Carrizo-Wilcox Aquifer Study

Final Contract Report

Submitted to Texas Commission on Environmental Quality
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Executive Summary Overview

The 81st Texas Legislature directed the Texas Commission on Environmental Quality (TCEQ) to *"conduct a study of the characteristics and impacts on groundwater planning in the Carrizo-Wilcox Aquifer."* (General Appropriations Act, Article VI, Texas Commission on Environmental Quality, Rider 36) In order to accomplish the legislative intent of this study, the TCEQ entered into a research contract with the Bureau of Economic Geology at The University of Texas at Austin (BEG) to collect and review a wide variety of information, develop datasets and conduct a series of analyses regarding current activities related to groundwater management of the Carrizo-Wilcox Aquifer in Texas.

This Executive Summary prepared by the BEG is submitted to fulfill requirements of the TCEQ Carrizo-Wilcox Study, Project 582-8-75374-119. Specifically, this Executive Summary provides an overview of results from the Carrizo-Wilcox Study (the Study). This Executive Summary is organized into the following five major thematic sections: (1) analysis and results from stakeholder surveys developed to solicit input from interested parties, including groundwater conservation districts (GCDs) with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, (2) summary of the adequacy of science utilized by GCDs during development and adoption of desired future conditions, management plans, rules, and formal procedures, (3) evaluation of desired future conditions, management plans, rules, regional water plans, and the potential for conflict, (4) an evaluation and critique of the State's Groundwater Availability Models for the Carrizo-Wilcox Aquifer, and (5) an assessment of whether the presence of anthropogenic contaminants in the recharge area of the Carrizo-Wilcox Aquifer and potential pollution of the aquifer are issues that should be addressed.

All information presented in this Executive Summary has been compiled and summarized from information contained in a series of eight Summary Reports developed to address specific tasks in the Study scope of work. These eight Summary Reports are available for review at the Study Website located at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.0 Survey Results from Interested Stakeholders

1.1 Carrizo-Wilcox Aquifer Stakeholders

At the beginning of the Study, our efforts were primarily focused on identifying, contacting, and soliciting feedback from targeted interest groups and individuals directly or indirectly involved with the Carrizo-Wilcox Aquifer. In order to compile and contact potential stakeholders of the Carrizo-Wilcox Aquifer, the following efforts were completed.

- A project website was created at http://www.beg.utexas.edu/cswr/aquiferstudy/ that contained a link inviting individuals and interested groups to sign up as a stakeholder.
- State agencies, trade and professional organizations such as Texas Alliance of Groundwater Districts, Texas Water Conservation Association, Texas Rural Water Association, and Texas Section American Water Works Association were contacted with requests to post links on the organization's websites advertising the Study and the request for stakeholders to participate.
- A list of water user groups with contact information from the 2006 and draft 2011 regional water plans for all regional water planning groups currently using or planning to use the Carrizo-Wilcox Aquifer at any point in the 50-year planning horizon were obtained from the TWDB.
- A list of water users of the Carrizo-Wilcox Aquifer and their contact information that have submitted a water use survey was obtained from the TWDB.
- A variety of sources were used to compile a complete list of all GCDs with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, including current contact information.
- Sign up lists from a 2009 Carrizo-Wilcox Aquifer Symposium held at Texas A&M University were obtained from the TWDB.

The final stakeholder list contains approximately 517 names, the majority of which include email contact information (see separate electronic attachment). This stakeholder list was used throughout the course of the Study to disseminate results, findings, and information on future meetings.

1.2 Carrizo-Wilcox Study Online Survey

The primary process for soliciting comments from stakeholders of the Carrizo-Wilcox Aquifer was through online surveys developed specifically for this Study. Two separate surveys were developed to solicit focused information from (1) interested parties and from (2) GCDs. Draft surveys were presented to TCEQ for review prior to their release. Complete surveys are available for review at the Study Website located at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.3 Summary and Representative Responses to Carrizo-Wilcox Aquifer Study Survey

There are a variety of stakeholders within the Carrizo-Wilcox Aquifer, representing numerous interests such as municipalities, regional water suppliers, environmental interests, private property owners, agriculture, industry, and locally governed GCDs. All identified interests were invited to participate in the Study by responding to surveys developed to collect information regarding the Carrizo-Wilcox Aquifer and any predominant groundwater management and protection concerns. The following sections summarize selected responses to the survey questionnaires. For the complete set of responses, the reader is referred to the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/.

