing conjugate normal faults: Bulletin of the American Association of Petroleum Geologists. V. 84. pp. 1543–1559.

Ferrill, D. A., and Morris, A. P., 2003, Dilatational normal faults: Journal of Structural Geology, v. 25, p. 183-196.

Ferrill, David A., Sims, Darrell W., Franklin Nathan, Morris, Alan P., Waiting, Deborah J.,2004, Structural Controls on the Edwards Aquifer/Trinity Aquifer interface in the Helotes quadrangle, Texas. Southwest Research Institute, San Antonio, TX 78238-5166 Department of Earth and Environmental Science, University of Texas at San Antonio.

Ferrill, D.A., Sims, D.W., Franklin, N., Morris, A.P., and Waiting, D.J. 2005. Structural Controls on the Edward Aquifer/Trinity Aquifer Interface in the Helotes Quadrangle, Texas. Final report prepared for the Edwards Aquifer Authority and the US Army Corps of Engineers.

Fetter C.W. 2001 Applied Hydrogeology (Fourth Edition), Prentice Hall Inc.

Gao, Chaochao., Robock, Alan., Ammann, Caspar. 2008. Volcanic forcing of climate over the past 1500 years: An improved ice core-based index for climate models, Journal of Geophysical Research. VOL. 113, D23111, doi:10.1029/2008JD010239, 2008.

Garza, S. 1962. Recharge, discharge, and changes in ground-water storage in the Edwards and associated limestones, San Antonio area, Texas, A progress report on studies, 1955-59: Texas Water Engineers Bull. 6201. 51 p.

Garza, S. 1966. Ground-water resources of the Edwards and associated limestones, San Antonio area, Texas, A progress report on studies, 1960-64: Texas Water Engineers Report 34. 36 p.

Green, R.T. 2006, Preliminary Investigation of the Groundwater Systems in the Wintergarden Groundwater Conservation District. Southwest Research Institute. Conducted for the Wintergarden Groundwater Conservation District.

Green, R.T., Beretti, F.P., Franklin, N.M., Ferrill D.A., Klar R.V., Morris, A.P., 2006, Evaluation of the Edwards Aquifer in Kinney and Uvalde Counties, Texas. Southwest Research Institute. Conducted for the Edwards Aquifer Authority.

Green, R.T., Bertetti, F.P., Wilcox B.P., McGinnis R.N., 2008, Investigation of the Groundwater Systems in the Wintergarden Groundwater Conservation District—Phase II. Southwest Research Institute. Conducted for the Wintergarden Groundwater Conservation District.

Green, R.T., Bertetti, F.P., McGinnis, Ronald., 2009a, Analysis of the Water Resources of the Area Centered Within and Near Uvalde and Zavala Counties and Review of a Report on a Potential Well Field and Pipeline in Uvalde County, Texas Final Report *Prepared for* City of Uvalde and Wintergarden Groundwater Conservation District *Prepared by* Geosciences and Engineering Division Southwest Research Institute, SWRI Project No. 20-14842

Green, Ronald. T, Beretti, Paul. F, McGinnis., 2009b, Investigating the Secondary Aquifers of the Uvalde County Underground water Conservation District Final Report. Geosciences and Engineering Division Southwest Research Institute.

Green,R.T., Bertetti, F.P., McGinnis, Ronald.,2009, Analysis of the Water Resources of the Area Centered Within and Near Uvalde and Zavala Counties and Review of a Report on a Potential Well Field and Pipeline in Uvalde County, Texas Final Report *Prepared for* City of Uvalde and Wintergarden Groundwater Conservation District *Prepared by* Geosciences and Engineering DivisionSouthwest Research Institute,SWRI Project No. 20-14842

Green, R.T., Bertetti F.P., McGinnis, Ronald., 2009, Measureing Floodplain Hydraulics of the Frio River where it Overlies the Edwards Aquifer, Final Report, Geosciences and Engineering Division Southwest Research Institute.

Green, R.T., and Bertetti, F.P.,2010, Investigating the Water Resources of the Western-Edwards Trinity Aquifer Final Report: Sutton County Groundwater Conservation District, Geosciences and Engineering Division Southwest Research Institute.

Green, R.T., Bertetti F.P., Hernandaz, Mariano., 2011, Ground Water Piracy in Semi-Arid Karst Terrains. U.S. Geological Survey Karst Interest Group Proceedings, Fayetteville Arkansas. p. 123-131

Green, R.T., Beretti, F.P., McGinnis, Ronald., Prikryl James., 2012, Measure Floodplain Hydraulics of Seco Creek and Medina River where They Overlie the Edwards Aquifer, Final report. Geosciences andEngineering Division Southwest Research Institute.

Groshen, G.E. 1996. Hydrogeologic factors that affect the flow path of water in selected zones of the Edwards Aquifer in the San Antonio region, Texas. U.S. Geologic Survey Water-Resources Investigation report 96-4046. 73p.

Groshen, G.E. and P.M. Buszka. 1997. Hydrogeologic framework and geochemistry of the Edwards Aquifer saline-water zone, south central Texas. U.S. Geologic Survey Water-Resources Investigation report 97-4133. 47p.

Halihan, Todd, Mace, R. E., and Sharp, J. M, 2000, Flow in the San Antonio segment of the Edwards aquifer; matrix, fractures, or conduits? *in* Sasowsky, I. D., and Wicks, C. M., Groundwater flow and contaminant transport in carbonate aquifers: Brookfield, Vermont, A. A. Balkema, p. 129-146.

Hamilton, Mark J.M., Esquilin, Roberto., Schindel, Geary M,. 2006. Edwards Aquifer Authority Synoptic Water Level Program 1999-2004 Report. http://www.edwardsaquifer.org

Hamilton, J.M., Johnson, Steve., Esquilin, Roberto., Burgoon, Chandal., Luevano, Gizelle., Gregory, David., Mireles, Jesse., Gloyd, Ron., Schindel, M. G,. 2012. Edwards Aquifer Authority Hydrologic Data Report for 2011.

Hauwert, N.M., 2009, Groundwater flow and recharge within the Barton Springs segment of t he Edwards aquifer, southern Travis and northern Hays Counties, Texas: Unpublished Ph.D. dissertation, University of Texas, Austin, 328 p.

Holt, C.L.R. 1956. Geology and water-resources of Medina County, Texas. Texas Board of Water Engineers Bulletin 5601. 97 p.

Holt, C.L.R., Jr. 1959. Geology and ground-water resources of Kinney County, Texas. U.S. Geological Survey Water-Supply Paper 1422. 213 p.

Hovorka, S.D., S.C., Ruppel, A.R. Dutton, and J. Yeh. 1993. Edwards Aquifer storage assessment, Kinney County to Hays County, Texas. The University of Texas at Austin, Bureau of Economic Geology, contract report to the Edwards Underground Water District under Contract No. 93-04-FO, 101 p.

Hovaorka, S.D., R.E. Mace, and E.W. Collins. 1995. Regional distribution of permeability in the Edwards Aquifer. Edwards Underground Water District Report 95-02. 128 p.

Hovorka, S. D., Dutton, A. R., Ruppel, S. C., and Yeh, J. S., 1996, Edwards aquifer ground-water resources: geologic controls on porosity development in platform carbonates, South Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 238, 75 p.

Hovorka, S. D., and Mace, R. E., 1997, Interplay of karst, fractures, and permeability in the Cretaceous Edwards aquifer: analogs for fractured carbonate reservoirs: Society of Petroleum Engineers Annual Conference, Geological Field Trip Guidebook, 35 p.

Hovorka, S. D., Mace, R. E., and Collins. E.W., 1998, Permeability structure of the Edwards Aquifer, south Texas—implications for aquifer management: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 250.

Hovorka, S.D., Thandar Phu, J. P. Nicot., Lindley, Adrien., 2004, Refining the Conceptual Model for Flow in the Edwards Aquifer—Characterizing the Role of Fractures and Conduits in the BFZ Segment: Final Contract, Bureau of Economic Geology.

Inglehart, H.H.,1967., Occurrence and Quality of Ground Water in Crockett County, Texas. Texas Water Development Board.Report 47.150 p.

Klimchouk, A. B., Ford, D. C., Palmer, A. N., and Dreybrodt, Wolfgang, eds., 2000, Speleogenesis—evolution of karst aquifers: National Speleological Society, Huntsville, Alabama, 527 p.

Klimchouk, A., 2007, Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective. Special Paper no. 1, National Cave and Karst Research Institute, Carlsbad, NM, 106 pp.

Kuniansky, E.L., and K.Q. Holligan., 1994, Simulations of flow in the Edwards-Trinity Aquifer system and contiguous hydraulically connected units, west-central Texas. U.S. Geological Survey. Water-Resources Investigations Report 93-4039. 40 p.

Labauch, Stephan E., 1997, Tectonic Map of Texas. Bauru of Economic Geology. http://www.beg.utexas.edu/UTopia/images/pagesizemaps/tectonic.pdf Accessed April 20th, 2013.

Longley, Glen, 1986, The biota of the Edwards aquifer and the implications for biozoogeography, *in* Abbott, P. L. and Woodruff, C. M., Jr., eds., The Balcones Escarpment, Central Texas: Geological Society of America, p. 51-54: http://www.lib.utexas.edu/geo/BalconesEscarpment/pages51-54.html

Mace, R. E., and Hovorka, S. D., 2000, Estimating porosity and permeability in a karstic aquifer using core plugs, well tests, and outcrop measurements, *in* Sasowsky, I. D., and Wicks, C. M., Groundwater flow and contaminant transport in carbonate aquifers: Brookfield, Vermont, A. A. Balkema, p. 93-111.

Maclay, R.W., P.L. Rettman, and T.A. Small. 1980. Hydrochemical data for the Edwards Aquifer in the San Antonio area, Texas. Texas Department of Water Resources. LP-131. 38 p.

Maclay, R.W., T.A. Small, and P.L. Rettman. 1981. Location and analysis of borehole data for the Edwards Aquifer in the San Antonio area, Texas. Texas Department of Water Resources. LP-139. 88 p.

Maclay, R.W., and T.A. Small. 1983. Hydrostratigraphic subdivisions and fault barriers of the Edwards Aquifer, south-central Texas. U.S.A.: Journal of Hydrology. V. 61. 127–146 p.

Maclay, R.W., and T.A. Small. 1984. Carbonate geology and hydrology of the Edwards Aquifer in the San Antonio area, Texas: U.S. Geological Survey Open-File Report OFR 83-537, 72 p. 14 sheets.

Maclay, R.W. and T.A. Small. 1986. Carbonate geology and hydrology of the Edwards Aquifer in the San Antonio area, Texas. Texas Water Development Board Report 296. 90 p.

Maclay, R.W. and L.F. Land. 1988. Simulation of flow in the Edwards Aquifer, San Antonio Region,Texas, and refinement of storage flow concepts. U.S. Geological Survey Water-Supply Paper 2336. 48 p.

Maclay, R.W. 1989. Edwards Aquifer in San Antonio: Its hydrogeology and management: South Texas Geological Society Bulletin, V. 30, no. 4, 11–28 p.

Maclay, R.W. 1995. Geology and hydrogeology of the Edwards Aquifer in the San Antonio area, Texas .U.S. Geological Survey Water-Resources Investigations Report 95-4186. 64 p+ attachments.

Mosher, S., Levine,J.S.F.,Carlson, W.D.,2007, Mesoproterozoic plate tectonics: A collisional model for the Grenville-aged orogenic belt in the Llano uplift, central Texas, The Geological Society of America V. 36.

Musgrove, M., Fahlquist, L., Stanton, G.P., Houston, N.A., and Lindgren, R.J., 2011, Hydrogeology, Chemical Characteristics, and Water Sources and Pathways in the Zone of Contribution of Public-Supply Well in San Antonio, Texas: U.S. Geological Survey Scientific Investigation Report 2011-5146, 194p.

Ogden, A. E., Quick, R. A., Rothermel, S. R., Lundsford, D. L., 1986, Hydrological and hydrochemical investigation of the Edwards aquifer in the San Marcos area, Hays County, Texas: Edwards Aquifer Research and Data Center, San Marcos, Texas, 364 p.

Painter, Scott., Jiang, Yefang, Woodbury, Allan., 2002, Edwards aquifer parameter estimation project final report: Southwest Research Institute, variably paginated.

Palmer, A. N., 1991, Origin and morphology of limestone caves: Geological Society of America Bulletin, v. 103.

Palmer, A. N., 2007, Cave Geology, Cave Books.

Powers, J, J. and Shevenell, Lisa, 1999, Transmissivity estimates from well hydrographs in karst and fractured aquifers: Ground Water, v. 38 no. 3, p. 361-369.

Raye, U., Anthony, E.Y.,Stern, R.J., Kimura, J., Ren, M., Chang, Q., and Tani, K. (2011). Composition of the Mantle Lithosphere Beneath South-Central Laurentia: Evidence form peridotite xenoliths, Knippa, Texas, Geosphere,7(3), 710-723. doi:10.1130/GES001618.1

Rose, P.R., 1972, Edwards Group, surface and subsurface, central Texas. Bureau of Economic Geology Report of Investigations 74:1-198.

Scanlon, B. R., Mace, R. E., Smith, Brian., Hovorka, Susan., Dutton, A. R., Reedy, Robert., 2001, Groundwater availability in the Barton Springs segment of the Edwards aquifer, Texas: numerical simulation through 2050: The University of Texas at Austin, Bureau of Economic Geology open file report http://www.beg.utexas.edu/environqlty/vadose/pdfs/webbio_pdfs/BartonSpringsFinalReportFeb2002.pdf, 99 p.

Schindel, G. M., Johnson, S. B., Worthington, S. R. H., Alexander, E. C., Jr., Alexander, Scott., Schnitz, Lewis., 2002, Groundwater chemistry changes during a recharge event in the karstic Edwards Aquifer, San Antonio, TX, Geologicial Society of America Abstracts with Program. http://gsa.confex.com/gsa/2002AM/finalprogram/abstract_44210.htm

Schindel, G.M., Johnson, Steven.,Alexander, E. Calvin., 2008, Hypogene processes in the Edwards aquifer in South-Central Texas, a new conceptual model to explain squifer dynamics: Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, Search and Discovery Article #80019.

Schultz, A. L., 1992, Using geophysical logs in the Edwards aquifer to estimate water quality along the freshwater/saline-water interface (Uvalde to San Antonio, Texas): Edwards Underground Water District Report 92-03, 47 p.

Schultz, A. L., 1994, Review and update of the position of the Edwards aquifer freshwater/saline-water interface from Uvalde to Kyle, Texas: Edwards Underground Water District Report 94-05.

