

# Identification of Potential Brackish Groundwater Production Areas -Nacatoch Aquifer

## TWDB Contract Number 1600011952

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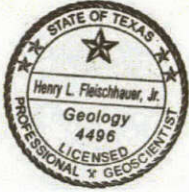
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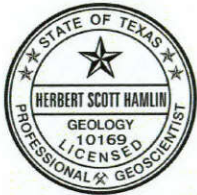
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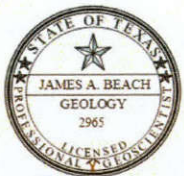
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## **1 Executive Summary**

House Bill 30 was passed in 2015 by the 84<sup>th</sup> Texas Legislature with a goal to identify and designate local or regional brackish groundwater production zones in areas of the state with moderate to high availability of brackish groundwater that can be used to reduce the use of fresh groundwater. The goal of these studies is to identify potential production areas that can provide brackish water over a 30 to 50-year time period using the Nacatoch Aquifer Groundwater Availability Model and the application of best available science.

Potential production area may only exist in locations that meet the criteria of House Bill 30. House Bill 30 states that these areas:

- Are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any area of the same or other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids level of 1,000 milligrams per liter or less at the time of designation of the zones.
- Are not located in an aquifer, subdivision of an aquifer, or geologic stratum that has an average total dissolved solids level of more than 1,000 milligrams per liter and is serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones, or in an area of a geologic stratum that is designated or used for wastewater injection through the use of injection wells or disposal wells permitted under Chapter 27.
- Are not located in an area of the Edwards Aquifer subject to the jurisdiction of the Edwards Aquifer Authority; the boundaries of the Barton Springs-Edwards Aquifer Conservation District; the Harris-Galveston Subsidence District; or the Fort Bend Subsidence District.

Using the exclusion criteria stated in House Bill 30, four potential production areas were delineated in areas outlying the excluded areas. Pumping impacts from the potential production areas were estimated using low, medium and high-volume pumping scenarios of 100, 200 and 500 acre-feet per year assuming both 30 and 50 years of production. This drawdown analysis was performed to characterize the effect pumping in these areas would have on existing exclusion wells. Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The approximate minimum drawdowns are based on the 100 acre-feet 30-year scenarios, and maximums are based on the 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown. Volume estimates were not calculated for the potential production areas.

To monitor pumping volumes from wells completed in brackish production areas, it is recommended that 1) meters be installed on each well to track pumping volumes, 2) metered volumes are recorded monthly, and 3) monitoring wells are designated to track water level changes resulting from brackish production. Monitoring wells should be located between existing users excluded by House Bill 30 criteria and brackish production wells. The number of

monitoring wells located peripheral to brackish pumping that are necessary to characterize the impacts of pumping upon existing users will be driven by several site-specific factors, including (but not limited to) distance to nearest exclusion well, monitoring well candidate locations, as well as landowner and property access issues.

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume.

## **2 Introduction**

House Bill 30 was passed in 2015 by the 84<sup>th</sup> Texas Legislature with a goal to identify and designate local or regional brackish groundwater production zones in areas of the state with moderate to high availability of brackish groundwater that can be used to reduce the use of fresh groundwater. This legislation was driven by the recent severe drought coupled with continuous population growth in Texas.

The first four aquifers to be evaluated include: the Carrizo-Wilcox Aquifer within GMA-13 (between the Colorado River and the Rio Grande), the Blaine, Rustler, and Gulf Coast Aquifers. These aquifer studies were finalized in August 2016. Three additional aquifers - the Blossom, Nacatoch and Trinity Aquifers – evaluations must be completed by August 2017. Any other aquifers with potential brackish production zones need to be evaluated by December 1, 2022.

The Nacatoch Aquifer of northeast Texas occurs in a narrow band that extends from near the Navarro-Limestone County line northward through the communities of Kaufman and Commerce, and then eastward through Bowie County and beyond into Arkansas (George, Mace, & Petrossian, 2011) (Figure 2-1). The project area for the Nacatoch Aquifer includes the downdip portion of the Nacatoch Formation that is estimated to have a total dissolved solids concentration up to 10,000 milligrams per liter. This area incorporates all of the geophysical log locations that were analyzed for water quality estimates. The project area encompasses 8,118 square miles as shown in Figure 2-1.

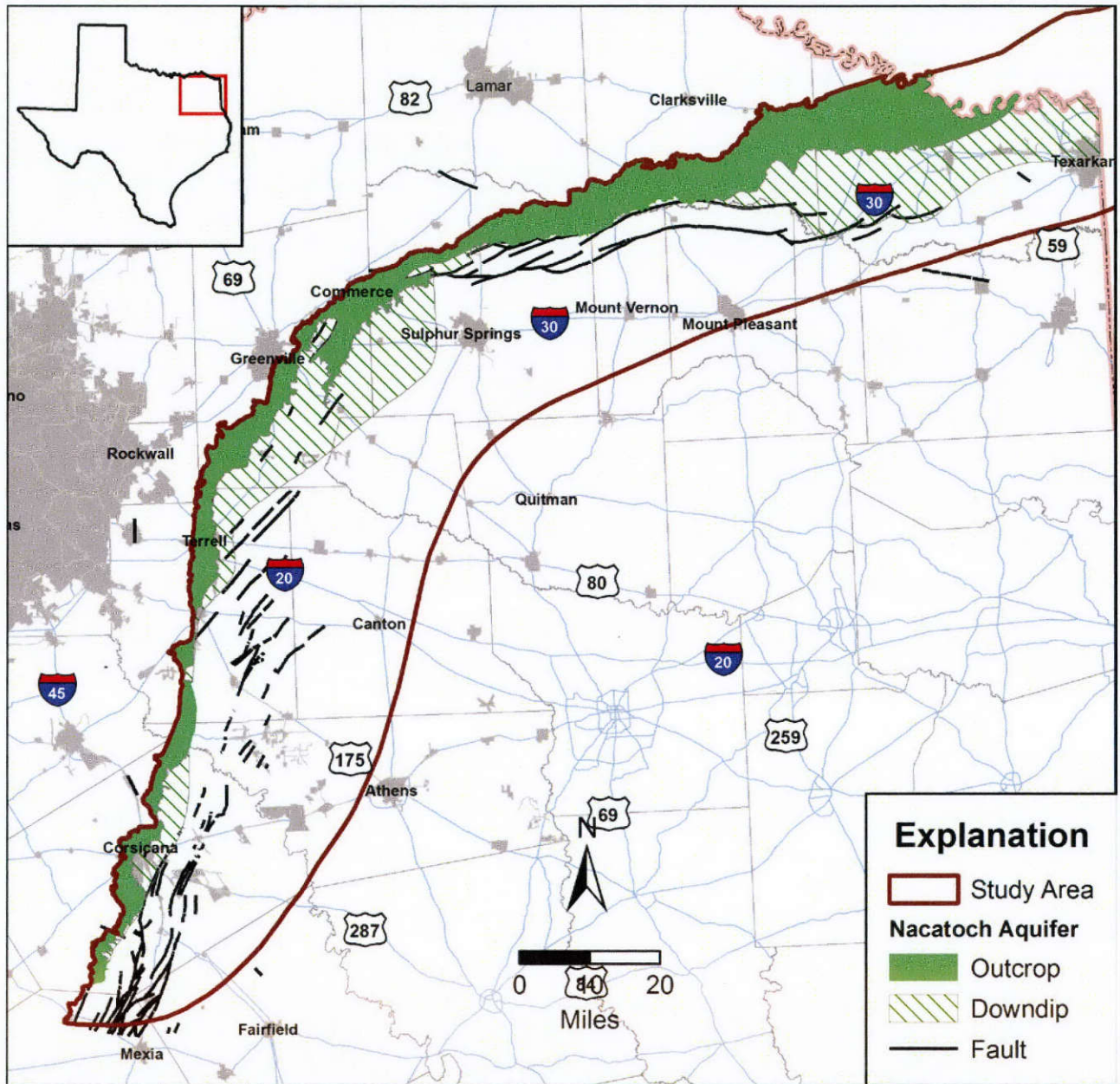


Figure 2-1. Project area.

### **3 Project Deliverables**

Project deliverables include: this report, an ArcGIS geodatabase, and geophysical log metadata to be uploaded to the BRACS database. Data used for the completion of this project includes: water quality analytical data, geophysical logs, and water well reports from multiple sources. No geophysical logs or water quality results were used for this project from sources other than TWDB, therefore none are provided with this project as a deliverable.

Metadata from geophysical log analyses have been provided in the BRACS database format that is structurally identical to Meyer (2014). The applicable source data has been integrated within an ESRI geodatabase format consistent with TWDB standard data model framework for delivery.

The results and evaluation of these data are discussed in this report. Any data that was incorporated into the results of this study have been provided to the TWDB with this report. Volumetric analyses were performed using the Nacatoch Groundwater Availability Model and best available science.

### **4 Project Area**

The Nacatoch Aquifer of northeast Texas occurs in a narrow band that extends from near the Navarro-Limestone County line northward through the communities of Kaufman and Commerce, and then eastward through Bowie County and beyond into Arkansas. Geologic mapping of the Nacatoch Sand extends further southward through Limestone and Falls Counties; however, the Nacatoch Sand in this area is recognized as non-water bearing and is therefore not included in the aquifer delineation. The project area includes the Nacatoch Aquifer outcrop, local alluvium and terrace deposits, and its downdip/subsurface extent for a distance from zero to approximately 15 miles. Due to faulting, very little outcrop occurs in the central portion of the aquifer extent in the general area of the City of Commerce (Figure 2-1). Significant areas of the lateral outcrop are covered by silt and sand floodplain deposits (mapped as alluvium and terrace deposits).

The project area is contained within two water planning regions, Region C in the southwestern half and Regions D (North East Texas) in the northern half (Figure 4-1). Only the western Henderson County portion of the Neches and Trinity Valleys Groundwater Conservation District is impacted significantly by the study area, although Freestone County of the Mid-East Texas Groundwater Conservation District lies only slightly outside the area (Figure 4-2). The downdip limit of the Nacatoch Aquifer generally occurs at the eastern border of Groundwater Management Area 8, while Groundwater Management Area 11 lies immediately to the east (Figure 4-3).

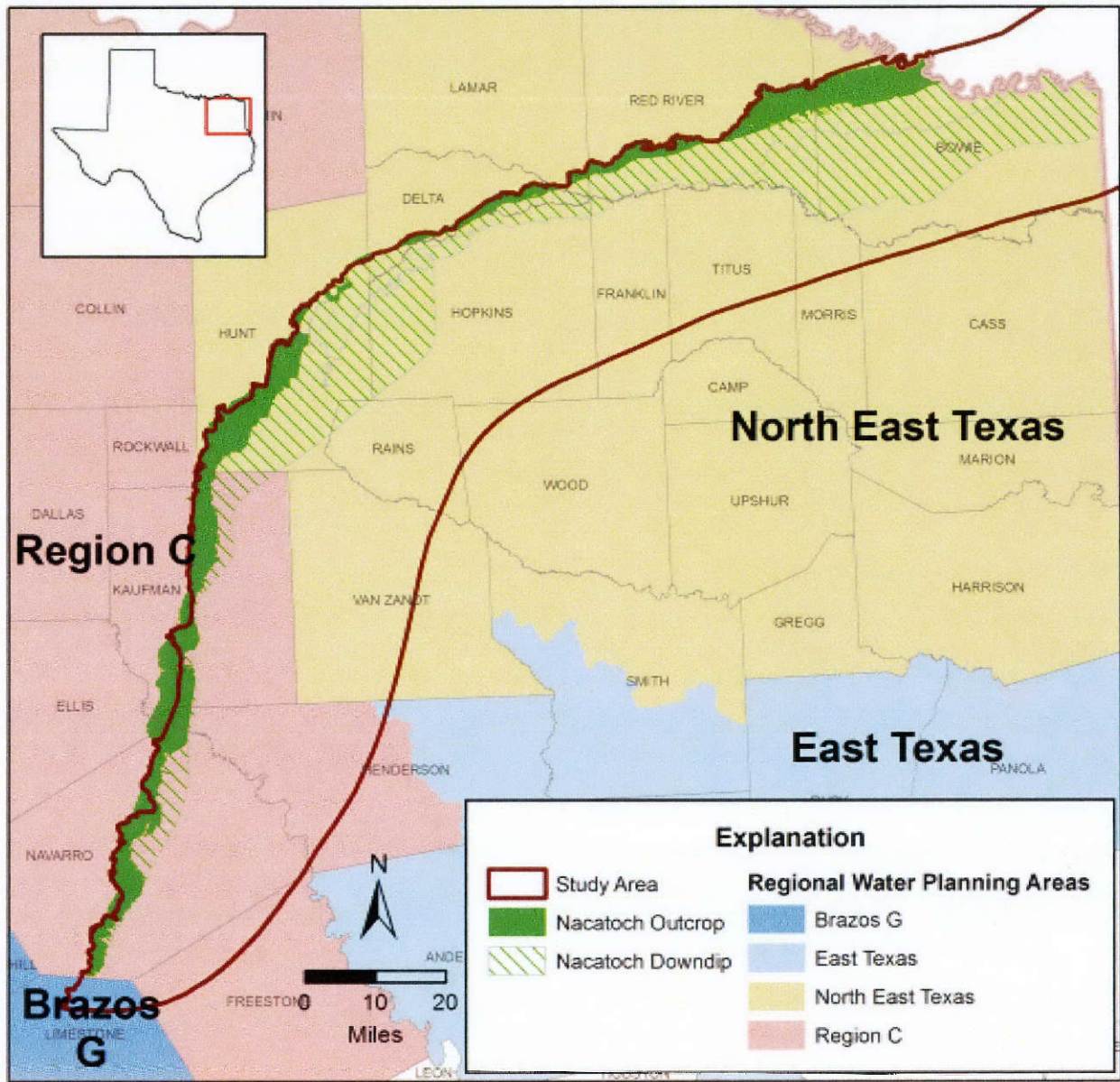


Figure 4-1. Regional water planning areas.



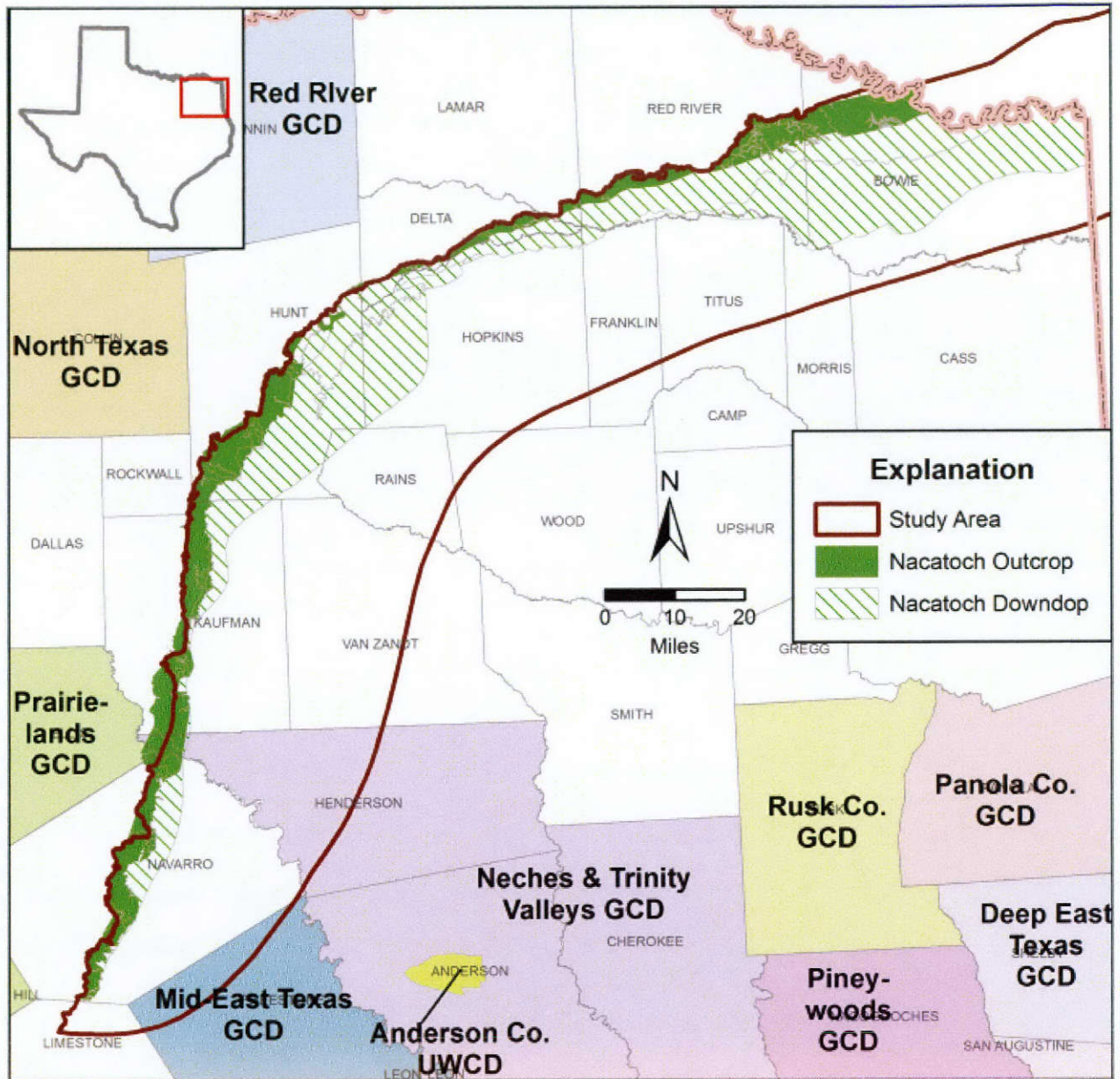


Figure 4-2. Groundwater conservation districts.

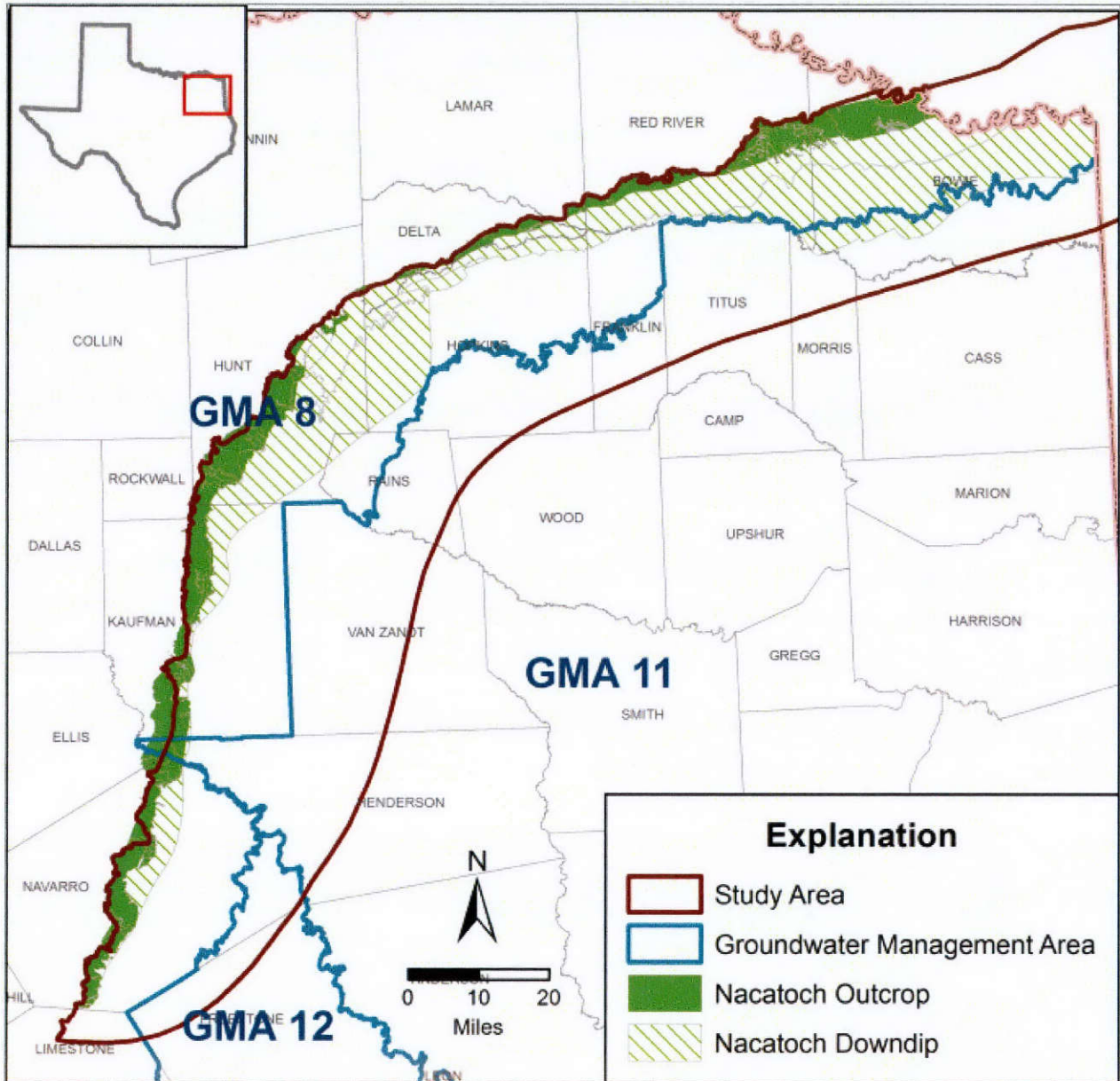


Figure 4-3. Groundwater management areas.

## 5 Hydrogeologic Setting

### 5.1 Geology

The generalized stratigraphic chart showing the Nacatoch Sand and adjacent formations is shown in Table 5-1. The Nacatoch outcrop and subcrop have an overall northeast to southwest trend in the northern part of the basin, changing to a north-south trend in the western part. Cretaceous sediments of the older Taylor Group lie west of the Nacatoch Sand outcrops. To the east lie younger sands and clays of the Midway Group. Alluvium along the major drainages in the area, as seen in Figure 5-1, also form a part of the Nacatoch Aquifer system.

The structural framework of the Nacatoch Aquifer can base its configuration on three principal components: deposition into the East Texas Basin, deltaic sedimentation processes, and stratigraphic off sets resulting from the Mexia-Talco Fault Zone.

Net sand thickness is greatest within the Pittsburg syncline where it straddles the state line in eastern Bowie and Cass Counties. Elsewhere, increased sand thickness over 100 feet occur in southern Red River and northern Titus Counties, eastern Hunt and western Delta Counties, and in southern Hunt County. These areas of greater thickness indicate focal points of original sediment input into the East Texas Basin. Net sand thickness decreases to 100 feet or less between these sediment input areas, and from central Kaufman County southward, net sand thickness is reduced to approximately 20 feet.

The Mexia-Talco fault zone consisting primarily of strike-oriented normal faults that often formed grabens disrupts the basinward dip of the Nacatoch Aquifer layers. The faulting generally causes the normal downdip flow of groundwater to be halted or diverted, thus limiting the downdip extent of fresh water in the aquifer (Ashworth, 1988).

There are two grabens adjacent to the Nacatoch outcrop (Figure 5-1). One is located in northern Hopkins, Franklin, Titus, and Morris Counties. The other is located to the south in Navarro, Freestone and Limestone counties.

The Nacatoch Aquifer is composed of sand sequences of the Nacatoch Sand interbedded with impermeable layers of mudstone or clay, the latter acting as aquitards that prevent mixing of waters from the different producing zones (LBG-Guyton Associates; NRS Consulting Engineers, 2003). These well-sorted, very fine to fine grained marine sandstones are coarsening upwards, calcitic to unconsolidated, glauconitic, and commonly contain shell fragments (McGowen & Lopez, 1983).

A geologic cross section location map is included on Figure 5-2. Sand distribution within the Navarro is shown in the stratigraphic section (X-X') along formation strike in Figure 5-3. Dip sections A-A' (Figure 5-4), B-B' (Figure 5-5), and C-C' (Figure 5-6) show the south-easterly dipping formations, and the Nacatoch and lower Navarro sands.

**Table 5-1. Generalized stratigraphic chart for the Nacatoch Aquifer (in gray) and adjacent geologic units.**

Era	System	Series	Group	Formation	
Cenozoic	Tertiary	Paleocene	Wilcox	Calvert Bluff Formation	
				Simsboro Formation	
				Hooper Formation	
			Midway	Undifferentiated	
Mesozoic	Cretaceous	Gulfian	Navarro	Kemp Clay	
				Corsicana Marl	
				Nacatoch Sand	
				Lower Navarro/Neylandville Marl	
			Taylor	Upper part Taylor Marl	
				Pecan Gap Chalk	Annona Chalk
				Wolfe City Sand	
				Lower Taylor	
			Austin	Gober Chalk	
				Brownstown Marl	
				Blossom Sand	
				Bonham Marl	
				Ector Tongue	
			Eagle Ford	Eagleford Shale (Sub-Clarksville Member)	

Source: Baker, 1995.

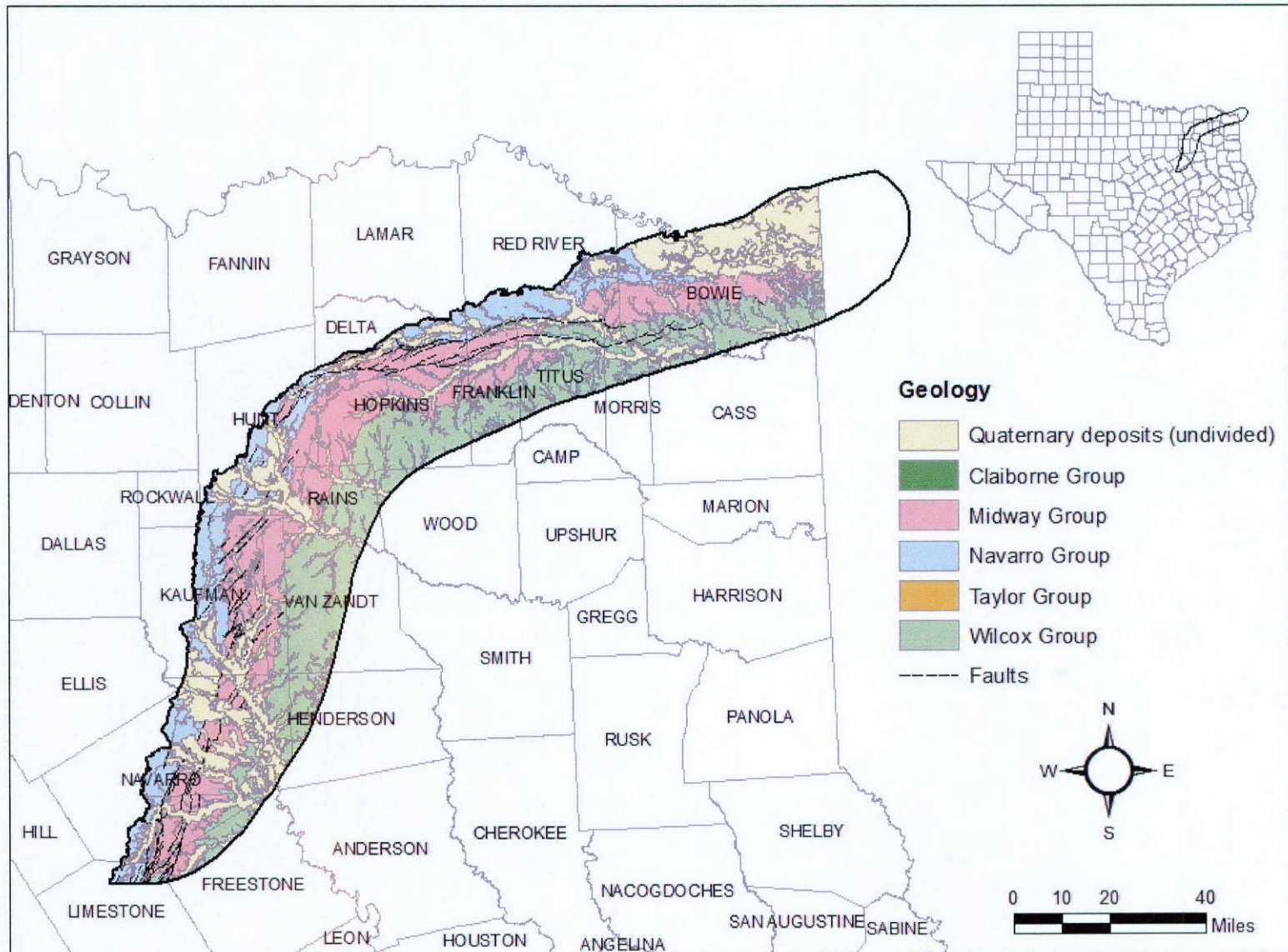


Figure 5-1. Geologic map of project area.

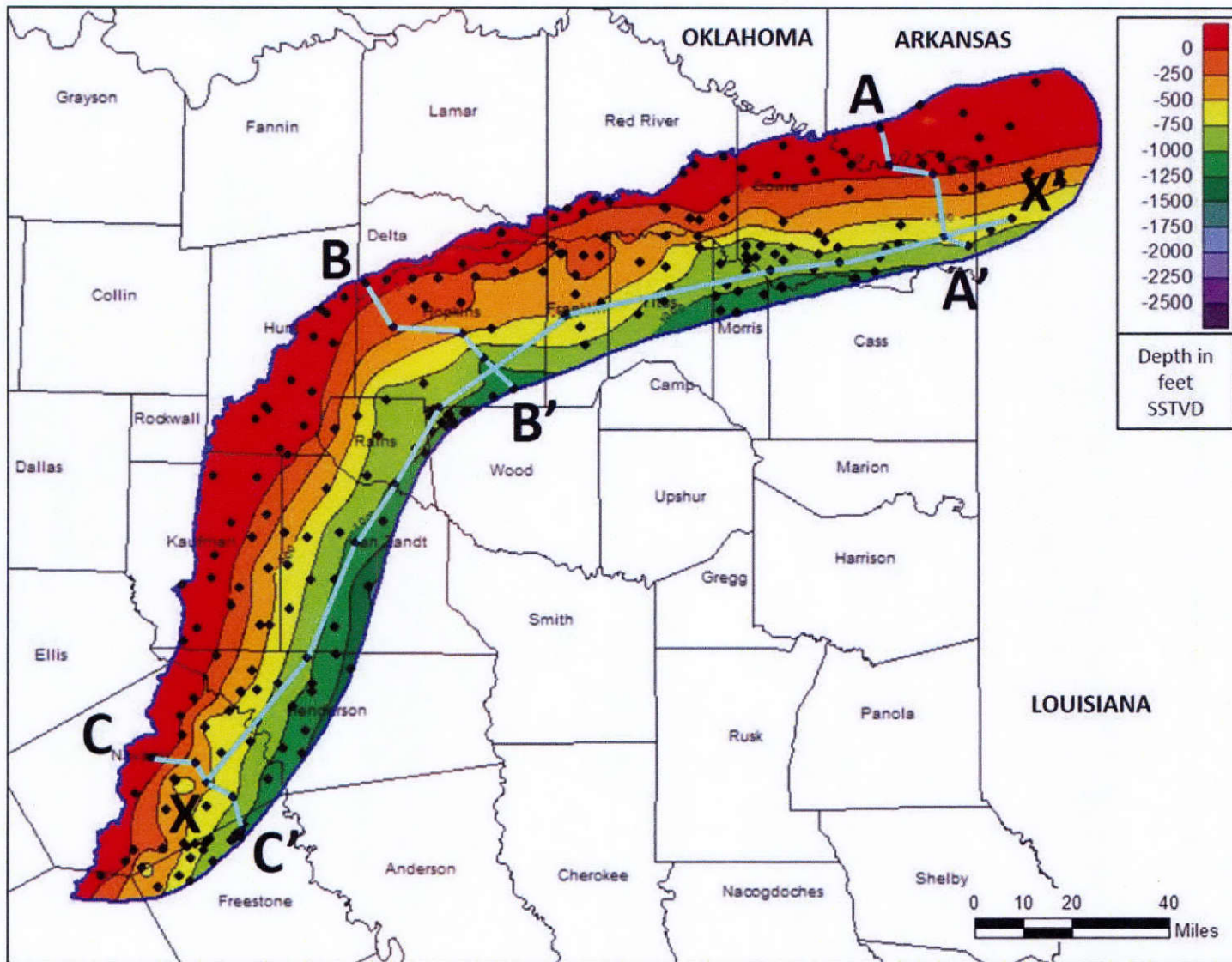


Figure 5-2. Location of cross sections on top of Nacatoch structure map.

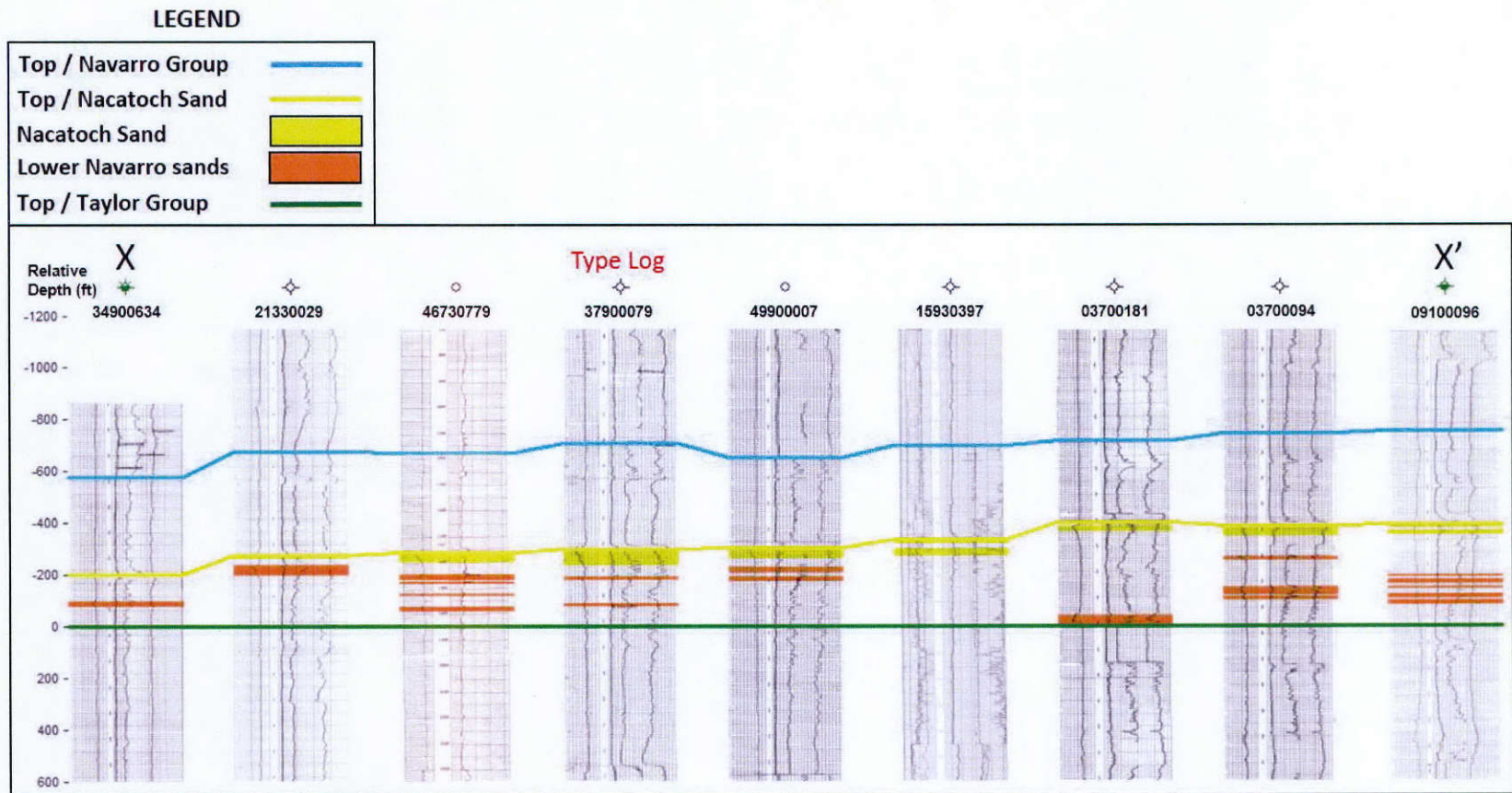


Figure 5-3. Stratigraphic section X-X' along strike (top of Taylor Group).

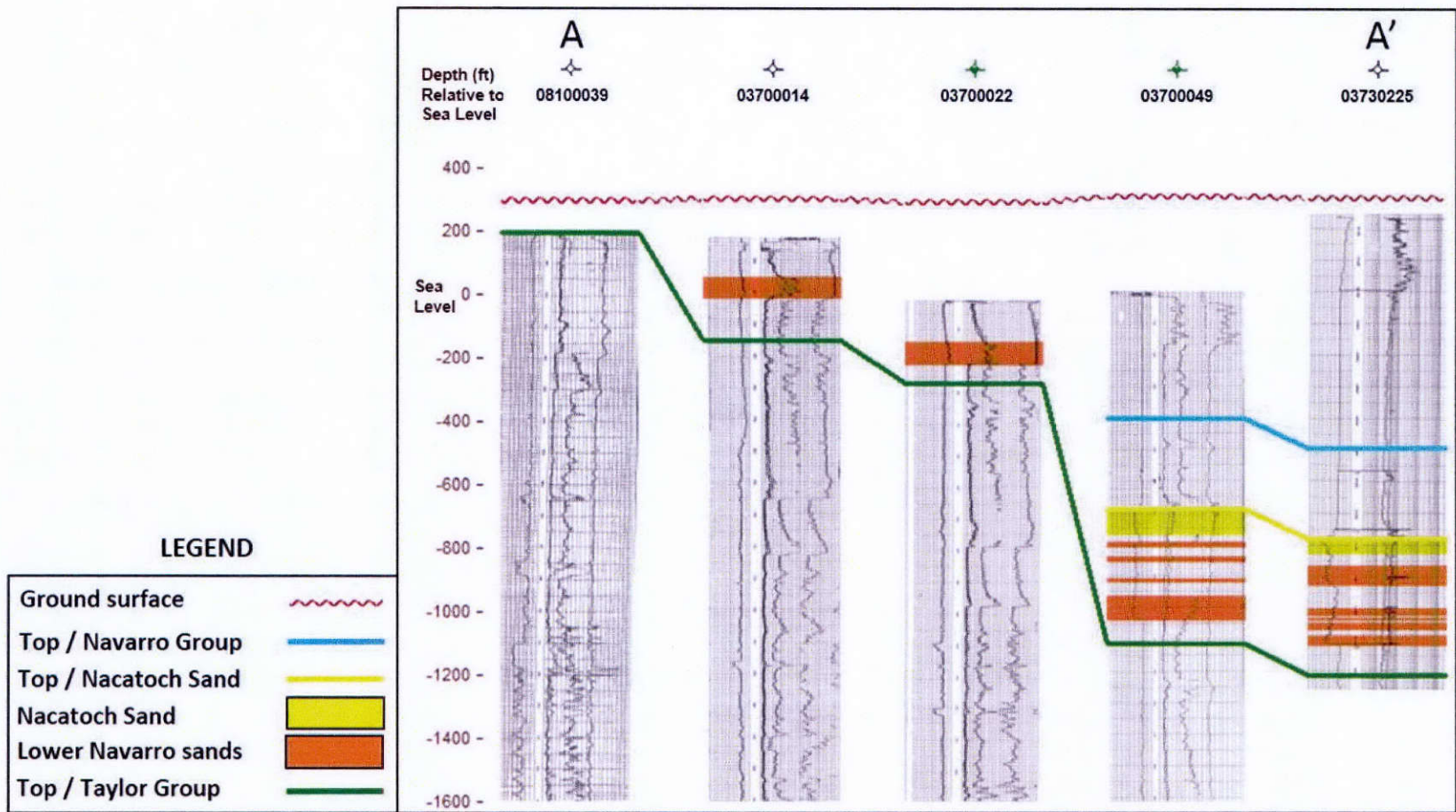


Figure 5-4. Structural section A-A' along formation dip direction.



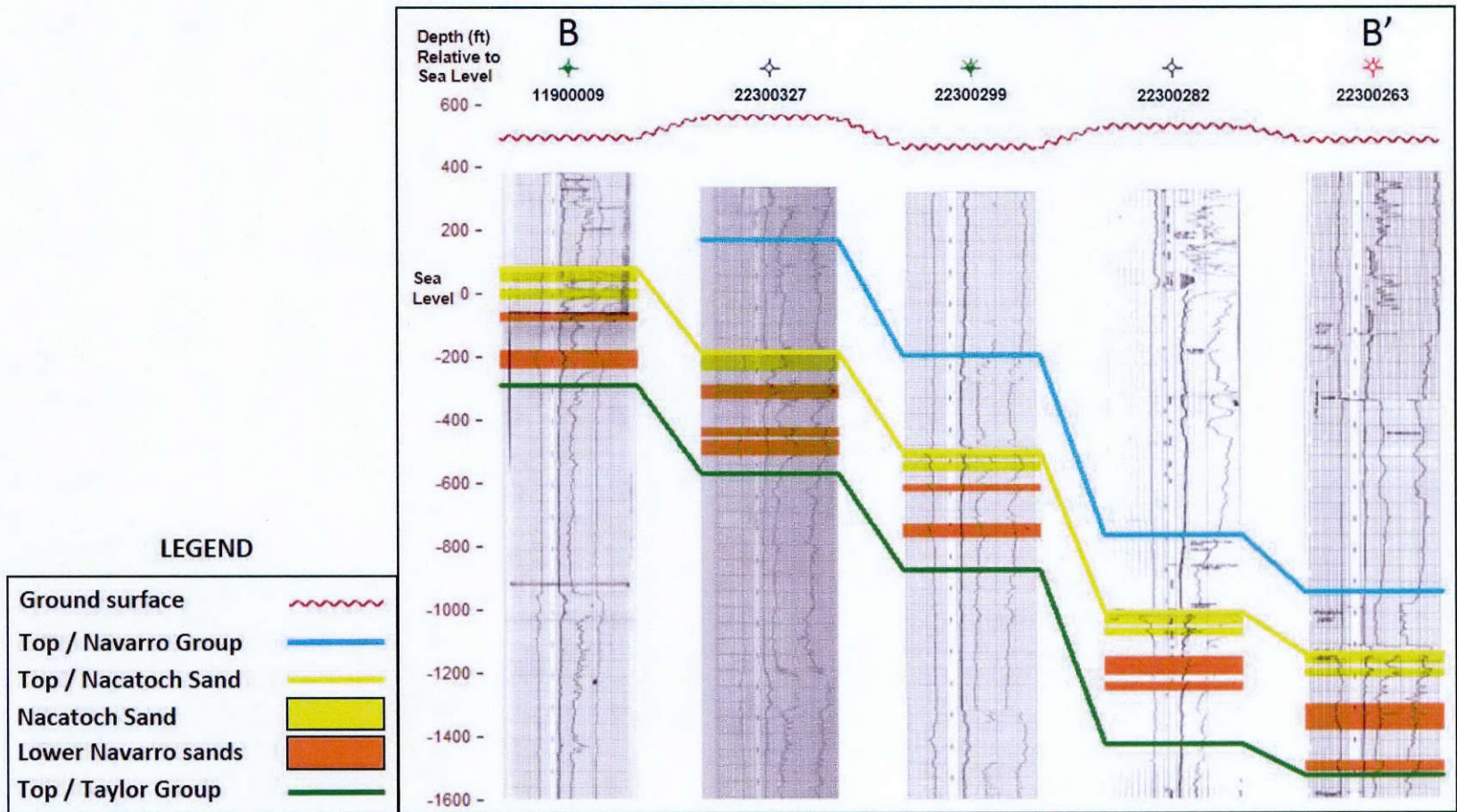


Figure 5-5. Structural section B-B' along formation dip direction.

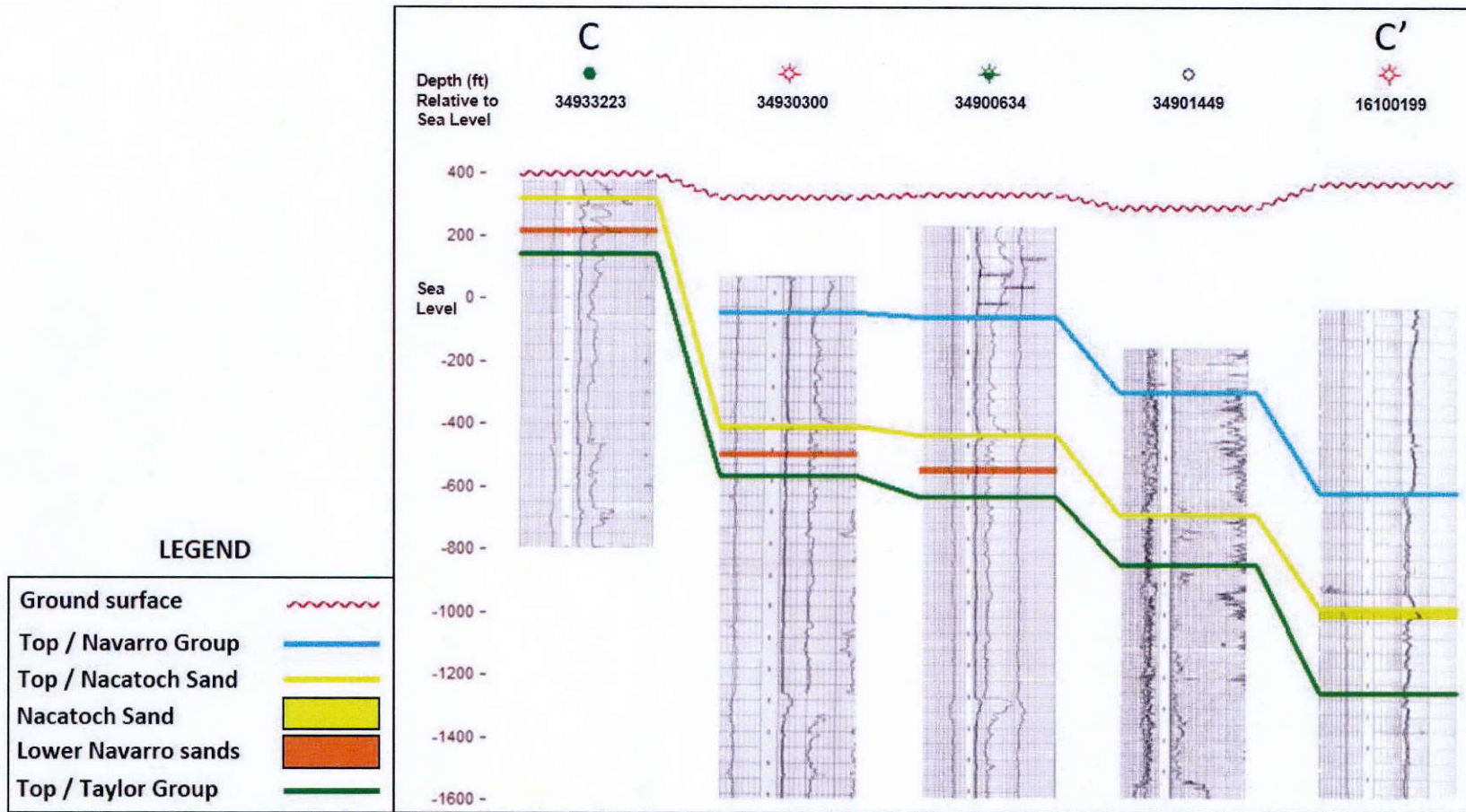


Figure 5-6. Structural section C-C' along formation dip direction.

## **5.2 Groundwater**

The Nacatoch Aquifer (designated as a minor aquifer) occurs between other major and minor aquifers. Older aquifer formations in the area include the Woodbine and Blossom minor aquifers, which both underlie the Nacatoch Aquifer. Separated primarily by the Midway formation, the Carrizo-Wilcox major aquifer overlies the Nacatoch Aquifer further downdip. The extents of the major and minor aquifers as defined by the TWDB are shown in Figure 5-7 and Figure 5-8, respectively.

The TWDB reports freshwater saturated aquifer thickness of 50 feet on average (George, Mace, & Petrossian, 2011). Approximately 80 feet of alluvium occurs along major drainages that is hydraulically connected to the Nacatoch Sand, and is part of the aquifer system. Groundwater in this aquifer is usually under artesian conditions. An exception occurs in shallow wells where water table conditions exist due to outcropping of the aquifer. The Mexia-Talco Fault Zone interrupts the normal down-dip flow of groundwater, and generally delineates the subsurface limit of the aquifer (George, Mace, & Petrossian, 2011) (LBG-Guyton Associates; NRS Consulting Engineers, 2003).

Major rivers intersecting the model area include the Trinity, Sabine, Sulphur, and Red. The major rivers in the model area tend to flow year around, and are typically considered to be gaining (i.e. groundwater flows into the rivers most of the time). Under predevelopment conditions, groundwater flow in the Nacatoch Aquifer is elevation-driven from the higher elevation outcrops to the lower elevation stream valleys and, in areas where faulting does not disturb aquifer continuity, to the confined sections of the aquifers. Prior to significant resource development, recharge occurring as a result of infiltration and stream loss was balanced by discharge to streams and springs in the outcrop, and through cross-formational flow (Beach, et al., 2009).

Water level data includes data from both the TWDB groundwater database and the State Driller Report database between years 2008 and 2016. Generally, direction of groundwater flows radially away from the topographically-higher land elevations between the river basins towards the river channels (Figure 5-9). For example, groundwater flows to the northeast (Sabine River) and to the south (Trinity River) away from the higher elevations in northern Kaufman County. Similarly, groundwater flows to the southwest, south and southeast towards the Sulphur River radially away from the data point shown in southern Red River County. Figure 5-10 shows the same data presented as depth to water measurements.

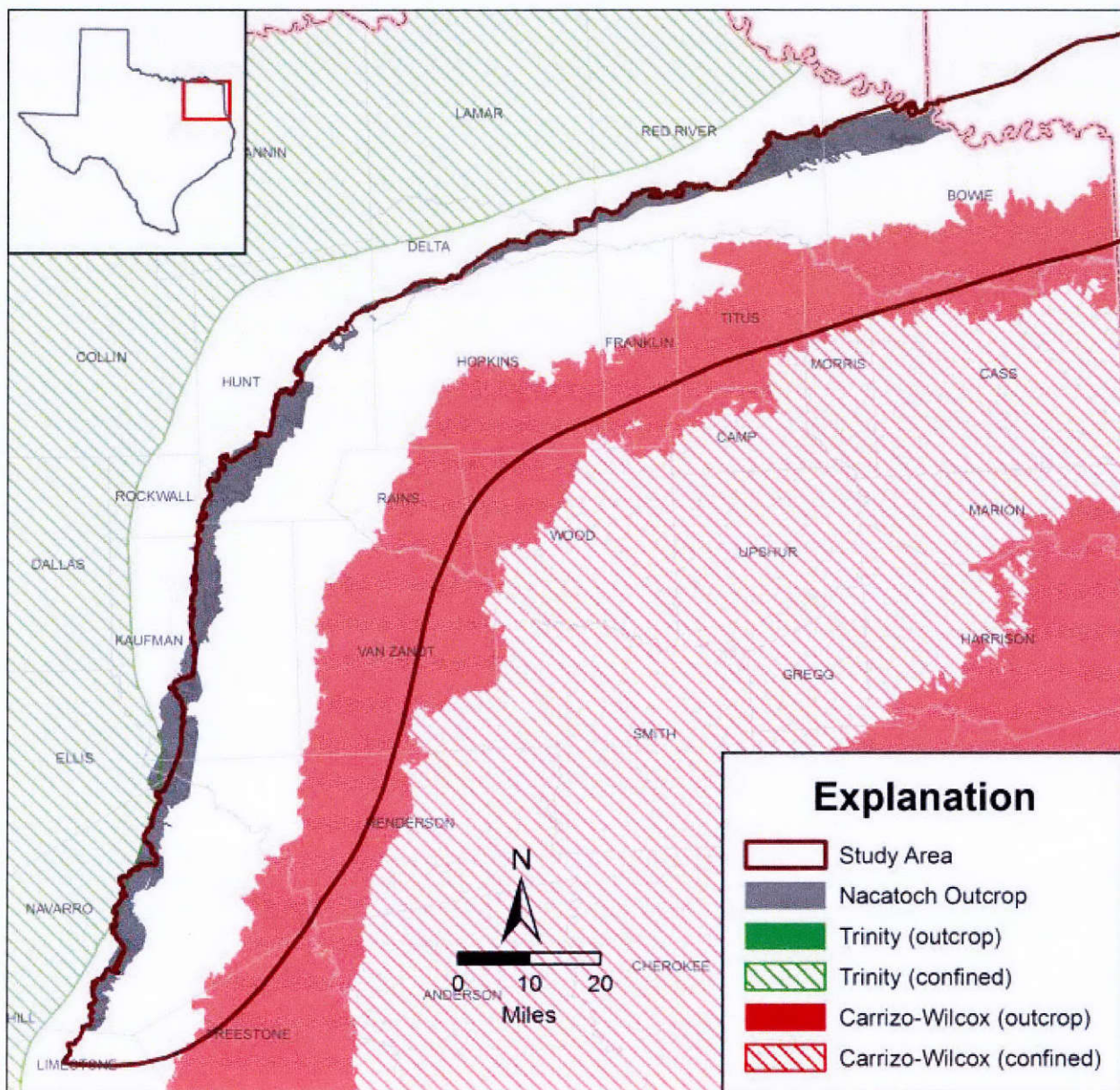


Figure 5-7. Major aquifers.

