

# **RPSEA**

## ***Feasibility of Using Alternative Water Sources for Shale Gas Well Completions — Final Report***

***Report No. 08122-05.08A***

### ***Barnett and Appalachian Shale Water Management and Reuse Technologies***

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# **Feasibility of Using Alternative Water Sources for Shale Gas Well Completions**

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## ABSTRACT

The study presented in this document investigates alternative sources of water to be used in the last completion phase (so-called “fracing”) of gas wells in the Barnett Shale play. It focuses on more rural counties (Montague, Jack, Palo Pinto, Parker, Erath, Hood, Somervell, Bosque, and Hill) located to the west of the core area (Denton, Johnson, Tarrant, and Wise Counties) where the Trinity aquifer is thin or absent. Millions of gallons are needed to perform the completion phase before gas wells are put online, and, in the past years, gas operators have mostly used (1) groundwater from dedicated supply wells tapping the Trinity Aquifer, (2) surface water from large reservoirs and rivers, purchasing it from water-rights owners (private or state agencies such as river authorities), and, to a lesser extent, (3) surface water from private ponds and other water bodies, (4) treated water from municipalities and industrial users, and (5) water recycled from previous fracking operations. As gas production moves away from the core area toward the north, south, and west to access the remainder of the play, gas operators are faced with two challenges: (1) increased water scarcity and (2) measured reluctance to impact domestic and public water supplies.

The study analyzes three sources with the potential to meet those goals: (1) treated wastewater outfalls from waste water treatment plants; (2) small water bodies outside the State regulation of surface water, and (3) smallish groundwater aquifers in Paleozoic-age disconnected sand bodies west of the more plentiful Trinity aquifer. Treated waste water amount and chemical quality was obtained by mining TCEQ and federal databases and their characteristics are fairly constant throughout the year. All non-State surface water bodies were inventoried through satellite orthoimagery coverage. They were sorted into 6 size categories and computed for two selected years assumed to be representative of Texas climate cyclicity (“normal” wet and “normal” dry). The study assumes that the only water available from the surface water bodies is the balance between wet and dry conditions and that that volume is to be spent in the course of two years. The surface water quality is understood to be fresh. Groundwater availability was inferred from the construction and running of a numerical model of aquifers covering pre-Trinity Paleozoic formations making up the subsurface geology of the area of study. The development of the model was done following informal guidelines set by the State GAM program and entailed (1) development of a conceptual model that consists of a shallow flow system quickly discharging baseflow water to the streams with a general head gradient to the north; (2) a thorough and lengthy phase of data gathering (top and bottom of layers, hydraulic conductivity values) from the literature and from public-domain databases; and (3) a calibration phase of matching modeled heads to observed heads. Those aquifers provide fresh to brackish water from generally low-yield wells. The fact that the State of Texas has never catalogued North-Central Texas Paleozoic aquifers even as minor aquifers, and this is borne out by our study, strongly suggests that they can only provide small amounts of water. This, in turn, suggests that obtaining meaningful amounts of water will require long and deep screened intervals tapping into more brackish sections and producing a degraded water quality. The amount of water available was computed by taking into account projected water use from all other users (as prepared by the TWDB) and assuming that an average cumulative drawdown of 5 feet across the entire study area in the next 50 years was acceptable to all stakeholders. This value is consistent with values accepted in the State for other small aquifers. Although aquifers do contain immense amounts of

water, the amount that can be withdrawn is quickly limited by negative environmental and other impacts.

We developed an Arc-GIS tool to determine the amount of water available at any point of the study area from the three characterized water sources within a given radius (note that water might be available too from more common sources such as large reservoirs). They were chosen at 5, 10, and 15 miles. To understand the adequacy of the resource, ~1000 points were selected on a regular grid covering the area of interest and statistics on water availability were then derived. To allow for comparison of water availability all sources use the same reference unit of million gallons per month. Results suggest that, assuming a dense development of the gas resource, in most cases, enough water is theoretically available on average (~40 million gallons available vs. ~10 million gallons used per month in a 5-mile radius). However, more than half of the total is surface water making it very susceptible to droughts. Droughts will do more than drying up the surface water resource, it will also limit access to treated waste water and groundwater as conservation takes place and as more users rely on groundwater, respectively. From an economic standpoint all the alternative sources described in the study are very fragmented leading to a diffuse ownership and a likely expensive water gathering system.

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## LIST OF ACRONYMS

AF	Acre-foot
BSWCMC	Barnett Shale Water Conservation and Management Committee
GAM	Groundwater Availability Model
GCD	Groundwater conservation district
gpm	Gallon per minute
MGD	Million gallons per day
PWS	Public water system
SES	Steam electric station
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TNRIS	Texas Natural Resources Information System
TSS	Total suspended solids
TWDB	Texas Water Development Board
WWTP	Wastewater treatment plant

# 1 Introduction

This report documents findings of Task 6.0, “Determine Feasibility of Using Alternative Water Sources” of the “Barnett and Appalachian Shale Water Management and Reuse Technologies” project funded by RPSEA. It summarizes results of the milestone report of Year 1 (attached as Attachment E) and details findings of Year 2.

The impetus for the work was a realization that development for gas production in the Barnett Shale area is expanding to the west, north, and south of the core area into areas with few known groundwater resources and with some of the surface-water resources tied up for municipal use (Figure 1 shows footprint of the Trinity aquifer, Figure 2 depicts Barnett Shale well location as of mid-2011, Figure 3 displays surface-water features, and Figure 4 shows the counties of interest). There is a clear need for a coordinated approach to locating alternate sources of water and evaluating various means of water delivery to alleviate potential water-availability constraints on Barnett Shale production over the next decades. The objectives of the study as a whole were to:

1. Gather baseline data and determine current and predicted water use for all purposes,
2. Review water-quality specifications required to perform frac jobs developed by the Barnett Shale Water Conservation and Management Committee (BSWCMC) Frac Job Expert Panel and determine technical and economic feasibility of utilizing alternate sources of water,
3. Inventory sources of surface water,
4. Inventory nonconventional water sources: desalination concentrates, reclaimed water from treatment plants, low-salinity produced water, dewatering activities, etc.,
5. Interview and interact with industry operators to learn about current practices of locating alternate sources of water in counties with water limitations,
6. Determine water compositions of alternate water sources by obtaining existing data (from TWDB and TCEQ), and
7. Determine possible interactions between sources.

The overall goal was for BSWCMC/RPSEA/GTI to visualize water availability and quality below some cost threshold from any location in the study area. Although the project did not propose an economic model, all the ingredients but cost to build such model are presented below. In summary, the current model computes how much water is available within a given radius of any point in the area of interest. Three categories of water source were analyzed: outfall from small waste water treatment plants, small surface water bodies, and small aquifers. A description of the tool is provided in Attachment A whereas results are presented in the next section. Attachment B contains results of the waste water treatment plant inventory. Attachment C summarizes the surface water body study and Attachment D presents a relatively thorough study of the so-called Paleozoic aquifers of North Central Texas overlying most of the Barnett Shale footprint (except the core area).

Contributors to the work include Steve Walden and Russ Baier from Steve Walden Consulting and Cliff Lam, undergraduate at UT, for the WWTP study; Teresa Howard from the Center for Space Research at UT for the water features study; Brad Wolaver, Yun Huang, and Ruth Costley, researchers at BEG, and Ed McGlynn, Mary Hingst, and Joy Mercier graduate students at UT, for the groundwater study; and Cari Breton at BEG for help on the GIS work. Gil Strassberg developed the ArcGIS tool.

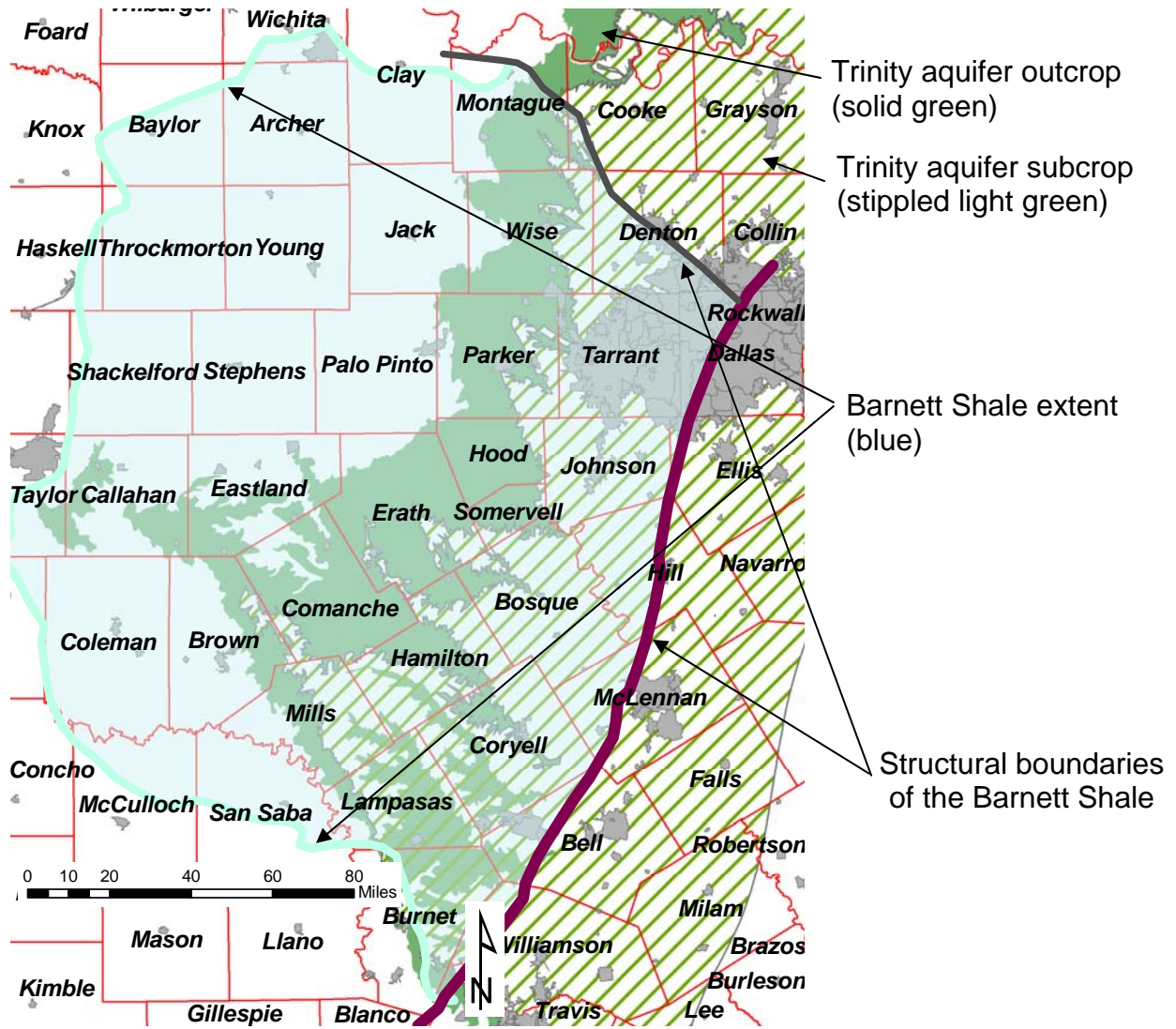
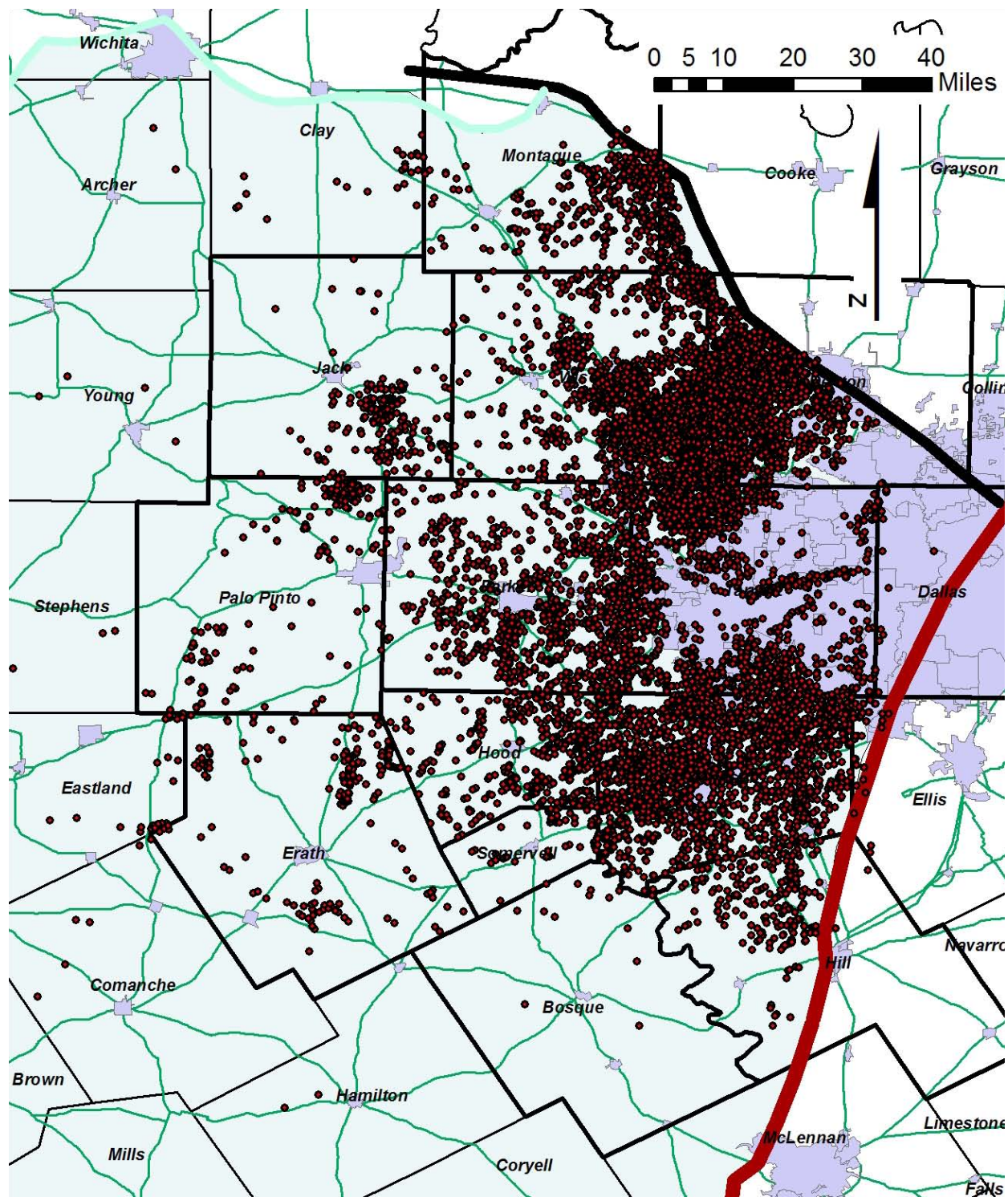


Figure 1. Barnett Shale and Trinity aquifer extents.



Note: county boundaries of area of study highlighted by thicker solid lines

Figure 2. Barnett Shale well locations (>15,000 wells as of mid-2011)

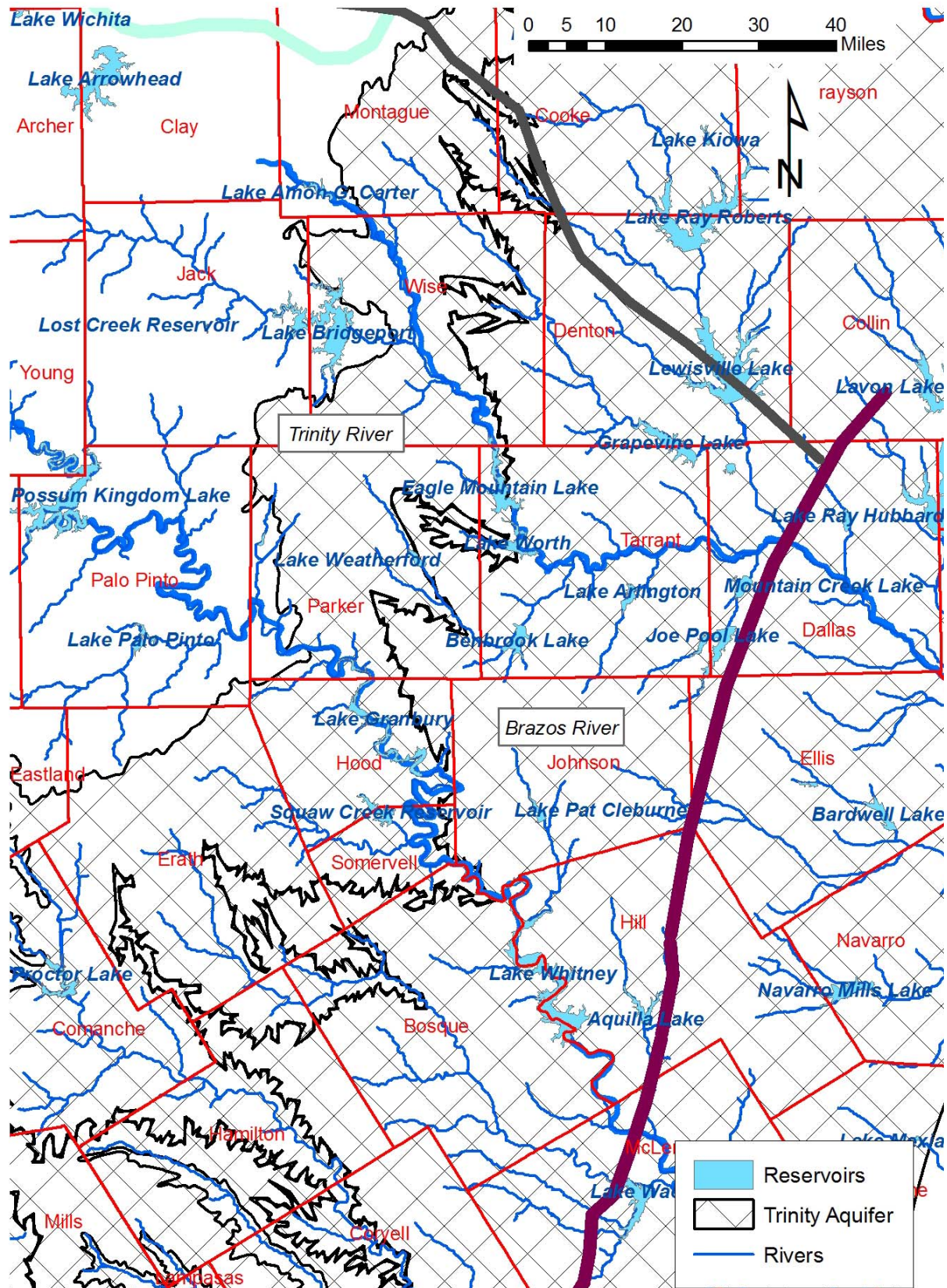
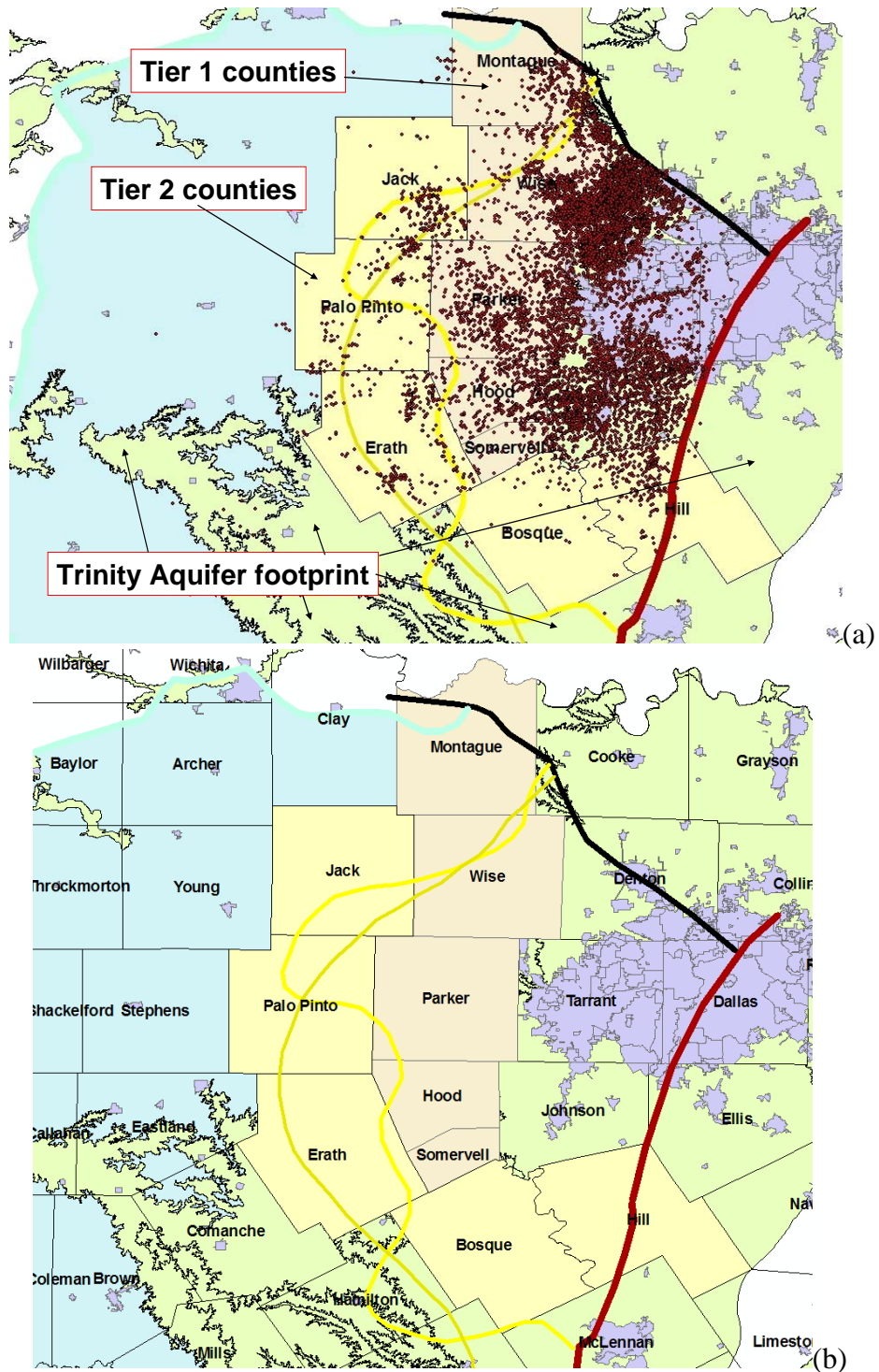


Figure 3. Rivers and reservoirs in the study area.



Note: Maps show Barnett Shale footprint, Dallas-Fort Worth metroplex, and gas-well locations through 2008. The 10 counties of initial interest are also shown: Tier1, the closest to the core area (Montague, Wise, Parker, Wood, and Somervell) and Tier2 (Jack, Palo Pinto, Erath, Bosque, and Hill). Area approximately delimited by yellow lines represents sections of shale with sufficient thermal maturity. (b) Addition of Denton, Tarrant, Johnson, and Dallas Counties.

Figure 4. Map displaying counties of interest.

## 2 Summary of Source Investigation

### 2.1 Waste Water Treatment Plant Outfall

There are approximately 160 waste water treatment plants in the area of study, 5 of them are very large (>100 MGD) and are not included in the study. Most of them are small to very small (see Attachment E). Not considering the large plants, average outfall flow is 0.689 MGD but median is much lower at 0.087 MGD. Percentiles are as follow: 95<sup>th</sup> = 4.3 MGD, 75<sup>th</sup> = 0.37 MGD, 50<sup>th</sup> = 0.087 MGD, 25<sup>th</sup> = 0.01; 5<sup>th</sup> = 0.002; minimum <0.001 MGD. Those rates are fairly constant throughout the year.

### 2.2 Surface Water Bodies

Numerous water bodies are present (for example, Figure 5) and represent a substantial amount of water even without including large lakes. Detailed statistics are presented in Attachment C. Overall there was ~31,200 and ~12,400 small water bodies totaling ~51,000 and 23,500 acres in wet and dry conditions of the selected years, respectively. Because depth of the surface water bodies is not well-know there is some uncertainty in the amount of water available. However, minimum and maximum depth are relatively well constrained. Water volume depends on weather conditions but is approximately 0.54 million AF in wet conditions and 0.2 million AF in dry conditions (Table 1), again not including large reservoirs. An important assumption applicable to smaller stock ponds is that they are filled up only through run-off and precipitation not through groundwater pumping. The assumption is reasonable as there is a large difference in number and total surface area between wet and dry years. Another concern was that the opportunity of selling water to the industry would incite landowners (how many ponds were on private land as opposed to federal, state, or city property was not explored) to create stock ponds filled with groundwater. This concern does not seem to bear out as comparison in water body count and total surface area between the reference years chosen as wet (1997) and dry (1999) (still early in the history of the play at which time gas production was restricted to the core area East of the zone of interest) and later years (2003 to 2010) shows no difference in water body coverage and count. The category 0.1-0.5 ha (0.04 – 0.20 acre) is the most numerous but the 1-10 ha (0.4 – 4 acre) covers the most surface area and contains the largest water volume (Figure 6). Note the sharp decrease in count, measured area, and estimated volume from wet to dry years.

Table 1. Summary of water body study

	Count	Measured Area (acres)	Estimated Volume (thousand AF)	Count	Measured Area (acres)	Estimated Volume (thousand AF)
	1997 (wet year)			1999 (dry year)		
< 0.1 ha	9,548	2,119	12.7	4,299	955	2.9
0.1 - 0.5 ha	14,209	9,685	58.1	5,323	3,428	17.1
0.5 - 1 ha	4,260	7,294	65.6	1,248	2,163	15.1
1 - 10 ha	2,943	18,612	223.3	1,366	10,020	90.2
10 - 20 ha	169	5,742	68.9	95	3,240	29.2
> 20 ha	75	7,505	112.6	33	3,546	42.6
<b>Total</b>	<b>31,204</b>	<b>50,957</b>	<b>541</b>	<b>12,364</b>	<b>23,352</b>	<b>197</b>

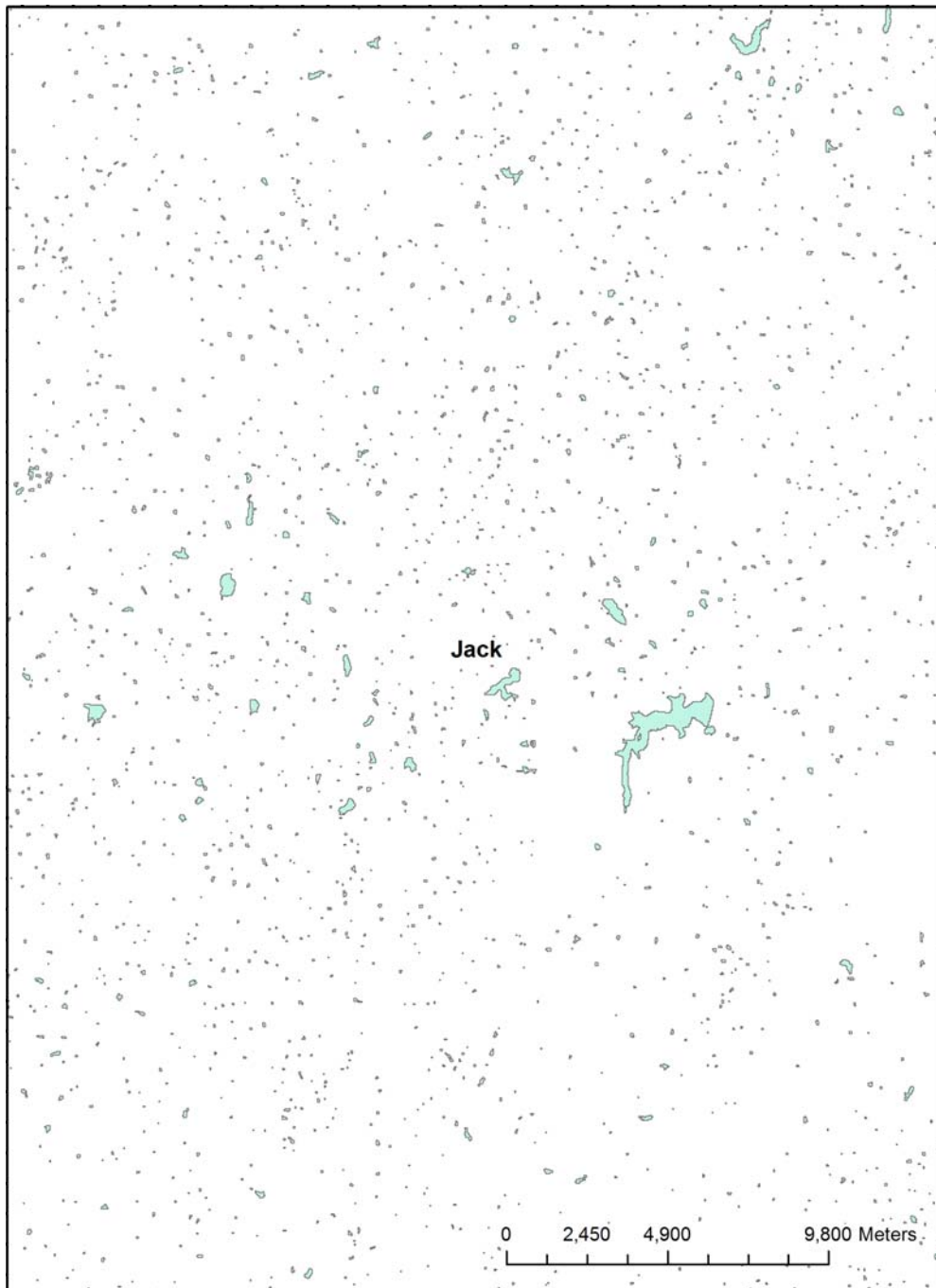
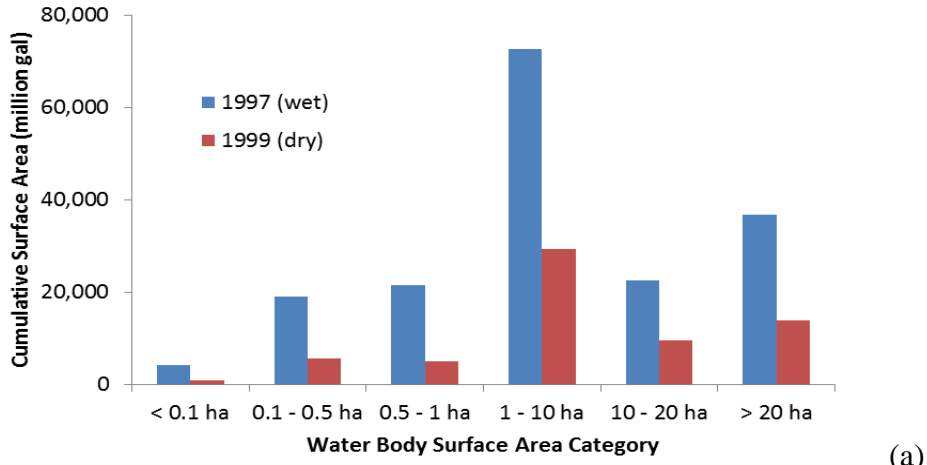
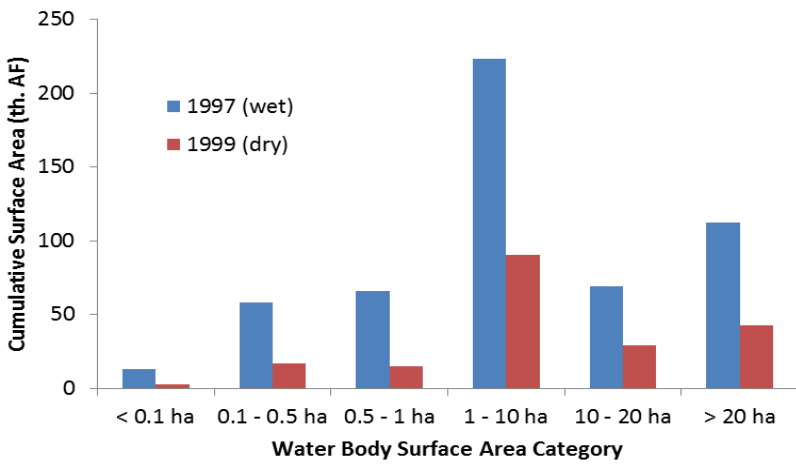


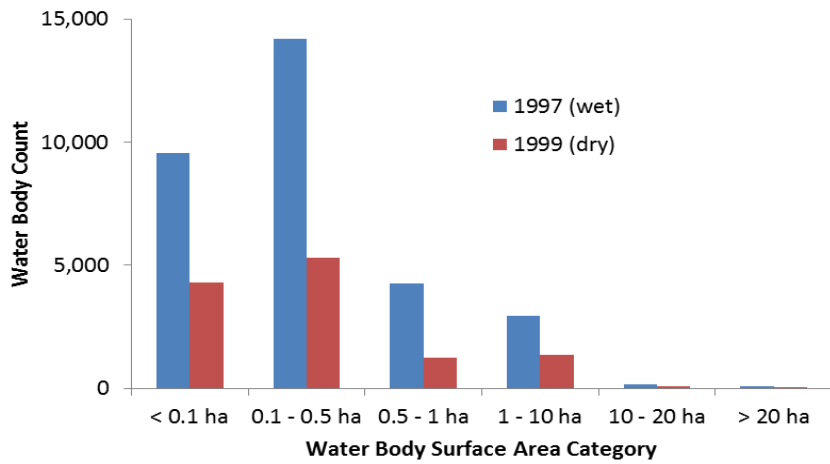
Figure 5. Example of water body distribution (Jack County, wet year 1997)



(a)



(b)



(c)

Figure 6. Summary of water body study: volume in million gallons (a) and thousand acre-feet (b) and count (c)  
 [1 acre = 4047 m<sup>2</sup> x 1.0 m = 1.07 million gallons; 1 hectare = 2.471 acres]

## 2.3 Paleozoic Aquifers

Little is known about those Paleozoic aquifers in the footprint of the Barnett Shale (outside of the Trinity Aquifer). Although part of a larger hydrological system, most of them are small in size barely covering a fraction of a county. Some are used for municipal water use (Montague County) but overall there is a need to determine what their capacity (how much water they hold), their yield (how much water can be produced from them), and water quality (is it fresh or brackish). It is important to characterize those aquifers as they might be the only water source in large sections of the Barnett Shale footprint, with no surface water bodies and no water treatment plant in those sparsely populated areas.

Aquifers, even small ones, do contain large volumes of water. However, most of it is not accessible without severe consequences (drying of springs, no base flow, disappearance of phreatophytes, subsidence, necessary lowering of pumps, etc). The beginning sections of Attachment D describe a way to assess the acceptable water volumes to withdraw that consists in an agreed-upon average water drop (also called drawdown). In agreement with the bottom up approach generally accepted for water management in Texas (and neglecting complexities brought out by local conservation district rules, rule of capture, exemptions for oil and gas industry), local stakeholders determine the acceptable drawdown level. Towards the end of the project during Summer 2011, we performed a quick survey and contacted several small utilities (Table 2) and asked the following questions: (1) Are you satisfied with the adequacy of your current supply?; (2) What is your perception of the Barnett Shale fracking in your area? The success rate was about 44%, that is, out of 9 utilities contacted, 4 responded. They were all concerned by the Barnett Shale development because of potential depletion of the aquifer and because there is no substitute to groundwater in their area. 3 out of the 4 respondents mentioned that they have not access to surface water. In agreement with those concerns and as explained in Attachment D, we computed the pumping level (including all uses) corresponding to an average drawdown of 5 feet in 50 years (in 2060). However, as displayed in Table 3 and depicted in Figure 7, drawdowns are not constant throughout the area. Note that a simple geometric analysis (5 ft times specific yield times aquifer surface area) is inaccurate and that a numerical model was needed because aquifers are by nature dynamic systems with water coming in (through recharge) and out (to stream baseflow for example) in a complex way.

Making use of information presented in Attachment D (giving time-constant but county-varying permissible pumping levels in addition to the “natural” use), the modeling suggest that current pumping can be increased **on average** by a factor of 200% and that the aquifer will still meet the average 5-ft requirement (Table 4). However it is clear that, as depicted on Figure 7, relatively large areas of the region of interest will not be able to achieve such a large pumping increase.

An evaluation of Paleozoic water well characteristics in our 2,474-well database reveals median values for depth of 200 feet, discharge rate of 11 gallons per minute, and screen length of 35 feet. Our work also shows that 25<sup>th</sup> to 90<sup>th</sup> percentile transmissivity and permeability vary spatially across the study area within two log cycles. We assume that aquifer properties are similarly homogeneous with depth. Groundwater total dissolved solids are generally potable <300 feet, but increase rapidly down dip. Thus, in order to produce required water volume, we recommend wells with long (i.e., possibly 100s of feet) well screens. To assure that produced water is of acceptable water quality we suggest that groundwater quality be characterized prior to completion using the approach of the TCEQ Surface Casing Division. A small-radius pilot borehole can be drilled relatively rapidly and inexpensively though the longest section that could

be potentially screened. Standard, inexpensive well logs could be run on the borehole (i.e., SP, gamma, resistivity) for two purposes: (1) to identify permeable sand layers – which can be used to inform selection of final well screened intervals, and (2) to estimate groundwater salinity using the SP log following the approach of Estepp (2010). The SP log salinity estimate can be used to plan the final well total depth – avoiding completion in section with groundwater salinity above acceptable limits. The pilot borehole can be reamed out to the total recommended depth – potentially saving money by avoiding drilling the wider diameter final borehole into potentially unproductive deeper zones. Casing and screen can be selected based upon geophysical logs run in the pilot borehole to optimize the well design to only screen across permeable, sand-rich horizons – also potentially saving money.

Table 2. Public water systems extracting water from the Paleozoic aquifers (from TCEQ PWS database)

PWS	WATER SOURCE	WELL DEPTH	AQUIFER	AQUIFER_NAME	COUNTY	Disch. (GPM)	LATITUDE DD	LONGITUDE DD	PWS NAME
0390013	G0390013B	453	321CSCO	Pennsylvanian Age A.	Clay	90	33.63064575	98.01481628	City of Bellevue
1190001	G1190001B	275	321CSCO	Paleozoic Erathem Age A.	Jack	90	33.17731476	98.37545013	City of Bryson
1190008	G1190008D	200	321PLPN	Pennsylvanian Age A.	Jack	50	33.03366667	98.02388611	Mitchell RV Park
1190005	G1190005D	280	321PLPN	Pennsylvanian Age A.	Jack	23	33.03059006	98.07444	Perrin Water System
1690006	G1690006G	700	321CSCO	Pennsylvanian Age A.	Montague	150	33.68832779	97.52497101	City of Saint Jo
1690009	G1690009E	720	300PLZC	Paleozoic Erathem Age A.	Montague	133	33.83555603	97.64994049	Nocona Hills WSC
1690009	G1690009B	310	318WCHT	Permian Age A.	Montague	110	33.83845556	97.62058333	Nocona Hills WSC
1690007	G1690007C	500	300PLZC	Paleozoic Erathem Age A.	Montague	70	33.45064545	97.76604462	Sunset Water System
1690014	G1690014B	210	318WCHT	Permian Age A.	Montague	60	33.67536111	97.90467778	Gold Burg High School
1690011	G1690011A	500	300PLZC	Paleozoic Erathem Age A.	Montague	60	33.87747192	97.64012146	Oak Shores Water System
1820052	G1820052A	360	324MLWL	Pennsylvanian Age A.	Palo Pinto	15	32.8136	98.11408611	Famous Mineral Water
2490001	G2490001B	381	300PLZC	Paleozoic Erathem Age A.	Wise	131	33.35933056	97.69505833	City of Alvord
2490001	G2490001A	415	300PLZC	Paleozoic Erathem Age A.	Wise	120	33.36277771	97.69222226	City of Alvord
2490033	G2490033G	147	300PLZC	Paleozoic Erathem Age A.	Wise	20	33.16977778	97.834	Bay Landing at Runaway Bay

Table 3. Summary of simulated drawdown

Layer#	Layer Name	Mean Drawdown (ft)	Maximum Drawdown (ft)	Cell Count
1	Wichita	14.1	72	3168
2	Cisco	6.2	174	15,703
3	Canyon	3.9	95	8773
4	Strawn	3.0	633*	17,695
<b>Weighted Average (ft)</b>		<b>5.06</b>		<b>45,339</b>

\*: the presence of dry cells in the model towards the end of the runs makes this maximum dubious and not necessarily realistic

Table 4. Aquifer pumping summary

<b>County</b>	<b>Total Pumping* (m<sup>3</sup>/d)</b>	<b>Add. Pumping** (m<sup>3</sup>/d)</b>	<b>Add. Pumping** (MGD)</b>	<b>Add. Pumping** (MGal/yr)</b>
Archer	2,228	0	0	0
Callahan	263	0	0	0
Clay	27,500	23,949	6.33	2,311
Eastland	2,196	0	0	0
Erath	1,644	938	0.25	91
Jack	14,400	11,849	3.13	1,143
Montague	8,951	8,019	2.12	774
Palo Pinto	13,126	9,450	2.50	912
Parker	2,018	1,463	0.39	141
Shackelford	357	0	0	0
Stephens	4,034	0	0	0
Throckmorton	428	0	0	0
Wichita	1,517	0	0	0
Wise	2,326	1,738	0.46	168
Young	2,404	0	0	0
<b>Grand Total</b>	<b>83,391</b>	<b>57,406</b>	<b>15.17</b>	<b>5,539</b>

\*: Average of year 2010-2060; variations from average are small (~1,000 m<sup>3</sup>/d); total pumping include the so-called additional pumping category

\*\* : Additional pumping required to reach the drawdown goal of 5 feet, only in those county in which hydraulic fracturing is likely to take place.

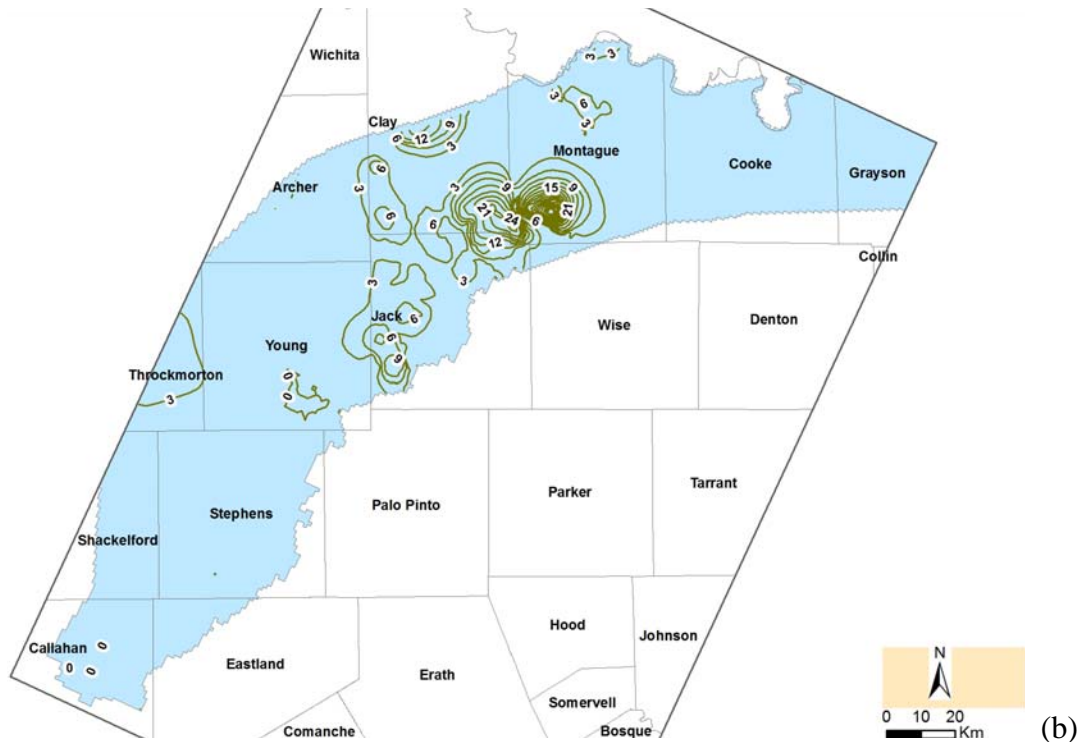
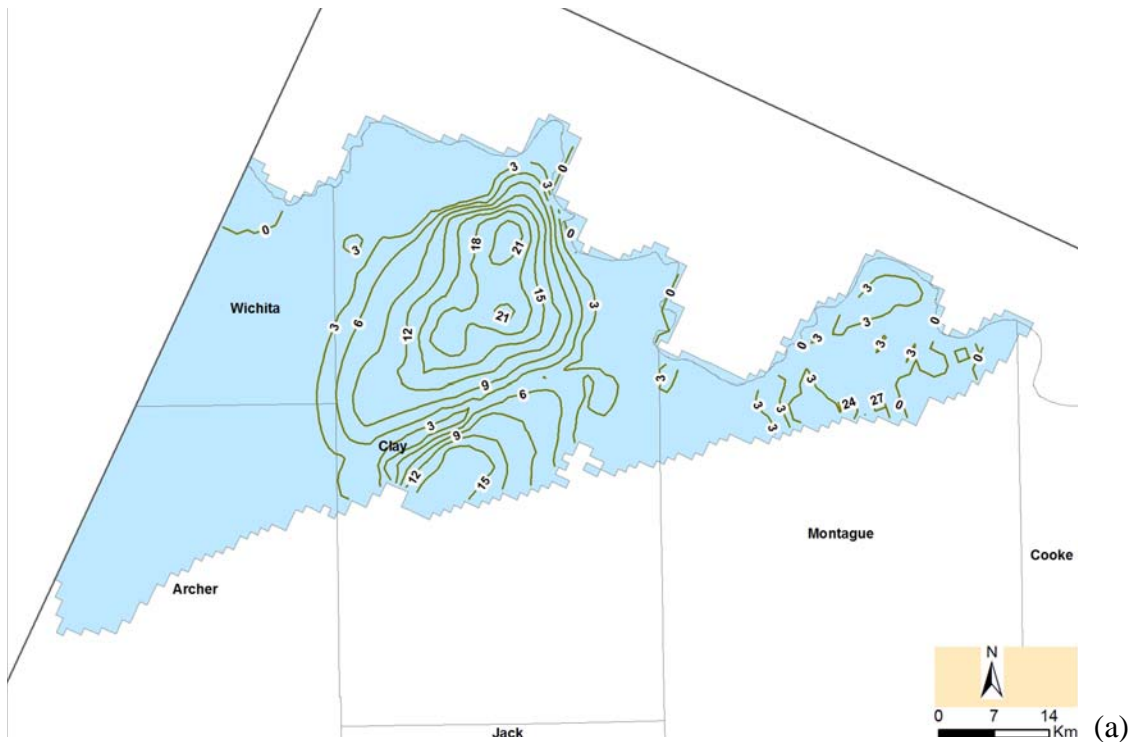


Figure 7. Simulated drawdown between 2010 and 2060 (3 m contour interval) for Wichita (a), Cisco (b), Canyon (c), and Strawn (d) layers

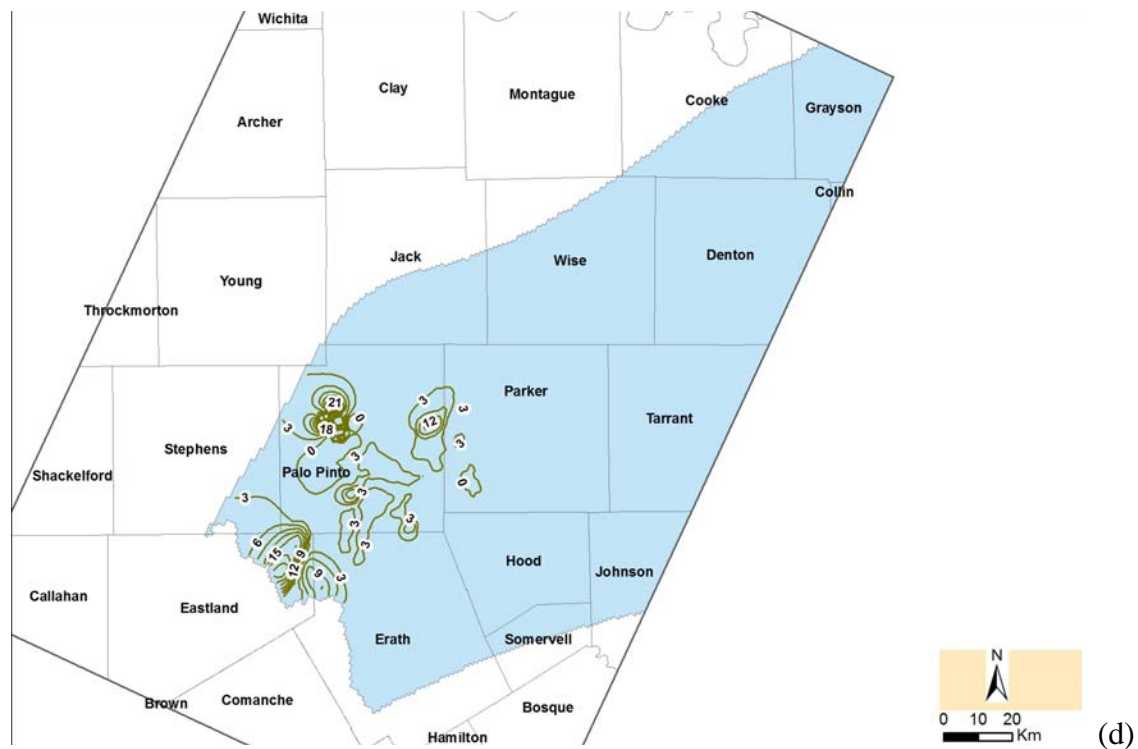
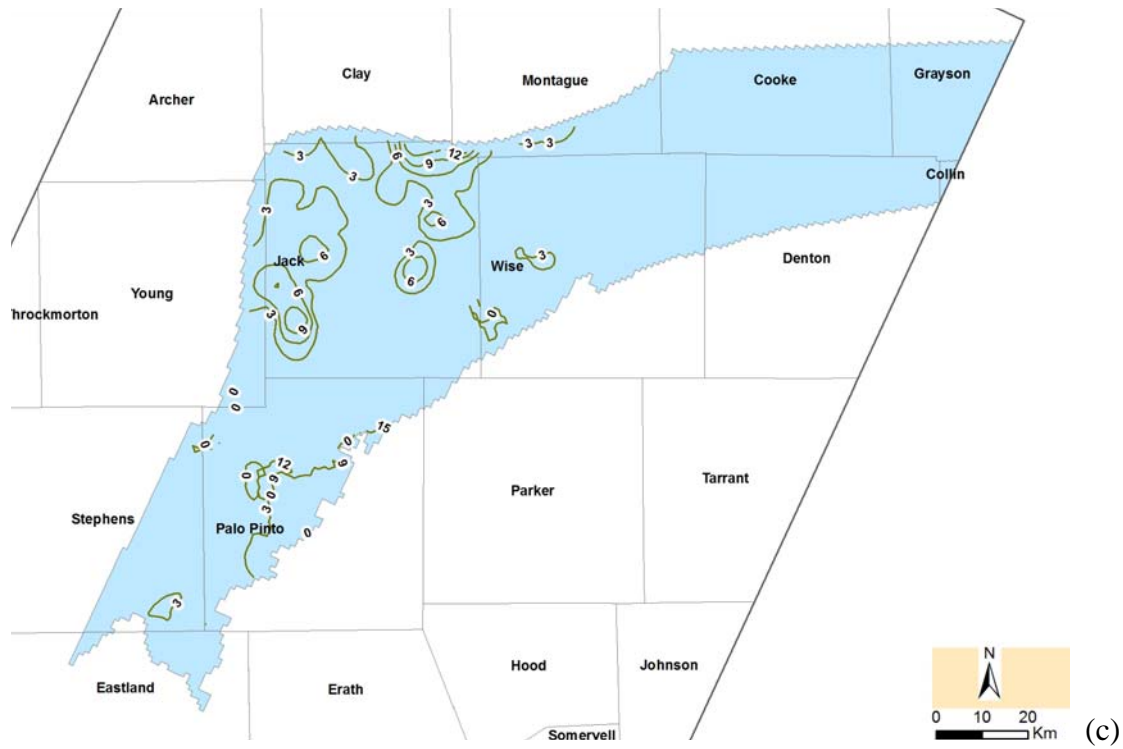


Figure 7. Simulated drawdown between 2010 and 2060 (3 m contour interval) for Wichita (a), Cisco (b), Canyon (c), and Strawn (d) layers (continued)

## 3 Overall Results

### 3.1 Definition of Availability

Treatment plant outfall, surface water bodies, and aquifers represent vastly different water source types. A unifying concept consists in characterizing them by two parameters: capacity or storage and yield. The former addresses how much water is available at a given time, the latter informs on how fast the water can be accessed. Treatment plant outfalls have no capacity but sustained known yield. If the water is not used immediately it is discharged into streams or lakes, becomes water of the state, and is lost for the purpose of this work. Aquifers have a large storage capacity but delivery of the water is constrained by the maximum well yield and the ability of the aquifer to recover. It should be noted to this project restricts itself to alternate sources of water, that is, the Trinity Aquifer, major aquifer overlying the core area of the Barnett Shale is not part of the study. Surface water bodies are relatively numerous and widespread across the area of interest but most of them are small with limited capacity even few large bodies exist. To summarize, treatment plants: no capacity, possibly large yield; surface water bodies: large capacity, medium to large yield; aquifers: medium capacity, small yield. A third qualifier (distance) can be added and defined with the same two end members: treatment plants exist only at very well-defined locations and are not that common whereas aquifers are ubiquitous even if not necessarily productive at every location. Surface water bodies are relatively common but mostly small. In the surface water study presented in Attachment C, a dry year and a wet year are used as representative end members.

Although the three categories have their own units of convenience, we need to express them under a unique system in order to compare them. Several approaches can be devised to reach such objective. The approach chosen in this work is to notice that operators store most of the needed frac water on site in the few weeks leading to the fracking of the well. We assumed that that lead time is one month ( $1/12^{\text{th}}$  of a year). Treatment plant data is expressed as a rate (gallons per day, gpd) and represents an annual average expressed as an average daily rate. We assume such water source is available year-round. Surface water body reference characteristic is volume. However, not all of the water is necessarily available. The primary purpose of the ponds / water bodies is irrigation, cattle, and for the smallest stock ponds fish farming. We assume that the true water available is the volume difference between wet and dry years. How much can be withdrawn from them in a short period of time is more related to pump power. Another, maybe more relevant, factor is how fast the ponds can be replenished. Making the assumption that Texas weather oscillates between “normal” dry and “normal” wet years on average, this volume of water can be used up over a period of 24 months.

The amount of water stored in aquifers is large but not all is available and it can be withdrawn, in this particular study, only at relatively low rate. Total available water results from a combination of water available in unconfined (or water-table) and confined sections of the aquifers. The former consists of actual drainage of the pore space whereas the latter represents water made available through the drop in pressure in the aquifer without actual drainage of the pore space. Confined conditions typically occur with stacked aquifers with only the top one being unconfined. The numerical model developed in this study consists of 4 units whose most of available water is understood being unconfined. The aquifer metric used is based on the assumption that an average drop across the whole area of interest of 5 feet in 50 years is acceptable (including all groundwater use from all other users). With the help of the aquifer

numerical model, we were able to determine the level of pumping that would generate such an average drawdown. An additional element is the ability of the aquifer to provide such water. At the county level, the topmost cells (that is, the shallowest aquifer at that location) included in the 33% highest percentile of transmissivity were selected. Transmissivity is the product of hydraulic conductivity and aquifer thickness measuring the ability of the aquifer to provide a sustained rate. Although all topmost cells in a given county were assigned the same pumping rate, variability arises because they are clustered following geological parameters (see Attachment D). Aquifer water availability is then defined as the amount of water that can be pumped in a month from the aquifer.

To illustrate and contrast results from the different water sources, we calculated the amount of water available from points on a grid (Figure 8). They are numerous enough (982 points) to be representative of any point in the area of interest ( $\Delta x = 4406$  m and  $\Delta y = 4530$  m). The tool could be used at any given point outside of the chosen set and is accurate for treatment plants, somewhat less accurate for surface water bodies (because of the uncertainty on depth), and the uncertainty is higher for groundwater use because the model is regional in nature (that is, acceptable in its general behavior but not necessarily accurate at the local scale). At each point of the grid, we computed water availability in a 5-mile (8 km), 10-mile (16 km), and 15-mile (24 km) radius (respectively, Figure 9, Figure 11, and Figure 13). Note that only alternate water sources are considered. Large lakes, most dam reservoirs, and the Trinity Aquifer, when available, are not included in the water availability figures.

Not surprisingly the amount of water available increases as the search radius increases. For treatment plants, from none (in most cases) or less than 5 million gallons per month (8-km radius case) to none (~30% of cases) to less than 15 million gallons per month in the 16-km radius case to none (in ~15% of cases) to a solid 5 to 10 million gallons per month and a large spread all the way to 180 million gallons per month in the 24-km radius case. Surface water is generally available (except at 10 to 15% of the locations) with a large spread and no clear mode to 150, 400, and 800 million gallons per month in the 8-, 16-, and 24-km radius case, respectively. Groundwater is not available from wells with sufficient yield at 50%, 33%, and 21% of the locations in the 8-, 16-, and 24-km radius case, respectively. When it is available amount ranges from a few million gallons per month to ~30, ~80, and ~150 million gallons per month in the 8-, 16-, and 24-km radius case, respectively. The combined amount displays a clear mode at ~35 million gallons per month with a long tail to ~150 million gallons per month in the 8-km radius case but is more uniformly distributed in the 16- and 24-km radius case ranging from almost nothing to 500 and 950 million gallons per month, respectively.

The average distance (Figure 10a, Figure 12a, and Figure 14a) weighted by water amount has modes (with a small spread) at 3.5, 6.5, and 10.5 km in the 8-, 16-, and 24-km radius case, respectively. Attachment D documents well discharge from multiple domestic wells. Because of the construction of the database, several, sometimes many, wells fall at the same location (centers of map quadrangles). One can then take the median or 95<sup>th</sup> percentile well discharge at the quadrangle locations, contour the values and interpolate them at the model grid centers, and then sample the grid centers at the 982 locations depicted in Figure 8. The median value is representative of what a typical domestic well would withdraw from the aquifer but most likely the aquifer can supply more water than withdrawn for domestic use. In that sense the 95<sup>th</sup> percentile is closer to what a higher capacity well would provide to operators. Figure 10b-c, Figure 12b-c, and Figure 14b-c show a large range for both the median and 95<sup>th</sup> percentile cases.

The six plots are not very different; they all show a broad mode in the 30-40 gpm range. Such a range, assuming continuous pumping for a month, would yield between 1.3 and 1.75 million gallons. The median transmissivity (of all grid cells within the stated radius) displayed in Figure 10d, Figure 12d, and Figure 14d provides information on the potential of the aquifer to deliver water. The parameter has a wide range (from ~0 to >1000 ft<sup>2</sup>/day) but with a mode around a 300 ft<sup>2</sup>/day. It corresponds, assuming a productive thickness of 50 ft to a conductivity of 6 ft/day (equivalent to a permeability of 2.1 darcy). These are small transmissivity values. Percentile information from the data presented in Figure 9 to Figure 14 is presented in Table 5.

Table 5. Summary of results: water availability distribution by category

	Treatment Plant (Mgal/month)	Surface Water (Mgal/month)	Ground water (Mgal/month)	Combined (Mgal/month)	Average Weighted Distance (miles)	Groundwater Discharge Median (gpm)	Groundwater Discharge 95th Percen. (gpm)	Transmissivity Median (ft <sup>2</sup> /day)	Transmissivity 95th Percen. (ft <sup>2</sup> /day)
<b>5 miles (8 km) radius</b>									
5 <sup>th</sup> Percen.	0.0	0.0	0.0	5.2	2.7	8.8	14.8	3.3	35.2
Median	0.0	35.9	0.0	42.7	3.3	27.6	33.4	301	767
95 <sup>th</sup> Percen.	45.6	98.3	22.6	118	4.0	42.6	49.4	1675	3799
<b>10 miles (16 km) radius</b>									
5 <sup>th</sup> Percen.	0.0	0.0	0.0	33.6	5.7	9.4	18.6	4.6	158
Median	7.1	183	8.9	223	6.6	27.5	36.2	316	1239
95 <sup>th</sup> Percen.	117.1	358	70.6	447	7.6	39.4	49.6	1195	3859
<b>15 miles (24 km) radius</b>									
5 <sup>th</sup> Percen.	0.0	0.0	0.0	79.4	8.8	10.0	21.2	5.7	297
Median	44.7	382	31.5	462	10.0	27.4	37.8	316	1750
95 <sup>th</sup> Percen.	167.7	682	121	838	11.1	37.2	52.5	744	3315

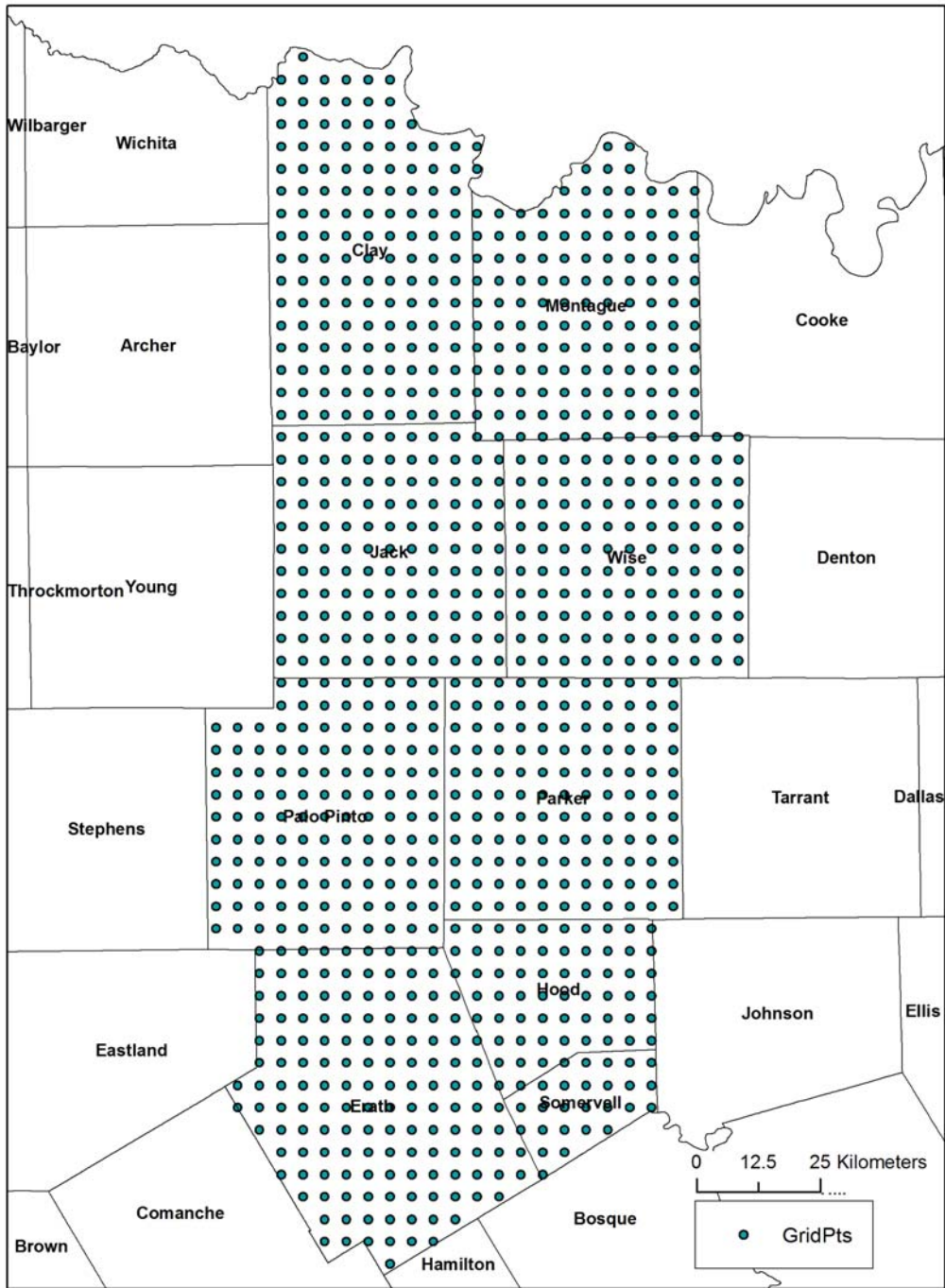


Figure 8. Location of gridpoints used to build parameter histograms

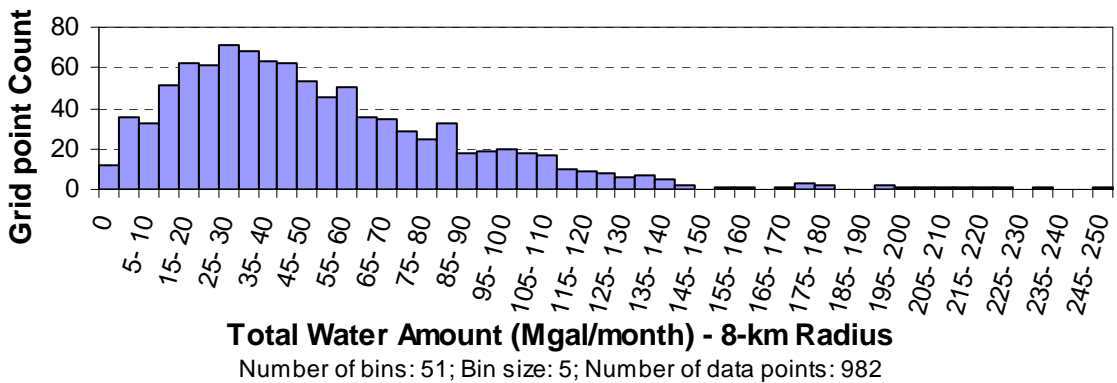
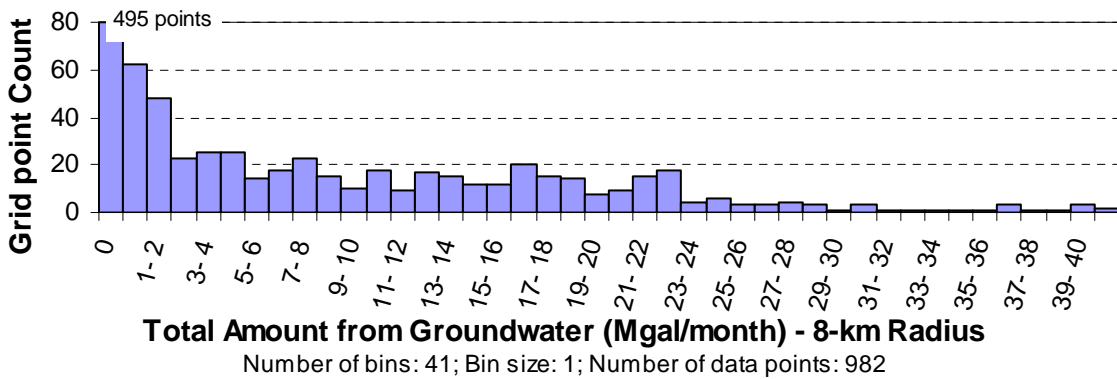
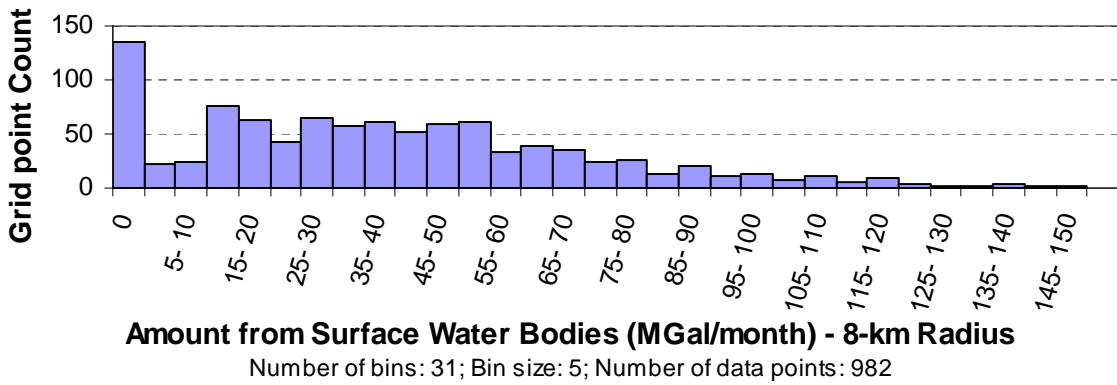
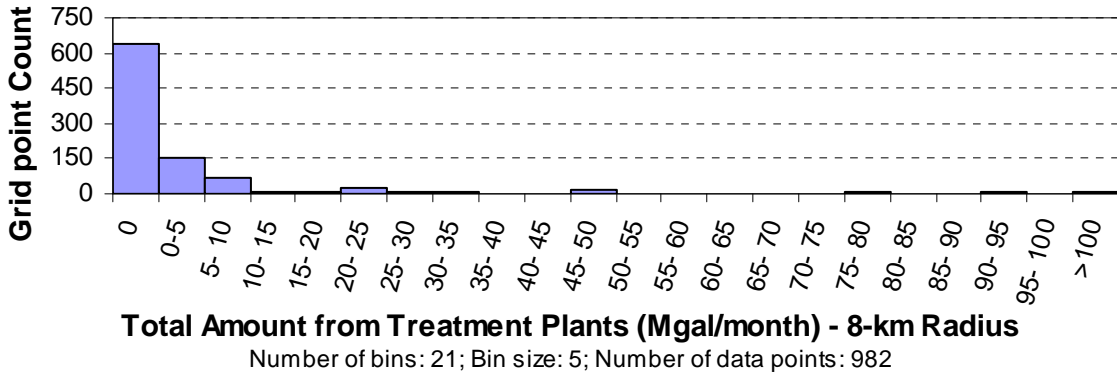
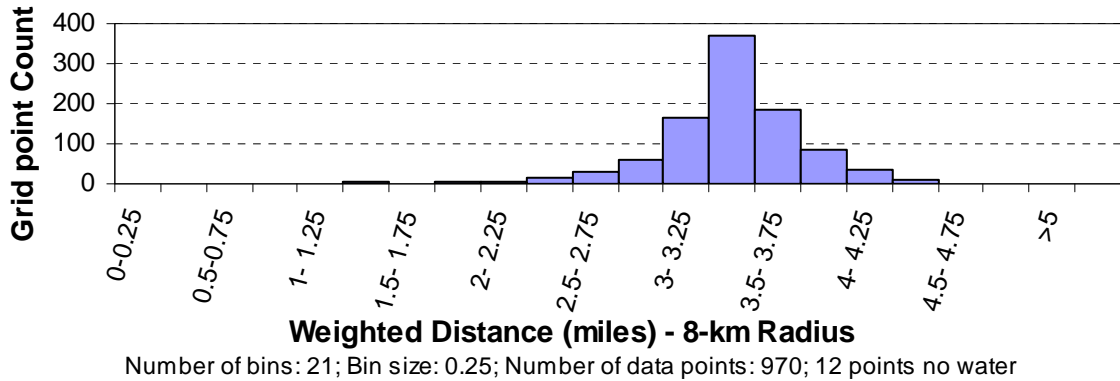
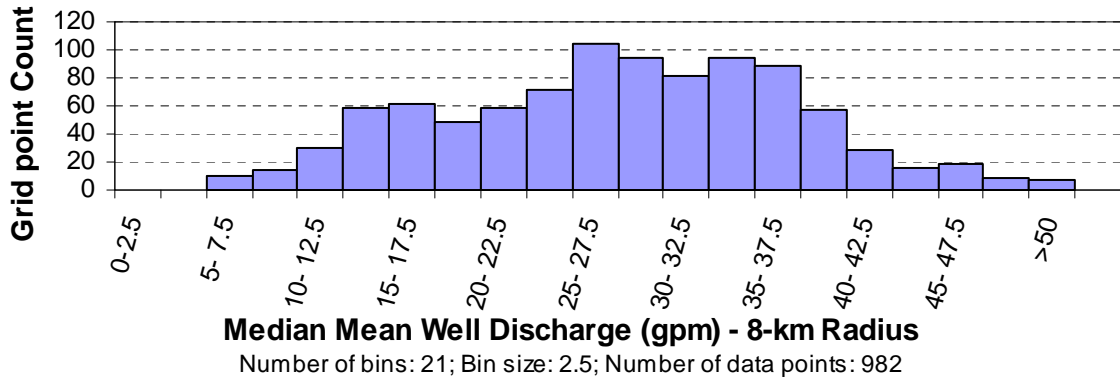


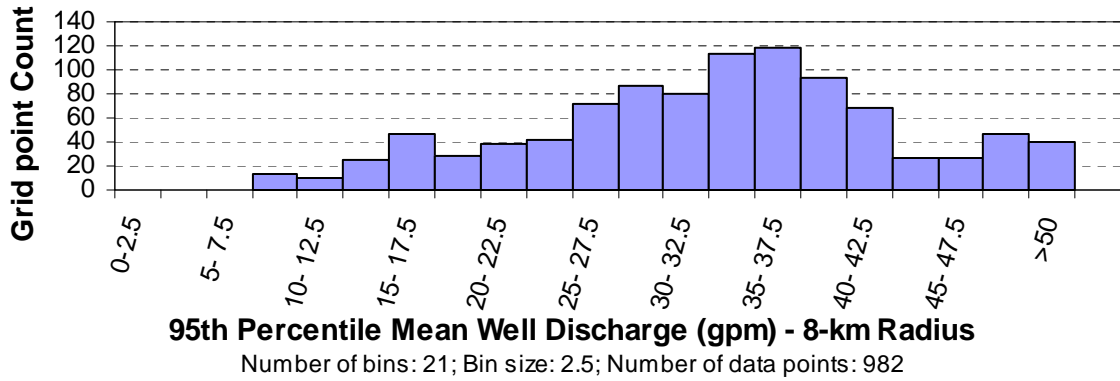
Figure 9. Distribution of available water within a 8-km radius from treatment plants, surface water bodies, aquifers, and combined sources.



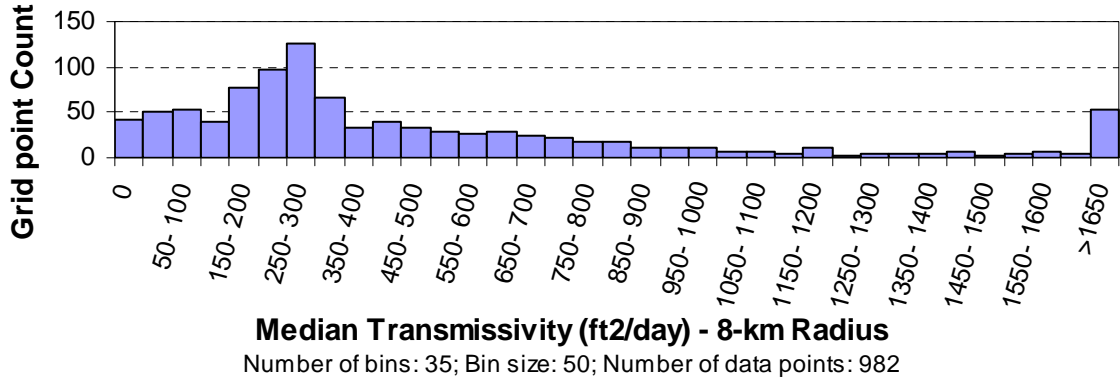
(a)



(b)



(c)



(d)

Figure 10. Distribution of weighted distance, median and 95<sup>th</sup> percentile mean well discharge, and median transmissivity in a 8-km radius.

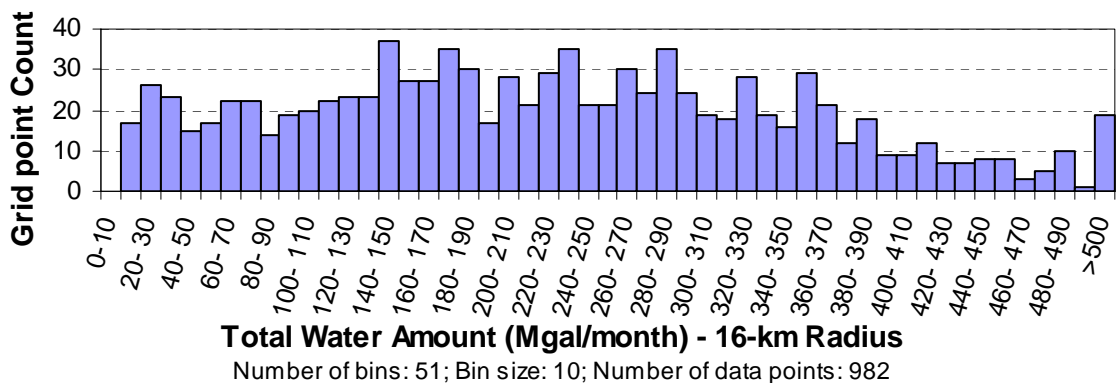
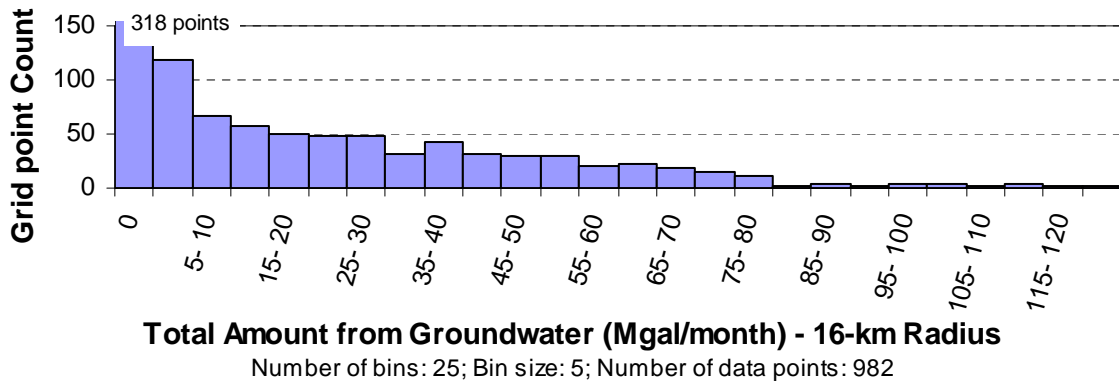
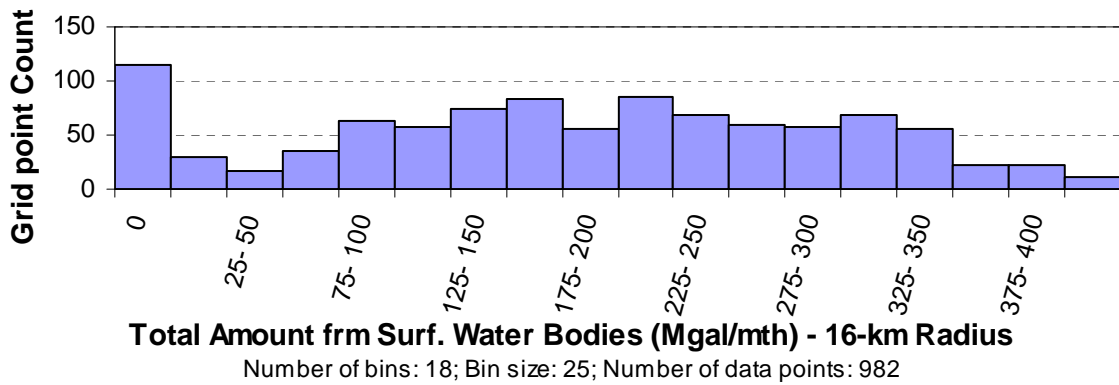
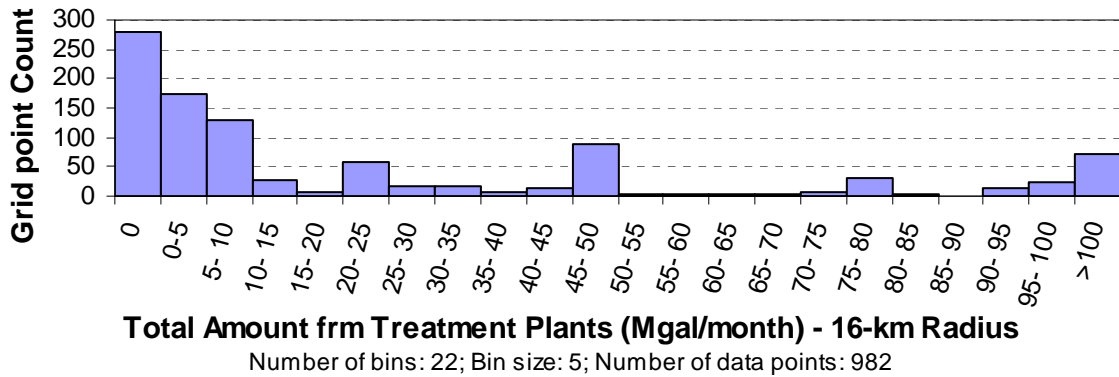
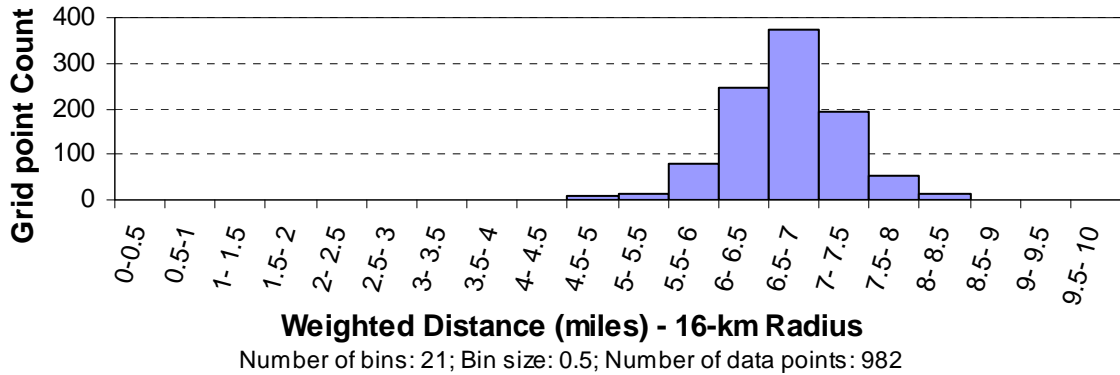
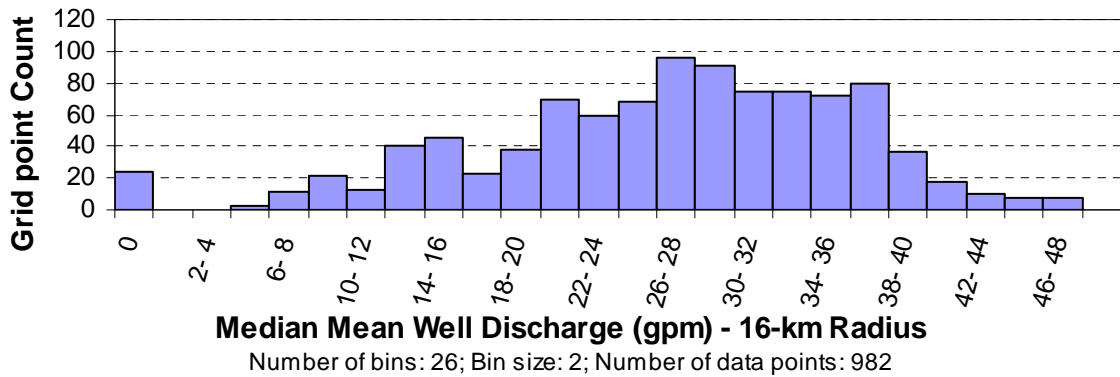


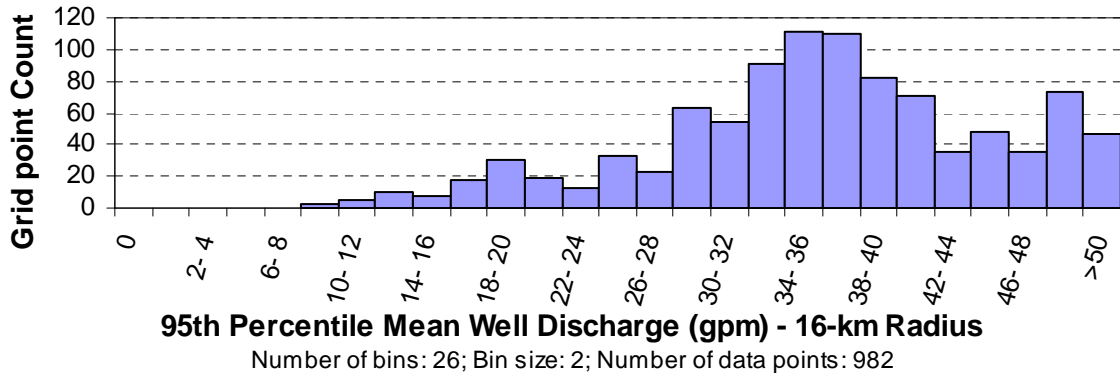
Figure 11. Distribution of available water within a 16-km radius from treatment plants, surface water bodies, aquifers, and combined sources.



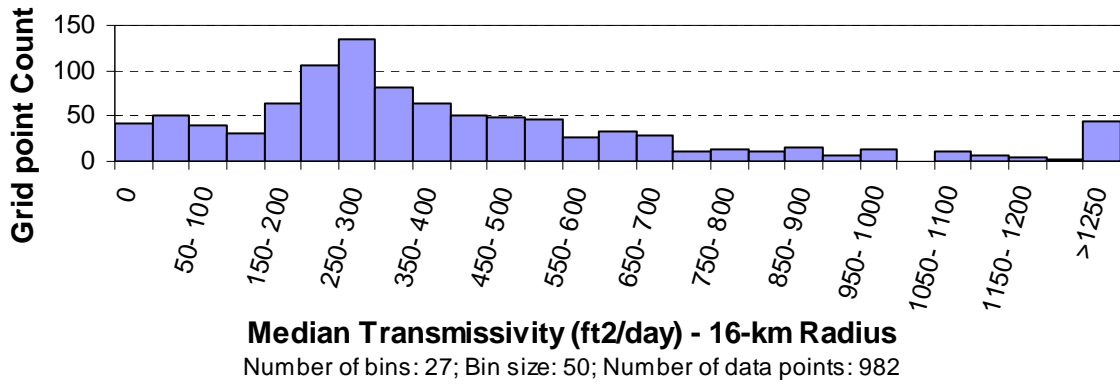
(a)



(b)

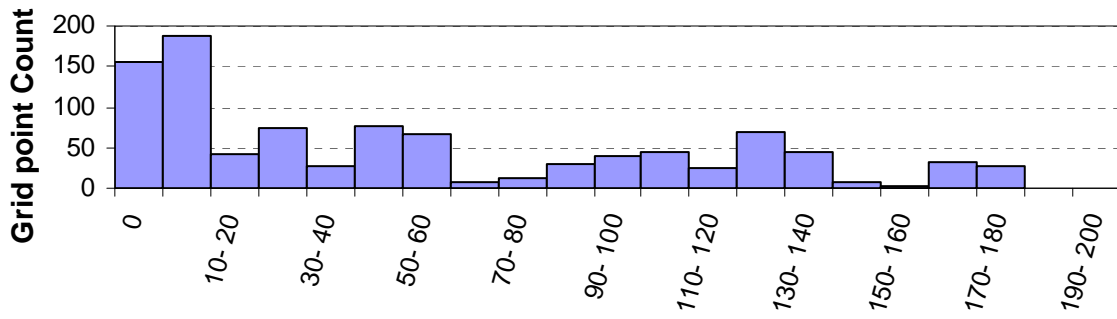


(c)



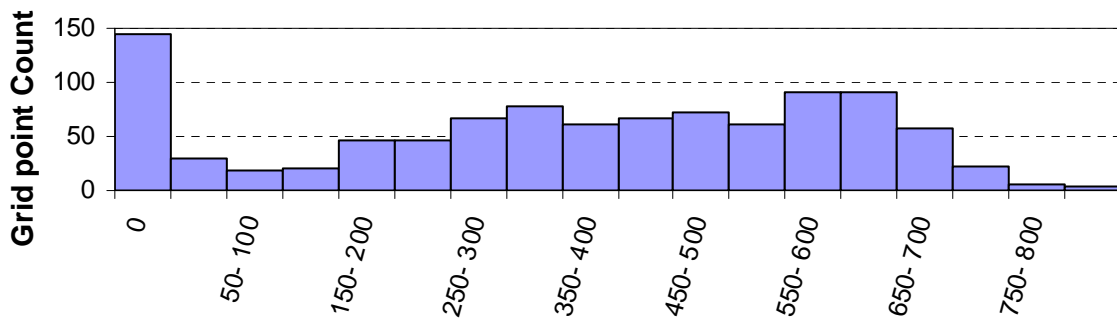
(d)

Figure 12. Distribution of weighted distance, median and 95<sup>th</sup> percentile mean well discharge, and median transmissivity in a 16-km radius.



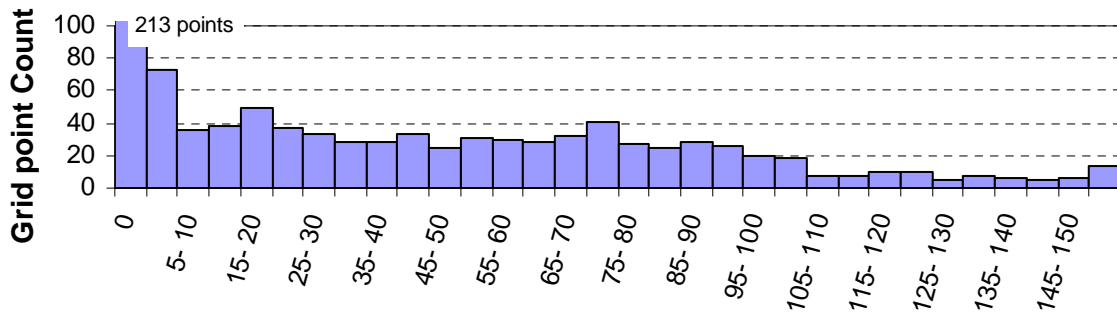
**Total Amount from Treatment Plants (Mgal/month) - 24-km Radius**

Number of bins: 21; Bin size: 10; Number of data points: 982



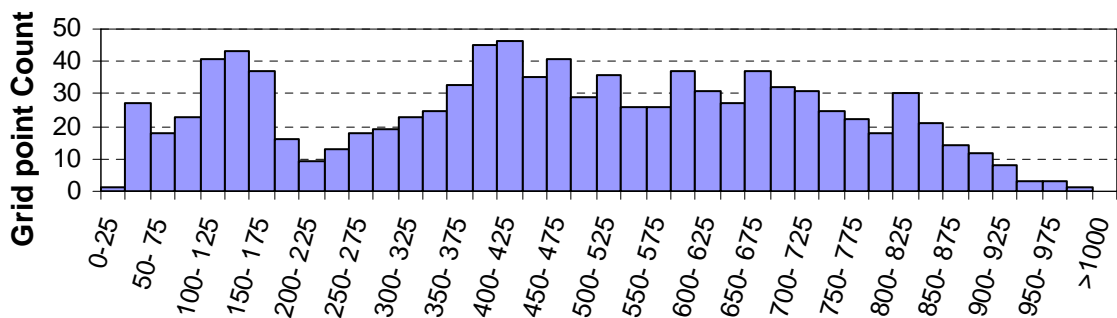
**Total Amount from Surf. Water Bodies (Mgal/mth) - 24-km Radius**

Number of bins: 17; Bin size: 50; Number of data points: 982



**Total Amount from Groundwater (Mgal/month) - 24-km Radius**

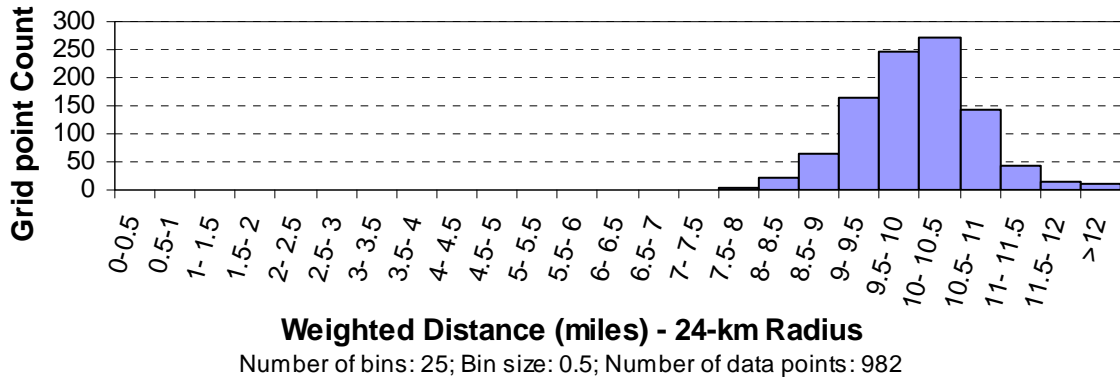
Number of bins: 31; Bin size: 5; Number of data points: 982



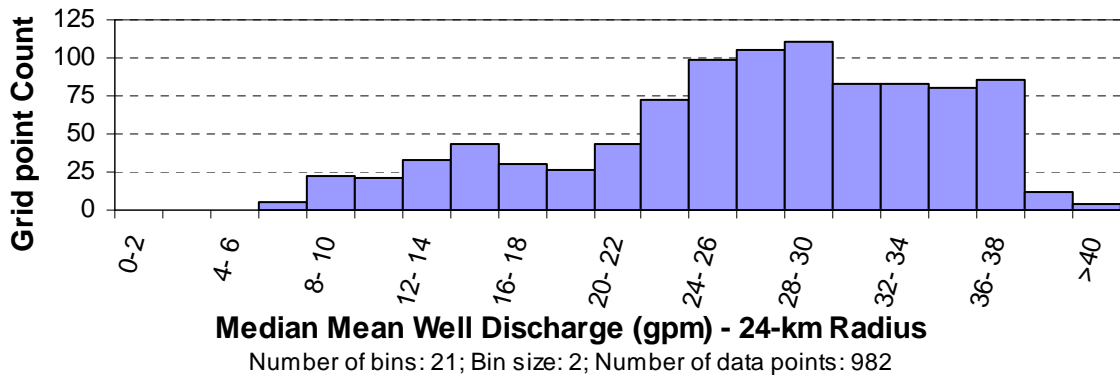
**Total Water Amount (Mgal/month) - 24-km Radius**

Number of bins: 41; Bin size: 25; Number of data points: 982

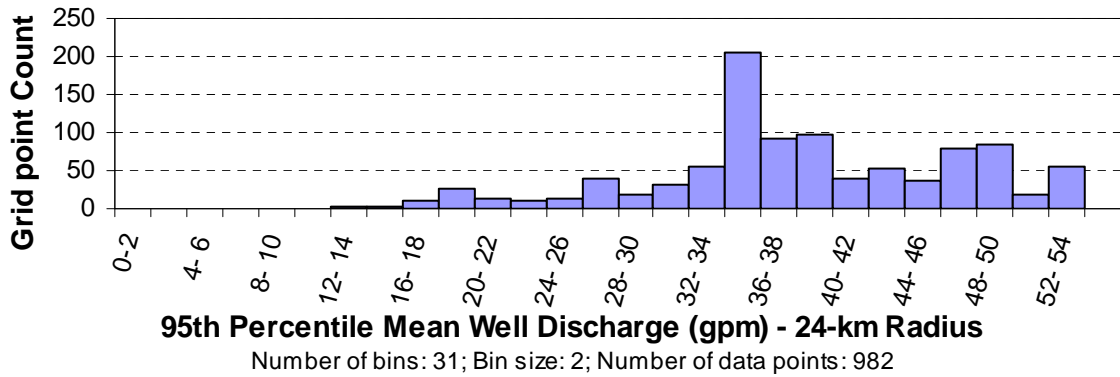
Figure 13. Distribution of available water within a 24-km radius from treatment plants, surface water bodies, aquifers, and combined sources.



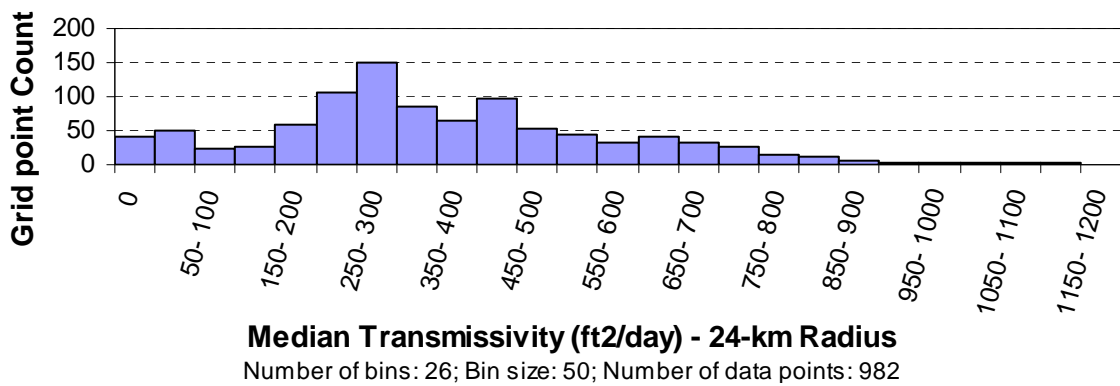
(a)



(b)



(c)



(d)

Figure 14. Distribution of weighted distance, median and 95<sup>th</sup> percentile mean well discharge, and median transmissivity in a 24-km radius.

## 4 Technical and Economic Feasibility

Table 5 suggests that, in 50% of cases, at least 42.7 million gallons will be available per month in any 8-km (5-mile radius, that can be understood as a square with 8.85-mile sides without loss of generality). To put the matter in perspective, assuming a spacing between laterals of 1,000 feet, an average water intensity of 1000 gal/foot, and a maximum coverage of laterals for gas production yields  $5280 \times 5280 \text{ ft}^2 / 1000 \text{ ft} \times 1000 \text{ gal/ft}$ , that is, a maximum water use of 27.88 million gallons per square mile or 2190 million gallons to be distributed through time. Assuming an active life of 20 years of fracking in a given area, this level of water use amounts to a water use of 9.1 million gallons per month.

Taking the analysis further, in “normal conditions” with wet and dry cycles the amount of water seems adequate, however it is very dispersed and distributed spatially, at the exception of a few larger waste water treatment plants. In addition, surface water does represent a significant fraction of the available water. In times of sustained drought (>2 years), there is no surface water available and the groundwater resource is somewhat reduced as all users relying on surface water will fall back on groundwater. Waste water treatment plant outfall availability will also be reduced because water conservation will be emphasized and because cities and towns may preempt the use of the treated water. Table 5 suggests that a drought scenario will prevent operators from using local water. The median for the 8-km radius case shows that only surface water is a plausible source of water, it will not be available during a drought. Operators would have to go further out from the well location to access the needed water. The median available water for the 16-km case is 223 million gallon per month of which ~80% is surface water not accessible in time of drought, the remainder of about 30 million gallons consists of approximately 60% groundwater and 40% treatment plant outfall (note that the median of the sum is not necessarily the sum of the medians). Because all of it will not be accessible, the amount of water theoretically available becomes very close to the amount required by operators.

What is missing from this document is a detailed economic analysis, the discussion above does not include the possibility that not all the water is actually accessible to operators because of land ownership or other factors. The extreme fragmentation of the resource also suggests a pipeline gathering system greater than 60 miles per well or equivalently trucking the water from many different places, many undoubtedly without easy road access.

Overall, in normal conditions, operators should find enough water from surface water bodies complemented by groundwater and possibly waste water treatment plant outfall. The major issue is the extreme fragmentation of the resource among many small water bodies, low-yield water wells, and some waste water streams, generating a collection cost that may not be overcome in the less productive areas of the play. In addition, drought conditions will seriously handicap production of these western counties of the Barnett play unless water is brought in from far away from either conventional or possibly alternative resources.

## 5 References

Estepp, J. D., 2010, Determining Groundwater Quality Using Geophysical Logs. Draft report 2010-XX., Austin, Texas Commission on Environmental Quality, 86p.

Nicot J.-P., Hebel A., Ritter S., Walden S., Baier R., Galusky P., Beach J., Kyle R., Symank L., Breton .C., 2011, Current and Projected Water Use in the Texas Mining and Oil and Gas Industry. Bureau of Economic Geology, The University of Texas at Austin, report prepared for the Texas Water Development Board, pp. 357.

TWDB, 2012, Water For Texas, 2012 State Water Plan



## **6 Attachment A: Water Modeling Tool Documentation**



# Water Analysis Tool – Documentation

by Gil Strassberg, Consultant to UT-BEG

December 2011

*[IMPORTANT NOTE added by PI: This tool was developed for the only purpose of facilitating the academic research performed specifically for this RPSEA project by UT-BEG staff– It was not designed and is not meant to be used by other groups. As such, this documentation provides an overview of the tool instructions but is not necessarily complete.]*

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## 1. General:

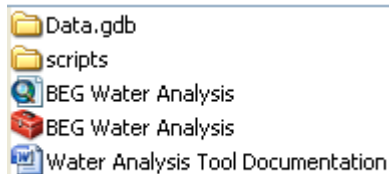
The tool creates summaries for a number of types of features surrounding a selected point.

The process includes:

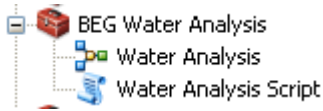
1. User specifies coordinates for a new point to be assessed.
2. User specifies a search radius around the point.
3. A search radius is created around the assessed point.
4. Features (WTP, WB, and model points) are selected within the search radius.
5. Summary statistics are calculated.
6. A new point is created in the Assessed Points feature class.
7. Summary statistics are written to appropriate fields in the Assessed Points feature class.
8. Summary report is created.

## 2. Data and Tools:

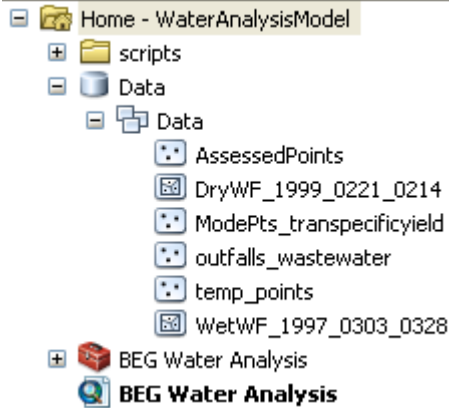
- The tool and data should be structured in the following data structure:



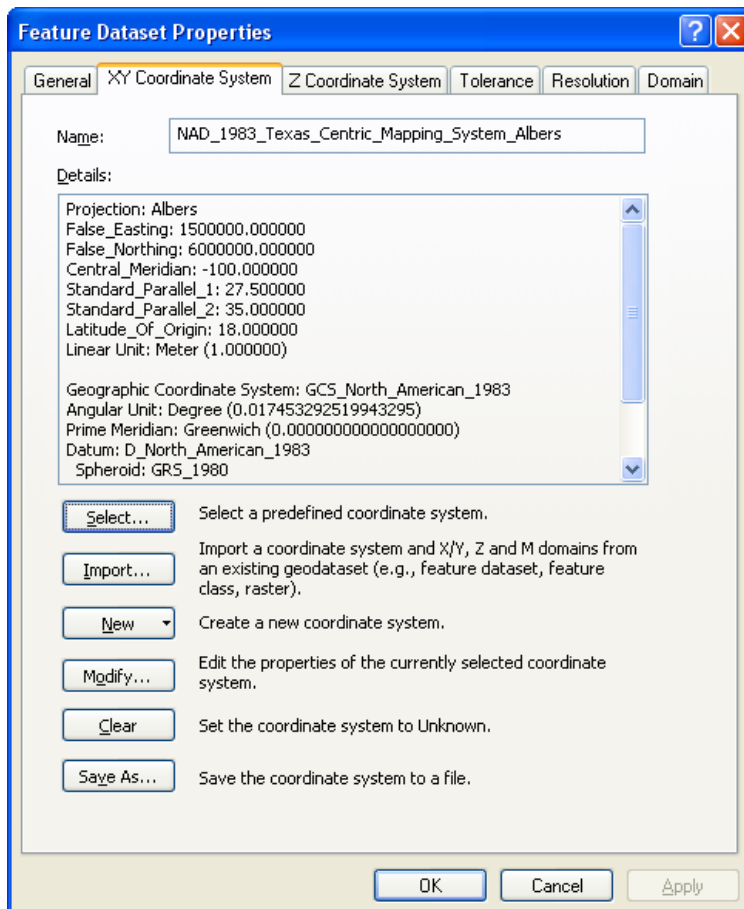
- 
- The tool is coded as a Python script that is wrapped in an ArcGIS Script tool and Model.
- The script is located in the scripts folder.
- The BEG Water Analysis toolbox contains an ArcGIS Script tool and Model (these reference the python script located in the scripts folder).



- The data for running the tool is located in the **Data** file geodatabase.



- The necessary feature classes are located in the Data feature dataset. All the datasets have the same spatial reference.



### 3. Methodology:

The tool is based on 4 input feature classes:

1. Water Treatment Plant (WTP):

- This feature class represents the volume of water from treatment plants.
- Each feature in the feature class should have a **Volume** field representing the volume from the treatment plant in MGD.
- An average weighted distance is calculated for the points within the search radius. The formula used to weigh the distance is:

$$D_{weighted} = \frac{\sum d_i \times V_i}{\sum V_i}$$

Where  $d_i$  is the distance from each WTP to the assessed point and  $V_i$  is the volume of the WTP.

2. Water Bodies (WB) for wet period:

- Each water body should have a field named **Hectares** that gives the area of the water body.
- The volume of water in the WB is calculated by multiplying the area of the features by a specified height.
- An average weighted distance is calculated for the WB within the search radius. The formula used to weigh the distance is:

$$D_{weighted} = \frac{\sum d_i \times V_i}{\sum V_i}$$

Where  $d_i$  is the distance from the centroid of each WB to the assessed point and  $V_i$  is the volume of the WB.

The volume of the WB is calculated by:

$$V_{WB} = A_{hectares} \times 10,000 \times H_{WB}$$

Where  $A_{hectares}$  is the area of the WB read from the Hectares field and  $H_{WB}$  is the height specified for the WB.

3. Water Bodies (WB) for dry period:

- Each water body should have a field named **Hectares** that gives the area of the water body.
- The volume of water in the WB is calculated by multiplying the area of the features by a specified height.
- An average weighted distance is calculated for the WB within the search radius (equations are similar to the for the wet period).

4. Groundwater model points:

- Each point should have three fields: **Transmissivity**, **well\_yield**, and **top33**.

- Values in the top33 field are 0 or 1, 0 specifying that the point is not within the top 33 percent of values and 1 that it is within the top 33 percent of the values.
- For each set of the selected points percentiles (5, 30, 50, 70, and 95) are calculated and the number of top33 points is counted.
- The number of points and the average distance from the assessed point is reported.

## 4. Running the tool:

Tool input parameters include:

1. **Assessed Points** – point feature class where the output points will be created. The Assessed Points feature class must include a set of fields so the tool can write the summary statistics to the fields. The fields include:

Field name	Type	Description
Pt_X	Double	X coordinate of the assessed point
Pt_Y	Double	Y coordinate of the assessed point
Search_Radius	String	Search radius specified by user
WTP_Count	Double	Count of WTP features within the search radius
WTP_Volume	Double	Calculated volume of WTP features within the search radius
WTP_W_Dist	Double	Volume weighted distance of WTP features within the search radius
Wet_WB_Count	Double	Count of WB within the search radius for the wet scenario
Wet_WB_Area	Double	Area of WB within the search radius for the wet scenario
Wet_WB_Volume	Double	Volume of WB within the search radius for the wet scenario
Wet_WB_W_Dist	Double	Volume weighted distance of WB features within the search radius for the wet scenario
Dry_WB_Count	Double	Count of WB within the search radius for the dry scenario
Dry_WB_Area	Double	Area of WB within the search radius for the dry scenario
Dry_WB_Volume	Double	Volume of WB within the search radius for the dry scenario
Dry_WB_W_Dist	Double	Volume weighted distance of WB features within the search radius for the dry scenario
GW_Pt_Count	Double	Count of groundwater model points (cells) within the search radius
GW_Pt_Avg_Dist	Double	Average distance of groundwater model points (cells) within the search radius
GW_Pt_Top33_Count	Double	Count of groundwater model points/cells that are within the top 33 percent (top33 field =1) within the search radius
GW_wy_p5	Double	Water yield value at the 5 <sup>th</sup> percentile from the groundwater model points within the search radius

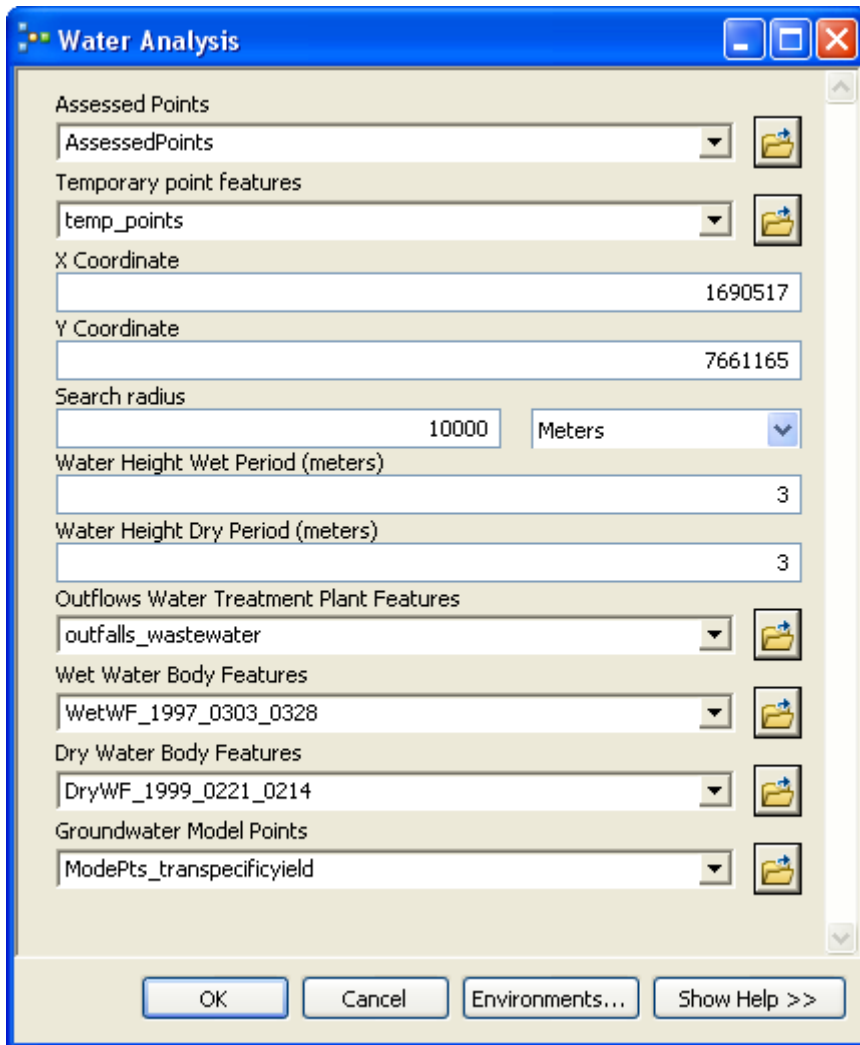
GW_wy_p30	Double	Water yield value at the 5 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_wy_p50	Double	Water yield value at the 50 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_wy_p70	Double	Water yield value at the 70 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_wy_p95	Double	Water yield value at the 95 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_tr_p5	Double	Transmissivity value at the 5 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_tr_p30	Double	Transmissivity value at the 30 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_tr_p50	Double	Transmissivity value at the 50 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_tr_p70	Double	Transmissivity value at the 70 <sup>th</sup> percentile from the groundwater model points within the search radius
GW_tr_p95	Double	Transmissivity value at the 95 <sup>th</sup> percentile from the groundwater model points within the search radius

2. **Temporary point features** – feature class holding a temporary point that is being assessed. The temporary point is overwritten every time the tool is executed.
3. **X Coordinate** – X coordinate of the assessed point to be created. Make sure the coordinates are in the correct map units (for the base data provided with the tool this is meters, based on the Texas\_Centric\_Mapping\_System\_Albers spatial reference).
4. **Y Coordinate** – Y coordinate of the assessed point to be created. Make sure the coordinates are in the correct units for the base data provided with the tool this is meters, based on the Texas\_Centric\_Mapping\_System\_Albers spatial reference).
5. **Search Radius** – the search radius for selecting features (WTP, WB, model points) around the assessed point.
6. **Water Height Wet Period** – height of water in WB for wet period. **Value should be in meters.**
7. **Water Height Dry Period** – height of water in WB for dry period. **Value should be in meters.**
8. **Outflows Water Treatment Plant Features** – Point features representing WTP.
9. **Wet Water Body Features** – Polygon features representing water bodies during wet periods.

10. **Dry Water Body Features** – Polygon features representing water bodies during dry periods.

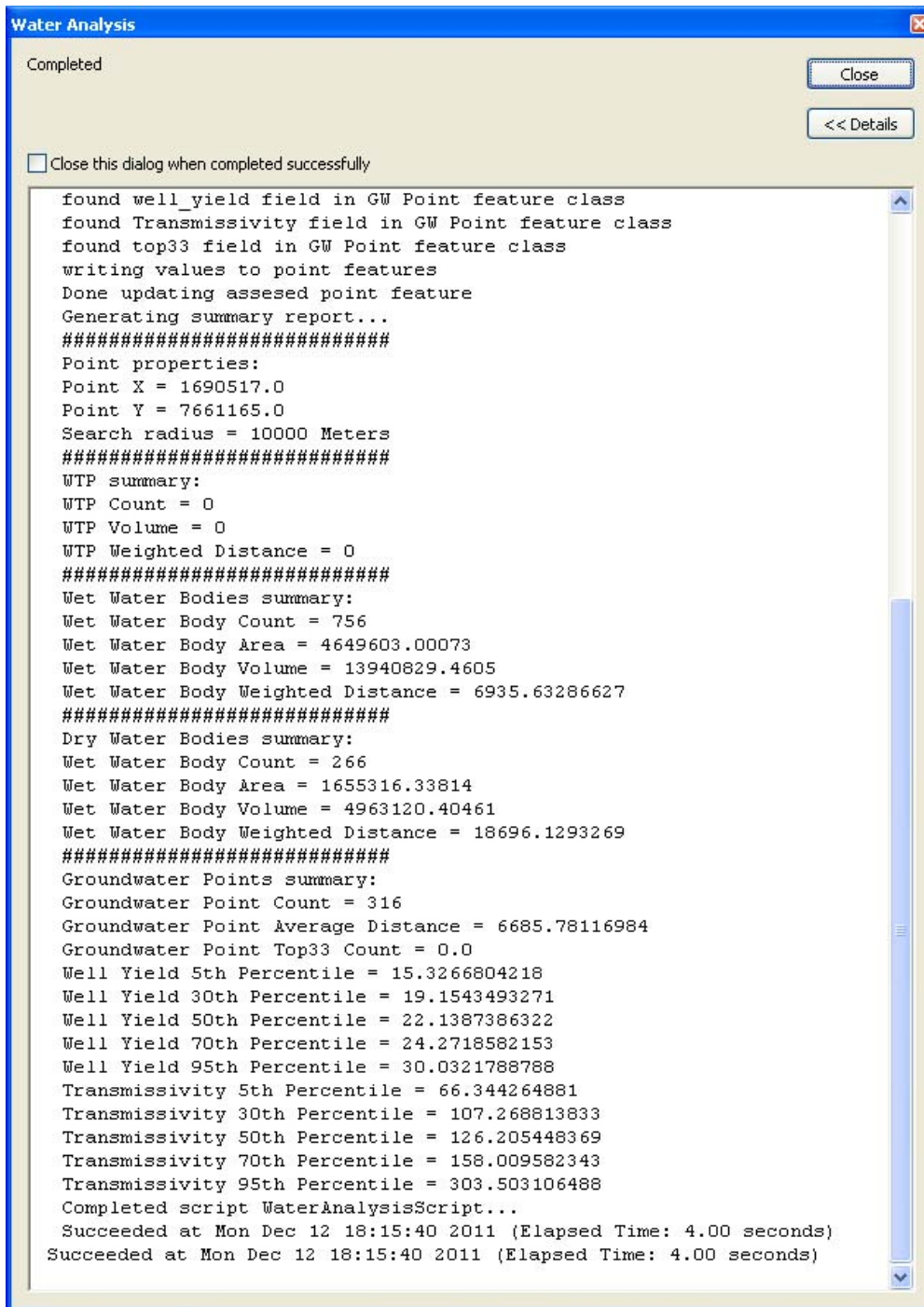
11. **Groundwater Model Points** – point features representing groundwater model nodes at which aquifer properties are calculated.

The following figure shows an example of parameters used to run the model.



## 5. Tool summary report:

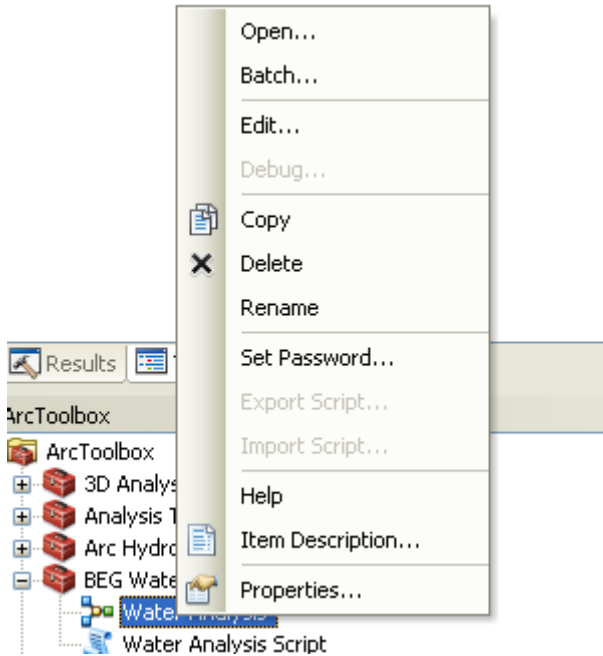
The model generates a summary report within the model results window. An example of the summary report is shown in the following figure.



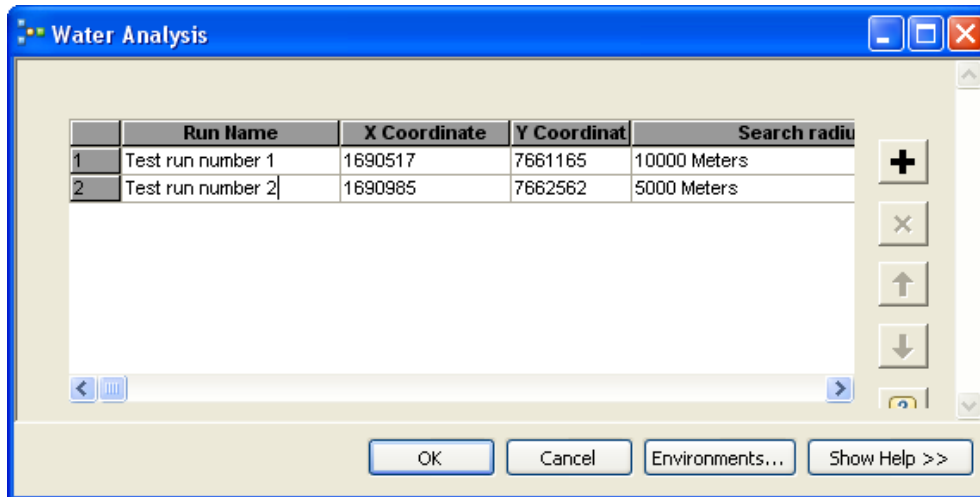
## 6. Running the tool in batch mode

The tool can be run in batch mode to process a set of points by using the built-in Batch process available for any ArcGIS model. You can use the following the steps to batch run the tool:

1. Open the Batch interface by right clicking on the model and selecting **Batch...**



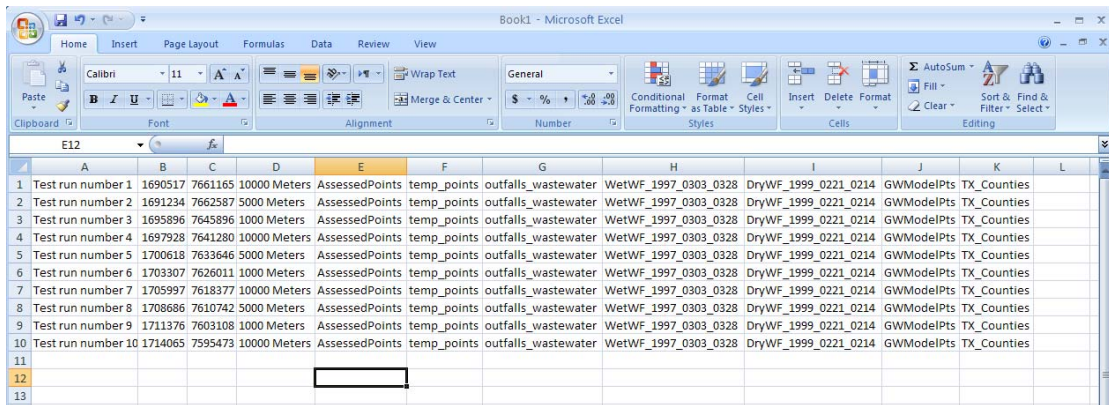
2. Fill in the parameters. You can add rows using the Add Row button (+).



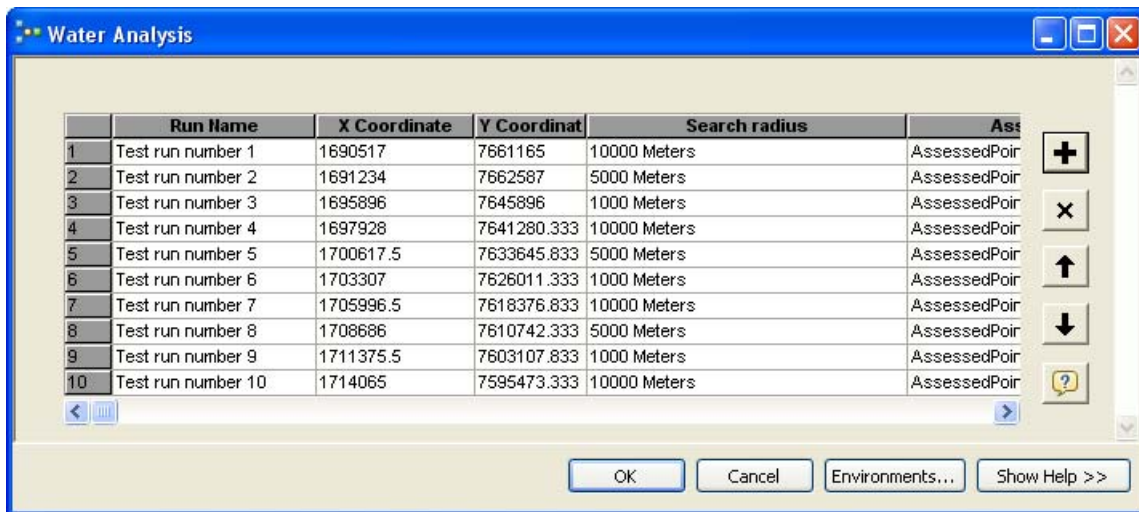
3. Select OK to run the tool in batch mode.

You can also prepare the inputs for the batch process in Excel and copy them over to the ArcGIS batch interface:

1. In the batch mode interface, select the row with the filled in parameter values and copy/paste to excel.
2. Fill in as many rows you want in excel.



3. In ArcGIS batch mode use the Add Row button (+) to add as many rows you need (this should match the number of rows you created in Excel). Tip – you can create a number of rows (e.g. 10 rows) select all of them and then every time you use the Add Row button it will add that number of rows.
4. Copy and paste from Excel to the Batch form (you need to select the rows in batch mode and then select **Paste** to paste the values from Excel into the selected rows).



## 7. Modifying water height parameters for water body volume calculations

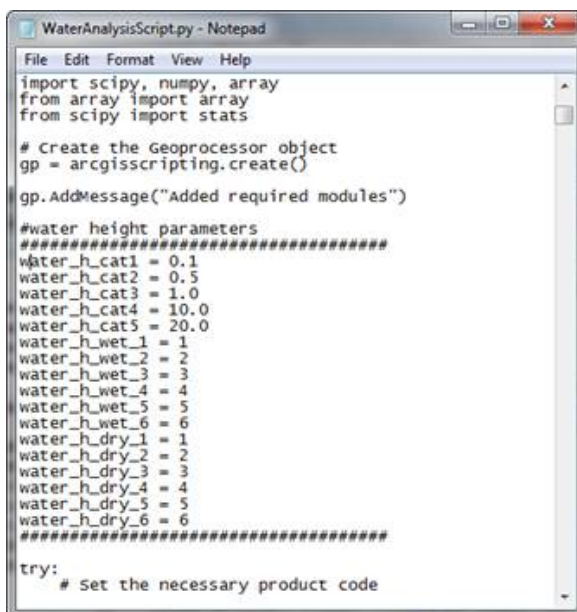
Water body volumes are calculated by multiplying the area of the water body by a specified height. The heights vary based on the size of the water body and based on the wet and dry scenarios.

Water bodies are divided into six categories based on the area (A) of the water body:

- $A < 0.1$  hectares
- $0.1 < A < 0.5$  hectares
- $0.5 < A < 1.0$  hectares
- $1.0 < A < 10$  hectares
- $10 < A < 20$  hectares
- $20 < A$  hectares

The water depth associated with each category can be modified by editing the Python script behind the model. The script is located in the Scripts folder. To modify the heights:

1. Open the script in any text editor.
2. Scroll down to the section with the title “water height parameters. You can modify the height parameters for the wet and dry periods. There are 6 values for the 6 different categories outlined (0.1 acres, 0.5, 1.0, 10, and 20 hectares).
3. Modify the parameters named `water_h_wet_X` or `water_h_dry_X` where X is the category (e.g. X = 1 for the first category and X = 6 for the last category).



```
WaterAnalysisScript.py - Notepad
File Edit Format View Help
import scipy, numpy, array
from array import array
from scipy import stats

# Create the Geoprocessor object
gp = arcgisscripting.create()
gp.AddMessage("Added required modules")

#water height parameters
#####
water_h_cat1 = 0.1
water_h_cat2 = 0.5
water_h_cat3 = 1.0
water_h_cat4 = 10.0
water_h_cat5 = 20.0
water_h_wet_1 = 1
water_h_wet_2 = 2
water_h_wet_3 = 3
water_h_wet_4 = 4
water_h_wet_5 = 5
water_h_wet_6 = 6
water_h_dry_1 = 1
water_h_dry_2 = 2
water_h_dry_3 = 3
water_h_dry_4 = 4
water_h_dry_5 = 5
water_h_dry_6 = 6
#####

try:
    # set the necessary product code
```

4. Save and close the script file. You can now run the model with the modified height parameters.

## **7 Attachment B: Waste Water Treatment Plant Inventory**



Documentation of the treatment plant subtask is presented in Section 6 and Appendix A of Attachment E.