Shevenell, Lisa, 1996. Analysis of well hydrographs in a karst aquifer: estimates of specific yields and continuum transmissivities: Journal of Hydrology, v. 174, p. 331-355.

Smith, D. V., Smith, B. D. Blome, C. D., Pierce, H. A., and. Lambert R. B, 2002, Cretaceous volcanic intrusives in the Edwards aquifer, Texas, as identified from a high-resolution aeromagnetic survey, http://txwww.cr.usgs.gov/aquifer/GSAposter_9NEW.pdf

Smith, Brian A., Hunt, Brian B., Schindel, M. Geary., 2005, Groundwater Flow in the Edwards Aquifer: Comparison of Groundwater Modeling and Dye Trace Results.

Stanton. G.P., Processes and Controls Affecting Anisotropic Flow in the Boone- St. Joe Aquifer In Northwestern Arkansas: unpublished M.S. thesis, University of Arkansas, Fayetteville.

Veni, George., 2009, The Great Plains, *in* Palmer, A.N., and Palmer, M.V., eds., Caves and Karst of the USA: National Speleological Society, Inc., p.200-210.

Welder, A.F., and Reeves, D.R., 1962, Geology and Ground-Water resources of Uvalde County, Texas: U.S. Geological Survey Bulletin 6212.

White, W.B., 2006, Fifty years of karst hydrology and hydrogeology: 1953–2003. In: Harmon RS, Wicks C (eds) Perspectives on karst geomorphology, hydrology, and geochemistry: a tribute volume to Derek C. Ford and William B. White. Geol Soc Am Spec Pap 404:139–152.

Williams, John, 2003, Borehole geophysics for investigation of ground-water contamination in fractured bedrock: U.S. Geologic Survey, Troy, New York.

Woodruff, C. M., and Abbott, P. L., 1986, Stream piracy and evolution of the Edwards Aquifer along the Balcones Escarpment, Central Texas, *in* Abbot, P. L., and Woodruff, C. M., Jr. eds., The Balcones Escarpment, central Texas: Geological Society of America Annual Meeting, p. 77-100.

Worthington, S. R.H., in prep, Conduits and turbulent flow in the Edwards Aquifer, Worthington Groundwater, contract report to Edwards Aquifer Authority.

Young, S.C., Doherty, J., Budge, R., Deeds, N., 2009, Application of PEST to recalibrate the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers – DRAFT. Contract report for the Texas Water Development Board by URS Corporation, Watermark Numerical Pty, Ltd, and Intera In

Appendix A: Correlated agency tracking numbers and study designations JA #.

[Appendix A abbreviations are as follows: JA ID – Jennifer Adkins Identifier; Owner – last reported owner to agencies searched; State Well – number assigned by Texas Water Development Board; State Tracker – number assigned by ; TWDB API – Texas Water Development Board American Petroleum Institute unique oil well number; TWDB Q NUM – Texas Water Development Board Q Number; USGS ID – United States Geological Survey Identifier; EAA ID – Edwards Aquifer Authority Identifier; SWRI ID – South West Research Institute Identifier; Historic ID – Historic Records Identifier in the TX database]

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 001	Box K, Limited, Jane Kennedy-Dure	6942903							
JA 002	Box K, Limited, Jane Kennedy-Dure	6943701							
JA 003	Briscoe Ranch, Inc.	6950310							
JA 004	Repeated entry. Deleted								
JA 005	Clifford Gee	6943101							
JA 006	Clyde Watkins	6942912							H-5-188
JA 007	Frank Speir	6942706							H-4-121
JA 009	Dolph Briscoe Jr.	6942716							
JA 010	Bobby De Rusha	6942710							
JA 011	Pete Stoy	6942606							
JA 012	Pete Stoy	6943406							
JA 013	Jane Kennedy-Dure	6942901							
JA 014	TPWD_Garner State Park	6927108							
JA 015	Edwards Underground	6936402							

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 016	Edwards Aquifer Authority	6942709							
JA 017	SAWS	6952202							
JA 018	G. C. Magruder Gulf Oil Corp.	6927601		42000000050000	Q-30				
JA 019	John Brigman	6943203							
JA 020	Maurice Rimkus	69433304							
JA 021	SAWS Turner Johnson	6952404					S.A. Water System		H-6-93
JA 022	Boyer Chisum	7040901					Edwards Aquifer Authority. Nueces River		G-3-19
JA 020	Maurice Rimkus	69433304							
JA 023	Susie White	6945402				YP-69-45-402			
JA 024	City of Sabinal	6945405							I-4-34
JA 025	City of Sabinal	6945406				YP-69-45-406			
JA 026	L.R. Cole	6945103				TD-69-45-103			
JA 027	Lester Matheney	6945203				TD-69-45-203			
JA 028	Lloyd Brown	6951204				YP-69-51-204			
JA 029	Lloyd H. Brown, Jr	6951205				YP-69-51-205			
JA 030	Eddie Koch	6944109							H-3-67
JA 031	Smith Brothers	6944203				YP-69-44-203			
JA 032	Jess Ward	6944204				YP-69-44-204			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 033	Eddie Faulkenberg	6944402				YP-69-44-402			
JA 034	T. M. Woodley, Jr.	6944405				YP-69-44-405			
JA 035	Harold Henkel	6943902							H-6-92
JA 036	Eddy Carnes	6943917				YP-69-43-917			
JA 037	John Dodson	6944101				YP-69-44-101			
JA 038	Maurice Rimkus	6943302				YP-69-43-302			
JA 039	Maurice Rimkus	6943303				YP-69-43-303	Rimkus02		
JA 040	Marvin Verstuyft	6943306				YP-69-43-306			
JA 041	Bruce Gilleland	6943503				YP-69-43-503			
JA 042	H. O. Niemeyer	6943601				YP-69-43-601			
JA 043	T. M. Woodley	6953701		42463001010000	Q-20				I-7-15
JA 038	Maurice Rimkus	6943302				YP-69-43-302			
JA 044	Dolph Briscoe	6952201							H-6-95
JA 045	Pat Johnson	6952403				YP-69-52-403			
JA 046	SAWS	6944902				YP-69-44-902			
JA 047	B.J. McCombs	6954602				TD-69-54-602			
JA 048	Cecil Reagan	6944806				YP-69-44-806a			
JA 049	Leslie Pepper	6945701				YP-69-45-701a			
JA 050	SAWS	6951606				YP-69-51-606			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 051	Hubert Waldrip	6944301				YP-69-44-301			
JA 052	Darlene Schaefer	6944302				YP-69-44-302			
JA 053	Mack Woodley, Jr.	6944601				YP-69-44-601			
JA 054	Charles Wooten	6944808				YP-69-44-808a			
JA 055	Thelma Thompson	6951301a				YP-69-51-301a			
JA 056	Edwards Aquifer Authority	6937402				YP-69-37-402			
JA 057	E. W. Knippa	6943804				YP-69-43-804			
JA 058	John Miyakawa	6943916				YP-69-43-916			
JA 059	Dick Swartz	6954201				TD-69-54-201			
JA 060	Mechler Bros.	6936602				YP-69-36-602			
JA 061	Henry Brothers	6936904				YP-69-36-904			
JA 062	Elmer Knippa	6943605				YP-69-43-605			
JA 063	Knippa WSC	6943606				YP-69-43-606			
JA 064	J. Allen Carnes	6942606					W101-586		H-5-109
JA 056	Edwards Aquifer Authority	6937402				YP-69-37-402			
JA 065	Ray Carnes	6951408				YP-69-51-408			
JA 066	Bobby De Rusha	6943403				YP-69-43-403			
JA 067	Jane Kennedy	6942902				YP-69-42-902			
JA 068	Homer Hargrove	6942911							H-5-185

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 069	Ms. T. R. Hutcherson	6943106							H-2-32
JA 070	H. H. Toone	6950309				YP-69-50-309			
JA 071	City of Uvalde	6951104				YP-69-51-104			
JA 072	La Moca Ranch	6951602							H-5-72A
JA 073	Sam Henderson	6945802							I-4-54
JA 074	Southwest Texas Jr.	6951102				YP-69-51-102			
JA 075	Agape Ranch	6951203				YP-69-51-203			
JA 076	Peyton & Roberts	6945501							I-4-51
JA 077	Russell Rehm	6945504							I-4-53
JA 078	Leslie Pepper	6945701				YP-69-45-701b			
JA 079	James Braden	6945702							I-4-52
JA 080	James J. Braden	6945703				YP-69-45-703			
JA 081	Werner Wiebolt	6945704							I-4-55
JA 082	Dolph Briscoe	6944703				YP-69-44-703			
JA 083	Linda Lively_Herndon	6944704a							H-6-89
JA 084	Cecil Reagan	6944806				YP-69-44-806b			
JA 085	Cecil Reagan	6944807				YP-69-44-807			
JA 074	Southwest Texas Jr.	6951102				YP-69-51-102			
JA 086	Ed Knippa	6943802				YP-69-43-802			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 087	E.W. Knippa	6943803				YP-69-43-803			
JA 088	E. W. Knippa	6943908				YP-69-43-908			
JA 089	Clint Bratcher	6943909				YP-69-43-909			
JA 090	Rickey Gimbler	6943912				YP-69-43-912			
JA 091	F. W. Langer	6944102				YP-69-44-102			
JA 092	Bruce Bishop	6944103							H-3-65
JA 093	Don Alspaugh	6944105				YP-69-44-105			
JA 094	Bruce Bishop	6944106				YP-69-44-106			
JA 095	Carl Mueke	6944110				YP-69-44-110			
JA 096	Jim Bediger	6944201				YP-69-44-201			
JA 097	H.C. Tindall	6944303				YP-69-44-303			
JA 098	Carson Wells	6944304				YP-69-44-304			
JA 099	J.V. Ranch	6944305				YP-69-44-305			
JA 100	George Knippa	6944401				YP-69-44-401			
JA 101	Sammy Newman	6944404				YP-69-44-404			
JA 102	T. M. Woodley, Jr	6944406				YP-69-44-406			
JA 103	Alvin Dornbush	6944407				YP-69-44-407			
JA 104	Eddie Faulkenberg	6944502				YP-69-44-502			
JA 105	Paul Dornbush	6944503							H-6-91

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 106	Lester Gilleland	6943502				YP-69-43-502			
JA 092	Bruce Bishop	6944103							H-3-65
JA 107	Knippa WSC	6943603							H-6-87
JA 108	Bobby De Rusha	6943402				YP-69-43-402			
JA 109	Julia J. Kennedy	6943408				YP-69-43-408			
JA 110	Dolph Briscoe	6943103				YP-69-43-103			
JA 111	Robert Buchanan	6943202							H-2-30
JA 112	Weldon Gilleland	6943205				YP-69-43-205			
JA 113	A. C. Sanderlin	6943301				YP-69-43-301b	Sanderlin		
JA 114	Roger and Marvin	6943305				YP-69-43-305			
JA 115	Marvin Verstuyft	6943307				YP-69-43-307			
JA 116	Maurice Rimkus	6943308				YP-69-43-308			
JA 117	Pete Stoy	6942606							H-5-109
JA 118	Senesa Ranch	6955701				TD-69-55-701			
JA 119	Cleary Farms	6946404				TD-69-46-404			
JA 120	Wimpy Wismer	6946405				TD-69-46-405			
JA 121	Edgar Kincaid	6945101							I-1-19
JA 122	George Driskill_Driskill Feed Yard	6945102				TD-69-45-102			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 123	L.R. Cole	6945104				TD-69-45-104			
JA 124	L.R. Cole & Sons	6945105				TD-69-45-105			
JA 125	M. S. Oliver	6945108				TD-69-45-108			
JA 126	Frederick McIntosh	6945109				TD-69-45-109			
JA 127	Dan Saunders	6945201				TD-69-45-201			
JA 128	Dan Saunders	6945202				TD-69-45-202			
JA 129	Fred Anderson	6945301				TD-69-45-301			
JA 131	Fred C. Anderson	6945303				TD-69-45-303			
JA 132	Ernen Haby	6946101				TD-69-46-101			
JA 133	Woodrow Glasscock	6946102				YP-69-46-102			
JA 134	Robert R. Woodwward	6938101				TD-69-38-101			
JA 135	Retamco Inc.	6938103				TD-69-38-103			
JA 136	Oscar Nester	6946902							I-5-76
JA 137	James E. Amberson	693890				TD-69-38-905a			
JA 138	Lucian Ward	6955501							I-5-86
JA 139	T.R. Hutcherson	6943109				YP-69-43-109			
JA 140	Toni Hull	6943410				YP-69-43-410			
JA 141	Dolph Briscoe	6943105				YP-69-43-105			
JA 142	Gerald Haby	6943108				YP-69-43-108			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 143	James Ray Carnes, Jr.	6951401					Edwards Aquifer Authority Carnes Farm		
JA 144	Edwards Aquifer Authority - City of Uvalde	6950302					City of Uvalde		H-5-1
JA 145	Edwards Aquifer Authority	6943607					Edwards Aquifer Authority-Knippa		
JA 146	Edwards Aquifer Authority	6943409				YP-69-43-409	Edwards Aquifer Authority_North Uvalde Well		
JA 147	West Medina WSC	6938906				TD-69-38-906			
JA 148	Charley Zinsmeister	6943905							H-6-96
JA 149	Jo Ann Poerner	6938603				TD-69-38-603			
JA 150	Hugo A. Saathoff	6946602				TD-69-46-602			
JA 151	Frank Alderson	6946302				TD-69-46-302			
JA 152	Earl Rowe	6946301				TD-69-46-301			
JA 153	T.W. Wheeler	6947701							I-5-78
JA 154	Freddie Gruff	69389xxa	151050			TD-69-38-9xxa			
JA 155	West Medina WSC	69389xxb	165292			TD-69-38-9xxb			
JA 156	Edwind Dulin	69469xx	37192			TD-69-46-9xx	PERMIT 2004064		
JA 157	Philip Jung	68311xxa	48742			TD-68-31-1xxa			
JA 158	JAMES DUROW,JR.	68311xxb	74790			TD-68-31-1xxb	PERMIT C102-124		
JA 159	JAMES P. DOROW JR.	68311xx	78737			TD-68-31-1xxc	PERMIT C102-162 LOT 14		