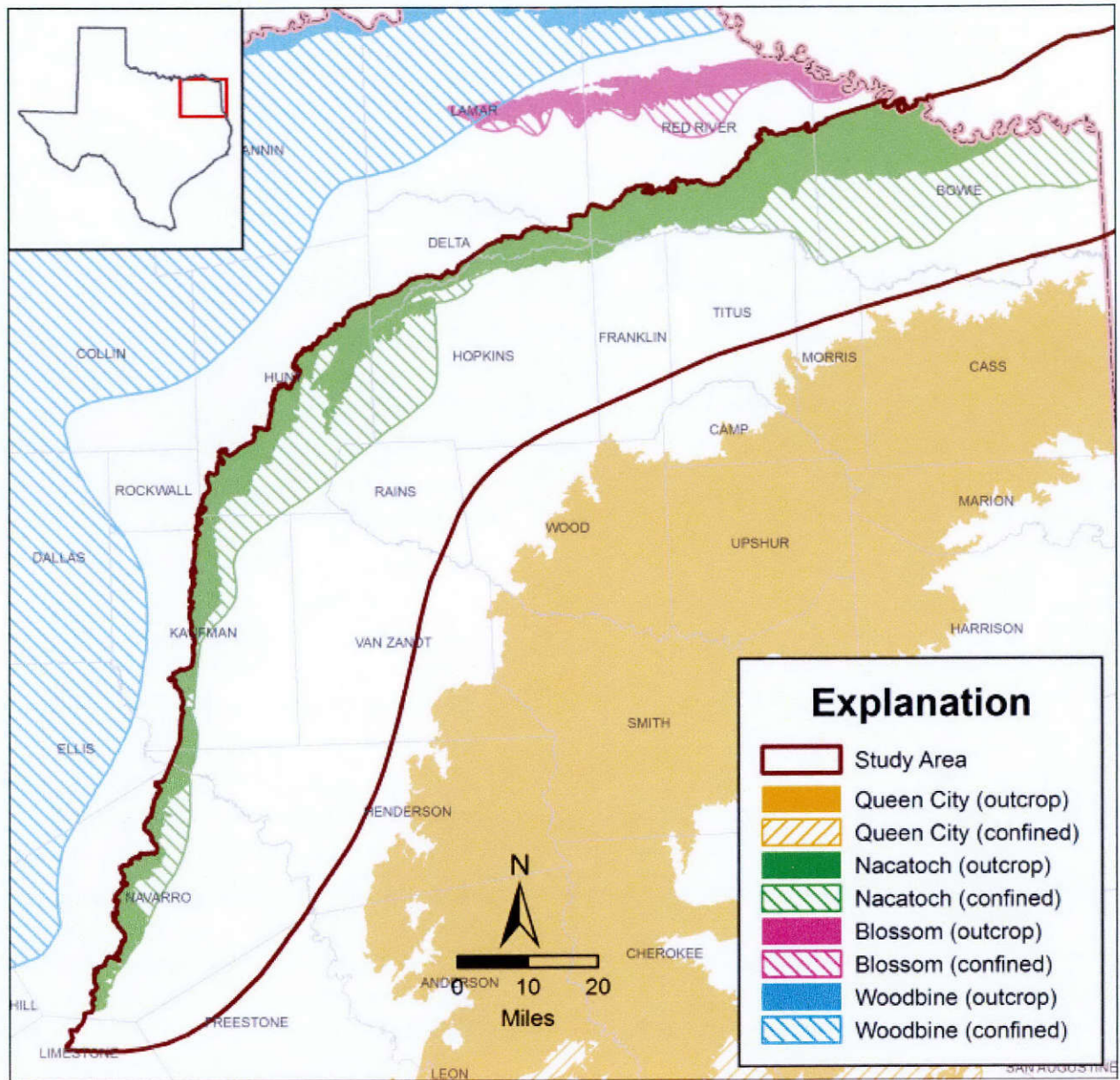


Figure 5-8. Minor aquifers.

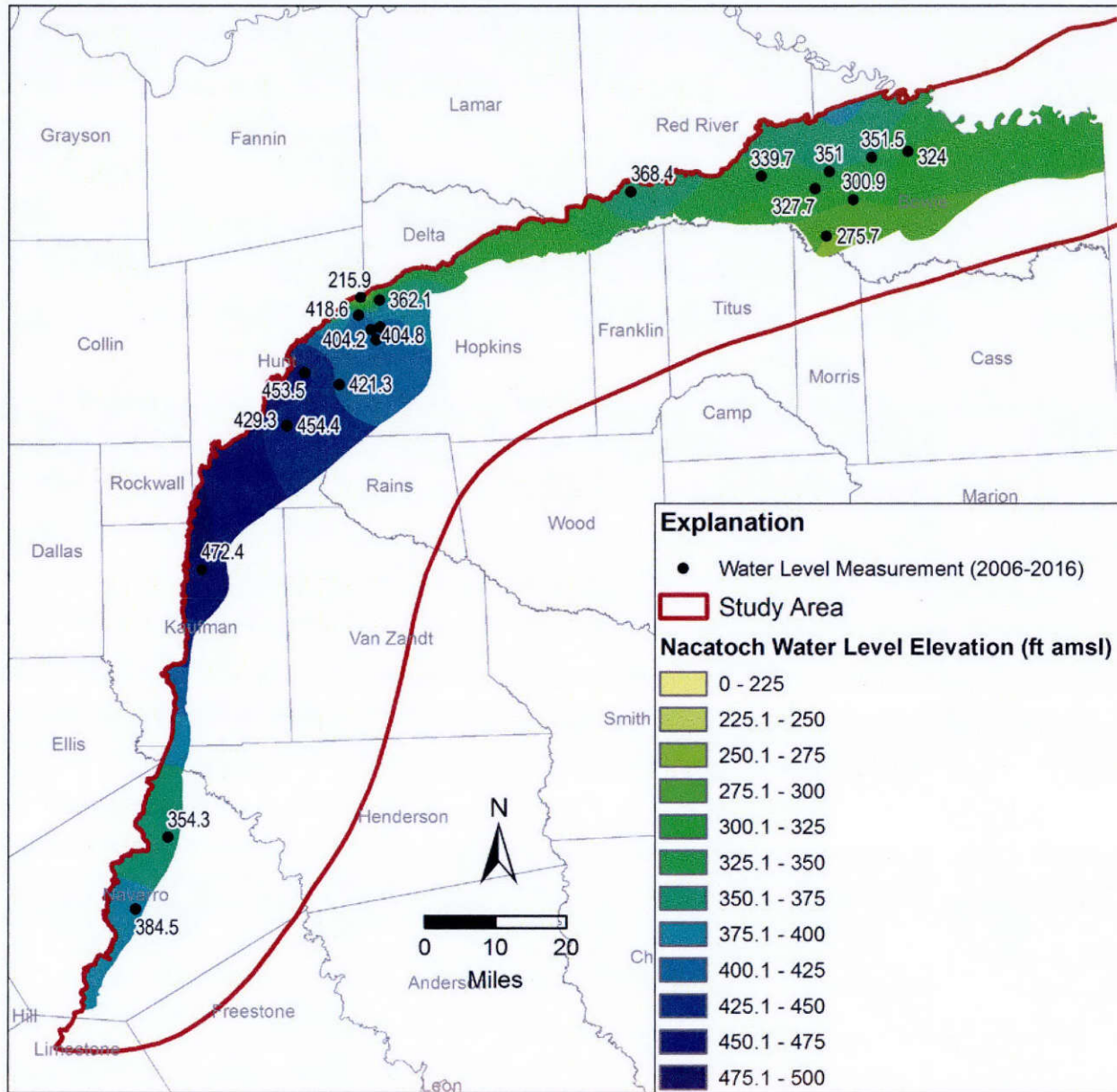


Figure 5-9. 2006 to 2016 groundwater elevations.

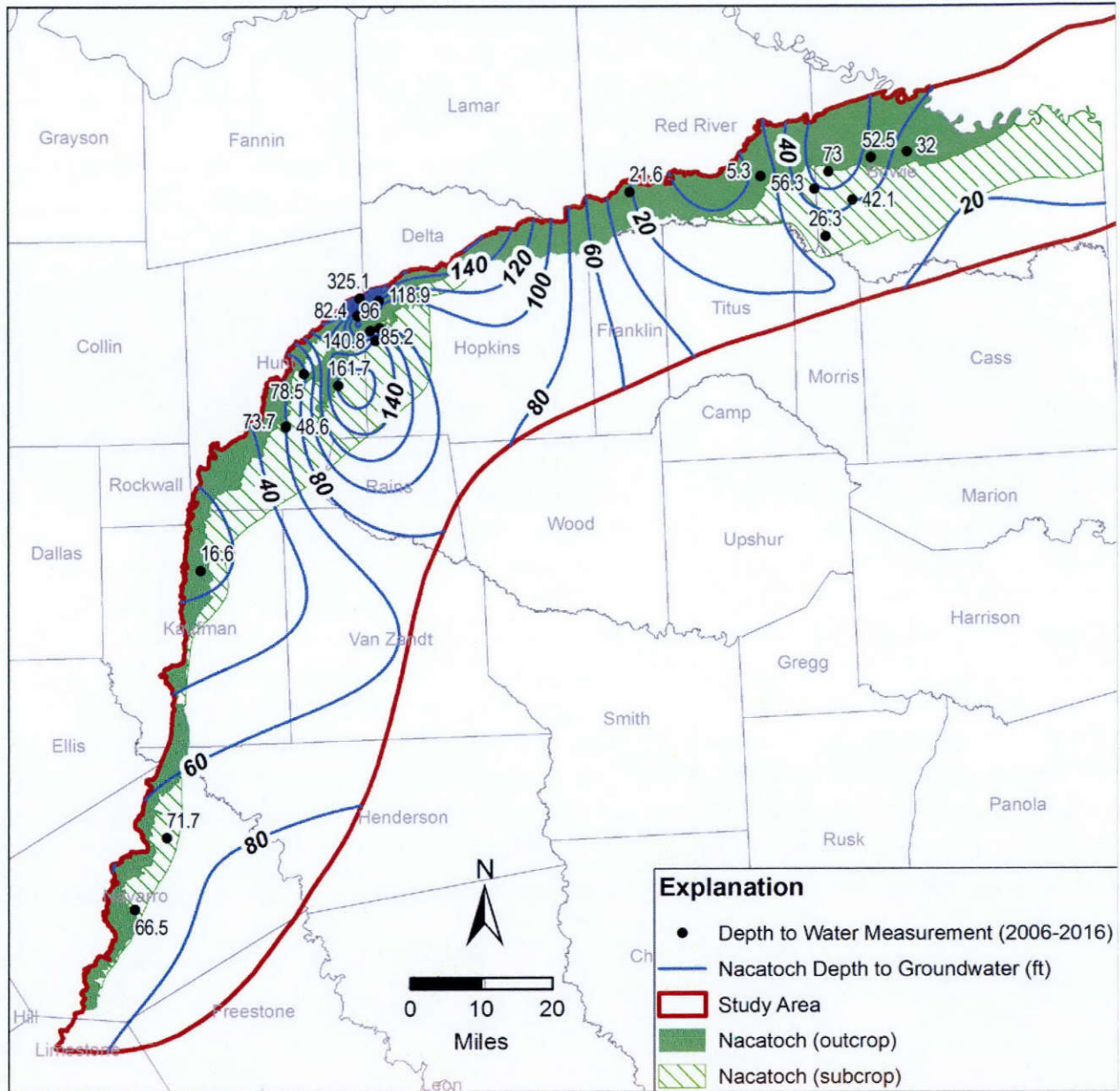


Figure 5-10. 2006 to 2016 depths to groundwater.

## 6 Groundwater Salinity Zones

Groundwater salinity zones are listed in Table 6-1. This report has delineated groundwater salinity zone boundaries in the Nacatoch up to 10,000 milligrams per liter total dissolved solids.

Salinity zones have been defined using existing water quality analytical data (measured total dissolved solids) from wells completed in the Nacatoch Formation, stratigraphic units determined from geophysical logs for which reasonable total dissolved solids estimates were calculated, and the total dissolved solids estimates from geophysical logs. Figure 6-1 shows the distribution of the analytical sample data total dissolved solids concentrations and Figure 6-2 maps the estimates derived from geophysical logs.

Fresh water occurs primarily in the outcrop, or within short distances downdip. Slightly saline groundwater is found frequently in the outcrop, but it dominates the downdip extent of the aquifer. An interesting feature of total dissolved solids distribution in Nacatoch Aquifer is the close proximity of wells with considerable differences in salinity, both in the outcrop and in the confined aquifer. In Bowie County, a moderately saline well with a total dissolved solids of 3,035 milligrams per liter occurs near a fresh water well with a total dissolved solids concentration of about 600 milligrams per liter.

**Table 6-1. Groundwater salinity classification summary.**

Groundwater Salinity classification	Range in TDS <sup>a</sup> (mg/L) <sup>b</sup>
Fresh	Less than 1,000
Slightly saline	1,001 to 3,000
Moderately saline	3,001 to 10,000
Very saline	10,000 to 35,000
Brine	Over 35,000

<sup>a</sup> TDS = total dissolved solids.

<sup>b</sup> mg/L = milligrams per liter.

Source: Modified from (Winslow & Kister, 1956).

### 6.1 Slightly Saline Zones

The findings of this report align with the current delineation of both the 1,000 and 3,000 milligrams per liter total dissolved solids extents. The delineation of the slightly saline zone is based on water quality sample data as shown in Figure 6-1. The water quality estimates from geophysical logs do not significantly modify the current downdip extent.



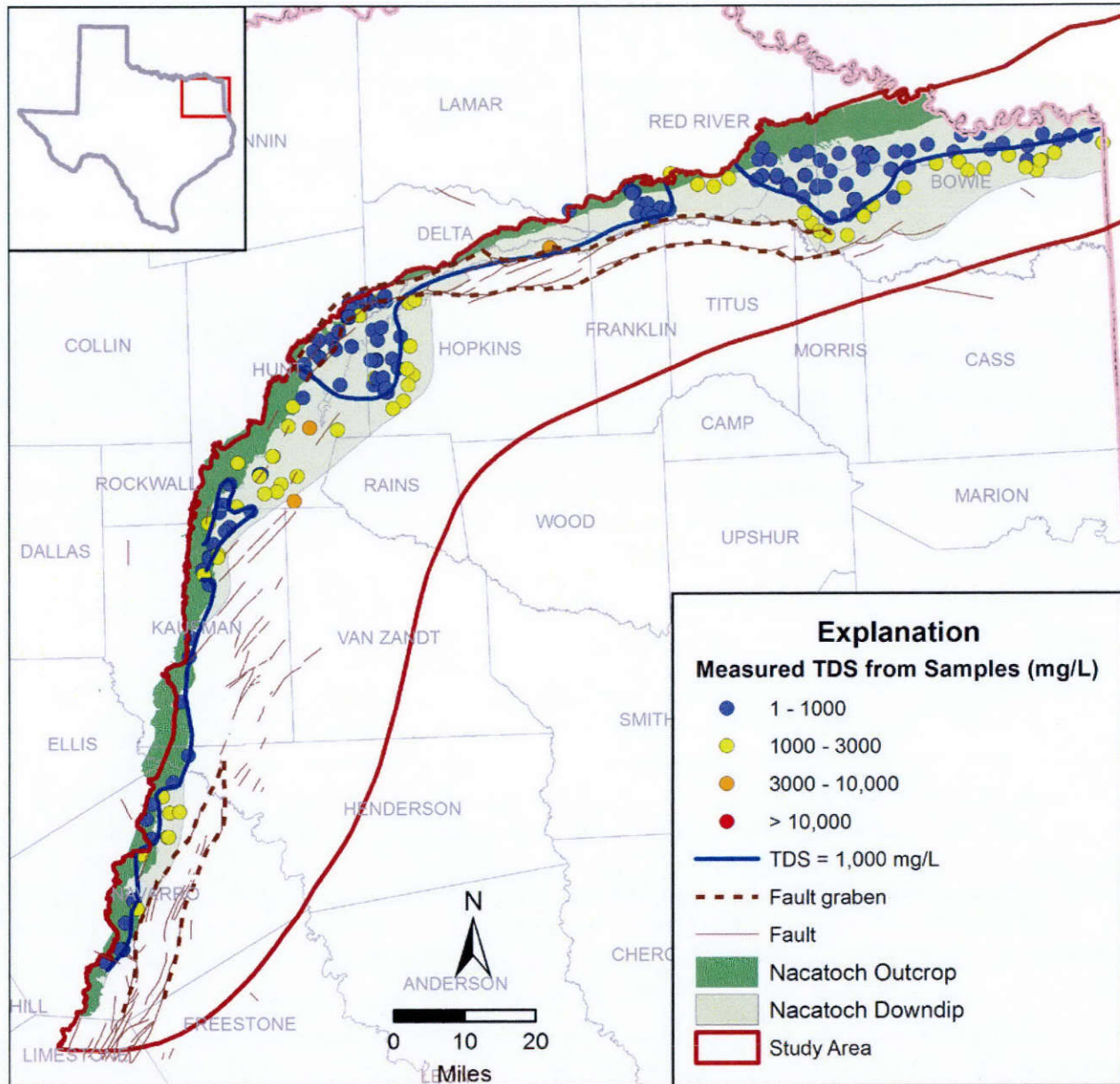


Figure 6-1. Distribution of measured total dissolved solids values.

## 6.2 Moderately Saline Zones

Moderately saline zones are those zones with total dissolved solids concentrations between 3,000 and 10,000 milligrams per liter. The findings of this report suggest that the fault grabens control the downdip extent of moderately saline waters where they exist, however, in other portions of the aquifer, it appears that the fault zone does not impact salinity distribution as significantly as it does near the grabens.

### **6.3 Very Saline and Brine Zones**

House Bill 30 only requires that the groundwater salinity zones in the Nacatoch Aquifer be delineated up to 10,000 milligrams per liter; therefore, very saline zones (10,000 to 35,000 milligrams per liter) and brine zones (greater than 35,000 milligrams per liter total dissolved solids) are not within the scope of this project.

### **6.4 Cross sections**

A total of five geophysical log cross-sections were created that show estimated total dissolved solids values derived from the logs at their respective depth intervals. Figure 6-3 shows the locations of the cross-sections and the cross-sections are presented in Figure 6-4 through Figure 6-8. The top and bottom depths of the Nacatoch Sand formation (Nacatoch Aquifer) are depicted on each cross-section using stratigraphic information developed by the Bureau of Economic Geology. Faults are represented diagrammatically on the cross-sections according to their mapped locations in the Geologic Atlas of Texas Geodatabase (1:250,000 scale). The distance between each well in units of feet is shown at the top of each cross-section. The BRACS ID and log image filename are also provided above each log.

Cross-section A-A' (Figure 6-4) extends from the outcrop area to outside the mapped extent of the aquifer in Hunt County. The up-dip half of cross-section A shows fresh water total dissolved solids estimates in the upper portions of the aquifer that ranged from 50 milligrams per liter to 920 milligrams per liter. A zone of moderately saline water was observed in sand layers below the fresh water zone on the first three logs of the cross-section (BRACS IDs 24559, 22004, 22007). BRACS well 24562 in the central portion of cross-section A-A' provided a total dissolved solids estimate in the slightly saline range at 1,610 milligrams per liter. The next log on the cross-section, BRACS well 21978, displays a transition to moderately saline groundwater across the entire thickness of the aquifer. This log has four sand intervals with total dissolved solids estimates of 3,530 milligrams per liter, 4,230 milligrams per liter, 6,160 milligrams per liter, and 6,650 milligrams per liter. This moderately saline groundwater zone extends through the two logs in the downdip direction, BRACS wells 24549 and 21991, which display total dissolved solids values ranging from 3,160 milligrams per liter to 4,940 milligrams per liter.

Cross-section B-B' (Figure 6-5) begins in the outcrop area and continues past the mapped extent of the aquifer in Hopkins County. The northernmost log on this cross-section, BRACS well 23587, is located in the outcrop area and exhibits total dissolved solids estimates that change from fresh groundwater in the upper part of the aquifer to slightly saline in the middle and moderately saline near the base. The total dissolved solids values vary from 980 milligrams per liter to 1,210 milligrams per liter and 5,370 milligrams per liter. Total dissolved solids estimates from BRACS well 23556, which is adjacent to BRACS 23587, are in the fresh range in the shallow part of the aquifer at 930 milligrams per liter and 950 milligrams per liter, and in the slightly saline range in the middle at 1,320 milligrams per liter. The deeper portion of the aquifer on this log has a moderately saline total dissolved solids value of 5,140 milligrams per liter. The other four logs on cross-section B-B' extend across the downdip area of the aquifer. These logs exhibit increasing total dissolved solids values in the downdip direction. BRACS well 25974 is located within 100 feet of the mapped boundary of the aquifer and provided a total dissolved solids estimate of 3,310 milligrams per liter. BRACS wells 25992 and 20037 had higher total dissolved solids values that were also in the moderately saline range. Groundwater quality transitions into the very saline range between BRACS wells 20037 and 34616. The total

dissolved solids estimates from well 34616 are 10,750 milligrams per liter and 11,420 milligrams per liter.

Cross-section C-C' (Figure 6-6) presents six geophysical logs with three logs located in the aquifer outcrop area in Red River County, two logs in Franklin County, and one in Titus County. The first three logs exhibit variability in water quality across the aquifer outcrop area. BRACS well 36027 has fresh groundwater total dissolved solids estimates and the deeper estimate is lower at 590 milligrams per liter than the shallow one at 830 milligrams per liter. The next well, BRACS 15006, provided total dissolved solids values at shallow depths of about 200 feet that are in the slightly saline range at 1,370 milligrams per liter and 1,230 milligrams per liter. BRACS well 35971 displays another fresh groundwater area with a total dissolved solids estimate of 510 milligrams per liter. BRACS well 21230 on cross-section C-C', located within a graben, has a total dissolved solids value of 9,900 milligrams per liter. The other two logs on this cross-section, BRACS wells 21245 and 21470, have total dissolved solids estimates in the very saline range. The aquifer salinity level in well 21245 is 10,950 milligrams per liter and in well 21470 it is 11,280 milligrams per liter.

Cross-section D-D' (Figure 6-7) extends from the aquifer outcrop area in Red River County into the downdip area of the aquifer in Bowie County. BRACS wells 17831 and 25922, located in the outcrop area and positioned on the left side of the cross-section, exhibit higher salinity levels than the adjacent log in the figure, BRACS well 17826. Well 17831 has a slightly saline aquifer total dissolved solids value of 2,310 milligrams per liter, well 25922 has a moderately saline aquifer total dissolved solids value of 5,970 milligrams per liter, and well 17826 has a slightly saline aquifer total dissolved solids of 1,830 milligrams per liter. Decreasing aquifer salinity levels continue across the next two logs on cross-section D-D'; BRACS wells 17840 and 17837. Well 17840 has a slightly saline total dissolved solids estimate of 1,510 milligrams per liter in the lower portion of the aquifer and well 17837 has a slightly saline total dissolved solids estimate of 1,290 milligrams per liter in the upper section. A moderately saline total dissolved solids value of 3,950 milligrams per liter was identified in a sand layer situated in the lower half of the aquifer in well 17837. The last three logs on cross-section D-D' exhibit moderately to very saline total dissolved solids estimates. One sand layer near the base of the aquifer was analyzed in BRACS well 26090 and it has a very saline total dissolved solids value of 12,720 milligrams per liter. Salinity levels are relatively lower in the aquifer in the next well, BRACS well 26087, with moderately saline total dissolved solids estimates of 6,130 milligrams per liter and 9,840 milligrams per liter. Very saline total dissolved solids levels are observed in BRACS well 26098 at 11,350 milligrams per liter and 10,530 milligrams per liter.

Cross-section E-E' (Figure 6-8) begins in the outcrop area in Bowie County and extends beyond the mapped extent of the aquifer in Morris County. Water quality deteriorates in the downdip direction on this cross-section. Slightly saline aquifer total dissolved solids levels are present in the updip portion of the cross-section at 1,190 milligrams per liter and 2,360 milligrams per liter in BRACS wells 19413 and 25729, respectively. Moderately saline groundwater is present in the aquifer at BRACS well locations 26087 and 23788. BRACS well 26087 has total dissolved solids estimates of 6,130 milligrams per liter and 9,840 milligrams per liter while well 23788 has total dissolved solids estimates of 5,560 milligrams per liter and 8,090 milligrams per liter. BRACS well 23801 has a very saline aquifer total dissolved solids estimate of 10,730 milligrams per liter and BRACS well 23772 also has a very saline aquifer total dissolved solids estimate of 13,690 milligrams per liter.

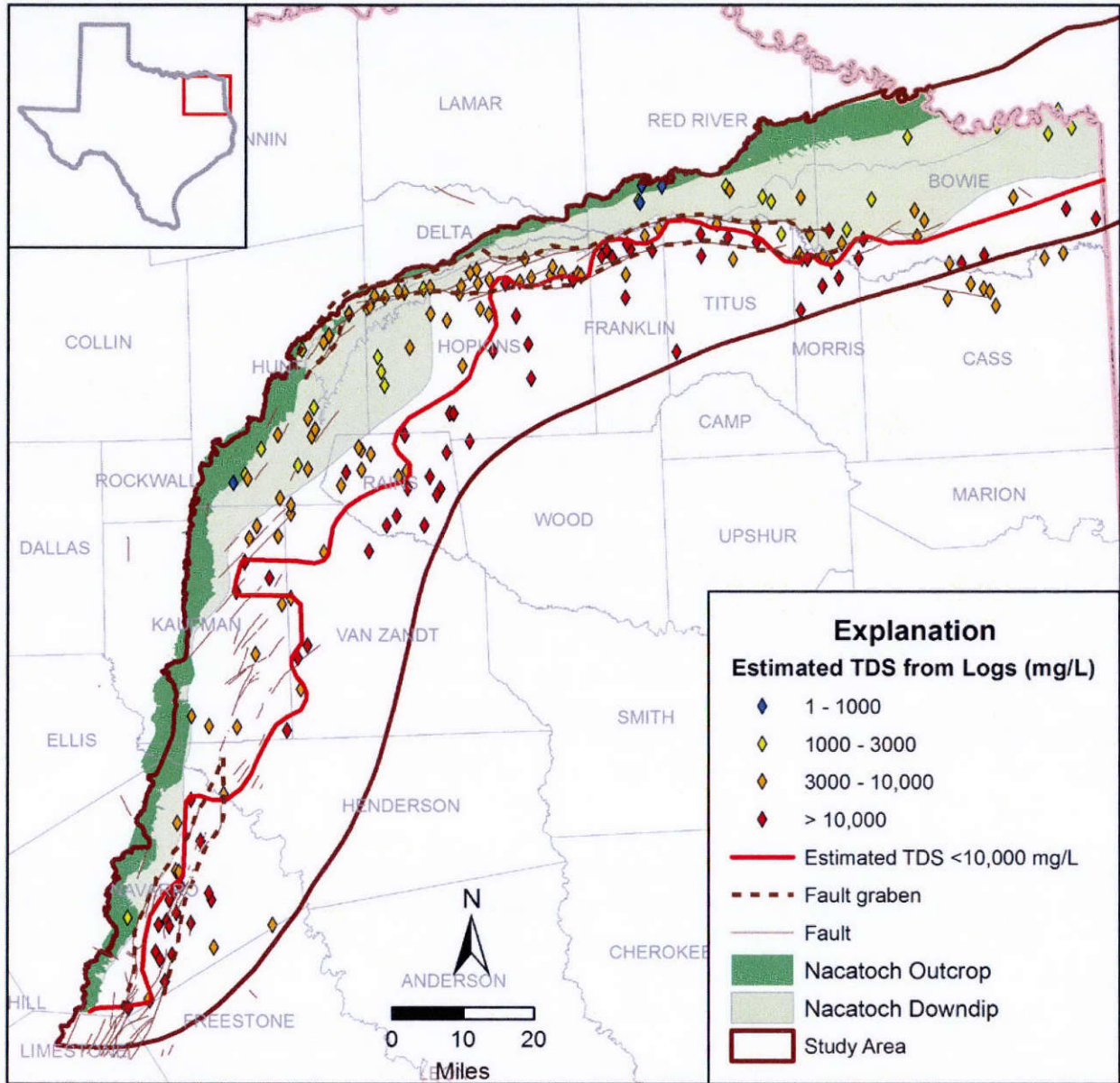


Figure 6-2. Distribution of estimated total dissolved solids values.

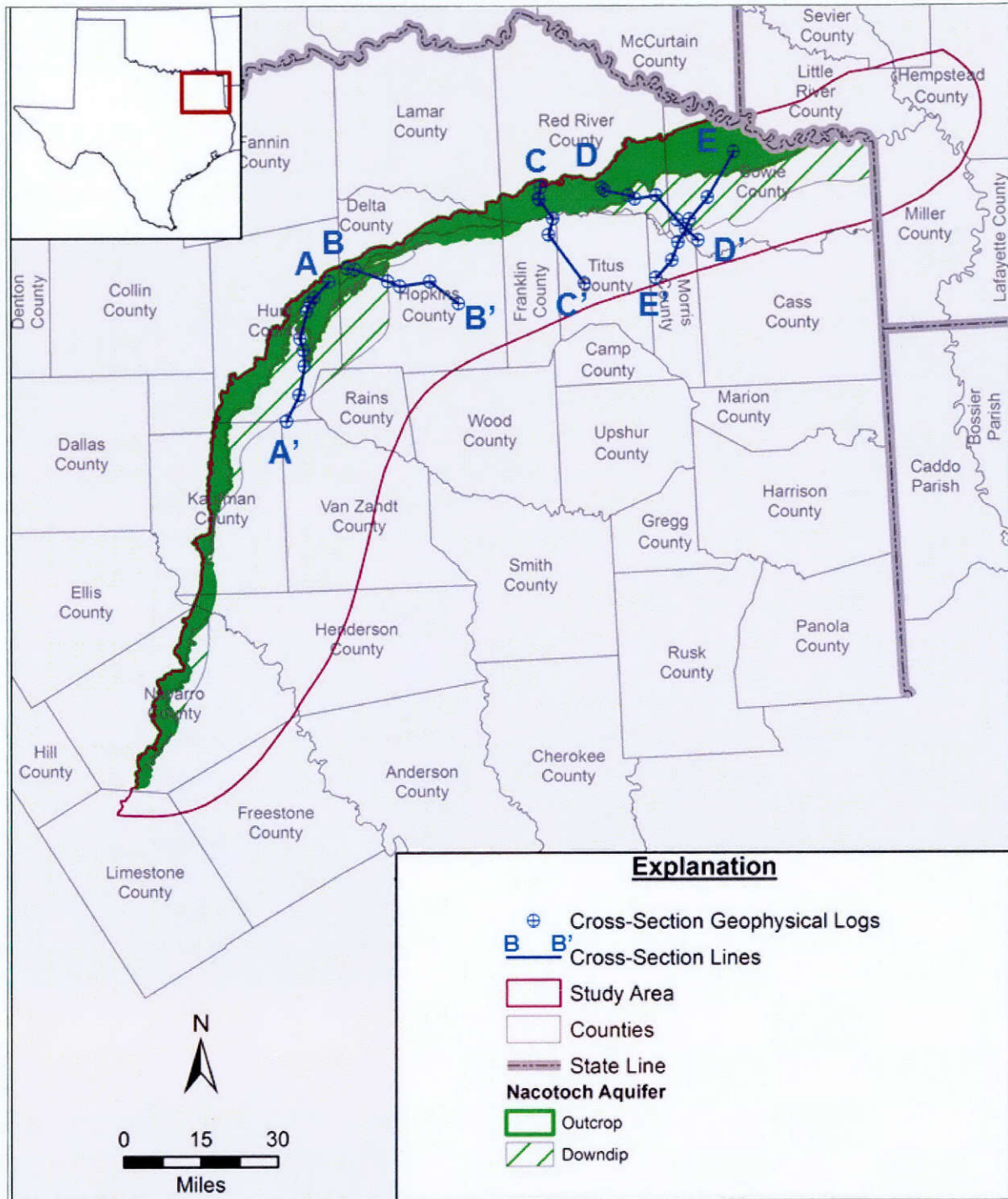


Figure 6-3. Cross section locations.

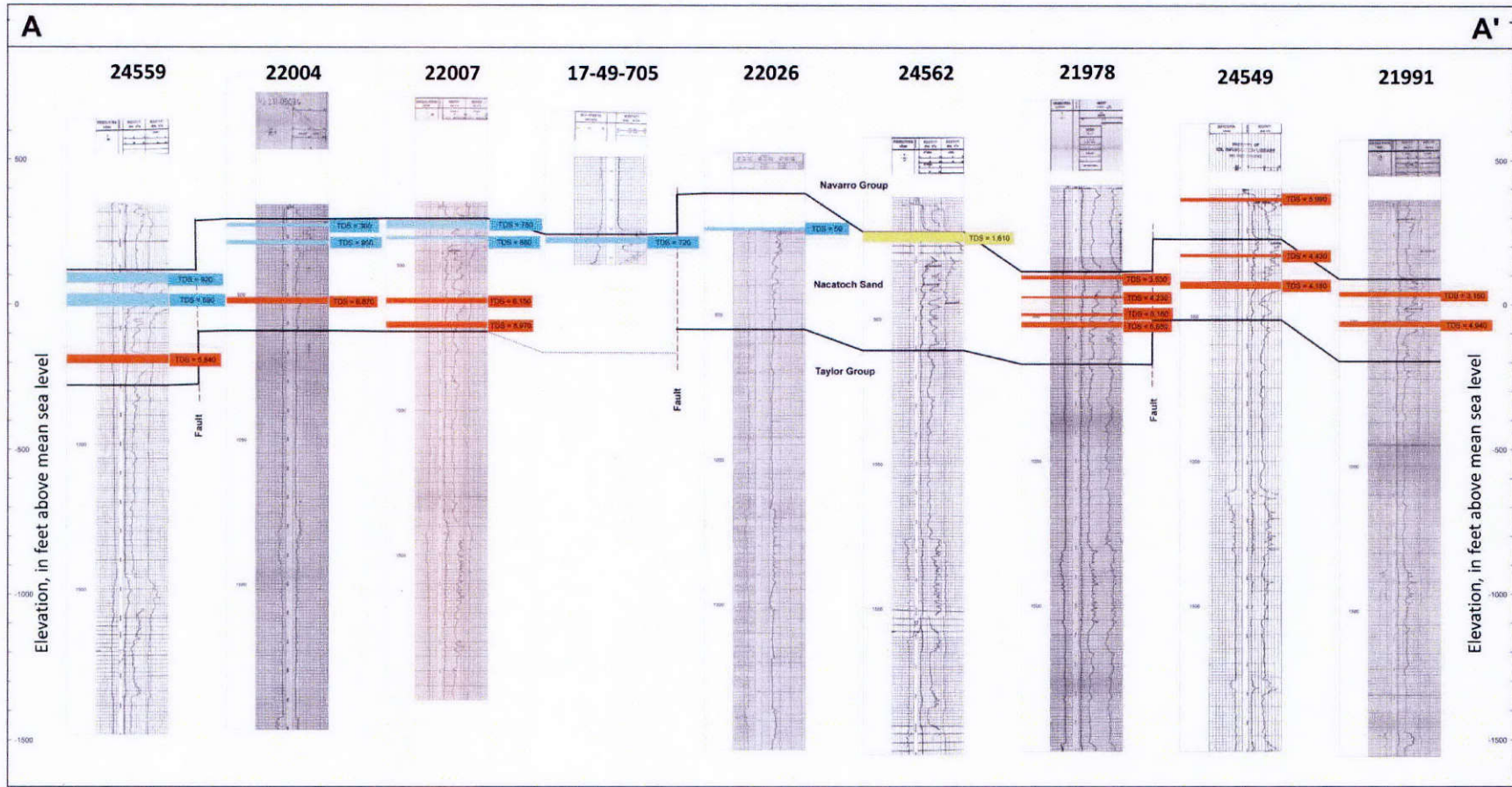


Figure 6-4. Cross section A-A'.

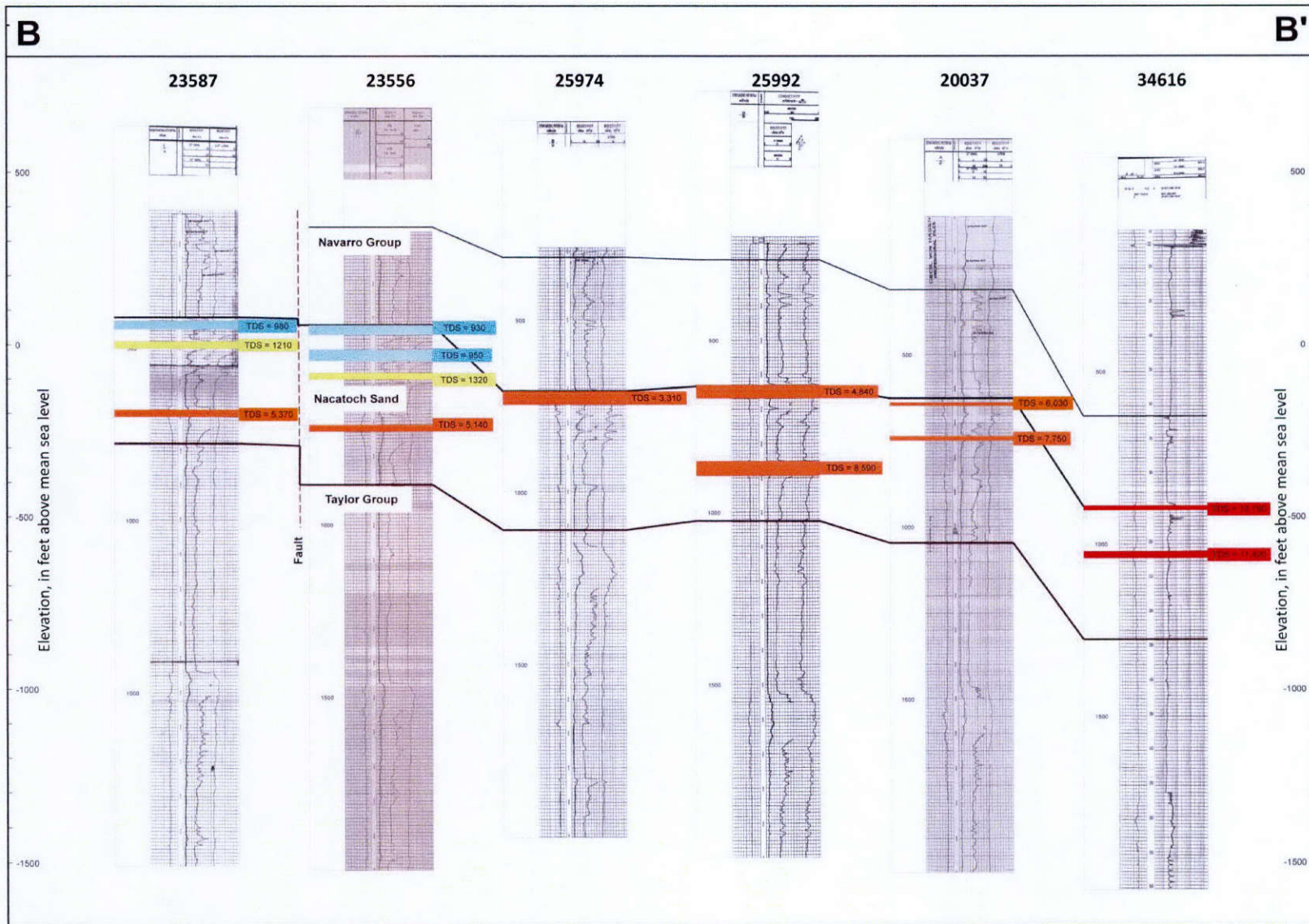


Figure 6-5. Cross section B-B'.

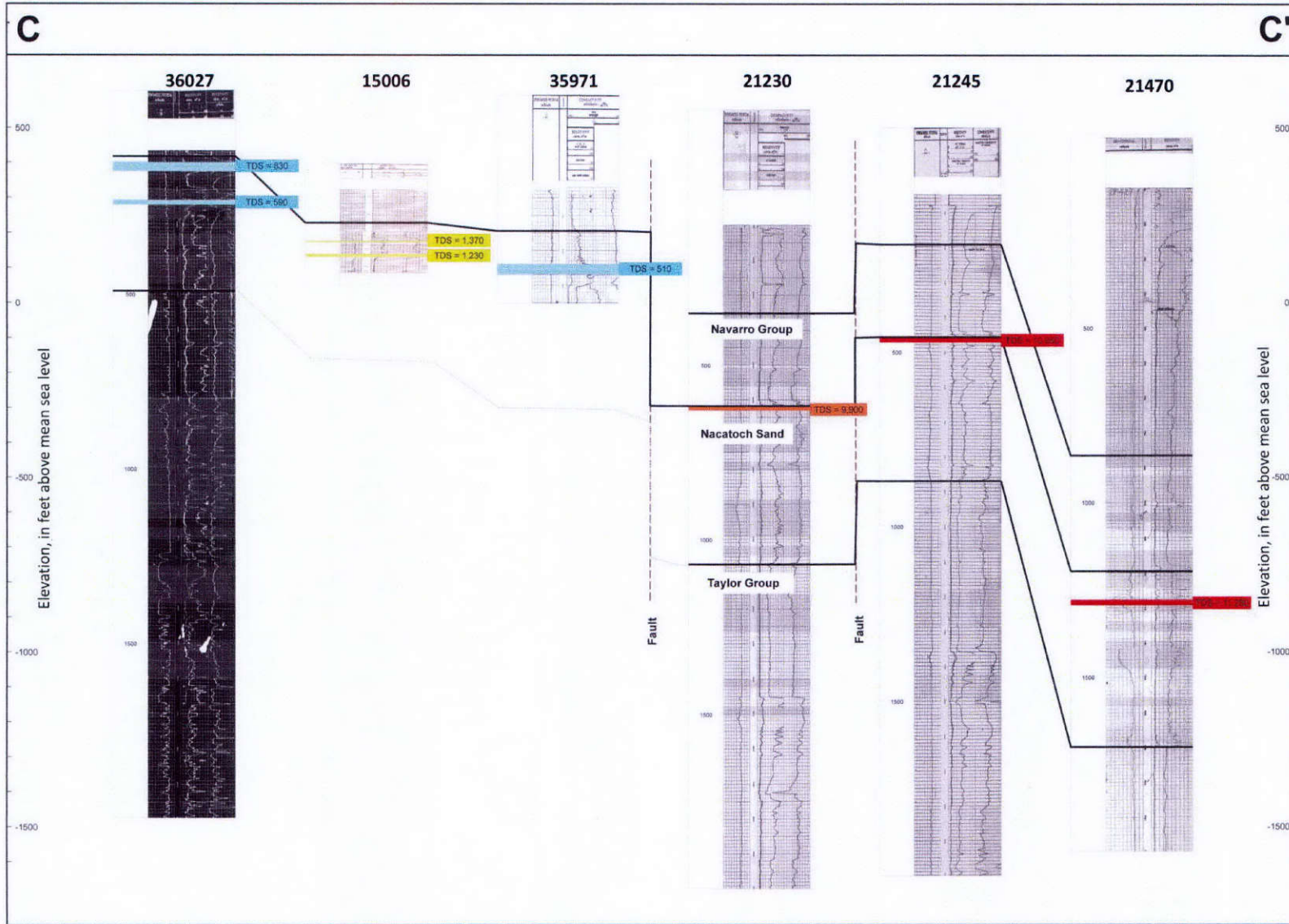


Figure 6-6. Cross section C-C'.



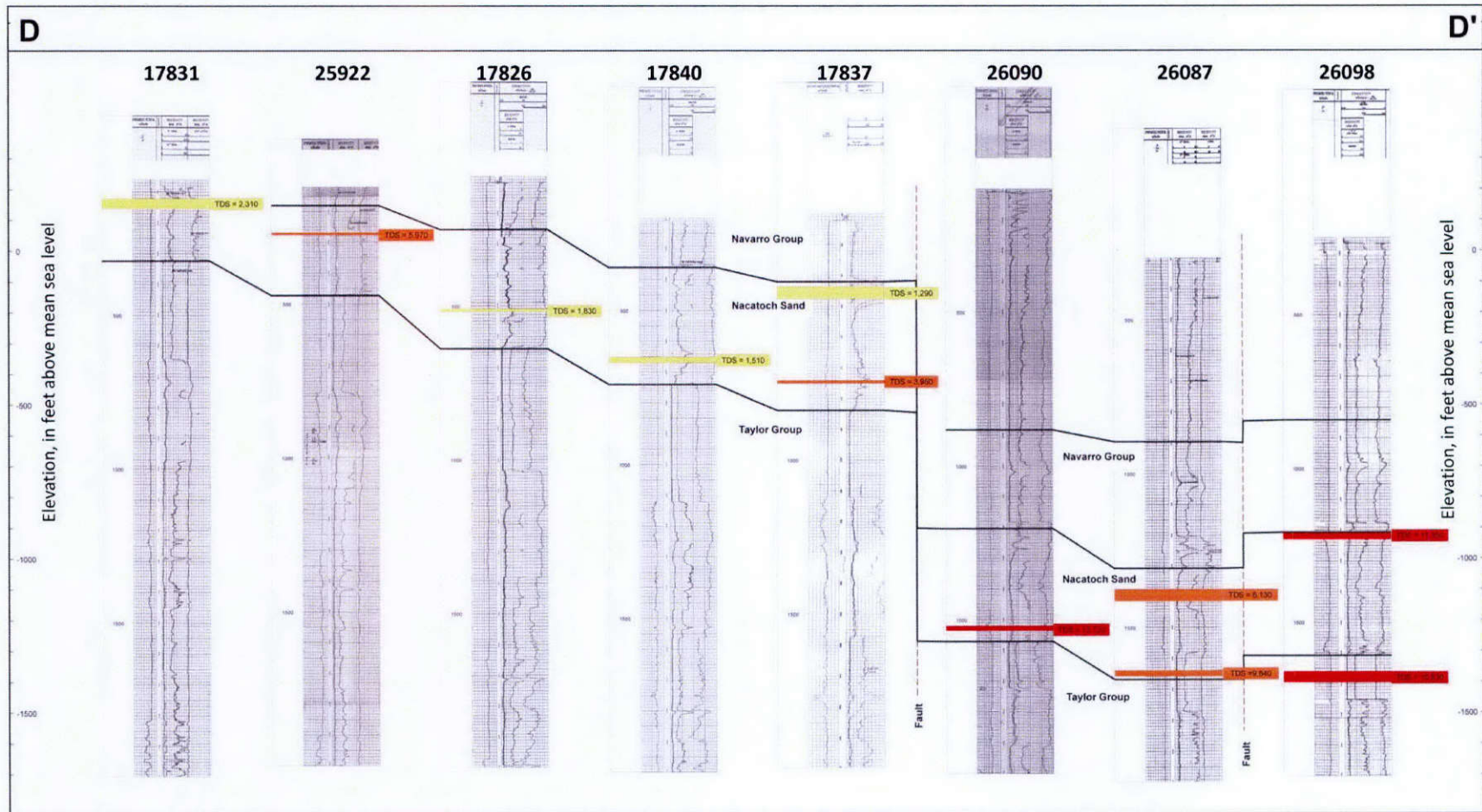


Figure 6-7. Cross section D-D'.

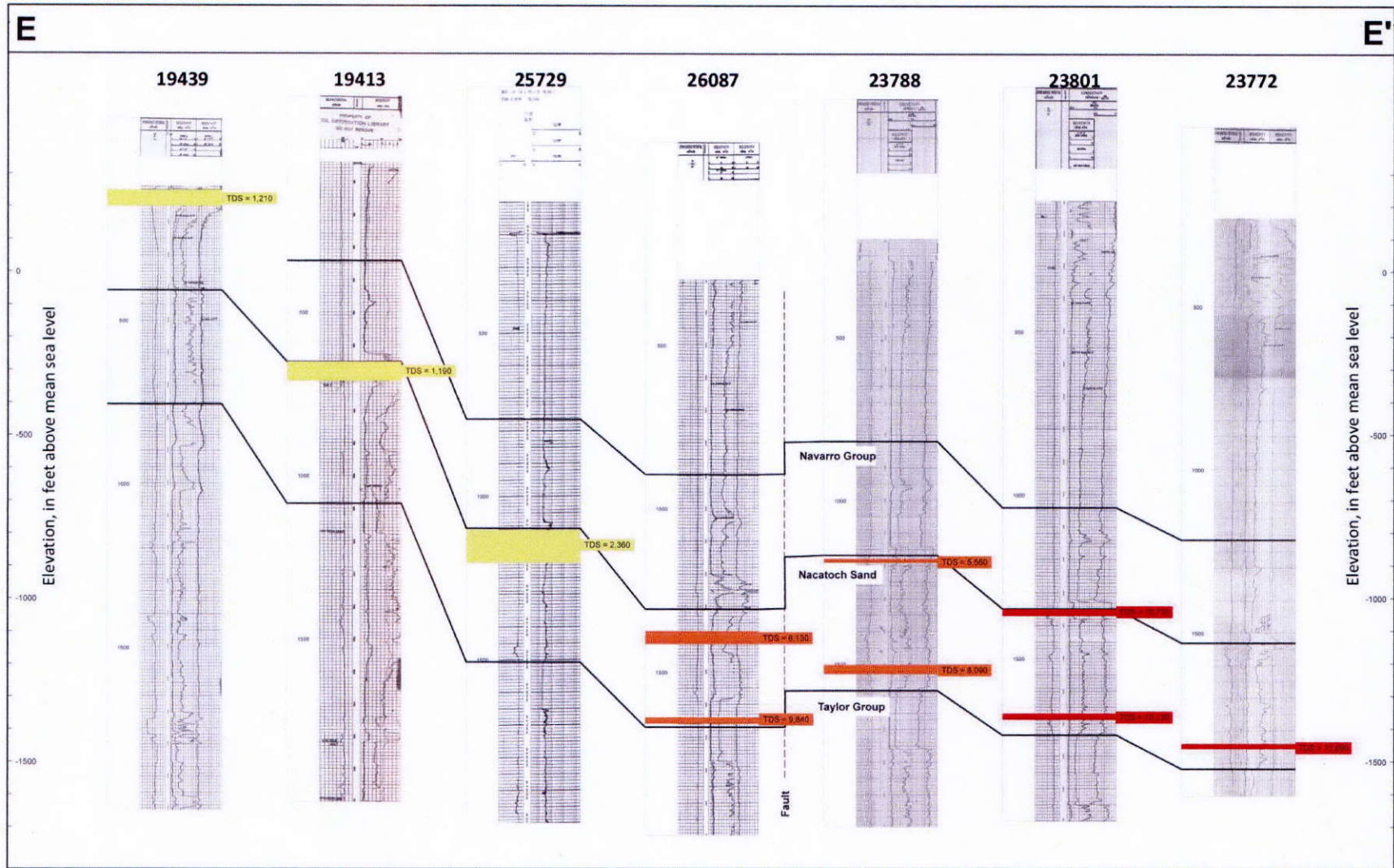


Figure 6-8. Cross section E-E'.