## **8 Attachment C: Surface Water Body Study**



This attachment details steps followed to assess the amount of water available from small water bodies. The following sections show how satellite imagery was used to count water bodies through the years and sort them according to size. However there is an important missing element that was not accessible to us during the study: average depth. Although it is conceivable to use satellite data in terms of attenuation contrast of different wavelengths and similar metrics, they are heavily impacted by water turbidity, making an automated approach practically infeasible. Physically measuring depth of thousands of water bodies was obviously not a viable solution either. A solution that could lead to accurate depth estimates but applicable only to impoundments consists in obtaining topography of the bottom of the water body before it is impounded and in relating it to the current water level. It was not implemented for lack of time. The approach we used was to rely on the fairly narrow range of average depths known to occur from small stock ponds to large lakes and reservoirs in the state. Table 6 shows average depth compiled from an array of state agencies. Average depth is very well constrained and stays between a very small range independently of the size of the water body (Figure 15) from 10 to 45 feet, even including large water bodies outside of the area of interest (not shown). Smaller stock ponds are generally constructed (various web sites) with an average depth of 6 feet. There is anecdotal evidence that some of the currently existing ponds, especially smaller ponds, are filled with groundwater. To limit double-counting (counted both in the surface water and groundwater categories), the basis for cumulative surface area during wet and dry periods was chosen to be prior to the expanding period of shale gas operations. We faced a difficult choice in deciding average depths to use in computing volume of water bodies (Table 7). We chose the typically reported depth for the smaller bodies and an average depth of 15 ft for the largest water bodies and a sliding scale for water bodies of intermediate size. The 15-ft value was estimated by inspection of Figure 15. Average depth during dry periods was estimated to be 2 to 3 feet below that of wet periods.

The rest of Attachment C presents methodology and results computing commutative surface area of water bodies of various size.

Table 6. Average and/or maximum depth of selected Texas water bodies

Lake	Area (acres)	County	Maximum Depth (ft)	Average Depth (ft)
Arrowhead	1848	Clay	50	17.5
Nocoma	1323	Montague	80	28
Bridgeport	11954	Wise	85	29.75
Possum Kingdom	15588	Palo Pinto	145	37*
Palo Pinto	2399	Palo Pinto	47	16.45
Mineral Wells	440	Parker	30	10.5
Weatherford	1158	Parker	39	13.65
Gransbury	8130	Hood	75	26.25
Squaw Creek	3275	Hood	125	
Pat Cleburne	1558	Johnson	64	22.4
Benbrook	3770	Tarrant	70	23*
Eagle Mountain	8738	Tarrant	47	16.45
Grapevine	7280	Denton	65	22.75

\*: actual data; all others computed from average = 0.35×maximum

Source: <http://www.touringtexas.com/lakes.htm>;  
<http://www.tpwd.state.tx.us/fishboat/fish/recreational/lakes/>

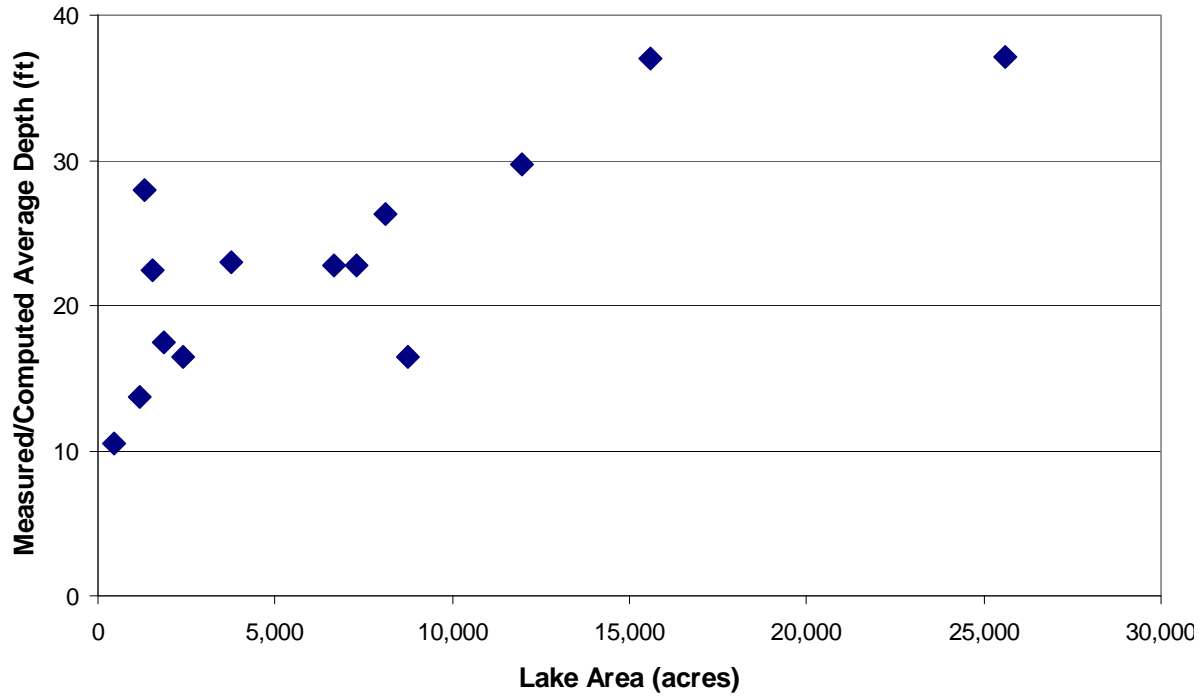


Figure 15. Crossplot of area vs. average depth of large water body within the area of interest

Table 7. Water depth estimates as a function of water body size

Pond area (ha)	Feet		Meters	
	wet	dry	wet	dry
<0.1	6	3	1.83	0.91
0.1-0.5	6	5	1.83	1.52
0.5-1	9	7	2.74	2.13
1-10	12	9	3.66	2.74
10-20	12	9	3.66	2.74
>20	15	12	4.57	3.66

1 ha = 10,000 m<sup>2</sup> = 10,000 m<sup>2</sup> / 4047 m<sup>2</sup>/acres = 2.47 acres

1 acre = 0.405 ha; 20 ha = ~50 acres

**Technical and Economic Feasibility of Utilizing Alternate Sources of Water in the Barnett Shale Area**

**Funded by Gas Technology Institute (GTI)**

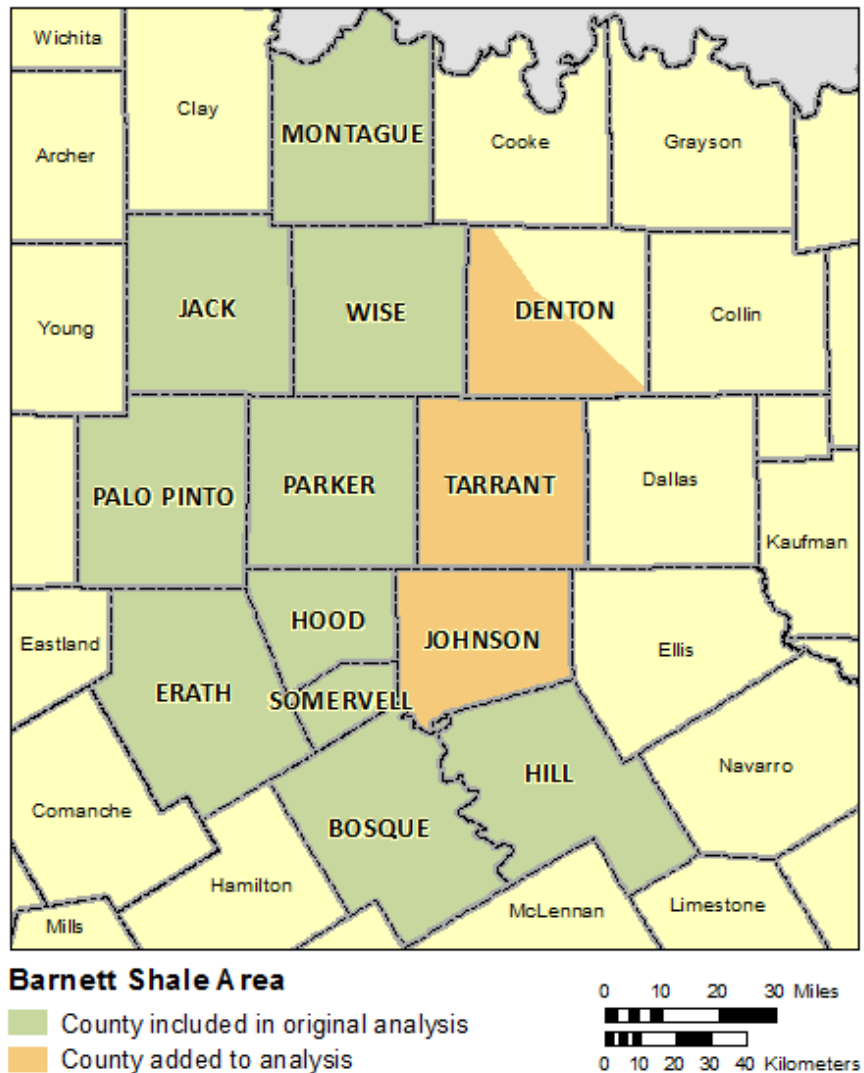
**P.I.: Jean-Philippe “JP” Nicot, Bureau of Economic Geology**

**Progress Report: December 9, 2011**

**Teresa Howard, Center for Space Research**

***Task 2: Inventory Water Sources***

*Task 2-1:* The extended inventory of non-state regulated surface water features in the footprint of the Barnett Shale in Montague, Wise, Parker, Hood, Somervell, Jack, Palo Pinto, Erath, Bosque, and Hill counties is nearing completion. Three counties, Tarrant, Johnson and half of Denton, were added to the analysis area of interest (Figure 1).



**Figure 1. Counties included in satellite image analysis.**

Two Landsat satellite passes, typically called paths, cover the area of interest, including the additional three counties. The passes are path 28 on the west and path 27 on the east (Figure 2). Two Landsat images per path are required to cover the area of interest. Jack and Palo Pinto counties and most of Erath and Montague counties are contained within Path 28. Montague, Wise, Denton, Parker, Tarrant, Hood, Somervell, Johnson, Bosque and Hill counties are contained within Path 27.

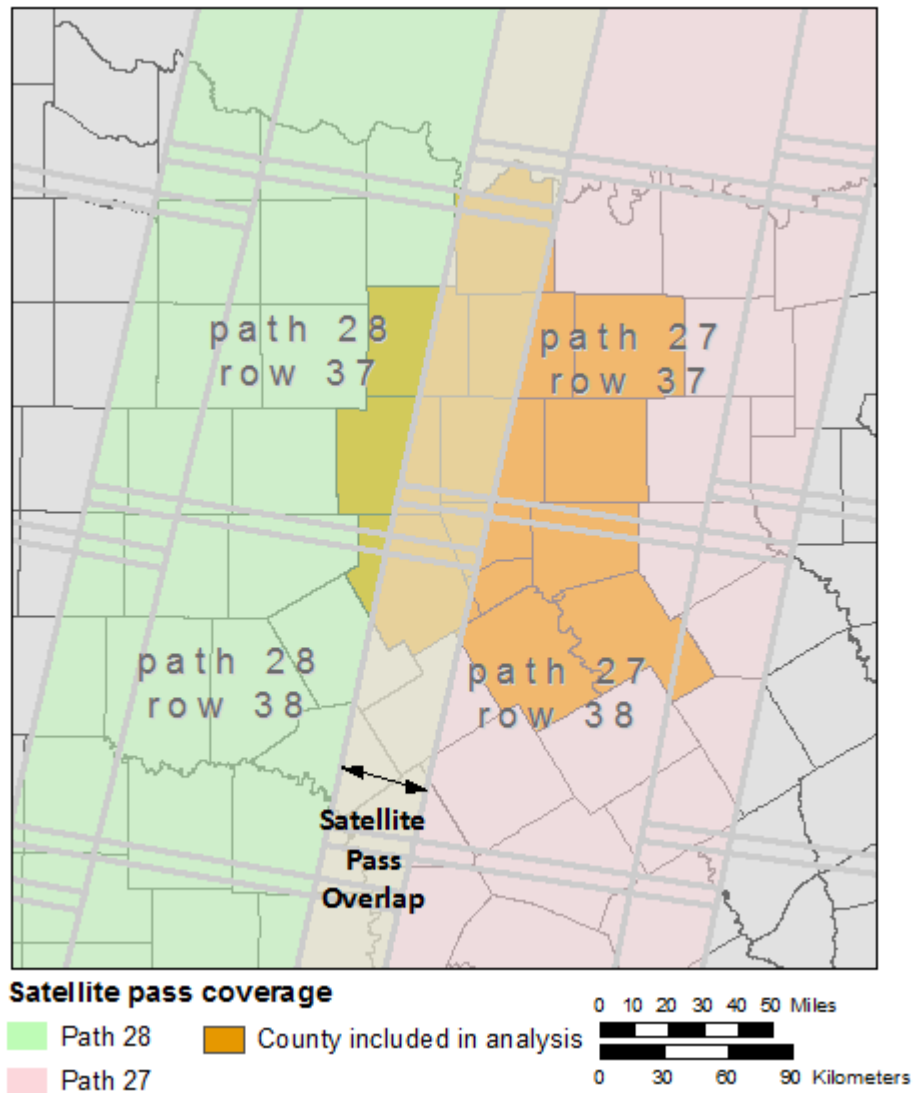
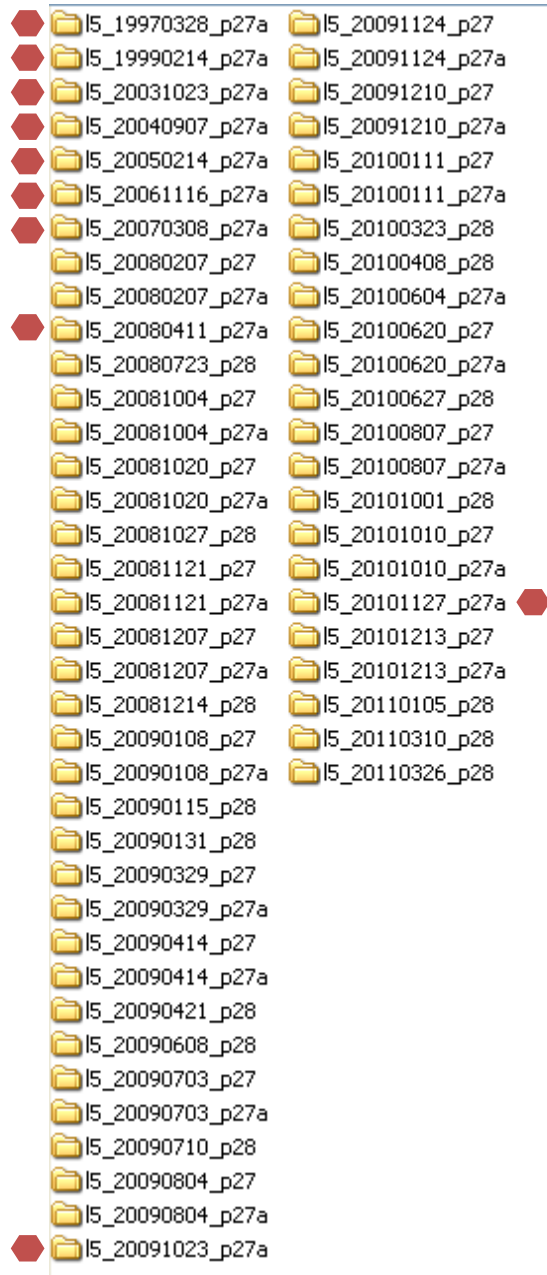


Figure 2. Landsat satellite passes in relationship to study area.

Previously, ten dates for each path were selected for the analysis. For the follow on analysis, the three additional counties contained within Path 27 were processed for the dates chosen previously (Figure 3). New dates were chosen for the years 2008, 2009 and 2010. A total of 23

possible dates were identified for path 28 and 21 possible dates were identified for path 27. Candidate images were downloaded and screened for cloud cover. They were separated into three categories based on suitability for the analysis. Category 1, the best candidates, included 12 scenes for path 28 and 11 scenes for path 27. Category 2 included six and three scenes



**Figure 3. Landsat 5 Thematic Mapper collection dates chosen for the extended analysis. Entries marked by red hexagons indicate areas added to analysis for the dates chosen for the previous analysis. P27a refers to the 3 counties added to the analysis.**

respectively for paths 28 and 27. Twelve marginally suitable scenes were delegated to Category 3 and not used in the analysis. Ultimately fourteen new dates were chosen for path 28 and seventeen new dates were selected for path 27. One early January 2011 date was paired with a mid-December 2010 date, but no other 2011 images were included in the final analysis. Subsequently, certain county coverages were eliminated from the final dataset, primarily due to excessive localized cloud cover. Table 1 gives an accounting of excluded dates and provides a key to image overlap. The tables in Appendix X, which provide the summary statistics for each county by date, include a reference to Year 1, Date 1, Year 2 and Date 2. Year and Date 1 correspond to path 28 image dates; Year and Date 2 reference path 27 dates. Figure 2 represents general overlap. For the analysis, however, all overlap was trimmed to match a narrower strip, as overlap varies with each satellite pass. In the earlier analysis, overlap was preserved in all but three counties (Figure 4). In the follow-on analysis, overlap was kept only for the two counties that required it, Montague and Erath, since dates were not paired well for all cases.

**Table 1. Image dates excluded from final analysis by county. Overlap status relates to the dates shown in the tables of Appendix X.**

County	Count	Excluded Dates	Overlap Status
Bosque	24	12/10/2009, 8/7/2010, 10/10/2010	None: Path 27 only
Denton	28	none	None: Path 27 only
Erath	27	8/7/2010	Always: Path 28 & Path 27
Hill	24	12/10/2009, 8/7/2010, 10/10/2010	None: Path 27 only
Hood	27	none	Overlap 1st analysis; Path 27 only for new analysis
Jack	23	none	Overlap 1st analysis; Path 28 only for new analysis
Johnson	28	none	None: Path 27 only
Montague	29	none	Always: Path 28 & Path 27
Palo Pinto	21	7/23/2008, 6/27/2010	Overlap 1st analysis; Path 28 only for new analysis
Parker	27	none	Overlap 1st analysis; Path 27 only for new analysis
Somervell	27	none	None: Path 27 only
Tarrant	27	11/27/2010	None: Path 27 only
Wise	27	none	Overlap 1st analysis; Path 27 only for new analysis

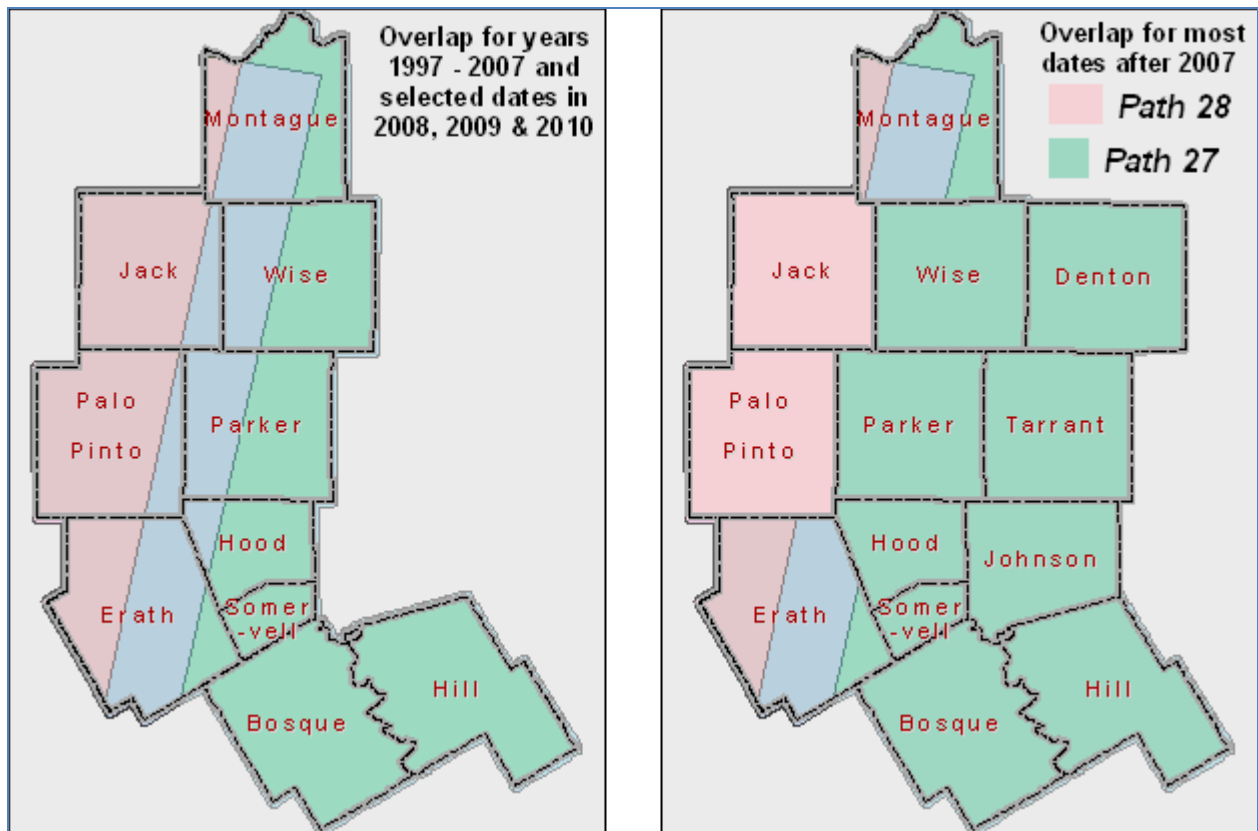


Figure 4. Overlap in the original and the follow-on analysis.

The Landsat 5 Thematic Mapper data were preprocessed and mosaicked by path (Figure 2). Each image mosaic was processed according to Chavez's modified COST model using procedures developed at the Arizona Remote Sensing Center (ARSC 2002). The COST model removes most atmospheric noise, adjusting individual cell values so that they are more similar across image dates (Chavez 1996, Mauz 2002).

The preprocessed data were subdivided into tiles. Next the multi-band tiles were entered into a geographic object-based image analysis program where each tile was segmented into objects of varying size and classified using an iterative process that first identifies and flags large reservoirs and then identifies water bodies of increasingly smaller sizes. Some features as small as a quarter acre were identified. Subsequent review in comparison with recent aerial photography confirmed that many of these features were correctly identified.

The geographic object-based image analysis program, eCognition, hearkens to a traditional photo-interpretation approach in that its tools can assess qualities such as shape, size, texture,

and proximity in addition to the spectral information analyzed for other automated image classification approaches. The tools can also incorporate attribute information from GIS data (Navular 2007). For the current project, reservoirs exceeding 0.2 square kilometers in size were used to initialize surface water classification. Data were segmented and re-segmented into objects of varying size. With each iteration, objects were reevaluated until final classification criteria were applied. Long, sinuous features were flagged as riparian areas, also excluded. The Normalized Difference Water Index (NDWI) was applied to separate water from non-water features and to further classify water pixels into three levels: total water, mostly water, and half water (Lei *et al.* 2009). Water features were also classified by size. The classification algorithm was developed using image subsets and subsequently applied to all image data sets in a semi-automated fashion.

Following image classification, results were exported into a common raster data format. Included in the results were objects classified as medium and large reservoirs, rivers, and other surface water features classed by area extent. The latter water features were exported as unified objects where possible and, in parallel, as objects classed by water content: 100% water, 75-99% water content, and 50-74% water content. Water content could be used to further refine water area.

To complete the project, all tiled results were exported into a standard image processing application, ERDAS Imagine 2010, complete image mosaics were constructed. The reconstructed classified image data were exported into a vector GIS format. Within a GIS environment (ArcGIS Desktop) classification results were compared to source Landsat images and to high spatial resolution National Agricultural Imagery Program (NAIP) aerial photography, available from the Texas Natural Resources Information System as a web mapping service, commonly referred to as a WMS (USDA TNIRIS 2011). GIS tools were used to eliminate most false positive objects, including cloud shadow, shadow in terrain, wet soil in fallow fields, water pooling in stream beds, river water not classified as such, large pools of water in riverine floodplains, urban infrastructure, and occasional sensor artifacts.

Once editing was completed, features identified as surface water that met project criteria were extracted. An additional step was added to the analysis for the follow-on analysis. An aggregation algorithm was applied in order to combine adjacent polygons that share a common point. Since the source information for the image analysis is pixel-based and the pixels were

not generalized during their transformation from raster to vector, resulting polygons have stair-stepped edges. Some features are formed by squares and rectangles along a diagonal. In the GIS environment, such features are not automatically unified for summary statistics. Aggregation combines the separate polygons into a single coherent object. Aggregation was applied to the results of the 10 county analyses from the earlier phase of the project as well as to the new data sets. The tables of summary statistics include data for all of the counties for all of the years and months of the analysis.

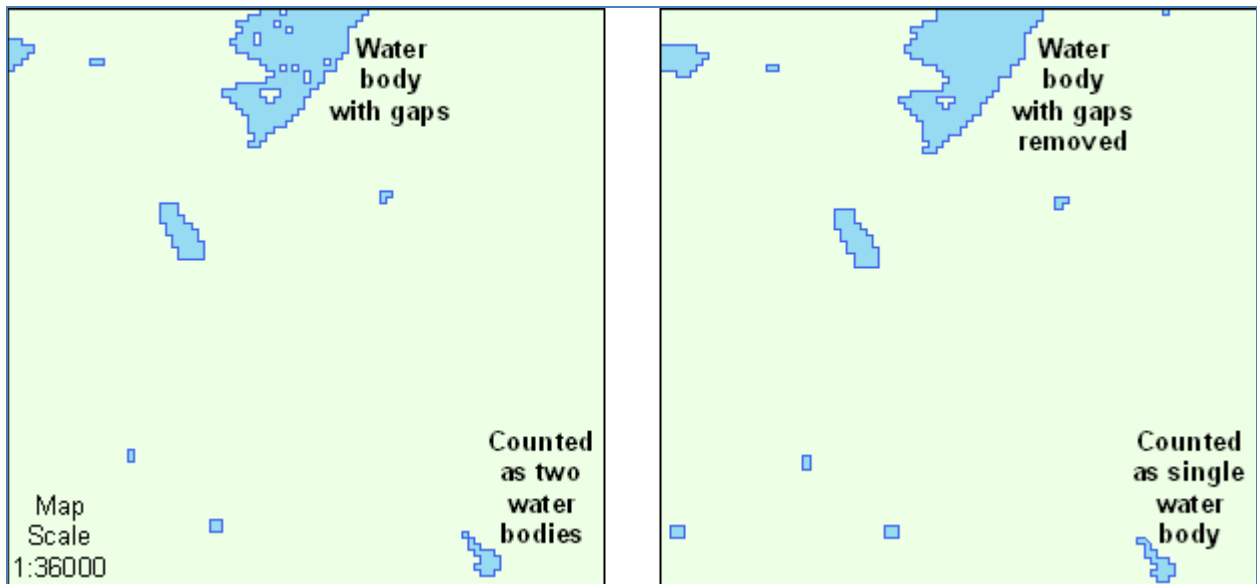


Figure 5. Example data in Somervell County on May 14, 2009 before (left) and after (right) aggregation.

The water feature data sets were clipped by county boundaries and aggregated. After aggregation, water features were classified by surface area. The class breaks are based on hectares, since the source data area units are meters. Table 2 shows the class breaks chosen. Summary statistics for each county are presented in Appendix 1.

Table 2. Relationship of class breaks used for summary statistics with pixel counts and area in acres. Acre ranges are approximate.

Class Breaks	Pixel counts	Range in acres
< 0.1 ha	1	< 0.25
0.1 - 0.5 ha	> 1 - 5	0.25 - 1.24
0.5 - 1 ha	> 5 - 11	1.25 - 2.4
1 - 10 ha	> 11 - 111	2.5 - 24
10 - 20 ha	> 111 - 222	25 - 50
> 20 ha	> 222	> 50

## References

Arizona Remote Sensing Center (ARSC). Landsat 5 atmospheric and radiometric correction. Last modified on December 30, 2002. Last accessed on December 8, 2011.

[http://arsc.arid.arizona.edu/resources/image\\_processing/landsat/ls5-atmo.html](http://arsc.arid.arizona.edu/resources/image_processing/landsat/ls5-atmo.html)

Chavez, P. S., Jr. 1996. Image-based atmospheric corrections: Revisited and improved. *Photogrammetric Engineering and Remote Sensing* 62 (9): 1025-1036.

Lei, J., Zhang, L., and Wylie, B. 2009. Analysis of dynamic thresholds for the normalized difference water index. *Photogrammetric Engineering & Remote Sensing*, 75 (11): 1307-1317.

Mauz, K. 2002. New and improved procedure for minimum DN selection for input to the COST model for atmospheric correction. Last modified on January 9, 2002. Last accessed on December 8, 2011. [http://arsc.arid.arizona.edu/resources/image\\_processing/landsat/minimum-dn.html](http://arsc.arid.arizona.edu/resources/image_processing/landsat/minimum-dn.html)

Navular, Kumar. 2007. Multispectral analysis using the object-oriented paradigm. Boca Raton: CRC Press.

TNRIS. 2011. Web Mapping Services (WMS) URL. Last accessed on December 8, 2011.

[http://www.tnris.org/get-data?quicktabs\\_2=3](http://www.tnris.org/get-data?quicktabs_2=3)

USDA. 2011. Farm Service Agency. NAIP Imagery. Last modified on August 18, 2011. Last accessed on December 8, 2011. <http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai>

Bosque County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	688	152.76	0.22	0.01	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	649	435.13	0.67	0.44	1.22	0.23	0.78
Year 2	1997	0.5 - 1 ha	166	282.22	1.70	1.33	2.45	0.37	1.11
Date 2	0328	1 - 10 ha	180	1213.50	6.74	2.56	24.13	5.00	21.57
		10 - 20 ha	9	319.03	35.45	27.13	43.81	5.44	16.68
		> 20 ha	5	502.28	100.46	53.26	205.83	66.70	152.56
<b>Baseline Wet</b>		<b>Total</b>	<b>1697</b>	<b>2904.91</b>	<b>1.71</b>	<b>0.01</b>	<b>205.83</b>		<b>205.82</b>
Year 1		< 0.1 ha	314	69.72	0.22	0.11	0.22	0.01	0.11
Date 1		0.1 - 0.5 ha	348	236.21	0.68	0.25	1.22	0.23	0.97
Year 2	1999	0.5 - 1 ha	111	195.68	1.76	1.33	2.45	0.37	1.11
Date 2	0214	1 - 10 ha	126	918.37	7.29	2.56	24.24	5.32	21.68
		10 - 20 ha	5	148.23	29.65	26.24	35.14	3.55	8.90
		> 20 ha	5	330.53	66.11	49.82	116.31	28.21	66.50
<b>Baseline Dry</b>		<b>Total</b>	<b>909</b>	<b>1898.74</b>	<b>2.09</b>	<b>0.11</b>	<b>116.31</b>		<b>116.20</b>
Year 1		< 0.1 ha	547	121.46	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	536	346.74	0.65	0.25	1.22	0.22	0.97
Year 2	2003	0.5 - 1 ha	129	233.74	1.81	1.33	2.45	0.37	1.11
Date 2	1023	1 - 10 ha	147	1109.64	7.55	2.56	24.57	5.67	22.02
		10 - 20 ha	6	177.94	29.66	26.69	32.94	2.50	6.25
		> 20 ha	7	482.54	68.93	51.37	109.90	20.88	58.53
		<b>Total</b>	<b>1372</b>	<b>2472.06</b>	<b>1.80</b>	<b>0.03</b>	<b>109.90</b>		<b>109.87</b>
Year 1		< 0.1 ha	1095	243.11	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	900	597.17	0.66	0.25	1.22	0.23	0.97
Year 2	2004	0.5 - 1 ha	211	363.06	1.72	1.33	2.45	0.35	1.11
Date 2	0907	1 - 10 ha	263	1750.30	6.66	2.56	24.02	4.76	21.46
		10 - 20 ha	20	644.17	32.21	25.13	46.70	6.63	21.57
		> 20 ha	5	348.78	69.76	52.04	112.98	25.78	60.94
		<b>Total</b>	<b>2494</b>	<b>3946.58</b>	<b>1.58</b>	<b>0.00</b>	<b>112.98</b>		<b>112.97</b>
Year 1		< 0.1 ha	702	155.31	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	823	556.16	0.68	0.34	1.22	0.23	0.88
Year 2	2005	0.5 - 1 ha	211	363.17	1.72	1.33	2.45	0.37	1.11
Date 2	0214	1 - 10 ha	217	1586.57	7.31	2.56	23.57	5.34	21.02
		10 - 20 ha	12	361.87	30.16	25.35	36.92	4.17	11.56
		> 20 ha	5	593.27	118.65	50.04	214.50	67.62	164.46
		<b>Total</b>	<b>1970</b>	<b>3616.35</b>	<b>1.84</b>	<b>0.00</b>	<b>214.50</b>		<b>214.50</b>
Year 1		< 0.1 ha	125	27.42	0.22	0.01	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	157	101.72	0.65	0.44	1.20	0.23	0.75
Year 2	2006	0.5 - 1 ha	68	122.09	1.80	1.33	2.45	0.38	1.11
Date 2	1116	1 - 10 ha	93	655.84	7.05	2.67	23.35	4.93	20.68
		10 - 20 ha	5	161.24	32.25	25.13	39.36	7.01	14.23
		> 20 ha	1	73.84	73.84	73.84	73.84	0.00	0.00
		<b>Total</b>	<b>449</b>	<b>1142.15</b>	<b>2.54</b>	<b>0.01</b>	<b>73.84</b>		<b>73.83</b>

Bosque County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	332	73.84	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	469	319.28	0.68	0.25	1.22	0.24	0.97
Year 2	2007	0.5 - 1 ha	134	239.63	1.79	1.33	2.45	0.37	1.11
Date 2	0308	1 - 10 ha	151	1017.46	6.74	2.67	22.46	4.83	19.79
		10 - 20 ha	10	305.90	30.59	24.91	41.59	5.12	16.68
		> 20 ha	2	129.43	64.72	52.48	76.95	17.30	24.47
<b>Total</b>			<b>1098</b>	<b>2085.54</b>	<b>1.90</b>	<b>0.22</b>	<b>76.95</b>		<b>76.73</b>
Year 1		< 0.1 ha	382	84.76	0.22	0.07	0.22	0.01	0.15
Date 1		0.1 - 0.5 ha	445	305.50	0.69	0.29	1.11	0.24	0.82
Year 2	2008	0.5 - 1 ha	172	297.12	1.73	1.33	2.45	0.34	1.11
Date 2	0207	1 - 10 ha	209	1488.23	7.12	2.56	24.46	5.06	21.90
		10 - 20 ha	15	452.14	30.14	24.91	42.92	5.18	18.01
		> 20 ha	8	615.34	76.92	56.27	129.32	25.70	73.05
<b>Total</b>			<b>1231</b>	<b>3243.08</b>	<b>2.63</b>	<b>0.07</b>	<b>129.32</b>		<b>129.25</b>
Year 1		< 0.1 ha	767	170.41	0.22	0.06	0.22	0.01	0.16
Date 1		0.1 - 0.5 ha	726	488.09	0.67	0.33	1.22	0.24	0.89
Year 2	2008	0.5 - 1 ha	195	336.57	1.73	1.33	2.45	0.39	1.11
Date 2	0411	1 - 10 ha	218	1620.12	7.43	2.67	24.02	5.19	21.35
		10 - 20 ha	15	455.02	30.33	25.35	37.47	4.06	12.12
		> 20 ha	6	434.16	72.36	51.15	129.41	29.20	78.26
<b>Total</b>			<b>1927</b>	<b>3504.36</b>	<b>1.82</b>	<b>0.06</b>	<b>129.41</b>		<b>129.36</b>
Year 1		< 0.1 ha	295	65.56	0.22	0.18	0.22	0.00	0.04
Date 1		0.1 - 0.5 ha	320	213.58	0.67	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	142	247.08	1.74	1.33	2.45	0.36	1.11
Date 2	1004	1 - 10 ha	160	1213.85	7.59	2.56	24.46	5.41	21.91
		10 - 20 ha	6	170.17	28.36	25.35	35.36	4.10	10.01
		> 20 ha	5	348.36	69.67	50.43	112.12	26.03	61.70
<b>Total</b>			<b>928</b>	<b>2258.59</b>	<b>2.43</b>	<b>0.18</b>	<b>112.12</b>		<b>111.94</b>
Year 1		< 0.1 ha	374	82.96	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	386	245.87	0.64	0.36	1.22	0.23	0.86
Year 2	2008	0.5 - 1 ha	146	252.75	1.73	1.33	2.45	0.35	1.11
Date 2	1020	1 - 10 ha	178	1343.78	7.55	2.67	24.35	5.43	21.68
		10 - 20 ha	6	172.55	28.76	26.35	32.02	2.42	5.67
		> 20 ha	5	333.77	66.75	49.59	113.18	26.23	63.59
<b>Total</b>			<b>1095</b>	<b>2431.69</b>	<b>2.22</b>	<b>0.05</b>	<b>113.18</b>		<b>113.13</b>
Year 1		< 0.1 ha	176	38.94	0.22	0.03	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	236	163.52	0.69	0.26	1.22	0.24	0.97
Year 2	2008	0.5 - 1 ha	90	152.76	1.70	1.33	2.45	0.36	1.11
Date 2	1121	1 - 10 ha	144	1015.76	7.05	2.56	24.24	5.02	21.68
		10 - 20 ha	5	165.91	33.18	25.13	46.59	9.94	21.46
		> 20 ha	4	270.32	67.58	49.59	104.75	25.69	55.15
<b>Total</b>			<b>655</b>	<b>1807.21</b>	<b>2.76</b>	<b>0.03</b>	<b>104.75</b>		<b>104.72</b>

Bosque County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	166	36.54	0.22	0.03	0.22	0.02	0.20
Date 1		0.1 - 0.5 ha	212	145.02	0.68	0.44	1.22	0.23	0.78
Year 2	2008	0.5 - 1 ha	96	169.21	1.76	1.33	2.45	0.35	1.11
Date 2	1207	1 - 10 ha	135	1036.78	7.68	2.67	24.57	5.61	21.91
		10 - 20 ha	7	223.93	31.99	24.91	44.34	7.35	19.44
		> 20 ha	3	203.94	67.98	50.04	101.86	29.36	51.82
<b>Total</b>			<b>619</b>	<b>1815.42</b>	<b>2.93</b>	<b>0.03</b>	<b>101.86</b>		<b>101.83</b>
Year 1		< 0.1 ha	196	43.55	0.22	0.18	0.22	0.00	0.04
Date 1		0.1 - 0.5 ha	250	171.48	0.69	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	95	168.21	1.77	1.33	2.45	0.35	1.11
Date 2	0108	1 - 10 ha	145	1075.32	7.42	2.67	24.46	5.46	21.79
		10 - 20 ha	8	283.50	35.44	25.35	49.15	9.13	23.80
		> 20 ha	4	259.42	64.86	49.82	102.08	24.94	52.26
<b>Total</b>			<b>698</b>	<b>2001.48</b>	<b>2.87</b>	<b>0.18</b>	<b>102.08</b>		<b>101.90</b>
Year 1		< 0.1 ha	441	97.88	0.22	0.03	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	542	372.32	0.69	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	169	287.75	1.70	1.33	2.45	0.37	1.11
Date 2	0329	1 - 10 ha	191	1425.75	7.46	2.47	23.57	5.55	21.10
		10 - 20 ha	8	282.86	35.36	26.24	48.12	7.03	21.88
		> 20 ha	5	324.34	64.87	50.04	103.41	21.99	53.37
<b>Total</b>			<b>1356</b>	<b>2790.89</b>	<b>2.06</b>	<b>0.03</b>	<b>103.41</b>		<b>103.39</b>
Year 1		< 0.1 ha	477	105.72	0.22	0.03	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	557	376.39	0.68	0.40	1.22	0.24	0.83
Year 2	2009	0.5 - 1 ha	187	327.31	1.75	1.33	2.45	0.36	1.11
Date 2	0414	1 - 10 ha	197	1379.88	7.00	2.67	24.46	5.15	21.79
		10 - 20 ha	9	269.73	29.97	24.91	38.25	4.88	13.34
		> 20 ha	10	646.48	64.65	50.48	102.75	15.24	52.26
<b>Total</b>			<b>1437</b>	<b>3105.50</b>	<b>2.16</b>	<b>0.03</b>	<b>102.75</b>		<b>102.72</b>
Year 1		< 0.1 ha	443	97.75	0.22	0.01	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	466	315.96	0.68	0.44	1.23	0.24	0.79
Year 2	2009	0.5 - 1 ha	143	255.75	1.79	1.33	2.45	0.38	1.11
Date 2	0703	1 - 10 ha	161	1157.73	7.19	2.56	23.13	5.19	20.57
		10 - 20 ha	10	338.46	33.85	25.58	45.37	8.09	19.79
		> 20 ha	4	280.95	70.24	50.04	106.75	26.64	56.71
<b>Total</b>			<b>1227</b>	<b>2446.60</b>	<b>1.99</b>	<b>0.01</b>	<b>106.75</b>		<b>106.74</b>
Year 1		< 0.1 ha	805	178.11	0.22	0.01	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	553	367.55	0.66	0.30	1.22	0.23	0.93
Year 2	2009	0.5 - 1 ha	172	295.00	1.72	1.33	2.45	0.33	1.11
Date 2	0804	1 - 10 ha	188	1333.95	7.10	2.56	23.91	5.25	21.35
		10 - 20 ha	13	403.61	31.05	24.76	45.15	6.04	20.38
		> 20 ha	3	243.87	81.29	56.35	105.90	24.77	49.54
<b>Total</b>			<b>1734</b>	<b>2822.09</b>	<b>1.63</b>	<b>0.01</b>	<b>105.90</b>		<b>105.89</b>

Bosque County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	908	201.93	0.22	0.21	0.22	0.00	0.01
Date 1		0.1 - 0.5 ha	916	612.73	0.67	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	269	467.78	1.74	1.33	2.45	0.38	1.11
Date 2	1023	1 - 10 ha	294	2013.56	6.85	2.56	24.24	4.99	21.68
		10 - 20 ha	8	227.29	28.41	25.35	32.47	2.49	7.12
		> 20 ha	7	585.30	83.61	53.60	110.27	21.07	56.68
<b>Total</b>			<b>2402</b>	<b>4108.59</b>	<b>1.71</b>	<b>0.21</b>	<b>110.27</b>		<b>110.06</b>
Year 1		< 0.1 ha	851	188.62	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	732	492.50	0.67	0.28	1.22	0.24	0.94
Year 2	2009	0.5 - 1 ha	214	381.44	1.78	1.33	2.45	0.38	1.11
Date 2	1124	1 - 10 ha	227	1592.76	7.02	2.56	22.02	4.89	19.46
		10 - 20 ha	8	235.15	29.39	26.02	39.81	4.53	13.79
		> 20 ha	7	549.97	78.57	57.82	130.21	27.13	72.38
<b>Total</b>			<b>2039</b>	<b>3440.45</b>	<b>1.69</b>	<b>0.02</b>	<b>130.21</b>		<b>130.19</b>
Year 1		< 0.1 ha	231	50.98	0.22	0.05	0.22	0.02	0.17
Date 1		0.1 - 0.5 ha	294	202.23	0.69	0.44	1.11	0.24	0.67
Year 2	2010	0.5 - 1 ha	127	225.84	1.78	1.33	2.45	0.38	1.11
Date 2	0111	1 - 10 ha	177	1336.25	7.55	2.56	24.46	5.73	21.91
		10 - 20 ha	9	269.10	29.90	25.35	37.81	3.83	12.45
		> 20 ha	5	351.11	70.22	50.93	112.84	25.56	61.91
<b>Total</b>			<b>843</b>	<b>2435.52</b>	<b>2.89</b>	<b>0.05</b>	<b>112.84</b>		<b>112.79</b>
Year 1		< 0.1 ha	1138	251.71	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	932	624.54	0.67	0.40	1.22	0.23	0.83
Year 2	2010	0.5 - 1 ha	284	497.43	1.75	1.33	2.45	0.37	1.11
Date 2	0620	1 - 10 ha	293	2067.37	7.06	2.67	24.69	4.87	22.02
		10 - 20 ha	21	669.26	31.87	25.69	46.26	5.47	20.57
		> 20 ha	7	522.57	74.65	58.71	129.64	25.45	70.93
<b>Total</b>			<b>2675</b>	<b>4632.88</b>	<b>1.73</b>	<b>0.00</b>	<b>129.64</b>		<b>129.64</b>
Year 1		< 0.1 ha	585	129.80	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	879	588.02	0.67	0.26	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	248	432.78	1.75	1.33	2.45	0.35	1.11
Date 2	1127	1 - 10 ha	248	1771.24	7.14	2.56	24.46	5.20	21.91
		10 - 20 ha	14	411.96	29.43	25.13	37.70	3.39	12.57
		> 20 ha	6	453.67	75.61	55.60	131.68	28.07	76.08
<b>Total</b>			<b>1980</b>	<b>3787.46</b>	<b>1.91</b>	<b>0.03</b>	<b>131.68</b>		<b>131.65</b>
Year 1		< 0.1 ha	253	56.27	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	368	253.55	0.69	0.36	1.22	0.24	0.86
Year 2	2010	0.5 - 1 ha	122	217.59	1.78	1.33	2.45	0.37	1.11
Date 2	1213	1 - 10 ha	182	1266.32	6.96	2.67	24.24	5.05	21.57
		10 - 20 ha	9	277.77	30.86	25.35	48.04	7.12	22.68
		> 20 ha	4	293.94	73.49	56.27	118.08	29.88	61.81
<b>Total</b>			<b>938</b>	<b>2365.43</b>	<b>2.52</b>	<b>0.22</b>	<b>118.08</b>		<b>117.86</b>



Denton County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	302	67.06	0.22	0.16	0.22	0.00	0.06
Date 1		0.1 - 0.5 ha	326	220.06	0.68	0.33	1.22	0.24	0.89
Year 2	1997	0.5 - 1 ha	118	205.69	1.74	1.33	2.45	0.37	1.11
Date 2	0328	1 - 10 ha	125	987.55	7.90	2.67	24.57	6.27	21.91
		10 - 20 ha	14	428.33	30.60	25.58	42.92	4.99	17.35
		> 20 ha	2	106.08	53.04	50.26	55.82	3.93	5.56
<b>Baseline Wet</b>		<b>Total</b>	<b>887</b>	<b>2014.78</b>	<b>2.27</b>	<b>0.16</b>	<b>55.82</b>		<b>55.66</b>
Year 1		< 0.1 ha	152	33.80	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	184	121.97	0.66	0.44	1.22	0.24	0.78
Year 2	1999	0.5 - 1 ha	51	84.95	1.67	1.33	2.45	0.37	1.11
Date 2	0214	1 - 10 ha	96	778.93	8.11	2.67	23.80	5.94	21.13
		10 - 20 ha	6	194.37	32.40	26.46	41.37	6.05	14.90
		> 20 ha	1	49.59	49.59	49.59	49.59	0.00	0.00
<b>Baseline Dry</b>		<b>Total</b>	<b>490</b>	<b>1263.63</b>	<b>2.58</b>	<b>0.22</b>	<b>49.59</b>		<b>49.37</b>
Year 1		< 0.1 ha	245	54.43	0.22	0.17	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	326	225.35	0.69	0.44	1.22	0.24	0.78
Year 2	2003	0.5 - 1 ha	127	228.37	1.80	1.33	2.45	0.36	1.11
Date 2	1023	1 - 10 ha	118	911.30	7.72	2.67	24.24	6.02	21.57
		10 - 20 ha	9	301.05	33.45	25.13	49.07	7.64	23.94
		> 20 ha	1	53.37	53.37	53.37	53.37	0.00	0.00
		<b>Total</b>	<b>826</b>	<b>1773.87</b>	<b>2.15</b>	<b>0.17</b>	<b>53.37</b>		<b>53.21</b>
Year 1		< 0.1 ha	317	70.31	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	402	273.78	0.68	0.44	1.19	0.25	0.75
Year 2	2004	0.5 - 1 ha	151	251.52	1.67	1.33	2.45	0.33	1.11
Date 2	0907	1 - 10 ha	158	1143.64	7.24	2.67	24.24	5.58	21.57
		10 - 20 ha	10	333.37	33.34	25.35	47.15	7.49	21.79
		> 20 ha	2	118.20	59.10	54.49	63.72	6.53	9.23
		<b>Total</b>	<b>1040</b>	<b>2190.82</b>	<b>2.11</b>	<b>0.08</b>	<b>63.72</b>		<b>63.63</b>
Year 1		< 0.1 ha	386	85.80	0.22	0.18	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	645	430.28	0.67	0.28	1.22	0.24	0.94
Year 2	2005	0.5 - 1 ha	219	380.32	1.74	1.33	2.45	0.35	1.11
Date 2	0214	1 - 10 ha	181	1258.39	6.95	2.56	24.02	5.38	21.46
		10 - 20 ha	14	458.40	32.74	25.35	47.52	7.40	22.17
		> 20 ha	1	96.52	96.52	96.52	96.52	0.00	0.00
		<b>Total</b>	<b>1446</b>	<b>2709.70</b>	<b>1.87</b>	<b>0.18</b>	<b>96.52</b>		<b>96.34</b>
Year 1		< 0.1 ha	109	24.10	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	193	137.82	0.71	0.44	1.22	0.25	0.78
Year 2	2006	0.5 - 1 ha	91	161.32	1.77	1.33	2.45	0.38	1.11
Date 2	1116	1 - 10 ha	100	736.15	7.36	2.56	22.68	5.10	20.13
		10 - 20 ha	4	134.55	33.64	26.24	38.70	5.54	12.45
		<b>Total</b>	<b>497</b>	<b>1193.93</b>	<b>2.40</b>	<b>0.08</b>	<b>38.70</b>		<b>38.61</b>

Denton County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	336	74.33	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	526	354.32	0.67	0.27	1.22	0.24	0.96
Year 2	2007	0.5 - 1 ha	217	374.40	1.73	1.33	2.45	0.36	1.11
Date 2	0308	1 - 10 ha	173	1196.48	6.92	2.67	23.80	5.36	21.13
		10 - 20 ha	10	332.52	33.25	24.91	48.19	7.73	23.28
		> 20 ha	1	50.43	50.43	50.43	50.43	0.00	0.00
<b>Total</b>			<b>1263</b>	<b>2382.48</b>	<b>1.89</b>	<b>0.08</b>	<b>50.43</b>		<b>50.35</b>
Year 1		< 0.1 ha	303	67.39	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	463	312.48	0.67	0.39	1.22	0.23	0.83
Year 2	2008	0.5 - 1 ha	173	300.01	1.73	1.33	2.45	0.37	1.11
Date 2	0207	1 - 10 ha	162	1202.97	7.43	2.67	24.46	5.85	21.79
		10 - 20 ha	10	379.93	37.99	28.47	48.56	7.58	20.10
		> 20 ha	1	67.44	67.44	67.44	67.44	0.00	0.00
<b>Total</b>			<b>1112</b>	<b>2330.21</b>	<b>2.10</b>	<b>0.22</b>	<b>67.44</b>		<b>67.21</b>
Year 1		< 0.1 ha	380	83.98	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	552	383.14	0.69	0.33	1.22	0.24	0.89
Year 2	2008	0.5 - 1 ha	240	425.11	1.77	1.33	2.45	0.38	1.11
Date 2	0411	1 - 10 ha	196	1348.44	6.88	2.56	24.24	5.18	21.68
		10 - 20 ha	17	591.68	34.80	25.35	47.81	8.04	22.46
		> 20 ha	5	455.74	91.15	52.76	150.78	44.95	98.02
<b>Total</b>			<b>1390</b>	<b>3288.09</b>	<b>2.37</b>	<b>0.00</b>	<b>150.78</b>		<b>150.78</b>
Year 1		< 0.1 ha	293	64.82	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	455	305.55	0.67	0.44	1.22	0.23	0.78
Year 2	2008	0.5 - 1 ha	189	336.21	1.78	1.33	2.45	0.37	1.11
Date 2	1004	1 - 10 ha	182	1271.66	6.99	2.67	24.69	5.66	22.02
		10 - 20 ha	12	423.05	35.25	24.91	46.78	7.97	21.87
		> 20 ha	2	173.91	86.96	53.82	120.09	46.86	66.27
<b>Total</b>			<b>1133</b>	<b>2575.19</b>	<b>2.27</b>	<b>0.00</b>	<b>120.09</b>		<b>120.09</b>
Year 1		< 0.1 ha	258	57.16	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	400	281.47	0.70	0.44	1.11	0.23	0.67
Year 2	2008	0.5 - 1 ha	195	335.01	1.72	1.33	2.45	0.36	1.11
Date 2	1020	1 - 10 ha	179	1322.40	7.39	2.56	24.69	6.17	22.13
		10 - 20 ha	8	272.29	34.04	25.58	46.78	7.60	21.21
		> 20 ha	1	50.26	50.26	50.26	50.26	0.00	0.00
<b>Total</b>			<b>1041</b>	<b>2318.59</b>	<b>2.23</b>	<b>0.00</b>	<b>50.26</b>		<b>50.26</b>
Year 1		< 0.1 ha	181	40.13	0.22	0.15	0.22	0.01	0.07
Date 1		0.1 - 0.5 ha	305	224.17	0.73	0.40	1.11	0.24	0.71
Year 2	2008	0.5 - 1 ha	125	218.39	1.75	1.33	2.45	0.37	1.11
Date 2	1121	1 - 10 ha	137	1061.93	7.75	2.67	24.69	6.01	22.02
		10 - 20 ha	7	247.30	35.33	28.47	46.48	7.09	18.01
<b>Total</b>			<b>755</b>	<b>1791.93</b>	<b>2.37</b>	<b>0.15</b>	<b>46.48</b>		<b>46.33</b>

Denton County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	186	41.14	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	313	211.52	0.68	0.32	1.11	0.23	0.79
Year 2	2008	0.5 - 1 ha	132	228.48	1.73	1.33	2.45	0.35	1.11
Date 2	1207	1 - 10 ha	137	1014.27	7.40	2.56	22.68	5.65	20.13
		10 - 20 ha	8	275.25	34.41	24.91	47.81	7.81	22.91
<b>Total</b>			<b>776</b>	<b>1770.67</b>	<b>2.28</b>	<b>0.00</b>	<b>47.81</b>		<b>47.81</b>
Year 1		< 0.1 ha	242	53.39	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	348	225.80	0.65	0.30	1.11	0.22	0.81
Year 2	2009	0.5 - 1 ha	141	248.19	1.76	1.33	2.45	0.36	1.11
Date 2	0108	1 - 10 ha	141	1047.44	7.43	2.56	22.68	5.82	20.13
		10 - 20 ha	8	274.99	34.37	25.58	48.04	7.56	22.46
<b>Total</b>			<b>880</b>	<b>1849.82</b>	<b>2.10</b>	<b>0.00</b>	<b>48.04</b>		<b>48.04</b>
Year 1		< 0.1 ha	264	58.23	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	442	312.89	0.71	0.44	1.22	0.25	0.78
Year 2	2009	0.5 - 1 ha	191	333.20	1.74	1.33	2.45	0.35	1.11
Date 2	0329	1 - 10 ha	190	1284.33	6.76	2.56	24.69	5.28	22.13
		10 - 20 ha	11	370.28	33.66	25.13	48.03	8.11	22.90
		> 20 ha	2	113.98	56.99	50.48	63.49	9.20	13.01
<b>Total</b>			<b>1100</b>	<b>2472.91</b>	<b>2.25</b>	<b>0.00</b>	<b>63.49</b>		<b>63.49</b>
Year 1		< 0.1 ha	295	65.20	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	453	323.52	0.71	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	217	384.94	1.77	1.33	2.45	0.36	1.11
Date 2	0414	1 - 10 ha	195	1330.63	6.82	2.56	24.24	5.19	21.68
		10 - 20 ha	11	358.08	32.55	25.13	47.50	8.23	22.37
		> 20 ha	4	299.12	74.78	50.26	138.11	42.37	87.85
<b>Total</b>			<b>1175</b>	<b>2761.49</b>	<b>2.35</b>	<b>0.02</b>	<b>138.11</b>		<b>138.09</b>
Year 1		< 0.1 ha	391	86.48	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	641	433.32	0.68	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	273	483.38	1.77	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	242	1574.94	6.51	2.67	24.02	5.05	21.35
		10 - 20 ha	16	538.17	33.64	25.13	46.93	7.58	21.79
		> 20 ha	5	275.07	55.01	49.59	60.71	4.86	11.12
<b>Total</b>			<b>1568</b>	<b>3391.36</b>	<b>2.16</b>	<b>0.00</b>	<b>60.71</b>		<b>60.71</b>
Year 1		< 0.1 ha	393	87.28	0.22	0.10	0.22	0.01	0.12
Date 1		0.1 - 0.5 ha	556	379.56	0.68	0.29	1.22	0.24	0.94
Year 2	2009	0.5 - 1 ha	255	452.54	1.77	1.33	2.45	0.37	1.11
Date 2	0804	1 - 10 ha	224	1372.88	6.13	2.56	23.57	4.55	21.02
		10 - 20 ha	17	523.74	30.81	24.91	47.81	6.12	22.91
		> 20 ha	5	300.20	60.04	50.01	91.63	17.79	41.62
<b>Total</b>			<b>1450</b>	<b>3116.20</b>	<b>2.15</b>	<b>0.10</b>	<b>91.63</b>		<b>91.52</b>



Denton County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	411	91.31	0.22	0.17	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	504	349.02	0.69	0.26	1.22	0.24	0.96
Year 2	2009	0.5 - 1 ha	205	364.84	1.78	1.33	2.45	0.37	1.11
Date 2	1023	1 - 10 ha	214	1458.13	6.81	2.67	24.69	5.26	22.02
		10 - 20 ha	13	461.80	35.52	25.02	46.48	6.66	21.46
		> 20 ha	5	390.27	78.05	50.34	156.45	44.73	106.11
<b>Total</b>			<b>1352</b>	<b>3115.38</b>	<b>2.30</b>	<b>0.17</b>	<b>156.45</b>		<b>156.29</b>
Year 1		< 0.1 ha	335	73.97	0.22	0.06	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	508	352.88	0.69	0.34	1.11	0.24	0.77
Year 2	2009	0.5 - 1 ha	207	363.08	1.75	1.33	2.45	0.37	1.11
Date 2	1124	1 - 10 ha	199	1337.98	6.72	2.56	24.69	5.24	22.13
		10 - 20 ha	13	466.03	35.85	24.91	48.93	8.71	24.02
		> 20 ha	5	319.72	63.94	51.37	110.09	25.82	58.71
<b>Total</b>			<b>1267</b>	<b>2913.67</b>	<b>2.30</b>	<b>0.06</b>	<b>110.09</b>		<b>110.03</b>
Year 1		< 0.1 ha	376	83.01	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	527	345.81	0.66	0.30	1.11	0.24	0.81
Year 2	2009	0.5 - 1 ha	207	355.39	1.72	1.33	2.45	0.35	1.11
Date 2	1210	1 - 10 ha	186	1338.48	7.20	2.67	24.24	5.60	21.57
		10 - 20 ha	13	463.07	35.62	26.24	48.04	8.13	21.79
		> 20 ha	2	110.09	55.04	54.26	55.82	1.10	1.56
<b>Total</b>			<b>1311</b>	<b>2695.84</b>	<b>2.06</b>	<b>0.00</b>	<b>55.82</b>		<b>55.82</b>
Year 1		< 0.1 ha	261	57.80	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	435	294.57	0.68	0.30	1.22	0.24	0.92
Year 2	2010	0.5 - 1 ha	167	290.78	1.74	1.33	2.45	0.36	1.11
Date 2	0111	1 - 10 ha	158	1137.65	7.20	2.56	24.24	5.44	21.68
		10 - 20 ha	13	440.90	33.92	25.58	47.15	7.30	21.57
<b>Total</b>			<b>1034</b>	<b>2221.70</b>	<b>2.15</b>	<b>0.02</b>	<b>47.15</b>		<b>47.13</b>
Year 1		< 0.1 ha	430	95.58	0.22	0.18	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	536	368.88	0.69	0.33	1.22	0.25	0.89
Year 2	2010	0.5 - 1 ha	202	357.33	1.77	1.33	2.45	0.36	1.11
Date 2	0604	1 - 10 ha	225	1414.44	6.29	2.56	24.69	4.83	22.13
		10 - 20 ha	15	502.72	33.51	25.13	47.15	7.95	22.02
		> 20 ha	4	222.17	55.54	51.60	66.72	7.46	15.12
<b>Total</b>			<b>1412</b>	<b>2961.13</b>	<b>2.10</b>	<b>0.18</b>	<b>66.72</b>		<b>66.54</b>
Year 1		< 0.1 ha	414	91.85	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	696	490.95	0.71	0.44	1.22	0.25	0.78
Year 2	2010	0.5 - 1 ha	286	500.49	1.75	1.33	2.45	0.38	1.11
Date 2	0620	1 - 10 ha	252	1578.63	6.26	2.67	24.69	4.81	22.02
		10 - 20 ha	15	515.96	34.40	25.35	47.81	7.14	22.46
		> 20 ha	6	377.93	62.99	51.45	86.29	14.34	34.84
<b>Total</b>			<b>1669</b>	<b>3555.81</b>	<b>2.13</b>	<b>0.00</b>	<b>86.29</b>		<b>86.29</b>

Denton County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	462	102.50	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	652	460.23	0.71	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	275	483.11	1.76	1.33	2.45	0.37	1.11
Date 2	0807	1 - 10 ha	263	1585.59	6.03	2.67	24.24	4.51	21.57
		10 - 20 ha	17	556.46	32.73	24.91	44.70	6.50	19.79
		> 20 ha	5	421.64	84.33	51.38	194.93	61.99	143.55
<b>Total</b>			<b>1674</b>	<b>3609.52</b>	<b>2.16</b>	<b>0.00</b>	<b>194.93</b>		<b>194.93</b>
Year 1		< 0.1 ha	392	86.79	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	564	394.88	0.70	0.26	1.22	0.25	0.96
Year 2	2010	0.5 - 1 ha	235	411.85	1.75	1.33	2.45	0.37	1.11
Date 2	1010	1 - 10 ha	207	1392.64	6.73	2.56	24.46	5.11	21.91
		10 - 20 ha	19	639.50	33.66	25.13	48.48	7.75	23.35
		> 20 ha	2	111.50	55.75	52.79	58.71	4.19	5.92
<b>Total</b>			<b>1419</b>	<b>3037.15</b>	<b>2.14</b>	<b>0.02</b>	<b>58.71</b>		<b>58.69</b>
Year 1		< 0.1 ha	566	124.93	0.22	0.01	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	683	464.46	0.68	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	223	404.17	1.81	1.33	2.45	0.37	1.11
Date 2	1127	1 - 10 ha	241	1522.06	6.32	2.56	23.80	4.70	21.24
		10 - 20 ha	17	521.63	30.68	24.91	46.93	6.01	22.02
		> 20 ha	4	234.45	58.61	50.64	74.84	11.39	24.20
<b>Total</b>			<b>1734</b>	<b>3271.70</b>	<b>1.89</b>	<b>0.01</b>	<b>74.84</b>		<b>74.83</b>
Year 1		< 0.1 ha	240	53.07	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	372	256.51	0.69	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	135	236.18	1.75	1.33	2.45	0.36	1.11
Date 2	1213	1 - 10 ha	145	1086.25	7.49	2.67	24.46	5.90	21.79
		10 - 20 ha	9	325.89	36.21	26.24	44.92	7.16	18.68
		> 20 ha	1	50.59	50.59	50.59	50.59	0.00	0.00
<b>Total</b>			<b>902</b>	<b>2008.50</b>	<b>2.23</b>	<b>0.00</b>	<b>50.59</b>		<b>50.59</b>



Erath County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	1326	294.56	0.22	0.01	0.22	0.01	0.21
Date 1	0303	0.1 - 0.5 ha	2186	1475.59	0.68	0.25	1.22	0.25	0.97
Year 2	1997	0.5 - 1 ha	592	1009.40	1.71	1.25	2.47	0.34	1.22
Date 2	0328	1 - 10 ha	326	2197.12	6.74	2.47	24.40	5.38	21.93
		10 - 20 ha	26	905.82	34.84	25.03	48.04	7.20	23.00
		> 20 ha	22	1631.24	74.15	49.44	212.34	40.20	162.90
<b>Baseline Wet</b>		<b>Total</b>	<b>4478</b>	<b>7513.73</b>	<b>1.68</b>	<b>0.01</b>	<b>212.34</b>		<b>212.33</b>
Year 1	1999	< 0.1 ha	503	111.74	0.22	0.10	0.22	0.01	0.12
Date 1	0221	0.1 - 0.5 ha	731	449.20	0.61	0.25	1.22	0.25	0.97
Year 2	1999	0.5 - 1 ha	149	260.74	1.75	1.33	2.46	0.36	1.13
Date 2	0214	1 - 10 ha	137	1139.02	8.31	2.48	24.02	5.59	21.54
		10 - 20 ha	19	578.85	30.47	25.13	41.81	4.57	16.68
		> 20 ha	4	281.45	70.36	51.15	89.85	21.25	38.70
<b>Baseline Dry</b>		<b>Total</b>	<b>1543</b>	<b>2821.00</b>	<b>1.83</b>	<b>0.10</b>	<b>89.85</b>		<b>89.75</b>
Year 1	2003	< 0.1 ha	729	161.89	0.22	0.10	0.22	0.01	0.12
Date 1	1014	0.1 - 0.5 ha	1097	675.59	0.62	0.25	1.22	0.25	0.97
Year 2	2003	0.5 - 1 ha	178	299.85	1.68	1.33	2.46	0.34	1.13
Date 2	1023	1 - 10 ha	161	1156.63	7.18	2.49	23.37	5.06	20.89
		10 - 20 ha	29	924.13	31.87	24.91	41.37	5.10	16.46
		> 20 ha	4	301.66	75.41	55.04	114.51	27.60	59.47
		<b>Total</b>	<b>2198</b>	<b>3519.75</b>	<b>1.60</b>	<b>0.10</b>	<b>114.51</b>		<b>114.41</b>
Year 1	2004	< 0.1 ha	1174	260.68	0.22	0.01	0.22	0.01	0.21
Date 1	1016	0.1 - 0.5 ha	1572	994.84	0.63	0.25	1.22	0.25	0.97
Year 2	2004	0.5 - 1 ha	308	525.66	1.71	1.30	2.47	0.34	1.17
Date 2	0907	1 - 10 ha	220	1558.05	7.08	2.51	23.28	5.44	20.77
		10 - 20 ha	33	1139.33	34.53	25.15	44.61	5.87	19.46
		> 20 ha	4	310.93	77.73	52.71	118.90	29.62	66.19
		<b>Total</b>	<b>3311</b>	<b>4789.51</b>	<b>1.45</b>	<b>0.01</b>	<b>118.90</b>		<b>118.88</b>
Year 1	2005	< 0.1 ha	965	214.42	0.22	0.12	0.22	0.00	0.10
Date 1	0221	0.1 - 0.5 ha	1769	1154.91	0.65	0.25	1.20	0.25	0.95
Year 2	2005	0.5 - 1 ha	418	701.94	1.68	1.27	2.46	0.34	1.19
Date 2	0214	1 - 10 ha	281	1895.55	6.75	2.48	24.41	5.44	21.93
		10 - 20 ha	34	1226.94	36.09	24.91	48.26	6.04	23.35
		> 20 ha	8	626.63	78.33	50.71	123.47	26.64	72.77
		<b>Total</b>	<b>3475</b>	<b>5820.38</b>	<b>1.67</b>	<b>0.12</b>	<b>123.47</b>		<b>123.35</b>
Year 1	2006	< 0.1 ha	409	90.96	0.22	0.22	0.22	0.00	0.00
Date 1	1123	0.1 - 0.5 ha	532	337.83	0.64	0.25	1.22	0.26	0.97
Year 2	2006	0.5 - 1 ha	114	192.36	1.69	1.33	2.45	0.37	1.12
Date 2	1116	1 - 10 ha	131	1087.10	8.30	2.54	24.08	5.79	21.55
		10 - 20 ha	14	453.01	32.36	24.91	42.78	5.92	17.87
		> 20 ha	2	139.06	69.53	58.93	80.12	14.98	21.19
		<b>Total</b>	<b>1202</b>	<b>2300.31</b>	<b>1.91</b>	<b>0.22</b>	<b>80.12</b>		<b>79.90</b>

Erath County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1583	351.54	0.22	0.01	0.22	0.01	0.21
Date 1	0331	0.1 - 0.5 ha	2261	1494.78	0.66	0.25	1.22	0.23	0.97
Year 2	2007	0.5 - 1 ha	624	1061.29	1.70	1.29	2.47	0.36	1.18
Date 2	0308	1 - 10 ha	345	2164.01	6.27	2.50	23.57	4.99	21.08
		10 - 20 ha	37	1343.53	36.31	25.35	48.93	7.54	23.57
		> 20 ha	15	1055.55	70.37	50.26	172.39	31.88	122.13
<b>Total</b>			<b>4865</b>	<b>7470.70</b>	<b>1.54</b>	<b>0.01</b>	<b>172.39</b>		<b>172.38</b>
Year 1	2008	< 0.1 ha	1148	254.90	0.22	0.03	0.22	0.01	0.19
Date 1	0418	0.1 - 0.5 ha	1750	1119.09	0.64	0.25	1.20	0.25	0.95
Year 2	2008	0.5 - 1 ha	382	659.81	1.73	1.33	2.45	0.34	1.12
Date 2	0411	1 - 10 ha	276	1965.52	7.12	2.49	24.11	5.51	21.62
		10 - 20 ha	35	1204.72	34.42	25.13	48.93	5.96	23.80
		> 20 ha	5	403.46	80.69	54.49	116.76	31.88	62.27
<b>Total</b>			<b>3596</b>	<b>5607.49</b>	<b>1.56</b>	<b>0.03</b>	<b>116.76</b>		<b>116.72</b>
Year 1	2008	< 0.1 ha	895	196.61	0.22	0.00	0.22	0.02	0.22
Date 1	0723	0.1 - 0.5 ha	1259	845.44	0.67	0.25	1.22	0.24	0.97
Year 2	2008	0.5 - 1 ha	319	551.45	1.73	1.27	2.45	0.37	1.18
Date 2	0207	1 - 10 ha	266	1974.81	7.42	2.56	24.46	5.46	21.91
		10 - 20 ha	32	1061.55	33.17	25.35	46.48	5.34	21.13
		> 20 ha	6	497.48	82.91	50.26	121.09	34.26	70.83
<b>Total</b>			<b>2777</b>	<b>5127.32</b>	<b>1.85</b>	<b>0.00</b>	<b>121.09</b>		<b>121.09</b>
Year 1	2008	< 0.1 ha	560	123.95	0.22	0.00	0.22	0.01	0.22
Date 1	1027	0.1 - 0.5 ha	570	375.57	0.66	0.25	1.22	0.23	0.97
Year 2	2008	0.5 - 1 ha	152	266.85	1.76	1.33	2.45	0.39	1.11
Date 2	1004	1 - 10 ha	171	1376.21	8.05	2.56	23.57	5.58	21.02
		10 - 20 ha	22	707.88	32.18	25.58	47.81	5.72	22.24
		> 20 ha	3	271.38	90.46	82.06	104.14	11.95	22.08
<b>Total</b>			<b>1478</b>	<b>3121.85</b>	<b>2.11</b>	<b>0.00</b>	<b>104.14</b>		<b>104.14</b>
Year 1	2008	< 0.1 ha	514	113.89	0.22	0.02	0.22	0.01	0.20
Date 1	1027	0.1 - 0.5 ha	555	367.79	0.66	0.25	1.22	0.23	0.97
Year 2	2008	0.5 - 1 ha	158	280.08	1.77	1.33	2.45	0.38	1.11
Date 2	1020	1 - 10 ha	170	1406.46	8.27	2.56	23.13	5.61	20.57
		10 - 20 ha	21	683.53	32.55	25.58	47.37	5.72	21.79
		> 20 ha	2	186.70	93.35	85.18	101.52	11.56	16.34
<b>Total</b>			<b>1420</b>	<b>3038.45</b>	<b>2.14</b>	<b>0.02</b>	<b>101.52</b>		<b>101.50</b>
Year 1	2008	< 0.1 ha	434	96.15	0.22	0.02	0.22	0.01	0.20
Date 1	1027	0.1 - 0.5 ha	477	314.62	0.66	0.25	1.22	0.23	0.97
Year 2	2008	0.5 - 1 ha	133	237.27	1.78	1.33	2.45	0.40	1.11
Date 2	1121	1 - 10 ha	157	1315.41	8.38	2.56	24.69	5.73	22.13
		10 - 20 ha	19	590.57	31.08	25.58	44.26	5.29	18.68
		> 20 ha	2	184.07	92.03	85.18	98.89	9.70	13.71
<b>Total</b>			<b>1222</b>	<b>2738.08</b>	<b>2.24</b>	<b>0.02</b>	<b>98.89</b>		<b>98.87</b>

Erath County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2008	< 0.1 ha	336	74.14	0.22	0.02	0.22	0.02	0.21
Date 1	1214	0.1 - 0.5 ha	422	278.79	0.66	0.42	1.22	0.23	0.80
Year 2	2008	0.5 - 1 ha	123	214.39	1.74	1.33	2.45	0.37	1.11
Date 2	1207	1 - 10 ha	131	1093.22	8.35	2.67	23.80	5.13	21.13
		10 - 20 ha	21	671.41	31.97	24.91	46.48	6.40	21.57
		> 20 ha	2	173.68	86.84	83.83	89.85	4.25	6.02
<b>Total</b>			<b>1035</b>	<b>2505.63</b>	<b>2.42</b>	<b>0.02</b>	<b>89.85</b>		<b>89.83</b>
Year 1	2009	< 0.1 ha	326	71.87	0.22	0.00	0.22	0.02	0.22
Date 1	0115	0.1 - 0.5 ha	430	281.03	0.65	0.28	1.22	0.22	0.95
Year 2	2009	0.5 - 1 ha	104	183.48	1.76	1.33	2.45	0.37	1.11
Date 2	0108	1 - 10 ha	137	1177.45	8.59	2.67	24.69	5.48	22.02
		10 - 20 ha	18	593.91	32.99	26.02	44.48	5.99	18.46
		> 20 ha	4	340.52	85.13	70.05	95.07	11.01	25.02
<b>Total</b>			<b>1019</b>	<b>2648.25</b>	<b>2.60</b>	<b>0.00</b>	<b>95.07</b>		<b>95.07</b>
Year 1	2009	< 0.1 ha	573	126.31	0.22	0.00	0.22	0.02	0.22
Date 1	0421	0.1 - 0.5 ha	724	478.07	0.66	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	177	304.01	1.72	1.33	2.45	0.35	1.11
Date 2	0329	1 - 10 ha	179	1338.79	7.48	2.67	24.46	5.32	21.79
		10 - 20 ha	23	770.60	33.50	24.91	47.81	7.28	22.91
		> 20 ha	2	174.17	87.09	85.88	88.29	1.70	2.41
<b>Total</b>			<b>1678</b>	<b>3191.95</b>	<b>1.90</b>	<b>0.00</b>	<b>88.29</b>		<b>88.29</b>
Year 1	2009	< 0.1 ha	582	128.53	0.22	0.00	0.22	0.02	0.22
Date 1	0421	0.1 - 0.5 ha	686	451.11	0.66	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	171	295.67	1.73	1.33	2.45	0.35	1.11
Date 2	0414	1 - 10 ha	188	1360.25	7.24	2.56	24.46	5.27	21.91
		10 - 20 ha	22	748.47	34.02	24.91	47.81	7.41	22.91
		> 20 ha	3	265.05	88.35	87.36	89.40	1.02	2.05
<b>Total</b>			<b>1652</b>	<b>3249.09</b>	<b>1.97</b>	<b>0.00</b>	<b>89.40</b>		<b>89.40</b>
Year 1	2009	< 0.1 ha	747	165.67	0.22	0.00	0.22	0.01	0.22
Date 1	0608	0.1 - 0.5 ha	796	512.09	0.64	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	175	298.78	1.71	1.33	2.45	0.35	1.11
Date 2	0703	1 - 10 ha	171	1281.12	7.49	2.56	24.69	5.51	22.13
		10 - 20 ha	19	634.71	33.41	24.91	47.15	7.43	22.24
		> 20 ha	2	165.98	82.99	81.84	84.14	1.63	2.30
<b>Total</b>			<b>1910</b>	<b>3058.36</b>	<b>1.60</b>	<b>0.00</b>	<b>84.14</b>		<b>84.14</b>
Year 1	2009	< 0.1 ha	676	149.92	0.22	0.01	0.22	0.01	0.21
Date 1	0710	0.1 - 0.5 ha	742	479.76	0.65	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	181	312.52	1.73	1.25	2.45	0.37	1.19
Date 2	0703	1 - 10 ha	171	1278.20	7.47	2.67	24.46	5.46	21.79
		10 - 20 ha	18	593.13	32.95	24.91	47.81	7.49	22.91
		> 20 ha	2	162.67	81.33	80.28	82.38	1.48	2.10
<b>Total</b>			<b>1790</b>	<b>2976.19</b>	<b>1.66</b>	<b>0.01</b>	<b>82.38</b>		<b>82.37</b>

Erath County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	1045	231.71	0.22	0.02	0.22	0.01	0.21
Date 1	0710	0.1 - 0.5 ha	1136	756.43	0.67	0.25	1.22	0.24	0.97
Year 2	2009	0.5 - 1 ha	222	378.57	1.71	1.25	2.45	0.36	1.19
Date 2	0804	1 - 10 ha	201	1510.43	7.51	2.67	24.69	5.51	22.02
		10 - 20 ha	20	677.19	33.86	26.02	47.81	6.71	21.79
		> 20 ha	2	164.84	82.42	80.28	84.56	3.02	4.27
<b>Total</b>			<b>2626</b>	<b>3719.17</b>	<b>1.42</b>	<b>0.02</b>	<b>84.56</b>		<b>84.54</b>
Year 1	2009	< 0.1 ha	1044	231.76	0.22	0.01	0.22	0.01	0.21
Date 1	0928	0.1 - 0.5 ha	1467	978.79	0.67	0.27	1.23	0.25	0.95
Year 2	2009	0.5 - 1 ha	372	641.62	1.72	1.24	2.47	0.36	1.23
Date 2	1023	1 - 10 ha	244	1769.75	7.25	2.49	24.24	5.43	21.75
		10 - 20 ha	29	993.61	34.26	25.22	48.93	7.52	23.71
		> 20 ha	4	274.67	68.67	52.44	78.73	12.26	26.29
<b>Total</b>			<b>3160</b>	<b>4890.19</b>	<b>1.55</b>	<b>0.01</b>	<b>78.73</b>		<b>78.72</b>
Year 1	2010	< 0.1 ha	1187	262.47	0.22	0.00	0.22	0.01	0.22
Date 1	0323	0.1 - 0.5 ha	1538	1057.98	0.69	0.25	1.22	0.24	0.97
Year 2	2009	0.5 - 1 ha	400	679.97	1.70	1.33	2.45	0.36	1.11
Date 2	1124	1 - 10 ha	312	2119.22	6.79	2.56	24.24	5.14	21.68
		10 - 20 ha	32	1092.73	34.15	25.13	46.70	6.24	21.57
		> 20 ha	5	389.28	77.86	52.04	117.30	33.70	65.25
<b>Total</b>			<b>3474</b>	<b>5601.66</b>	<b>1.61</b>	<b>0.00</b>	<b>117.30</b>		<b>117.30</b>
Year 1	2010	< 0.1 ha	1043	230.58	0.22	0.00	0.22	0.01	0.22
Date 1	0323	0.1 - 0.5 ha	1474	1011.31	0.69	0.25	1.22	0.24	0.97
Year 2	2009	0.5 - 1 ha	375	635.33	1.69	1.33	2.45	0.35	1.11
Date 2	1210	1 - 10 ha	313	2062.49	6.59	2.56	23.57	4.97	21.02
		10 - 20 ha	31	1038.99	33.52	25.13	46.70	6.83	21.57
		> 20 ha	5	393.64	78.73	51.37	115.64	32.21	64.27
<b>Total</b>			<b>3241</b>	<b>5372.34</b>	<b>1.66</b>	<b>0.00</b>	<b>115.64</b>		<b>115.64</b>
Year 1	2010	< 0.1 ha	1210	267.05	0.22	0.01	0.22	0.02	0.22
Date 1	0408	0.1 - 0.5 ha	1425	959.91	0.67	0.28	1.22	0.24	0.95
Year 2	2010	0.5 - 1 ha	380	654.86	1.72	1.29	2.45	0.37	1.15
Date 2	0620	1 - 10 ha	303	2202.08	7.27	2.64	24.69	5.50	22.04
		10 - 20 ha	33	1161.63	35.20	26.02	46.93	5.46	20.91
		> 20 ha	4	339.35	84.84	55.15	118.73	32.62	63.58
<b>Total</b>			<b>3355</b>	<b>5584.87</b>	<b>1.66</b>	<b>0.01</b>	<b>118.73</b>		<b>118.72</b>
Year 1	2010	< 0.1 ha	1211	266.90	0.22	0.00	0.22	0.02	0.22
Date 1	0627	0.1 - 0.5 ha	1547	1041.12	0.67	0.25	1.22	0.24	0.97
Year 2	2010	0.5 - 1 ha	381	654.27	1.72	1.33	2.45	0.37	1.11
Date 2	0620	1 - 10 ha	317	2267.30	7.15	2.56	24.69	5.37	22.13
		10 - 20 ha	32	1113.70	34.80	26.02	46.70	5.12	20.68
		> 20 ha	5	370.10	74.02	53.71	120.01	28.24	66.30
<b>Total</b>			<b>3493</b>	<b>5713.39</b>	<b>1.64</b>	<b>0.00</b>	<b>120.01</b>		<b>120.01</b>

Erath County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>	2010	< 0.1 ha	1128	249.99	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	1001	0.1 - 0.5 ha	1205	793.23	0.66	0.25	1.22	0.23	0.97
<b>Year 2</b>	2010	0.5 - 1 ha	295	505.10	1.71	1.27	2.45	0.36	1.18
<b>Date 2</b>	1010	1 - 10 ha	244	1690.25	6.93	2.56	23.35	4.98	20.79
		10 - 20 ha	32	1067.78	33.37	25.13	48.04	6.02	22.91
		> 20 ha	4	310.14	77.53	53.82	120.32	30.69	66.50
<b>Total</b>			<b>2908</b>	<b>4616.49</b>	<b>1.59</b>	<b>0.00</b>	<b>120.32</b>		<b>120.32</b>
<b>Year 1</b>	2010	< 0.1 ha	837	185.19	0.22	0.02	0.22	0.01	0.20
<b>Date 1</b>	1118	0.1 - 0.5 ha	989	657.07	0.66	0.44	1.22	0.23	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	269	450.88	1.68	1.33	2.45	0.33	1.11
<b>Date 2</b>	1127	1 - 10 ha	208	1575.52	7.57	2.56	24.69	5.42	22.13
		10 - 20 ha	31	1039.56	33.53	26.24	43.14	5.02	16.90
		> 20 ha	4	306.46	76.62	55.71	113.20	26.67	57.49
<b>Total</b>			<b>2338</b>	<b>4214.67</b>	<b>1.80</b>	<b>0.02</b>	<b>113.20</b>		<b>113.18</b>
<b>Year 1</b>	2011	< 0.1 ha	455	100.48	0.22	0.02	0.22	0.02	0.21
<b>Date 1</b>	0105	0.1 - 0.5 ha	522	333.73	0.64	0.25	1.21	0.22	0.95
<b>Year 2</b>	2010	0.5 - 1 ha	152	269.43	1.77	1.33	2.45	0.37	1.11
<b>Date 2</b>	1213	1 - 10 ha	148	1214.02	8.20	2.53	24.69	5.52	22.15
		10 - 20 ha	26	829.42	31.90	25.13	49.37	5.97	24.24
		> 20 ha	3	235.84	78.61	49.82	110.63	30.53	60.81
<b>Total</b>			<b>1306</b>	<b>2982.91</b>	<b>2.28</b>	<b>0.02</b>	<b>110.63</b>		<b>110.61</b>

Hill County Summary statistics for Water Features in Acres									
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	819	182.14	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	721	474.48	0.66	0.44	1.11	0.23	0.67
<b>Year 2</b>	1997	0.5 - 1 ha	201	352.33	1.75	1.33	2.45	0.36	1.11
<b>Date 2</b>	0328	1 - 10 ha	199	1373.23	6.90	2.53	23.13	4.94	20.60
		10 - 20 ha	19	642.50	33.82	25.91	48.82	6.86	22.91
		> 20 ha	1	55.49	55.49	55.49	55.49	0.00	0.00
<b>Baseline Wet</b>		<b>Total</b>	<b>1960</b>	<b>3080.17</b>	<b>1.57</b>	<b>0.22</b>	<b>55.49</b>		<b>55.27</b>
<b>Year 1</b>		< 0.1 ha	492	109.42	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	454	304.68	0.67	0.44	1.22	0.24	0.78
<b>Year 2</b>	1999	0.5 - 1 ha	130	225.06	1.73	1.33	2.45	0.38	1.11
<b>Date 2</b>	0214	1 - 10 ha	163	1247.19	7.65	2.67	24.57	5.53	21.91
		10 - 20 ha	16	525.77	32.86	25.27	45.15	6.98	19.88
<b>Baseline Dry</b>		<b>Total</b>	<b>1255</b>	<b>2412.12</b>	<b>1.92</b>	<b>0.22</b>	<b>45.15</b>		<b>44.92</b>
<b>Year 1</b>		< 0.1 ha	698	155.23	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	634	418.10	0.66	0.44	1.22	0.24	0.78
<b>Year 2</b>	2003	0.5 - 1 ha	189	328.42	1.74	1.33	2.45	0.35	1.11
<b>Date 2</b>	1023	1 - 10 ha	164	1171.99	7.15	2.56	24.02	4.87	21.46
		10 - 20 ha	15	484.85	32.32	25.13	46.48	6.64	21.35
		> 20 ha	2	248.86	124.43	56.71	192.15	95.77	135.44
		<b>Total</b>	<b>1702</b>	<b>2807.45</b>	<b>1.65</b>	<b>0.22</b>	<b>192.15</b>		<b>191.93</b>
<b>Year 1</b>		< 0.1 ha	1262	280.66	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	1167	763.68	0.65	0.44	1.22	0.23	0.78
<b>Year 2</b>	2004	0.5 - 1 ha	262	447.51	1.71	1.33	2.45	0.35	1.11
<b>Date 2</b>	0907	1 - 10 ha	241	1620.72	6.72	2.56	23.24	5.04	20.68
		10 - 20 ha	16	548.43	34.28	26.24	48.26	6.87	22.02
		> 20 ha	1	61.94	61.94	61.94	61.94	0.00	0.00
		<b>Total</b>	<b>2949</b>	<b>3722.94</b>	<b>1.26</b>	<b>0.22</b>	<b>61.94</b>		<b>61.71</b>
<b>Year 1</b>		< 0.1 ha	770	171.24	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	925	610.36	0.66	0.44	1.22	0.23	0.78
<b>Year 2</b>	2005	0.5 - 1 ha	262	455.80	1.74	1.33	2.45	0.38	1.11
<b>Date 2</b>	0214	1 - 10 ha	220	1489.10	6.77	2.53	23.35	4.66	20.82
		10 - 20 ha	25	810.18	32.41	25.13	48.04	6.41	22.91
		<b>Total</b>	<b>2202</b>	<b>3536.69</b>	<b>1.61</b>	<b>0.22</b>	<b>48.04</b>		<b>47.81</b>
<b>Year 1</b>		< 0.1 ha	201	44.70	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	251	169.58	0.68	0.44	1.22	0.24	0.78
<b>Year 2</b>	2006	0.5 - 1 ha	77	135.99	1.77	1.33	2.45	0.37	1.11
<b>Date 2</b>	1116	1 - 10 ha	100	674.19	6.74	2.67	20.02	4.62	17.35
		10 - 20 ha	3	95.85	31.95	30.47	33.80	1.70	3.34
		<b>Total</b>	<b>632</b>	<b>1120.31</b>	<b>1.77</b>	<b>0.22</b>	<b>33.80</b>		<b>33.58</b>

Hill County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	603	134.10	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	669	442.01	0.66	0.44	1.22	0.23	0.78
Year 2	2007	0.5 - 1 ha	198	347.91	1.76	1.33	2.45	0.39	1.11
Date 2	0308	1 - 10 ha	183	1231.18	6.73	2.56	23.35	4.81	20.79
		10 - 20 ha	10	330.15	33.01	26.02	46.48	6.23	20.46
<b>Total</b>			<b>1663</b>	<b>2485.35</b>	<b>1.49</b>	<b>0.22</b>	<b>46.48</b>		<b>46.26</b>
Year 1		< 0.1 ha	646	142.87	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	791	535.28	0.68	0.29	1.22	0.24	0.93
Year 2	2008	0.5 - 1 ha	262	458.03	1.75	1.33	2.45	0.36	1.11
Date 2	0207	1 - 10 ha	220	1534.98	6.98	2.56	24.24	5.29	21.68
		10 - 20 ha	15	481.35	32.09	25.13	46.04	6.05	20.91
<b>Total</b>			<b>1934</b>	<b>3152.50</b>	<b>1.63</b>	<b>0.00</b>	<b>46.04</b>		<b>46.03</b>
Year 1		< 0.1 ha	1106	245.97	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	1232	807.79	0.66	0.44	1.22	0.23	0.78
Year 2	2008	0.5 - 1 ha	350	621.15	1.77	1.33	2.45	0.38	1.11
Date 2	0411	1 - 10 ha	307	1957.94	6.38	2.51	22.91	4.55	20.40
		10 - 20 ha	20	717.15	35.86	26.46	49.15	6.68	22.68
		> 20 ha	3	158.79	52.93	50.15	56.93	3.55	6.78
<b>Total</b>			<b>3018</b>	<b>4508.79</b>	<b>1.49</b>	<b>0.22</b>	<b>56.93</b>		<b>56.71</b>
Year 1		< 0.1 ha	595	131.72	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	631	424.43	0.67	0.37	1.22	0.23	0.85
Year 2	2008	0.5 - 1 ha	211	371.07	1.76	1.33	2.45	0.38	1.11
Date 2	1004	1 - 10 ha	193	1325.64	6.87	2.56	24.46	5.18	21.91
		10 - 20 ha	9	333.04	37.00	28.69	47.59	7.24	18.90
<b>Total</b>			<b>1639</b>	<b>2585.89</b>	<b>1.58</b>	<b>0.00</b>	<b>47.59</b>		<b>47.59</b>
Year 1		< 0.1 ha	584	129.45	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	642	430.58	0.67	0.25	1.23	0.24	0.99
Year 2	2008	0.5 - 1 ha	218	389.50	1.79	1.33	2.45	0.38	1.11
Date 2	1020	1 - 10 ha	204	1404.99	6.89	2.53	24.46	5.06	21.93
		10 - 20 ha	9	297.54	33.06	26.55	45.81	6.92	19.26
<b>Total</b>			<b>1657</b>	<b>2652.05</b>	<b>1.60</b>	<b>0.00</b>	<b>45.81</b>		<b>45.81</b>
Year 1		< 0.1 ha	304	67.52	0.22	0.17	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	356	242.79	0.68	0.38	1.11	0.24	0.73
Year 2	2008	0.5 - 1 ha	131	230.99	1.76	1.33	2.45	0.38	1.11
Date 2	1121	1 - 10 ha	144	1038.70	7.21	2.67	24.02	5.28	21.35
		10 - 20 ha	6	185.25	30.88	25.13	42.48	6.55	17.35
<b>Total</b>			<b>941</b>	<b>1765.26</b>	<b>1.88</b>	<b>0.17</b>	<b>42.48</b>		<b>42.31</b>

Hill County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	274	60.73	0.22	0.07	0.22	0.01	0.15
Date 1		0.1 - 0.5 ha	363	240.89	0.66	0.37	1.11	0.22	0.74
Year 2	2008	0.5 - 1 ha	133	237.10	1.78	1.33	2.45	0.38	1.11
Date 2	1207	1 - 10 ha	147	1065.05	7.25	2.67	24.69	5.27	22.02
		10 - 20 ha	5	155.45	31.09	25.13	42.26	6.82	17.12
<b>Total</b>			<b>922</b>	<b>1759.22</b>	<b>1.91</b>	<b>0.07</b>	<b>42.26</b>		<b>42.19</b>
Year 1		< 0.1 ha	373	82.80	0.22	0.07	0.22	0.01	0.15
Date 1		0.1 - 0.5 ha	469	326.35	0.70	0.37	1.22	0.24	0.85
Year 2	2009	0.5 - 1 ha	150	257.90	1.72	1.33	2.45	0.36	1.11
Date 2	0108	1 - 10 ha	160	1122.65	7.02	2.67	22.24	4.99	19.57
		10 - 20 ha	8	241.31	30.16	24.80	42.26	5.99	17.46
<b>Total</b>			<b>1160</b>	<b>2031.00</b>	<b>1.75</b>	<b>0.07</b>	<b>42.26</b>		<b>42.19</b>
Year 1		< 0.1 ha	741	164.37	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	869	584.23	0.67	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	289	502.36	1.74	1.33	2.45	0.38	1.11
Date 2	0329	1 - 10 ha	261	1714.31	6.57	2.56	23.80	4.84	21.24
		10 - 20 ha	16	544.01	34.00	26.02	48.26	5.90	22.24
<b>Total</b>			<b>2176</b>	<b>3509.28</b>	<b>1.61</b>	<b>0.00</b>	<b>48.26</b>		<b>48.26</b>
Year 1		< 0.1 ha	953	211.37	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	1017	680.87	0.67	0.27	1.22	0.24	0.95
Year 2	2009	0.5 - 1 ha	311	547.46	1.76	1.33	2.45	0.37	1.11
Date 2	0414	1 - 10 ha	282	1845.39	6.54	2.47	24.46	4.92	21.99
		10 - 20 ha	16	539.09	33.69	25.35	48.04	5.70	22.68
		> 20 ha	1	50.82	50.82	50.82	50.82	0.00	0.00
<b>Total</b>			<b>2580</b>	<b>3875.00</b>	<b>1.50</b>	<b>0.00</b>	<b>50.82</b>		<b>50.82</b>
Year 1		< 0.1 ha	868	191.80	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	953	641.00	0.67	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	290	514.62	1.77	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	233	1519.34	6.52	2.56	22.91	4.70	20.35
		10 - 20 ha	18	598.35	33.24	25.80	46.26	6.40	20.46
<b>Total</b>			<b>2362</b>	<b>3465.11</b>	<b>1.47</b>	<b>0.00</b>	<b>46.26</b>		<b>46.26</b>
Year 1		< 0.1 ha	1029	227.58	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	999	656.11	0.66	0.29	1.22	0.23	0.93
Year 2	2009	0.5 - 1 ha	308	531.61	1.73	1.33	2.45	0.35	1.11
Date 2	0804	1 - 10 ha	254	1655.13	6.52	2.67	24.69	4.73	22.02
		10 - 20 ha	16	506.03	31.63	25.13	45.59	6.46	20.46
<b>Total</b>			<b>2606</b>	<b>3576.47</b>	<b>1.37</b>	<b>0.00</b>	<b>45.59</b>		<b>45.59</b>

Hill County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	1115	247.97	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	1261	848.66	0.67	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	406	720.11	1.77	1.33	2.45	0.38	1.11
Date 2	1023	1 - 10 ha	357	2290.00	6.41	2.67	23.80	4.57	21.13
		10 - 20 ha	22	796.17	36.19	26.02	49.37	6.84	23.35
		> 20 ha	6	636.38	106.06	49.59	288.89	91.40	239.30
<b>Total</b>			<b>3167</b>	<b>5539.30</b>	<b>1.75</b>	<b>0.22</b>	<b>288.89</b>		<b>288.67</b>
Year 1		< 0.1 ha	1058	233.48	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	1026	700.00	0.68	0.29	1.22	0.24	0.93
Year 2	2009	0.5 - 1 ha	345	613.05	1.78	1.33	2.45	0.37	1.12
Date 2	1124	1 - 10 ha	326	2156.01	6.61	2.52	24.69	4.89	22.16
		10 - 20 ha	27	909.37	33.68	24.91	49.15	7.20	24.24
		> 20 ha	12	1482.32	123.53	51.15	264.87	65.53	213.72
<b>Total</b>			<b>2794</b>	<b>6094.22</b>	<b>2.18</b>	<b>0.00</b>	<b>264.87</b>		<b>264.87</b>
Year 1		< 0.1 ha	298	66.05	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	374	265.27	0.71	0.36	1.11	0.25	0.75
Year 2	2010	0.5 - 1 ha	160	283.00	1.77	1.33	2.45	0.34	1.11
Date 2	0111	1 - 10 ha	173	1277.35	7.38	2.56	24.69	5.58	22.13
		10 - 20 ha	15	454.13	30.28	24.91	40.03	5.48	15.12
<b>Total</b>			<b>1020</b>	<b>2345.80</b>	<b>2.30</b>	<b>0.00</b>	<b>40.03</b>		<b>40.03</b>
Year 1		< 0.1 ha	1366	301.85	0.22	0.00	0.25	0.02	0.24
Date 1		0.1 - 0.5 ha	1675	1101.34	0.66	0.39	1.22	0.23	0.83
Year 2	2010	0.5 - 1 ha	503	878.26	1.75	1.33	2.45	0.37	1.11
Date 2	0620	1 - 10 ha	385	2397.51	6.23	2.56	24.24	4.56	21.68
		10 - 20 ha	21	713.64	33.98	26.46	49.37	6.25	22.91
		> 20 ha	9	1079.95	119.99	56.27	368.29	98.54	312.02
<b>Total</b>			<b>3959</b>	<b>6472.54</b>	<b>1.63</b>	<b>0.00</b>	<b>368.29</b>		<b>368.28</b>
Year 1		< 0.1 ha	1040	231.29	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	1148	765.82	0.67	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	293	513.48	1.75	1.33	2.45	0.36	1.11
Date 2	1127	1 - 10 ha	290	1910.57	6.59	2.56	24.24	4.79	21.68
		10 - 20 ha	16	504.39	31.52	25.13	45.59	5.58	20.46
		> 20 ha	1	50.26	50.26	50.26	50.26	0.00	0.00
<b>Total</b>			<b>2788</b>	<b>3975.81</b>	<b>1.43</b>	<b>0.22</b>	<b>50.26</b>		<b>50.04</b>
Year 1		< 0.1 ha	439	97.44	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	567	387.84	0.68	0.38	1.22	0.23	0.84
Year 2	2010	0.5 - 1 ha	173	299.42	1.73	1.27	2.45	0.36	1.18
Date 2	1213	1 - 10 ha	191	1355.95	7.10	2.67	24.69	5.28	22.02
		10 - 20 ha	8	255.98	32.00	25.58	40.25	5.78	14.68
<b>Total</b>			<b>1378</b>	<b>2396.62</b>	<b>1.74</b>	<b>0.05</b>	<b>40.25</b>		<b>40.20</b>



Hood County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	417	92.33	0.22	0.01	0.22	0.01	0.21
Date 1	0303	0.1 - 0.5 ha	502	336.83	0.67	0.25	1.22	0.25	0.97
Year 2	1997	0.5 - 1 ha	143	247.23	1.73	1.33	2.46	0.35	1.13
Date 2	0328	1 - 10 ha	89	475.89	5.35	2.48	22.24	4.40	19.76
		10 - 20 ha	1	29.06	29.06	29.06	29.06	0.00	0.00
		> 20 ha	1	73.29	73.29	73.29	73.29	0.00	0.00
<b>Baseline Wet</b>		<b>Total</b>	<b>1153</b>	<b>1254.62</b>	<b>1.09</b>	<b>0.01</b>	<b>73.29</b>		<b>73.28</b>
Year 1	1999	< 0.1 ha	192	42.60	0.22	0.12	0.22	0.01	0.10
Date 1	0221	0.1 - 0.5 ha	215	143.95	0.67	0.25	1.19	0.25	0.93
Year 2	1999	0.5 - 1 ha	42	70.44	1.68	1.33	2.45	0.30	1.11
Date 2	0214	1 - 10 ha	42	252.07	6.00	2.49	24.54	4.40	22.06
		10 - 20 ha	1	60.41	60.41	60.41	60.41	0.00	0.00
<b>Baseline Dry</b>		<b>Total</b>	<b>492</b>	<b>569.47</b>	<b>1.16</b>	<b>0.12</b>	<b>60.41</b>		<b>60.29</b>
Year 1	2003	< 0.1 ha	379	84.26	0.22	0.20	0.22	0.00	0.03
Date 1	1014	0.1 - 0.5 ha	385	252.49	0.66	0.25	1.20	0.25	0.95
Year 2	2003	0.5 - 1 ha	87	151.78	1.74	1.31	2.45	0.37	1.14
Date 2	1023	1 - 10 ha	65	430.25	6.62	2.56	22.02	5.05	19.45
		10 - 20 ha	2	60.21	30.10	25.29	34.92	6.80	9.62
		> 20 ha	1	69.63	69.63	69.63	69.63	0.00	0.00
		<b>Total</b>	<b>919</b>	<b>1048.63</b>	<b>1.14</b>	<b>0.20</b>	<b>69.63</b>		<b>69.43</b>
Year 1	2004	< 0.1 ha	570	126.43	0.22	0.05	0.22	0.01	0.17
Date 1	1016	0.1 - 0.5 ha	510	334.81	0.66	0.25	1.20	0.24	0.95
Year 2	2004	0.5 - 1 ha	139	237.12	1.71	1.32	2.45	0.36	1.13
Date 2	0907	1 - 10 ha	88	515.78	5.86	2.47	20.29	4.49	17.81
		10 - 20 ha	5	145.08	29.02	25.80	35.58	3.89	9.79
		> 20 ha	1	69.83	69.83	69.83	69.83	0.00	0.00
		<b>Total</b>	<b>1313</b>	<b>1429.05</b>	<b>1.09</b>	<b>0.05</b>	<b>69.83</b>		<b>69.77</b>
Year 1	2005	< 0.1 ha	354	78.73	0.22	0.22	0.22	0.00	0.00
Date 1	0221	0.1 - 0.5 ha	576	390.99	0.68	0.25	1.23	0.25	0.97
Year 2	2005	0.5 - 1 ha	146	247.49	1.70	1.33	2.46	0.33	1.13
Date 2	0214	1 - 10 ha	92	545.97	5.93	2.52	23.80	4.77	21.28
		10 - 20 ha	3	92.33	30.78	28.69	34.47	3.21	5.78
		> 20 ha	1	75.68	75.68	75.68	75.68	0.00	0.00
		<b>Total</b>	<b>1172</b>	<b>1431.19</b>	<b>1.22</b>	<b>0.22</b>	<b>75.68</b>		<b>75.46</b>
Year 1	2006	< 0.1 ha	195	43.35	0.22	0.20	0.22	0.00	0.02
Date 1	1123	0.1 - 0.5 ha	251	174.59	0.70	0.25	1.18	0.26	0.93
Year 2	2006	0.5 - 1 ha	78	137.97	1.77	1.33	2.45	0.36	1.11
Date 2	1116	1 - 10 ha	52	317.20	6.10	2.67	18.90	3.94	16.23
		10 - 20 ha	1	33.14	33.14	33.14	33.14	0.00	0.00
		> 20 ha	1	66.47	66.47	66.47	66.47	0.00	0.00
		<b>Total</b>	<b>578</b>	<b>772.71</b>	<b>1.34</b>	<b>0.20</b>	<b>66.47</b>		<b>66.27</b>

Hood County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	375	83.30	0.22	0.15	0.22	0.00	0.07
Date 1	0331	0.1 - 0.5 ha	556	383.20	0.69	0.25	1.22	0.25	0.97
Year 2	2007	0.5 - 1 ha	162	282.48	1.74	1.31	2.45	0.36	1.14
Date 2	0308	1 - 10 ha	109	558.09	5.12	2.48	21.34	3.43	18.86
		10 - 20 ha	4	125.85	31.46	26.02	36.92	4.50	10.90
		> 20 ha	1	73.72	73.72	73.72	73.72	0.00	0.00
<b>Total</b>			<b>1207</b>	<b>1506.64</b>	<b>1.25</b>	<b>0.15</b>	<b>73.72</b>		<b>73.57</b>
Year 1		< 0.1 ha	253	56.18	0.22	0.14	0.22	0.01	0.09
Date 1		0.1 - 0.5 ha	411	280.30	0.68	0.39	1.22	0.24	0.83
Year 2	2008	0.5 - 1 ha	128	221.48	1.73	1.33	2.45	0.34	1.11
Date 2	0207	1 - 10 ha	83	506.20	6.10	2.67	21.57	4.28	18.90
		10 - 20 ha	4	130.99	32.75	26.02	42.03	7.02	16.01
		> 20 ha	1	158.79	158.79	158.79	158.79	0.00	0.00
<b>Total</b>			<b>880</b>	<b>1353.93</b>	<b>1.54</b>	<b>0.14</b>	<b>158.79</b>		<b>158.65</b>
Year 1	2008	< 0.1 ha	536	118.99	0.22	0.08	0.22	0.01	0.14
Date 1	0418	0.1 - 0.5 ha	678	447.43	0.66	0.25	1.22	0.24	0.97
Year 2	2008	0.5 - 1 ha	205	347.41	1.69	1.31	2.45	0.35	1.14
Date 2	0411	1 - 10 ha	128	720.78	5.63	2.48	23.02	3.91	20.54
		10 - 20 ha	4	136.40	34.10	30.47	37.81	4.03	7.34
		> 20 ha	1	70.32	70.32	70.32	70.32	0.00	0.00
<b>Total</b>			<b>1552</b>	<b>1841.32</b>	<b>1.19</b>	<b>0.08</b>	<b>70.32</b>		<b>70.24</b>
Year 1		< 0.1 ha	201	44.56	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	261	181.09	0.69	0.40	1.11	0.25	0.72
Year 2	2008	0.5 - 1 ha	88	158.46	1.80	1.33	2.45	0.39	1.11
Date 2	1004	1 - 10 ha	70	415.36	5.93	2.67	17.57	3.57	14.90
		10 - 20 ha	2	72.28	36.14	32.91	39.36	4.56	6.45
		> 20 ha	1	144.45	144.45	144.45	144.45	0.00	0.00
<b>Total</b>			<b>623</b>	<b>1016.20</b>	<b>1.63</b>	<b>0.08</b>	<b>144.45</b>		<b>144.36</b>
Year 1		< 0.1 ha	163	36.16	0.22	0.14	0.22	0.01	0.09
Date 1		0.1 - 0.5 ha	251	172.98	0.69	0.40	1.11	0.25	0.72
Year 2	2008	0.5 - 1 ha	88	148.23	1.68	1.33	2.45	0.37	1.11
Date 2	1020	1 - 10 ha	69	421.94	6.12	2.67	20.55	4.01	17.89
		10 - 20 ha	2	66.05	33.03	29.36	36.70	5.19	7.34
		> 20 ha	1	49.71	49.71	49.71	49.71	0.00	0.00
<b>Total</b>			<b>574</b>	<b>895.06</b>	<b>1.56</b>	<b>0.14</b>	<b>49.71</b>		<b>49.57</b>
Year 1		< 0.1 ha	158	35.14	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	227	156.59	0.69	0.44	1.11	0.23	0.67
Year 2	2008	0.5 - 1 ha	68	117.98	1.74	1.33	2.45	0.37	1.11
Date 2	1121	1 - 10 ha	62	355.84	5.74	2.67	16.01	3.37	13.34
		10 - 20 ha	3	102.86	34.29	28.69	41.03	6.25	12.34
<b>Total</b>			<b>518</b>	<b>768.41</b>	<b>1.48</b>	<b>0.22</b>	<b>41.03</b>		<b>40.81</b>

Hood County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	138	30.60	0.22	0.14	0.22	0.01	0.09
Date 1		0.1 - 0.5 ha	218	150.69	0.69	0.44	1.11	0.24	0.67
Year 2	2008	0.5 - 1 ha	70	121.84	1.74	1.33	2.45	0.36	1.11
Date 2	1207	1 - 10 ha	56	339.23	6.06	2.67	18.68	3.83	16.01
		10 - 20 ha	2	59.38	29.69	26.02	33.36	5.19	7.34
		> 20 ha	1	51.60	51.60	51.60	51.60	0.00	0.00
<b>Total</b>			<b>485</b>	<b>753.35</b>	<b>1.55</b>	<b>0.14</b>	<b>51.60</b>		<b>51.46</b>
Year 1		< 0.1 ha	155	34.38	0.22	0.14	0.22	0.01	0.09
Date 1		0.1 - 0.5 ha	227	151.03	0.67	0.44	1.11	0.23	0.67
Year 2	2009	0.5 - 1 ha	83	145.56	1.75	1.33	2.45	0.43	1.11
Date 2	0108	1 - 10 ha	63	393.65	6.25	2.67	21.57	4.23	18.90
		10 - 20 ha	2	59.16	29.58	25.35	33.80	5.98	8.45
<b>Total</b>			<b>530</b>	<b>783.78</b>	<b>1.48</b>	<b>0.14</b>	<b>33.80</b>		<b>33.67</b>
Year 1		< 0.1 ha	304	67.39	0.22	0.09	0.22	0.01	0.13
Date 1		0.1 - 0.5 ha	381	257.44	0.68	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	117	208.83	1.78	1.33	2.45	0.37	1.11
Date 2	0329	1 - 10 ha	88	509.36	5.79	2.67	24.02	4.05	21.35
		10 - 20 ha	2	61.38	30.69	24.91	36.47	8.18	11.56
		> 20 ha	2	121.21	60.60	60.05	61.16	0.79	1.11
<b>Total</b>			<b>894</b>	<b>1225.61</b>	<b>1.37</b>	<b>0.09</b>	<b>61.16</b>		<b>61.07</b>
Year 1		< 0.1 ha	315	69.97	0.22	0.14	0.22	0.00	0.09
Date 1		0.1 - 0.5 ha	401	268.44	0.67	0.39	1.22	0.23	0.83
Year 2	2009	0.5 - 1 ha	112	191.04	1.71	1.33	2.45	0.35	1.11
Date 2	0414	1 - 10 ha	100	598.53	5.99	2.67	24.24	4.62	21.57
		10 - 20 ha	1	36.92	36.92	36.92	36.92	0.00	0.00
		> 20 ha	1	65.27	65.27	65.27	65.27	0.00	0.00
<b>Total</b>			<b>930</b>	<b>1230.16</b>	<b>1.32</b>	<b>0.14</b>	<b>65.27</b>		<b>65.14</b>
Year 1		< 0.1 ha	304	67.60	0.22	0.21	0.22	0.00	0.01
Date 1		0.1 - 0.5 ha	335	228.79	0.68	0.27	1.22	0.24	0.95
Year 2	2009	0.5 - 1 ha	112	194.93	1.74	1.33	2.45	0.39	1.11
Date 2	0703	1 - 10 ha	91	562.54	6.18	2.67	20.79	4.43	18.13
		10 - 20 ha	2	62.94	31.47	25.58	37.36	8.33	11.79
		> 20 ha	1	66.05	66.05	66.05	66.05	0.00	0.00
<b>Total</b>			<b>845</b>	<b>1182.85</b>	<b>1.40</b>	<b>0.21</b>	<b>66.05</b>		<b>65.84</b>
Year 1		< 0.1 ha	544	120.36	0.22	0.01	0.22	0.01	0.21
Date 1		0.1 - 0.5 ha	576	383.03	0.66	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	129	225.62	1.75	1.33	2.45	0.38	1.11
Date 2	0804	1 - 10 ha	115	700.98	6.10	2.67	22.91	4.23	20.24
		10 - 20 ha	1	37.14	37.14	37.14	37.14	0.00	0.00
		> 20 ha	1	67.72	67.72	67.72	67.72	0.00	0.00
<b>Total</b>			<b>1366</b>	<b>1534.84</b>	<b>1.12</b>	<b>0.01</b>	<b>67.72</b>		<b>67.71</b>

Hood County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	489	108.64	0.22	0.17	0.22	0.00	0.05
Date 1	0928	0.1 - 0.5 ha	599	400.91	0.67	0.31	1.23	0.24	0.92
Year 2	2009	0.5 - 1 ha	168	288.94	1.72	1.25	2.45	0.34	1.19
Date 2	1023	1 - 10 ha	157	953.36	6.07	2.53	24.24	4.91	21.71
		10 - 20 ha	2	63.60	31.80	26.69	36.92	7.23	10.23
		> 20 ha	1	77.36	77.36	77.36	77.36	0.00	0.00
<b>Total</b>			<b>1416</b>	<b>1892.82</b>	<b>1.34</b>	<b>0.17</b>	<b>77.36</b>		<b>77.19</b>
Year 1		< 0.1 ha	414	91.85	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	476	326.63	0.69	0.27	1.22	0.24	0.95
Year 2	2009	0.5 - 1 ha	144	251.97	1.75	1.33	2.45	0.36	1.11
Date 2	1124	1 - 10 ha	120	711.56	5.93	2.67	22.91	4.59	20.24
		10 - 20 ha	3	109.75	36.58	30.80	43.14	6.21	12.34
<b>Total</b>			<b>1157</b>	<b>1491.77</b>	<b>1.29</b>	<b>0.00</b>	<b>43.14</b>		<b>43.14</b>
Year 1		< 0.1 ha	323	71.40	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	398	275.38	0.69	0.39	1.22	0.24	0.83
Year 2	2009	0.5 - 1 ha	124	221.30	1.78	1.24	2.45	0.39	1.20
Date 2	1210	1 - 10 ha	101	604.95	5.99	2.56	23.35	4.39	20.79
		10 - 20 ha	3	101.97	33.99	29.80	38.14	4.17	8.34
		> 20 ha	1	50.04	50.04	50.04	50.04	0.00	0.00
<b>Total</b>			<b>950</b>	<b>1325.04</b>	<b>1.39</b>	<b>0.00</b>	<b>50.04</b>		<b>50.04</b>
Year 1		< 0.1 ha	139	30.61	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	197	132.35	0.67	0.44	1.22	0.23	0.78
Year 2	2010	0.5 - 1 ha	81	144.67	1.79	1.33	2.45	0.37	1.11
Date 2	0111	1 - 10 ha	71	445.66	6.28	2.67	22.68	4.64	20.02
		10 - 20 ha	2	57.16	28.58	25.80	31.36	3.93	5.56
<b>Total</b>			<b>490</b>	<b>810.44</b>	<b>1.65</b>	<b>0.00</b>	<b>31.36</b>		<b>31.35</b>
Year 1		< 0.1 ha	662	146.80	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	693	459.67	0.66	0.27	1.22	0.23	0.95
Year 2	2010	0.5 - 1 ha	217	375.81	1.73	1.33	2.45	0.36	1.11
Date 2	0620	1 - 10 ha	159	901.56	5.67	2.56	21.35	3.92	18.79
		10 - 20 ha	6	171.24	28.54	25.35	32.47	3.24	7.12
		> 20 ha	2	139.89	69.94	64.05	75.84	8.33	11.79
<b>Total</b>			<b>1739</b>	<b>2194.97</b>	<b>1.26</b>	<b>0.00</b>	<b>75.84</b>		<b>75.83</b>
Year 1		< 0.1 ha	933	206.74	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	800	526.57	0.66	0.39	1.22	0.23	0.83
Year 2	2010	0.5 - 1 ha	216	371.87	1.72	1.33	2.45	0.36	1.11
Date 2	0807	1 - 10 ha	147	928.65	6.32	2.67	24.46	4.61	21.79
		10 - 20 ha	5	173.25	34.65	29.13	40.25	5.36	11.12
		> 20 ha	1	61.16	61.16	61.16	61.16	0.00	0.00
<b>Total</b>			<b>2102</b>	<b>2268.23</b>	<b>1.08</b>	<b>0.02</b>	<b>61.16</b>		<b>61.14</b>

Hood County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	465	103.20	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>		0.1 - 0.5 ha	518	347.06	0.67	0.27	1.22	0.24	0.95
<b>Year 2</b>	2010	0.5 - 1 ha	166	294.23	1.77	1.33	2.45	0.39	1.11
<b>Date 2</b>	1010	1 - 10 ha	108	669.86	6.20	2.67	23.57	4.65	20.91
		10 - 20 ha	5	152.65	30.53	25.58	36.25	4.88	10.67
		> 20 ha	1	69.61	69.61	69.61	69.61	0.00	0.00
<b>Total</b>			<b>1263</b>	<b>1636.61</b>	<b>1.30</b>	<b>0.01</b>	<b>69.61</b>		<b>69.60</b>
<b>Year 1</b>	2010	< 0.1 ha	413	91.80	0.22	0.16	0.24	0.00	0.07
<b>Date 1</b>	1118	0.1 - 0.5 ha	659	432.18	0.66	0.37	1.22	0.23	0.85
<b>Year 2</b>	2010	0.5 - 1 ha	187	318.00	1.70	1.33	2.45	0.37	1.11
<b>Date 2</b>	1127	1 - 10 ha	133	798.27	6.00	2.67	19.79	4.15	17.12
		10 - 20 ha	5	155.68	31.14	25.35	37.58	5.29	12.23
		> 20 ha	1	72.28	72.28	72.28	72.28	0.00	0.00
<b>Total</b>			<b>1398</b>	<b>1868.21</b>	<b>1.34</b>	<b>0.16</b>	<b>72.28</b>		<b>72.11</b>
<b>Year 1</b>		< 0.1 ha	199	44.07	0.22	0.12	0.22	0.01	0.11
<b>Date 1</b>		0.1 - 0.5 ha	257	177.27	0.69	0.44	1.11	0.23	0.67
<b>Year 2</b>	2010	0.5 - 1 ha	86	146.89	1.71	1.33	2.45	0.36	1.11
<b>Date 2</b>	1213	1 - 10 ha	81	501.67	6.19	2.47	24.46	4.81	21.99
		10 - 20 ha	3	102.52	34.17	27.13	42.92	8.03	15.79
<b>Total</b>			<b>626</b>	<b>972.42</b>	<b>1.55</b>	<b>0.12</b>	<b>42.92</b>		<b>42.80</b>



Jack County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	1060	234.84	0.22	0.00	0.22	0.01	0.22
Date 1	0303	0.1 - 0.5 ha	2214	1545.03	0.70	0.25	1.22	0.24	0.97
Year 2	1997	0.5 - 1 ha	744	1259.82	1.69	1.26	2.47	0.34	1.22
Date 2	0328	1 - 10 ha	363	1851.66	5.10	2.49	24.69	3.64	22.20
		10 - 20 ha	8	265.43	33.18	26.02	40.11	5.00	14.09
		> 20 ha	13	1416.65	108.97	54.93	574.89	140.83	519.96
<b>Baseline Wet</b>		<b>Total</b>	<b>4402</b>	<b>6573.44</b>	<b>1.49</b>	<b>0.00</b>	<b>574.89</b>		<b>574.89</b>
Year 1	1999	< 0.1 ha	445	98.82	0.22	0.07	0.22	0.01	0.15
Date 1	0221	0.1 - 0.5 ha	428	273.84	0.64	0.25	1.22	0.24	0.97
Year 2	1999	0.5 - 1 ha	88	149.55	1.70	1.32	2.45	0.35	1.13
Date 2	0214	1 - 10 ha	69	436.71	6.33	2.50	23.00	4.31	20.50
		10 - 20 ha	5	172.24	34.45	28.02	41.37	5.82	13.34
		> 20 ha	4	630.04	157.51	51.37	464.14	204.45	412.76
<b>Baseline Dry</b>		<b>Total</b>	<b>1039</b>	<b>1761.22</b>	<b>1.70</b>	<b>0.07</b>	<b>464.14</b>		<b>464.06</b>
Year 1	2003	< 0.1 ha	818	181.40	0.22	0.01	0.22	0.01	0.21
Date 1	1014	0.1 - 0.5 ha	995	620.62	0.62	0.25	1.22	0.24	0.97
Year 2	2003	0.5 - 1 ha	196	330.39	1.69	1.33	2.45	0.34	1.11
Date 2	1023	1 - 10 ha	101	605.33	5.99	2.56	20.68	4.24	18.11
		10 - 20 ha	5	204.65	40.93	38.25	44.92	2.93	6.67
		> 20 ha	3	642.05	214.02	57.60	497.72	246.12	440.12
		<b>Total</b>	<b>2118</b>	<b>2584.44</b>	<b>1.22</b>	<b>0.01</b>	<b>497.72</b>		<b>497.71</b>
Year 1	2004	< 0.1 ha	1189	264.04	0.22	0.02	0.22	0.01	0.21
Date 1	1016	0.1 - 0.5 ha	1796	1199.09	0.67	0.25	1.22	0.24	0.97
Year 2	2004	0.5 - 1 ha	438	749.06	1.71	1.26	2.46	0.36	1.20
Date 2	0907	1 - 10 ha	207	1121.77	5.42	2.47	24.69	4.14	22.21
		10 - 20 ha	8	301.60	37.70	27.40	46.93	6.96	19.52
		> 20 ha	4	761.70	190.43	54.04	545.53	237.58	491.49
		<b>Total</b>	<b>3642</b>	<b>4397.26</b>	<b>1.21</b>	<b>0.02</b>	<b>545.53</b>		<b>545.52</b>
Year 1	2005	< 0.1 ha	1131	250.81	0.22	0.02	0.23	0.01	0.21
Date 1	0221	0.1 - 0.5 ha	1725	1143.01	0.66	0.25	1.20	0.24	0.95
Year 2	2005	0.5 - 1 ha	391	656.65	1.68	1.26	2.45	0.33	1.19
Date 2	0214	1 - 10 ha	186	1077.12	5.79	2.52	23.57	4.42	21.05
		10 - 20 ha	8	298.03	37.25	26.02	46.67	7.91	20.65
		> 20 ha	4	729.01	182.25	52.93	528.41	231.56	475.48
		<b>Total</b>	<b>3445</b>	<b>4154.63</b>	<b>1.21</b>	<b>0.02</b>	<b>528.41</b>		<b>528.39</b>
Year 1	2006	< 0.1 ha	606	134.53	0.22	0.01	0.22	0.01	0.21
Date 1	1123	0.1 - 0.5 ha	613	382.00	0.62	0.25	1.22	0.23	0.97
Year 2	2006	0.5 - 1 ha	87	150.40	1.73	1.33	2.47	0.34	1.14
Date 2	1116	1 - 10 ha	68	448.27	6.59	2.53	20.76	4.55	18.23
		10 - 20 ha	3	94.68	31.56	29.07	33.58	2.29	4.51
		> 20 ha	3	608.36	202.79	49.93	481.04	241.37	431.11
		<b>Total</b>	<b>1380</b>	<b>1818.25</b>	<b>1.32</b>	<b>0.01</b>	<b>481.04</b>		<b>481.03</b>

Jack County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1558	345.70	0.22	0.00	0.22	0.01	0.22
Date 1	0331	0.1 - 0.5 ha	2469	1676.52	0.68	0.25	1.22	0.24	0.97
Year 2	2007	0.5 - 1 ha	763	1308.26	1.71	1.33	2.47	0.36	1.14
Date 2	0308	1 - 10 ha	463	2527.16	5.46	2.47	24.69	4.04	22.21
		10 - 20 ha	13	456.25	35.10	26.80	48.04	7.27	21.24
		> 20 ha	16	2088.69	130.54	51.60	619.37	137.91	567.77
<b>Total</b>			<b>5282</b>	<b>8402.59</b>	<b>1.59</b>	<b>0.00</b>	<b>619.37</b>		<b>619.37</b>
Year 1	2008	< 0.1 ha	1276	283.14	0.22	0.02	0.22	0.01	0.20
Date 1	0418	0.1 - 0.5 ha	2285	1540.36	0.67	0.25	1.22	0.25	0.97
Year 2	2008	0.5 - 1 ha	694	1193.77	1.72	1.32	2.46	0.35	1.14
Date 2	0411	1 - 10 ha	366	1929.53	5.27	2.48	24.69	3.92	22.21
		10 - 20 ha	6	210.34	35.06	25.35	48.70	9.10	23.35
		> 20 ha	11	1222.10	111.10	51.05	568.22	152.75	517.17
<b>Total</b>			<b>4638</b>	<b>6379.25</b>	<b>1.38</b>	<b>0.02</b>	<b>568.22</b>		<b>568.20</b>
Year 1	2008	< 0.1 ha	1493	330.91	0.22	0.01	0.24	0.01	0.23
Date 1	0723	0.1 - 0.5 ha	2270	1550.69	0.68	0.25	1.22	0.23	0.97
Year 2		0.5 - 1 ha	673	1158.81	1.72	1.30	2.45	0.36	1.15
Date 2		1 - 10 ha	313	1696.22	5.42	2.53	23.57	4.02	21.05
		10 - 20 ha	11	375.96	34.18	25.35	49.37	7.15	24.02
		> 20 ha	6	975.20	162.53	52.04	622.71	226.01	570.67
<b>Total</b>			<b>4766</b>	<b>6087.78</b>	<b>1.28</b>	<b>0.01</b>	<b>622.71</b>		<b>622.70</b>
Year 1	2008	< 0.1 ha	839	186.18	0.22	0.09	0.22	0.01	0.14
Date 1	1027	0.1 - 0.5 ha	951	619.26	0.65	0.44	1.11	0.22	0.67
Year 2		0.5 - 1 ha	200	344.99	1.72	1.33	2.45	0.36	1.11
Date 2		1 - 10 ha	120	750.00	6.25	2.48	21.35	4.35	18.87
		10 - 20 ha	7	248.53	35.50	27.13	48.37	7.88	21.24
		> 20 ha	3	643.17	214.39	60.49	511.73	257.56	451.24
<b>Total</b>			<b>2120</b>	<b>2792.12</b>	<b>1.32</b>	<b>0.09</b>	<b>511.73</b>		<b>511.65</b>
Year 1	2008	< 0.1 ha	629	139.64	0.22	0.09	0.22	0.01	0.14
Date 1	1214	0.1 - 0.5 ha	579	371.96	0.64	0.44	1.22	0.23	0.78
Year 2		0.5 - 1 ha	91	152.95	1.68	1.33	2.45	0.32	1.11
Date 2		1 - 10 ha	86	539.14	6.27	2.67	23.80	4.51	21.13
		10 - 20 ha	4	144.22	36.06	32.25	38.70	2.80	6.45
		> 20 ha	4	273.77	68.44	49.59	111.64	29.38	62.05
<b>Total</b>			<b>1393</b>	<b>1621.67</b>	<b>1.16</b>	<b>0.09</b>	<b>111.64</b>		<b>111.56</b>
Year 1	2009	< 0.1 ha	562	124.99	0.22	0.22	0.22	0.00	0.00
Date 1	0115	0.1 - 0.5 ha	622	398.64	0.64	0.44	1.11	0.22	0.67
Year 2		0.5 - 1 ha	98	162.81	1.66	1.33	2.45	0.32	1.11
Date 2		1 - 10 ha	88	538.75	6.12	2.67	22.68	4.28	20.02
		10 - 20 ha	5	180.03	36.01	31.36	39.59	3.17	8.23
		> 20 ha	4	626.38	156.59	50.26	464.81	205.54	414.54
<b>Total</b>			<b>1379</b>	<b>2031.60</b>	<b>1.47</b>	<b>0.22</b>	<b>464.81</b>		<b>464.58</b>