1.4 Interested Parties' Responses

There were 65 unique responses received, either directly to the BEG (via email or other correspondence) or through the online Carrizo-Wilcox Aquifer Interested Parties Survey.

In the Interested Parties Survey, participants were asked to *"Provide a brief description of any predominant groundwater management or protection issues and concerns related to the Carrizo-Wilcox Aquifer."* This was the question for which almost all responses were focused. Generally, the responses can be divided into four broad categories:

- Wholesale and retail water providers concerned about the future of groundwater management in the Carrizo-Wilcox Aquifer
- Environmental interests concerned with inadequate focus on environmental protection during adoption of desired future conditions, management plans, and rules by Carrizo-Wilcox GCDs
- Citizens concerned about property rights being violated by the Lost Pines Groundwater Conservation District
- Citizens in Gonzales County concerned about their ability to sell their groundwater due to actions by the Gonzales County Groundwater Conservation District

Wholesale and retail water providers survey comments focused on a number of issues related to their ability to continue to provide water supplies to their current and future customers. For example, San Antonio Water System and Schertz Seguin Local Government Corporation commented on difficulties they experienced during water supply project implementation due to inconsistencies in the permitting process from one district to another and their inability to obtain long-term commitments for water supply permits. San Antonio Water System commented regarding the variability in local groundwater conservation district philosophies and rules that "*This regulatory inconsistency adds unnecessary difficulty to both long-term planning for water supply projects, as well as planning for the aquifer on a hydrologic basis."* Canyon Regional Water Authority commented that the "crisis" in management of the Carrizo-Wilcox Aquifer is not based on actual hydrologic data. Specifically, Canyon Regional Water Authority commented that, "*Over the past several years, public awareness of groundwater issues and concerns over the availability of future supplies has grown dramatically. Fueling much of the anxiety is a fear of the impending "drying up" of Texas' aquifers. However, the common perception that we are recklessly "mining" groundwater and that future generations will be left with meager and dwindling supplies is unfounded. On the contrary, the large amount of available hydrogeologic data indicates that the Carrizo-Wilcox aquifers are vast and largely underdeveloped resources that contain enough water to supply all of Central and South Texas' needs for centuries."*

The City of Bryan submitted two sets of comments to the Study. The following is a portion of the comments submitted by the City of Bryan along with recommendations:

"…When Senate Bill 2 passed in 2001, the Texas Water Development Board was directed to 'designate groundwater management areas covering all major and minor aquifers in the state…Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources. To the extent feasible, the groundwater management area shall coincide with the boundaries of a groundwater reservoir or a subdivision of a groundwater reservoir.' (Sec. 35.004, Senate Bill 2, 77th Texas Legislature).

In response to this directive, the Texas Water Development Board designated 16 groundwater management areas, based almost exclusively on the boundaries of major and minor aquifers throughout the state. Recognizing the natural hydrologic divide effect that the Colorado and Trinity rivers have on groundwater flow in this critical groundwater resource, the Carrizo-Wilcox Aquifer, which covers all or parts of more than 60 counties in Texas, was divided into three groundwater management areas.

It is noteworthy to reflect on the directive from the Texas Legislature in 2001, 'Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources'. If the Carrizo-Wilcox Aquifer is to be managed as effectively as possible in order to ensure that it remains a high quality, cost-effective, reliable water supply for the citizens of Texas, including the City of Bryan, then the most effective form of groundwater management should be utilized. However, the Carrizo-Wilcox Aquifer is currently managed, in part by 24 groundwater conservation districts, and in other areas, still has no management.* (*- reader's note - for this study, it has been determined that there are 21 confirmed GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.)