## 7 Previous Investigations

Cretaceous strata in Texas are divisible into two distinguishable series, the lower Comanche Series and the upper Gulf Series (Sellards, Adkins, & Plummer, 1932). The Navarro Group, which includes the Nacatoch Sand, occurs at the top of this Gulf Series.

Veatch (1906) is credited with introducing the name “Nacatoch Sand”. In this report, Veatch provides the following narrative in describing this unit that included both the mid-Navarro sands and underlying Saratoga Chalk:

*Above the Marlbrook Marl is a series of sandy beds (stratigraphic definition), which are of vast economic importance to the strip of country along the Iron Mountain Railway between Arkadelphia and Texarkana, since they are the main water supply source of that region.*

*The outcrop at Nacatoch Bluff, on the Little Missouri River, in Clark County (Arkansas, the type locality), is one of the most complete exposures occurring along this belt and shows the calcareous and quartzitic rocks which, when encountered in wells, are called “water rocks”.*

The East Texas Basin is the structural feature that most influenced the depositional environment within which the sands and clays of the Nacatoch were deposited. Numerous reports are listed in the reference section that pertain to the origin, development, and geometry of the East Texas Basin; bordering fault zones and their impacts on oil and gas production; and the Basin’s internal salt tectonics. Wood and Guevara (1981) produced regional cross sections across the entire East Texas Basin, followed by McGowen and Lopez (1983) who described the depositional systems of the Nacatoch Sand.

Reports that discuss the hydrologic characterization of the Nacatoch Aquifer at specified locations include the following:

- Baker (1971) – *Occurrence and availability of groundwater in the vicinity of Commerce, Texas.*
- Baker and others (1963) – *Reconnaissance investigation of the groundwater resources of the Sabine River Basin, Texas.*
- Baker and others (1963) – *Reconnaissance investigation of the groundwater resources of the Red River, Sulphur River, and Cypress Creek Basins.*
- Broadhurst (1944) – *Development of groundwater for public supply at Commerce, Hunt County, Texas.*
- Peckham and others (1963) – *Reconnaissance investigation of the groundwater resources of the Trinity River Basin.*
- Rose (1945) – *Groundwater in the Greenville area, Hunt County, Texas.*

The extents of additional selected TWDB and Bureau of Economic Geology report study areas are shown in Figure 7-1.

In 1988, John Ashworth developed the first regional comprehensive assessment of the groundwater availability of the Nacatoch Aquifer in Texas (1988). Five cored test holes drilled for this project provided depositional stratigraphic information that assisted in understanding the lateral connectivity of individual sand beds, as well as yield and water quality characteristics of each sand bed. Ashworth also demonstrated the downdip groundwater flow restriction created by the offset faults of the Mexia-Talco Fault Zone. Working with Ashworth on the Nacatoch

Aquifer project, Knight (1984) described the mineral content of the core and cutting samples, and developed his interpretation of Nacatoch Sand deltaic facies.

In 2009, the Nacatoch Groundwater Availability Model was developed as a tool to better understand the flow system within the aquifer and to support planning efforts (Beach, et al., 2009). The conceptual model divides the aquifer system into two layers. The top layer represents the Midway confining unit except in areas where river alluvium and terrace deposits overlay the Nacatoch Sands. The bottom layer represents the Nacatoch Sands. In areas where the alluvium and terrace deposits are present, they are generally interconnected with the Nacatoch. Underlying the Nacatoch is the Neylandville or Marlbrook unit, which is treated as no flow boundary in the model. The Nacatoch and alluvium deposits receive recharge from precipitation and groundwater discharges to local streams and rivers, of which a portion is lost to evapotranspiration. Recharge into the Nacatoch Aquifer was estimated through baseflow regression analysis and varies with annual precipitation. Evapotranspiration was simulated in the riparian area and a vegetation coefficient was used to adjust potential evapotranspiration for different types of vegetation. Initial estimates of aquifer hydraulic properties were estimated from existing aquifer test data, but the data were limited.

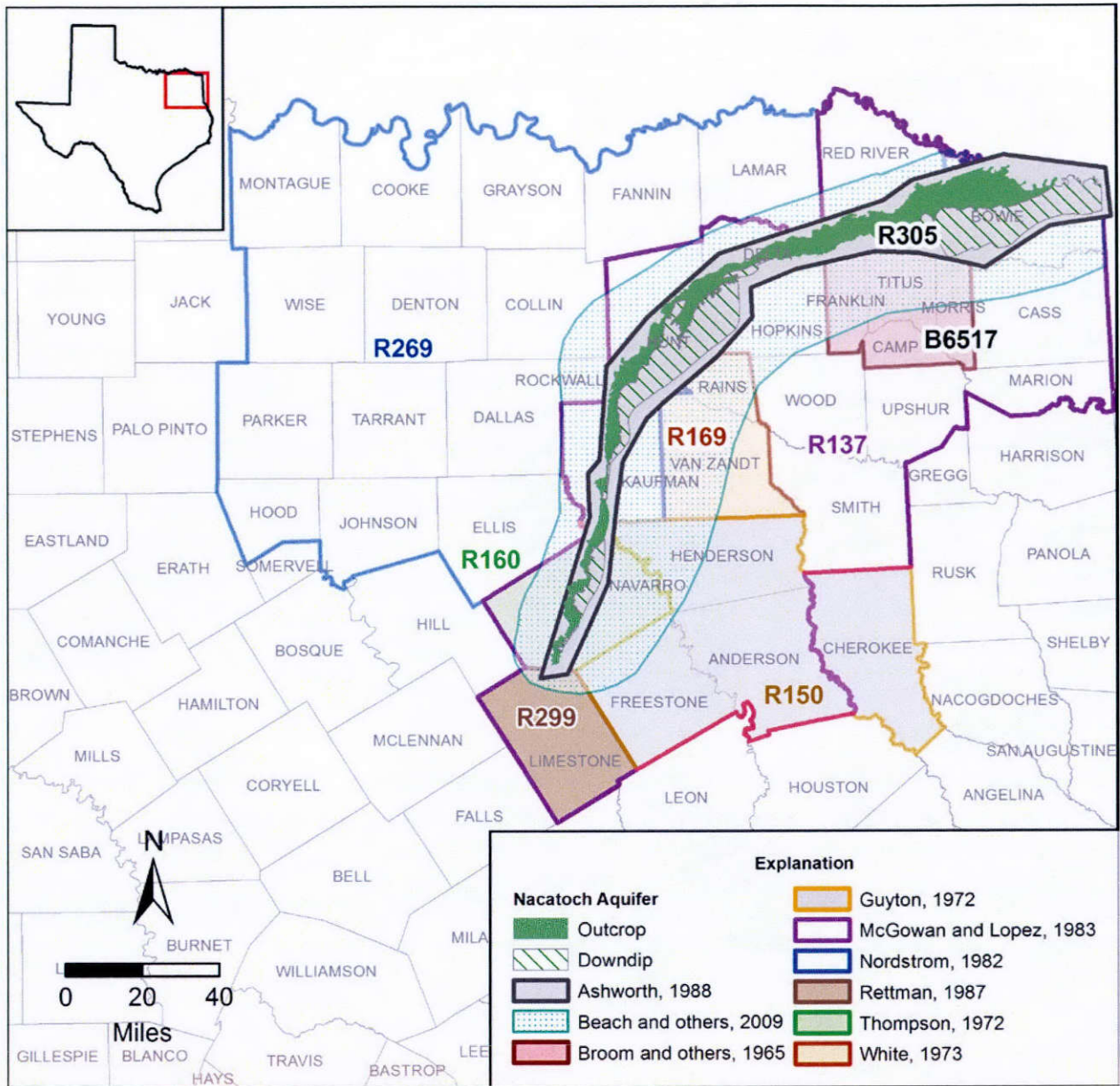


Figure 7-1. Selected report study areas.

## **8 Data Collection and Analysis**

This section provides an overview of the data collection and analyses undertaken for geologic, hydrologic, and water quality assessments.

### **8.1 Geologic Data for Stratigraphic Analyses**

Available information from water wells along with oil and gas wells were used to develop the stratigraphic and hydraulic characteristics of the Nacatoch Aquifer. Data sources include:

- The Bureau of Economic Geology Geophysical Log Facility
- The TWDB BRACS database
- The TWDB Q-log database

Stratigraphic analyses were conducted to estimate tops of the Taylor Group, the Nacatoch Sand (within the Navarro Group), and the Navarro Group. The Taylor/Navarro and Navarro/Midway boundaries cannot be identified without detailed paleontological data. As a result, the tops in this study were estimated based on geophysical and lithologic logs from a Bureau of Economic Geology report (Wood & Guevara, 1981), and extrapolated based on lithologic characteristics of the logs.

### **8.2 Geophysical Log Data for Water Quality Estimates**

#### **8.2.1 Data Sources and Curve Types**

The primary source of Nacatoch geophysical logs is the TWDB BRACS Database (478 logs). These log data include many of the old paper logs housed at the Railroad Commission of Texas Groundwater Advisory Unit (GAU) (formerly the Texas Commission on Environmental Quality Surface Casing Division). The majority of the log curves available to characterize the Nacatoch are spontaneous potential and resistivity/induction curves as shown in Table 8-1. Groundwater salinity in the Nacatoch Aquifer was estimated at various locations and depths by analyzing geophysical logs. The dataset used for the analysis was obtained from the TWDB BRACS geophysical log collection and consisted of 505 log image files.

Each geophysical log selected for analysis was visually inspected and analyzed using Schlumberger's BlueView software (version 1.0.64). Each log was visually inspected for its suitability to analysis; a spontaneous potential (SP) or deep resistivity log was present that intersected the Nacatoch Aquifer and the image quality was adequate. A spreadsheet was developed to automate the calculations involved in the various geophysical log analyses. A total of 324 salinity estimates were produced using this spreadsheet with well locations shown in Figure 8-1.

The spreadsheet developed for log analysis populates user-input data across multiple worksheets. The spreadsheet corrects depths obtained from the log to true depths using the datum height provided in the log header and includes a field for drilling mud type. Also included are fields for the resistivities of the drilling mud and mud filtrate as well as analyst comments. Water chemistry data is used in the interpretation of geophysical logs to establish a statistical relationship between the total dissolved solids concentration and electrical conductivity and to identify groundwater that is dominated by anions other than chloride.

Table 8-1. BRACS database Nacatoch log curve types.

Curve type	Count
Caliper	3
Density	1
Dual induction	25
Dual induction focused	8
Electric	56
Gamma ray	20
High resolution	1
Induction	77
Laterolog	3
Microlog	1
Neutron	1
Porosity	1
Resistivity	198
Spectral density	1
Spherically focused	2
Spontaneous potential	267
Tension	1

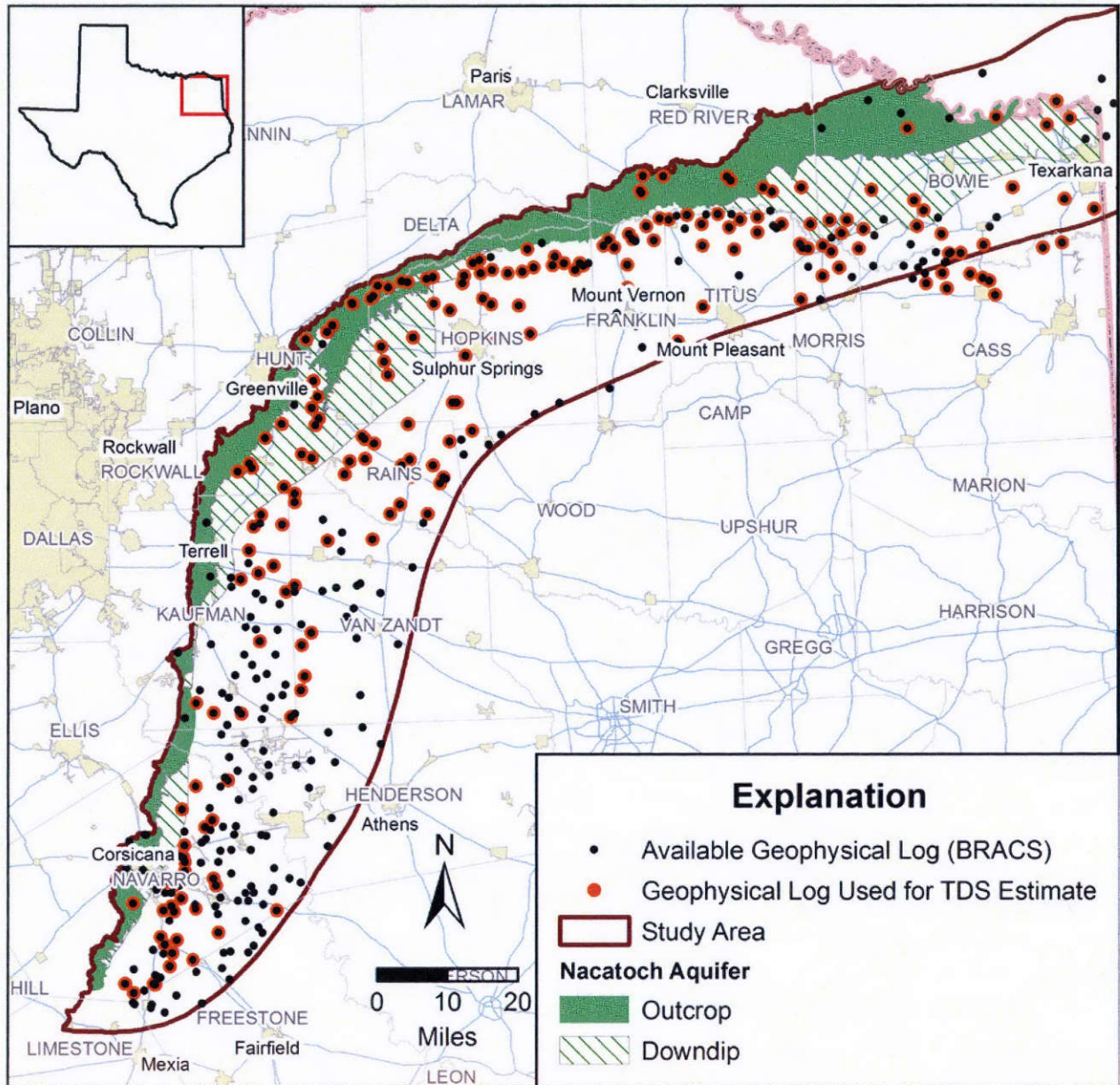


Figure 8-1. Geophysical logs used for water quality estimates.



### 8.2.2 Geophysical Well Log Parameter Calibration

A total of six wells with both water quality data and geophysical well logs were identified in the project area and used to calibrate log interpretation parameters using the Rwa Minimum method (Table 8-2). The Rwa Minimum method provided the most consistent results across a range of total dissolved solids concentrations and various drilling mud types and does not require a mud filtrate resistivity value, which is not always provided in the log header. The calibration procedure consisted of obtaining a deep resistivity value from a log and adjusting the porosity and cementation exponent until satisfactory agreement with the corrected total dissolved solids value was achieved. A freshwater ion correction for bicarbonate was applied as appropriate using the value provide by Estep (2010). The lithology parameter (a) was assumed to be equal to 1.0 for sand layers.

Cementation exponent values of 1.3, 1.4, or 1.5 were used for each calibration point. These values correspond to the values for fine to medium, slightly cemented sand given by Kwader (1986). Layers deeper than 700 feet were assigned a cementation exponent of 1.5 conforming to the calibration achieved with BRACS well 14850 at target depths of 705 and 727 feet. Porosity values of 0.32, 0.33, and 0.40 were applied in the calibration process. Most sandy layers analyzed for water quality down to 700 feet below ground surface in the project area were assigned a porosity of 0.33 percent and a cementation exponent of 1.4 (which is unitless).

Several other water wells with geophysical logs were not included in the calibration process for various reasons. BRACS wells 15005 and 35971 both have state well number 1739508 assigned to them and have the same geophysical log in files G19400001B\_SPR.pdf and Q70\_387.tif, respectively. The log from well 35971 was used for calibration because its mapped location is coincident to state well number 1739508. Data from state well number 3307903 is not in the project water quality dataset due to not meeting the charge balance requirement of five percent. State well number 1750706 and BRACS well 14850 are located relatively close to one another at about 1.1 miles and the geophysical log from BRACS well 14850 was selected for calibration instead of state well number 1750706 because well 14850 has brackish groundwater, thicker sand layers, and a better quality geophysical log.

**Table 8-2. Calibration of total dissolved solids calculation using Rwa method.**

BRACS ID	SWN /Alt. ID	County	Corrected TDS <sup>c</sup> (mg/L) <sup>a</sup>	Rwa Method estimated TDS <sup>c</sup> (mg/L) <sup>a</sup>	Porosity	Cementation exponent	Percent error
14850	G1120001E	Hopkins	1,307.5	1,320 <sup>b</sup>	0.33	1.5	1.0
14862	1749316	Hunt	745.5	735 <sup>b</sup>	0.33	1.4	-1.4
14866	G1160081B	Hunt	891.9	880	0.33	1.4	-1.3
15007	1739510	Red River	482.7	510	0.40	1.3	-5.4
35971	1739508	Red River	456.4	510	0.40	1.3	12
None	1749705	Hunt	722.1	720	0.32	1.3	-0.3

<sup>a</sup> Milligrams per liter.

<sup>b</sup> Average value from two sand layers within sample interval.

<sup>c</sup> Total dissolved solids.

### **8.2.3 Specific Conductance and total dissolved solids Relationship**

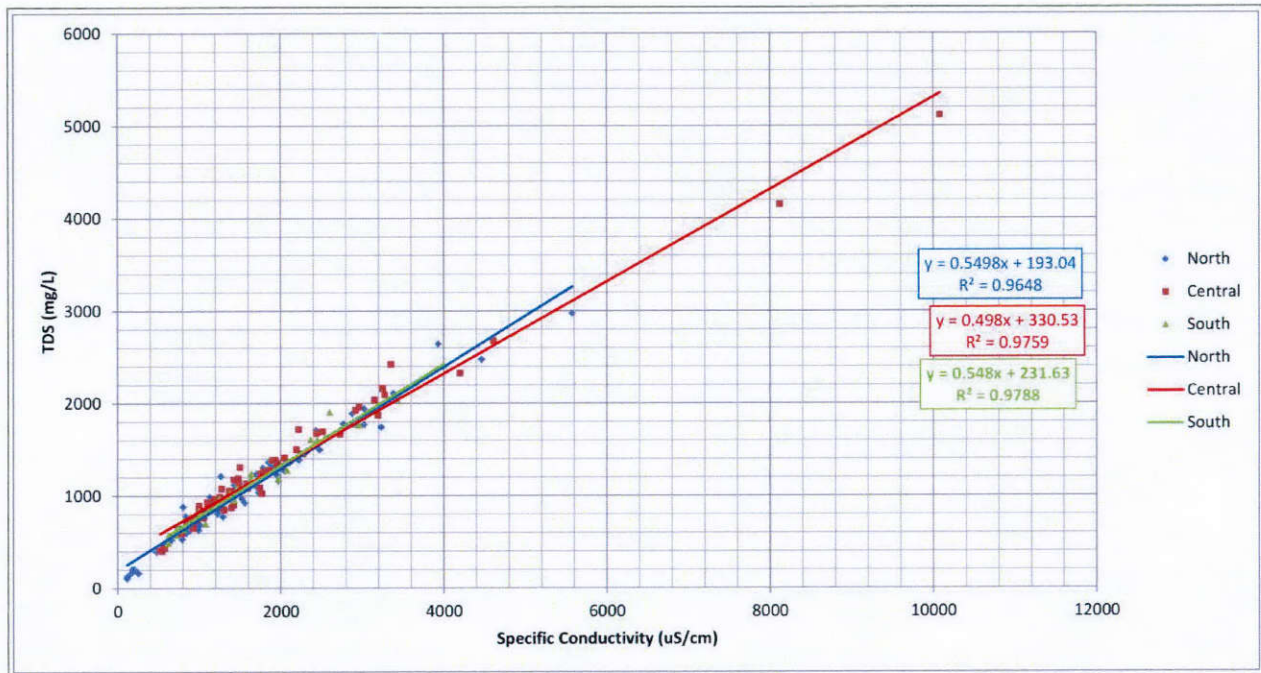
Estimating the salinity of groundwater from geophysical logs is possible because an approximately linear relationship exists between total dissolved solids and specific conductivity. Linear regression was used to determine the conductivity to total dissolved solids conversion factor, referred to as  $C_t$  in Table 8-3, which is slope of the line. The conductivity-to-total dissolved solids conversion factor, referred to as  $C_t$ , is the slope of the linear regression line fit to the data. A total of 186 wells had samples with total dissolved solids and specific conductance pairs. The most recent sample was selected in wells having more than one pair.

The regression relationship was examined from several perspectives. First, the regression was defined using all data points across the entire region. This was compared with relationships defined using data with total dissolved solids < 3,000 milligrams per liter and total dissolved solids > 3,000 milligrams per liter. Finally, the relationship was examined geographically by defining separate relationships in the northern, central, and southern part of the study area. The slopes of fitted lines from all relationships varied from 0.47 to 0.56, and correlation coefficients varied from 0.96 to 1.00. Ultimately, it was decided to use geographically defined conductivity-to-total dissolved solids values which are summarized in Table 8-3 below. The plot is shown in Figure 8-2.

**Table 8-3. Specific conductivity – Total dissolved solids conversion factor.**

Region	Ct <sup>a</sup>	Counties used for determination	Extrapolated counties
North	0.55	Bowie, Red River	Cass, Morris, Titus, Franklin
Central	0.50	Delta, Hopkins, Hunt	Rains, Wood
South	0.55	Henderson, Kaufman, Navarro	Freestone, Van Zandt

<sup>a</sup> Conductivity-to-total dissolved solids conversion factor



**Figure 8-2. Total dissolved solids vs. specific conductivity.**

### 8.3 Water Quality Data

Groundwater chemistry data were sought from government agency databases and published reports, including the TWDB Groundwater Database, the U.S. Geological Survey National Water Information System and Produced Water Database, and files of the Texas Commission on Environmental Quality. The TWDB has records for 400 water samples from 207 wells completed in the Nacatoch Aquifer and is the primary source for these data. Three Nacatoch analyses were found in the U.S. Geological Survey Produced Water Database, and three usable analyses were obtained from Texas Commission on Environmental Quality records. Data tables in several older TWDB reports (Guyton, 1972), (Nordstrom, 1982), and (Thompson, 1972) were reviewed for analysis records not found in the TWDB Database.

Data were screened using criteria based on Kreitler and others (2013) which focus on known well production depth or well depth, locational accuracy, and charge balance. TWDB includes a field in its database for charge balance, which was independently verified. Some sodium

concentrations are calculated which results in a sample analysis that is always balanced. Samples with calculated sodium concentrations were also eliminated. This review of the data resulted in a working dataset of 360 analyses from 195 Nacatoch wells.

The following criteria were applied to screen water chemistry data for acceptability:

1. The well must have a known depth or completion interval.
2. The location accuracy must be plus or minus one minute.
3. The aquifer code must be Nacatoch Sand. Wells with multiple aquifers or unknown aquifers were not used.
4. Sodium must be measured, not calculated.
5. Charge balance must be plus or minus five percent.

Most of the data from the TWDB Groundwater Database meet these criteria. The results of screening are shown in Table 8-4.

**Table 8-4. Data failures for screening criteria.**

Criterion	Failure count
1. Known depth or completion interval?	1
2. Location known within +/- one minute?	3
3. Aquifer code indicates Nacatoch	0
4. Sodium concentration is measured (not “calculated”)	34
5. Charge balance within +/- five percent	19

Two samples collected from the Nacatoch Formation are in the U.S. Geological Survey’s Produced Waters Database. One sample is located in Titus County in the Talco field near Talco, Texas, however no precise location information was provided. This sample has a total dissolved solids concentration of 25,165 milligrams per liter. The second sample is from Wood County and is located a couple of miles northeast of Quitman, Texas and has a total dissolved solids of 30,451 milligrams per liter. These wells were included for informational purposes as they represent a very saline water end member for Nacatoch groundwater. Knowing an accurate location was not a critical factor in their use.

The TWDB Database has a field in the Well Table with quantified accuracy entries such as “5 seconds” and “1 minute,” but it also has non-quantified entries such as “Global Positioning System.” Most hand-held Global Positioning System receivers are capable of 30-meter accuracy, assuming that they are set to a datum that is appropriate for North America. Texas Commission on Environmental Quality data tables have undefined field entries of 10 and 30, which appear to represent 10-meter and 30-meter accuracy.

Sodium concentrations are flagged as “calculated” in 34 records from the TWDB Groundwater Database. Calculating sodium concentrations was a common practice in earlier analytical work due to the difficulty of measurement. These samples necessarily balance since sodium was calculated to make up the charge difference between anions and cations. As a result, and as a consequence, the quality of the analyses cannot be assessed. The TWDB Groundwater Database

includes a field for charge balance analysis. However, we verified charge balance independently.

Laboratory measured total dissolved solids was compared to calculated total dissolved solids using Collier's (1993) Equation 3-1 which is given as:

$$TDS = \text{total of ions} + SiO_2 - (0.5083) \times HCO_3$$

Units for all constituent concentrations are in milligrams per liter. We eliminated 55 samples for unacceptable quality failures, namely charge balance, absence of depth or completion data, or calculated values of major constituents. A total of 361 samples from 186 well locations were retained. Fifty-five samples were eliminated for unacceptable quality failures.

A few database entries were checked against scanned laboratory reports that are available on the TWDB website. The discrepancies found were minor typographical errors in the tenths or hundredths position of the decimal fraction and did not affect the charge balance.

The TWDB Groundwater Database lists Storet Codes for analyses. The data downloaded on July 1, 2016 indicated that the units for Calcium and Magnesium were "milligrams per liter as CaCO<sub>3</sub>." However, the analyses balance as is, and converting to milligrams per liter of the cation resulted in unbalanced analyses. This apparent error in the Storet Codes was verified with Ms. Janie Hopkins of the TWDB on August 3, 2016.

Total Dissolved Solids analyses of Nacatoch samples are described in the TWDB database as "Solids, Dissolved, Sum of Constituents" indicating that the total dissolved solids is calculated from the concentrations of measured cations and anions. However, the total dissolved solids concentrations in the database are on average 22 percent lower than the sum of the measured constituents, suggesting that the listed total dissolved solids is from analysis by evaporation to dryness. In the evaporation method, some bicarbonate is lost from the residue by conversion to carbonate. Adjusting the total dissolved solids using the correction given in Collier (1993, p.58-59) gives a total dissolved solids value that generally agrees with true sum of constituents to within about one percent. The corrected total dissolved solids is used in the water quality assessments of this study. This approach compensates for the absence of silica, fluoride, or nitrate analyses in some samples.

Collection and reliability remarks in the TWDB Groundwater Database call attention to field sampling procedures concerning purging, filtering, preservation and holding times. No acceptance standard was developed using these remarks. Charge balance is accepted as an indication of the quality of the analyses, but it is acknowledged that sample representativeness could be questioned due to purging practices or collection location, such as from a pressure tank.

After screening, 360 analyses representing 195 wells were available for use in this study. However, in determining total dissolved solids/conductivity relationships, only the most recent analysis was used from wells with multiple samplings over time.

#### **8.4 Water Level Data**

Water level data includes data from the TDWB groundwater database between years 2006 and 2016. A total of 226 water level measurements were found for 21 Nacatoch wells. All measurements were averaged for each well location to derive an average water level measurement for the eleven-year period of record. Of the 226 water level measurements, 208

were flagged “P” for publishable and 18 were flagged “Q” for questionable. The measurements flagged “Q” were not outliers and did not affect the average water levels.

## 9 Aquifer Hydraulic Properties

Specific capacity data for 65 wells completed in the Nacatoch Aquifer was compiled from TWDB records. Of these, 10 wells also had transmissivity calculated from pumping tests in Myers (1969), Ashworth (1988), or Christian and Wuerch (2012). A linear relationship was derived from specific capacity and transmissivity data from these 10 wells and used to estimate transmissivity in the remaining wells for which there was only specific capacity data.

Hydraulic conductivity was estimated using screened interval thickness as equivalent to aquifer thickness for all wells, and the locations of the wells with hydraulic conductivity estimates is presented in Figure 9-1. Specific capacity, transmissivity, and hydraulic conductivity data for the Nacatoch Aquifer wells are summarized in Table 9-1. Aquifer properties by well are included as Appendix 9-4.

**Table 9-1. Summary of Nacatoch Aquifer hydraulic properties.**

	Specific Capacity (gpm/ft) <sup>a</sup>	Transmissivity (gal/day-ft) <sup>b</sup>	Hydraulic Conductivity (ft/day) <sup>c</sup>
<b>Average</b>	1.22	1,686	4.98
<b>Maximum</b>	13.80	13,127	56.60
<b>Minimum</b>	0.04	206	0.49
<b>Median</b>	0.50	1,220	2.95

<sup>a</sup> Gallons per minute per foot.

<sup>b</sup> Gallons per day per foot.

<sup>c</sup> Feet per day.

A much smaller data set (seven wells) was available for wells with specific capacity data completed in alluvium in the project area. All of the alluvium hydraulic property data came from wells completed in the northeastern portion of the model area. Of these seven wells, only one had transmissivity calculated from a pumping test in Myers (Myers, 1969). Therefore, transmissivity for the six wells completed in alluvial deposits with only specific capacity data was estimated using the relationship given in Driscoll (Groundwater and Wells, 1986) for unconfined aquifers:

$$\text{Specific capacity} \left( \frac{\text{gpm}}{\text{ft}} \right) = \text{Transmissivity} \left( \frac{\text{gpm}}{\text{ft}} \right) \div 1,500$$

This relationship is approximate because it is based on assumed values in the log term of the modified non-equilibrium equation of Cooper and Jacob (1946). Taking the logarithm of these assumed values tends to mute inaccuracies in the assumptions, leading to the approximation

above. Hydraulic conductivity was estimated using screened interval thickness as equivalent to aquifer thickness for these seven wells, and the locations and estimated hydraulic conductivities of the wells are presented in Figure 9-1. Specific capacity, transmissivity, and hydraulic conductivity data for the alluvial wells are summarized in Table 9-2 and Appendix 19-4.

**Table 9-2. Summary of alluvium hydraulic properties.**

	Specific Capacity (gpm/ft) <sup>a</sup>	Transmissivity (gal/day-ft) <sup>b</sup>	Hydraulic Conductivity (ft/day) <sup>c</sup>
<b>Average</b>	1.76	3,528	33.58
<b>Maximum</b>	4.63	13,127	56.61
<b>Minimum</b>	0.50	750	16.71
<b>Median</b>	0.60	900	30.99

<sup>a</sup> Gallons per minute per foot.

<sup>b</sup> Gallons per day per foot.

<sup>c</sup> Feet per day.

No storativity values calculated from pumping tests were found in the TWDB data or in Myers (1969), or Christian and Wuerch (2012). Freeze and Cherry (1979) indicate that the storativity in confined aquifers usually range in value from 0.005 to 0.00005. The specific yields of unconfined aquifers are much higher than the storativities of confined aquifers, and generally range from 0.01 to 0.30 (Freeze & Cherry, 1979). We found no data regarding the vertical hydraulic conductivity or estimated anisotropy in the hydraulic conductivity tensor. Regional estimates of horizontal to vertical hydraulic conductivity ratios range from 10 to 10000.

#### *Modified Cooper-Jacob Equation Derivation*

The Cooper-Jacob equation can be derived from a derivation of the Theis Equation which is

$$h - h_0 = \frac{Q}{4\pi T} \int_u^\infty \frac{e^{-u} du}{u} \tag{Eqn. 1}$$

where,

$$u = \frac{r^2 S}{4Tt}. \tag{Eqn. 2}$$

The integral of  $u$  is known as the Well Function,  $W(u)$ , which is can be expressed as,

$$h - h_0 = \frac{Q}{4\pi T} W(u). \tag{Eqn. 3}$$

The Well Function can be represented as an infinite series for the semilog method of pump test interpretation. The Theis Equation then becomes,

$$h - h_0 = \frac{Q}{4\pi T} \left( -0.5772 - \ln u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} + \dots \right) \quad \text{Eqn. 4}$$

Cooper and Jacob noted that for small  $u$  the sum of the series beyond  $\ln u$  becomes negligible, so that

$$h - h_0 = \frac{Q}{4\pi T} (-0.5772 - \ln u) \quad \text{Eqn. 5}$$

Since  $\ln u = 2.3 \log u$ ,  $-\ln u = \ln 1/u$ ,  $\ln 1.78 = 0.5772$ , and substituting Eqn. 2 for  $u$ , the Modified Cooper-Jacob Equation becomes

$$h - h_0 = \frac{2.303Q}{4\pi T} \log\left(\frac{2.25Tt}{r^2S}\right) \quad \text{Eqn. 6}$$

$h - h_0$  = drawdown, feet

$Q$  = pump rate, cubic feet per day

$T$  = Transmissivity, square feet per day

$t$  = time, day

$S$  = storativity (dimensionless)

$r$  = radial distance to well, feet

Source: (Freeze & Cherry, 1979).



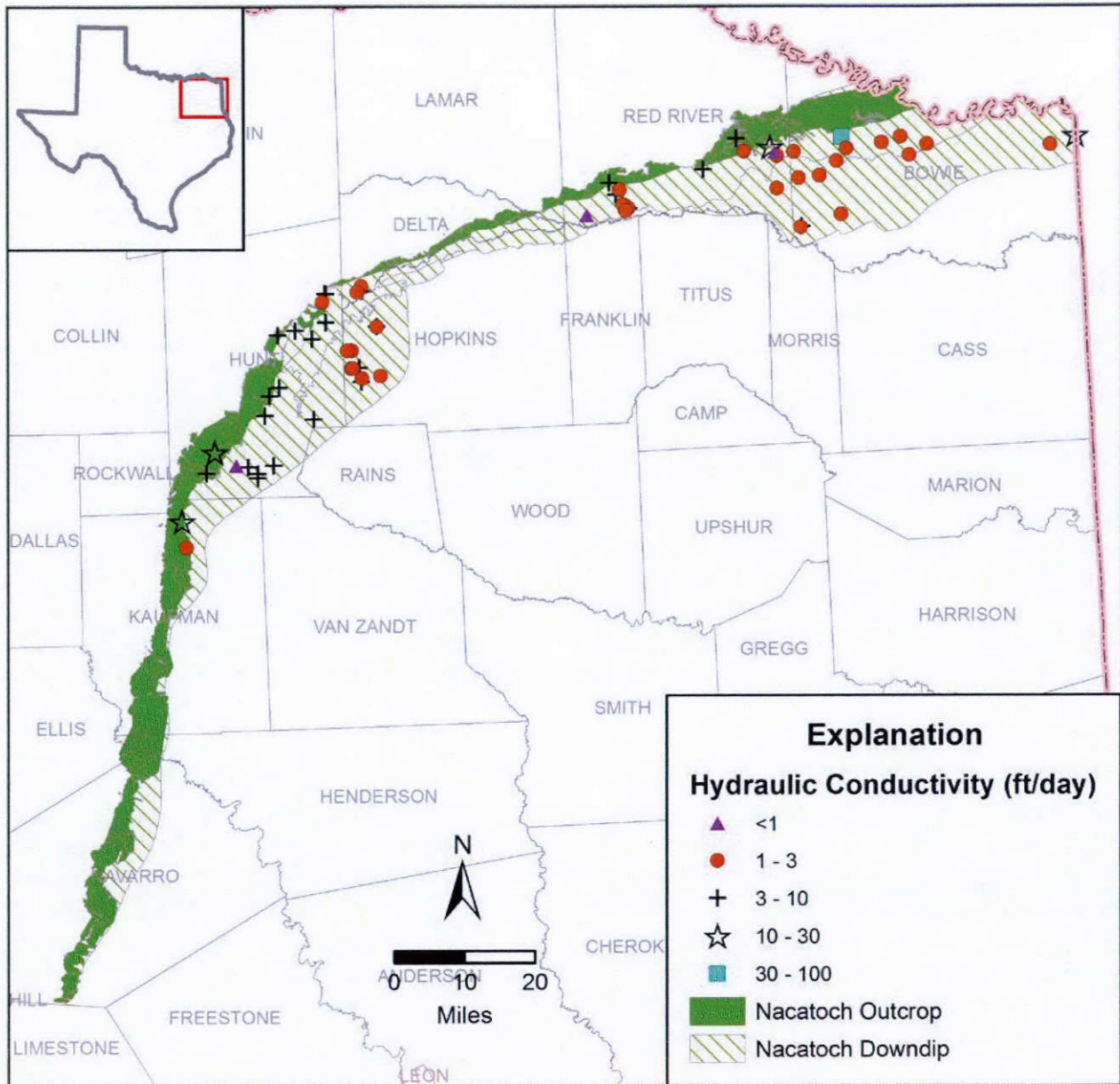


Figure 9-1. Nacatoch Aquifer hydraulic conductivity estimates.

## **10 Water Quality Data**

### **10.1 Dissolved Minerals**

Total dissolved solids is a measure of the dissolved mineral content in water and is a simple indicator of water quality. The United States Environmental Protection Agency has set a secondary drinking water standard of 500 milligrams per liter total dissolved solids while Texas Commission on Environmental Quality has set a secondary standard of 1,000 milligrams per liter (30 TAC §290.118). The concern with total dissolved solids arises from taste, hardness, scale, and staining issues associated with higher concentrations. Distribution of total dissolved solids is mapped in Figure 10-1.

The spatial distribution of anions is shown in Figure 10-2. Sulfate occurs as the dominant or principle anion mainly in wells scattered through the outcrop. Bicarbonate occurs as the dominant anion in the outcrop and in the areas of the subcrop where Nacatoch sands are thicker. Chloride typically occurs as the dominant anion downdip from the bicarbonate-dominated areas. Nacatoch groundwater becomes increasingly chloride-rich as depth and distance from the outcrop increase.

Figure 10-3 and Figure 10-4 show the groundwater composition on a Piper diagram for wells in the outcrop and wells in subcrop (confined) parts of the aquifer. Sodium and bicarbonate are the dominant ions in both outcrop and subcrop. However, the proportions of calcium, chloride and sulfate are higher in the outcrop, so that composition is more variable. In downdip parts of the aquifer, calcium and sulfate decrease so that the groundwater composition tends to vary between sodium bicarbonate and sodium chloride.

Recognition of these regional trends is important for estimating groundwater total dissolved solids from geophysical logs. In downdip areas where water wells and water quality analyses are absent, it appears safe to assume that groundwater is chloride-dominated and that corrections are unnecessary. Figure 10-10 and Figure 10-12 show the distribution of bicarbonate and sulfate, respectively, as a percentage of total dissolved solids. Corrections may be necessary in areas where the percentage exceeds 50 percent. Wells exceeding 50 percent bicarbonate are interspersed with wells having less than 50 percent bicarbonate. Wells with greater than 50 percent sulfate are few and widely scattered.

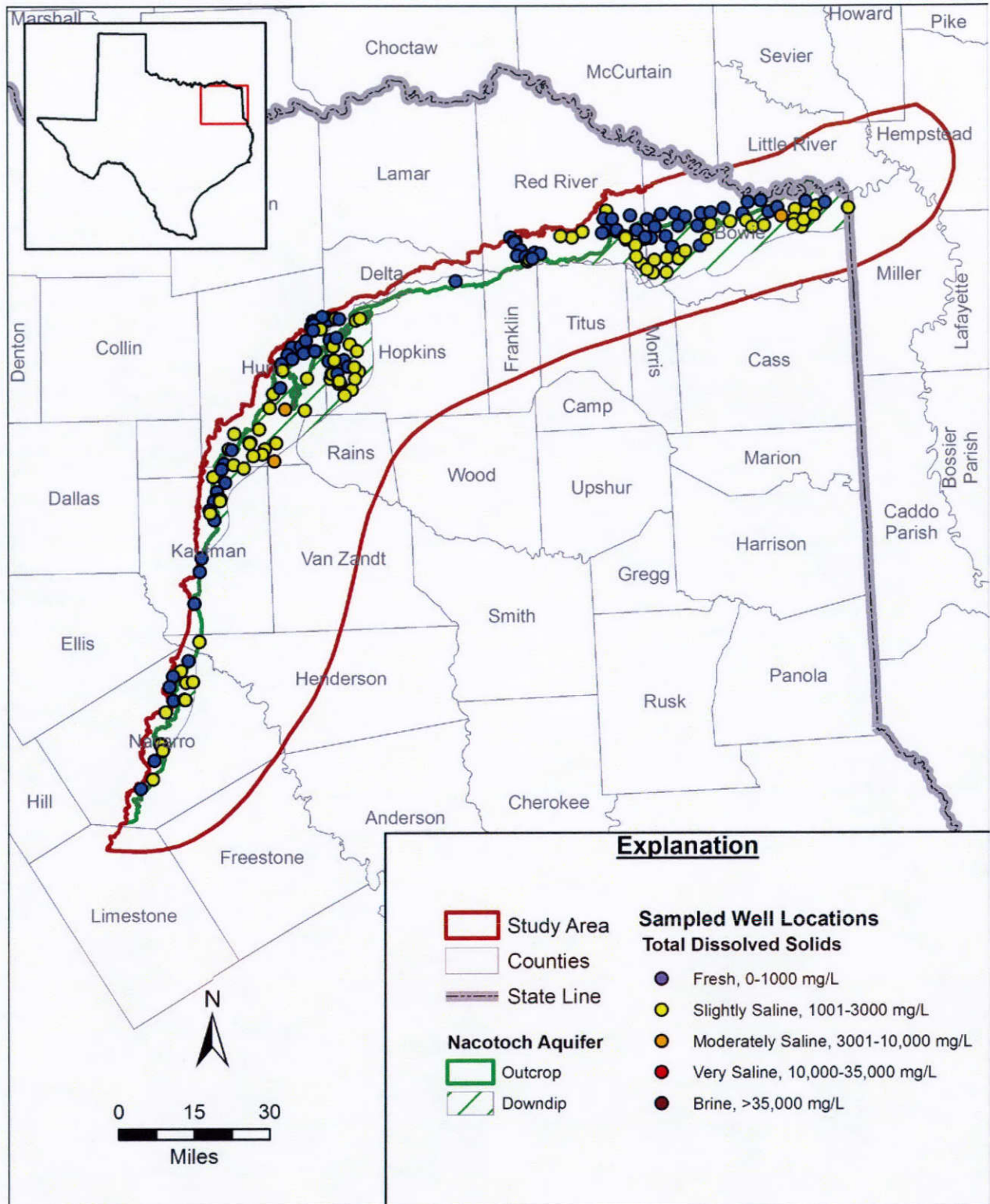


Figure 10-1. Distribution of total dissolved solids concentrations.

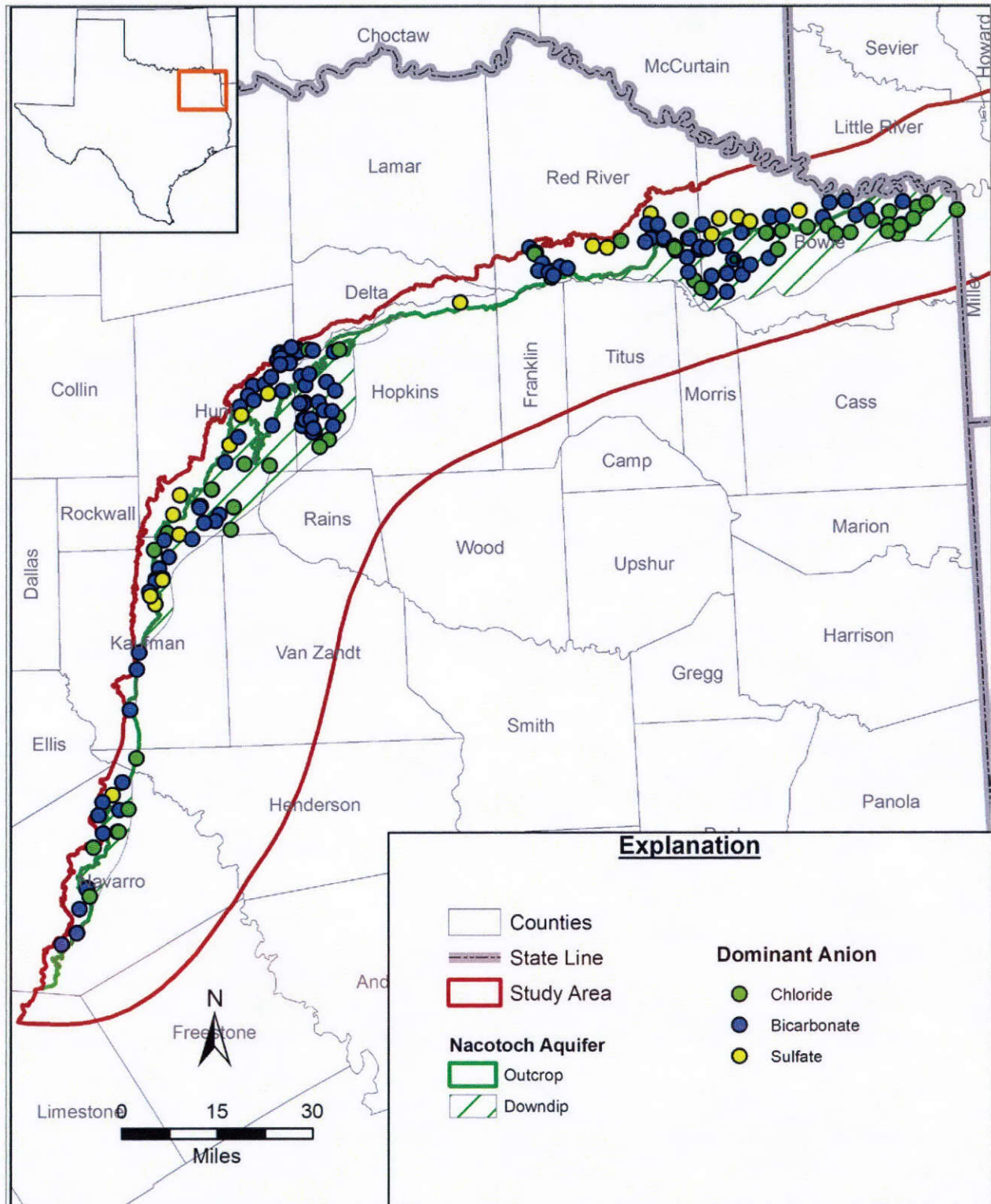


Figure 10-2. Distribution of dominant anions.

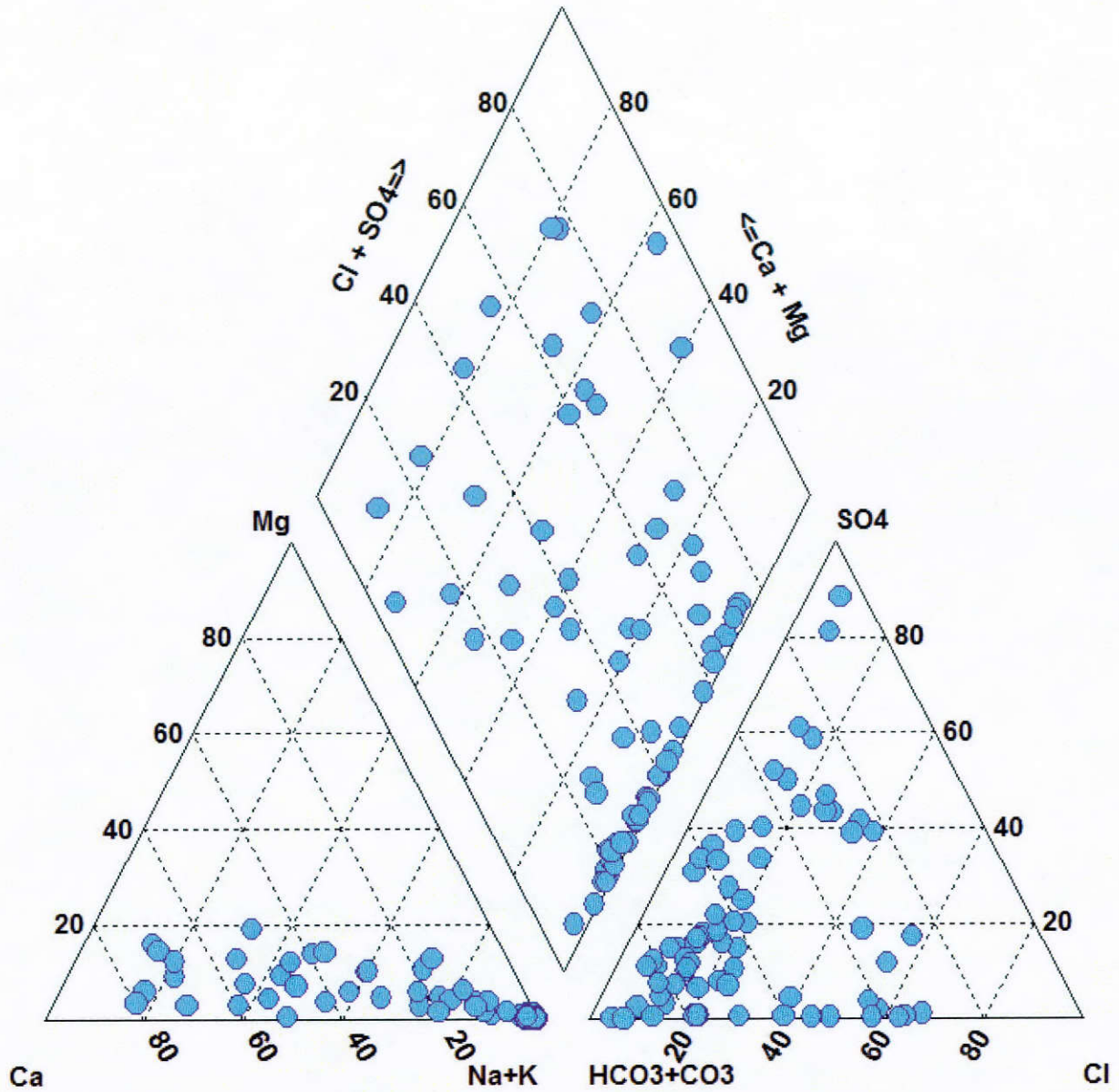


Figure 10-3. Composition of groundwater in the outcrop.