Jack County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	680	151.23	0.22	0.22	0.22	0.00	0.00
Date 1	0131	0.1 - 0.5 ha	824	534.86	0.65	0.44	1.22	0.22	0.78
Year 2		0.5 - 1 ha	128	215.74	1.69	1.33	2.45	0.34	1.11
Date 2		1 - 10 ha	100	614.81	6.15	2.67	24.46	4.38	21.79
		10 - 20 ha	5	182.92	36.58	33.36	38.47	1.97	5.12
		> 20 ha	4	638.27	159.57	52.93	469.03	206.34	416.10
<b>Total</b>			<b>1741</b>	<b>2337.84</b>	<b>1.34</b>	<b>0.22</b>	<b>469.03</b>		<b>468.81</b>
Year 1	2009	< 0.1 ha	683	151.90	0.22	0.22	0.22	0.00	0.00
Date 1	0421	0.1 - 0.5 ha	847	560.30	0.66	0.44	1.22	0.23	0.78
Year 2		0.5 - 1 ha	204	350.82	1.72	1.33	2.45	0.39	1.11
Date 2		1 - 10 ha	104	645.95	6.21	2.67	21.79	4.22	19.13
		10 - 20 ha	4	147.00	36.75	35.58	37.36	0.84	1.78
		> 20 ha	4	668.52	167.13	50.71	491.94	216.62	441.23
<b>Total</b>			<b>1846</b>	<b>2524.48</b>	<b>1.37</b>	<b>0.22</b>	<b>491.94</b>		<b>491.71</b>
Year 1	2009	< 0.1 ha	1021	226.49	0.22	0.08	0.24	0.01	0.17
Date 1	0608	0.1 - 0.5 ha	1262	826.42	0.65	0.31	1.22	0.23	0.91
Year 2		0.5 - 1 ha	287	486.21	1.69	1.33	2.45	0.36	1.11
Date 2		1 - 10 ha	139	785.34	5.65	2.67	21.79	3.85	19.13
		10 - 20 ha	6	215.06	35.84	28.02	44.26	6.91	16.23
		> 20 ha	3	657.84	219.28	60.27	494.16	239.03	433.89
<b>Total</b>			<b>2718</b>	<b>3197.36</b>	<b>1.18</b>	<b>0.08</b>	<b>494.16</b>		<b>494.08</b>
Year 1	2009	< 0.1 ha	1204	267.26	0.22	0.09	0.22	0.01	0.13
Date 1	0710	0.1 - 0.5 ha	1387	917.49	0.66	0.25	1.24	0.23	0.99
Year 2		0.5 - 1 ha	335	555.82	1.66	1.33	2.45	0.33	1.11
Date 2		1 - 10 ha	169	924.67	5.47	2.56	22.02	4.07	19.46
		10 - 20 ha	6	216.28	36.05	29.36	48.82	7.32	19.46
		> 20 ha	3	646.06	215.35	60.71	503.06	249.39	442.34
<b>Total</b>			<b>3104</b>	<b>3527.57</b>	<b>1.14</b>	<b>0.09</b>	<b>503.06</b>		<b>502.97</b>
Year 1	2009	< 0.1 ha	1021	226.48	0.22	0.02	0.22	0.01	0.21
Date 1	0928	0.1 - 0.5 ha	1326	878.57	0.66	0.25	1.23	0.24	0.98
Year 2	2009	0.5 - 1 ha	330	560.49	1.70	1.24	2.46	0.36	1.22
Date 2	1023	1 - 10 ha	190	988.53	5.20	2.49	23.35	3.74	20.87
		10 - 20 ha	9	314.63	34.96	24.91	48.99	9.88	24.08
		> 20 ha	4	652.59	163.15	56.13	447.01	190.02	390.88
<b>Total</b>			<b>2880</b>	<b>3621.30</b>	<b>1.26</b>	<b>0.02</b>	<b>447.01</b>		<b>447.00</b>
Year 1	2010	< 0.1 ha	1218	270.49	0.22	0.10	0.22	0.01	0.13
Date 1	0323	0.1 - 0.5 ha	2474	1747.67	0.71	0.26	1.22	0.24	0.97
Year 2		0.5 - 1 ha	942	1633.77	1.73	1.33	2.45	0.38	1.11
Date 2		1 - 10 ha	452	2433.20	5.38	2.56	23.35	3.78	20.79
		10 - 20 ha	13	414.46	31.88	24.91	43.14	5.02	18.24
		> 20 ha	11	1262.31	114.76	52.26	596.02	160.40	543.76
<b>Total</b>			<b>5110</b>	<b>7761.90</b>	<b>1.52</b>	<b>0.10</b>	<b>596.02</b>		<b>595.92</b>

Jack County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2010	< 0.1 ha	1214	269.17	0.22	0.09	0.24	0.01	0.15
Date 1	0408	0.1 - 0.5 ha	1879	1280.79	0.68	0.25	1.22	0.24	0.97
Year 2		0.5 - 1 ha	575	985.23	1.71	1.33	2.45	0.36	1.11
Date 2		1 - 10 ha	295	1657.13	5.62	2.67	22.46	3.89	19.79
		10 - 20 ha	9	301.96	33.55	26.46	48.48	7.11	22.02
		> 20 ha	10	1100.85	110.09	50.04	551.76	156.12	501.72
<b>Total</b>			<b>3982</b>	<b>5595.13</b>	<b>1.41</b>	<b>0.09</b>	<b>551.76</b>		<b>551.67</b>
Year 1	2010	< 0.1 ha	1494	331.79	0.22	0.08	0.24	0.01	0.16
Date 1	0627	0.1 - 0.5 ha	2564	1730.00	0.67	0.25	1.22	0.23	0.97
Year 2		0.5 - 1 ha	661	1104.88	1.67	1.33	2.45	0.35	1.11
Date 2		1 - 10 ha	327	1836.50	5.62	2.56	24.69	4.27	22.13
		10 - 20 ha	9	335.37	37.26	25.13	46.93	7.84	21.79
		> 20 ha	7	997.33	142.48	49.82	562.88	186.48	513.06
<b>Total</b>			<b>5062</b>	<b>6335.87</b>	<b>1.25</b>	<b>0.08</b>	<b>562.88</b>		<b>562.80</b>
Year 1	2010	< 0.1 ha	1399	310.33	0.22	0.08	0.24	0.01	0.17
Date 1	1001	0.1 - 0.5 ha	1679	1120.72	0.67	0.25	1.22	0.24	0.97
Year 2		0.5 - 1 ha	408	694.76	1.70	1.33	2.45	0.35	1.11
Date 2		1 - 10 ha	209	1175.14	5.62	2.47	22.68	4.08	20.21
		10 - 20 ha	9	322.03	35.78	25.80	47.81	8.73	22.02
		> 20 ha	4	772.49	193.12	61.60	535.75	228.93	474.15
<b>Total</b>			<b>3708</b>	<b>4395.46</b>	<b>1.19</b>	<b>0.08</b>	<b>535.75</b>		<b>535.67</b>
Year 1	2010	< 0.1 ha	787	174.60	0.22	0.03	0.22	0.01	0.20
Date 1	1118	0.1 - 0.5 ha	1048	693.58	0.66	0.44	1.22	0.23	0.78
Year 2	2010	0.5 - 1 ha	245	418.44	1.71	1.33	2.45	0.35	1.11
Date 2	1127	1 - 10 ha	132	831.06	6.30	2.56	24.69	4.34	22.13
		10 - 20 ha	9	303.79	33.75	27.58	46.26	7.24	18.68
		> 20 ha	5	758.37	151.67	49.59	499.94	195.32	450.35
<b>Total</b>			<b>2226</b>	<b>3179.84</b>	<b>1.43</b>	<b>0.03</b>	<b>499.94</b>		<b>499.92</b>
Year 1	2011	< 0.1 ha	784	173.88	0.22	0.08	0.22	0.01	0.15
Date 1	0105	0.1 - 0.5 ha	969	619.42	0.64	0.44	1.22	0.22	0.78
Year 2		0.5 - 1 ha	171	290.31	1.70	1.33	2.45	0.35	1.11
Date 2		1 - 10 ha	127	801.72	6.31	2.59	24.24	4.79	21.65
		10 - 20 ha	8	286.00	35.75	26.02	48.70	7.67	22.68
		> 20 ha	4	692.87	173.22	53.37	479.26	204.52	425.89
<b>Total</b>			<b>2063</b>	<b>2864.21</b>	<b>1.39</b>	<b>0.08</b>	<b>479.26</b>		<b>479.18</b>



Johnson County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	628	139.59	0.22	0.18	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	621	410.88	0.66	0.44	1.22	0.24	0.78
Year 2	1997	0.5 - 1 ha	161	273.10	1.70	1.33	2.45	0.36	1.11
Date 2	0328	1 - 10 ha	111	717.64	6.47	2.56	24.69	5.10	22.13
		10 - 20 ha	8	237.78	29.72	25.13	40.92	4.98	15.79
		> 20 ha	2	203.05	101.52	98.30	104.75	4.56	6.45
<b>Baseline Wet</b>		<b>Total</b>	<b>1531</b>	<b>1982.04</b>	<b>1.29</b>	<b>0.18</b>	<b>104.75</b>		<b>104.57</b>
Year 1		< 0.1 ha	491	109.20	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	521	340.54	0.65	0.44	1.11	0.23	0.67
Year 2	1999	0.5 - 1 ha	125	212.05	1.70	1.33	2.45	0.38	1.11
Date 2	0214	1 - 10 ha	84	604.44	7.20	2.67	24.69	5.48	22.02
		10 - 20 ha	7	206.90	29.56	25.65	41.59	5.65	15.94
		> 20 ha	2	203.94	101.97	98.52	105.42	4.87	6.89
<b>Baseline Dry</b>		<b>Total</b>	<b>1230</b>	<b>1677.07</b>	<b>1.36</b>	<b>0.22</b>	<b>105.42</b>		<b>105.19</b>
Year 1		< 0.1 ha	494	109.86	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	412	270.22	0.66	0.26	1.22	0.23	0.96
Year 2	2003	0.5 - 1 ha	107	183.09	1.71	1.28	2.45	0.36	1.16
Date 2	1023	1 - 10 ha	83	598.35	7.21	2.67	24.02	5.40	21.35
		10 - 20 ha	6	172.39	28.73	24.94	37.58	4.55	12.64
		> 20 ha	2	183.92	91.96	80.73	103.19	15.88	22.46
		<b>Total</b>	<b>1104</b>	<b>1517.84</b>	<b>1.37</b>	<b>0.22</b>	<b>103.19</b>		<b>102.97</b>
Year 1		< 0.1 ha	649	144.33	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	625	410.22	0.66	0.26	1.22	0.23	0.96
Year 2	2004	0.5 - 1 ha	165	284.67	1.73	1.33	2.45	0.36	1.11
Date 2	0907	1 - 10 ha	111	735.07	6.62	2.67	24.69	4.92	22.02
		10 - 20 ha	8	241.70	30.21	24.91	42.70	5.76	17.79
		> 20 ha	2	187.70	93.85	74.72	112.98	27.05	38.25
		<b>Total</b>	<b>1560</b>	<b>2003.69</b>	<b>1.28</b>	<b>0.22</b>	<b>112.98</b>		<b>112.75</b>
Year 1		< 0.1 ha	749	166.46	0.22	0.11	0.22	0.00	0.11
Date 1		0.1 - 0.5 ha	999	660.11	0.66	0.26	1.11	0.23	0.85
Year 2	2005	0.5 - 1 ha	250	428.44	1.71	1.33	2.45	0.36	1.11
Date 2	0214	1 - 10 ha	143	903.81	6.32	2.67	24.46	5.04	21.79
		10 - 20 ha	8	248.99	31.12	25.80	43.14	5.49	17.35
		> 20 ha	2	195.26	97.63	90.07	105.19	10.69	15.12
		<b>Total</b>	<b>2151</b>	<b>2603.07</b>	<b>1.21</b>	<b>0.11</b>	<b>105.19</b>		<b>105.08</b>
Year 1		< 0.1 ha	444	98.57	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	534	362.07	0.68	0.28	1.22	0.24	0.94
Year 2	2006	0.5 - 1 ha	175	307.99	1.76	1.33	2.45	0.36	1.11
Date 2	1116	1 - 10 ha	121	774.95	6.40	2.67	23.80	5.24	21.13
		10 - 20 ha	4	113.09	28.27	26.91	31.69	2.30	4.78
		> 20 ha	2	184.81	92.41	90.74	94.07	2.36	3.34
		<b>Total</b>	<b>1280</b>	<b>1841.48</b>	<b>1.44</b>	<b>0.05</b>	<b>94.07</b>		<b>94.02</b>

Johnson County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	731	162.17	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	1075	730.37	0.68	0.35	1.22	0.24	0.88
Year 2	2007	0.5 - 1 ha	348	609.58	1.75	1.33	2.45	0.36	1.11
Date 2	0308	1 - 10 ha	224	1251.87	5.59	2.67	24.69	4.27	22.02
		10 - 20 ha	9	275.40	30.60	26.24	40.70	4.75	14.46
		> 20 ha	2	197.93	98.97	90.96	106.97	11.32	16.01
<b>Total</b>			<b>2389</b>	<b>3227.32</b>	<b>1.35</b>	<b>0.05</b>	<b>106.97</b>		<b>106.92</b>
Year 1		< 0.1 ha	597	132.64	0.22	0.09	0.22	0.01	0.13
Date 1		0.1 - 0.5 ha	910	619.23	0.68	0.26	1.11	0.24	0.85
Year 2	2008	0.5 - 1 ha	284	496.83	1.75	1.33	2.45	0.36	1.11
Date 2	0207	1 - 10 ha	218	1195.34	5.48	2.67	23.57	4.34	20.91
		10 - 20 ha	8	240.98	30.12	24.91	42.48	5.39	17.57
		> 20 ha	3	286.00	95.33	80.06	105.64	13.49	25.58
<b>Total</b>			<b>2020</b>	<b>2971.02</b>	<b>1.47</b>	<b>0.09</b>	<b>105.64</b>		<b>105.54</b>
Year 1		< 0.1 ha	773	171.74	0.22	0.09	0.22	0.00	0.13
Date 1		0.1 - 0.5 ha	877	575.35	0.66	0.26	1.22	0.23	0.96
Year 2	2008	0.5 - 1 ha	330	591.68	1.79	1.33	2.45	0.37	1.11
Date 2	0411	1 - 10 ha	234	1273.93	5.44	2.56	24.24	4.14	21.68
		10 - 20 ha	11	330.66	30.06	24.91	42.48	4.76	17.57
		> 20 ha	1	102.97	102.97	102.97	102.97	0.00	0.00
<b>Total</b>			<b>2226</b>	<b>3046.33</b>	<b>1.37</b>	<b>0.09</b>	<b>102.97</b>		<b>102.88</b>
Year 1		< 0.1 ha	505	112.31	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	598	401.35	0.67	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	215	382.63	1.78	1.33	2.45	0.37	1.11
Date 2	1004	1 - 10 ha	199	1084.23	5.45	2.56	23.80	4.28	21.24
		10 - 20 ha	4	120.73	30.18	25.10	40.25	7.09	15.16
		> 20 ha	2	156.12	78.06	49.59	106.53	40.26	56.93
<b>Total</b>			<b>1523</b>	<b>2257.37</b>	<b>1.48</b>	<b>0.22</b>	<b>106.53</b>		<b>106.30</b>
Year 1		< 0.1 ha	518	115.01	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	594	406.77	0.68	0.26	1.22	0.25	0.96
Year 2	2008	0.5 - 1 ha	224	392.61	1.75	1.33	2.45	0.40	1.11
Date 2	1020	1 - 10 ha	201	1115.39	5.55	2.67	24.46	4.36	21.79
		10 - 20 ha	5	163.98	32.80	25.58	43.59	8.13	18.01
		> 20 ha	1	105.19	105.19	105.19	105.19	0.00	0.00
<b>Total</b>			<b>1543</b>	<b>2298.95</b>	<b>1.49</b>	<b>0.03</b>	<b>105.19</b>		<b>105.16</b>
Year 1		< 0.1 ha	310	68.61	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	402	277.10	0.69	0.33	1.22	0.24	0.89
Year 2	2008	0.5 - 1 ha	166	296.56	1.79	1.33	2.45	0.38	1.11
Date 2	1121	1 - 10 ha	151	830.43	5.50	2.67	22.91	4.30	20.24
		10 - 20 ha	3	101.86	33.95	27.13	39.59	6.31	12.45
		> 20 ha	1	101.86	101.86	101.86	101.86	0.00	0.00
<b>Total</b>			<b>1033</b>	<b>1676.41</b>	<b>1.62</b>	<b>0.05</b>	<b>101.86</b>		<b>101.80</b>

Johnson County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	286	63.60	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	418	290.56	0.70	0.44	1.11	0.23	0.67
Year 2	2008	0.5 - 1 ha	169	314.99	1.86	1.33	2.45	0.40	1.11
Date 2	1207	1 - 10 ha	129	762.46	5.91	2.67	22.77	4.65	20.10
		10 - 20 ha	3	99.19	33.06	27.80	36.47	4.62	8.67
		> 20 ha	1	100.08	100.08	100.08	100.08	0.00	0.00
<b>Total</b>			<b>1006</b>	<b>1630.88</b>	<b>1.62</b>	<b>0.22</b>	<b>100.08</b>		<b>99.86</b>
Year 1		< 0.1 ha	375	83.40	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	558	380.74	0.68	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	171	314.36	1.84	1.33	2.45	0.39	1.11
Date 2	0108	1 - 10 ha	152	871.62	5.73	2.56	24.24	4.55	21.68
		10 - 20 ha	4	129.32	32.33	26.90	39.81	6.20	12.91
		> 20 ha	1	99.63	99.63	99.63	99.63	0.00	0.00
<b>Total</b>			<b>1261</b>	<b>1879.06</b>	<b>1.49</b>	<b>0.22</b>	<b>99.63</b>		<b>99.41</b>
Year 1		< 0.1 ha	626	139.09	0.22	0.09	0.22	0.01	0.13
Date 1		0.1 - 0.5 ha	788	531.06	0.67	0.30	1.22	0.24	0.92
Year 2	2009	0.5 - 1 ha	265	463.22	1.75	1.33	2.45	0.36	1.11
Date 2	0329	1 - 10 ha	217	1163.10	5.36	2.56	24.02	4.11	21.46
		10 - 20 ha	6	187.05	31.17	26.46	37.14	3.78	10.67
		> 20 ha	2	163.46	81.73	55.15	108.31	37.58	53.15
<b>Total</b>			<b>1904</b>	<b>2646.98</b>	<b>1.39</b>	<b>0.09</b>	<b>108.31</b>		<b>108.21</b>
Year 1		< 0.1 ha	629	139.48	0.22	0.02	0.22	0.01	0.21
Date 1		0.1 - 0.5 ha	873	580.15	0.66	0.30	1.22	0.23	0.92
Year 2	2009	0.5 - 1 ha	283	490.24	1.73	1.33	2.45	0.37	1.11
Date 2	0414	1 - 10 ha	228	1210.77	5.31	2.67	23.57	3.87	20.91
		10 - 20 ha	8	249.54	31.19	25.35	37.14	3.74	11.79
		> 20 ha	2	166.13	83.06	56.49	109.64	37.58	53.15
<b>Total</b>			<b>2023</b>	<b>2836.31</b>	<b>1.40</b>	<b>0.02</b>	<b>109.64</b>		<b>109.62</b>
Year 1		< 0.1 ha	626	139.02	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	848	575.42	0.68	0.25	1.22	0.24	0.97
Year 2	2009	0.5 - 1 ha	289	504.59	1.75	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	231	1225.39	5.30	2.67	24.69	3.83	22.02
		10 - 20 ha	9	283.85	31.54	25.35	39.14	4.52	13.79
		> 20 ha	1	109.64	109.64	109.64	109.64	0.00	0.00
<b>Total</b>			<b>2004</b>	<b>2837.90</b>	<b>1.42</b>	<b>0.08</b>	<b>109.64</b>		<b>109.56</b>
Year 1		< 0.1 ha	711	158.03	0.22	0.18	0.22	0.00	0.05
Date 1		0.1 - 0.5 ha	856	564.59	0.66	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	297	507.94	1.71	1.33	2.45	0.36	1.11
Date 2	0804	1 - 10 ha	251	1275.82	5.08	2.56	22.68	3.59	20.13
		10 - 20 ha	10	297.50	29.75	24.91	40.48	4.67	15.57
		> 20 ha	1	112.98	112.98	112.98	112.98	0.00	0.00
<b>Total</b>			<b>2126</b>	<b>2916.86</b>	<b>1.37</b>	<b>0.18</b>	<b>112.98</b>		<b>112.80</b>

Johnson County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	786	174.80	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	854	584.35	0.68	0.26	1.22	0.24	0.96
Year 2	2009	0.5 - 1 ha	367	642.28	1.75	1.33	2.45	0.35	1.11
Date 2	1023	1 - 10 ha	253	1342.26	5.31	2.56	22.68	3.88	20.13
		10 - 20 ha	13	404.72	31.13	25.13	43.59	5.84	18.46
		> 20 ha	4	327.37	81.84	49.82	114.76	33.09	64.94
<b>Total</b>			<b>2277</b>	<b>3475.78</b>	<b>1.53</b>	<b>0.22</b>	<b>114.76</b>		<b>114.53</b>
Year 1		< 0.1 ha	706	156.89	0.22	0.15	0.22	0.00	0.07
Date 1		0.1 - 0.5 ha	1015	704.10	0.69	0.26	1.22	0.24	0.96
Year 2	2009	0.5 - 1 ha	366	636.36	1.74	1.33	2.45	0.36	1.11
Date 2	1124	1 - 10 ha	261	1400.98	5.37	2.56	24.46	4.05	21.91
		10 - 20 ha	11	339.23	30.84	25.80	42.92	4.94	17.12
		> 20 ha	2	203.27	101.63	94.74	108.53	9.75	13.79
<b>Total</b>			<b>2361</b>	<b>3440.83</b>	<b>1.46</b>	<b>0.15</b>	<b>108.53</b>		<b>108.38</b>
Year 1		< 0.1 ha	592	131.47	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	853	586.28	0.69	0.26	1.22	0.24	0.96
Year 2	2009	0.5 - 1 ha	312	545.84	1.75	1.33	2.45	0.37	1.11
Date 2	1210	1 - 10 ha	234	1333.01	5.70	2.56	23.80	4.35	21.24
		10 - 20 ha	7	220.50	31.50	25.91	38.92	4.53	13.01
		> 20 ha	2	191.15	95.57	87.07	104.08	12.03	17.01
<b>Total</b>			<b>2000</b>	<b>3008.25</b>	<b>1.50</b>	<b>0.03</b>	<b>104.08</b>		<b>104.05</b>
Year 1		< 0.1 ha	341	75.84	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	495	336.72	0.68	0.26	1.11	0.24	0.85
Year 2	2010	0.5 - 1 ha	227	415.21	1.83	1.33	2.45	0.38	1.11
Date 2	0111	1 - 10 ha	150	931.17	6.21	2.67	22.46	4.93	19.79
		10 - 20 ha	7	201.16	28.74	25.80	36.70	3.81	10.90
		> 20 ha	2	191.70	95.85	92.52	99.19	4.72	6.67
<b>Total</b>			<b>1222</b>	<b>2151.79</b>	<b>1.76</b>	<b>0.22</b>	<b>99.19</b>		<b>98.97</b>
Year 1		< 0.1 ha	794	176.36	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	882	584.21	0.66	0.26	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	339	596.07	1.76	1.33	2.45	0.37	1.11
Date 2	0604	1 - 10 ha	289	1527.19	5.28	2.56	24.46	3.91	21.91
		10 - 20 ha	9	265.58	29.51	25.58	37.81	3.69	12.23
		> 20 ha	2	183.48	91.74	78.51	104.97	18.71	26.46
<b>Total</b>			<b>2315</b>	<b>3332.87</b>	<b>1.44</b>	<b>0.00</b>	<b>104.97</b>		<b>104.97</b>
Year 1		< 0.1 ha	831	184.73	0.22	0.14	0.22	0.00	0.08
Date 1		0.1 - 0.5 ha	1246	842.72	0.68	0.25	1.22	0.24	0.97
Year 2	2010	0.5 - 1 ha	478	833.87	1.74	1.33	2.45	0.36	1.11
Date 2	0620	1 - 10 ha	328	1790.28	5.46	2.56	24.46	4.12	21.91
		10 - 20 ha	10	318.43	31.84	26.02	43.59	4.75	17.57
		> 20 ha	2	192.37	96.19	77.84	114.53	25.95	36.70
<b>Total</b>			<b>2895</b>	<b>4162.40</b>	<b>1.44</b>	<b>0.14</b>	<b>114.53</b>		<b>114.39</b>

Johnson County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	838	186.21	0.22	0.12	0.22	0.00	0.11
Date 1		0.1 - 0.5 ha	1139	766.20	0.67	0.35	1.22	0.24	0.87
Year 2	2010	0.5 - 1 ha	437	768.32	1.76	1.33	2.45	0.37	1.11
Date 2	0807	1 - 10 ha	339	1814.34	5.35	2.56	24.24	3.95	21.68
		10 - 20 ha	7	224.15	32.02	24.91	44.03	5.89	19.13
		> 20 ha	2	185.92	92.96	69.16	116.76	33.65	47.59
<b>Total</b>			<b>2762</b>	<b>3945.15</b>	<b>1.43</b>	<b>0.12</b>	<b>116.76</b>		<b>116.64</b>
Year 1		< 0.1 ha	780	173.22	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	973	658.94	0.68	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	392	689.95	1.76	1.33	2.45	0.35	1.11
Date 2	1010	1 - 10 ha	253	1370.11	5.42	2.56	24.69	4.18	22.13
		10 - 20 ha	10	343.39	34.34	26.91	48.59	7.63	21.68
		> 20 ha	2	198.82	99.41	94.96	103.86	6.29	8.90
<b>Total</b>			<b>2410</b>	<b>3434.44</b>	<b>1.43</b>	<b>0.08</b>	<b>103.86</b>		<b>103.78</b>
Year 1		< 0.1 ha	1136	251.88	0.22	0.01	0.22	0.01	0.21
Date 1		0.1 - 0.5 ha	1207	800.32	0.66	0.26	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	420	741.24	1.76	1.33	2.45	0.37	1.11
Date 2	1127	1 - 10 ha	319	1640.23	5.14	2.56	24.24	3.78	21.68
		10 - 20 ha	13	395.14	30.40	24.91	44.92	5.30	20.02
		> 20 ha	1	134.99	134.99	134.99	134.99	0.00	0.00
<b>Total</b>			<b>3096</b>	<b>3963.80</b>	<b>1.28</b>	<b>0.01</b>	<b>134.99</b>		<b>134.99</b>
Year 1		< 0.1 ha	398	88.23	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	623	433.99	0.70	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	242	422.22	1.74	1.33	2.45	0.37	1.11
Date 2	1213	1 - 10 ha	160	944.08	5.90	2.67	24.02	4.98	21.35
		10 - 20 ha	6	171.16	28.53	24.91	38.70	5.10	13.79
		> 20 ha	2	187.26	93.63	86.29	100.97	10.38	14.68
<b>Total</b>			<b>1431</b>	<b>2246.94</b>	<b>1.57</b>	<b>0.05</b>	<b>100.97</b>		<b>100.91</b>



Montague County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	917	203.76	0.22	0.13	0.22	0.00	0.10
Date 1	0303	0.1 - 0.5 ha	1635	1143.75	0.70	0.25	1.22	0.25	0.97
Year 2	1997	0.5 - 1 ha	526	903.39	1.72	1.29	2.47	0.34	1.18
Date 2	0328	1 - 10 ha	419	2566.86	6.13	2.47	24.32	4.57	21.85
		10 - 20 ha	20	707.84	35.39	24.82	47.96	7.69	23.15
		> 20 ha	4	454.98	113.74	65.01	218.17	70.94	153.16
<b>Baseline Wet</b>		<b>Total</b>	<b>3521</b>	<b>5980.57</b>	<b>1.70</b>	<b>0.13</b>	<b>218.17</b>		<b>218.04</b>
Year 1	1999	< 0.1 ha	217	48.26	0.22	0.22	0.22	0.00	0.00
Date 1	0221	0.1 - 0.5 ha	363	210.55	0.58	0.25	1.20	0.26	0.95
Year 2	1999	0.5 - 1 ha	74	128.91	1.74	1.32	2.45	0.35	1.13
Date 2	0214	1 - 10 ha	118	794.11	6.73	2.51	22.88	4.44	20.37
		10 - 20 ha	6	165.33	27.55	24.91	35.48	4.09	10.57
		> 20 ha	4	787.40	196.85	52.93	518.52	219.34	465.59
<b>Baseline Dry</b>		<b>Total</b>	<b>782</b>	<b>2134.54</b>	<b>2.73</b>	<b>0.22</b>	<b>518.52</b>		<b>518.30</b>
Year 1	2003	< 0.1 ha	489	108.73	0.22	0.20	0.22	0.00	0.02
Date 1	1014	0.1 - 0.5 ha	758	467.58	0.62	0.25	1.22	0.26	0.97
Year 2	2003	0.5 - 1 ha	190	316.30	1.66	1.29	2.45	0.31	1.15
Date 2	1023	1 - 10 ha	166	1039.78	6.26	2.49	23.96	4.13	21.46
		10 - 20 ha	9	286.28	31.81	26.91	39.36	4.42	12.46
		> 20 ha	3	263.07	87.69	55.60	151.01	54.84	95.41
		<b>Total</b>	<b>1615</b>	<b>2481.75</b>	<b>1.54</b>	<b>0.20</b>	<b>151.01</b>		<b>150.80</b>
Year 1	2004	< 0.1 ha	1037	230.62	0.22	0.22	0.22	0.00	0.00
Date 1	1016	0.1 - 0.5 ha	1718	1120.19	0.65	0.25	1.22	0.26	0.97
Year 2	2004	0.5 - 1 ha	478	815.93	1.71	1.25	2.46	0.34	1.21
Date 2	0907	1 - 10 ha	365	2295.55	6.29	2.48	24.55	4.65	22.07
		10 - 20 ha	14	496.79	35.49	25.44	46.67	6.65	21.22
		> 20 ha	4	408.20	102.05	52.59	218.84	78.33	166.25
		<b>Total</b>	<b>3616</b>	<b>5367.28</b>	<b>1.48</b>	<b>0.22</b>	<b>218.84</b>		<b>218.61</b>
Year 1	2005	< 0.1 ha	925	205.20	0.22	0.00	0.22	0.01	0.22
Date 1	0221	0.1 - 0.5 ha	1852	1199.30	0.65	0.25	1.22	0.27	0.97
Year 2	2005	0.5 - 1 ha	457	789.06	1.73	1.25	2.47	0.34	1.22
Date 2	0214	1 - 10 ha	341	2067.46	6.06	2.47	24.21	4.29	21.74
		10 - 20 ha	16	566.57	35.41	25.07	48.16	7.15	23.08
		> 20 ha	3	367.62	122.54	70.28	207.94	74.57	137.66
		<b>Total</b>	<b>3594</b>	<b>5195.21</b>	<b>1.45</b>	<b>0.00</b>	<b>207.94</b>		<b>207.94</b>
Year 1	2006	< 0.1 ha	429	95.29	0.22	0.15	0.22	0.00	0.08
Date 1	1123	0.1 - 0.5 ha	649	404.70	0.62	0.25	1.22	0.26	0.97
Year 2	2006	0.5 - 1 ha	124	209.27	1.69	1.26	2.47	0.33	1.21
Date 2	1116	1 - 10 ha	145	830.61	5.73	2.47	20.24	3.46	17.77
		10 - 20 ha	8	244.18	30.52	25.09	43.14	7.68	18.06
		> 20 ha	2	526.76	263.38	162.57	364.19	142.57	201.62
		<b>Total</b>	<b>1357</b>	<b>2310.81</b>	<b>1.70</b>	<b>0.15</b>	<b>364.19</b>		<b>364.04</b>

Montague County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1421	315.73	0.22	0.03	0.22	0.01	0.19
Date 1	0331	0.1 - 0.5 ha	2126	1405.52	0.66	0.25	1.23	0.25	0.97
Year 2	2007	0.5 - 1 ha	636	1109.97	1.75	1.24	2.47	0.34	1.23
Date 2	0308	1 - 10 ha	496	3027.89	6.10	2.47	24.46	4.32	21.99
		10 - 20 ha	33	1068.98	32.39	24.92	47.78	6.40	22.86
		> 20 ha	12	1096.98	91.42	52.07	228.62	57.31	176.55
<b>Total</b>			<b>4724</b>	<b>8025.06</b>	<b>1.70</b>	<b>0.03</b>	<b>228.62</b>		<b>228.59</b>
Year 1	2008	< 0.1 ha	1060	235.19	0.22	0.06	0.22	0.01	0.16
Date 1	0418	0.1 - 0.5 ha	2199	1445.81	0.66	0.25	1.23	0.27	0.97
Year 2	2008	0.5 - 1 ha	624	1070.28	1.72	1.29	2.45	0.35	1.16
Date 2	0411	1 - 10 ha	502	3001.62	5.98	2.47	24.64	4.61	22.16
		10 - 20 ha	14	516.71	36.91	27.35	48.96	8.27	21.60
		> 20 ha	5	488.22	97.64	52.77	213.94	65.88	161.17
<b>Total</b>			<b>4404</b>	<b>6757.84</b>	<b>1.53</b>	<b>0.06</b>	<b>213.94</b>		<b>213.88</b>
Year 1	2008	< 0.1 ha	804	178.61	0.22	0.05	0.22	0.01	0.18
Date 1	0723	0.1 - 0.5 ha	954	633.49	0.66	0.38	1.21	0.23	0.83
Year 2	2008	0.5 - 1 ha	254	441.31	1.74	1.33	2.47	0.36	1.13
Date 2	0207	1 - 10 ha	217	1423.47	6.56	2.56	23.80	4.14	21.24
		10 - 20 ha	12	388.61	32.38	26.24	39.59	5.22	13.34
		> 20 ha	2	147.56	73.78	67.50	80.06	8.89	12.57
<b>Total</b>			<b>2243</b>	<b>3213.05</b>	<b>1.43</b>	<b>0.05</b>	<b>80.06</b>		<b>80.02</b>
Year 1	2008	< 0.1 ha	837	185.98	0.22	0.06	0.22	0.01	0.16
Date 1	1027	0.1 - 0.5 ha	861	577.39	0.67	0.25	1.22	0.24	0.97
Year 2	2008	0.5 - 1 ha	237	411.23	1.74	1.33	2.45	0.37	1.11
Date 2	1004	1 - 10 ha	187	1197.57	6.40	2.67	19.79	3.81	17.12
		10 - 20 ha	9	287.85	31.98	25.80	42.92	5.74	17.12
		> 20 ha	2	132.99	66.50	60.94	72.06	7.86	11.12
<b>Total</b>			<b>2133</b>	<b>2793.02</b>	<b>1.31</b>	<b>0.06</b>	<b>72.06</b>		<b>72.00</b>
Year 1	2008	< 0.1 ha	731	162.57	0.22	0.22	0.22	0.00	0.00
Date 1	1027	0.1 - 0.5 ha	805	539.54	0.67	0.25	1.22	0.24	0.97
Year 2	2008	0.5 - 1 ha	218	375.80	1.72	1.33	2.45	0.34	1.11
Date 2	1020	1 - 10 ha	189	1201.44	6.36	2.56	19.79	3.79	17.24
		10 - 20 ha	10	317.81	31.78	28.02	42.92	4.72	14.90
		> 20 ha	2	132.32	66.16	60.94	71.39	7.39	10.45
<b>Total</b>			<b>1955</b>	<b>2729.47</b>	<b>1.40</b>	<b>0.22</b>	<b>71.39</b>		<b>71.17</b>
Year 1	2008	< 0.1 ha	372	82.73	0.22	0.22	0.22	0.00	0.00
Date 1	1027	0.1 - 0.5 ha	495	337.32	0.68	0.38	1.18	0.24	0.80
Year 2	2008	0.5 - 1 ha	150	262.82	1.75	1.33	2.45	0.36	1.11
Date 2	1121	1 - 10 ha	143	916.54	6.41	2.67	23.35	3.99	20.68
		10 - 20 ha	7	208.72	29.82	24.91	38.92	5.07	14.01
		> 20 ha	2	116.31	58.16	55.38	60.94	3.93	5.56
<b>Total</b>			<b>1169</b>	<b>1924.45</b>	<b>1.65</b>	<b>0.22</b>	<b>60.94</b>		<b>60.71</b>

Montague County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2008	< 0.1 ha	415	91.83	0.22	0.02	0.22	0.01	0.20
Date 1	1214	0.1 - 0.5 ha	474	314.10	0.66	0.25	1.22	0.23	0.97
Year 2	2008	0.5 - 1 ha	119	212.22	1.78	1.33	2.45	0.37	1.11
Date 2	1207	1 - 10 ha	128	856.05	6.69	2.67	24.24	4.44	21.57
		10 - 20 ha	5	159.90	31.98	27.35	38.92	4.43	11.56
		> 20 ha	2	115.65	57.82	57.60	58.05	0.31	0.44
<b>Total</b>			<b>1143</b>	<b>1749.75</b>	<b>1.53</b>	<b>0.02</b>	<b>58.05</b>		<b>58.03</b>
Year 1	2009	< 0.1 ha	397	87.95	0.22	0.03	0.22	0.01	0.19
Date 1	0115	0.1 - 0.5 ha	410	268.97	0.66	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	106	183.88	1.73	1.33	2.45	0.33	1.11
Date 2	0108	1 - 10 ha	131	827.62	6.32	2.67	24.24	4.15	21.57
		10 - 20 ha	6	184.14	30.69	25.13	37.14	4.61	12.01
		> 20 ha	2	118.31	59.16	56.71	61.60	3.46	4.89
<b>Total</b>			<b>1052</b>	<b>1670.88</b>	<b>1.59</b>	<b>0.03</b>	<b>61.60</b>		<b>61.57</b>
Year 1	2009	< 0.1 ha	463	102.79	0.22	0.05	0.22	0.01	0.18
Date 1	0421	0.1 - 0.5 ha	814	552.41	0.68	0.25	1.22	0.23	0.97
Year 2	2009	0.5 - 1 ha	234	403.33	1.72	1.33	2.45	0.36	1.11
Date 2	0329	1 - 10 ha	186	1189.29	6.39	2.67	22.02	4.07	19.35
		10 - 20 ha	9	325.10	36.12	27.35	46.00	6.93	18.64
		> 20 ha	2	134.10	67.05	55.38	78.73	16.51	23.35
<b>Total</b>			<b>1708</b>	<b>2707.03</b>	<b>1.58</b>	<b>0.05</b>	<b>78.73</b>		<b>78.68</b>
Year 1	2009	< 0.1 ha	615	136.31	0.22	0.00	0.22	0.01	0.22
Date 1	0421	0.1 - 0.5 ha	888	617.23	0.70	0.26	1.22	0.24	0.96
Year 2	2009	0.5 - 1 ha	261	453.47	1.74	1.33	2.45	0.38	1.11
Date 2	0414	1 - 10 ha	199	1264.16	6.35	2.67	22.46	3.88	19.79
		10 - 20 ha	10	345.16	34.52	25.24	44.92	7.33	19.68
		> 20 ha	3	189.87	63.29	55.38	78.95	13.56	23.57
<b>Total</b>			<b>1976</b>	<b>3006.20</b>	<b>1.52</b>	<b>0.00</b>	<b>78.95</b>		<b>78.95</b>
Year 1	2009	< 0.1 ha	1061	234.94	0.22	0.00	0.22	0.01	0.22
Date 1	0608	0.1 - 0.5 ha	1305	866.79	0.66	0.25	1.22	0.24	0.97
Year 2	2009	0.5 - 1 ha	398	690.68	1.74	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	282	1829.08	6.49	2.53	21.24	4.33	18.71
		10 - 20 ha	14	455.40	32.53	25.35	44.92	7.15	19.57
		> 20 ha	2	159.90	79.95	71.61	88.29	11.79	16.68
<b>Total</b>			<b>3062</b>	<b>4236.79</b>	<b>1.38</b>	<b>0.00</b>	<b>88.29</b>		<b>88.29</b>
Year 1	2009	< 0.1 ha	1075	238.06	0.22	0.00	0.22	0.01	0.22
Date 1	0710	0.1 - 0.5 ha	1328	883.45	0.67	0.25	1.22	0.24	0.98
Year 2	2009	0.5 - 1 ha	394	682.69	1.73	1.33	2.45	0.36	1.11
Date 2	0703	1 - 10 ha	287	1831.01	6.38	2.56	21.24	4.26	18.68
		10 - 20 ha	14	459.52	32.82	25.80	44.92	6.98	19.13
		> 20 ha	2	157.90	78.95	71.61	86.29	10.38	14.68
<b>Total</b>			<b>3100</b>	<b>4252.62</b>	<b>1.37</b>	<b>0.00</b>	<b>86.29</b>		<b>86.29</b>

Montague County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	1093	241.14	0.22	0.00	0.24	0.02	0.24
Date 1	0710	0.1 - 0.5 ha	1310	880.48	0.67	0.25	1.22	0.24	0.98
Year 2	2009	0.5 - 1 ha	371	647.11	1.74	1.25	2.45	0.36	1.20
Date 2	0804	1 - 10 ha	281	1780.00	6.33	2.56	22.80	4.31	20.24
		10 - 20 ha	12	407.04	33.92	25.80	44.26	6.50	18.46
		> 20 ha	2	156.45	78.23	70.17	86.29	11.40	16.12
<b>Total</b>			<b>3069</b>	<b>4112.21</b>	<b>1.34</b>	<b>0.00</b>	<b>86.29</b>		<b>86.29</b>
Year 1	2009	< 0.1 ha	1035	230.16	0.22	0.20	0.22	0.00	0.02
Date 1	0928	0.1 - 0.5 ha	1593	1067.40	0.67	0.30	1.23	0.25	0.93
Year 2	2009	0.5 - 1 ha	520	887.84	1.71	1.24	2.47	0.36	1.23
Date 2	1023	1 - 10 ha	391	2321.16	5.94	2.48	23.99	4.25	21.51
		10 - 20 ha	15	515.44	34.36	25.58	44.03	6.87	18.46
		> 20 ha	4	521.62	130.40	52.59	201.27	78.24	148.68
<b>Total</b>			<b>3558</b>	<b>5543.62</b>	<b>1.56</b>	<b>0.20</b>	<b>201.27</b>		<b>201.06</b>
Year 1	2010	< 0.1 ha	757	167.04	0.22	0.00	0.23	0.02	0.23
Date 1	0323	0.1 - 0.5 ha	993	669.20	0.67	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	303	531.18	1.75	1.31	2.45	0.38	1.14
Date 2	0111	1 - 10 ha	275	1687.56	6.14	2.48	24.24	4.20	21.76
		10 - 20 ha	13	427.58	32.89	26.46	39.59	4.81	13.12
		> 20 ha	3	351.38	117.13	61.38	191.70	67.17	130.32
<b>Total</b>			<b>2344</b>	<b>3833.94</b>	<b>1.64</b>	<b>0.00</b>	<b>191.70</b>		<b>191.70</b>
Year 1	2010	< 0.1 ha	885	194.65	0.22	0.00	0.24	0.02	0.24
Date 1	0323	0.1 - 0.5 ha	1282	873.53	0.68	0.44	1.22	0.24	0.79
Year 2	2009	0.5 - 1 ha	377	657.62	1.74	1.33	2.45	0.37	1.11
Date 2	1124	1 - 10 ha	312	1952.53	6.26	2.50	23.91	4.29	21.40
		10 - 20 ha	14	470.17	33.58	24.71	42.70	6.32	17.99
		> 20 ha	3	360.36	120.12	70.39	191.68	63.52	121.29
<b>Total</b>			<b>2873</b>	<b>4508.87</b>	<b>1.57</b>	<b>0.00</b>	<b>191.68</b>		<b>191.68</b>
Year 1	2010	< 0.1 ha	878	192.20	0.22	0.00	0.23	0.03	0.23
Date 1	0323	0.1 - 0.5 ha	1110	734.18	0.66	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	315	542.68	1.72	1.33	2.47	0.38	1.13
Date 2	1210	1 - 10 ha	286	1769.30	6.19	2.48	23.80	4.22	21.32
		10 - 20 ha	12	402.76	33.56	25.35	42.03	5.57	16.68
		> 20 ha	3	354.63	118.21	64.05	192.28	66.40	128.23
<b>Total</b>			<b>2604</b>	<b>3995.75</b>	<b>1.53</b>	<b>0.00</b>	<b>192.28</b>		<b>192.28</b>
Year 1	2010	< 0.1 ha	1275	282.45	0.22	0.00	0.22	0.01	0.22
Date 1	0408	0.1 - 0.5 ha	1605	1079.85	0.67	0.25	1.22	0.24	0.97
Year 2	2010	0.5 - 1 ha	466	818.39	1.76	1.33	2.47	0.38	1.13
Date 2	0620	1 - 10 ha	376	2427.80	6.46	2.53	24.24	4.61	21.71
		10 - 20 ha	16	543.31	33.96	24.91	47.15	7.09	22.24
		> 20 ha	3	227.87	75.96	61.30	93.85	16.51	32.55
<b>Total</b>			<b>3741</b>	<b>5379.68</b>	<b>1.44</b>	<b>0.00</b>	<b>93.85</b>		<b>93.85</b>

Montague County			Summary statistics for Water Features in Acres						
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>	2010	< 0.1 ha	1278	282.69	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	0627	0.1 - 0.5 ha	1706	1148.53	0.67	0.44	1.22	0.23	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	504	885.55	1.76	1.33	2.47	0.37	1.13
<b>Date 2</b>	0620	1 - 10 ha	383	2454.44	6.41	2.53	24.24	4.54	21.71
		10 - 20 ha	16	550.43	34.40	24.91	47.15	7.12	22.24
		> 20 ha	3	231.40	77.13	67.05	91.63	12.87	24.57
<b>Total</b>			<b>3890</b>	<b>5553.05</b>	<b>1.43</b>	<b>0.00</b>	<b>91.63</b>		<b>91.63</b>
<b>Year 1</b>	2010	< 0.1 ha	1339	296.48	0.22	0.02	0.22	0.01	0.20
<b>Date 1</b>	0627	0.1 - 0.5 ha	1927	1305.33	0.68	0.32	1.22	0.23	0.90
<b>Year 2</b>	2010	0.5 - 1 ha	589	1022.01	1.74	1.27	2.45	0.36	1.17
<b>Date 2</b>	0807	1 - 10 ha	424	2646.34	6.24	2.56	24.69	4.44	22.13
		10 - 20 ha	12	435.56	36.30	28.69	46.48	6.64	17.79
		> 20 ha	3	232.72	77.57	66.59	91.63	12.80	25.04
<b>Total</b>			<b>4294</b>	<b>5938.43</b>	<b>1.38</b>	<b>0.02</b>	<b>91.63</b>		<b>91.61</b>
<b>Year 1</b>	2010	< 0.1 ha	982	216.91	0.22	0.00	0.22	0.02	0.22
<b>Date 1</b>	1001	0.1 - 0.5 ha	1167	789.91	0.68	0.32	1.22	0.23	0.90
<b>Year 2</b>	2010	0.5 - 1 ha	339	595.22	1.76	1.33	2.45	0.37	1.11
<b>Date 2</b>	1010	1 - 10 ha	289	1874.05	6.48	2.56	22.02	4.09	19.46
		10 - 20 ha	15	472.40	31.49	25.24	43.14	6.18	17.90
		> 20 ha	2	148.23	74.11	73.61	74.61	0.71	1.00
<b>Total</b>			<b>2794</b>	<b>4096.72</b>	<b>1.47</b>	<b>0.00</b>	<b>74.61</b>		<b>74.61</b>
<b>Year 1</b>	2010	< 0.1 ha	1039	231.07	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>	1118	0.1 - 0.5 ha	1458	964.99	0.66	0.41	1.22	0.23	0.81
<b>Year 2</b>	2010	0.5 - 1 ha	404	697.53	1.73	1.33	2.45	0.35	1.11
<b>Date 2</b>	1127	1 - 10 ha	302	2037.07	6.75	2.67	24.24	4.54	21.57
		10 - 20 ha	12	421.44	35.12	26.46	45.81	7.10	19.35
		> 20 ha	2	261.09	130.55	72.95	188.15	81.46	115.20
<b>Total</b>			<b>3217</b>	<b>4613.18</b>	<b>1.43</b>	<b>0.22</b>	<b>188.15</b>		<b>187.92</b>
<b>Year 1</b>	2011	< 0.1 ha	526	112.34	0.21	0.00	0.22	0.04	0.22
<b>Date 1</b>	0105	0.1 - 0.5 ha	553	359.59	0.65	0.30	1.22	0.23	0.93
<b>Year 2</b>	2010	0.5 - 1 ha	155	272.15	1.76	1.32	2.45	0.35	1.12
<b>Date 2</b>	1213	1 - 10 ha	188	1280.13	6.81	2.67	24.69	4.71	22.02
		10 - 20 ha	7	231.24	33.03	26.46	38.47	4.05	12.01
		> 20 ha	2	129.66	64.83	61.16	68.50	5.19	7.34
<b>Total</b>			<b>1431</b>	<b>2385.10</b>	<b>1.67</b>	<b>0.00</b>	<b>68.50</b>		<b>68.50</b>



Palo Pinto County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	1002	222.45	0.22	0.08	0.22	0.01	0.14
Date 1	0303	0.1 - 0.5 ha	1760	1218.79	0.69	0.25	1.22	0.25	0.97
Year 2	1997	0.5 - 1 ha	572	981.18	1.72	1.33	2.45	0.34	1.11
Date 2	0328	1 - 10 ha	354	2076.72	5.87	2.49	24.69	4.61	22.20
		10 - 20 ha	10	314.59	31.46	25.58	47.77	7.23	22.20
		> 20 ha	5	623.04	124.61	75.84	182.81	42.40	106.97
<b>Baseline Wet</b>		<b>Total</b>	<b>3703</b>	<b>5436.77</b>	<b>1.47</b>	<b>0.08</b>	<b>182.81</b>		<b>182.73</b>
Year 1	1999	< 0.1 ha	409	90.88	0.22	0.13	0.23	0.00	0.10
Date 1	0221	0.1 - 0.5 ha	559	367.59	0.66	0.25	1.19	0.24	0.93
Year 2	1999	0.5 - 1 ha	128	220.66	1.72	1.31	2.45	0.38	1.14
Date 2	0214	1 - 10 ha	111	818.50	7.37	2.49	23.76	5.35	21.27
		10 - 20 ha	4	370.21	92.55	60.27	126.91	27.56	66.64
<b>Baseline Dry</b>		<b>Total</b>	<b>1211</b>	<b>1867.84</b>	<b>1.54</b>	<b>0.13</b>	<b>126.91</b>		<b>126.78</b>
Year 1	2003	< 0.1 ha	707	157.23	0.22	0.22	0.22	0.00	0.00
Date 1	1014	0.1 - 0.5 ha	771	496.69	0.64	0.25	1.22	0.25	0.97
Year 2	2003	0.5 - 1 ha	138	239.32	1.73	1.26	2.45	0.35	1.19
Date 2	1023	1 - 10 ha	117	784.69	6.71	2.49	22.68	4.90	20.20
		10 - 20 ha	3	92.52	30.84	25.83	36.00	5.09	10.17
		> 20 ha	5	450.59	90.12	58.38	124.12	29.72	65.74
		<b>Total</b>	<b>1741</b>	<b>2221.04</b>	<b>1.28</b>	<b>0.22</b>	<b>124.12</b>		<b>123.90</b>
Year 1	2004	< 0.1 ha	1047	232.67	0.22	0.12	0.22	0.00	0.10
Date 1	1016	0.1 - 0.5 ha	1195	769.84	0.64	0.25	1.22	0.24	0.97
Year 2	2004	0.5 - 1 ha	246	424.72	1.73	1.31	2.45	0.35	1.14
Date 2	0907	1 - 10 ha	173	1126.88	6.51	2.47	23.80	5.06	21.32
		10 - 20 ha	4	141.34	35.33	26.91	42.26	6.87	15.35
		> 20 ha	5	546.01	109.20	67.16	129.02	25.36	61.85
		<b>Total</b>	<b>2670</b>	<b>3241.46</b>	<b>1.21</b>	<b>0.12</b>	<b>129.02</b>		<b>128.89</b>
Year 1	2005	< 0.1 ha	836	185.75	0.22	0.14	0.22	0.00	0.09
Date 1	0221	0.1 - 0.5 ha	1331	911.85	0.69	0.25	1.22	0.25	0.97
Year 2	2005	0.5 - 1 ha	357	609.57	1.71	1.33	2.46	0.35	1.14
Date 2	0214	1 - 10 ha	232	1411.57	6.08	2.47	24.46	4.42	21.99
		10 - 20 ha	8	233.00	29.13	24.79	37.58	4.93	12.80
		> 20 ha	6	603.92	100.65	51.15	130.89	33.91	79.74
		<b>Total</b>	<b>2770</b>	<b>3955.67</b>	<b>1.43</b>	<b>0.14</b>	<b>130.89</b>		<b>130.75</b>
Year 1	2006	< 0.1 ha	575	127.88	0.22	0.22	0.22	0.00	0.00
Date 1	1123	0.1 - 0.5 ha	552	353.72	0.64	0.25	1.21	0.25	0.96
Year 2	2006	0.5 - 1 ha	117	200.00	1.71	1.26	2.45	0.35	1.19
Date 2	1116	1 - 10 ha	121	752.60	6.22	2.54	22.24	4.76	19.70
		10 - 20 ha	2	60.49	30.25	27.13	33.36	4.40	6.23
		> 20 ha	5	418.43	83.69	57.60	108.86	22.93	51.26
		<b>Total</b>	<b>1372</b>	<b>1913.13</b>	<b>1.39</b>	<b>0.22</b>	<b>108.86</b>		<b>108.63</b>

Palo Pinto County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1404	311.53	0.22	0.05	0.22	0.01	0.17
Date 1	0331	0.1 - 0.5 ha	2080	1391.68	0.67	0.25	1.23	0.23	0.97
Year 2	2007	0.5 - 1 ha	640	1111.22	1.74	1.33	2.46	0.36	1.13
Date 2	0308	1 - 10 ha	394	2292.91	5.82	2.47	24.35	4.19	21.88
		10 - 20 ha	15	475.48	31.70	26.46	43.14	4.85	16.68
		> 20 ha	10	926.81	92.68	49.82	134.85	32.79	85.03
<b>Total</b>			<b>4543</b>	<b>6509.63</b>	<b>1.43</b>	<b>0.05</b>	<b>134.85</b>		<b>134.80</b>
Year 1	2008	< 0.1 ha	1135	251.96	0.22	0.10	0.22	0.01	0.12
Date 1	0418	0.1 - 0.5 ha	1826	1231.04	0.67	0.25	1.22	0.26	0.97
Year 2	2008	0.5 - 1 ha	488	846.32	1.73	1.33	2.46	0.36	1.13
Date 2	0411	1 - 10 ha	312	1810.40	5.80	2.49	24.46	4.20	21.98
		10 - 20 ha	12	411.33	34.28	25.13	49.15	7.32	24.02
		> 20 ha	5	622.20	124.44	102.30	147.00	18.04	44.70
<b>Total</b>			<b>3778</b>	<b>5173.25</b>	<b>1.37</b>	<b>0.10</b>	<b>147.00</b>		<b>146.91</b>
Year 1	2008	< 0.1 ha	661	146.94	0.22	0.16	0.22	0.00	0.06
Date 1	1027	0.1 - 0.5 ha	766	503.15	0.66	0.32	1.22	0.23	0.91
Year 2		0.5 - 1 ha	173	299.11	1.73	1.33	2.45	0.37	1.11
Date 2		1 - 10 ha	149	1024.79	6.88	2.67	24.21	5.39	21.54
		10 - 20 ha	6	184.88	30.81	24.91	39.25	5.55	14.34
		> 20 ha	5	509.06	101.81	60.49	124.10	25.30	63.60
<b>Total</b>			<b>1760</b>	<b>2667.95</b>	<b>1.52</b>	<b>0.16</b>	<b>124.10</b>		<b>123.93</b>
Year 1	2008	< 0.1 ha	453	100.65	0.22	0.13	0.22	0.00	0.09
Date 1	1214	0.1 - 0.5 ha	526	339.02	0.64	0.32	1.11	0.23	0.80
Year 2		0.5 - 1 ha	145	259.38	1.79	1.33	2.45	0.37	1.11
Date 2		1 - 10 ha	135	958.50	7.10	2.59	24.24	5.59	21.65
		10 - 20 ha	4	130.99	32.75	25.13	43.14	7.54	18.01
		> 20 ha	5	485.71	97.14	57.38	118.54	25.33	61.16
<b>Total</b>			<b>1268</b>	<b>2274.25</b>	<b>1.79</b>	<b>0.13</b>	<b>118.54</b>		<b>118.41</b>
Year 1	2009	< 0.1 ha	404	89.69	0.22	0.13	0.22	0.01	0.09
Date 1	0115	0.1 - 0.5 ha	470	310.34	0.66	0.32	1.22	0.24	0.91
Year 2		0.5 - 1 ha	126	219.40	1.74	1.33	2.45	0.39	1.11
Date 2		1 - 10 ha	126	930.01	7.38	2.56	24.46	5.63	21.91
		10 - 20 ha	3	103.75	34.58	28.24	41.59	6.70	13.34
		> 20 ha	5	479.93	95.99	58.05	121.21	24.10	63.16
<b>Total</b>			<b>1134</b>	<b>2133.12</b>	<b>1.88</b>	<b>0.13</b>	<b>121.21</b>		<b>121.08</b>
Year 1	2009	< 0.1 ha	477	105.71	0.22	0.04	0.22	0.01	0.18
Date 1	0131	0.1 - 0.5 ha	604	404.52	0.67	0.32	1.22	0.23	0.91
Year 2		0.5 - 1 ha	146	259.31	1.78	1.33	2.45	0.39	1.11
Date 2		1 - 10 ha	136	996.91	7.33	2.55	23.91	5.68	21.36
		10 - 20 ha	4	125.79	31.45	26.69	35.36	4.53	8.67
		> 20 ha	5	492.60	98.52	59.82	124.54	24.55	64.72
<b>Total</b>			<b>1372</b>	<b>2384.84</b>	<b>1.74</b>	<b>0.04</b>	<b>124.54</b>		<b>124.50</b>

Palo Pinto County			Summary statistics for Water Features in Acres						
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	644	143.07	0.22	0.13	0.22	0.00	0.09
Date 1	0421	0.1 - 0.5 ha	738	487.97	0.66	0.44	1.22	0.23	0.78
Year 2		0.5 - 1 ha	187	322.18	1.72	1.33	2.45	0.36	1.11
Date 2		1 - 10 ha	132	966.03	7.32	2.67	24.02	5.45	21.35
		10 - 20 ha	4	135.88	33.97	30.47	38.03	3.21	7.56
		> 20 ha	5	498.28	99.66	64.83	119.87	23.04	55.04
<b>Total</b>			<b>1710</b>	<b>2553.40</b>	<b>1.49</b>	<b>0.13</b>	<b>119.87</b>		<b>119.74</b>
Year 1	2009	< 0.1 ha	881	195.55	0.22	0.02	0.22	0.01	0.20
Date 1	0608	0.1 - 0.5 ha	936	610.06	0.65	0.32	1.23	0.23	0.91
Year 2		0.5 - 1 ha	217	368.18	1.70	1.33	2.45	0.36	1.11
Date 2		1 - 10 ha	145	1005.59	6.94	2.56	23.80	5.16	21.24
		10 - 20 ha	6	177.25	29.54	25.35	35.81	4.66	10.45
		> 20 ha	5	501.28	100.26	68.05	130.55	23.91	62.49
<b>Total</b>			<b>2190</b>	<b>2857.90</b>	<b>1.30</b>	<b>0.02</b>	<b>130.55</b>		<b>130.53</b>
Year 1	2009	< 0.1 ha	881	195.80	0.22	0.15	0.22	0.00	0.07
Date 1	0710	0.1 - 0.5 ha	968	631.32	0.65	0.32	1.23	0.23	0.90
Year 2		0.5 - 1 ha	225	380.13	1.69	1.33	2.45	0.35	1.11
Date 2		1 - 10 ha	151	1038.91	6.88	2.56	24.69	5.07	22.13
		10 - 20 ha	6	202.40	33.73	25.80	42.70	7.35	16.90
		> 20 ha	5	492.05	98.41	67.61	129.66	23.49	62.05
<b>Total</b>			<b>2236</b>	<b>2940.61</b>	<b>1.32</b>	<b>0.15</b>	<b>129.66</b>		<b>129.51</b>
Year 1	2009	< 0.1 ha	867	192.32	0.22	0.04	0.24	0.01	0.21
Date 1	0928	0.1 - 0.5 ha	1147	752.35	0.66	0.37	1.23	0.24	0.86
Year 2	2009	0.5 - 1 ha	275	473.21	1.72	1.25	2.45	0.35	1.20
Date 2	1023	1 - 10 ha	212	1338.18	6.31	2.49	24.69	4.74	22.20
		10 - 20 ha	7	245.98	35.14	25.86	47.81	8.59	21.96
		> 20 ha	5	472.94	94.59	50.23	124.92	29.61	74.70
<b>Total</b>			<b>2513</b>	<b>3474.98</b>	<b>1.38</b>	<b>0.04</b>	<b>124.92</b>		<b>124.89</b>
Year 1	2010	< 0.1 ha	1169	259.42	0.22	0.02	0.24	0.01	0.22
Date 1	0323	0.1 - 0.5 ha	1978	1377.36	0.70	0.26	1.22	0.24	0.96
Year 2		0.5 - 1 ha	641	1133.93	1.77	1.33	2.45	0.38	1.11
Date 2		1 - 10 ha	467	2699.45	5.78	2.56	24.69	4.12	22.13
		10 - 20 ha	15	496.03	33.07	25.35	41.81	5.39	16.46
		> 20 ha	7	706.66	100.95	50.15	154.79	41.96	104.64
<b>Total</b>			<b>4277</b>	<b>6672.85</b>	<b>1.56</b>	<b>0.02</b>	<b>154.79</b>		<b>154.77</b>
Year 1	2010	< 0.1 ha	1146	254.07	0.22	0.01	0.22	0.01	0.22
Date 1	0408	0.1 - 0.5 ha	1473	996.50	0.68	0.32	1.22	0.23	0.91
Year 2		0.5 - 1 ha	400	682.37	1.71	1.33	2.45	0.34	1.11
Date 2		1 - 10 ha	290	1750.27	6.04	2.56	24.46	4.53	21.91
		10 - 20 ha	12	412.84	34.40	26.91	47.37	7.13	20.46
		> 20 ha	5	559.77	111.95	70.94	134.99	26.02	64.05
<b>Total</b>			<b>3326</b>	<b>4655.81</b>	<b>1.40</b>	<b>0.01</b>	<b>134.99</b>		<b>134.99</b>

Palo Pinto County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>	2010	< 0.1 ha	1100	244.02	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	1001	0.1 - 0.5 ha	1414	939.04	0.66	0.28	1.22	0.23	0.94
<b>Year 2</b>		0.5 - 1 ha	311	540.14	1.74	1.33	2.45	0.38	1.11
<b>Date 2</b>		1 - 10 ha	217	1372.77	6.33	2.67	24.46	4.76	21.79
		10 - 20 ha	7	250.60	35.80	26.02	48.93	7.49	22.91
		> 20 ha	5	538.64	107.73	66.27	134.55	26.33	68.28
<b>Total</b>			<b>3054</b>	<b>3885.21</b>	<b>1.27</b>	<b>0.00</b>	<b>134.55</b>		<b>134.55</b>
<b>Year 1</b>	2010	< 0.1 ha	668	148.29	0.22	0.06	0.22	0.01	0.16
<b>Date 1</b>	1118	0.1 - 0.5 ha	786	516.52	0.66	0.36	1.22	0.23	0.87
<b>Year 2</b>	2010	0.5 - 1 ha	188	334.03	1.78	1.25	2.45	0.38	1.20
<b>Date 2</b>	1127	1 - 10 ha	164	1026.75	6.26	2.56	22.24	4.30	19.68
		10 - 20 ha	6	189.37	31.56	26.46	38.92	4.40	12.45
		> 20 ha	6	563.96	93.99	58.46	126.54	29.47	68.09
<b>Total</b>			<b>1818</b>	<b>2778.91</b>	<b>1.53</b>	<b>0.06</b>	<b>126.54</b>		<b>126.48</b>
<b>Year 1</b>	2011	< 0.1 ha	523	116.09	0.22	0.13	0.22	0.01	0.09
<b>Date 1</b>	0105	0.1 - 0.5 ha	644	430.10	0.67	0.32	1.22	0.24	0.91
<b>Year 2</b>		0.5 - 1 ha	145	253.62	1.75	1.33	2.45	0.36	1.11
<b>Date 2</b>		1 - 10 ha	142	971.91	6.84	2.56	22.24	4.97	19.68
		10 - 20 ha	6	189.53	31.59	25.13	37.14	5.39	12.01
		> 20 ha	5	483.71	96.74	56.27	116.09	24.43	59.82
<b>Total</b>			<b>1465</b>	<b>2444.95</b>	<b>1.67</b>	<b>0.13</b>	<b>116.09</b>		<b>115.96</b>



Parker County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	948	210.30	0.22	0.05	0.22	0.01	0.17
Date 1	0303	0.1 - 0.5 ha	1499	1006.54	0.67	0.25	1.22	0.26	0.97
Year 2	1997	0.5 - 1 ha	403	694.79	1.72	1.33	2.47	0.35	1.13
Date 2	0328	1 - 10 ha	304	1825.09	6.00	2.47	23.24	4.29	20.77
		10 - 20 ha	11	419.87	38.17	29.47	48.69	5.86	19.22
		> 20 ha	8	919.70	114.96	50.11	399.64	117.63	349.53
<b>Baseline Wet</b>		<b>Total</b>	<b>3173</b>	<b>5076.29</b>	<b>1.60</b>	<b>0.05</b>	<b>399.64</b>		<b>399.59</b>
Year 1	1999	< 0.1 ha	430	95.26	0.22	0.06	0.22	0.01	0.16
Date 1	0221	0.1 - 0.5 ha	680	434.71	0.64	0.25	1.22	0.25	0.97
Year 2	1999	0.5 - 1 ha	153	269.43	1.76	1.26	2.47	0.36	1.21
Date 2	0214	1 - 10 ha	146	966.56	6.62	2.47	24.02	4.56	21.55
		10 - 20 ha	9	293.22	32.58	26.13	48.89	7.77	22.76
		> 20 ha	5	530.84	106.17	57.69	167.69	45.00	109.99
<b>Baseline Dry</b>		<b>Total</b>	<b>1423</b>	<b>2590.01</b>	<b>1.82</b>	<b>0.06</b>	<b>167.69</b>		<b>167.63</b>
Year 1	2003	< 0.1 ha	617	136.67	0.22	0.03	0.22	0.01	0.20
Date 1	1014	0.1 - 0.5 ha	881	542.72	0.62	0.25	1.22	0.26	0.97
Year 2	2003	0.5 - 1 ha	157	270.73	1.72	1.33	2.46	0.34	1.13
Date 2	1023	1 - 10 ha	154	958.22	6.22	2.48	23.44	4.25	20.96
		10 - 20 ha	8	244.36	30.54	24.85	44.37	7.04	19.51
		> 20 ha	5	336.31	67.26	54.27	98.08	17.83	43.80
		<b>Total</b>	<b>1822</b>	<b>2489.01</b>	<b>1.37</b>	<b>0.03</b>	<b>98.08</b>		<b>98.05</b>
Year 1	2004	< 0.1 ha	904	200.46	0.22	0.05	0.22	0.01	0.17
Date 1	1016	0.1 - 0.5 ha	1215	757.14	0.62	0.25	1.22	0.25	0.97
Year 2	2004	0.5 - 1 ha	249	429.35	1.72	1.30	2.45	0.32	1.14
Date 2	0907	1 - 10 ha	207	1291.94	6.24	2.48	24.63	4.16	22.15
		10 - 20 ha	12	392.63	32.72	25.45	44.92	5.80	19.47
		> 20 ha	3	262.40	87.47	60.80	127.43	35.25	66.63
		<b>Total</b>	<b>2590</b>	<b>3333.92</b>	<b>1.29</b>	<b>0.05</b>	<b>127.43</b>		<b>127.38</b>
Year 1	2005	< 0.1 ha	719	159.08	0.22	0.00	0.22	0.01	0.22
Date 1	0221	0.1 - 0.5 ha	1367	914.14	0.67	0.25	1.24	0.26	0.98
Year 2	2005	0.5 - 1 ha	354	603.66	1.71	1.33	2.45	0.34	1.12
Date 2	0214	1 - 10 ha	262	1510.05	5.76	2.49	22.86	3.85	20.37
		10 - 20 ha	13	441.89	33.99	27.04	45.37	5.83	18.33
		> 20 ha	5	811.66	162.33	66.94	325.92	103.24	258.98
		<b>Total</b>	<b>2720</b>	<b>4440.47</b>	<b>1.63</b>	<b>0.00</b>	<b>325.92</b>		<b>325.92</b>
Year 1	2006	< 0.1 ha	394	87.24	0.22	0.05	0.24	0.01	0.19
Date 1	1123	0.1 - 0.5 ha	617	402.90	0.65	0.25	1.22	0.26	0.97
Year 2	2006	0.5 - 1 ha	177	309.66	1.75	1.33	2.45	0.34	1.11
Date 2	1116	1 - 10 ha	142	927.12	6.53	2.55	21.82	4.68	19.26
		10 - 20 ha	5	153.64	30.73	25.13	38.18	4.82	13.05
		> 20 ha	3	271.74	90.58	59.16	131.85	37.34	72.70
		<b>Total</b>	<b>1338</b>	<b>2152.29</b>	<b>1.61</b>	<b>0.05</b>	<b>131.85</b>		<b>131.80</b>

Parker County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1019	225.73	0.22	0.03	0.22	0.01	0.20
Date 1	0331	0.1 - 0.5 ha	1571	1051.81	0.67	0.25	1.22	0.24	0.97
Year 2	2007	0.5 - 1 ha	435	740.78	1.70	1.26	2.46	0.34	1.20
Date 2	0308	1 - 10 ha	331	1802.03	5.44	2.48	22.36	3.70	19.88
		10 - 20 ha	15	495.85	33.06	25.10	44.20	6.27	19.09
		> 20 ha	5	654.60	130.92	66.50	248.50	78.80	182.00
<b>Total</b>			<b>3376</b>	<b>4970.80</b>	<b>1.47</b>	<b>0.03</b>	<b>248.50</b>		<b>248.47</b>
Year 1		< 0.1 ha	549	121.16	0.22	0.01	0.22	0.02	0.21
Date 1		0.1 - 0.5 ha	817	545.03	0.67	0.28	1.22	0.23	0.95
Year 2	2008	0.5 - 1 ha	247	432.97	1.75	1.33	2.45	0.37	1.11
Date 2	0207	1 - 10 ha	205	1328.80	6.48	2.56	24.69	4.52	22.13
		10 - 20 ha	11	368.51	33.50	26.02	48.48	6.38	22.46
		> 20 ha	3	908.52	302.84	75.28	708.58	352.25	633.30
<b>Total</b>			<b>1832</b>	<b>3705.00</b>	<b>2.02</b>	<b>0.01</b>	<b>708.58</b>		<b>708.57</b>
Year 1	2008	< 0.1 ha	1062	235.26	0.22	0.01	0.22	0.01	0.22
Date 1	0418	0.1 - 0.5 ha	1823	1180.75	0.65	0.25	1.22	0.27	0.97
Year 2	2008	0.5 - 1 ha	499	860.25	1.72	1.31	2.46	0.33	1.15
Date 2	0411	1 - 10 ha	381	2115.12	5.55	2.49	23.80	4.08	21.31
		10 - 20 ha	13	473.60	36.43	25.24	48.03	6.87	22.79
		> 20 ha	5	2672.69	534.54	54.39	2292.45	983.16	2238.06
<b>Total</b>			<b>3783</b>	<b>7537.67</b>	<b>1.99</b>	<b>0.01</b>	<b>2292.45</b>		<b>2292.44</b>
Year 1		< 0.1 ha	564	125.32	0.22	0.14	0.22	0.00	0.08
Date 1		0.1 - 0.5 ha	636	415.77	0.65	0.33	1.22	0.23	0.89
Year 2	2008	0.5 - 1 ha	192	333.12	1.74	1.28	2.45	0.33	1.16
Date 2	1004	1 - 10 ha	164	1079.10	6.58	2.56	24.46	4.67	21.91
		10 - 20 ha	7	213.28	30.47	26.02	40.59	4.94	14.57
		> 20 ha	4	895.92	223.98	71.83	667.85	295.94	596.02
<b>Total</b>			<b>1567</b>	<b>3062.51</b>	<b>1.95</b>	<b>0.14</b>	<b>667.85</b>		<b>667.71</b>
Year 1		< 0.1 ha	511	113.46	0.22	0.06	0.22	0.01	0.16
Date 1		0.1 - 0.5 ha	606	397.53	0.66	0.31	1.22	0.23	0.91
Year 2	2008	0.5 - 1 ha	201	351.50	1.75	1.33	2.45	0.36	1.11
Date 2	1020	1 - 10 ha	166	1126.67	6.79	2.56	24.46	4.93	21.91
		10 - 20 ha	7	215.28	30.75	25.80	41.14	5.32	15.35
		> 20 ha	3	2208.49	736.16	70.61	2046.92	1135.20	1976.31
<b>Total</b>			<b>1494</b>	<b>4412.92</b>	<b>2.95</b>	<b>0.06</b>	<b>2046.92</b>		<b>2046.86</b>
Year 1		< 0.1 ha	313	69.35	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	416	284.00	0.68	0.44	1.11	0.24	0.67
Year 2	2008	0.5 - 1 ha	151	260.87	1.73	1.33	2.45	0.34	1.11
Date 2	1121	1 - 10 ha	136	890.26	6.55	2.67	23.13	4.50	20.46
		10 - 20 ha	7	205.16	29.31	26.02	37.25	4.17	11.23
		> 20 ha	5	946.62	189.32	64.38	373.62	128.90	309.24
<b>Total</b>			<b>1028</b>	<b>2656.25</b>	<b>2.58</b>	<b>0.03</b>	<b>373.62</b>		<b>373.59</b>

Parker County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	325	72.10	0.22	0.06	0.22	0.01	0.16
Date 1		0.1 - 0.5 ha	404	269.63	0.67	0.31	1.11	0.23	0.80
Year 2	2008	0.5 - 1 ha	164	278.88	1.70	1.33	2.45	0.34	1.11
Date 2	1207	1 - 10 ha	132	919.72	6.97	2.67	24.35	4.95	21.68
		10 - 20 ha	6	184.03	30.67	26.46	39.92	5.11	13.45
		> 20 ha	4	753.22	188.30	57.34	534.97	231.79	477.63
<b>Total</b>			<b>1035</b>	<b>2477.58</b>	<b>2.39</b>	<b>0.06</b>	<b>534.97</b>		<b>534.91</b>
Year 1		< 0.1 ha	327	72.43	0.22	0.06	0.22	0.01	0.16
Date 1		0.1 - 0.5 ha	479	323.56	0.68	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	153	267.76	1.75	1.33	2.45	0.35	1.11
Date 2	0108	1 - 10 ha	146	1013.58	6.94	2.56	23.57	5.03	21.02
		10 - 20 ha	5	162.46	32.49	29.13	41.59	5.19	12.45
		> 20 ha	3	780.13	260.04	65.50	613.36	306.51	547.87
<b>Total</b>			<b>1113</b>	<b>2619.92</b>	<b>2.35</b>	<b>0.06</b>	<b>613.36</b>		<b>613.30</b>
Year 1		< 0.1 ha	473	104.77	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	644	433.75	0.67	0.35	1.11	0.24	0.76
Year 2	2009	0.5 - 1 ha	245	422.63	1.73	1.33	2.45	0.36	1.11
Date 2	0329	1 - 10 ha	182	1197.78	6.58	2.56	24.57	4.76	22.02
		10 - 20 ha	7	222.51	31.79	25.58	46.26	7.12	20.68
		> 20 ha	3	841.76	280.59	76.28	663.63	331.97	587.34
<b>Total</b>			<b>1554</b>	<b>3223.21</b>	<b>2.07</b>	<b>0.03</b>	<b>663.63</b>		<b>663.60</b>
Year 1		< 0.1 ha	558	123.90	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	695	465.88	0.67	0.27	1.22	0.23	0.96
Year 2	2009	0.5 - 1 ha	242	431.75	1.78	1.33	2.45	0.38	1.11
Date 2	0414	1 - 10 ha	200	1315.43	6.58	2.67	24.24	4.74	21.57
		10 - 20 ha	6	203.27	33.88	29.80	45.59	6.02	15.79
		> 20 ha	3	856.97	285.66	75.06	673.75	336.50	598.69
<b>Total</b>			<b>1704</b>	<b>3397.21</b>	<b>1.99</b>	<b>0.03</b>	<b>673.75</b>		<b>673.71</b>
Year 1		< 0.1 ha	729	161.69	0.22	0.06	0.22	0.01	0.16
Date 1		0.1 - 0.5 ha	870	576.75	0.66	0.27	1.22	0.23	0.96
Year 2	2009	0.5 - 1 ha	247	427.11	1.73	1.33	2.45	0.34	1.11
Date 2	0703	1 - 10 ha	190	1282.37	6.75	2.56	24.13	4.81	21.57
		10 - 20 ha	7	219.50	31.36	25.24	45.48	6.57	20.24
		> 20 ha	3	747.33	249.11	77.06	567.00	275.61	489.94
<b>Total</b>			<b>2046</b>	<b>3414.76</b>	<b>1.67</b>	<b>0.06</b>	<b>567.00</b>		<b>566.93</b>
Year 1		< 0.1 ha	981	217.34	0.22	0.04	0.24	0.01	0.20
Date 1		0.1 - 0.5 ha	1146	770.33	0.67	0.28	1.22	0.24	0.95
Year 2	2009	0.5 - 1 ha	335	589.46	1.76	1.33	2.45	0.37	1.11
Date 2	0804	1 - 10 ha	209	1307.62	6.26	2.56	24.46	4.76	21.91
		10 - 20 ha	5	176.70	35.34	30.91	44.59	5.66	13.68
		> 20 ha	5	1042.48	208.50	70.28	570.00	210.76	499.72
<b>Total</b>			<b>2681</b>	<b>4103.93</b>	<b>1.53</b>	<b>0.04</b>	<b>570.00</b>		<b>569.95</b>

Parker County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	1001	221.92	0.22	0.03	0.24	0.01	0.21
Date 1	0928	0.1 - 0.5 ha	1408	926.87	0.66	0.37	1.23	0.24	0.86
Year 2	2009	0.5 - 1 ha	433	754.45	1.74	1.24	2.47	0.36	1.23
Date 2	1023	1 - 10 ha	320	1964.50	6.14	2.48	24.20	4.53	21.72
		10 - 20 ha	10	339.42	33.94	25.34	47.87	7.81	22.53
		> 20 ha	4	720.19	180.05	75.61	453.13	182.32	377.52
<b>Total</b>			<b>3176</b>	<b>4927.34</b>	<b>1.55</b>	<b>0.03</b>	<b>453.13</b>		<b>453.10</b>
Year 1		< 0.1 ha	778	172.79	0.22	0.07	0.22	0.01	0.15
Date 1		0.1 - 0.5 ha	999	658.65	0.66	0.27	1.22	0.23	0.95
Year 2	2009	0.5 - 1 ha	314	543.68	1.73	1.33	2.45	0.38	1.11
Date 2	1124	1 - 10 ha	219	1416.98	6.47	2.56	23.13	4.51	20.57
		10 - 20 ha	10	340.93	34.09	25.80	46.70	7.30	20.91
		> 20 ha	2	270.10	135.05	96.07	174.02	55.12	77.95
<b>Total</b>			<b>2322</b>	<b>3403.12</b>	<b>1.47</b>	<b>0.07</b>	<b>174.02</b>		<b>173.95</b>
Year 1		< 0.1 ha	603	133.60	0.22	0.04	0.22	0.01	0.18
Date 1		0.1 - 0.5 ha	753	499.36	0.66	0.28	1.22	0.24	0.95
Year 2	2009	0.5 - 1 ha	273	466.53	1.71	1.28	2.45	0.35	1.16
Date 2	1210	1 - 10 ha	201	1357.36	6.75	2.56	24.69	4.84	22.13
		10 - 20 ha	8	282.89	35.36	28.24	45.92	6.13	17.68
		> 20 ha	3	644.92	214.97	72.72	472.56	223.48	399.84
<b>Total</b>			<b>1841</b>	<b>3384.66</b>	<b>1.84</b>	<b>0.04</b>	<b>472.56</b>		<b>472.52</b>
Year 1		< 0.1 ha	416	92.02	0.22	0.05	0.22	0.01	0.18
Date 1		0.1 - 0.5 ha	529	361.53	0.68	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	173	291.20	1.68	1.33	2.45	0.35	1.11
Date 2	0111	1 - 10 ha	166	1081.30	6.51	2.56	24.02	4.57	21.46
		10 - 20 ha	7	226.84	32.41	27.58	38.47	4.39	10.90
		> 20 ha	3	1489.04	496.35	66.05	1326.70	719.26	1260.65
<b>Total</b>			<b>1294</b>	<b>3541.94</b>	<b>2.74</b>	<b>0.05</b>	<b>1326.70</b>		<b>1326.65</b>
Year 1		< 0.1 ha	1056	234.04	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	1320	894.29	0.68	0.41	1.22	0.24	0.81
Year 2	2010	0.5 - 1 ha	395	692.94	1.75	1.33	2.45	0.37	1.11
Date 2	0620	1 - 10 ha	298	1869.21	6.27	2.56	24.46	4.60	21.91
		10 - 20 ha	13	448.83	34.53	26.91	44.92	5.75	18.01
		> 20 ha	5	968.20	193.64	49.59	662.18	263.54	612.59
<b>Total</b>			<b>3087</b>	<b>5107.51</b>	<b>1.65</b>	<b>0.03</b>	<b>662.18</b>		<b>662.15</b>
Year 1		< 0.1 ha	1120	248.51	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	1331	890.57	0.67	0.27	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	400	697.13	1.74	1.33	2.45	0.39	1.11
Date 2	0807	1 - 10 ha	268	1827.15	6.82	2.56	24.46	5.03	21.91
		10 - 20 ha	11	396.97	36.09	25.35	48.04	7.20	22.68
		> 20 ha	3	645.61	215.20	79.39	442.23	197.87	362.84
<b>Total</b>			<b>3133</b>	<b>4705.94</b>	<b>1.50</b>	<b>0.03</b>	<b>442.23</b>		<b>442.20</b>

Parker County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	941	208.71	0.22	0.03	0.22	0.01	0.19
<b>Date 1</b>		0.1 - 0.5 ha	1116	741.22	0.66	0.37	1.22	0.24	0.86
<b>Year 2</b>	2010	0.5 - 1 ha	350	611.25	1.75	1.33	2.45	0.38	1.11
<b>Date 2</b>	1010	1 - 10 ha	223	1525.22	6.84	2.67	23.80	4.61	21.13
		10 - 20 ha	11	372.18	33.83	27.35	44.70	5.10	17.35
		> 20 ha	3	749.36	249.79	72.61	559.55	269.18	486.93
<b>Total</b>			<b>2644</b>	<b>4207.95</b>	<b>1.59</b>	<b>0.03</b>	<b>559.55</b>		<b>559.51</b>
<b>Year 1</b>	2010	< 0.1 ha	927	205.23	0.22	0.01	0.22	0.01	0.22
<b>Date 1</b>	1118	0.1 - 0.5 ha	1282	849.23	0.66	0.29	1.22	0.23	0.94
<b>Year 2</b>	2010	0.5 - 1 ha	370	648.79	1.75	1.33	2.45	0.37	1.11
<b>Date 2</b>	1127	1 - 10 ha	251	1695.17	6.75	2.56	24.46	4.80	21.91
		10 - 20 ha	12	403.64	33.64	26.02	46.26	5.46	20.24
		> 20 ha	2	259.45	129.72	70.69	188.76	83.49	118.07
<b>Total</b>			<b>2844</b>	<b>4061.52</b>	<b>1.43</b>	<b>0.01</b>	<b>188.76</b>		<b>188.75</b>
<b>Year 1</b>		< 0.1 ha	430	95.27	0.22	0.05	0.22	0.01	0.18
<b>Date 1</b>		0.1 - 0.5 ha	573	377.12	0.66	0.33	1.22	0.23	0.89
<b>Year 2</b>	2010	0.5 - 1 ha	178	303.76	1.71	1.33	2.45	0.35	1.11
<b>Date 2</b>	1213	1 - 10 ha	158	1130.62	7.16	2.56	22.35	4.65	19.79
		10 - 20 ha	8	244.75	30.59	25.13	43.03	5.87	17.90
		> 20 ha	3	602.91	200.97	63.16	437.56	205.82	374.40
<b>Total</b>			<b>1350</b>	<b>2754.43</b>	<b>2.04</b>	<b>0.05</b>	<b>437.56</b>		<b>437.51</b>

Somervell County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	163	36.03	0.22	0.01	0.22	0.02	0.21
Date 1		0.1 - 0.5 ha	134	89.18	0.67	0.44	1.11	0.24	0.67
Year 2	1997	0.5 - 1 ha	42	73.19	1.74	1.33	2.45	0.38	1.11
Date 2	0328	1 - 10 ha	35	190.22	5.43	2.67	15.57	3.31	12.90
		10 - 20 ha	3	98.63	32.88	27.35	35.69	4.78	8.34
		> 20 ha	1	57.82	57.82	57.82	57.82	0.00	0.00
<b>Baseline Wet</b>		<b>Total</b>	<b>378</b>	<b>545.08</b>	<b>1.44</b>	<b>0.01</b>	<b>57.82</b>		<b>57.81</b>
Year 1		< 0.1 ha	87	19.24	0.22	0.11	0.22	0.01	0.11
Date 1		0.1 - 0.5 ha	90	57.16	0.64	0.41	1.11	0.23	0.70
Year 2	1999	0.5 - 1 ha	21	36.51	1.74	1.33	2.45	0.41	1.11
Date 2	0214	1 - 10 ha	27	186.23	6.90	2.67	21.13	5.81	18.46
		10 - 20 ha	1	34.58	34.58	34.58	34.58	0.00	0.00
<b>Baseline Dry</b>		<b>Total</b>	<b>226</b>	<b>333.72</b>	<b>1.48</b>	<b>0.11</b>	<b>34.58</b>		<b>34.47</b>
Year 1		< 0.1 ha	120	26.48	0.22	0.01	0.22	0.02	0.21
Date 1		0.1 - 0.5 ha	114	73.14	0.64	0.44	1.22	0.24	0.78
Year 2	2003	0.5 - 1 ha	30	47.93	1.60	1.33	2.45	0.36	1.11
Date 2	1023	1 - 10 ha	30	194.65	6.49	2.67	20.68	4.19	18.01
		10 - 20 ha	2	81.51	40.75	33.03	48.48	10.93	15.46
		<b>Total</b>	<b>296</b>	<b>423.69</b>	<b>1.43</b>	<b>0.01</b>	<b>48.48</b>		<b>48.47</b>
Year 1		< 0.1 ha	244	54.14	0.22	0.09	0.22	0.01	0.13
Date 1		0.1 - 0.5 ha	189	125.34	0.66	0.44	1.15	0.22	0.70
Year 2	2004	0.5 - 1 ha	44	73.13	1.66	1.33	2.22	0.34	0.89
Date 2	0907	1 - 10 ha	42	251.56	5.99	2.67	18.01	3.75	15.35
		10 - 20 ha	3	107.42	35.81	24.91	47.15	11.13	22.24
		> 20 ha	2	133.99	67.00	57.71	76.28	13.13	18.57
		<b>Total</b>	<b>524</b>	<b>745.57</b>	<b>1.42</b>	<b>0.09</b>	<b>76.28</b>		<b>76.19</b>
Year 1		< 0.1 ha	153	33.53	0.22	0.00	0.24	0.02	0.24
Date 1		0.1 - 0.5 ha	181	122.43	0.68	0.44	1.11	0.24	0.67
Year 2	2005	0.5 - 1 ha	50	87.28	1.75	1.27	2.45	0.33	1.18
Date 2	0214	1 - 10 ha	38	254.95	6.71	2.67	19.79	4.14	17.12
		10 - 20 ha	4	139.78	34.94	28.02	46.93	8.33	18.90
		<b>Total</b>	<b>426</b>	<b>637.96</b>	<b>1.50</b>	<b>0.00</b>	<b>46.93</b>		<b>46.92</b>
Year 1		< 0.1 ha	70	15.57	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	78	51.23	0.66	0.41	1.11	0.22	0.70
Year 2	2006	0.5 - 1 ha	19	34.53	1.82	1.33	2.45	0.44	1.11
Date 2	1116	1 - 10 ha	35	188.84	5.40	2.67	14.90	3.34	12.23
		10 - 20 ha	2	66.13	33.07	32.47	33.67	0.85	1.20
		<b>Total</b>	<b>204</b>	<b>356.30</b>	<b>1.75</b>	<b>0.22</b>	<b>33.67</b>		<b>33.44</b>



Somervell County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	107	23.49	0.22	0.06	0.22	0.02	0.16
Date 1		0.1 - 0.5 ha	131	89.67	0.68	0.44	1.11	0.21	0.67
Year 2	2007	0.5 - 1 ha	34	59.38	1.75	1.33	2.45	0.35	1.11
Date 2	0308	1 - 10 ha	45	295.23	6.56	2.61	18.13	4.05	15.51
		10 - 20 ha	2	89.74	44.87	42.92	46.81	2.75	3.89
<b>Total</b>			<b>319</b>	<b>557.51</b>	<b>1.75</b>	<b>0.06</b>	<b>46.81</b>		<b>46.75</b>
Year 1		< 0.1 ha	90	19.54	0.22	0.01	0.22	0.03	0.21
Date 1		0.1 - 0.5 ha	126	83.08	0.66	0.44	1.11	0.22	0.67
Year 2	2008	0.5 - 1 ha	44	75.59	1.72	1.33	2.45	0.33	1.11
Date 2	0207	1 - 10 ha	47	318.48	6.78	2.67	19.78	4.04	17.11
		10 - 20 ha	4	138.98	34.75	24.90	48.48	11.51	23.59
		> 20 ha	1	62.05	62.05	62.05	62.05	0.00	0.00
<b>Total</b>			<b>312</b>	<b>697.72</b>	<b>2.24</b>	<b>0.01</b>	<b>62.05</b>		<b>62.03</b>
Year 1		< 0.1 ha	177	39.03	0.22	0.06	0.22	0.02	0.16
Date 1		0.1 - 0.5 ha	201	134.45	0.67	0.44	1.23	0.24	0.79
Year 2	2008	0.5 - 1 ha	46	77.25	1.68	1.33	2.45	0.34	1.11
Date 2	0411	1 - 10 ha	49	318.39	6.50	2.56	24.24	4.30	21.68
		10 - 20 ha	3	111.64	37.21	28.24	48.70	10.46	20.46
		> 20 ha	1	123.65	123.65	123.65	123.65	0.00	0.00
<b>Total</b>			<b>477</b>	<b>804.41</b>	<b>1.69</b>	<b>0.06</b>	<b>123.65</b>		<b>123.59</b>
Year 1		< 0.1 ha	92	19.97	0.22	0.01	0.22	0.03	0.21
Date 1		0.1 - 0.5 ha	107	71.54	0.67	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	30	48.37	1.61	1.33	2.22	0.28	0.89
Date 2	1004	1 - 10 ha	45	244.10	5.42	2.56	17.35	3.16	14.79
		10 - 20 ha	1	32.02	32.02	32.02	32.02	0.00	0.00
		> 20 ha	3	536.08	178.69	63.72	338.93	143.08	275.21
<b>Total</b>			<b>278</b>	<b>952.08</b>	<b>3.42</b>	<b>0.01</b>	<b>338.93</b>		<b>338.92</b>
Year 1		< 0.1 ha	98	21.32	0.22	0.01	0.23	0.03	0.22
Date 1		0.1 - 0.5 ha	105	67.28	0.64	0.41	1.11	0.22	0.70
Year 2	2008	0.5 - 1 ha	40	67.69	1.69	1.33	2.45	0.37	1.11
Date 2	1020	1 - 10 ha	43	278.09	6.47	2.59	21.79	4.39	19.21
		10 - 20 ha	2	84.70	42.35	37.22	47.48	7.25	10.26
		> 20 ha	1	119.43	119.43	119.43	119.43	0.00	0.00
<b>Total</b>			<b>289</b>	<b>638.52</b>	<b>2.21</b>	<b>0.01</b>	<b>119.43</b>		<b>119.41</b>
Year 1		< 0.1 ha	62	13.49	0.22	0.04	0.22	0.03	0.18
Date 1		0.1 - 0.5 ha	62	40.11	0.65	0.44	1.11	0.22	0.67
Year 2	2008	0.5 - 1 ha	23	38.40	1.67	1.33	2.45	0.33	1.11
Date 2	1121	1 - 10 ha	37	205.82	5.56	2.67	19.90	3.63	17.24
		10 - 20 ha	2	72.95	36.47	33.14	39.81	4.72	6.67
		> 20 ha	1	115.20	115.20	115.20	115.20	0.00	0.00
<b>Total</b>			<b>187</b>	<b>485.97</b>	<b>2.60</b>	<b>0.04</b>	<b>115.20</b>		<b>115.16</b>

Somervell County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	48	10.36	0.22	0.03	0.22	0.03	0.20
Date 1		0.1 - 0.5 ha	57	36.55	0.64	0.44	1.11	0.20	0.67
Year 2	2008	0.5 - 1 ha	25	45.59	1.82	1.33	2.45	0.44	1.11
Date 2	1207	1 - 10 ha	35	223.53	6.39	2.53	18.79	3.88	16.26
		10 - 20 ha	2	72.83	36.42	33.69	39.14	3.85	5.45
		> 20 ha	1	112.98	112.98	112.98	112.98	0.00	0.00
<b>Total</b>			<b>168</b>	<b>501.85</b>	<b>2.99</b>	<b>0.03</b>	<b>112.98</b>		<b>112.95</b>
Year 1		< 0.1 ha	57	12.21	0.21	0.00	0.22	0.04	0.22
Date 1		0.1 - 0.5 ha	63	40.30	0.64	0.26	1.19	0.24	0.93
Year 2	2009	0.5 - 1 ha	26	45.81	1.76	1.33	2.45	0.38	1.11
Date 2	0108	1 - 10 ha	37	256.19	6.92	2.67	19.68	4.40	17.01
		10 - 20 ha	2	75.28	37.64	32.47	42.81	7.31	10.34
		> 20 ha	1	119.87	119.87	119.87	119.87	0.00	0.00
<b>Total</b>			<b>186</b>	<b>549.67</b>	<b>2.96</b>	<b>0.00</b>	<b>119.87</b>		<b>119.87</b>
Year 1		< 0.1 ha	84	17.78	0.21	0.00	0.22	0.04	0.22
Date 1		0.1 - 0.5 ha	112	76.81	0.69	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	34	55.04	1.62	1.33	2.44	0.31	1.10
Date 2	0329	1 - 10 ha	49	340.26	6.94	2.67	23.35	4.61	20.68
		10 - 20 ha	1	36.03	36.03	36.03	36.03	0.00	0.00
		> 20 ha	2	199.71	99.86	51.82	147.89	67.93	96.07
<b>Total</b>			<b>282</b>	<b>725.63</b>	<b>2.57</b>	<b>0.00</b>	<b>147.89</b>		<b>147.89</b>
Year 1		< 0.1 ha	96	20.92	0.22	0.01	0.22	0.03	0.21
Date 1		0.1 - 0.5 ha	123	83.26	0.68	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	31	52.82	1.70	1.33	2.45	0.39	1.11
Date 2	0414	1 - 10 ha	50	354.45	7.09	2.67	23.35	4.63	20.68
		10 - 20 ha	1	37.81	37.81	37.81	37.81	0.00	0.00
		> 20 ha	2	204.60	102.30	52.04	152.56	71.08	100.52
<b>Total</b>			<b>303</b>	<b>753.86</b>	<b>2.49</b>	<b>0.01</b>	<b>152.56</b>		<b>152.55</b>
Year 1		< 0.1 ha	110	23.73	0.22	0.01	0.22	0.03	0.21
Date 1		0.1 - 0.5 ha	112	74.47	0.66	0.26	1.11	0.23	0.85
Year 2	2009	0.5 - 1 ha	34	59.35	1.75	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	45	276.13	6.14	2.67	17.35	3.46	14.69
		10 - 20 ha	1	24.91	24.91	24.91	24.91	0.00	0.00
		> 20 ha	3	251.86	83.95	53.82	135.33	44.71	81.51
<b>Total</b>			<b>305</b>	<b>710.46</b>	<b>2.33</b>	<b>0.01</b>	<b>135.33</b>		<b>135.31</b>
Year 1		< 0.1 ha	298	65.07	0.22	0.00	0.22	0.03	0.22
Date 1		0.1 - 0.5 ha	219	141.71	0.65	0.44	1.11	0.22	0.67
Year 2	2009	0.5 - 1 ha	48	83.40	1.74	1.33	2.45	0.38	1.11
Date 2	0804	1 - 10 ha	59	387.28	6.56	2.53	20.91	4.10	18.38
		10 - 20 ha	1	32.69	32.69	32.69	32.69	0.00	0.00
		> 20 ha	2	195.04	97.52	52.49	142.56	63.69	90.07
<b>Total</b>			<b>627</b>	<b>905.19</b>	<b>1.44</b>	<b>0.00</b>	<b>142.56</b>		<b>142.55</b>

Somervell County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	166	36.54	0.22	0.01	0.22	0.02	0.21
Date 1		0.1 - 0.5 ha	181	121.18	0.67	0.44	1.11	0.24	0.67
Year 2	2009	0.5 - 1 ha	58	97.46	1.68	1.33	2.45	0.34	1.11
Date 2	1023	1 - 10 ha	47	318.77	6.78	2.67	22.46	4.76	19.79
		10 - 20 ha	2	77.28	38.64	33.80	43.48	6.84	9.67
		> 20 ha	1	155.23	155.23	155.23	155.23	0.00	0.00
<b>Total</b>			<b>455</b>	<b>806.46</b>	<b>1.77</b>	<b>0.01</b>	<b>155.23</b>		<b>155.22</b>
Year 1		< 0.1 ha	188	40.85	0.22	0.00	0.22	0.03	0.22
Date 1		0.1 - 0.5 ha	187	122.50	0.66	0.44	1.22	0.23	0.78
Year 2	2009	0.5 - 1 ha	52	89.13	1.71	1.31	2.45	0.32	1.13
Date 2	1124	1 - 10 ha	49	333.72	6.81	2.67	20.57	4.39	17.90
		10 - 20 ha	1	26.91	26.91	26.91	26.91	0.00	0.00
		> 20 ha	2	208.27	104.14	57.60	150.67	65.81	93.07
<b>Total</b>			<b>479</b>	<b>821.38</b>	<b>1.71</b>	<b>0.00</b>	<b>150.67</b>		<b>150.67</b>
Year 1		< 0.1 ha	156	34.08	0.22	0.01	0.22	0.03	0.21
Date 1		0.1 - 0.5 ha	150	99.25	0.66	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	50	84.53	1.69	1.33	2.45	0.36	1.11
Date 2	1210	1 - 10 ha	46	292.62	6.36	2.56	17.79	3.64	15.23
		10 - 20 ha	3	96.85	32.28	26.91	38.47	5.83	11.56
		> 20 ha	1	418.99	418.99	418.99	418.99	0.00	0.00
<b>Total</b>			<b>406</b>	<b>1026.32</b>	<b>2.53</b>	<b>0.01</b>	<b>418.99</b>		<b>418.98</b>
Year 1		< 0.1 ha	22	4.80	0.22	0.13	0.22	0.02	0.09
Date 1		0.1 - 0.5 ha	29	19.39	0.67	0.44	1.22	0.26	0.78
Year 2	2010	0.5 - 1 ha	16	27.66	1.73	1.33	2.22	0.26	0.89
Date 2	0111	1 - 10 ha	19	147.23	7.75	2.89	19.35	4.54	16.46
		10 - 20 ha	2	74.28	37.14	30.47	43.81	9.44	13.34
		> 20 ha	1	134.10	134.10	134.10	134.10	0.00	0.00
<b>Total</b>			<b>89</b>	<b>407.47</b>	<b>4.58</b>	<b>0.13</b>	<b>134.10</b>		<b>133.97</b>
Year 1		< 0.1 ha	379	83.44	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	252	169.05	0.67	0.26	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	63	109.72	1.74	1.25	2.45	0.34	1.20
Date 2	0620	1 - 10 ha	60	415.71	6.93	2.67	19.13	4.43	16.46
		10 - 20 ha	3	93.96	31.32	28.80	36.03	4.08	7.23
		> 20 ha	2	225.73	112.87	50.48	175.25	88.22	124.76
<b>Total</b>			<b>759</b>	<b>1097.60</b>	<b>1.45</b>	<b>0.00</b>	<b>175.25</b>		<b>175.25</b>
Year 1		< 0.1 ha	368	81.35	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	242	159.26	0.66	0.26	1.22	0.23	0.96
Year 2	2010	0.5 - 1 ha	59	102.83	1.74	1.33	2.45	0.36	1.11
Date 2	0807	1 - 10 ha	57	375.90	6.59	2.67	20.91	4.12	18.24
		10 - 20 ha	3	115.26	38.42	27.13	48.26	10.64	21.13
		> 20 ha	2	250.86	125.43	73.84	177.03	72.97	103.19
<b>Total</b>			<b>731</b>	<b>1085.46</b>	<b>1.48</b>	<b>0.00</b>	<b>177.03</b>		<b>177.03</b>

Somervell County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	175	38.11	0.22	0.00	0.22	0.03	0.22
<b>Date 1</b>		0.1 - 0.5 ha	184	125.88	0.68	0.26	1.22	0.24	0.96
<b>Year 2</b>	2010	0.5 - 1 ha	64	112.50	1.76	1.33	2.45	0.36	1.11
<b>Date 2</b>	1010	1 - 10 ha	59	416.06	7.05	2.67	23.57	4.53	20.91
		10 - 20 ha	4	170.55	42.64	37.14	48.04	4.45	10.90
		> 20 ha	1	168.35	168.35	168.35	168.35	0.00	0.00
<b>Total</b>			<b>487</b>	<b>1031.44</b>	<b>2.12</b>	<b>0.00</b>	<b>168.35</b>		<b>168.35</b>
<b>Year 1</b>		< 0.1 ha	137	29.97	0.22	0.00	0.22	0.03	0.22
<b>Date 1</b>		0.1 - 0.5 ha	216	147.25	0.68	0.44	1.22	0.23	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	55	91.97	1.67	1.33	2.45	0.34	1.11
<b>Date 2</b>	1127	1 - 10 ha	58	395.13	6.81	2.67	24.46	4.57	21.79
		10 - 20 ha	3	110.42	36.81	25.24	46.70	10.83	21.46
		> 20 ha	1	163.68	163.68	163.68	163.68	0.00	0.00
<b>Total</b>			<b>470</b>	<b>938.42</b>	<b>2.00</b>	<b>0.00</b>	<b>163.68</b>		<b>163.68</b>
<b>Year 1</b>		< 0.1 ha	78	16.72	0.21	0.00	0.22	0.04	0.22
<b>Date 1</b>		0.1 - 0.5 ha	78	53.64	0.69	0.40	1.11	0.26	0.71
<b>Year 2</b>	2010	0.5 - 1 ha	26	46.68	1.80	1.33	2.45	0.39	1.11
<b>Date 2</b>	1213	1 - 10 ha	42	274.83	6.54	2.56	22.80	4.66	20.24
		10 - 20 ha	1	40.48	40.48	40.48	40.48	0.00	0.00
		> 20 ha	1	114.87	114.87	114.87	114.87	0.00	0.00
<b>Total</b>			<b>226</b>	<b>547.22</b>	<b>2.42</b>	<b>0.00</b>	<b>114.87</b>		<b>114.87</b>



Tarrant County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	213	46.85	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	267	176.58	0.66	0.44	1.22	0.22	0.78
Year 2	1997	0.5 - 1 ha	113	195.35	1.73	1.33	2.45	0.35	1.11
Date 2	0328	1 - 10 ha	135	982.82	7.28	2.47	23.57	5.39	21.10
		10 - 20 ha	11	380.49	34.59	26.44	43.59	5.62	17.15
		> 20 ha	3	610.03	203.34	111.86	322.47	107.99	210.61
<b>Baseline Wet</b>		<b>Total</b>	<b>742</b>	<b>2392.12</b>	<b>3.22</b>	<b>0.00</b>	<b>322.47</b>		<b>322.47</b>
Year 1		< 0.1 ha	168	37.36	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	241	165.39	0.69	0.44	1.22	0.25	0.78
Year 2	1999	0.5 - 1 ha	87	155.23	1.78	1.33	2.45	0.38	1.11
Date 2	0214	1 - 10 ha	106	767.86	7.24	2.67	22.46	5.05	19.79
		10 - 20 ha	8	248.25	31.03	25.80	39.59	4.55	13.79
		> 20 ha	2	304.90	152.45	113.64	191.26	54.88	77.62
<b>Baseline Dry</b>		<b>Total</b>	<b>612</b>	<b>1678.99</b>	<b>2.74</b>	<b>0.22</b>	<b>191.26</b>		<b>191.04</b>
Year 1		< 0.1 ha	189	41.84	0.22	0.03	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	273	185.68	0.68	0.42	1.22	0.24	0.80
Year 2	2003	0.5 - 1 ha	132	231.18	1.75	1.33	2.45	0.36	1.11
Date 2	1023	1 - 10 ha	144	1032.43	7.17	2.67	24.46	4.95	21.79
		10 - 20 ha	6	182.92	30.49	25.58	39.36	4.98	13.79
		> 20 ha	3	446.57	148.86	83.84	257.76	94.90	173.91
		<b>Total</b>	<b>747</b>	<b>2120.61</b>	<b>2.84</b>	<b>0.03</b>	<b>257.76</b>		<b>257.73</b>
Year 1		< 0.1 ha	231	51.15	0.22	0.05	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	333	232.16	0.70	0.42	1.22	0.24	0.80
Year 2	2004	0.5 - 1 ha	157	269.65	1.72	1.33	2.45	0.34	1.11
Date 2	0907	1 - 10 ha	165	1153.42	6.99	2.67	23.13	4.66	20.46
		10 - 20 ha	10	323.81	32.38	26.02	47.15	6.83	21.13
		> 20 ha	3	615.59	205.20	82.51	271.99	106.39	189.48
		<b>Total</b>	<b>899</b>	<b>2645.77</b>	<b>2.94</b>	<b>0.05</b>	<b>271.99</b>		<b>271.94</b>
Year 1		< 0.1 ha	244	53.78	0.22	0.03	0.22	0.02	0.20
Date 1		0.1 - 0.5 ha	395	265.96	0.67	0.44	1.22	0.24	0.78
Year 2	2005	0.5 - 1 ha	215	370.37	1.72	1.33	2.45	0.35	1.11
Date 2	0214	1 - 10 ha	201	1382.19	6.88	2.67	24.46	4.75	21.79
		10 - 20 ha	10	347.05	34.70	25.13	41.37	5.12	16.23
		> 20 ha	4	802.40	200.60	50.48	392.30	160.62	341.82
		<b>Total</b>	<b>1069</b>	<b>3221.75</b>	<b>3.01</b>	<b>0.03</b>	<b>392.30</b>		<b>392.28</b>
Year 1		< 0.1 ha	146	32.47	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	253	175.11	0.69	0.42	1.22	0.24	0.80
Year 2	2006	0.5 - 1 ha	148	263.54	1.78	1.33	2.45	0.36	1.11
Date 2	1116	1 - 10 ha	136	877.62	6.45	2.56	23.57	4.36	21.02
		10 - 20 ha	5	150.56	30.11	26.69	32.47	2.34	5.78
		> 20 ha	3	507.51	169.17	56.93	354.05	161.33	297.12
		<b>Total</b>	<b>691</b>	<b>2006.81</b>	<b>2.90</b>	<b>0.22</b>	<b>354.05</b>		<b>353.83</b>

Tarrant County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	237	52.37	0.22	0.05	0.22	0.02	0.17
Date 1		0.1 - 0.5 ha	402	282.86	0.70	0.44	1.22	0.24	0.78
Year 2	2007	0.5 - 1 ha	238	421.60	1.77	1.33	2.45	0.37	1.11
Date 2	0308	1 - 10 ha	234	1427.45	6.10	2.56	23.13	4.23	20.57
		10 - 20 ha	15	482.04	32.14	24.91	46.15	6.12	21.24
		> 20 ha	5	876.68	175.34	56.04	453.46	161.30	397.42
<b>Total</b>			<b>1131</b>	<b>3543.00</b>	<b>3.13</b>	<b>0.05</b>	<b>453.46</b>		<b>453.41</b>
Year 1		< 0.1 ha	211	46.48	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	417	292.33	0.70	0.44	1.22	0.25	0.78
Year 2	2008	0.5 - 1 ha	214	379.18	1.77	1.33	2.45	0.37	1.11
Date 2	0207	1 - 10 ha	202	1304.67	6.46	2.67	21.57	4.52	18.90
		10 - 20 ha	14	452.13	32.29	25.58	48.70	6.70	23.13
		> 20 ha	5	1519.62	303.92	56.71	1124.87	462.78	1068.16
<b>Total</b>			<b>1063</b>	<b>3994.42</b>	<b>3.76</b>	<b>0.00</b>	<b>1124.87</b>		<b>1124.87</b>
Year 1		< 0.1 ha	259	57.18	0.22	0.00	0.22	0.02	0.22
Date 1		0.1 - 0.5 ha	400	287.15	0.72	0.28	1.11	0.24	0.83
Year 2	2008	0.5 - 1 ha	219	387.72	1.77	1.33	2.45	0.35	1.11
Date 2	0411	1 - 10 ha	244	1491.34	6.11	2.56	24.46	4.16	21.91
		10 - 20 ha	18	621.18	34.51	25.35	47.48	6.92	22.13
		> 20 ha	4	1723.78	430.95	79.39	1262.98	558.37	1183.59
<b>Total</b>			<b>1144</b>	<b>4568.35</b>	<b>3.99</b>	<b>0.00</b>	<b>1262.98</b>		<b>1262.98</b>
Year 1		< 0.1 ha	205	45.59	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	364	259.98	0.71	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	207	361.95	1.75	1.33	2.45	0.38	1.11
Date 2	1004	1 - 10 ha	202	1278.38	6.33	2.67	21.13	4.30	18.46
		10 - 20 ha	9	294.01	32.67	25.13	42.92	5.55	17.79
		> 20 ha	5	720.00	144.00	56.04	351.83	122.01	295.79
<b>Total</b>			<b>992</b>	<b>2959.91</b>	<b>2.98</b>	<b>0.22</b>	<b>351.83</b>		<b>351.61</b>
Year 1		< 0.1 ha	199	44.26	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	345	241.19	0.70	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	204	360.52	1.77	1.33	2.45	0.39	1.11
Date 2	1020	1 - 10 ha	198	1289.00	6.51	2.67	22.68	4.75	20.02
		10 - 20 ha	9	303.79	33.75	26.24	40.25	5.24	14.01
		> 20 ha	4	634.16	158.54	51.26	400.53	162.85	349.27
<b>Total</b>			<b>959</b>	<b>2872.91</b>	<b>3.00</b>	<b>0.22</b>	<b>400.53</b>		<b>400.31</b>
Year 1		< 0.1 ha	175	38.92	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	284	204.84	0.72	0.34	1.22	0.26	0.89
Year 2	2008	0.5 - 1 ha	153	274.33	1.79	1.33	2.45	0.40	1.11
Date 2	1121	1 - 10 ha	151	915.89	6.07	2.67	22.91	4.15	20.24
		10 - 20 ha	10	311.13	31.11	24.91	41.14	5.21	16.23
		> 20 ha	3	500.61	166.87	68.28	338.04	148.81	269.76
<b>Total</b>			<b>776</b>	<b>2245.72</b>	<b>2.89</b>	<b>0.22</b>	<b>338.04</b>		<b>337.82</b>

Tarrant County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	164	36.47	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	306	205.29	0.67	0.44	1.22	0.23	0.78
Year 2	2008	0.5 - 1 ha	162	288.23	1.78	1.33	2.45	0.36	1.11
Date 2	1207	1 - 10 ha	147	961.09	6.54	2.53	24.24	4.67	21.71
		10 - 20 ha	7	228.96	32.71	28.24	44.48	5.76	16.23
		> 20 ha	3	496.61	165.54	60.27	341.60	153.45	281.33
<b>Total</b>			<b>789</b>	<b>2216.64</b>	<b>2.81</b>	<b>0.22</b>	<b>341.60</b>		<b>341.38</b>
Year 1		< 0.1 ha	191	42.31	0.22	0.06	0.22	0.01	0.17
Date 1		0.1 - 0.5 ha	362	253.66	0.70	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	155	277.10	1.79	1.33	2.45	0.38	1.11
Date 2	0108	1 - 10 ha	160	1019.29	6.37	2.67	24.46	4.59	21.79
		10 - 20 ha	7	224.17	32.02	26.91	43.59	5.42	16.68
		> 20 ha	3	518.40	172.80	72.72	345.38	150.09	272.66
<b>Total</b>			<b>878</b>	<b>2334.94</b>	<b>2.66</b>	<b>0.06</b>	<b>345.38</b>		<b>345.32</b>
Year 1		< 0.1 ha	248	54.83	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	359	254.06	0.71	0.44	1.22	0.25	0.78
Year 2	2009	0.5 - 1 ha	208	374.28	1.80	1.33	2.45	0.37	1.11
Date 2	0329	1 - 10 ha	242	1493.93	6.17	2.56	22.68	4.25	20.13
		10 - 20 ha	11	378.96	34.45	25.13	48.93	8.35	23.80
		> 20 ha	4	797.06	199.27	59.82	452.35	174.04	392.53
<b>Total</b>			<b>1072</b>	<b>3353.12</b>	<b>3.13</b>	<b>0.02</b>	<b>452.35</b>		<b>452.33</b>
Year 1		< 0.1 ha	215	47.62	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	399	285.44	0.72	0.44	1.22	0.26	0.78
Year 2	2009	0.5 - 1 ha	225	400.27	1.78	1.33	2.45	0.37	1.11
Date 2	0414	1 - 10 ha	260	1686.54	6.49	2.56	24.02	4.59	21.46
		10 - 20 ha	13	456.91	35.15	26.69	48.48	8.05	21.79
		> 20 ha	5	1651.21	330.24	51.82	1325.03	556.76	1273.21
<b>Total</b>			<b>1117</b>	<b>4528.00</b>	<b>4.05</b>	<b>0.02</b>	<b>1325.03</b>		<b>1325.00</b>
Year 1		< 0.1 ha	267	58.82	0.22	0.02	0.22	0.02	0.20
Date 1		0.1 - 0.5 ha	412	305.02	0.74	0.44	1.22	0.25	0.78
Year 2	2009	0.5 - 1 ha	254	449.00	1.77	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	277	1780.89	6.43	2.56	24.46	4.57	21.91
		10 - 20 ha	11	354.27	32.21	25.13	45.37	6.33	20.24
		> 20 ha	5	1613.60	322.72	55.38	833.88	321.49	778.50
<b>Total</b>			<b>1226</b>	<b>4561.60</b>	<b>3.72</b>	<b>0.02</b>	<b>833.88</b>		<b>833.86</b>
Year 1		< 0.1 ha	285	62.81	0.22	0.01	0.22	0.02	0.21
Date 1		0.1 - 0.5 ha	409	292.45	0.72	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	245	442.45	1.81	1.33	2.45	0.37	1.11
Date 2	0804	1 - 10 ha	275	1715.47	6.24	2.47	23.69	4.33	21.21
		10 - 20 ha	13	468.70	36.05	24.91	48.48	7.28	23.57
		> 20 ha	5	1454.57	290.91	70.05	607.14	228.05	537.08
<b>Total</b>			<b>1232</b>	<b>4436.46</b>	<b>3.60</b>	<b>0.01</b>	<b>607.14</b>		<b>607.13</b>

Tarrant County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	230	51.14	0.22	0.21	0.22	0.00	0.01
Date 1		0.1 - 0.5 ha	389	275.08	0.71	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	207	366.05	1.77	1.33	2.45	0.39	1.11
Date 2	1023	1 - 10 ha	225	1460.69	6.49	2.67	24.46	4.65	21.79
		10 - 20 ha	10	338.26	33.83	26.24	43.14	7.43	16.90
		> 20 ha	4	1977.82	494.46	54.04	1364.39	614.57	1310.35
<b>Total</b>			<b>1065</b>	<b>4469.05</b>	<b>4.20</b>	<b>0.21</b>	<b>1364.39</b>		<b>1364.18</b>
Year 1		< 0.1 ha	230	50.97	0.22	0.03	0.24	0.01	0.22
Date 1		0.1 - 0.5 ha	409	291.34	0.71	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	212	377.11	1.78	1.33	2.45	0.37	1.11
Date 2	1124	1 - 10 ha	241	1542.10	6.40	2.56	24.24	4.72	21.68
		10 - 20 ha	11	387.40	35.22	25.13	43.48	6.26	18.35
		> 20 ha	6	899.14	149.86	49.82	463.47	158.81	413.65
<b>Total</b>			<b>1109</b>	<b>3548.06</b>	<b>3.20</b>	<b>0.03</b>	<b>463.47</b>		<b>463.45</b>
Year 1		< 0.1 ha	206	45.81	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	360	254.45	0.71	0.44	1.22	0.24	0.78
Year 2	2009	0.5 - 1 ha	205	360.95	1.76	1.33	2.45	0.38	1.11
Date 2	1210	1 - 10 ha	210	1328.38	6.33	2.56	24.69	4.64	22.13
		10 - 20 ha	11	374.85	34.08	25.35	47.15	7.49	21.79
		> 20 ha	7	917.27	131.04	50.26	419.21	131.90	368.95
<b>Total</b>			<b>999</b>	<b>3281.71</b>	<b>3.28</b>	<b>0.22</b>	<b>419.21</b>		<b>418.99</b>
Year 1		< 0.1 ha	150	33.36	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	322	224.08	0.70	0.44	1.22	0.23	0.78
Year 2	2010	0.5 - 1 ha	167	293.17	1.76	1.33	2.45	0.38	1.11
Date 2	0111	1 - 10 ha	172	1135.85	6.60	2.67	24.24	4.77	21.57
		10 - 20 ha	9	319.91	35.55	26.02	49.15	7.79	23.13
		> 20 ha	4	686.87	171.72	62.83	368.51	140.54	305.68
<b>Total</b>			<b>824</b>	<b>2693.24</b>	<b>3.27</b>	<b>0.22</b>	<b>368.51</b>		<b>368.29</b>
Year 1		< 0.1 ha	244	54.26	0.22	0.22	0.22	0.00	0.00
Date 1		0.1 - 0.5 ha	385	272.77	0.71	0.44	1.22	0.24	0.78
Year 2	2010	0.5 - 1 ha	200	350.71	1.75	1.33	2.45	0.35	1.11
Date 2	0604	1 - 10 ha	223	1482.73	6.65	2.56	24.24	4.48	21.68
		10 - 20 ha	12	428.67	35.72	26.02	49.37	8.42	23.35
		> 20 ha	5	810.96	162.19	50.26	421.44	157.09	371.18
<b>Total</b>			<b>1069</b>	<b>3400.10</b>	<b>3.18</b>	<b>0.22</b>	<b>421.44</b>		<b>421.22</b>
Year 1		< 0.1 ha	276	60.95	0.22	0.02	0.22	0.02	0.20
Date 1		0.1 - 0.5 ha	440	324.58	0.74	0.44	1.22	0.25	0.79
Year 2	2010	0.5 - 1 ha	248	430.47	1.74	1.33	2.45	0.34	1.11
Date 2	0620	1 - 10 ha	275	1811.79	6.59	2.67	24.69	4.50	22.02
		10 - 20 ha	8	278.22	34.78	26.46	44.26	6.43	17.79
		> 20 ha	8	1922.70	240.34	49.82	1160.23	375.96	1110.42
<b>Total</b>			<b>1255</b>	<b>4828.71</b>	<b>3.85</b>	<b>0.02</b>	<b>1160.23</b>		<b>1160.21</b>

Tarrant County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	281	62.09	0.22	0.02	0.22	0.02	0.20
<b>Date 1</b>		0.1 - 0.5 ha	416	290.67	0.70	0.44	1.22	0.24	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	250	453.27	1.81	1.33	2.45	0.38	1.11
<b>Date 2</b>	0807	1 - 10 ha	280	1863.52	6.66	2.49	22.57	4.65	20.09
		10 - 20 ha	17	575.34	33.84	24.91	48.70	7.60	23.80
		> 20 ha	5	928.05	185.61	54.26	503.06	182.98	448.79
<b>Total</b>			<b>1249</b>	<b>4172.94</b>	<b>3.34</b>	<b>0.02</b>	<b>503.06</b>		<b>503.04</b>
<b>Year 1</b>		< 0.1 ha	237	52.71	0.22	0.22	0.22	0.00	0.00
<b>Date 1</b>		0.1 - 0.5 ha	448	323.91	0.72	0.33	1.22	0.25	0.90
<b>Year 2</b>	2010	0.5 - 1 ha	226	396.10	1.75	1.33	2.45	0.38	1.11
<b>Date 2</b>	1010	1 - 10 ha	240	1499.62	6.25	2.56	24.24	4.51	21.68
		10 - 20 ha	14	483.38	34.53	25.13	48.37	8.08	23.24
		> 20 ha	7	892.92	127.56	50.93	404.98	124.59	354.05
<b>Total</b>			<b>1172</b>	<b>3648.63</b>	<b>3.11</b>	<b>0.22</b>	<b>404.98</b>		<b>404.76</b>
<b>Year 1</b>		< 0.1 ha	201	44.37	0.22	0.06	0.22	0.02	0.17
<b>Date 1</b>		0.1 - 0.5 ha	325	230.42	0.71	0.44	1.22	0.24	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	155	268.54	1.73	1.33	2.45	0.37	1.11
<b>Date 2</b>	1213	1 - 10 ha	164	1108.79	6.76	2.67	23.80	5.17	21.13
		10 - 20 ha	10	347.46	34.75	26.69	43.37	5.71	16.68
		> 20 ha	4	578.00	144.50	74.95	328.48	123.04	253.53
<b>Total</b>			<b>859</b>	<b>2577.58</b>	<b>3.00</b>	<b>0.06</b>	<b>328.48</b>		<b>328.42</b>



Wise County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	1997	< 0.1 ha	1065	236.25	0.22	0.00	0.22	0.01	0.22
Date 1	0303	0.1 - 0.5 ha	1695	1151.78	0.68	0.25	1.22	0.24	0.97
Year 2	1997	0.5 - 1 ha	479	816.12	1.70	1.26	2.45	0.34	1.19
Date 2	0328	1 - 10 ha	303	2153.65	7.11	2.47	24.69	5.32	22.21
		10 - 20 ha	29	992.27	34.22	25.35	47.37	6.77	22.02
		> 20 ha	8	851.58	106.45	51.76	271.03	73.75	219.27
<b>Baseline Wet</b>		<b>Total</b>	<b>3579</b>	<b>6201.65</b>	<b>1.73</b>	<b>0.00</b>	<b>271.03</b>		<b>271.03</b>
Year 1	1999	< 0.1 ha	399	88.74	0.22	0.22	0.22	0.00	0.00
Date 1	0221	0.1 - 0.5 ha	509	322.05	0.63	0.25	1.22	0.26	0.97
Year 2	1999	0.5 - 1 ha	89	154.19	1.73	1.33	2.45	0.36	1.11
Date 2	0214	1 - 10 ha	141	1109.53	7.87	2.50	23.57	5.25	21.08
		10 - 20 ha	8	242.12	30.27	25.80	46.39	6.72	20.59
		> 20 ha	6	427.41	71.23	52.11	94.44	16.50	42.33
<b>Baseline Dry</b>		<b>Total</b>	<b>1152</b>	<b>2344.03</b>	<b>2.03</b>	<b>0.22</b>	<b>94.44</b>		<b>94.22</b>
Year 1	2003	< 0.1 ha	730	162.16	0.22	0.02	0.24	0.01	0.23
Date 1	1014	0.1 - 0.5 ha	1022	651.64	0.64	0.25	1.22	0.25	0.97
Year 2	2003	0.5 - 1 ha	215	365.24	1.70	1.24	2.46	0.33	1.22
Date 2	1023	1 - 10 ha	193	1440.00	7.46	2.49	24.69	5.10	22.20
		10 - 20 ha	16	511.64	31.98	25.13	49.04	7.61	23.90
		> 20 ha	5	416.40	83.28	66.12	131.43	27.17	65.32
		<b>Total</b>	<b>2181</b>	<b>3547.08</b>	<b>1.63</b>	<b>0.02</b>	<b>131.43</b>		<b>131.41</b>
Year 1	2004	< 0.1 ha	1212	269.20	0.22	0.04	0.22	0.01	0.18
Date 1	1016	0.1 - 0.5 ha	1562	1009.26	0.65	0.25	1.22	0.25	0.97
Year 2	2004	0.5 - 1 ha	363	614.36	1.69	1.33	2.45	0.33	1.12
Date 2	0907	1 - 10 ha	249	1941.10	7.80	2.49	24.24	5.56	21.76
		10 - 20 ha	22	685.47	31.16	24.80	44.03	5.45	19.23
		> 20 ha	6	788.60	131.43	78.51	241.19	65.92	162.68
		<b>Total</b>	<b>3414</b>	<b>5307.99</b>	<b>1.55</b>	<b>0.04</b>	<b>241.19</b>		<b>241.14</b>
Year 1	2005	< 0.1 ha	1110	246.30	0.22	0.00	0.24	0.01	0.24
Date 1	0221	0.1 - 0.5 ha	1814	1197.13	0.66	0.25	1.22	0.25	0.97
Year 2	2005	0.5 - 1 ha	403	686.30	1.70	1.33	2.47	0.33	1.14
Date 2	0214	1 - 10 ha	283	2034.15	7.19	2.48	24.69	4.92	22.21
		10 - 20 ha	26	853.33	32.82	26.08	46.72	5.92	20.65
		> 20 ha	8	920.64	115.08	53.82	184.08	44.61	130.26
		<b>Total</b>	<b>3644</b>	<b>5937.85</b>	<b>1.63</b>	<b>0.00</b>	<b>184.08</b>		<b>184.08</b>
Year 1	2006	< 0.1 ha	297	65.86	0.22	0.04	0.22	0.01	0.18
Date 1	1123	0.1 - 0.5 ha	397	254.25	0.64	0.25	1.19	0.26	0.93
Year 2	2006	0.5 - 1 ha	76	133.62	1.76	1.33	2.45	0.35	1.11
Date 2	1116	1 - 10 ha	122	931.70	7.64	2.54	24.51	4.98	21.97
		10 - 20 ha	5	144.60	28.92	25.03	35.66	4.21	10.63
		> 20 ha	3	218.08	72.69	59.17	93.21	18.06	34.03

Wise County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2007	< 0.1 ha	1253	278.10	0.22	0.00	0.22	0.01	0.22
Date 1	0331	0.1 - 0.5 ha	1615	1076.17	0.67	0.25	1.23	0.24	0.97
Year 2	2007	0.5 - 1 ha	434	740.49	1.71	1.26	2.47	0.33	1.22
Date 2	0308	1 - 10 ha	267	1855.41	6.95	2.48	23.57	5.17	21.09
		10 - 20 ha	15	539.35	35.96	26.06	49.18	6.61	23.11
		> 20 ha	6	974.22	162.37	58.27	425.27	149.14	367.00
<b>Total</b>			<b>3590</b>	<b>5463.73</b>	<b>1.52</b>	<b>0.00</b>	<b>425.27</b>		<b>425.27</b>
Year 1		< 0.1 ha	668	147.82	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	840	553.54	0.66	0.44	1.22	0.23	0.78
Year 2	2008	0.5 - 1 ha	213	363.37	1.71	1.33	2.45	0.34	1.11
Date 2	0207	1 - 10 ha	200	1636.86	8.18	2.56	24.24	5.30	21.68
		10 - 20 ha	11	346.49	31.50	24.91	48.59	7.59	23.69
		> 20 ha	6	414.43	69.07	55.82	80.51	10.09	24.69
<b>Total</b>			<b>1938</b>	<b>3462.51</b>	<b>1.79</b>	<b>0.02</b>	<b>80.51</b>		<b>80.48</b>
Year 1	2008	< 0.1 ha	1541	342.00	0.22	0.00	0.22	0.01	0.22
Date 1	0418	0.1 - 0.5 ha	2479	1638.61	0.66	0.25	1.22	0.26	0.97
Year 2	2008	0.5 - 1 ha	697	1212.74	1.74	1.29	2.47	0.34	1.18
Date 2	0411	1 - 10 ha	468	3094.82	6.61	2.50	24.69	4.99	22.19
		10 - 20 ha	38	1244.17	32.74	24.94	46.70	6.07	21.77
		> 20 ha	14	1557.23	111.23	50.21	373.62	82.30	323.42
<b>Total</b>			<b>5237</b>	<b>9089.57</b>	<b>1.74</b>	<b>0.00</b>	<b>373.62</b>		<b>373.62</b>
Year 1		< 0.1 ha	746	165.42	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	777	511.53	0.66	0.36	1.22	0.23	0.87
Year 2	2008	0.5 - 1 ha	207	364.24	1.76	1.33	2.45	0.35	1.11
Date 2	1004	1 - 10 ha	197	1562.62	7.93	2.56	24.46	5.54	21.91
		10 - 20 ha	12	366.95	30.58	24.91	34.69	2.62	9.79
		> 20 ha	6	383.19	63.86	49.82	89.18	13.49	39.36
<b>Total</b>			<b>1945</b>	<b>3353.95</b>	<b>1.72</b>	<b>0.02</b>	<b>89.18</b>		<b>89.16</b>
Year 1		< 0.1 ha	677	150.23	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	675	444.59	0.66	0.36	1.22	0.23	0.87
Year 2	2008	0.5 - 1 ha	203	358.32	1.77	1.33	2.45	0.35	1.11
Date 2	1020	1 - 10 ha	189	1507.27	7.97	2.67	24.69	5.45	22.02
		10 - 20 ha	13	429.44	33.03	27.69	45.70	5.60	18.01
		> 20 ha	4	280.00	70.00	50.93	90.74	17.17	39.81
<b>Total</b>			<b>1761</b>	<b>3169.84</b>	<b>1.80</b>	<b>0.08</b>	<b>90.74</b>		<b>90.66</b>
Year 1		< 0.1 ha	315	69.81	0.22	0.04	0.22	0.01	0.18
Date 1		0.1 - 0.5 ha	422	288.56	0.68	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	135	236.06	1.75	1.30	2.45	0.38	1.14
Date 2	1121	1 - 10 ha	158	1244.80	7.88	2.67	24.46	5.42	21.79
		10 - 20 ha	10	303.12	30.31	25.80	41.14	4.62	15.35
		> 20 ha	3	223.40	74.47	59.49	86.51	13.75	27.02
<b>Total</b>			<b>1043</b>	<b>2365.75</b>	<b>2.27</b>	<b>0.04</b>	<b>86.51</b>		<b>86.47</b>

Wise County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1		< 0.1 ha	345	76.47	0.22	0.08	0.22	0.01	0.14
Date 1		0.1 - 0.5 ha	393	265.65	0.68	0.44	1.22	0.24	0.78
Year 2	2008	0.5 - 1 ha	119	206.62	1.74	1.33	2.45	0.37	1.11
Date 2	1207	1 - 10 ha	157	1227.00	7.82	2.56	24.57	5.37	22.02
		10 - 20 ha	7	221.51	31.64	26.46	38.47	4.75	12.01
		> 20 ha	4	295.56	73.89	57.16	82.73	11.67	25.58
<b>Total</b>			<b>1025</b>	<b>2292.82</b>	<b>2.24</b>	<b>0.08</b>	<b>82.73</b>		<b>82.65</b>
Year 1		< 0.1 ha	352	78.17	0.22	0.11	0.22	0.01	0.11
Date 1		0.1 - 0.5 ha	421	277.99	0.66	0.36	1.22	0.23	0.87
Year 2	2009	0.5 - 1 ha	130	223.33	1.72	1.27	2.45	0.34	1.18
Date 2	0108	1 - 10 ha	161	1249.74	7.76	2.56	24.13	5.36	21.57
		10 - 20 ha	6	189.93	31.65	27.35	47.81	8.01	20.46
		> 20 ha	4	267.54	66.89	56.71	78.51	10.15	21.79
<b>Total</b>			<b>1074</b>	<b>2286.70</b>	<b>2.13</b>	<b>0.11</b>	<b>78.51</b>		<b>78.39</b>
Year 1		< 0.1 ha	410	90.83	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	626	432.04	0.69	0.33	1.22	0.25	0.89
Year 2	2009	0.5 - 1 ha	236	414.62	1.76	1.33	2.45	0.38	1.11
Date 2	0329	1 - 10 ha	216	1535.54	7.11	2.67	24.46	4.95	21.79
		10 - 20 ha	12	414.32	34.53	27.35	48.04	6.36	20.68
		> 20 ha	3	245.08	81.69	62.49	96.96	17.57	34.47
<b>Total</b>			<b>1503</b>	<b>3132.44</b>	<b>2.08</b>	<b>0.02</b>	<b>96.96</b>		<b>96.94</b>
Year 1		< 0.1 ha	599	132.63	0.22	0.00	0.22	0.01	0.22
Date 1		0.1 - 0.5 ha	718	480.22	0.67	0.33	1.22	0.23	0.89
Year 2	2009	0.5 - 1 ha	237	417.10	1.76	1.33	2.45	0.38	1.11
Date 2	0414	1 - 10 ha	220	1606.44	7.30	2.67	24.24	5.07	21.57
		10 - 20 ha	11	362.06	32.91	24.91	45.59	7.12	20.68
		> 20 ha	5	455.69	91.14	60.05	157.46	39.43	97.41
<b>Total</b>			<b>1790</b>	<b>3454.14</b>	<b>1.93</b>	<b>0.00</b>	<b>157.46</b>		<b>157.46</b>
Year 1		< 0.1 ha	942	208.97	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	1056	705.25	0.67	0.42	1.22	0.24	0.81
Year 2	2009	0.5 - 1 ha	276	481.42	1.74	1.33	2.45	0.37	1.11
Date 2	0703	1 - 10 ha	228	1663.56	7.30	2.67	24.46	5.26	21.79
		10 - 20 ha	14	432.22	30.87	25.02	38.92	4.77	13.90
		> 20 ha	3	200.16	66.72	53.82	89.63	19.89	35.81
<b>Total</b>			<b>2519</b>	<b>3691.58</b>	<b>1.47</b>	<b>0.02</b>	<b>89.63</b>		<b>89.60</b>
Year 1		< 0.1 ha	1066	236.67	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	1251	826.71	0.66	0.33	1.22	0.23	0.89
Year 2	2009	0.5 - 1 ha	328	564.87	1.72	1.33	2.45	0.36	1.11
Date 2	0804	1 - 10 ha	242	1720.26	7.11	2.56	23.80	5.07	21.24
		10 - 20 ha	11	347.94	31.63	25.35	41.14	4.11	15.79
		> 20 ha	4	257.98	64.49	52.49	88.96	17.10	36.47
<b>Total</b>			<b>2902</b>	<b>3954.43</b>	<b>1.36</b>	<b>0.02</b>	<b>88.96</b>		<b>88.93</b>

Wise County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
Year 1	2009	< 0.1 ha	1397	310.41	0.22	0.00	0.24	0.01	0.24
Date 1	0928	0.1 - 0.5 ha	1852	1235.63	0.67	0.27	1.23	0.24	0.95
Year 2	2009	0.5 - 1 ha	528	893.57	1.69	1.24	2.45	0.33	1.20
Date 2	1023	1 - 10 ha	378	2639.78	6.98	2.48	23.27	5.16	20.79
		10 - 20 ha	22	699.25	31.78	25.58	42.48	4.58	16.90
		> 20 ha	10	772.96	77.30	49.50	130.64	24.86	81.14
<b>Total</b>			<b>4187</b>	<b>6551.61</b>	<b>1.56</b>	<b>0.00</b>	<b>130.64</b>		<b>130.64</b>
Year 1		< 0.1 ha	958	212.36	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	1149	759.78	0.66	0.31	1.22	0.23	0.92
Year 2	2009	0.5 - 1 ha	288	491.76	1.71	1.33	2.45	0.36	1.11
Date 2	1124	1 - 10 ha	263	1989.05	7.56	2.56	24.69	5.41	22.13
		10 - 20 ha	16	507.17	31.70	26.24	41.25	5.67	15.01
		> 20 ha	6	425.44	70.91	51.37	84.95	14.41	33.58
<b>Total</b>			<b>2680</b>	<b>4385.56</b>	<b>1.64</b>	<b>0.02</b>	<b>84.95</b>		<b>84.93</b>
Year 1		< 0.1 ha	872	193.24	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	997	655.85	0.66	0.30	1.22	0.24	0.92
Year 2	2009	0.5 - 1 ha	243	426.60	1.76	1.33	2.45	0.36	1.11
Date 2	1210	1 - 10 ha	238	1719.16	7.22	2.67	24.24	4.93	21.57
		10 - 20 ha	17	529.63	31.15	25.35	47.37	7.23	22.02
		> 20 ha	5	351.94	70.39	54.49	79.62	10.39	25.13
<b>Total</b>			<b>2372</b>	<b>3876.43</b>	<b>1.63</b>	<b>0.02</b>	<b>79.62</b>		<b>79.59</b>
Year 1		< 0.1 ha	725	160.94	0.22	0.04	0.22	0.01	0.18
Date 1		0.1 - 0.5 ha	765	499.39	0.65	0.33	1.11	0.22	0.78
Year 2	2010	0.5 - 1 ha	201	342.71	1.71	1.33	2.45	0.34	1.11
Date 2	0111	1 - 10 ha	201	1576.11	7.84	2.56	24.69	5.38	22.13
		10 - 20 ha	10	309.35	30.94	25.80	37.14	4.34	11.34
		> 20 ha	6	379.85	63.31	51.60	76.73	11.88	25.13
<b>Total</b>			<b>1908</b>	<b>3268.35</b>	<b>1.71</b>	<b>0.04</b>	<b>76.73</b>		<b>76.69</b>
Year 1		< 0.1 ha	1333	295.76	0.22	0.02	0.22	0.01	0.20
Date 1		0.1 - 0.5 ha	1601	1065.08	0.67	0.36	1.22	0.23	0.87
Year 2	2010	0.5 - 1 ha	377	658.26	1.75	1.33	2.45	0.38	1.11
Date 2	0620	1 - 10 ha	342	2474.98	7.24	2.56	24.69	5.20	22.13
		10 - 20 ha	23	737.13	32.05	24.91	41.81	4.99	16.90
		> 20 ha	10	850.10	85.01	63.83	107.42	15.05	43.59
<b>Total</b>			<b>3686</b>	<b>6081.31</b>	<b>1.65</b>	<b>0.02</b>	<b>107.42</b>		<b>107.39</b>
Year 1		< 0.1 ha	1499	332.53	0.22	0.03	0.22	0.01	0.19
Date 1		0.1 - 0.5 ha	1839	1219.14	0.66	0.28	1.22	0.23	0.94
Year 2	2010	0.5 - 1 ha	447	770.85	1.72	1.31	2.45	0.38	1.14
Date 2	0807	1 - 10 ha	345	2447.58	7.09	2.56	24.46	5.15	21.91
		10 - 20 ha	22	718.97	32.68	24.91	49.37	6.90	24.46
		> 20 ha	10	797.27	79.73	50.55	127.88	22.71	77.32
<b>Total</b>			<b>4162</b>	<b>6286.34</b>	<b>1.51</b>	<b>0.03</b>	<b>127.88</b>		<b>127.85</b>

Wise County		Summary statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year 1</b>		< 0.1 ha	1193	264.66	0.22	0.02	0.22	0.01	0.20
<b>Date 1</b>		0.1 - 0.5 ha	1337	875.44	0.65	0.25	1.22	0.23	0.97
<b>Year 2</b>	2010	0.5 - 1 ha	367	626.68	1.71	1.33	2.45	0.37	1.11
<b>Date 2</b>	1010	1 - 10 ha	302	2225.59	7.37	2.56	24.69	5.23	22.13
		10 - 20 ha	21	684.53	32.60	25.58	43.48	4.90	17.90
		> 20 ha	8	585.57	73.20	54.04	93.63	14.93	39.59
<b>Total</b>			<b>3228</b>	<b>5262.47</b>	<b>1.63</b>	<b>0.02</b>	<b>93.63</b>		<b>93.61</b>
<b>Year 1</b>	2010	< 0.1 ha	1156	256.50	0.22	0.01	0.22	0.01	0.22
<b>Date 1</b>	1118	0.1 - 0.5 ha	1593	1066.36	0.67	0.44	1.22	0.23	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	350	612.18	1.75	1.33	2.45	0.37	1.12
<b>Date 2</b>	1127	1 - 10 ha	284	2107.32	7.42	2.56	24.24	5.14	21.68
		10 - 20 ha	24	795.06	33.13	25.35	46.48	6.42	21.13
		> 20 ha	8	622.15	77.77	51.37	111.86	20.63	60.49
<b>Total</b>			<b>3415</b>	<b>5459.57</b>	<b>1.60</b>	<b>0.01</b>	<b>111.86</b>		<b>111.86</b>
<b>Year 1</b>		< 0.1 ha	518	114.95	0.22	0.08	0.22	0.01	0.14
<b>Date 1</b>		0.1 - 0.5 ha	586	384.74	0.66	0.44	1.22	0.23	0.78
<b>Year 2</b>	2010	0.5 - 1 ha	165	290.63	1.76	1.33	2.45	0.36	1.11
<b>Date 2</b>	1213	1 - 10 ha	196	1591.93	8.12	2.67	24.46	5.30	21.79
		10 - 20 ha	12	393.31	32.78	25.35	48.70	7.27	23.35
		> 20 ha	5	375.67	75.13	57.60	94.90	13.34	37.30
<b>Total</b>			<b>1482</b>	<b>3151.22</b>	<b>2.13</b>	<b>0.08</b>	<b>94.90</b>		<b>94.82</b>

# RPSEA

## *Feasibility of Using Alternative Water Sources for Shale Gas Well Completions — Final Report*

*Report No. 08122-05.08B*

## *Barnett and Appalachian Shale Water Management and Reuse Technologies*

**Contract 08122-05**

**February 28, 2012**

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Gas Technology Institute**

# **Feasibility of Using Alternative Water Sources for Shale Gas Well Completions**

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**January 2012**

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## **9 Attachment D: Study of North-Central Texas Paleozoic Aquifers**

This attachment details how the amount of groundwater available from local aquifers (the so-called Paleozoic aquifers) was determined. A simple numerical model, but with enough details, was built as detailed in later sections. The numerical model was built as a tool to determine the level of pumping that was sustainable according to generally accepted considerations (which, in this work, happens to be the pumping level corresponding to a 5 feet average drawdown).