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 160	GARY MONTGOMERY	69381xxa	136381			TD-69-38-1xxa	PERMIT C102-814		
JA 161	JOHN B. HOWDESHELL	69381xxb	190610			TD-69-38-1xxb			
JA 162	Frank L. Lester	69461xx	226714			TD-69-46-1xx			
JA 163	HERMINA A SITTRE TRUST	69466xx	35476			TD-69-46-6xx			
JA 164	William and Kreg Bedinghaus	69468xxa	123352			TD-69-46-8xxa			
JA 165	Townes Pressler	69468xxb	215447			TD-69-46-8xxb			
JA 167	Maurice Rimkus	69433xxc	248583			YP-69-43-3xxc	PERMIT C103-514		
JA 168	Emie Lara	69434xxa	14637			YP-69-43-4xxa			
JA 169	Curtis Nelson	69434xxb	17993			YP-69-43-4xxb			
JA 170	Curtis Nelson	69434xxd	4947			YP-69-43-4xxd			
JA 166	Mark Huffstedler	69429xx	21680			YP-69-42-9xx			
JA 171	THOMAS HUPP	69434xxe	179224			YP-69-43-4xxe	PERMIT C103-171		
JA 172	Linda Lively Herndon	69434xxf	2033			YP-69-43-4xxf			
JA 173	ROY ANGERMILLER	69436xx	178797			YP-69-43-6xx			
JA 174	Linda Lively Herndon	69437xxa	2031			YP-69-43-7xxa			
JA 175	Linda Lively Herndon	69437xxb	4946			YP-69-43-7xxb			
JA 176	NUNLEY BROS. RANCHES	69445xx	144874			YP-69-44-5xx			
JA 177	BOBBY McINTOSH	69454xx	136377			YP-69-45-4xx			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 178	KENNETH SPENCE	69457xx	66703			YP-69-45-7xx			
JA 179	BILL MARLIN	69512xxa	166168			YP-69-51-2xxa			
JA 180	JOEL GOODE III	69512xxb	60982			YP-69-51-2xxb			
JA 181	RICHARD MARLIN	69512xxc	97714			YP-69-51-2xxc			
JA 182	RUSSELL JAMES	69512xxe	157588			YP-69-51-2xxe			
JA 183	Thompson Ranch	69516xxa	252566			YP-69-51-6xxa			
JA 184	Bob Willoughby and Cecil Atkisson	69515xx	143198			YP-69-51-5xx			
JA 185	Bob Willoughby and Cecil Atkisson	69516xxc	143196			YP-69-51-6xxc			
JA 186	SPANISH DAGGER	69437xxc	90203			YP-69-43-7xxc			
JA 187	RAY DABNEY	69511xxb	240315			YP-69-51-1xxb	PERMIT C103-476		
JA 188	ROY HERNDON	69444xxa	249420			YP-69-44-4xxa			
JA 189	MARK BIELSTEIN	69512xxd	140280			YP-69-51-2xxd			
JA 190	KENNETH COLE	69449xx	217466			YP-69-44-9xx			
JA 191	ROY HERNDON	69444xxb	249419			YP-69-44-4xxb			
JA 184	Bob Willoughby and Cecil Atkisson	69515xx	143198			YP-69-51-5xx			
JA 192	MARK BIELSTEIN	69512xxd	140280			YP-69-51-2xxd			
JA 193	Willis Lucas and Ryan Lucas		293705	42000000220000					
JA 194	Van L. Crapps		186172	42000000230000			PERMIT C102-293		

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 195	Vicky Hagen		295625	42000000260000					
JA 196	A.M. RIMKUS		143491	42000000270000			PERMIT C102-854		
JA 197	CAROL MURPH		256860	42000000300000					
JA 198	Curtis Nelson		5759	42000000310000					
JA 199								Fry #2	
JA 200								Fry #1	
JA 201								Fry #7	
JA 202								Fry	
JA 203								Roberts	
JA 204								Ware	
JA 205	Emie Lara							Spurgeon	
JA 206								Ware	
JA 207	B. Kingston								
JA 208	Bob Willoughby								
JA 209	Torres Ready-Mix, Inc								
JA 210	Briscoe Ranch								
JA 211	Texas Ag. Research Extension								
JA 212	John D. Smith								
JA 213						TD69477xx			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 214						TD69555xxa			
JA 215						TD69555xxb			
JA 216						TD69631xx			
JA 217						YP69601xx			
JA 218						YP69612xx			
JA 219						YP69511xxc			
JA 220						YP69511xxa			
JA 221						YP69529xx			
JA 222	Alvin M. Rimkus					YP69433xxa			
JA 223						TD69536xx			
JA 224						YP69369xx			
JA 225						YP69455xx			
JA 226						YP69458xx			
JA 227						YP69532xx			
JA 228						TD69546xx			
JA 229						YP69432xx			
JA 230						YP69448xx			
JA 231						YP69516xxb			
JA 232						YP69527xx			

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 233						YP69538xx			
JA 234	Briscoe Ranch						69503BB		
JA 235	Lawrance Freisenhan			42000000190000					
JA 236	Mr Boehme			42000000200000					
JA 237	Don Batot			42000000220000					
JA 238	Mr Thomas			42000000230000					
JA 239	South Texas Aggregates(A1)			42000000240000					
JA 240	South Texas Aggregates(A2)			42000000250000					
JA 241	Vicky Jean Hagen			42000000270000					
JA 242	Bruce Gilleland			42000000290000					
JA 243	Gorman Drilling Co			42000000020000	Q-12				
JA 244	Gorman Drilling Co.			42000000040000	Q-23a				
JA 245	B and S Drilling Co			42000000070000	Q-40				
JA 246	Skidmore Energy			42463303000000	Q-45				
JA 247	GORMAN, G. W.			42463001140000	Q-16				
JA 248	GULF OIL CORP			42463000060000					
JA 249	Pan American Petroleum Corp			42463000550000	Q-36				
JA 250	Pan American Petroleum Corp			42463000500000					
JA 251	Pan American			42463000400000	Q-35				

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
	Petroleum Corp								
JA 252	W.J. STEEEGER			42463000630000	Q-14				
JA 253	GREAT WESTERN DRILLING COMPANY			42463302990000					
JA 254	GREAT WESTERN DRILLING CO.			42463302980000					
JA 255	IKE HOWETH			42463000560000	Q-4				
JA 256	GORMAN DRILLING CO			42463001020000	Q-2				
JA 257	GORMAN DRILLING CO			42463001040000	Q-18				
JA 258	GORMAN DRILLING CO			42463001050000	Q-20				
JA 259	GORMAN DRILLING CO			42463001090000	Q-5				
JA 260	GORMAN DRILLING CO			42463001100000	Q-6				
JA 261	GORMAN DRILLING CO			42463001110000	Q-7				
JA 262	GORMAN DRILLING CO			42463000670000	Q-34				
JA 263	GENERAL CRUDE OIL CO			42463302880000	Q-24				
JA 264	TIGER OIL & GAS CO			42463000710000					
JA 265	IKE HOWETH			42463001300000	Q-9				
JA 266	TENNECO OIL CO & PENNZOIL UNITED INC			42463000100000					
JA 267	TIGER OIL & GAS			42463000240000					

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 268	E.A. BRANHAM, ET AL			42463000530000	Q-22				
JA 269	W.J. STEEGER			42463000700000					
JA 270	TIGER OIL & GAS CO			42463000730000					
JA 271	BENNETT & SORRELLS			42463000980000					
JA 272	TIGER OIL & GAS CO			42463001060000					
JA 273	TIGER OIL & GAS CO			42463001070000					
JA 274	GORMAN DRILLING CO			42463001180000	Q-23				
JA 275	GORMAN DRILLINGCO			42463001190000	Q-19				
JA 276	GORMAN DRILLING CO			42463001220000	Q-17				
JA 277	TIGER OIL & GAS CO			42463001230000					
JA 278	ROBERT BEAMON			42463000470000					
JA 279	GENERAL CRUDE OIL CO				Q-25				
JA 280	TIGER OIL & GAS CO			42463000750000					
JA 281	GORMAN Drilling Co				Q-29				
JA 282	GORMAN DRILLING CO			42463001170000	Q-28				
JA 283	GORMAN DRILLING CO			42463001200000	Q-21a				
JA 284	TIGER OIL & GAS CO			42463001260000					
JA 285	GORMAN DRILLING CO			42463001280000					

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 286	WESTERN OIL DEV CO			42463001330000					
JA 287	INTERNATIONAL NUCLEAR CORP			42463001360000					
JA 288	Jerry V. Allen and wife, Vicki K. Allen	6943919					W101-416		
JA 289	Alvin M. Rimkus (Junk Yard Well)						W101-394		
JA 290	Malvern Benke and Deborah Benke						W101-594		
JA 291	Justin Speer						W102-432		
JA 292	Briscoe Ranch, Inc.	6950311					W101-699		
JA 293	Stanstell					YP-69-43-1AS			
JA 294	Bobbie Parten							UV56	
JA 295	ME (Jerry) Walker							UV97	
JA 296	Sandy Murrey (spurgeon)							UV101	
JA 297	O.E. Robinson							UV115	
JA 298	Uvalde Memorial Golf Course							UV125	
JA 299	Uvalde Auction/ Lewis or Earl Capt							UV134	
JA 300	Leeroy Rummel							UV142	
JA 301	(Steve) C.M. Dishman						Dishman02	UV144	
JA 302	Raul Perez							UV153	
JA 303	John Jacobs							UV160	

JA ID	Owner	State Well	State Tracker	TWDB API NUM	TWDB Q NUM	USGS ID	EAA ID	SWRI ID	Historic ID
JA 304	Bob Willoughby and Cecil Atkisson							UV161	
JA 305	Bob Willoughby and Cecil Atkisson							UV162	
JA 306	Tom Eckbomb(?)							UV181	
JA 307	Toni Hull Collins		18464						
JA 308	(Steve) C.M. Dishman						Dishman01		
JA 309	Jimmy Neutze						Neutz		
JA 310	Marvin Verstuyft						Verstuft		
JA 311	Jim Willingham						Sutherland		
JA 312	Justin Speer (Albert Foster Nelson)								
JA 313	Richie Aguero						Aguero		
JA 314	Arman Martinez						Martinez		
JA 315	Un-Known						Across 1434		
JA 316	Elroy and Margarita Guerra						Elroy		
JA 317	Bruce Gilleland and wife, Linda Gilleland						W101-470		

Appendix B: Well Inventory latitude, longitude, elevation, and sourcing.

[Appendix B includes previous abbreviations and new ones as follows: Latitude DD – Latitude Decimal Degrees; Longitude DD – Longitude Decimal Degrees; TWDB WIID System – Texas Water Development Board Water Information Integration and Dissemination, an online searchable database for Texas wells; Aquifer Code – number assigned by