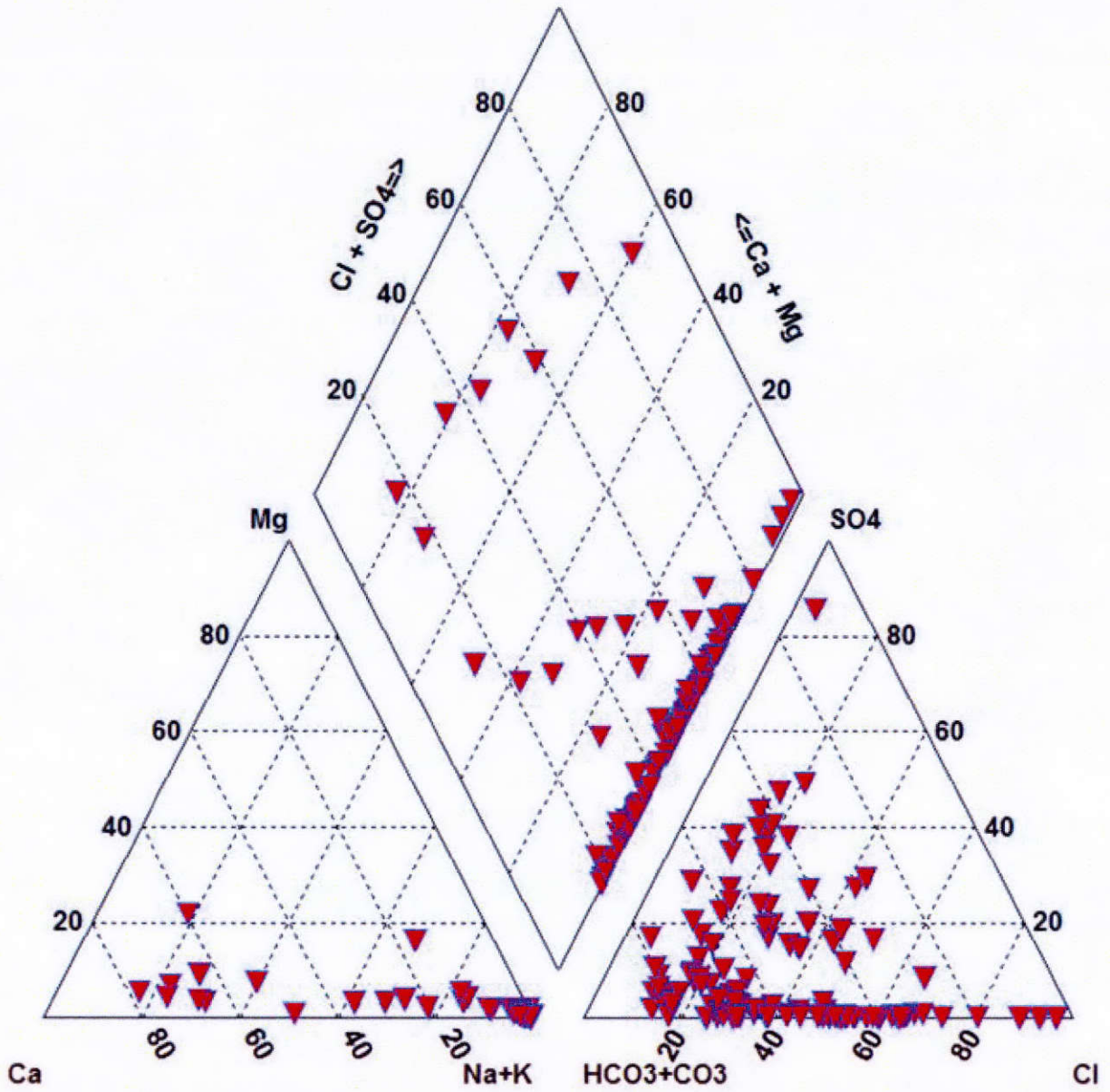


Figure 10-4. Composition of groundwater in the subcrop (confined).

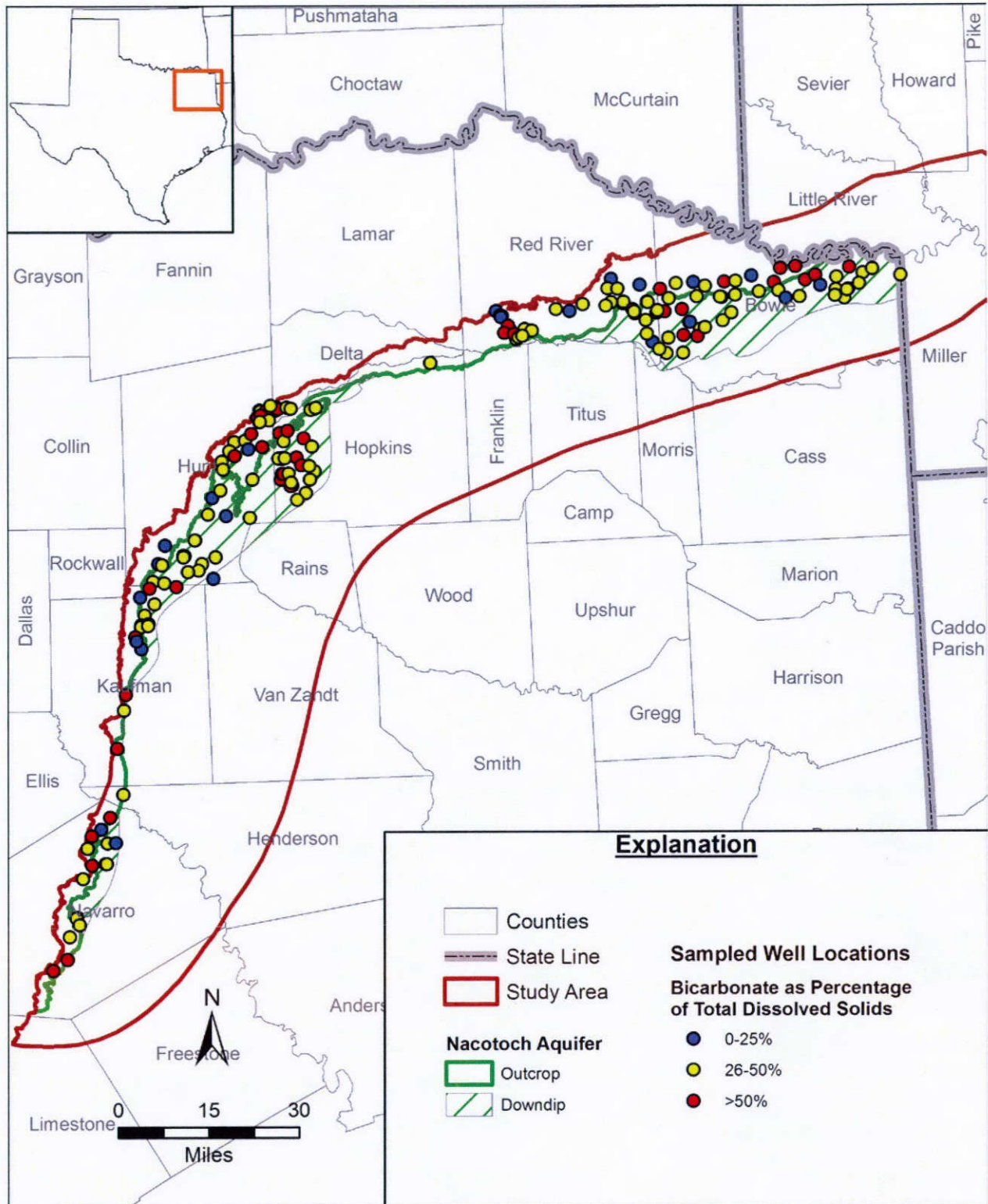


Figure 10-5. Bicarbonate percentage of total dissolved solids.

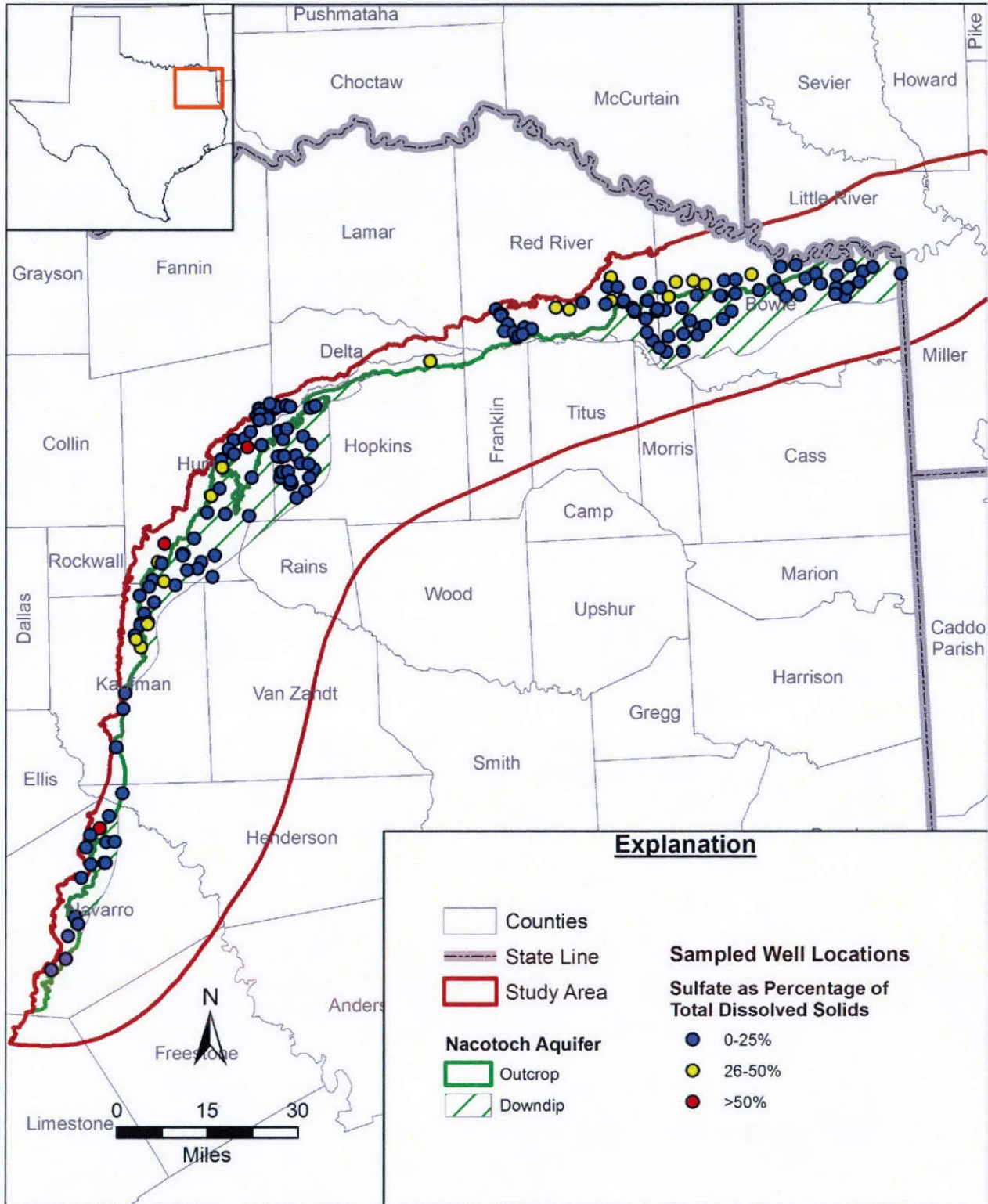


Figure 10-6. Sulfate percentage of total dissolved solids.



## **10.2 Radionuclides**

The U.S. Environmental Protection Agency has established standards for radionuclides in drinking water as follows:

- Alpha radiation, 15 picocuries per liter
- Beta radiation, 4 millirem per year, or 50 picocuries per liter
- $^{226}\text{Ra} + ^{228}\text{Ra}$ , 5 picocuries per liter combined
- Uranium, 30 micrograms per liter

The radionuclide data available in the Texas Water Development Board Groundwater Database are presented in Figure 10-7 through Figure 10-12, and are listed in Table 10-1. Detection of these parameters is restricted to alpha radiation, which in no instance exceeds drinking water standards.

Eight wells sampled for gross alpha and gross beta had concentrations below the maximum concentration level of 15 and 50 picocuries per liter, respectively, for drinking water, as enforced by the Texas Commission on Environmental Quality. Two wells were tested for radium 226 and 228 and were below the maximum concentration level of five picocuries per liter (combined total of both analytes). Four wells were tested for uranium and were found to have concentrations below the maximum concentration level of 30 micrograms per liter per year.

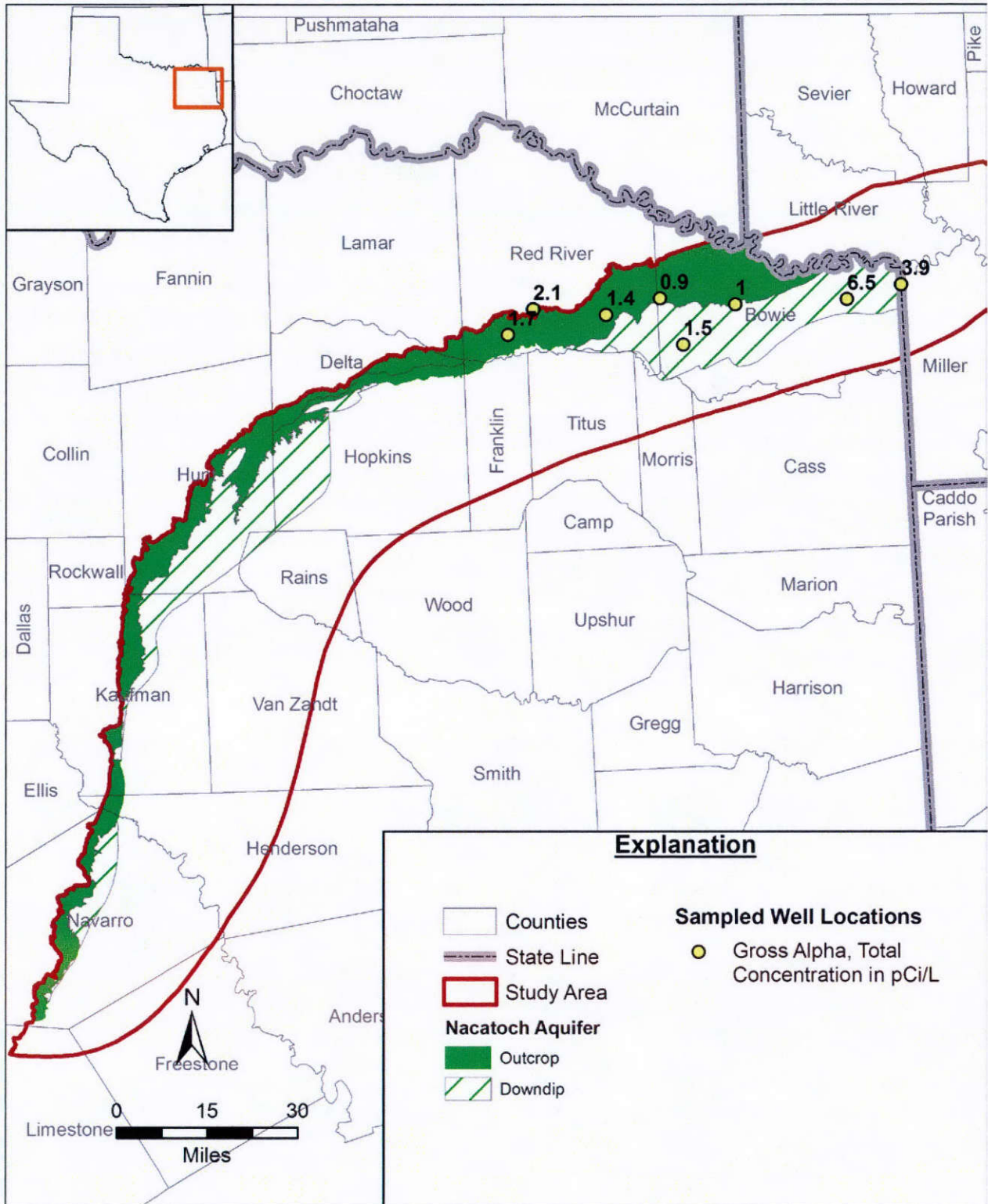


Figure 10-7. Distribution of gross-alpha radiation.

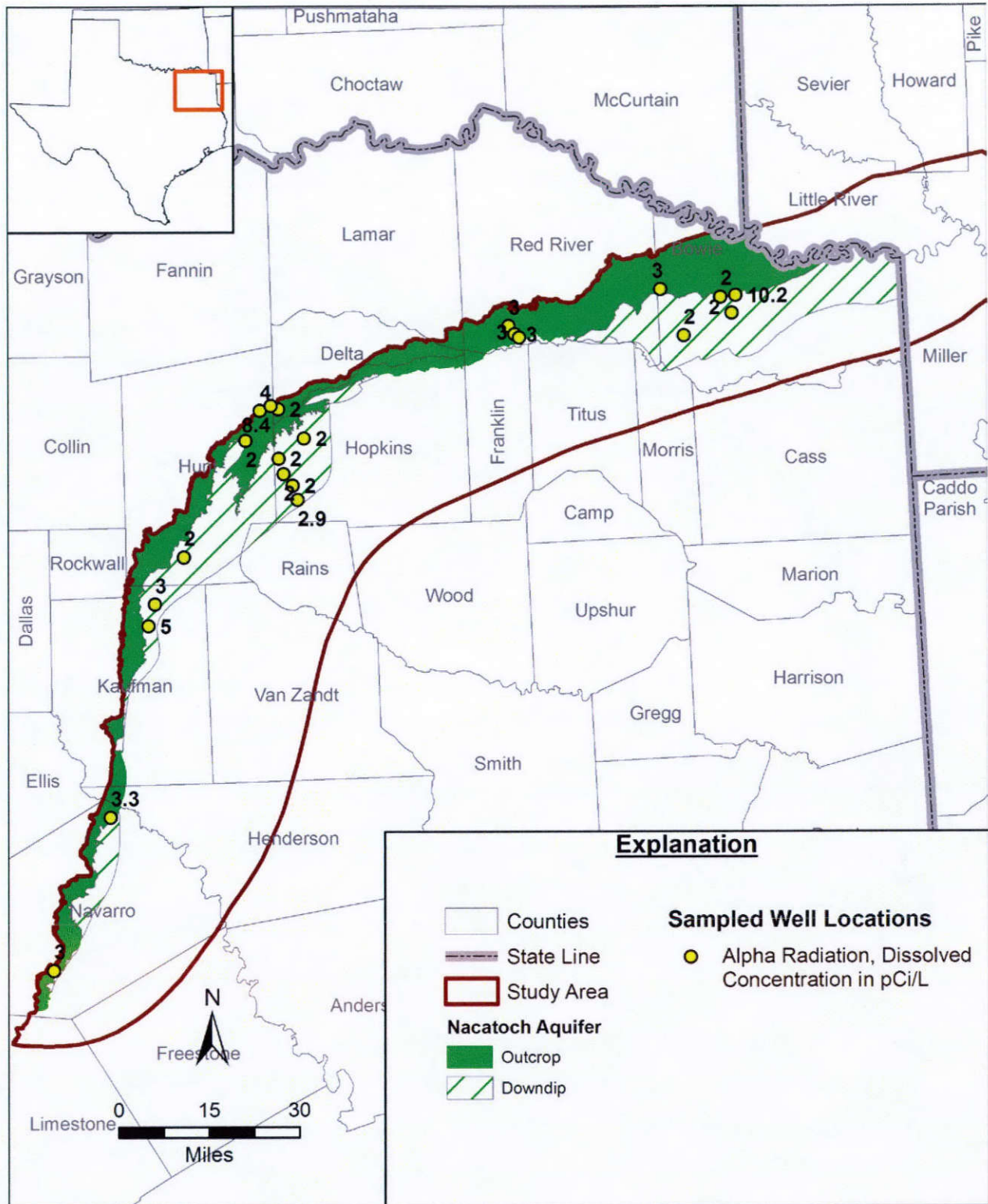


Figure 10-8. Distribution of alpha concentrations.

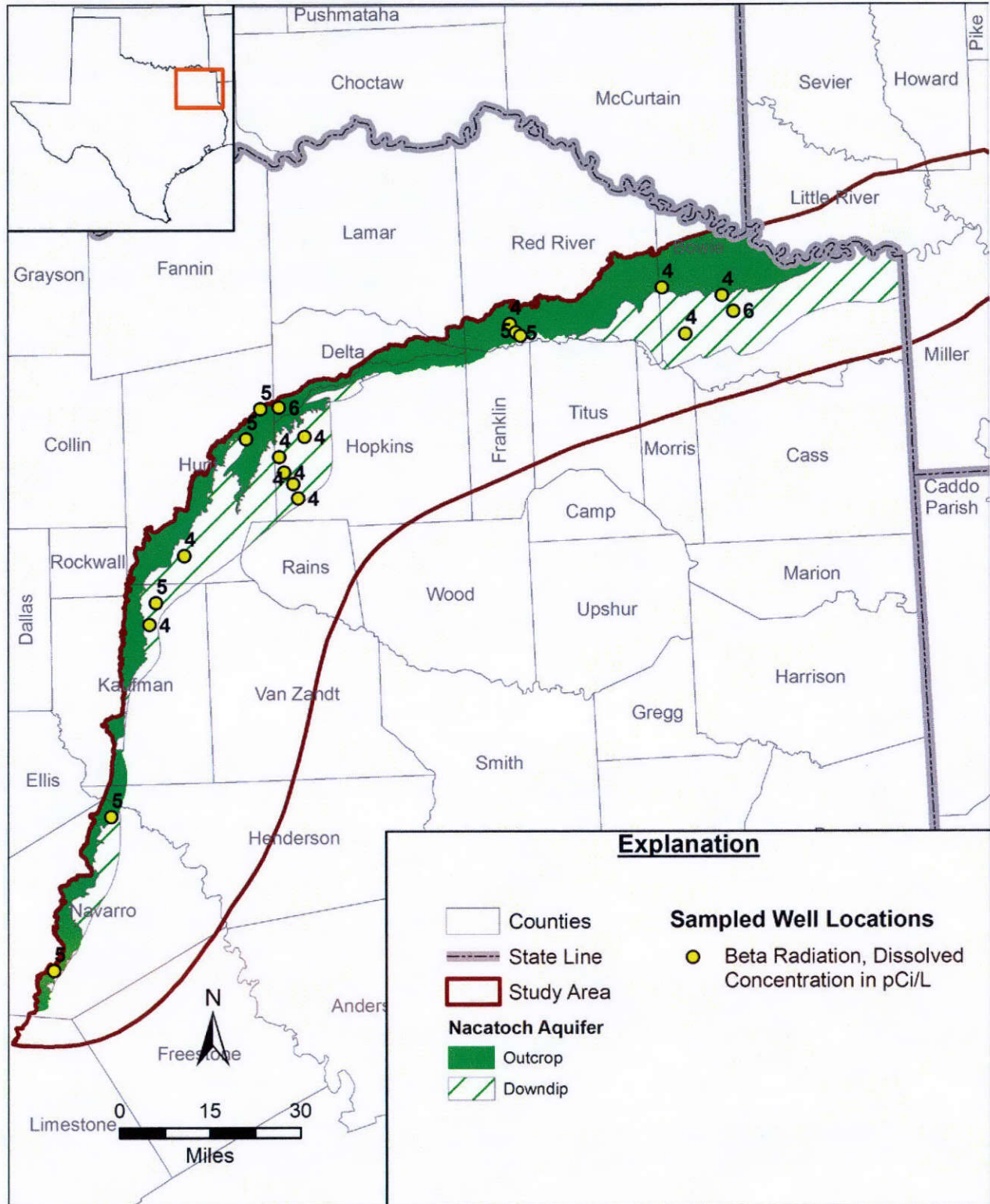


Figure 10-9. Distribution of beta radiation.

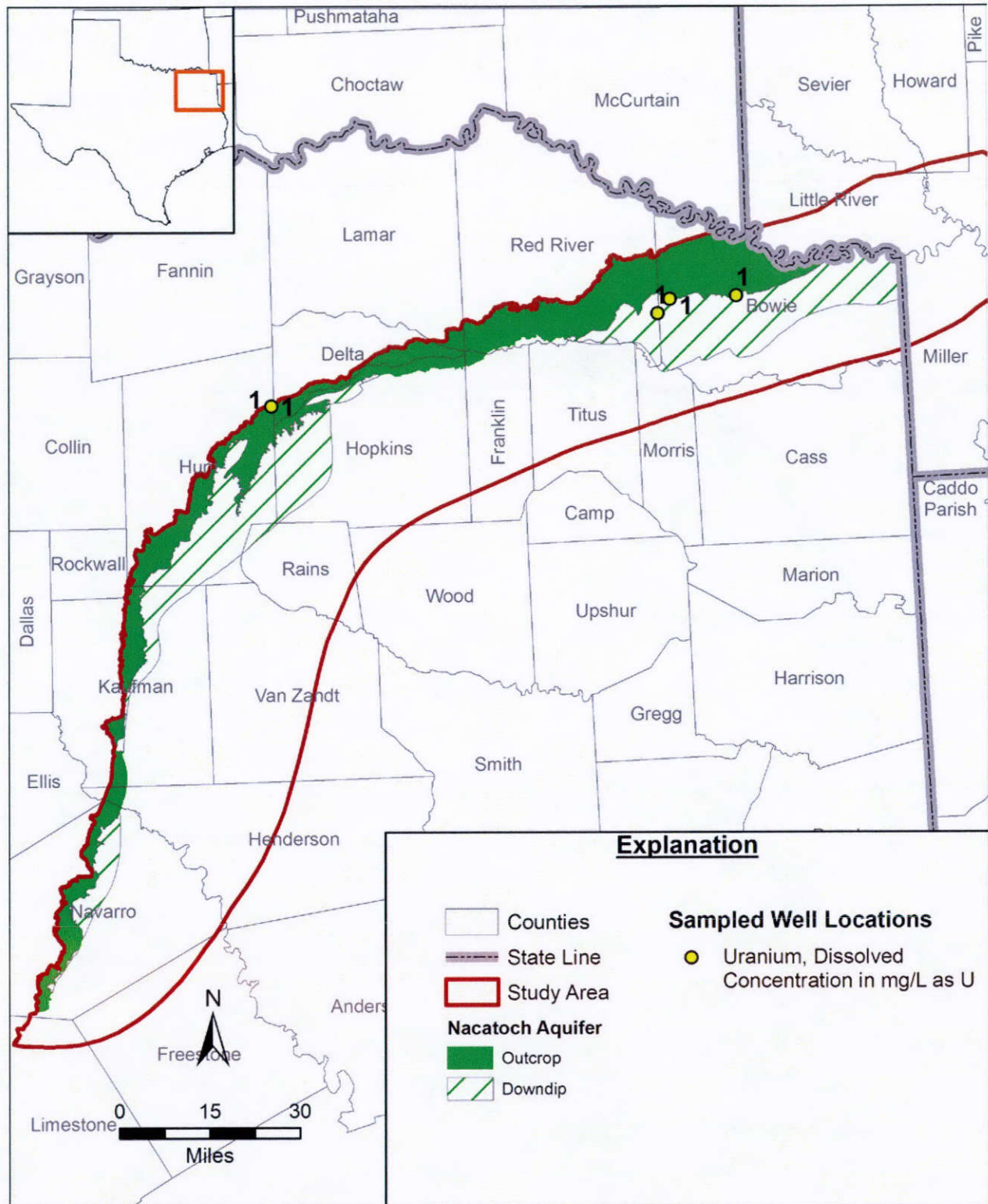


Figure 10-10. Distribution of uranium concentrations.

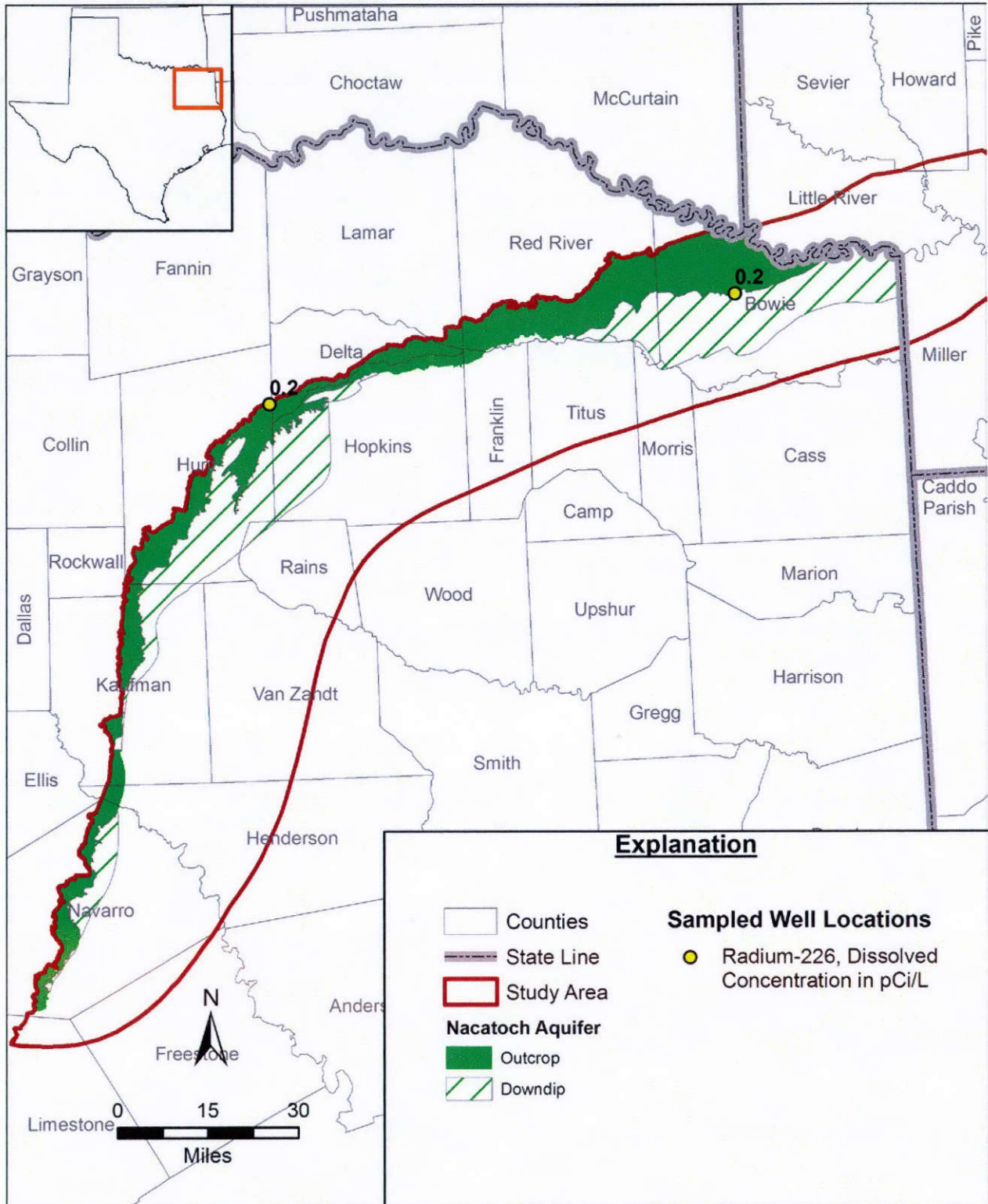


Figure 10-11. Distribution of Ra-226 concentrations.

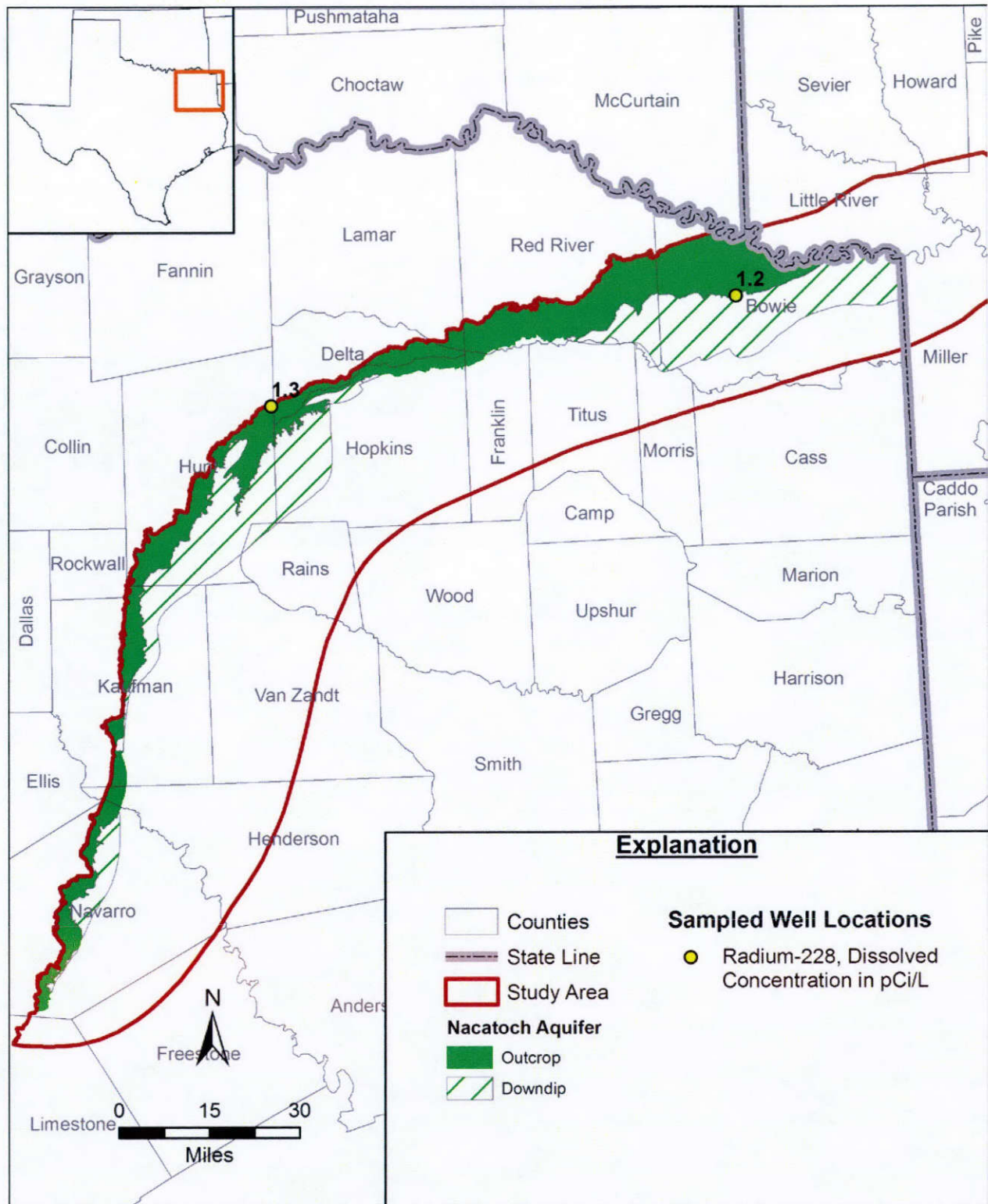


Figure 10-12. Distribution of Ra-228 concentrations.

**Table 10-1. Radiological data for the Nacatoch Aquifer.**

State Well Number	Date	Gross Alpha, Total (pCi/L) <sup>a</sup>	Alpha, Dissolved (pCi/L) <sup>a</sup>	Beta, Dissolved (pCi/L) <sup>a</sup>	<sup>226</sup> Ra, Dissolved (pCi/L) <sup>a</sup>	<sup>228</sup> Ra, Dissolved (pCi/L) <sup>a</sup>	Uranium (ug/L) <sup>b</sup>
1627701	9/22/1993		<3	<4			
	9/10/2001	<b>0.9</b>					
1632813	9/11/2001	<b>3.9</b>					
1633305	9/13/2001	<b>1.4</b>					
1634602	5/12/2010						<1
1635101	5/13/2010						<1
1635803	9/21/1993		<2	<4			
	9/11/2001	<b>1.5</b>					
1636205	9/21/1993		<2	<4			
1636306	9/11/2001	<b>1</b>					
	6/7/2011		<10.2		<0.2	<1.2	<1
1636601	9/21/1993		<2	<6			
1639206	9/11/2001	<b>6.5</b>					
1739510	9/16/1993		<3	<4			
	9/12/2001	<b>1.7</b>					
1739906	9/16/1993		<3	<5			
1739907	9/16/1993		<3	<5			
1740102	9/13/2001	<b>2.1</b>					
1741902	9/22/1993		<4	<5			
1742706	10/1/1993		<2	<6			
1742707	4/26/2010						<1
	6/9/2011		<8.4		<0.2	<1.3	<1
1749504	9/21/1993		<2	<5			
1750603	11/14/1991		<2	<4			
1750706	11/14/1991		<2	<4			
1758104	11/14/1991		<2	<4			
1758501	11/14/1991		<2	<4			
1758801	11/14/1991		<b>2.9</b>	<4			
3307906	9/21/1993		<2	<4			
3315402	9/22/1993		<3	<5			
3323107	9/21/1993		<5	<4			
3346707	9/16/1993		<b>3.3</b>	<5			
3904502	9/16/1993		<3	<5			

<sup>a</sup> Picocuries per liter.

<sup>b</sup> Micrograms per liter.

Source: Texas Water Development Board, Groundwater Database



## 11 Net Sand Analysis

The Nacatoch sand occurs in the middle of the Navarro Group below a marly unit that is identifiable in a number of wells. Sands of the middle and lower Navarro were picked on geophysical logs using SP and resistivity curves, and care was taken to avoid the shaly zones. The net sand thicknesses obtained were then gridded to produce net sand maps as shown in Figure 11-1 and Figure 11-2. Based on the maps, the Nacatoch Sand appears to be the thickest in northeastern Texas stretching into Arkansas, with net thicknesses greater than 150 feet (Figure 11-1); these sands are interpreted to be of tidal origin (McGowen & Lopez, 1983). The central part of the Nacatoch around Hunt County also reaches net sand thickness of almost 100 feet; these sands are interpreted to have been deposited by deltaic systems (McGowen & Lopez, 1983). In most areas, net sand thickness averages 50 feet or more. Multiple lower Navarro sands are also identifiable on most well logs. They appear more thinly bedded at log scale than the Nacatoch, with thick mudstones or clays separating coarsening upwards sand cycles. The lower Navarro net sand thickness varies from less than 25 feet to as high as 125 feet (Figure 11-2).

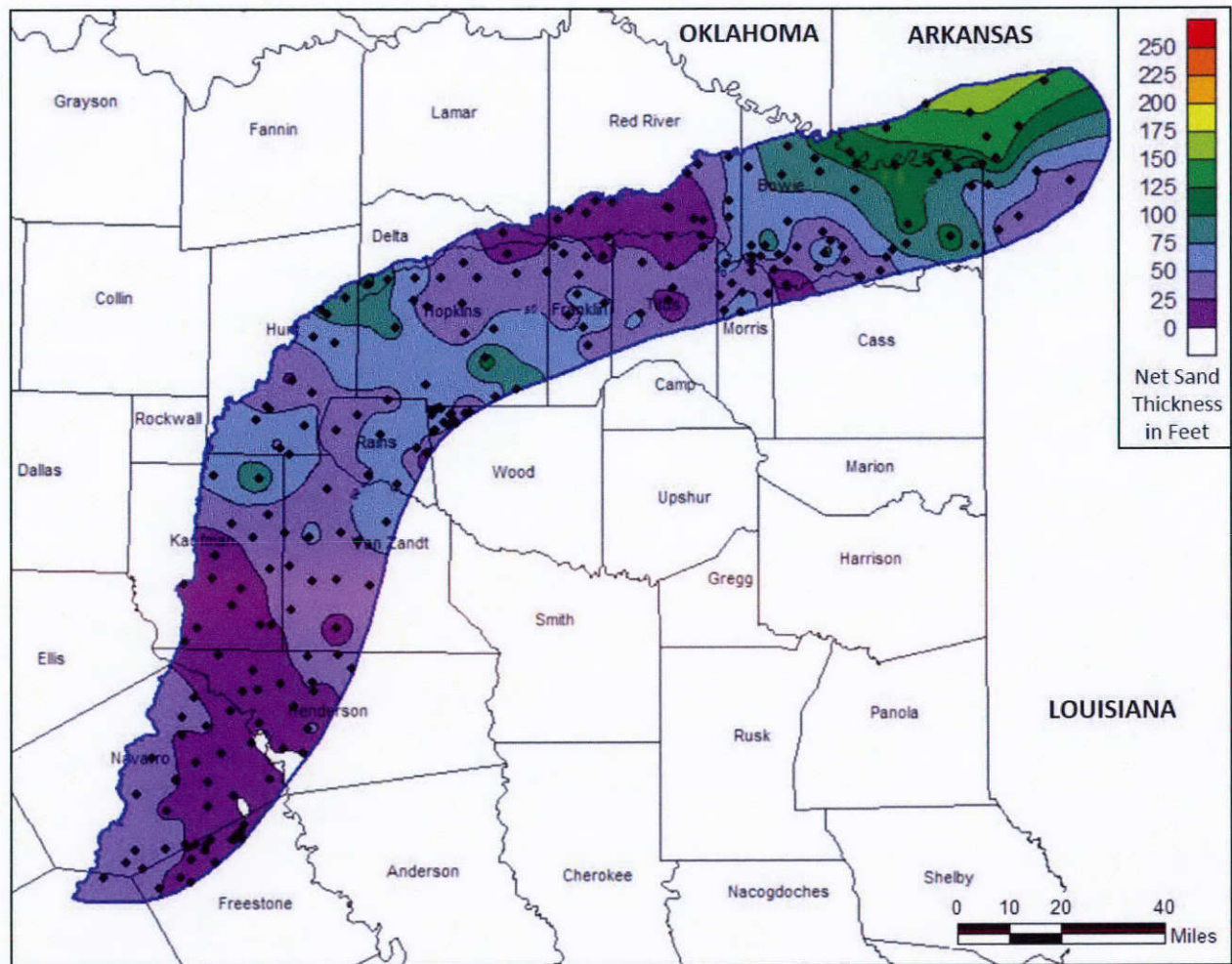


Figure 11-1. Net sand thickness of Nacatoch sand.

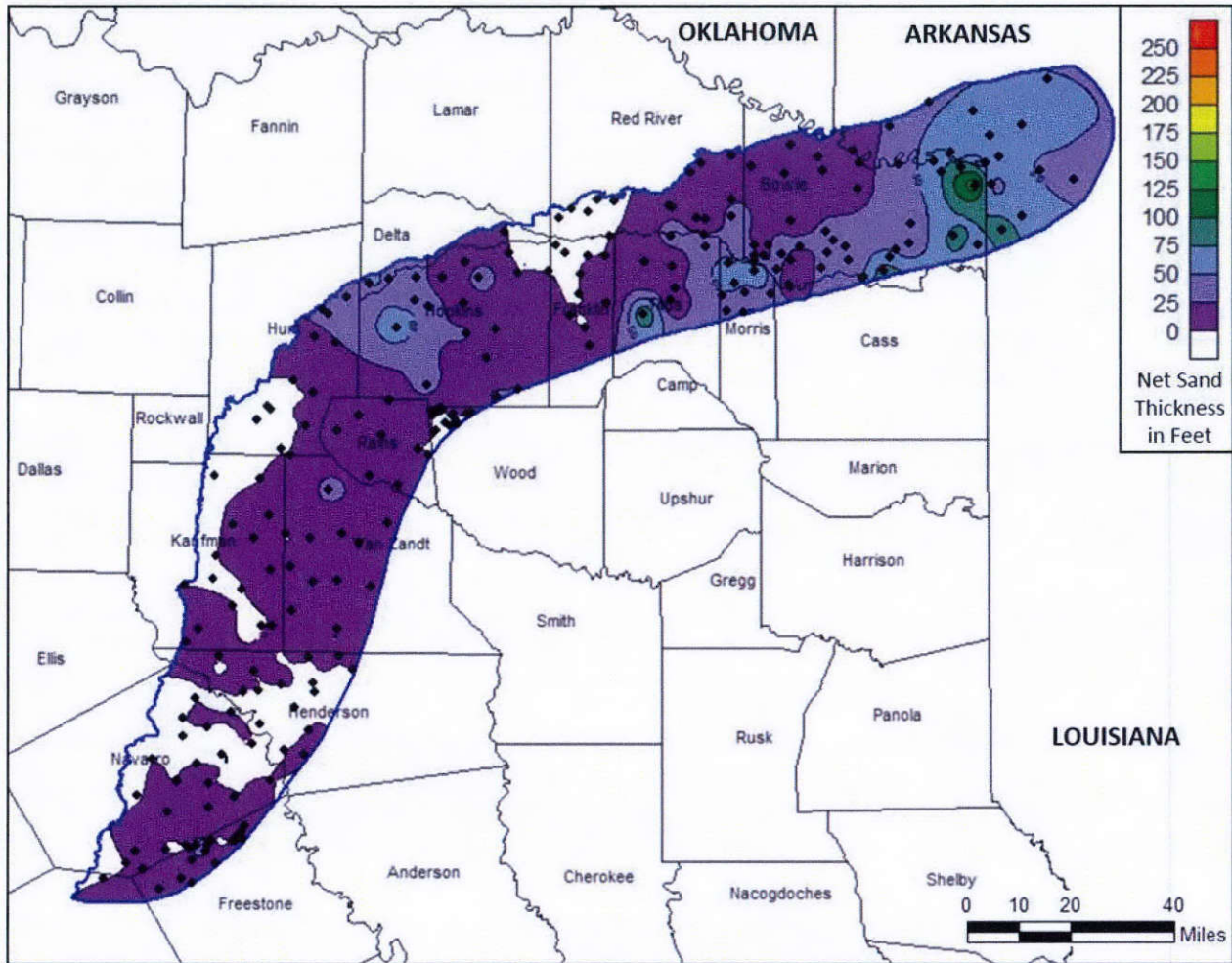


Figure 11-2. Net sand thickness of lower Navarro sands.

## 12 Groundwater Volume Methodology

The primary assumption made for the Nacatoch Aquifer was that total dissolved solids values do not vary vertically, and that the only relevant portion of the aquifer is in the basal sand unit.

The Nacatoch Aquifer surfaces were interpolated using ArcGIS Pro's geostatistical analyst package using empirical bayesian kriging. Along with the aquifer itself, the top and bottom of the basal sand unit was also interpolated. The thickness for both the aquifer and the basal sand was determined by the interpolated surfaces. The assumption of no vertical change in total dissolved solids values allowed for the total dissolved solids point values to be interpolated using the same method, but was confined to only to the basal sand unit. The interpolated total dissolved solids values were then zoned into the four salinity categories.

With the total dissolved solids zones defined, the top, bottom, and thickness of each zone could be extracted. With these values, along with water level, specific yield, and specific storage the volumes for each zone could be estimated. The water level data came from the TWDB's groundwater database and was based on 2006 readings, which were interpolated for the entire area of the aquifer. The specific yield and specific storage values were extracted from the draft

Nacatoch Aquifer groundwater availability model, taking the values from the third layer that represented the Basal sand unit. The method used to estimate the volumes is similar to the TERS calculations and was performed for each cell.

$$\text{Volume Unconfined: } V_{\text{unconfined}} = \text{Area} * S_y * (\text{Water Level} - \text{Bottom})$$

$$\text{Volume Confined: Total Volume} = V_{\text{confined}} + V_{\text{unconfined}}$$

$$V_{\text{confined}} = \text{Area} * S * (\text{Water level} - \text{Top})$$

$$V_{\text{unconfined}} = \text{Area} * S_y * \text{Thickness}$$

Variables:

$V_{\text{unconfined}}$  = storage volume due to water draining from the formation (Cubic feet)

$V_{\text{confined}}$  = storage volume due to elastic properties of aquifer and water (Cubic feet)

Area = area of the aquifer (square feet)

S = storativity (unitless)

$S_y$  = specific yield (1/feet)

Water Level = groundwater depth (feet)

Top = top depth of aquifer (feet)

Bottom = bottom depth of aquifer (feet)

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume. Table 12-1 summarizes volumes by salinity zone.

Tables 12-2 through 12-4 summarize the Nacatoch Aquifer salinity zone volumes within the project area by regional planning group, groundwater conservation district, and county, respectively. The North East Texas region (D) has a total in-place availability of 3,095,797 acre-feet; and Region C has approximately 758,430 acre-feet. The Neches and Trinity Valleys district has an estimated in-place volume of 221,766 acre-feet, mostly within the moderately saline zone. The three counties with the highest total volumes include Bowie (34%), Hopkins (12%), and Van Zandt (12%).

**Table 12-1. Nacatoch salinity zone volumes by zone (in acre-feet).**

<b>Salinity Zone</b>	<b>Unconfined</b>	<b>Confined</b>	<b>Total (acre-feet)</b>	<b>Percent</b>
Fresh	387,518	187,243	574,761	11%
Slightly Saline	497,987	1,270,726	1,768,713	32%
Moderately Saline	38,689	1,598,840	1,637,529	30%
Very Saline	13,183	1,451,129	1,464,312	27%
<b>Total</b>			<b>5,445,315</b>	<b>100%</b>

**Table 12-2. Salinity zone volumes by planning region (in acre-feet).**

<b>Region</b>	<b>Fresh</b>	<b>Slightly saline</b>	<b>Moderately saline</b>	<b>Very saline</b>	<b>Total</b>	<b>Percent</b>
North East Texas (D)	482,759	579,017	903,868	1,130,153	3,095,797	80%
East Texas (I)	N/A	N/A	3,529	N/A	3,529	0%
Region C	52,370	67,502	364,243	274,315	758,430	20%
Brazos G	N/A	N/A	N/A	19,767	19,767	1%
<b>Total</b>	<b>535,129</b>	<b>646,518</b>	<b>1,271,640</b>	<b>1,424,235</b>	<b>3,877,523</b>	<b>100%</b>
Percent volume by salinity zone	14%	17%	33%	37%	100%	

**Table 12-3. Salinity zone volumes by groundwater conservation district (in acre-feet).**

<b>Region</b>	<b>Fresh</b>	<b>Slightly saline</b>	<b>Moderately saline</b>	<b>Very saline</b>	<b>Total</b>	<b>Percent</b>
Neches and Trinity Valleys GCD	597	1,420	158,035	61,714	221,766	78%
Mid-East Texas GCD	N/A	N/A	34,122	28,181	62,303	22%
Prairielands GCD	N/A	12	1,272	N/A	1,284	0.4%
<b>Total</b>	<b>597</b>	<b>1,432</b>	<b>193,429</b>	<b>89,895</b>	<b>285,352</b>	
Percent volume by salinity zone	0%	1%	68%	32%	100%	

**Table 12-4. Salinity zone volumes by county (in acre-feet).**

<b>County</b>	<b>Fresh</b>	<b>Slightly saline</b>	<b>Moderately saline</b>	<b>Very saline</b>	<b>Total</b>	<b>Percent volume by county</b>
Red River	42,773	29,535	17,538	3,922	93,768	2%
Lamar	1,334	780	286		2,400	0%
Bowie	368,574	396,064	360,141	209,234	1,334,013	34%
Delta	4,177	12,918	10,357		27,452	1%
Hunt	42,184	57,219	19,490		118,893	3%
Titus		1,519	76,092	90,757	168,368	4%
Franklin			28,991	60,328	89,319	2%
Hopkins	25,379	83,768	181,785	175,772	466,704	12%
Morris			27,304	71,499	98,802	3%
Cass			31,744	2,908	34,652	1%
Wood				26,449	26,449	0.7%
Rockwall		457			457	0.01%
Rains		270	37,143	144,942	182,356	5%
Kaufman	36,418	36,775	105,564	32,359	211,116	5%
Van Zandt			111,717	344,489	456,206	12%
Ellis		12			12	0.00%
Henderson	597	1,374	158,744	62,135	222,849	6%
Navarro	15,355	29,019	70,880	152,661	267,915	7%
Freestone			34,014	28,181	62,194	2%
Limestone				19,948	19,948	0.51%
						100%
<b>Total</b>	<b>536,791</b>	<b>649,709</b>	<b>1,271,790</b>	<b>1,425,583</b>	<b>3,883,874</b>	
<b>Percent</b>	<b>14%</b>	<b>17%</b>	<b>33%</b>	<b>37%</b>	<b>100%</b>	

## **13 Geophysical Well Log Analysis and Methodology**

### **13.1 Geophysical Log Interpretation**

The Nacatoch Sand poses some challenges to total dissolved solids estimation using geophysical logs. In general, log interpretations require sand bodies that are shale free and thick enough to develop true resistivity and spontaneous potential. Nacatoch Aquifer sand bodies, however, are often thin and usually shaly. Spatial coverage of the study area by geophysical logs was fortunately not a problem.