### **9.1 How are groundwater availability and sustainability defined?**

In this section we explain the reasonable choice of an average drawdown of 5 feet over 50 years as the basis to define admissible pumping levels. The subsurface holds large amounts of water but in practice only a small amount is available for withdrawal and consumption. In predevelopment conditions (that is, before any pumping occurs), aquifers are typically in steady-state conditions with relatively stable water-level and inflows (through various recharge mechanisms) balancing outflows (for example, springs, leakage to other aquifers, discharge to rivers –called base flow). When development (pumping) begins, the water comes initially from storage then typically captures some water from the discharge pathways. Recharge could increase too in what has been called captured recharge because, as the regional water levels go down, less water is discharged through streams, increasing the amount of water available for pumping. However, this may have the effect of decreasing spring flow or river base flow (important during droughts). Such processes have been observed at many locations and have two implications of interest to this work: (1) only a numerical model can capture the intricacies of the relationships between the various components of the water cycle, and (2) only a relatively small amount of the water present in an aquifer can be practically extracted from the aquifer before detrimental impacts occur. Clearly there is no single or simple answer to the how-much-pumping question but the science community can provide tools in deciding the acceptable pumping level. In Texas, various governmental bodies help in determining the pumping threshold before these detrimental impacts occur. The concept of detrimental impact is also subject to discussion because some Texas aquifers are being mined. In such case detrimental impacts involve factors outside of the hydrogeologic realm and are societal or political in nature. Typically, such levels are set indirectly by one of the 16 Regional Water Planning Groups (RWPGs, <http://www.twdb.state.tx.us/wrpi/rwp/rwp.asp>, <http://www.twdb.state.tx.us/wrpi/rwp/3rdround/2011RWP.asp>) and 16 Groundwater Management Areas (GMAs, <http://www.twdb.state.tx.us/GwRD/GMA/gmahome.htm>) deciding what an acceptable impact would be for the different aquifers present within their geographic boundaries. The Paleozoic aquifers are contained in 3 RWPGs (Region B, Region C, and Brazos G) and 2 GMAs (GMA 6 and mostly GMA 8). Metrics chosen by the groups vary. Some groups focus on spring flow, allowing pumping as long as it does not let flow fall below some level, other groups focus on regional drawdowns, not allowing long-term pumping levels that would translate into a regional drawdown beyond an agreed-upon threshold, others set a minimum amount of water that must stay in the aquifer. Such conditions are called *Desired Future Conditions* (DFC's) in the Water Plan. Note that it is important to know if an aquifer is unconfined (water comes from true dewatering of the aquifer) or confined (aquifer stays fully saturated and water comes from depressurization of the aquifer) to appreciate the drawdown threshold. In the TWDB jargon, the pumping level corresponding to the DFCs is called Managed Available Groundwater (MAG). Following such procedure the TWDB updates and produces a State Water Plan in 5-year cycles (<http://www.twdb.state.tx.us/wrpi/swp/swp.asp>), the Paleozoic aquifers of North-Central Texas are not included in such a plan (because population is sparse and

also relies on surface water and because water is sometimes brackish and wells of low yield). For this reason, it is not known what an acceptable pumping level would be for the local population and economic activities, but a reasonable guess can be put forward by looking at how nearby aquifers are handled. The TWDB State Water Plan defines two closely related water volumes: “existing groundwater supplies” and “groundwater availability” (TWDB, 2011). The former describes the amount which can be immediately withdrawn from the subsurface whereas the latter represent the amount available regardless of legal or physical availability. This work discusses available groundwater from the Paleozoic aquifers.

A few DFC’s from across the state follows: GMA 11, in East Texas, includes the Northern Carrizo-Wilcox and overlying aquifers and its DFC’s are defined to allow up to 17 feet of drawdown. GMA 13, covering the southern Carrizo-Wilcox and overlying aquifers from the Mexican border to northeast of San Antonio, proposed an average drawdown of 23 ft. It also proposed an average drawdown of 2 ft on the Yegua-Jackson aquifer and an average artesian flow of 500 gpm for the Edwards aquifer in Frio County (south Texas). GMA 16 accepted an average 94 ft drawdown in the Southern Gulf Coast aquifers. Further north, GMA 15 covering the Central Gulf Coast aquifer planned a 12 ft average drawdown.

Eastern edge of GMA 6 includes Clay, Jack, and Palo Pinto counties, three western counties of the area of study. The focus of GMA 6 is mostly its western half with the Ogallala, Dockum, Blaine, and Seymour aquifers. Blaine Aquifer is also an aquifer hosted by Paleozoic rocks. DFC’s vary from 2 to 7 feet of average drawdown but also includes the possibility of pumping up to half of the water available in some unconfined areas of the Blaine aquifer. GMA 8 includes the other counties of the area of study but is mostly focused on the southeastern half of the area in the footprint of the Trinity and overlying aquifers. Unlike other GMAs that define DFC’s for their entire area, DFC’s in GMA 8 are county-based and vary from 0 to maybe 10 ft in the unconfined section to tens and sometimes hundreds of feet in the confined section.

Somewhat arbitrarily but consistent with numbers above and presented in Table 8. a maximum drawdown of 5 feet was chosen as a reasonable value for the Paleozoic aquifers.

Table 8. Desired Future Conditions drawdowns for selected GMAs.

<b>GMA #</b>	<b>Location in the State and aquifer name</b>	<b>Aver. DD</b>
<b>Selected aquifers in Texas</b>		
GMA 11	East Texas: confined and unconfined Northern CZWX and other aquifers	17 ft
GMA 13	South Texas Southern CZWZ and other aquifers	23 ft
GMA 16	South Texas Southern Gulf Coast	94 ft
GMA 15	Central Texas Central CZWX and other aquifers	12 ft
<b>Aquifers close to and similar to the Paleozoic Aquifers</b>		
GMA 6	Texas Panhandle: Blaine aquifer	2-7 ft
GMA 8	North-Central Texas: Trinity and overlying aquifers	unconfined <10 ft confined 100's ft

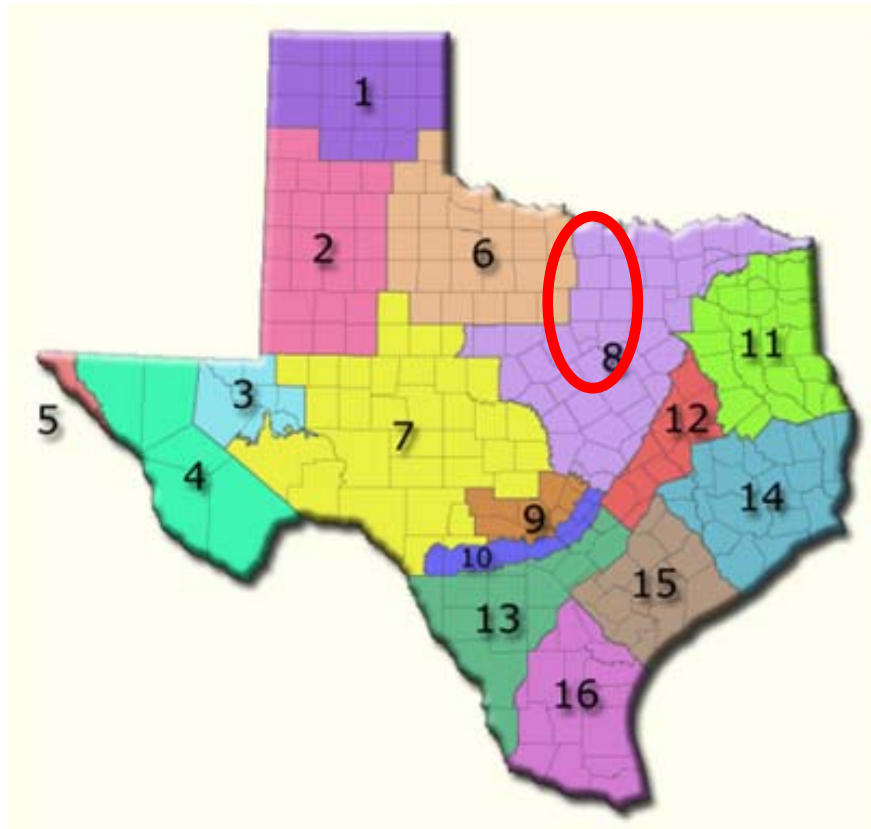


Figure 16. Map of GMAs and of area of interest (red ellipse)

## 9.2 How was the Pumpage Corresponding to the 5-ft Drawdown Determined?

The first step is to collect information on how much water has been withdrawn from the aquifers in the past (for all uses) and how much is projected to be withdrawn exclusive of fracing. One of the TWDB water planning databases contains historical pumping by county since 1980 (<http://www.twdb.state.tx.us/wushistorical>). Estimates for earlier years were made by assuming that population and groundwater use are linearly related. Census data has information about population (<https://www.tsl.state.tx.us/ref/abouttx/census.html>). Future water use by county is also provided in a TWDB file (<http://www.twdb.state.tx.us/wrpi/data/proj/2012demandproj.asp>) by county. Note that the current version of the TWDB future water use does not include fracing. In a second step, we added the fracking water use projections (Nicot et al., 2011). We conservatively assumed that all frac water would be groundwater. The annual projections were not directly used, instead the average for each county of the projections over the 30 additional years the play is projected to be active (to 2040) was used and then still used beyond the time the play was projected active (from 2040 to 2060). The county level has been determined as the most adequate for water use projections. It includes prospectivity considerations and likely general interest of the county from the oil and gas industry. In other words, it distributes the pumping across the area in a logical way instead of assuming pumping will be distributed evenly throughout the entire zone of interest. The third step was to multiply the average projections by a coefficient until the average drawdown condition of 5 ft (between 2010 and 2060) was met. The average drawdown was calculated on the cells with drawdown > 0. The final frac pumping is ~7

times the projected amount suggesting the aquifers can sustain such pumping levels at the regional level (Table 9). However, locally drawdowns can be much more pronounced (maximum is >100 ft).

Table 9. Time-constant pumping level in individual cells in addition to the natural pumping owing to all uses but fracking

County	Clay	Erath	Jack	Montague	Palo Pinto	Parker	Wise
<b>Pumping rate / cell (m<sup>3</sup>/day)</b>	27	14	17	27	14	19	22

Note: pumping is applied only to those cells within the 33<sup>rd</sup> high transmissivity percentage

### **9.3 Well Yield Estimate**

In addition to knowing how much water is present (capacity), it is also important to quantify availability, that is, well yield or how much water can be produced in a given amount of time. Well yields reported to TCEQ (see document below) do not necessarily represent the maximum yield of the aquifer because those wells are drilled for domestic use. They are not screened over the entire available thickness and probably do not withdraw water to capacity over their actual screened interval. However, they represent the physical evidence that the aquifer is able to sustain at least that pumping rate. Transmissivity values are better estimates but they have not been groundtruthed by actual pumping.

### **9.4 Water Quality**

A MS thesis partially funded by this project focused on the water quality of the Paleozoic aquifers. An excerpt of the draft is attached next and summarized in this section. According to the TWDB database, main source of information to this discussion (no samples were taken in the filed for this study), the median Total Dissolved Solid concentration is ~800 mg/L (up to 4,000 mg/L) (Table 2 of Appendix 1 of this attachment). The pH is generally relatively high, between 7 and 9, in agreement with a strong carbonate imprint. The ionic composition is very variable is likely the result of the mixing of two end members: a deeper sodium chloride and a shallower calcium bicarbonate member. Note that the database is likely biased towards fresher sections of the aquifers and not necessarily similar to the distribution resulting from sampling those aquifers according to a regular grid.

### **9.5 Description of Model of the Paleozoic Aquifers**

The following documents (Appendix 2 and Appendix 3) describe the construction of the model.

Appendix 1: Alternative Groundwater resources in North-Central Texas for the Development of the Barnett Shale Gas Play (MS thesis's excerpt) – Geochemical Analysis of Selected North-Central Texas Aquifers

Appendix 2: Evaluation of Paleozoic Aquifers of North Central Texas; Part I: Development of a Static Model for a Numerical Model

Appendix 3: Evaluation of Paleozoic Aquifers of North Central Texas; Part II: Groundwater Flow Model

## **(Draft) Abstract**

# **Alternative Groundwater resources in North-Central Texas for the development of the Barnett Shale Gas Play**

Edward R. McGlynn, M.S.

The University of Texas at Austin, 2012

Supervisors: Jack Sharp and J.-P. Nicot

Texas water resources are under pressure due to population growth expected in the coming decades, increasing industrial demands, and frequent periods of drought. With this increasing demand for limited water resources it is important to explore alternative water sources within the State. One of those resources that can be developed are the many small aquifers which have never been characterized but could be an alternative source of fresh and brackish water for agriculture, municipal, and industrial applications.

The natural gas industry's demand for water is growing in Texas as new drilling techniques such as hydraulic fracturing have opened new reserves previously considered economically non-viable. The development of smaller aquifers containing brackish water is a viable alternative to the gas industry's current reliance on fresh (potable) groundwater resources. The aquifer sections containing brackish water need to be mapped and characterized so they can be developed as an alternative water resource by the gas industry.

The Barnett Shale in North-central Texas is one of the first major gas plays in the United States to use the technique of hydraulic fracturing in field development. This technique requires large quantities of water to create the required hydraulic pressure down the gas well to fracture the normally low permeability shale. A typical horizontal well completion consumes approximately 3.0 to 3.5 million gallons (11.4 to 13.2 million liters) of fresh water. Projections of future groundwater demand for the Barnett Shale gas play total 417,000 AF, an annual average of 22,000 AF over the expected 2007-2025 development phase (Nicot 2009). This level of water demand has the gas industry and groundwater managers in the State exploring alternative sources of water for future development of the Barnett Shale.

One alternative source of water for the expanding footprint of the Barnett Shale gas play are the smaller Pennsylvanian aquifers on the western edge of the basin. These small aquifers are underutilized and contain waters with higher levels of TDS. These levels are, however, acceptable to the drilling industry. In order to characterize these aquifers, TWDB databases were utilized to analyze water chemistry and well productivity.

The aquifers of the study area are located primarily in Montague, Jack, Palo Pinto, Wise and Parker counties. Well depths range mostly between 30 and 500 feet (9.1 and 152.4 meters) below land surface. Yields from wells are variable, ranging from less than 5 to over 60 gpm (27.3 to over 327 m<sup>3</sup>/day). The specific capacity of the minor aquifers range mostly between 0.10 and 5.0 gpm/ft-drawdown, which indicates significant drawdown, will be required to meeting industry pumping rate requirements of 100 gpm (545 m<sup>3</sup>/day). To establish a pump rate of 100 gpm (545 m<sup>3</sup>/day), the drawdown would expect to range between 20 feet and 1000 feet (6 and 305 meters). Groundwater quality in the minor aquifers generally contains between 300 and 3800 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 220 mg/L, well within the industry requirement of less than 350 mg/L, pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding.

**Excerpts from draft thesis only**

**I. Study Area Description**

The focus of this study is the Fort Worth basin of north-central Texas which includes 14 counties with significant gas production: Bosque, Dallas, Denton, Erath, Hill, Hood, Jack, Johnson, Montague, Palo Pinto, Parker, Somervell, Tarrant, and Wise. These 14 counties will be referred to as the Tier I & II counties relative to the development of the Barnett Shale gas play (Figure 1). The Tier I counties were the first and primary areas developed in the Barnett shale play including Denton, Tarrant, Dallas, Johnson, Hill and Bosque. While the Tier II counties encompass the new region in which the developers of the Barnett play are migrating to.

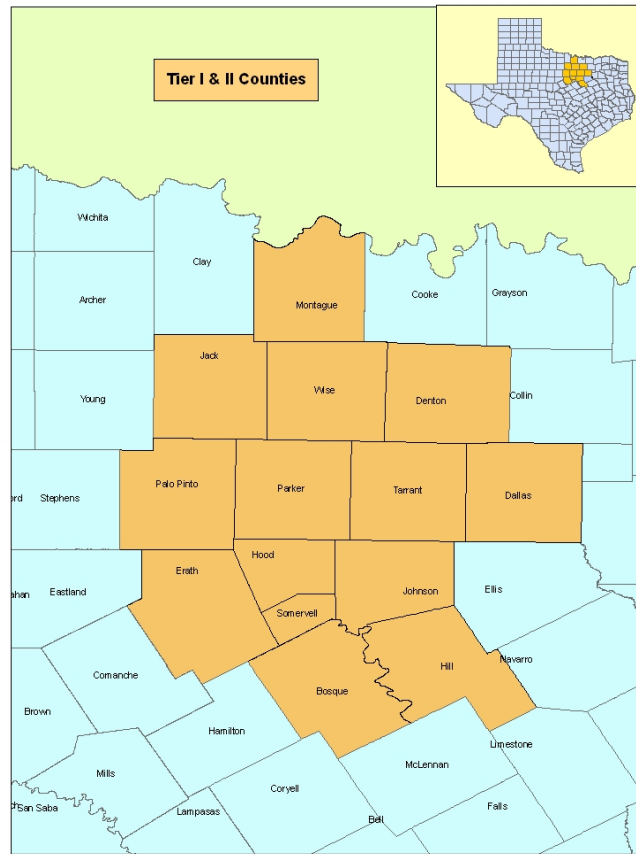


Figure 1. Study Area - Tier I & II Counties

Due to the current use and knowledge by the natural gas industry of the Cretaceous strata of the study area, the primary focus of this study is the Pennsylvanian strata. The Pennsylvanian area of north central Texas can be described as two great inliers of Carboniferous rocks that protrude through the Cretaceous strata on the east and dip beneath Permian rocks on the west and north. The two areas are separated by a narrow tongue of Cretaceous (Trinity) sand, and the southern outcrop rests against Ordovician rocks for a short distance along the Llano uplift. The total area covered by the Pennsylvanian is about 7,000 square miles. It includes the west part of Montague, the south-east part of Clay, the greater portion of Jack, Young, Stephens, Palo Pinto, Eastland, Brown, the east half of Coleman, the north part of San Saba, and the northeast of McCulloch counties. The shape and location of the Pennsylvanian area are shown on the index map (Figure 2).

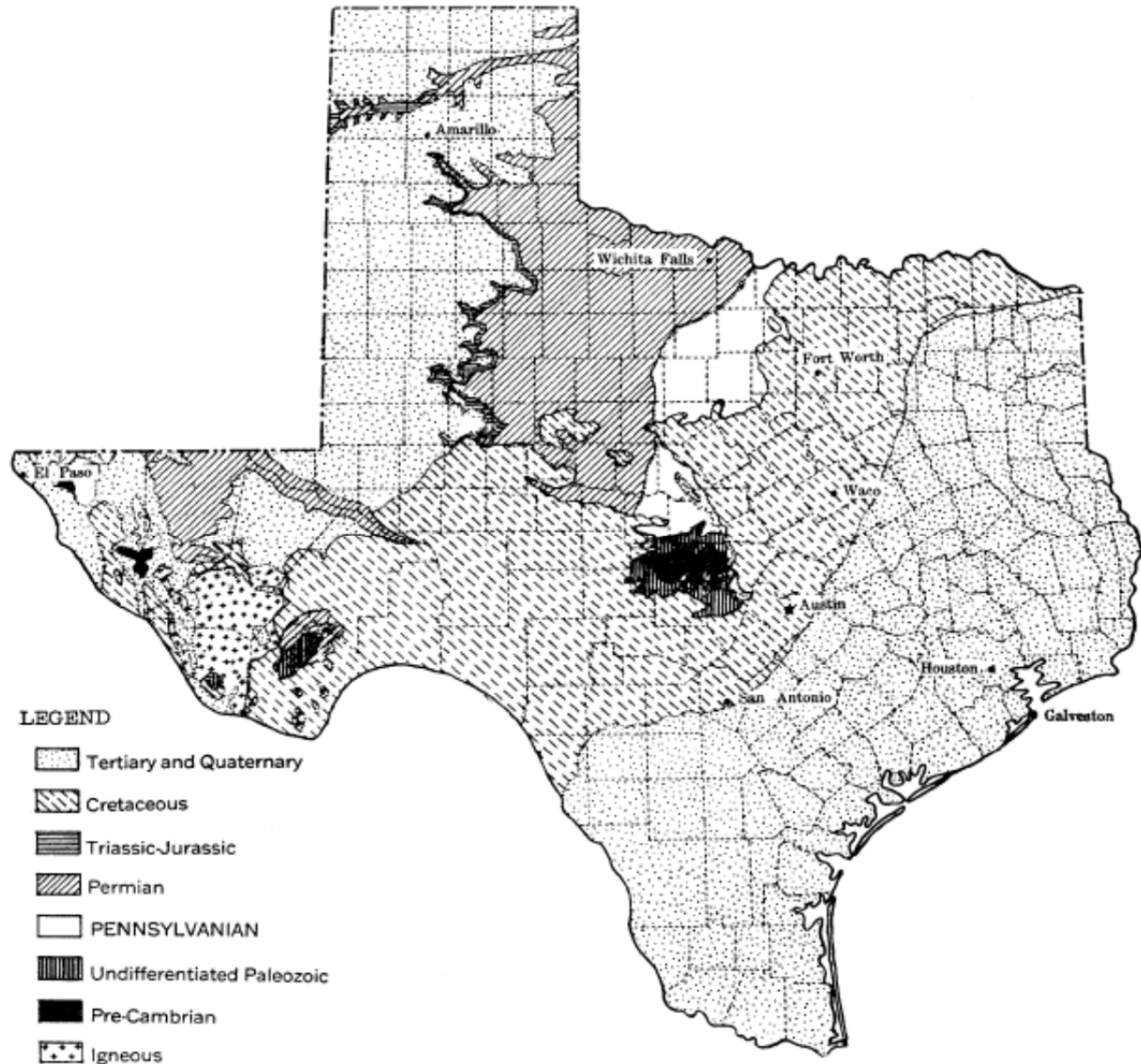


Figure 2. The Pennsylvanian area of north central Texas, Moore (1922)

## II. Geological setting

Stratigraphic units that supply fresh to slightly saline water to wells in the study area range in age from Paleozoic to Recent. The North Central Texas Region includes several prominent geologic structures, which include the Pennsylvanian and Permian Paleozoic and the Cretaceous strata of the Trinity aquifer.

### a. Regional Stratigraphy

The Cretaceous System is composed of two series, Gulf and Comanche, and each is divided into groups. The Gulf Series is divided into the following five groups: Navarro, Taylor, Austin, Eagle Ford, and Woodbine. The Comanche Series is divided into the following three groups: Washita, Fredericksburg, and Trinity. The Taylor and Eagle Ford Groups consist predominantly of shale, limestone, clay, and marl and yield only small amounts of water in localized areas (Nordstrom 1982). The Navarro and Austin Groups consist of chalk, limestone, marl, clay, and sand and,

except for the Nacatoch and Blossom Sands, yield only small amounts of water locally. The Nacatoch Sand of the Navarro Group and the Blossom Sand of the Austin Group yield small to moderate supplies of water to limited areas. The Woodbine Group is the only important aquifer of the Gulf Series in the area covered by this report. It consists of sand, sandstone, and clay and is capable of yielding small to large amounts of water. Both the Washita and Fredericksburg Groups of the Comanche Series consist predominantly of limestone, shale, clay, and marl and yield only small amounts of water to localized areas. The Trinity Group is the principal aquifer in the region and is divided into the Paluxy, Glen Rose, Twin Mountains, and Antlers Formations. The Paluxy consists of sand and shale and is capable of yielding small to moderate amounts of water. The Glen Rose is predominantly a limestone and yields small quantities of water only to localized areas. The Twin Mountains is composed of conglomerate, sand, and shale. It is the principal aquifer formation of Cretaceous age in the region and yields moderate to large amounts of water. The name Antlers Formation is applied north of the Glen Rose pinch-out, where the Paluxy and Twin Mountains coalesce to form one unit (Nordstrom 1982).

The Trinity Group of Cretaceous age contains the largest and most prolific aquifer in the study area. The aquifer consists of the Antlers, Twin Mountains and Paluxy Formations. The Antlers is a coalescence of the Paluxy and Twin Mountains in the northern part of the study area where the Glen Rose Formation is no longer traceable. The lower sands and shales of the Twin Mountains are the hydrologic equivalent of the basal portion of the Antlers. The younger Woodbine Group overlies the Fredericksburg and Washita Groups that function as an aquitard between the Woodbine and the stratigraphically lower Paluxy Formation (Baker 1990).

#### b. Structure

Pennsylvanian and Permian rocks in the outcrop along the west edge of the study area dip westward and northwestward at about 40 feet per mile (7.6 m/km). Permian beds probably extend not much farther eastward than Montague County (Nordstrom 1982). The Pennsylvanian sediments, which underlie the Cretaceous rocks in most of the remaining area, thicken from the outcrop eastward into the Fort Worth basin. The Cretaceous System forms a southeastward-thickening wedge extending across the area into a structural feature known as the East Texas basin. Thickness of these rocks ranges from zero in the west to nearly 7,500 feet (2,286 m) in the southeast. Regional dip is east and southeast at rates of about 15 to 40 feet per mile (2.8 to 7.6 m/km). The dip rate increases to as much as 300 feet per mile (57 m/km) on the southeastward-plunging ridge called the Preston anticline.

Quaternary deposits occur along the flood plains of the Brazos, Red, Sulphur, and Trinity Rivers and many of their main tributaries. Terraces, which represent remnants of older floodplain deposits of these drainage systems, occur at higher elevations along some of the rivers, particularly the Red River. Alluvial deposits are reported to be as thick as 70 feet (21 m) in Fannin County. Generally, the alluvial deposits are irregular in thickness and areal extent (Nordstrom 1982).

ERA	SYSTEM	SERIES	GROUP	FORMATION	APPOXIMATE MAXIMUM THICKNESS (FT)	HYDRAULIC PROPERTIES*	
Cenozoic	Quaternary	Recent	Alluvium	Alluvium	60	Yields small to large amounts of fresh water to wells along the rivers and their tributaries.	
		Pleistocene	Seymour	Seymour	125		
Mesozoic	Cretaceous	Gulf	Navarro	Kemp Clay, Corsicana Marl, Nacatoch Sand	800	Upper members are not known to yield water to wells in area; lower member yields small to moderate quantities of fresh to slightly saline water near the outcrop.	
				Taylor		Marlbrook Mar, Pecan Gap Chalk, Wolfe City -Ozan Formations	1500
			Austin	Gober Chalk, Brownstown Marl, Blossom Sand, Bonham Formation	700	Yields small to moderate quantities of fresh to moderately saline water to wells in northeastern part. Limited as an aquifer.	
			Eagle Ford		650	Yields small quantities of water to shallow wells.	
			Woodbine		700	Yields moderate to large quantities of fresh to slightly saline water to municipal, industrial and irrigation wells.	
		Comanche	Washita		1000	Yields small quantities of water to shallow wells.	
			Fredericksburg		250	Yields small quantities of water to shallow wells.	
			Trinity	Antlers	Paluxy	400	Yields small to moderate quantities of fresh to slightly saline water to wells.
					Glen Rose	1500	Yields small quantities of water in localized areas.
					Twin Mountains	1000	Yields moderate to large quantities of fresh to slightly saline water to wells.
Paleozoic	Permian	Wolfcamp	Cisco	Pueblo	100	Yields small to moderate quantities of fresh to moderately saline water for public supply, industrial, irrigation, domestic, and stock wells.	
	Pennsylvanian	Virgil		Harpersville	200		
				Thrifty	300		
		Graham		600			
			Canyon	Caddo Creek	300		
		Brad		400			
		Graford		600			
		Missouri	Palo Pinto	300			
			DesMoines	Strawn	Mineral Wells	1100	
	Brazos River	1400					
	Mingus						
	Grindstone Creek						
Lazy Bend							
*Yield of Wells: small -less than 100 gallons per minute (gpm); moderate - 100 to 1,000 gpm; large - more than 1,000 gpm Chemical Quality of Water: fresh -less than 1,000 milligrams per liter (mg/l); slightly saline - 1,000 to 3,000 mg/l; moderately saline - 3,000 to 10,000 mg/l; very saline - 10,000 to 35,000 mg/l; brine - more than 36,000 mg/l.							

Figure 3 Stratigraphy of North-Central Texas Study Area.

Modified from Nordstrom (1988), Duffin (1992) and Baker (1990)

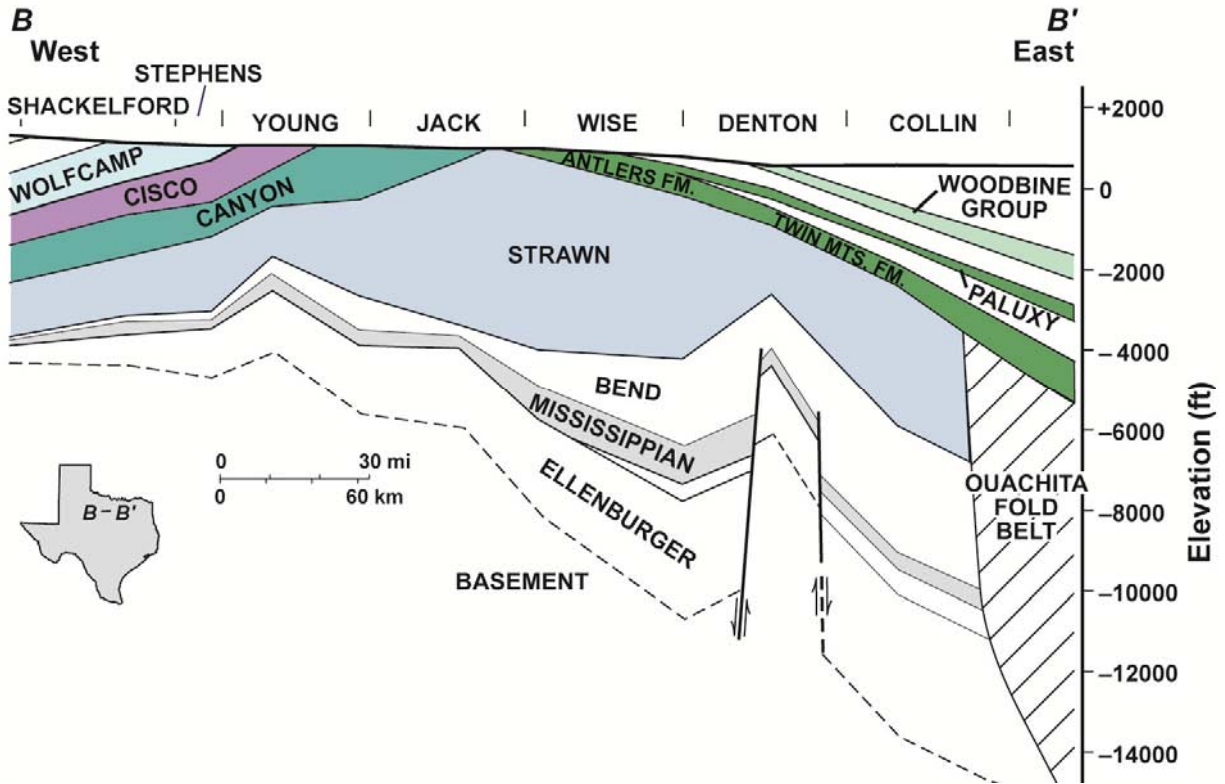


Figure 4a. Stratigraphic Section of Study Area – West to East

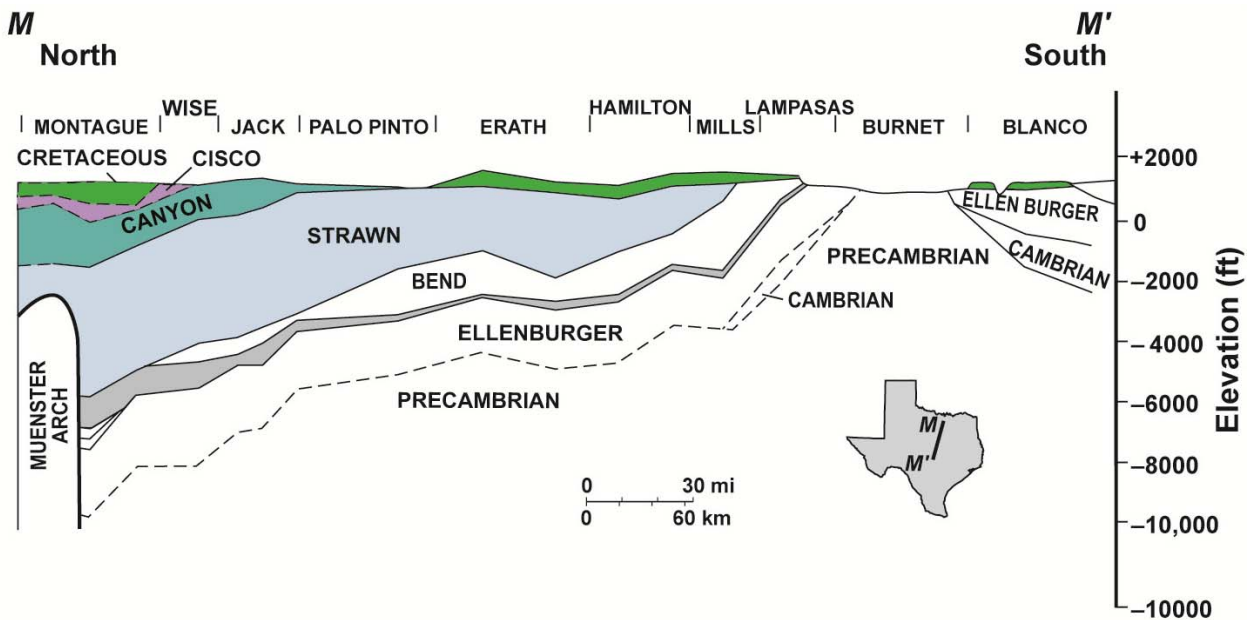


Figure 4b. Stratigraphic Section of Study Area – North to South

### III. Hydrogeology

#### a. Major Aquifers

##### **Trinity Aquifer**

The Trinity aquifer is a major aquifer that extends across much of the central and northeastern part of the State. Located in central Texas, the aquifer extends from the Red River to the eastern edge of Bandera and Medina counties, covering a total of 61 counties in the state (Ashworth et al., 1995). The aquifer's area of outcrop is 10,652 square miles (27,588 square kilometers) along its western length and the area of subsurface is 21,308 miles (34,291 km) primarily along its eastern length (Water for Texas, 2007).

Formations comprising the Trinity Group are (from youngest to oldest) the Paluxy, Glen Rose, and Travis Peak (see Figure 5). Up dipping, where the Glen Rose thins or is missing, the Paluxy and Twin Mountains combine to form the Antlers formation. The Antlers consists of up to 900 feet (274 meters) of sand and gravel, with clay beds in the middle section. Forming the upper unit of the Trinity Group, the Paluxy Formation consists of up to 400 feet (122 meters) of predominantly fine to coarse-grained sand inter-bedded with clay and shale. The formation pinches out down dip and does not occur south of the Colorado River (Bradley, 1999).

Underlying the Paluxy, the Glen Rose Formation forms a gulf-ward thickening wedge of marine carbonates consisting primarily of limestone. South of the Colorado River, the Glen Rose is the upper unit of the Trinity Group and is divisible into an upper and lower member (Nordstrom 1982).

The Trinity aquifer is comprised of sediments of the Trinity Group and is divided into lower, middle, and upper aquifers based on hydraulic characteristics of the sediments (Barker et al., 1990). The Lower Trinity aquifer consists of the Hosston and Sligo Formations in the subsurface and the Sycamore Sand in the outcrop area; the Middle Trinity aquifer consists of the Cow Creek Limestone, the Hensel Sand, and the Lower Member of the Glen Rose Limestone; and the Upper Trinity aquifer consists of the Upper Member of the Glen Rose Limestone. Low-permeable sediments in the lower and upper parts of the Glen Rose Limestone separate the Middle and Upper Trinity aquifers. The Lower and Middle Trinity aquifers are separated by the low permeability Hammett Shale (see Figure 2) (Mace et al., 2000). The basal parts of the Hosston Formation, the Sycamore Sand, and up dip parts of the Hensel Sand are mostly sand and contain some of the most permeable sediments in the Hill Country (Barker et al., 1994). The Cow Creek Limestone is highly permeable in outcrop but has relatively low permeability in the subsurface due to the precipitation of calcitic cements (Barker et al., 1994). Similarly, the lower parts of the Glen Rose Limestone are more permeable in outcrop areas than in deeper areas (Barker et al, 1994).

The most permeable sands of the Trinity aquifer can be found in the outcrop areas within Brown, Callahan, Comanche, Eastland and Erath counties. The permeability coefficients range from approximately 87 to 235 gallons per day per square foot (gpd/ft<sup>2</sup>) (SI unit  $3.8 \times 10^{-5}$  to  $1.03 \times 10^{-4}$  m<sup>3</sup>/s/m<sup>2</sup>). Because of this extreme range in permeability in water saturated sands, transmissibility values vary widely, ranging from zero to 20,000 gpd/ft (Klemt et al. 1975). The sands within the calcareous facies of the Trinity aquifer have extremely low permeabilities due to the cementation of the sands and range from 1 to 20 gpd/ft<sup>2</sup>, with coefficients of transmissibility ranging from zero to 1,000 gpd/ft (Klemt et al. 1975).

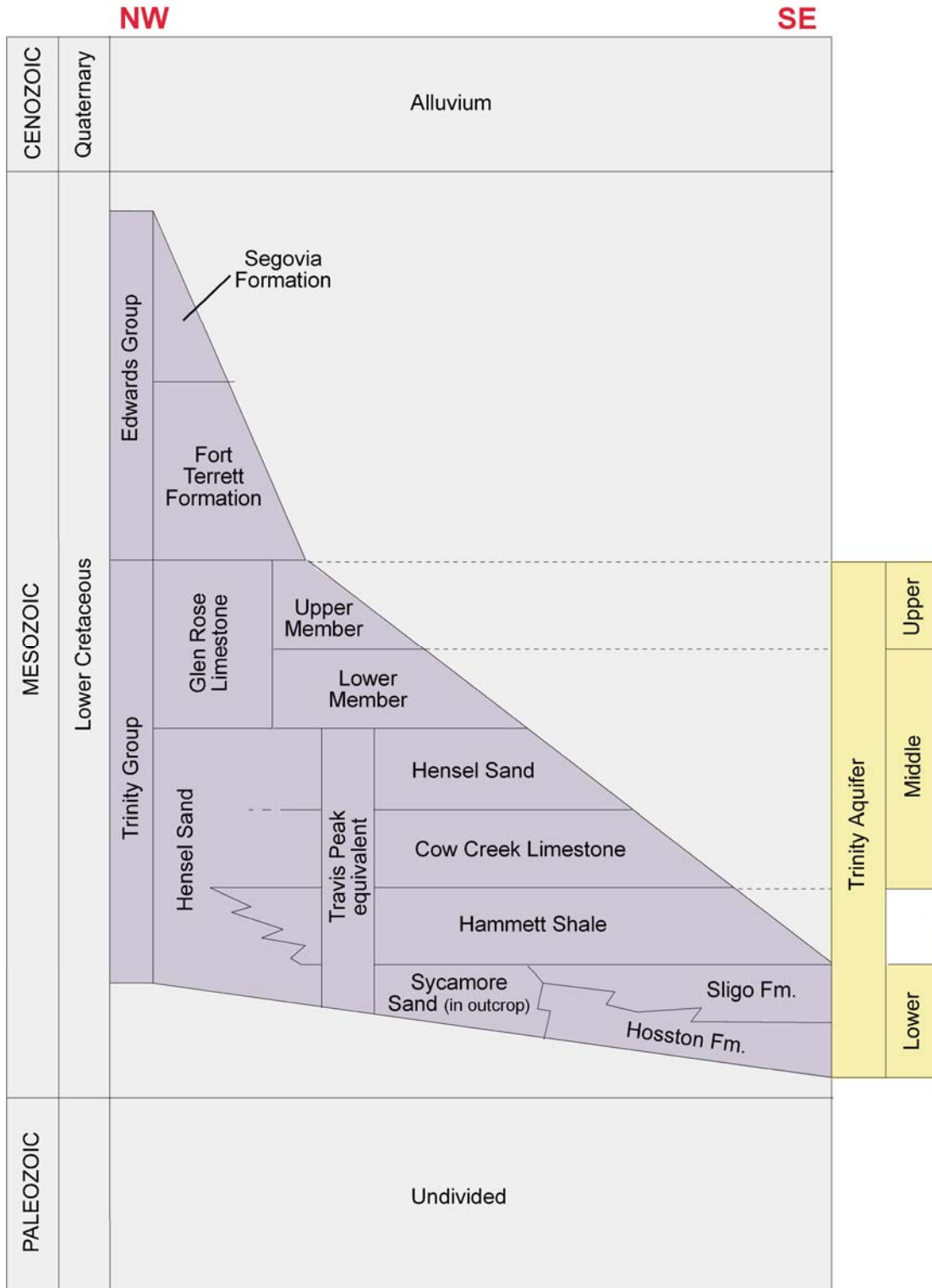


Figure 5. Trinity Aquifer Stratigraphic and Hydrostratigraphic Section (Mace 2000)

### Recharge & Discharge

Recharge to the aquifer is primarily in the form of infiltration of precipitation on the outcrop areas and seepage of water from lakes, rivers, unlined earthen ponds, losing streams, and return flows of water used to irrigate crops on the aquifer's surface. A significant portion of the recharged water reemerges as springs and seeps along the contact of the Edwards Group with the Upper Member of the Glen Rose Limestone and as baseflow in gaining river and stream reaches. Discharge from the aquifer also occurs due to subsurface flow into the Edwards aquifer as well as public and private wells (Veni, 1994).

### Water Quality

The Trinity aquifer water quality is generally good but very hard in the outcrop of the Trinity aquifer. Total dissolved solids increase to the east and southeast as the depth to the aquifer increases. Sulfate and chloride concentrations also tend to increase with depth (Water for Texas, 2007). Water quality ranges from fresh (less than 1,000 mg/l TOS) up to slightly saline (1,000 to 3,000 mg/l TOS). Chloride concentrations for the Trinity aquifer exceed the SCL of 300 mg/L in the western outcrop areas and the southeastern down-dip areas. Nitrate concentrations exceed the SCL of 44.3 mg /L (as nitrate) in the western outcrop. Sulfate concentrations of the Trinity aquifer exceed the SCL of 300 mg/L in the central and eastern section. High sulfate values may indicate an interconnection between the gypsum rich Glen Rose Formation and the formations it overlies (Bradley, 1999).

#### b. Minor Aquifers

### **Alluvium**

The recent alluvium of Quaternary age is a minor source of groundwater used primarily in the study area for livestock purposes. Alluvial deposits are found in the floodplains of the major tributaries of streams which make up the surface drainage system in the study area. Ground water in the alluvium is generally calcium bicarbonate water, very hard, normally of neutral pH, and of greatly varying dissolved-solids content. Due to the combination of naturally occurring poor quality water in many areas and the contamination by various activities occurring in the oil and gas industry, the overall quality of ground water obtained from alluvial deposits is poor for domestic purposes.

### **Brazos River Alluvium**

Water-bearing alluvial sediments occur in floodplain and terrace deposits of the Brazos River of southeast Texas. The Brazos River Alluvium aquifer, up to seven miles wide, stretches for 350 miles along the sinuous course of the river between southern Hill and Bosque counties and eastern Fort Bend County. Irrigation accounts for almost all of the pumpage from the aquifer (Cronin 1967). The Quaternary alluvial sediments consist of clay, silt, sand, and gravel, and generally are coarsest in the lower part of the accumulations. Saturated thickness of the alluvium is as much as 85 feet or more, with maximum thickness occurring in the central and southeastern parts of the aquifer. Some wells yield up to 1,000 gal/min, but the majority yields between 250 gal/min and 500 gal/min (Cronin 1967).

The chemical quality of the ground water varies widely. In many areas, concentrations of dissolved solids exceed 1,000 mg/l. Most of the Brazos River Valley irrigated with this ground water contains soils sufficiently permeable to alleviate any soil salinity problems. In some

places, the water from the aquifer is fresh enough to meet drinking water standards (Cronin 1967).

### **Cisco Group**

The Cisco group is comprised of fluvial-deltaic sediments of primarily sandstone with beds of limestone, shale, mudstone, and conglomerate (Kier 1979). The upper portion of the Texas Pennsylvanian included in the Cisco group is characterized by its more clastic sediments, its thin but persistent limestones, and the presence of coal. It includes all the beds between the Home Creek limestone of the Canyon and the lowermost beds containing Permian fossils. The change in the character of the rocks in passing from the Canyon to the Cisco is evidently the result of a diastrophic movement which made shallow the waters in northern Texas and which brought into them large amounts of coarse sand and gravel, chiefly from the north, for the northern portion of the Cisco is materially thicker and more clastic than the southern portion. The total thickness of the Cisco group is about 700 to 800 feet in the southern Pennsylvanian area and 1,400 to 1,500 feet in the north. Six formations have been recognized in the Cisco, as indicated in the foregoing table of stratigraphic divisions, in order from the base: Graham, Thrifty, Harpersville, and Pueblo. As a whole, the Cisco group is not more fossiliferous than other parts of the Texas Pennsylvanian, but some beds, as the upper shale of the Graham formation, are among the most fossiliferous in the mid-continent region (Moore 1922). The Cisco Group crops out in the southwest corner of Montague County and underlies the Wichita Group to the north. The Cisco Group consists of alternating beds of shale, sandstone, limestone, and conglomerate. As in the Wichita Group, there is less sand down-dip than in the outcrop. In the study area, rocks of Pennsylvanian age generally dip toward the west or northwest at a rate of approximately 50 feet per mile (9.5 m/km) and are overlain by the Trinity Group of Cretaceous age to the east (Nordstrom 1982).

The southern tip of the Cisco Group aquifers (Pennsylvanian) outcrops across northwestern Eastland County. The western edge in Eastland and Stephens Counties approaches 1,000 feet in thickness. The quality of water is variable but most wells sampled in the Cisco Group do not meet secondary drinking water standards. For the purpose of this option, a target of 1,500 mg/L TDS is assumed although this is well above the average of wells sampled as reported by Duffin and Beynon (1,014 mg/L). TDS has been measured as high as 3,700 mg/L in these aquifers (Nordstrom 1982).

The Cisco Group is the uppermost Pennsylvanian aged unit present in Central Texas. The Cisco Group outcrops in a 15 to 20 mile band in Concho, McCulloch, and Coleman Counties and rapidly dips into the subsurface away from the Llano Uplift area. The Cisco Group contains both the Thrifty and Graham Formations and is comprised of shales, sandstones, conglomerates, limestones, and coal beds. It is approximately 1,000 feet (305 meters) thick away from the outcrop, however net sand is only 10 to 15 percent of the total thickness. Porosities average 12 to 22 percent, and permeabilities range from 10 to 350 millidarcies (Core Laboratories, 1972).

The Cisco Group provides fresh to moderately saline water to wells in Coleman and Brown Counties, in and near where it outcrops. Of the water wells in the study area that are included in the TWDB database, just over half produce fresh water, with most of the remainder producing slightly saline (1,000-3,000 mg/L TDS) groundwater. A majority of these wells are less than 200 feet (61 meters) deep. In the down-dip areas, salinities of produced water from the Cisco have TDS ranging from 50,000 to 200,000 mg/L (LBG-Guyton 2004).

Because the Cisco produces groundwater with relatively low salinities, it may be considered a potential source of saline water, particularly in the eastern half of the region where the aquifer is found at shallower depths.

### **Thrifty Formation**

The Thrifty formation consists of thick shales which are less fossiliferous and brighter in color than those of the Graham, limestones which are thicker and somewhat more massive than those of other divisions of the Cisco, and some sandstone and coal. It has been mapped from Jermyn in Jack County through Young and Stephens counties to the border of the Cretaceous in Eastland County. In the northern Pennsylvanian area its thickness is about 150 to 200 feet (46 to 61 meters), in the southern, 100 to 125 feet (31 to 38 meters) (Moore 1922).

Thrifty Formation units listed in order from oldest to youngest are the Avis Sandstone, Ivan Limestone, Blach Ranch Limestone, and Breckenridge Limestone. Interspersed between these limestone sequences are numerous unnamed sandstone and mudstone units. The Avis Sandstone and many of the unnamed sandstone units provide small quantities of potable ground water to wells in northwest Jack County. Origin and stratigraphy of the sandstone units are similar to that of the Graham Formation (Nordstrom 1988).

### **Graham Formation**

The older or lower members of the Graham are present only in the north, pinching out southward and being overlapped by the younger or higher members. The formation is distinguished from the underlying beds by its very clastic character and thinner limestones, and from succeeding beds by its prolific and characteristic fauna (Moore 1922). Units making up the Graham Formation, listed in order from oldest to youngest, are the Finis Shale, Gonzales Creek Member, Bunger Limestone, Necessity Shale, Gunsight Limestone, and Wayland Shale. Water-bearing sandstone units within the Gonzales Creek Member constitute the major source of potable ground water in the Graham Formation. Numerous other unnamed sandstone beds occurring between major limestone sequences also provide a source of groundwater to domestic and livestock wells (Nordstrom 1988).

The Graham Formation forms the base of the Cisco Group and is overlain by the Thrifty Formation. Thicknesses of sandstone units vary considerably, due to the discontinuous nature of the beds. Sandstone origins are from two depositional systems fluvial and deltaic. Fluvial system units consist of braided facies of medium-to-coarse grained sandstones and conglomerate with cross-beds, chert pebbles, and little mud; meander belts of siltstone and fine-grained sandstones; distributary-channel fill of fine to medium grained sandstone; and valley fill fluvial of upward fining beds from coarse gravel to medium-grained sandstone with trough cross beds. Typical deltaic system facies in the Cisco Group are similar to those described in Canyon Group sequences. Bar-finger sandstones consisting of delta front, channel-mouth-bar, and distributary-channel facies are common, interspersed with mudstones of prodelta and inter-distributary origin (Nordstrom 1988).

### **Canyon Group**

The Pennsylvanian-age Canyon Group is located stratigraphically below the Cisco. The Canyon Group outcrops west and north of the Llano Uplift in Brown and McCulloch Counties, and, as with the Cisco, rapidly dips into the subsurface, occurring at depths of 3,000 feet (914 meters) within 50 miles (81 km) of the outcrop, and much greater depths throughout the rest of the study

area. Porosities of the thick limestone beds in the Canyon range from 5 to 25 percent, and the porosity of the reef facies may be as high as thirty percent locally. Permeabilities range from 1 to over 500 millidarcies (Core Laboratories, 1972).

The Canyon group includes the beds formed after the deposition of the coarse sandstones, conglomerates, shales, and coal of Strawn time, when the land to the east had been worn low, the accumulating sediments forming a series of thick limestones and fine calcareous clays, with only a few lenses of sandstone. The areal extent of the Canyon Group in Jack County occupies the southeastern half of the county except in those areas overlain by Cretaceous sediments of the Trinity Group. Groundwater is primarily obtained from the sandstone units located between major limestone sequences. Major sandstone units are found within the Palo Pinto Formation, Wolf Mountain Shale, Placid Shale, and Colony Creek Shale (Nordstrom 1988).

Groundwater occurs primarily within the sandstone units of the Canyon Group. It exists under water-table conditions along the outcrop and under artesian conditions down dip, where confining beds of limestone and shale overlie the aquifer. Groundwater flow is to the northwest and, locally, away from groundwater highs and toward the surface drainage system (Nordstrom 1988).

The Canyon provides some fresh but mostly slightly- to moderately-saline (1000 to 10,000 mg/L) water to wells that are less than 400 feet (122 meters) deep in and near the outcrop area. In down dip areas, limited quality data from Canyon produced water suggests a wide range of salinity, ranging from less than 10,000 mg/L to greater than 200,000 mg/L. As with other deeper, hydrocarbon-producing formations, the salinity of formation water may be more variable on a regional basis than the contours. Because the Canyon produces groundwater with relatively low salinities where the aquifer is found at depths of less than 5,000 feet (1524 meters), it may be a potential source of saline water (LBG-Guyton, 2004).

### **Colony Creek Formation**

Units of the Colony Creek Shale containing potable water consist primarily of fine-grained sandstone of delta-destructive, delta front, and distributary channel origin; and coarse-grained sandstone and conglomerate of fluvial channel origin. The predominant sequence could be summed up as fine grained deltaic sandstone units overlying and flanking sandy prodelta and interdeltic mudstone facies (Erxleben, 1975). As with the previous formations, emphasis is placed on the sandstone aquifer facies (Nordstrom 1988).

### **Palo Pinto Formation**

The Palo Pinto limestone is a thick, crystalline, dark gray rock made up typically of beds 2 to 6 inches in thickness and having a total thickness of 50 to 100 feet (15 to 30 meters). It forms a prominent escarpment across Palo Pinto County and has been traced for a long distance in the Brazos Valley. It has not, however, been identified south of the Cretaceous overlap in Eastland County which separates the Pennsylvanian outcrops. The chief distinguishing feature of the fossils which have been found in the Palo Pinto Formation is their very robust size, many species being represented by individuals more than twice the normal size (Moore 1922).

The Palo Pinto Formation dips northwestward and in general does not yield large quantities of fresh water to wells. The Palo Pinto Limestone is the only formation of the Canyon Group that crops out in Parker County's extreme northwest corner of the county but does not yield water to wells (Stramel 1951).

## **Strawn Group**

The Strawn group includes all the strata between the top of the Smithwick shale and the base of the Palo Pinto limestone in the Brazos River Valley or its stratigraphic equivalent in the Colorado River Valley. The rocks of this group are distinguished chiefly by their clastic character, especially the thickness of coarse sandstones, and by their irregularity in bedding. The two main areas of Strawn outcrop, one in the valley of Colorado River and the other in the valley of the Brazos, are broadly similar, but it has not been possible to identify divisions of the one in the other. The entire section of the Strawn is observable along Colorado River, but in the Brazos Valley a considerable thickness of beds belonging to the lower portion of the Strawn are not exposed on account of the Cretaceous overlap from the east (Moore 1922).

In the Brazos River Valley two main divisions of the Strawn have been identified, the Millsap Formation below and the Mineral Wells Formation above. Only the upper portion of the Millsap Formation is exposed at the surface, outcrops being found in the eastern part of the Strawn area near Millsap and along Brazos River in southwestern Parker County. The limestones which appear in this part of the section are quite unlike any beds observed in the Mineral Wells Formation (Moore 1922).

The Strawn Group, located stratigraphically below the Canyon, is a Pennsylvanian unit found throughout the study area, and includes the Lone Camp, Millsap Lake, and Kickapoo Creek Formations. The Strawn Group outcrops in a very wide area immediately north of the Llano Uplift, including the extreme western portions of McCulloch and Brown Counties. As with the other Pennsylvanian units, the Strawn rapidly dips into the subsurface away from the Llano Uplift, occurring at significant depths throughout much of the study area. Only in the easternmost counties in the planning area does the Strawn occur at depths of less than 5,000 feet. The Strawn Group consists of sandstones, shales, conglomerates, and limestones, and due to the variations in rock types, porosities and permeabilities are highly variable, with porosity ranges of 5 to 20 percent and permeability ranges of 5 to over 500 millidarcies (Core Laboratories, 1972). The Strawn is a significant hydrocarbon-producing formation, and quality data of produced water is available from this unit in its western extent. Produced formation water in the western extent of the Strawn is highly saline, with TDS concentrations of over 200,000 mg/L being common. A trend toward lower salinity (<50,000 mg/L) occurs in the aquifer's southeasterly extent (LBG-Guyton 2004).

## **Mineral Wells Formation**

The Mineral Wells Formation, part of the Pennsylvanian Strawn Group, consists of shale with inter-bedded sandstone and limestone. Sandstone and limestone members are the Hog Mountain Sandstone, informal sandstone unit 1, the Village Bend Limestone, Lake Pinto Sandstone, Dog Bend Limestone, informal sandstone unit 2 (Devils Hollow Sandstone), and the Turkey Creek Sandstone (Fisher 1996).

The Mineral Wells formation includes the sandstones and shales of the upper part of the Strawn in the Brazos River Valley above the Thurber coal. It is very well exposed in the vicinity of Mineral Wells and along Brazos River, its outcrop extending in a belt 10 to 15 miles wide from Erath to Jack and Wise counties. Four prominent sandstone members produce prominent escarpments which are the chief topographic features of the region. The shales are sandy and are at least in part very fossiliferous (Moore 1922). Shale portions of the Mineral Wells Formation vary from thin-bedded and fissile to blocky and show a range of greenish, bluish, reddish, and

yellowish-gray colors. The Hog Mountain Sandstone is the basal member of the Mineral Wells Formation and is about 25 ft. thick. Informal sandstone unit 1 is about 25ft above the Hog Mountain Sandstone and is conglomeratic. Village Bend Limestone is 10ft thick and is finely crystalline and weathers medium light gray to yellowish gray. The Lake Pinto Sandstone is about 50ft thick and is a medium-to fine-grained sandy shale that is pale grayish brown to reddish brown. The Dog Bend Sandstone is an algal wackestone to mudstone that is finely crystalline, locally sandy, and up to 5 ft thick (Fisher 1996).

Waters from the Mineral Wells formation are predominantly sodium bicarbonates in composition. Waters from the Strawn Group are mostly calcium bicarbonate in composition. The Texas Water Development Board (TWDB) does not consider the Mineral Wells or Strawn group to be a major source of groundwater (Fisher 1996).

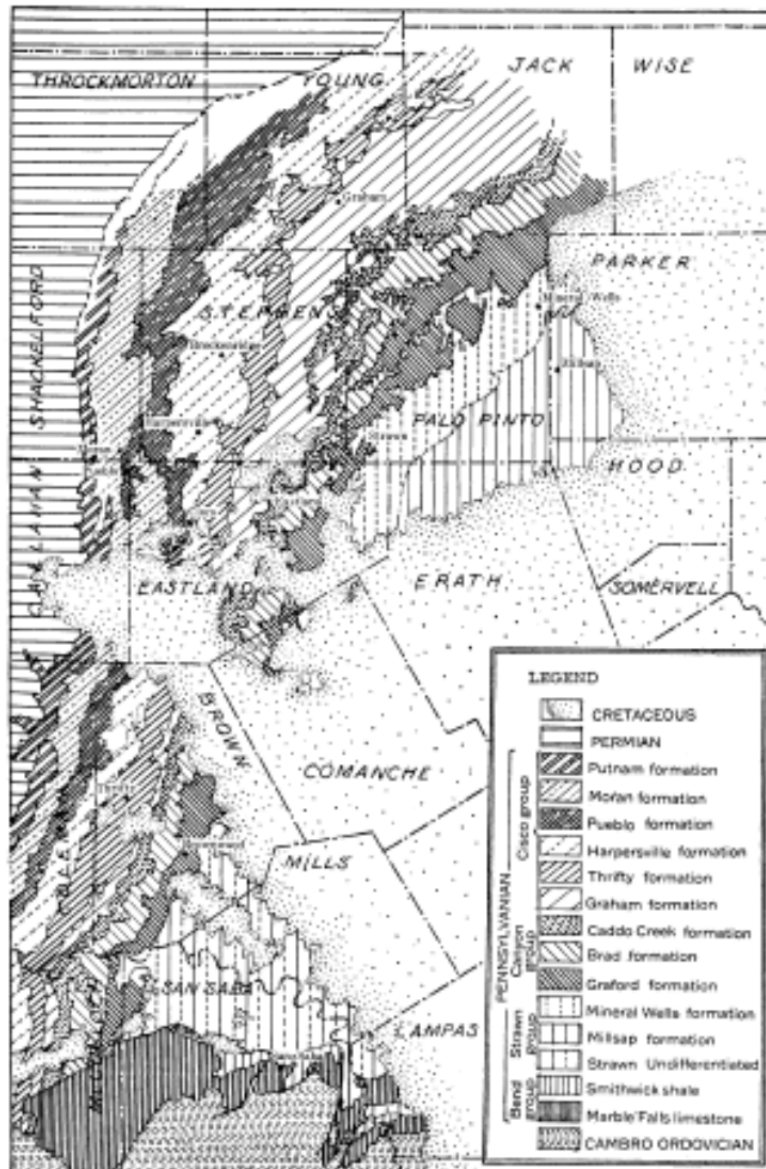


Figure 6. Outcrops of Pennsylvanian formations in north central Texas (Moore 1922)

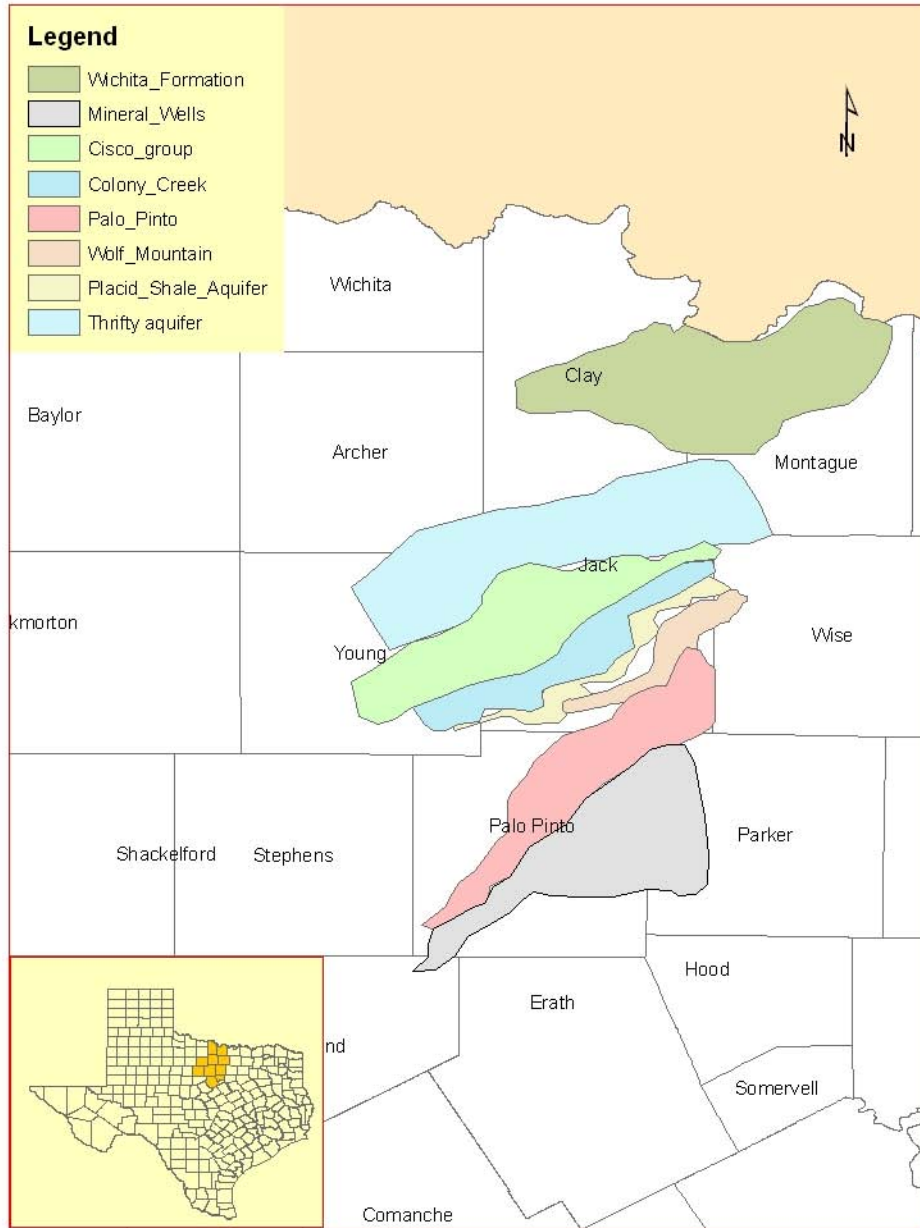


Figure 7. Minor Aquifers in Tier I & II

#### IV. Methods

##### a. Aquifer Data Analysis

##### i. Hydraulic Properties

The compilation of well depth, pumping rate, specific-capacity, and transmissivity for the minor aquifers in the study area included publically available data from the following sources: (1) Driller reports in the form of Access databases from the Texas Water Development Board (TWDB); and (2) Texas Public Water Supply (PWS) database from Texas Commission on Environmental Quality (TCEQ).

The TWDB groundwater database contains approximately 105,000 water quality samples from about 55,000 unique locations across the state. The well drawdown test data from the drilling reports including pumping rates, pump time and resulting drawdown were used to determine specific-capacity and transmissivity using standard Theis (1935) methods. Well drillers normally conduct a well performance test after completing drilling to determine specific-capacity. This test involves pumping the well at a constant rate for a period of time and the amount of drawdown is noted. Specific capacity,  $S_c$ , is then defined as the pumping rate,  $Q$ , divided by the amount of drawdown,  $s$  (Equation 1):

$$S_c = Q / s \quad \text{Eqn. 1}$$

Specific capacity is generally reported as discharge per unit of drawdown. For example, a well pumped at 100 gallons per minute (gpm) with 20 ft of drawdown would have specific capacity of 5 gpm/ft (Mace 1999). There is an analytical relationship between specific-capacity and transmissivity, so the specific-capacity data was used to estimate transmissivity based on the Theis (1935) nonequilibrium equation:

$$S_c = \frac{4\pi T}{\left[ \ln \left( \frac{2.25 T t_p}{r_w^2 S} \right) \right]} \quad \text{Eqn. 2}$$

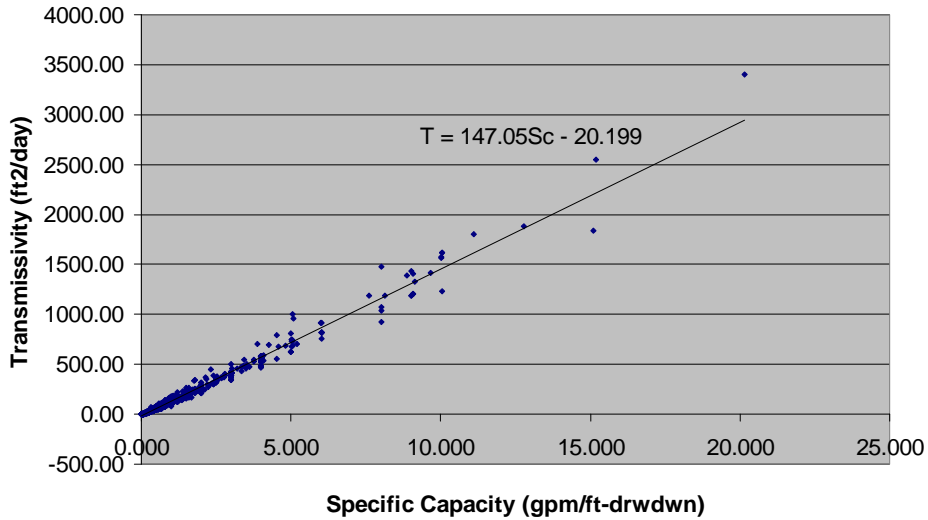
where  $S$  is the storativity of the aquifer,  $t_p$  is the time of production (that is, pumping) when the drawdown was measured, and  $r_w$  is the radius of the well in the screened interval. This equation assumes (1) a fully-penetrating well; (2) a homogeneous, isotropic porous media; (3) negligible well loss; (4) and an effective radius equal to the radius of the production well (Walton, 1970). The above equation cannot be explicitly solved for transmissivity, it must be solved graphically or iteratively (Mace 1999). Equation 2 was rearranged to solve for transmissivity using Equation 3 where an initial guess for  $T$  was used on the right-hand side of the equation and a plausible value of  $S$  was used.

$$T = S_c / 4\pi [\ln(2.25 T t_p) - \ln(r_w^2 S)] \quad \text{Eqn.3}$$

The database of wells in area of the minor aquifers included 2084 total wells with complete well performance data sets. General characteristics of the wells analyzed include: a mean depth of 118.5 feet with a range of 28.9 and 498.7 feet and a 50<sup>th</sup> percentile depth of 90 feet; a mean well diameter of 4.3 inches with a 50<sup>th</sup> percentile of 4.0 inches; and mean pumping rate of 21.9 gallons per minute (gpm) with a 50<sup>th</sup> percentile of 20 gpm; and a mean drawdown of 46.5 ft with a 50<sup>th</sup> percentile of 20 feet.

The specific capacity and related transmissivity for all wells appear log-normally distributed and have direct relationship as observed in the graph of specific capacity plotted against transmissivity. A best fit line using least square regression gives a relationship of  $T = 147 S_c - 20.2$  with a correlation coefficient,  $R^2$  of 0.98. Therefore, the relationship has a 98% prediction interval, which means an estimate of transmissivity from specific capacity has a confidence factor of 98%.

### Specific Capacity vs Transmissivity



The specific capacity ranges from 0.1 to 5 gpm/ft-drawdown with a mean of 1.05 gpm/ft and a 50<sup>th</sup> percentile of 0.7 gpm/ft. Transmissivity ranges from 4 to 420 ft<sup>2</sup>/day with a mean of 133 ft<sup>2</sup>/day and a 50<sup>th</sup> percentile of 80 ft<sup>2</sup>/day.

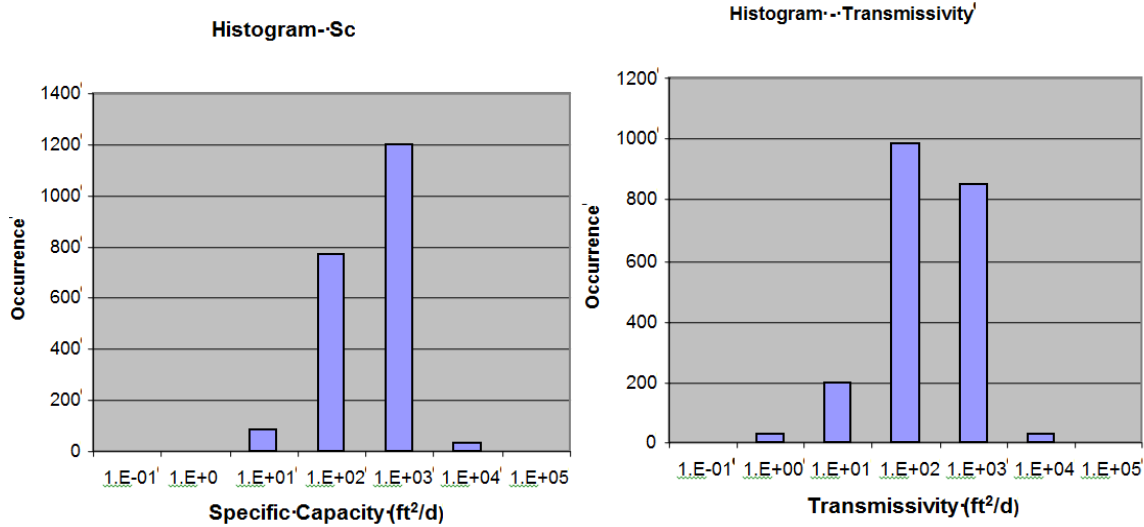


Figure 9. Histograms for specific capacity and transmissivity

The minor aquifers of the study area located primarily in the western counties of Montague, Jack, Palo Pinto, Wise and Parker. Well depths range mostly between 30 and 500 feet (9 and 152 meters) below land surface. Yields from wells are variable, ranging from less than 5 to over 60 gpm, well below the industry requirement of 100 gpm requiring the use of multiple wells. The specific capacity of the minor aquifers range mostly between 0.10 and 5.0 gpm/ft-drawdown, which indicates significant drawdown of the minor aquifers will be required to achieve the 100 gpm pumping rate required by the hydraulic fracturing industry. To establish a pump rate of 100 gpm, the drawdown would expect to range between 20 feet and 1000 feet (6 and 305 meters). Groundwater quality in the minor aquifers generally contains between 300 and 3800 mg/L TDS,

well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 220 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding.

Rank	Well Depth (ft)	Well Diameter (in.)	Pumping Rate (gpm)	Drawdown (ft)	Pump Test Time (hr)	Specific Capacity (gpm/ft drawdown)	Specific Capacity (ft <sup>2</sup> /day)	Transmissivity (ft <sup>2</sup> /day)
95th percentile	498.65	6	60.0	170	5	3.01	578.73	421.2
70th percentile	245	4.5	25.0	50	1	1.20	231.19	149.4
50th percentile	190	4	20.0	20	1	0.67	128.61	80.5
30th percentile	112.7	4	18.0	12	1	0.33	64.26	35.8
5th percentile	28.9	4	4.6	5	0.5	0.06	11.10	4.1
Min	12	2	0.3	1	0.25	0.01	1.60	0.2
Max	1010	12	200.0	370	41	20.16	3881.08	3400.3
Mean	118.5	4.3	21.9	46.5	2.1	1.05	201.30	133.6
Industry Requirements			> 100	< 350	< 8			

Table 1. Well data percentile distribution, range and mean.

As the minor aquifers in the western counties (Montague, Jack, Palo Pinto, Wise and Parker) were not identified by aquifer in the driller reports from the TWDB database, the well data was mapped in GIS using the 5-digit zip codes provided for each well. Using the zip code data provides greater resolution of the well data in GIS. The following four GIS maps of Montague, Jack, Palo Pinto, Wise and Parker counties, illustrate the distribution of well characteristics across county borders.

The map of well depth illustrates that the deeper wells are along the eastern side of the study area and north towards the Red River valley. Corresponding to the well depth, the pumping rates are also higher along the eastern side of the study area and north into Montague County. Specific conductivity and the directly related transmissivity are highest on in the eastern half of the study area and decline as you move west.

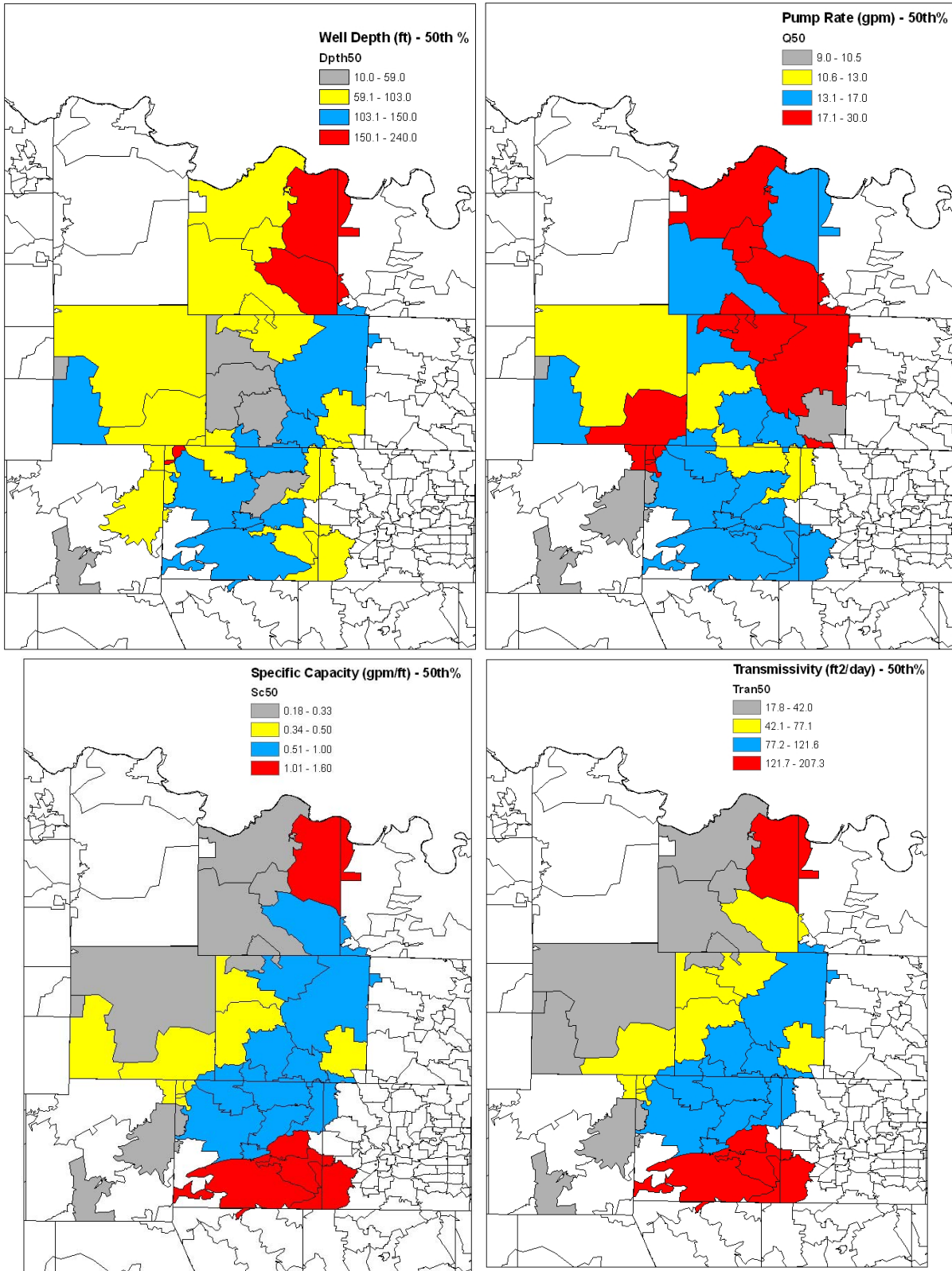


Figure 10. Depth, pump rate, specific capacity, and transmissivity by zip code for minor aquifers

ii. Water Quality

Chemical data were compiled from the TWDB’s electronic Microsoft Access database of wells installed after February 5, 2001 from the Texas Water Development Board Submitted Driller’s Report Database (Texas Water Development Board 2011). TWDB well data are submitted by drilling companies via the online Texas Well Report Submission and Retrieval System (Texas Department of Licensing and Regulation 2011).

Well data were collected on the concentration (in milliequivalents per liter) for all major cations and anions as well as the water’s total dissolved solids (TDS) and pH. This water chemistry data was analyzed using a Durov plot. Groundwater salinity in the minor aquifers generally ranges between 300 and 3800 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 220 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding.

When plotting all the minor aquifers together on a Durov plot most of the aquifers demonstrated similar water chemistry. The Durov plot showed the groundwater in the minor aquifers is predominately composed of bicarbonate and chloride anions, sodium and calcium cations, and low concentrations of dissolved solids and a pH range of 7 to 9.

Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Specific Conductivity
95th percentile	749	593	1700	221	8.8	3796	638	7823
70th percentile	518	151.3	235	78	8.3	1170	435	2183
50th percentile	425	78.5	120	35	8.1	758	357	1403
30th percentile	353	45	52	7	7.7	545	296	987
5th percentile	213	15	14	2	7.2	334	182	585
Min	39	4	4	1	6.3	108	40	178
Max	2026	4530	9572	920	11.5	14189	1660	34500
Industry Requirements			< 10,000	< 350	< 8	< 20,000		

Table 2. Summary of relevant information on Paleozoic aquifer water quality

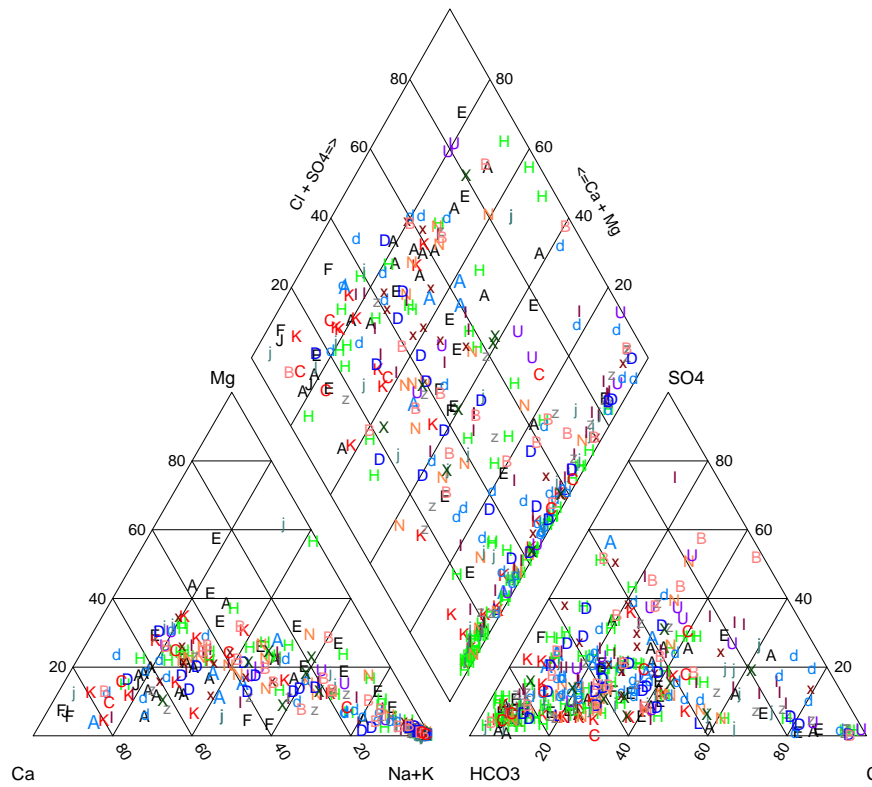
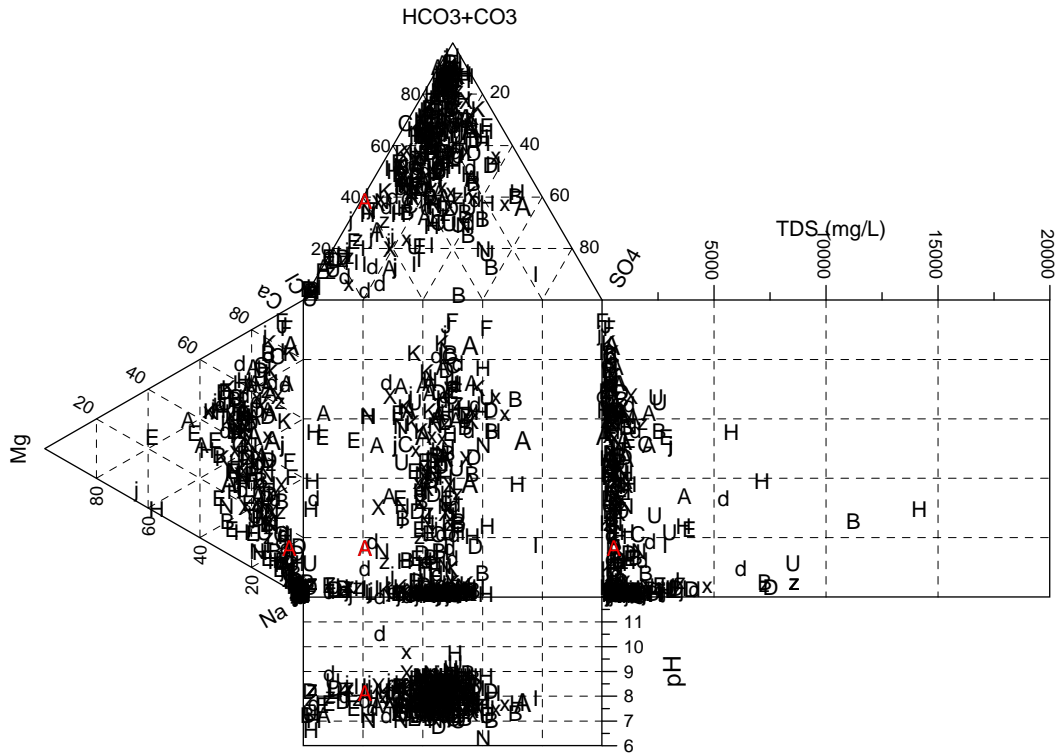


Figure 11. Chemical characteristics of all minor aquifers of the study area

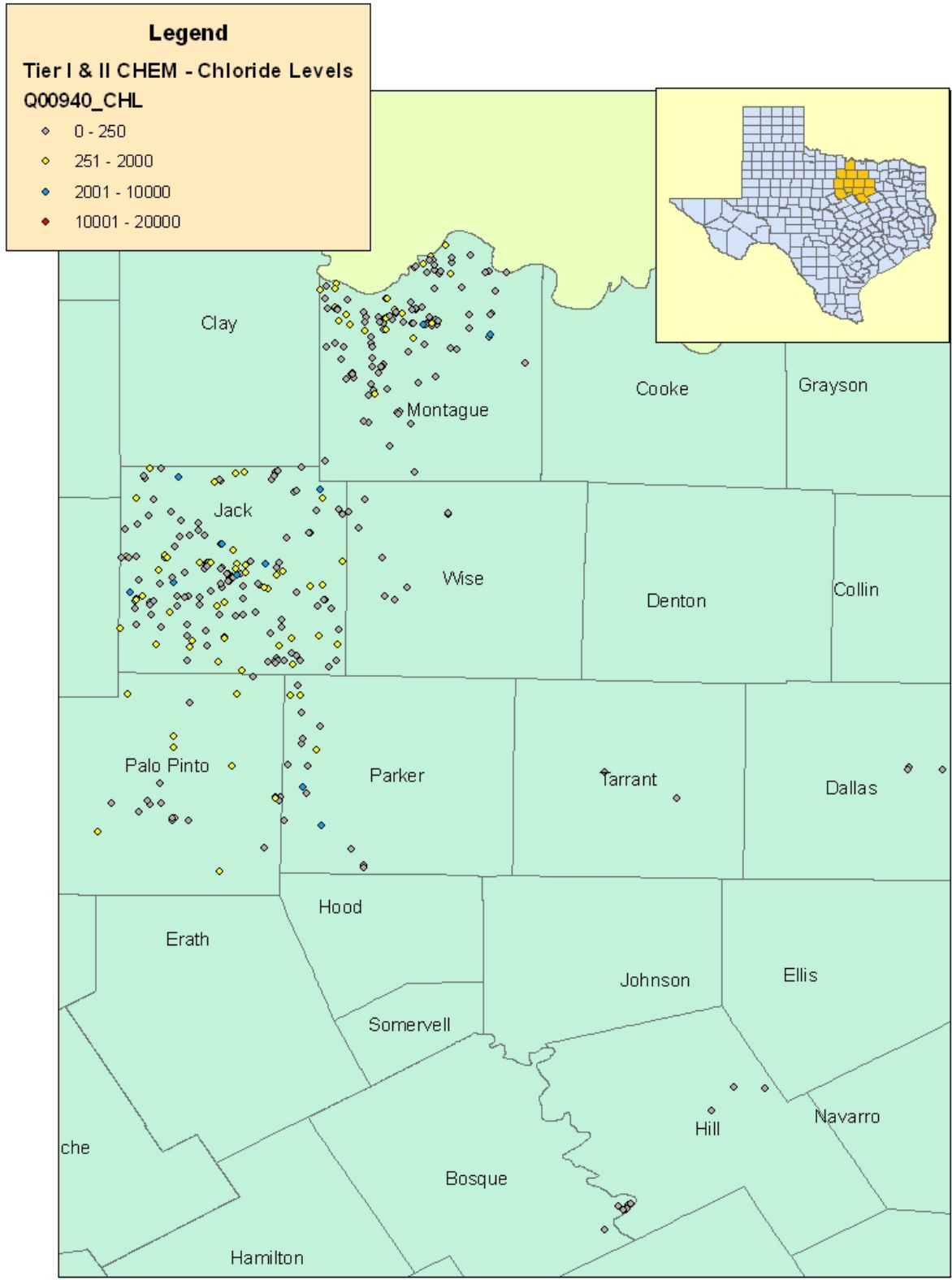
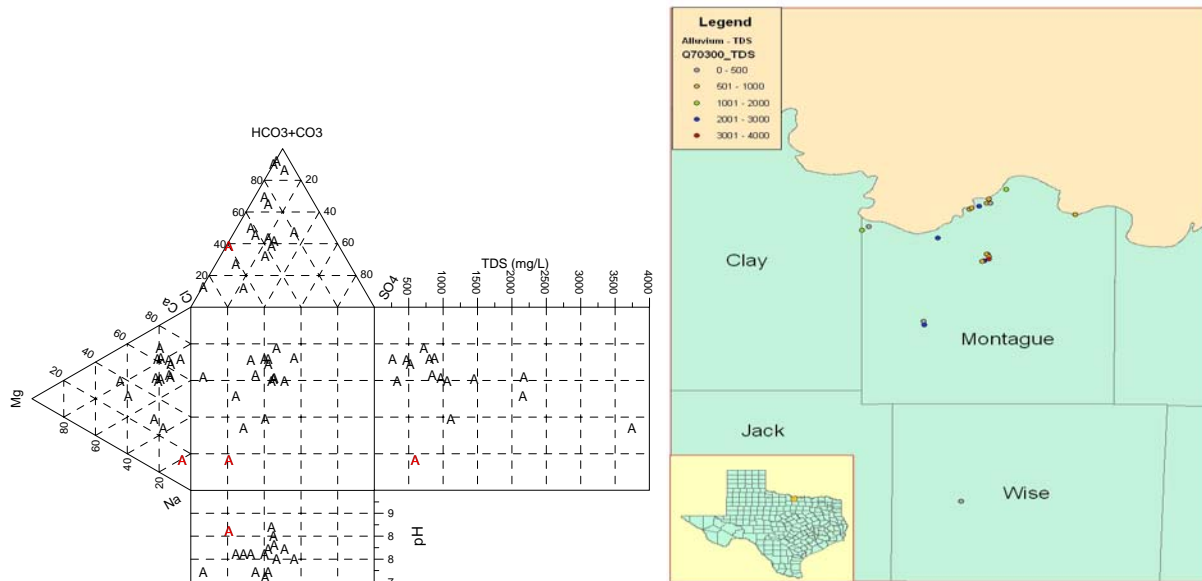


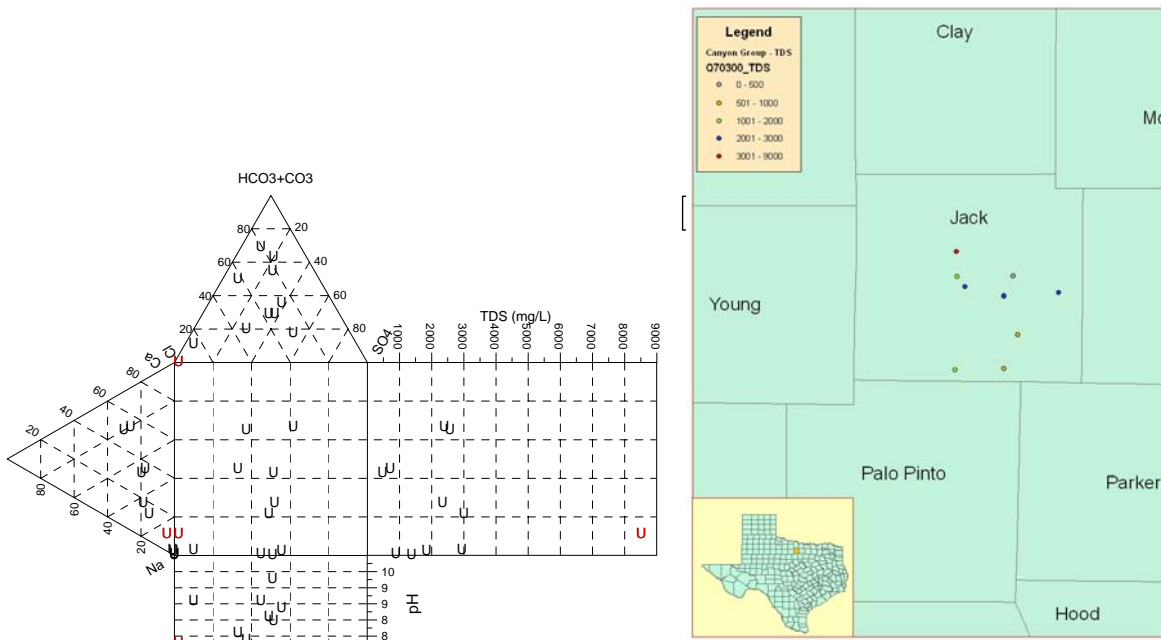
Figure 12. Chloride levels in water wells

The Alluvium aquifers in the region are generally is located in northern border of Montague County along the Red river and its tributaries. Well depths are generally shallow ranging mostly between 20 and 200 feet below land surface. Groundwater quality in the Alluvium aquifers are generally good containing between 300 and 3000 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 260 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 8 and 7, which is outside the industry requirement of less than 8 for waterflooding.. The Durov plot shows that the alluvium groundwater is predominately composed of bicarbonate and chloride anions, and sodium and calcium cations. The pH levels of the alluvium ground water are grouped primarily around 8 but ranges from 7 to 9. The concentrations of dissolved solids are loosely cluttered and ranges from 200 to 2000 mg/L.



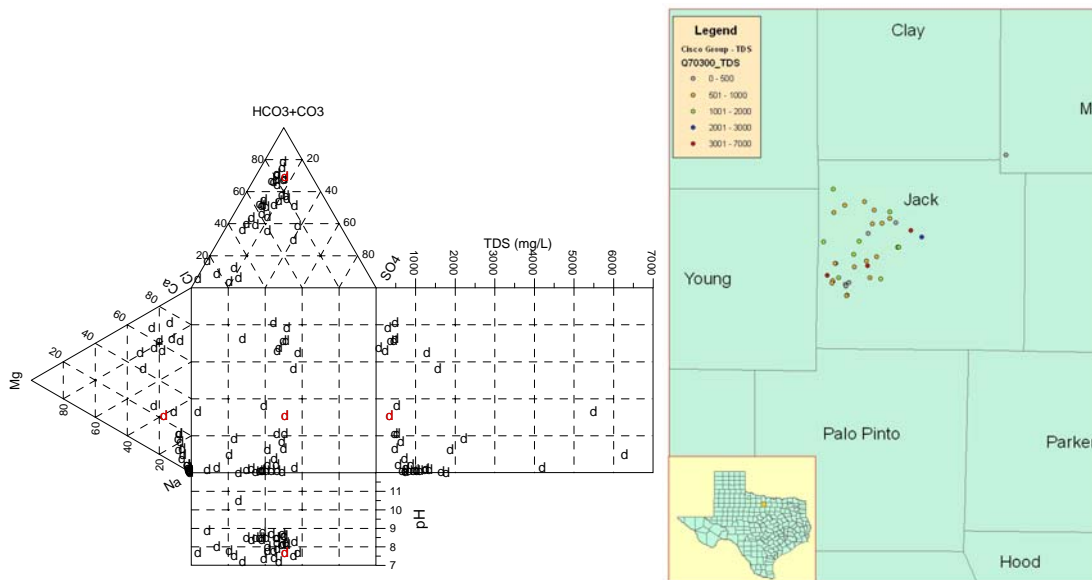
Alluvium									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	891	257	1285	256	8	2824	730	6383	183
70th percentile	464	132	230	153	8	1131	380	2145	61
50th percentile	405	49	157	104	8	820	332	1460	52
30th percentile	336	28	86	59	8	627	275	1175	34
5th percentile	242	13	16	18	7	318	199	579	22
Min	222	12	11	2	7	247	182	434	19
Max	2026	960	1770	443	9	3998	1660	7790	212
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Canyon Group aquifer is located in the eastern part of Jack County. Well depths range mostly between 50 and 600 feet below land surface. Groundwater quality in the Canyon Group generally contains between 500 and 5000 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 10 and 400 mg/L with 70 percentile below 140 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Canyon Group groundwater is not well grouped with respect to sulfate, bicarbonate and chloride anions, but sodium and calcium are the predominate cations. The pH levels of the Canyon Group groundwater are loosely clustered and range from 7 to 10. The concentrations of dissolved solids are also not well grouped and ranges from 300 to 3000 mg/L.



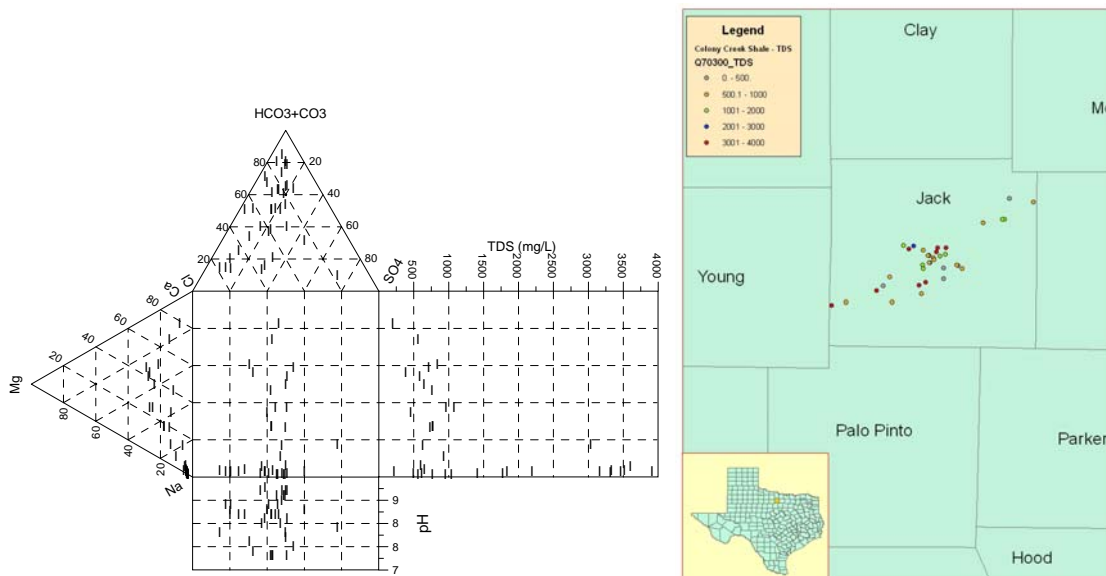
Canyon Group									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th perc.	786	899	3305	423	9	5745	728	11856	638
70th perc.	642	526	610	142	8	2559	540	4867	320
50th perc.	428	225	415	92	8	2331	351	3500	280
30th perc.	395	95	192	27	7	1365	324	2512	105
5th perc.	185	59	79	3	7	583	152	1161	53
Min	51	47	50	3	7	462	42	882	46
Max	886	990	5107	431	9	8502	730	17808	690
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Cisco Group aquifer is located in the western part of Jack County. Well depths range mostly between 70 and 500 feet below land surface. Groundwater quality in the Cisco Group generally contains between 300 and 4500 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 1 and 225 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Cisco Group groundwater is predominately bicarbonates and chloride anions and sodium and calcium cations. The pH levels of the Canyon Group groundwater are concentrated around 8 with a range from 7 to 9. The concentrations of dissolved solids are primarily grouped at less than 1000 mg/L with a range from 100 to 2000 mg/L.



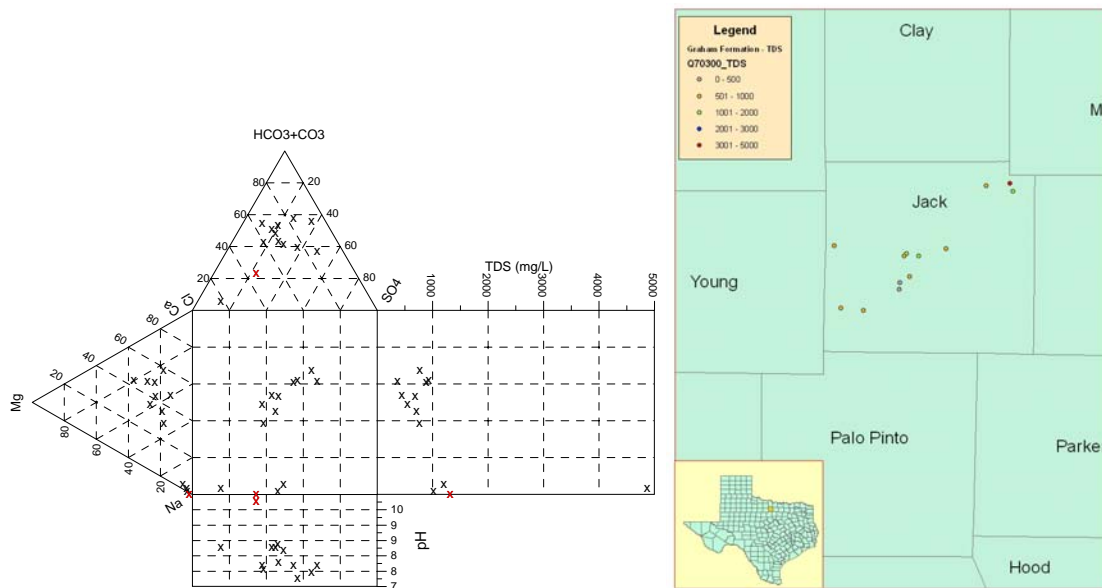
Cisco Group									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	643	462	2230	224	9	4492	534	9324	500
70th percentile	505	141	285	56	9	1270	454	2384	280
50th percentile	403	94	164	19	8	788	337	1413	205
30th percentile	321	67	71	6	8	561	295	1004	143
5th percentile	77	25	29	1	7	320	160	592	70
Min	39	7	13	1	7	108	40	178	70
Max	696	991	3192	556	12	6310	574	13104	515
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Colony Creek aquifer is located in Jack County running along a diagonal line from the northeast to the southwest. Well depths range mostly between 90 and 400 feet below land surface. Groundwater quality in the Colony Creek generally contains between 400 and 3500 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 128 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Colony Creek Shale groundwater is predominately bicarbonates and chloride anions and sodium and calcium cations. The pH levels of the Colony Creek Shale groundwater are loosely clustered and generally well distributed within a range of 7 to 10. The concentrations of dissolved solids range between 200 and 4000 mg/L but are primarily below 1000 mg/L.



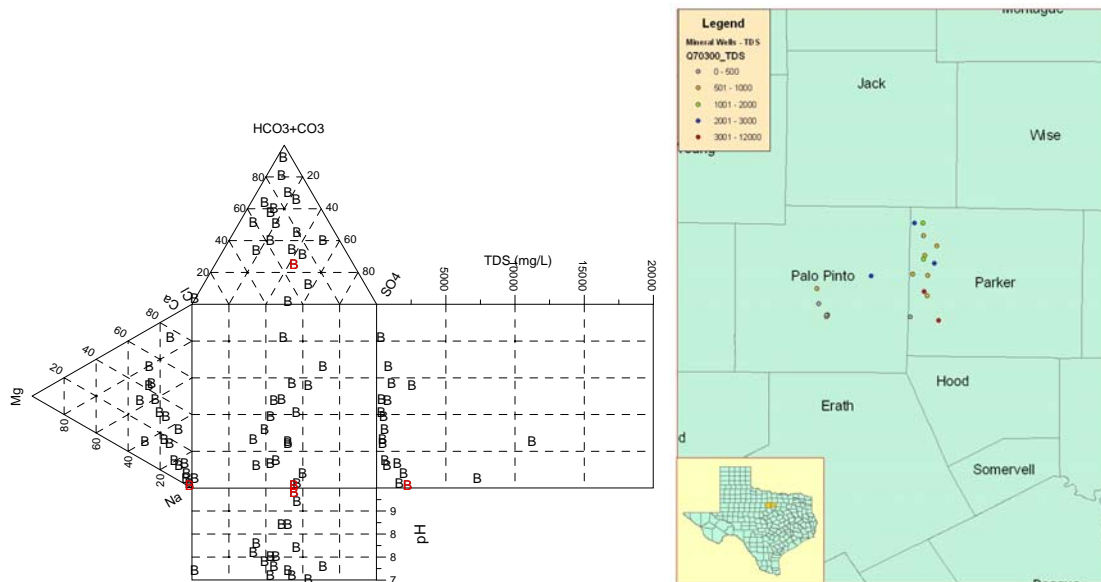
Colony Creek									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	694	933	1385	128	9	3585	582	7211	364
70th percentile	542	252	247	56	8	1539	461	2414	252
50th percentile	503	163	156	30	8	828	412	1606	211
30th percentile	444	74	73	14	8	697	364	1244	160
5th percentile	216	29	31	2	7	406	179	805	89
Min	168	12	26	2	7	253	138	480	70
Max	744	1691	1718	161	9	3968	610	8288	424
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Graham Formation is located in Jack County running along a diagonal line from the northeast to the southwest. Well depths range mostly between 20 and 300 feet below land surface. Groundwater quality in the Graham Formation generally contains between 400 and 2800 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 170 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Graham Formation groundwater has generally even concentrations of bicarbonate, sulfate and chloride anions and also even concentrations of sodium, calcium and magnesium cations. The pH levels of the Graham Formation groundwater are generally well distributed between 7 and 9. The concentrations of dissolved solids are primarily below 1000 mg/L.



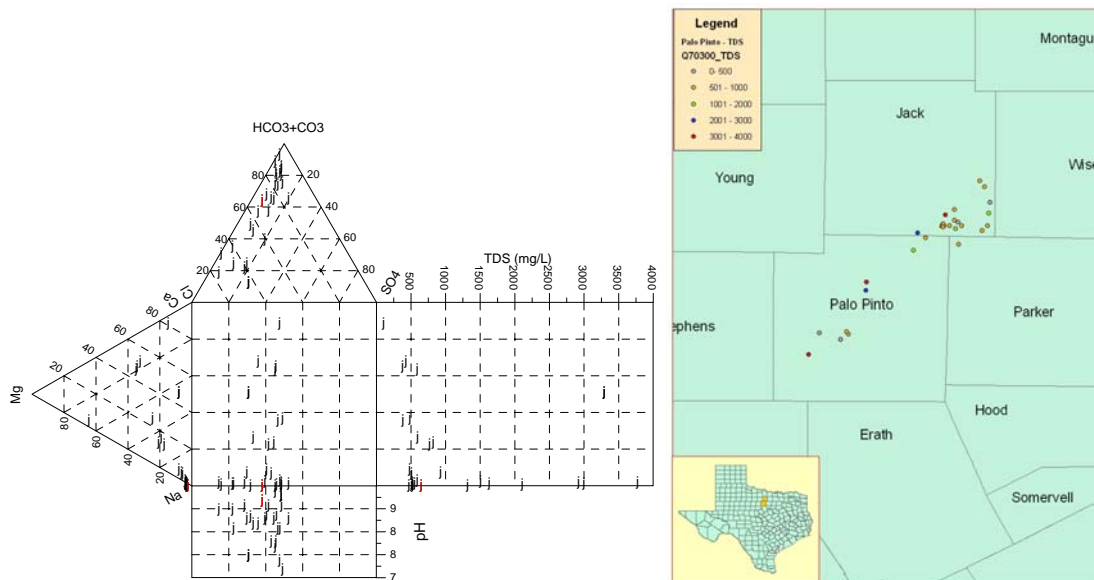
Graham Formation									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	592	408	1129	170	9	2789	490	5573	298
70th percentile	443	235	175	106	8	1017	410	1950	161
50th percentile	373	181	131	81	8	823	327	1595	120
30th percentile	323	150	110	61	8	753	282	1470	75
5th percentile	206	67	29	4	7	464	169	877	21
Min	150	60	29	2	7	418	123	780	20
Max	597	545	2337	170	10	4923	491	9856	360
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Mineral Wells aquifer is located in western Parker County and eastern Palo Pinto County. Well depths range mostly between 30 and 400 feet below land surface. Groundwater quality in the Mineral Wells aquifer generally contains between 400 and 8000 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 10 and 370 mg/L, with 70 percentile less than 100 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Mineral Wells groundwater is not well grouped but is primarily a combination of bicarbonates and chloride anions and sodium and calcium cations. The pH levels of the Mineral Wells groundwater is primarily less than 8 with a range of 7 to 10. The concentrations of dissolved solids range between 200 and 3000 mg/L.



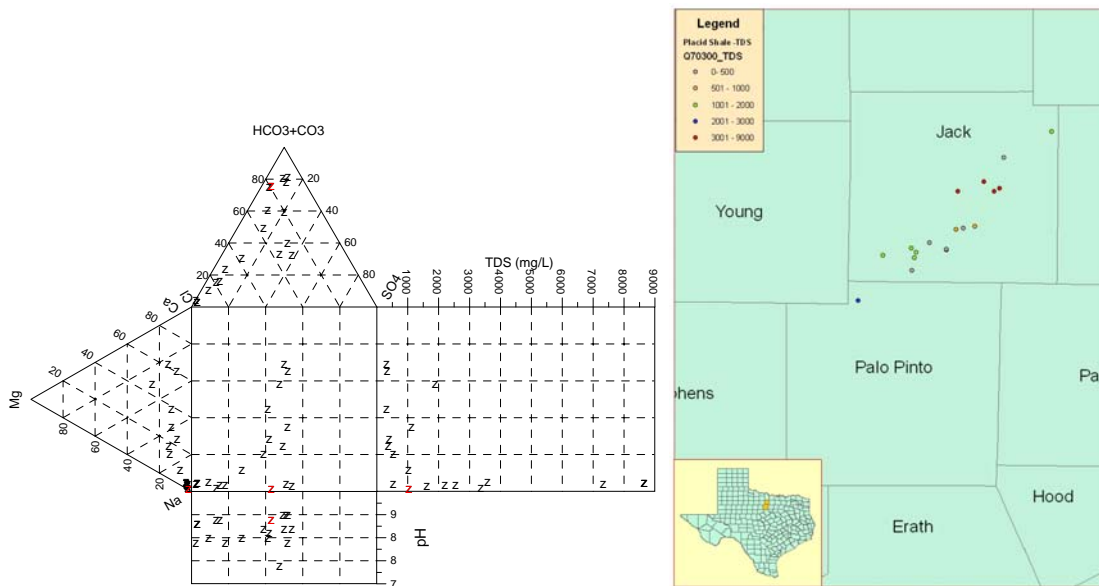
Mineral Wells									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	671	1443	3141	365	9	7749	550	12870	403
70th percentile	462	371	258	96	8	1668	378	2758	163
50th percentile	388	120	143	60	8	879	318	1490	103
30th percentile	335	76	111	38	7	625	274	1052	94
5th percentile	279	14	26	10	7	433	229	755	35
Min	156	5	11	6	7	411	128	742	30
Max	777	4530	4320	401	9	11303	637	14400	432
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Palo Pinto aquifer is located along a diagonal from southwest Jack County to southwest Palo Pinto County, primarily in Palo Pinto County. Well depths range mostly between 30 and 360 feet below land surface. Groundwater quality in the Palo Pinto aquifer generally contains between 400 and 3500 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 1 and 370 mg/L, with 70 percentile less than 50 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Palo Pinto groundwater is predominately bicarbonate and chloride anions and sodium and calcium cations. The pH levels of the Palo Pinto groundwater are concentrated around 9 and range from 7 to 10. The concentrations of dissolved solids are grouped around 500 mg/L with a range of 300 to 3000 mg/L.



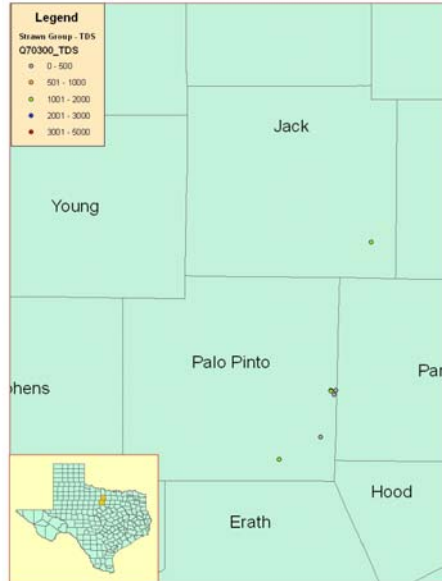
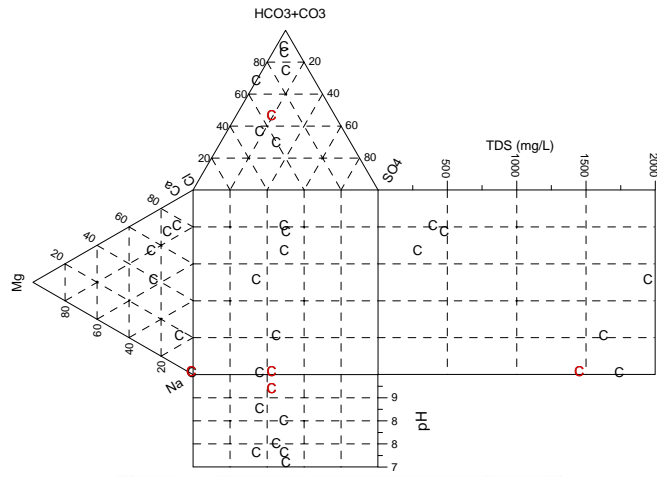
Palo Pinto Limestone									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	732	579	1154	362	9	3344	626	6642	357
70th percentile	573	100	334	44	8	1214	470	2094	252
50th percentile	477	57	104	12	8	643	415	1200	220
30th percentile	411	43	42	6	8	566	336	1033	173
5th percentile	274	15	23	1	7	435	224	846	35
Min	172	4	4	1	7	155	141	286	35
Max	790	664	1686	526	9	3825	647	7840	450
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Placid Shale aquifer is located primarily in Jack County running along a diagonal from the northeast of the county to the southwest. Well depths range mostly between 100 and 450 feet below land surface. Groundwater quality in the Placid Shale generally contains between 350 and 9000 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 4 and 130 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Placid Shale groundwater is predominately bicarbonate and chloride anions and sodium and calcium cations. The pH levels of the Placid Shale groundwater are concentrated around 8 and range from 7 to 9. The concentrations of dissolved solids are grouped around 500 mg/L with a range of 400 to 4000 mg/L.