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 001	29.265555	-99.762777	TWDB_WIID System	985	TWDB_Interpolated From Topo Map	218EBFZA
JA 002	29.261944	-99.737221	TWDB_WIID System	983	TWDB_Interpolated From Topo Map	218EBFZA
JA 004	Repeated Entry. Deleted					
JA 003	29.246944	-99.756666	TWDB_WIID System	965	TWDB_Interpolated From Topo Map	218EBFZA
JA 005	29.370277	-99.719166	TWDB_WIID System	1110	TWDB	218EBFZA
JA 006	29.266388	-99.77611	TWDB_WIID System	977	TWDB_Interpolated From Topo Map	218EDRDA
JA 007	29.280277	-99.855555	TWDB_WIID System	1004	TWDB_Interpolated From Topo Map	218EBFZA
JA 009	29.277777	-99.869166	TWDB_WIID System	1040	TWDB_Interpolated From Topo Map	218EDRDA
JA 010	29.283888	-99.862777	TWDB_WIID System	1018	TWDB_Interpolated From Topo Map	218EBFZA
JA 011	29.293888	-99.7525	TWDB_WIID System	1013	TWDB_Interpolated From Topo Map	218EBFZA
JA 012	29.308611	-99.749721	TWDB_WIID System	1012	TWDB_Interpolated From Topo Map	218EBFZA
JA 013	29.254722	-99.758888	TWDB_WIID System	987	TWDB_GPS	218EBFZA
JA 014	29.59111	-99.739166	TWDB_WIID System	1412	TWDB_Interpolated From Topo Map	217HSTN
JA 015	29.419443	-99.610277	TWDB_WIID System	1095	TWDB_Interpolated From Topo Map	218EBFZA
JA 016	29.275277	-99.862222	TWDB_WIID System	1005	TWDB_Interpolated From Topo Map	218EBFZA
JA 017	29.245555	-99.55	TWDB_WIID System	882	TWDB_Interpolated From Topo Map	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 018	29.555277	-99.642221	TWDB_WIID System	1849	TWDB_Digital Elevation Model	N/A
JA 019	29.33583	-99.69444	TWDB_WIID System	1047	Geophysical Log	218EBFZA
JA 020	29.33861	-99.645833	TWDB_WIID System	1034	Edwards Aquifer Authority	218EDRDA
JA 021	29.198888	-99.623888	TWDB_WIID System	877	TWDB_Interpolated From Topo Map	218EBFZA
JA 022	29.394721	-100.002222	TWDB_WIID System	1120	TWDB	218EDRDA
JA 023	29.311388	-99.483054	TWDB_WIID System	933	TWDB_Interpolated From Topo Map	218EBFZA
JA 024	29.327221	-99.46861	TWDB_WIID System	953	TWDB_Interpolated From Topo Map	218EDRDA
JA 025	29.319443	-99.469999	TWDB_WIID System	948	TWDB_Interpolated From Topo Map	218EDRDA
JA 026	29.345833	-99.464722	TWDB_WIID System	975	TWDB_Interpolated From Topo Map	218EDRDA
JA 027	29.362777	-99.455555	TWDB_WIID System	983	TWDB_Interpolated From Topo Map	218EBFZA
JA 028	29.213611	-99.695277	TWDB_WIID System	965	TWDB_Interpolated From Topo Map	218EDRDA
JA 029	29.215833	-99.693055	TWDB_WIID System	955	TWDB_Interpolated From Topo Map	112LEON
JA 030	29.337777	-99.586388	TWDB_WIID System	998	TWDB_Interpolated From Topo Map	218EBFZA
JA 031	29.365833	-99.571388	TWDB_WIID System	1012	TWDB_Interpolated From Topo Map	218EDRDA
JA 032	29.345555	-99.580277	TWDB_WIID System	1004	TWDB_GPS	218EDRDA
JA 033	29.329999	-99.59361	TWDB_WIID System	998	TWDB_Level or Other Surveying Method	218EBFZA
JA 034	29.310833	-99.610833	TWDB_WIID System	994	TWDB_Interpolated From Topo Map	218EBFZA
JA 035	29.276389	-99.633611	TWDB_WIID System	955	TWDB_Interpolated From Topo Map	218EDRDA
JA 036	29.25079261	-99.64532925	TWDB_WIID System	936	TWDB_GPS	218EDRDA
JA 037	29.371666	-99.620832	TWDB_WIID System	1053	TWDB_Interpolated From Topo Map	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 038	29.347221	-99.638888	TWDB_WIID System	1034	TWDB_Interpolated From Topo Map	218EBFZA
JA 039	29.35089	-99.63411	Leica Survey Grade	959.8812315	Leica Survey Grade	218EBFZA
JA 040	29.358611	-99.628054	TWDB_WIID System	1033	TWDB_Interpolated From Topo Map	218EDRDA
JA 041	29.291944	-99.689721	TWDB_WIID System	987	TWDB_GPS	218EBFZA
JA 042	29.32111	-99.663333	TWDB_WIID System	1019	TWDB_Interpolated From Topo Map	218EBFZA
JA 043	29.14746327	-99.47838039	TWDB_WIID System	746	TWDB_Interpolated From Topo Map	218EBFZA
JA 044	29.21912745	-99.57838369	TWDB_WIID System	882	TWDB_Interpolated From Topo Map	218EBFZA
JA 045	29.1985727	-99.6164404	TWDB_WIID System	875	TWDB_Interpolated From Topo Map	Pat Johnson
JA 046	29.269999	-99.505555	TWDB_WIID System	892	TWDB_Interpolated From Topo Map	218EBFZA
JA 047	29.182777	-99.27111	TWDB_WIID System	855	TWDB_Interpolated From Topo Map	218EDRDA
JA 048	29.25995929	-99.5425492	TWDB_WIID System	895	TWDB_Interpolated From Topo Map	218EBFZA
JA 049	29.28495849	-99.4786582	TWDB_WIID System	912	TWDB_Interpolated From Topo Map	218EBFZA
JA 050	29.193333	-99.632499	TWDB_WIID System	876	TWDB_Interpolated From Topo Map	SAWS
JA 051	29.353333	-99.513611	TWDB_WIID System	1003	TWDB_Interpolated From Topo Map	218EBFZA
JA 052	29.339999	-99.519721	TWDB_WIID System	988	Level or Other Surveying Method	218EBFZA
JA 053	29.314722	-99.529721	TWDB_WIID System	1002	TWDB_Interpolated From Topo Map	218EDRDA
JA 054	29.275277	-99.572499	TWDB_WIID System	936	TWDB_Interpolated From Topo Map	218EDRDA
JA 055	29.22551627	-99.64838589	TWDB_WIID System	905	TWDB_GPS	218EBFZA
JA 056	29.45328754	-99.4731015	TWDB_WIID System	1158	TWDB_Interpolated From Topo Map	218EDRDA
JA 057	29.2760704	-99.6933872	TWDB_WIID System	974	TWDB_GPS	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 058	29.281666	-99.647499	TWDB_WIID System	971	TWDB_Interpolated From Topo Map	218EDRDA
JA 059	29.212738	-99.2983744	TWDB_WIID System	871	TWDB_Interpolated From Topo Map	218EDRD
JA 060	29.4216218	-99.5281034	TWDB_WIID System	1096	TWDB_Interpolated From Topo Map	218EBFZA
JA 061	29.408611	-99.523332	TWDB_WIID System	1074	TWDB_GPS	218EDRDA
JA 062	29.29218096	-99.6347742	TWDB_WIID System	978	TWDB_Interpolated From Topo Map	218EBFZA
JA 063	29.3111111	-99.6405556	TWDB_WIID System	1006	TWDB_GPS	218EBFZA
JA 064	29.293888	-99.7525	TWDB_WIID System	1013	TWDB_Interpolated From Topo Map	218EBFZA
JA 065	29.18274011	-99.73699976	TWDB_WIID System	890	TWDB_Interpolated From Topo Map	218EBFZA
JA 066	29.3224582	-99.733666	TWDB_WIID System	1052	TWDB_Interpolated From Topo Map	UNKNOWN
JA 067	29.254444	-99.751944	TWDB_WIID System	994	TWDB_GPS	218EBFZA
JA 068	29.28861	-99.761666	TWDB_WIID System	997	TWDB_Interpolated From Topo Map	218EDRDA
JA 069	29.35551294	-99.740055	TWDB_WIID System	1084	TWDB_Interpolated From Topo Map	218EDRDA
JA 070	29.2485713	-99.7547781	TWDB_WIID System	972	TWDB_Interpolated From Topo Map	218EBFZA
JA 071	29.23634948	-99.74727787	TWDB_WIID System	943	TWDB_Interpolated From Topo Map	218EBFZA
JA 072	29.175518	-99.6356077	TWDB_WIID System	866	TWDB_Interpolated From Topo Map	218EBFZA
JA 073	29.288055	-99.455833	TWDB_WIID System	903	TWDB_Interpolated From Topo Map	218EDRDA
JA 074	29.222499	-99.731666	TWDB_WIID System	955	TWDB_Interpolated From Topo Map	218EBFZA
JA 075	29.213055	-99.685833	TWDB_WIID System	950	TWDB_Interpolated From Topo Map	218EDRDA
JA 076	29.312777	-99.451388	TWDB_WIID System	932	TWDB_Interpolated From Topo Map	218EBFZA
JA 077	29.293888	-99.456666	TWDB_WIID System	914	TWDB_Level or Other Surveying Method	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 078	29.284999	-99.47861	TWDB_WIID System	912	TWDB_Interpolated From Topo Map	218EBFZA
JA 079	29.267499	-99.49111	TWDB_WIID System	893	TWDB_Interpolated From Topo Map	218EBFZA
JA 080	29.264444	-99.47861	TWDB_WIID System	882	TWDB_Interpolated From Topo Map	218EDRDA
JA 081	29.287778	-99.466389	TWDB_WIID System	901	TWDB_Interpolated From Topo Map	218EBFZA
JA 082	29.2575	-99.586388	TWDB_WIID System	936	TWDB_Interpolated From Topo Map	218EBFZA
JA 083	29.2549596	-99.6111625	TWDB_WIID System	922	TWDB_Interpolated From Topo Map	218EBFZA
JA 084	29.26	-99.542499	TWDB_WIID System	895	TWDB_Interpolated From Topo Map	218EBFZA
JA 085	29.268332	-99.564444	TWDB_WIID System	926	TWDB_Interpolated From Topo Map	218EDRDA
JA 086	29.262777	-99.682221	TWDB_WIID System	952	TWDB_Interpolated From Topo Map	218EBFZA
JA 087	29.267499	-99.675832	TWDB_WIID System	903	TWDB_Interpolated From Topo Map	218EBFZA
JA 088	29.263888	-99.649444	TWDB_WIID System	948	TWDB_Interpolated From Topo Map	218EBFZA
JA 089	29.253611	-99.648888	TWDB_WIID System	941	TWDB_Interpolated From Topo Map	218EBFZA
JA 090	29.267499	-99.628054	TWDB_WIID System	950	TWDB_Interpolated From Topo Map	218EDRDA
JA 091	29.361666	-99.616666	TWDB_WIID System	1040	TWDB_Interpolated From Topo Map	218EBFZA
JA 092	29.346944	-99.622221	TWDB_WIID System	1020	TWDB_Interpolated From Topo Map	218EDRDA
JA 093	29.335833	-99.624999	TWDB_WIID System	1012	TWDB_Interpolated From Topo Map	218EBFZA
JA 094	29.350833	-99.611666	TWDB_WIID System	1013	TWDB_Interpolated From Topo Map	218EBFZA
JA 095	29.334721	-99.596944	TWDB_WIID System	1007	Digital Elevation Model	211BUDA
JA 096	29.361111	-99.58361	TWDB_WIID System	1020	TWDB_Interpolated From Topo Map	218EBFZA
JA 097	29.353333	-99.521666	TWDB_WIID System	1002	TWDB_Interpolated From Topo Map	218EDRDA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 098	29.338055	-99.529443	TWDB_WIID System	985	TWDB_Interpolated From Topo Map	218EDRDA
JA 099	29.364444	-99.522777	TWDB_WIID System	1010	TWDB_Interpolated From Topo Map	218EDRDA
JA 100	29.32611	-99.591666	TWDB_WIID System	993	TWDB_Interpolated From Topo Map	218EBFZA
JA 101	29.329166	-99.611944	TWDB_WIID System	1006	TWDB_Interpolated From Topo Map	218EBFZA
JA 102	29.31861	-99.615277	TWDB_WIID System	1000	TWDB_Interpolated From Topo Map	218EBFZA
JA 103	29.307222	-99.587777	TWDB_WIID System	977	TWDB_Interpolated From Topo Map	211ASTN
JA 104	29.314444	-99.574999	TWDB_WIID System	973	TWDB_Interpolated From Topo Map	218EBFZA
JA 105	29.312777	-99.582777	TWDB_WIID System	972	TWDB_Interpolated From Topo Map	218EBFZA
JA 106	29.329999	-99.685277	TWDB_WIID System	1031	TWDB_Interpolated From Topo Map	218EDRDA
JA 107	29.295833	-99.636666	TWDB_WIID System	985	TWDB_Interpolated From Topo Map	218EBFZA
JA 108	29.319443	-99.744999	TWDB_WIID System	1042	TWDB_Interpolated From Topo Map	218EBFZA
JA 109	29.328888	-99.713888	TWDB_WIID System	1073	TWDB_Interpolated From Topo Map	218EDRDA
JA 110	29.34801305	-99.7103319	TWDB_WIID System	1089	TWDB_Interpolated From Topo Map	218EBFZA
JA 111	29.3585683	-99.6953314	TWDB_WIID System	1068	TWDB_Level or Other Surveying Method	218EBFZA
JA 112	29.351388	-99.679166	TWDB_WIID System	1063	TWDB_Interpolated From Topo Map	218EDRDA
JA 113	29.37021	-99.6517	Leica Survey Grade	1011.390387	Leica Survey Grade	218EBFZA
JA 114	29.361388	-99.64611	TWDB_WIID System	1059	TWDB_Interpolated From Topo Map	218EBFZA
JA 115	29.344721	-99.630277	TWDB_WIID System	1026	TWDB_Interpolated From Topo Map	218EDRDA
JA 116	29.349721	-99.655833	TWDB_WIID System	1037	TWDB_Interpolated From Topo Map	218EDRDA
JA 117	29.293888	-99.7525	TWDB_WIID System	1013	TWDB_Interpolated From Topo Map	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 118	29.1519066	-99.2280937	TWDB_WIID System	710	TWDB_Interpolated From Topo Map	218EDRDA
JA 119	29.33329075	-99.36059887	TWDB_WIID System	1033	TWDB_Interpolated From Topo Map	218EDRDA
JA 120	29.29495771	-99.34920962	TWDB_WIID System	980	TWDB_Interpolated From Topo Map	218EDRDA
JA 121	29.368888	-99.468332	TWDB_WIID System	1005	TWDB_Interpolated From Topo Map	218EBFZA
JA 122	29.356111	-99.497499	TWDB_WIID System	1005	TWDB_Interpolated From Topo Map	218EBFZA
JA 123	29.335277	-99.461944	TWDB_WIID System	960	TWDB_Interpolated from Topo Map	218EDRDA
JA 124	29.367499	-99.463055	TWDB_WIID System	998	TWDB_Interpolated from Topo Map	218EDRDA
JA 125	29.359722	-99.467221	TWDB_WIID System	986	TWDB_Interpolated from Topo Map	211ANCC
JA 126	29.360277	-99.467221	TWDB_WIID System	985	TWDB_Interpolated from Topo Map	211ANCC
JA 127	29.373888	-99.430554	TWDB_WIID System	1002	TWDB_ (GPS)	218EDRDA
JA 128	29.359444	-99.421943	TWDB_WIID System	1022	TWDB_Interpolated from Topo Map	218EBFZA
JA 129	29.36861	-99.390833	TWDB_WIID System	985	TWDB_Interpolated from Topo Map	218EDRD
JA 131	29.359444	-99.382499	TWDB_WIID System	1005	TWDB_Interpolated from Topo Map	218EDRDA
JA 132	29.33440169	-99.34615341	TWDB_WIID System	1052	TWDB_Interpolated from Topo Map	218EDRDA
JA 133	29.363611	-99.344166	TWDB_WIID System	1079	TWDB_Interpolated from Topo Map	218EDRDA
JA 134	29.46912022	-99.33837582	TWDB_WIID System	1140	TWDB_Interpolated from Topo Map	218EDRD
JA 135	29.47273118	-99.35837638	TWDB_WIID System	1190	TWDB_Interpolated from Topo Map	218EDRDA
JA 136	29.275832	-99.282777	TWDB_WIID System	833	TWDB_Interpolated from Topo Map	218EDRD
JA 137	29.4013439	-99.280596	TWDB_WIID System	977	TWDB_Interpolated from Topo Map	218EBFZA
JA 138	29.176628	-99.1992041	TWDB_WIID System	736	TWDB_Interpolated from Topo Map	218EBFZA

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 139	29.350555	-99.741944	TWDB_WIID System	1081	TWDB_(GPS)	218EDRDA
JA 140	29.324721	-99.732499	TWDB_WIID System	1055	TWDB_(GPS)	218EDRDA
JA 141	29.33611	-99.72111	TWDB_WIID System	1075	TWDB_Interpolated from Topo Map	218EBFZA
JA 142	29.345833	-99.744166	TWDB_WIID System	1062	TWDB_Interpolated from Topo Map	218EDRDA
JA 143	29.178888	-99.734999	TWDB_WIID System	893	Interpolated from Topo Map	218EBFZA
JA 144	29.208611	-99.783888	TWDB_WIID System	905	TWDB_Level or Other Surveying Method	218EBFZA
JA 145	29.326388	-99.63861	TWDB_WIID System	1007	TWDB_Interpolated from Topo Map	218EDRDA
JA 146	29.32412484	-99.7300548	TWDB_WIID System	1054	TWDB_Interpolated from Topo Map	218EDRDA
JA 147	29.38884409	-99.2647618	TWDB_WIID System	950	TWDB_Interpolated from Topo Map	218EDRDA
JA 148	29.268888	-99.657777	TWDB_WIID System	960	TWDB_Interpolated from Topo Map	218EBFZA
JA 149	29.42273225	-99.27837416	TWDB_WIID System	990	TWDB_Interpolated from Topo Map	218EDRDA
JA 150	29.31773491	-99.26031774	TWDB_WIID System	909	TWDB_Interpolated From Topo Map	218EDRD
JA 151	29.34717819	-99.27448515	TWDB_WIID System	900	TWDB_Interpolated From Topo Map	218EDRDA
JA 152	29.37356653	-99.28420741	TWDB_WIID System	931	TWDB_Interpolated From Topo Map	218EDRD
JA 153	29.2575	-99.24833333	TWDB_WIID System	810	TWDB_Interpolated From Topo Map	218EDRD
JA 154	29.40861111	-99.26777778	TWDB_WIID System		Google Earth	
JA 155	29.38888889	-99.26472222	TWDB_WIID System		Google Earth	
JA 156	29.27944444	-99.27944444	TWDB_WIID System		Google Earth	
JA 157	29.46388889	-99.34527778	TWDB_WIID System	1335	TWDB_Garmin GPS 72	
JA 158	29.46805556	-99.37194444	TWDB_WIID System		Google Earth	