The following guidelines were developed to estimate total dissolved solids concentrations in the Nacatoch Aquifer using geophysical logs:

1. Examine sand beds that:
  - a. are at least 10 feet thick,
  - b. are shale-free,
  - c. have separation between the shallow and deep resistivity curves indicating invasion and therefore porosity, and
  - d. have SP development.
2. Select water quality corrections using analyses from nearby water wells. In downdip areas where water wells are not present, water quality should be set to “primarily NaCl” when the Rwa method is yielding an estimate of approximately 2,500 milligrams per liter or more.
3. Attempt to evaluate the majority of geophysical logs in the BRACS database within the project area by selecting at least one log per 2.5-minute grid cell in areas where multiple logs are present and analyzing suitable logs in all other areas to develop sufficient spatial coverage.
4. Attempt to evaluate at least one log on either side of a fault.
5. Continue log interpretation in a downdip direction until a trend of total dissolved solids levels greater than 10,000 milligrams per liter is obtained in the entire thickness of the aquifer or until log characteristics in an area indicate that further assessment is not warranted.

The conditions in the first standard are not perfectly attained in the majority of logs owing to the presence of thin, shaly beds. Bed thickness is a critical element in obtaining reliable measurements of true resistivity ( $R_t$ ) from the observed resistivity ( $R_o$ ) and for obtaining the static spontaneous potential (sSP) of a bed, which is its maximum SP value (see Appendix A-5 of this report for the table summarizing the effects of tool geometry on open hole logs from Collier, 1993, p. 139).

Porosity is a necessary input for total dissolved solids estimation. The Nacatoch log suite has many old logs and few have porosity logs through that interval. The available porosity logs in the Nacatoch are of poor quality, chiefly because of borehole rugosity. As a result, local estimates for this parameter are not used. Instead, values of 0.32 to 0.4 were used from the calibration process (Driscoll, 1986).

All total dissolved solids estimation methods were considered for this study, however, the only method that appears geospatially accurate when mapped with the sample data is the  $R_{wa}$  Minimum method. The other methods did not suggest any spatial consistency.

Example geophysical logs with total dissolved solids estimation using the  $R_{wa}$  method are shown in Figure 13-1. A step-by-step overview of the  $R_{wa}$  calculations is included in this section. A tabulation of relevant BRACS variables from the geophysical log on Figure 13-1 is included as Table 13-2.

The 10-foot minimum thickness is based primarily on the SP which needs at least this thickness of clean, shale-free sand to yield an approximation of the sSP (Asquith & Gibson, 1982, p. 28). However, note that the SP tool can only resolve beds 12 feet or more in thickness.

Short and long normal tools measure resistivity in the invaded zone (short normal) and uninvaded zone (long normal). The 16-inch normal requires a bed 60 inches thick and the 64-inch normal requires a bed 20 feet thick to develop a true resistivity under ideal conditions. Induction logs are better, with true resistivity being obtained in beds just slightly thicker than their electrode spacing. However, bed resolution is still a problem on standard-scale logs and expanded-scale logs are not always available in the Nacatoch interval. Most of the logs in the Nacatoch project area are either 16-inch/64-inch normal or 16-inch normal/40-inch induction logs.

Corrections to resistivity readings for environmental conditions are not made. The most obvious choice, given its influence, would be to correct for bed thickness effects. However, correction charts in the literature are developed for specific conditions which may not be met in individual wells (Collier, 1993, p. 159). More importantly, correction charts are not available for all of the various logging systems encountered in the Nacatoch log suite.

Corrections are normally applied in several methods when bicarbonate or sulfate comprises more than 50 percent of the total dissolved solids. Numerous water wells exceed this limit. The difficulty is that such wells are situated near wells with concentrations of less than 50 percent of total dissolved solids so that it is not always clear whether a correction should be applied to a particular log.

Porosity is a necessary input for total dissolved solids estimation. The Nacatoch log suite has many old logs and few have porosity logs through that interval. The available porosity logs in the Nacatoch are of poor quality, chiefly because of borehole rugosity. As a result, local estimates for this parameter are not used. Instead, values of 0.32 to 0.4 were used from the calibration process (Driscoll, 1986).

All total dissolved solids estimation methods were considered for this study, however, the only method that appears geospatially accurate when mapped with the sample data is the  $R_{wa}$  Minimum method. The other methods did not suggest any spatial consistency.

A step-by-step overview of the  $R_{wa}$  calculations is included in this section. An example geophysical log with total dissolved solids estimation using the  $R_{wa}$  method is shown in Figure 13-1. A type log which illustrates log signatures of the Nacatoch and surrounding geological units is included as Figure 13-2. A tabulation of relevant BRACS variables from the geophysical log on Figure 13-1 is included as Table 13-1.

### 13.2 Estimation Using the $R_{wa}$ Total Dissolved Solids Minimum Method

The  $R_{wa}$  minimum total dissolved solids method is based upon Archie's water saturation equation applied in a shale free, water-saturated formation (Schlumberger, 2009).

Four parameters are required to use the  $R_{wa}$  minimum total dissolved solids method:

- Deep resistivity ( $R_t$ )
- Porosity ( $\phi$ )
- Cementation exponent ( $m$ ) A dimensionless, empirically-derived parameter related to the degree of matrix cementation
- Lithology parameter ( $a$ )

Using the four parameters, calculation of the estimated total dissolved solids concentration proceeds using the following process reproduced from Estep (2010):

1. Select a deep resistivity ( $\sim R_t$ ) value from the electric log.
2. Compute total porosity from a neutron-density porosity log. Average the neutron porosity ( $\phi_N$ ) and density porosity ( $\phi_D$ ):

$$3. (\phi_{ND}) = \sqrt{\frac{\phi_N^2 + \phi_D^2}{2}}$$

4. Determine a value for the cementation exponent ( $m$ ) from:
  - a. Pickett Plot – Plot of porosity ( $\phi$ ) versus  $R_o$ . An offset well may be acceptable if there is no porosity log on the subject well or
  - b. Best estimate – based upon reservoir description from driller's log. Set  $a = 1$ , then selecting the proper cementation exponent;

5. Solve for  $R_{wa}$ :

$$R_{wa} = \frac{\phi^m \cdot R_t}{a}$$

6. Freshwater ion correction for  $R_{wa}$

If high bicarbonates are present, then apply Alger's (1966) equation:

$$R_{wa(\text{cor})} = 1.75 \cdot R_{wa}$$

For sodium bicarbonate groundwater, use:

$$R_{wa(\text{cor})} = 1.33 \cdot R_{wa}$$

7. Calculate formation temperature ( $T_f$ ) using the bottom-hole temperature (TBH), which is the temperature in degrees F at the bottom of the hole at the time the well was logged (from the log header), and surface temperature ( $T_s$ ), which is a 30-year climatic normal.

$$T_f = (TBH - T_s) \frac{\text{formation depth}}{\text{total depth}} + T_s$$



8. Convert  $R_{wa(corr)}$  at  $T_f$  to  $R_w$  at 75°F with

$$R_{w75} = R_{wa(corr)} \left( \frac{T_f}{75} \right)$$

9. Convert formation water resistivity at 75°F ( $R_{w75}$ ) to specific conductance at 75°F ( $C_{w75}$ ) with

$$C_{w75} = \frac{10,000}{R_{w75}}$$

10. Solve for total dissolved solids using the specific conductivity-total dissolved solids conversion factor (ct) in

$$\text{total dissolved solids} = ct \cdot C_{w75}$$

Where  $ct = C_w$ -total dissolved solids conversion factor and  $C_{w75}$  = Specific conductivity at 75°F.

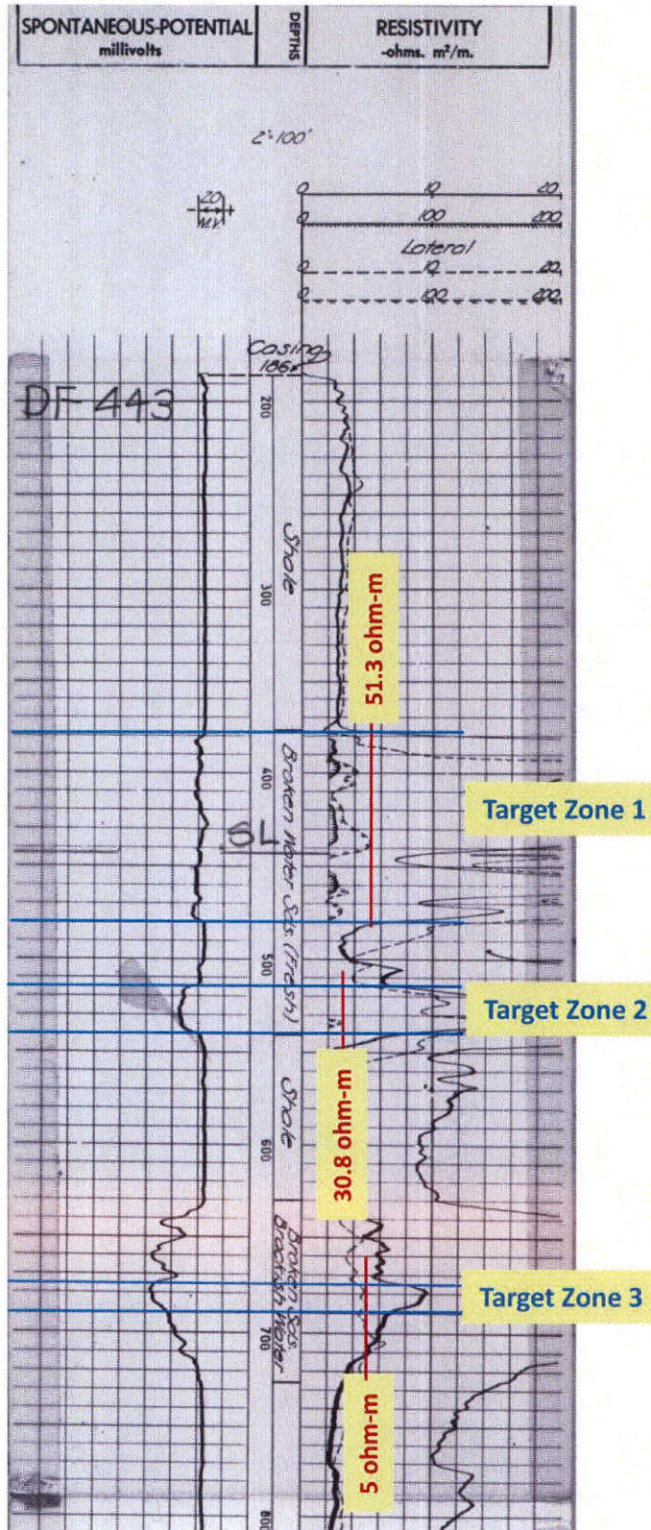


Figure 13-1. BRACS ID# 23582 geophysical log Ro values.

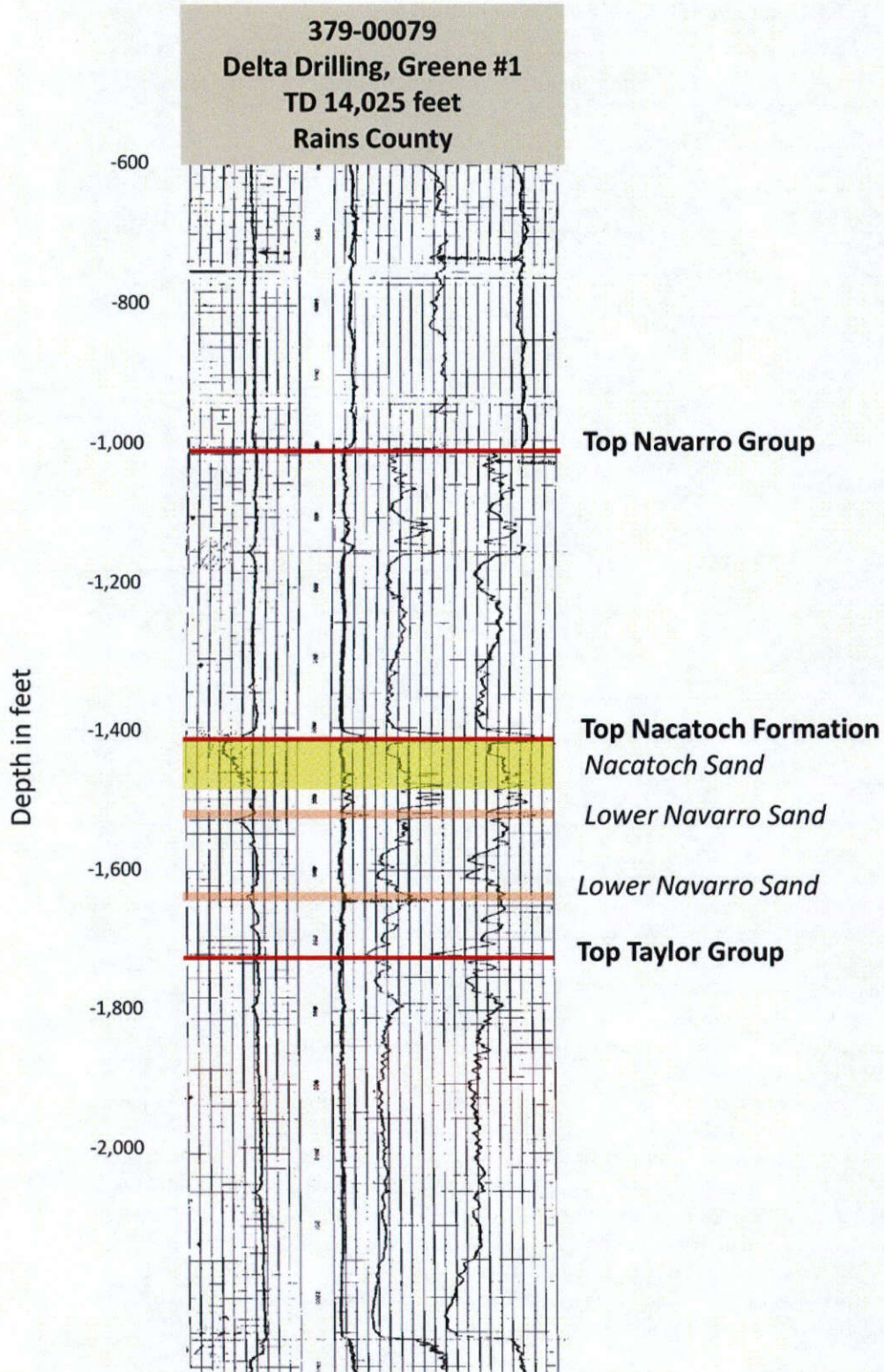


Figure 13-2. Type log.

**Table 13-1. Total dissolved solids estimates using Rwa method for log in Figure 13-1.**

Field description	Target zone 1	Target zone 2	Target zone 3
WELL ID	23582	23582	23582
DF	435	535	680
TDS INTERPRETED	660	1,070	4,790
RO	51.3	30.8	5.0
A	1	1	1
M	1.4	1.4	1.4
PHI	0.33	0.33	0.33
CT	0.5	0.5	0.5
RWE	10.9	6.5	1.1
RWE RW COR	1.33	1.33	1.0
RW COR	8.2	4.9	1.1
RW 75	7.6	4.7	1.0
CW	1,313	2,137	9,590
DT	4,699	4,699	4,699
TS	63	63	63
TBH	138	138	138
TF	69.9	71.5	73.9

WELL\_ID: BRACS unique well ID.

DF: Depth of the assessed formation of interest, not corrected for Kelly bushing height. Units are feet below ground surface.

TDS\_INTERPRETED: Interpreted total dissolved solids (TDS) concentration at the depth of formation. The units are milligrams per liter total dissolved solids.

RO: Resistivity of the saturated formation in units of ohm-meter. The formation should be 100 percent saturated with water.

A: Lithology of tortuosity factor in Archie's Law.

M: Cementation exponent in Archie's Law.

PHI: Porosity data were not available for the Nacatoch. Assumed a porosity of 0.33 in thick sand with high deep resistivity or prominent negative deflection on SP.

CT: Total dissolved solids divided by specific conductance. The field value is less than one and is dimensionless.

RWE: Resistivity of water equivalent in units of ohm-meter.

RWE\_RW\_COR: Correction factor for high anion waters using the SP and Rwa minimum method (Estep, 1998). The value units are dimensionless.

RW\_COR: Resistivity of the water as determined by geophysical well log analysis. Units are ohm-meters.

RW75: Resistivity of the water as determined by geophysical well log analysis corrected for 75 degrees Fahrenheit. Units are ohm-meters.

CW: Conductivity of the water as determined by geophysical well log analysis corrected for 75 degrees Fahrenheit. Units are microsiemens per meter.

DT: The total depth of the log (not the total depth of the hole).

RMF\_COR: Correction factor for resistivity of the mud filtrate when using the SP method of analysis.

TS: Temperature at the ground surface. Temperature is in units of degrees Fahrenheit.

TBH: Temperature at the bottom of the hole at the time the well was logged. Temperature is in units of degrees Fahrenheit.

TF: The temperature at the depth of formation of interest [DF]. Units are degrees Fahrenheit.

## 14 Potential Brackish Groundwater Production Area Analysis and Modeling Methodology

### 14.1 Exclusion Criteria

Potential production area may only exist in locations that meet the criteria of House Bill 30. House Bill 30 states that these areas:

- *Are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any area of the same or other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids level of 1,000 milligrams per liter or less at the time of designation of the zones.*
- *Are not located in an aquifer, subdivision of an aquifer, or geologic stratum that has an average total dissolved solids level of more than 1,000 milligrams per liter and is serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones, or in an area of a geologic stratum that is designated or used for wastewater injection through the use of injection wells or disposal wells permitted under Chapter 27.*

Using these criteria for guidance, several public supply, irrigation, domestic, and injection wells were determined to qualify for exclusion. Two-mile buffer zones were applied to all Nacatoch wells. One-mile buffers were applied to wells found in the state driller report database (Figure 14-1). The summary table (Table 14-1) lists the type of well and total count of the wells found. Alluvium wells completed within less than 200 feet of vertical separation from the top of the Nacatoch were excluded. Injection wells with injection zones located within 300 vertical feet of either the top of the Nacatoch Formation or the base of the Taylor Group were excluded. Most of these are located in the southern fault graben, thus the entire graben has been excluded. Tables of all excluded wells are included as Appendix 19-1. Any area between the 1,000 and 10,000 milligrams per liter total dissolved solids extents that were not excluded using these criteria were considered for evaluation as potential production areas (Figure 14-2). Some portions of the potential production areas extend past the estimated 10,000 milligrams per liter limit merely to simplify the modeling task (Figure 14-3 and Figure 14-4).

**Table 14-1. Exclusion wells summary.**

Source	Well use	Count	Aquifer
Texas Commission on Environmental Quality	Public Supply	88	Nacatoch
Texas Commission on Environmental Quality	Public Supply	1	Alluvium
TWDB groundwater database	Domestic	188	Nacatoch
TWDB groundwater database	Irrigation	8	Nacatoch
TWDB groundwater database	Public Supply	74	Nacatoch
State Driller Report database	Domestic	231	Nacatoch, Alluvium
State Driller Report database	Irrigation	16	Nacatoch, Alluvium
State Driller Report database	Public Supply	1	Nacatoch, Alluvium
Railroad Commission Class II wells	Injection, Disposal	431	Nacatoch

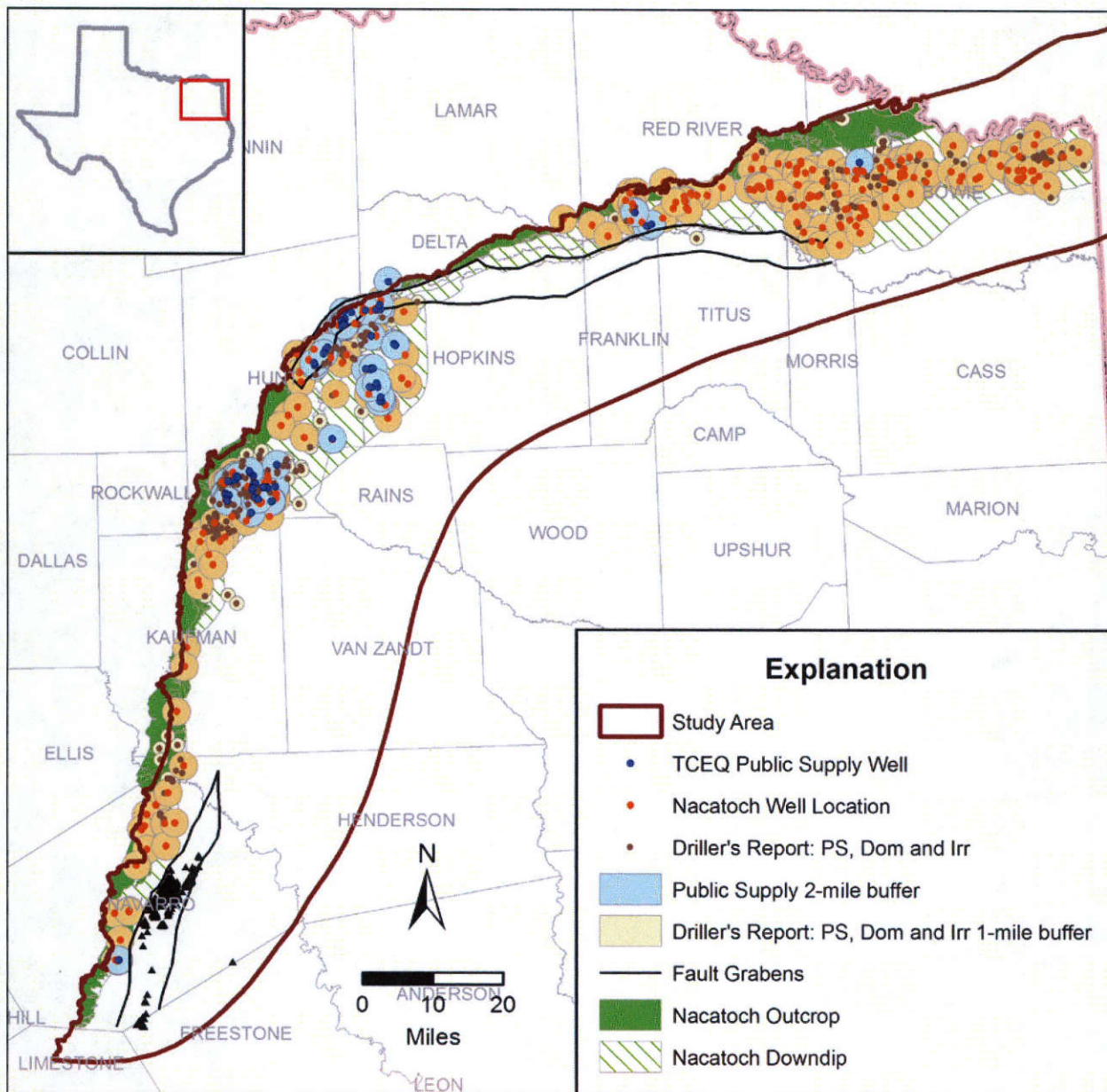


Figure 14-1. Exclusion areas for wells, injection wells and faults.

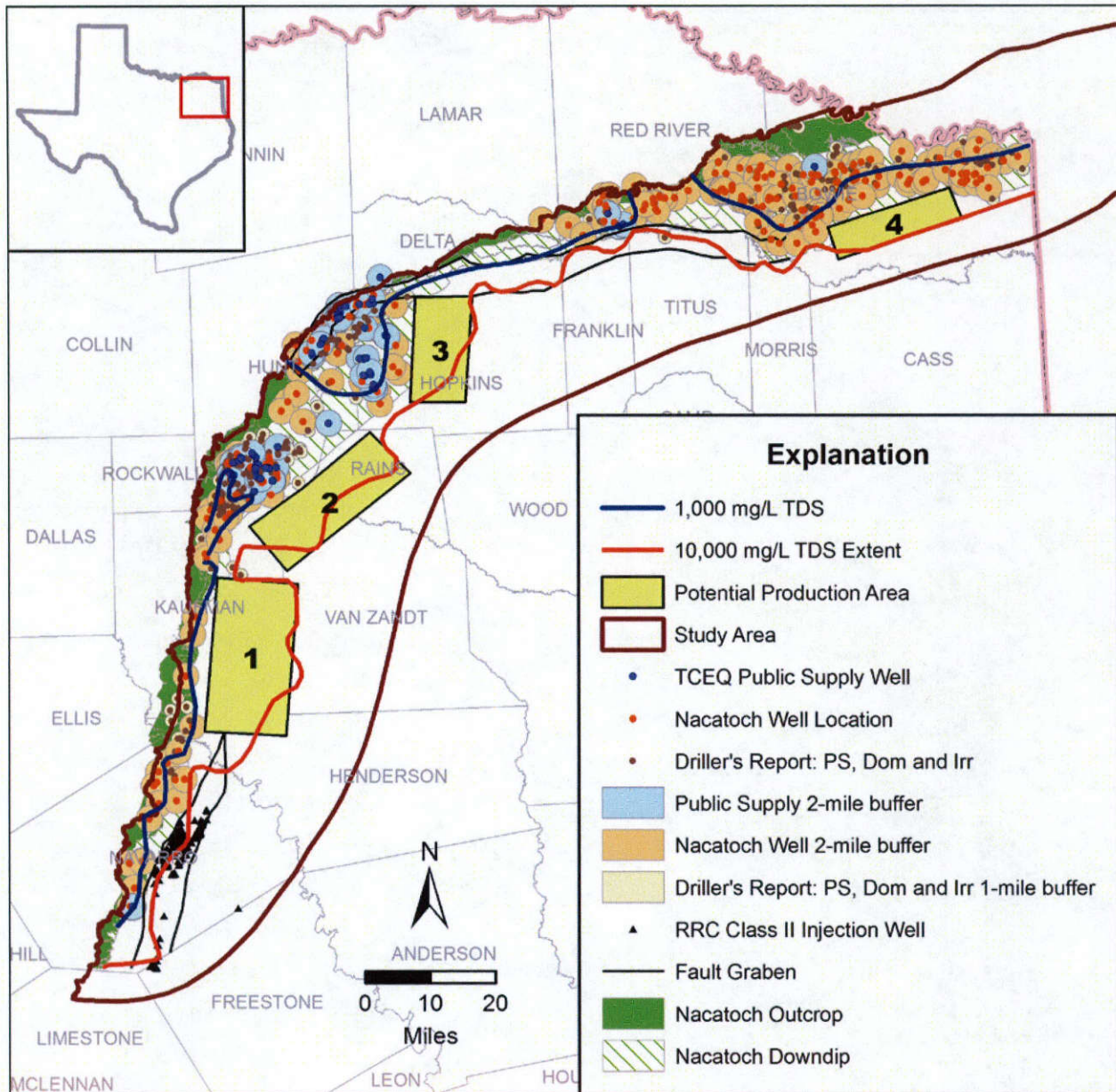


Figure 14-2. Exclusion areas and potential production areas.

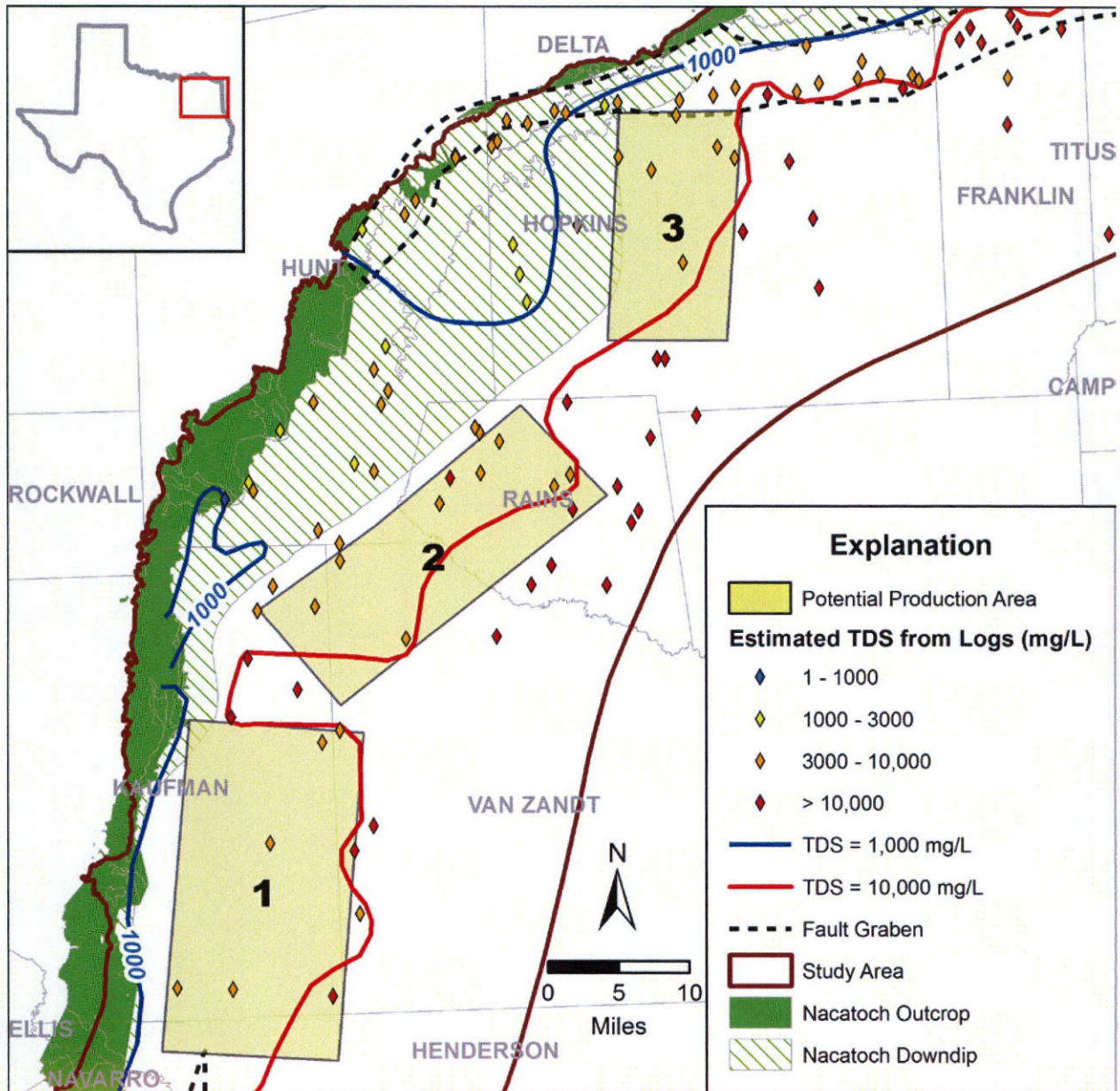


Figure 14-3. Potential production areas 1, 2 and 3.



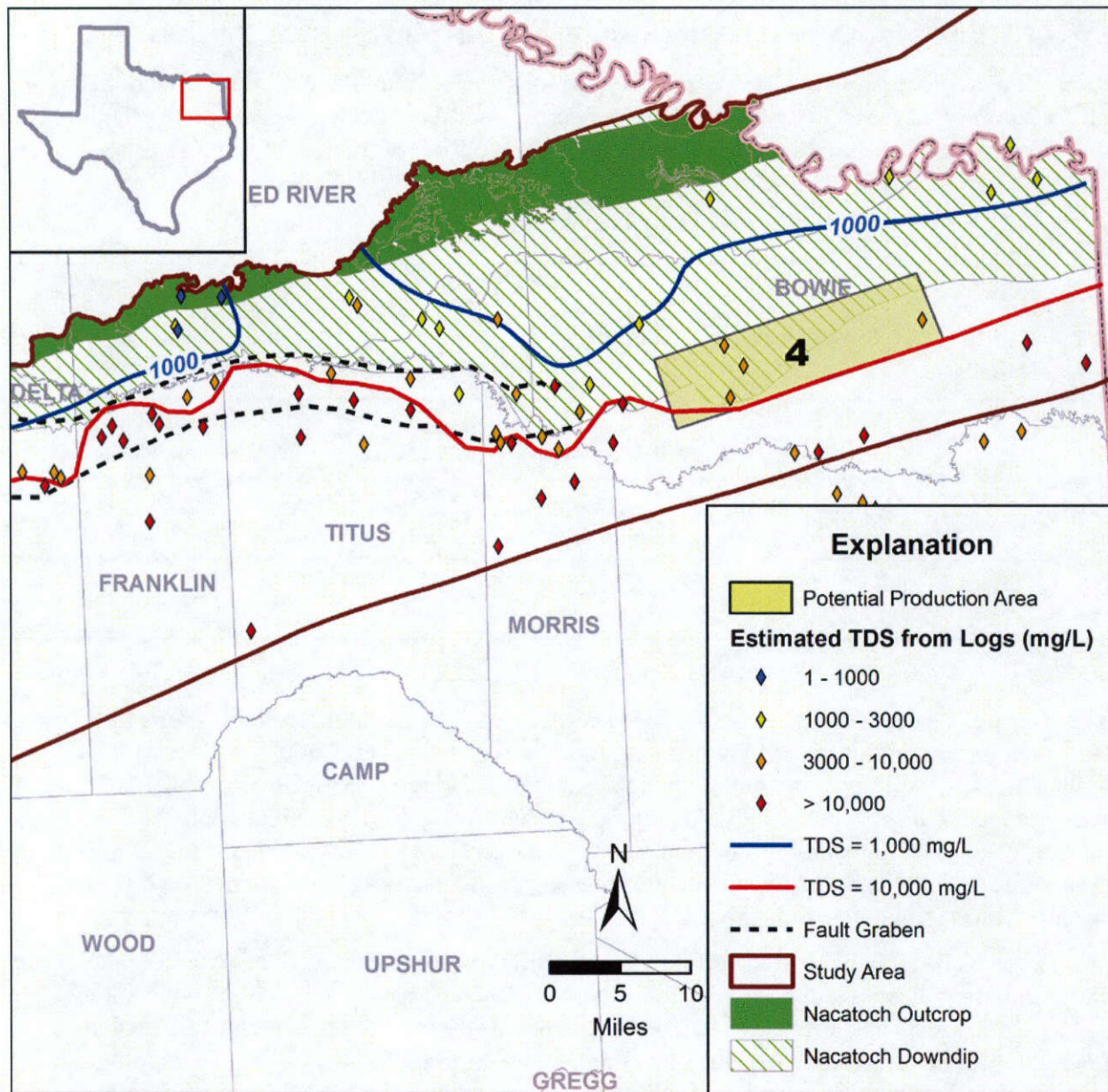


Figure 14-4. Potential production area 4.

## 14.2 Pumping Analysis and Results For 30- and 50-Year Periods

This drawdown analysis was performed for the four potential production areas to understand the effect pumping in these areas would have on nearby locations. Each potential production area was pumped at a low, medium, and high rate and for a period of 30 and 50 years (Table 14-2).

Table 14-2. Nacatoch Aquifer simulated pumping volumes.

Pumping range	Pumping volume (acre-feet per year)
Low	100
Medium	200
High	500

The well field set up was the same for each scenario, but placed in different locations throughout the potential production areas to understand the different effects they could have at various locations. The well field set up remained the same as a series of six wells offset by 4,000 feet. It was assumed that the wells fully screened the sand portions of the Nacatoch Aquifer. The properties for each potential production area were taken from the Nacatoch Groundwater Availability Model and averaged over the potential production area. The values used for each potential production area are shown in table 14-3.

Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The drawdown contours for each of the selected well fields and associated potential production areas are included as Figure 14-5 through Figure 14-28. The approximate minimum and maximum impact, in feet of drawdown, to the nearest exclusion wells at each of the potential production areas are summarized in Table 14-4. Minimum drawdowns are 100 acre-feet 30-year scenarios, and maximums are from 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown.

The Theis analysis assumes the standard assumptions such as fully penetrating well screen, constant pumping rate, and homogenous and isotropic confined aquifer. This analysis is limited in that it cannot show changes in pumping through time, recharge, or regional factors that could influence water levels through time.

**Table 14-3. Nacatoch Aquifer properties for the modeled potential production areas.**

<b>Potential production area</b>	<b>Average storativity</b>	<b>Average transmissivity (gallons per day per foot)</b>
1	$1.4 \times 10^{-5}$	5,850
2	$2.7 \times 10^{-5}$	11,460
3	$3.1 \times 10^{-5}$	4,588
4	$3.1 \times 10^{-5}$	13,935

**Table 14-4. Summary of estimated impact on nearest exclusion wells, in feet of drawdown**

<b>Potential production area</b>	<b>Minimum drawdown (feet)</b>	<b>Maximum drawdown (feet)</b>
1	7	35
2	0	20
3	8	70
4	0	20

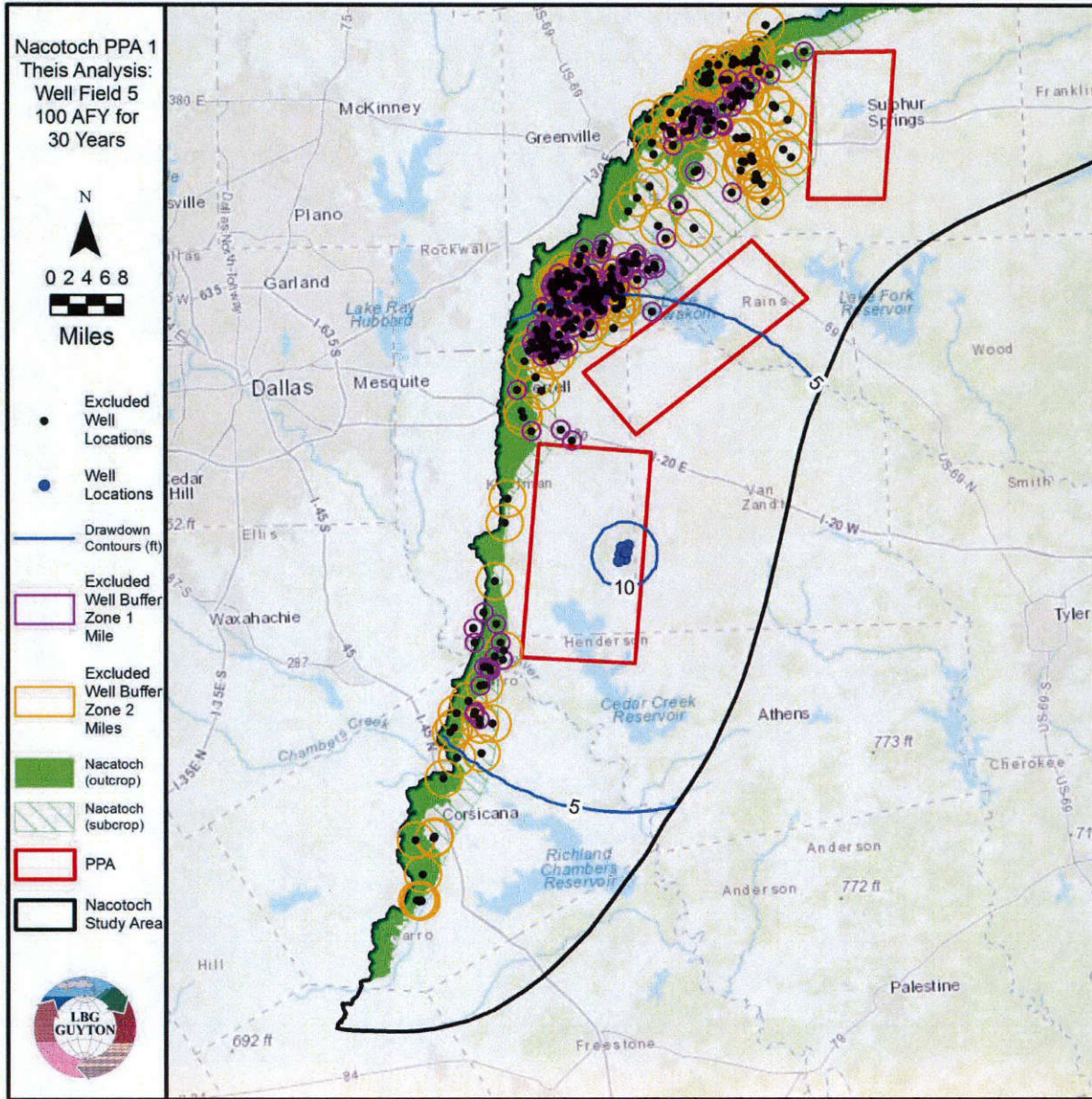


Figure 14-5. Potential production area 1: 30-year drawdown at 100 acre-feet per year.

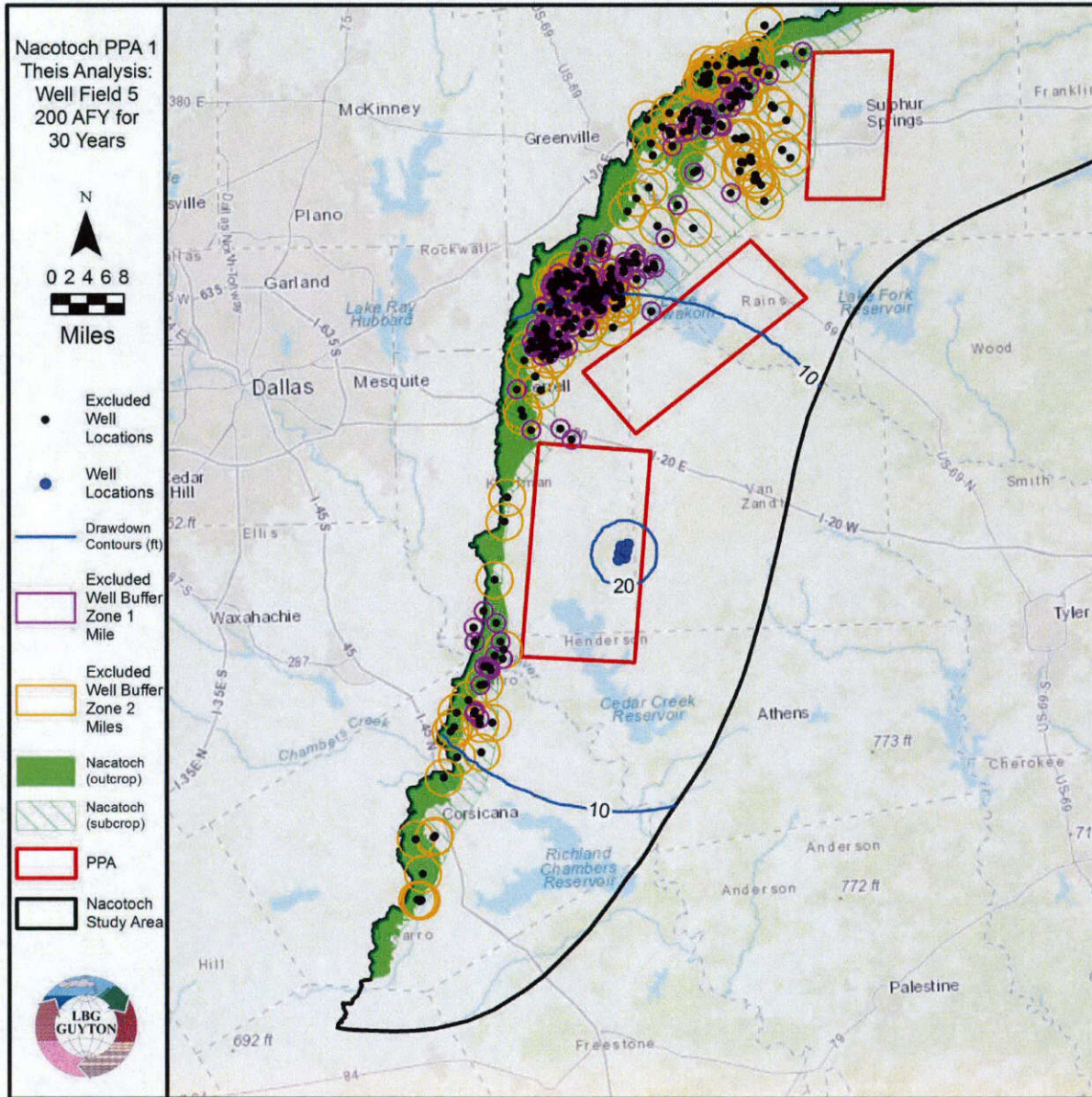


Figure 14-6. Potential production area 1: 30-year drawdown at 200 acre-feet per year.

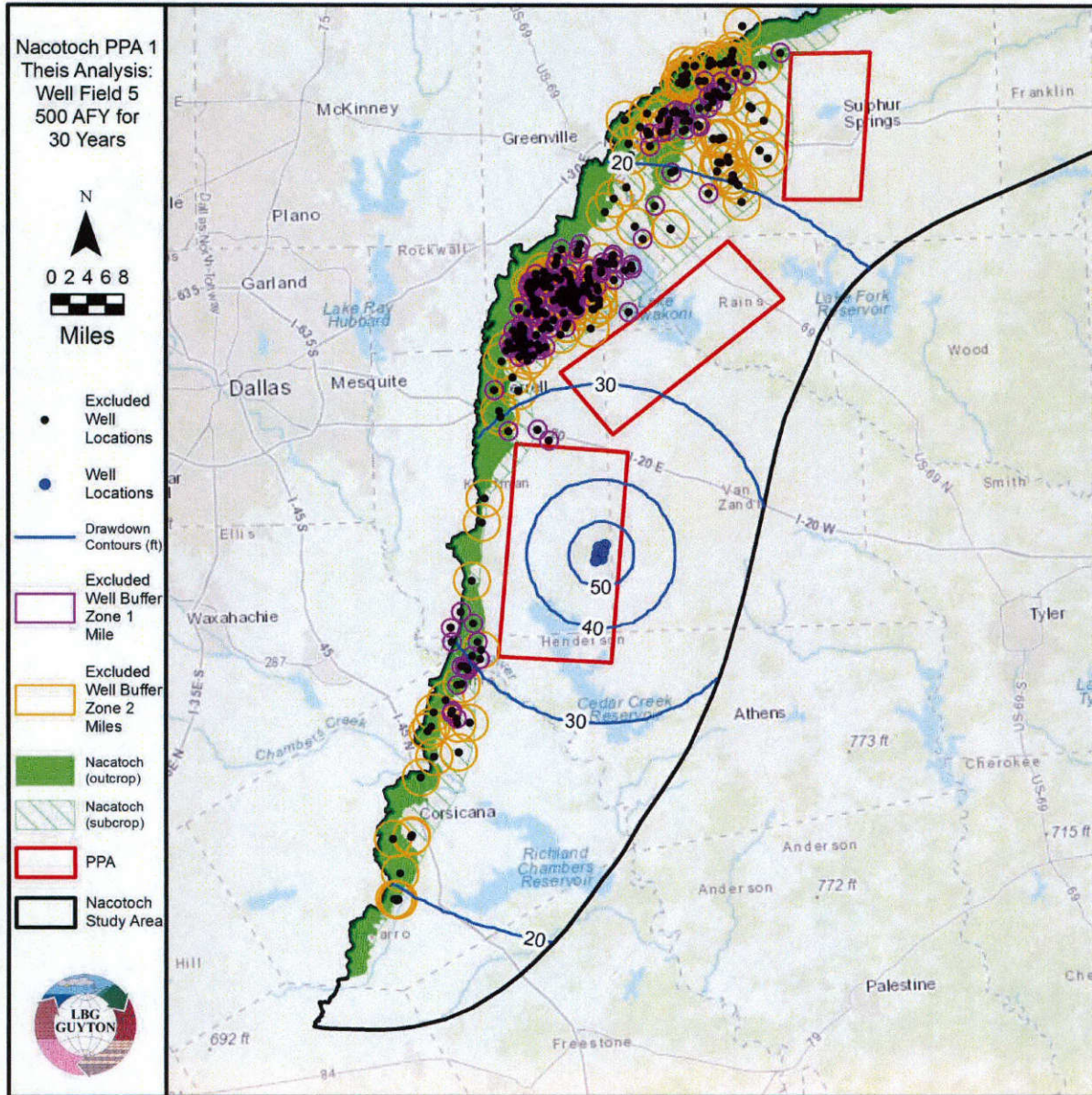


Figure 14-7. Potential production area 1: 30-year drawdown at 500 acre-feet per year.

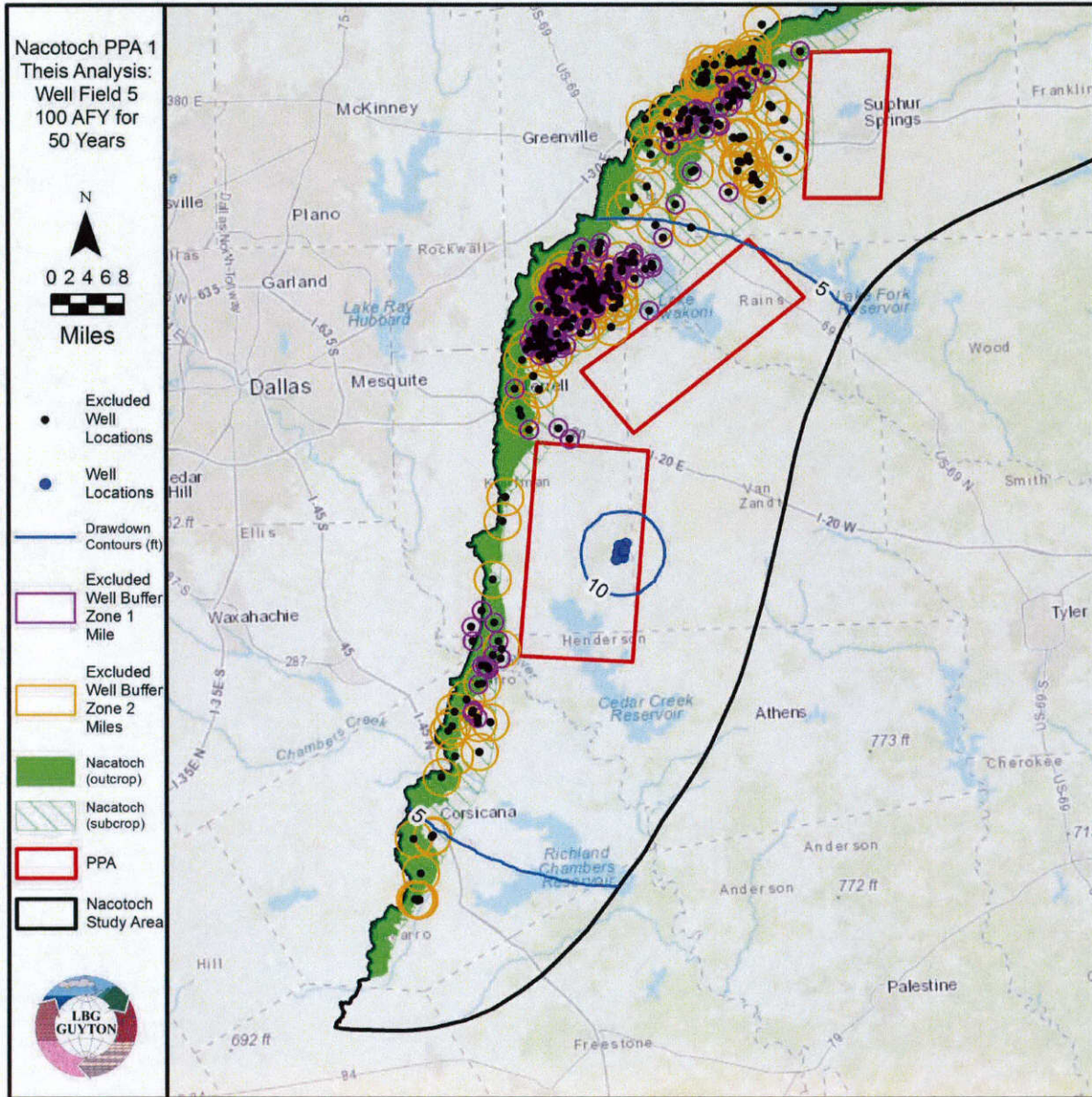


Figure 14-8. Potential production area 1: 50-year drawdown at 100 acre-feet per year.