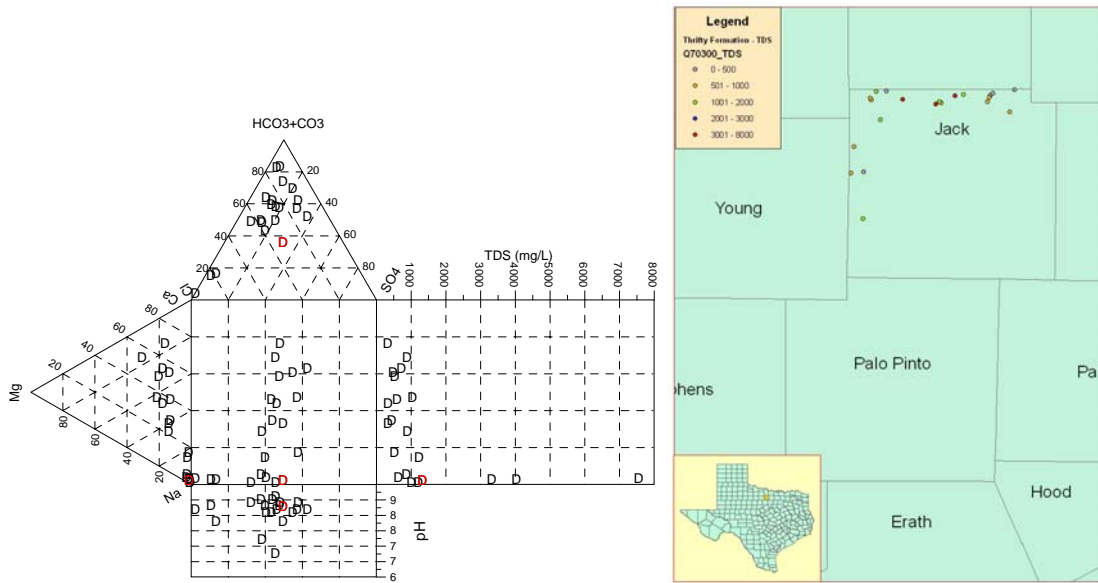


Placid Shale									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	671	497	5008	130	9	8715	552	17920	426
70th percentile	487	168	1253	85	8	2851	406	5738	243
50th percentile	373	127	326	45	8	1432	312	2688	219
30th percentile	332	61	102	27	8	588	280	1090	197
5th percentile	234	34	25	8	8	372	192	675	119
Min	226	21	15	4	7	365	185	665	100
Max	871	505	5008	310	9	8715	758	17920	544
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

(Strawn Group)

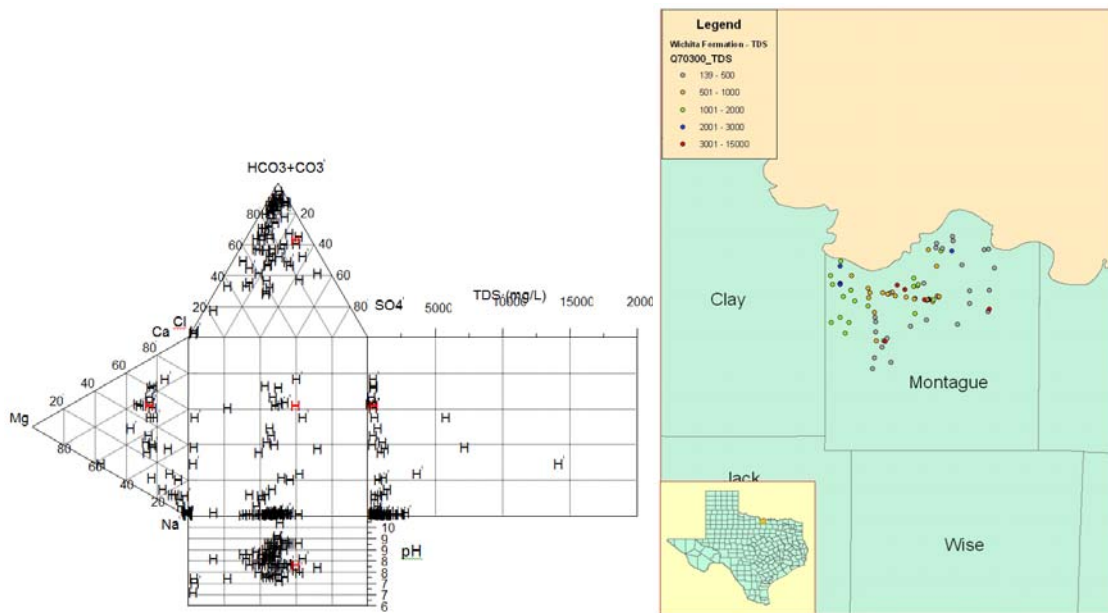


The Thrifty Formation is located along the northern and eastern border area of Jack County. Well depths range mostly between 100 and 300 feet below land surface. Groundwater quality in the Thrifty Formation generally contains between 300 and 4000 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 30 and 140 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Thrifty Formation groundwater is predominately bicarbonate and chloride anions and sodium and calcium cations. The pH levels of the Thrifty Formation groundwater are concentrated around 8.5 and range from 7 to 9. The concentrations of dissolved solids are grouped around 500 mg/L with a range of 300 to 1500 mg/L.



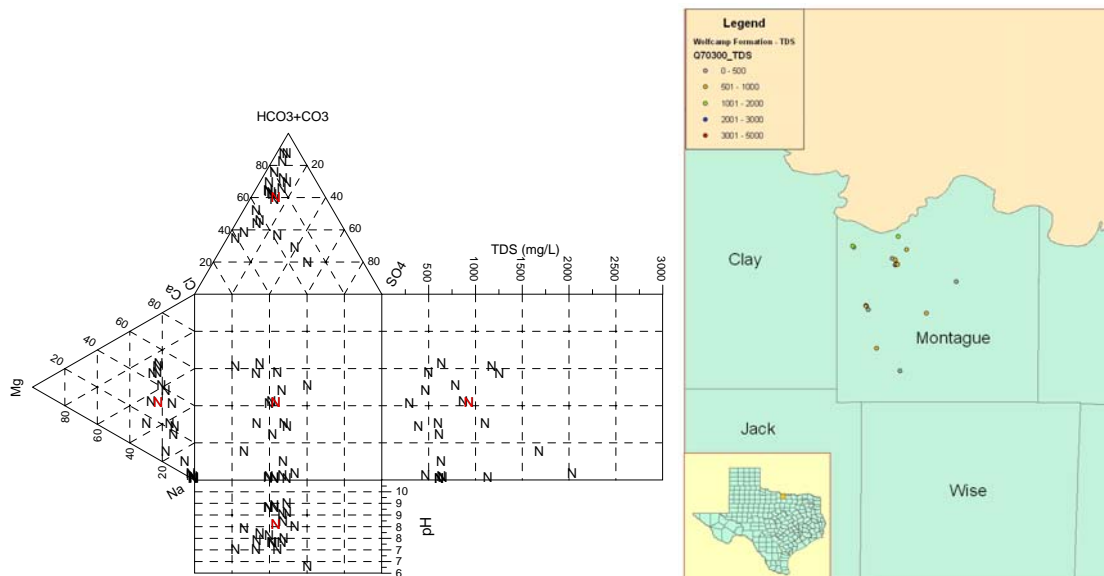
Thrifty Formation									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	644	257	1988	136	9	4034	528	8512	285
70th percentile	500	148	212	82	8	1046	410	2024	225
50th percentile	439	94	111	46	8	872	360	1424	200
30th percentile	334	67	69	29	8	530	276	1008	180
5th percentile	290	18	28	3	7	337	249	610	98
Min	266	16	21	3	7	327	218	608	60
Max	721	326	4424	171	9	7559	625	16240	358
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Wichita Formation is located in central and northwestern Montague County. Well depths range mostly between 70 and 500 feet below land surface. Groundwater quality in the Wichita Formation generally contains between 300 and 3300 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 2 and 100 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Wichita Formation groundwater is predominately bicarbonate and chloride anions while the cations are not well grouped relative to sodium, calcium and magnesium. The pH levels of the Wichita Formation groundwater are concentrated around 8.5 and range from 7 to 10.5. The concentrations of dissolved solids are grouped around 700 mg/L with a range of 300 to 3000 mg/L.



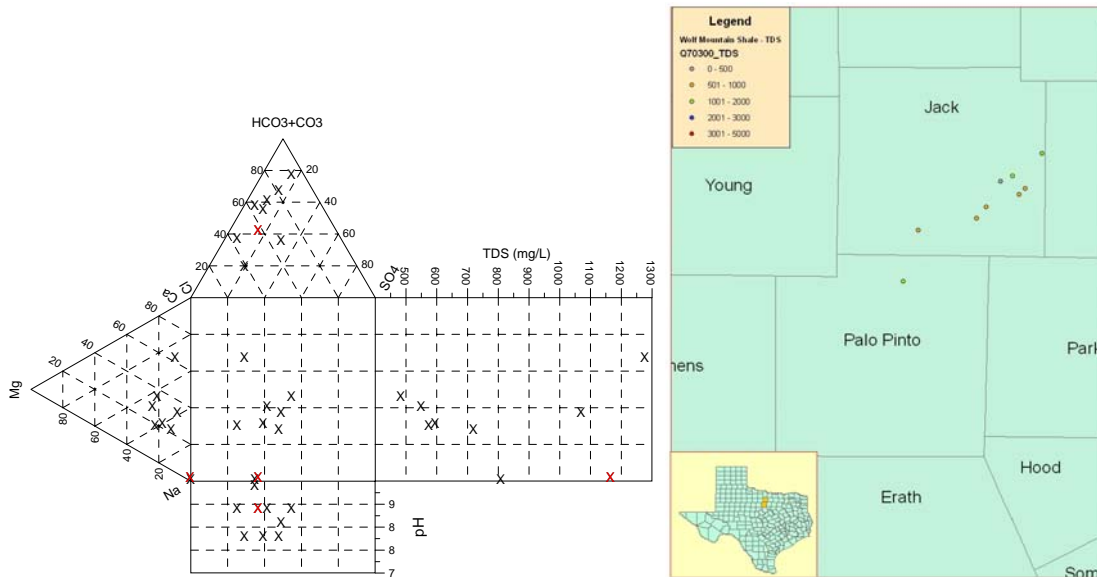
Wichita Formation									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	870	480	1347	107	9	3254	722	6664	485
70th percentile	539	134	214	25	8	1162	464	2156	247
50th percentile	460	55	84	4	8	712	392	1250	206
30th percentile	376	32	29	2	8	493	320	886	168
5th percentile	256	15	9	2	7	350	209	627	74
Min	61	8	5	1	7	139	50	245	21
Max	1391	1260	9572	920	10	14189	1140	34500	700
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Wolfcamp Formation is located in central and western Montague County. Well depths range mostly between 30 and 400 feet below land surface. Groundwater quality in the Wolfcamp Formation generally very good containing between 400 and 1700 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 1 and 210 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 7, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Wolfcamp Formation groundwater is predominately bicarbonate and chloride anions and sodium and calcium cations. The pH levels of the Wolfcamp Formation groundwater are concentrated around 8.5 and range from 6 to 9.5. The concentrations of dissolved solids are not well grouped and are evenly distributed between 300 and 1300 mg/L.



Wolfcamp Formation									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	694	290	461	206	9	1661	592	3334	355
70th percentile	561	99	164	74	8	915	481	1718	213
50th percentile	458	61	113	40	8	640	395	1192	162
30th percentile	409	43	69	15	7	614	338	1093	80
5th percentile	192	23	35	1	7	397	157	715	18
Min	144	14	25	1	6	298	118	540	18
Max	732	620	580	219	9	2035	600	3744	393
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

The Wolf Mountain Shale aquifer is located in the southeastern corner of Jack County. Well depths range mostly between 70 and 530 feet below land surface. Groundwater quality in the Wolf Mountain Shale generally very good containing between 500 and 1300 mg/L TDS, well under the industry waterflooding requirement of less than 20,000 mg/L TDS. Calcium levels generally range between 4 and 210 mg/L, well within the industry requirement of less than 350 mg/L. pH levels range between 9 and 8, which is outside the industry requirement of less than 8 for waterflooding. The Durov plot shows that the Wolf Mountain groundwater is predominately bicarbonate and chloride anions and sodium and calcium cations. The pH levels of the Wolf Mountain groundwater are concentrated around 8.5 and range from 8 to 10. The concentrations of dissolved solids are grouped around 550 mg/L with a range of 400 to 800 mg/L.



Wolf Mountain Shale									
Rank	Bicarb (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	pH	TDS	Alkalinity	Spec Cond	Well Depth (ft.)
95th percentile	510	238	402	212	9	1230	427	2493	529
70th percentile	445	117	211	58	8	963	381	1839	374
50th percentile	389	65	175	56	8	717	319	1296	175
30th percentile	366	53	111	42	8	580	302	1137	124
5th percentile	245	33	47	4	8	507	202	954	69
Min	234	31	22	3	8	481	194	872	45
Max	520	265	474	275	9	1274	428	2704	550
Industry Requirements			< 10,000	< 350	< 8	< 20,000			

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Aquifer	System	Series	Group	Rock Characteristics	Water Bearing Characteristics	County																
						Bosque	Dallas	Denton	Erath	Hill	Hood	Jack	Johnson	Montague	Palo Pinto	Parker	Somervell	Tarrant	Wise			
Edwards	Cretaceous	Comanche	Fredericksburg	hard fossiliferous limestone, reef material, shale, cherty and dolomite	Yields small to large amounts of water																	
Antlers	Cretaceous	Comanche	Trinity	fine to coarse grain sand with shale and streaks of limestone	Yields small to moderate amounts of water			X						X								X
Glen Rose	Cretaceous	Comanche	Trinity	limestone, shale and anhydrite	locally yields small amounts of usable water												X	X	X			
Hensell	Cretaceous	Comanche	Trinity	conglomerate, fine to coarse grained sands, sandstone, siltstone, sandy shale and limestone	Yields small to large amounts of water	X			X	X										X		
Hosston	Cretaceous	Comanche	Trinity	conglomerate, fine to coarse grained sands, sandstone, siltstone, sandy shale and limestone	Yields moderate to large amounts of water	X			X	X			X							X		
Paluxy	Cretaceous	Comanche	Trinity	fine to medium grain sands	Yields small to medium amounts of water	X	X	X	X	X	X		X					X	X	X	X	
Pearsall	Cretaceous	Comanche	Trinity	predominantly shale interbedded with sand	locally yields small amounts of water					X												
Travis peak	Cretaceous	Comanche	Trinity	calcareous sands and silts, conglomerates,				X		X			X				X	X	X			

Aquifer	System	Series	Group	Rock Characteristics	Water Bearing Characteristics	County															
						Bosque	Dallas	Denton	Erath	Hill	Hood	Jack	Johnson	Montague	Palo Pinto	Parker	Somervell	Tarrant	Wise		
				and limestones.																	
Twin Mountain	Cretaceous	Comanche	Trinity	medium- to coarse-grained sands, silty clays, and conglomerates		x	x	x	x		x		x		x	x	x	x	x	x	
Washita (Wichita)	Cretaceous	Comanche	Washita	fossiliferous limestone, marl, and clay, some sand near top	yields small quantities of water to shallow wells	x								x							
Austin Chalk	Cretaceous	Gulf	Austin	chalky limestone, fine to medium sands, fossiliferous	locally yields small amounts of water		x			x											
Eagle Ford Shale	Cretaceous	Gulf	Eagle Ford	shale with thin beds of sandstone and limestone	Yields small quantities of water to shallow wells					x											
Woodbine	Cretaceous	Gulf	Woodbine	ferruginous sand, sandstone, shale, sandy shale clay	Yields small to medium amounts of water		x	x		x			x								x
Brazos Alluvium	Quaternary/Penn.	DesMoines	Strawn	alluvial sediments consist of clay, silt, sand, and gravel,	Yields small to medium amounts of water (250-500 gpm)	x				x											
Mineral Wells	Pennsylvania	DesMoines	Strawn	shale with interbedded sandstone, limestone and conglomerate	small quantities of water of slightly to moderately brackish water.							x			x	x					
Graham Formation	Pennsylvania	Missouri	Cisco	numerous lenticular sandstone deposits, thin limestone, shale and siltstone	yields small quantities of fresh to slightly saline water							x		x							

Aquifer	System	Series	Group	Rock Characteristics	Water Bearing Characteristics	County															
						Bosque	Dallas	Denton	Erath	Hill	Hood	Jack	Johnson	Montague	Palo Pinto	Parker	Somervell	Tarrant	Wise		
Thrifty Formation	Pennsylvania	Virgil	Cisco	Numerous lenticular sandstone deposits, thin limestone, shale and siltstone	yields small quantities of fresh to slightly saline water								X		X						
Colony Creek Shale	Pennsylvania	Canyon	Canyon										X								X
Palo Pinto	Pennsylvania	Canyon	Canyon	limestone and marl with some sandstone and shale	yields small quantities of fresh to slightly saline water								X			X	X				
Wolf Mountain Shale	Pennsylvania	Canyon	Canyon	Shale, sandstone and limestone	yields small quantities of fresh to slightly saline water								X			X					
Taylor Marl					Yields small quantities		X														
Gonzalos Creek Member (Graham formation)	Pennsylvania	Missouri	Cisco	Numerous lenticular sandstone deposits, thin limestone, shale and siltstone	yields small quantities of fresh to slightly saline water																
Paleozoic														X		X					X
Alluvium													X	X	X	X					X

**Feasibility of Using Alternative Water Sources  
for Barnett Shale Gas Well Completions:  
Evaluation of Paleozoic Aquifers of North Central Texas  
Part I: Development of a Static Model for a Numerical Model**

**BY**

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## **ABSTRACT**

This report presents the first characterization of North Central Texas Paleozoic aquifers for Barnett Shale hydraulic fracturing water supply. Barnett Shale is one of the largest gas play in U.S., facilitated by hydraulic fracturing, which uses between two and six million gallons per well. Gas wells in eastern play currently use mix of surface water sources and groundwater from Trinity Aquifer. However, the western play is limited by scarce surface water resources and thin or absent Trinity aquifer. Thus, continued Barnett expansion requires new water sources. The research focuses on Barnett Shale but the approach has application to shale gas development in other water-stressed regions.

We evaluate North Central Texas Paleozoic aquifer sandstone distribution in outcrop and subsurface, evaluate aquifer properties in a 2,474-well database — including well discharge rate, specific capacity, transmissivity, hydraulic conductivity, and well characteristics (i.e., diameter, depth, screen length), compile water quality data (total dissolved solids and major ions). We integrate net sand thickness maps for Paleozoic Strawn, Canyon, Cisco, and Wichita Groups with aquifer hydraulic properties and groundwater quality. With the exception of wells completed in Canyon Group limestone near Possum Kingdom Reservoir and wells in the Trinity aquifer footprint that are likely dual completion Trinity and Paleozoic aquifer wells, transmissivity and hydraulic conductivity of most wells (25<sup>th</sup> to 90<sup>th</sup> percentile) range within two log cycles. Thus, our analysis generally does not suggest that wells be completed one portion of the study area favoring another: Paleozoic aquifer properties appear to be homogeneous. We do recommend that future Paleozoic aquifer hydraulic fracturing supply wells be completed in the four groups studied with screen intervals in excess of 200 feet to provide sufficient water quantity, but still avoiding saline groundwater.



## INTRODUCTION

This report evaluates groundwater availability from a potential Barnett Shale hydraulic fracturing water supply source from Paleozoic sandstone aquifers in a nine-county area of North Central Texas (**Figure 1**). Continued Barnett Shale expansion depends on access to water resources of sufficient quantity and quality, as hydraulic fracturing can use over 3.5 million gallons per well completion. Traditionally, eastern Barnett wells were fraced using groundwater from Trinity aquifer wells, but as development moves west of the Dallas-Fort Worth area, the Trinity aquifer is thin or absent, and river water is difficult or expensive to acquire (**Figure 1**). Thus, resolving water supply bottleneck is critical for continued Barnett Shale development.

This work addresses the problem of increasing water available for Barnett Shale hydraulic fracturing by presenting the first evaluation of North Central Texas Paleozoic groundwater resources. This report presents previously uncompiled North Central Texas Paleozoic sandstone distribution, hydraulic parameters, and groundwater quality. Specifically, this work (1) Characterizes the spatial distribution of Paleozoic sandstone in outcrop and the subsurface; (2) Evaluates hydraulic properties of Paleozoic sandstone, including specific capacity, transmissivity, and hydraulic conductivity, using aquifer pumping test data from Texas Commission on Environmental Quality (TCEQ) and Texas Water Development Board (TWDB); (3) Compiles summary groundwater quality data; and (4) Presents a preliminary estimate of groundwater available for hydraulic fracturing using Paleozoic sandstones. These data are used to (1) support the construction of a numerical groundwater flow model to evaluate groundwater availability, and (2) run a

GIS analysis to assess the proximity and utility of different water sources to a given Barnett Shale well location – both will be completely separately.

### **BARNETT SHALE DEVELOPMENT AND WATER SUPPLY LIMITATIONS**

Recent technological advances, especially hydraulic fracturing, have facilitated the extraction of natural gas from previously uneconomic shale formations (Curtis 2002). One such play is the Barnett Shale of North Central Texas (Pollastro, Hill et al. 2003; Montgomery, Jarvie et al. 2005; Loucks and Ruppel 2007; Pollastro, Jarvie et al. 2007). In the 1990s, Barnett Shale gas development began in southeast Wise County and rapidly expanded north into Montague Co., east into Denton Co., south into the Dallas-Fort Worth metroplex of Tarrant County and now includes sixteen counties in North Central Texas (**Figure 1**) (Railroad Commission of Texas 2011).

Each well completion by hydraulic fracturing can use over 3.5 million gallons of water in a period of hours to few days (Railroad Commission of Texas 2011). From 1993 to 2011, gas production and associated water use for hydraulic fracturing has increased, with a cumulative water use of around 130,000 acre-feet to generate a cumulative gas production of nearly 10 trillion cubic feet (TCF) (**Figure 2**). Large water volumes are required for this development and water supplies are becoming tighter. In 2005, 60 percent of the water used in North Central Texas hydraulic fracturing was sourced from groundwater in the Trinity and Woodbine aquifers (Harden & Assoc. 2007). However, as Barnett Shale development moves north, west, and south, the Trinity aquifer is thin or absent (**Figure 2**). Furthermore public and private surface water resources are highly allocated and expensive where available. As a result, novel hydraulic fracturing water sources are being developed, including capture and reuse of produced hydraulic fracturing water (Railroad Commission of Texas 2011). New groundwater sources are

also being considered for Barnett Shale hydraulic fracturing. This research presents the first evaluation of North Central Texas Paleozoic sandstone aquifers for use as a Barnett Shale hydraulic fracturing resource.

## **DESCRIPTION OF STUDY AREA**

This research evaluates groundwater availability from Paleozoic strata in a 7,545 mi<sup>2</sup> (19,541 km<sup>2</sup>), nine county area of North Central Texas west of the Dallas-Fort Worth metroplex, including Clay, Erath, Jack, Hood, Palo Pinto, Parker, Montague, Somervell, and Wise Counties (**Figure 2**). No major metropolitan area is located in the study area, but smaller towns include Henrietta, Nocona, Ringgold, St. Jo, Bridgeport, Chico, Decatur, Jacksboro, Perrin, Graford, Mineral Wells, Strawn, Bowie, Weatherford, Granbury, Glen Rose, Dublin, and Stephenville.

North Central Texas average annual precipitation (1951–1983) ranges 28–32 inches per year (Larkin and Bomar 1983). Mean January low and high temperatures (1951–1983) are around 30° and 56°F (respectively) and July mean low and high temperatures are around 73° and 98°F (respectively) (Larkin and Bomar 1983). The landscape is characterized by gently rolling erosional topography (elevation 750 to 1,300 feet) with hills formed by sandstone called “cuestas” and flat valleys formed by erosion of shale (Bayha 1967; U.S. Geological Survey 2011). Brazos, Red, and Trinity Rivers and their tributaries cross the region (U.S. Geological Survey 2011). Major reservoirs include Lake Nocona, Lake Jacksboro, Lake Bridgeport, Lake Weatherford, Palo Pinto Creek Reservoir, Squaw Creek, Lake Granbury, and Possum Kingdom Lake.

Thousands relatively low yield wells (to be discussed in detail later in this report) source Paleozoic aquifers for domestic and stock uses (Bayha 1967) (Texas Commission on Environmental Quality 2011; Texas Water Development Board 2011; Texas Water

Development Board 2011). Public water supplies also use Paleozoic aquifers, including several towns in Montague, Wise, Jack, Palo Pinto, and Parker Counties (Texas Commission on Environmental Quality 2009). Groundwater is used for irrigation in Clay (61% of irrigation), Erath (49%), Palo Pinto (26%), and Montague Counties (9%) but TWDB reporting does not specify if the source is a Paleozoic, Trinity, or alluvial aquifer (Texas Water Development Board 2011). Groundwater is not used for agriculture in Jack, Hood, Somervell, and Wise Counties (Texas Water Development Board 2011).

### **REGIONAL GEOLOGIC SETTING**

This report investigates Pennsylvanian and Permian Paleozoic strata of North Central Texas (Desmoines to Leonard Series) deposited in the Eastern Shelf of the Permian Basin which overlie the Barnett Shale west of the Dallas-Fort Worth area (**Figure 3**). In the eastern half of the study area, Cretaceous strata of the Trinity aquifer are unconformably deposited upon the Paleozoic section (**Figure 4**). Geology of North Central Texas Paleozoic strata are well discussed in the open literature (Wermund, Jenkins et al. 1962; McGowen, Hentz et al. 1967; Wermund and Jenkins 1969; Barnes 1972; Brown, Cleaves et al. 1973; Galloway and L. Frank Brown 1973; Erxleben 1974; Cleaves 1975; Erxleben 1975; Kier, Brown et al. 1979; Brown, Solis-Iriarte et al. 1987; Hentz and Brown 1987; Hentz 1988; Jones and Hentz 1988; Brown, Solis-Iriarte et al. 1990; Bradshaw and Mazzullo 1996; Brown, Ambrose et al. 2009).

The entire Paleozoic section shown on **Figure 4** is comprised of fluvial-deltaic and fluvial deposits from sediment sources from the Ouachita and Arbuckle mountains to the east and north of the study areas (respectively). During Strawn group deposition, westward dipping beds of alternating sandstone and shale were deposited by deltas which prograded across the gently dipping, low accommodation Concho Shelf (Cleaves 1975;

Kier, Brown et al. 1979). As uplift decreased and erosion progressed in the Ouachita Mountains, sediment input declined and a more carbonate bank, shale-rich environment persisted throughout the deposition of the Canyon Group (Erxleben 1974; Erxleben 1975; Kier, Brown et al. 1979). Uplift of the Ouachita Mountains increased again in the upper Permian, leading to active deposition of sand-rich Cisco Group (and Bowie Group updip, continental Cisco Group equivalent) strata alternating with more shale-rich rocks (Kier, Brown et al. 1979; Brown, Solis-Iriarte et al. 1987; Brown, Solis-Iriarte et al. 1990). Sediment influx diminished during upper Cisco and Bowie Group deposition (Wolfcamp Series) as Ouachita Mountain uplift again declined. The trend in lower sediment input continued from uppermost Cisco Group deposition into Wichita-Albany Group (Wolfcamp-Leonard Series), with updip fluvial deposition along a low-relief coastal plain (Wichita Group) grading westward into a mud-rich sedimentary deposition and shallow, low-relief carbonate bank (Hentz 1988).

Paleozoic rocks crop out where not covered by Trinity aquifer strata, generally in the western half of the nine county study area (McGowen, Hentz et al. 1967; Barnes 1972; Hentz and Brown 1987) (**Figure 3**). Paleozoic strata dip westward in the southern study area and change strike to the north of the study area where they dip north. Dip is toward the Permian Basin generally around  $0.5^\circ$  (Wermund, Jenkins et al. 1962; Hentz 1988) (**Figure 5, Figure 6, and Figure 7**). In outcrop, Paleozoic strata are generally undeformed and non-faulted.

The entire Paleozoic section is comprised of alternating fine-grained coarse-grained sediments with intermittent limestone beds. Sandstone deposition is highly discontinuous and no attempt has been made by previous researchers to correlate individual sand layers (Erxleben 1974; Cleaves 1975; Erxleben 1975; Hentz 1988;

Brown, Solis-Iriarte et al. 1990). With the exception of the Winchell Limestone and Ranger Limestone, most limestone beds are only a few feet thick (Barnes 1972).

### **Wichita and Albany Groups**

The continental Wichita Group and equivalent marine Albany Group are lower Permian age strata of Wolfcamp series comprised of highly heterogeneous marginal marine and marine facies of shale and sandstone (Hentz 1988). The Wichita Group is of fining-upwards sandstone deposited in continental conditions along the piedmont that drained the Ouachita highlands at Northeast margin of Midland Basin Eastern shelf (**Figure 8**) (Hentz 1988). Deposits of the piedmont to upper coastal plain are comprised of channel deposits, sandy braided and mixed load rivers. River deposits are have overbank mudstones, channel and crevasse splay sandstones, and marsh claystones. Upper coastal plain has mud-rich meandering rivers, sandy ephemeral streams, and mudflats. Mapable sandstone bodies are regionally discontinuous (Hentz and Brown 1987). Sandstone is interfingered along strike with limestone and mudstone. Relative Wichita sand percent decreases from sand-rich strata in the east to mud-rich strata in the western outcrop. Sand-rich braided stream systems are located in Montague County and Eastern Clay County. Mudstone-dominated, tidal flat, shallow shelf marine strata of the fluvial-deltaic Albany Group become more prevalent west of Central Clay County.

For ease of reporting, we combine and present the continental Wichita Group and marine Albany group. Both groups were deposited at the same time. The Wichita group has a higher sand percent and covers more of the study area, so were refer to the two lumped groups as the Wichita Group.

## **Cisco and Bowie Groups**

Similarly, we combine equivalent marine, fluvial-deltaic Cisco Group and continental Bowie Group strata into one lumped group we refer to here as Cisco Group. The Cisco group is comprised of fluvial-deltaic sediments of primarily sandstone with beds of limestone, shale, mudstone, and conglomerate (Kier, Brown et al. 1979; Brown, Solis-Iriarte et al. 1987; Brown, Solis-Iriarte et al. 1990) (**Figure 9**). The Cisco Group is comprised of sixteen lithogenetic units defined with coastal onlap limestone sequences (e.g., nearshore, shelf, shelf-edge, slope systems) and progradational/aggradational terrigenous clastic sequences (fluvial-deltaic and slope/basin sequences) (Brown, Solis-Iriarte et al. 1987; Brown, Solis-Iriarte et al. 1990).

The Cisco Group was deposited from the upper Pennsylvanian to lower Permian during the Virgil to Wolfcamp Series (Brown, Solis-Iriarte et al. 1987; Brown, Solis-Iriarte et al. 1990) during four major depositional phases (1) Home Creek to Breckenridge interval, a thick fluvial-deltaic, thick shelf-margin deltaic, slope, basinal systems with thin shelf-edge limestone, (2) Breckenridge to Saddle Creek interval, a thinner platform fluvial-deltaic, thick shelf-margin deltaic, slope, and basinal system, (3) Saddle Creek to Dothan interval, a thick proximal fluvial system of thin platform fluvial-deltaic system with moderately thick shelf and shelf edge limestone, and (4) Dothan to Coleman Junction interval, a thick shelf and shelf edge limestone with poor developed platform fluvial-deltaic system.

Despite the location in the Cisco Group, sands are highly heterogeneous. No attempt was made by Brown (Brown, Solis-Iriarte et al. 1987; Brown, Solis-Iriarte et al. 1990) to correlate individual sand layers. Regionally extensive limestone marker beds, however, permit the segregation of high highstand/lowstand regressive sequences (Brown, Solis-Iriarte et al. 1990).

## **Canyon**

The Canyon Group is a primarily marine, fluvial-deltaic and carbonate system deposited during the Missourian Series of the Pennsylvanian (Erxleben 1974; Erxleben 1975) (**Figure 10**). The Canyon Group differs from the overlying Cisco Group and underlying Strawn Group in that it was deposited during a period of decreased uplift in the Ouachita Mountains which resulted in a decreased sediment supply. Consequently, Canyon Group strata reflect a higher percentage of finer-grained (e.g., shale) and carbonate strata. Sandstone body facies include valley-fill, distributary channel-fill, and delta-front deposits. Valley-fill deposits are comprised of fining upward sequences of gravel and coarse sand. Distributary channel-fill is comprised of massive, fine- to medium-grained sand. Delta-front deposits are finest-grained, thin-bedded, sheet sandstone and siltstone.

Discontinuous sand units (Pearson 2007) are found within shale Formations that comprise the Canyon Group. Ranger Limestone and Winchell Limestone form palisades surrounding Possum Kingdom Reservoir, while other Canyon Group limestone beds are generally no more than a few feet thick.

## **Strawn**

The Strawn Group is a primarily marine, fluvial-deltaic system (Cleaves 1975). The upper Strawn was deposited by the Perrin delta and has net sandstone <50 to >140 feet. The lower Strawn is comprised of several sandstone units. Sediments of the Strawn Group were deposited during relatively high sedimentary input during multiple delta progradations (**Figure 11**). Diagenetic cements comprise up to 47% of Strawn Group rock volume and reduced initial porosity in several ways: chlorite rim growth around quartz grains, an average of 11% syntaxial quartz overgrowth, calcite (as well as iron-calcite, ankerite, and kaolinite) cementation (Land and Dutton 1978).

## **HYDROGEOLOGY**

A review of open literature reveals that the Texas Water Development Board has published several hydrogeology reports for Paleozoic aquifers in counties in the study area, including Jack (Nordstrom 1988), Montague (Bayha 1967), Parker (Stramel 1951; Fisher, Mace et al. 1996), and Palo Pinto Counties (Fisher, Mace et al. 1996). Reports have also been produced on the overlying Trinity aquifer (Beynon 1991; R.W. Harden & Associates 2004; Harden & Assoc. 2007). However, no report synthesizes groundwater availability for Paleozoic aquifers in North Central Texas, which is one objective of this work.

### **Wichita**

No report is available in the open literature on the hydrogeology of the Wichita Group. However, one report discusses groundwater in Montague County (Bayha 1967), which includes work on the Wichita Group.

### **Cisco**

Groundwater is produced primarily from numerous sandstone bodies interspersed between shale and thinner limestone beds (Nordstrom 1988). Water quality >100,000 mg/L down dip (Texas Water Development Board 1972). Most potable groundwater is produced from sandstone units ten to 50 feet thick, that thins to Northeast (Hentz and Brown 1987). Sandstone bodies are highly discontinuous in the Cisco (Nordstrom 1988) – in fact Brown et al. (1990) did not attempt to do well to well correlation of sandstones. Groundwater also has a large range in water quality laterally and vertically.

### **Canyon**

Groundwater is produced from sandstone between limestone beds (Nordstrom 1988). The Canyon Group has three sandstone intervals found in shale in which

groundwater occurs that range from 50 to 150 feet. Depth to water is approximately 100 feet, slightly to moderately saline near outcrop and  $>100,000$  mg/L down dip (Texas Water Development Board 1972). In addition to sandstone, some wells completed in Winchell Limestone (50 to 70 feet thick) and Ranger Limestone (190 feet thick) in the vicinity of Possum Kingdom Reservoir (Barnes 1972) are artesian, suggesting significant limestone permeability (Texas Commission on Environmental Quality 2011).

### **Strawn**

Similarly to the Wichita Group, no report focuses on the hydrogeology of the Strawn Group. However, one TWDB focuses on the Strawn Group in Parker County (Stramel 1951). We do know that groundwater produced in Palo Pinto County with  $\text{Na-HCO}_3$  composition from sandstone beds 25 to 50 feet thick (Fisher, Mace et al. 1996).

### **Trinity Aquifer**

While not the focus of this study, it is important to be aware that the Trinity aquifer overlies Paleozoic strata in the eastern half of the study area (Hentz and Brown 1987). Here, the Cretaceous Trinity aquifer forms a thin veneer in SE half of Montague County and majority of Wise County (except for NE corner). To learn more about the Trinity aquifer, please refer to (Bayha 1967; Nordstrom 1982; Nordstrom 1988; Beynon 1991; R.W. Harden & Associates 2004; Harden & Assoc. 2007). A groundwater availability model (GAM) was constructed for the Trinity aquifer, but it did not include Paleozoic strata (R.W. Harden & Associates 2004; Harden & Assoc. 2007). In fact, the Trinity GAM considers the base of Cretaceous as an impermeable boundary with no Trinity-Paleozoic cross-formational flow. However, Paleozoic sediments are unconformably overlain by basal Trinity aquifer sands and hydraulic communication is likely, but not investigated by this research.

## **Existing Hydrogeologic Data**

Some hydrogeologic data are available for Paleozoic aquifers in the study area. In particular, selected aquifer tests have been conducted in Palo Pinto and Montague Counties (Meyers 1969; Fisher, Mace et al. 1996). Paleozoic strata were included in the groundwater availability model for the Seymour aquifer west of the study area (Ewing, Jones et al. 2004).

Groundwater quality data are available in the county reports (Bayha 1967; Nordstrom 1988), in addition to a report on saline groundwater (Texas Water Development Board 1972), and also from water well databases (Texas Commission on Environmental Quality 2011; Texas Water Development Board 2011; Texas Water Development Board 2011).

## **METHODS**

This research addresses the questions of (1) Where are Paleozoic sands in North Central Texas; and (2) How much groundwater is available? To this end, this work (1) Reviews of literature, (2) Compiles well pumping test data for hydraulic parameter estimation, (3) Develops a conceptual hydrogeologic model of North Central Texas Paleozoic aquifers in the Barnett Shale Play using a GIS framework by (3a) Delineating Paleozoic aquifer sands using surface geology maps, subsurface well log data, (3b) Constraining the groundwater flow systems using hydraulic conductivity data and well discharge rates from aquifer pumping tests from TCEQ and TWDB databases and Groundwater total dissolved solid data to infer where Paleozoic sands are currently recharged, and (4) Developing structural maps.

## **LITERATURE REVIEW**

Our literature review included searches of the online databases GeoRef, Google Scholar, and ISI Web of Knowledge. We also searched catalogues of Bureau of Economic Geology and University of Texas Walter Geology libraries. Search terms included: Paleozoic, North Central Texas, Bowie Group, Canyon Group, Cisco Group, Strawn Group, Wichita Group, and also Clay, Erath, Jack, Hood, Montague, Palo Pinto, Parker, Somervell, and Wise Counties. The references were initially organized into general groups of geochemistry, hydrogeology, stratigraphy, and structure.

## **DATA COMPILATION**

We compiled data from publically available sources related to groundwater quality, groundwater wells, hydraulic parameters, and water supply type. We reviewed

TWDB hydrogeology reports available online (Texas Water Development Board 2011), BEG open file reports, and theses and dissertations from The University of Texas at Austin and Baylor University.

During our compilation of pumping test data, we evaluated publicly available well completion reports from two sources, TCEQ (2011) and TWDB (2011). TCEQ well completion reports are available as scanned PDF documents of wells installed prior to February 5, 2001. Texas Water Development Board Submitted Driller's Report Database contains wells installed after February 5, 2001 and contains wells submitted on an entirely optional basis via the online Texas Well Report Submission and Retrieval System maintained by the Texas Department of Licensing and Regulation (Texas Department of Licensing and Regulation 2011) and also TWDB permit applications. We downloaded and inspected paper copies of well completion reports in the TCEQ database and downloaded the TWDB database.

Well completion reports were entered into Excel spreadsheet. Significant editing of the TWDB "Casing, Blank Pipe, and Well Screen Data" was required. Spreadsheet information includes: well ID no., data source, County, 2.5-minute U.S. Geologic Survey quad in which the well is located, well depth, screened interval (which used to estimate hydraulic conductivity), depth to water (relative to ground level datum), diameter of borehole, casing, and screen, discharge rate, drawdown, pumping duration, test type (i.e., jetted, pumped, bailed, etc.), specific capacity (calculated with discharge rate and drawdown), transmissivity (estimated analytically using specific capacity, discharge rate, pumping duration, well diameter, and drawdown), and hydraulic conductivity.

The majority of wells in the study area are small diameter domestic wells and step-drawdown tests data to estimate hydraulic properties are unavailable. Thus an analytical approach was used to estimate hydraulic parameters (Mace and Smyth 2003).

Latitude and longitude presented in TCEQ and TWDB well completion report databases is often too unreliable to plot. Thus, well locations were plotted at the centroid of the 2.5-minute U.S.G.S. quad in which the well is located. Wells in either database do not provide information as to the aquifer in which the well is completed. Thus, the elevation of the screen midpoint is used compared with structural maps generated by this work to assign an aquifer to the well (i.e., Strawn, Canyon, Cisco, or Wichita).

## **HYDROGEOLOGIC CONCEPTUAL MODEL DEVELOPMENT**

### **Maps of Paleozoic Sand Distribution: Strawn, Canyon, Cisco, and Wichita Groups**

We delineated sandstone bodies likely to host groundwater in extractable quantities by integrating outcrop sand maps and subsurface well log data within a structural context. Initially, the four groups that comprise the Paleozoic section of North Central Texas (i.e., Strawn, Canyon, Cisco, and Wichita) were delineated in GIS from the 1:250,000 digital Geologic Atlas of Texas (Pearson 2007). We combined contemporaneously deposited predominantly non-marine Bowie Group with the predominantly down-dip marine equivalent Cisco Group and we subsequently refer the combined group as the Cisco Group. Similarly, we combined predominantly non-marine Wichita Group with the predominantly down-dip marine equivalent Albany Group into one Wichita Group. Sand distribution within each of the four major groups was mapped independently.

#### ***Delineation of Group Tops***

Next, we delineated subsurface tops of each group using GIS to integrate net sand thickness into a three-dimensional framework suitable for conversion to numerical groundwater flow model layers.

Strawn Group posed the greatest challenge to map in the subsurface for a number of reasons. First, rocks of the Cretaceous age Trinity aquifer unconformably overlie the Strawn Group and limits outcrop area to a roughly 40 by 80 kilometer portion of Southeast Palo Pinto County, far north Erath County, and far west Parker County (**Figure 3**). Second, Cleaves (Cleaves 1975) limited subsurface mapping to the west of the outcrop zone; thus, no subsurface data were available for the subcrop east of the outcrop. To address these challenges, the Strawn Group layer top was delineated using a variety of methods. Where Strawn crops out, the layer top was assumed to be ground surface extracted from the one arc-second (approximately 30-meter resolution) National Elevation Dataset (U.S. Geological Survey 2011). Strawn subcrop top to the west and northwest of the outcrop was estimated using a structural contour map of the regionally extensive Dog Bend Limestone marker bed (**Figure 12**) located in the Upper Strawn Group (Wermund, Jenkins et al. 1962). We use the Dog Bend Limestone Base to infer the dip of the Strawn top. So that the eastern extent of the Dog Bend Limestone map coincided with the western limit of the Strawn Group outcrop, we added 170 meters to the Dog Bend Limestone structural map. Where the Strawn is found unconformably below Cretaceous strata of the Trinity aquifer east of eastern Montague and Wise county — and east of the area shown on the Dog Bend Limestone structure map — we infer top of the Strawn Group using structural contours of the base of the Cretaceous (**Figure 13**) (Nordstrom 1982).

The Canyon Group layer top was delineated using National Elevation Data (U.S. Geological Survey 2011) for the outcrop zone and structural contours of the base of the Cretaceous (Nordstrom 1982) for the portion of the Canyon underlying the Trinity aquifer. The subcrop of the Canyon to the west of the outcrop zone was extrapolated using a structural contour map of the Home Creek Limestone top (**Figure 14**) (Wermund Paleozoic Aquifers. Part I: Structure

and Jenkins 1969) which Erxleben (Erxleben 1974; Erxleben 1975) defines as the top of the Canyon Group.

The Cisco Group layer top was chosen using National Elevation Data (U.S. Geological Survey 2011) for the outcrop zone, structural contours of the base of the Cretaceous (Nordstrom 1982) for the portion of the Cisco underlying the Trinity aquifer. The Cisco subcrop to the west of the outcrop was computed using trigonometry considering the width of the outcrop assuming a regional dip. A dip of 0.5 degrees was estimated using the Home Creek Limestone top structural contour map (Wermund and Jenkins 1969). The bed perpendicular Cisco thickness of the Cisco was calculated using Equation 1, where:

$$L = \tan(\sigma) * W, \quad (\text{Eqn. 1})$$

where,  $L$  = bed-perpendicular thickness,  $\sigma$  = bed dip, and  $W$  = outcrop width.

Thus, the top of the Cisco was calculated by adding the computed Cisco thickness to the top of the Canyon.

The Wichita Group layer top was compiled from National Elevation Data (U.S. Geological Survey 2011) for the outcrop zone and structural contours of the base of the Cretaceous (Nordstrom 1982) for the portion of the Cisco underlying the Trinity aquifer. In the subsurface, the Wichita top was delineated using the same trigonometric approach of the Cisco Group (Equation 1) using a regional dip of 0.5 degrees and the outcrop width.

### ***Sand Distribution in Outcrop***

Outcrop sand distribution was delineated using Geologic Atlas of Texas sandstone member polygons (Pearson 2007). Within each of the four groups, all polygons in the MemberPoly250K feature class in the MEMBER\_CD field that started with “ss” (indicating an undifferentiated sandstone member) or that were specifically listed in the Geologic Atlas of Texas map sheet notes as a sandstone member were plotted to create the sandstone outcrop map show in (**Figure 3**). For example, regionally correlable sandstone bodies such as |Pa, the Avis Sandstone and |Pgc, the Gonzales Creek Member, both of the undivided Thrifty and Graham Formations of the Cisco Group were included as specifically named sandstone members. All polygons in the “MEMBER\_CD” field that were shale based on the GAT map sheet notes were omitted. Similarly, limestone beds were omitted because they are typically only a few feet thick in the study area. However, we plotted Winchell Limestone and Ranger Limestone of the Canyon Group, which form outcrops in the vicinity of Possum Kingdom Reservoir and have a total thickness of ~240 feet (McGowen, Hentz et al. 1967). An evaluation of well pumping tests (discussed later) shows that some wells in the TCEQ database (Texas Commission on Environmental Quality 2011) completed in limestone near Possum Kingdom Reservoir are artesian, suggesting significant permeability in these two limestone formations (**Figure 3**).

### ***Sand Distribution in Subsurface***

Subsurface sand distribution for Strawn, Canyon, and Cisco Groups was compiled from maps done by previous researchers using well log analyses (Cleaves 1975; Erxleben 1975; Brown, Solis-Iriarte et al. 1987) (**Figure 15, Figure 16, and Figure 17**). The Wichita group lacked subsurface data, so subsurface sand distribution was inferred from surface sand mapping (Hentz and Brown 1987) and a conceptual sedimentary Paleozoic Aquifers. Part I: Structure

depositional model (Hentz 1988). Initial sand mapping was refined based on conceptual sedimentary depositional models (Cleaves 1975; Erxleben 1975; Brown, Solis-Iriarte et al. 1987; Hentz 1988) and Geologic Atlas of Texas map sheet notes (McGowen, Hentz et al. 1967; Barnes 1972; Hentz and Brown 1987).

Previous studies of the Strawn, Canyon, and Cisco Groups (Cleaves 1975; Erxleben 1975; Brown, Solis-Iriarte et al. 1990) mapped subsurface sand distribution using an extensive petroleum well log database of ~5,000 geophysical logs. We scanned sand maps for: (1) Strawn Group (Cleaves 1975) – Plate XVII is already a net sand map – of individual sand facies, including Dobbs Valley, Ada, Brazos River, Hog Mountain, Lake Pinto, Devil’s Hollow, and Turkey Creek Fluvial-Deltaic Facies; (2) Canyon Group (Erxleben 1975) – Plates IV, VI, and VIII – net sandstone thicknesses of the Wolf Mountain Shale, Placid Shale, and Colony Creek Shale Intervals; and (3) sandstone isoliths for sixteen cyclic sequences of the Cisco Group (Brown, Solis-Iriarte et al. 1987). No subsurface sand distribution data are available for the Wichita Group.

All scanned subsurface sand distribution maps were georeferenced in ArcMap version 10 geographic information system (GIS) to North American Albers Equal Area Conic projection (Environmental Systems Research Institute 2010). Sand thickness contours were digitized in GIS. ArcMap Spatial Analyst Topo to Raster command used to interpolate sand thickness to a grid. Sand thickness improperly interpolated less than zero were replaced with zero-foot values using ArcMap Spatial Analyst Reclassify command. Cleaves (1975) presented Strawn Group subsurface sand distribution as a net sandstone isopach map that was digitized directly (**Figure 15**). In contrast, Canyon and Cisco Groups have multiple sand intervals (three and sixteen, respectively); thus, individual gridded rasters of sand thickness were summed in ArcMap Spatial Analyst Add command to create a net sand thickness raster (**Figure 16 and Figure 17**).

As subsurface sand distribution data are unavailable for the Wichita Group, we relied on general trends in sandstone and sand grain size distribution (Hentz 1988). At the eastern border of Montague County, we assumed a sand content of 40 percent which graded smoothly to 10 percent at the western border of Clay County (Hentz 1988). We assumed a 20 percent subsurface sand content and smoothly graded into the higher sand content to the east (Hentz 1988).

### **Constraining Aquifers Using Groundwater Total Dissolved Solids**

We use maps of total dissolved solids (TDS) concentration in Strawn, Canyon, and Cisco Groups groundwater (Texas Water Development Board 1972) to make inferences into groundwater recharge pathways from the outcrop into the subsurface. No groundwater TDS data are available in the open literature for the Wichita Group, so we do not use a groundwater TDS constraining approach for this group. We assume that the subsurface is being recharge only where groundwater TDS is relatively low. Report 157 by the Texas Water Development Board (1972) uses TDS inferred from borehole geophysical logs in a relatively sparse well network to delineate 50,000 and 100,000 milligram per liter (mg/L) TDS groundwater contours (**Figure 18, Figure 19, and Figure 20**). We assume that groundwater >50,000 mg/L TDS is not actively recharged. Thus, portions of the study area with elevated groundwater TDS are omitted from the active groundwater flow system and not considered part of the hydrogeologic conceptual model.

### **Evaluation of Aquifer Hydraulic Properties from Well Pumping Tests**

With the goal of evaluating aquifer hydraulic parameters, we present a preliminary database of well pumping tests compiled from well completion reports in publicly available TCEQ and TWDB databases (Texas Commission on Environmental Quality 2011; Texas Water Development Board 2011) for a rectangular region that

encompasses the nine county study area. We manually entered PDF scans of TCEQ well completion reports downloaded from the website (Texas Commission on Environmental Quality 2011). TCEQ database includes wells installed prior to February 5, 2001. We downloaded the electronic Microsoft Access database of wells installed after February 5, 2001 from the Texas Water Development Board Submitted Driller's Report Database (Texas Water Development Board 2011). TWDB well data are submitted by drilling companies via the online Texas Well Report Submission and Retrieval System (Texas Department of Licensing and Regulation 2011). Because well completion data (e.g., screen top and bottom, casing start and end depth, borehole diameter, well screen and casing diameter, etc.) are entered into one field of the database by the drilling company, we edited database records considerably to put it into a usable format for spreadsheet analysis.

We initially constructed a database with pumping test data from 7,614 wells, 4,559 of which we entered from TCEQ and 3,055 from the TWDB. Next, we deleted 2,619 wells obviously screened in the Trinity aquifer or alluvium (i.e., based on location, depth, and lithology encountered during drilling), had mislabeled location outside of the study area, dry holes, artesian (e.g., 71 wells screened in limestone near Possum Kingdom Reservoir), or incomplete data, resulting in a preliminary database of 4,995 wells. Of the 4,995 wells in the preliminary database, 1,524 did not have well borehole data. However, 3,471 wells have well borehole radius. Thus, in order to increase the number of wells in the database from which we can calculate aquifer hydraulic properties, we use a well borehole radius mode of 7.875 inches to populate wells without well borehole radius data. A total of 820 wells in the preliminary database did not have drawdown data needed to estimate aquifer hydraulic properties.

Wells screened in alluvial aquifers were removed from the database. The Red River forms the northern boundary of Clay and Montague Counties. Along with its tributaries, the Red River has a large alluvial aquifer. Alluvial aquifers are also associated with the Trinity and Brazos Rivers. Wells screened in alluvium were eliminated from the database by comparing the well location with surface geology. Alluvium, terrace deposits, and windblown deposits from the Geologic Atlas of Texas (Pearson 2007) was plotted in GIS with well location. Wells lacked latitude and longitude and were plotted at the centroid of an approximately seven square mile, 2.5-minute quadrangle (approximately 2.9 miles east-west by 2.4 miles north-south). The lithologic log of each well located in a quadrangle with Alluvium, terrace deposits, and windblown deposits was evaluated. Wells located along the Red River in Clay County are completed primarily in alluvium with a total depth generally less than 50 feet. Conversely, wells in Montague County along the Red River are deeper (i.e., greater than 80 feet), screened at depths below unconsolidated sands (i.e., strata described as “surface sand” in well lithologic logs), and completed in sands bounded by shale indicative of Paleozoic strata that is absent in alluvium. A similar approach identified wells screened in the alluvial aquifers of the Trinity and Brazos Rivers. A total of 144 well were identified as completed in alluvium are not considered in the evaluation of Paleozoic aquifers.

Wells screened in the Trinity aquifer were also removed from the database. Every county in the study area, except Clay County, has Trinity aquifer outcrop (**Figure 3**). We eliminate Trinity aquifer wells from the preliminary well database by assigning each well to one of the four geologic groups (e.g., Strawn, Canyon, Cisco, Wichita Group) based on well depth and geologic structure of the four groups. We compare the well screen midpoint, which is computed as the average of the top most and bottom most screen, with the top of each Group layer that we generated in GIS. A well screen midpoint elevation

that is located between the top and bottom elevation of a certain layer is assigned to that layer. To account for uncertainty in our analysis, wells likely screened in the Trinity aquifer that did not have well depth more than approximately ten percent deeper than the base Trinity were omitted from the database. Based on this analysis, we refined the preliminary database (which contained alluvial and Trinity aquifer wells), resulting in a final Paleozoic well database comprised of 2,474 wells, with 434 wells in Strawn Group, 496 wells in Canyon Group, 1,340 wells in Cisco Group, and 204 wells in Wichita Group.

While the final well database includes 2,474 wells screened in Paleozoic strata, not all of the wells have complete data. In order to understand the characteristics of wells in the database, we evaluate the wells using standard statistics (**Table 1** and **Table 2** and **Figure 21**). The database is almost entirely comprised of narrow domestic wells with a median diameter of 4.5 inches and a 90<sup>th</sup> percentile depth value of 370.4 feet. Most of the wells are shallow, with a median depth of around 200 feet. As many of the wells are domestic, median screen length is 35 feet. Median discharge rate for the entire database is 11 gallons per minute, with a 90<sup>th</sup> percentile value of 30 gallons per minute (**Table 1**). The respective median pumping rates for the Strawn, Canyon, Cisco, and Wichita Groups are 14, 10, 12, and 7 gallons per minute (**Table 2**). Most well pumping tests lasted one hour, as is typical for domestic water well construction.

We also compiled water quality results from TWDB (2011), which are shown in **Table 3**. Water quality for the wells in the database is potable, with median values for pH=8.1, bicarbonate = 425 mg/L, sulfate = 78 mg/L, chloride = 120 mg/L, total dissolved solids = 758 mg/L, and alkalinity = 357 mg/L.

### *Estimation of Transmissivity from Specific Capacity*

The well pumping test database was analyzed for transmissivity (T) and hydraulic conductivity (K). Ideally, T, K and storativity (S) can be estimated by analyzing time-drawdown data collected during multi-well aquifer pumping test (Theis 1935). However, TWDB and TCEQ data are primarily for domestic wells with simple one-well tests. We estimate T and K from specific capacity data because the TCEQ and TWDB databases do not have multi-well aquifer pumping test data for the study area. Furthermore, only five tests were available in open literature in Montague County (Meyers 1969) and four in Fort Wolter on the Palo Pinto-Parker County border (Fisher, Mace et al. 1996). Estimating T and K from specific capacity data is not as accurate as multi-well time-drawdown data analysis, but because of the lack of multi-well aquifer pumping tests we generate aquifer hydraulic properties from specific capacity data.

Several approaches are available in the open literature to estimate T from specific capacity data, which are summarized in Mace and Smyth (2003). We use the iterative analytical solution presented by Mace and Smyth (2003). Well performance tests done by drillers of domestic wells typically pump or bail a well at a constant discharge rate ( $Q$ ), and measure drawdown ( $s$ ) from static, pre-development groundwater level to get specific capacity ( $S_c$ ) using Equation 2, where:

$$S_c = \frac{Q}{s} \quad (\text{Eqn. 2})$$

We use the analytical relationship presented by Theis (1935) shown in Equation 3

$$S_c = \frac{4\pi T}{\left[ \ln \left( \frac{2.25 T t_p}{r_w^2 S} \right) \right]} \quad (\text{Eqn. 3})$$

Where  $\ln$  is the natural logarithm,  $t_p$  is the time of production (i.e., pumping or bailing time),  $r_w$  is the radius of the well in the screen interval (measured as the borehole radius), and  $S$  is the storativity of the aquifer.

We rearrange Equation 3 and solve Equation 4 iteratively in spreadsheet

$$T = \left( \frac{S_s}{4\pi} \right) [\ln(2.25Tt_p) - \ln(r_w^2 S)] \quad . \quad (\text{Eqn. 4})$$

We use an initial guess for  $T$  on the right-hand side of the equation and assume a plausible value of  $S$ .

All 2,474 wells in our database had all the information required for estimating  $T$  iteratively using the Theis (1935) analytical relationship. However, 25 wells had zero drawdown and 465 wells failed to converge on a solution, resulting in 1,984 wells for which  $T$  was estimated. Hydraulic conductivity ( $K$ ) was calculated from  $T$  using Equation 5:

$$K = \frac{T}{b} \quad , \quad (\text{Eqn. 5})$$

where  $b$  is total screened interval. Of 1,984 wells, 998 had total screen length data needed to calculate  $K$ . Thus, we used the median screen length of 35 feet for wells without screen length data to increase the number of calculated hydraulic conductivity values possible (**Figure 22**).

### ***Comparing Population Density with Well Density***

We evaluate the location of Paleozoic wells in the database to answer the question if well location is a function of population density or unfavorable geology. To address this question we created a map of relative population density using year 2000 U.S. Census Data (U.S. Census Bureau 2000), as 2010 Census results were not available yet online and we would not expect North Central Texas population density to change appreciably from 2000 to 2010. First, Arc GIS TIGER/Line® Shapefiles of U.S. Census blocks were downloaded from the U.S. Census Bureau (2000) for Clay, Erath, Hood, Jack, Montague, Palo Pinto, Parker, Somervell, and Wise Counties. Then, year 2000 population data (P.1 Total Population table) for was downloaded from the U.S. Census (2000) for each Census block for the counties of interest, for a total of 17,234 Census blocks. Optional geographic identifiers (G001. Geographic Identifiers) were selected during Excel file downloading so that the file contained population and land and water area (and other values not pertinent). Because land and water area are provided in square meters, population density per square mile of total surface area was calculated in Excel for each census block (University of Georgia Libraries 2004) using Equation 6:

$$\text{population density} = \text{total population} / ((\text{land area} + \text{water area}) / 2589988) \text{ .(Eqn. 6)}$$

Text format latitude and longitude were converted to numbers using the Excel concatenate, left, and right expressions. Finally, block data shapefiles were loaded into ArcMap version 10. The spreadsheet of population density was added to ArcMap, plotted as X-Y data with NAD 1983 Geographic projection and exported as a new shape file of population density at a point that is situated inside of a Census block shapefile polygon, and added back into ArcMap. The spatial join command with target = polygon blocks,

join = point population density, join option = one-to-one, and match = intersect was used to create new shapefile that presented population density for each year 2000 U.S. Census block for the nine counties in the study area.

We find that population density is highest in Southeast Montague County, Wise, Parker, Hood, Somervell, and Erath Counties (**Figure 23**). Coincidentally, the highest population density is also located along the outcrop zone of the Trinity aquifer. Higher population density in Clay, Jack, and Palo Pinto Counties is limited to a few towns. The spatial distribution of 2.5-minute quadrangles with wells screened in the Paleozoic are located primarily in the western two-thirds of the study area both in higher and lower population density zones. Thus, well locations do not appear to be influenced by zones of favorable geology. Gaps in domestic well coverage also correspond to low population density; thus, if wells are not present in an area, it does not necessarily mean that hydraulic conductivity is low in that location.

## **NUMERICAL GROUNDWATER FLOW MODEL SIMULATIONS**

### **Conceptual Groundwater Flow Model of North Central Texas Paleozoic Strata**

In support of groundwater development (which will be discussed in more detail in a later report), here we discuss how the hydrogeologic conceptual model is translated into groundwater model layers and properties.

#### **Layers and Grid**

We convert our hydrogeologic conceptual model of four Groups into layers that can be used for simulating groundwater flow by considering sand fraction, groundwater TDS, and permeability distribution.

### ***Sand Fraction***

Net sand thickness was calculated for the Strawn, Canyon, and Cisco Groups using data from the open literature (Erxleben 1974; Cleaves 1975; Erxleben 1975; Brown, Solis-Iriarte et al. 1990). For the Strawn group, Cleaves (1975) presents a net sandstone isolith map. Net sandstone maps for the Colony Creek Formation, Placid Formation, and Wolf Mountain Formation of the Canyon Group were contoured and summed in GIS (Erxleben 1974; Erxleben 1975). Sands deposited during sixteen cyclic cycles of the Cisco Group were contoured and summed in GIS (Brown, Solis-Iriarte et al. 1990). For the Strawn, Canyon, and Cisco Groups, the sand fraction, or percent of a Group layer comprised of sandstone, was calculated by dividing net sand thickness of a Group by the total thickness of a Group. For the Wichita Group, sand fraction was extrapolated in GIS assuming a sand fraction of 40 percent on the eastern portion of the outcrop of the Nocona Formation grading smoothly to a sand fraction of 10 percent in the western portion of the outcrop in the study area based on field mapping by Hentz (1988). For the Canyon, Cisco, and Wichita Groups, the thickness of the Group was calculated in GIS using the model layer tops calculated previously. However, net sand thickness evaluated by Cleaves (1975) is less than the total thickness of the Strawn Group because of dip to the west and east. Thus, we calculated sand fraction for the Strawn Group by assuming a false layer bottom elevation of -1,697 meters.

### ***Delineation of Percent of Model Layer Active***

We used an approach that mapped zero and one lines, representing the percent of a given cell that is active (from 0 to 100) in order to account for the fact that groundwater TDS increases down dip, caused by a lesser degree of groundwater circulation (**Figure 24**). Thus, we placed a one line to trace the eastern extent of the outcrop. We then drew a zero line to the west of the outcrop zone that generally paralleled the 50,000 mg/L TDS Paleozoic Aquifers. Part I: Structure Page 35 of 87

line (Texas Water Development Board 1972). The zero and one line could also be moved to capture areas of high or low sand fraction. The area between the zero and one lines was then interpolated in GIS using inverse distance weighting (IDW). The Strawn followed a similar approach but it was given two zero lines on both sides of the outcrop whose central axis corresponded to the one line: one to the west in the downdip direction similar to the other formations and one to the East underneath the Trinity to account for likely hydraulic connection between the aquifers.

### ***Permeability Distribution***

Similarly, permeability (in the form of hydraulic conductivity) also needs to be populated in the model layers. Thus, we plotted log hydraulic conductivity on the sand fraction maps. We contoured hydraulic conductivity values following the data and also general sand depositional patterns from the literature (Erxleben 1974; Cleaves 1975; Erxleben 1975; Hentz 1988; Brown, Solis-Iriarte et al. 1990) following the principle that higher sand fraction also means larger sand bodies and higher hydraulic conductivity (**Figure 8, Figure 9, Figure 10, and Figure 11**). During Strawn Group deposition, sand was deposited in two major deltas: Bowie and Perrin. The Bowie Delta deposited sands in East North East-West South West trend across Clay and Montague Counties. The Perrin Delta deposited sands roughly East-West across Jack, Parker, Palo Pinto, and Wise Counties. Several smaller bayhead deltas deposited sands in a South East-North West direction in South East Palo Pinto, Hood, and Erath Counties. During Canyon deposition the Henrietta Fan Delta System deposited sand sloughed off the Arbuckle Mountains in Oklahoma in a North-South direction in Clay and Montague Counties. The Perrin Delta System persisted and deposited sands in a roughly East-West to Southeast-Northwest orientation primarily in Jack County and also Southwest Wise and Northwest Parker

Counties. A carbonate-rich lagoon dominated Palo Pinto County (and further Southwest). Sands were deposited in sixteen cyclical sequences of the Cisco Group; however, the general trend was deposition from Northeast-Southwest and East-West from Bowie Complex (delta) and other sediment sources along the Ouachita Mountain front. For Wichita Group, sand was deposited from East-West from Ouachita Foldbelt and also North-South from Arbuckle Mountains giving trend of higher sand to the East in piedmont and coastal plain fluvial deposition, and lower sand content in West in tidal flats with more mud.

## **RESULTS AND DISCUSSION**

We present the first North Central Texas Paleozoic aquifer characterization, in an area where water supply for hydraulic fracturing constrains Barnett Shale expansion. We include the following results in this report: (1) Characteristics of wells and water quality in our database, (2) Distribution of sand in outcrop and subsurface, (4) An evaluation of aquifer hydraulic parameters, and (5) An initial assessment of groundwater availability from Paleozoic aquifers.

### **DATA COMPILATION**

In this report, we present a database of wells in the nine county study area of North Central Texas compiled from TCEQ (2011) and TWDB (2011) (**Table 1** and **Table 2**)

### **HYDROGEOLOGIC CONCEPTUAL MODEL**

#### **Paleozoic Sandstone Distribution in Outcrop**

Sandstone is distributed irregularly in outcrop (**Figure 3**) and forms small hills called “cuestas” surrounded by more shale-rich valleys. Strawn Group sandstone is found in roughly two southwest-northeast trending bands separated by a larger area dominated by siltstone. Canyon Group sandstone is scarce in outcrop and limited to updip (i.e., eastern) portions of the northern outcrop. Outcrops of Ranger and Winchell Limestone (**Figure 4**) dominate about half the down dip extent of Canyon Group outcrop. By visual inspection, the Cisco Group has the highest percent of sandstone in outcrop, which is found interspersed with more shale-rich areas. In general, two strike-oriented bands of shale are found in the east-center and far west of the outcrop. Also, Cisco Group

sandstone in outcrop is slightly greater to the north. Wichita Group has comparatively low sandstone in outcrop, and a higher percentage in the east.

### **Paleozoic Sand Distribution in Subsurface**

Here we present maps of net sand and sand fraction for each of the four groups. Net sandstone thickness in the Strawn Group ranges from around 450 to >600 meters in the study area (**Figure 25**). Sand fraction appears evenly spaced because of the high overall thickness of the layer in excess of 1,700 meters. Canyon Group net sandstone thickness ranges from around 50 to >250 meters in the study area; however near the outcrop zone maximum sandstone thickness is >100 meters (**Figure 26**). Sand fraction is variable from <10 to >30 percent near the outcrop zone. Cisco Group net sandstone thickness ranges from around 50 to >150 meters in the study area (**Figure 27**). Cisco Group Sand fraction is variable from <10 to >30 percent near the outcrop zone and is less heterogeneous than Canyon Group sand distribution. Wichita Group Sand fraction decreases from around 20 percent in the east to <10 in the west (**Figure 28**).

### **Evaluation of Aquifer Hydraulic Parameters From Well Pumping Tests**

Most wells discharge at a rate between six and 30 gallons per minute (25<sup>th</sup> and 90<sup>th</sup> percentile, respectively) (**Figure 29**). Elevated discharge rates appear primarily in the southeastern half of the Cisco Group outcrop, far eastern Wichita Group, irregularly throughout the Strawn Group, and in the vicinity of Possum Kingdom Reservoir, where limestone strata of the Canyon Group (Winchell and Ranger Limestone) appear to be in hydraulic communication with the Brazos River. Some wells have elevated discharge rates — 750 gpm (maximum), 40 gpm (95<sup>th</sup> percentile), and 90 gpm (99<sup>th</sup> percentile) — which are most likely wells with dual completion in the Paleozoic and Trinity aquifer. Wells in the database were selected based on screen interval and our geologic model to

be completed in Paleozoic strata; however, uncertainties may have included some wells in the Trinity aquifer footprint to be included that are screened across homogeneous, indistinguishable sands at the base of the Trinity and top of the Paleozoic.

Specific capacity results highest overall in the Strawn Group. Isolated, elevated specific capacity regions are also found in Canyon Group limestone, portions of the Cisco Group, and western Wichita Group (**Figure 30**). Transmissivity values are variable across the study area, but are high in the Strawn Group, portions of the Canyon Group, and also the southeast outcrop area of the Cisco Group and easternmost Wichita Group (**Figure 31**). Hydraulic conductivity appears relatively homogeneous when presented in the log scale (**Figure 32**). Median log transmissivity value for all four groups is 1.1 (**Table 4**). Strawn Group has the highest median value of log transmissivity (1.4), followed by Canyon (1.3), Wichita (1.1), and Cisco (1.0). However, given the uncertainties in our analysis, the results suggest a relatively homogeneous spatial distribution of relatively low transmissivity across the study area. Median log hydraulic conductivity for all four groups is around -0.2 (**Table 6**). Strawn Group has the highest median value of log hydraulic conductivity (0.41), followed by Canyon (0.31), Wichita (0.45), and Cisco (0.42). As with transmissivity, hydraulic conductivity values are generally uniform, with all wells between 25<sup>th</sup> and 90<sup>th</sup> percentile within two log cycles.

## CONCLUSIONS

Despite heterogeneity in Paleozoic aquifer surface and subsurface sand distribution, hydraulic properties of wells in our database are remarkably uniform (and also meager, when compared to the Trinity aquifer). Transmissivity and hydraulic conductivity values for 25<sup>th</sup> to 90<sup>th</sup> percentile wells are within two log cycles. Well discharge rates are generally low, but typical for domestic wells (25<sup>th</sup> to 90<sup>th</sup> percentile wells range from six to 30 gpm). Wells with discharge rate greater than 40 gpm (95<sup>th</sup> percentile) are possible completed in both Trinity and Paleozoic aquifers, reflecting uncertainties in our geologic model and also screen length assumption of 35 feet for wells lacking these data. Other high-discharge wells are completed in Canyon Group limestone strata around Possum Kingdom Reservoir, suggesting hydraulic communication with Brazos River in these wells. Elsewhere in the study area, wells are not typically completed in limestone. Future hydraulic fracturing wells should have a screen length longer than the median value of 35 feet in order to produce sufficient water. Groundwater quality in wells completed in the first 300 feet is generally potable (90<sup>th</sup> percentile well depth of around 370 feet). However, groundwater salinity increases rapidly downdip to >100,000 mg/L TDS, suggesting limited recharge and poor hydraulic communication of deep sand bodies with sand in outcrop. Thus, we recommend that future hydraulic fracture supply generally have a total depth less than X,XXX feet to produce groundwater of suitable quality.

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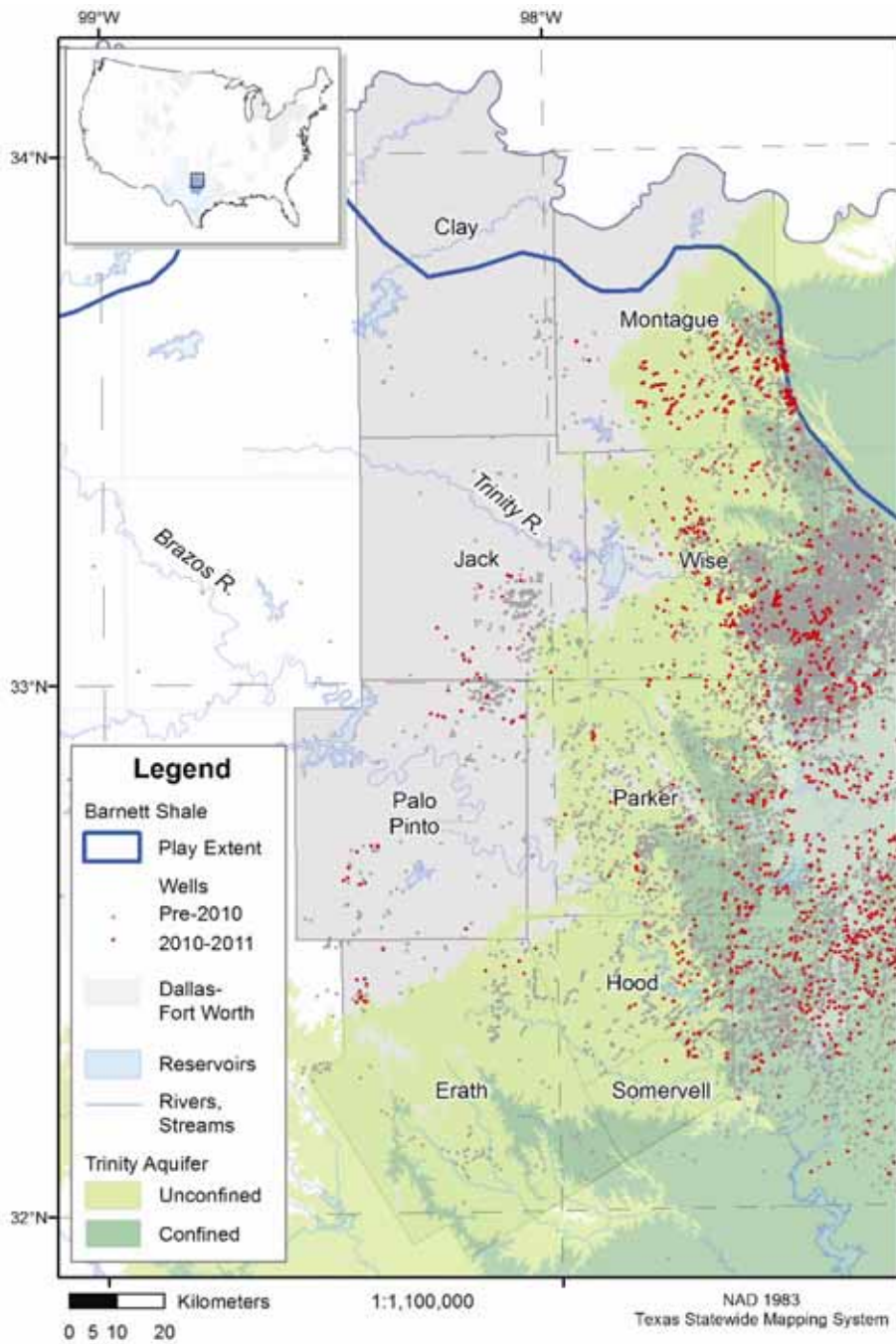
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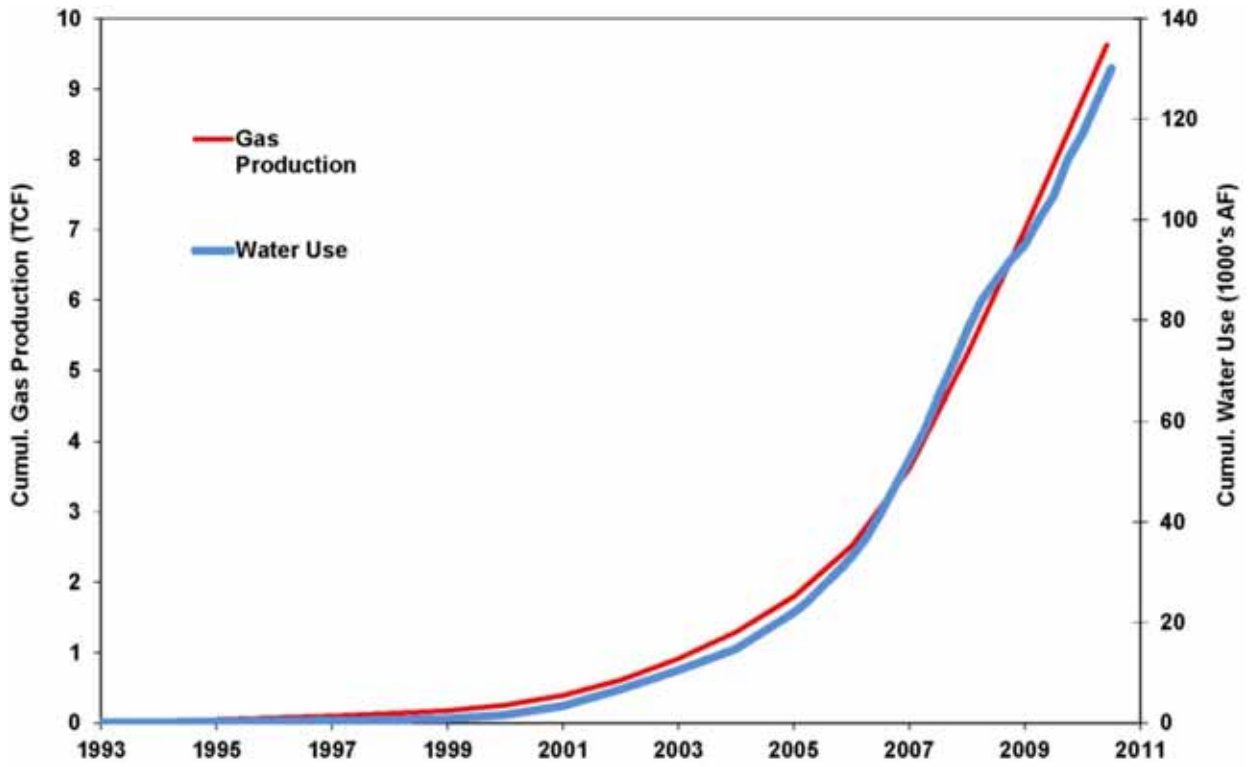
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## **FIGURES**



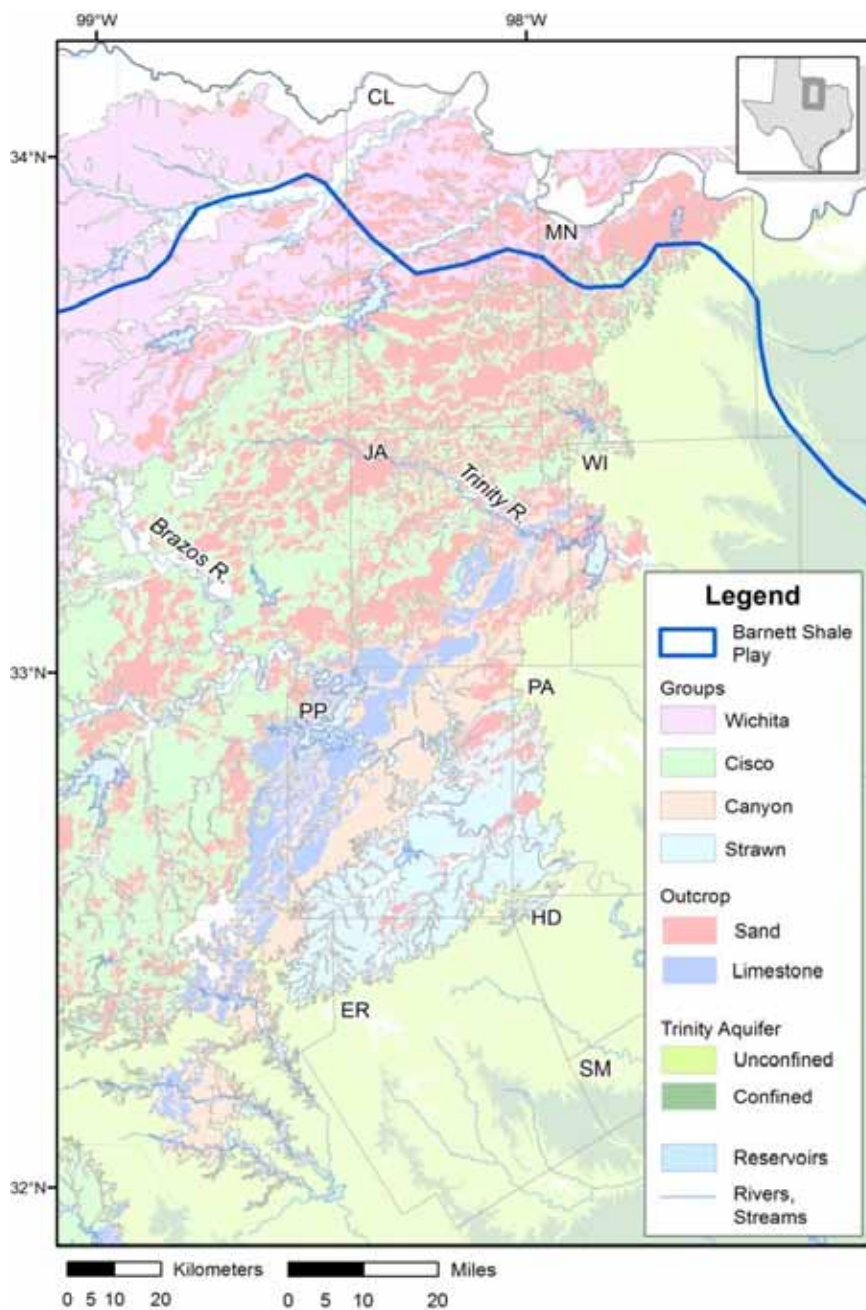
**Figure 1. Regional Geologic Setting: Barnett Shale Play, Gas Well Locations, Trinity Aquifer, and Study Area Location**

Barnett Shale Play wells from 1993 to 2010 (IHS Energy 2011). Inset map shows study location and unconventional shale gas plays in the United States (U.S. Energy Information Administration 2011). The study area is focused in nine county area of North Central Texas to the west of Dallas-Fort Worth.



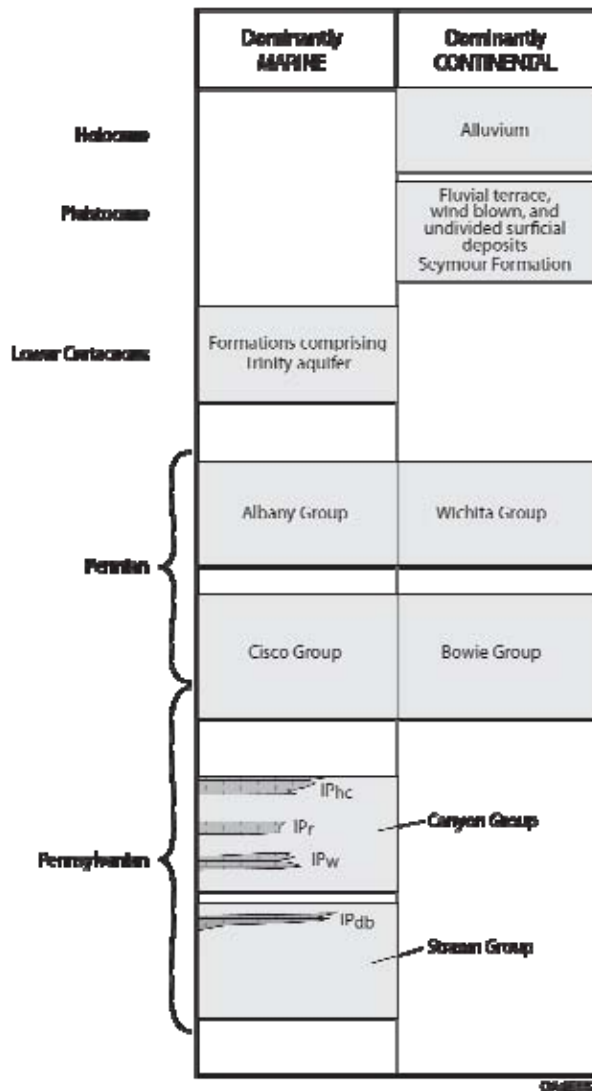
**Figure 2. Barnett Shale Gas Production and Water Use: 1993 to 2011**

Figure is compiled from IHS Energy (2011) and Railroad Commission of Texas (2011) databases.



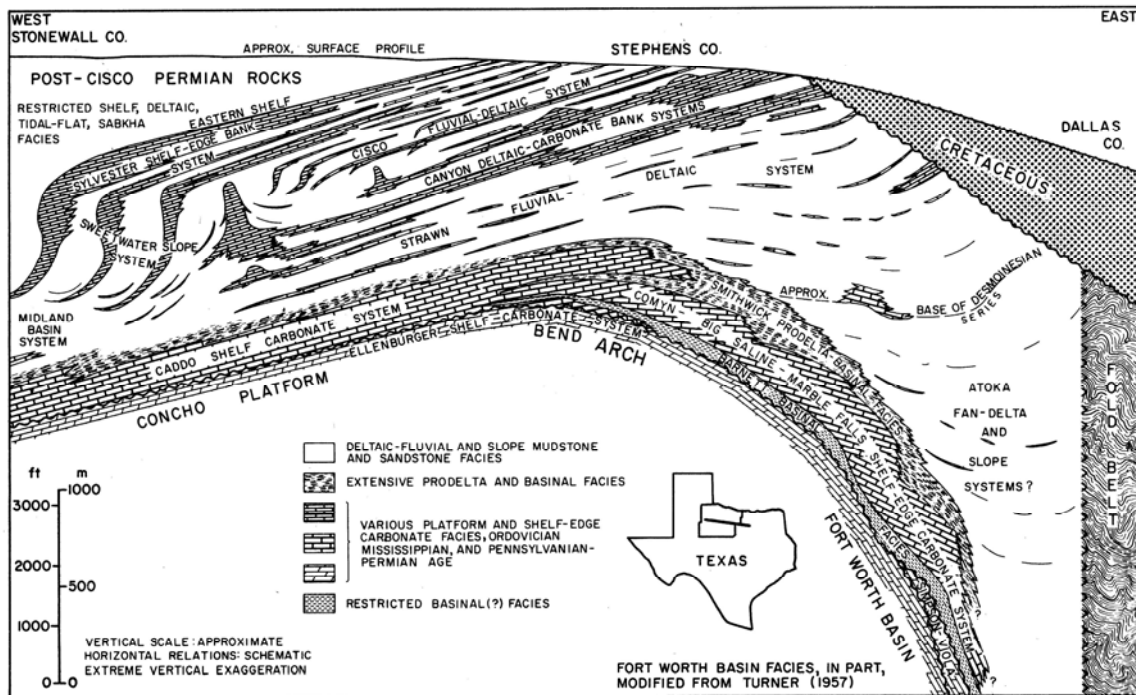
**Figure 3. Geologic Map of the Study Area**

Geology is compiled from digital Geologic Atlas of Texas and geologic map sheets (McGowen, Hentz et al. 1967; Barnes 1972; Hentz and Brown 1987; Pearson 2007).



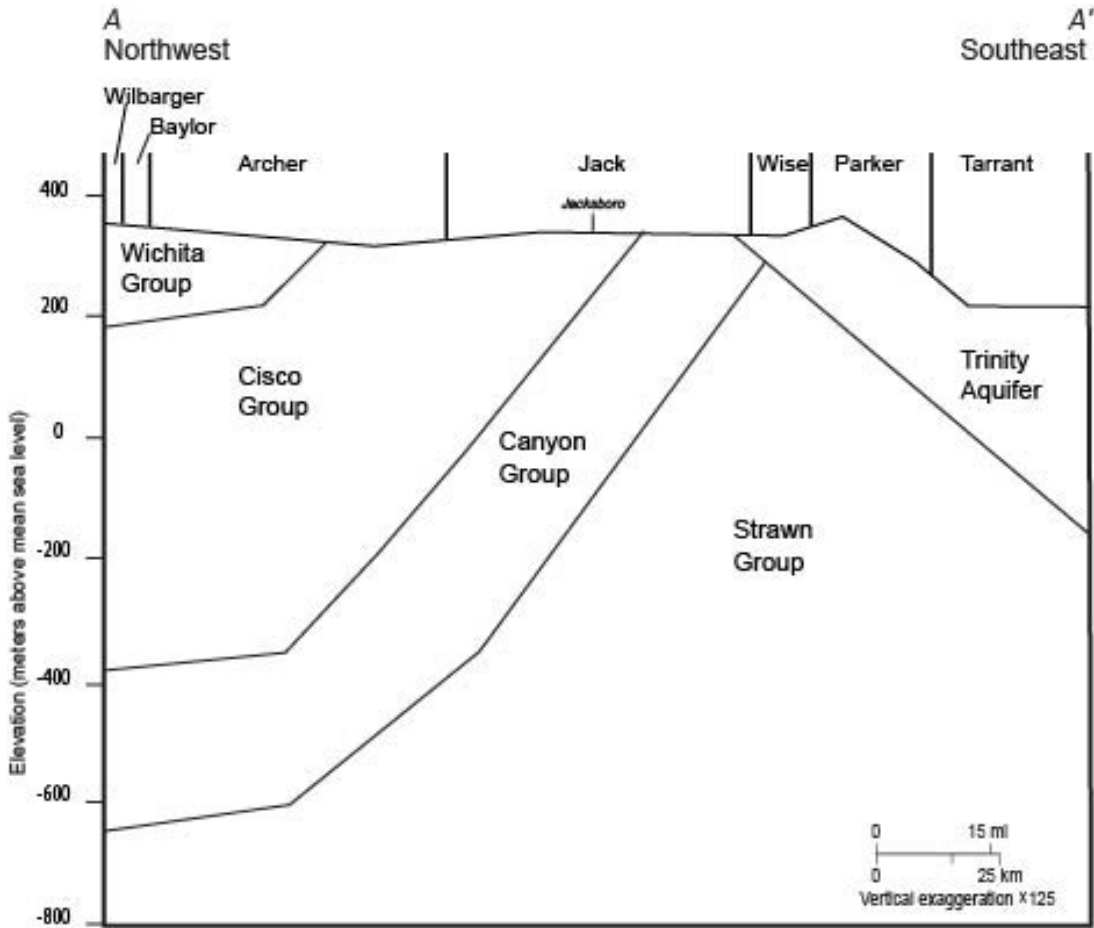
**Figure 4. Generalized Chronostratigraphic Colum**

Stratigraphy is synthesized from several publications (Wermund, Jenkins et al. 1962; McGowen, Hentz et al. 1967; Wermund and Jenkins 1969; Barnes 1972; Brown, Cleaves et al. 1973; Galloway and L. Frank Brown 1973; Erxleben 1974; Cleaves 1975; Erxleben 1975; Kier, Brown et al. 1979; Brown, Solis-Iriarte et al. 1987; Hentz and Brown 1987; Hentz 1988; Jones and Hentz 1988; Brown, Solis-Iriarte et al. 1990; Bradshaw and Mazzullo 1996; Brown, Ambrose et al. 2009). |P<sub>hc</sub> is Home Creek Limestone, |P<sub>r</sub> is Ranger Limestone, |P<sub>w</sub> is Winchell Limestone, and |P<sub>db</sub> is Dog Bend Limestone.



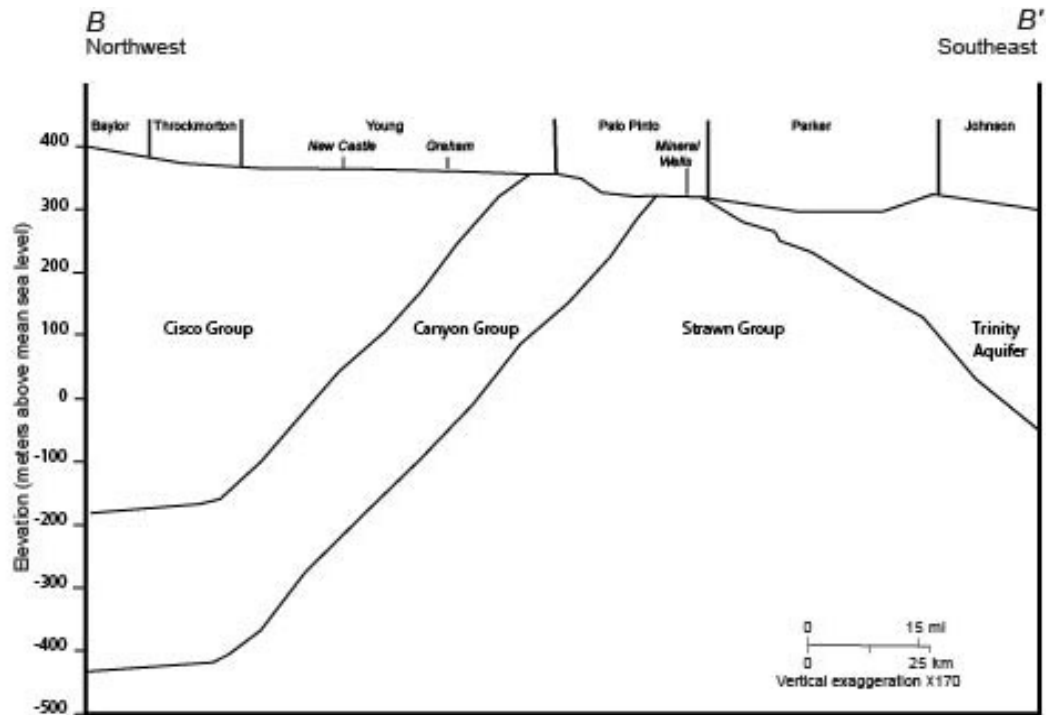
**Figure 5. Generalized Depositional Systems Tracts of North Central Texas**

The Paleozoic of North Central Texas is comprised of four generalized groups: Strawn Group, Canyon Group, Cisco Group, and post-Cisco Permian rocks of the Wichita Group (Brown, Cleaves et al. 1973).



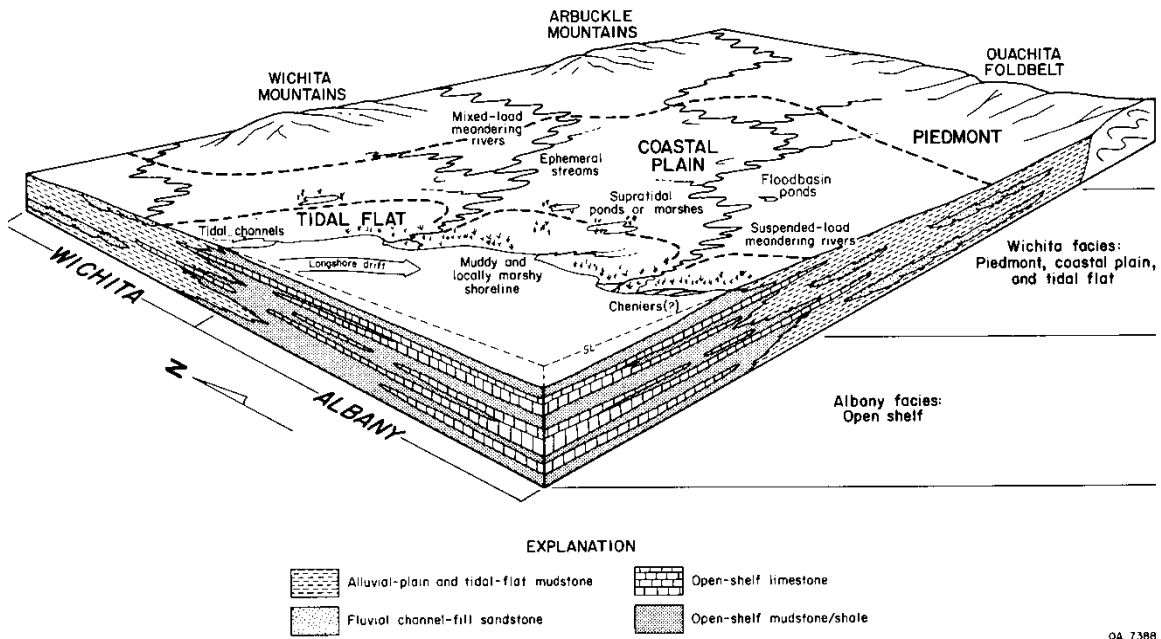
**Figure 6. Hydrogeologic Cross Section A-A'**

Cross section is a synthesis of existing outcrop and subsurface data (Wermund, Jenkins et al. 1962; Wermund and Jenkins 1969; Erxleben 1974; Cleaves 1975; Erxleben 1975; Nordstrom 1982; Hentz 1988; Brown, Solis-Iriarte et al. 1990; Pearson 2007; U.S. Geological Survey 2011).



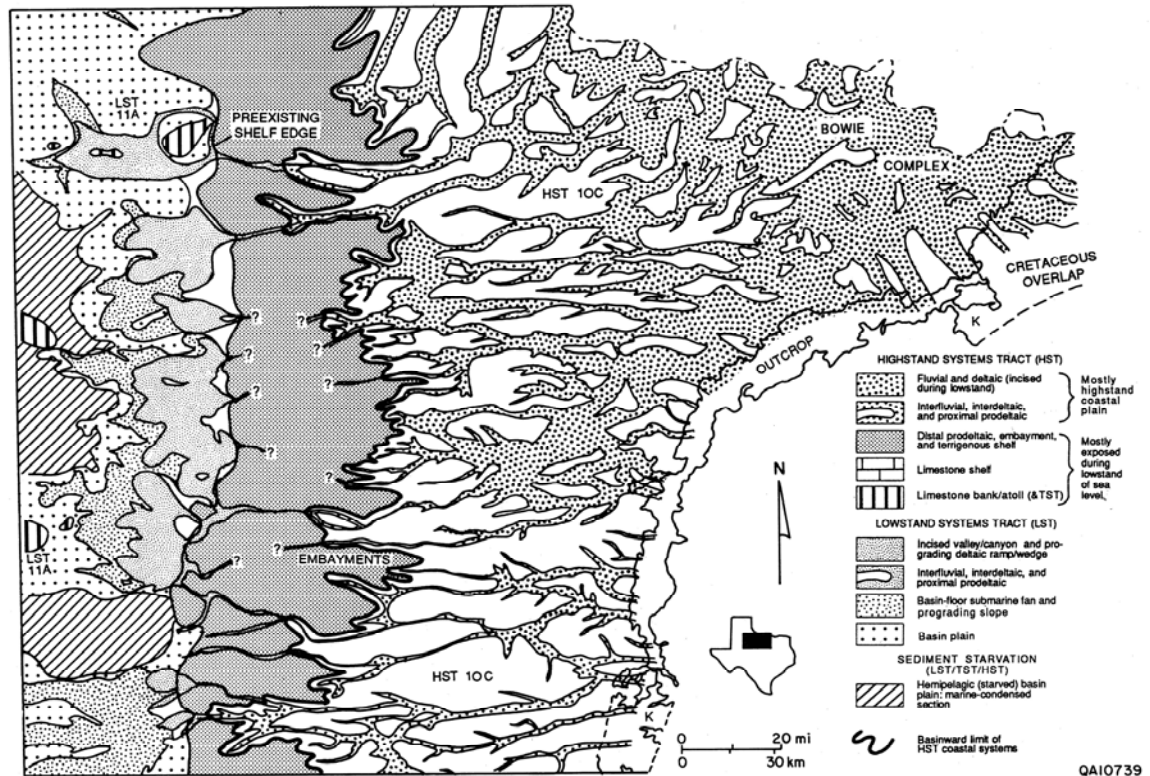
**Figure 7. Hydrogeologic Cross Section B-B'**

Cross section is a synthesis of existing outcrop and subsurface data (Wermund, Jenkins et al. 1962; Wermund and Jenkins 1969; Erxleben 1974; Cleaves 1975; Erxleben 1975; Nordstrom 1982; Hentz 1988; Brown, Solis-Iriarte et al. 1990; Pearson 2007; U.S. Geological Survey 2011).



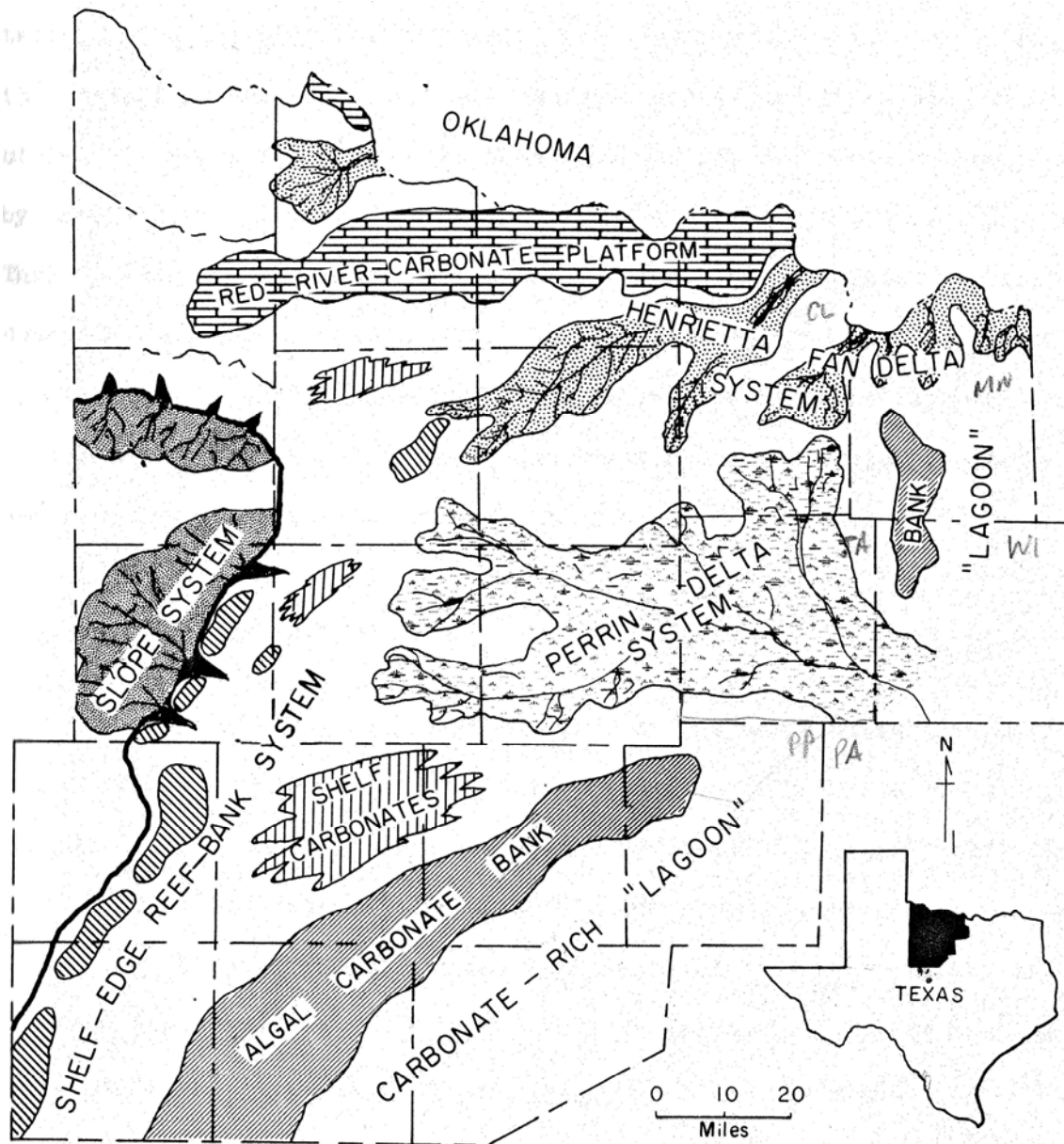
**Figure 8. Schematic Paleoenvironment of Wichita and Albany Groups**

Wichita Group was deposited in predominantly in fluvial settings of piedmont and coastal plain and Albany Group was deposited in predominantly marine tidal flats (Hentz 1988).



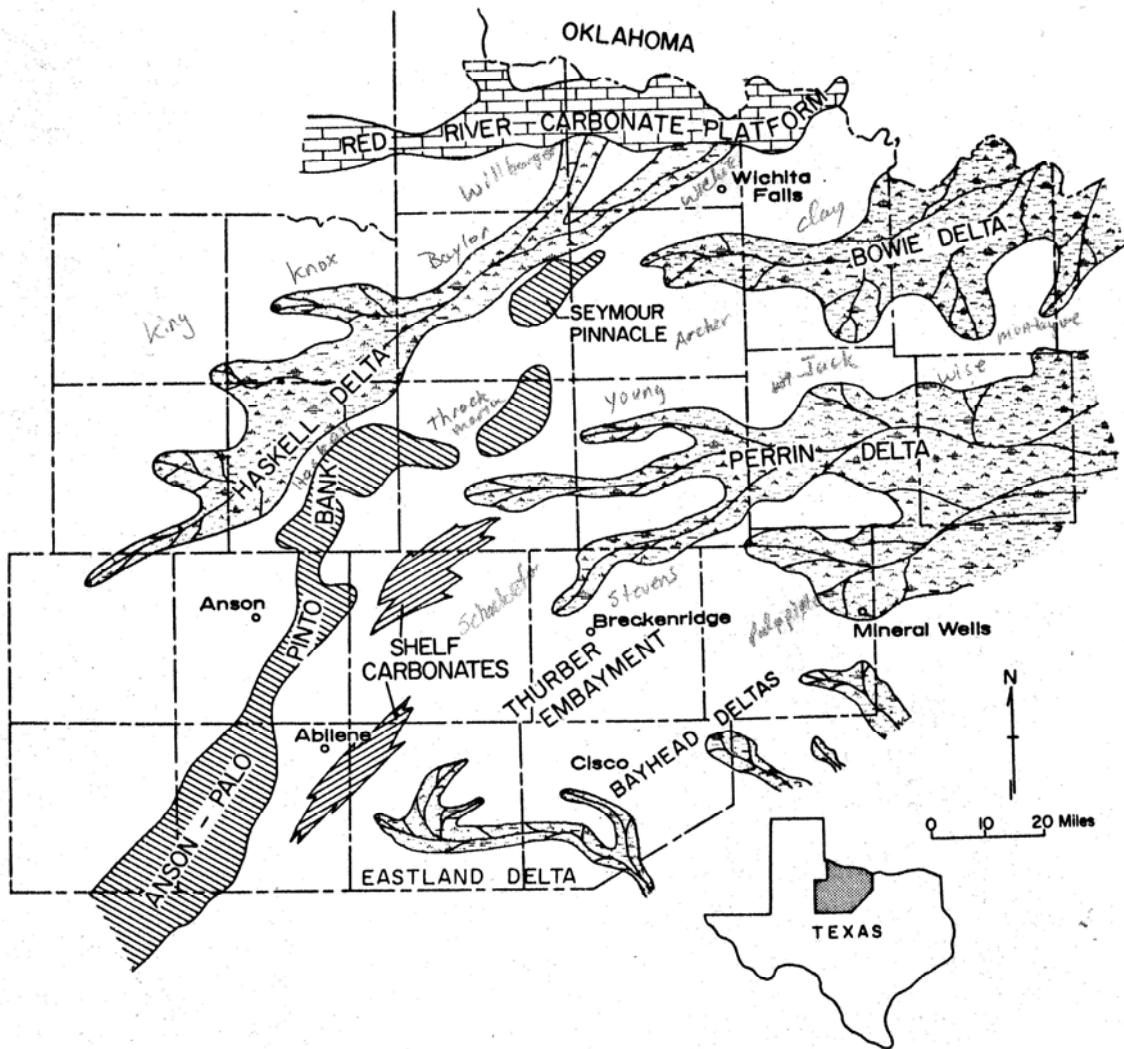
**Figure 9. Generalized Depositional Systems Cisco Group**

Cisco Group is comprised of highly heterogeneous sandstone and shale deposited in predominantly marine, fluvial-deltaic settings with sediment sourced from the Ouachita and Arbuckle Mountains and deposited on the Eastern Shelf of the Permian Basin (Brown, Solis-Iriarte et al. 1990).



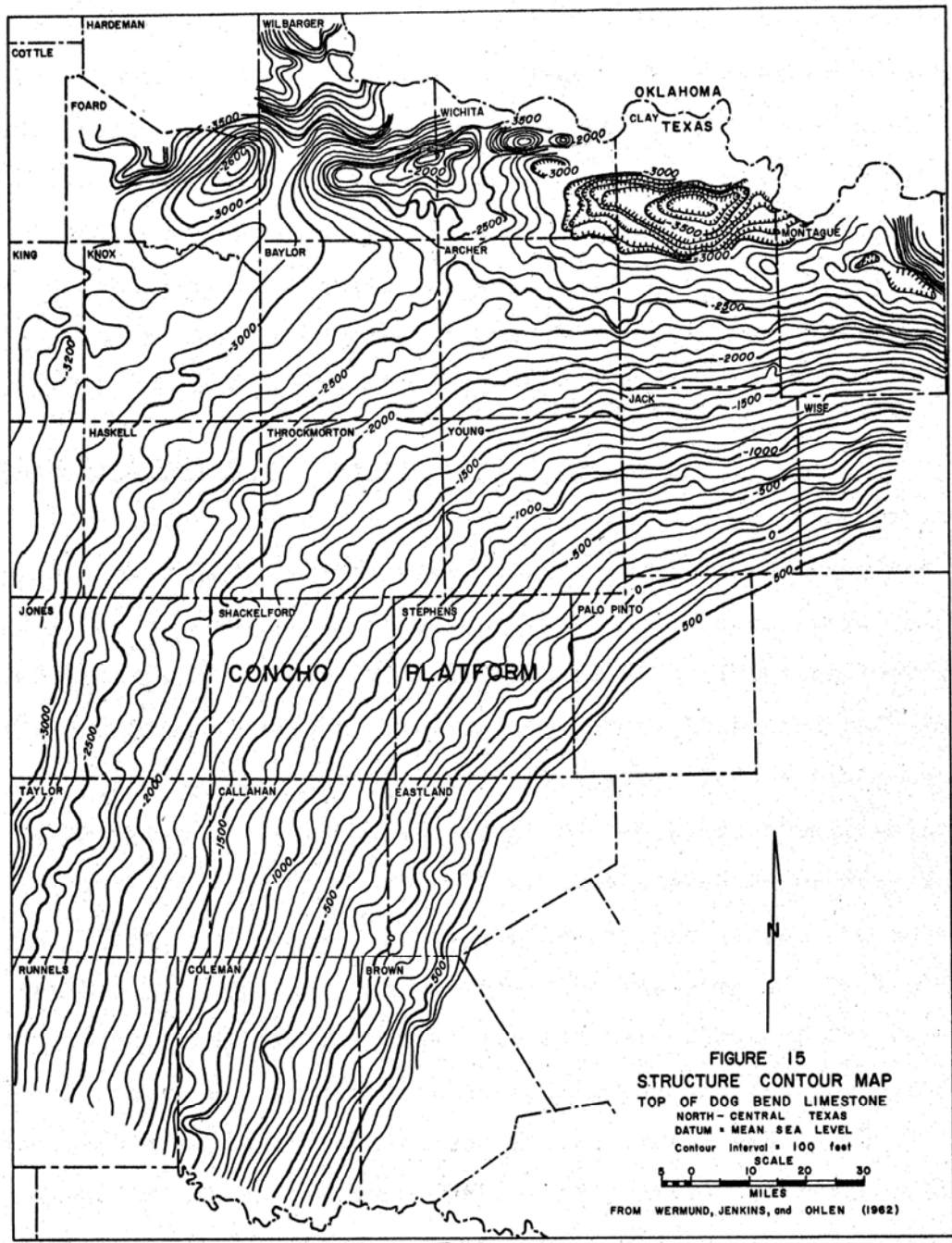
**Figure 10. Generalized Depositional Systems of Canyon Group**

Canyon Group is a predominantly marine, fluvial-deltaic and carbonate bank setting resulting from a reduced sediment input sourced from the Ouachita and Arbuckle Mountains comprised of heterogeneous sandstone and siltstone, in addition to limestone beds (Erxleben 1974; Erxleben 1975).



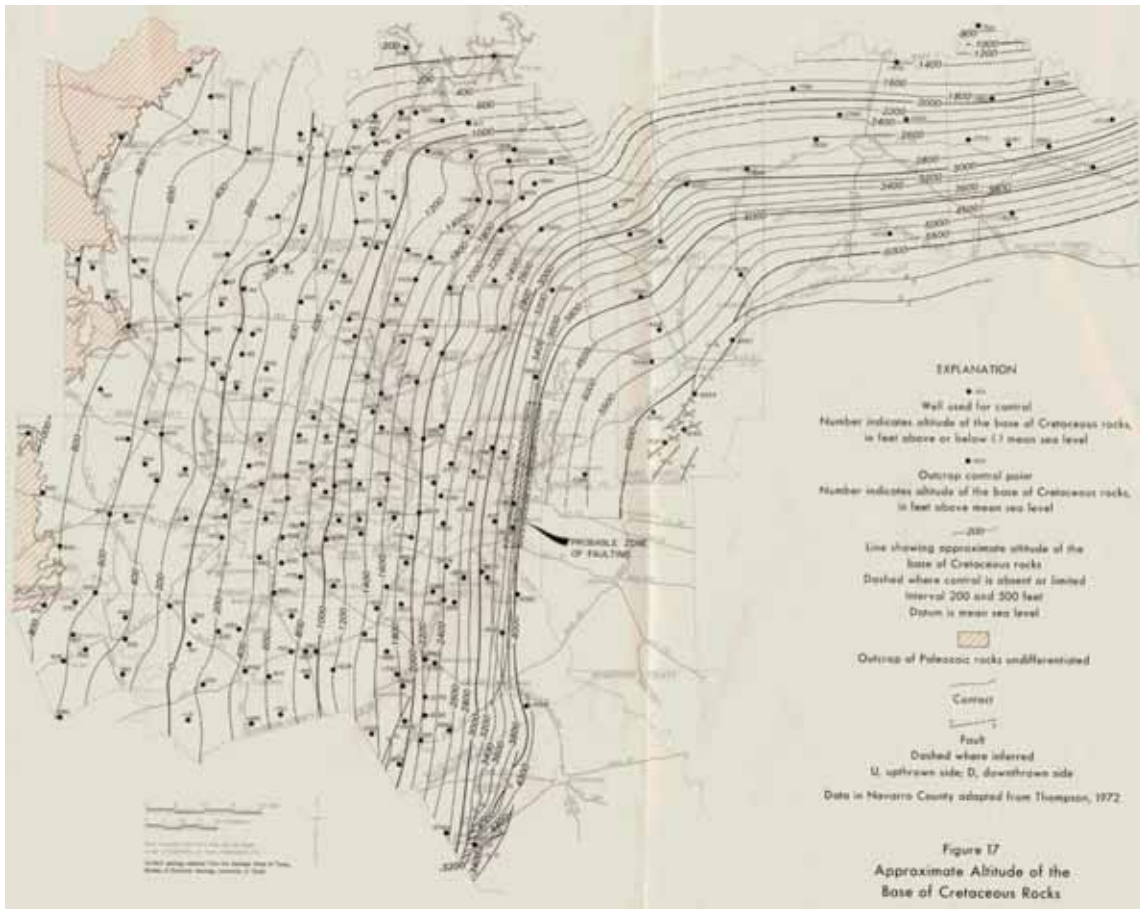
**Figure 11. Generalized Depositional Systems of Strawn Group**

Similarly to the Cisco Group, the Strawn Group is comprised of highly heterogeneous sandstone and shale deposited in predominantly marine, fluvial-deltaic settings with sediment sourced from the Ouachita and Arbuckle Mountains and deposited on the Eastern Shelf of the Permian (Cleaves 1975).



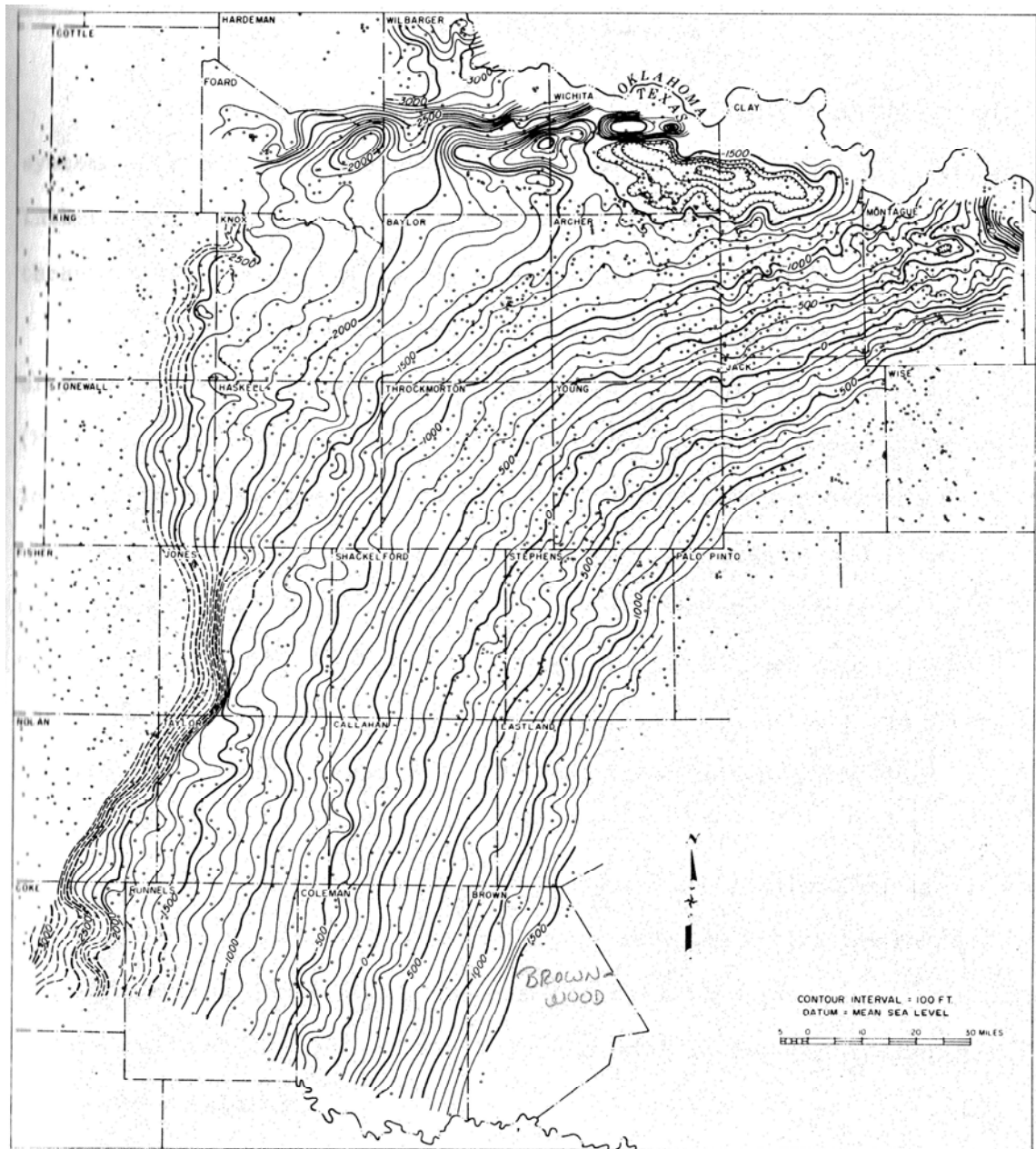
**Figure 12. Structural Contour Map of the Dog Bend Limestone**

The Dog Bend Limestone is used to delineate the upper Strawn Group. Figure after Wermund et al. (1962).



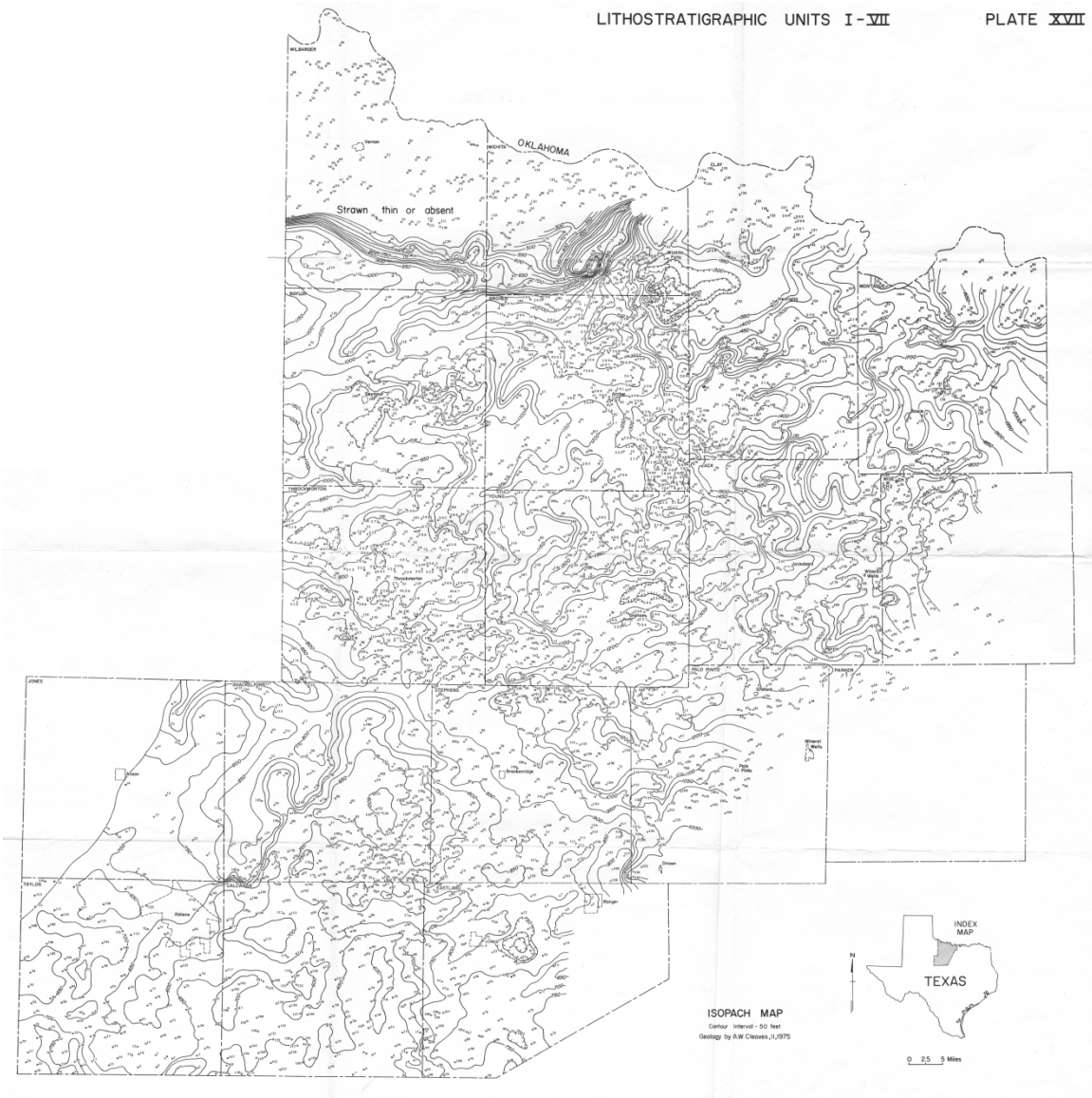
**Figure 13. Approximate Altitude of the Base of Cretaceous Rocks**

The base of the Cretaceous (i.e., Trinity aquifer) is used to infer the top of the Strawn, Canyon, and Cisco Groups where overlain by Trinity aquifer. Figure after (Nordstrom 1982).



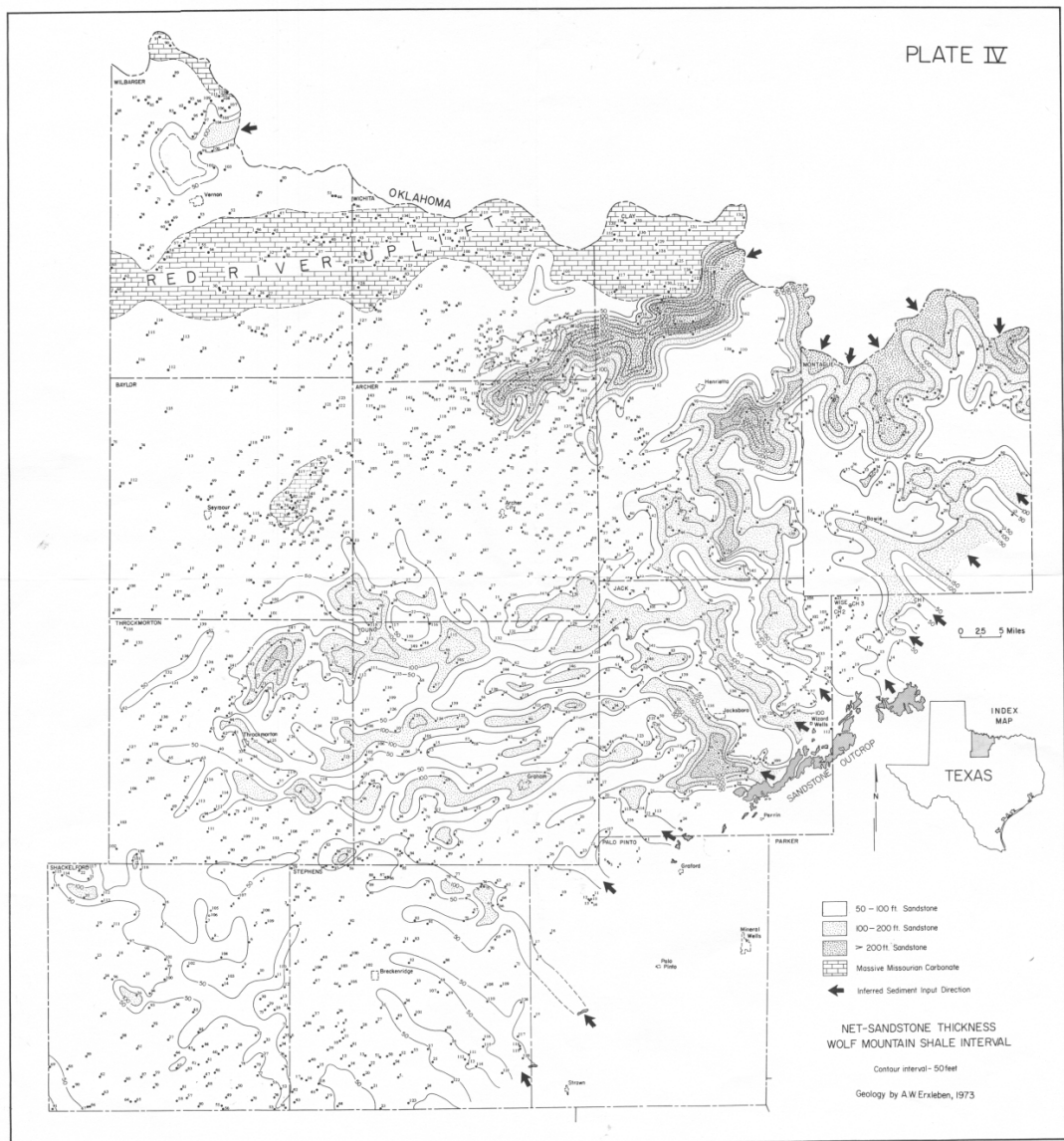
**Figure 14. Structural Contour Map of Home Creek Limestone**

The Home Creek Limestone is used to delineate top of the Canyon Group. Figure after Wermund and Jenkins (1969).