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 159	29.46888889	-99.37222222	TWDB_WIID System		Google Earth	
JA 160	29.47111111	-99.37388889	TWDB_WIID System		Google Earth	
JA 161	29.46888889	-99.36722222	TWDB_WIID System		Google Earth	
JA 162	29.372778	-99.349167	TWDB_WIID System		Google Earth	
JA 163	29.31301287	-99.28670747	TWDB_WIID System		Google Earth	
JA 164	29.25944444	-99.33111111	TWDB_WIID System	945	TWDB_Garmin etrex	
JA 165	29.27166667	-99.3325	TWDB_WIID System		Google Earth	
JA 166	29.260833	-99.755278	TWDB_WIID System		Google Earth	
JA 167	29.348611	-99.656111	TWDB_WIID System		Google Earth	
JA 168	29.331389	-99.743889	TWDB_WIID System		Google Earth	
JA 169	29.329722	-99.735278	TWDB_WIID System	940	TWDB_Magellan GPS	
JA 170	29.325278	-99.733889	TWDB_WIID System		Google Earth	
JA 171	29.306667	-99.748333	TWDB_WIID System	1034	TWDB_Magellan GPS	
JA 172	29.300278	-99.725833	TWDB_WIID System		Google Earth	
JA 173	29.318333	-99.640556	TWDB_WIID System		Google Earth	
JA 174	29.288611	-99.725833	TWDB_WIID System		Google Earth	
JA 175	29.277778	-99.744167	TWDB_WIID System		Google Earth	
JA 176	29.324444	-99.569444	TWDB_WIID System		Google Earth	
JA 177	29.306667	-99.465278	TWDB_WIID System		Google Earth	
JA 178	29.285833	-99.481667	TWDB_WIID System		Google Earth	

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 179	29.241389	-99.685278	TWDB_WIID System	900	TWDB_Magellan GPS	
JA 180	29.237222	-99.685556	TWDB_WIID System	965	TWDB_Magellan GPS	
JA 181	29.236111	-99.685	TWDB_WIID System	964	TWDB_Magellan GPS	
JA 182	29.213611	-99.674444	TWDB_WIID System		Google Earth	
JA 183	29.203889	-99.635	TWDB_WIID System	876	TWDB_Garmin GPS	
JA 184	29.198611	-99.671667	TWDB_WIID System	850	TWDB_Garmin etrex	
JA 185	29.203611	-99.666944	TWDB_WIID System	884	TWDB_Garmin etrex	
JA 186	29.265833	-99.711667	TWDB_WIID System	975	TWDB_Magellan GPS	
JA 187	29.243333	-99.734722	TWDB_WIID System		Google Earth	
JA 188	29.2925	-99.623333	TWDB_WIID System		Google Earth	
JA 189	29.230556	-99.681111	TWDB_WIID System	920	TWDB_Magellan GPS	
JA 190	29.279167	-99.501111	TWDB_WIID System		Google Earth	
JA 191	29.296389	-99.620833	TWDB_WIID System		Google Earth	
JA 192	29.230556	-99.681111	TWDB_WIID System	920	TWDB_Magellan GPS	
JA 193	29.298889	-99.691111	TWDB_WIID System	1007	Google Earth	
JA 194	29.317222	-99.6875	TWDB_WIID System	1062	Google Earth	
JA 195	29.271667	-99.759722	TWDB_WIID System	995	Google Earth	
JA 196	29.288056	-99.762778	TWDB_WIID System	1004	Google Earth	
JA 197	29.286944	-99.878889	TWDB_WIID System	1023	Google Earth	
JA 198	29.329167	-99.728611	TWDB_WIID System	1057	Google Earth	

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 199	29.361944	-99.745556	SWRI	1090	SWRI	
JA 200	29.361667	-99.745556	SWRI	1090	SWRI	
JA 201	29.36	-99.745833	SWRI	1083	SWRI	
JA 202	29.36	-99.745556	SWRI	1087	SWRI	
JA 203	29.746944	-99.746944	SWRI	1054	SWRI	
JA 204	29.3225	-99.731667	SWRI	1052	SWRI	
JA 205	29.369167	-99.750278	SWRI	1120	SWRI	
JA 206	29.3325	-99.765833	SWRI	1057	SWRI	
JA 207	29.24166	-99.81707	SWRI	882	Static_Elevation SWRI	
JA 208	29.23691	-99.82745	SWRI	881	Static_Elevation SWRI	
JA 209	29.24579	-99.79076	SWRI	878	Static_Elevation SWRI	
JA 210	29.24693	-99.75681	SWRI	869	Static_Elevation SWRI	
JA 211	29.2167	-99.75534	SWRI	870	Static_Elevation SWRI	
JA 212	29.23925	-99.83805	SWRI	886	Static_Elevation SWRI	
JA 213	29.27523599	-99.24337278				
JA 214	29.18218338	-99.20614883	USGS	762.1591187	USGS_DEMelev	
JA 215	29.19718289	-99.19753756		759.3258667	USGS_DEMelev	
JA 216	29.11107464	-99.21892647				
JA 217	29.0985763	-99.60338439	USGS	848.1691895	USGS_DEMelev	
JA 218	29.11857531	-99.44393462	USGS	720.300354	USGS_DEMelev	

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 219	29.21412796	-99.73255518	USGS	939.5228272	USGS_DEMelev	
JA 220	29.23301625	-99.74172214	USGS	967.9953003	USGS_DEMelev	
JA 221	29.15940738	-99.53949353	USGS	812.8804932	USGS_DEMelev	
JA 222	29.33551321	-99.64782995	USGS	1031.518311	USGS_DEMelev	
JA 223	29.18412823	-99.38948845	USGS	891.3668213	USGS_DEMelev	
JA 224	29.41384424	-99.53032577	USGS	1083.56897	USGS_DEMelev	
JA 225	29.30162467	-99.45282391	USGS	920.394165	USGS_DEMelev	
JA 226	29.26995877	-99.4361569	USGS	885.5553589	USGS_DEMelev	
JA 227	29.2357931	-99.4189341	USGS	823.6846314	USGS_DEMelev	
JA 228	29.17357267	-99.2889293	USGS	776.4664917	USGS_DEMelev	
JA 229	29.33606888	-99.6947759	USGS	1047.220093	USGS_DEMelev	
JA 230	29.29051414	-99.56699427	USGS	943.0649414	USGS_DEMelev	
JA 231	29.19385069	-99.63199647	USGS	873.4643555	USGS_DEMelev	
JA 232	29.13690825	-99.59060624	USGS	833.0015259	USGS_DEMelev	
JA 233	29.13885224	-99.4228228	USGS	798.458252	USGS_DEMelev	
JA 234	29.24693	-99.75681				
JA 235	29.26583	-99.63639		948		
JA 236	29.34222	-99.67389		1045		
JA 237	29.36667	-99.63472		1055		
JA 238	29.32389	-99.73167		1058		

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 239	29.29444	-99.64500		982		
JA 240	29.29806	-99.64556		950		
JA 241	29.27267	-99.76272		996		
JA 242	29.28108	-99.70011		980		
JA 243	29.105502	-99.454067		718		
JA 244	29.124888	-99.431754		841		
JA 245	29.147588	-99.704935		858		
JA 246	29.09139294	-99.43367305		701		
JA 247	29.12194183	-99.43836332		786		
JA 248	29.56509913	-99.64862004		858		
JA 249	29.20970914	-99.69676184		948		
JA 250	29.24696793	-99.71248234		947.5		
JA 251	29.13342159	-99.97511022		875		
JA 252	29.12600198	-99.62021939		896		
JA 253	29.28762676	-100.0456032		1082		
JA 254	29.28039683	-100.1029851		1102		
JA 255	29.231802	-99.676199		915		
JA 256	29.14680109	-99.48190496		747		
JA 257	29.14265124	-99.4803949		745		
JA 258	29.14265124	-99.4803949		753		

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 259	29.13242145	-99.44093344		777		
JA 260	29.13837121	-99.43823336		807		
JA 261	29.12990155	-99.44233348		777		
JA 262	29.15012104	-99.50201568		795		
JA 263	29.10271283	-99.57396791		890.03		
JA 264	29.09663305	-99.58221816		886.3		
JA 265	29.10246263	-99.45419385		718		
JA 266	29.38262376	-99.46786398		801		
JA 267	29.10274282	-99.5926985		847.4		
JA 268	29.200198	-99.76886		984.4		
JA 269	29.1032128	-99.60489889		880		
JA 270	29.10274282	-99.5926985		881		
JA 271	29.23647752	-99.41936301		827		
JA 272	29.13230168	-99.49031524		758		
JA 273	29.12628187	-99.48294496		732		
JA 274	29.1237117	-99.42659289		823		
JA 275	29.11412202	-99.41921259		769		
JA 276	29.11204228	-99.45555393		752		
JA 277	29.10580254	-99.46022409		960		
JA 278	29.09119305	-99.8630868		806.53		

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 279	29.12339207	-99.62248946		823.47		
JA 280	29.098033	-99.57648798		894.85		
JA 281				746		
JA 282	29.13147141	-99.4261129		762		
JA 283	29.11566202	-99.43140304		807		
JA 284	29.10992257	-99.49670545		754		
JA 285	29.09988291	-99.48870514		572		
JA 286	29.09515298	-99.46812436		723		
JA 287	29.125282	-99.53005654		781		
JA 288	29.258333	-99.648611				
JA 289	29.336111	-99.6475	Garmin Handheld GPS	1034	Geophysical Log	
JA 290	29.266389	-99.648889				
JA 291	29.328944	-99.691278				
JA 292	29.237778	-99.7625				
JA 293	29.508889	-99.718694	Garmin	1279.53	Google Earth	
JA 294	29.329831	-99.690752		1037.2	874.02	
JA 295	29.3387	-99.74927		963.627918	Leica Survey Grade	
JA 296	29.368608	-99.746844		1109	1011.7	
JA 297	29.379184	-99.744839		1134.5	1017.9	
JA 298	29.204355	-99.774753		888.408	864.41	

JA ID	Latitude DD	Longitude DD	Coordinate Source	Elevation	Elevation Source	Aquifer Code
JA 299	29.232692	-99.790704		917.911	869.61	
JA 300	29.242318	-99.8155		942.272	891.07	
JA 301	29.36378	-99.70422	Leica Survey Grade	1021.449409	Leica Survey Grade	
JA 302	29.211446	-99.769312		922.867	885.42	
JA 303	29.199918	-99.833933		912.817	860.92	
JA 304	29.202115	-99.682768		886.909	837.51	
JA 305	29.198696	-99.671813		873.28	824.88	
JA 306	29.380184	-99.622867		1052.299	788.3	
JA 307	29.32422222	-99.73097222	Garmin	1059	Garmin	218EDRDA
JA 308	29.36363	-99.7059	Leica Survey Grade	1028.402789	Leica Survey Grade	
JA 309	29.27033	-99.76647	Leica Survey Grade	925.5119063	Leica Survey Grade	
JA 310	29.35688	-99.63496	Leica Survey Grade	971.0779838	Leica Survey Grade	
JA 311	29.34013	-99.74011	Leica Survey Grade	985.983693	Leica Survey Grade	
JA 312	29.32883333	-99.69141667	Garmin	1041	Garmin	
JA 313	29.33576	-99.75476	Leica Survey Grade	969.039762	Leica Survey Grade	218EDRDA
JA 314	29.33529	-99.78434	Leica Survey Grade	1001.400098	Leica Survey Grade	
JA 315	29.32731	-99.76767	Leica Survey Grade	949.0883506	Leica Survey Grade	
JA 316	29.32444	-99.74705	Leica Survey Grade	978.7864486	Leica Survey Grade	
JA 317	29.321306	-99.699528	Garmin	1026.9	Google Earth	

Appendix C: Well Inventory driller, depth, and construction

[Appendix C includes previous abbreviations and new ones as follows: Date Drilled – MM/DD/YYYY format, 0's act as place holders for unknown exact dates. Read date from right to left for easiest decrypting.]