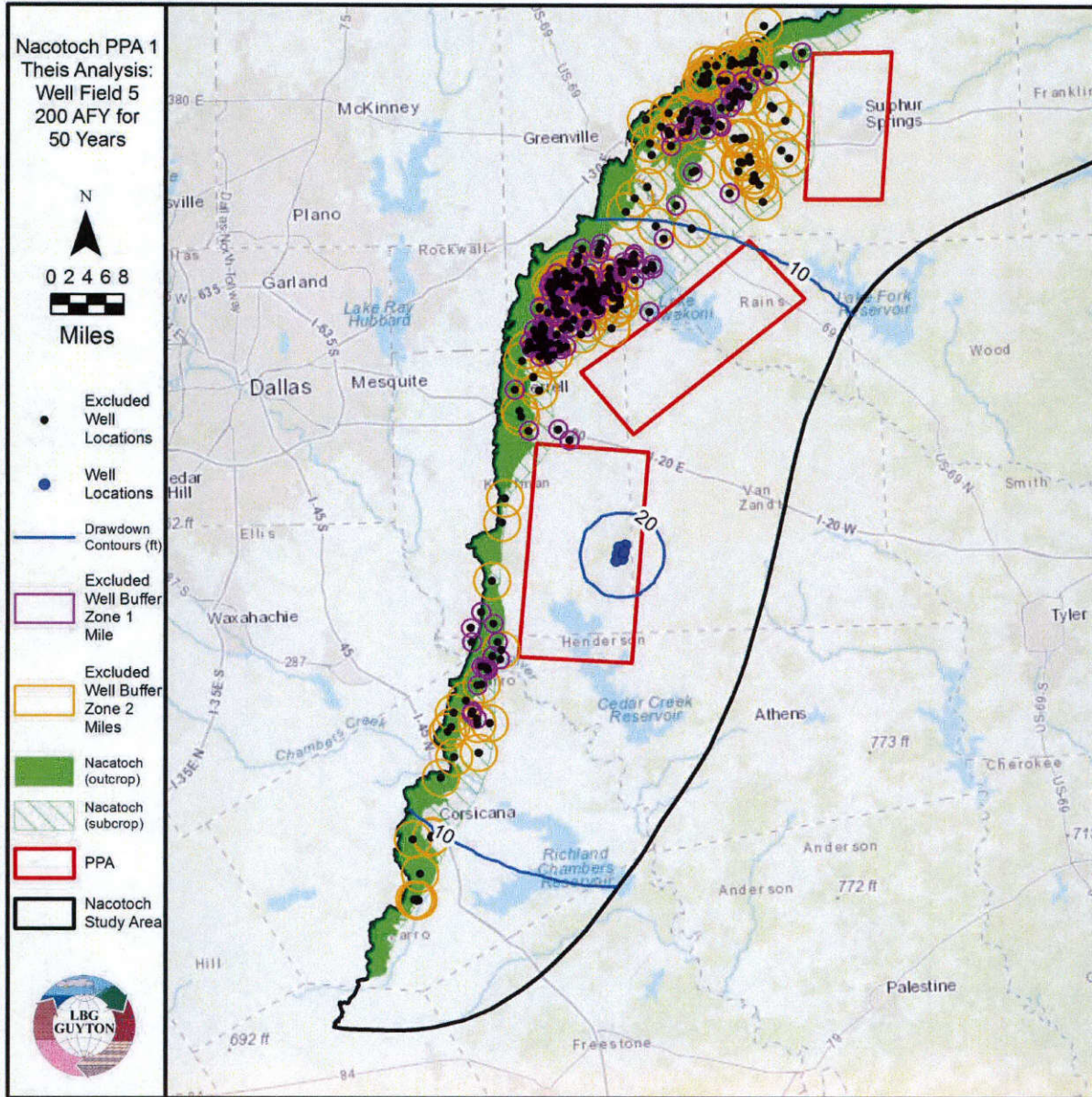


Figure 14-9. Potential production area 1: 50-year drawdown at 200 acre-feet per year.



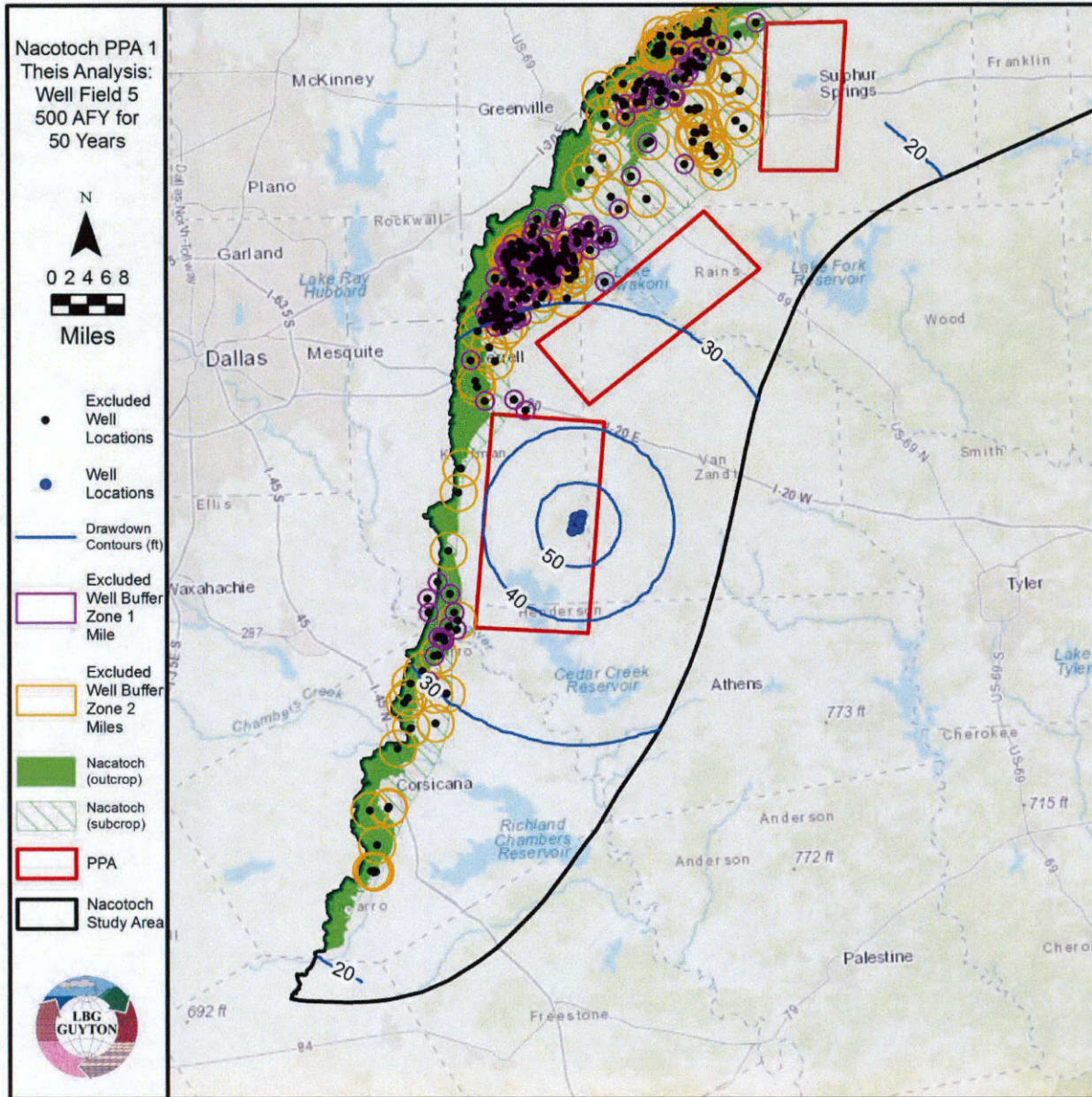


Figure 14-10. Potential production area 1: 50-year drawdown at 500 acre-feet per year.

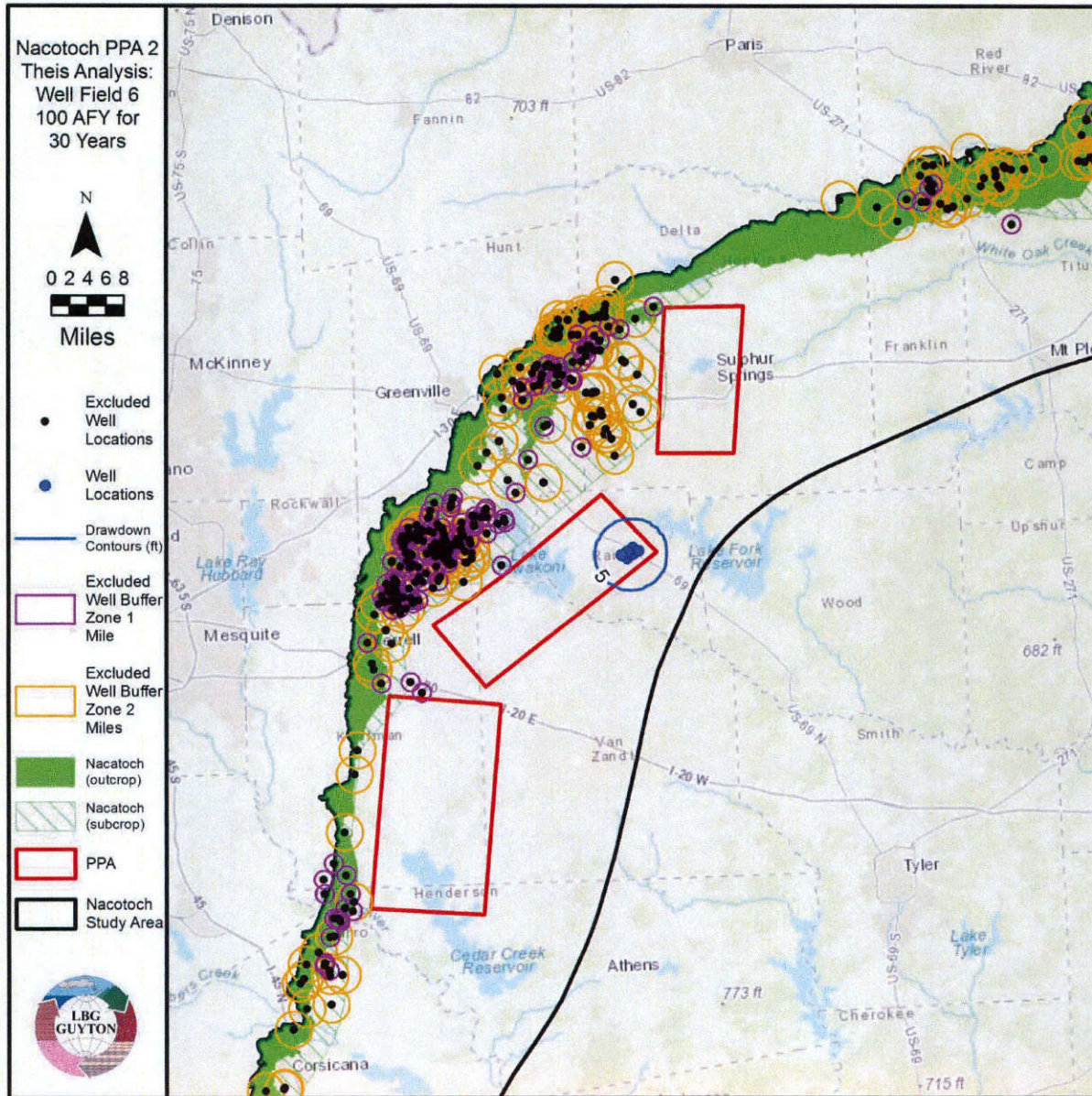


Figure 14-11. Potential production area 2: 30-year drawdown at 100 acre-feet per year.

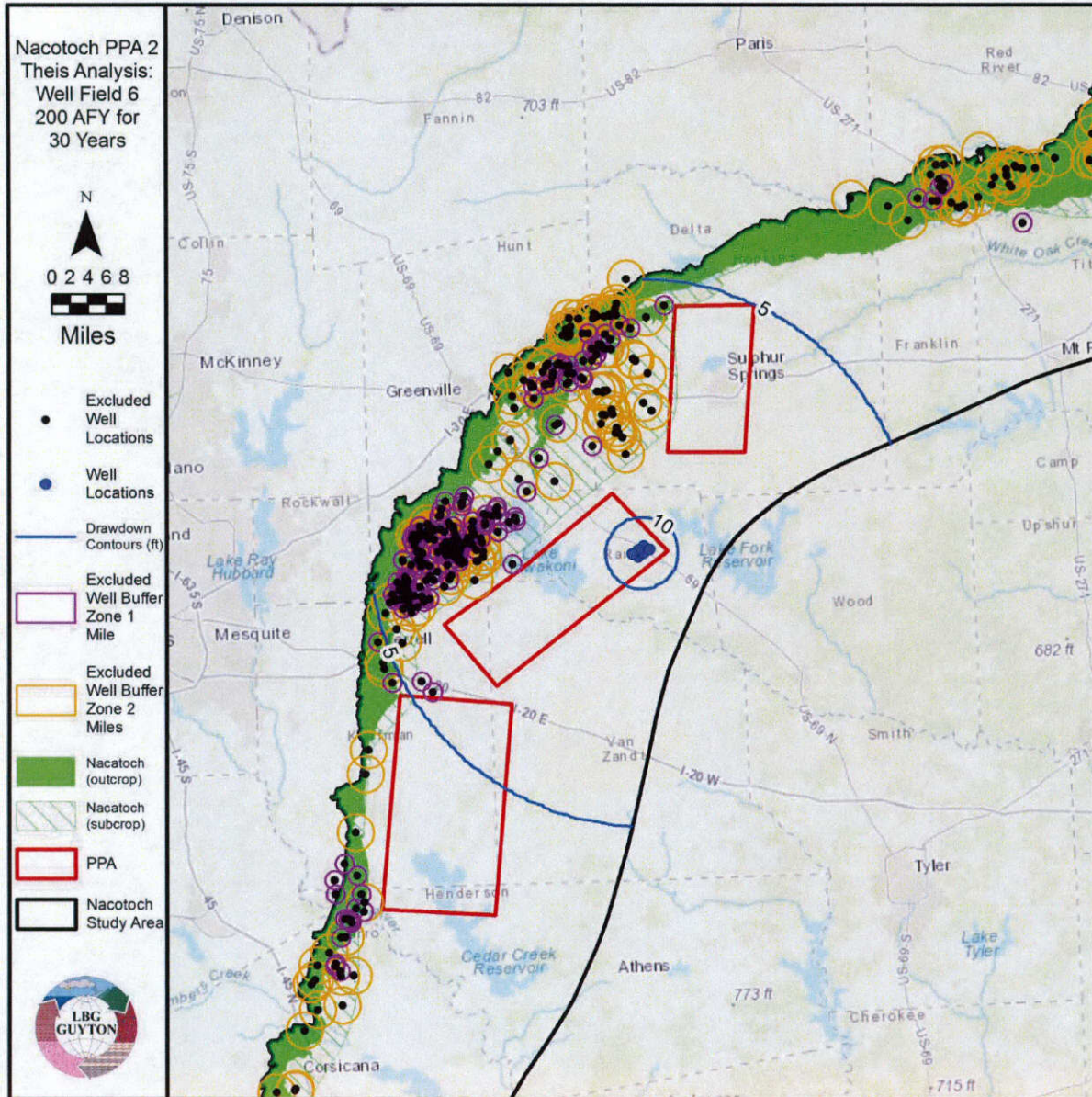


Figure 14-12. Potential production area 2: 30-year drawdown at 200 acre-feet per year.

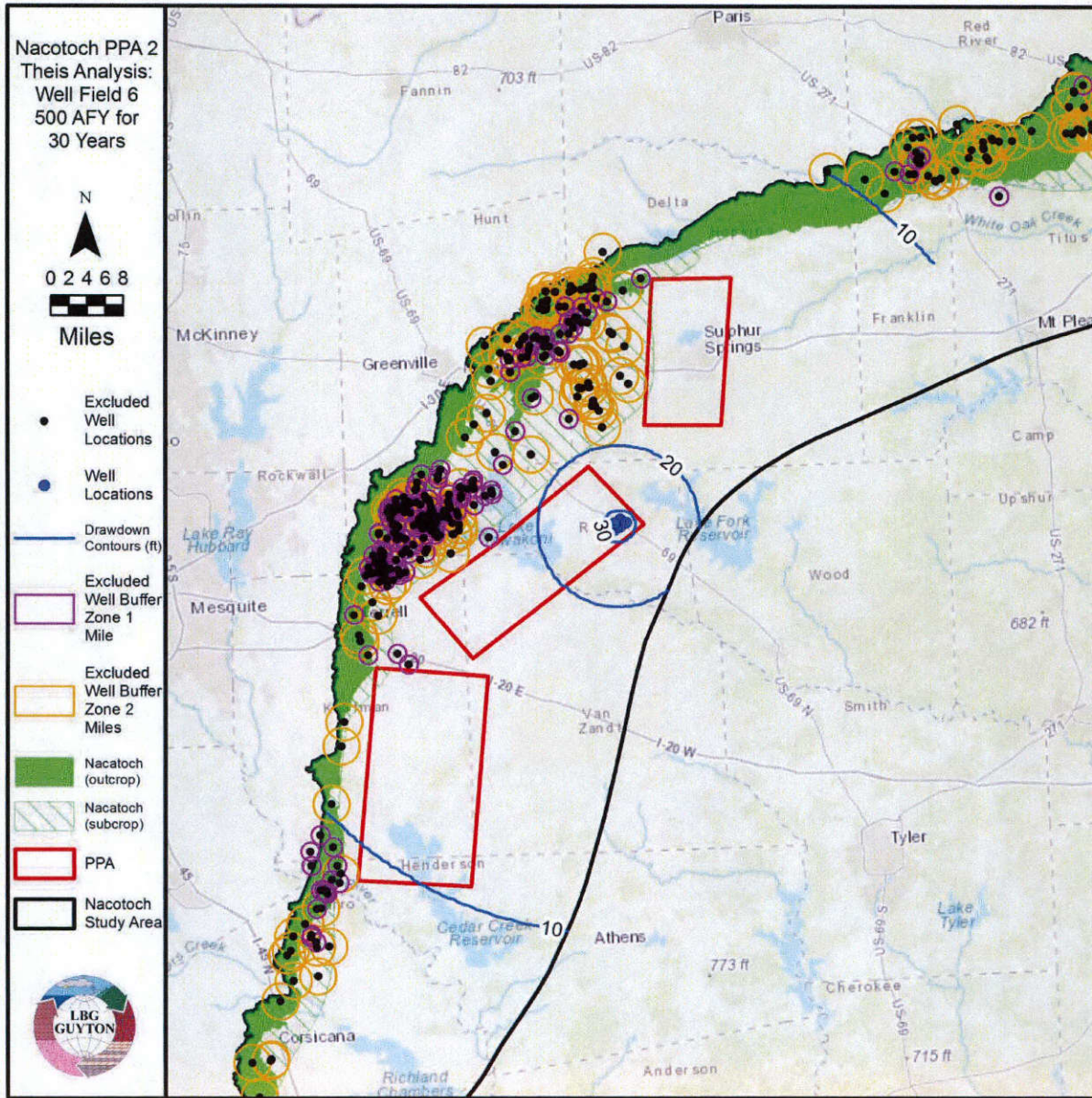


Figure 14-13. Potential production area 2: 30-year drawdown at 500 acre-feet per year.

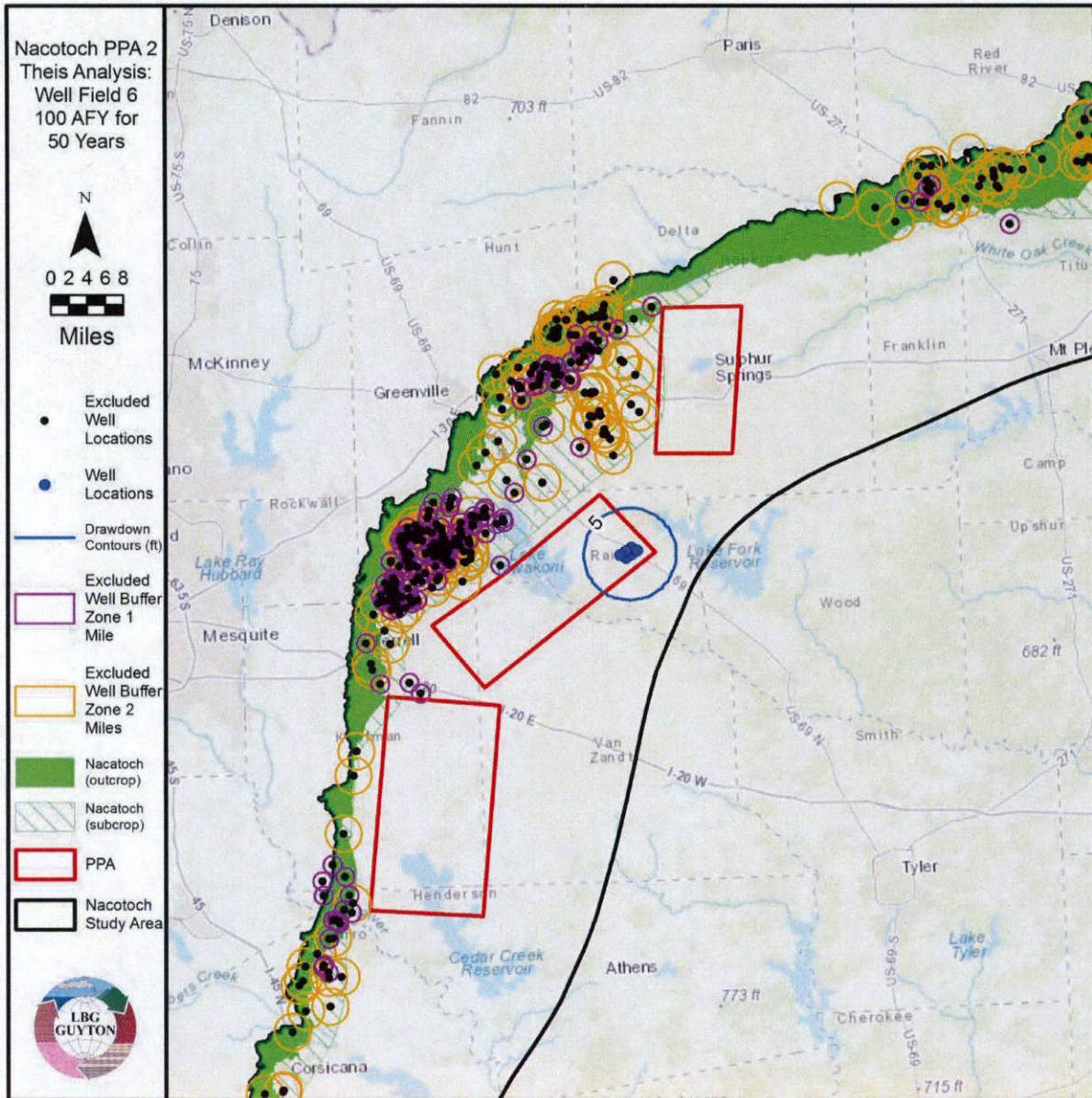


Figure 14-14. Potential production area 2: 50-year drawdown at 100 acre-feet per year.

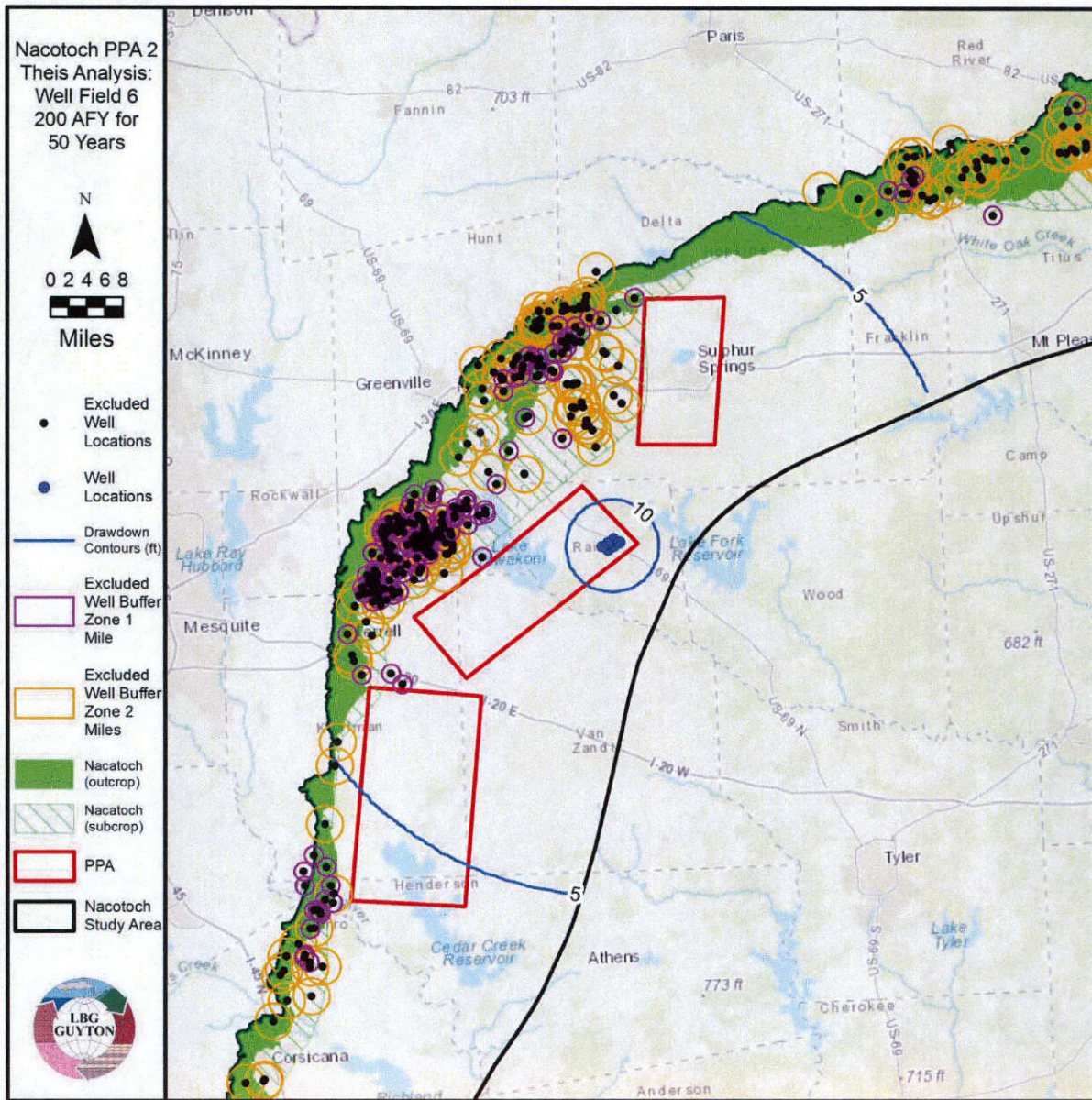


Figure 14-15. Potential production area 2: 50-year drawdown at 200 acre-feet per year.

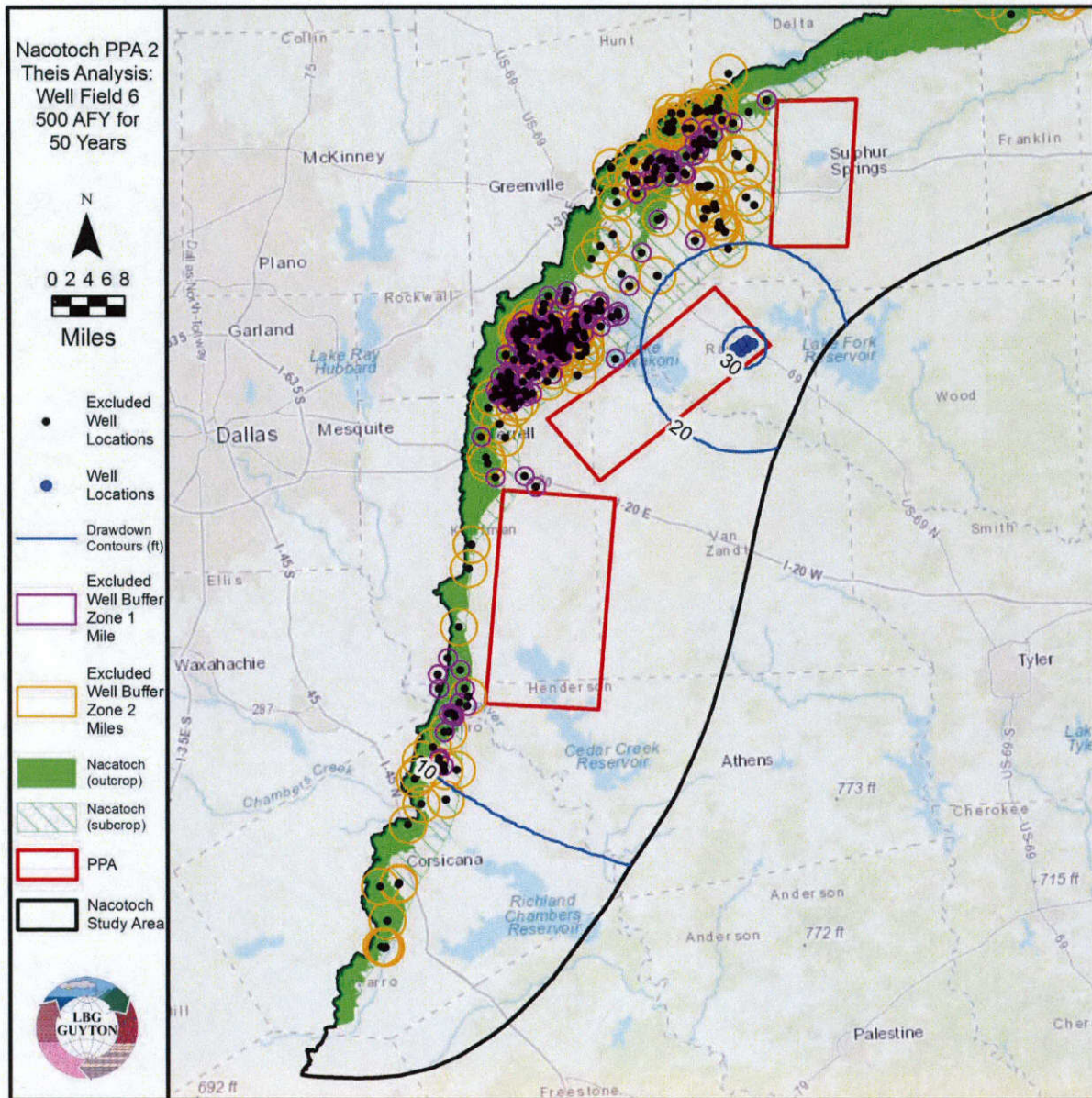


Figure 14-16. Potential production area 2: 50-year drawdown at 500 acre-feet per year.

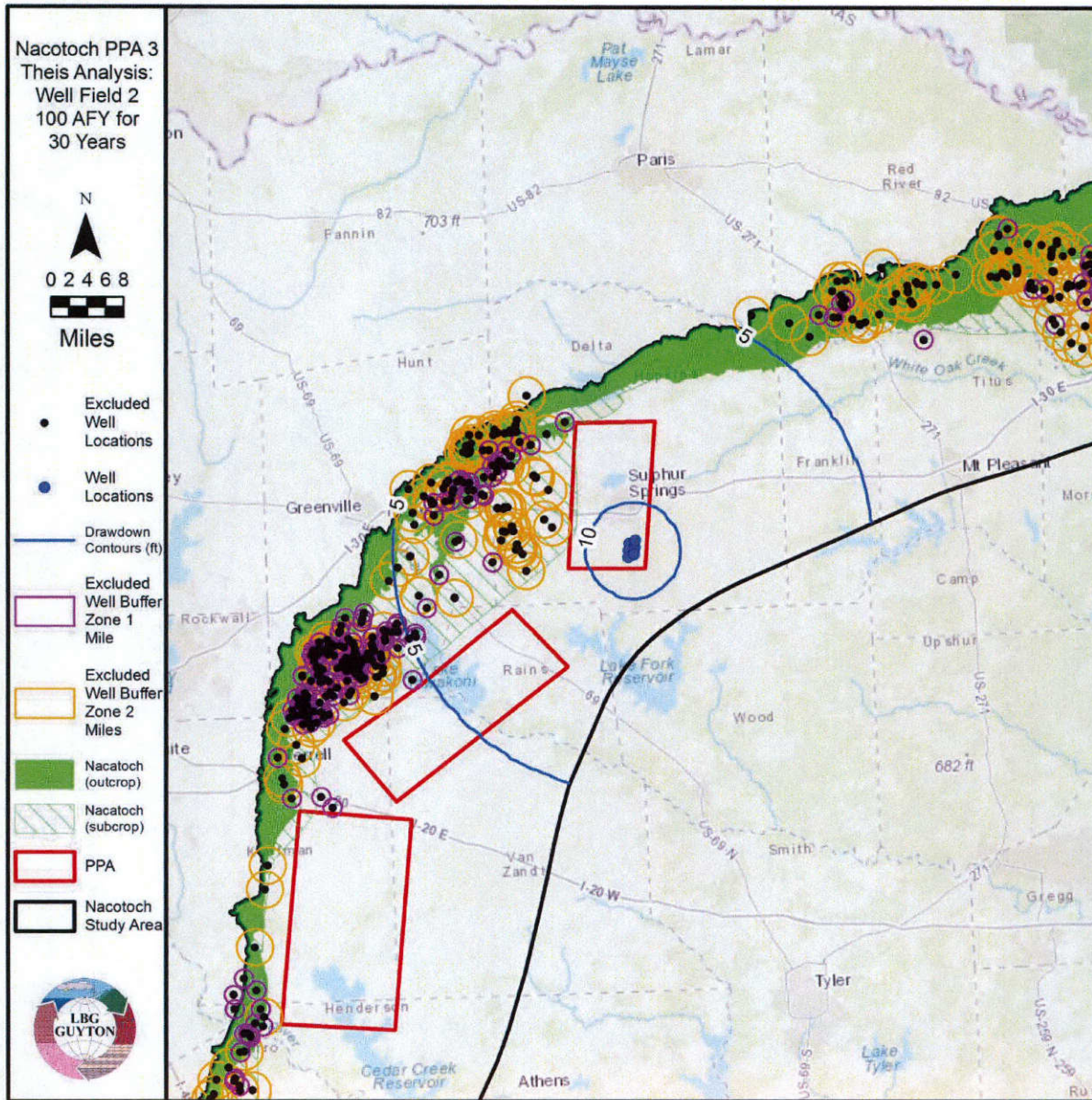


Figure 14-17. Potential production area 3: 30-year drawdown at 100 acre-feet per year.



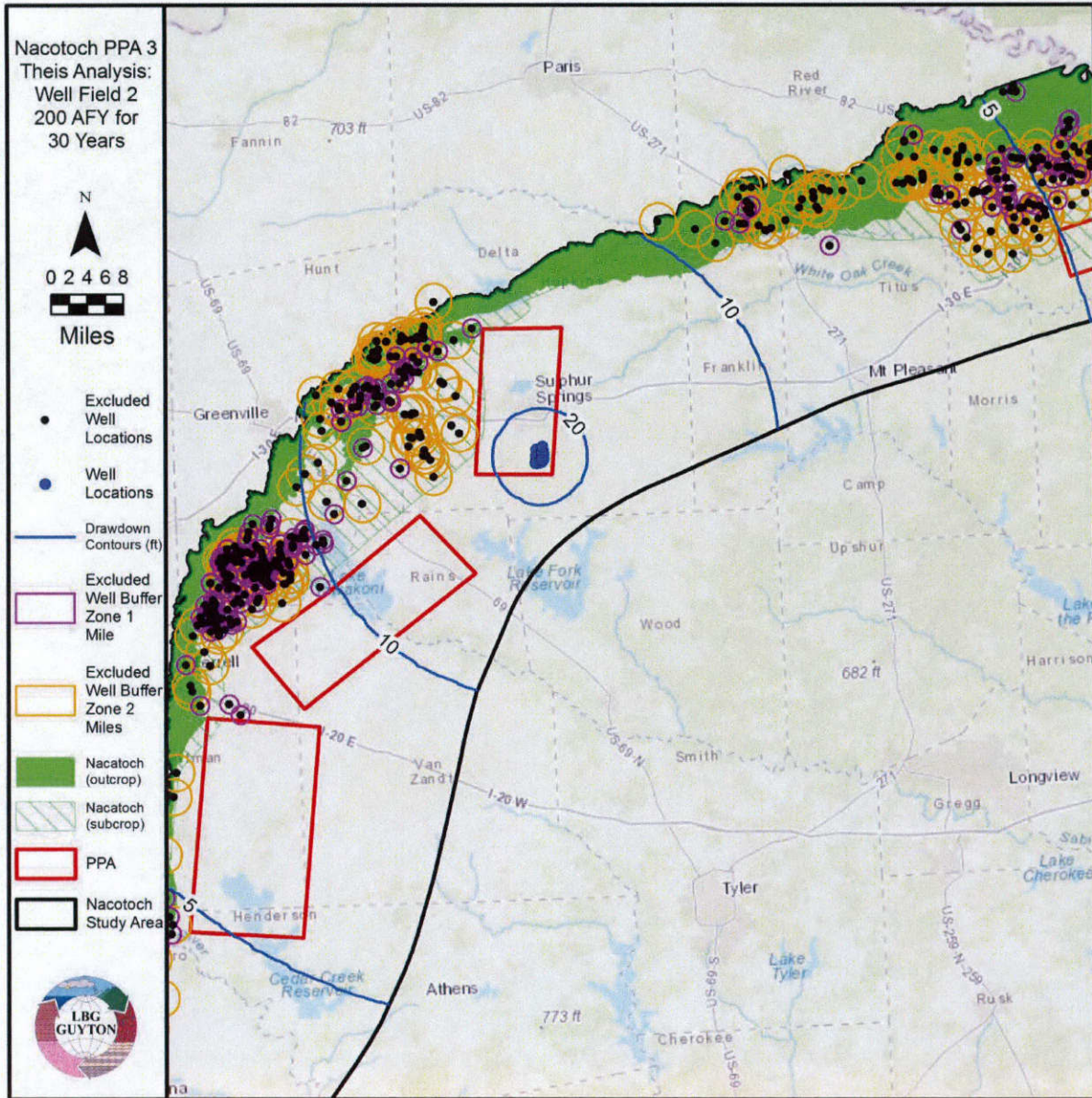


Figure 14-18. Potential production area 3: 30-year drawdown at 200 acre-feet per year.

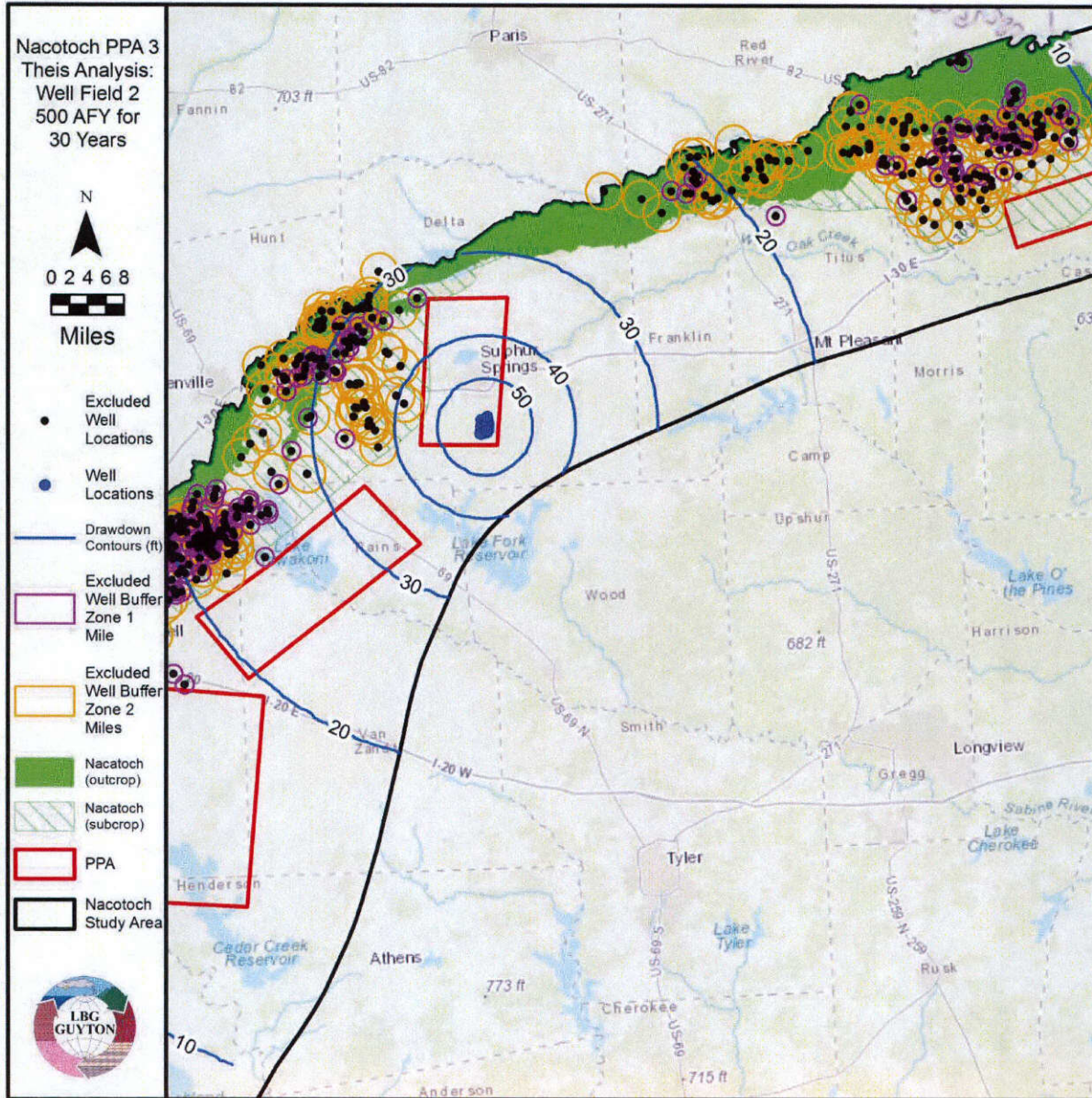


Figure 14-19. Potential production area 3: 30-year drawdown at 500 acre-feet per year.

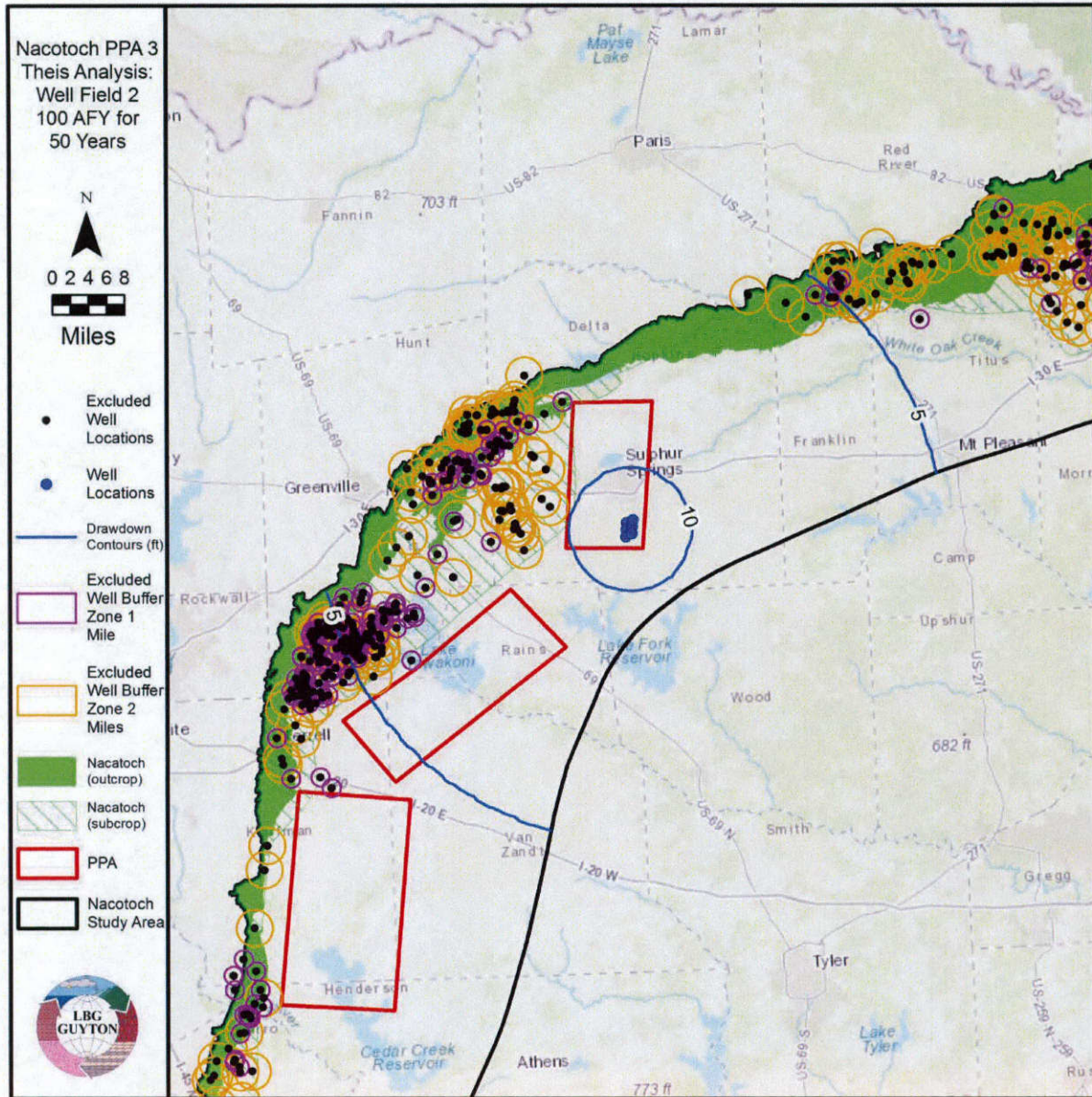


Figure 14-20. Potential production area 3: 50-year drawdown at 100 acre-feet per year.

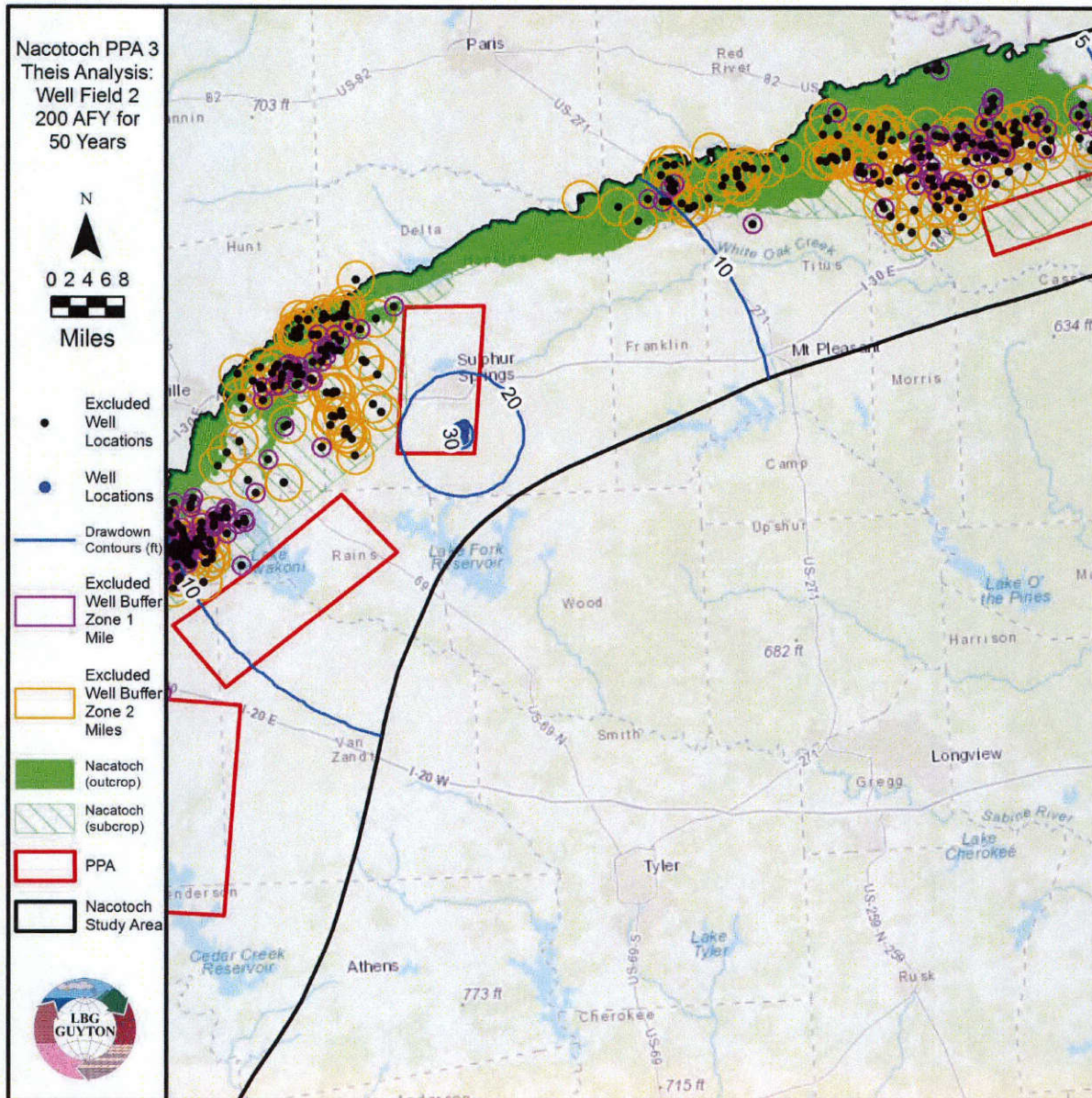


Figure 14-21. Potential production area 3: 50-year drawdown at 200 acre-feet per year.

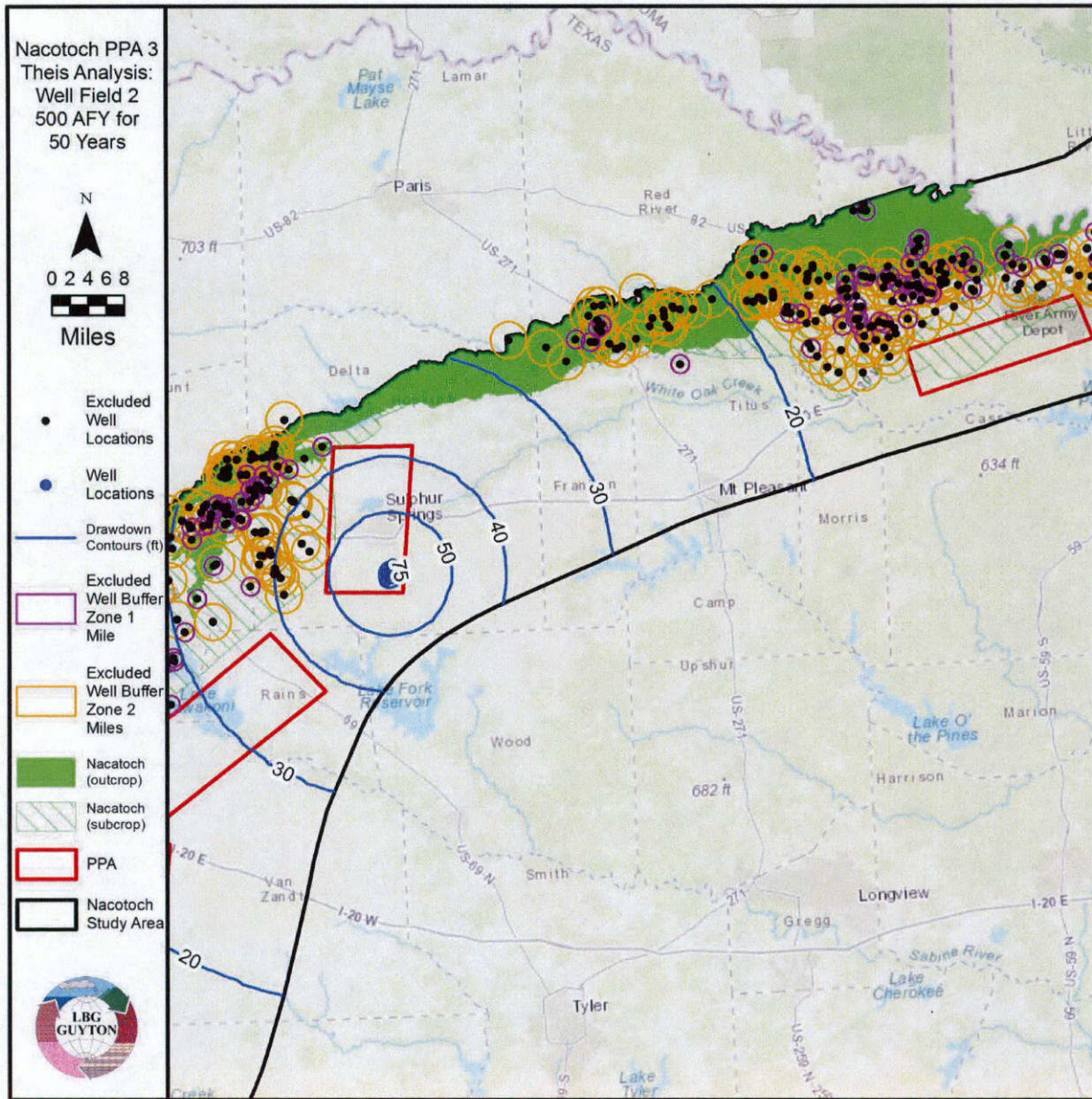


Figure 14-22. Potential production area 3: 50-year drawdown at 500 acre-feet per year.