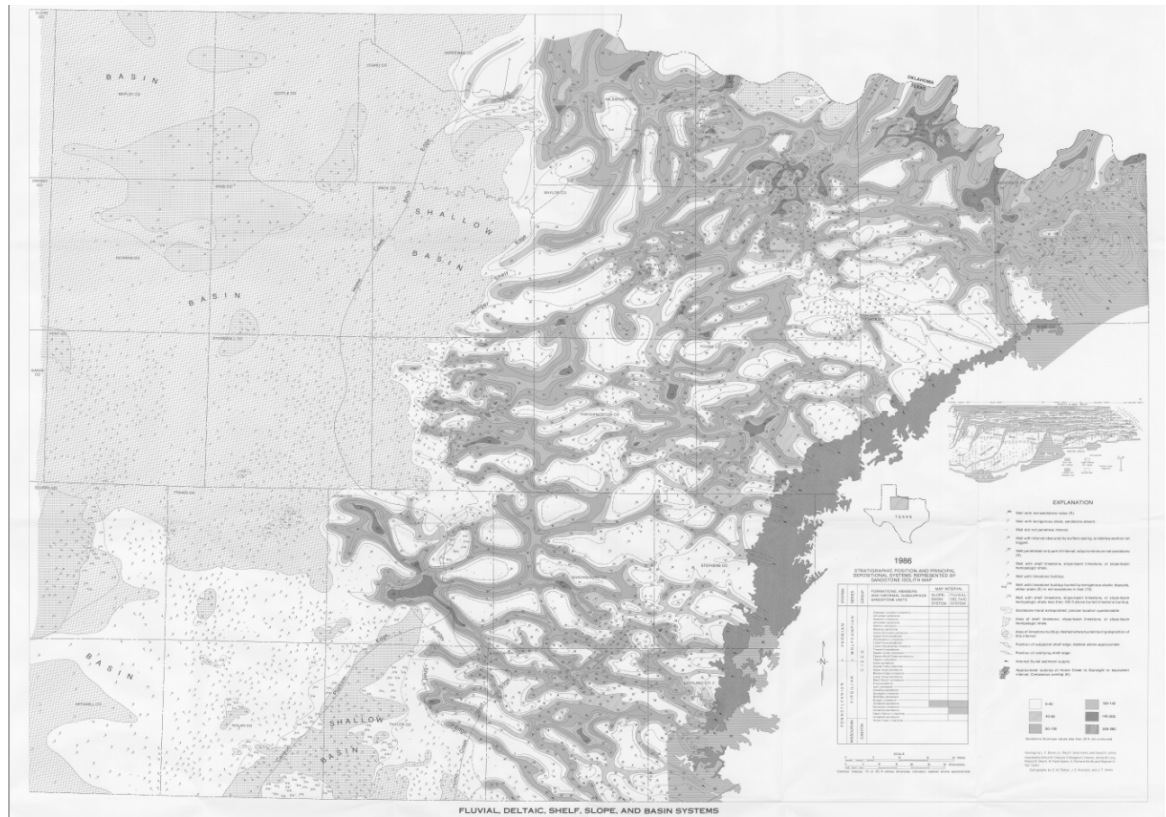
**Figure 15. Subsurface Sand Distribution: Strawn Group**

Net sand map for the Strawn Group after Cleaves (1975).



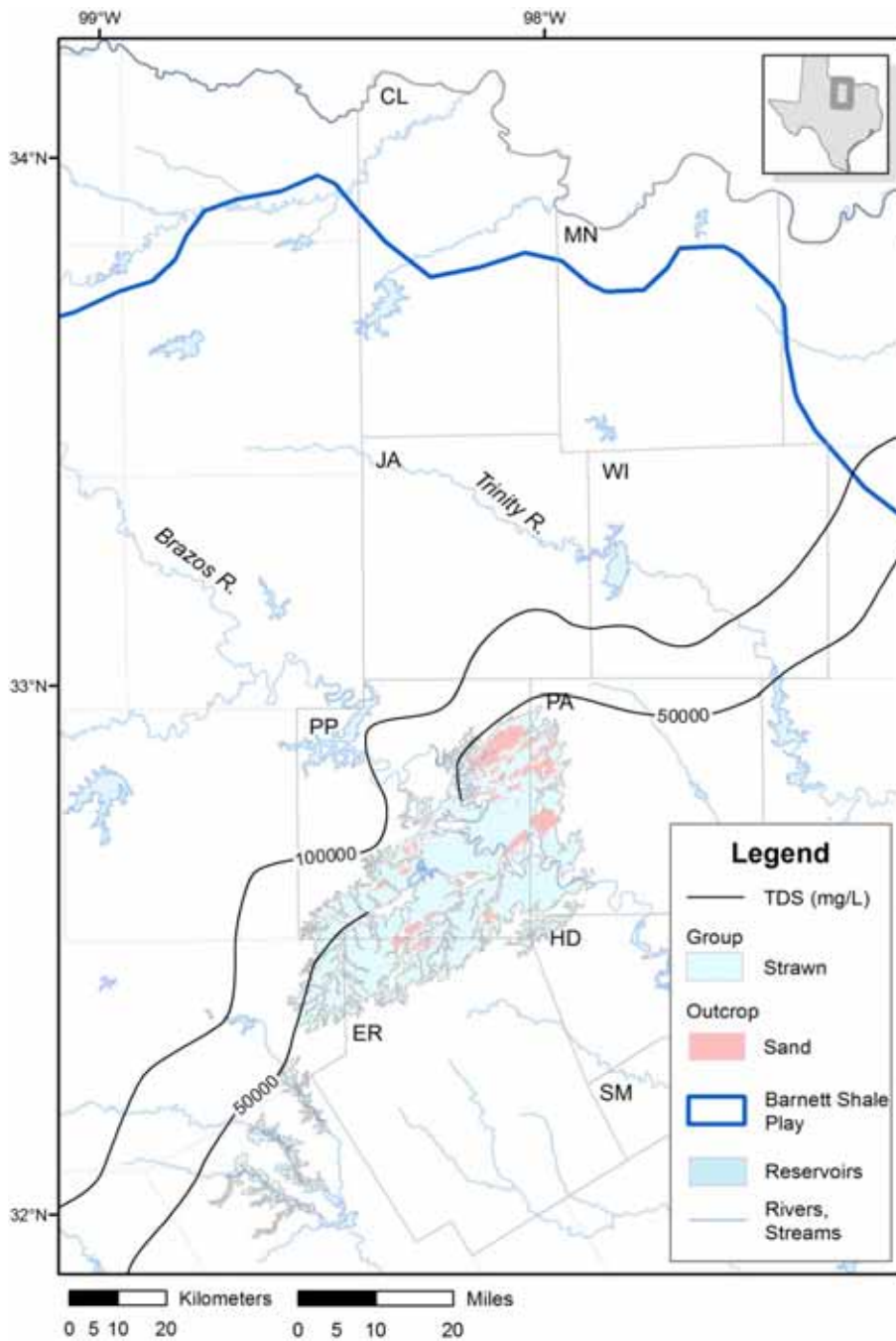
**Figure 16. Representative Subsurface Sand Distribution: Canyon Group**

Net sand map for one of three sandstone intervals of the Canyon Group after Erxleben (1975).



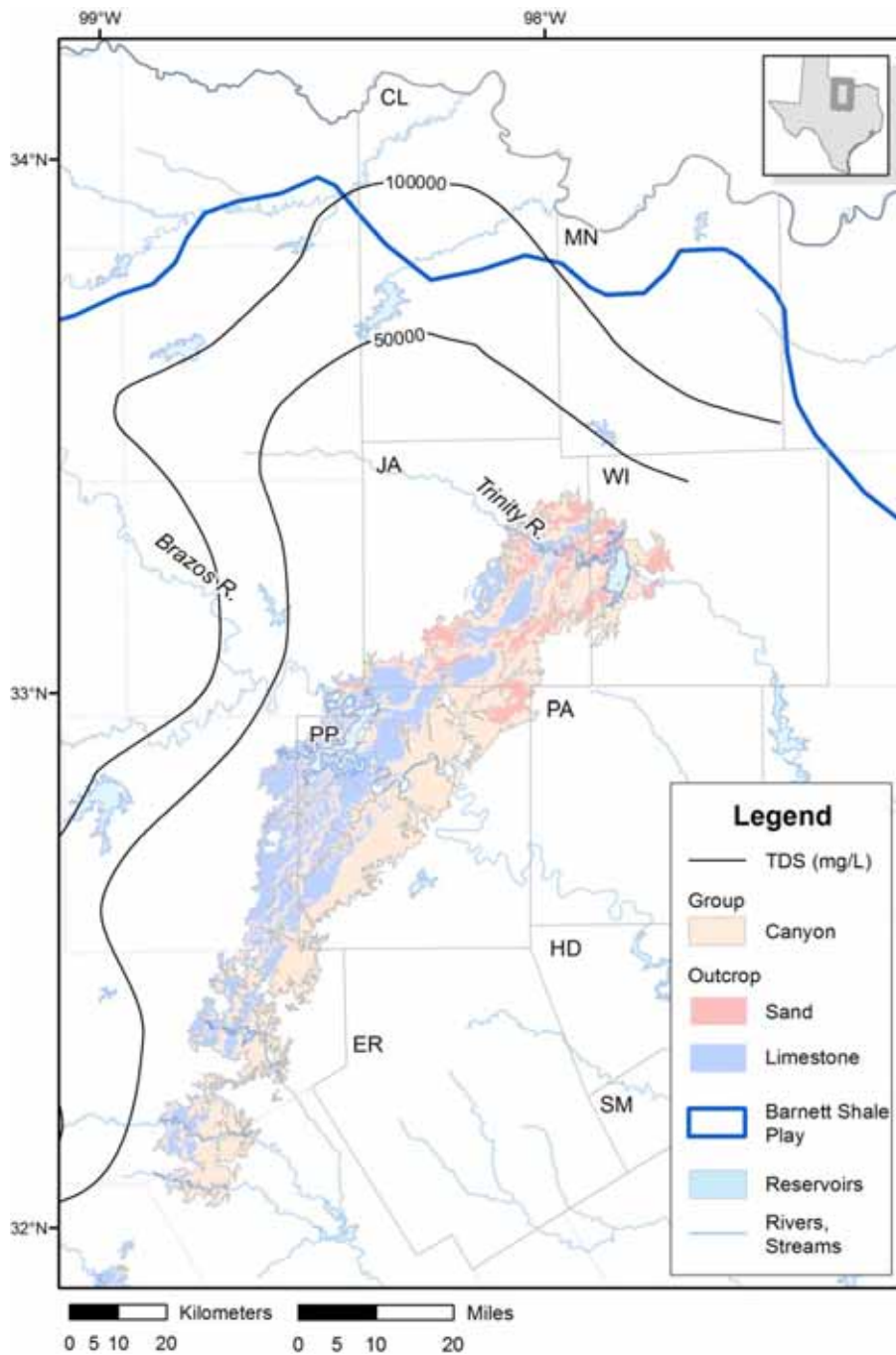
**Figure 17. Representative Subsurface Sand Distribution: Cisco Group**

Net sand map for one of sixteen sandstone intervals of the Cisco Group (from the sandstone-rich lower Cisco Group) after Brown (1990).



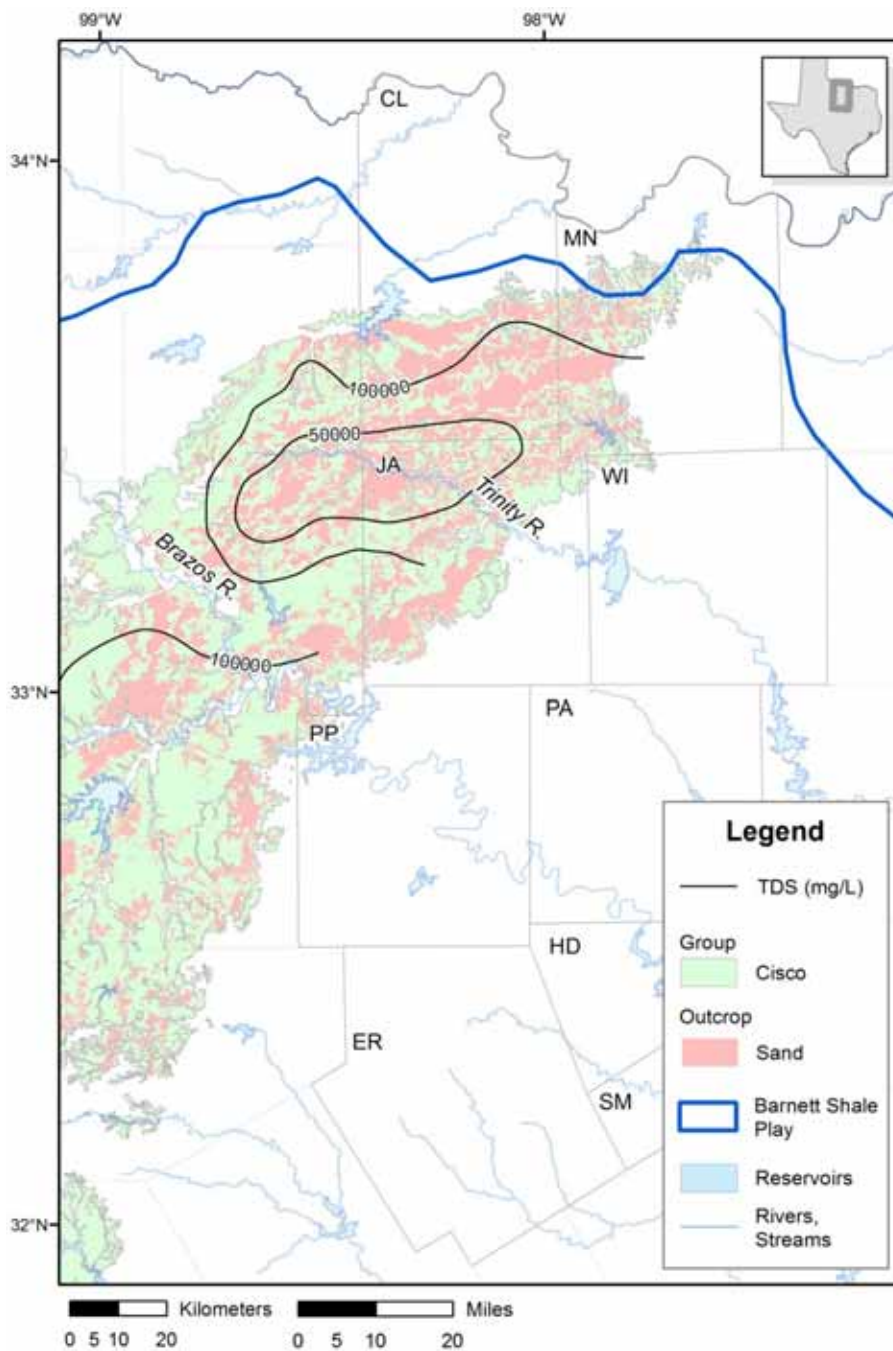
**Figure 18. Groundwater Total Dissolved Solids: Strawn Group**

Groundwater salinity from Texas Water Development Board (1972).



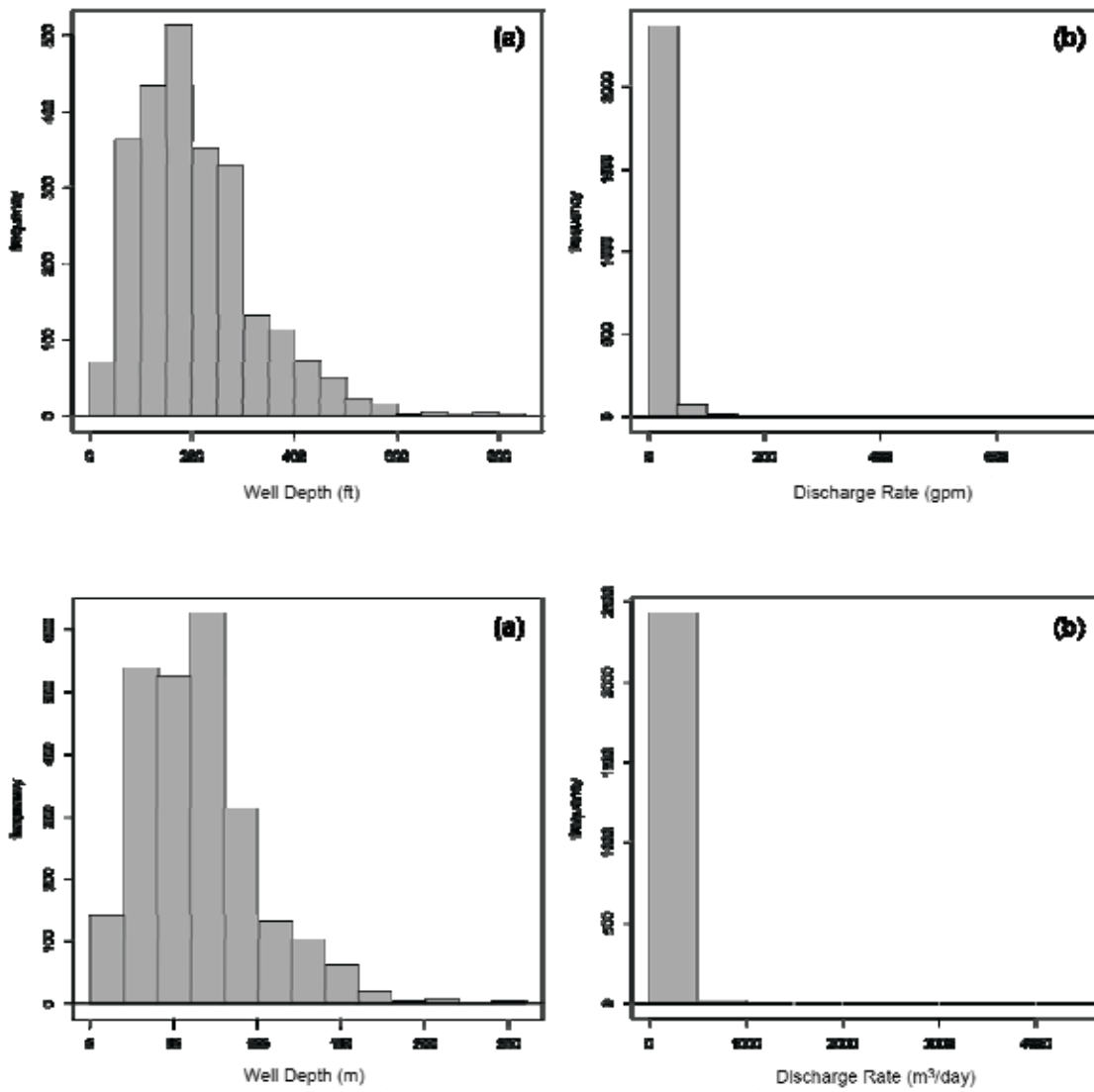
**Figure 19. Groundwater Total Dissolved Solids: Canyon Group**

Groundwater salinity from Texas Water Development Board (1972).



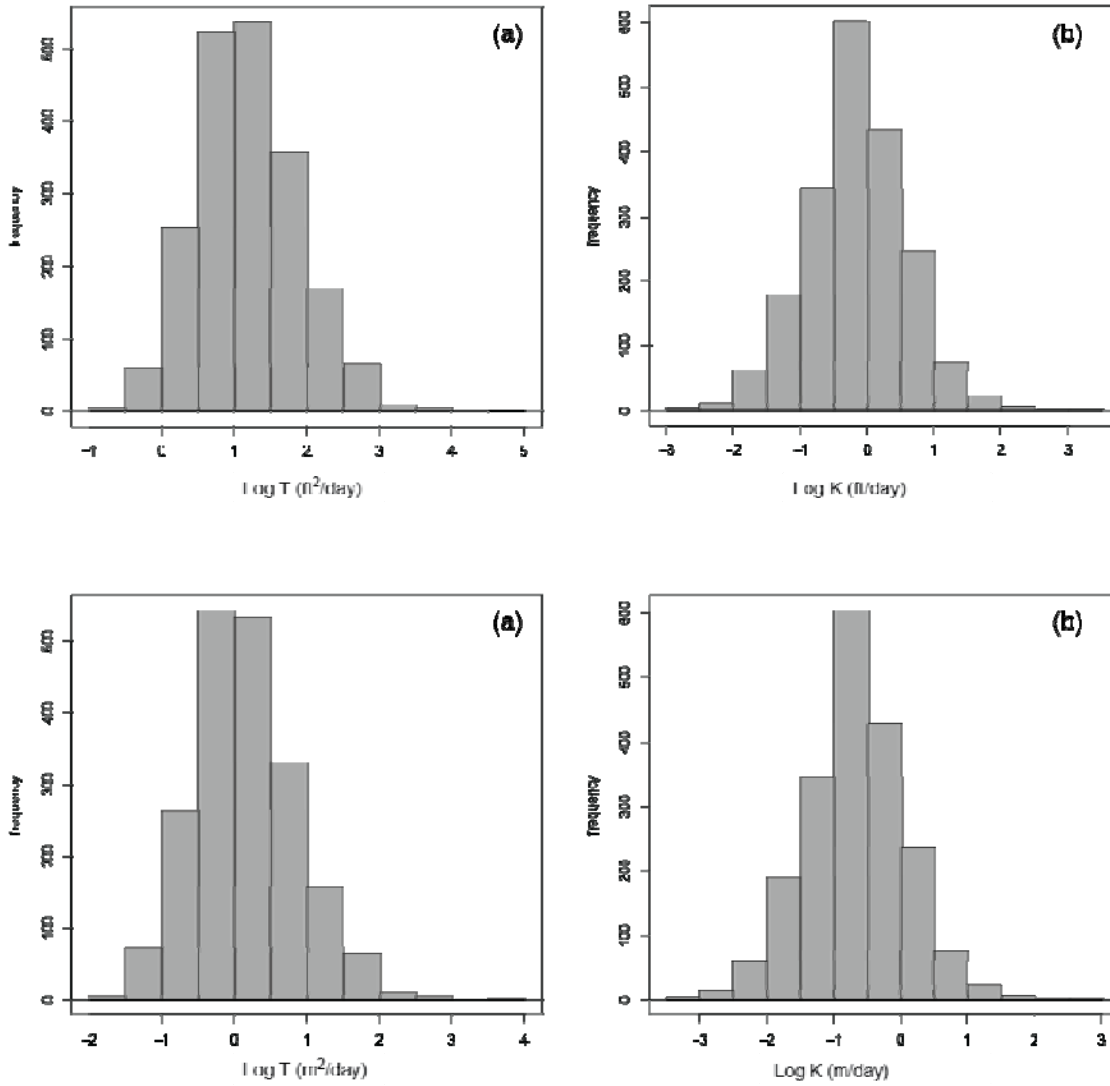
**Figure 20. Groundwater Total Dissolved Solids: Cisco Group**

Groundwater salinity from Texas Water Development Board (1972).



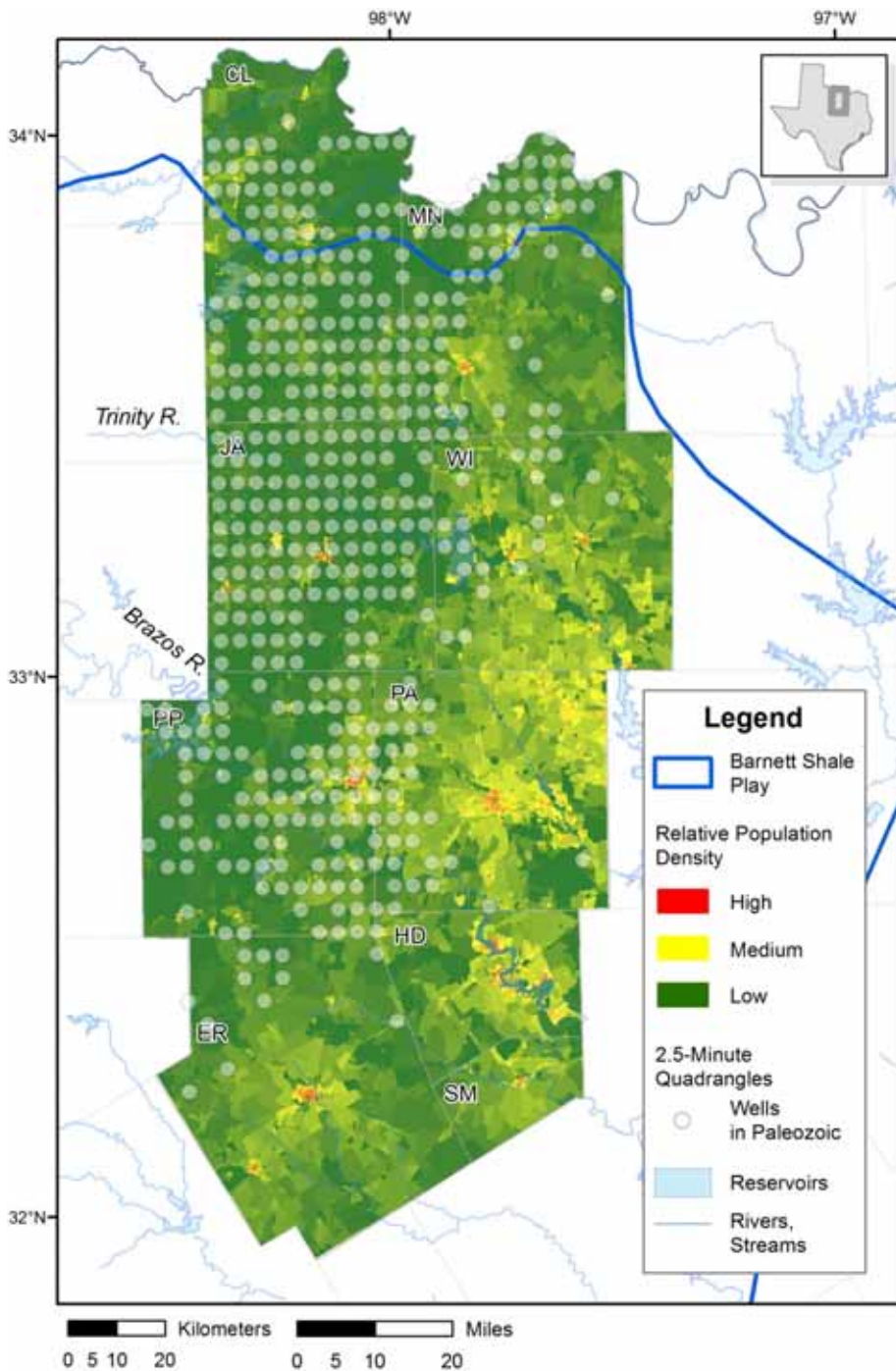
**Figure 21. General Characteristics of Well Depth and Discharge Rate**

(a) Well depth, (b) Discharge rate; in english and SI units



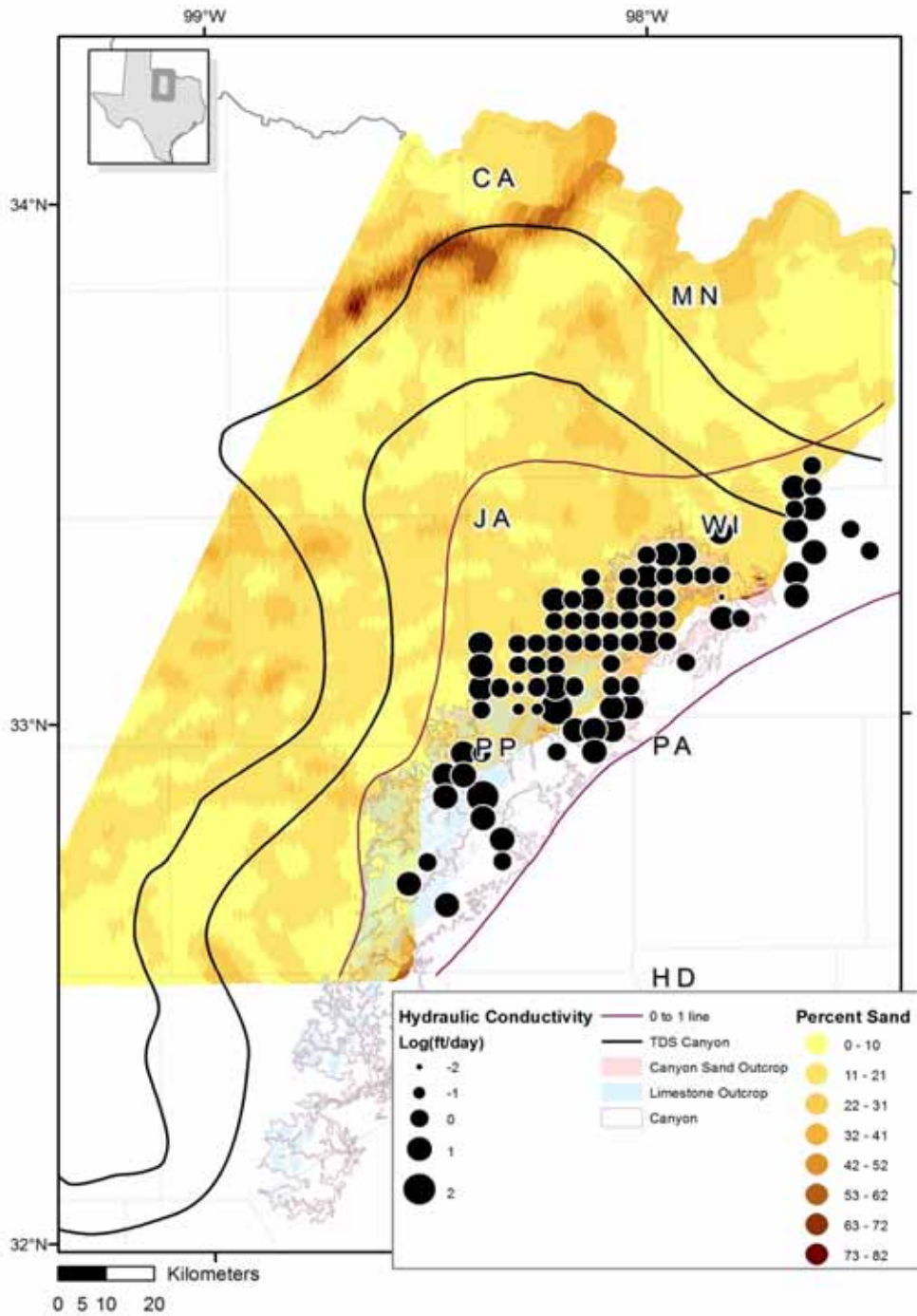
**Figure 22. General Characteristics of Transmissivity and Hydraulic Conductivity**

(a) Transmissivity, (b) Hydraulic conductivity; in english and SI units



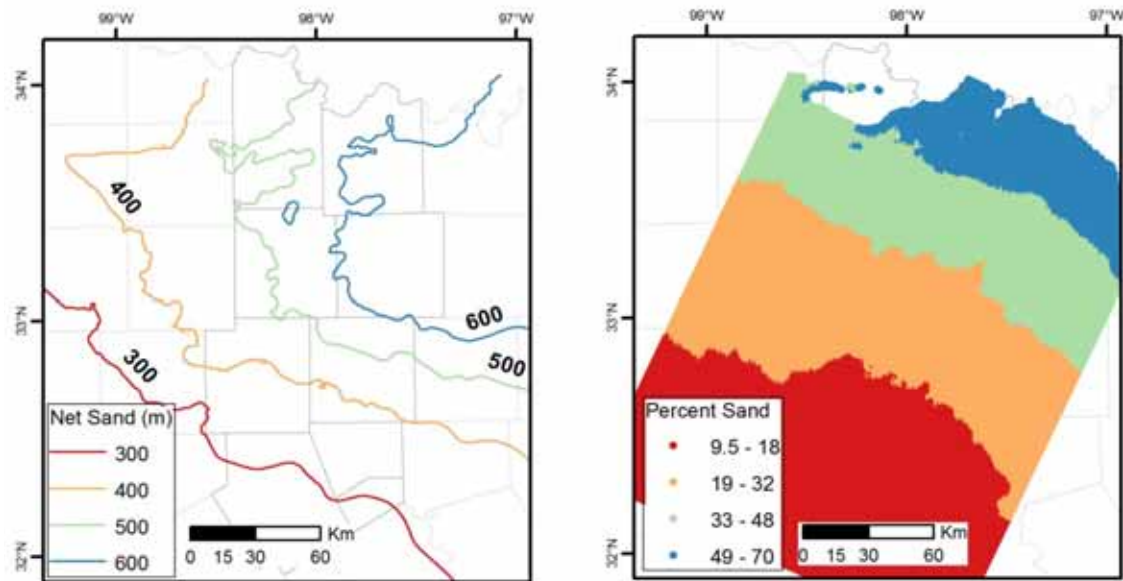
**Figure 23. Population Density and Quadrangles with Paleozoic Wells**

Population density data are from U.S. Census Bureau (2000).



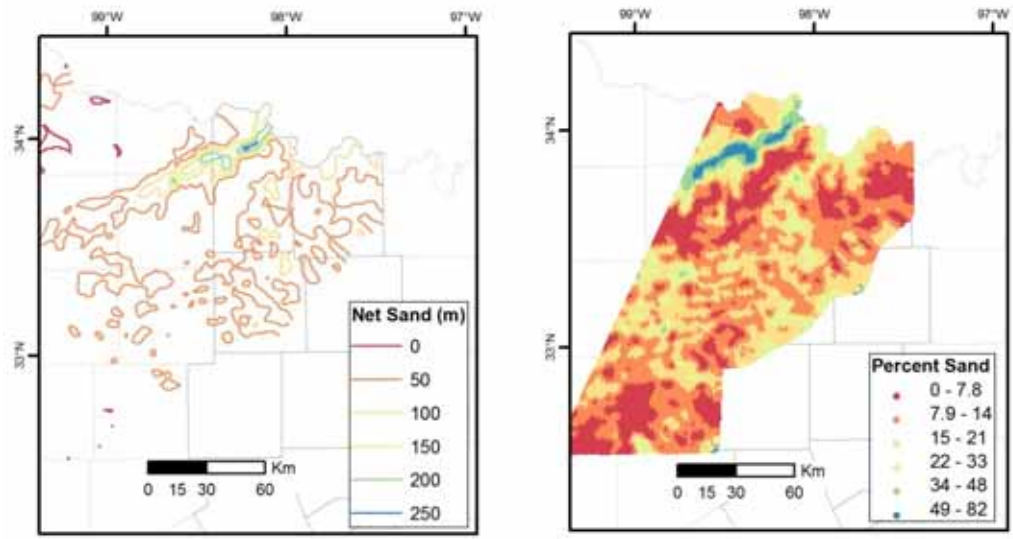
**Figure 24. Interpolation Method for Hydraulic Conductivity**

Zero and one lines reflect spatial distribution of groundwater salinity from Texas Water Development Board (1972) and outcrop from (Pearson 2007).



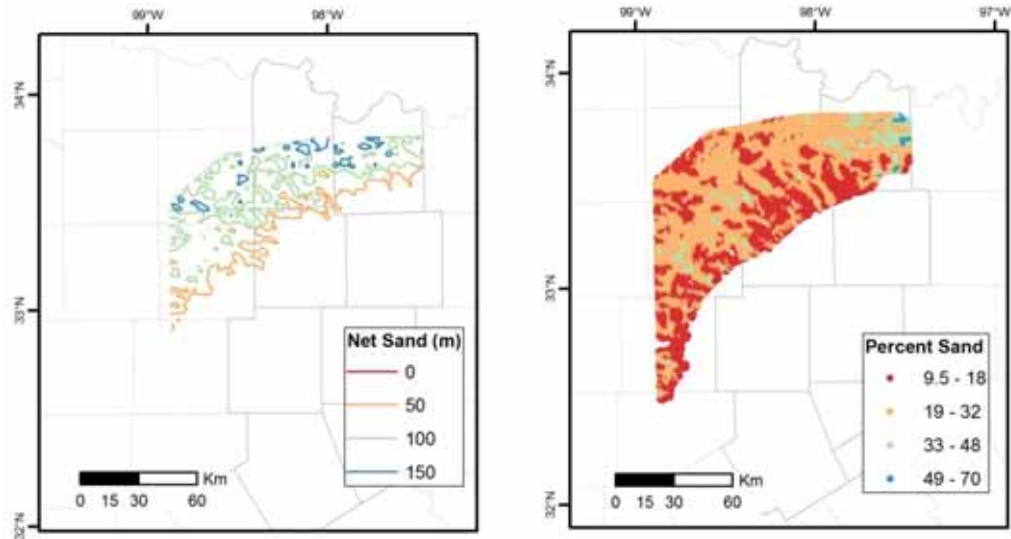
**Figure 25. Subsurface Sand Distribution: Strawn Group**

(A) Net sand thickness, (B) Sand fraction. Net sand thickness indicated by contours from Cleaves (1975). Sand fraction is net sand thickness divided by layer thickness.



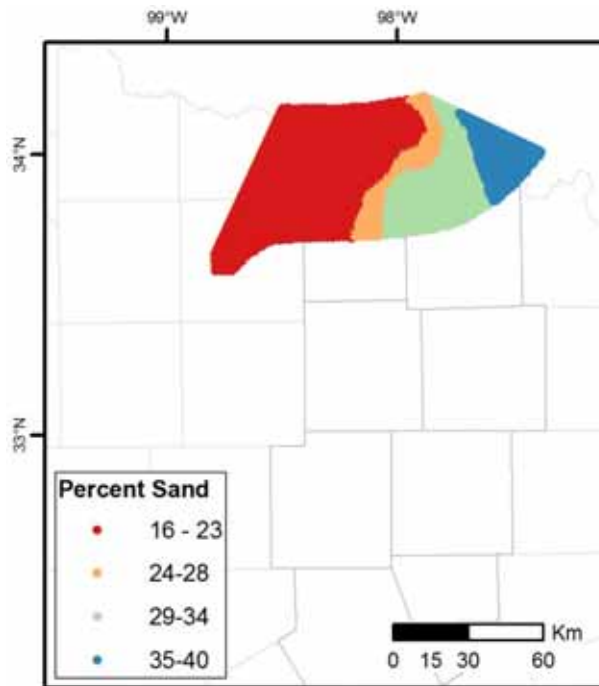
**Figure 26. Subsurface Sand Distribution: Canyon Group**

(A) Net sand thickness, (B) Sand fraction. Net sand thickness indicated by countours from Erxleben (1975). Sand fraction is net sand thickness divided by layer thickness.



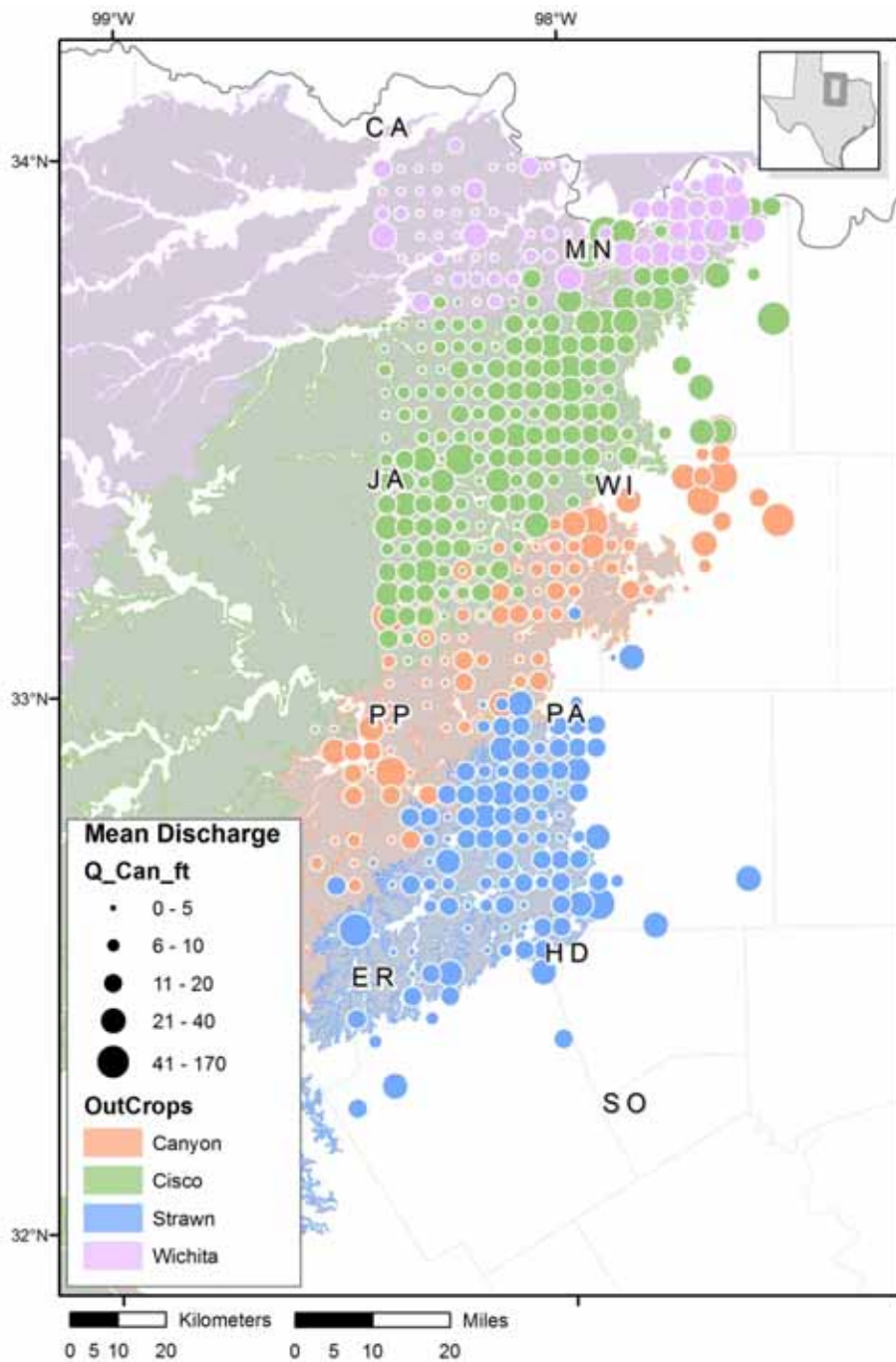
**Figure 27. Subsurface Sand Distribution: Cisco Group**

(A) Net sand thickness, (B) Sand fraction. Net sand thickness indicated by countours from Brown (1990). Sand fraction is net sand thickness divided by layer thickness.

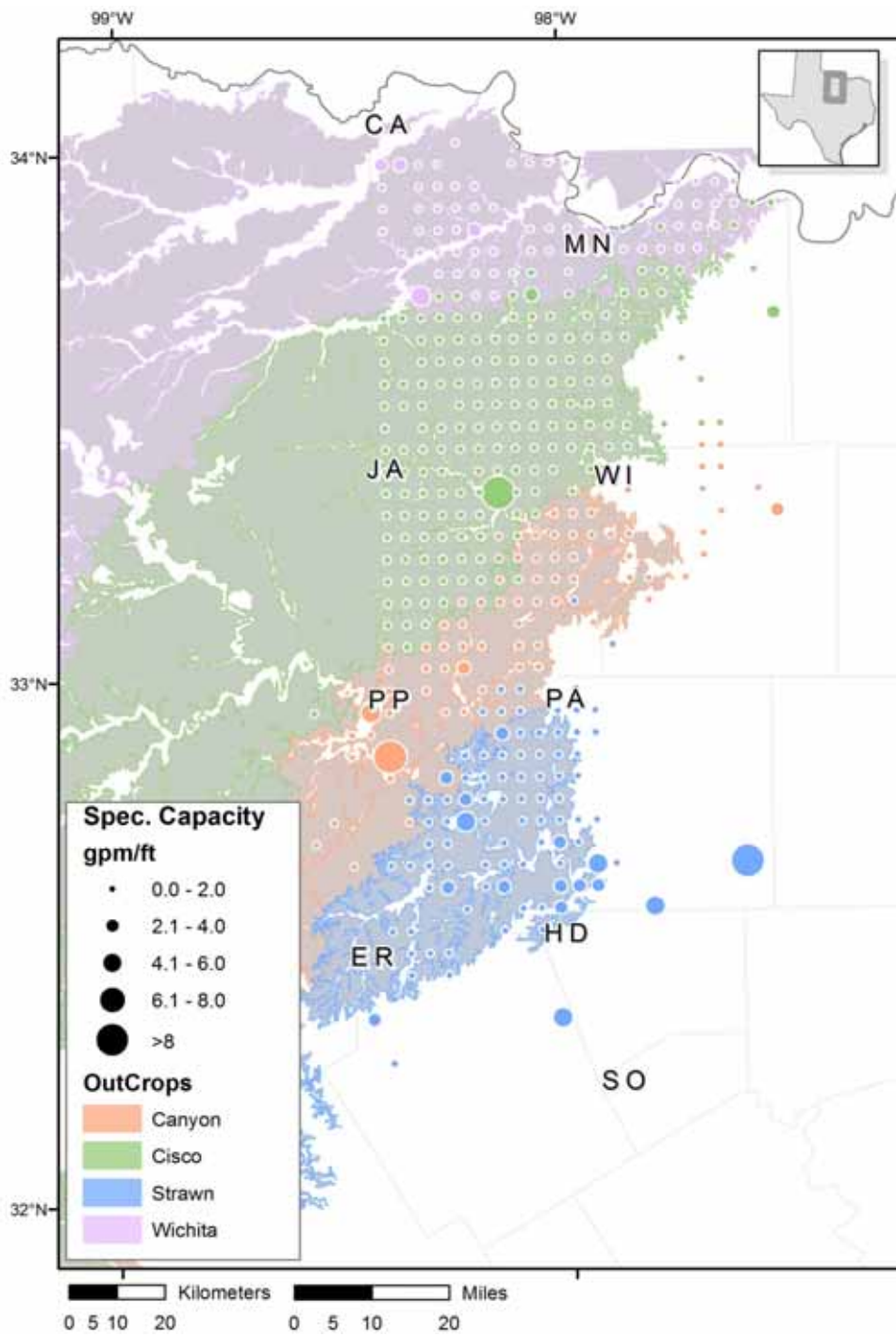


**Figure 28. Subsurface Sand Distribution: Wichita Group**

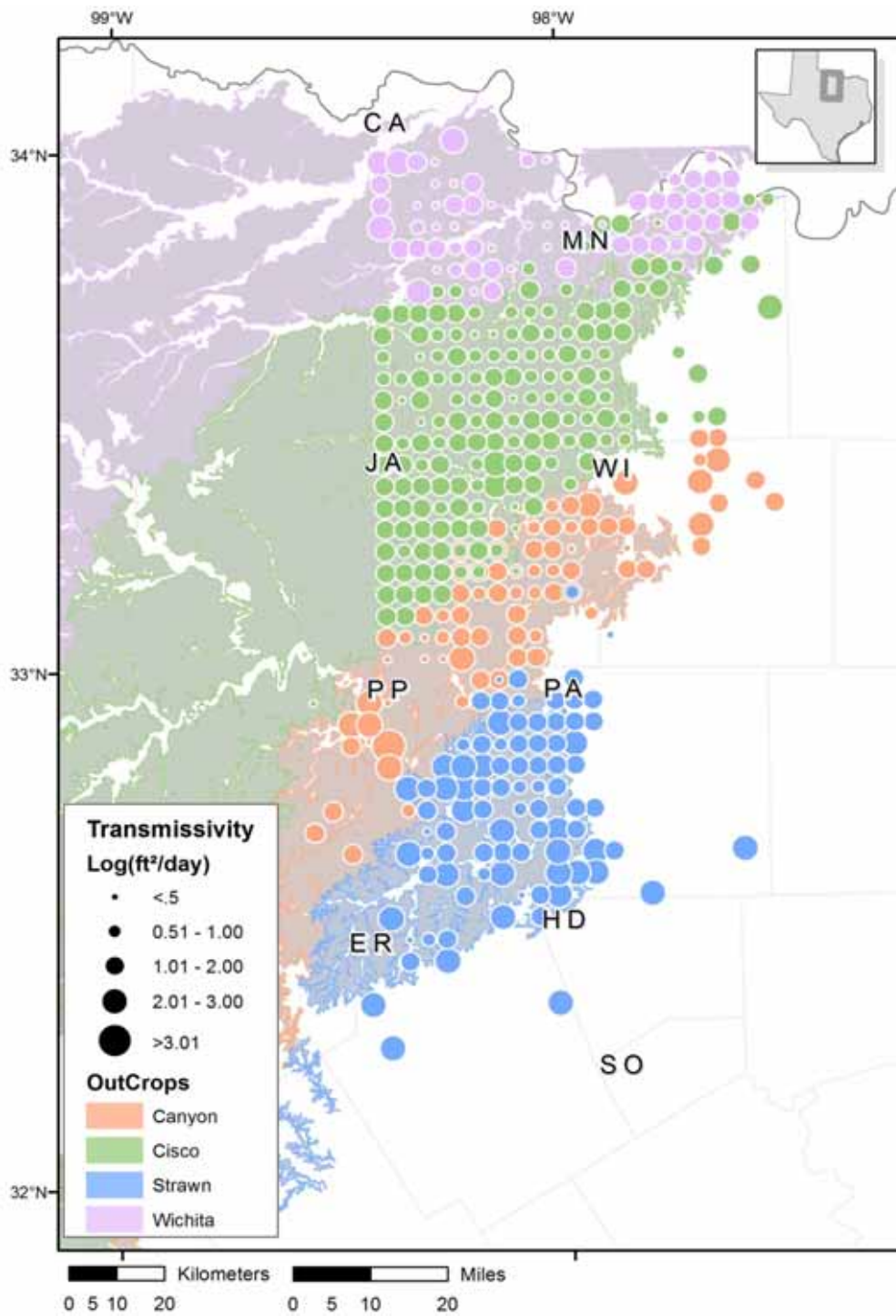
Sandstone net sand maps are not available for the Wichita Group. Sand fraction estimated following Hentz (1988).



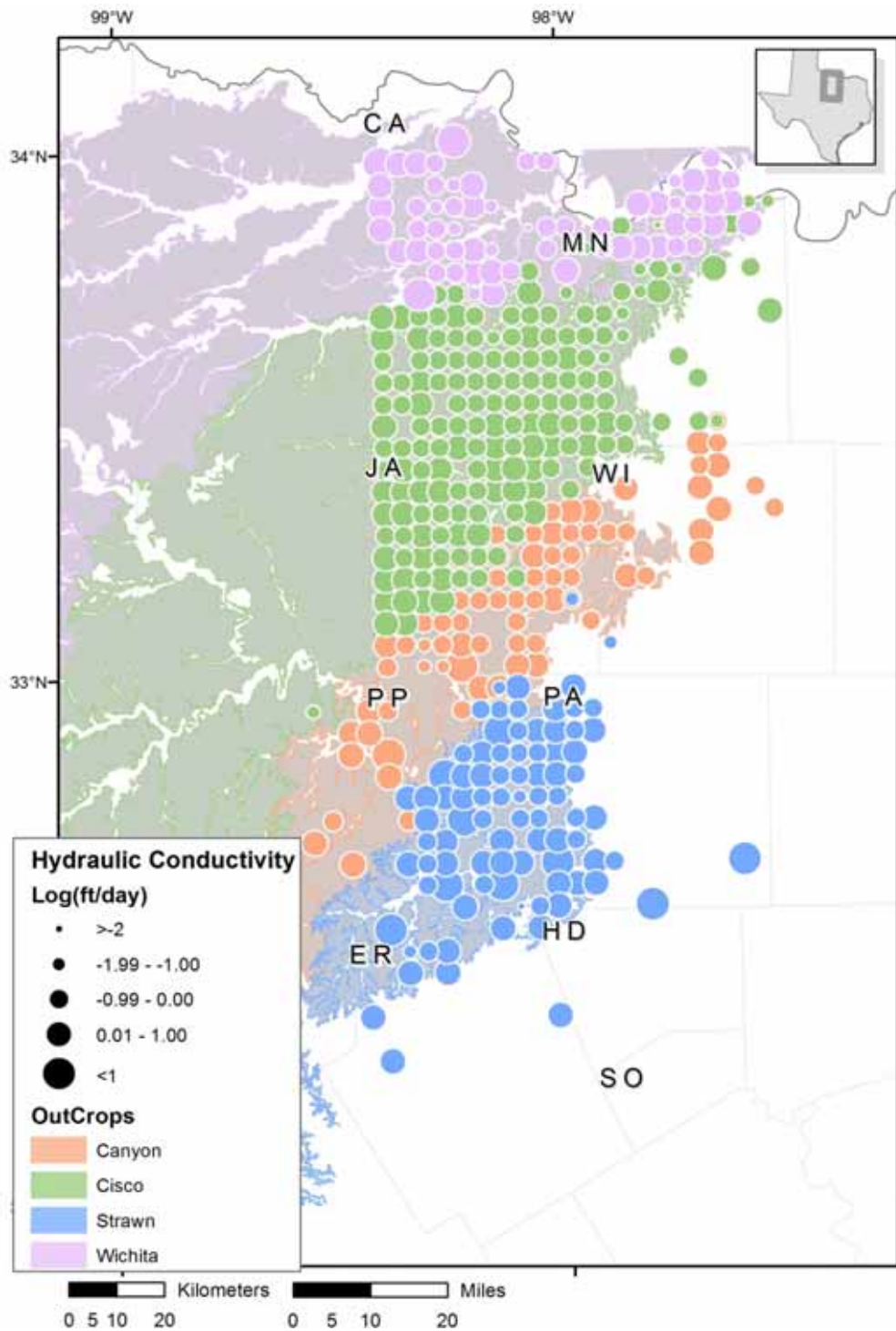
**Figure 29. Spatial Distribution of Discharge Rate**



**Figure 30. Spatial Distribution of Specific Capacity**



**Figure 31. Spatial Distribution of Transmissivity**



**Figure 32. Spatial Distribution of Hydraulic Conductivity**

## TABLES

**Table 0. Characteristics of Initial, Preliminary, and Final Well Databases**

Sources of data: TCEQ (2011) and TWDB (2011).

	Total	Percent
<b>Initial Well Database</b>	<b>7,614</b>	-
Trinity aquifer wells (1st pass), dry holes, wells mislocated outside study area	2,548	33
Artesian wells screened in limestone near Possum Kingdom Reservoir	71	1
<b>Preliminary Well Database</b>	<b>4,995</b>	-
Wells without borehole radius	1,524	31
Wells without drawdown data	820	16
Alluvial aquifer wells	144	3
Trinity aquifer wells (2nd pass)	2,377	48
<b>Final Well Database</b>	<b>2,474</b>	-
Strawn Group	434	18
Canyon Group	496	20
Cisco Group	1,340	54
Wichita Group	204	8

**Table 1. Characteristics of Wells and Tests in the Database**

n: number of values, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile, <sup>a</sup> geometric mean,

<b>Parameter</b>	<b>Units</b>	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean</b>	<b>Std. Dev.</b>
<b>Diameter</b>	Inches	2,441	4.0	4.5	5.0	5.0	4.6	0.8
<b>Depth</b>	Feet	2,469	120.0	200.0	270.0	370.4	182.3 <sup>a</sup>	114.7
<b>Screen length</b>	Feet	2,474	20.0	35.0	40.0	100.0	37.2 <sup>a</sup>	59.8
<b>Discharge rate</b>	gpm	2,449	6.0	11.0	20.0	30.0	9.8 <sup>a</sup>	23.4
<b>Pumping time</b>	Hours	2,409	1	1	1	2	1.1 <sup>a</sup>	15.5

<b>Parameter</b>	<b>Units</b>	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean</b>	<b>Std. Dev.</b>
<b>Diameter</b>	cm	2,441	10.2	11.4	12.7	12.7	11.6	2.0
<b>Depth</b>	m	2,469	36.6	61.0	82.3	112.9	55.6 <sup>a</sup>	35.0
<b>Screen length</b>	m	2,474	6.1	10.7	12.2	30.5	11.4 <sup>a</sup>	18.2
<b>Discharge rate</b>	m <sup>3</sup> /day	2,449	32.7	60.0	109.0	163.5	53.6 <sup>a</sup>	127.5
<b>Pumping time</b>	Hours	2,409	1	1	1	2	1.1 <sup>a</sup>	15.5

**Table 2. Discharge Rate of Wells in the Database**

n: number of values, gpm: gallons per minute, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile, <sup>a</sup> geometric mean.

<b>Parameter</b>	<b>Units</b>	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean <sup>a</sup></b>	<b>Std. Dev.</b>
<b>Strawn</b>	gpm	432	8	14	20	35	11.4	22.2
<b>Canyon</b>	gpm	476	4	10	20	30	8.1	40.4
<b>Cisco</b>	gpm	1337	7	12	20	30	10.7	15.4
<b>Wichita</b>	gpm	204	3	7	20	30	6.4	11.5

n: number of values, ft<sup>3</sup>/day: cubic feet per day, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile, <sup>a</sup> geometric mean.

<b>Parameter</b>	<b>Units</b>	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean <sup>a</sup></b>	<b>Std. Dev.</b>
<b>Strawn</b>	ft <sup>3</sup> /day	432	1540.0	2695.0	3850.0	6737.5	2194.5	4271.9
<b>Canyon</b>	ft <sup>3</sup> /day	476	577.5	1925.0	3465.0	5775.0	1559.3	7654.4
<b>Cisco</b>	ft <sup>3</sup> /day	1337	134735	2310.0	3850.0	5775.0	2059.8	2961.4
<b>Wichita</b>	ft <sup>3</sup> /day	204	577.5	1347.5	3850.0	5775.0	1232.0	2219.3

### Table 3. Groundwater Quality Summary Statistics

Wells from the Texas Water Development Board Groundwater Database (2011) that are located outside of Trinity aquifer footprint are assumed to be screened in Paleozoic aquifers. Water quality results are reported in milligrams per liter, with the exception of dimensionless pH values.

Percentile	pH	Bicarbonate	Sulfate	Chloride	Total Dissolved Solids (TDS)	Alkalinity
95 <sup>th</sup>	8.8	749	593	1,700	3,796	638
70 <sup>th</sup>	8.3	518	151	235	1,170	434
50 <sup>th</sup>	8.1	425	78	120	758	357
30 <sup>th</sup>	7.7	353	45	52	545	296
5 <sup>th</sup>	7.2	213	15	14	334	182
Max	11.5	2,026	4,530	9,572	14,189	1,660

**Table 4. Log Transmissivity Values Estimated from Pumping Test Analysis  
(ENGLISH UNITS)**

Hydarulic conductivity in feet per day (*feet<sup>2</sup>/day*). n: number of values, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile.

	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean</b>	<b>Std. Dev.</b>
<b>All Tests</b>	1984	0.72	1.1	1.6	2.1	1.2	0.70
<b>Strawn</b>	329	1.0	1.4	2.2	2.6	1.5	Ab
<b>Canyon</b>	352	0.81	1.3	1.7	2.1	1.3	Ab
<b>Cisco</b>	1152	0.67	1.0	1.5	1.9	1.1	Ab
<b>Wichita</b>	151	0.58	1.1	1.5	2.1	1.1	Cb

**Table 5. Log Transmissivity Values Estimated from Pumping Test Analysis (SI UNITS)**

Hydraulic conductivity in feet per day ( $m^2/day$ ). n: number of values, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile.

	n	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	90 <sup>th</sup>	Mean	Std. Dev.
<b>All Tests</b>	1984	-0.31	0.096	0.59	1.1	0.15	0.70
<b>Strawn</b>	329	-0.011	0.41	1.2	1.6	0.50	Ab
<b>Canyon</b>	352	-0.22	0.31	0.69	1.1	0.26	Ab
<b>Cisco</b>	1152	-0.36	-0.029	0.42	0.83	0.029	Ab
<b>Wichita</b>	151	-0.45	0.072	0.45	1.1	0.055	Cb

**Table 6. Log Hydraulic Conductivity Values Estimated from Pumping Test Analysis  
(ENGLISH UNITS)**

Hydraulic conductivity in feet per day (*feet/day*). n: number of values, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile.

	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean</b>	<b>Std. Dev.</b>
<b>All Tests</b>	1984	-0.62	-0.16	0.30	0.74	-0.17	0.74
<b>Strawn</b>	329	-0.46	0.10	0.66	1.1	0.097	0.82
<b>Canyon</b>	352	-0.52	-0.073	0.36	0.79	-0.098	0.68
<b>Cisco</b>	1152	-0.69	-0.24	0.14	0.63	-0.27	0.69
<b>Wichita</b>	151	-0.78	-0.11	0.37	0.80	-0.14	0.82

**Table 7. Log Hydraulic Conductivity Values Estimated from Pumping Test Analysis  
(SI UNITS)**

Hydraulic conductivity in feet per day (m/day). n: number of values, 25<sup>th</sup>: 25<sup>th</sup> percentile, 50<sup>th</sup> percentile (median), 75<sup>th</sup> percentile, 90<sup>th</sup> percentile.

	<b>n</b>	<b>25<sup>th</sup></b>	<b>50<sup>th</sup></b>	<b>75<sup>th</sup></b>	<b>90<sup>th</sup></b>	<b>Mean</b>	<b>Std. Dev.</b>
<b>All Tests</b>	1984	-1.1	-0.68	-0.22	0.22	-0.68	0.74
<b>Strawn</b>	329	-0.97	-0.41	0.14	0.59	-0.42	0.82
<b>Canyon</b>	352	-1.0	-0.59	-0.16	0.27	-0.61	0.68
<b>Cisco</b>	1152	-1.2	-0.76	-0.37	0.11	-0.78	0.69
<b>Wichita</b>	151	-1.3	-0.63	-0.15	0.29	-0.66	0.82



# **RPSEA**

## ***Feasibility of Using Alternative Water Sources for Shale Gas Well Completions — Final Report***

***Report No. 08122-05.08C***

### ***Barnett and Appalachian Shale Water Management and Reuse Technologies***

***Contract 08122-05***

***February 28, 2012***

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**Prepared for  
Gas Technology Institute**

# **Feasibility of Using Alternative Water Sources for Shale Gas Well Completions**

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Teresa Howard<sup>2</sup>, Ruth A. Costley<sup>1</sup>, Cari Breton<sup>1</sup>,  
Steven Walden<sup>3</sup>, Russell Baier<sup>3</sup>, and Gil Strassberg<sup>4</sup>  
with students  
Ed McGlynn, Mary Hingst, Joy Mercier, and Cliff Lam**

**January 2012**

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## **9 Attachment D: Study of North-Central Texas Paleozoic Aquifers**

**Evaluation of Paleozoic Aquifers of North Central Texas.  
Part II: Groundwater Flow Model**

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## 1. INTRODUCTION

Barnet Shale, in the north-central Texas, west of Dallas-Fort Worth, is one of the largest gas plays in the US. It is under rapid development with hydraulic fracturing technique. The shale gas development using this technique currently use about 20,000 m<sup>3</sup> of water per well per year (Nicot et al. 2011). Water use for gas production is projected to rise in the next 20 plus years and gradually decrease for another 20 years. The region has seen gas production increase for the past decade and water stress is evident even in the current condition. Surface water supply is constrained by available water rights and more productive groundwater supply is only available to the east in Trinity/Woodbine aquifers or to the west in Seymour/Blaine aquifers. Therefore, feasibility of using Paleozoic aquifers for additional water supply is of practical interest. The objective of this modeling study is to evaluate this feasibility and quantitatively evaluate the potential effect of additional water withdrawal on the aquifers. The tasks include: 1) compile baseline data such as hydraulic conductivity, model structure (top and bottom elevations of hydrostratigraphic units), and sand distribution to characterize the water bearing units; 2) develop conceptual and numerical groundwater flow model; 3) evaluate feasibility and potential effect of additional withdrawal from the Paleozoic aquifers. Task 1 is documented in a companion report. This report document tasks 2 and 3.

## 2. STUDY AREA

The study area is located in North-Central Texas. The model area covers about 46,000 km<sup>2</sup>, including all or part of 19 counties (Figure 2.1). Paleozoic units (from the youngest to the oldest, Wichita, Cisco, Canyon and Strawn) are the focus of this study. Those units dip generally to the west. To the east, Paleozoic units underlie the Cretaceous Trinity Units. To the west in the Permian Basin, Paleozoic units underlie Quaternary-age Seymour Formation. The model extends to the Red River in the northeast and San Saba or Leon Rivers to the southwest. Nine counties are of particular interest and they are Clay, Erath, Hood, Jack, Montague, Palo Pinto, Parker, Somervell, and Wise. Major rivers run across the model area mostly subparallel to the dip direction. The region in general has gentle terrain. As shown in Figure 2.2, the terrain slopes from west or southwest to east or northeast. The climate is classified as subtropical subhumid (Larkin and Bomar 1983). Annual precipitation is about 800 mm based on PRISM data (PRISM Climate Group 2004). The model area is dominated by grassland (50%). Other land use land cover types include woodland (27%), cultivated land (12%), and urban (7%).

### 3. LITERATURE REVIEW

The Paleozoic aquifers have not been a focus of any modeling studies. However, in the last decade, TWDB has initiated groundwater availability modeling (GAM) program and a series of groundwater flow models have been built for the minor and major aquifers in Texas. This includes GAM for the Trinity aquifer to the east (Bené and Harden 2004) and Seymour aquifer to the west of the study area (Ewing et al. 2004). The relative boundary of the Trinity North GAM, Seymour GAM and the model for Paleozoic aquifers (this study) is shown in Figure 3.1. It is noted that although Trinity North GAM covers this study area, Paleozoic units were not included in the Trinity North GAM. The boundary between Trinity and Paleozoic was set as no-flow in Trinity North GAM.

Seymour GAM included shallow portion of the Paleozoic units as one layer that has hydraulic connection with Seymour pods. The Paleozoic units included in Seymour GAM are the Quartermaster Formation, the Whitehorse Group, the Pease River Group, the Clear Fork Group and part of the Wichita Group.

## 4. REGIONAL HYDROLOGY

This section includes discussion of water levels, groundwater flow, recharge, and surface water features. Data compiled and analyzed in this section are used to support development of the conceptual model and numerical model for the Paleozoic aquifers.

### ***4.1 Water levels and regional groundwater flow***

Water-level data for the Paleozoic aquifers were obtained from the TWDB groundwater database. In order to evaluate the water levels with respect to each model layer, the layer into which the wells are completed was determined. This was done primarily based on reported stratigraphic unit into which the wells were completed. The distribution of wells was then checked visually in GIS. The revealed inconsistencies were corrected. For example, many wells completed in Archer City formation were labeled as Wichita wells in the database, but should be included as Cisco wells in this study. Well completion intervals were also compared with the developed top and bottom elevation of each group. However, due to uncertainty in top and bottom elevation estimates, classification will not change unless there is unambiguous evidence. Multiple completion wells were excluded in the selection. A total of 1270 wells were selected, 72 in Wichita, 922 in Cisco, 237 in Canyon and 39 in Strawn.

Water-levels are not measured regularly in wells. The coverage of water-level data for a particular month or year is sparse. In order to evaluate water level change with time, wells with more than 10 measurements were selected. Hydrographs of water level vs. time for wells that have coefficients of variation larger than 0.8 are shown in Figure 4.1. Those selections represent wells with largest variation of water levels over time. From the graph, it can be seen that no systematic trend is detected.

To simplify analysis, in the absence of systematic trend, average water level over time for each well is obtained. Water level elevation was posted for each layer as shown in Figure 4.2 through 4.5. A general pattern of groundwater flow in Paleozoic aquifers can be summarized. Groundwater flows from high elevation to low elevation and discharges to the rivers. Rivers could recharge the aquifer under favorable conditions. This observation is consistent with theoretical analysis of gravity-driven groundwater flows.

#### ***4.2 Estimating recharge using chloride mass balance***

A variety of methods are available to estimate precipitation recharge to aquifers (Scanlon et al. 2002). In Trinity Northern GAM (Bené and Harden 2004), recharge was estimated based on annual precipitation and scaled by factors relating to land cover, soil permeability and underlying geology. For the outcrop area within Texas and near the major users, the average recharge rate input into the model is about 35 mm/yr (1.4 in/yr) with the majority of area less than 25 mm/yr (1 in/yr). In Seymour GAM (Ewing et al. 2004), recharge was estimated based on rainfall-runoff modeling. However, recharge estimates were then re-distributed based on topology. The calibrated recharge distribution averaged 48 mm/yr (1.9 in/yr) in Seymour and ranged from 20 to 65 mm/yr (0.8 to 2.5 in/yr) among Seymour pods. Unsaturated zone modeling by Keese et al. (2005) indicates diffuse recharge in the area about 10-30 mm/yr.

Chloride mass balance approach is used in this study. The basic principle is that chloride input from precipitation balances chloride output in recharge. Chloride concentrations in precipitation were obtained from the National Atmospheric Deposition Program. To account for dry fallout, chloride concentrations in precipitation were doubled,

which is consistent with total chloride fallout based on pre-bomb  $^{36}\text{Cl}/\text{Cl}$  ratios at Amarillo (Scanlon and Goldsmith 1997).

The study area was divided into 10 zones. Groundwater chloride concentrations were obtained from TWDB database using wells within those zones. Chloride concentration was limited to the measurements taken in the period from 1951 to 2000. A median value in each zone is used to represent average groundwater chloride concentration in that zone. Table 4.1 shows recharge rates by zones based on this analysis. Figure 4.6 shows distribution of recharge estimates by zone across the study area. Average recharge across the region is about 2.7 mm/yr. Lower recharge rates were observed in the southwest of the study area and higher recharge rates were observed in the area close to Trinity outcrops. However, spatial pattern is not consistent across the entire study region. For example, close to the Trinity outcrop, zone 2 has low recharge rate, indicating likely data bias. Recharge estimates using this approach were considered as long-term net recharge from precipitation.

### **4.3 Surface water features**

Surface water features like rivers, streams, and lakes can interact with groundwater in various degrees. Rivers and streams can either lose water to or gain water from the underlying aquifer when they flow across the aquifer outcrops. Groundwater discharges through springs and seeps where the water table intersects the land surface. Lakes may provide a potential site of focused recharge or discharge depending on difference between the water table and the elevation of the lake.

Data of major rivers in the study area comes from EPA Enhanced River Reach file version 2. Figure 4.7 shows the distribution of the stream network in the study area.

Stream gains or losses from the aquifer cannot be easily quantified. One major attempt was made by Slade et al. (2002). They compiled results of 366 gain/loss studies conducted throughout Texas since 1918. Within this study area, six sites were reported. All of them are located along upstream reaches of Hubbard Creek that drains into the Brazos River (Figure 4.8). The results are mixed – one reach is gaining while the next could be losing. This indicates active exchange between rivers and the aquifer if those numbers are representative. In addition, the flow reported in their study represents a snapshot of the condition during their study period, not the long-term average.

Several reservoirs are located in the active model domain. Reservoir storage changes over season and through water use. However, water use data are hardly available. In addition, reservoirs in this region experience significant amount of evaporation as well. Simple conceptualization about if a reservoir gain water or loss water to the aquifer is not attempted in this study. However, since reservoirs are located along rivers, it is assumed that reservoirs can be represented in the stream package.

#### ***4.4 Aquifer discharge through pumping***

The population density in the study area is low except in a few small cities. TWDB groundwater database has one water level measurement in 1901, followed by about 60 water level measurements taken in 1937. It seems it is reasonable to assume the aquifer withdrawal started around 1900s.

TWDB conducted historical water use survey and has data from 1980. A summary of nine counties of interest is shown in figure 4.9. Pumping for power and manufacture uses was not included because they are negligible compared to other use categories. Most

water uses are for public supply (municipal) and domestic (stock). Therefore, it is reasonable to obtain historical pumping by correlating with population.

Historical and projected population in the study area was obtained from TWDB. In developing State Water Plan, TWDB provided the projected amount of water use in each county. Based on this, linear interpolation was used to extrapolate the amount of pumping back to 1900. Figure 4.10 shows the variation of the amount of pumping estimated based on population. This amount of estimated pumping is termed “background pumping” in this study. Nicot et al. (2011) estimated the amount of frac pumping in the study area. The frac pumping is added on top of the background pumping and is also shown in Figure 4.10 as difference between the total and background pumping.

## 5. CONCEPTUAL MODEL OF GROUNDWATER FLOW IN THE AQUIFERS

The Paleozoic aquifer system is conceptualized as four units capable of producing groundwater at low rates (Well yield in some locations may be moderate). From youngest to oldest, the units are the Wichita Group, Cisco Group, Canyon Group and Strawn Group. These units lie conformably in that order but Trinity overlies unconformably on the Strawn Group to the east. Each group contains several formations. Most formations consist of a mixture of limestone, shale and sandstone. Although more productive sandstone and sometimes limestone units are identifiable in the study area, the model conceptualizes each group as a hydro-stratigraphic unit, i.e., a layer in the numerical model. Further vertical stratification is possible when more data becomes available.

Because of overall low permeability of the sediments and limited recharge in the region, the hydraulic interactions between those units are restricted. Groundwater flow in each unit can be strongly influenced by surface water features. However, the degree of surface water and groundwater interaction is unknown. A study done by Core Laboratories Inc. (1972) indicates high salinity content and gradient in the downdip direction. Therefore, while the outcrop portion of each group was included in the model as much as possible; the downdip portion of each group that was included in the model is only extended to the boundary marked by high salinity. Between the contact of Paleozoic and Trinity, exchange of flow could occur. Such flow may not be important to Trinity but could be an appreciable amount for the Paleozoic units. Explicit consideration is warranted in this model.

Other than precipitation recharge, leakage from streams is another source of aquifer inflow. Higher-order rivers and streams, mostly intermittent and perennial, were implemented as both recharge and discharge mechanism using streamflow routing package. Lower-order rivers and streams, mostly ephemeral, were implemented as drains.

Most recharge will discharge through baseflow or groundwater evapotranspiration. Some will become transient storage. Groundwater withdrawal for human consumption, including agricultural and industrial uses, represents additional discharge mechanism in the development period.

Pumping withdrawal from the Paleozoic aquifers has been relatively low. Drawdown is typically localized and regional water levels have not been highly impacted by development.

## **6. MODEL DESIGN**

### ***6.1 Grid and boundaries***

The computer program selected for simulating the Paleozoic aquifer system is MODFLOW-2000 (Harbaugh et al. 2000). MODFLOW-2000 is a three-dimensional finite-difference groundwater flow simulation program with a modular design to incorporate various boundary conditions. Groundwater Vistas (Rumbaugh and Rumbaugh 2007), which is a GUI pre- and post-processor for MODFLOW, was used to construct the model.

The finite difference grid is 1x1 km throughout the model domain. The model has 180 rows and 256 columns. The grid was oriented so the main axis is aligned to the perceived main flow direction. Vertically, the model is divided into four model layers, representing each of those four groups.

The lateral extent of the model area is defined based on the study interest and physical or hydraulic boundaries. The interest area of this modeling exercise consists of nine counties (Figure 1.1). The northwest and southeast boundaries were set far away from the interest area to minimize the boundary effect on the interest area. Those boundaries were set as no flow. The northeast boundary is set at the Red River, a major river in the study area. The Red River is implemented as a constant head boundary condition. The southwest boundary is set at a watershed divide, a ridge along hills, and implemented as a no flow boundary.

The bottom boundary was set as no flow. The contact between Paleozoic and Trinity was implemented as head-dependent flow boundary condition using general head boundary (GHB) package.

## **6.2 Implementation of recharge and pumping discharge**

Recharge estimated in Section 4.2 serves as basis for recharge used in the model. Since recharge estimates represent long-term average, recharge was not varied through time in the transient period. Recharge values in each polygon were assigned to corresponding outcrop cells. Recharge to the Trinity and to the inactive model domain was excluded.

Pumping discharge was allocated to top 50% high permeability cells. The amount of pumping varied annually in the transient period. Because pumping was calculated on a per county basis, some pumping shown in 4.10 was allocated outside the active model area.

## **6.3 Rivers and streams implementation**

Stream network across the outcrops in the model region acts as a head-dependent flow boundary condition for the top active model cells. EPA Enhanced River Reach File 2 was used to identify the stream network. The streamflow routing package (Prudic 1989) was used to simulate stream/aquifer interaction. Streams were arranged by levels in the reach file and stream level less than three were selected for stream package implementation and others were implemented as drains.

The stream package allows stream gaining or losing by comparing the head in the stream cell and the head in the aquifer while keep tracking the amount of streamflow in the channel. The selected streams were numbered as reaches and segments as required by the stream package. Stream bed elevation was set as surface elevation minus 10 meters. The stream bed was assigned a two meter thickness. Streamflow rate at the starting reach of each segment was taken as mean flow rate for that segment in

the Enhanced River Reach file. The conductance term were estimated based on physical parameters of the stream. The distribution of stream cells in the model area is shown in Figure 6.1.

The drain package allows groundwater discharge once the head in the aquifer is higher than the elevation of the drain. Elevation for a drain cell was set as surface elevation minus seven meters. The distribution of drain cells is also shown in Figure 6.1.

#### ***6.4 Implementation of constant head and GHB conditions***

Red river cells were identified and the length of rivers within each cell was calculated. The boundary heads were set as surface elevation minus 5 meters. The distribution of constant head cells is shown in Figure 6.1.

Model cells in the active domain and overlain by Trinity were identified. A general head boundary condition (GHB) was implemented in each one to represent exchange of flow between the Paleozoic and Trinity. The boundary head values for the GHB were set as Trinity heads in 1890 condition and were obtained from Trinity North GAM. The distribution of GHB cells is shown in Figure 6.2.

#### ***6.5 Model geometric and hydraulic parameters***

The development of the model structure (top and bottom elevations) and hydraulic conductivity data for each of the model units were documented in the companion report. Hydraulic conductivity was viewed as horizontally isotropic ( $K_x=K_y$ ) but vertical anisotropy was set as 10. The specific yield was assumed to be homogeneous and was assigned a value of 0.05 for all geologic units. Meyers (1969) reported two storage coefficient values (  $2e-6$  and  $4e-6$ ) from the pumping test conducted in Montague County but no information of screen interval was provided. Fisher et al. (1996) conducted study

in Parker and Palo Pinto Counties and assumed storativity of  $1e-5$  for two pumping tests. The screen interval for both wells was 3 m. storativity values were divided by screen interval to obtain specific storage ( $3e-6 \text{ m}^{-1}$ ). This specific storage value is used for all geologic units.

## **7. MODELING APPROACHES**

Because of data limitation and time constraints, the Paleozoic aquifer system model was set to be both interpretive and predictive. It is set as interpretive because the basic objective for this modeling exercise is to have a framework so the system dynamics can be understood further. This basic tenet dictates less concentration on model calibration but more on conceptual understanding and alternative parameterization. It is also set as predictive because the model is expected to approximate the physical system reasonably well. By incorporating stresses in the predictive mode, system responses can be evaluated.

## **8. RESULTS**

The constructed model includes steady state simulation and transient simulation. The steady state model represents the long-term average before appreciable development began. The stresses do not include pumping withdrawal. The transient model simulates the system under annual stresses from 1900 to 2060.

### ***8.1 Steady-state simulation***

Volumetric water budget from steady-state simulation is summarized in table 8.1. The percentage error is -0.22. In summary, streams gain water from the aquifers. Red River also gains water from the aquifers. There is a small amount of flow from the Paleozoic aquifers to the Trinity.

Head targets were compared with simulated steady-state heads. Figure 8.1 to 8.4 show the comparison graphically. Residual mean is -21 m, standard deviation 28 m, minimum -322 m and maximum 56 m. The ratio of standard deviation over the observed range in target head values is 6%. The statistics excluded three cells that were dry in steady-state.

### ***8.2 Transient simulation***

Volumetric water budget changes with each stress period. As an example, water budget for 2010 is given in Table 8.2. Compared to the steady-state budget, flow to the rivers and flow to the Trinity were all reduced slightly. It is noted that pumping discharge in 2010 represents about 40% of recharge.

The transient simulation run included frac pumping from 2010 to 2038. Average drawdown between 2010 and 2060 is 0.76 m with a minimum of -31 m and a maximum of 18 m.

## 9. DISCUSSION

The groundwater flow model for the Paleozoic aquifers simulated water level at target locations reasonably well. Those targets are mostly located in outcrop area. Therefore, simulation of flow in the further downdip section (away from target locations) appears to be more uncertain. In the model development, some dry cell problems exist. Most dry cells are located in the edge of the outcrop. So it is likely those cells are physically dry or it is related to inaccurate representation of formation thickness. Some flooding (simulated water level elevations are higher than land surface elevations) cells are also noticed. Those are mostly in the region where recharge takes place in the very low permeability cells. So either inaccurate spatial distribution of recharge or permeability estimates contributed to the problem. However, those problems seem to be localized and it is not expected to have major effect on the overall performance of the model.

No formal calibration was conducted in the model development. Alternative parameterization or revised conceptual model was engaged when the model suggest a refinement is needed.

The numerical model is an abstraction of the real system. The development of the model for Paleozoic aquifers is limited by available data and our conceptual understanding of the system. Additional flow targets would further constrain the model. As the system simulated is mostly unconfined, an investigation of surface water and groundwater interaction in the region would enhance our conceptual understanding of the system.

## 10. CONCLUSIONS

The developed numerical model for the Paleozoic aquifers consists of four layers, representing Wichita, Cisco, Canyon, and Strawn groups. It included steady-state simulation and transient simulation. The model incorporated stresses such as surface water and groundwater interaction, exchange of flow between Trinity and Paleozoic, and pumping discharge. Simulated flow between Paleozoic and Trinity is small. While precipitation is the primary recharge mechanism, discharge to the streams is the primary discharge mechanism.

The Paleozoic aquifers have been an important resource for small community and rural residents. The model results suggest some additional development is plausible. The model distributed the pumping stress spatially in a manner that may not be realistic in order to obtain an average effect. Distribution of more permeable sandstone units also shows high spatial variation. Large development in one specific region needs to be carefully evaluated in the context of local hydrology.

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Slade RM, Jr., Bentley JT, Michaud D (2002) Results of streamflow gain-loss studies in Texas, with emphasis on gains from and losses to major and minor aquifers, Texas, 2000. U. S. Geological Survey.

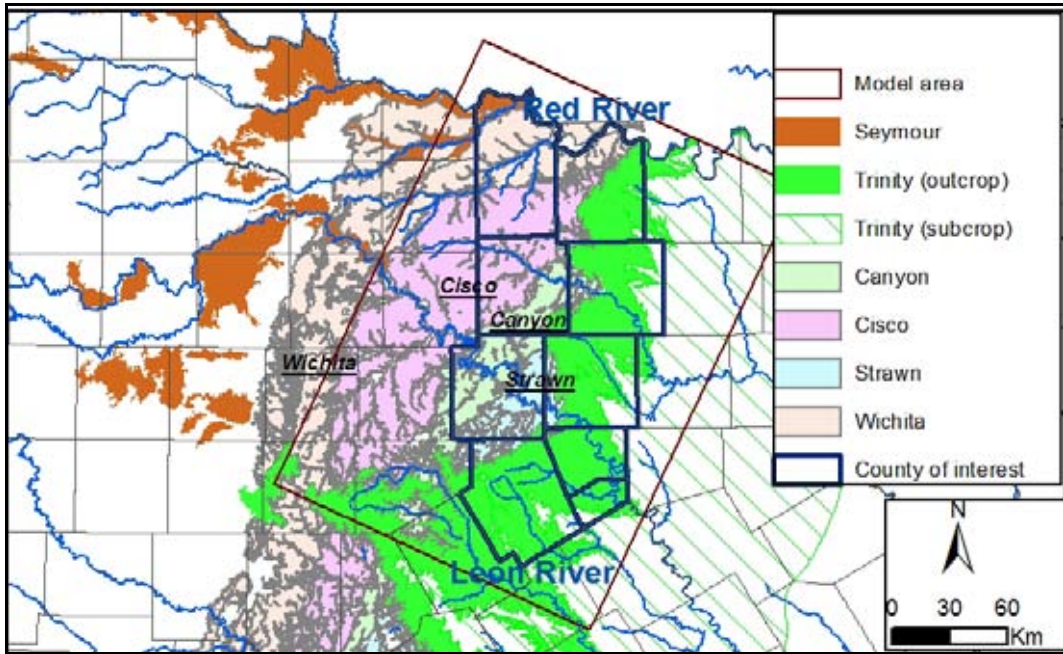


Figure 2.1 Study area and generalized geological units

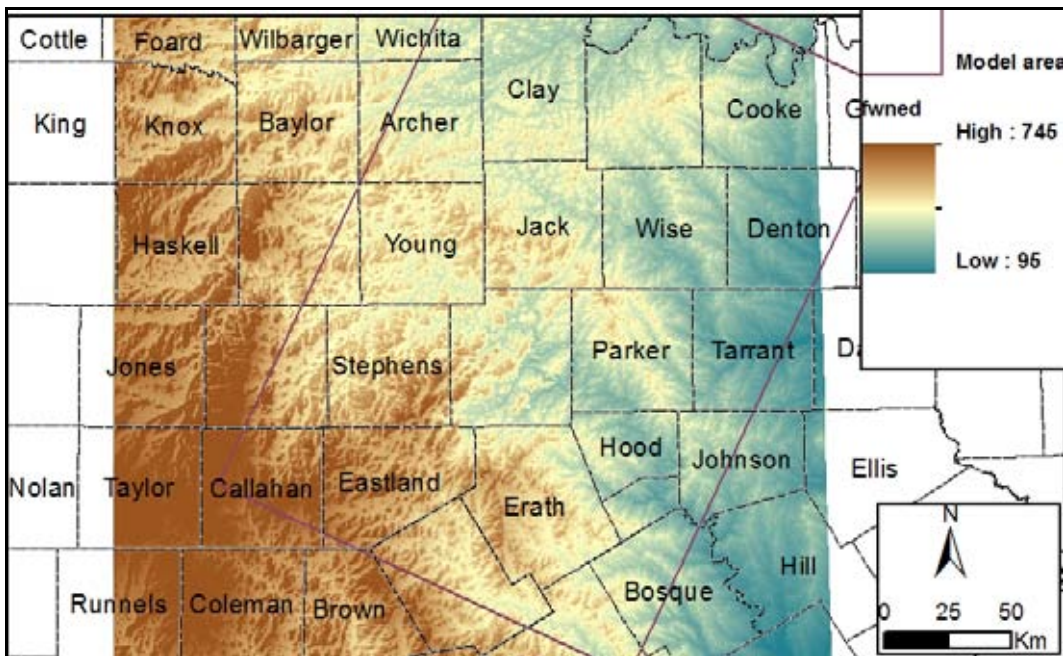


Figure 2.2 Land surface elevations (m amsl) in the study area

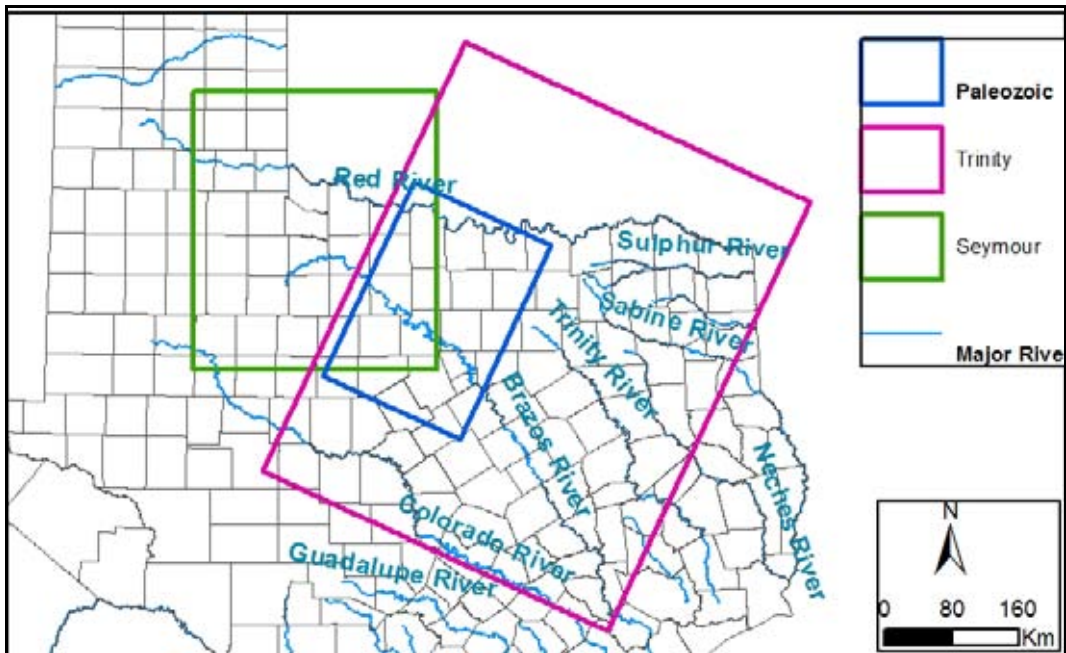
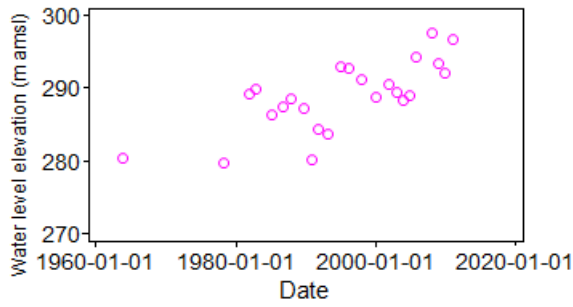
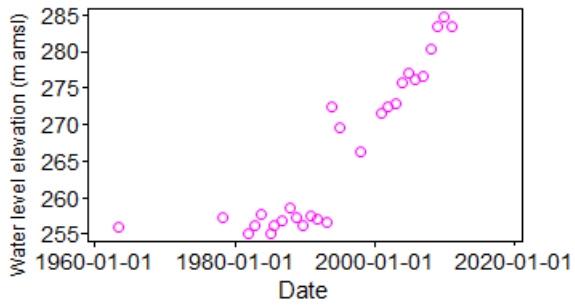


Figure 3.1 Boundary of previous modeling studies that overlap the current study area and extent of Paleozoic aquifer model

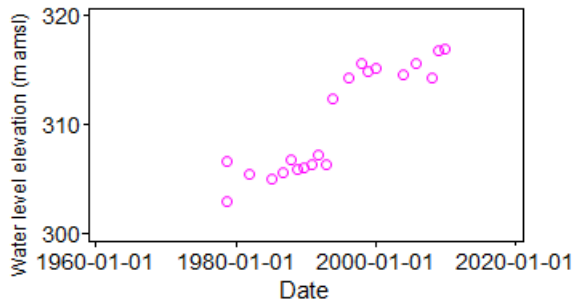
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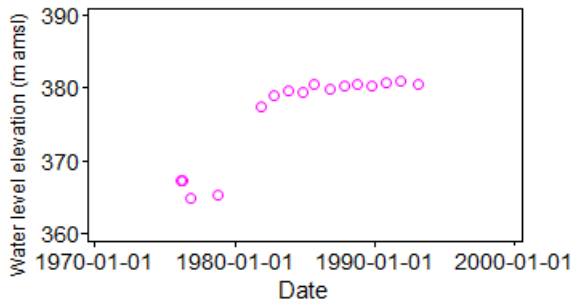
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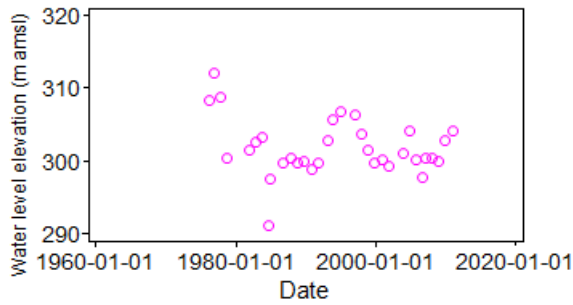
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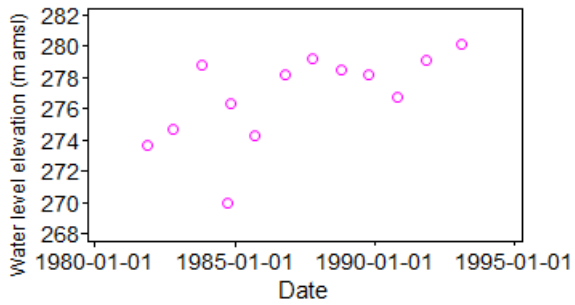
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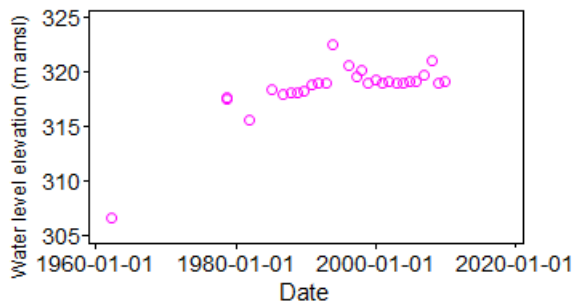
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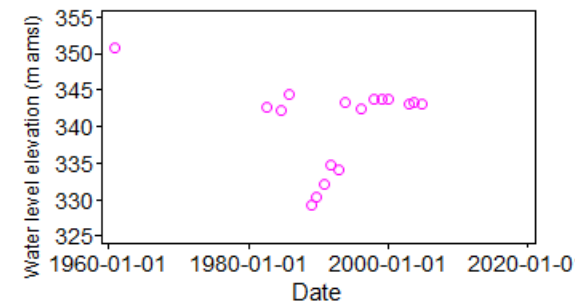


Figure 4.1 Hydrograph of selected wells with large water level variation over time. Swn=state well numer

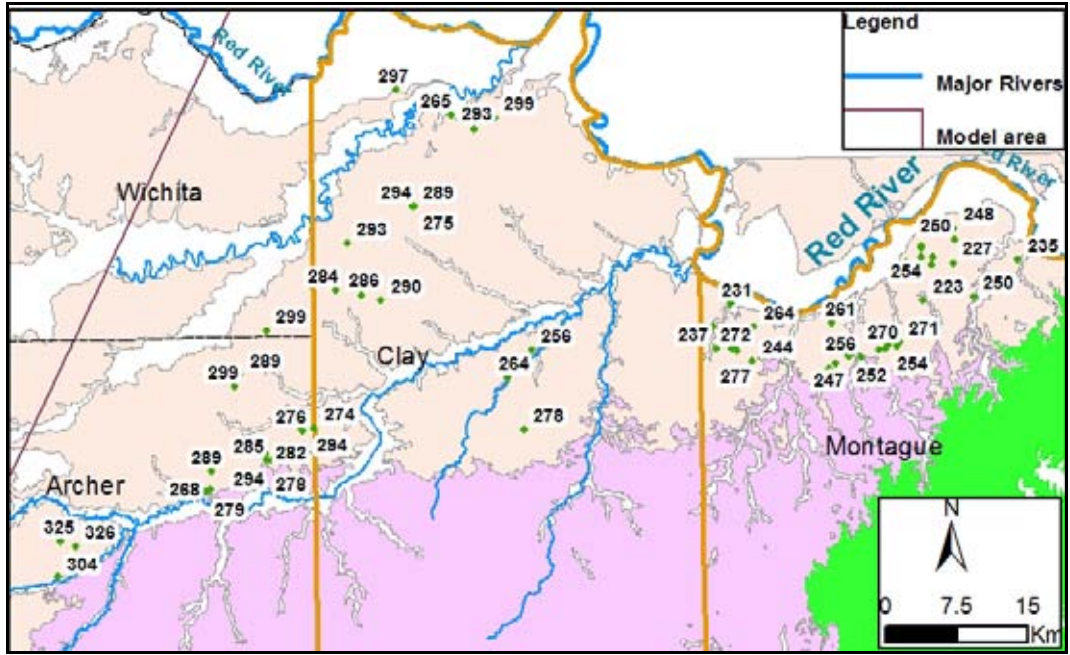


Figure 4.2 Wichita wells with water level (m amsl)

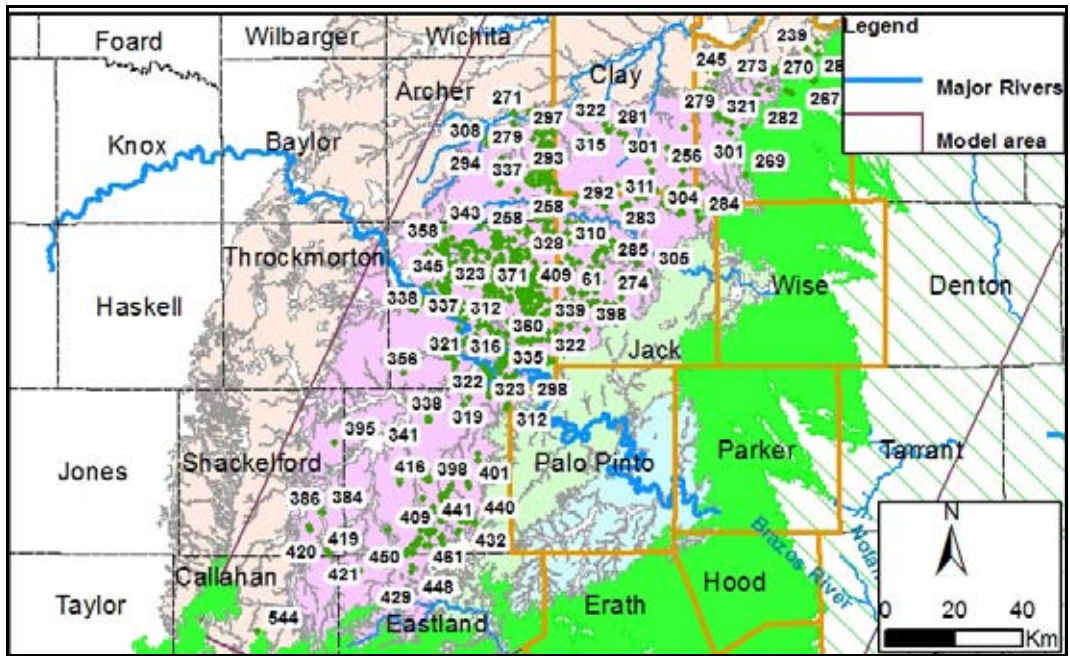


Figure 4.3 Cisco wells with water level (m amsl)

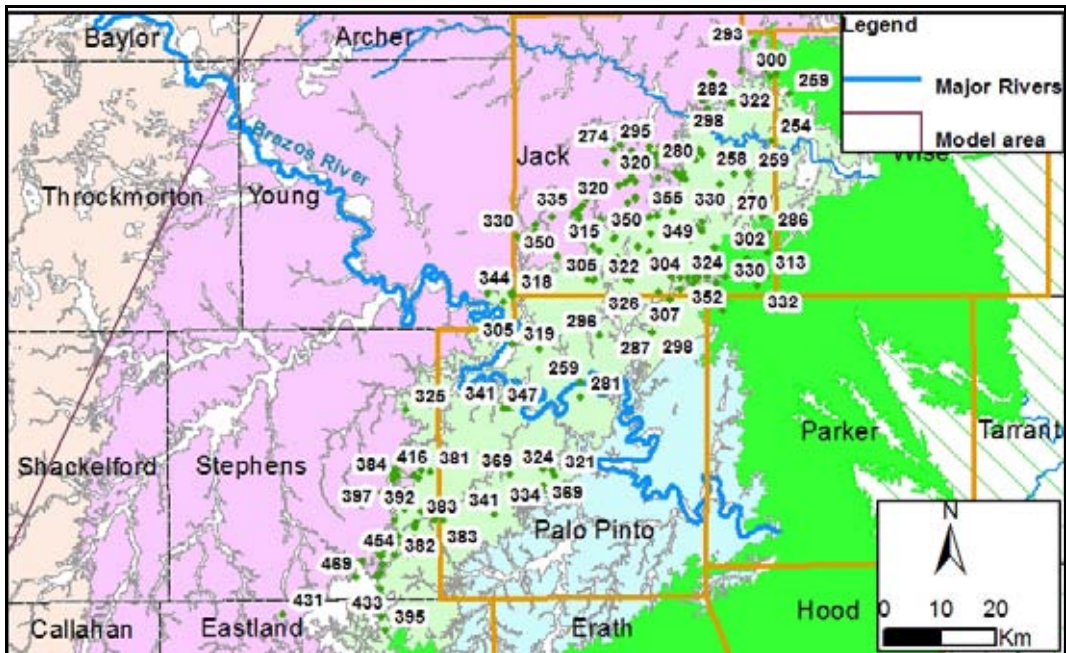


Figure 4.4 Canyon wells with water level (m amsl)

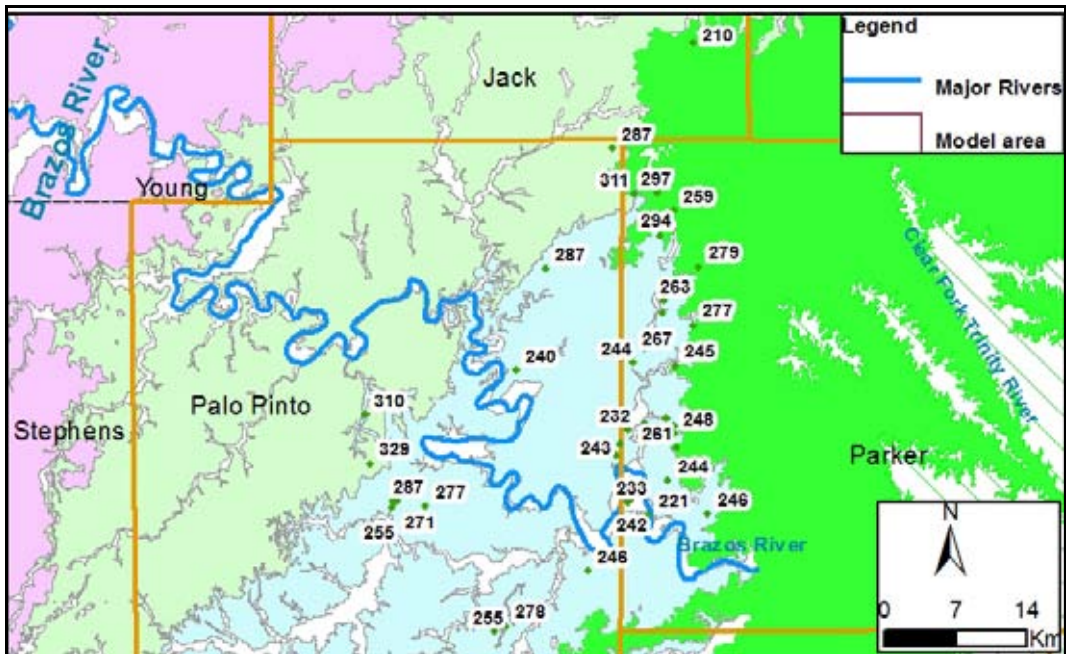


Figure 4.5 Strawn wells with water level (m amsl)

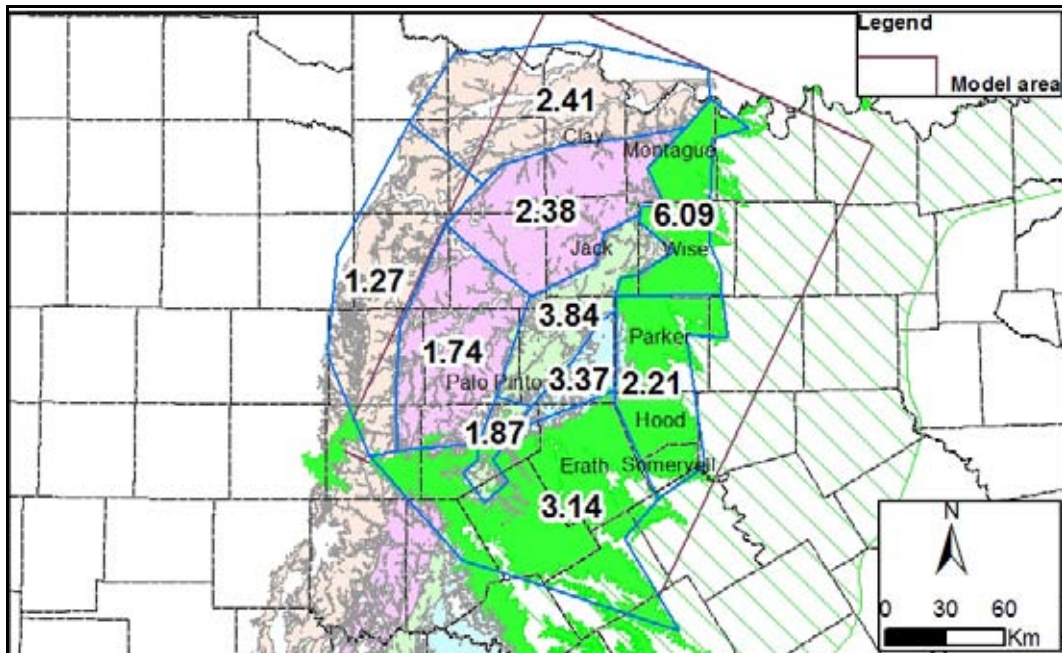


Figure 4.6 Recharge rates by zone based on chloride mass balance analysis (cm/yr)

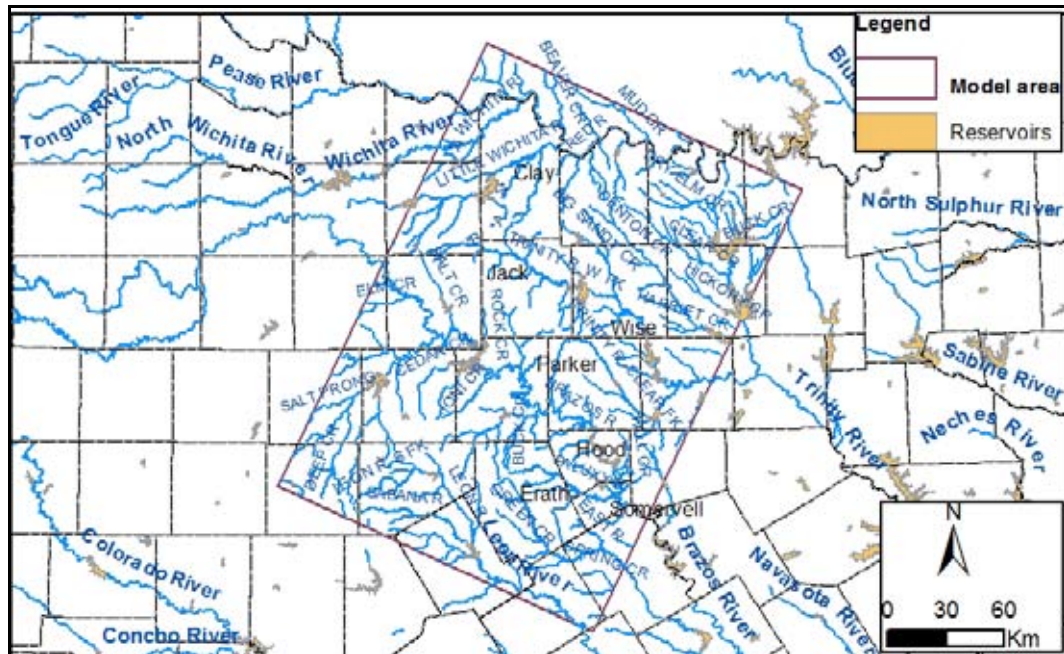


Figure 4.7 Surface water features in or near the study area. The stream network shown in the model area is based on EPA Enhanced river reach file version 2.

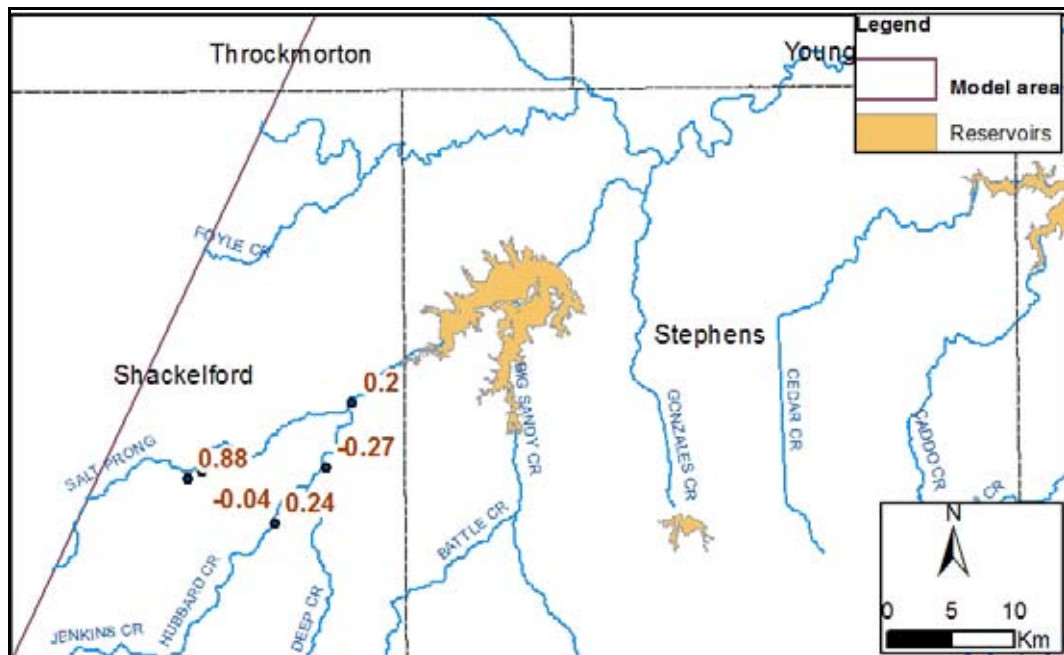


Figure 4.8 Gain loss along river reaches as reported by Slade (2002) in the active model area.

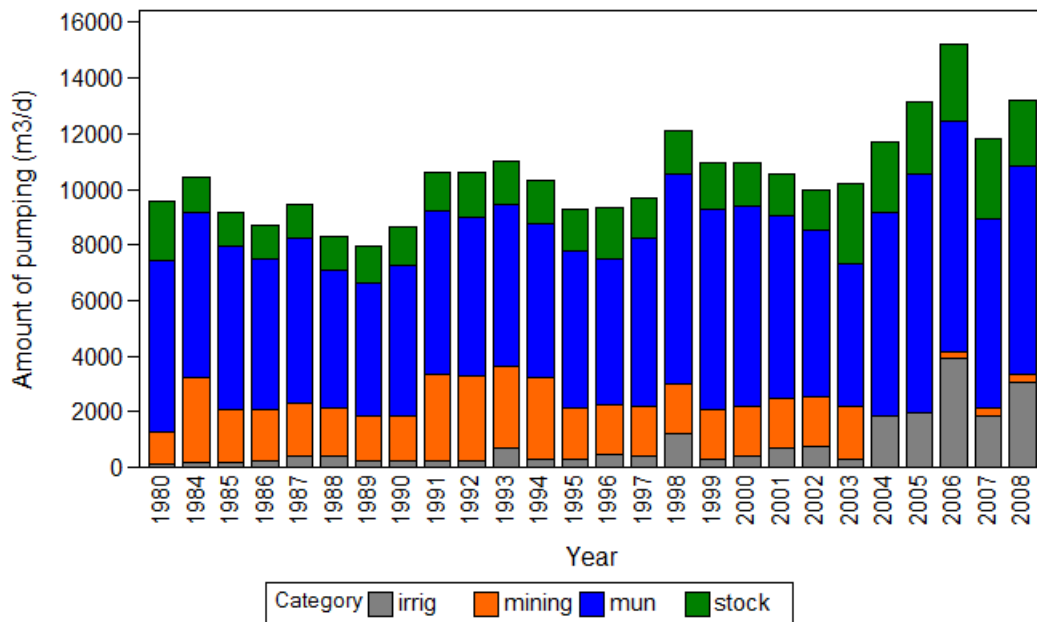


Figure 4.9 Total amount of pumping in nine counties by category. Data from TWDB water use survey.

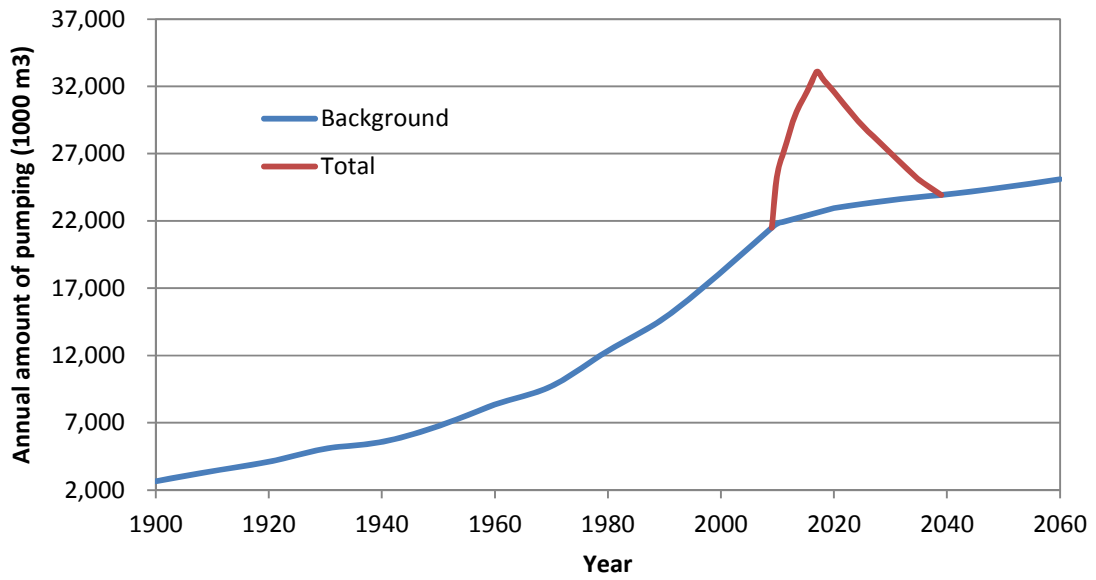


Figure 4.10. Groundwater withdrawal from the Paleozoic aquifers

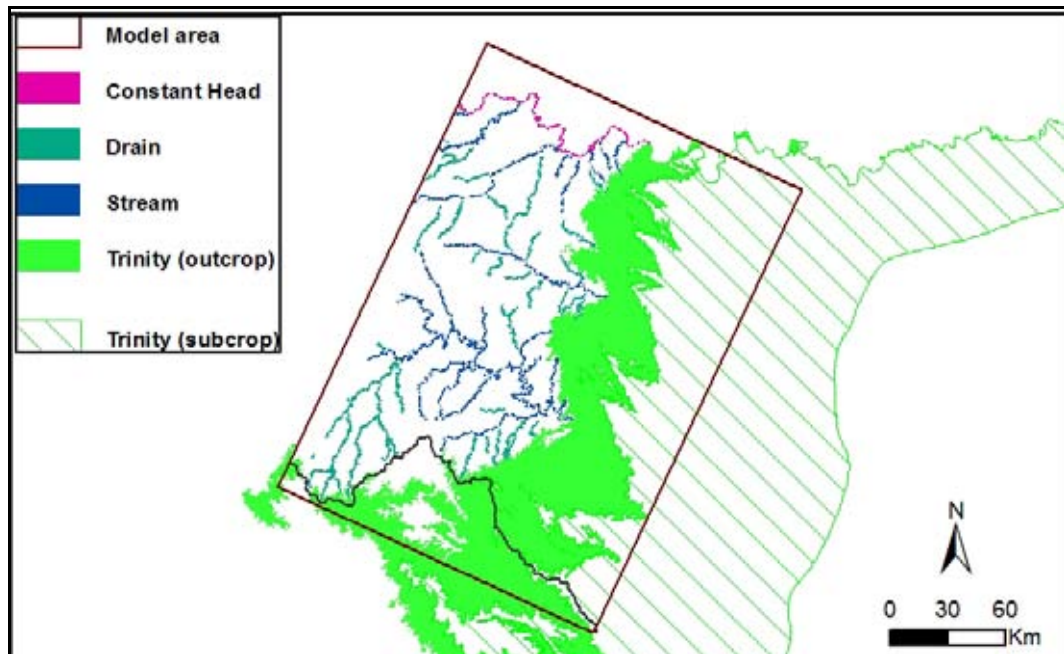


Figure 6.1 Distribution of stream, drain, and constant head cells

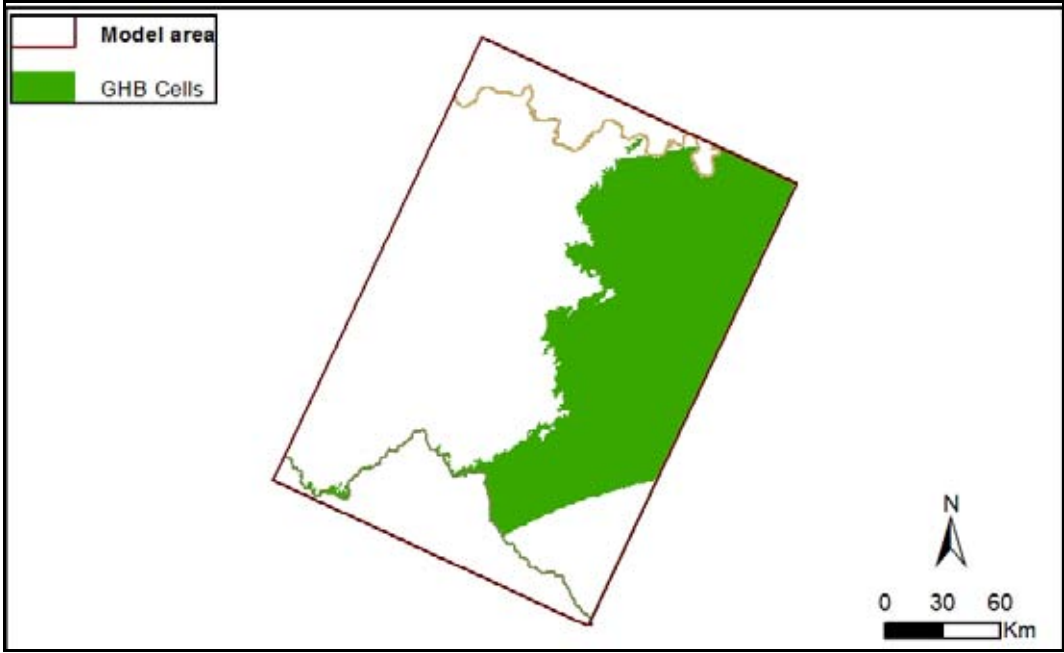


Figure 6.2 Distribution of general head boundary cells

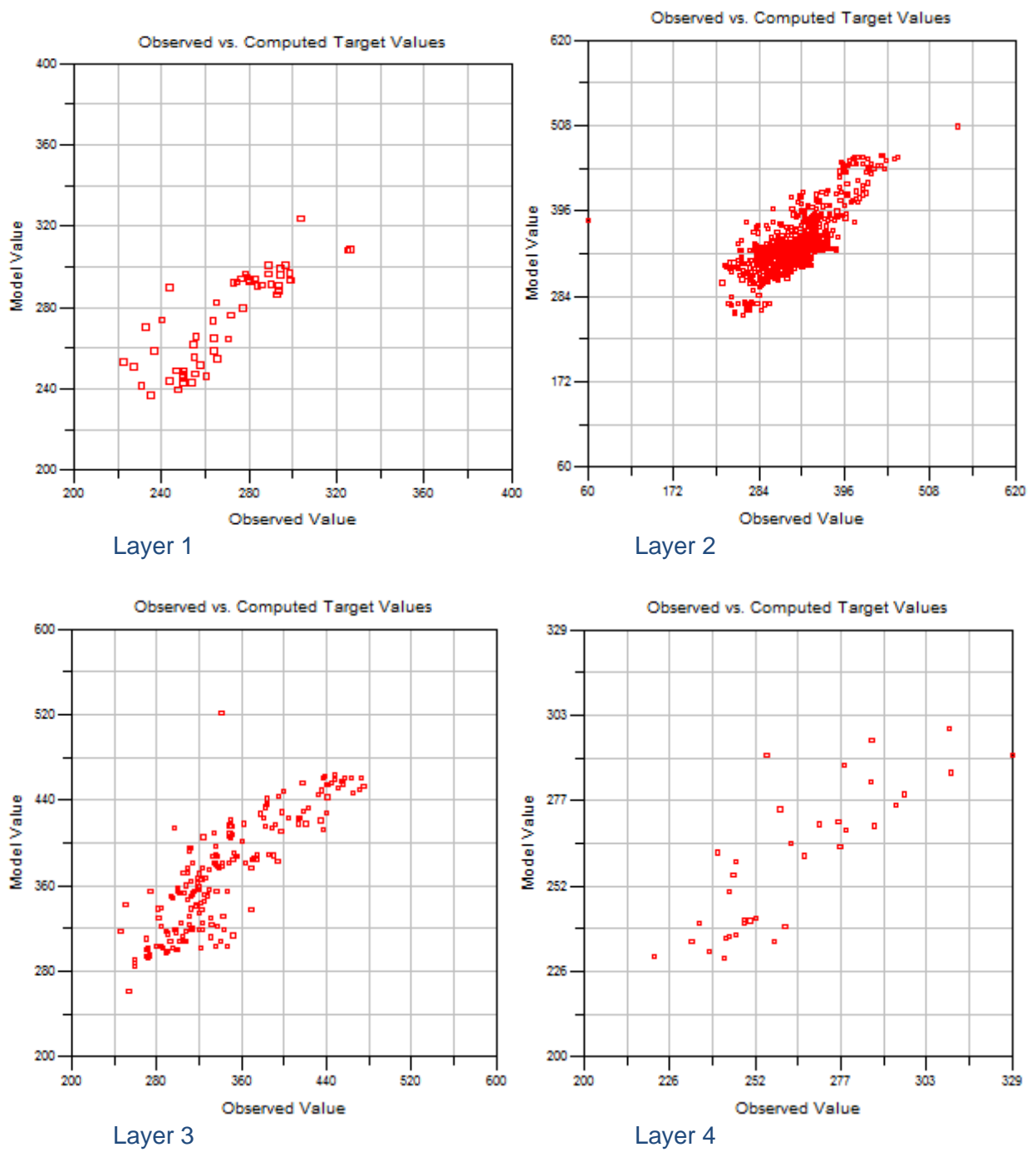


Figure 8.1 Observed and simulated heads at target locations in four layers

Table 4.1 Recharge rates based on chloride mass balance analysis of groundwater chloride concentration

Zone	area (km <sup>2</sup> )	precipitation (mm/yr)	CLin (mg/L)	CLgw (mg/L)	Recharge (mm/yr)
1	2,927	899	0.444	66	6.09
2	3,899	851	0.516	199	2.21
3	9,076	775	0.586	145	3.14
4	1,162	797	0.508	120	3.37
5	3,020	816	0.48	102	3.84
6	729	742	0.546	217	1.87
7	5,435	798	0.454	152	2.38
8	5,214	719	0.504	208	1.74
9	6,877	788	0.424	139	2.41
10	5,973	692	0.472	258	1.27

CLin= chloride concentration from input; and CLgw=chloride concentration in groundwater

Table 8.1 Steady-state volumetric water budget for the entire model area (m<sup>3</sup>/day)

	GHB	Stream	Constant Head	Recharge	Drain	Total
In	804	7,964	2,402	128,298	0	139,469
Out	940	95,796	5,515	0	37,522	-139,774
Net	-137	-87,832	-3,113	128,298	-37,522	279,242

Table 8.2 Transient simulation (2010) volumetric water budget for the entire model area (m<sup>3</sup>/day)

	GHB	Stream	Constant Head	Storage	Recharge	Well	Drain	Total
In	839	8,308	2,450	41,669	128,298	0	0	181,564
Out	922	88,510	5,389	2,683	0	51,081	33,311	181,896
Net	-83	-80,201	-2,939	38,985	128,298	-51,081	-33,311	-331

## **10 Attachment E: Year 1 Milestone Report**



This attachment contains, for completeness and easy reference, the interim report submitted at the end of Year 1.

***Feasibility of Using Alternative Water  
Sources for Shale Gas Well  
Completions —  
A Preliminary Guidance Document on  
Current Practices in the Barnett***

***Report No. 08122-05.02***

***Barnett and Appalachian Shale  
Water Management and Reuse  
Technologies***

**Contract 08122-05**

**February 22, 2011**

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## ABSTRACT

This document presents early results of a study investigating alternative sources of water to be used in the last completion phase (so-called “fracing”) of gas wells in the Barnett Shale play. Millions of gallons is needed to perform the fracing operation, and in the past few years gas operators have used (1) groundwater from dedicated supply wells, (2) surface water from water-rights owners (private or state agencies such as river authorities), (3) surface water from private ponds and other water bodies, (4) treated water from municipalities and industrial users, and (5) water recycled from previous fracing operations. As gas production moves away from the core area (Denton, Johnson, Tarrant, and Wise Counties) toward the north, south, and west to access the remainder of the play, gas operators are faced with two challenges: (1) increased water scarcity and (2) measured reluctance to impact domestic and public water supplies. This study analyzes three potential sources able to meet those goals: (1) small ponds outside the State regulation of surface water, (2) smallish groundwater aquifers west of the more plentiful Trinity aquifer, and (3) treated wastewater outfalls. Different alternative sources were inventoried through orthoimagery coverage to detect all non-State-water bodies, an analysis of the groundwater literature supplemented by perusal of State agency databases, and a thorough examination of relevant wastewater databases (State and Federal), respectively.

Historical data and projections estimated that as much as 40,000 AF of water could be used every year to frac wells. This figure compares well with water available from non-State-surface-water bodies (>100,000 AF at any given time), groundwater (>25,000 AF available per year), and wastewater outfall (>100,000 AF/ yr).

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## **LIST OF ACRONYMS**

AF	Acre-foot
BSWCMC	Barnett Shale Water Conservation and Management Committee
GCD	Groundwater conservation district
gpm	Gallon per minute
MGD	Million gallons per day
PWS	Public water system
SES	Steam electric station
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TNRIS	Texas Natural Resources Information System
TSS	Total suspended solids
TWDB	Texas Water Development Board
WWTP	Wastewater treatment plant

# 1 Introduction

This report documents preliminary results of year 1 of Task 6.0, “Determine Feasibility of Using Alternative Water Sources.” The impetus of the work was a realization that development for gas production in the Barnett Shale area is expanding to the west, north, and south of the core area into areas with few known groundwater resources and with some of the surface-water resources tied up for municipal use (Figure 1 shows footprint of the Trinity aquifer, Figure 2 depicts Barnett Shale well location as of early 2011, Figure 3 displays surface-water features, and Figure 4 shows the counties of interest). There is a clear need for a coordinated approach to locating alternate sources of water and evaluating various means of water delivery to alleviate potential water-availability constraints on Barnett Shale production over the next 20 yr. The objectives of the study as a whole are to

1. Gather baseline data and determine current and predicted water use for all purposes,
2. Review water-quality specifications required to perform frac jobs developed by the Barnett Shale Water Conservation and Management Committee (BSWCMC) Frac Job Expert Panel and determine technical and economic feasibility of utilizing alternate sources of water,
3. Inventory sources of surface water,
4. Inventory nonconventional water sources: desalination concentrates, reclaimed water from treatment plants, low-salinity produced water, dewatering activities, etc.,
5. Interview and interact with industry operators to learn about current practices of locating alternate sources of water in counties with water limitations,
6. Determine water compositions of alternate water sources by obtaining existing data (from TWDB and TCEQ), and
7. Determine possible interactions between sources.