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 001	9011973	James (Ted) A.	430	TWDB			
JA 002	1101973	Ted Letsilnger	560	Driller's Log	Air Rotary	Open Hole	Steel
JA 004	Repeated entry. Deleted.						
JA 003	1001974	Brooks Drilling	550	Driller's Log	Cable-tool	Open Hole	Steel
JA 005	1001968	Pepper Irrigation	673	TWDB	Cable-tool	Open Hole	Steel
JA 006	9001956	Tex King	389	TWDB			
JA 007	1964	J. R. Johnson	480	Driller's Log	Hydraulic Rotary		Steel
JA 009	4151985	Sprugeon Drilling Co.	270	Driller's Log	Cable-tool	Open Hole	Steel
JA 010	4251972	Sprugeon Drilling Co.	280	Driller's Log	Cable-tool	Open Hole	Steel
JA 011	7001952	Sprugeon Drilling Co.	525	TWDB		Open Hole	
JA 012	1955	N_A	518	TWDB	Hydraulic Rotary		
JA 013	8081973	James (Ted) A.	510	Driller's Log	Air Rotary		
JA 014	5001992	L & J Construction and Properties Inc.	1080	Driller's Log	Air Rotary	Open Hole	Steel
JA 015	8081993	Cenizo Drilling	620	TWDB			Steel
JA 016	6211973	TWDB	721	Geophysical Log	Hydraulic Rotary	Open Hole	Steel
JA 017	12101998	TWDB	1500	Geophysical Log	Hydraulic Rotary	Open Hole	Steel
JA 018	5001962	Gulf Oil Corporation	7596	Geophysical Log			

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 019	1966	A.C. Sanderlin	758	Geophysical Log	Cable-tool	Open Hole	Steel
JA 020	6001974	A.C. Sanderlin	833	Edwards Aquifer Authority		Open Hole	Steel
JA 021	9001966	Pepper Irrigation Co	1262	Driller's Log	Cable-tool	Open Hole	Steel
JA 022	4001957	A. Smith	140	TWDB			
JA 023	3081965	J. Roberts	1161	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 024	00001953	J. Roberts	1211	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 025	10001987	Davenport Drilling	1500	Driller's Log	Cable-tool	Open Hole	Steel
JA 026	1171979	Johnson Brothers	1402	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 027	2001968	Pepper Irrigation Co	1248	Driller's Log	Cable-tool	Open Hole	Steel
JA 028	08301979	Letsinger	630	TWDB			
JA 029	11141978	R. G. Wilson	62	TWDB			
JA 030	00001966	A. C. Sanderlin	1000	Driller's Log	Cable-tool	Open Hole	Steel
JA 031	12211985	Davenport Well	913	Driller's Log	Cable-tool	Open Hole	Steel
JA 032	03241984	Stricker Drilling	982	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 033	11261969	Box Drilling Co.	943	Driller's Log	Cable-tool	Open Hole	Steel
JA 034	10221977	Johnson Drilling	1322	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 035	11211964	J. R. Johnson	1476	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 036	06141986	Stricker Drilling	1196	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 037	05311966	A. C. Sanderlin	561	Driller's Log	Cable-tool	Open Hole	Steel
JA 038	05001968	Brooks Drilling	630	Driller's Log	Cable-tool	Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 039	07001970	A. C. Sanderlin	750	Driller's Log	Cable-tool	Open Hole	Steel
JA 040	01241986	Davenport Well	915	Driller's Log	Cable-tool	Open Hole	Steel
JA 041	03111999	Wilson Drilling	402	Driller's Log	Air Percussion	Explained in Remarks	Steel
JA 042	00001967	A. C. Sanderlin	850	Driller's Log	Cable-tool	Open Hole	Steel
JA 043	00001960	Gorman Drilling	2575	Owner	Hydraulic Rotary	Perforated or Slotted	Steel
JA 044	04041966	Johnson Drilling &	1556	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 045	10001973	Henry Brooks	1400	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 046	03151999	TWDB	1560	Geophysical Log	Hydraulic Rotary	Open Hole	Steel
JA 047	08091978	Johnson Brothers	2465	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 048	12001972	King Drilling Co.	1650	Driller's Log	Cable-Tool	Open Hole	Steel
JA 049	04001967	Pepper Irrigation	1706	Driller's Log	Cable-Tool	Open Hole	Steel
JA 050	04171999	TWDB	1400	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 051	05001968	KTM Drilling Co.	1317	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 052	05001968	KTM Drilling Co.	1299	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 053	11151971	Bolin Well Service	1550	Driller's Log			
JA 054	00001974	A.C. Sanderlin			Cable-Tool	Open Hole	Steel
JA 055	00001968	Ted Letsinger	1050	Driller's Log	Cable-tool	Open Hole	Steel
JA 056	01001974	Texas Water	694	Another Government Agency	Hydraulic Rotary	Open Hole	Steel
JA 057	12001970	A.C. Sanderlin	987	Driller's Log	Cable-Tool	Open Hole	Steel
JA 058	04181974	J.R. Johnson	1408	Driller's Log		Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 059	03251963	Gulf Oil	2230	Driller's Log			
JA 060		Pennington	700	TWDB			
JA 061	11001981	A.C. Sanderlin	750	Driller's Log	Cable-tool	Open Hole	Steel
JA 062	08001973	Henry Brooks	1302	TWDB	Hydraulic Rotary	Open Hole	Steel
JA 063	03101978	A. C. Sanderlin	698	TWDB	Cable-tool	Open Hole	Steel
JA 064	7001952	Lynn Spurgeon	525	TWDB		Open Hole	
JA 065	03001978	Letsinger & Sons	630	Geophysical Log		Open Hole	
JA 066	01001968	K.T.M. Drilling Co.					Steel
JA 067	06151973	James (Ted) A.	585	Driller's Log	Air Rotary	Open Hole	
JA 068	02001956	Spurgeon Drilling	800	TWDB			
JA 069	00001952	U. Serber	560	Geophysical Log	Hydraulic Rotary	Open Hole	
JA 070	07011973	Letsinger & Sons	580	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 071	11001974	Wright Drilling Co.	430	Driller's Log	Air Rotary	Open Hole	Steel
JA 072	05001962	J. Roberts	2309	Driller's Log		Open Hole	Steel
JA 073	00001966	Billie Wright Taylor	1280	TWDB	Hydraulic Rotary	Open Hole	Steel
JA 074	08201970	Sonora Drilling Co.	391	Driller's Log	Cable-Tool	Open Hole	Steel
JA 075	04221980	Sonora Drilling Co.	750	Driller's Log	Air Rotary	Open Hole	Steel
JA 076	11001963	J. R. Johnson	1384	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 077	10001965	T & H Drilling Co.	1510	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 078	04001967	Pepper Irrigation	1706	Driller's Log	Cable-Tool	Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 079	07071965	J. R. Johnson	1685	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 080	05071967	Johnson & Johnson	1675	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 081	00001966	Bill Taylor	1655	TWDB	Hydraulic Rotary	Open Hole	Steel
JA 082	09001967	KTM Drilling Co.	1685	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 083	00001964	J. Roberts	1794	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 084	12001972	King Drilling Co.	1650	Driller's Log	Cable-Tool	Open Hole	Steel
JA 085	06091986	Roy L. Stricker	1200	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 086	00001965	A. C. Sanderlin	916	Driller's Log	Cable-tool	Open Hole	Steel
JA 087	07001969	A. C. Sanderlin	1072	Driller's Log	Cable-tool	Open Hole	Steel
JA 088	08001967	K T M Drilling, Inc.	1010	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 089	08001967	K T M Drilling, Inc.	1305	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 090	03121969	Johnson & Johnson	1246	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 091	05001967	A. C. Sanderlin	659	Another Government Agency	Cable-tool	Open Hole	Steel
JA 092	08001966	A. C. Sanderlin	675	Driller's Log	Cable-tool	Open Hole	Steel
JA 093	06231969	Box Drilling Co.	880	Driller's Log	Cable-tool	Open Hole	Steel
JA 094	12001971	A. C. Sanderlin	815	Driller's Log	Cable-tool	Open Hole	Steel
JA 095	00001905	Tyler	516	TWDB			
JA 096	07051966	A. C. Sanderlin	1128	Driller's Log	Cable-tool	Open Hole	Steel
JA 097	07291977	J.R. Johnson	1200	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 098	10251979	Johnson Brothers	1398	Driller's Log	Hydraulic Rotary	Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 099	09221982	Haskin Pump service,	1040	Driller's Log	Air Rotary	Open Hole	Steel
JA 100	00001968	A. C. Sanderlin	862	Driller's Log	Cable-tool	Open Hole	Steel
JA 101	07001969	A. C. Sanderlin	1081	Driller's Log	Cable-tool	Open Hole	Steel
JA 102	08101978	Johnson Bros. Well	1165	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 103	03261985	Spurgeon Drilling	100	Driller's Log	Air Rotary	Perforated or Slotted	PVC, Fiberglass,
JA 104	04001965	J. W. Roberts	1380	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 105	00001964	J. Roberts	1500	TWDB_Owner			
JA 106	05141971	King Drilling Co.	888	Driller's Log	Cable-tool	Open Hole	Steel
JA 107	08151962	Bob Johnson	1376	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 108	08001967	K.T.M. Drilling, Inc	640	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 109	08251976	J.A. Letsinger	730	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 110	08001967	K.T.M. Drilling Co.	740	Geophysical Log	Hydraulic Rotary	Open Hole	Steel
JA 111	08001957	R. V. Raney	721	Driller's Log		Open Hole	Steel
JA 112	02001969	Henry Brooks	700	Driller's Log	Cable-tool	Open Hole	Steel
JA 113	00001967	A.C. Sanderlin	730	Driller's Log	Cable-Tool	Open Hole	Steel
JA 114	05001976	A. C. Sanderlin	784	Geophysical Log	Cable-tool	Open Hole	Steel
JA 115	01001986	Davenport Drilling	834	Driller's Log	Cable-tool	Open Hole	Steel
JA 116	10001978	A.C. Sanderlin	754	Driller's Log	Cable-tool	Open Hole	Steel
JA 117	07001952	Lynn Spurgeon	525	TWDB		Open Hole	
JA 118	00001975	J.R. Johnson	2861	Driller's Log	Hydraulic Rotary	Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 119	01221980	Johnson Brothers	1640	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 120	09131984	Johnson Brothers	1785	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 121	01001967	Pepper Irrigation Co	1248	Driller's Log	Cable-tool	Open Hole	Steel
JA 122	00001968	A. C. Sanderlin	1595	Driller's Log	Cable-tool	Open Hole	Steel
JA 123	07131979	Johnson Brothers	1815	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 124	07301983	Stricker Drilling	1170	Driller's Log	Hydraulic Rotary	Open Hole	Concrete
JA 125	01291982	W. R. Kellner	100	TWDB			
JA 126	02171981	Doyle Ely	120	TWDB			
JA 127	02001967	Pepper Irrigation Co	1365	Driller's Log	Cable-tool	Open Hole	Steel
JA 128	01001967	Pepper Irrigation Co	1252	Driller's Log	Cable-tool	Open Hole	Steel
JA 129	01101972	Crawford Gordon	1600	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 131	08101984	Johnson Brothers	1410	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 132	05001979	Johnson Brothers	1428	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 133	01011980	Johnson Brothers	1369	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 134	12301968	Spurgeon Drilling Co	625	Driller's Log	Cable-tool	Open Hole	Steel
JA 135	07011982	Wilson Drilling Co.	478	Driller's Log	Cable-tool	Open Hole	Steel
JA 136	03001955	Johnny Roberts	1313	TWDB_Owner	Hydraulic Rotary	Open Hole	Steel
JA 137	03021972	Brooks Drilling Co.	997	Driller's Log	Cable-Tool	Open Hole	Steel
JA 138	00001965	Pan American Oil Co	2550	Geophysical Log	Hydraulic Rotary	Perforated or Slotted	Steel
JA 139	00001987	T. R. Hutcherson	434	Driller's Log		Open Hole	Steel

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 140	03192003	Spurgeon Drilling Co	340	Driller's Log	Air Rotary	Open Hole	PVC, Fiberglass,
JA 141	10011967	King Drilling Co.	756	Driller's Log	Cable-tool	Open Hole	Steel
JA 142	10011969	Spurgeon Drilling	425	Driller's Log	Cable-tool	Open Hole	Steel
JA 143	1961	Garmon Brothers	400	Driller's Log	Cable-tool	Open Hole	Steel
JA 144			287	TWDB	Dug	Open Hole	Steel
JA 145	9001989	Davenport Drilling	902	TWDB_Owner	Air Rotary	open Hole	Steel
JA 146	09001989	Davenport	882	TWDB	Air Rotary	Open Hole	Steel
JA 147	06001985	Meadows Drilling.	940	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 148	11151965	King Drilling Co.	1298	Driller's Log	Cable-tool	Open Hole	Steel
JA 149	05011977	Brooks Drilling	713	Driller's Log	Cable-tool	Open Hole	Steel
JA 150	07101971	Brooks Drilling	1685	Driller's Log	Cable-tool	Open Hole	Steel
JA 151	07301976	J.R. Johnson	1406	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 152	03001968	J.R. Johnson	1000	Driller's Log	Hydraulic Rotary	Open Hole	Steel
JA 153	00001955	J.E. Hillier	1999	Geophysical Log		Open Hole	Steel
JA 154		Stewart Shepherd	480	Driller's Log	Air Rotary	Straight wall	
JA 155	12192008	James Forehand / Kevin Kerry	985	Driller's Log	Mud Rotary	Open Hole	
JA 156		Cary Spurgeon	220	Driller's Log	Air Hammer	Straight wall	
JA 157	9302004	Randy Roberts	380	Driller's Log	Air Rotary		
JA 158	1182006	Cary Spurgeon	320	Driller's Log	Air Hammer	Straight wall	
JA 159	332006	Cary Spurgeon	400	Driller's Log	Air Hammer	Straight wall	

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 160	2272008	Cary Spurgeon	350	Driller's Log	Air Hammer	Straight wall	
JA 161	8122009	Cary Spurgeon	400	Driller's Log	Air Hammer	Straight wall	
JA 162	3272009	John Shepherd	80	Driller's Log	Air Hammer	Straight wall	
JA 163	2232004	Stewart Shepherd	60	Driller's Log	Mud Rotary		
JA 164	7232007	Clifton E. Wilson	1350	Driller's Log	Air Rotary	Open Hole	
JA 165	2102007	Larry Dennis	1650	Driller's Log	Mud Rotary	Open Hole	
JA 166	5252003	Robert G. Wilson	120	Driller's Log	Air Rotary	Open Hole	
JA 167	3232011	Cary Spurgeon	460	Driller's Log	Air Hammer	Straight wall	
JA 168	9262002	Cary Spurgeon	300	Driller's Log	Air Rotary	Straight wall	
JA 169	3112003	Cary Spurgeon	300	Driller's Log	Air Rotary	Straight wall	
JA 170	1282002	Cary Spurgeon	440	Driller's Log	Air Rotary	Straight wall	
JA 171	5202009	Cary Spurgeon	300	Driller's Log	Air Hammer	Straight wall	
JA 172	7242001	Cary Spurgeon	290	Driller's Log	Air Rotary	Straight wall	
JA 173	5152009	Cary Spurgeon	300	Driller's Log	Air Rotary	Open Hole	
JA 174	752001	Cary Spurgeon	420	Driller's Log	Air Rotary	Open Hole	
JA 175	1262002	Cary Spurgeon	240	Driller's Log	Air Rotary	Straight wall	
JA 176	6172008	Cary Spurgeon	220	Driller's Log	Air Hammer	Straight wall	
JA 177	2292008	Cary Spurgeon	200	Driller's Log	Air Hammer	Straight wall	
JA 178	972005	Cary Spurgeon	160	Driller's Log	Air Hammer	Straight wall	
JA 179	1202009	Cary Spurgeon	260	Driller's Log	Air Hammer	Straight wall	