Therefore, the City of Bryan requests;

- *Continued legislative review to ensure hydrologically-based management of the Carrizo-Wilcox Aquifer,*
- *Continued legislative support for financial resources necessary to develop, update, and maintain science necessary to make sound policy and regulatory decisions, and*
- *Legislative review regarding ownership of groundwater as it relates to investments made by political subdivisions, such as the City of Bryan, to ensure that these investments will not be negatively harmed by any adopted desired future conditions or regulatory methods developed and adopted by groundwater conservation districts."*

The Brazos River Authority, a large wholesale water supplier over a significant portion of the Carrizo-Wilcox Aquifer expressed concerns regarding (1) GCDs that treat local use differently than nonlocal use in permitting, (2) that current regulations encourage "use it or lose it" mentality, i.e., current district rules give no incentive to keep water in place, (3) the rules do not address conjunctive use with any specificity and in practice work against the concept, (4) permits give no assurance to continued access to the water in the "out" years, and (5) differences in groundwater management philosophies of adjacent GCDs managing and regulating essentially the same supply of water will result in recurring problems and conflicts with no clear solutions.

Environmental Stewardship submitted comments regarding concerns that the groundwater management area joint planning process and individual GCDs need to adequately capture the need to sustain spring flows and base flows to streams and rivers as a component of establishing desired future conditions. Environmental Stewardship's primary conclusion is that the groundwater management area process and GCDs have a duty and obligation to include rivers, streams and springs in the adopted desired future conditions of the Carrizo-Wilcox Aquifer.

Thirty-five comment letters (form letters) were received from landowners who are concerned that their property rights are being violated through the actions of the Lost Pines Groundwater Conservation District. This letter states that the moratorium placed on groundwater permits in the Lost Pines Groundwater Conservation District is preventing the citizens from selling their water to the Guadalupe-Blanco River Authority for future water supplies. The letter is reproduced below in its entirety.

"As a constituent landowner in Texas, I am writing to let you know I feel my property rights are being violated. The Lost Pines Groundwater Conservation District (LPGCD) is blocking my rights to sell my ground water. The Rule of Capture has been in effect in the State of Texas since 1904. Although tested more than once, the Texas State Supreme Court has upheld this law in every case. The legislative creation of groundwater conservation districts has, because of the actions and policy of our local district, taken away my rights to my water, and has given it to the District. The District is not bound to either its constituents or science. "Life" terms for board members, and appointee vs. elected official status, gives board members free rein to act on political motivation and personal bias, with no accountability to anyone. Across the state, districts are "hoarding" resources that are the property rights of landowners. The Carrizo Wilcox aquifer has more than enough water to meet the projected demands in our district for decades beyond the 50-year planning period. The Guadalupe Blanco Water Authority has signed a letter of intent to purchase much needed municipal water supplies from my land, water that I have a legal right to sell. In addition, the project would generate considerable revenues for our county. The Lost Pines Groundwater Conservation District is attempting to block this sale. The District has placed a moratorium on issuing any permits for water to be exported outside the district pending the setting of Desired Future Conditions (DFC's) by the TWDB. The neighboring district, Post Oak Savannah Groundwater Conservation District, does not have a moratorium and is still issuing permits regardless of the DFC's. The district has denied the landowners the right to participate or comment on rules, reservations, or any action that could impact landowners by refusing to post all meetings, except their regularly scheduled monthly meetings, and denying attendance in any meeting met with less than a forum. Therefore, the LPGCD is interfering with the free market system and placing all landowners within the District at a disadvantage because of denying due process."

Thirteen comments were received from a group of landowners and board members of Gonzales-Carrizo Management, Inc. This is a group of landowners who organized and arranged to lease groundwater to Texas Water Alliance—a division of the San Jose Water Company. These survey responders state that they own property in eastern Gonzales County. This set of comments states, "*Our main concern is being able to lease our water rights. We want parity (for our eastern side of the county) with the western side of the county, with regard to the number of allocable acre feet that we are allowed to lease*."