The overall goal is for BSWCMC/RPSEA/GTI to visualize water availability and quality below some cost threshold from any location in the study area. This interim report focuses on Subtask 5 but could not be completed without input and results from Subtasks 1 through 4, which set the stage. Subtasks 1 through 5 will be revisited in the final topical report because operators’ approaches and technologies evolve fairly quickly in the play. An interesting development is the current focus on the so-called combo play located in Clay and Montague Counties in the north section of the Barnett Shale footprint. The combined production of oil and gas makes the area more attractive, given currently depressed gas prices. Subtasks 6 and 7 will be fully addressed in the final topical report. The spatial focus of this study includes 14 counties with significant gas production: Bosque, Dallas, Denton, Erath, Hill, Hood, Jack, Johnson, Montague, Palo Pinto, Parker, Somervell, Tarrant, and Wise.

This preliminary guidance document mostly follows subtasks in the order that they are listed: (1) a section on background information of current water use in the Barnett Shale and relevant conclusions from the expert panel on water quality, (2) a discussion of surface-water bodies, and (3) a discussion of nonconventional water sources. Contributors to the work include Steve Walden and Russ Baier from Steve Walden Consulting and Cliff Lam, undergraduate at UT, for the WWTP study; Teresa Howard from the Center for Space Research at UT for the water features study; Ed McGlynn, graduate student at UT, for the groundwater study; and Cari Breton at BEG for help on the GIS work. Some of the contacts were made through the BSWCMC (<http://www.barnettshalewater.org/index.html>)

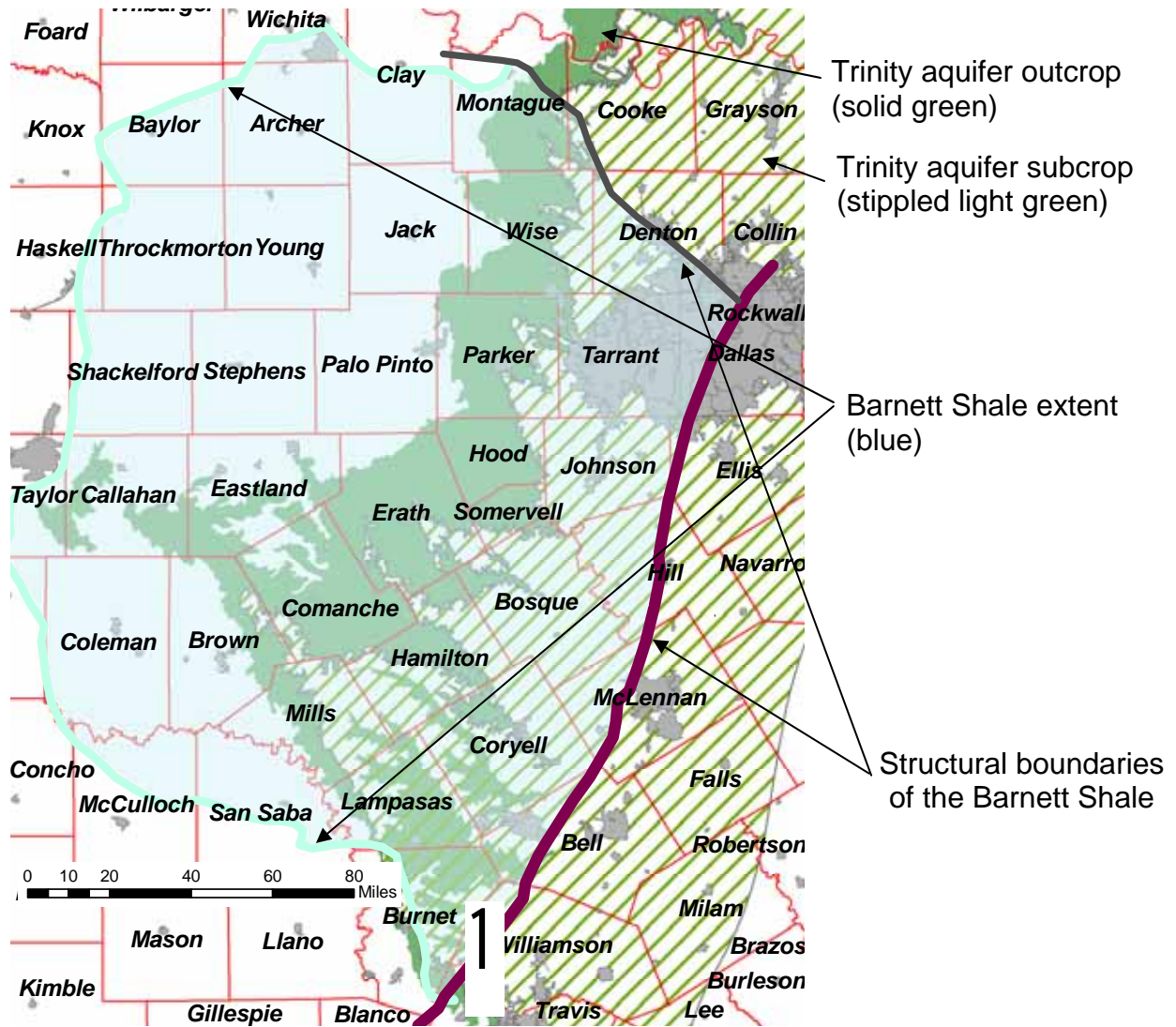
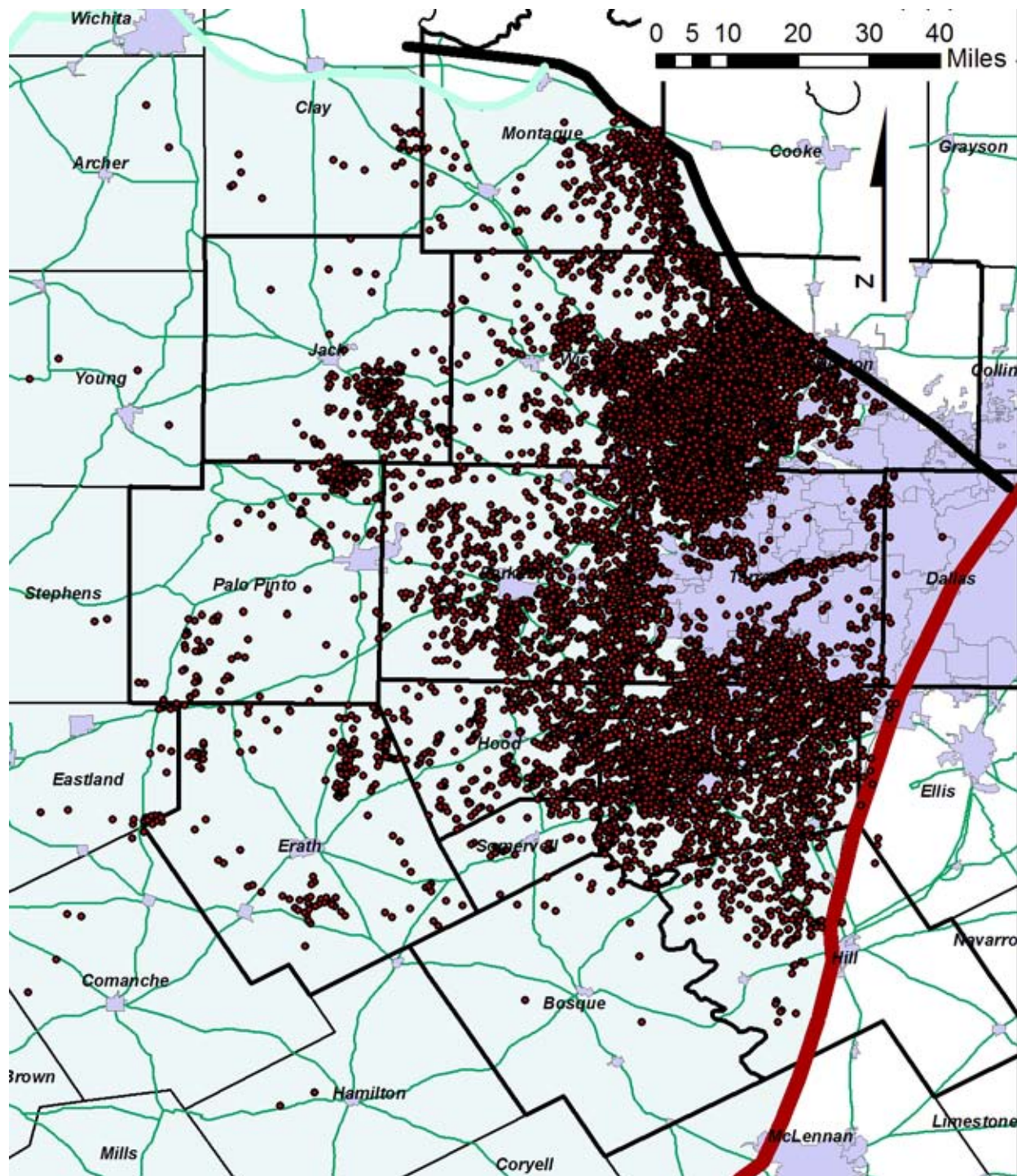


Figure 1. Barnett Shale and Trinity aquifer extents.



Note: county boundaries of area of study highlighted by thicker solid lines

Figure 2. Barnett Shale well locations (>15,000 wells as of end of 2010)

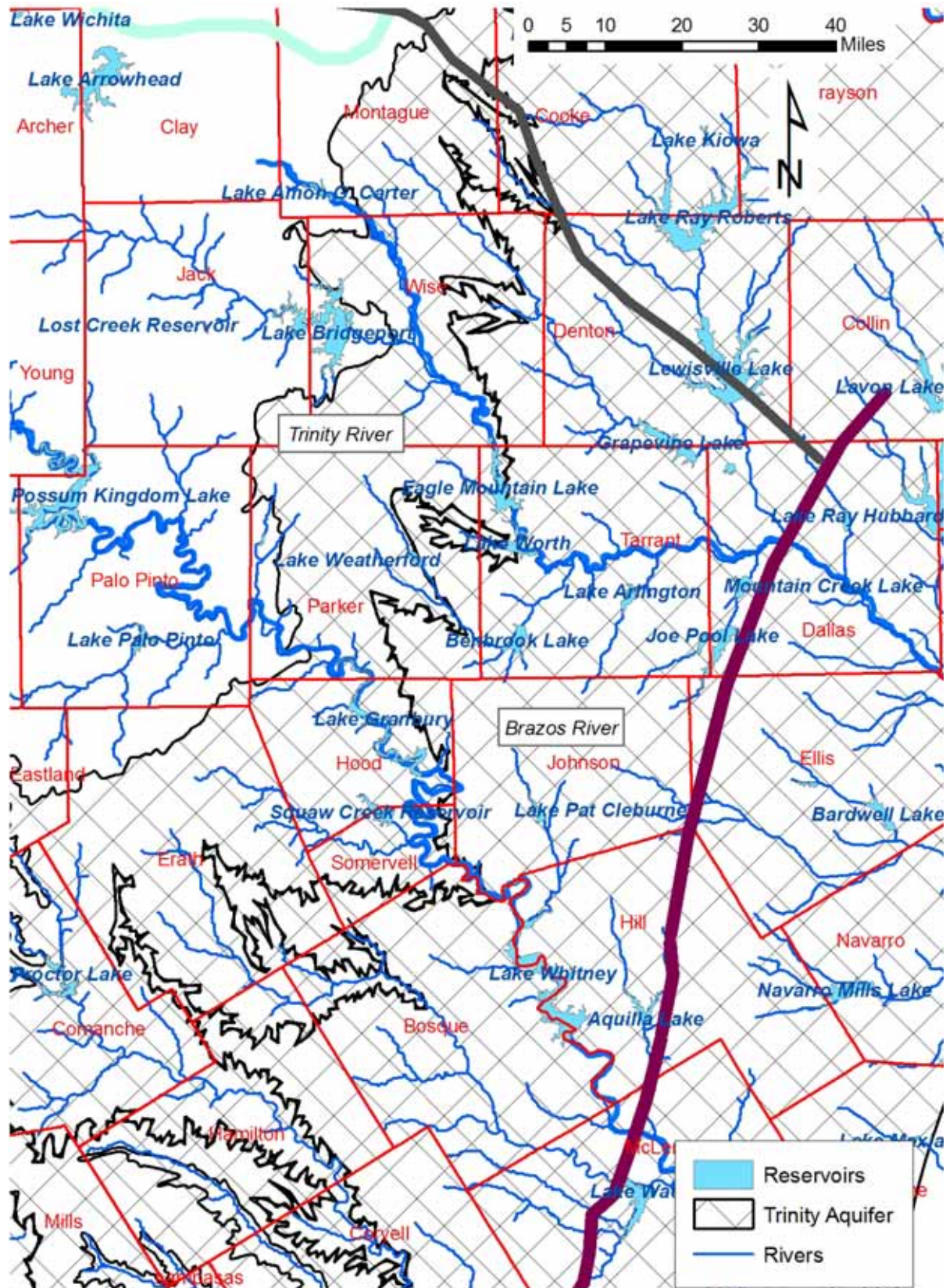
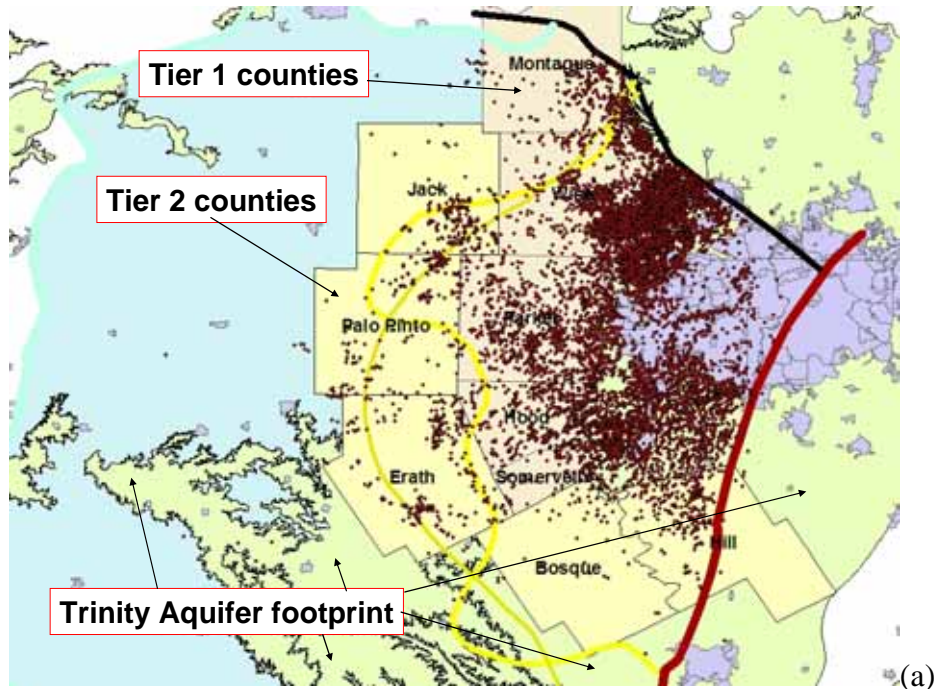


Figure 3. Rivers and reservoirs in the study area.



Note: Maps show Barnett Shale footprint, Dallas-Fort Worth metroplex, and gas-well locations through 2008. The 10 counties of initial interest are also shown: Tier1, the closest to the core area (Montague, Wise, Parker, Wood, and Somervell) and Tier2 (Jack, Palo Pinto, Erath, Bosque, and Hill). Area approximately delimited by yellow lines represents sections of shale with sufficient thermal maturity. (b) Addition of Denton, Tarrant, Johnson, and Dallas Counties.

Figure 4. Map displaying counties of interest.

## 2 Current Practices

Although operators typically declare to the State legal authority (RRC) how much water and how much proppant they use during well stimulation, there is no legal requirement to declare the source of frac makeup water or the quality of the water being used. Although known anecdotally, comprehensive information is hard to obtain. The general picture emerging from conversations with operators is that the search for water is done in a mostly ad hoc fashion, with operators at the corporate level not tracking the source of the frac water very well or unwilling to share to ensure their competitive advantage. In other words, access to and knowledge of the different approaches to satisfy water needs are possible, but more quantitative results with breakup figures among the different approaches are more difficult to compile.

There are several ways to access information about current practices put forward by gas operators to obtain water for frac jobs: formal surveys, literature review and conference proceedings and attendance, and direct interaction with managers or technical experts in charge of well completions. The first option was not retained because of the typical low return as experienced by BEG in previous projects. The second option is appropriate, and a lot could be gained because, in general, the information is dense, consistent, and thorough. A drawback might be that data could be outdated. The third option is likely the best if the person of interest has time to devote to answering questions, which is unfortunately rarely the case.

Information used in this document was gleaned from literature search, interactions with experts at conferences or other private meetings, and phone calls. In 2010, the top 10 producers were, in decreasing order of production, Devon, Chesapeake, XTO (Exxon), EOG, Quicksilver, Encana, Range, Carrizo, Williams, and Burlington (Conoco-Phillips), with the first three dominating the play (RRC website). Information was also obtained through direct interaction with staff members of some of these companies.

Water sources fall into three broad categories: surface water, groundwater, and a composite group. Typically water is either trucked or piped to location. Needed injection rates cannot be matched by truck traffic or pipeline-flow rate, so water is generally stored on site in a tank battery or in an impoundment. For example, Chesapeake uses ponds holding several millions of gallons of water that can be used to drill and frac several wells within a radius of 1 or 2 miles.

Surface waters include lakes and rivers, for which a permit is needed, but also artificial ponds, whose water originates from the subsurface, and impoundments. Groundwater is pumped from wells drilled by the operator or owned by a nearby landowner. The last category is composed of what could be termed unconventional or alternative sources of water, including municipal water (which initially may be groundwater, surface water, or a mix of both) and wastewater from municipal or industrial facilities, to which recycled flowback water can be added. Another source not commonly present in the Barnett footprint is acid mine drainage.

The latest reliable piece of information on groundwater–surface water split dates back a few years. The source of fresh water was nearly even in 2005 between surface water and groundwater (estimated at 53% and 47%, respectively), and it was projected that by 2007 the fraction of fresh water from surface water would rise to ~59% as drilling activity expanded in the Fort Worth metropolitan area (Galusky, 2007). Information from other shale-gas plays can also reveal other companies' approaches to water management in the Barnett play. For example, Veil (2010) reported on water management in the Marcellus but focused mostly on the disposal of

wastewater and Gaudlip et al. (2008) investigated approaches used in the Marcellus a few years ago.

Table 1 summarizes qualitatively current approaches. Large surface-water bodies and groundwater are likely conventional targets. Surface-water bodies can be managed by municipal, State, State-initiated, or Federal entities (U.S. Department of Agriculture, U.S. Corps of Engineers). Operators can, for example, contract with the Brazos River Authority (BRA), which controls surface water in the south section of the study area (Figure 3) or with the Trinity River or Red River Authority which controls surface water farther north. As far as we know, water use by category for river authorities is not specific enough to carve out the part related to fracing. For example, BRA sells ~2% of the water (that it is allowed by the State to sell) for mining use that includes fracing but possibly other uses. Municipal water is also a target of choice, especially in urban environments with no access to surface water and limited access to groundwater. For example, the City of Arlington, Tarrant County, provides a maximum of 3% of its 140-MGD capacity to gas operators (J. J. Hunt, Arlington Water Utilities, oral communication, 2010). This amount is apparently enough to frac 300+ wells every year, but how much of that water is actually used for fracing is unclear.

As an example, Chesapeake (2008 presentation) has the following approximate source breakdown: surface water 35% (Brazos River Authority, Trinity River Authority, U.S. Corps of Engineers), private water 25% (private lakes and ponds and stock tanks), water-supply wells 25% (all but three had already been drilled), municipal water purchases 15% (Arlington, Burleson, Cleburne, Crowley, Keene, Fort Worth, and Grand Prairie), and reuse/wastewater < 1%.

There is also a move toward using brackish and saline water, including flowback, produced water, and water originating from shallow and deep aquifers. In some cases, operators might then run into obstacles (see Section 3.2). Recycling is also an option but not hotly pursued in the Barnett play because disposal (mostly into the underlying Ellenburger) is more convenient and, currently, cheaper. On a per-well basis, initial flowback water requiring limited treatment amounts to 200,000 gal (M. Mantell, Chesapeake, GWPC Conference, January 2010), or only ~5% of the amount injected. Transporting such a small fraction of the water needed to frac another well causes logistical problems, unless the well is on a multiwell pad. The 20 to 30% flowback recovered in the 2 weeks following stimulation can be reused, but, for some of it, only after having received a more expensive treatment to remove the excess salinity through evaporative thermal or membrane reverse osmosis processes. More innovative approaches yielding lesser volumes of water include reuse of drilling wastewater and use of excess water collected during wet months or heavy precipitations events. Blending of water from different sources, and particularly of different quality, has become more widespread in the past few years (and has compounded geochemical compatibility and scaling issues).

The work in this report is described along three fronts: (1) groundwater not related to the Trinity aquifer (the regional aquifer tapped by municipalities), (2) non-State surface waters, and (3) municipal and industrial sources. Groundwater and surface water, being broadly distributed, natural water sources, are less controllable in terms of quantity and quality through time. The next section (Section 3) gives details on water-quantity and water-quality requirements. Section 4 endeavors to explain the use of small ponds by the industry by examining pond supply through time and under different climatic conditions (wet year, dry year). This information may suggest new approaches to the industry for coping with the lack of easily accessible groundwater.

Section 5 investigates availability of groundwater outside the Trinity aquifer, particularly in terms of volume, water volume, and well yield. Lastly, Section 6 describes options for the use of nonconventional sources of water and the availability of this water for future completions in the Barnett Shale.

As the population within the Barnett Shale footprint continues to grow and as demands for fresh water intensify, it may be strategically important in the long term for the industry to develop fewer water-intensive fracs. In the midterm, the ability of the industry to process its flowback and produced water for reuse in frac jobs will be of tactical significance as a means of reducing fresh-water demand in the shale-gas industry. Further improvement in industry fresh-water demand could be achieved through improved additives and treatment technologies to use with saline water produced from deeper saline aquifers (e.g., Ferguson and Johnson, 2009). Auxiliary water use such as drilling could also move from water-based mud to air drilling as much as possible. In the interval, alternate sources such as (nonpotable) brackish aquifers could help in the transition.

Table 1. Summary of water sources and assessment of use in the Barnett play.

Source	Water Quality			Water Use***
	Fresh*	Brackish	Saline**	
<b>Surface Water</b>				
Lakes, rivers	√			++++
		√		++
Ponds	√			+++
<b>Groundwater</b>				
Shallow depth	√			++++
Shallow to intermediate depth		√		++
Deep aquifer and produced water			√	+
<b>Unconventional / Reuse</b>				
Municipal WS	√			+++
Industrial WW	√			+
Municipal WW	√			++
Minimally treated flowback	√	√		++
Recycled flowback	√			++
Mining impoundments or ponds				-

\* defined as <1,000 mg/L

\*\* defined as >20,000 mg/L (see Section 3)

\*\*\* qualitatively defined as heavy (++++), significant (+++), marginal (++), emerging (+), or very minor (-) use

WS= water supply; WW= wastewater

## 3 Water-Quantity and Water-Quality Requirements

### 3.1 Water-Quantity Requirements

Fracing needed to open up flow pathways to produce gas requires large amounts of water, and those details will not be discussed here. The Barnett Shale play has used ~100,000 AF of fresh water (1 AF = 325,851 gal = 7,758 bbl) (Figure 5) and is currently using ~25,000 AF/yr, with a dip in 2009–2010 because of economic circumstances and low gas prices. As described in Bené et al. (2007) and Nicot and Potter (2007), this amount of water is small compared with the volumes needed for municipal and other uses. The State of Texas as a whole uses 18+ million AF/yr of fresh water (TWDB, 2007). Initially in the 1990's and early 2000's, most fraced wells were vertical, but, beginning in 2003–04, drilling of horizontal wells grew fast and now dominates the play (Figure 6). Vertical wells were used mostly in the core area, close to Fort Worth, in Denton, Johnson, Tarrant, and Wise Counties. This comment is important because horizontal wells consume more water than vertical wells on average and, thus, require more plentiful water sources. Vertical wells use ~1 to 1.5 million gal per frac job (Figure 7a and Figure 8a), whereas horizontal wells consume 3+ million gal (Figure 7b and Figure 8b). In general, water must be delivered during fracing in a short amount of time (~1 day), and water is stored onsite while the well is being drilled (~3 weeks). This requirement translates into a constraint for water sources to be able to provide this volume in the allotted time. Of course, water demands for completions become larger in magnitude and more complex (with regard to timing of delivery) as the industry moves toward the use of multiple-well pads (Figure 9). Three million gal in 3 weeks requires a pumping rate of ~100 gal per minute (gpm) or 0.14 MGD (*gpm* and *MGD* are customary units for well pumpage and treatment plants, respectively). Bené et al. (2007) suggested that the groundwater–surface water split was ~50-50%, but the data are not easy to access and the issue has become more complicated by the use of recycling. The split most likely varies in space and time because operators are opportunistic.

### 3.2 Water-Quality Requirements

A report was obtained from a Hydraulic Fracturing Expert Panel conducted by the BSWCMC that described the minimum quality of water needed to conduct hydraulic fracturing without compromising the quality of shale-gas well completions (Hayes, 2007). The report discusses critical parameters on total dissolved solids (TDS), ionic make-up, and other requirements of fracing fluids. Some of the key elements are:

- Consistency in fluid composition, which relates to water amount—that is, a source large enough to provide water for at least a significant fraction of the job,
- Circum-neutral pH (6–8) for optimal biocide use,
- Low hardness (Ca <350 mg/L) to limit polyacrylamide friction reducer demand,
- TDS as measured by chloride; use of water with a chlorinity of 10 g/L (~16–17 g/L TDS) is still appropriate according to all panel members; high TDS (Cl >35,000 mg/L) is detrimental to friction reducers,
- Total suspended solids (TSS) <50–100 mg/L, and
- Sulfate that must be watched closely because of the impact of sulfate-reducing bacteria and because of scale-forming BaSO<sub>4</sub> with a very low solubility product.

Other parameters to be considered include iron, boron (premature cross-linkage), and dissolved O<sub>2</sub> (bacteria). These observations are confirmed by other statements available online. However, note that the Hydraulic Fracturing Expert Panel was conducted more than 3 yr ago and that the technology is quickly advancing. Another issue becoming more prevalent is the increase in the number of stages and total water volume requirements. A related concern involves the management of the chemical compatibility of waters that are more and more likely to be of from different origins (blending) as the required amount increases.

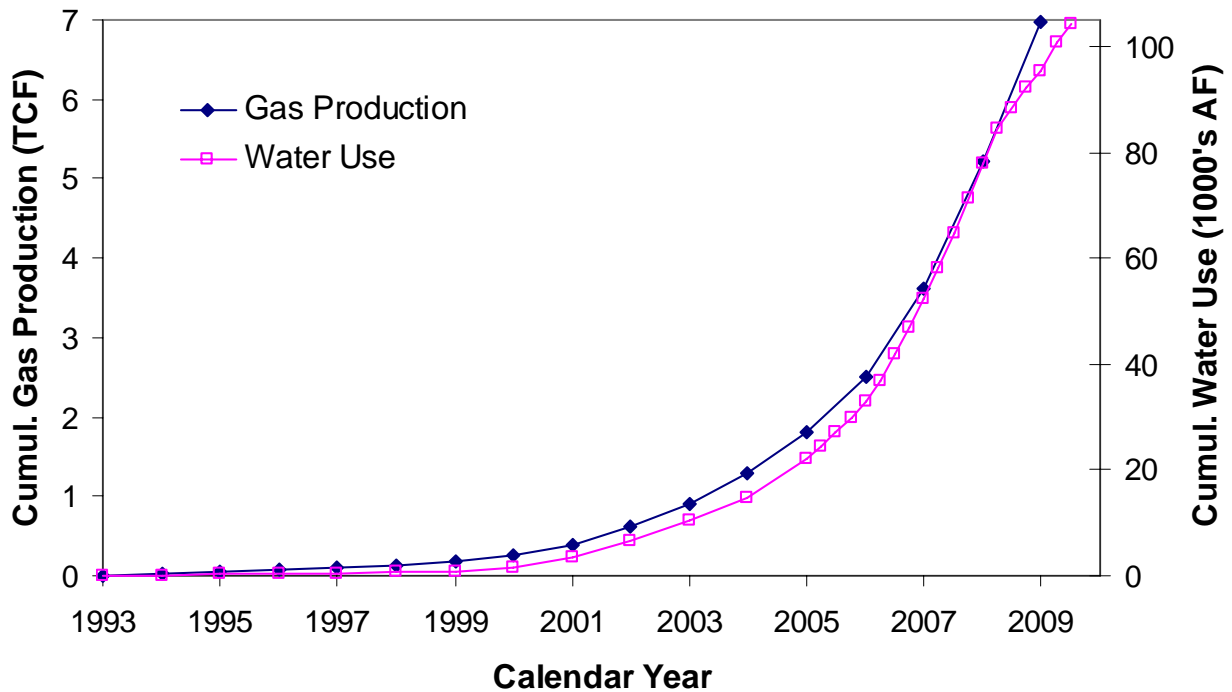


Figure 5. Cumulative gas production and water use in Barnett Shale play from origins.

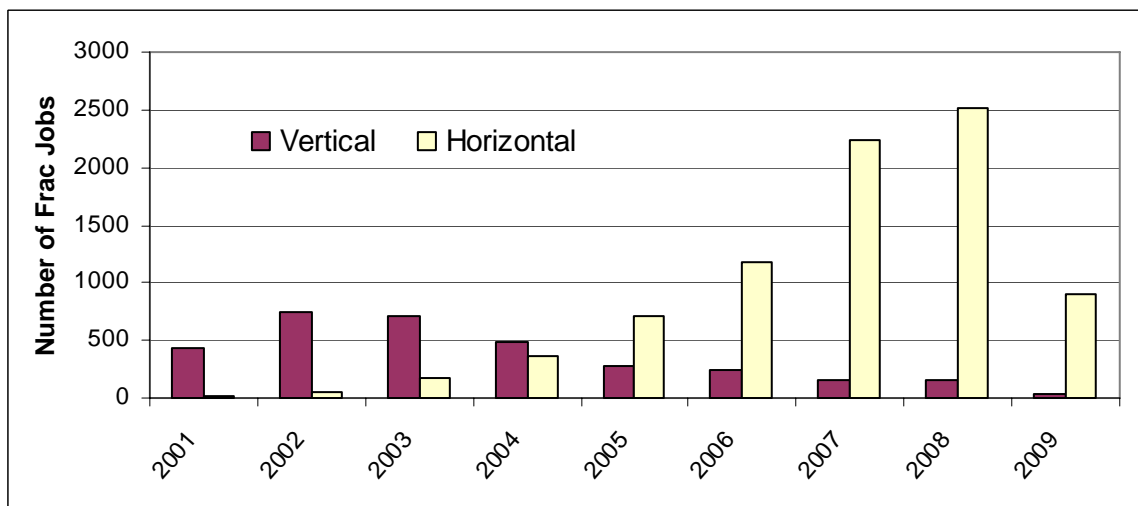
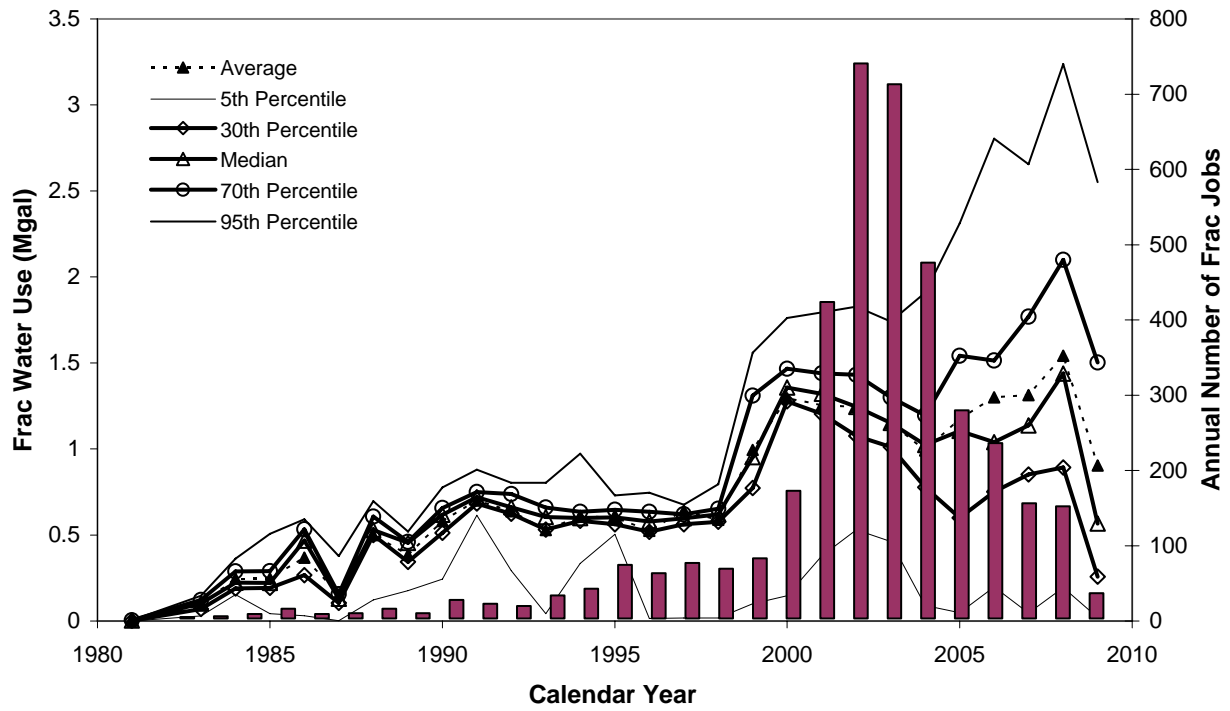
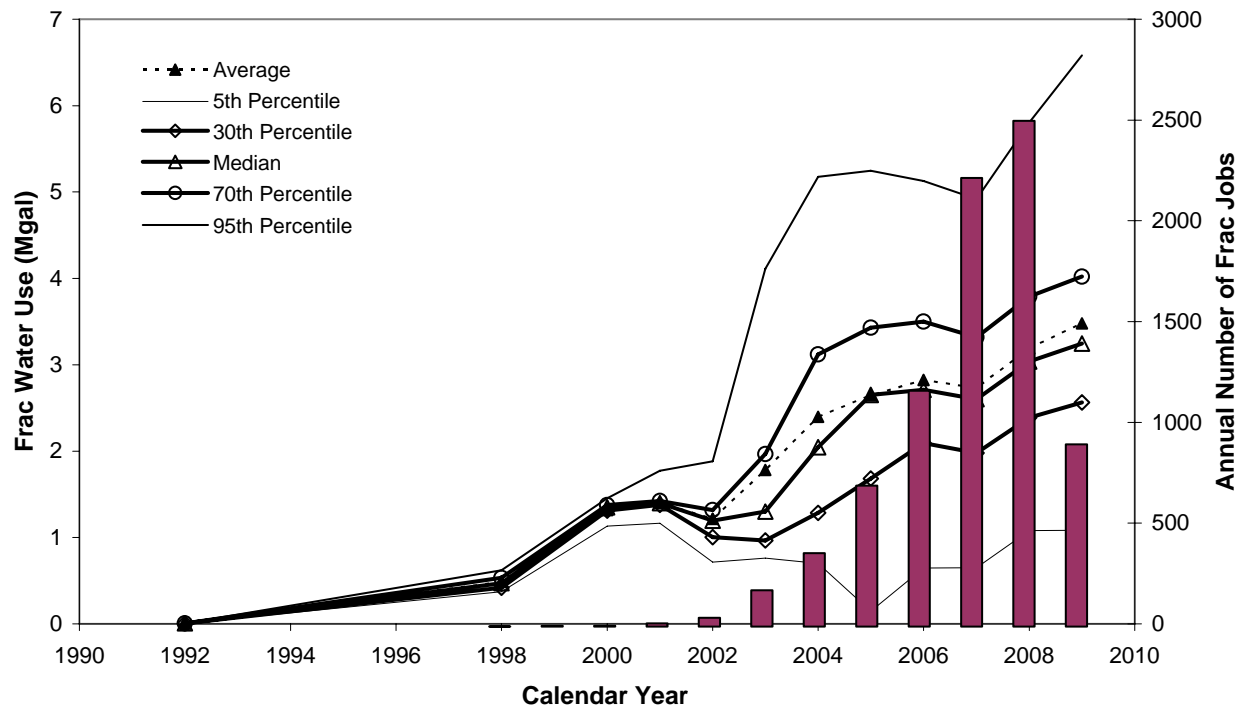


Figure 6. Barnett Shale—vertical vs. horizontal and directional wells through time.

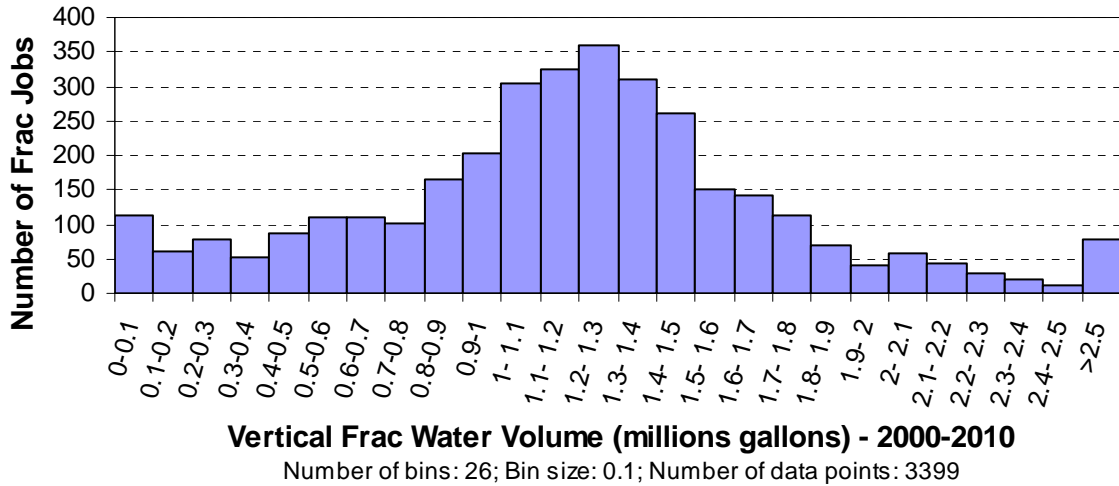


(a)

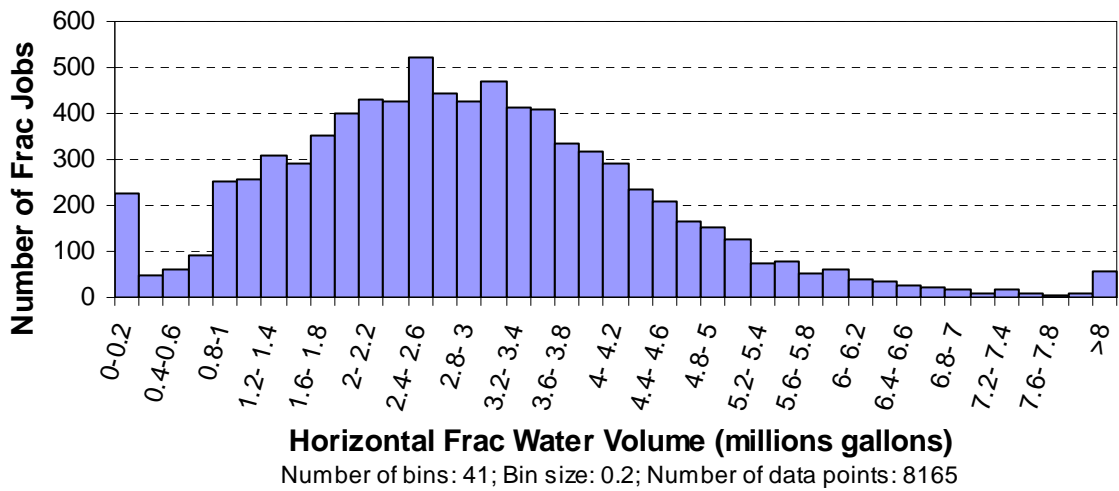


(b)

Figure 7. Barnett Shale—annual number of frac jobs superimposed on annual average, median, and other percentiles of individual-well frac-water use for (a) vertical wells and (b) horizontal wells.

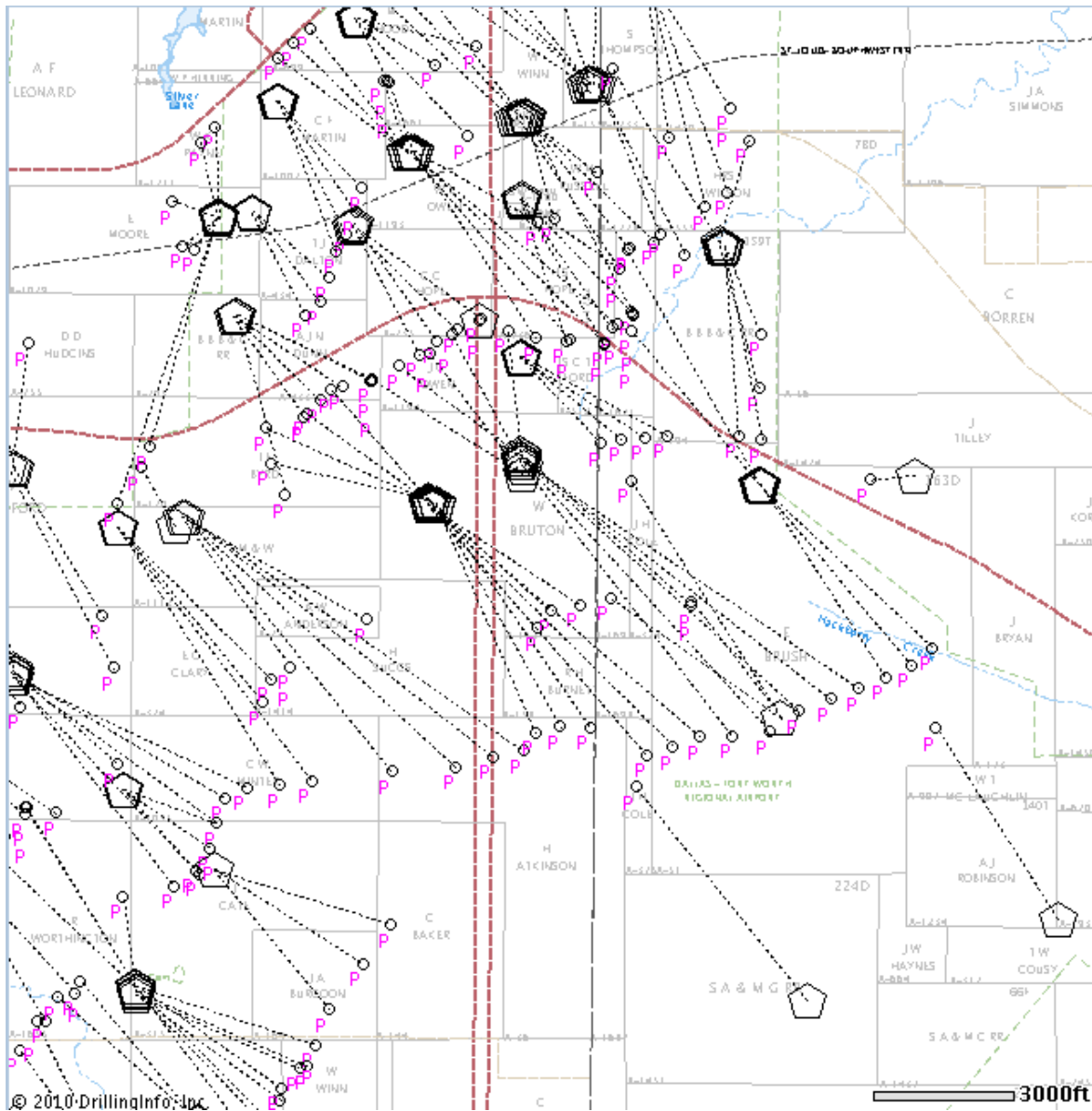


(a)



(b)

Figure 8. Barnett Shale—histograms of frac-water use for 2000–2010 (a) vertical wells and (b) horizontal wells.



Note: map displays an average drainage area of ~80 acres/well (laterals not pads) where laterals are dense. Pentagons depict locations of multilateral well pads, whereas dotted lines depict different laterals originating from the same well pad. Laterals are more or less parallel because they are oriented perpendicular to the local minimum horizontal stress. Underlying gray boundaries denote property lines (not relevant to the discussion).

Figure 9. Example of Barnett Shale density of laterals (Dallas-Tarrant County line).

## 4 Surface-Water Bodies

Surface water in Texas, such as rivers and lakes (Figure 3), is owned by the State, which grants the right to use it to different entities. Typically a permit is needed to retrieve the water unless it falls under an “exempt use.” Exempt uses include “domestic and livestock use,” for which impounding and storing of water are allowed on properties adjoining a stream but not greater than 200 AF (65 million gal) on average in any consecutive 12 months. This water cannot be sold, however. For the water to be used for that purpose, the landowner would need to ensure that the potential buyer (gas operator) obtained a temporary permit from TCEQ. If a surplus of water is not appropriated, temporary permits can be granted relatively easily. Clearly, during drought, when junior water rights might not be fulfilled, temporary permit requests will not be approved. Processing in regional TCEQ offices is generally quick, provided the volume requested is, at most, less than 10 AF (3.26 million gal) in a calendar year. In addition, surface runoff, as long as it has not entered a natural water course, belongs to the landowner, not the State.

As detailed next, orthoimagery coverage (publicly available from Texas Natural Resources Information System, or TNRIS) was used to inventory surface-water bodies. In addition, the TCEQ Central Registry (see Section 6) was also used to examine and evaluate other program-related datasets for further water-availability potential. These included water rights, utilities, and public water system/supply programs. Water-rights permit holders are authorized to withdraw a designated amount of water from surface-water sources for industrial, agricultural, municipal, and other uses. Approximately 570 entities hold water-rights permits in the initial 10-county study area. Utilities are established entities approved by the TCEQ to provide water and wastewater services to specified geographic areas of the state. Approximately 250 utilities are authorized in the 10-county area. Public water systems (PWS) cover a broad spectrum of public or privately owned facilities, ranging from cities to neighborhood water-supply systems to individual businesses that provide potable water to customers. Approximately 530 PWSs exist in the study area. Because all of these entities are already committed to providing existing or future uses of water in the area, they were determined to be unlikely sources of available water for fracturing operations.

### 4.1 Water-Body Statistics—Satellite-Imagery Study

The inventory of non-State-regulated surface-water features in the footprint of the Barnett Shale in Montague, Wise, Parker, Hood, Somervell, Jack, Palo Pinto, Erath, Bosque, and Hill Counties is nearing completion (Figure 10). Previously, the wettest and driest months from 1995 through 2000 (that is, before gas-drilling activities) were identified. Within the counties of interest, greatest departures from normal mean precipitation for 1971 through 2000, both wet and dry, occurred in the month of February (Figure 11). The wettest month was February 1997 in which a mean monthly precipitation of 7.7 inches was recorded. The driest month occurred 2 years later. For the 10-county area, the driest year in the region of interest occurred in 1999; 1997 was the wettest year.

Two Landsat satellite passes, typically called *paths*, are required to cover the area of interest. These are Path 28 to the west and Path 27 to the east (Figure 12). Two Landsat images per path are required to cover the area of interest. Previously all potential Landsat images for the period of interest (1995 through the present) were prescreened. In total 60 cloud-free candidates and 20

additional candidates were potentially useful in some capacity. Table 2 shows the image candidates chosen for time-series analysis and a brief synopsis of collection conditions in relation to monthly mean precipitation. The image candidates for 2010 were updated when cloud-free observations were made in November of that year. Preference was given to single date collections by path and near-date collections for adjacent paths. For example, the dry baseline image for Path 27 uses data collected on February 14, 1999, for the east half of the area of interest. A near-date image collected on February 21, 1999, was chosen for Path 28. Although the latter image was collected during the month ranked as third-driest, the mean monthly precipitation and the 7-day time proximity made it the best match. Images representing the wettest baseline dataset were chosen in a similar manner. For 2003 through 2010, preference was given to same-date images collected along each path. The final choice was based on date proximity of adjacent path collections.

Landsat 5 Thematic Mapper data were preprocessed and mosaicked by path. Alternative methods for preprocessing and classification were tested. In the final processing for identification of non-State-regulated water features from Landsat satellite data currently under way, each image mosaic is processed to remove most atmospheric noise. Vegetation indices, water indices, and a texture measure are calculated. The preprocessed data are subdivided into tiles. Next the multiband tiles are entered into a geographic, object-based, image-analysis program in which each tile is segmented into objects of varying size and classified using an iterative process that first identifies and flags large reservoirs and then identifies water bodies of increasingly smaller sizes. Some features as small as a quarter acre are identified, but the most reliably identified features are 1 acre in size or larger.

Following image classification, results were exported into a common raster data format. Included in the results were objects classified as medium and large reservoirs, rivers, and other surface-water features classed by area extent. The latter water features were exported as unified objects and, in parallel, as objects classified according to water content: 100% water, 75–99 % water content, and 50–74% water content. All tiled results were exported to a conventional image-processing application to reconstruct complete image mosaics. The reconstructed classified image data were exported into a vector GIS format. Within a GIS environment, classification results were compared with source Landsat images. GIS tools were used to eliminate most false-positive objects, including mosaic seam lines, cloud shadow, shadow in terrain, wet soil in fallow fields, water pooling in streambeds, river water not classified as such, and large pools of water in riverine floodplains. The data review also revealed some missed opportunities, but it was not feasible to correct omissions in a timely manner. The area of image overlap was scrutinized. For 6 of the 10 yr analyzed, <9 days elapsed between collection periods. For three of the remaining years, the gap was more than 3 weeks. The largest gap was 39 days in 2004. Consequently, it was decided to merge data collected during a single year to create 10 datasets. Appendix B contains summary statistics describing results, which are arranged by county geography, from north to south and west to east. Results are analyzed in Section 4.2.

Figure 13 and Figure 14 show representative results using Path 27 data from multiple years: 1997, 1999, 2005, and 2010. The area depicted shows the intersection of three counties of interest: Hood, Erath, and Somervell. The smallest identified features are 0.22 acres in size (30- $\times$ 30-m pixels) but might be slightly larger or smaller in actuality. Graphics are displayed at a slightly greater resolution than is appropriate for 30-m Landsat data, so the reader can see

changes in smaller features over time. Some change in feature size is evident in the time-series sample. Note that the number of the smallest water features fluctuates over time.

Note also that some features might be missing in the final classifications and that some features identified as water might not be water in actuality. Several factors determine which features are properly classified. In general, filtering out features represented by 1 to 3 pixels is preferable because of uncertainties in the classifications. However, these smallest features are retained at this time. A review of selected features in comparison with recent high-resolution aerial images indicates that many correspond to water features. Note that feature areas as presented in the tables of Appendix B necessarily represent metrics based on pixel size.

## **4.2 Surface-Water-Body Analysis**

The objective of this part of Section 4 is to assess how much water is potentially available from small private ponds and whether impact of well-completion activities can be seen in a history of pond count and surface area. Note that satellite imagery provides access to the area covered by a water body not to its depth, although it makes sense to positively correlate area and depth. We plan to further investigate this relationship to better constrain the amount of water available. Figure 15 displays examples of plots prepared for all counties in Appendix C. Type 1 plots (Figure 15) display cumulative area at selected times (as discussed in the previous section). In a given county, the area varies by a factor of 3 as a function of precipitation. Type 2 plots, illustrating variations in pond count of different sizes at selected times, consistently show that small ponds are numerous, which is not only an advantage for servicing well pads distributed across the county, but also they are sensitive to weather variations (wet/dry periods). Type 3 plots display completion counts (extracted from the IHS Energy database and calculated on a 1/10 of a year basis) and pond intensity and try to discern impact of fracing on amount of water stored in ponds.

Typical surface area values ranges from <1,000 to <10,000 acres, depending on the county and time. Another way to present the information is to normalize the cumulative pond area by the county area (Figure 16) or to normalize the pond count (all sizes) by the county area (Figure 17). A representative value is 4 acres of (non-State) surface water per square mile, or 0.25 acre per 40 acres. Assuming a depth of 5 ft on average, this is a water volume of ~0.4 Mgal/40 acres. Adding the time dimension shows that this amount of water is more than sufficient to meet all fracing needs. If the play is active for several decades and the pond can be naturally replenished (that is, with precipitation and runoff, not through groundwater pumping or owner intervention) several times a year, the amount of water available is beyond what is needed for a generic well. Another way to present the information that may be simpler is to compare projections for annual needs at the county level to approximate pond volume. Annual needs are estimated to be close to an average of 2,000 AF/yr/county (Nicot et al., 2011), which is covered by the 1,000- to 10,000-acre range with a 5-ft nominal depth.

Comparison with National Weather Service data (<http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?WWDI~getstate~USA>) shows that pond area is correlated with precipitation (Figure 18 and Figure 19) but requires more analysis. Gaining a better understanding of the split between stored groundwater and surface-water runoff (still unknown) is also important in fully accessing the true amount of water available in ponds and other surface-water bodies.

Table 2. Precipitation extremes and Landsat data availability.

Mean Monthly Precip. (inches)	Mo	Yr	Path	Location of AOI	Date Landsat Collection	Rank (1995–1999) or Departure from Normal (2003–2010)	Precipitation Comparison Status	Mean Monthly Normal Precip. (inches)
0.13	Feb	1999	27	East	2/14/1999	Driest	Baseline	1.9
0.15	Feb	1999	28	West	2/21/1999	3rd driest	Baseline	1.8
7.8	Feb	1997	27	East	3/3/1997	Wettest	Baseline	2.0
5.5	Mar	1997	28	West	3/28/1997	4th wettest	Baseline	2.5
2.3	Oct	2003	27	East	10/23/2003	Drier than normal	Oct mean	3.9
2.9	Oct	2003	28	West	10/14/2003	Drier than normal	Sep/Oct mean	3.4
3.1	Sep	2004	27	East	9/7/2004	Near normal	Aug/Sep mean	2.7
2.5	Oct	2004	28	West	10/16/2004	Drier than normal	Sep/Oct mean	3.4
2.3	Feb	2005	27	East	2/14/2005	Near normal	Jan/Feb mean	1.9
2.2	Feb	2005	28	West	2/21/2005	Near normal	Feb mean	2.0
2.5	Nov	2006	27	East	11/16/2006	Drier than normal	Oct/Nov mean	3.1
1.6	Nov	2006	28	West	11/23/2006	Drier than normal	Nov mean	2.1
4.0	Mar	2007	27	East	3/8/2007	Wetter than normal	Feb/Mar mean	2.5
6.5	Mar	2007	28	West	3/31/2007	Wetter than normal	Mar mean	2.5
4.8	Apr	2008	27	East	4/11/2008	Wetter than normal	Mar/Apr mean	2.8
4.8	Apr	2008	28	West	4/18/2008	Wetter than normal	Mar/Apr mean	2.6
8.4	Oct	2009	27	East	10/23/2009	Wetter than normal	Oct mean	3.9
5.9	Sep	2009	28	West	9/28/2009	Wetter than normal	Sep mean	3.0
n/a	Jun	2010	27	East	11/27/2010	n/a	n/a	n/a
n/a	Apr	2010	28	West	11/18/2010	n/a	n/a	n/a

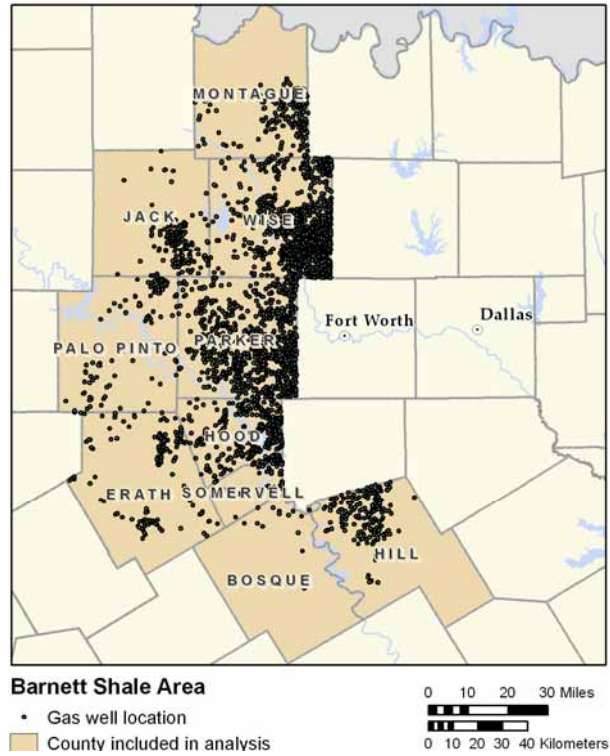


Figure 10. Project area counties and distribution of Barnett Shale wells.

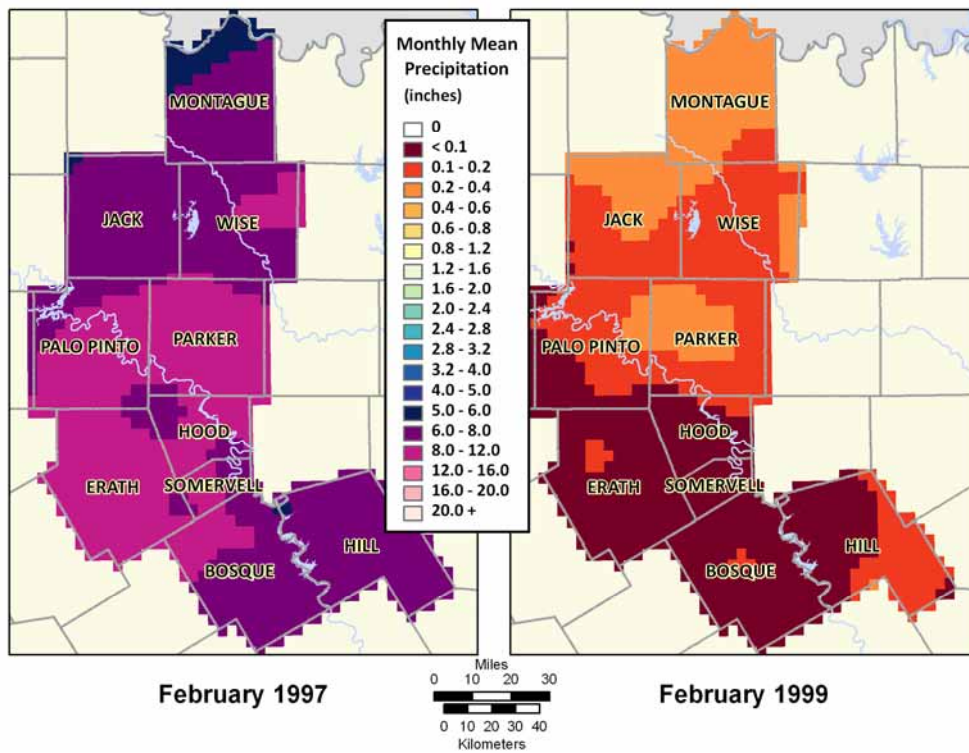


Figure 11. Wettest and driest months, 1995–2000.

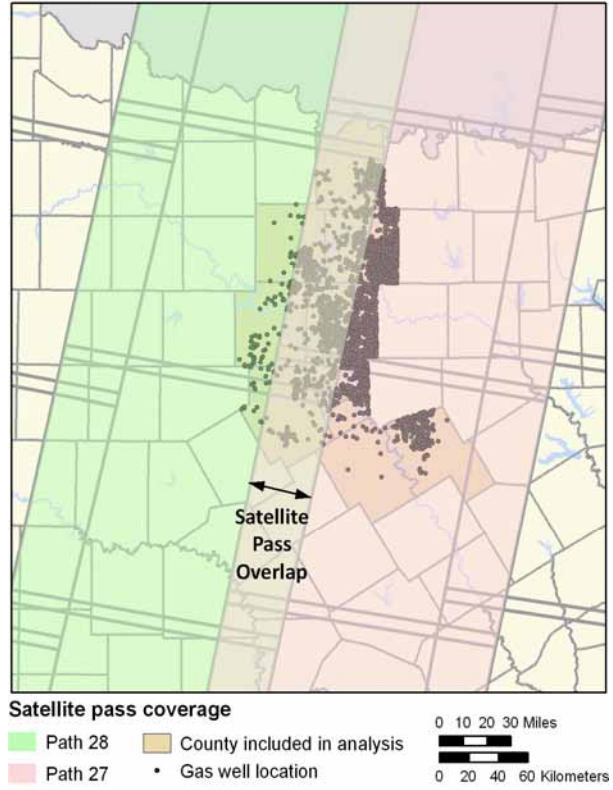


Figure 12. Landsat Paths 28 and 27 in relation to the study area.

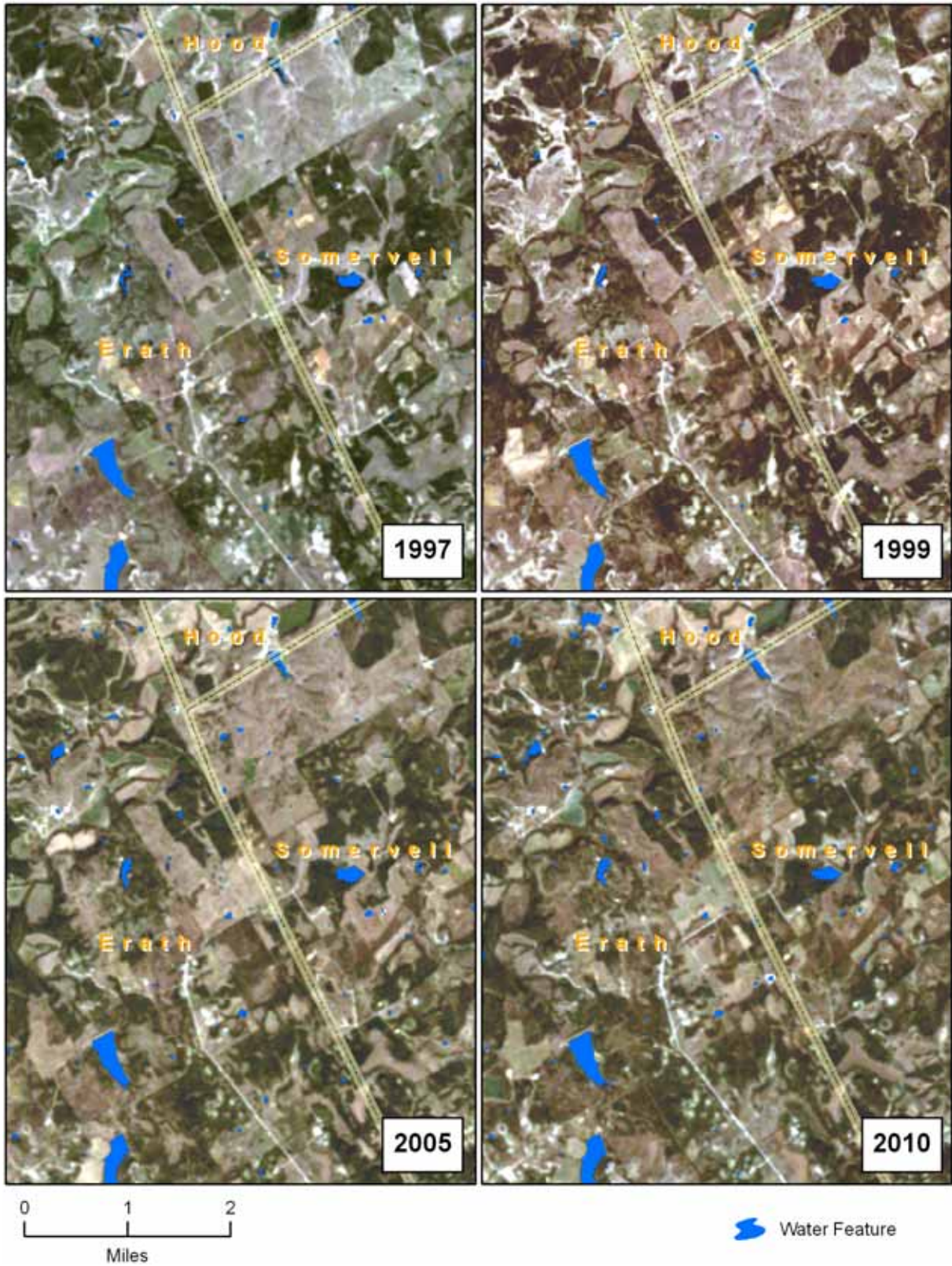


Figure 13. Surface-water features identified during multiple years and shown with source Landsat images.

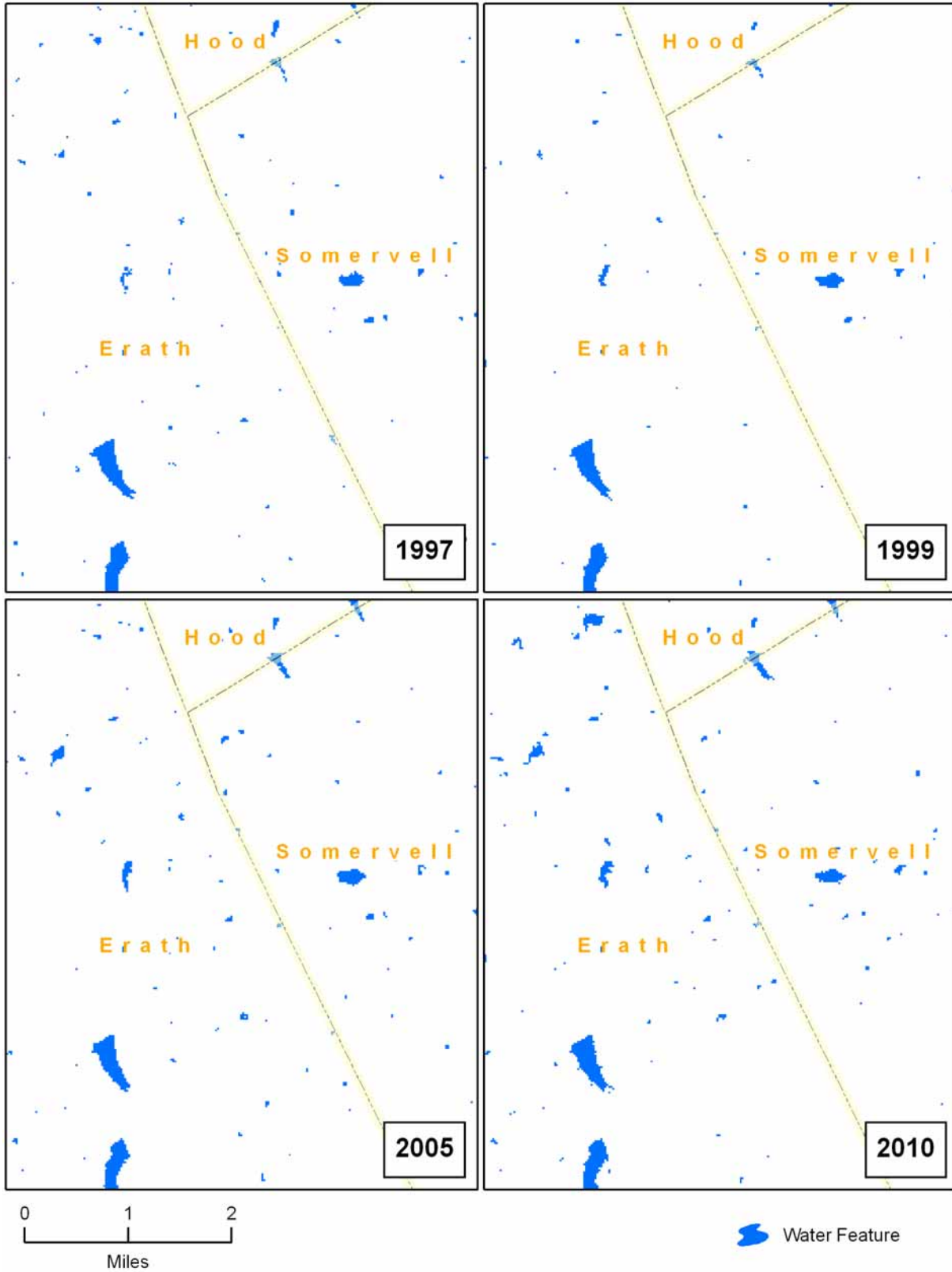
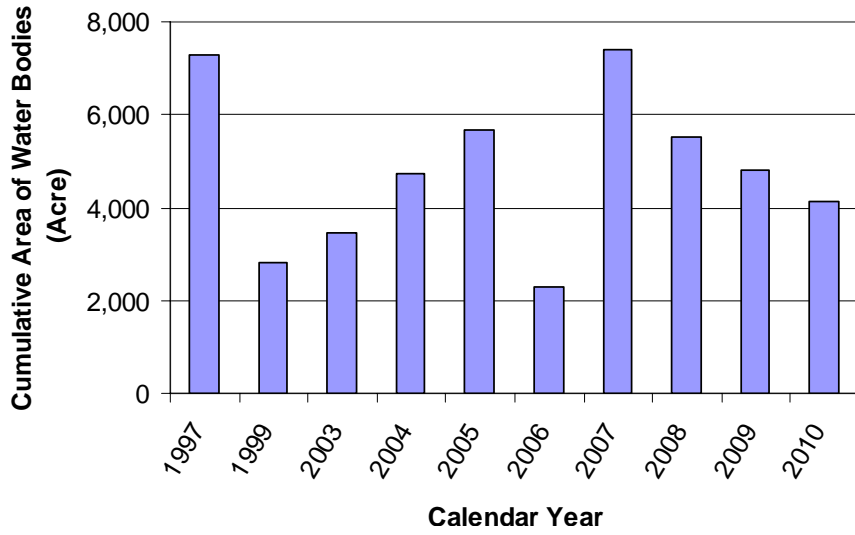
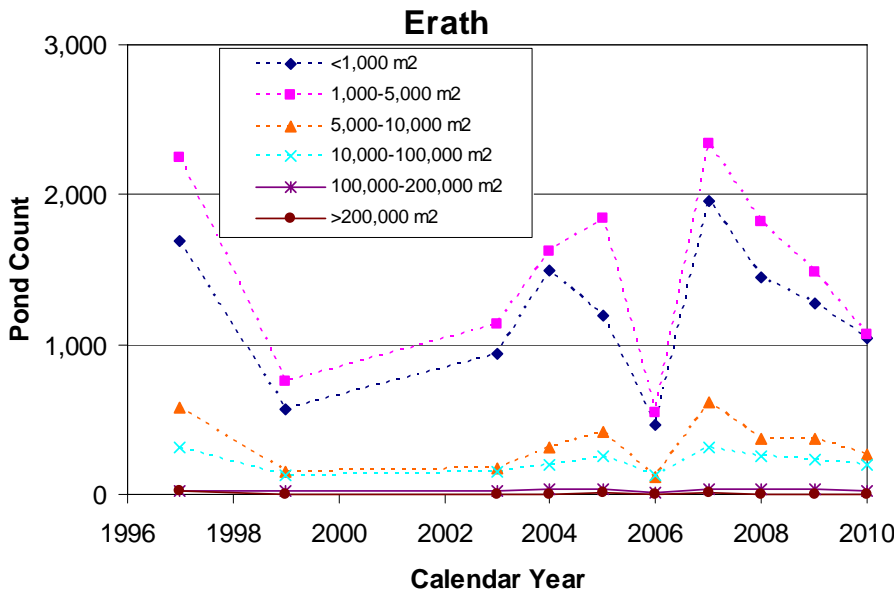


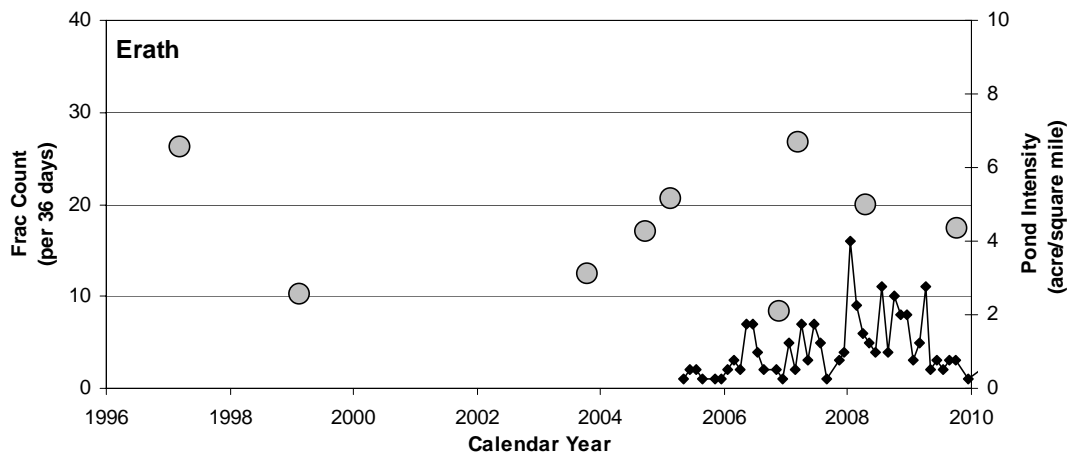
Figure 14. Surface-water features identified during multiple years without image backdrops.



Type 1 plot



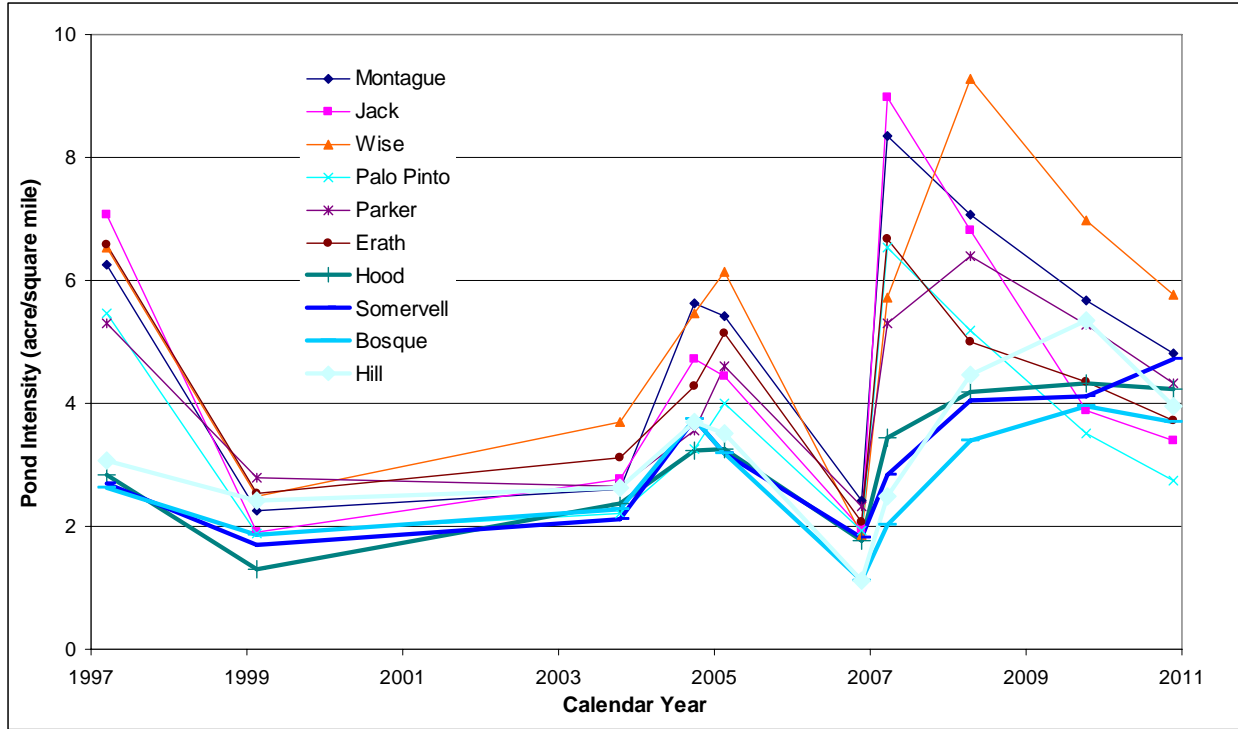
Type 2 plot



Type 3 plot

Note: 1997: preactivity wettest month; 1999 preactivity driest month

Figure 15. Example (Erath County) of plots presented in Appendix C.



Note: straight line segments are not meant to infer that interpolation is linear between data points (actually it is very likely that is not) but for ease of reading.

Figure 16. Pond intensity (acre per square mile) for selected times.

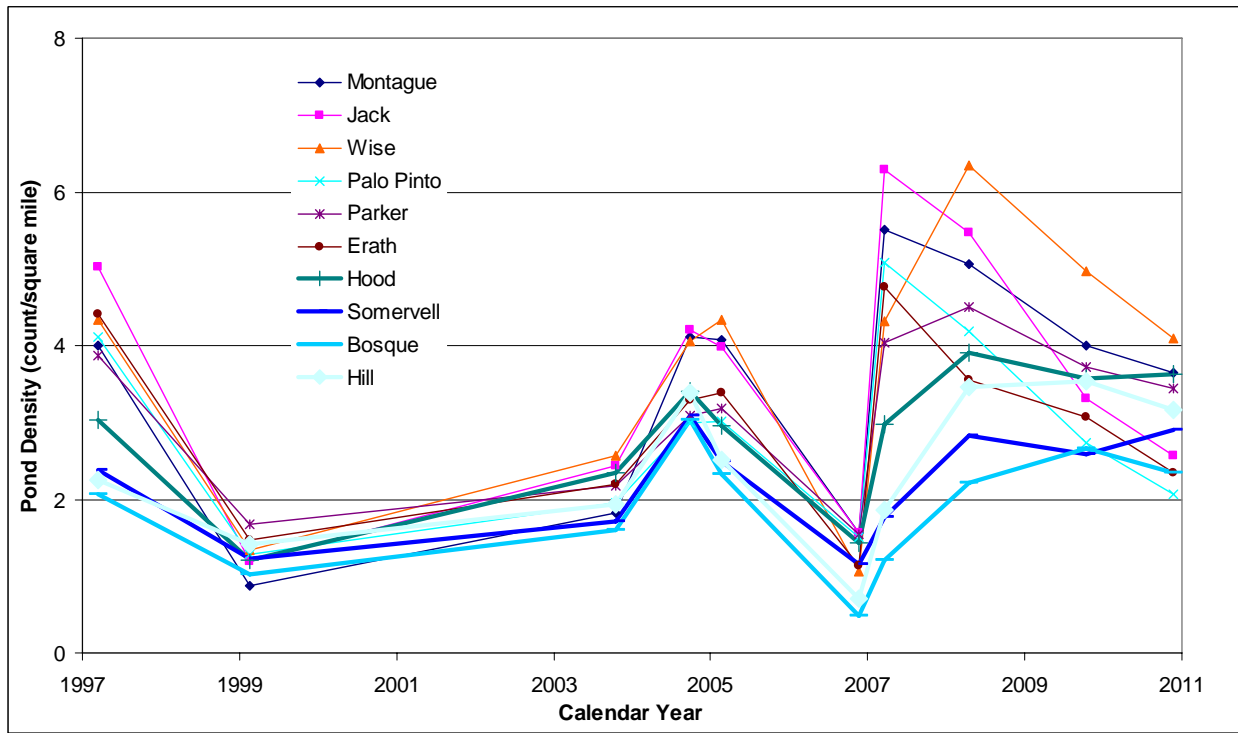
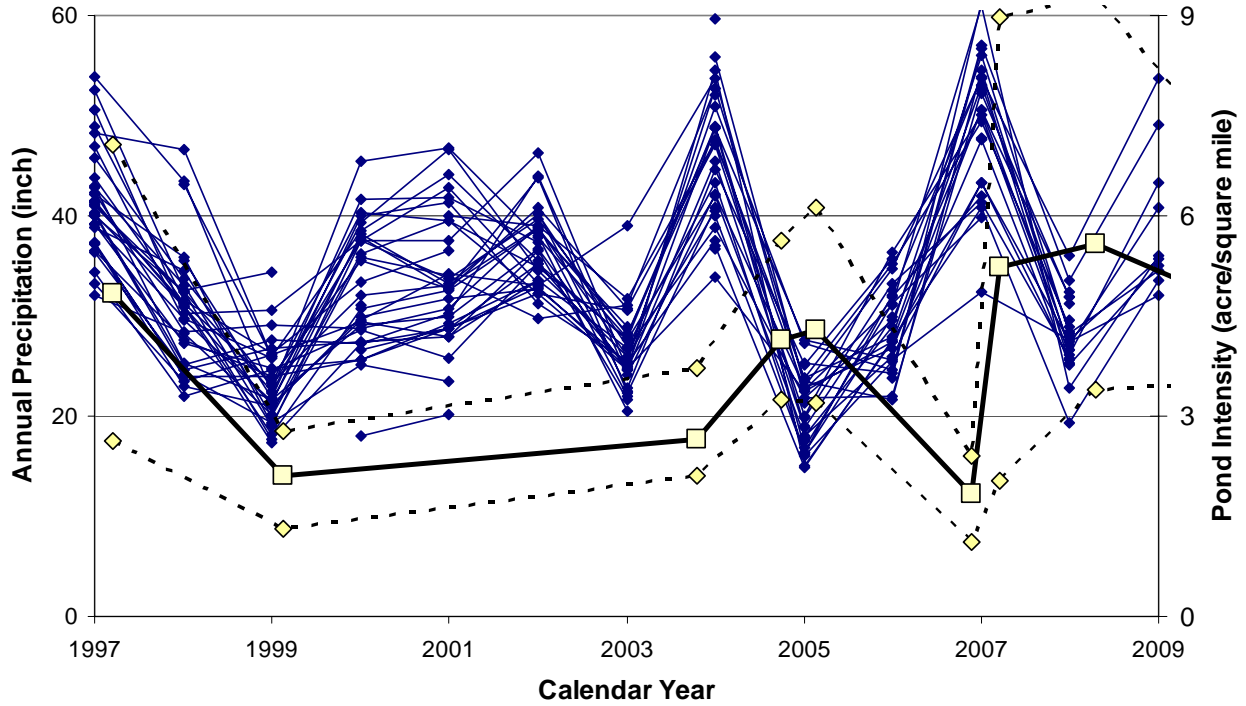


Figure 17. Pond density (pond count per square mile) for selected times.



Note: solid lines: 43 weather stations covering the 10-county area of interest; open symbols: pond intensity.

Figure 18. Comparison of annual precipitation (and minimum, average, and maximum pond intensity).

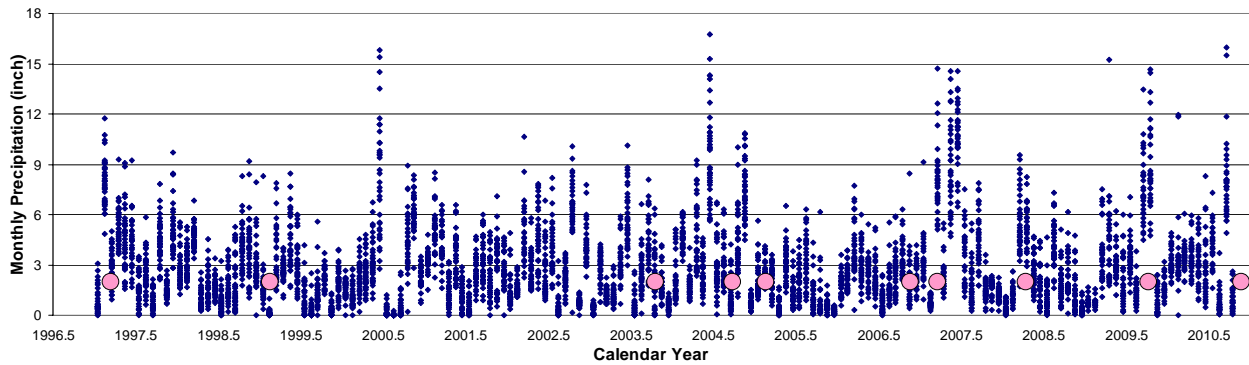


Figure 19. Monthly precipitation (small dots) and time location of orthoimagery results (large circles).

## 5 Groundwater

Generally groundwater belongs to the landowner under the rule of capture. Groundwater is managed by pseudo-governmental entities called Groundwater Conservation Districts (GCDs), often corresponding to a single county. If the property is not part of any GCD, the rule of capture fully applies, and the landowner is free to first pump and then sell as much water as he/she wishes. Within the confines of a GCD, some rules apply. Most of the area of interest is part of a GCD, except for Palo Pinto and Jack Counties (Figure 20). Not coincidentally these two counties also have a limited amount of good-quality groundwater.

A literature survey of aquifers existing in the footprint of the study area was performed and other information on them was gathered as well. The major aquifer in the area is the Trinity aquifer (Figure 1), but several counties also include smaller aquifers in Paleozoic formations in Palo Pinto and Jack Counties, as well as bits of Montague, Wise, Parker, and Erath. These smaller aquifers contain significant amounts of brackish water; in this analysis, both fresh-and brackish-water aquifers are of interest.

Overall, groundwater resources in the study area can be categorized into two groups: Trinity aquifer resources and all others (Figure 21). The Trinity aquifer outcrop is elongated north-south and covers, from north to south, most of or a sizable fraction of Montague, Wise, Parker, Hood, and Erath Counties. East of these counties the Trinity aquifer is confined (from north to south, Cooke, Denton, Tarrant, Johnson, Hill, and Bosque Counties), and water is more plentiful. Farther east, the Woodbine aquifer (a minor aquifer) crops out in the east section of Cooke, Denton, Tarrant, and Johnson Counties. No TWDB-defined major or minor aquifer lies west of the Trinity aquifer, only relatively limited sand lenses. Jack and Palo Pinto Counties are entirely outside the Trinity footprint. Montague, Wise, Parker, Hood, and Erath Counties are on the Trinity outcrop, which is thin in much of or in the west half of the counties. The Trinity aquifer, whose sediments are of Cretaceous age, is contained in the first formation deposited on top of older Paleozoic formations. They dip toward the southeast toward the Gulf, whereas Paleozoic formations dip toward the center of the basin, currently located in the Midland area (Figure 22). The Trinity aquifer outcrop is particularly thin in parts of Montague and Wise Counties, where wells are drilled through it to reach underlying Paleozoic aquifers. Figure 23 depicts the distribution of PWS wells (not domestic wells). Apparently when available, the Trinity aquifer is used heavily (although the Dallas-Fort Worth metroplex uses mostly surface water for municipal purposes). Some Paleozoic aquifers are also a good source of fresh water, with rates as high as 150 gpm in Montague County.

The TCEQ PWS database provides mostly flow-rate information about municipal wells and other regulated entities; water-quality information is not as complete. The TWDB Driller database ([http://www.twdb.state.tx.us/GwRD/waterwell/well\\_info.asp](http://www.twdb.state.tx.us/GwRD/waterwell/well_info.asp)) contains data about domestic wells and provides more information on both well and aquifer characteristics. Note that any water well drilled in Texas needs to be reported to TCEQ. Some drillers do so electronically, and their applications are available through the TWDB website. Others file their applications in a paper format, and extracting the information would require much more time to sift through the files. Data to be extracted are yield ( $Q$  or flow rate) sustained by wells and drawdown ( $s$ ). Most well files provide that information; however, most wells are domestic and do not pump as much water as the well can provide. This information is available through computation of specific

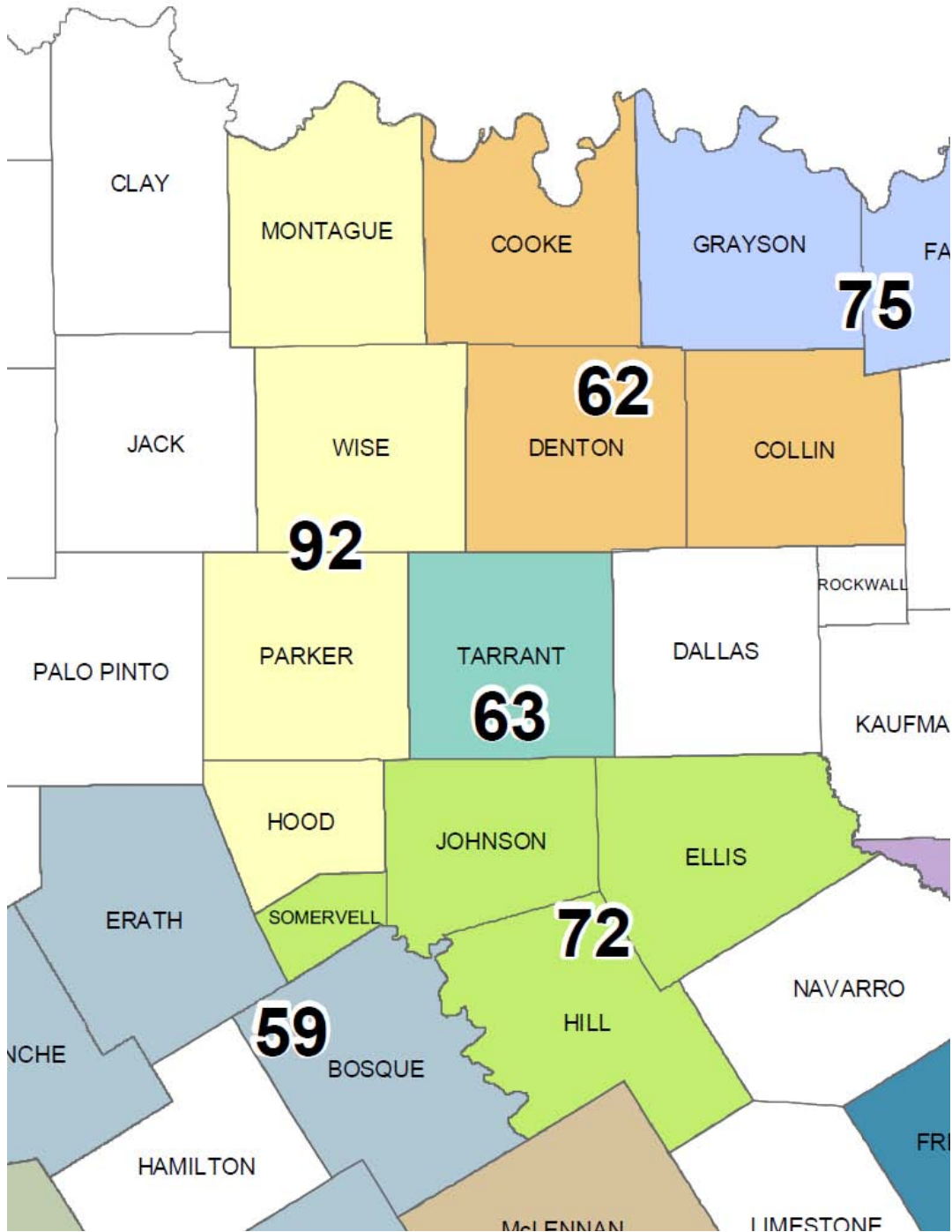
discharge ( $Q/s$  or flow rate over drawdown), although it is harder to obtain because many drillers do not report drawdowns.

Clearly a better understanding of Paleozoic aquifers is needed, particularly their recharge processes and flow systems. TWDB has understandably been focusing on much larger, more heavily used aquifers across the state, although these Paleozoic aquifers are locally important. Typically in a period of drought, water users rely more on groundwater than on surface water, but how resilient to drought is groundwater if most of the flow system has short pathways and quickly discharges into streams and rivers? Further work is needed to compare water level as a function of time and precipitation. Paleozoic aquifers are typically small, with a footprint of less than a county in area. Limited information about one of them is provided next.

Avakian and Wermund (1994) studied the Mineral Wells aquifer in Palo Pinto County. The Mineral Wells Formation generally consists of thin sandstones and limestones embedded within mostly shaly sediments. Near the city of Mineral Wells in Palo Pinto County, where the formation is 700 ft thick (Avakian and Wermund, 1994, p. 21), seven nonshale units can be counted with the following thicknesses: 25 ft (Hog Mountain Sandstone); 10 ft (unknown); <50 ft (Lake Pinto Sandstone); and 5 ft, 12 ft, and <50 ft (Turkey Creek Sandstone), from oldest to youngest (note that names vary in different publications). Avakian and Wermund (1994) found that the Hog Mountain Sandstone (I<sub>Phm</sub> in Brown et al., 1972) can be followed ~5 or 6 miles east of the city of Mineral Wells. The Turkey Creek Sandstone (I<sub>Ptc</sub> in Brown et al., 1972) can be followed 25+ miles until it disappears under the Cretaceous; it is probably hydraulically connected to the sands of the Twin Mountains Formation and possibly recharged through them. TDSs are close to the 1,000 mg/L threshold and frequently above it. Formations seem unconnected, and water levels in wells seem to reflect local precipitation (Avakian and Wermund, 1994, p. 57). Many low-yield wells tap (or at least used to tap) these formations (Fisher et al., 1996, p. 7). Water drillers go down 500 ft to reach these formations, and they report that traces of oil or gas are currently encountered below ~250 ft (p. 7) [see Parker County recent incident]. Fisher et al. (1996, p. 17) also noted that wells are constructed deep to increase well storage and ensure steady water supply. Fisher et al. (1996) performed well testing and extensive sampling.

Table 3. Characteristics of small aquifers outside Trinity aquifer footprint.

<b>Percentile</b>	<b>Bicarb (mg/l)</b>	<b>Sulfate (mg/l)</b>	<b>Chloride (mg/l)</b>	<b>pH</b>	<b>TDS</b>	<b>Alkalinity</b>	<b>Specific Capacity (gpm/ft drawdown)</b>	<b>Transmissivity (ft<sup>2</sup>/day)</b>	<b>Well Depth (ft)</b>
95th	749	593	1,700	8.8	3,796	638	5.01	964.2	499
70th	518	151	235	8.3	1170	434	1.70	327.6	245
50th	425	78	120	8.1	758	357	1.00	192.6	190
30th	353	45	52	7.7	545	296	0.50	96.3	113
5th	213	15	14	7.2	334	182	0.10	19.3	29
Max	2,026	4530	9,572	11.5	14,189	1,660	40.1	7,722.5	1,010



Source: TWDB website

Note: 75: Red River GCD; 62: North Texas GCD; 92: Upper Trinity GCD; 63: Northern Trinity GCD; 72: Prairielands GCD; 59: Middle Trinity GCD.

Figure 20. Map of groundwater conservation districts.

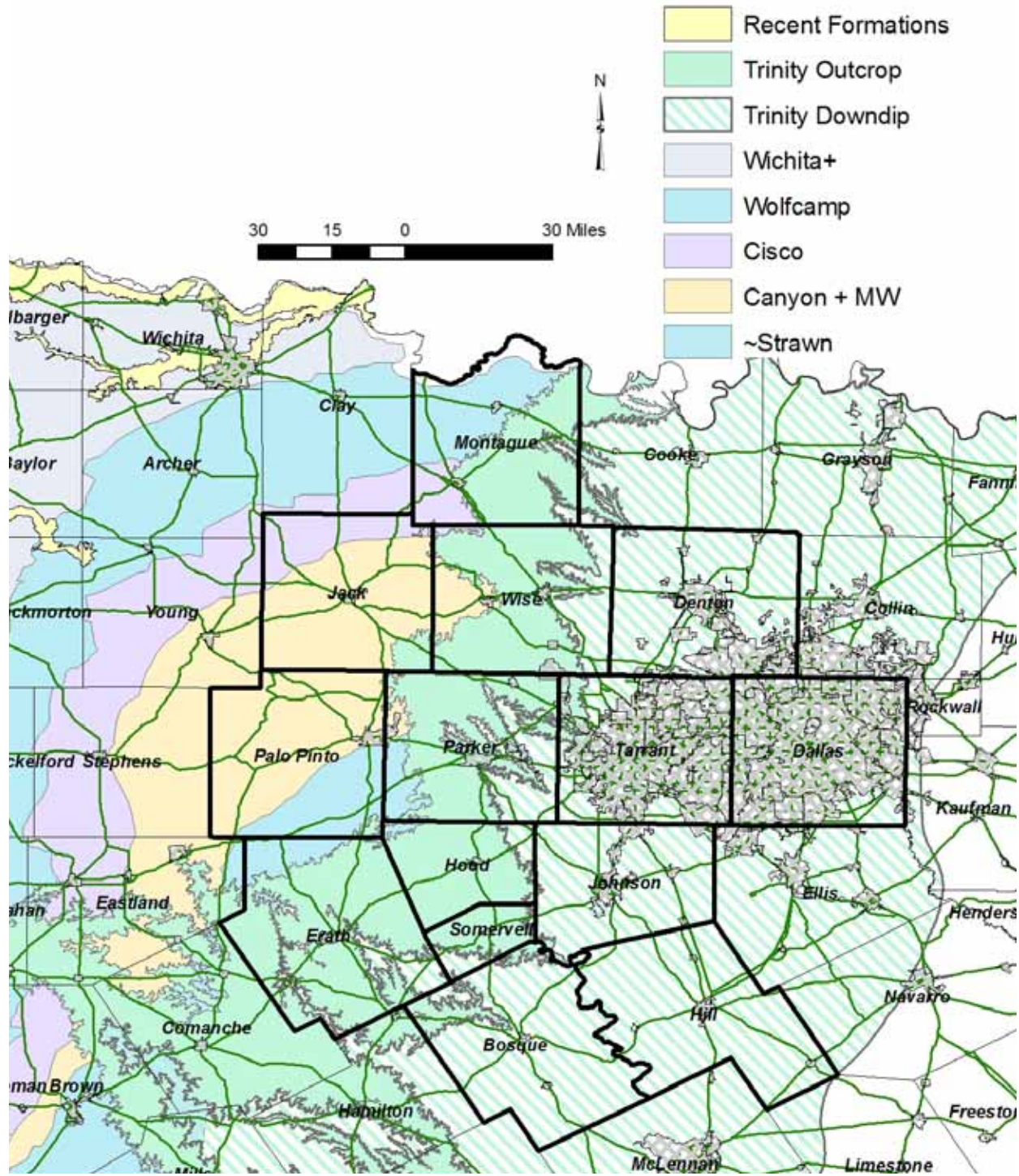
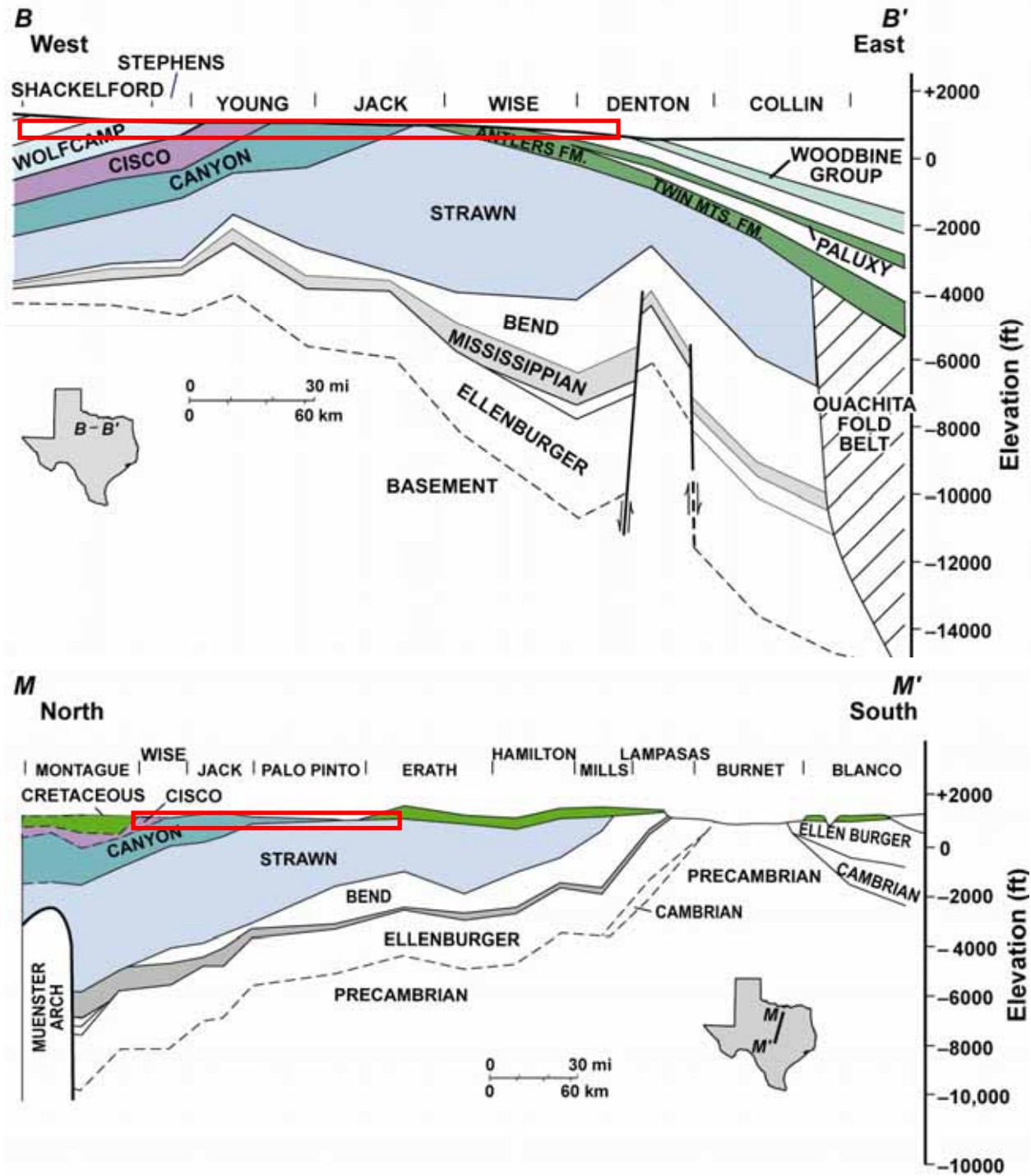
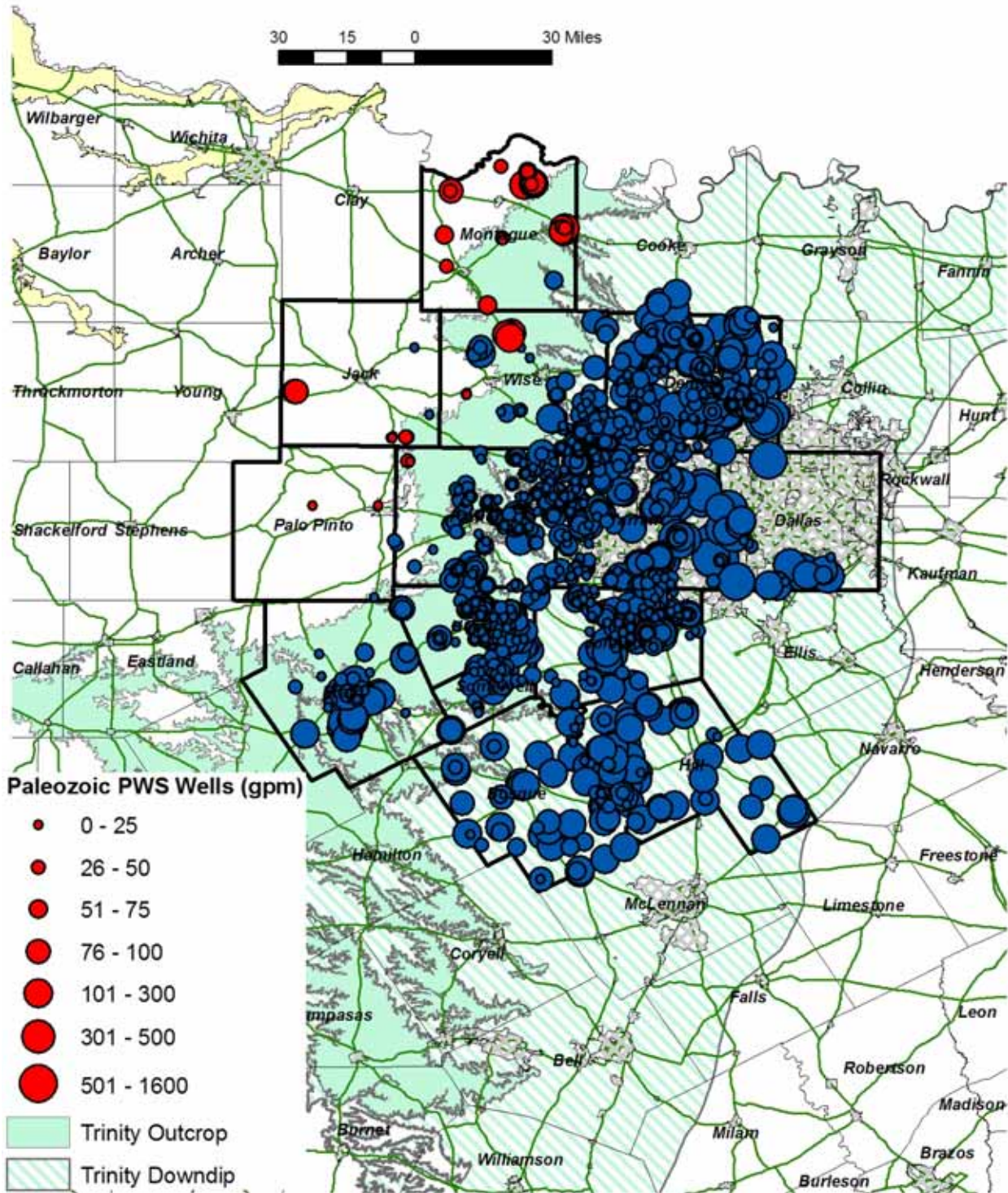


Figure 21. Tentative map of Paleozoic formations in north-central Texas.



Note: Barnett Shale of Mississippian age included in gray-colored horizon.

Figure 22. West-east and north-south geologic cross sections of study area.



Note: highest Paleozoic well rate is 150 gpm.

Figure 23. Public water-supply wells tapping Paleozoic aquifers (red) and all others (blue), mostly Trinity but also Woodbine and alluvium.

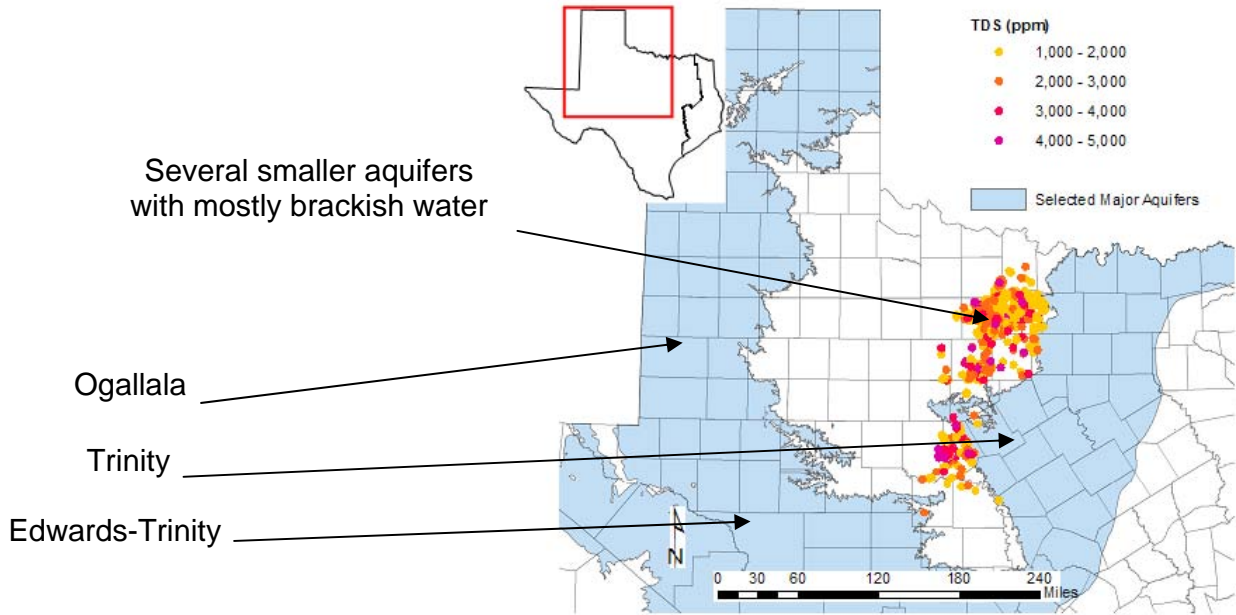


Figure 24. Brackish water is common in Paleozoic aquifers.

## 6 Nonconventional Water Sources

### 6.1 What are they?

This task consists of an inventory of all nonconventional water sources, such as desalination plants, mines with dewatering operations, produced water from conventional oil and gas operations, and, most likely with the highest potential, WWTP outfalls.

### 6.2 WWTP Data Source

This project was initiated to research available data on potential sources of water of sufficient quantity and quality in the large Barnett Shale natural gas field in north-central Texas west of the Dallas-Fort Worth metropolitan area. The study focused on identifying available water sources in a 10-county area, including Bosque, Erath, Hood, Hill, Jack, Montague, Palo Pinto, Parker, Somervell, and Wise Counties. Examinations were later expanded to Tarrant and Johnson Counties and parts of Denton County (west of IH 35) as well (Figure 4).

TCEQ maintains an electronic Central Registry database of information on all companies and facilities regulated by the various rules and programs of the agency. The database (<http://www12.tceq.state.tx.us/crpub/index.cfm?fuseaction=regent.RNSearch>), accessible through the TCEQ website, was initially queried to identify all large industrial or municipal operations in the area by examining data for various TCEQ program areas, including air, water-rights, stormwater, and wastewater permits.

Because the intent of the project was to identify sources of water that were not committed to other uses, we decided to examine only wastewater dischargers in greater detail. A methodical search was conducted for every active wastewater discharge permit by county to obtain facility identification, ownership, and other registration information. Research was also conducted on the TCEQ Central Records to obtain hardcopies of critical portions of permit documents. Specific information regarding the regulated entity, contact information, description of type of source and discharges at the facilities, effluent flow and parameter discharge limitations, sampling and reporting requirements, and geographic coordinates are recorded in the permits. Information on ~143 individual permits was retrieved.

To ensure completeness, a listing of all cities and towns within the Barnett Shale study area was obtained from Texas Home Locators (<http://texas.hometownlocator.com/index.cfm>). A comparison was made to determine whether the incorporated areas were included in the wastewater discharger data obtained from TCEQ and EPA. Most incorporated cities appeared to have wastewater treatment systems included in the datasets, whereas others may have been served by county or regional systems or depended to a large extent on onsite sewage treatment. The greatest gaps appeared to be in Denton, Tarrant, and Parker Counties, and additional investigation may be necessary to obtain more data on the wastewater systems in these areas. However, most missing treatment facilities are associated with communities that are small and may not represent significant potential water sources.

Most wastewater dischargers permitted by TCEQ (<http://www.tceq.state.tx.us/gis/sites.html>) under the Texas Pollutant Discharge Elimination System (TPDES) must file quarterly effluent monitoring reports with EPA into the Permit Compliance System (PCS) and the Integrated Compliance Information System—National Pollutant Discharge Elimination System (ICIS-

NPDES), which is gradually replacing PCS. This reporting data may be accessed through EPA’s Enforcement and Compliance History On-Line (ECHO) system (<http://www.epa-echo.gov/cgi-bin/effluentsquery.cgi>). From this site, data were obtained regarding average and maximum flow rates (MGD) through the treatment plant, as well as average concentrations of dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, sulfate, and chlorine (in milligrams per liter, mg/L). Maximum and minimum pH and chlorine levels were also retrieved. Available information was analyzed for the 3-yr period from October 2006 through September 2009 and recorded on a comprehensive spreadsheet for each permitted discharge by county. The number of facilities examined in each county is as follows:

- Bosque County—11
- Erath County—3
- Hill County—14
- Hood County—15
- Jack County—2
- Montague County—4
- Palo Pinto County—11
- Parker County—11
- Somervell County—5
- Wise County—14
- Denton County—16
- Johnson County—17
- Tarrant County—20

In most counties, several TCEQ permits were identified for wastewater dischargers for which no corresponding EPA data were available. In some cases, it was determined that the permits had been terminated or were inactive.

Geographic coordinates were obtained from TCEQ permit files and from a TCEQ database of wastewater outfalls. These data were compared to determine similarities and significant differences. Whereas most of the coordinates for the same identified facilities were similar, permit files seemed to be the most accurate and up to date. During examination of the two coordinate datasets, it was observed that a small number of dischargers were not included in either database and/or had no current effluent reporting information. Additional effort was made to obtain information regarding these dischargers. But, in most cases, the wastewater permits had been either terminated or were inactive. Most also appeared to be sources that would not be expected to generate significant flows, such as small commercial sites, private resorts or camps, schools, or community systems.

## 6.3 Results

### 6.3.1 Wastewater Flow

Assuming that ~3.5 million gal of fresh water must be used for a single fracking operation, it is useful to further categorized wastewater dischargers in each county according to their daily volume of effluent to determine the sources with the greatest potential to provide sufficient water to meet that demand. If a wastewater discharger produces >0.1 MGD, sufficient water could be obtained within ~1 month from that single source to support one hydraulic fracturing completion of a horizontal shale gas well. Smaller dischargers could also be used if more time were allocated to accumulating water or if water were obtained from multiple sources. Figure 26 shows wastewater dischargers in each county in the study area with a distribution of the approximate daily volume of effluent that may be available for acquisition and use. Figure 26a shows that flow rates are dominated by the Fort Worth WWTP in Tarrant County, followed by many large and medium-sized facilities in Denton County, whose grand total is ~52 MGD. Because these

two counties are different in their plant count or volume from those of the remaining 11 counties, Figure 26b displays outfall flow rate for all facilities but the Fort Worth WWTP and facilities with a capacity of >1 MGD in Denton County; they are included in Figure 26c, which shows these >1-MGD facilities. Most counties have a larger facility (county seat) and several other smaller dischargers.

The largest wastewater discharger in the study area by far is the Comanche Peak Steam Electric Station (SES) (Somervell County), with a reported effluent flow of 2,844 MGD. Other large dischargers include Decordova SES (Hood County) with 441 MGD, Randle W. Miller SES (Palo Pinto County) with 119 MGD, Handley SES (Tarrant County) with 219 MGD, and the City of Fort Worth Village Creek WWTP (Tarrant County) with 116 MGD. The four SES facilities' outfalls are once-through cooling outfalls and cannot be considered available. Some of the same SES facilities do have a regular wastewater outfall, whose rates are more on par with those of other facilities.

Other dischargers that reported >1.0 MGD include City of Lewisville (Denton County), Stewart Creek WWTP (Denton County), City of Stephenville (Erath County), Hillsboro WWTP (Hill County), Southeast Plan WWTP (Hood County), City of Cleburne (Johnson County), Randle W. Miller WWTP #2 (Palo Pinto County), City of Weatherford (Parker County), City of Grapevine (Tarrant County), and Hanson Aggregates, Inc. (Wise County). Large cities and power plants dominate these larger sources. A relatively wide gap exists in most counties between larger dischargers (>0.1 MGD) and much smaller dischargers (<0.05 MGD), reflecting the differences in wastewater plants that serve concentrated population centers and those that serve small communities and dispersed commercial operations (Figure 27a–c). A large percentage of wastewater dischargers in the study area have reported average effluent flows less than 0.025 MGD. Unless several of these small dischargers were in the immediate area of a proposed gas well and could be combined, it may be difficult to utilize them as practical sources of fracing water.

Combined, nonpower sources total 224 MGD, half of which comes from the Fort Worth Village Creek WWTP (Tarrant County). The remaining 108 MGD, or 121,000 AF/yr, is the equivalent of two to three times the anticipated maximum annual consumption in the Barnett play (Nicot et al., 2011).

### **6.3.2 Wastewater Quality**

Water quality from wastewater-treatment facilities is generally good and is closely regulated by TCEQ to prevent violations of surface-water-quality standards in rivers, streams, and lakes. Specific effluent standards in the permits of individual plants can vary, depending on the type of wastewater being treated (municipal, commercial, industrial), the designated use of the receiving water body, and the current degree of water-quality impairment. However, most effluent limitations for the parameters evaluated in this report include

- Biochemical oxygen demand (5-day) (BOD5)—30-day average of no more than 10 mg/L and a daily maximum of no more than 45 mg/L;
- Total suspended solids (TSS)—30-day average of no more than 15 mg/L and a daily maximum of no more than 40 mg/L;
- Residual chlorine—minimum of at least 2.0 mg/L and a maximum of 4.0 mg/L at all times;
- pH—minimum of 6.0 (standard units) and a maximum of 9.0 at all times;

- Dissolved oxygen (DO)—minimum of between 2.0 and 5.0 mg/L, depending on aquatic life use of the receiving stream; and
- Effluent limits on certain nutrients and other compounds, such as nitrogen, phosphate, sulfate, and chlorine, which are also placed on some permits.

With a few exceptions, the actual average and maximum values for these parameters reported by dischargers are generally well within established standards, with fluctuations occurring only during rare instances of noncompliance. The data provided in this report were obtained from monthly self-monitoring reports to the EPA recorded on the automated ECHO system. BOD5 and TSS values are averages of all available data from the reported 30-day averages over the 3-yr period from October 2006 through September 2009. Chlorine residual and pH maximums and minimums and minimum DO values are also averages over that same period of time. Overall, 25th and 75th percentiles are: BOD5: 3–7.5 mg/L; TSS: 3.5–14.0 mg/L; chlorine: 1–3.5 mg/L; pH: 6.9–7.9; DO: 5–7 mg/L. There is little information on the TDS, but, by law, it has to be less than 1,000 mg/L. The high O<sub>2</sub> concentration is an impediment for use in fracing operations, but one that can be overcome easily.

# Wastewater Dischargers - Barnett Shale Water Study Area

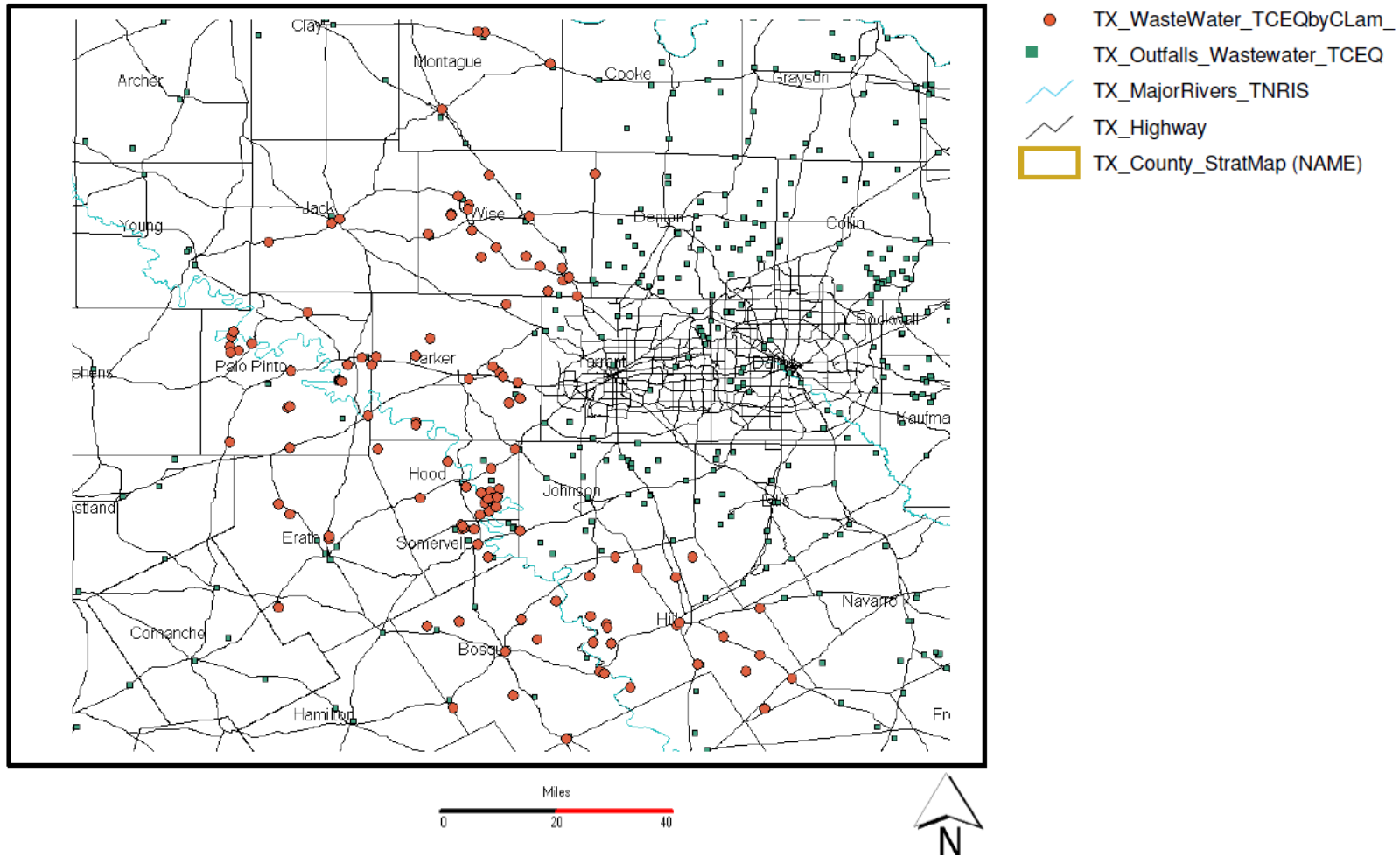
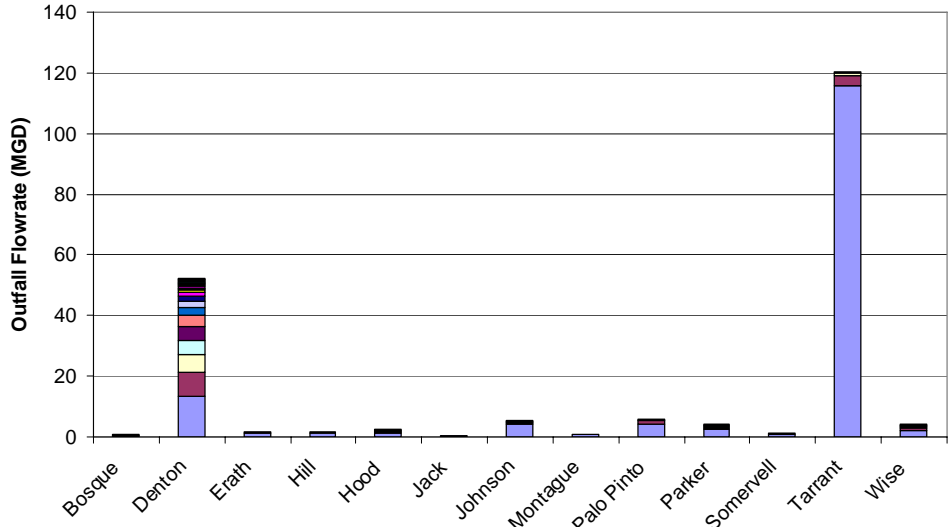
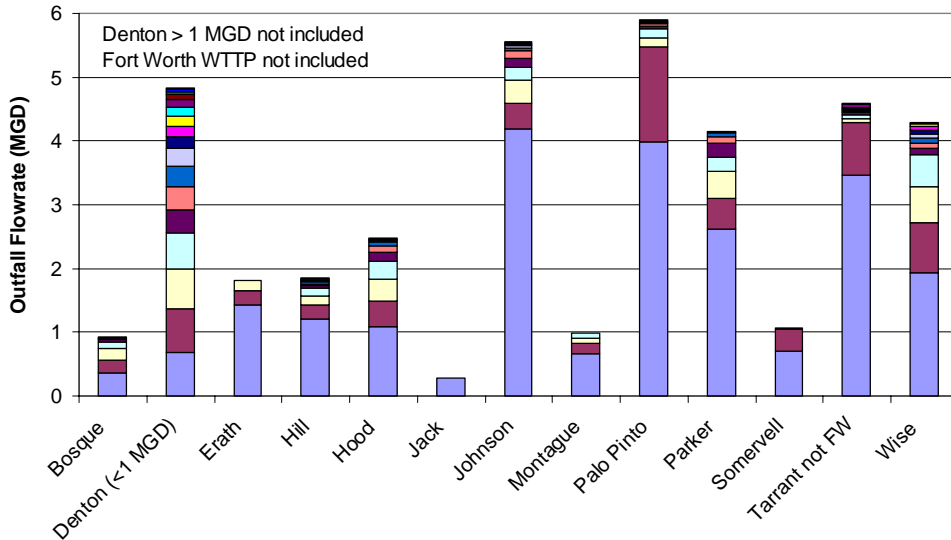


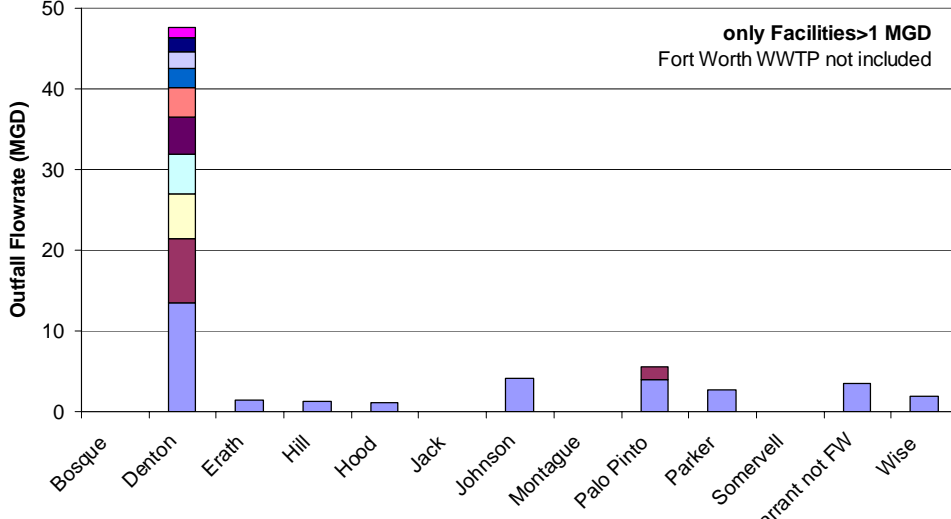
Figure 25. Map showing municipal and industrial wastewater facilities listed in the TCEQ Wastewater Outfall database (green dots) vs. those facilities for which we have chemical and flow-rate information (red dots—most masking green dots).



(a)



(b)



(c)

Note: colors represent different facilities in each county  
Figure 26. Distribution of wastewater facilities sorted by county according to their discharge rates.