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 180	5252005	Cary Spurgeon	240	Driller's Log	Air Hammer	Straight wall	
JA 181	1182006	Cary Spurgeon	260	Driller's Log	Air Hammer	Straight wall	
JA 182	10222008	Cary Spurgeon	115	Driller's Log	Air Hammer	Straight wall	
JA 183	3102011	Jimmy Duane Wilson Jr.	200	Driller's Log	Air Hammer	Straight wall	
JA 184	5172008	Clifton E. Wilson	740	Driller's Log	Air Rotary	Open Hole	
JA 185	5152008	Clifton E. Wilson	140	Driller's Log	Air Rotary	Open Hole	
JA 186	8122006	Cary Spurgeon	220	Driller's Log	Air Hammer	Straight wall	
JA 187	152011	Cary Spurgeon	243	Driller's Log	Air Hammer	Straight wall	
JA 188	472011	Cary Spurgeon	200	Driller's Log	Air Hammer	Straight wall	
JA 189	3172008	Cary Spurgeon	200	Driller's Log	Air Hammer	Straight wall	
JA 190	482010	Thomas Wright	1480	Driller's Log	Air Rotary	Open Hole	
JA 191	452011	Cary Spurgeon	180	Driller's Log	Air Hammer	Straight wall	
JA 192	3172008	Cary Spurgeon	200	Driller's Log	Air Hammer	Straight wall	
JA 193	7272012	Clifton E. Wilson	660	Driller's Log	Air Hammer		
JA 194	822006	Adam Cruz	460	Driller's Log	Air Rotary	Straight wall	
JA 195	8162012	Donnie Davenport	460	Driller's Log	Air Rotary	Open Hole	
JA 196	5242008	Sprugeon Drilling Co.	295	Driller's Log	Air Hammer	Straight wall	
JA 197	682011	Sprugeon Drilling Co.	300	Driller's Log	Air Hammer	Straight wall	
JA 198	382002	Cary Spurgeon	500	Driller's Log	Air Rotary	Open Hole	
JA 199							

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 200							
JA 201							
JA 202							
JA 203							
JA 204							
JA 205							
JA 206							
JA 207							
JA 208							
JA 209							
JA 210							
JA 211							
JA 212							
JA 213		USGS					
JA 214		USGS		Geophysical Log			
JA 215							
JA 216		EAA					
JA 217		W.J.Steeger		Geophysical Log			
JA 218		Gorman Drilling					
JA 219		Pan American Pet.		Geophysical Log			

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 220		Shell		Geophysical Log			
JA 221		USGS		Geophysical Log			
JA 222				Geophysical Log			
JA 223		Edward J. Ford		Geophysical Log			
JA 224				Geophysical Log			
JA 225		EAA		Geophysical Log			
JA 226		S.G.Nelson		Geophysical Log			
JA 227		Bennet		Geophysical Log			
JA 228		Ginter & Warren		Geophysical Log			
JA 229				Geophysical Log			
JA 230				Geophysical Log			
JA 231		Douglas Downing		Geophysical Log			
JA 232		International Nuc.		Geophysical Log			
JA 233		Gorman Drilling		Geophysical Log			
JA 234							
JA 235		EAA					
JA 236		EAA					
JA 237		EAA					
JA 238		EAA					
JA 239		EAA					

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 240		EAA					
JA 241		EAA					
JA 242		EAA					
JA 243		TWDB					
JA 244		TWDB					
JA 245		TWDB					
JA 246		TWDB					
JA 247		TWDB					
JA 248		TWDB					
JA 249		TWDB					
JA 250		TWDB					
JA 251		TWDB					
JA 252		TWDB					
JA 253		TWDB					
JA 254		TWDB					
JA 255		TWDB					
JA 256		TWDB					
JA 257		TWDB					
JA 258		TWDB					
JA 259		TWDB					

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 260		TWDB					
JA 261		TWDB					
JA 262		TWDB					
JA 263		TWDB					
JA 264		TWDB	1116				
JA 265		TWDB	5627				
JA 266		TWDB	4560				
JA 267		TWDB	805				
JA 268		TWDB	3015				
JA 269		TWDB	4015				
JA 270		TWDB	1380				
JA 271		TWDB	4505				
JA 272		TWDB	1104				
JA 273		TWDB	1200				
JA 274		TWDB	2430				
JA 275		TWDB	2175				
JA 276		TWDB	1300				
JA 277		TWDB	1127				
JA 278		TWDB	2610				
JA 279		TWDB	1366				

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 280		TWDB	1153				
JA 281		TWDB	720				
JA 282		TWDB	2405				
JA 283		TWDB	1324				
JA 284		TWDB	1495				
JA 285		TWDB	1200				
JA 286		TWDB	1510				
JA 287		TWDB	4890				
JA 288							
JA 289							
JA 290							
JA 291							
JA 292							
JA 293							
JA 294							
JA 295							
JA 296							
JA 297							
JA 298							
JA 299							

JA_ID	Date Drilled	Driller	Well Depth (feet)	Source Of Depth	Construct Method	Completion	Casing Material
JA 300							
JA 301		Cary Spurgeon					
JA 302							
JA 303							
JA 304							
JA 305							
JA 306							
JA 307	3/24/2003	Cary Spurgeon	340	Driller's Log	Air Rotary	Straight Wall	
JA 308		Cary Spurgeon					
JA 309							
JA 310							
JA 311							
JA 312							
JA 313							
JA 314							
JA 315							
JA 316							
JA 317							

Appendix D: Well Inventory type, owner contact, and comments

[Appendix D includes previous abbreviations and new ones as follows: WL – Water Level; QW – Water Quality;

JA ID	Well Type	Owner Contact	Comments	Source
JA 001	Irrigation		WL and QW tables in this study	EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 002	Irrigation		WL and QW tables in this study	EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 004	Repeated entry. Deleted.			
JA 003	Irrigation			EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 005	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 006	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 007	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 009	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 010	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 011	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 012	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 013	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 014	Public Supply			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 015	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 016	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 017	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 018	Oil or Gas			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 019	Irrigation			EAA_TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 020	Domestic Irrigation		WL and QW tables in this study	EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 021	Irrigation	TWDB		EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 022	Observation	A. Smith		EAA_TWDB WIID, http://wiid.twdb.state.tx.us/
JA 023	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 024	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 025	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 026	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 027	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 028	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 029	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 030	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 031	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 032	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 033	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 034	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 035	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 036	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 037	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 038	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 039	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/ : Synoptic Water Level Study Table 3

JA ID	Well Type	Owner Contact	Comments	Source
JA 040	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 041	Domestic			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 042	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 043	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 044	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 045	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 046	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 047	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 048	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 049	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 050	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 051	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 052	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 053	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 054	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 055	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 056	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 057	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 058	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 059	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 060	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 061	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 062	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 063	Public Supply			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 064	Irrigation	(830) 591-3351_P.O. Box 1418, Uvalde, TX. 78802-1418		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 065	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 066	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 067	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 068	Oil or Gas			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 069	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 070	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 071	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 072	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 073	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 074	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 075	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 076	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 077	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 078	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 079	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 080	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 081	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 082	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 083	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 084	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 085	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 086	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 087	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 088	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 089	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 090	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 091	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 092	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 093	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 094	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 095	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 096	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 097	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 098	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 099	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 100	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 101	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 102	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 103	Domestic			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 104	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 105	Plugged Destroyed			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 106	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 107	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 108	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 109	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 110	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 111	Stock			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 112	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 113	Domestic_Stock			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 114	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 115	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 116	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 117	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 118	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 119	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 120	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 121	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 122	Irrigation_Stock			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 123	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 124	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 125	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 126	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 127	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 128	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 129	Domestic		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 131	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 132	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 133	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 134	Withdrawal of Water		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 135	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 136	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 137	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 138	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 139	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 140	Domestic			TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 141	Withdrawal of Water			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 142	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 143	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 144	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 145	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 146	Observation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 147	Pump Supply		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 148	Irrigation			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 149	Domestic Stock			TWDB WIID, http://wiid.twdb.state.tx.us/
JA 150	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 151	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 152	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 153	Irrigation		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 154	Domestic		Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 155	Public Supply	PO BOX 365 D; Hanis, TX 78850	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 156	Domestic	PO Box 1688 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 157	Domestic	8144 F M 1796 D' Hanis, TX 78850	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 158	Domestic	8485 C.R. 311 D' Hanis, TX 78850	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 159	Domestic	8485 C.R. 311 D' Hanis, TX 78850	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 160	Domestic	13703 TURTLE CROSS San Antonio, TX 78253	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 161	Domestic	103 NOPAL COVE Buda, TX 78610	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 162	Stock	13023 Country Ledge San Antonio, TX 78216	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 163	Irrigation	PO BOX 83 Hondo, TX 78861		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 164	Domestic	2203 Cr 520 D' Hanis, TX 78850	Medina County	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 165	Irrigation	500 Dallas Street Ste 2920 Houston, TX 77002		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 166	Irrigation	112 Cottonwood Uvalde , Tx 78801		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 167	Domestic	6 LEONA HEIGHTS DR. Uvalde, TX 78801		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 168	Domestic	P.O. BOX 5501 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 169	Domestic	P.O.BOX 46 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 170	Domestic	P.O.BOX 46 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 171	Stock	P.O. BOX 169 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 172	Domestic	801 CHERRY ST UVALDE , TX 78801		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 173	Stock	P.O. BOX 1905 Uvalde, TX 78802		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 174	Domestic	801 CHERRY ST UVALDE , TX 78801	George Herndon died & daughter Linda Lively Herndon now owns	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 175	Domestic	801 CHERRY ST UVALDE , TX 78801	George Herndon died & daughter Linda Lively Herndon now owns	TWDB WIID, http://wiid.twdb.state.tx.us/
JA 176	Stock	P.O. BOX 308 SABINAL , TX 78881		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 177	Domestic	P.O. BOX 805 SABINAL , TX 78881		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 178	Stock	P.O. BOX 1164 SABINAL , TX 78881		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 179	Stock	5730 F.M. 1023 UVALDE , TX 78801		TWDB WIID, http://wiid.twdb.state.tx.us/
JA 180	Domestic	2612 GARNER FIELD RD. UVALDE , TX 78801		TWDB WIID, http://wiid.twdb.state.tx.us/

JA ID	Well Type	Owner Contact	Comments	Source
JA 181	Domestic	2670 GARNER FIELD RD. UVALDE , TX 7880		
JA 182	Stock	2663 GARNER FIELD RD. UVALDE , TX 78801		
JA 183	Domestic	P.O. Box 1576 Uvalde , TX 78802		
JA 184	Stock	P.O.Box 986 Uvalde , TX 78802		
JA 185	Stock	P.O.Box 986 Uvalde , TX 78802		
JA 186	Domestic	P.O. BOX 1589 UVALDE , TX 78802		
JA 187	Domestic	P.O. BOX1629 UVALDE , TX 78802		
JA 188	Stock	12179 HWY 90 E. KNIPPA , TX 78870		
JA 189	Stock	91 GARDINER ST. DARIEN , CT 06820		
JA 190	Irrigation	18325 FM 471 S NATALIA , TX 78059		
JA 191	Domestic	12179 HWY 90 E. KNIPPA , TX 78870		
JA 192	Stock	91 GARDINER ST. DARIEN , CT 06820		
JA 193	Domestic	551 Link Rd.,STE C League City , TX 77573		
JA 194	Domestic	P.O. Box 337 Hondo , TX 78661		
JA 195	Irrigation	5180 HWY 83 North Uvalde , TX 78801		
JA 196	Domestic	6 LEONA HEIGHTS DR. Uvalde, TX 78801		
JA 197	Stock	133 C.R. 404 UVALDE , TX 78801		
JA 198	Domestic	P. O. BOX 46 UVALDE , TX 78801		
JA 199			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 200			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI

JA ID	Well Type	Owner Contact	Comments	Source
JA 201			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 202			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 203			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 204			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 205			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 206			Wells used to define the Knippa Gap (Hydrology of the Uvalde	SWRI
JA 207				SWRI
JA 208				SWRI
JA 209				SWRI
JA 210				SWRI
JA 211				SWRI
JA 212				SWRI
JA 213				SWRI
JA 214				USGS
JA 215				EAA
JA 216				USGS
JA 217				USGS
JA 218				USGS
JA 219				USGS
JA 220				USGS

JA ID	Well Type	Owner Contact	Comments	Source
JA 221				USGS
JA 222				USGS
JA 223				USGS
JA 224				USGS_EAA
JA 225				USGS_EAA
JA 226				USGS
JA 227				USGS
JA 228				USGS
JA 229				USGS_EAA
JA 230				USGS_EAA
JA 231				USGS_EAA
JA 232				USGS
JA 233				USGS
JA 234				USGS
JA 235	Residential			USGS
JA 236				USGS
JA 237	Irrigation			USGS
JA 238				USGS
JA 239				USGS
JA 240				USGS

JA ID	Well Type	Owner Contact	Comments	Source
JA 241				USGS
JA 242	Monitoring			USGS
JA 243	Oil or Gas			USGS
JA 244	Oil or Gas			USGS
JA 245	Oil or Gas			
JA 246	Oil or Gas			
JA 247	Oil or Gas			
JA 248	Oil or Gas			
JA 249	Oil or Gas			
JA 250	Oil or Gas			
JA 251	Oil or Gas			
JA 252	Oil or Gas			
JA 253	Oil or Gas			
JA 254	Oil or Gas			
JA 255	Oil or Gas			
JA 256	Oil or Gas			
JA 257	Oil or Gas			
JA 258	Oil or Gas			
JA 259	Oil or Gas			
JA 260	Oil or Gas			

JA ID	Well Type	Owner Contact	Comments	Source
JA 261	Oil or Gas			
JA 262	Oil or Gas			
JA 263	Oil or Gas			
JA 264	Oil or Gas			
JA 265	Oil or Gas			
JA 266	Oil or Gas			
JA 267	Oil or Gas			
JA 268	Oil or Gas			
JA 269	Oil or Gas			
JA 270	Oil or Gas			
JA 271	Oil or Gas			
JA 272	Oil or Gas			
JA 273	Oil or Gas			
JA 274	Oil or Gas			
JA 275	Oil or Gas			
JA 276	Oil or Gas			
JA 277	Oil or Gas			
JA 278	Oil or Gas			
JA 279	Oil or Gas			
JA 280	Oil or Gas			

JA ID	Well Type	Owner Contact	Comments	Source
JA 281	Oil or Gas			
JA 282	Oil or Gas			
JA 283	Oil or Gas			
JA 284	Oil or Gas			
JA 285	Oil or Gas			
JA 286	Oil or Gas			
JA 287	Oil or Gas			
JA 288	Irrigation	(830) 591-7879: P.O. Box 1532, Uvalde, TX. 78802		
JA 289	Livestock	(830) 278-3305: 6 Leona Heights Drive, Uvalde, TX. 78801		
JA 290	Irrigation	830) 363-7537: 341 CR 515, D'Hanis, TX 78850		
JA 291	Irrigation	(830) 591-8036:2182 FM 117, Uvalde, TX. 78801		
JA 292	Irrigation	(830) 278-9171: 200 E. Nopal Street, Uvalde, TX. 78802		
JA 293	Livestock		Two wells close together one for Geochemical sample, one for	Synoptic Water Level Study_Table; Geochemical Samples Table
JA 294				
JA 295	Domestic			Synoptic Water Level Study_Table 3
JA 296				
JA 297				
JA 298				
JA 299				
JA 300				

JA ID	Well Type	Owner Contact	Comments	Source
JA 301	Domestic			Synoptic Water Level Study_Table 3
JA 302				
JA 303				
JA 304				
JA 305				
JA 306				
JA 307	Domestic	F.M. 2690 UVALDE , TX 78801		
JA 308	Domestic Stock			
JA 309	Domestic		Old Irrigation	Synoptic Water Level Study_Table 3
JA 310	Domestic		Hard to get Water Level (Lost E-line)	Synoptic Water Level Study_Table 3
JA 311	Domestic			Synoptic Water Level Study_Table 3
JA 312	Irrigation		Hard to get Water Level (Hang up)	Synoptic Water Level Study_Table 3
JA 313	Domestic			Synoptic Water Level Study_Table 3
JA 314	Domestic			Synoptic Water Level Study_Table 3
JA 315	Domestic		Abandoned Across the street from house 1434 (Lonesome Dove Rd)	Synoptic Water Level Study_Table 3
JA 316	Domestic		New well/house	Synoptic Water Level Study_Table 3
JA 317	Irrigation			Geochemical Samples_Table 4

Appendix E: Geophysical Log Interpretations for Top of Edwards Formation

[Appendix E includes previous abbreviations and new ones as follows: Elevation GL – Elevation Ground Level; Accuracy 1-10 – Log interpretation accuracy 1 being worst, 10 being best.]