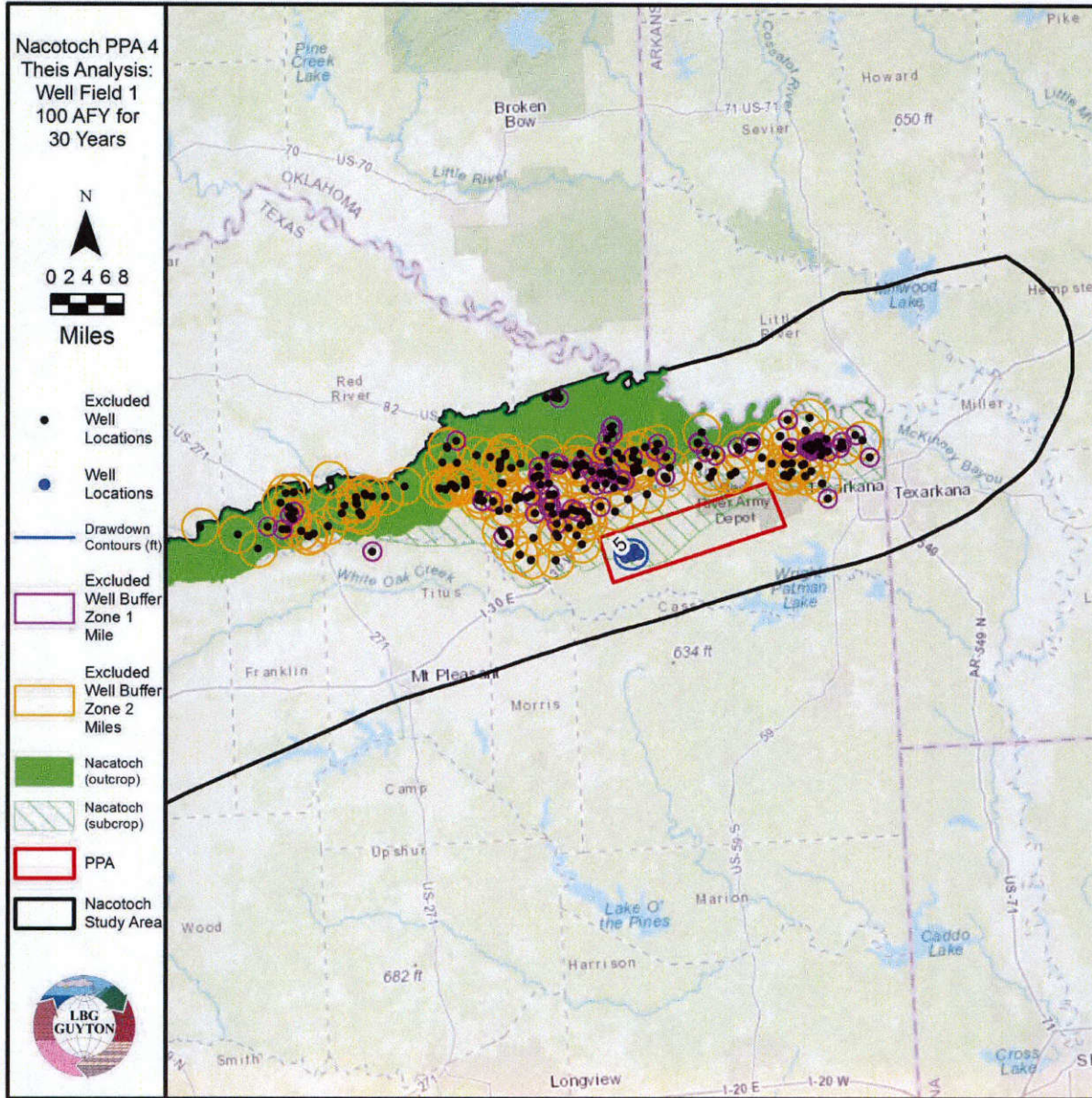


Figure 14-23. Potential production area 4: 30-year drawdown at 100 acre-feet per year.

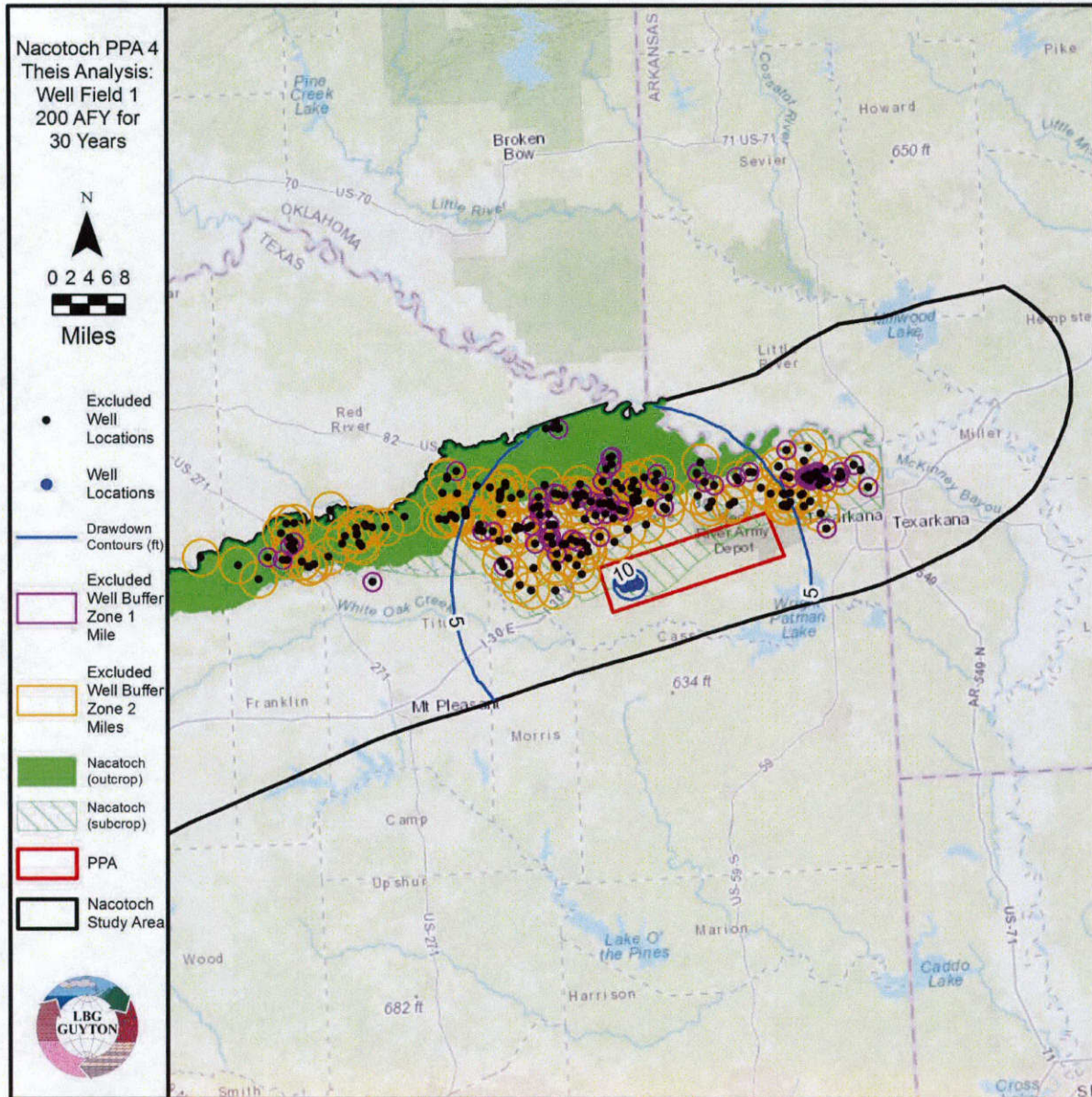


Figure 14-24. Potential production area 4: 30-year drawdown at 200 acre-feet per year.

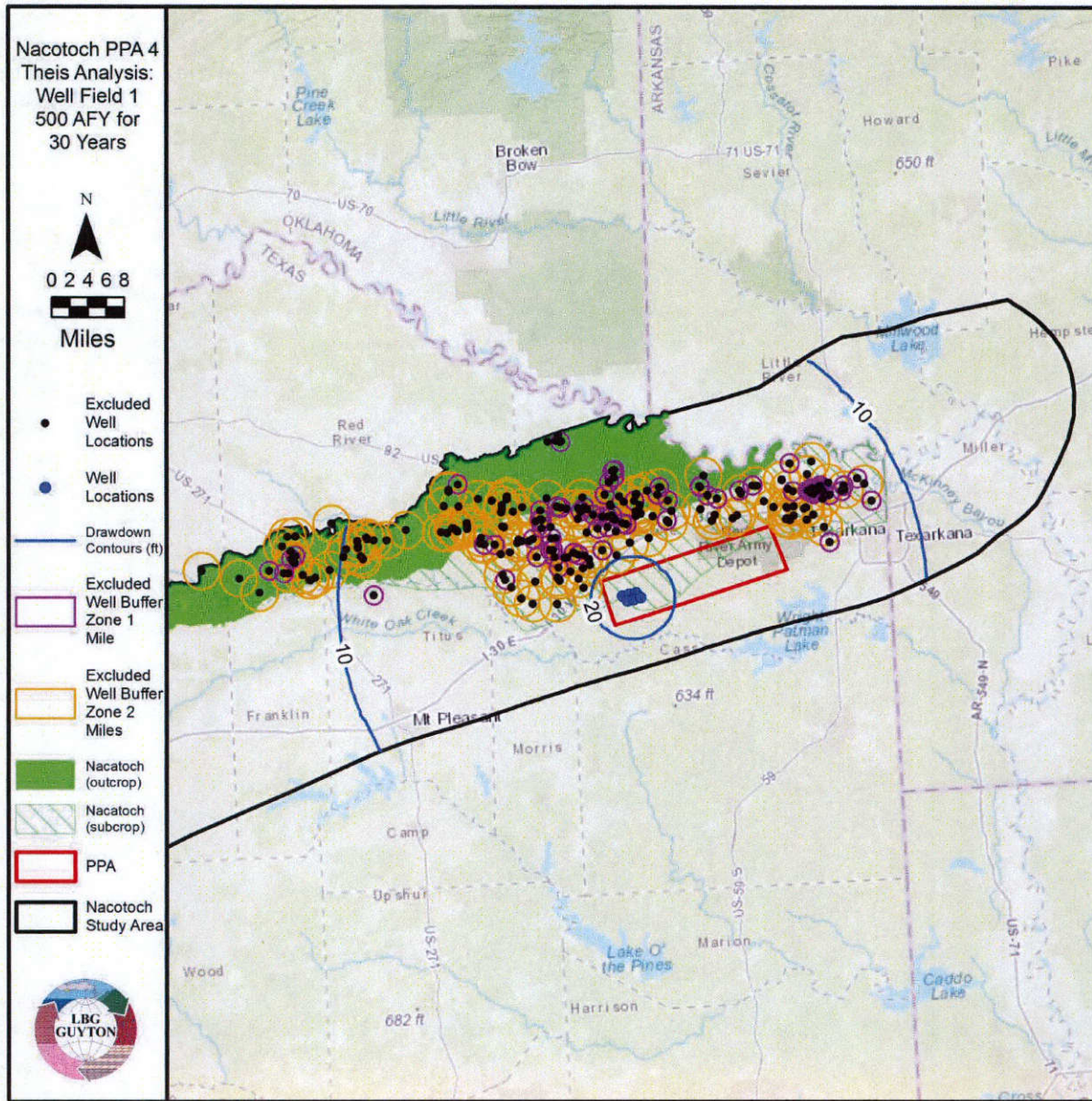


Figure 14-25. Potential production area 4: 30-year drawdown at 500 acre-feet per year.



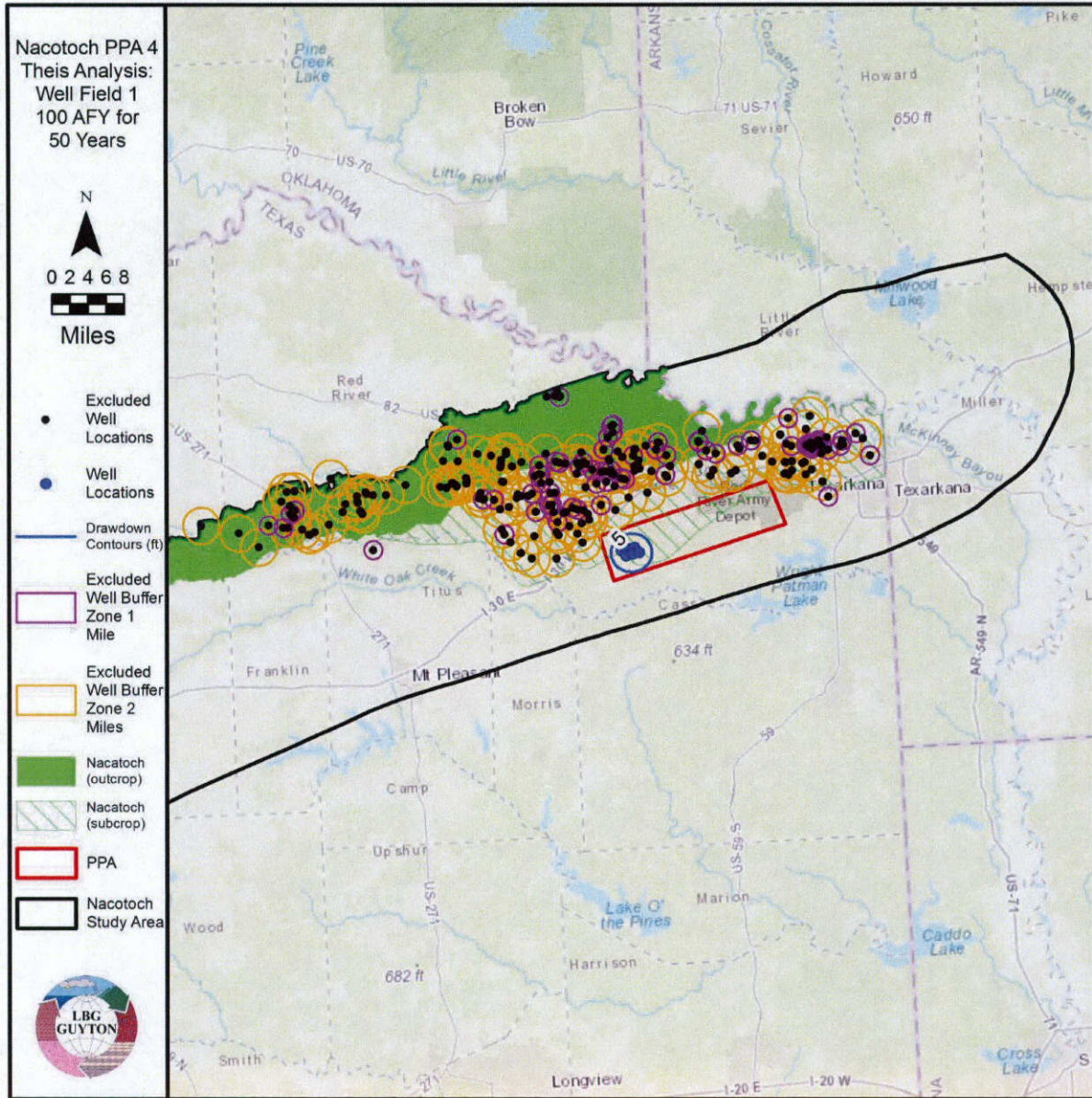


Figure 14-26. Potential production area 4: 50-year drawdown at 100 acre-feet per year.

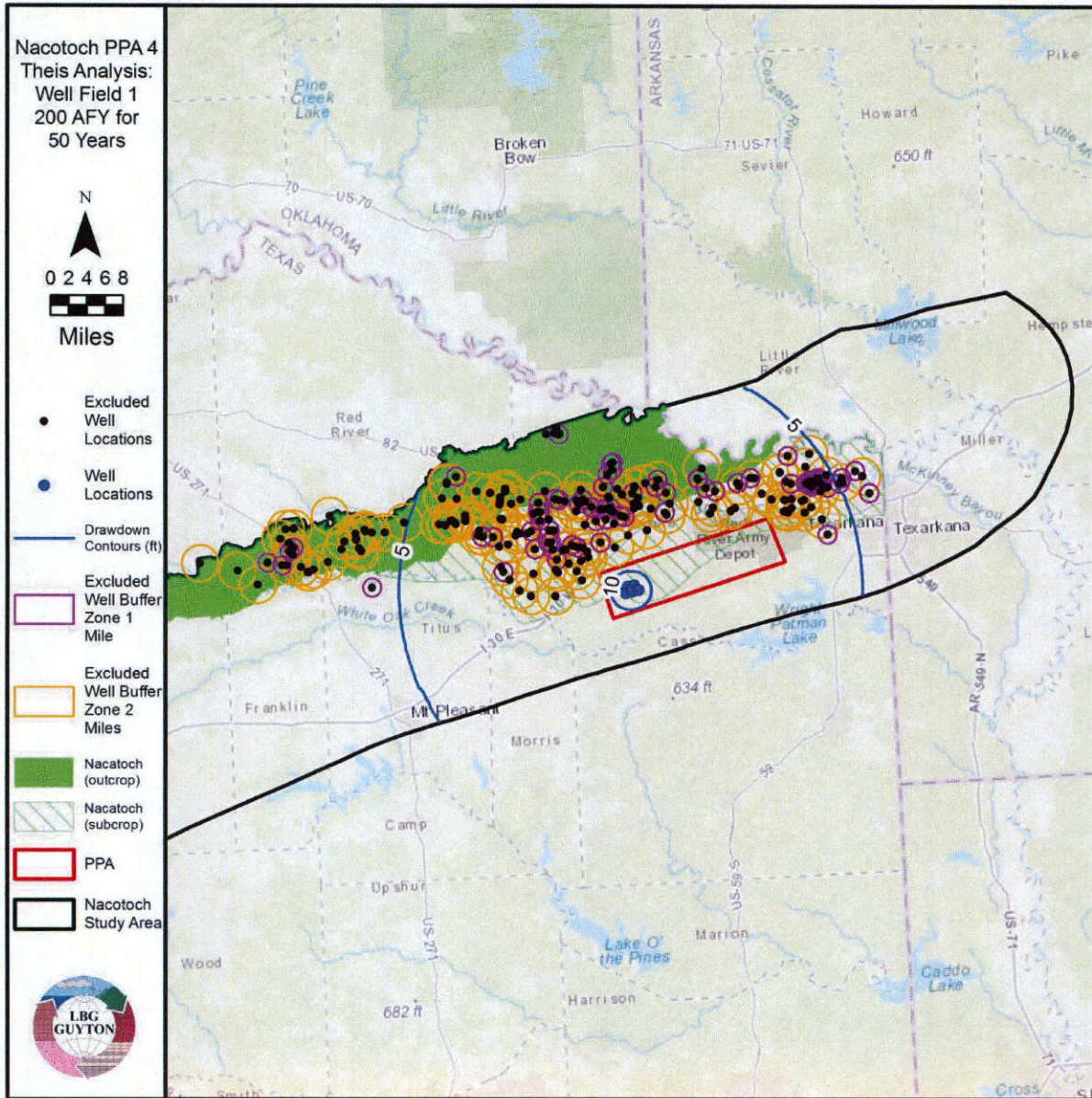


Figure 14-27. Potential production area 4: 50-year drawdown at 200 acre-feet per year.

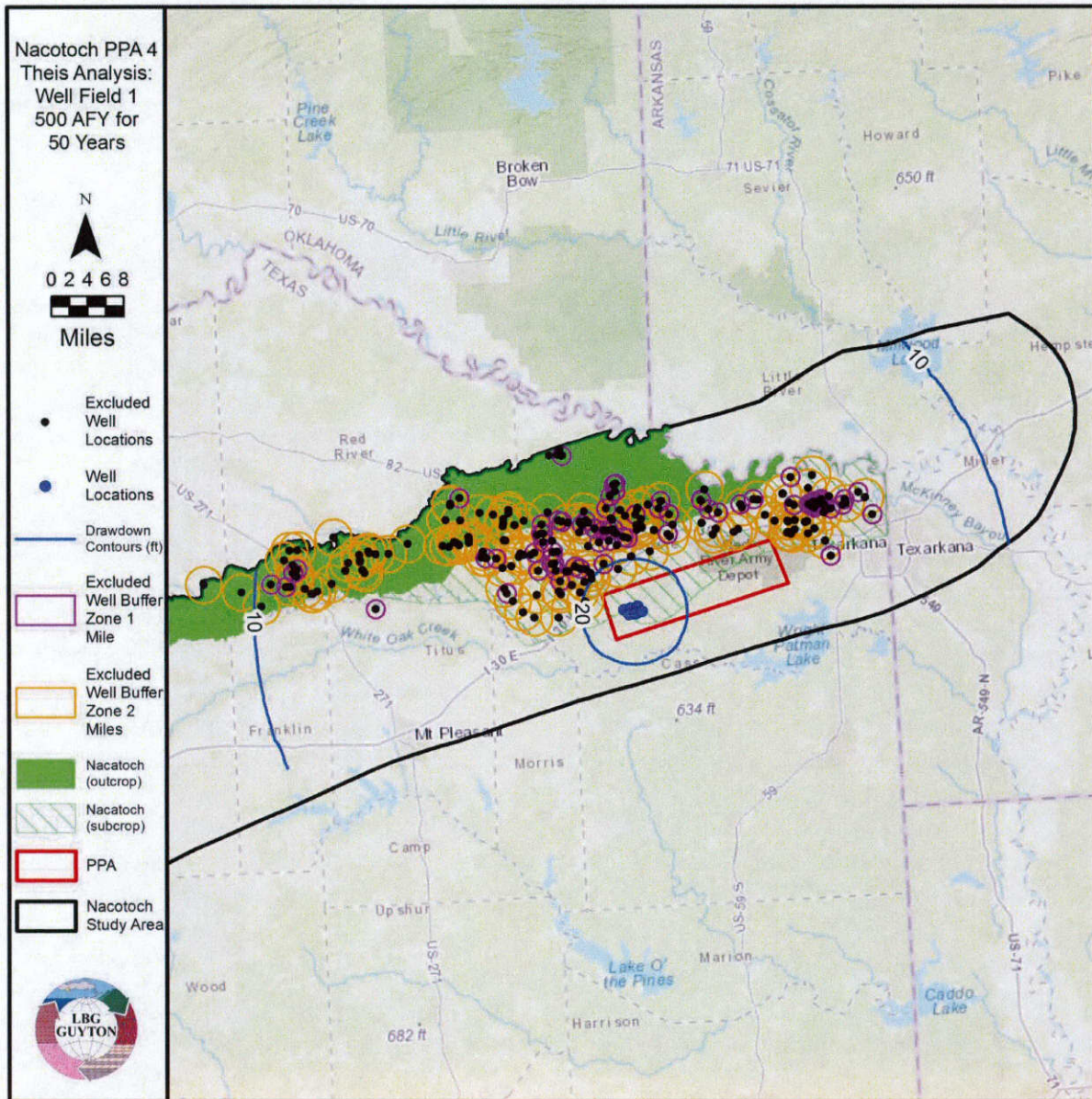


Figure 14-28. Potential production area 4: 50-year drawdown at 500 acre-feet per year.

### **14.3 Limitations**

One major limitation of this study was the lack of geophysical log data and water sample data that were able to be paired for the calibration of total dissolved solids concentrations. Diligent effort was made to find any and all existing pairs for this purpose; however, resulting matches were limited.

### **15 Future Improvements**

Further investigative efforts that would be invaluable for the application of the results of this project would be test hole drilling and aquifer testing within the potential production areas to verify and/or revise the predicted production volumes that have been calculated for this project. Water quality sampling and geophysical logging of any test holes would also be essential to confirming and/or revising expected total dissolved solids concentrations.

### **16 Conclusions**

Using the exclusion criteria stated in House Bill 30, four potential production areas were delineated in areas outlying the excluded areas. Pumping impacts from the potential production areas were estimated using low, medium and high-volume pumping scenarios of 100, 200 and 500 acre-feet per year assuming both 30 and 50 years of production. This drawdown analysis was performed to characterize the effect pumping in these areas would have on existing exclusion wells. Numerous well fields were modeled for each potential production area. The well fields selected for each potential production area are those wellfields which have the least extensive amount of up-dip drawdown. The approximate minimum drawdowns are based on the 100 acre-feet 30-year scenarios, and maximums are based on the 500 acre-feet 50-year scenarios. Potential production areas 2 and 4 appear to have the least impact to up-dip exclusion wells with 0 to 20 feet of drawdown. Volume estimates were not calculated for the potential production areas.

To monitor pumping volumes from wells completed in brackish production areas, it is recommended that 1) meters be installed on each well to track pumping volumes, 2) metered volumes are recorded monthly, and 3) monitoring wells are designated to track water level changes resulting from brackish production. Monitoring wells should be located between existing users excluded by House Bill 30 criteria and brackish production wells. The number of monitoring wells located peripheral to brackish pumping that are necessary to characterize the impacts of pumping upon existing users will be driven by several site-specific factors, including (but not limited to) distance to nearest exclusion well, monitoring well candidate locations, as well as landowner and property access issues.

The modeling results indicate that there are approximately 5,445,315 acre-feet of in-place groundwater within the Nacatoch Aquifer in the project area. An estimated 574,761 acre-feet, or eleven percent, of the available groundwater is within the fresh water zone. Slightly saline and moderately saline water estimated volumes are 1,768,713 acre-feet (32 percent) and 1,637,529 acre-feet (30 percent), respectively. The very saline estimated volume within the project area is estimated to be 1,464,312 acre-feet (27 percent) of the total estimated volume.

## **17 Acknowledgements**

We would like to thank the Innovative Water Technologies staff at TWDB for their guidance and patience during the preparation and completion of this project, specifically: Jean Perez, John Meyer and Erika Mancha. Technical consulting staff which made significant contributions to this project include: Lou Fleischhauer, Matthew Wise, Peter George and Peter Schulmeyer (Collier Consulting, Inc.); Scott Hamlin, Bridget Scanlon, J.P. Nicot and Amy Banerji (The University of Texas Bureau of Economic Geology); and Brant Konetchy (LBG-Guyton Associates). We would also like to acknowledge the Texas State Legislature for providing the funding for this project and making this work possible.

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Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1625901	M. R. Drum	Domestic	120	Red River
1625902	Alton Kenney	Domestic	120	Red River
1625903	Dan King	Domestic	60	Red River
1626701	Buford Ward	Domestic	195	Red River
1626801	M. F. Anderson	Domestic	200	Red River
1626802	M. T. Story	Domestic	48	Red River
1626902	Joe Yates	Domestic	80	Red River
1626903	R. E. Stanley	Domestic	40	Red River
1626904	C. L. Jackson	Domestic	150	Red River
1626906	F. C. Stevens	Domestic	60	Red River
1627701	Ms. A. Brower	Domestic	160	Bowie
1627802	Mable Garland	Domestic	100	Bowie
1628802	Loyd Yates	Domestic	200	Bowie
1628803	Charles Carey	Domestic	140	Bowie
1628901	Paul Goodwin	Domestic	190	Bowie
1628902	Richard LaGwinn	Domestic	200	Bowie
1629701	A.R. Anderson	Domestic	150	Bowie
1629702	John Warren	Domestic	120	Bowie
1629903	Alberta Phillips	Domestic	143	Bowie
1630802	T.L. Sellers	Domestic	587	Bowie
1630903	Jimmie Daniels	Domestic	164	Bowie
1631501	C.M. Gay	Domestic	320	Bowie
1631701	Mrs. Byron Berkman	Domestic	1100	Bowie
1631702	Mrs. Byron Barkman	Domestic	520	Bowie
1631802	Mrs. John Barkman	Domestic	180	Bowie
1631901	Bill Avery	Domestic	317	Bowie
1632704	John Addington	Domestic	553	Bowie
1632803	David Musselman	Domestic	390	Bowie

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1633101	W. S. Hunter	Domestic	180	Red River
1633102	Cross Arrow Ranch	Domestic	367	Red River
1633302	Leon Baird	Domestic	210	Red River
1633303	J. V. Baird	Domestic	370	Red River
1633305	A. B. Baird	Domestic	180	Red River
1634101	A.W. Jackson	Domestic	170	Red River
1634102	U. Humphries	Domestic	286	Red River
1634104	Herb Stanphill	Domestic	263	Red River
1634105	Bobby Lipe	Domestic	403	Red River
1634108	D. Minter	Domestic	343	Red River
1634109	Marvin Sterman	Domestic	343	Red River
1634110	Harold Peek	Domestic	243	Red River
1634111	C. D. Floyd	Domestic	208	Red River
1634301	Sam Hilton	Domestic	303	Red River
1634302	C. E. O'Bier	Domestic	200	Red River
1634303	J. A. Houser	Domestic	220	Red River
1634304	Don Cole	Domestic	305	Red River
1634504	Owen and Keys Well No. 1	Domestic	350	Red River
1634508	Dick Bench	Domestic	580	Red River
1634601	Paul Megason	Domestic	536	Red River
1634602	Bob Pirkey	Domestic	456	Red River
1634603	Alford York	Domestic	480	Red River
1634901	D. W. Burkhead	Domestic	1050	Red River
1634903	J.H. Raleigh	Domestic	635	Red River
1635101	Mrs. Otto Tidwell	Domestic	320	Bowie
1635201	B.B. Randolph	Domestic	380	Bowie
1635301	Johnnie Fowler	Domestic	170	Bowie
1635302	J. Wood Ranch	Domestic	400	Bowie

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1635304	E.L. Hawkins	Domestic	280	Bowie
1635305	JAMES STURDIVANT	Domestic	220	Bowie
1635401	D.V. Pirkey	Domestic	500	Bowie
1635402	Lawrence Day	Domestic	467	Red River
1635403	Dwight Wood	Domestic	480	Bowie
1635501	Neil Proctor	Domestic	500	Bowie
1635601	R.W. Bass	Domestic	673	Bowie
1635603	Eldon R. Allen	Domestic	610	Bowie
1635701	C.L. Plumlee	Domestic	900	Bowie
1635802	Leon McMillion	Domestic	924	Bowie
1635803	Bill Robinson	Domestic	906	Bowie
1635901	William B. Humphries	Domestic	780	Bowie
1635902	Mr. Rodgers	Domestic	705	Bowie
1635903	Mr. Tucker	Domestic	940	Bowie
1636101	C.B. Barkley	Domestic	220	Bowie
1636102	Frank Soares	Domestic	500	Bowie
1636201	Herman Hudson	Domestic	200	Bowie
1636202	Austin Chapel	Domestic	350	Bowie
1636203	C.V. Holt	Domestic	380	Bowie
1636204	Carl Wittle	Domestic	300	Bowie
1636205	Lillie Beggs	Domestic	385	Bowie
1636301	A.C. Williams	Domestic	280	Bowie
1636302	O.A Estes	Domestic	360	Bowie
1636304	A.R. Anderson	Domestic	360	Bowie
1636305	A.R. Anderson	Domestic	420	Bowie
1636306	Huley Russell	Domestic	430	Bowie
1636401	Mrs. Susie Jackson	Domestic	580	Bowie
1636502	Danny Watson	Domestic	675	Bowie

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1636601	Gary Williams	Domestic	550	Bowie
1636701	Sam Hall Jr.	Domestic	744	Bowie
1636702	W.L. May	Domestic	734	Bowie
1637101	L.R. Atkin	Domestic	420	Bowie
1637103	W.A. Adcock	Domestic	650	Bowie
1637202	Norris Crosby	Domestic	440	Bowie
1637301	J.L. Forrester	Domestic	500	Bowie
1637303	Frank Autrey	Domestic	737	Bowie
1637401	Wilbert Barthel	Domestic	800	Bowie
1638101	Jerry Gildon	Domestic	655	Bowie
1638201	Keith Springer	Domestic	770	Bowie
1638302	A.R. Goodwin	Domestic	720	Bowie
1638303	Ms. James Terral	Domestic	676	Bowie
1639101	A.L. Mize	Domestic	670	Bowie
1639102	W.E. Taylor	Domestic	600	Bowie
1639103	J.K. Austin	Domestic	780	Bowie
1639108	Hignight	Domestic	575	Bowie
1639202	C.C. Goodwin	Domestic	628	Bowie
1639203	T.A. Taylor	Domestic	630	Bowie
1639204	Reymond Kirkman	Domestic	585	Bowie
1639206	Betty Pendley	Domestic	600	Bowie
1639301	Jimmy Clem	Domestic	375	Bowie
1639601	Top Freeman	Domestic	780	Bowie
1643102	C. N. Dalby	Domestic	1100	Red River
1643103	B. D. English	Domestic	1270	Bowie
1643202	J.B. Lesley	Domestic	1220	Bowie
1738401	C. L. Kennedy	Domestic	20	Lamar
1738901	W. O. Woods	Domestic	32	Red River

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1739201	Roy D. Jones	Domestic	82	Red River
1739202	W. C. Mauldin	Domestic	20	Red River
1739502	R.V. Kunkel	Domestic	60	Red River
1739504	F. M. Foster	Domestic	23	Red River
1739505	W.A. Cotton	Domestic	112	Red River
1739701	Homer Scoggins	Domestic	58	Red River
1739801	J. Roberts	Domestic	310	Red River
1740101	Otha White	Domestic	90	Red River
1740201	L. Eudy	Domestic	50	Red River
1740301	A. W. Harvell	Domestic	340	Red River
1740303	Charlie Green	Domestic	290	Red River
1740304	P. L. Brooks	Domestic	220	Red River
1740401	Ray Early	Domestic	380	Red River
1740402	Doyle Brooks	Domestic	200	Red River
1740501	Harmen Belcher	Domestic	57	Red River
1740502	Fred White	Domestic	27	Red River
1740503	Kenneth Brown	Domestic	385	Red River
1740504	W. C. Garmon	Domestic	23	Red River
1740505	C. C. Cannon	Domestic	303	Red River
1742703	George Hoffman	Domestic	416	Delta
1742704	Robert Shipp	Domestic	460	Delta
1742705	E. R. Petty	Domestic	460	Delta
1742804	Harold Collar	Domestic	460	Delta
1742805	O. E. Scott	Domestic	470	Delta
1742902	Howard Mobley	Domestic	280	Hopkins
1749317	McCasland	Domestic	320	Hunt
1749401	Richard George	Domestic	261	Hunt
1749704	Charles Bowen	Domestic	281	Hunt

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1749801	L. E. Holley	Domestic	105	Hunt
1749901	W. Gaudreau	Domestic	220	Hunt
1749902	P. E. Hartline	Domestic	225	Hunt
1750501	Don Smith 14654 Hwy 11 Crumby	Domestic	370	Hopkins
1750901	Doug Jourdan	Domestic	762	Hopkins
1757201	Paul Fry	Domestic	301	Hunt
1758101	B. D. Wells	Domestic	764	Hopkins
1758301	Bill Tate	Domestic	1027	Hopkins
1758303	Cecil Dickens	Domestic	943	Hopkins
1758503	Mrs. T. D. Duke	Domestic	930	Hopkins
1758801	Truman Dickens	Domestic	1018	Hopkins
1856602	Danny Keene	Domestic	140	Hunt
1856901	Jack Wall	Domestic	268	Hunt
1864301	Jerry Nowlin	Domestic	220	Hunt
1864501	J. P. Martin	Domestic	115	Hunt
1864602	L. E. Shrum	Domestic	160	Hunt
1864903	H. A. Conovar	Domestic	600	Hunt
3307501	Larry Roberts	Domestic	120	Hunt
3314601	Lon Akin	Domestic	85	Kaufman
3314901	John Booth	Domestic	165	Kaufman
3315102	Richard Akin	Domestic	80	Kaufman
3315201	Susie Holt	Domestic	145	Hunt
3315302	Travis Stodgill	Domestic	550	Kaufman
3315401	R. L. Wiley	Domestic	230	Kaufman
3316104	Frank Reedy	Domestic	560	Hunt
3316106	W. O. Walls	Domestic	338	Hunt
3322305	Fuller's Towing	Domestic	100	Kaufman
3322602	R. K. Ramsey	Domestic	57	Kaufman

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
3323101	Pat Johnson	Domestic	160	Kaufman
3330501	Charles Dykes	Domestic	100	Kaufman
3330801	Lenilu Adams	Domestic	90	Kaufman
3338403	A. L. Potts	Domestic	54	Kaufman
3345901	L. B. Sands	Domestic	48	Navarro
3346204		Domestic	60	Henderson
3346707	R.W. Thomas	Domestic	70	Navarro
3353201		Domestic	44	Navarro
3353202	J. Arnett	Domestic	34	Navarro
3353204		Domestic	20	Navarro
3353302		Domestic	150	Navarro
3353501		Domestic	39	Navarro
3353601	Bryant Cotton Co.	Domestic	200	Navarro
3353801	E. T. Denn	Domestic	29	Navarro
3354109		Domestic	230	Navarro
3360901	Mrs. N. Watts	Domestic	26	Navarro
3361401	J. D. McManus	Domestic	127	Navarro
3361402	B. Carpenter	Domestic	181	Navarro
3904609		Domestic	39	Navarro
3905104	C. J. Davis	Domestic	70	Navarro
1634501	Owen and Keys, Well No. 1	Irrigation	0	Red River
1638102	Red River Parts and Equipment Company	Irrigation	650	Bowie
1643303	J.M. Proctor	Irrigation	1200	Bowie
1749315	Jess Buker	Irrigation	300	Hunt
1864801	Herb Williams	Irrigation	240	Hunt
3307703	H. E. Borden	Irrigation	80	Hunt
3314602	Lewis Slaughter	Irrigation	123	Kaufman
3315402	Highland Memorial Gardens	Irrigation	240	Kaufman

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1628801	Jones Crossing School	Public Supply	250	Bowie
1631704	B.G. Butler	Public Supply	415	Bowie
1639104	Plattner's MHP Well #2 (Roosevelt)	Public Supply	864	Bowie
1639105	Plattner's MHP Well #3 (Victory)	Public Supply	800	Bowie
1639106	George Manning	Public Supply	780	Bowie
1739206	City of Bogata, New Well No.1	Public Supply	115	Red River
1739508	City of Bogata Well No.4	Public Supply	351	Red River
1739509	City of Bogata Well No.5	Public Supply	257	Red River
1739510	City of Bogata Well #6	Public Supply	300	Red River
1739901	City of Talco Well No.1	Public Supply	408	Red River
1739906	Talco-Bogata Ind. Sch. Dist.	Public Supply	300	Red River
1739907	City of Talco Well No.2	Public Supply	430	Red River
1741902	City of Commerce Well #2	Public Supply	580	Hunt
1741905	City of Commerce Horton Well No. 5	Public Supply	510	Hunt
1742706	City of Commerce Horton Field Well #4	Public Supply	510	Delta
1742806	City of Commerce Horton Well No. 1	Public Supply	540	Delta
1742807	City of Commerce Horton Well No. 2	Public Supply	635	Delta
1742808	City of Commerce Horton Well No. 3	Public Supply	538	Delta
1749306	City of Commerce New Well No. 5	Public Supply	542	Hunt
1749310	East Texas State University	Public Supply	466	Hunt
1749311	East Texas State University	Public Supply	483	Hunt
1749316	Maloy WSC	Public Supply	538	Hunt
1749504	Campbell Water Supply Well No. 2	Public Supply	388	Hunt
1749505	Campbell WSC. Well No. 1	Public Supply	0	Hunt
1749705	Campbell Water Supply Well No. 3	Public Supply	427	Hunt
1750403	Gafford Chapel Water Supply Corp.	Public Supply	640	Hopkins
1750601	Gafford Chapel Water Supply Corp. (#2)	Public Supply	690	Hopkins
1750603	Gafford Chapel Water Supply Corp. (#3)	Public Supply	640	Hopkins



Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
1750704	City of Cumby Well #2	Public Supply	750	Hopkins
1750705	City of Cumby Well #3	Public Supply	845	Hopkins
1750706	City of Cumby Well #4	Public Supply	752	Hopkins
1758102	Miller Grove WSC (Cash Well)	Public Supply	942	Hopkins
1758104	Miller Grove Water Supply Corp.	Public Supply	854	Hopkins
1758201	Miller Grove WSC Well #3	Public Supply	950	Hopkins
1758501	Miller Grove WSC Well #1	Public Supply	909	Hopkins
1758502	Miller Grove WSC Well #2	Public Supply	875	Hopkins
1758504	Miller Grove WSC Well #6	Public Supply	946	Hopkins
3307502	Country Wood	Public Supply	275	Hunt
3307503	Country Wood	Public Supply	260	Hunt
3307504	Country Wood	Public Supply	198	Hunt
3307505	Country Wood	Public Supply	306	Hunt
3307602	Taylor Water Co.	Public Supply	235	Hunt
3307603	Taylor Water Co.	Public Supply	235	Hunt
3307801	Oak Lake	Public Supply	80	Hunt
3307802	Whispering Oaks	Public Supply	239	Hunt
3307803	Crazy Horse Subd. New well #1	Public Supply	180	Hunt
3307804	Crazy Horse Subd. New well #2	Public Supply	180	Hunt
3307906	City of Quinlan Well #4	Public Supply	400	Hunt
3307907	Taylor Water Co.	Public Supply	400	Hunt
3307908	Taylor Water Co.	Public Supply	400	Hunt
3307909	Shady Oaks	Public Supply	190	Hunt
3307910	Shady Oaks	Public Supply	185	Hunt
3307911	Jimmy Seay	Public Supply	290	Hunt
3308405	Tawakoni Water Utility	Public Supply	231	Hunt
3308701	Tawakoni Water Utility	Public Supply	362	Hunt
3308702	Tawakoni Water Utility	Public Supply	177	Hunt

Appendix 19-1. TWDB wells which meet House Bill 30 exclusion criteria.

State well number	Owner name	Primary water use	Well depth (ft)	County name
3308703	Tawakoni Water Utility	Public Supply	174	Hunt
3308704	Tawakoni Water Utility	Public Supply	214	Hunt
3308705	Tawakoni Water Utility	Public Supply	212	Hunt
3308706	Tawakoni Water Utility	Public Supply	224	Hunt
3308707	Tawakoni Water Utility	Public Supply	232	Hunt
3308802	Taylor Water Co.	Public Supply	420	Hunt
3308803	Taylor Water Co.	Hunt		
3308805	Taylor Water Co.	Public Supply	406	Hunt
3315303	Helen Taylor	Public Supply	575	Hunt
3315304	Helen Taylor	Public Supply	680	Hunt
3316103	Mulberry Cove Water Supply Corporation	Public Supply	480	Hunt
3316109	Tawakoni Water Utility	Public Supply	490	Hunt
3401201	City of Lone Oak	Public Supply	524	Hunt
3904602	H. R. Stroube, Richland City,	Public Supply	120	Navarro
3904603	H. R. Stroube, Richland City,	Public Supply	119	Navarro
3904604	H. R. Stroube, Richland City,	Public Supply	120	Navarro
3904605	H. R. Stroube, Richland City,	Public Supply	119	Navarro
3904607	H. R. Stroube, Richland City,	Public Supply	119	Navarro
3904608	H. R. Stroube, Richland City,	Public Supply	119	Navarro

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

Water source	System name	State well number	Aquifer	Well depth (ft)
G0190001A	CITY OF DE KALB		Alluvium	91
G2250002A	CITY OF TALCO	1739901	Nacatoch	408
G2250002B	CITY OF TALCO	1739907	Nacatoch	420
G2250002C	CITY OF TALCO		Nacatoch	394
G1940001B	CITY OF BOGATA	1739508	Nacatoch	300
G1940001D	CITY OF BOGATA	1739510	Nacatoch	300
G1750020A	CITY OF RICHLAND	3904602	Nacatoch	120
G1750020B	CITY OF RICHLAND	3904605	Nacatoch	120
G1750020C	CITY OF RICHLAND	3904604	Nacatoch	120
G1750020D	CITY OF RICHLAND	3904607	Nacatoch	120
G1750020E	CITY OF RICHLAND	3904608	Nacatoch	120
G0600017A	WEST DELTA WSC		Nacatoch	190
G1120001A	CITY OF CUMBY	1750703	Nacatoch	710
G1120001B	CITY OF CUMBY	1750704	Nacatoch	750
G1120001C	CITY OF CUMBY	1750705	Nacatoch	809
G1120001D	CITY OF CUMBY	1750706	Nacatoch	752
G1120001E	CITY OF CUMBY		Nacatoch	820
G1120014A	GAFFORD CHAPEL WSC	1750603	Nacatoch	640
G1120014B	GAFFORD CHAPEL WSC	1750601	Nacatoch	690
G1120014C	GAFFORD CHAPEL WSC	1750403	Nacatoch	422
G1120014D	GAFFORD CHAPEL WSC	1750602	Nacatoch	650
G1120016A	MILLER GROVE WSC		Nacatoch	909
G1120016B	MILLER GROVE WSC		Nacatoch	875
G1120016C	MILLER GROVE WSC		Nacatoch	950
G1120016D	MILLER GROVE WSC		Nacatoch	845

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

Water source	System name	State well number	Aquifer	Well depth (ft)
G1120016E	MILLER GROVE WSC		Nacatoch	840
G1120016F	MILLER GROVE WSC		Nacatoch	946
G1120016G	MILLER GROVE WSC		Nacatoch	900
G1120016H	MILLER GROVE WSC		Nacatoch	890
G1160003A	CITY OF COMMERCE	1741902	Nacatoch	580
G1160003B	CITY OF COMMERCE		Nacatoch	550
G1160003C	CITY OF COMMERCE	1742806	Nacatoch	540
G1160003D	CITY OF COMMERCE	1742807	Nacatoch	635
G1160003E	CITY OF COMMERCE	1742808	Nacatoch	538
G1160003F	CITY OF COMMERCE	1742706	Nacatoch	510
G1160003G	CITY OF COMMERCE	1741905	Nacatoch	510
G1160006A	CITY OF LONE OAK		Nacatoch	510
G1160007A	CITY OF QUINLAN	3307906	Nacatoch	400
G1160007B	CITY OF QUINLAN		Nacatoch	432
G1160007C	CITY OF QUINLAN		Nacatoch	300
G1160007D	CITY OF QUINLAN		Nacatoch	415
G1160008A	TEXAS A&M UNIVERSITY COMMERCE	1749304	Nacatoch	440
G1160008B	TEXAS A&M UNIVERSITY COMMERCE	1749303	Nacatoch	454
G1160008C	TEXAS A&M UNIVERSITY COMMERCE	1749310	Nacatoch	466
G1160008D	TEXAS A&M UNIVERSITY COMMERCE	1749311	Nacatoch	483
G1160011A	ROCKWALL EAST MINI RANCH		Nacatoch	186
G1160011B	ROCKWALL EAST MINI RANCH		Nacatoch	186
G1160017A	CAMPBELL WSC	1749505	Nacatoch	437
G1160017B	CAMPBELL WSC	1749504	Nacatoch	367
G1160017C	CAMPBELL WSC	1749705	Nacatoch	418

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

Water source	System name	State well number	Aquifer	Well depth (ft)
G1160017D	CAMPBELL WSC		Nacatoch	414
G1160017E	CAMPBELL WSC		Nacatoch	484
G1160034A	MALOY WSC	1749316	Nacatoch	528
G1160034B	MALOY WSC		Nacatoch	528
G1160052A	COMBINED CONSUMERS SUD	3308704	Nacatoch	214
G1160052B	COMBINED CONSUMERS SUD	3308705	Nacatoch	212
G1160052C	COMBINED CONSUMERS SUD	3308706	Nacatoch	224
G1160052D	COMBINED CONSUMERS SUD	3308707	Nacatoch	232
G1160052E	COMBINED CONSUMERS SUD		Nacatoch	350
G1160052F	COMBINED CONSUMERS SUD		Nacatoch	220
G1160052G	COMBINED CONSUMERS SUD		Nacatoch	284
G1160052I	COMBINED CONSUMERS SUD		Nacatoch	570
G1160052J	COMBINED CONSUMERS SUD	3316103	Nacatoch	480
G1160063A	QUINLAN NORTH SUBDIVISION	3307602	Nacatoch	235
G1160063B	QUINLAN NORTH SUBDIVISION	3307603	Nacatoch	235
G1160064A	QUINLAN SOUTH SUBDIVISION	3307907	Nacatoch	400
G1160064B	QUINLAN SOUTH SUBDIVISION	3307908	Nacatoch	400
G1160064C	QUINLAN SOUTH SUBDIVISION		Nacatoch	320
G1160066A	BARROW SUBDIVISION	3315301	Nacatoch	531
G1160066B	BARROW SUBDIVISION	3315303	Nacatoch	557
G1160066C	BARROW SUBDIVISION	3315304	Nacatoch	0
G1160067C	CRAZY HORSE SUBDIVISION	3307803	Nacatoch	180
G1160067D	CRAZY HORSE SUBDIVISION	3307804	Nacatoch	180
G1160067E	CRAZY HORSE SUBDIVISION		Nacatoch	175
G1160067F	CRAZY HORSE SUBDIVISION		Nacatoch	170

Appendix 19-1. Texas Commission on Environmental Quality wells which meet House Bill 30 exclusion criteria.