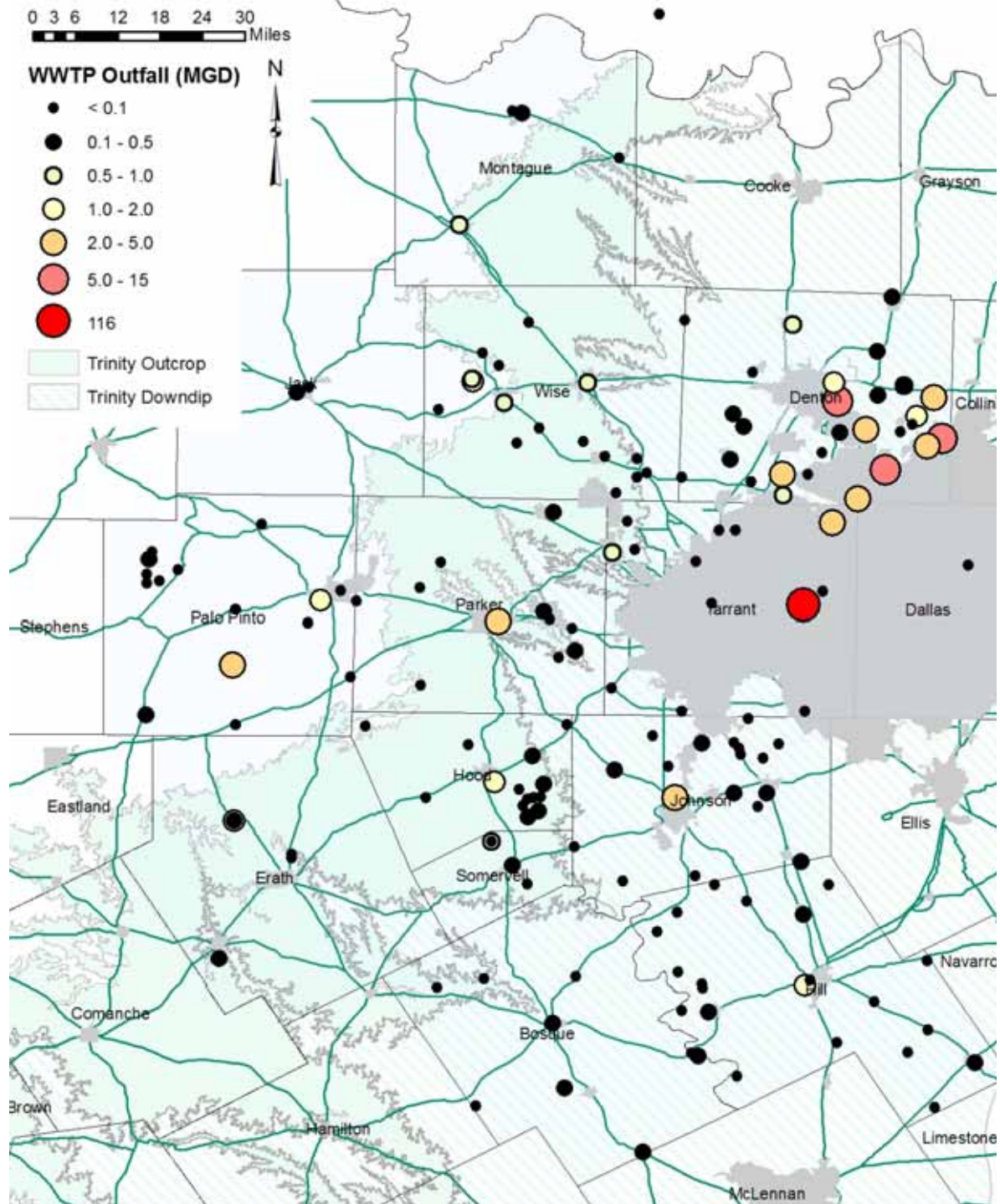
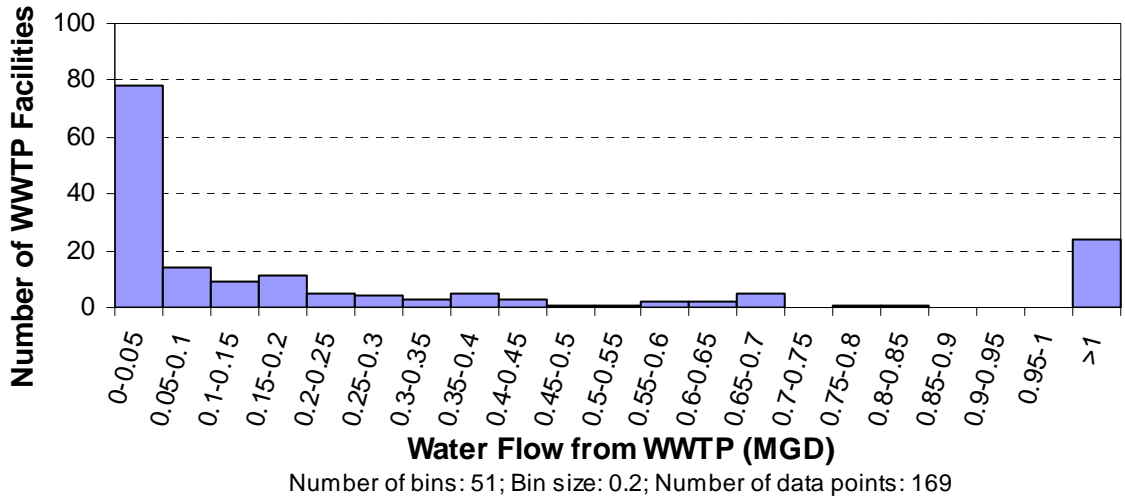
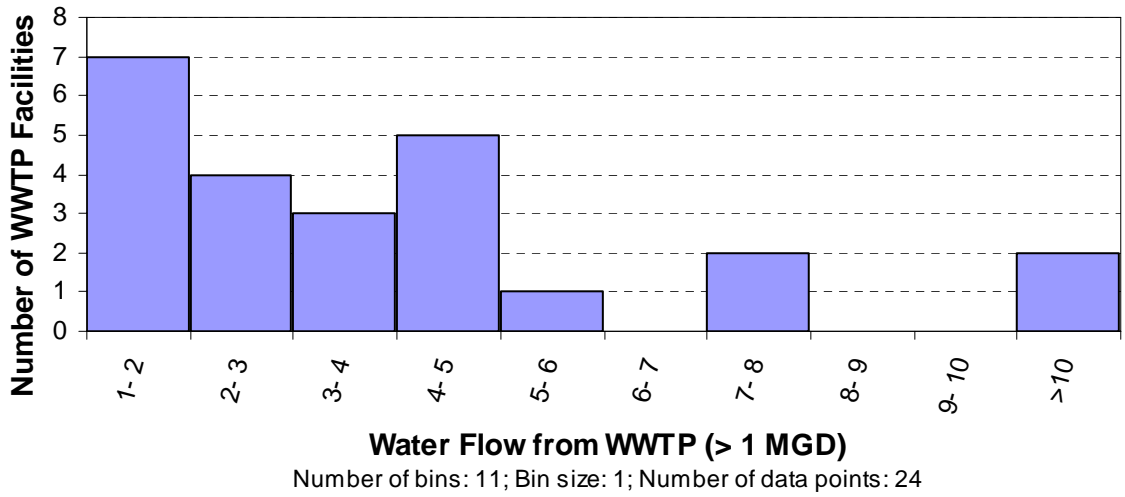


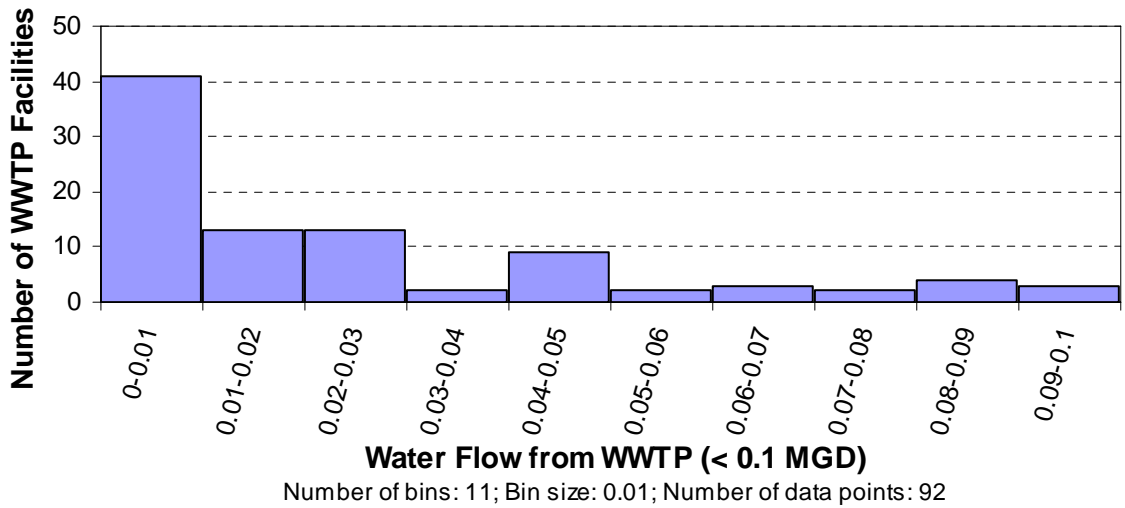
Figure 27. All dischargers within the study area separated into groups on the basis of various flow rates (<0.05 MGD; 0.05–0.1 MGD; 0.1–1.0 MGD; >1.0 MGD).



(a)



(b)



(c)

Figure 28. Flow-rate distribution of WWTP: (a) all plants, (b) plants with average flow >1 MGD, and (c) plants with average flow <0.1 MGD.

## **7 Summary and Conclusions**

This preliminary report documents the current but fast-changing practices of the gas industry to access water in the Barnett Shale footprint and analyzes potential sources of water alternative to large surface water bodies and the local major aquifer (the Trinity Aquifer). They include treated water from wastewater treatment plants, groundwater from smallish possibly slightly brackish aquifers, and farmer ponds and other non-state surface water bodies. A first-order estimate of the amount of water available consists of more than 100,000 AF at any given time in non-State-surface-water bodies, more than 25,000 AF available per year from groundwater, and more than 100,000 AF available per year from wastewater outfalls. Those figures compare well with the maximum projected annual water use of 40,000 AF. However, spatial match between water sources and points of use remain an issue and is the subject of an analysis being currently conducted.

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## 9 Appendix A: Characteristics of WWTP Outfalls

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
<b>Bosque</b>										
WQ0010043001	CITY OF CLIFTON WWTF	0.357	4.24	3.24	0.99	2.50	6.86	7.07	5.15	
WQ0010113001	CITY OF MERIDIAN	0.201	3.56	6.71	1.29	3.25	7.23	7.80	6.36	
WQ0004167000	BOSQUE COUNTY POWER PLANT	0.183			0.03	0.04	6.91	8.07		
WQ0010307001	CITY OF VALLEY MILLS WWTP	0.112	3.91	6.26	1.13	1.91	7.45	7.79	5.19	
WQ0012217001	CITY OF MORGAN	0.027	19.71	54.23			8.16	8.77	6.16	
WQ0014169001	CITY OF CRANFILLS GAP WWTP	0.022	4.77	13.16	1.42	2.95	7.32	7.67	5.73	
WQ0011565001	CITY OF IREDELL WWTP	0.013	8.03	8.03	1.62	2.47	7.44	7.77	5.55	
WQ0013536001	CAMP JOHN MARC WWTF	0.011	5.28	11.53	1.19	1.98	7.72	8.30		
WQ0013436001	WALNUT SPRINGS CITY OF WWTP	0.001	23.06	68.15			8.43	9.00	5.99	
WQ0013982001	KOPPERL ISD WWTP	0.001	6.89	11.53	1.09	2.53	7.35	7.93	4.33	
WQ0012087001	WHITNEY POWERHOUSE WWTP	0.000	5.70	19.23	1.38	3.61	7.15	8.03	6.68	
<b>Denton</b>										
WQ0010027003	PECAN CREEK WATER RECLAMATION PLANT	13.457	2.21	3.05			6.98	7.35	6.60	0.23
WQ0010662001	CITY OF LEWISVILLE	7.986	4.58	1.57	1.16		6.45	7.10	7.31	
WQ0010172003	STEWART CREEK WEST PLANT	5.529	2.94	1.92			6.77	7.35	6.63	2.44
WQ0013457001	DENTON CREEK REGIONAL WWTP	4.976	1.95	3.54			6.81	7.39	6.84	0.79
WQ0011321001	TOWN OF FLOWER MOUND WWTF	4.541	5.07	3.09			6.86	7.48	7.45	0.84
WQ0010698001	UTRWD LAKEVIEW REGIONAL WATER RECLAMATION PLANT	3.739	2.31	1.55			6.76	7.26	5.48	
WQ0011570001	STEWART CREEK WWTP	2.290	2.46	2.72			6.93	7.26	6.86	1.34
WQ0014245001	PANTHER CREEK WWTP	2.062	3.07	0.82			6.71	7.34	6.29	0.15
WQ0011600001	TOWN OF LITTLE ELM	1.731	3.19	2.44			7.09	7.49	7.48	0.38

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0004336000	DENTON RECYCLE CENTER	1.291					7.03	8.21		
WQ0010271001	CITY OF SANGER	0.683	2.31	4.69	1.31	2.13	7.45	7.68	8.81	1.26
WQ0014372001	SANGER WWTP	0.683	2.31	4.69	1.31	2.13	7.45	7.68	8.81	1.26
WQ0011593001	TROPHY CLUB MUD	0.624	3.64	3.09			7.44	7.83	6.50	0.19
WQ0010698002	UTRWD RIVERBEND REGIONAL WATER RECLAMATION PLANT	0.569	2.16	1.77			6.94	7.70	6.53	0.39
WQ0010361001	CITY OF PILOT POINT	0.366	2.27	4.45	1.12	3.51	7.00	7.66	6.94	0.42
WQ0003840000	SEWELL CLAY MINE	0.365		6.00			6.77	6.77		
WQ0010698002	UTRWD RIVERBEND REGIONAL WATER RECLAMATION PLANT	0.305	2.16	1.79			6.94	7.71	6.54	0.40
WQ0011312001	CITY OF JUSTIN	0.296	7.05	15.33	1.01	2.69	7.24	7.59	5.97	2.32
WQ0010027004	ROBSON RANCH TREATMENT PLANT	0.179	7.47	1.06			8.04	8.04	5.92	0.41
WQ0013647001	AUBREY WWTP	0.159	2.44	4.59	1.26	3.39	7.37	7.86	4.61	0.79
WQ0010064001	CITY OF AUBREY	0.159	2.44	4.59	1.26	3.39	7.37	7.86	4.61	0.79
WQ0014323001	UTRWD PENINSILA REGIONAL WATER RECLAMATION PLANT	0.152	2.06	1.14			6.77	7.47	5.80	0.21
WQ0011287003	PONDER WWTP	0.103	5.44	8.57	1.14	3.62	7.38	7.80	7.66	0.63
WQ0010729001	CITY OF KRUM	0.087	26.39	28.86			7.94	7.94		
WQ0013434001	CITY OF HACKBERRY	0.043	11.94	14.69	0.70	2.98	7.07	7.12	5.45	15.70
WQ0014186001	SHALE CREEK WWTP	0.033	4.29	11.31	1.36	3.42	7.28	7.73	7.47	1.47
WQ0013732001	ROCKY POINT MHP FLOWER MOUND	0.015	5.46	8.42	1.17	3.65	6.75	7.22	4.74	4.50
WQ0014139001	NORTHLAKE VILLAGE MHP	0.007	2.67	3.09	1.36	3.26	6.92	6.92	7.24	
WQ0013785001	HIDDEN COVE PARK WWTP	0.003	3.17	7.34	1.06	2.92	7.86	8.03	6.55	
WQ0012605002	BRIARWOOD RETREAT	0.002	4.53	8.02	1.03	3.20	7.99	8.28	7.75	
<b>Denton -West</b>										
WQ0010662001	CITY OF LEWISVILLE	7.986	4.58	1.57	1.16		6.45	7.10	7.31	
WQ0013457001	DENTON CREEK REGIONAL WWTP	4.976	1.95	3.54			6.81	7.39	6.84	0.79

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0011321001	TOWN OF FLOWER MOUND WWTF	4.541	5.07	3.09			6.86	7.48	7.45	0.84
WQ0011570001	STEWART CREEK WWTP	2.290	2.46	2.72			6.93	7.26	6.86	1.34
WQ0010271001	CITY OF SANGER	0.683	2.31	4.69	1.31	2.13	7.45	7.68	8.81	1.26
WQ0011593001	TROPHY CLUB MUD	0.624	3.64	3.09			7.44	7.83	6.50	0.19
WQ0003840000	SEWELL CLAY MINE	0.365		6.00			6.77	6.77		
WQ0011312001	CITY OF JUSTIN	0.296	7.05	15.33	1.01	2.69	7.24	7.59	5.97	2.32
WQ0010027004	ROBSON RANCH TREATMENT PLANT	0.179	7.47	1.06			8.04	8.04	5.92	0.41
WQ0010064001	CITY OF AUBREY	0.159	2.44	4.59	1.26	3.39	7.37	7.86	4.61	0.79
WQ0011287003	PONDER WWTP	0.103	5.44	8.57	1.14	3.62	7.38	7.80	7.66	0.63
WQ0010729001	CITY OF KRUM	0.087	26.39	28.86			7.94	7.94		
WQ0014186001	SHALE CREEK WWTP	0.033	4.29	11.31	1.36	3.42	7.28	7.73	7.47	1.47
WQ0013732001	ROCKY POINT MHP FLOWER MOUND	0.015	5.46	8.42	1.17	3.65	6.75	7.22	4.74	4.50
WQ0014139001	NORTHLAKE VILLAGE MHP	0.007	2.67	3.09	1.36	3.26	6.92	6.92	7.24	
WQ0012605002	BRIARWOOD RETREAT	0.002	4.53	8.02	1.03	3.20	7.99	8.28	7.75	
<b>Erath</b>										
WQ0010290001	CITY OF STEPHENVILLE	1.432								
WQ0010405001	DUBLIN WWTF	0.210	18.51	34.85			8.12	8.99	7.61	3.65
WQ0010290001	CITY OF STEPHENVILLE	0.178								
WQ0004314000	MILK TRANSPORT SERVICES									
WQ0003074000	SCHREIBER FOODS									
<b>Hill</b>										
WQ0010630001	HILLSBORO WWTP	1.215	2.35	2.21		0.07	6.48	7.16	6.30	0.29
WQ0011408002	POLK STREET WWTP	0.212	10.95	18.03			8.50	9.21	4.85	0.86
WQ0010534001	CITY OF HUBBARD WWTP	0.136	3.76	6.23	0.98	2.75	7.30	8.09	5.86	0.54
WQ0010423001	CITY OF ITASCA WWTP	0.134	5.36	14.60	1.15	3.26	7.34	7.72	6.94	

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0013786002	WHITE BLUFF WWTP	0.041	7.74	14.33	1.32	3.03	7.26	7.62	5.36	
WQ0010820001	CITY OF BLUM WWTP	0.023	4.57	7.36	1.25	3.05	7.38	7.73	4.34	
WQ0011544001	CITY OF ABBOTT WWTP	0.022	18.50	39.95			8.14	8.71	5.31	
WQ0010514001	CITY OF MALONE WWTF	0.019	5.93	6.93	1.31	2.35	7.32	7.42	4.16	
WQ0011542001	CITY OF BYNUM WWTP	0.014	7.42	10.99	1.41	2.53	6.74	7.28	4.47	
WQ0012279001	CITY OF COVINGTON WWTP	0.013	24.64	77.92			8.48	9.66	6.23	
WQ0013621001	PENELOPE SANITATION DEPT.-WWTP	0.011	34.35	152.77			8.66	8.67	7.93	
WQ0011464001	CITY OF MOUNT CALM WWTP	0.009	32.57	121.61			8.76	9.04	7.55	
WQ0013075001	MHC TT LAKE WHITNEY PRESERVE	0.008	4.71	7.08	1.44	2.01	7.27	7.62	4.23	
WQ0013271001	CITY OF MERTENS WWTF	0.006	31.00	187.67			8.30	8.30	10.50	
WQ0014883001	LAKE WHITNEY RESORTS, LLC									
WQ0013891001	LAKE WHITNEY RESORTS, LLC									
WQ0002726000	VLASIC FARMS									
WQ0004497000	OWL LIVESTOCK									
WQ0011276001	PRESBYTERIAN CHILDERN'S HOME									
WQ0013820001	LATHAM SPRINGS BAPTIST ENCAMPMENT									
<b>Hood</b>										
WQ0001481000	DECORDOVA SES	441.316				0.06				
WQ0010178002	SOUTHEAST PLANT WWTP	1.078	2.90	3.13			7.32	7.51	5.62	0.40
WQ0002889000	LAKE GRANBURY SURFACE WATER	0.421					7.39	7.78		
WQ0004288000	WOLF HOLLOW I, L.P.-POWER PLT.	0.341	5.29			0.12	7.36	8.28		0.23
WQ0014211001	DECORDOVA BEND ESTATES WWTP	0.272	2.76	3.58	7.23	7.49	1.03	3.55	7.00	0.25
WQ0014212001	ACTON MUD- PECAN PLANTATION	0.150	3.70	4.83	1.03	3.54	7.18	7.40	5.76	
WQ0002678000	OAK TRAIL SHORES-EDR - WWTP	0.084					7.37	7.78		
WQ0014233001	CITY OF TOLAR	0.059	3.49	5.97	1.80	3.36	7.32	7.68	5.92	

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0013022001	BLUE WATER SHORES	0.022	9.25	15.18	1.26	3.50	7.40	7.85	5.84	
WQ0013786001	CANYON CREEK WWTP	0.015	7.92	13.73	0.93	3.27	7.96	8.33	7.14	
WQ0014147001	TREATY OAKS WWTF	0.009	4.50	7.85	1.15	3.57	7.44	7.97	8.05	0.15
WQ0013025001	RIDGE UTILITIES WWTF	0.007	7.09	11.69	1.00	3.70	7.67	8.12	6.75	
WQ0014805001	CITY OF CRESSON WWTP 1	0.005	2.68	3.84	1.44	3.41	7.03	7.23	4.55	0.23
WQ0013590001	CITY OF LIPAN WWTP	0.004	22.08	57.88			8.48	9.16	8.07	
WQ0013809001	FALL CREEK UTILITY CO, INC.	0.003	7.71	13.48	1.01	2.90	7.19	7.83	4.61	
WQ0001481000	DECORDOVA SES									
WQ0004288000	WOLF HOLLOW I, L.P.-POWER PLT.									
<b>Jack</b>										
WQ0010994001	CITY OF JACKSBORO WWTF	0.278	4.05	5.39	1.15	2.07	7.40	7.86	7.21	0.14
WQ0010994002	CITY OF JACKSBORO WWTF	0.005		3.66			7.57	7.75		
WQ0010135001	CITY OF BRYSON									
<b>Johnson</b>										
WQ0010006001	CITY OF CLEBURNE WWTP	4.184	2.24	3.15			6.61	7.29	5.66	0.25
WQ0014350001	JOHNSON COUNTY SUD WWTF	0.402	3.96	6.33	1.19	3.71	6.49	6.91	6.95	0.84
WQ0010611002	CITY OF KEENE	0.369	2.29	2.97	1.06	3.44	7.10	7.51	7.61	1.82
WQ0010567001	CITY OF ALVARADO	0.191	23.61	55.10			7.74	8.14	5.22	23.22
WQ0010180001	CITY OF GRANDVIEW	0.157	2.72	5.07	1.27	3.73	7.41	7.76	5.17	0.42
WQ0010542001	CITY OF GODLEY	0.114	10.33	15.49	1.83	2.36	7.38	7.57	5.91	6.96
WQ0013546001	CITY OF RIO VISTA	0.048	2.98	4.83	1.01	3.39	7.37	7.76	5.03	0.54
WQ0013769001	COUNTRY VISTA PLANT	0.028	5.37	7.98	1.12	2.70	7.30	7.56	4.85	
WQ0013846001	GRAND RANCH PHASE 2	0.016	4.93	10.07	1.06	2.63	7.34	7.69	6.83	
WQ0014411001	BLUE WATER OAKS POA	0.013	4.51	9.54	1.07	2.64	7.47	7.83	4.49	0.46
WQ0014680001	RV RANCH WWTP	0.009	15.56	31.15	0.96	1.64	7.35	7.72	4.15	

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	CI min (mg/L)	CI max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0013868001	WALNUT CREEK MHP	0.008	9.83	13.94	1.82	3.08	7.25	7.81	5.11	
WQ0013376001	OAK RIDGE SQUARE MHP	0.006	19.51	26.99	1.48	2.89	7.06	7.08	3.01	
WQ0014373001	THE RETREAT WWTP	0.005	2.89	5.52	1.23	2.82	7.54	8.11	4.62	
WQ0014101001	ALVARADO ISD	0.004	3.63	7.29	1.26	3.32	7.48	7.81	6.82	
WQ0014556001	PLEASANT OAKS MHP	0.003	13.84	18.19	1.58	2.36	7.20	7.78	4.72	
WQ0014790001	JOHNSON CO NORTHBOUND REST AREA WWTP	0.003	7.11	12.46	1.15	3.54	7.05	7.65	7.93	
<b>Montague</b>										
WQ0010071003	CITY OF BOWIE WWTF	0.658	2.09	2.59			7.44	7.67	7.54	0.11
WQ0010355003	CITY OF NOCONA SOUTH WWTP	0.168	2.38	5.07	1.41	3.33	7.02	7.47	5.01	
WQ0010355002	CITY OF NOCONA WWTF	0.088	2.17	4.31	1.33	3.21	6.93	7.36	4.53	
WQ0014496001	CITY OF SAINT JO WWTP	0.077	2.71	6.48	1.12	2.05	7.16	7.96	4.30	0.60
<b>Palo Pinto</b>										
WQ0001903000	RANDLE W. MILLER SEGS - WWTP	118.864								
WQ0001903000	RANDLE W. MILLER SEGS - WWTP	3.978		29.21			7.85	8.17		
WQ0010585001	POLLARD CREEK WWTP	1.503	3.45	1.75	1.00	0.08	6.91	7.49	7.08	0.75
WQ0004325000	GEORGE N. BAILEY, JR. - WWTP	0.145		24.81			7.57	7.82		
WQ0010326001	CITY OF STRAWN - WWTP	0.127	21.55	31.21			7.73	8.12	4.24	
WQ0002461000	SPORTMAN'S WORLD MUD	0.044					7.39	7.88		
WQ0002789000	DOUBLE DIAMOND UTILITIES CO	0.043	15.00	13.00			7.34	8.00		
WQ0011698001	PALO PINTO COUNTY WWTF	0.022	7.42	5.01	1.11	3.64	7.01	7.01	6.68	
WQ0010722001	CITY OF GRAFORD WWTP	0.020	22.81	55.84			8.09	8.86	6.17	
WQ0011311001	PALO PINTO COUNTY RA - WWTP	0.005	9.62	15.00	1.25	5.12	6.51	7.24	7.86	
WQ0014173001	HILL COUNTY HARBOR WWTF	0.002	3.80	7.90	1.15	4.03	6.95	7.42	7.06	1.98
WQ0004891000	BAR-B TRAVEL PLAZA									

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004820000	METROPLEX QUARRY									
WQ0004894000	BUCKLEY OIL COMPANY									
WQ0014511001	GAINES BEND UTILITIES, INC									
WQ0012330001	SPORTSMAN'S WORLD MUNICIPAL									
<b>Parker</b>										
WQ0010380002	CITY OF WEATHERFORD WWTP	2.622	1.98	1.07			7.17	7.60	6.48	0.83
WQ0010585004	WILLOW CREEK WWTP	0.473	3.28	2.78		0.08	6.76	7.45	7.20	0.37
WQ0014198001	WEATHERFORD WATER PURIFICATION	0.422		11.58			7.58	7.89		
WQ0010847001	CITY OF ALEDO WWTP	0.231	6.40	7.75	1.06	2.69	7.47	7.48	6.45	2.65
WQ0010649001	CITY OF SPRINGTOWN - WWTP	0.226	6.26	13.37	1.08	3.49	6.93	7.26	6.10	0.93
WQ0013834001	CITY OF WILLOW PARK - WWTP	0.095	5.20	11.18	1.01	3.20	7.74	8.15	7.82	2.81
WQ0001904000	NORTH TEXAS SES - WWTP	0.060		2.96			7.55	8.07		
WQ0014003001	COWTOWN RV PARK WWTF	0.009	7.02	8.13	1.42	2.22	7.37	7.40	4.41	
WQ0014163001	SUGARTREE WWTF	0.006	6.25	9.57	1.01	3.46	7.13	7.53	6.61	
WQ0013589001	PEASTER I.S.D. WWTP	0.006	6.97	22.10	1.32	2.75	7.36	7.56	5.37	1.14
WQ0003835000	PHILIPS ELECTRONICS	0.001					7.28	7.52		
WQ0001904000	NORTH TEXAS SES - WWTP			4.84			7.55	8.06		
WQ0004852000	PARKER COUNTY SPECIAL UTILITY DISTRICT									
WQ0013798002	BROCK INDEPENDENT SCHOOL DISTRICT									

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0013759001	CITY OF WILLOW PARK									
<b>Somervell</b>										
WQ0001854000	COMANCHE PEAK SES	2843.694								
WQ0001854000	COMANCHE PEAK SES	0.695		8.56			7.35	7.99		
WQ0010177001	CITY OF GLEN ROSE WWTP	0.344	3.23	3.01	2.45	3.33	7.29	7.84	7.81	0.81
WQ0001854000	COMANCHE PEAK SES	0.021	3.67	5.34			6.72	6.95		
WQ0010895001	RIVERBEND RETREAT CENTER -WWTP	0.007	5.43	6.84	1.35	2.89	7.12	7.75	4.31	
WQ0001854000	COMANCHE PEAK SES									
WQ0001854000	COMANCHE PEAK SES									
WQ0001854000	COMANCHE PEAK SES									
WQ0001401000	UNIMIN CORP - CLEBURNE PLANT									
<b>Tarrant</b>										
WQ0000552000	HANDLEY STEAM ELECTRIC STATION	218.514								
WQ0010494013	CITY OF FORTH WORTH VILLAGE CREEK WWTP	115.831	2.02	2.28			6.92	7.39	6.48	0.19
WQ0010486002	CITY OF GRAPEVINE	3.458	2.44	1.30			6.76	7.64	6.83	0.39
WQ0011183003	ASH CREEK PLANT	0.833	3.17	2.05	1.05	2.38	7.05	7.52	6.98	0.91
WQ0013036001	PINE TREE MHP	0.065	3.15	3.80	1.40	2.20	7.05	7.05	4.70	
WQ0010486003	SOUTHWEST PLANT	0.046	4.22	8.34	1.18	4.20	7.82	7.83	7.50	
WQ0013518001	MAYFAIR ADDITION	0.046	5.76	9.20	1.05	2.90	7.43	7.71	4.92	9.02
WQ0012536002	NORTH PLANT	0.023	3.28	3.30	1.25	1.90	7.05	7.05	5.85	
WQ0013831001	PINE TREE	0.023	3.28	3.30	1.25	1.90	7.05	7.05	5.85	
WQ0012536001	SOUTH PLANT	0.023	3.28	3.30	1.25	1.90	7.05	7.05	5.85	
WQ0012723001	BENBROOK VILLAGE MHP	0.023	7.74	14.92	1.20	3.73	7.56	7.60	5.36	
WQ0003993000	ARLINGTON PUMPING STATION PIPELINE BREAKOUT STATION	0.021			6.49	7.03				

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0010791001	OAK GROVE AIRPORT	0.007	7.68	8.26	1.27	2.70	6.99	7.48	3.75	3.96
WQ0003730000	CHEVRON FORTH WORTH TERMINAL	0.006					8.49	8.44		
WQ0012807001	GOLDEN TRIANGLE ESTATES	0.006	8.84	13.82	0.92	2.95	7.05	7.07	3.96	
WQ0011032001	ALTA VISTA MOBILE HOME PARK	0.006	4.29	6.71	1.52	2.71	6.93	6.93	4.54	
WQ0011123001	FORTH WORTH BOAT CLUB	0.005	3.60	4.55	1.29	3.54	7.42	7.42	4.51	
WQ0012982001	REGENCY CONVERSIONS	0.002	2.86	4.45	1.11	3.67	7.54	7.56	4.88	
WQ0002831000	REAGENT CHEMICAL & RESEARCH	0.002	38.12				6.67	6.81		3.17
WQ0012909001	EAGLE MOUNTAIN RV PARK	0.001	4.44	4.87	1.30	3.65	7.33	7.33	4.99	
<b>Wise</b>										
WQ0001406001	HANSON AGGREGATES, INC.	1.937		9.67			8.05	8.15		
WQ0010009001	CITY OF DECATUR WWTP	0.790	3.15	2.33			7.07	7.82	6.96	0.24
WQ0010389002	CITY OF BRIDGEPORT WWTF	0.553	3.17	3.94	0.98	3.46	6.87	7.26	5.96	2.18
WQ0001406000	HANSON AGGREGATES, INC.	0.504		26.40			7.92	8.08		
WQ0010131001	CITY OF BOYD WWTP	0.097	4.57	15.92	0.94	2.70	7.51	7.62	7.29	
WQ0010862001	CITY OF RUNAWAY BAY WWTP	0.096	3.47	3.17	1.15	3.06	6.94	7.51	6.97	2.61
WQ0010701002	WESTSIDE WWTF	0.071	4.21	7.51	1.00	2.90	7.11	7.73	6.65	1.67
WQ0010023001	CITY OF CHICO	0.066	28.53	28.73	0.89	4.06	7.41	7.73	5.69	15.24
WQ0014339001	CITY OF ALVORD WWTP	0.060	4.84	8.76	0.99	3.98	7.36	7.75	5.69	0.67
WQ0011626001	CITY OF NEWARK WWTF	0.049	4.67	13.89	1.01	4.67	7.43	7.80	6.67	0.64
WQ0010701001	CITY OF RHOME	0.044	36.25	63.88			7.97	9.05	7.99	
WQ0013439001	PARADISE ISD WWTF	0.017	8.16	9.43	1.35	3.00	7.13	7.13	4.85	
WQ0014306001	SLIDELL I.S.D. - WWTP	0.007	2.60	5.53	1.54	3.30	7.42	7.42	7.52	
WQ0013427001	GARRETT CREEK RANCH WWTP	0.001	6.91	9.16	1.34	2.75	7.57	7.80	3.67	
WQ0001214000	LIMESTONE MINING AND PROCESSIN									
WQ0000679000	HANSON AGGREGATES, INC.									

TPDES #	Regulated Entity	Average Monthly Discharge Conditions (PCS database)								
		Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Cl min (mg/L)	Cl max (mg/L)	pH Min	pH Max	DO (mg/L)	N (mg/L)
WQ0014841001	IVY VALLEY UTILITIES, LP									
WQ0011382001	FORTH WORTH INDEPENDENT SCHOOL DISTRICT									
WQ0014910001	CHISOLM SPRINGS									

# 10 Appendix B: Summary Statistics for Water Features

Water-feature statistics for the following counties:

Montague, Jack, Wise, Palo Pinto, Parker, Erath, Hood, Somervell, Bosque, and Hill

Montague County		Summary Statistics for Water Features in Acres							
		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1118	248.24	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	1714	1189.07	0.69	0.25	1.20	0.25	0.95
<b>Date 2</b>	Mar 28	0.5 - 1 ha	522	898.21	1.72	1.29	2.47	0.35	1.18
		1 - 10 ha	404	2441.15	6.04	2.47	24.32	4.53	21.85
		10 - 20 ha	20	693.91	34.70	24.82	47.96	7.22	23.15
		> 20 ha	4	452.36	113.09	64.50	218.17	71.45	153.67
<b>Baseline Wet</b>		<b>Total</b>	<b>3782</b>	<b>5922.95</b>	<b>26.08</b>	<b>0.01</b>	<b>218.17</b>		<b>218.16</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	263	58.49	0.22	0.22	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	360	206.90	0.57	0.25	1.19	0.27	0.94
<b>Date 2</b>	Feb 21	0.5 - 1 ha	71	123.17	1.73	1.32	2.45	0.35	1.13
		1 - 10 ha	118	788.69	6.68	2.49	22.55	4.44	20.06
		10 - 20 ha	6	165.33	27.55	24.91	35.48	4.09	10.57
		> 20 ha	4	786.85	196.71	52.93	517.98	219.07	465.05
<b>Baseline Dry</b>		<b>Total</b>	<b>822</b>	<b>2129.43</b>	<b>38.91</b>	<b>0.22</b>	<b>517.98</b>		<b>517.76</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	598	132.97	0.22	0.20	0.22	0	0.02
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	775	478.28	0.62	0.25	1.20	0.26	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	182	304.92	1.68	1.29	2.45	0.32	1.15
		1 - 10 ha	161	997.15	6.19	2.50	23.96	3.95	21.45
		10 - 20 ha	9	283.77	31.53	26.91	38.03	4.15	11.12
		> 20 ha	3	261.54	87.18	54.49	151.01	55.28	96.52
		<b>Total</b>	<b>1728</b>	<b>2458.63</b>	<b>21.24</b>	<b>0.20</b>	<b>151.01</b>		<b>150.80</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1296	288.22	0.22	0.22	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1749	1127.17	0.64	0.25	1.20	0.26	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	472	807.28	1.71	1.31	2.46	0.35	1.15
		1 - 10 ha	353	2206.49	6.25	2.48	23.83	4.50	21.35
		10 - 20 ha	15	539.64	35.98	25.44	46.67	6.75	21.22
		> 20 ha	3	354.05	118.02	62.49	218.39	87.09	155.90
		<b>Total</b>	<b>3888</b>	<b>5322.85</b>	<b>27.14</b>	<b>0.22</b>	<b>218.39</b>		<b>218.17</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1184	262.80	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1894	1221.45	0.64	0.25	1.21	0.27	0.96
<b>Date 2</b>	Feb 21	0.5 - 1 ha	435	746.98	1.72	1.25	2.47	0.34	1.22
		1 - 10 ha	337	1988.81	5.90	2.47	22.67	4.07	20.20
		10 - 20 ha	16	554.69	34.67	25.07	45.21	6.30	20.13
		> 20 ha	3	366.28	122.09	69.83	207.05	74.22	137.22
		<b>Total</b>	<b>3869</b>	<b>5141.02</b>	<b>27.54</b>	<b>0.00</b>	<b>207.05</b>		<b>207.05</b>

**Montague County**

**Summary Statistics for Water Features in Acres**

<b>Year</b>	<b>2006</b>	< 0.1 ha	545	121.09	0.22	0.15	0.22	0	0.08
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	660	409.29	0.62	0.25	1.21	0.26	0.96
<b>Date 2</b>	Nov 23	0.5 - 1 ha	115	193.38	1.68	1.33	2.47	0.32	1.14
		1 - 10 ha	146	850.12	5.82	2.48	20.24	3.67	17.75
		10 - 20 ha	8	244.18	30.52	25.09	43.14	7.68	18.06
		> 20 ha	3	466.14	155.38	51.37	252.20	100.60	200.82
		<b>Total</b>	<b>1477</b>	<b>2284.20</b>	<b>32.37</b>	<b>0.15</b>	<b>252.20</b>		<b>252.05</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1797	399.13	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	2268	1469.74	0.65	0.25	1.23	0.25	0.97
<b>Date 2</b>	Mar 31	0.5 - 1 ha	628	1089.41	1.73	1.29	2.47	0.34	1.18
		1 - 10 ha	477	2905.78	6.09	2.47	23.14	4.28	20.67
		10 - 20 ha	30	958.12	31.94	25.38	47.33	5.38	21.96
		> 20 ha	12	1092.83	91.07	52.07	228.62	57.07	176.55
		<b>Total</b>	<b>5212</b>	<b>7915.02</b>	<b>21.95</b>	<b>0.01</b>	<b>228.62</b>		<b>228.61</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1427	316.81	0.22	0.06	0.22	0.01	0.16
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	2253	1465.01	0.65	0.25	1.23	0.27	0.97
<b>Date 2</b>	Apr 18	0.5 - 1 ha	621	1068.28	1.72	1.30	2.45	0.35	1.14
		1 - 10 ha	479	2869.63	5.99	2.47	24.64	4.58	22.16
		10 - 20 ha	15	552.81	36.85	25.35	48.96	8.28	23.61
		> 20 ha	4	419.92	104.98	52.74	213.28	73.21	160.53
		<b>Total</b>	<b>4799</b>	<b>6692.44</b>	<b>25.07</b>	<b>0.06</b>	<b>213.28</b>		<b>213.22</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1237	275.08	0.22	0.20	0.22	0	0.02
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1631	1084.57	0.66	0.30	1.23	0.25	0.93
<b>Date 2</b>	Oct 23	0.5 - 1 ha	519	883.89	1.70	1.24	2.47	0.36	1.23
		1 - 10 ha	377	2263.67	6.00	2.48	24.02	4.33	21.54
		10 - 20 ha	15	529.81	35.32	26.46	44.03	6.98	17.57
		> 20 ha	3	334.26	111.42	59.38	201.27	78.14	141.89
		<b>Total</b>	<b>3782</b>	<b>5371.28</b>	<b>25.89</b>	<b>0.20</b>	<b>201.27</b>		<b>201.06</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1274	283.33	0.22	0.22	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1477	968.45	0.66	0.41	1.11	0.23	0.70
<b>Date 2</b>	Nov 27	0.5 - 1 ha	400	686.27	1.72	1.33	2.45	0.36	1.11
		1 - 10 ha	291	1948.85	6.70	2.67	24.24	4.46	21.57
		10 - 20 ha	12	415.21	34.60	26.02	44.26	6.53	18.24
		> 20 ha	2	261.09	130.55	72.95	188.15	81.46	115.20
		<b>Total</b>	<b>3456</b>	<b>4563.19</b>	<b>29.07</b>	<b>0.22</b>	<b>188.15</b>		<b>187.92</b>

Jack County

Summary Statistics for Water Features in Acres

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1238	274.43	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	2301	1598.48	0.69	0.25	1.20	0.24	0.95
<b>Date 2</b>	Mar 28	0.5 - 1 ha	722	1229.36	1.70	1.33	2.47	0.35	1.15
		1 - 10 ha	343	1776.17	5.18	2.48	23.80	3.78	21.32
		10 - 20 ha	9	294.01	32.67	26.02	40.11	4.83	14.09
		> 20 ha	12	1341.32	111.78	53.17	558.66	141.58	505.49
<b>Baseline Wet</b>		<b>Total</b>	<b>4625</b>	<b>6513.77</b>	<b>25.37</b>	<b>0.00</b>	<b>558.66</b>		<b>558.65</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	503	111.72	0.22	0.07	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	433	270.28	0.62	0.25	1.20	0.23	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	87	147.25	1.69	1.32	2.45	0.35	1.13
		1 - 10 ha	67	421.38	6.29	2.50	23.00	4.29	20.50
		10 - 20 ha	5	171.80	34.36	27.58	41.37	5.94	13.79
		> 20 ha	5	627.82	125.56	51.37	338.26	122.82	286.89
<b>Baseline Dry</b>		<b>Total</b>	<b>1100</b>	<b>1750.25</b>	<b>28.13</b>	<b>0.07</b>	<b>338.26</b>		<b>338.19</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	941	208.75	0.22	0.01	0.22	0	0.21
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	1007	625.47	0.62	0.25	1.19	0.24	0.93
<b>Date 2</b>	Oct 23	0.5 - 1 ha	192	322.13	1.68	1.33	2.45	0.35	1.11
		1 - 10 ha	95	561.87	5.91	2.56	20.46	4.14	17.89
		10 - 20 ha	5	198.22	39.64	35.36	44.92	3.58	9.56
		> 20 ha	3	641.83	213.94	57.60	497.50	246.00	439.90
		<b>Total</b>	<b>2243</b>	<b>2558.27</b>	<b>43.67</b>	<b>0.01</b>	<b>497.50</b>		<b>497.49</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1427	316.97	0.22	0.02	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1817	1200.44	0.66	0.25	1.19	0.24	0.93
<b>Date 2</b>	Oct 16	0.5 - 1 ha	435	737.72	1.70	1.33	2.46	0.36	1.13
		1 - 10 ha	190	1037.61	5.46	2.50	22.24	4.12	19.74
		10 - 20 ha	8	297.84	37.23	26.02	46.70	7.18	20.68
		> 20 ha	4	758.59	189.65	54.04	545.53	238.00	491.49
		<b>Total</b>	<b>3881</b>	<b>4349.17</b>	<b>39.15</b>	<b>0.02</b>	<b>545.53</b>		<b>545.52</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1342	297.74	0.22	0.02	0.23	0.01	0.21
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1769	1158.99	0.66	0.25	1.20	0.24	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	374	626.45	1.67	1.31	2.45	0.33	1.14
		1 - 10 ha	177	1029.67	5.82	2.52	23.57	4.49	21.05
		10 - 20 ha	7	264.23	37.75	26.99	45.12	6.57	18.13
		> 20 ha	5	726.34	145.27	52.93	400.31	145.75	347.38
		<b>Total</b>	<b>3674</b>	<b>4103.41</b>	<b>31.90</b>	<b>0.02</b>	<b>400.31</b>		<b>400.29</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	656	145.65	0.22	0.01	0.22	0	0.21
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	614	375.38	0.61	0.25	1.20	0.23	0.95
<b>Date 2</b>	Nov 23	0.5 - 1 ha	87	151.32	1.74	1.33	2.47	0.35	1.14

**Jack County**

**Summary Statistics for Water Features in Acres**

		1 - 10 ha	68	434.30	6.39	2.53	20.76	4.49	18.23
		10 - 20 ha	3	94.68	31.56	29.07	33.58	2.29	4.51
		> 20 ha	4	605.36	151.34	49.59	362.50	143.44	312.91
		<b>Total</b>	<b>1432</b>	<b>1806.70</b>	<b>31.98</b>	<b>0.01</b>	<b>362.50</b>		<b>362.49</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1949	432.65	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	2619	1750.44	0.67	0.25	1.21	0.24	0.95
<b>Date 2</b>	Mar 31	0.5 - 1 ha	760	1304.33	1.72	1.33	2.47	0.36	1.14
		1 - 10 ha	441	2385.64	5.41	2.47	24.69	3.91	22.21
		10 - 20 ha	10	361.17	36.12	27.35	48.04	6.80	20.68
		> 20 ha	16	2046.10	127.88	51.37	604.91	134.47	553.54
		<b>Total</b>	<b>5795</b>	<b>8280.34</b>	<b>28.67</b>	<b>0.00</b>	<b>604.91</b>		<b>604.91</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1631	362.09	0.22	0.02	0.22	0.01	0.20
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	2372	1583.27	0.67	0.25	1.21	0.25	0.95
<b>Date 2</b>	Apr 18	0.5 - 1 ha	669	1140.64	1.70	1.32	2.46	0.35	1.14
		1 - 10 ha	350	1807.82	5.17	2.48	24.69	3.71	22.21
		10 - 20 ha	6	231.80	38.63	25.35	48.70	9.00	23.35
		> 20 ha	10	1164.72	116.47	49.43	567.33	159.60	517.90
		<b>Total</b>	<b>5038</b>	<b>6290.34</b>	<b>27.14</b>	<b>0.02</b>	<b>567.33</b>		<b>567.31</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1189	263.84	0.22	0.02	0.22	0	0.21
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1348	887.74	0.66	0.25	1.23	0.24	0.98
<b>Date 2</b>	Oct 23	0.5 - 1 ha	322	548.29	1.70	1.24	2.46	0.36	1.22
		1 - 10 ha	177	931.75	5.26	2.49	22.68	3.78	20.20
		10 - 20 ha	9	304.63	33.85	24.91	48.99	9.82	24.08
		> 20 ha	4	640.81	160.20	56.13	435.45	184.29	379.32
		<b>Total</b>	<b>3049</b>	<b>3577.05</b>	<b>33.65</b>	<b>0.02</b>	<b>435.45</b>		<b>435.43</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	908	201.51	0.22	0.03	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1085	718.93	0.66	0.44	1.11	0.23	0.67
<b>Date 2</b>	Nov 27	0.5 - 1 ha	236	398.31	1.69	1.33	2.45	0.35	1.11
		1 - 10 ha	129	790.17	6.13	2.67	23.13	4.25	20.46
		10 - 20 ha	10	334.70	33.47	27.58	43.14	6.46	15.57
		> 20 ha	4	692.09	173.02	49.59	496.61	216.48	447.01
		<b>Total</b>	<b>2372</b>	<b>3135.72</b>	<b>35.87</b>	<b>0.03</b>	<b>496.61</b>		<b>496.58</b>

Wise County

Summary Statistics for Water Features in Acres

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1389	308.30	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	1828	1225.04	0.67	0.25	1.19	0.24	0.93
<b>Date 2</b>	Mar 28	0.5 - 1 ha	486	828.27	1.70	1.32	2.45	0.35	1.13
		1 - 10 ha	285	2053.08	7.20	2.47	23.80	5.46	21.32
		10 - 20 ha	28	926.77	33.10	24.91	47.37	6.50	22.46
		> 20 ha	8	725.97	90.75	51.81	129.43	32.33	77.62
<b>Baseline Wet</b>		<b>Total</b>	<b>4024</b>	<b>6067.43</b>	<b>22.27</b>	<b>0.00</b>	<b>129.43</b>		<b>129.43</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	468	104.08	0.22	0.22	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	540	337.42	0.62	0.25	1.20	0.26	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	89	154.72	1.74	1.33	2.45	0.36	1.11
		1 - 10 ha	139	1119.62	8.05	2.50	24.69	5.36	22.19
		10 - 20 ha	10	343.98	34.40	25.35	48.17	8.37	22.81
		> 20 ha	4	256.55	64.14	52.11	76.28	9.90	24.17
<b>Baseline Dry</b>		<b>Total</b>	<b>1250</b>	<b>2316.37</b>	<b>18.20</b>	<b>0.22</b>	<b>76.28</b>		<b>76.06</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	887	197.08	0.22	0.02	0.24	0	0.23
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	1061	669.98	0.63	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	214	363.32	1.70	1.31	2.45	0.34	1.14
		1 - 10 ha	197	1538.95	7.81	2.49	24.69	5.21	22.20
		10 - 20 ha	15	439.22	29.28	25.13	39.14	4.55	14.01
		> 20 ha	3	228.59	76.20	69.74	82.60	6.43	12.87
		<b>Total</b>	<b>2377</b>	<b>3437.12</b>	<b>19.31</b>	<b>0.02</b>	<b>82.60</b>		<b>82.59</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1500	333.18	0.22	0.04	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1612	1035.87	0.64	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	367	620.76	1.69	1.29	2.46	0.33	1.17
		1 - 10 ha	253	2023.20	8.00	2.49	24.46	5.59	21.97
		10 - 20 ha	20	629.53	31.48	24.91	38.47	4.56	13.57
		> 20 ha	5	418.79	83.76	69.39	108.75	14.77	39.36
		<b>Total</b>	<b>3757</b>	<b>5061.32</b>	<b>20.96</b>	<b>0.04</b>	<b>108.75</b>		<b>108.70</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1386	307.53	0.22	0.00	0.24	0.01	0.24
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1914	1252.04	0.65	0.25	1.21	0.25	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	394	664.15	1.69	1.33	2.47	0.32	1.14
		1 - 10 ha	304	2210.06	7.27	2.48	24.69	5.08	22.21
		10 - 20 ha	20	653.50	32.68	26.24	46.29	5.90	20.04
		> 20 ha	7	599.81	85.69	51.82	133.44	27.74	81.62
		<b>Total</b>	<b>4025</b>	<b>5687.11</b>	<b>21.37</b>	<b>0.00</b>	<b>133.44</b>		<b>133.44</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	356	78.98	0.22	0.04	0.22	0	0.18
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	417	267.67	0.64	0.25	1.20	0.27	0.95
<b>Date 2</b>	Nov 23	0.5 - 1 ha	76	134.76	1.77	1.33	2.45	0.36	1.12
		1 - 10 ha	121	917.70	7.58	2.50	24.51	4.85	22.00

**Wise County**

**Summary Statistics for Water Features in Acres**

		10 - 20 ha	4	117.44	29.36	26.05	35.42	4.25	9.37
		> 20 ha	3	216.69	72.23	58.72	92.60	17.95	33.88
<b>Total</b>			<b>977</b>	<b>1733.24</b>	<b>18.64</b>	<b>0.04</b>	<b>92.60</b>		<b>92.55</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1574	349.49	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	1712	1123.94	0.66	0.25	1.19	0.24	0.93
<b>Date 2</b>	Mar 31	0.5 - 1 ha	418	717.24	1.72	1.31	2.46	0.34	1.15
		1 - 10 ha	271	1866.33	6.89	2.48	23.72	5.06	21.24
		10 - 20 ha	15	528.81	35.25	26.46	45.64	6.19	19.17
		> 20 ha	7	713.89	101.98	55.21	171.81	51.58	116.60
<b>Total</b>			<b>3997</b>	<b>5299.69</b>	<b>24.45</b>	<b>0.00</b>	<b>171.81</b>		<b>171.81</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	2063	457.93	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	2612	1710.45	0.65	0.25	1.22	0.26	0.97
<b>Date 2</b>	Apr 18	0.5 - 1 ha	698	1204.65	1.73	1.32	2.47	0.34	1.15
		1 - 10 ha	462	3212.24	6.95	2.48	24.46	5.23	21.99
		10 - 20 ha	37	1227.36	33.17	24.91	48.62	7.33	23.72
		> 20 ha	9	782.16	86.91	54.49	123.65	25.03	69.16
<b>Total</b>			<b>5881</b>	<b>8594.79</b>	<b>21.61</b>	<b>0.00</b>	<b>123.65</b>		<b>123.65</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1739	386.47	0.22	0.00	0.24	0	0.24
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1951	1287.79	0.66	0.27	1.23	0.24	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	512	867.58	1.69	1.24	2.45	0.33	1.20
		1 - 10 ha	369	2601.05	7.05	2.49	24.43	5.07	21.95
		10 - 20 ha	24	778.65	32.44	25.13	48.51	6.34	23.38
		> 20 ha	7	537.58	76.80	54.49	95.87	19.08	41.39
<b>Total</b>			<b>4602</b>	<b>6459.12</b>	<b>19.81</b>	<b>0.00</b>	<b>95.87</b>		<b>95.87</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1477	327.89	0.22	0.01	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1668	1101.16	0.66	0.44	1.11	0.23	0.67
<b>Date 2</b>	Nov 27	0.5 - 1 ha	351	612.41	1.74	1.33	2.45	0.37	1.11
		1 - 10 ha	272	2060.07	7.57	2.67	24.69	5.22	22.02
		10 - 20 ha	24	746.80	31.12	25.35	43.81	5.59	18.46
		> 20 ha	6	491.27	81.88	57.60	111.86	18.85	54.26
<b>Total</b>			<b>3798</b>	<b>5339.60</b>	<b>20.53</b>	<b>0.01</b>	<b>111.86</b>		<b>111.86</b>

**Palo Pinto County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1278	283.83	0.22	0.08	0.22	0.01	0.14
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	1844	1259.64	0.68	0.25	1.19	0.25	0.93
<b>Date 2</b>	Mar 28	0.5 - 1 ha	562	961.55	1.71	1.33	2.45	0.35	1.11
		1 - 10 ha	335	1959.97	5.85	2.49	24.69	4.59	22.20
		10 - 20 ha	9	280.58	31.18	25.35	45.50	7.26	20.15
		> 20 ha	5	620.60	124.12	73.84	182.59	42.89	108.75
<b>Baseline Wet</b>		<b>Total</b>	<b>4033</b>	<b>5366.16</b>	<b>27.29</b>	<b>0.08</b>	<b>182.59</b>		<b>182.51</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	448	99.49	0.22	0.13	0.23	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	576	376.15	0.65	0.25	1.19	0.24	0.93
<b>Date 2</b>	Feb 21	0.5 - 1 ha	127	220.82	1.74	1.31	2.45	0.38	1.14
		1 - 10 ha	106	789.29	7.45	2.49	23.76	5.30	21.27
		10 - 20 ha							
		> 20 ha	4	369.77	92.44	59.82	126.91	27.74	67.09
<b>Baseline Dry</b>		<b>Total</b>	<b>1261</b>	<b>1855.51</b>	<b>20.50</b>	<b>0.13</b>	<b>126.91</b>		<b>126.78</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	856	190.37	0.22	0.22	0.22	0	0.00
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	813	517.77	0.64	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	136	232.69	1.71	1.33	2.45	0.36	1.11
		1 - 10 ha	111	756.48	6.82	2.49	24.69	4.99	22.20
		10 - 20 ha	1	30.25	30.25	30.25	30.25	0.00	0.00
		> 20 ha	5	447.93	89.59	57.16	124.12	30.22	66.96
		<b>Total</b>	<b>1922</b>	<b>2175.48</b>	<b>21.54</b>	<b>0.22</b>	<b>124.12</b>		<b>123.90</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1312	291.61	0.22	0.12	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1223	778.49	0.64	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	226	384.97	1.70	1.31	2.45	0.36	1.14
		1 - 10 ha	165	1072.74	6.50	2.47	23.80	4.94	21.32
		10 - 20 ha	3	113.09	37.70	32.81	42.26	4.73	9.45
		> 20 ha	5	544.45	108.89	66.94	129.01	25.35	62.07
		<b>Total</b>	<b>2934</b>	<b>3185.35</b>	<b>25.94</b>	<b>0.12</b>	<b>129.01</b>		<b>128.89</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1003	222.89	0.22	0.14	0.22	0.00	0.09
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1355	924.93	0.68	0.25	1.20	0.25	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	356	603.87	1.70	1.33	2.46	0.35	1.14
		1 - 10 ha	223	1384.78	6.21	2.47	24.24	4.47	21.77
		10 - 20 ha	6	175.68	29.28	24.78	35.69	4.90	10.91
		> 20 ha	6	602.14	100.36	51.15	130.89	33.68	79.74
		<b>Total</b>	<b>2949</b>	<b>3914.30</b>	<b>23.07</b>	<b>0.14</b>	<b>130.89</b>		<b>130.75</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	674	149.89	0.22	0.22	0.22	0	0.00
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	567	359.11	0.63	0.25	1.21	0.25	0.96
<b>Date 2</b>	Nov 23	0.5 - 1 ha	108	185.68	1.72	1.32	2.45	0.36	1.13
		1 - 10 ha	116	715.19	6.17	2.54	20.91	4.74	18.37

**Palo Pinto County**

**Summary Statistics for Water Features in Acres**

		10 - 20 ha	2	58.93	29.47	27.13	31.80	3.30	4.67
		> 20 ha	5	417.76	83.55	56.93	108.86	23.12	51.92
<b>Total</b>			<b>1472</b>	<b>1886.58</b>	<b>20.29</b>	<b>0.22</b>	<b>108.86</b>		<b>108.63</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1784	396.04	0.22	0.05	0.22	0.01	0.17
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	2174	1432.12	0.66	0.25	1.23	0.23	0.97
<b>Date 2</b>	Mar 31	0.5 - 1 ha	631	1083.95	1.72	1.33	2.46	0.35	1.13
		1 - 10 ha	375	2197.36	5.86	2.47	24.69	4.24	22.21
		10 - 20 ha	12	375.18	31.27	26.24	42.70	5.44	16.46
		> 20 ha	10	919.36	91.94	49.82	134.85	33.04	85.03
<b>Total</b>			<b>4986</b>	<b>6404.01</b>	<b>21.94</b>	<b>0.05</b>	<b>134.85</b>		<b>134.80</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1419	315.08	0.22	0.10	0.22	0.01	0.12
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	1889	1266.92	0.67	0.25	1.20	0.26	0.95
<b>Date 2</b>	Apr 18	0.5 - 1 ha	484	836.11	1.73	1.33	2.46	0.36	1.13
		1 - 10 ha	294	1736.80	5.91	2.51	24.46	4.24	21.95
		10 - 20 ha	10	354.92	35.49	26.24	49.15	7.30	22.91
		> 20 ha	5	583.51	116.70	72.28	146.34	29.52	74.06
<b>Total</b>			<b>4101</b>	<b>5093.35</b>	<b>26.79</b>	<b>0.10</b>	<b>146.34</b>		<b>146.24</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1009	223.79	0.22	0.04	0.24	0	0.21
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1169	756.88	0.65	0.37	1.23	0.24	0.86
<b>Date 2</b>	Oct 23	0.5 - 1 ha	278	480.61	1.73	1.25	2.45	0.36	1.20
		1 - 10 ha	205	1268.74	6.19	2.49	24.69	4.47	22.20
		10 - 20 ha	8	281.97	35.25	25.82	47.81	7.97	21.99
		> 20 ha	4	422.67	105.67	80.06	124.88	18.67	44.82
<b>Total</b>			<b>2673</b>	<b>3434.66</b>	<b>24.95</b>	<b>0.04</b>	<b>124.88</b>		<b>124.85</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	827	183.65	0.22	0.06	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	841	550.32	0.65	0.36	1.11	0.24	0.76
<b>Date 2</b>	Nov 27	0.5 - 1 ha	189	334.38	1.77	1.25	2.45	0.38	1.20
		1 - 10 ha	153	949.82	6.21	2.67	22.24	4.24	19.57
		10 - 20 ha	5	159.15	31.83	26.46	38.92	4.51	12.45
		> 20 ha	5	501.50	100.30	55.38	126.54	28.17	71.17
<b>Total</b>			<b>2020</b>	<b>2678.83</b>	<b>23.50</b>	<b>0.06</b>	<b>126.54</b>		<b>126.48</b>

**Parker County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1288	285.92	0.22	0.05	0.22	0.01	0.17
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	1575	1048.19	0.67	0.25	1.21	0.26	0.96
<b>Date 2</b>	Mar 28	0.5 - 1 ha	393	676.39	1.72	1.33	2.47	0.35	1.13
		1 - 10 ha	295	1779.93	6.03	2.47	22.08	4.24	19.61
		10 - 20 ha	10	350.51	35.05	25.70	48.69	6.70	23.00
		> 20 ha	6	753.82	125.64	50.11	398.98	136.52	348.87
<b>Baseline Wet</b>		<b>Total</b>	<b>3567</b>	<b>4894.76</b>	<b>28.22</b>	<b>0.05</b>	<b>398.98</b>		<b>398.92</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	511	113.27	0.22	0.06	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	705	452.14	0.64	0.25	1.22	0.25	0.97
<b>Date 2</b>	Feb 21	0.5 - 1 ha	164	288.26	1.76	1.31	2.47	0.37	1.16
		1 - 10 ha	141	963.41	6.83	2.47	24.43	4.83	21.96
		10 - 20 ha	10	316.62	31.66	25.92	44.22	5.99	18.29
		> 20 ha	4	434.11	108.53	65.16	135.88	30.32	70.72
<b>Baseline Dry</b>		<b>Total</b>	<b>1535</b>	<b>2567.82</b>	<b>24.94</b>	<b>0.06</b>	<b>135.88</b>		<b>135.82</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	779	172.66	0.22	0.03	0.22	0	0.20
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	905	549.97	0.61	0.25	1.21	0.26	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	153	261.44	1.71	1.33	2.46	0.32	1.13
		1 - 10 ha	158	1043.89	6.61	2.48	24.02	4.77	21.54
		10 - 20 ha	8	259.74	32.47	24.85	43.81	7.34	18.97
		> 20 ha	2	158.12	79.06	64.72	93.41	20.29	28.69
		<b>Total</b>	<b>2005</b>	<b>2445.81</b>	<b>20.11</b>	<b>0.03</b>	<b>93.41</b>		<b>93.38</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1137	252.28	0.22	0.05	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1246	761.80	0.61	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	252	430.06	1.71	1.30	2.45	0.33	1.14
		1 - 10 ha	197	1251.09	6.35	2.48	24.63	4.19	22.15
		10 - 20 ha	12	396.79	33.07	25.45	44.92	6.89	19.47
		> 20 ha	2	195.49	97.74	71.61	123.87	36.96	52.26
		<b>Total</b>	<b>2846</b>	<b>3287.51</b>	<b>23.28</b>	<b>0.05</b>	<b>123.87</b>		<b>123.82</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	886	196.22	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1423	945.80	0.66	0.25	1.24	0.26	0.98
<b>Date 2</b>	Feb 21	0.5 - 1 ha	363	618.07	1.70	1.33	2.45	0.34	1.12
		1 - 10 ha	248	1442.75	5.82	2.49	22.19	3.88	19.71
		10 - 20 ha	13	437.36	33.64	27.04	44.48	5.82	17.44
		> 20 ha	6	602.24	100.37	56.84	153.67	36.32	96.83
		<b>Total</b>	<b>2939</b>	<b>4242.44</b>	<b>23.74</b>	<b>0.00</b>	<b>153.67</b>		<b>153.67</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	459	101.69	0.22	0.05	0.24	0	0.19
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	634	408.74	0.64	0.25	1.22	0.27	0.97
<b>Date 2</b>	Nov 23	0.5 - 1 ha	176	306.13	1.74	1.33	2.45	0.34	1.11
		1 - 10 ha	140	909.71	6.50	2.55	21.82	4.68	19.26

**Parker County**

**Summary Statistics for Water Features in Acres**

		10 - 20 ha	5	153.22	30.64	25.13	38.18	4.87	13.05
		> 20 ha	3	260.42	86.81	58.71	121.21	31.72	62.49
<b>Total</b>			<b>1417</b>	<b>2139.93</b>	<b>21.09</b>	<b>0.05</b>	<b>121.21</b>		<b>121.15</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1267	280.88	0.22	0.03	0.22	0.01	0.20
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	1682	1122.87	0.67	0.25	1.20	0.24	0.95
<b>Date 2</b>	Mar 31	0.5 - 1 ha	425	723.17	1.70	1.30	2.46	0.34	1.16
		1 - 10 ha	322	1757.61	5.46	2.48	23.40	3.84	20.92
		10 - 20 ha	13	414.48	31.88	25.13	40.92	4.82	15.79
		> 20 ha	5	591.22	118.24	66.50	225.59	66.14	159.10
<b>Total</b>			<b>3714</b>	<b>4890.24</b>	<b>26.36</b>	<b>0.03</b>	<b>225.59</b>		<b>225.57</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1358	301.10	0.22	0.01	0.22	0.01	0.22
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	1914	1225.84	0.64	0.25	1.20	0.27	0.95
<b>Date 2</b>	Apr 18	0.5 - 1 ha	488	839.97	1.72	1.31	2.46	0.33	1.15
		1 - 10 ha	369	2113.32	5.73	2.49	23.63	4.19	21.14
		10 - 20 ha	13	501.91	38.61	26.78	48.03	7.54	21.25
		> 20 ha	4	913.60	228.40	80.06	407.87	150.66	327.81
<b>Total</b>			<b>4146</b>	<b>5895.73</b>	<b>45.89</b>	<b>0.01</b>	<b>407.87</b>		<b>407.87</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1213	269.06	0.22	0.03	0.24	0	0.21
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1446	943.63	0.65	0.37	1.23	0.24	0.86
<b>Date 2</b>	Oct 23	0.5 - 1 ha	435	758.55	1.74	1.24	2.47	0.36	1.23
		1 - 10 ha	316	1926.38	6.10	2.48	24.45	4.58	21.98
		10 - 20 ha	8	273.32	34.16	26.24	47.87	7.82	21.63
		> 20 ha	5	702.44	140.49	74.50	284.67	85.77	210.16
<b>Total</b>			<b>3423</b>	<b>4873.39</b>	<b>30.56</b>	<b>0.03</b>	<b>284.67</b>		<b>284.63</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1205	267.06	0.22	0.01	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1344	881.65	0.66	0.29	1.19	0.23	0.90
<b>Date 2</b>	Nov 27	0.5 - 1 ha	383	665.81	1.74	1.33	2.45	0.36	1.11
		1 - 10 ha	235	1638.70	6.97	2.67	24.24	4.93	21.57
		10 - 20 ha	9	302.90	33.66	26.02	46.26	6.35	20.24
		> 20 ha	2	232.63	116.31	69.39	163.24	66.36	93.85
<b>Total</b>			<b>3178</b>	<b>3988.74</b>	<b>26.59</b>	<b>0.01</b>	<b>163.24</b>		<b>163.23</b>

**Erath County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1696	376.85	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	2252	1498.17	0.67	0.25	1.20	0.25	0.95
<b>Date 2</b>	Mar 28	0.5 - 1 ha	575	978.62	1.70	1.30	2.47	0.34	1.17
		1 - 10 ha	309	2096.65	6.79	2.47	24.40	5.36	21.93
		10 - 20 ha	25	893.25	35.73	24.91	49.25	7.70	24.34
		> 20 ha	21	1436.14	68.39	49.44	138.55	26.14	89.11
<b>Baseline Wet</b>		<b>Total</b>	<b>4878</b>	<b>7279.67</b>	<b>18.92</b>	<b>0.01</b>	<b>138.55</b>		<b>138.54</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	572	127.09	0.22	0.10	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	751	460.35	0.61	0.25	1.19	0.25	0.94
<b>Date 2</b>	Feb 21	0.5 - 1 ha	147	255.33	1.74	1.33	2.45	0.36	1.12
		1 - 10 ha	133	1110.94	8.35	2.48	23.96	5.57	21.48
		10 - 20 ha	19	573.74	30.20	25.13	41.81	4.45	16.68
		> 20 ha	4	279.55	69.89	51.15	89.85	21.17	38.70
<b>Baseline Dry</b>		<b>Total</b>	<b>1626</b>	<b>2807.00</b>	<b>18.50</b>	<b>0.10</b>	<b>89.85</b>		<b>89.75</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	939	208.59	0.22	0.10	0.22	0	0.12
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	1133	690.35	0.61	0.25	1.20	0.25	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	177	295.63	1.67	1.33	2.46	0.34	1.13
		1 - 10 ha	152	1136.16	7.47	2.49	23.37	5.43	20.89
		10 - 20 ha	26	835.59	32.14	24.91	40.92	4.90	16.01
		> 20 ha	4	298.66	74.66	53.82	114.51	28.30	60.69
		<b>Total</b>	<b>2431</b>	<b>3464.98</b>	<b>19.46</b>	<b>0.10</b>	<b>114.51</b>		<b>114.41</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1491	331.18	0.22	0.01	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1617	1015.93	0.63	0.25	1.21	0.25	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	308	526.20	1.71	1.32	2.47	0.34	1.15
		1 - 10 ha	196	1432.02	7.31	2.49	22.98	5.53	20.50
		10 - 20 ha	33	1117.83	33.87	25.15	43.68	5.62	18.54
		> 20 ha	4	306.83	76.71	52.26	117.12	29.31	64.86
		<b>Total</b>	<b>3649</b>	<b>4729.99</b>	<b>20.07</b>	<b>0.01</b>	<b>117.12</b>		<b>117.11</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1189	264.23	0.22	0.12	0.22	0	0.10
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1846	1200.60	0.65	0.25	1.20	0.25	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	418	704.37	1.69	1.30	2.46	0.33	1.16
		1 - 10 ha	258	1774.08	6.88	2.48	24.41	5.52	21.93
		10 - 20 ha	34	1213.59	35.69	24.91	48.26	6.21	23.35
		> 20 ha	7	528.19	75.46	50.71	123.47	27.78	72.77

**Erath County**

**Summary Statistics for Water Features in Acres**

		<b>Total</b>	<b>3752</b>	<b>5685.07</b>	<b>20.10</b>	<b>0.12</b>	<b>123.47</b>		<b>123.35</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	464	103.19	0.22	0.22	0.22	0	0
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	539	341.55	0.63	0.25	1.22	0.26	0.96
<b>Date 2</b>	Nov 23	0.5 - 1 ha	112	188.36	1.68	1.33	2.45	0.37	1.12
		1 - 10 ha	129	1088.17	8.44	2.54	24.68	5.98	22.14
		10 - 20 ha	13	427.35	32.87	25.87	42.48	5.65	16.61
		> 20 ha	2	138.80	69.40	58.93	79.87	14.80	20.93
		<b>Total</b>	<b>1259</b>	<b>2287.43</b>	<b>18.87</b>	<b>0.22</b>	<b>79.87</b>		<b>79.64</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1955	434.28	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	2337	1529.98	0.65	0.25	1.21	0.23	0.96
<b>Date 2</b>	Mar 31	0.5 - 1 ha	609	1028.49	1.69	1.29	2.47	0.35	1.18
		1 - 10 ha	318	2033.47	6.39	2.48	23.57	5.10	21.10
		10 - 20 ha	37	1322.46	35.74	25.35	48.93	7.41	23.57
		> 20 ha	15	1034.08	68.94	50.26	154.69	27.80	104.43
		<b>Total</b>	<b>5271</b>	<b>7382.75</b>	<b>18.94</b>	<b>0.01</b>	<b>154.69</b>		<b>154.69</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1452	322.51	0.22	0.03	0.22	0.01	0.19
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	1822	1157.43	0.64	0.25	1.20	0.25	0.95
<b>Date 2</b>	Apr 18	0.5 - 1 ha	368	635.36	1.73	1.33	2.45	0.34	1.12
		1 - 10 ha	257	1853.24	7.21	2.49	23.67	5.52	21.18
		10 - 20 ha	34	1170.03	34.41	25.13	48.93	5.89	23.80
		> 20 ha	5	398.97	79.79	52.03	116.76	32.77	64.72
		<b>Total</b>	<b>3938</b>	<b>5537.54</b>	<b>20.67</b>	<b>0.03</b>	<b>116.76</b>		<b>116.72</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1272	282.47	0.22	0.01	0.22	0	0.21
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1488	985.34	0.66	0.27	1.23	0.25	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	375	649.17	1.73	1.24	2.47	0.36	1.23
		1 - 10 ha	235	1694.22	7.21	2.49	24.24	5.40	21.75
		10 - 20 ha	29	996.50	34.36	25.22	48.93	7.43	23.71
		> 20 ha	3	218.49	72.83	64.36	78.73	7.52	14.37
		<b>Total</b>	<b>3402</b>	<b>4826.19</b>	<b>19.50</b>	<b>0.01</b>	<b>78.73</b>		<b>78.72</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1045	231.45	0.22	0.02	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1066	704.99	0.66	0.44	1.11	0.23	0.67
<b>Date 2</b>	Nov 27	0.5 - 1 ha	263	440.12	1.67	1.33	2.45	0.33	1.11
		1 - 10 ha	195	1517.00	7.78	2.67	24.46	5.60	21.79
		10 - 20 ha	28	932.50	33.30	26.24	42.48	5.06	16.23
		> 20 ha	4	304.01	76.00	53.60	113.20	27.31	59.60

**Erath County**

**Summary Statistics for Water Features in Acres**

	<b>Total</b>	<b>2601</b>	<b>4130.07</b>	<b>19.94</b>	<b>0.02</b>	<b>113.20</b>	<b>113.18</b>
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**Hood County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	571	126.35	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	522	340.24	0.65	0.25	1.20	0.24	0.94
<b>Date 2</b>	Mar 28	0.5 - 1 ha	141	242.95	1.72	1.33	2.46	0.34	1.13
		1 - 10 ha	76	409.09	5.38	2.48	21.35	4.47	18.87
		10 - 20 ha	1	28.62	28.62	28.62	28.62	0	0
		> 20 ha	1	73.28	73.28	73.28	73.28	0	0
<b>Baseline Wet</b>	<b>Total</b>		<b>1312</b>	<b>1220.52</b>	<b>18.31</b>	<b>0.00</b>	<b>73.28</b>		<b>73.28</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	221	49.05	0.22	0.12	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	219	146.37	0.67	0.25	1.19	0.26	0.93
<b>Date 2</b>	Feb 21	0.5 - 1 ha	41	69.44	1.69	1.33	2.45	0.30	1.11
		1 - 10 ha	41	240.06	5.86	2.49	24.54	4.34	22.06
		10 - 20 ha							
		> 20 ha	1	59.23	59.23	59.23	59.23	0	0
<b>Baseline Dry</b>	<b>Total</b>		<b>523</b>	<b>564.16</b>	<b>13.53</b>	<b>0.12</b>	<b>59.23</b>		<b>59.11</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	466	103.61	0.22	0.20	0.22	0	0.03
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	397	261.25	0.66	0.25	1.20	0.26	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	83	145.52	1.75	1.31	2.45	0.38	1.14
		1 - 10 ha	61	387.62	6.35	2.56	21.49	4.85	18.93
		10 - 20 ha	2	59.96	29.98	25.05	34.92	6.98	9.87
		> 20 ha	1	68.32	68.32	68.32	68.32	0	0
	<b>Total</b>		<b>1010</b>	<b>1026.28</b>	<b>17.88</b>	<b>0.20</b>	<b>68.32</b>		<b>68.12</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	723	160.46	0.22	0.05	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	529	340.15	0.64	0.25	1.20	0.24	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	127	218.56	1.72	1.32	2.45	0.36	1.13
		1 - 10 ha	85	521.12	6.13	2.47	24.46	5.14	21.99
		10 - 20 ha	3	89.33	29.78	25.80	35.58	5.14	9.79
		> 20 ha	1	69.04	69.04	69.04	69.04	0.00	0.00
	<b>Total</b>		<b>1468</b>	<b>1398.66</b>	<b>17.92</b>	<b>0.05</b>	<b>69.04</b>		<b>68.98</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	439	97.63	0.22	0.22	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	607	405.53	0.67	0.25	1.20	0.25	0.95
<b>Date 2</b>	Feb 21	0.5 - 1 ha	144	245.36	1.70	1.33	2.46	0.34	1.13
		1 - 10 ha	86	487.74	5.67	2.52	23.80	4.57	21.28

		10 - 20 ha	3	91.01	30.34	28.02	34.47	3.59	6.45
		> 20 ha	1	75.66	75.66	75.66	75.66	0.00	0.00
		<b>Total</b>	<b>1280</b>	<b>1402.92</b>	<b>19.04</b>	<b>0.22</b>	<b>75.66</b>		<b>75.43</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	229	50.91	0.22	0.20	0.22	0	0.02
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	258	181.08	0.70	0.25	1.18	0.26	0.93
<b>Date 2</b>	Nov 23	0.5 - 1 ha	77	133.54	1.73	1.33	2.45	0.35	1.11
		1 - 10 ha	50	302.73	6.05	2.67	18.46	3.82	15.79
		10 - 20 ha	1	33.14	33.14	33.14	33.14	0.00	0.00
		> 20 ha	1	64.77	64.77	64.77	64.77	0.00	0.00
		<b>Total</b>	<b>616</b>	<b>766.17</b>	<b>17.77</b>	<b>0.20</b>	<b>64.77</b>		<b>64.57</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	441	97.85	0.22	0.09	0.22	0.01	0.13
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	577	391.78	0.68	0.25	1.20	0.25	0.94
<b>Date 2</b>	Mar 31	0.5 - 1 ha	156	267.50	1.71	1.31	2.46	0.35	1.15
		1 - 10 ha	104	534.83	5.14	2.48	21.00	3.40	18.53
		10 - 20 ha	4	125.85	31.46	26.02	36.92	4.50	10.90
		> 20 ha	1	73.72	73.72	73.72	73.72	0.00	0.00
		<b>Total</b>	<b>1283</b>	<b>1491.53</b>	<b>18.82</b>	<b>0.09</b>	<b>73.72</b>		<b>73.63</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	673	149.46	0.22	0.08	0.22	0.01	0.14
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	682	443.40	0.65	0.25	1.19	0.24	0.93
<b>Date 2</b>	Apr 18	0.5 - 1 ha	209	355.47	1.70	1.31	2.45	0.36	1.14
		1 - 10 ha	118	661.75	5.61	2.48	22.02	3.73	19.54
		10 - 20 ha	4	133.29	33.32	29.13	37.81	4.24	8.67
		> 20 ha	1	68.02	68.02	68.02	68.02	0.00	0.00
		<b>Total</b>	<b>1687</b>	<b>1811.39</b>	<b>18.25</b>	<b>0.08</b>	<b>68.02</b>		<b>67.94</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	609	135.33	0.22	0.17	0.22	0	0.05
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	609	404.29	0.66	0.31	1.23	0.24	0.92
<b>Date 2</b>	Oct 23	0.5 - 1 ha	168	286.49	1.71	1.33	2.45	0.34	1.11
		1 - 10 ha	156	924.38	5.93	2.53	24.24	4.71	21.71
		10 - 20 ha	1	36.92	36.92	36.92	36.92	0.00	0.00
		> 20 ha	1	76.85	76.85	76.85	76.85	0.00	0.00
		<b>Total</b>	<b>1544</b>	<b>1864.27</b>	<b>20.38</b>	<b>0.17</b>	<b>76.85</b>		<b>76.68</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	556	123.61	0.22	0.16	0.24	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	699	451.53	0.65	0.37	1.11	0.23	0.74
<b>Date 2</b>	Nov 27	0.5 - 1 ha	181	309.35	1.71	1.33	2.45	0.37	1.11
		1 - 10 ha	127	748.84	5.90	2.67	23.35	4.24	20.68
		10 - 20 ha	4	128.10	32.02	27.13	37.58	5.33	10.45
		> 20 ha	1	70.05	70.05	70.05	70.05	0.00	0.00
		<b>Total</b>	<b>1568</b>	<b>1831.48</b>	<b>18.43</b>	<b>0.16</b>	<b>70.05</b>		<b>69.89</b>

**Somervell County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1118	248.24	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	1714	1189.07	0.69	0.25	1.20	0.25	0.95
<b>Date 2</b>	Mar 28	0.5 - 1 ha	522	898.21	1.72	1.29	2.47	0.35	1.18
		1 - 10 ha	404	2441.15	6.04	2.47	24.32	4.53	21.85
		10 - 20 ha	20	693.91	34.70	24.82	47.96	7.22	23.15
		> 20 ha	4	452.36	113.09	64.50	218.17	71.45	153.67
<b>Baseline Wet</b>		<b>Total</b>	<b>3782</b>	<b>5922.95</b>	<b>26.08</b>	<b>0.01</b>	<b>218.17</b>		<b>218.16</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	263	58.49	0.22	0.22	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	360	206.90	0.57	0.25	1.19	0.27	0.94
<b>Date 2</b>	Feb 21	0.5 - 1 ha	71	123.17	1.73	1.32	2.45	0.35	1.13
		1 - 10 ha	118	788.69	6.68	2.49	22.55	4.44	20.06
		10 - 20 ha	6	165.33	27.55	24.91	35.48	4.09	10.57
		> 20 ha	4	786.85	196.71	52.93	517.98	219.07	465.05
<b>Baseline Dry</b>		<b>Total</b>	<b>822</b>	<b>2129.43</b>	<b>38.91</b>	<b>0.22</b>	<b>517.98</b>		<b>517.76</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	598	132.97	0.22	0.20	0.22	0	0.02
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	775	478.28	0.62	0.25	1.20	0.26	0.95
<b>Date 2</b>	Oct 23	0.5 - 1 ha	182	304.92	1.68	1.29	2.45	0.32	1.15
		1 - 10 ha	161	997.15	6.19	2.50	23.96	3.95	21.45
		10 - 20 ha	9	283.77	31.53	26.91	38.03	4.15	11.12
		> 20 ha	3	261.54	87.18	54.49	151.01	55.28	96.52
		<b>Total</b>	<b>1728</b>	<b>2458.63</b>	<b>21.24</b>	<b>0.20</b>	<b>151.01</b>		<b>150.80</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1296	288.22	0.22	0.22	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1749	1127.17	0.64	0.25	1.20	0.26	0.95
<b>Date 2</b>	Oct 16	0.5 - 1 ha	472	807.28	1.71	1.31	2.46	0.35	1.15
		1 - 10 ha	353	2206.49	6.25	2.48	23.83	4.50	21.35
		10 - 20 ha	15	539.64	35.98	25.44	46.67	6.75	21.22
		> 20 ha	3	354.05	118.02	62.49	218.39	87.09	155.90
		<b>Total</b>	<b>3888</b>	<b>5322.85</b>	<b>27.14</b>	<b>0.22</b>	<b>218.39</b>		<b>218.17</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	1184	262.80	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	1894	1221.45	0.64	0.25	1.21	0.27	0.96
<b>Date 2</b>	Feb 21	0.5 - 1 ha	435	746.98	1.72	1.25	2.47	0.34	1.22
		1 - 10 ha	337	1988.81	5.90	2.47	22.67	4.07	20.20
		10 - 20 ha	16	554.69	34.67	25.07	45.21	6.30	20.13
		> 20 ha	3	366.28	122.09	69.83	207.05	74.22	137.22
		<b>Total</b>	<b>3869</b>	<b>5141.02</b>	<b>27.54</b>	<b>0.00</b>	<b>207.05</b>		<b>207.05</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	545	121.09	0.22	0.15	0.22	0	0.08

**Somervell County**

**Summary Statistics for Water Features in Acres**

<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	660	409.29	0.62	0.25	1.21	0.26	0.96
<b>Date 2</b>	Nov 23	0.5 - 1 ha	115	193.38	1.68	1.33	2.47	0.32	1.14
		1 - 10 ha	146	850.12	5.82	2.48	20.24	3.67	17.75
		10 - 20 ha	8	244.18	30.52	25.09	43.14	7.68	18.06
		> 20 ha	3	466.14	155.38	51.37	252.20	100.60	200.82
<b>Total</b>			<b>1477</b>	<b>2284.20</b>	<b>32.37</b>	<b>0.15</b>	<b>252.20</b>		<b>252.05</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	1797	399.13	0.22	0.01	0.22	0.01	0.21
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	2268	1469.74	0.65	0.25	1.23	0.25	0.97
<b>Date 2</b>	Mar 31	0.5 - 1 ha	628	1089.41	1.73	1.29	2.47	0.34	1.18
		1 - 10 ha	477	2905.78	6.09	2.47	23.14	4.28	20.67
		10 - 20 ha	30	958.12	31.94	25.38	47.33	5.38	21.96
		> 20 ha	12	1092.83	91.07	52.07	228.62	57.07	176.55
<b>Total</b>			<b>5212</b>	<b>7915.02</b>	<b>21.95</b>	<b>0.01</b>	<b>228.62</b>		<b>228.61</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1427	316.81	0.22	0.06	0.22	0.01	0.16
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	2253	1465.01	0.65	0.25	1.23	0.27	0.97
<b>Date 2</b>	Apr 18	0.5 - 1 ha	621	1068.28	1.72	1.30	2.45	0.35	1.14
		1 - 10 ha	479	2869.63	5.99	2.47	24.64	4.58	22.16
		10 - 20 ha	15	552.81	36.85	25.35	48.96	8.28	23.61
		> 20 ha	4	419.92	104.98	52.74	213.28	73.21	160.53
<b>Total</b>			<b>4799</b>	<b>6692.44</b>	<b>25.07</b>	<b>0.06</b>	<b>213.28</b>		<b>213.22</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1237	275.08	0.22	0.20	0.22	0	0.02
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1631	1084.57	0.66	0.30	1.23	0.25	0.93
<b>Date 2</b>	Oct 23	0.5 - 1 ha	519	883.89	1.70	1.24	2.47	0.36	1.23
		1 - 10 ha	377	2263.67	6.00	2.48	24.02	4.33	21.54
		10 - 20 ha	15	529.81	35.32	26.46	44.03	6.98	17.57
		> 20 ha	3	334.26	111.42	59.38	201.27	78.14	141.89
<b>Total</b>			<b>3782</b>	<b>5371.28</b>	<b>25.89</b>	<b>0.20</b>	<b>201.27</b>		<b>201.06</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1274	283.33	0.22	0.22	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1477	968.45	0.66	0.41	1.11	0.23	0.70
<b>Date 2</b>	Nov 27	0.5 - 1 ha	400	686.27	1.72	1.33	2.45	0.36	1.11
		1 - 10 ha	291	1948.85	6.70	2.67	24.24	4.46	21.57
		10 - 20 ha	12	415.21	34.60	26.02	44.26	6.53	18.24
		> 20 ha	2	261.09	130.55	72.95	188.15	81.46	115.20
<b>Total</b>			<b>3456</b>	<b>4563.19</b>	<b>29.07</b>	<b>0.22</b>	<b>188.15</b>		<b>187.92</b>

**Bosque County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1025	227.71	0.22	0.01	0.22	0.01	0.22
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	705	456.70	0.65	0.44	1.11	0.23	0.67
<b>Date 2</b>	Mar 28	0.5 - 1 ha	163	280.88	1.72	1.33	2.45	0.39	1.11
		1 - 10 ha	167	1157.90	6.93	2.67	22.91	5.11	20.24
		10 - 20 ha	6	204.60	34.10	27.13	43.81	6.36	16.68
		> 20 ha	4	299.56	74.89	51.37	128.18	35.76	76.80
<b>Baseline Wet</b>		<b>Total</b>	<b>2070</b>	<b>2627.36</b>	<b>19.75</b>	<b>0.01</b>	<b>128.18</b>		<b>128.17</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	422	93.74	0.22	0.11	0.22	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	367	244.22	0.67	0.25	1.11	0.23	0.86
<b>Date 2</b>	Feb 21	0.5 - 1 ha	103	184.64	1.79	1.33	2.45	0.38	1.11
		1 - 10 ha	125	940.25	7.52	2.67	24.24	5.41	21.57
		10 - 20 ha	3	82.95	27.65	25.58	30.47	2.53	4.89
		> 20 ha	5	327.09	65.42	49.82	113.87	27.21	64.05
<b>Baseline Dry</b>		<b>Total</b>	<b>1025</b>	<b>1872.90</b>	<b>17.21</b>	<b>0.11</b>	<b>113.87</b>		<b>113.76</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	747	165.93	0.22	0.03	0.22	0	0.19
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	576	370.62	0.64	0.25	1.11	0.23	0.86
<b>Date 2</b>	Oct 23	0.5 - 1 ha	135	237.74	1.76	1.33	2.45	0.36	1.11
		1 - 10 ha	143	1059.49	7.41	2.67	24.24	5.54	21.57
		10 - 20 ha	4	110.09	27.52	24.91	29.58	1.97	4.67
		> 20 ha	5	338.83	67.77	51.37	108.53	24.18	57.16
		<b>Total</b>	<b>1610</b>	<b>2282.70</b>	<b>17.55</b>	<b>0.03</b>	<b>108.53</b>		<b>108.50</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1582	351.41	0.22	0.00	0.22	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	988	629.94	0.64	0.25	1.11	0.22	0.86
<b>Date 2</b>	Oct 16	0.5 - 1 ha	212	365.39	1.72	1.33	2.45	0.38	1.11
		1 - 10 ha	246	1747.44	7.10	2.67	24.69	5.11	22.02
		10 - 20 ha	12	368.95	30.75	25.35	45.81	6.03	20.46
		> 20 ha	4	287.06	71.77	50.48	112.31	28.33	61.83
		<b>Total</b>	<b>3044</b>	<b>3750.20</b>	<b>18.70</b>	<b>0.00</b>	<b>112.31</b>		<b>112.31</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	981	217.58	0.22	0.00	0.22	0.01	0.22
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	921	603.54	0.66	0.28	1.11	0.23	0.83
<b>Date 2</b>	Feb 21	0.5 - 1 ha	206	358.06	1.74	1.33	2.45	0.38	1.11
		1 - 10 ha	209	1462.91	7.00	2.67	23.80	5.07	21.13
		10 - 20 ha	10	322.92	32.29	26.02	41.59	5.29	15.57

**Bosque County**

**Summary Statistics for Water Features in Acres**

		> 20 ha	3	232.21	77.40	61.56	106.38	25.13	44.83
		<b>Total</b>	<b>2330</b>	<b>3197.22</b>	<b>19.88</b>	<b>0.00</b>	<b>106.38</b>		<b>106.38</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	153	33.65	0.22	0.01	0.22	0	0.22
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	169	107.86	0.64	0.44	1.11	0.23	0.67
<b>Date 2</b>	Nov 23	0.5 - 1 ha	73	132.77	1.82	1.33	2.45	0.39	1.11
		1 - 10 ha	89	647.17	7.27	2.67	23.35	4.97	20.68
		10 - 20 ha	4	136.11	34.03	25.13	39.36	6.67	14.23
		> 20 ha	1	73.84	73.84	73.84	73.84	0.00	0.00
		<b>Total</b>	<b>489</b>	<b>1131.39</b>	<b>19.63</b>	<b>0.01</b>	<b>73.84</b>		<b>73.83</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	427	94.96	0.22	0.22	0.22	0	0
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	492	328.29	0.67	0.25	1.11	0.23	0.86
<b>Date 2</b>	Mar 31	0.5 - 1 ha	130	234.63	1.80	1.33	2.45	0.38	1.11
		1 - 10 ha	149	1009.23	6.77	2.67	21.79	4.79	19.13
		10 - 20 ha	8	243.74	30.47	24.91	41.59	5.86	16.68
		> 20 ha	2	128.32	64.16	51.37	76.95	18.09	25.58
		<b>Total</b>	<b>1208</b>	<b>2039.17</b>	<b>17.35</b>	<b>0.22</b>	<b>76.95</b>		<b>76.73</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1046	232.46	0.22	0.06	0.22	0.01	0.16
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	754	496.20	0.66	0.33	1.11	0.24	0.78
<b>Date 2</b>	Apr 18	0.5 - 1 ha	191	325.14	1.70	1.33	2.45	0.38	1.11
		1 - 10 ha	219	1572.78	7.18	2.67	24.69	5.21	22.02
		10 - 20 ha	15	477.04	31.80	25.80	47.59	5.70	21.79
		> 20 ha	4	312.84	78.21	54.71	129.41	34.60	74.71
		<b>Total</b>	<b>2229</b>	<b>3416.46</b>	<b>19.96</b>	<b>0.06</b>	<b>129.41</b>		<b>129.36</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1127	250.63	0.22	0.21	0.22	0	0.01
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	978	647.61	0.66	0.25	1.11	0.24	0.86
<b>Date 2</b>	Oct 23	0.5 - 1 ha	269	468.36	1.74	1.33	2.45	0.38	1.11
		1 - 10 ha	283	1898.58	6.71	2.67	23.13	4.76	20.46
		10 - 20 ha	8	228.84	28.61	25.35	33.14	3.10	7.78
		> 20 ha	6	483.04	80.51	53.15	108.53	21.46	55.38
		<b>Total</b>	<b>2671</b>	<b>3977.07</b>	<b>19.74</b>	<b>0.21</b>	<b>108.53</b>		<b>108.31</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	902	200.30	0.22	0.03	0.22	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	949	612.71	0.65	0.26	1.11	0.23	0.85
<b>Date 2</b>	Nov 27	0.5 - 1 ha	238	413.21	1.74	1.33	2.45	0.35	1.11
		1 - 10 ha	244	1712.44	7.02	2.67	24.69	5.24	22.02
		10 - 20 ha	13	376.29	28.95	25.35	36.70	3.20	11.34

**Bosque County**

**Summary Statistics for Water Features in Acres**

> 20 ha	5	386.95	77.39	54.26	131.68	30.97	77.41
<b>Total</b>	<b>2351</b>	<b>3701.90</b>	<b>19.33</b>	<b>0.03</b>	<b>131.68</b>		<b>131.65</b>

**Hill County**

**Summary Statistics for Water Features in Acres**

		Category	Count	Sum	Mean	Minimum	Maximum	Std Dev	Range
<b>Year</b>	<b>1997</b>	< 0.1 ha	1016	225.953	0.222	0.222	0.222	0	0
<b>Date 1</b>	Mar 3	0.1 - 0.5 ha	799	524.185	0.656	0.445	1.112	0.233	0.667
<b>Date 2</b>	Mar 28	0.5 - 1 ha	189	329.589	1.744	1.334	2.446	0.370	1.112
		1 - 10 ha	184	1310.795	7.124	2.669	23.129	5.148	20.460
		10 - 20 ha	19	630.045	33.160	25.131	47.815	6.862	22.684
		> 20 ha							
<b>Baseline Wet</b>	<b>Total</b>		<b>2207</b>	<b>3020.567</b>	<b>8.581</b>	<b>0.222</b>	<b>47.815</b>		<b>47.592</b>
<b>Year</b>	<b>1999</b>	< 0.1 ha	620	137.885	0.222	0.222	0.222	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	471	309.351	0.657	0.445	1.112	0.239	0.667
<b>Date 2</b>	Feb 21	0.5 - 1 ha	126	214.833	1.705	1.334	2.446	0.383	1.112
		1 - 10 ha	158	1226.063	7.760	2.669	24.463	5.581	21.795
		10 - 20 ha	15	497.720	33.181	25.575	44.924	6.845	19.348
		> 20 ha							
<b>Baseline Dry</b>	<b>Total</b>		<b>1390</b>	<b>2385.852</b>	<b>8.705</b>	<b>0.222</b>	<b>44.924</b>		<b>44.701</b>
<b>Year</b>	<b>2003</b>	< 0.1 ha	885	196.819	0.222	0.222	0.222	0	0
<b>Date 1</b>	Oct 14	0.1 - 0.5 ha	665	435.227	0.654	0.445	1.112	0.241	0.667
<b>Date 2</b>	Oct 23	0.5 - 1 ha	176	303.124	1.722	1.334	2.446	0.344	1.112
		1 - 10 ha	160	1130.211	7.064	2.669	24.019	4.917	21.350
		10 - 20 ha	16	518.402	32.400	25.131	46.481	7.051	21.350
		> 20 ha							
	<b>Total</b>		<b>1902</b>	<b>2583.783</b>	<b>8.413</b>	<b>0.222</b>	<b>46.481</b>		<b>46.258</b>
<b>Year</b>	<b>2004</b>	< 0.1 ha	1635	363.616	0.222	0.222	0.222	0	0
<b>Date 1</b>	Sep 7	0.1 - 0.5 ha	1198	765.483	0.639	0.445	1.112	0.227	0.667
<b>Date 2</b>	Oct 16	0.5 - 1 ha	255	436.339	1.711	1.334	2.446	0.356	1.112
		1 - 10 ha	222	1505.613	6.782	2.669	21.795	4.887	19.126
		10 - 20 ha	17	565.105	33.241	26.243	48.260	6.961	22.017
		> 20 ha							
	<b>Total</b>		<b>3327</b>	<b>3636.156</b>	<b>8.519</b>	<b>0.222</b>	<b>48.260</b>		<b>48.037</b>
<b>Year</b>	<b>2005</b>	< 0.1 ha	974	216.613	0.222	0.222	0.222	0	0
<b>Date 1</b>	Feb 14	0.1 - 0.5 ha	991	644.945	0.651	0.445	1.112	0.226	0.667
<b>Date 2</b>	Feb 21	0.5 - 1 ha	277	485.266	1.752	1.334	2.446	0.384	1.112

**Hill County**

**Summary Statistics for Water Features in Acres**

		1 - 10 ha	212	1446.678	6.824	2.669	24.241	4.824	21.572
		10 - 20 ha	20	661.180	33.059	25.131	48.037	6.540	22.907
		> 20 ha							
		<b>Total</b>	<b>2474</b>	<b>3454.681</b>	<b>8.502</b>	<b>0.222</b>	<b>48.037</b>		<b>47.815</b>
<b>Year</b>	<b>2006</b>	< 0.1 ha	241	53.597	0.222	0.222	0.222	0	0
<b>Date 1</b>	Nov 16	0.1 - 0.5 ha	271	181.919	0.671	0.445	1.112	0.236	0.667
<b>Date 2</b>	Nov 23	0.5 - 1 ha	84	147.448	1.755	1.334	2.446	0.370	1.112
		1 - 10 ha	94	657.844	6.998	2.669	22.017	4.861	19.348
		10 - 20 ha	2	64.050	32.025	31.135	32.914	1.258	1.779
		> 20 ha							
		<b>Total</b>	<b>692</b>	<b>1104.858</b>	<b>8.334</b>	<b>0.222</b>	<b>32.914</b>		<b>32.692</b>
<b>Year</b>	<b>2007</b>	< 0.1 ha	744	165.462	0.222	0.222	0.222	0	0
<b>Date 1</b>	Mar 8	0.1 - 0.5 ha	702	455.909	0.649	0.445	1.112	0.230	0.667
<b>Date 2</b>	Mar 31	0.5 - 1 ha	200	350.717	1.754	1.334	2.446	0.380	1.112
		1 - 10 ha	169	1154.007	6.828	2.669	23.351	4.791	20.683
		10 - 20 ha	10	321.583	32.158	25.353	46.481	6.604	21.128
		> 20 ha							
		<b>Total</b>	<b>1825</b>	<b>2447.678</b>	<b>8.322</b>	<b>0.222</b>	<b>46.481</b>		<b>46.258</b>
<b>Year</b>	<b>2008</b>	< 0.1 ha	1468	326.476	0.222	0.222	0.222	0	0
<b>Date 1</b>	Apr 11	0.1 - 0.5 ha	1286	831.806	0.647	0.445	1.112	0.233	0.667
<b>Date 2</b>	Apr 18	0.5 - 1 ha	345	605.804	1.756	1.334	2.446	0.384	1.112
		1 - 10 ha	287	1850.833	6.449	2.509	22.907	4.594	20.398
		10 - 20 ha	22	771.933	35.088	25.575	49.149	7.476	23.574
		> 20 ha							
		<b>Total</b>	<b>3408</b>	<b>4386.850</b>	<b>8.832</b>	<b>0.222</b>	<b>49.149</b>		<b>48.927</b>
<b>Year</b>	<b>2009</b>	< 0.1 ha	1380	306.905	0.222	0.222	0.222	0	0
<b>Date 1</b>	Sep 28	0.1 - 0.5 ha	1318	874.679	0.664	0.445	1.112	0.234	0.667
<b>Date 2</b>	Oct 23	0.5 - 1 ha	404	712.331	1.763	1.334	2.446	0.371	1.112
		1 - 10 ha	345	2194.148	6.360	2.669	23.796	4.534	21.128
		10 - 20 ha	23	802.623	34.897	25.353	49.372	6.935	24.019
		> 20 ha	5	384.298	76.860	50.261	95.852	17.578	45.591
		<b>Total</b>	<b>3475</b>	<b>5274.983</b>	<b>20.128</b>	<b>0.222</b>	<b>95.852</b>		<b>95.630</b>
<b>Year</b>	<b>2010</b>	< 0.1 ha	1300	289.113	0.222	0.222	0.222	0	0
<b>Date 1</b>	Nov 18	0.1 - 0.5 ha	1244	819.525	0.659	0.445	1.112	0.234	0.667
<b>Date 2</b>	Nov 27	0.5 - 1 ha	285	490.825	1.722	1.334	2.446	0.364	1.112
		1 - 10 ha	272	1809.182	6.651	2.669	24.019	4.855	21.350
		10 - 20 ha	15	491.270	32.751	25.131	46.925	6.914	21.795

**Hill County**

**Summary Statistics for Water Features in Acres**

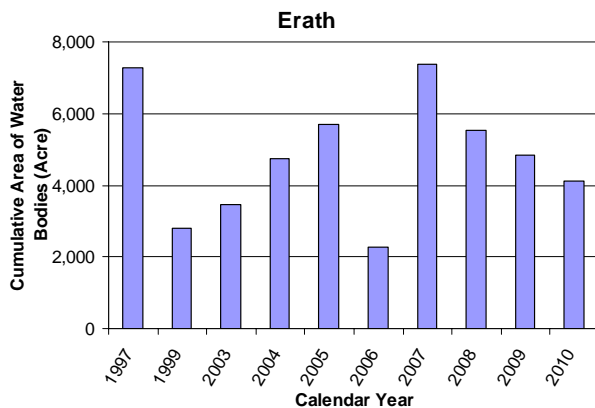
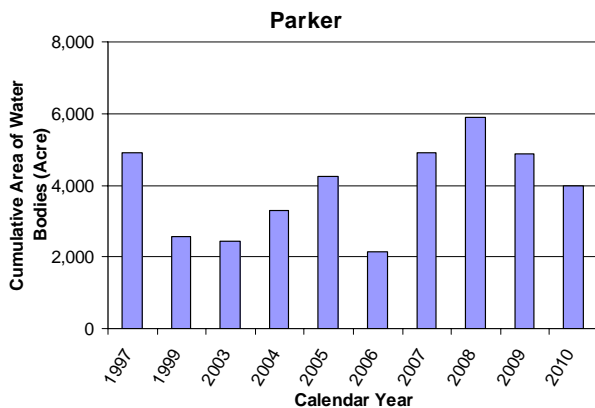
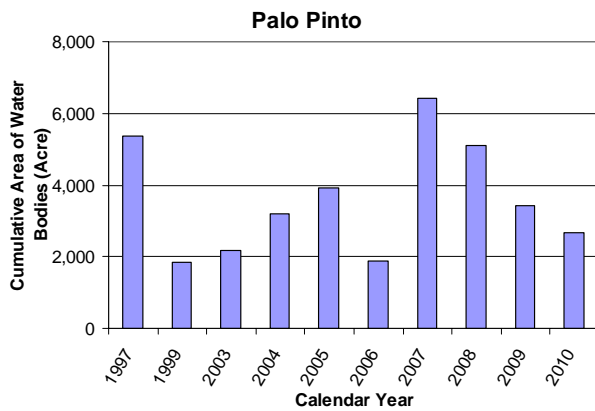
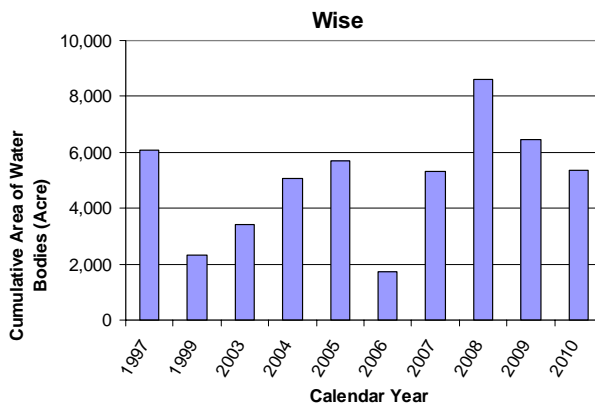
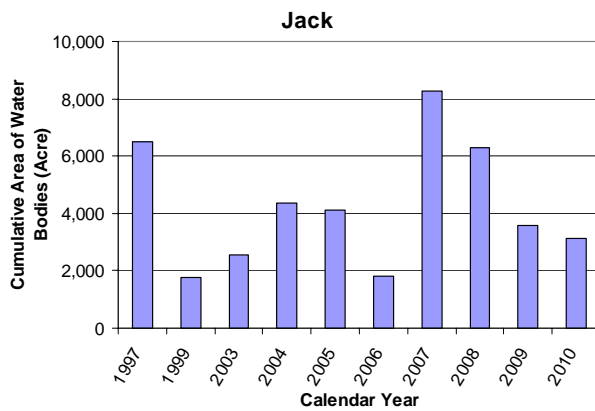
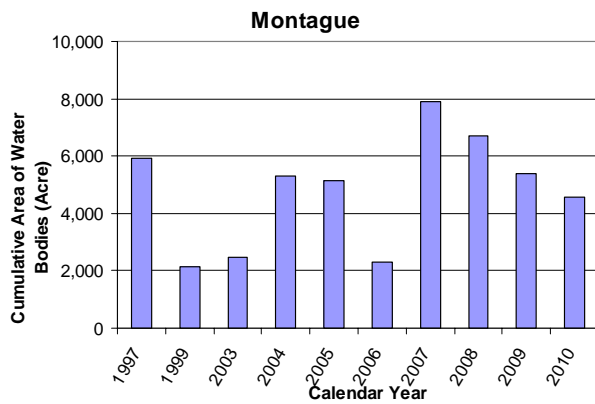
	> 20 ha						
<b>Total</b>	<b>3116</b>	<b>3899.916</b>	<b>8.401</b>	<b>0.222</b>	<b>46.925</b>	<b>46.703</b>	

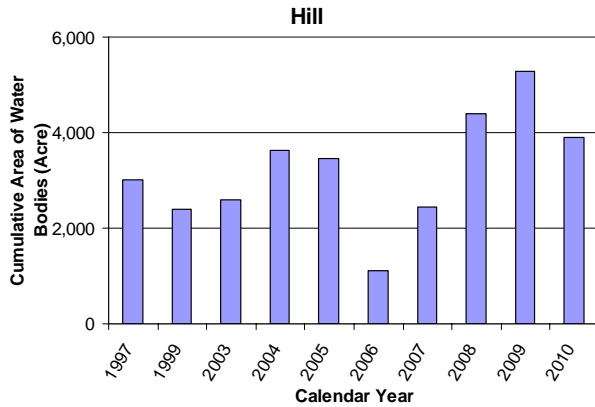
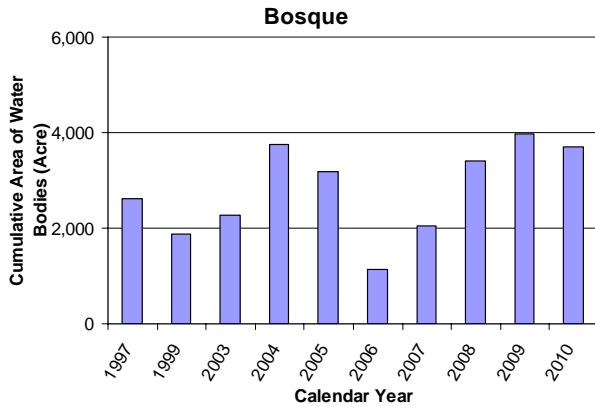
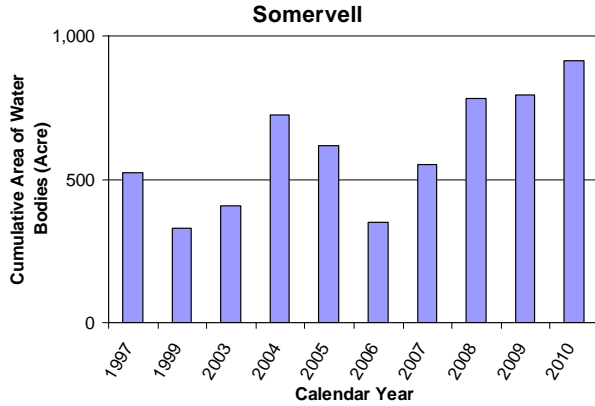
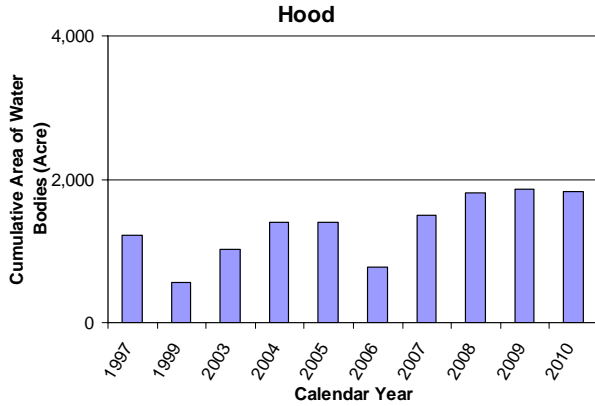
# 11 Appendix C: Plotting Results of Surface-Water-Body Study

This appendix presents three sets of plots:

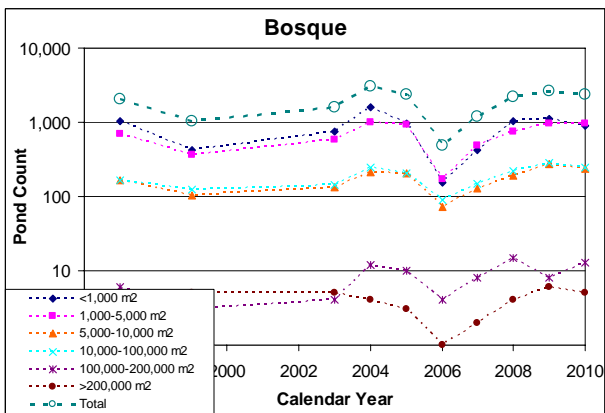
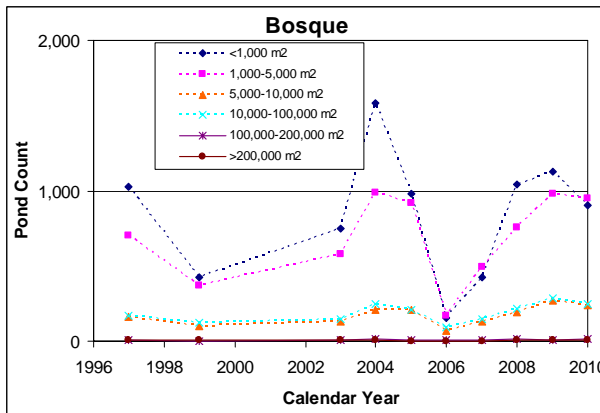
- Water-body cumulative surface area per county for selected times
- Water-body count per county for selected times
- Comparison of pond intensity (acre per square mile for each county) and drilling activity

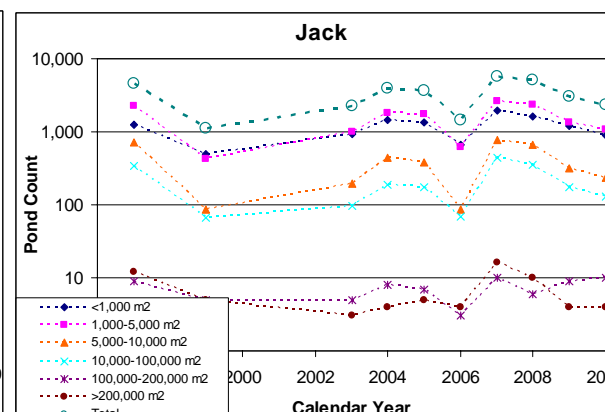
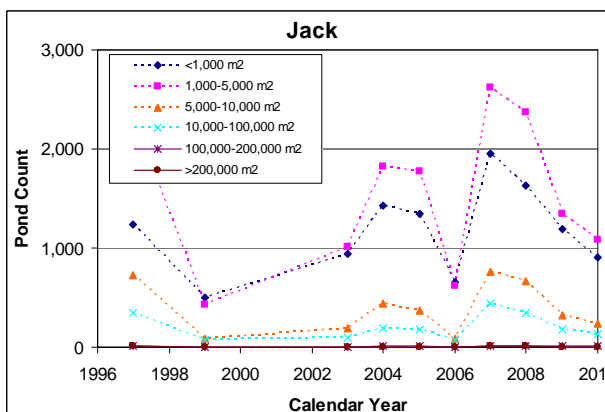
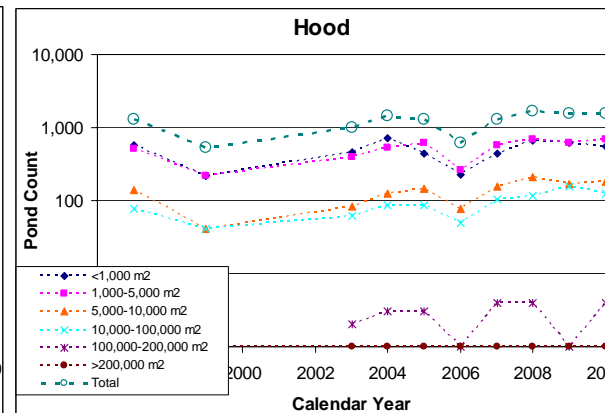
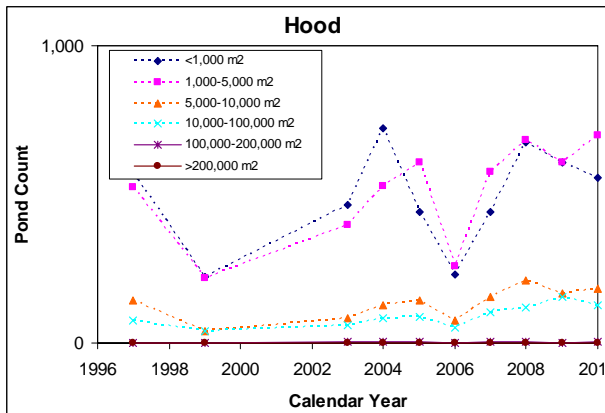
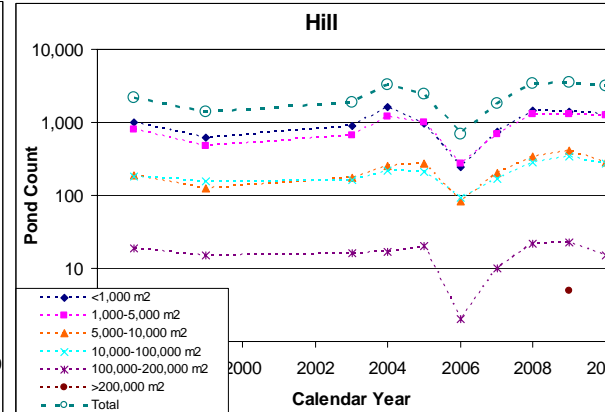
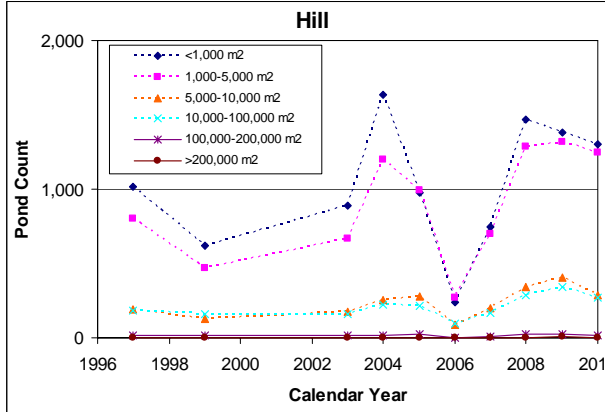
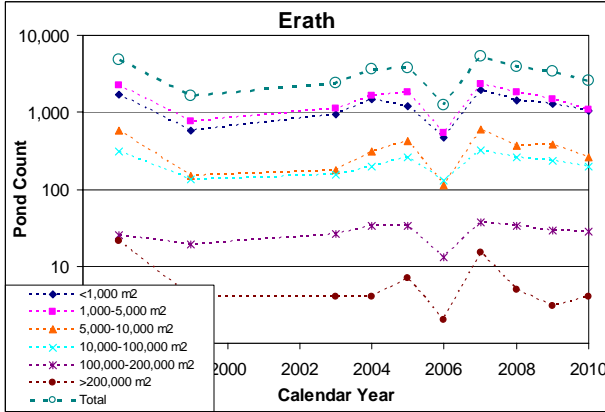
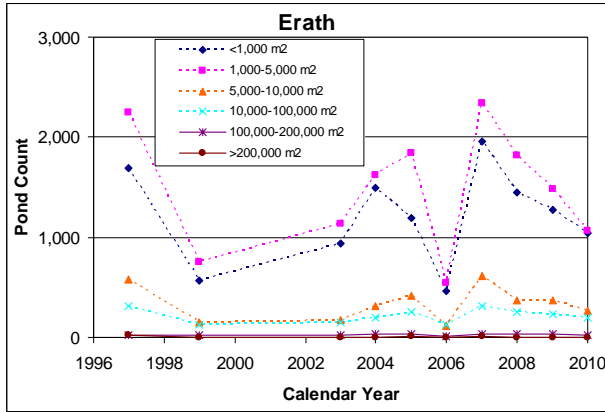
1- Plots displaying for each county (Montague, Jack, Wise, Palo Pinto, Parker, Erath, Hood, Somervell, Bosque, and Hill) the cumulative surface area of non-state waters for selected times, as described in the main text.

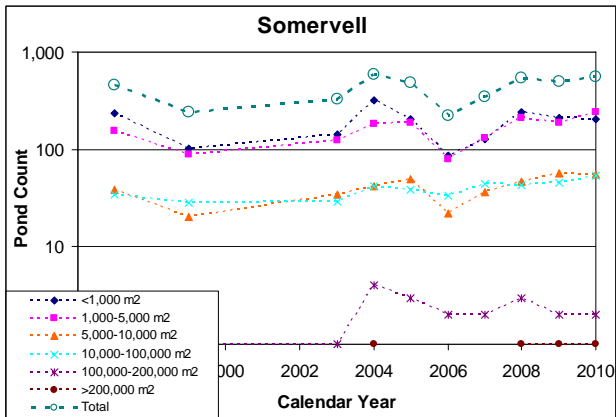
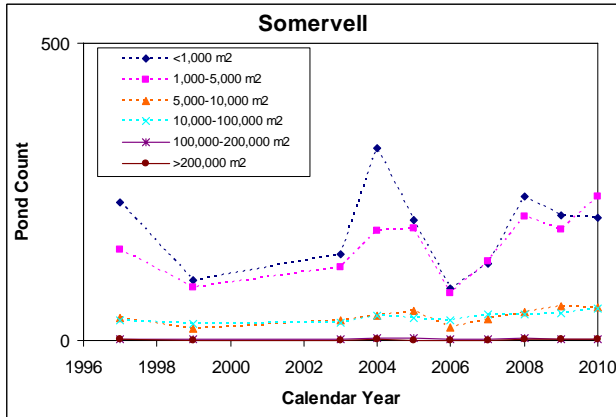
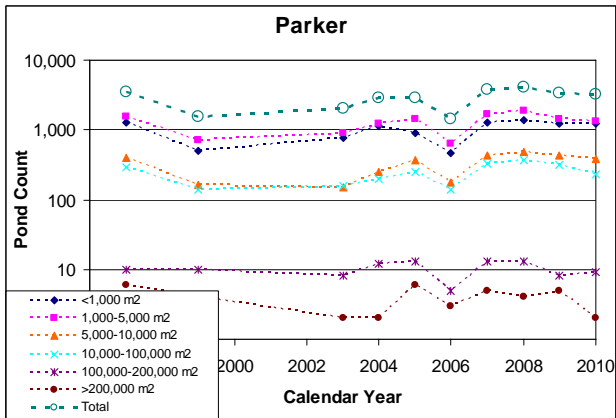
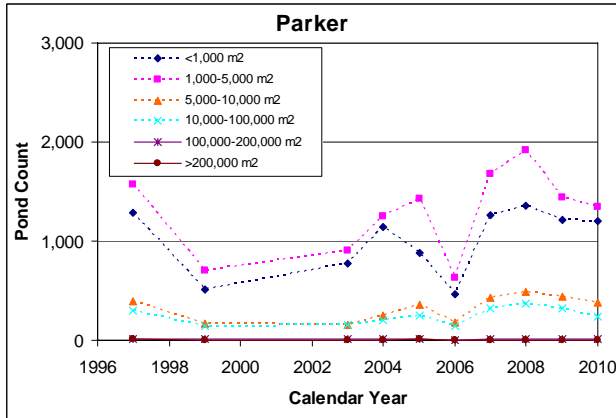
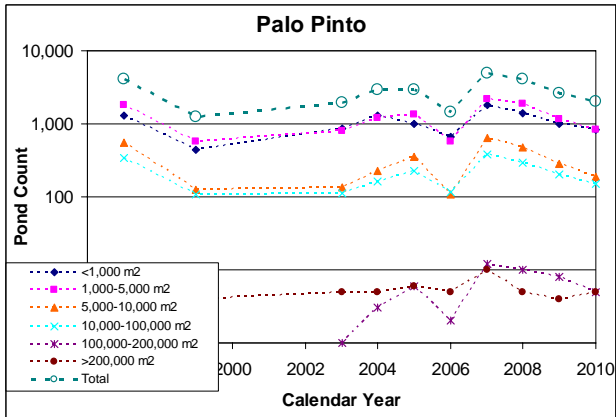
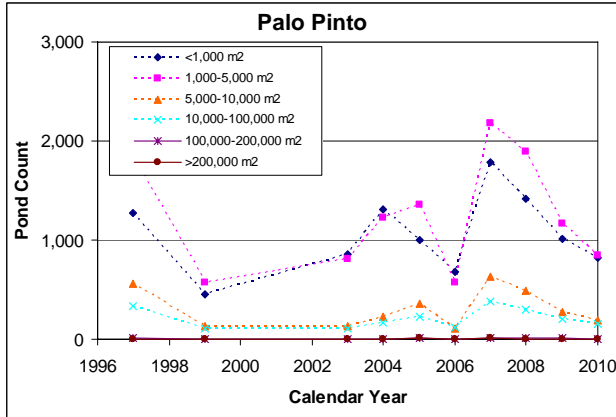
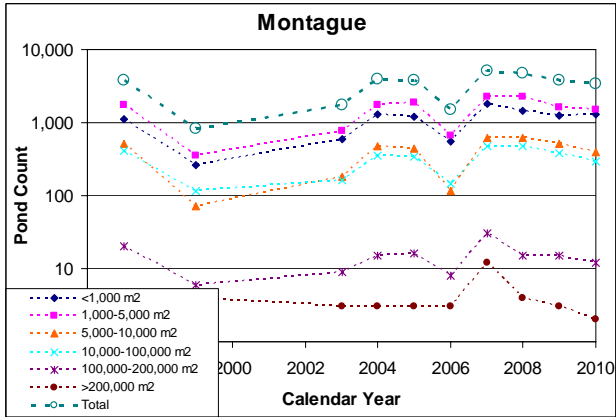
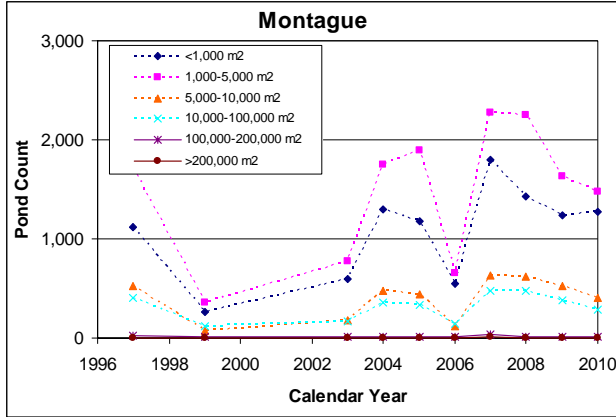


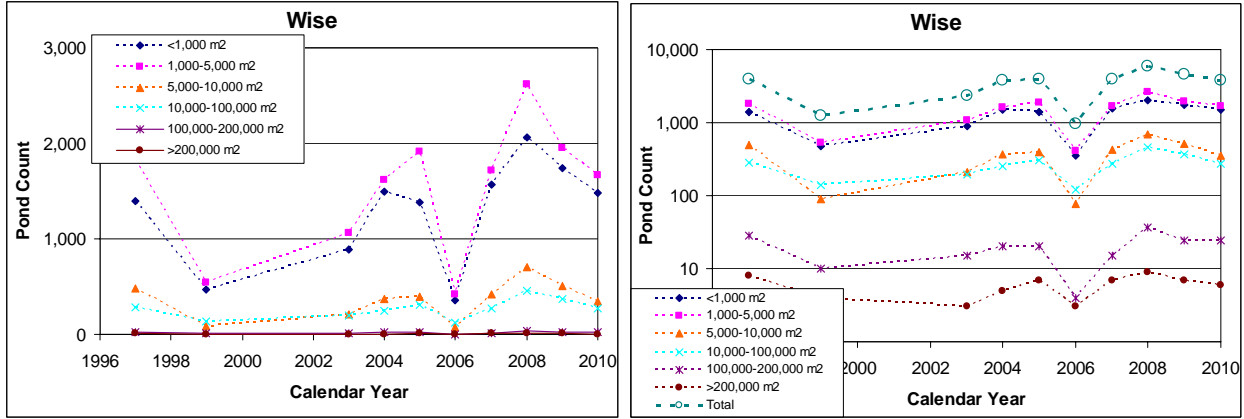


2- Plots (linear scale and log scale on left-hand and right-hand sides, respectively) displaying number of ponds in each category (<1,000 m<sup>2</sup>, between 1,000 and 5,000 m<sup>2</sup>, between 5,000 and 10,000 m<sup>2</sup>, between 10,000 and 100,000 m<sup>2</sup>, between 100,000 and 200,000 m<sup>2</sup>, and >200,000 m<sup>2</sup>) for each county (Montague, Jack, Wise, Palo Pinto, Parker, Erath, Hood, Somervell, Bosque, and Hill) for selected times, as described in the main text.









3- Plots contrasting completion count (extracted from IHS Energy database and calculated on a 1/10 of a year basis) and pond intensity (acre per square mile) per county (Montague, Jack, Wise, Palo Pinto, Parker, Erath, Hood, Somervell, Bosque, and Hill).