JA ID	Latitude DD	Longitude DD	Elevation GL	Well Depth	Elevation Relative Sea Level	Top of Edwards (ft)	Bottom of Edwards (ft)	Accuracy 1-10
JA 005	29.370277	-99.719166	1110	673	952	158	673	9
JA 006	29.266388	-99.77611	977	389	742	235	389	9
JA 007	29.280277	-99.855555	1004	480	898	106	480	9
JA 008	29.243055	-99.755555	958	230	833	125	230	8
JA 009	29.277777	-99.869166	1040	270	995	45	270	10
JA 010	29.283888	-99.862777	1018	280	968	50	280	10
JA 012	29.308611	-99.749721	1012	518	779	233	518	9
JA 013	29.254722	-99.758888	987	510	617	370	510	8
JA 014	29.59111	-99.739166	1402	1080	355	1047	1080	7
JA 016	29.273332	-99.862777	1005	721	358	647	721	6
JA 017	29.245555	-99.55	880	1500	-90	970	1171	9
JA 018	29.555277	-99.642221	1849	7596	-173	2022	3052	6
JA 019	29.33583	-99.69444	1047	758	928	119		10
JA 020	29.33639	-99.64750	1034	833	743.45	290.55	810	10
JA 043	29.147221	-99.478054	750	2483	-1160	1910	2483	2
JA 046	29.269999	-99.505555	898	1560	-172	1070	1560	9
JA 050	29.193333	-99.632499	876	1400	119	757	1043	9

JA ID	Latitude DD	Longitude DD	Elevation GL	Well Depth	Elevation Relative Sea Level	Top of Edwards (ft)	Bottom of Edwards (ft)	Accuracy 1-10
JA 057	29.27611	-99.692499	974	987	614	360	887	9
JA 062	29.29417	-99.63111	978	1302	298	680		10
JA 068	29.28861	-99.761666	996.6	800	811.6	185	620	10
JA 117	29.293888	-99.7525	1013	525	733	280	525	10
JA 139	29.350556	-99.708611	1081	434	936	145	620*	9
JA 140	29.324722	-99.7325	1055	340	777	278	-	9
JA 141	29.335278	-99.719444	1074	756	829	245	-	9
JA 142	29.345	-99.743889	1061	425	1001	60		9
JA 144	29.208611	-99.783888	904.9	287	646.9	258		10
JA 146	29.32417	-99.73000	1055	881.3	810	245		10
JA 168	29.331389	-99.743889	1046	300	892	154	-	9
JA 169	29.329722	-99.735278	1046	300	871	175	-	9
JA 170	29.325278	-99.733889	1046	440	826	220	-	9
JA 174	29.288611	-99.725833	1079	420	849	230	420	10
JA 175	29.277778	-99.744167	1018	240	872	146	240	8
JA 193	29.298889	-99.691111	1007	660	767	240	660	8
JA 194	29.317222	-99.6875	1062	460	971	91	460	7
JA 195	29.271667	-99.759722	995	460	810	185	460	9
JA 196	29.288056	-99.762778	1004	295	784	220	295	10
JA 197	29.286944	-99.878889	1023	300	903	120	300	10

JA ID	Latitude DD	Longitude DD	Elevation GL	Well Depth	Elevation Relative Sea Level	Top of Edwards (ft)	Bottom of Edwards (ft)	Accuracy 1-10
JA 198	29.329167	-99.728611	1057	500	832	225	-	9
JA 199	29.361944	-99.745556	1090		790	300	-	9
JA 200	29.361667	-99.745556	1090		1058	32	-	9
JA 201	29.36	-99.745833	1083		1083	1083	-	9
JA 202	29.36	-99.745556	1087		1072	15	-	9
JA 203	29.746944	-99.746944	1054		979	75	616	9
JA 204	29.3225	-99.731667	1052		782	270	-	9
JA 205	29.369167	-99.750278	1120		1120	1120	820	9
JA 206	29.3325	-99.765833	1057		857	200	507*	9
JA 235	29.26583	-99.63639	948	1076	147	801		10
JA 236	29.34222	-99.67389	1045	740	1008	37		10
JA 237	29.36667	-99.63472	1055	658	866	189		10
JA 238	29.32389	-99.73167	1058	900	803	255		10
JA 239	29.29444	-99.64500	982	1152	425	557		10
JA 240	29.29806	-99.64556	950	915	432	518		10
JA 241	29.27267	-99.76272	996	330	689	307		10
JA 242	29.28108	-99.70011	980	345	720	260		10
JA 243	29.105502	-99.454067	718	1199	-272	990	1199	9
JA 244	29.124888	-99.431754	841	2430	-1482	2323	2430	5
JA 245	29.147588	-99.704935	858	1711	250	608	1711	3

JA ID	Latitude DD	Longitude DD	Elevation GL	Well Depth	Elevation Relative Sea Level	Top of Edwards (ft)	Bottom of Edwards (ft)	Accuracy 1-10
JA 246	29.09139294	-99.43367305	701	1209	-372	1073	1209	3
JA 247	29.12194183	-99.43836332	786	2990	-377	1163	1756	7
JA 248	29.56509913	-99.64862004	858	1711	-502	1360	1711	2
JA 249	29.20970914	-99.69676184	948	2602	-167	1115	2602	7
JA 250	29.24696793	-99.71248234	947.5	3000	-395.5	1343	2135	5
JA 251	29.13342159	-99.97511022	875	3464	-607	1482	2412	7
JA 252	29.12600198	-99.62021939	896	4000	-931	1827	2625	6
JA 253	29.28762676	-100.0456032	1058	6000	129	929	990	3
JA 254	29.28039683	-100.1029851	1102	3843	636	466	1500	3
JA 255	29.231802	-99.676199	915	3688	353	562	1210	10
JA 256	29.14680109	-99.48190496	747	3694	-291	1038	1630	3
JA 257	29.14265124	-99.4803949	745	1599	-575	1320	1599	7
JA 258	29.14265124	-99.4803949	753	1541	-643	1396	1541	8
JA 259	29.13242145	-99.44093344	777	2292	-236	1013	1364	3
JA 260	29.13837121	-99.43823336	807	4545	-276	1083	1835	3
JA 261	29.12990155	-99.44233348	777	950	-77	854	950	3
JA 262	29.15012104	-99.50201568	795	1500	-410	1205	1500	6
JA 263	29.10271283	-99.57396791	890.03	1380	-241.97	1132	1380	8
JA 264	29.09663305	-99.58221816	886.3	1116	-163.7	1050	1116	10
JA 265	29.10246263	-99.45419385	718	5627	-1647	2365	2600	8

JA ID	Latitude DD	Longitude DD	Elevation GL	Well Depth	Elevation Relative Sea Level	Top of Edwards (ft)	Bottom of Edwards (ft)	Accuracy 1-10
JA 266	29.38262376	-99.46786398	801	4560	-1074	1875	2640	6
JA 268	29.200198	-99.76886	984.4	3015	-200.6	1185	1861	7
JA 269	29.1032128	-99.60489889	880	4015	-1318	2198	2900	9
JA 270	29.10274282	-99.5926985	881	1380	-301	1182	1384	8
JA 271	29.23647752	-99.41936301	827	4505	-281	1108	1800	8
JA 272	29.13230168	-99.49031524	758	1104	-215	973	1107	9
JA 273	29.12628187	-99.48294496	732	1200	-358	1090	1200	8
JA 274	29.1237117	-99.42659289	823	2430	-440	1263	2057	6
JA 275	29.11412202	-99.41921259	769	2175	-571	1340	1817	9
JA 276	29.11204228	-99.45555393	752	1300	-310	1062	1300	8
JA 277	29.10580254	-99.46022409	960	1127	-132	1092	1127	7
JA 278	29.09119305	-99.8630868	806.53	2610	-1125.47	1932	2610	9
JA 279	29.12339207	-99.62248946	823.47	1366	-96.53	920	1366	9
JA 280	29.098033	-99.57648798	894.85	1153	-167.15	1062	1153	9
JA 282	29.13147141	-99.4261129	762	2405	-492	1254	1705	9
JA 283	29.11566202	-99.43140304	807	1324	-285	1092	1324	8
JA 284	29.10992257	-99.49670545	754	1495	-368	1122	1495	9
JA 285	29.09988291	-99.48870514	572	1200	-420	992	1200	9
JA 286	29.09515298	-99.46812436	723	1510	-285	1008	1512	7
JA 287	29.125282	-99.53005654	781	4890	-1551	2332	2332	6

Appendix F: Water Levels Relating to the Knippa Gap Study Area July 2011

[Appendix F includes previous abbreviations and new ones as follows: Point Class – ; Point ID – Point identifier within GPS; WGS84 Elev – Datum WGS84 Elevation; ELEV Ftamsl – Elevation in feet above mean sea level; MSL WL – Mean Sea Level Water Level.]

JA ID	Date Time	Point Class	Point ID	WGS84 Elev(m)	ELEV Ftamsl	Elev Source	Depth Water (ft)	Top Casing (ft)	MSL WL(ft)
JA 002	8/8/2012 12:30	NAV	1224	277.08134	909.06	Leica Survey Grade	155.64	0.38	753.80
JA 013	8/8/2012 12:43	NAV	1225	268.41774	880.64	Leica Survey Grade	110.13	1.25	771.76
JA 019	Aug-12			320.7317073	1052.00	GoogleEarth	234.27	1.41	819.14
JA 039	8/6/2012 15:22	NAV	1207	292.57179	959.88	Leica Survey Grade	310.04	2.00	651.84
JA 063	Aug-12			306.7073171	1006.00	TWDB	273.63	1.41	733.78
JA 064	8/6/2012 11:21	NAV	1201	282.99367	928.46	Leica Survey Grade	181.22	1.67	748.90
JA 065	8/6/2012 11:04	NAV	1200	288.55414	946.70	Leica Survey Grade	65.20	1.67	883.17
JA 067	8/8/2012 13:14	NAV	1227	275.75132	904.70	Leica Survey Grade	155.96	1.17	749.90
JA 109	8/7/2012 9:29	NAV	1212	304.67437	999.59	Leica Survey Grade	259.36	1.17	741.39
JA 113	8/7/2012 15:43	NAV	1219	308.27178	1011.39	Leica Survey Grade	298.15	0.00	713.24
JA 140	8/7/2012 8:41	NAV	1211	299.52089	982.68	Leica Survey Grade	227.30	1.00	756.38
JA 167	Aug-12			317.0731707	1040.00	GoogleEarth	303.27	1.29	738.02
JA 168	8/6/2012 11:51	NAV	1202	318.83224	1046.04	Leica Survey Grade	151.83	0.54	894.75
JA 172	8/8/2012 9:43	NAV	1221	293.14666	961.77	Leica Survey Grade	218.64	0.67	743.79

JA ID	Date Time	Point Class	Point ID	WGS84 Elev(m)	ELEV Ftamsl	Elev Source	Depth Water (ft)	Top Casing (ft)	MSL WL(ft)
JA 174	Aug-12			305.7926829	1003.00	GoogleEarth	168.51	0.75	835.24
JA 175	Aug-12			316.7682927	1039.00	Garmin	187.21	1.25	853.04
JA 289	Aug-12			315.2439024	1034.00	Geophysical Log	298.40	0.50	736.10
JA 293	8/0/2012			353.6585366	1160.00	Garmin	173.48	0.00	986.52
JA 295	8/6/2012 13:46	NAV	1204	293.71378	963.63	Leica Survey Grade	192.05	0.00	771.58
JA 301	8/7/2012 12:08	NAV	1215	311.33777	1021.45	Leica Survey Grade	211.88	9.04	818.61
JA 307	8/7/2012 8:41			322.8658537	1059.00	Garmin	234.19	0.67	825.48
JA 308	8/7/2012 11:57	NAV	1214	313.45716	1028.40	Leica Survey Grade	225.75	1.25	803.90
JA 309	8/8/2012 10:03	NAV	1222	282.09602	925.51	Leica Survey Grade	154.66	1.04	771.90
JA 310	8/7/2012 15:27	NAV	1218	295.98456	971.08	Leica Survey Grade	314.47	0.83	657.44
JA 311	8/7/2012 12:32	NAV	1216	300.52782	985.98	Leica Survey Grade	208.04	0.00	777.95
JA 312	Aug-12			317.3780488	1041.00	Garmin	239.77	0.00	801.23
JA 313	8/6/2012 14:01	NAV	1205	295.36331	969.04	Leica Survey Grade	194.83	0.17	774.37
JA 314	8/6/2012 16:31	NAV	1208	305.22674	1001.40	Leica Survey Grade	211.97	0.17	789.59
JA 315	8/6/2012 17:58	NAV	1209	289.28212	949.09	Leica Survey Grade	188.11	0.83	761.81
JA 316	8/7/2012 8:17	NAV	1210	298.3341	978.79	Leica Survey Grade	212.74	2.00	768.05