Water source	System name	State well number	Aquifer	Well depth (ft)
G1160069A	LITTLE CREEK ACRES		Nacatoch	172
G1160081A	WHISPERING OAKS WATER COOP		Nacatoch	200
G1160081B	WHISPERING OAKS WATER COOP		Nacatoch	236
G1160089A	CADDO MESA WSC		Nacatoch	287
G1160091A	4 R RANCH WATER 2	3307909	Nacatoch	190
G1160091B	4 R RANCH WATER 2	3307910	Nacatoch	185
G1160091C	4 R RANCH WATER 2		Nacatoch	192
G1160093A	COUNTRY WOOD ESTATES	3307504	Nacatoch	198
G1160093B	COUNTRY WOOD ESTATES	3307503	Nacatoch	260
G1160093C	COUNTRY WOOD ESTATES		Nacatoch	280
G1160093D	COUNTRY WOOD ESTATES	3307502	Nacatoch	275
G1160093E	COUNTRY WOOD ESTATES	3307505	Nacatoch	306
G1160097A	W OAKS PHOENIX CORP		Nacatoch	212
G1160097B	W OAKS PHOENIX CORP		Nacatoch	320

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
3292	Jim Elder	Kaufman	Terrell	11/8/2001	155
3491	Hugh Arrendondo	Kaufman	Terrell	11/15/2001	167
4076	Sonia	Navarro	Chatfiel	12/28/2001	100
4239	Allan Hester	Navarro		1/11/2002	120
13819	Delphin Germany	Bowie	Dekalb	9/13/2002	170
17943	Bethlehem Baptist Church	Bowie	Dekalb	2/3/2003	72
17947	Jeff Flowers Poultry Farm	Bowie	Dekalb	2/4/2003	70
17949	Jeff Flowers Poultry Farm	Bowie	Dekalb	2/5/2003	71
23065	WALTER DAVIS	Bowie	DEKALB	6/3/2003	148
25477	Richard Hall	Kaufman	Kemp	9/12/2003	51
28385	WILLIAM WHITSON	Bowie	DEKALB	10/1/2003	300
28388	BRUCE WHITSON	Bowie	DEKALB	10/4/2003	310
28391	LORI STRAND	Bowie	DEKALB	10/10/2003	650
34176	Ken Adams	Hunt	Quinlan	5/1/2003	70
34182	Larry Lane	Kaufman	Terrell	6/15/2003	173
34186	Gary Dalton	Hunt	Quinlan	6/25/2003	132
34466	Tyler Martin	Bowie	Texarkana	7/15/2003	40
36105	CAVIN FANNIN POULTRY	Bowie	DEKALB	3/10/2004	438
37438	TIM FANNIN	Bowie	DEKALB	3/26/2004	360
47577	James Sturidvant	Bowie	Dekalb	9/10/2004	220
49044	P.E. Hartline	Hopkins	Cumby	11/16/2004	
64265	RUSTY MARSACK	Bowie	DEKALB	5/16/2005	320
69739	Robert Lee	Kaufman	Terrell	10/26/2005	52
70637	Robert Rhoads	Red River	Same	2/4/2004	75
79764	Hazel Mitchell	Bowie	New Boston	3/26/2004	60
80622	STEVE STARRETT	Bowie	DEKALB	2/18/2006	280
80623	JASON CULPEPPER	Bowie	DEKALB	2/21/2006	320

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
80624	HELEN WHITTLE	Bowie	DEKALB	2/24/2006	240
82133	JOE HOUSE	Bowie	DEKALB	3/16/2006	200
82988	MARIO GARCIA	Bowie	NEW	4/30/2006	68
85341	Charlie Sparks	Hunt	Terrell	3/10/2004	90
85335	Sandra Snyder	Kaufman	Terrell	3/9/2004	84
85397	Joe Cannon	Hunt	Quinlan	3/29/2004	220
85398	Pat Weatherly	Hunt	Quinlan	3/23/2004	280
87683	JOSE GAMINO	Kaufman	KEMP	7/14/2006	
88809	Mike Lee	Hunt	Quinlan	8/12/2003	264
88770	Don Seawright	Hunt	Quinlan	7/21/2003	168
88771	Thomas McClemme	Kaufman	Terrell	8/4/2003	105
88772	Thomas McClemme	Kaufman	Terrell	8/25/2003	105
88813	Jason Armstrong	Hunt	Quinlan	9/3/2003	190
88836	Arthur Masters	Hunt	Quinlan	9/17/2003	225
90752	Barbara Hornick	Navarro	Timothy	8/18/2006	100
94880	George Patterson	Hopkins	Sulphur	3/17/2006	262
98752	ARMSTRONG RANCH	Red River	AVERY	10/3/2006	300
98762	HAROLD TOTTY	Red River	AVERY	10/11/2006	380
110820	JIM MILLS	Bowie	DEKALB	3/20/2007	82
114134	Carl W Jones	Red River	Bogata	11/15/2006	252
118003	Richard Stewart	Kaufman	Terrell	9/22/2004	110
118581	Kevin Crockett	Hunt	Campbell	9/16/2004	48
119771	dean	Red River	Avery	5/27/2007	140
120660	Thomas Meurer	Kaufman	Terrell	8/22/2007	390
122797	BENNY HERMAN	Hunt	CUMBY	10/28/2003	300
123291	MIKE LILLY	Bowie	SAME	10/27/2003	43
133149	Taylor, Tray	Hunt	Quinlan	11/28/2007	171



Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
133303	Scott Clarey	Bowie	dekalb	2/1/2008	300
134243	David and Connie Rowe	Bowie	Texarkana	2/4/2008	57
134832	Robert Trumble	Bowie	Texarkana	1/11/2008	52
142259	BARRY AUSTIN	Navarro	CHATFIELD	4/20/2008	
146339	hu sun duke	Bowie	dekalb	6/6/2008	200
146548	Hartsbluff Game Ranch	Franklin	Talco	6/5/2008	502
150052	bill toten	Bowie	De Kalb	3/3/2008	80
150054	David goodwin	Bowie	De Kalb	7/19/2008	70
150056	amanda goodwin	Bowie	De Kalb	5/15/2008	75
150057	ricks	Bowie	De Kalb	3/8/2008	75
152597	Sidney Stone	Hunt	Quinlan	7/2/2005	224
152603	Dan Cantrell	Hunt	Quinlan	7/20/2005	224
152608	Richard Kennedy	Hunt	Quinlan	8/1/2005	90
154462	Scott McCool	Bowie		6/7/2005	42
154804	Monte Randolph	Red River	Bogata	8/31/2005	175
164800	J R F Enterprises	Hunt	Quinlan	8/6/2004	185
164788	Pat Bellinger	Kaufman	Terrell	9/13/2004	108
164797	Kevin Keck	Hunt	Quinlan	8/10/2004	160
167750	Darryl Holcomb	Bowie	Dekalb	12/15/2006	575
173542	ANGEL JOSE RODRIGUEZ	Navarro	CHATFIELD	2/10/2009	
174403	Joe Robbins	Bowie	Texarkana	6/6/2006	45
176657	Thomas Clayton	Red River	Lydia	3/19/2009	720
177263	Stace Hayward	Hunt	Terrell	7/3/2006	105
177265	Sean Morris	Kaufman	Terrell	7/5/2006	90
177266	Tom Cheney	Hunt	Terrell	7/6/2006	130
177268	Stanley Ewaniak	Kaufman	Terrell	7/7/2006	91
177272	Jerry Hinojosa	Hunt	Terrell	7/10/2006	80

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
177273	Bill Randall	Hunt	Terrell	7/11/2006	74
177276	George Dugger	Hunt	Terrell	7/12/2006	70
177284	Jeff Adams	Hunt	Quinlan	7/18/2006	70
177299	Weathers Concrete	Hunt	Quinlan	8/14/2006	160
177307	Shuck Wieland	Kaufman	Terrell	8/31/2006	240
177334	Donald Woodruff	Bowie	DeKalb	2/18/2009	
181492	Dan Garrett	Hunt	Quinlan	11/30/2005	96
181493	Rocky Johnson	Hunt	Quinlan	12/1/2005	80
181453	Dick Tymer	Hunt	Quinlan	10/22/2005	298
181464	Helen Ballard	Kaufman	Terrell	11/4/2005	85
181468	Walter Dodge	Hunt	Quinlan	11/5/2005	84
181471	Walter Dodge	Hunt	Quinlan	11/7/2005	80
181472	Walter Dodge	Hunt	Quinlan	11/10/2005	78
181494	Christin Neubaur	Hunt	Campbell	12/6/2005	60
183248	C.T. Mitchell Const.	Bowie	Texarkana	5/18/2004	369
190873	Joe Miller	Hunt	Quinlan	2/12/2006	255
190875	Allien Myer	Hunt	Quinlan	2/14/2006	143
191140	rolling homes	Bowie	De Kalb	9/18/2008	
192330	Don Zachary	Hunt	Campbell	7/11/2009	200
192331	Don Sachary	Hunt	Campbell	7/10/2009	200
192332	Alex Cardenas	Hunt	Campbell	7/18/2009	242
192333	Shirley Wilson	Hunt	Quinlan	7/21/2009	140
192334	Tom White	Hunt	Quinlan	7/30/2009	258
193055	David Sevehla	Rockwall	Rockwall	9/30/2006	53
194538	Dwight Hawkins	Kaufman	Terrell	3/7/2006	122
194559	Arley Sansom	Hunt	Quinlan	3/15/2006	225
194560	Trey Griffith	Kaufman		3/29/2006	122

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
194561	Terry Chambers	Kaufman	Terrell	3/31/2006	105
196543	Star Mobile Homes	Bowie	Dekalb	5/21/2009	
196576	Mike Hatfield	Hunt	same	8/20/2009	238
196578	Ron Blaske	Hunt		8/29/2009	230
196682	Wallace Watson	Hunt		8/24/2009	178
196865	Lance Simpson	Bowie	Texarkana	10/19/2009	55
197151	Aiken, Jimmy	Bowie	Texarkana	4/12/2008	
197268	Palmer, Curtis	Bowie	Wamba	8/19/2008	
210543	Barry Austin	Navarro	Chatfield	2/21/2010	
216168	Evalyne Clements	Bowie	DeKalb	2/22/2010	
220061	Robert Maxwell	Bowie	Texarkana	8/13/2007	55
221830	Charles Morse	Hunt	Quinlan	4/2/2009	190
221833	Richard Depp	Kaufman	Terrell	4/6/2009	94
221835	Lymon Peterman	Hunt	Quinlan	4/8/2009	84
221840	Nick Wilton	Hunt	Quinlan	2/22/2007	268
221845	Jim L. Raney	Hopkins	Cumby	3/1/2007	280
221884	Bruce Hudson	Hunt	Campbell	5/1/2007	123
221889	Eddie Williams	Hunt	Quinlan	5/3/2007	84
221904	James Sutton	Hunt	Quinlan	5/19/2007	160
221908	Fred Wiese	Hunt	Quinlan	10/3/2007	255
221910	Larry Jones	Kaufman	Terrell	10/9/2007	118
221911	Wesley Patton	Kaufman	Terrell	10/11/2007	118
221915	Ron Kifer	Hunt	Quinlan	11/16/2007	96
221916	Kyle Shannon	Kaufman	Terrell	11/19/2007	95
221918	Dave Cella	Kaufman	Terrell	11/20/2007	108
221921	Stefan Gradanay	Hunt	Quinlan	4/22/2008	226
221922	D. Garrett	Hunt	Quinlan	4/24/2008	192

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
221924	Mark Baird	Hunt	Terrell	5/1/2008	144
221925	Kenneth Jones	Kaufman	Terrell	5/19/2008	105
221929	Septimo Landeverde	Hunt	Quinlan	7/3/2008	140
221931	Brad Erwin	Kaufman	Terrell	7/21/2008	110
221938	Bonnie Hart	Hunt	Quinlan	8/7/2008	195
221948	James Yonker	Hopkins	Cumby	9/16/2008	268
221954	Keith Siebolt	Hunt	Quinlan	11/27/2008	165
221957	Texas A&M Commerce	Hunt	Commerce	6/2/2009	103
221958	Texas A&M Commerce	Hunt	Commerce	6/2/2009	100
222558	John Gregory	Bowie	Texarkana	5/27/2007	56
222873	John Campbell	Bowie	Dekalb	9/3/2007	630
222881	Gary Northam Construction	Bowie	Texarkana	5/17/2007	48
222912	Ken Hawkins	Bowie	Texarkana	9/12/2007	38
224450	Dave Stotcher	Kaufman		6/7/2010	136
226793	Mike Cole	Kaufman		8/14/2007	90
227119	vivian raymond	Bowie	De Kalb	11/12/2009	65
228086	HMW Special Utility District	Harris	Cypress	8/25/2009	398
229291	Oscar Smith III	Henderson	Seven Points	7/24/2010	60
230279	Brown, John M.	Bowie	Texarkana	6/22/2010	
230323	MLM Construction	Bowie	Texarkana	6/4/2010	
231599	Maria Gutierrez	Kaufman		8/4/2010	90
231577	Jim Nichols	Kaufman		8/2/2010	105
231593	Raymond Delton	Kaufman		8/3/2010	96
233180	McCan, Eugene	Hunt		8/29/2010	202
234206	Bob Gunter	Hopkins	Cumby	7/20/2007	276
234856	Stanley Henderson	Hunt		9/5/2010	180
234857	Vincent Rendevez	Hunt		9/7/2010	195

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
234861	Chuck Adams	Hunt		9/20/2010	96
236984	Eslinger	Hunt	same	10/12/2010	232
237661	Vic Cox	Red River	Bogata	10/12/2010	152
239773	Ken Parker	Hopkins		11/3/2010	240
239774	Joe Hobbs	Kaufman		11/1/2010	110
241121	Kelly Poole	Hunt	Quinlan	6/14/2005	216
241461	David Wallace	Hunt	Campbell	6/5/2005	110
241466	Bill Miller	Hunt	Campbell	5/30/2005	230
241467	Robert Griffith	Hunt	Quinlan	5/26/2005	156
241469	Johnny Calvert	Hunt	Campbell	5/24/2005	205
243007	Dr. Howard Morris	Bowie	Texarkana	9/15/2003	70
254483	Jake Bell	Hunt		4/8/2011	188
254503	Cesar Renalos	Hunt		4/19/2011	190
256012	Wright, William	Bowie	Texarkana	12/3/2010	
256022	Yarberry, John	Bowie	Texarkana	11/12/2010	
256071	Flanery, John	Bowie	New Boston	9/9/2010	
258628	Clint Hutchins	Hopkins		5/6/2011	354
258840	Mike Featherston	Hunt		6/13/2011	100
258847	Linda Wheatly	Hunt		6/18/2011	268
264494	Doug Lavern	Hunt		7/5/2011	215
264663	Quinlan School District	Hunt		8/19/2011	322
269773	Joe W. Heather	Henderson	Kemp	9/19/2011	26
270130	Roy Lorance	Bowie	Hooks	8/12/2011	
272864	Stacey Smith	Hunt		10/11/2011	175
272867	Shelly Smith	Kaufman		10/12/2011	120
273138	Kim Sosebee	Hunt		10/19/2011	280
273922	John Hughes	Henderson	Kemp	10/4/2011	71

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
278238	John Felshiem	Hunt		12/13/2011	220
278239	Alton Folmar	Hunt		12/10/2011	220
278240	Q.I.S.D	Hunt		12/16/2011	262
278242	Mike Wesley	Hunt		1/4/2012	160
278243	Ruby Murphy	Hunt		1/6/2012	145
281981	Don Reneau	Kaufman	Kemp	3/3/2012	52
290718	Eddie Bobo	Henderson	Kemp	5/22/2012	70
291155	Frank Akenback	Hunt		5/4/2012	160
291160	Bruce Allen	Hunt		5/15/2012	298
295451	Mark Cherry	Bowie	De Kalb	4/23/2012	250
295454	David Sealing	Bowie	De Kalb	7/30/2012	480
297879	Quinlan school district	Hunt		7/23/2012	160
298475	Becky Lindsey	Red River	Avery	7/23/2012	662
301227	Nick Shaffer	Hunt		8/13/2012	128
301228	Kirk Lane	Kaufman		8/30/2012	212
305533	ARNOLD BARFIELD	Bowie	NEW	8/10/2012	42
307810	Chris Jabin	Hunt	Lone Oak	11/14/2012	315
308638	Casey Romans	Hopkins		11/16/2012	314
308820	Bobby Parks	Hunt		12/7/2012	274
309165	Darrel Tucker	Bowie	Dekalb	12/7/2012	
311106	Mark McCrary	Bowie	DeKalb	1/19/2013	
321812	Paul Wiley	Kaufman		5/2/2013	132
321815	Stillwater construction	Hunt		5/24/2013	120
331825	Norvelle Walker	Bowie	De Kalb	11/10/2010	38
331885	G.W. Farr	Bowie	New Boston	10/1/2011	73
331897	Tommy Baggett	Bowie	New Boston	8/13/2012	166
331955	Chris Loveall	Bowie	Texarkana	3/16/2012	725

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
331963	Hal Lovance	Bowie	Hooks	7/15/2011	56
331987	Austin Chapel Bap. Ch.	Bowie	De Kalb	8/16/2012	280
331992	Danny Rich	Bowie	De Kalb	3/16/2013	350
332147	Lone Star Custom Homes	Bowie	Texarkana	11/2/2011	40
332191	Trey Fuzy	Bowie	Texarkana	7/6/2011	45
332209	Taylor Custom Homes	Bowie	Texarkana	6/16/2011	53
333435	MARY LIGHTFOOT	Kaufman	TERRELL	9/2/2006	
333485	J KENNEDY	Hunt	QUINLAN	9/13/2006	
333489	J KENNEDY	Hunt	QUINLAN	9/12/2006	
333494	JAMES DENNIS	Kaufman	TERRELL	9/11/2006	
333593	RAY COX	Hunt	QUINLAN	6/27/2006	
333617	OSCAR STARBUCK	Hunt	QUINLAN	5/31/2006	
333632	JOE KILLIAN	Hopkins	COMMERCE	5/12/2006	
333652	MIKE WARD	Hunt	QUINLAN	5/10/2006	
334112	Ernest Smith	Hunt	Commerce	9/16/2005	288
336716	TAFFY JONES	Hunt	QUINLAN	4/27/2013	224
338317	Christina Buxton	Bowie	DeKalb	7/26/2013	
338351	Robert Hill	Bowie	Hooks	10/12/2006	65
338355	Teresa McKee	Bowie	New Boston	10/9/2006	84
338362	J.T. Calhoun	Bowie	DeKalb	10/4/2006	337
339123	Kitty Cernock	Hunt	Terrell	5/25/2006	80
339890	Alex Bitner	Hunt		7/3/2013	90
340275	TJ Dodge	Hunt		7/9/2013	80
340279	Soloman	Hunt		7/17/2013	110
340284	Fannie Nichols	Hunt		8/6/2013	340
342493	David Dewitter	Navarro	Chatfield	8/17/2013	60
351701	Barry Ragle	Hunt		11/28/2013	0

Appendix 19-1. State driller report wells which meet House Bill 30 exclusion criteria.

Tracking number	Owner name	County	City	Date drilled	Total depth (ft)
351699	J.L.Morse	Hunt		11/20/2013	0
351700	John Munoz	Hunt		11/22/2013	0
354674	Michael Starcher	Navarro	Chatfield	1/25/2014	
361069	Mark Dunlap	Hunt	Cambell	4/11/2014	0



Appendix 19-2. GIS datasets.

GIS dataset descriptions have been included in the report text where applicable.

Appendix 19-3. GIS file names and codes.

File content	File name	File type
Available Geophysical Log (BRACS)	BRACS AvailableLogs	Point shapefile
Cities and Towns	Cities and Towns	Polyline shapefile
Counties in GAM projection	Counties_GAM	Polyline shapefile
Faults	Faults_clip	Polyline shapefile
Study area in GAM projection	GAMstudyarea	Polyline shapefile
Study area geology	GEOL_StudyArea	Polygon shapefile
Groundwater Management Area	groundwater_management_areas_01_23_14	Polygon shapefile
Nacatoch Well Location	GWDB_clipped_NCTC2	Point shapefile
Nacatoch Well 2-mile buffer	GWDB_clipped_NCTC2buffer2mi	Polygon shapefile
Measured TDS from Samples (mg/L)	GWDB_TDS_211NCTC	Point shapefile
Hydraulic Conductivity (ft/day)	hyd_prop_GAM	Point shapefile
Major Roads	Major Roads	Polyline shapefile
Nacatoch downdip	MinAq_NACATOCH	Polygon shapefile
Study Area extents	MOD_Grid_extent	Polygon shapefile
Fault Grabens	MTfaultsgrabens	Polyline shapefile
Alpha radiation	NAC_Alpha_LF	Point shapefile
Beta radiation	NAC_Beta_LF	Point shapefile
Gross Alpha	NAC_Gross_Alpha_LF	Point shapefile
Groundwater information point locations	NAC_GW_Classes	Point shapefile
Geophysical Log Used for TDS Estimate	Nac_Log_TDS_Summary	Point shapefile
Radium 226	NAC_Ra226_LF	Point shapefile
Radium 228	NAC_Ra228_LF	Point shapefile
Major Aquifers	new_major_aquifers_dd	Polygon shapefile
Minor Aquifers	new_minor_aquifers_dd	Polygon shapefile
Nacatoch outcrop	Outcrop_clipped	Polygon shapefile
Previous study	Outline_349	Polygon shapefile
Previous study	Outline_B6517	Polygon shapefile
Previous study	Outline_R150	Polygon shapefile
Previous study	Outline_R160	Polygon shapefile
Previous study	Outline_R169	Polygon shapefile
Previous study	Outline_R269	Polygon shapefile
Previous study	Outline_R299	Polygon shapefile
Potential Production Area	PPA3	Polygon shapefile
Public Supply 2-mile buffer	PWS_clipped_buffer2mi2	Polygon shapefile
Previous study	R137_TestMerged	Polygon shapefile
Previous study	R305	Polygon shapefile
Regional Water Planning Areas	Regional_Water_Planning_Areas	Polygon shapefile
RRC Class II Injection Well - Excluded	RRCclass2_excl2	Point shapefile
Nacatoch sample locations	Sampled_Nacatoch_Wells_no_dups_LF	Point shapefile
Driller's Report: PS, Dom and Irr 1-mile buffer	SDRDB_studyarea_PSIrrDom_Only_clip 1mi_buffer3	Polygon shapefile

Appendix 19-3. GIS file names and codes.

File content	File name	File type
Driller's Report: PS, Dom, and Irr	SDRDB_studyarea_PSIrrDom_Only_clip 3	Point shapefile
StratMap_City_Poly_v4	StratMap_City_Poly_v4	Polygon shapefile
Estimated TDS <10,000 mg/L Extent	T10K_tds_extent	Polyline shapefile
1,000 TDS	T1Ktds	Polyline shapefile
TCEQ Public Supply Well	TCEQ_Pswells_clip2	Point shapefile
Texas_Major_Hwy_NAD_83	Texas_Major_Hwy_NAD_83	Polyline shapefile
State line	texas_outline_gamcopy	Polyline shapefile
Nacatoch depth to groundwater (ft)	twdb_10yr_avg_con_clipped	Polyline shapefile
Groundwater Conservation Districts	TWDB_GCDs_082014	Polygon shapefile
Depth to Water (2006-2016)	WL_nac_TWDB_10yr_avg	Point shapefile

Appendix 19-3. GIS file names and codes.

Surface description	Surface file
Outline of aquifer model	Aquifer Model Outline
Bottom of Nacatoch Aquifer, ft amsl	Bot_Nac
Confined unit of aquifer	Confined Area
Fresh water bottom depth, ft	fr bot
Fresh water percent sand	fr ps
Fresh water thickness, ft	fr thk
Fresh water top depth, ft	fr top
Fresh water volume, ac-ft	fr vol
Moderately saline bottom depth, ft	ms bot
Moderately saline percent sand	ms ps
Moderately saline thickness, ft	ms thk
Moderately saline top depth, ft	ms top
Moderately saline volume, ac-ft	ms vol
Nacatoch Elevation clipped	Nac elev clip
Snap grid	Snap_Nac
Slightly saline bottom depth, ft	ss bot
Slightly saline percent sand	ss ps
Slightly saline thickness, ft	ss thk
Slightly saline top depth, ft	ss top
Slightly saline volume, ac-ft	ss vol
Thickness of Nacatoch Aquifer, feet	Thk_Nac
Top of Nacatoch Aquifer ft amsl	Top_Nac
Unconfined unit of aquifer	Unconfined Area
Very saline bottom depth, ft	vs bot
Very saline percent sand	vs ps
Very saline thickness, ft	vs thk
Very saline top	vs top
Very saline volume, ac-ft	vs vol
Depth of water level	wl depths

Appendix 19-4. Aquifer properties.

State well number	Aquifer	Test yield (Gpm)	Drawdown (ft)	Specific capacity	Transmissivity (gpd/ft)	Hydraulic conductivity (ft/d)
1619803	Alluvium	65	28	2.3	3,482	46.6
1627101	Alluvium	6	10	0.6	900	40.1
1627102	Alluvium	6	12	0.5	750	16.7
1627301	Alluvium	6	10	0.6	900	24.1
1628602	Alluvium	6	10	0.6	900	20.1
1628702	Alluvium	162	35	4.6	13,127	56.6
1628709	Alluvium	102	33	3.1	4,636	31.0
1640102	Nacatoch	107	81	1.3	206	3.0
1625902	Nacatoch	10	10	1	1,546	3.4
1626802	Nacatoch	5	18	0.3	1,077	28.8
1627701	Nacatoch	6	20	0.3	1,090	1.8
1628702	Nacatoch	63	0	13.8	13,127	56.6
1629702	Nacatoch	6	15	0.4	1,155	2.1
1629901	Nacatoch	15	70	0.2	1,025	2.1
1632813	Nacatoch	50	40	1.3	1,709	11.4
1633101	Nacatoch	10	50	0.2	1,025	4
1637202	Nacatoch	10	35	0.3	1,084	2.4
1643101	Nacatoch	6	30	0.2	1,025	2.2
1643103	Nacatoch	30	322	0.1	953	3.5
1739501	Nacatoch	100	60	1.7	2,002	5.1
1739905	Nacatoch	172	350	0.5	1,220	2.3
1741901	Nacatoch	285	0	5.1	2,670	9.4
1741902	Nacatoch	285	31	9.3	2,660	5.9
1742806	Nacatoch	200	192	1	2,300	3
1742807	Nacatoch	254	211	1.2	2,570	3.1
1742808	Nacatoch	183	178	1	2,150	3
1749304	Nacatoch	252	180	1.4	2,000	3
1749401	Nacatoch	15	138	0.1	960	6.4
1749601	Nacatoch	23	75	0.3	1,097	7.3
1749801	Nacatoch	8	10	0.8	1,416	5.3
1750705	Nacatoch	56	194	0.3	1,090	1.9
1758201	Nacatoch	60	32	1.9	2,133	4

Appendix 19-4. Aquifer properties.

State well number	Aquifer	Test yield (Gpm)	Drawdown (ft)	Specific capacity	Transmissivity (gpd/ft)	Hydraulic conductivity (ft/d)
1758504	Nacatoch	60	150	0.4	1,155	2.3
1758604	Nacatoch	55	155	0.4	1,136	3
1856602	Nacatoch	10	20	0.5	1,220	7.8
1864501	Nacatoch	7	53	0.1	979	4.5
1864602	Nacatoch	14	20	0.7	1,351	6.9
1864803	Nacatoch	0	0	0	3,290	7.3
3307501	Nacatoch	10	70	0.1	986	13.2
3308707	Nacatoch	50	50	1	1,546	4.1
3308801	Nacatoch	16	80	0.2	1,025	7.2
3308802	Nacatoch	20	25	0.8	1,416	6.3
3308804	Nacatoch	20	25	0.8	1,416	6.3
3314602	Nacatoch	30	30	1	1,546	10.3
3401201	Nacatoch	90	81	1.1	1,611	4.7

Appendix 19-5. Effects of tool geometry on common open hole logs.

Logging Tool	Emitter to receiver spacing (inches)	Minimum vertical resolution (inches)	Minimum bed thickness for true log values under ideal conditions (inches)	Approximate depth of investigation (inches)	Circumference of 8-3/4 inch borehole surveyed (%)
Calipers					
3-Arm bow spring recorded with:					
Induction electric		18		0	25
Compensated electric		18		0	25
1-Arm					
Compensated density		6		0	6
Sidewall epithermal neutron		6		0	6
2-Arm					
Proximity-microlog		12		0	36
Microlaterolog		12		0	36
4-Arm					
4-Arm dual caliper		1		0	4
High resolution 4-arm diplog					
SP		12		0	100
Gamma ray		24		6	100
Single point resistance	2-3	2-3	--	6	100
Resistivity					
16" Normal	16	24	60	32	100
64" Normal	64	96	240	128	100
18' 8" Lateral	224	240	448	224	100
Dual induction					
SFL	12	12	12	40	100
Medium induction	40	48	48	70	100
Deep induction	40	48	48	120	100
Laterolog 3					
Laterolog 7	12	12	24	120	
Laterolog 8	32	32	30		
Laterolog 8	14	14	24		
Dual laterolog					
Shallow laterolog	24	24	30	30	100
Deep laterolog	24	24	30	120	100
Microlog					
Micro inverse	1	2		1	7
Micro normal	2	4		2	7
Proximity log	1	12	4	10	7
Microlaterolog	1	4	4	4	7
Porosity					
Sidewall sonic		6		0 to 4	4
Compensated sonic	12-36	12-36	24	0 to 4	100
Compensated density	18	18	24	4	12
Compensated neutron	24	24	24	8	30

This table provides average values. Values may vary depending upon the particular brand of logging equipment and the specific borehole conditions.

**General Report Comments**

1. Thank you for working with us to get the report for this project delivered.

**Response not required**

2. Professional Geologists and Engineers must affix their seals and sign the final report.

**Complete**

3. Please spell out House Bill 30 in the report to limit variations of abbreviations.

**Complete**

4. Please refer to Contract Exhibit D for BRACS contract report requirements.

**Response not required**

5. Please enlarge all figures to cover the full page and make them legible.

**Complete**

6. Please provide one image per figure.

**Complete**

7. Please spell out all acronyms except for TWDB and BRACS and spell out all units of measurement.

**Complete**

8. Please refer to the Brackish Aquifer Characterization System as "BRACS" throughout the report.

**Complete**

9. Please ensure all figure captions are thorough, correct, and provide one caption per figure (for example: Figure 4 1. a) Regional water planning areas, b) groundwater conservation districts and c) groundwater management areas.)

**Complete**

10. Please clip the study area polygon and all derivative figures to the western end of the Nacatoch Aquifer outcrop.

**Complete**

11. Please provide a section on recommendations for monitoring groundwater production in Potential Production Areas.

**Provided general recommendations**

12. Please define the study area consistently in the report and deliverables. The report figures have differing study areas (for example Figure 6-1 and 6-2).

**Complete**



**Specific Report Comments**

1. Page 1. Executive Summary: Considering providing volumes of groundwater in acre-feet in addition to the percentage provided in the report.

**Complete**

2. Page 4. Section 5.1: please elaborate on geological nature of the Nacatoch sand and on faulting, its effects on geological structure (grabens specifically), and groundwater quality.

**Complete**

3. Page 8 – 10. Figure 5-3, Figure 5-4, Figure 5-5, and Figure 5-5:

- a. Please provide an additional image with cross-section locations.
- b. Please remove structure map from cross-section images.
- c. Please change figure orientation to landscape.
- d. Label the axes correctly in the left and right of each image (the current images state “subsea depth”.)
- e. Please correct API numbers on well labels.

**Complete**

4. Page 14. Table 6-1: color the Brine classification cell according to Wilson and Kister’s color ramp.

**Complete**

5. Page 16. Figure 6-1: Please provide separate figures for measured and estimated salinity.

**Complete**

6. Page 16. Figure 6-1: Please revise measured TDS values to reflect well control data within the study area.

**Complete**

7. Page 16. Section 6.3: Please move Figure 6-1 to the end of Section 6.1.

**Complete**

8. Page 17. Section 6.3: Please move Figure 6-2 to the end of Section 6.3.

**Complete**

9. Page 18. Fifth sentence: Please move the remainder of this paragraph to a new paragraph.

**Complete**

10. Page 19 – 23. Figure 6-3, Figure 6-4, Figure 6-5, Figure 6-6, and Figure 6-7:

- a. Please provide clearer labels for well logs presented in cross-sections
- b. Please label the axes on the left and right of each image.

**Complete**

Appendix 19-6. Comments and Responses.

11. Page 24. Sixth paragraph: Please include report names when listing previous hydrologic characterization work done in the area.

**Complete**

12. Page 26. Table 8-1: Please move table past the third paragraph and fit the whole table in one page.

**Complete**

13. Page 26. Section 8.2.1, first paragraph: Please replace "TWDB Brackish Resources Aquifer Characterization System BRACS Team" to "TWDB BRACS Database".

**Complete**

14. Page 28. Figure 8-1: Please increase the font size of figure.

**Complete**

15. Page 28. Section 8.2.2: Please move section to page 29.

**Complete**

16. Page 30. Figure8-2: Please make figure clearer and please provide a right border.

**Complete**

17. Page 32. Section8.4: Please move section to the previous page.

**Complete**

18. Page 33. Last paragraph: Please derive the Cooper and Jacob equation of modified non-equilibrium.

**Complete**

19. Page 34. Table 9-3: Please move table to an appendix section.

**Complete**

20. Page 38 through 41. Figure 10-1a, 10-3a, 10-3b, 10-4, 10-5, and 10-6. Please label counties on the figures.

**Complete**

21. Page 40 and 41. Please remove less than (<) from figures and label counties.

**Complete**

22. Page 43 and 44. Figures 11-1 and 11-2: Please make the scale in the figures more legible.

**Complete**

23. Page 46. Figure12-3: Please correct the figure's color scheme to reflect the color ramp from Winslow and Kister.

**Figure removed**

24. Page 46. Section 12.2: please include interpolated salinity zone surfaces in the final report.

**Surfaces have been included**

Appendix 19-6. Comments and Responses.

25. Page 49. Section 13: please provide a type log figure to illustrate and describe the geophysical properties of the Nacatoch formation, there is a type log on cross-section X-X'.

**Complete**

26. Page 51. Table 13-1: Please move table to an appendix section.

**Complete**

27. Page 52. Section 13.2: Please define bottom hole temperature (TBH) on point 7.

**Complete**

28. Page 56. Section 14.1: All four potential productions areas are delineated past the 10,000 mg/L TDS extend. Please confirm and provide data points to support the delineations.

**Complete**

29. Page 58. Please provide a map of Potential Production Areas without exclusion zones in the same figure.

**Complete**

30. Page 59. Section 14.2: Please provide drawdown tables for the three pumping scenarios for each potential production area, if available.

**Tables are not available**

31. Page 60. Figure 14-4 to 14-10: Please provide additional figures that show exclusion wells and their buffers to determine the drawdown effects nearby wells.

**Complete**

32. Page 64. Section 16: Please elaborate on salinity calculation methodology, PPA designation methodology.

**Complete**

33. Page 64. Section 17: Please change "Ericka" to "Erika".

**Complete**

34. Page 64. Section 16, second paragraph, last sentence: Please clarify "Fresh and slightly saline water represent 16 and 26 percent of all available Blossom groundwater and moderately saline groundwater contributes about 15 percent of the estimated storage volume located in the project area."

**Complete**

35. Page A-27. Appendix 19.3: Please reposition tables so that they appear below the title of the appendix section they are under, instead of the following page.

**Complete**

**Data Comments**

1. Please refer to Contract Exhibit G for BRACS contract data requirements.

**Response not required**

Appendix 19-6. Comments and Responses.

2. Table tblGeophysicalLog\_Header is missing data from the following fields and needs to be incorporated into the table. Fields include TS, DT, TBH, RM, RM\_TEMP, RMF, and RMF\_TEMP.

**Fields have been included**

3. Table tblWell\_Geology has 130 records containing a value in the field [hydrochemical\_tds\_zone] indicating a salinity analysis was performed (confirmed with records in the table tblGeophysicalLog\_WQ). However, these 130 records do not have a corresponding record in the following tables:
  - a. table tblWell\_Geology indicating the stratigraphic name, top and bottom depths
  - b. table tblGeophysicalLog\_Header
  - c. table tblWell\_Location

**Records have been added**

4. Please provide the digital geophysical well logs for these 130 wells

**Logs have been provided**

5. Please add these records to the appropriate tables with complete attributes. Adding these records to the table tblGeophysicalLog\_Header will ensure there is a complete record of information including TS and TBH for wells used for salinity analysis. The records are listed in the following table:

Well ID	Well ID	Well ID	Well ID	Well ID
1592	20107	21530	23577	26044
1594	20112	21532	23579	26046
1944	20137	21663	23582	26349
1947	20139	21678	23775	26485
1952	20164	21969	23789	27814
2309	20167	21986	23794	29038
14850	20184	21988	23799	29196
14858	20310	21995	24552	30060
14859	20322	22004	24562	30861
14862	20334	22007	24718	31489
14866	20351	22017	24723	31704
15006	20353	22026	24731	32425
15007	20356	22034	24751	33277
17826	21173	22699	24814	33494
17831	21175	22709	24817	33496
17848	21206	22711	24947	33857
18567	21246	22715	24956	35024
19119	21255	22724	25935	35905
19129	21469	22729	25977	35971
19153	21472	22732	25980	36027
19156	21496	22736	25986	36892
19434	21497	22780	25988	37519
20034	21499	22784	25990	37529
20084	21501	22797	25995	37690
20087	21504	23107	26027	50287
20102	21519	23556	26031	50288

Appendix 19-6. Comments and Responses.

**Records have been added**

6. Each of the 195 wells in the table tblWell\_Geology that contains a value in the field [hydrochemical\_tds\_zone] will need to have a corresponding record added to this table with the field [geologic\_pick] = Hydrochemical, the field [stratigraphic\_name] = Nacatoch Formation, and corresponding values in the fields [depth\_top] and [depth\_bottom] that reflect the top and bottom of the salinity zone. Many wells contain multiple salinity zones within the Nacatoch Formation, so this vertical salinity must be reflected in the geology table.

**Records have been added**

7. The table tblWell\_Geology has multiple records with incorrect top and bottom depths since the thickness is negative. These lithologic records are in wells: 21978, 25974, 22007, 21678, 26098, 26090, and 21530.

**Records have been revised**

8. The table tblWell\_Geology design contains two key fields: the Well\_ID and the Record\_Number. The record number must be a unique integer, sequentially increasing numbers, from top to bottom depth. Many records with both lithology and stratigraphic data have the same record numbers. For example, well 17837 has lithology records with record numbers 1 through 5 and stratigraphic records with record numbers 1 through 3. Please correct these problems.

**Record numbers have been revised**

9. The table tblWell\_Geology contains lithologic, stratigraphic, and hydrochemical records. Please ensure that the top and bottom depth values for the stratigraphic records are consistent with the lithologic and hydrochemical records. For example, well 19441 indicates the Nacatoch Formation stratigraphic record has a top depth of 1288 and a bottom depth of 1749. The lithologic record with hydrochemical analysis indicates the Nacatoch Formation sand has a top depth of 1270.

**Records have been revised**

10. The table tblWell\_Geology contains lithologic records. The lithology provided for the Nacatoch Formation must describe the entire formation. Many wells are incomplete and 130 wells have no corresponding stratigraphic record (a previous comment) so the analysis for completeness cannot be made. Please check each well and add new lithology records as appropriate.

**Records have been added**

11. The table tblGeophysicalLog\_WQ is missing the Tf (Temperature of formation) for 145 of the 309 records. These wells were used to determine an interpreted total dissolved solids concentration. Please provide this required information.

**Records have been added**

12. The table tblGeophysicalLog\_WQ includes the field [source\_porosity] with a value of "Driscoll1986". The draft report does not describe the source of porosity data representative of the Nacatoch Formation. Please provide the page number in the Driscoll 1986 reference that contains Nacatoch Formation porosity data.

**Reference has been revised**

Appendix 19-6. Comments and Responses.

13. The table tblGeophysicalLog\_WQ\_Method contains a record for well 20351. There are no corresponding record(s) for this well in the table tblGeophysicalLog\_WQ. Please add this record to table tblGeophysicalLog\_WQ or provide an alternative explanation for this missing record.

**Record has been added**

14. The field Df (Depth of formation) in tables tblGeophysicalLog\_WQ and tblGeophysicalLog\_WQ\_Method is defined in the BRACS Database Data Dictionary, second edition, as follows:

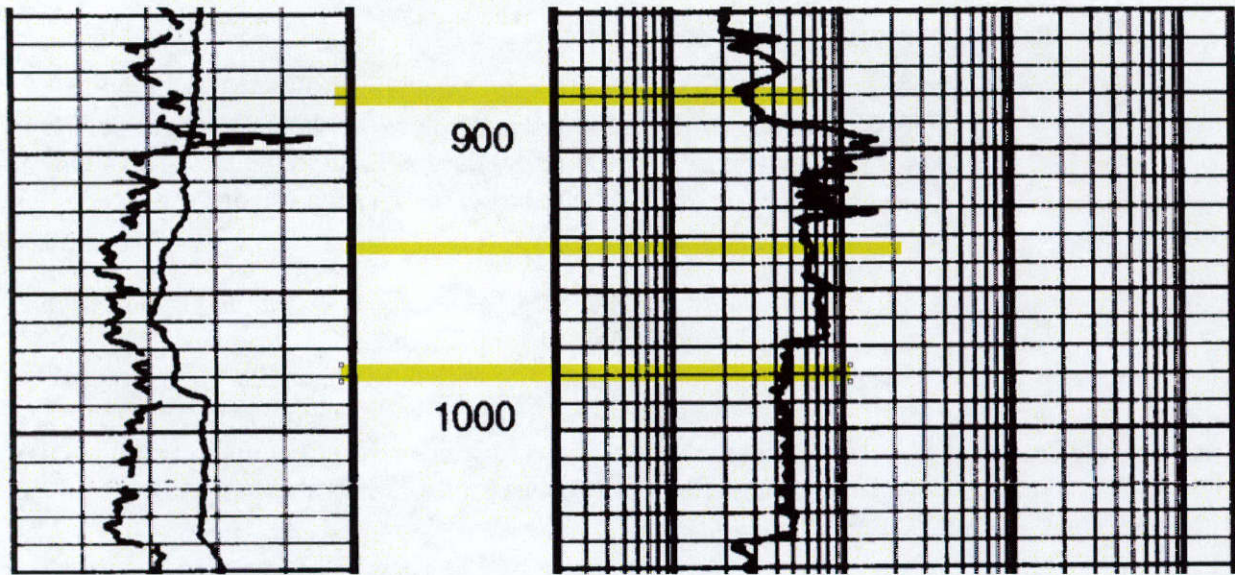
**DF** This is the third key field for this table. This value is based on the depth of the assessed formation of interest. The units are feet below ground surface, and this value is not corrected for kelly bushing height.

The depth value is that point on the geophysical well log where the tool values are measured. Typically, the point is within a relatively thick and mineralogically uniform lithologic unit where bed boundary effects are minimal.

It appears from analysis of several geophysical well logs that the value Df does not meet this definition and the resistivity values in field Ro do not match the log values at depth Df. The following figure is taken from well 25716:

<b>MAIN PASS</b>			<b>SFL Unaveraged (SFLU)</b>		
			0.2	(OHMM)	2000
			<b>IL-Medium Resistivity (ILM)</b>		
<b>SP (SP)</b>			0.2	(OHMM)	2000
-160	(MV)	40	<b>IL-Deep Resistivity (ILD)</b>		
<b>Gamma Ray (GR)</b>			0.2	(OHMM)	2000
0	(GAPI)	150			

Appendix 19-6. Comments and Responses.



The following table indicates the differences in resistivity taken from table tblGeophysicalLog\_WQ\_Method compared with the resistivity read from the geophysical well log:

Df	CCI Ro	TWDB Ro
880	14	2.7
935	6.9	6.5
980	4	4.5

Clearly the resistivity at depth 880 is completely different. The values at the other two depths are within the margin of error in reading the logs. The values at depths 880 and 980 are probably shales and not sands.

Please provide a discussion of how you determined the Df value and corresponding resistivity values. If necessary, make corrections to tables tblGeophysicalLog\_WQ and tblGeophysicalLog\_WQ\_Method in order to meet the definition of field Df.

**Kelly bushing corrections have been removed**

15. Comparison of the resistivity data in table tblGeophysicalLog\_WQ\_Method and the geophysical well logs indicates that some logs were misinterpreted. For example, well 22780 at a depth of 1477 has a resistivity value of 1.7 ohm-meters listed in the table. The geophysical well log indicates 6 ohm-meters. In this example, 1.7 ohm-meters would provide a TDS of 13,889, but a value of 6 ohm-meters would provide a TDS of 3,906. This is a significant error, please correct.

**Kelly bushing corrections have been removed**

16. In the course of addressing all of these comments, please double check the depths, resistivity values, lithology, and interpreted total dissolved solids concentrations of every well and correct the tables and derivative products as needed.

Appendix 19-6. Comments and Responses.

**Kelly bushing corrections have been removed**

17. Comparison of the tables tblWell\_Geology and tblGeophysicalLog\_WQ\_Method indicated that three wells (20356, 32425, and 21501) have records where the top and bottom depth of the sand investigated for salinity (in tblWell\_Geology) does not match the field Df (depth of formation in table tblGeophysicalLog\_WQ\_Method). Please correct these discrepancies.

**Kelly bushing corrections have been removed**

Comparison of the tables tblWell\_Geology and tblGeophysicalLog\_WQ\_Method indicated that only 93 of 308 records used to interpret total dissolved solids in table tblGeophysicalLog\_WQ\_Method matched the corresponding value in the table tblWell\_Geology. The following table shows the results of 10 wells where we used the same input parameters to calculate an interpreted total dissolved solids concentration and compared these results to the values provided in the tables. It appears the data in table tblGeophysicalLog\_WQ\_Method is incorrect.

Well ID	Df	CCI Hydrochemical Zone tblWell_Geology	CCI TDS tblGeophysicalLog_WQ_Method	TWDB calculated TDS
50287	758	Very saline	970	11702
50288	802	Very saline	1760	14103
36892	1108	Very saline	770	12791
25716	880	Slightly saline	12900	1943
25716	935	Moderately saline	19090	3901
21519	1282	Slightly saline	14630	2806
22004	323	Fresh	15340	975
22004	520	Moderately saline	3890	6944
22699	1395	Very saline	470	11364
25995	875	Moderately saline	18190	8333
23582	435	Fresh	2260	655
23582	535	Slightly saline	6720	1064
23582	680	Moderately saline	540	4762

Please verify every record and provide corrected tables for tblWell\_Geology and tblGeophysicalLog\_WQ\_Method. If the impact of these errors has been incorporated into any derivative tables or GIS files, please let us know and provide those corrected files.

**TDS values have been corrected**

18. Evaluation of table tblGeophysicalLog\_WQ\_Method indicates that the field [geophysical\_log] contains some errors. In cases where an induction resistivity tool was used to determine a formation resistivity value, the standard term resistivity was written to the table (for example, well 25716). Please make these corrections as appropriate.

**Appropriate corrections have been made**

19. Please make sure that the following GIS Shapefiles conform to the following requirements:

- a. All GIS files will be compatible with ESRI ArcGIS version 10.2.



Appendix 19-6. Comments and Responses.

b. All GIS files should adhere to the Texas State Mapping System, Albers Equal Area standard.

Projection: Albers

False\_Easting: 4921250.0

False\_Northing: 19685000.0

Central\_Meridian: -100.0

Standard\_Parallel\_1: 27.5

Standard\_Parallel\_2: 35.0

Latitude\_Of\_Origin: 31.25

Linear Unit: Foot\_US (0.3048006096012192)

Geographic Coordinate System: GCS\_North\_American\_1983

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D\_North\_American\_1983

Spheroid: GRS\_1980

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314140356

Inverse Flattening: 298.257222101

20. Please see Attachment 1 for a complete list of shapefiles that need to adhere to the BRACS contract data requirements.

**Complete**

21. Please provide raster files for the maps in Figure 5-3, Figure 5-4, Figure 5-5, and Figure 5-5.

**These are not GIS files**

22. Please provide complete lithology information for the net sands analysis.

**BEG sand tops and bottoms for net sand maps provided in separate spreadsheet.**

23. Please revise the excel spreadsheet calculator's methodology for the Rwa Minimum method of calculating salinity from geophysical well logs.

a. The freshwater ion correction for Rwa should be:

If high bicarbonates are present, then apply Alger's (1966) equation:

$$Rwa(\text{cor}) = 1.75 \cdot Rwa$$

For sodium bicarbonate groundwater, use:

$$Rwa(\text{cor}) = 1.33$$

Appendix 19-6. Comments and Responses.

The spreadsheet calculator formula states:

=IFERROR ([@Rwe]/[@[Cf\_H2O\_Type]], ""), please correct.

**Calculator is correct, no changes were necessary**

b. To solve for TDS using the specific conductivity-TDS conversion factor (ct), the equation is:

$$\text{TDS} = \text{ct} \cdot \text{Cw75},$$

The spreadsheet calculator formula states:

=IFERROR(10000/[@[Rw\_Cor\_75]], ""), please correct.

**Calculator is correct, no changes were necessary**

24. Please re-interpolate all surfaces to reflect well control data within the study area.

- |           |           |
|-----------|-----------|
| a. fr_top | k. ms_top |
| b. fr_bot | l. ms_bot |
| c. fr_thk | m. ms_thk |
| d. fr_ps  | n. ms_ps  |
| e. fr_vol | o. ms_vol |
| f. ss_top | p. vs_top |
| g. ss_bot | q. vs_bot |
| h. ss_thk | r. vs_thk |
| i. ss_ps  | s. vs_ps  |
| j. ss_vol | t. vs_vol |

**Complete**

25. Please regenerate TDS lines to reflect well control data within the study area.

- a. T1Ktds
- b. T10K\_tds\_extent

**TDS lines are correct; no changes were made to contours**

26. Please correct data structure for all MXD figure files, the data structure is broken and does not match the data structure of the associated geodatabase. This problem can be solved by relative linking of the MXD files.

**Complete**

27. Please label MXD figure files to reflect figure names (for example Figure XX-XX Caption.mxd.)

**Complete**

28. Please provide raster image files for net sand images (Figures 11-1 and 11-2).

**These are not GIS files**

29. Please provide MXD files and associated shapefiles for the numerical model result figures. (Figures 14-3 through 14-10).

**Provided shapefiles of drawdown contours and base map template used to make the figures**

**Modeling Comments – Added via email**

1. The Theis model calculations seem correct (for the given property values); however, the storativity values used for the modeling do not seem correct. Table 14-3 of the report lists the storativity values as  $1 \times 10^{-5}$ . The specific storage in the Nacatoch GAM is equal to  $1 \times 10^{-5}$  in the model areas which would make the storativity values range from 0.001 to 0.003. In addition, the model calculations actually used storativity of  $5 \times 10^{-5}$  for the drawdown calculations (based on Theis function input file provided with the deliverable). They may need to either recalculate the Theis drawdown maps or make clear in the text that they used a storativity value of  $5 \times 10^{-5}$ .

**The range of values for specific storage in layer 2 (Nacatoch) in the Nacatoch GAM is from  $1 \times 10^{-7}$  to  $1 \times 10^{-5}$  (see table 8.1.1 in Nacatoch GAM Report). We are using layer 2 data for this analysis from the GAM. The range for storativity after multiplying by the thickness is between 0.01 to  $1 \times 10^{-6}$  for the entire area of the GAM. (The suggested S value seems large).**

**For the potential production areas, they are as shown here:**

PPA	Average Storativity
1	1.41E-05
2	2.70E-05
3	3.11E-05
4	3.11E-05

2. The hydraulic conductivity value for potential production area 3 seems very high compared to the value in the Nacatoch GAM. In the GAM the hydraulic conductivity in that area is less than 1 foot per day; however, the Theis modeling used 3.5 feet per day (7,752 gpd/ft). Is it possible that hydraulic conductivities from Table 9.3 were used for the Theis modeling rather than values from the GAM itself? If this is the case the text should be clear about that.

**Layer 2 of the Nacatoch Aquifer GAM was used for the hydraulic conductivity values, and within the area of potential production area 3 it is split between values between 0.1 and 3.5 feet per day. Initially, only the higher hydraulic conductivity value was used in this area. That has been corrected to take the average hydraulic conductivity over the potential production area, lowering the overall transmissivity (Table 14-3).**

3. I suggest that they add some discussion on the Theis method with assumptions and limitations of the approach.

**Complete.**

Appendix 19-6. Comments and Responses.

4. In the conclusions the report states that the modeling results indicate that ~42,000,000 acre-feet of in-place groundwater exist. This number is probably based on the framework from the GAM; however, the brief write-up may be interpreted to mean that the Theis modeling would suggest this amount is available in the potential production areas. I suggest they make a clear distinction between the Theis modeling results and the volumetric calculation from the GAM.

**Complete**