In response to a request to *"Provide a list, with sufficient detail to allow for an availability analysis, of any new or alternative water management strategies that are being considered for future implementation that may impact groundwater availability in the Carrizo-Wilcox Aquifer, but are not currently in the regional and state water plans"*, two responses were received. First, the Schertz-Seguin Local Government Corporation submitted a preliminary project description for expansion of the existing Schertz-Seguin Local Government Corporation Project well fields in Gonzales and Guadalupe counties to include wells and/or well fields in Wilson County to provide a project yield of 10,000 acre feet per year by the year 2020. Second, Environmental Stewardship submitted a substantial set of comments and information that supported the process of establishing desired future conditions. Environmental Stewardship has been involved in the joint planning process leading to the establishments of desired future conditions, and is supporting the need to ensure sustainable management of the groundwater resources including the protection of spring flow and base flow into streams and rivers from the Carrizo-Wilcox Aquifer. Due to the volume of information submitted by Environmental Stewardship, the reader is encouraged to review the complete set of comments and information submitted by Environmental Stewardship on this survey request at the Study website. Canyon Regional Water Authority submitted a lengthy commentary under this question, titled *Observations on the Regulation of the Carrizo-Wilcox Aquifer in Central and South Central Texas*. However, the content of this commentary was determined to not be related to this question. It is included in its entirety on the Study website link for survey responses.

One question from the Interested Parties Survey asked *"Are you aware of any compatibility issues that have already been documented or that may occur as a result of the implementation of any district's management plan? If yes, please describe the nature of the compatibility issue."* Six "yes" responses addressing Question 7 were received, all but one of which were from either wholesale or retail water suppliers. The main concerns raised were (1) conflicts between GCDs over different approaches to the issuance of production permits and in their interpretation and application of Chapter 36 requirements, (2) conflicts between regional water planning groups and GCDs in that the regional water planning groups have incorporated water supplies from the Carrizo-Wilcox Aquifer in volumes that are reported to be in excess of what the Carrizo-Wilcox Aquifer ecosystem can sustain, (3) that GCDs through the groundwater management area joint planning process should submit desired future conditions that are based on preferred hydrogeologic parameters and not geographically specific production amounts, which will allow

TWDB to calculate a managed available groundwater estimate for the GCDs to manage, and (4) absence of required coordination between GCDs and regional water planning groups will lead to significant uncertainty about the reliability of water management strategies in the regional water plans. There were 12 “no” responses.

Another question posed in the Interested Party Survey was *“Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current or potential aquifer contamination.”* The Schertz-Seguin Local Government Corporation reported that “…there are numerous wells in the Carrizo Formation. Some are old wells that were originally used for irrigation of crops. There are also numerous oil wells that have been converted to water wells. Some of these wells are deteriorated and should be plugged but landowners are reluctant to assume financial responsibility for maintaining wells that are no longer in use.” Bexar Metropolitan Water District pointed to possible management or regulatory gaps because of the many different GCDs and their rules and the lack of consistency between them. The absence of any interstate and bi-national management of the aquifer could lead to potential future contamination of the aquifer. The City of Bryan reported that they were unaware of what regulatory controls are in place to manage the recharge zone. The City of Bryan went on to suggest that the recharge zone should be considered a sensitive area in order to protect these areas from sources of contamination such as from manufacturing or commercial industries. Forty-eight respondents did not answer this question.

Finally, a few other comments were received regarding the need for the Study and other issues that were not specific to the questions posed in the survey. These comments are included in the online database.

1.5 Carrizo-Wilcox Aquifer Groundwater Conservation Districts’ Responses

For the purposes of this Study, 21 confirmed GCDs are recognized as having statutory responsibilities regarding the management and conservation of groundwater resources in the Carrizo-Wilcox Aquifer. The 21 GCDs are:

1. Anderson County Groundwater Conservation District
2. Bee Groundwater Conservation District
3. Bluebonnet Groundwater Conservation District
4. Brazos Valley Groundwater Conservation District
5. Evergreen Underground Water Conservation District
6. Fayette County Groundwater Conservation District
7. Gonzales County Underground Water Conservation District
8. Guadalupe County Groundwater Conservation District

9. Live Oak Underground Water Conservation District
10. Lost Pines Groundwater Conservation District
11. McMullen Groundwater Conservation District
12. Medina County Groundwater Conservation District
13. Mid-East Texas Groundwater Conservation District
14. Neches and Trinity Valleys Groundwater Conservation District
15. Panola County Groundwater Conservation District
16. Pineywoods Groundwater Conservation District
17. Plum Creek Conservation District which is a WC&ID
18. Post Oak Savannah Groundwater Conservation District
19. Rusk County Groundwater Conservation District
20. Uvalde County Underground Water Conservation District
21. Wintergarden Groundwater Conservation District

The confirmation election for the Harrison County Groundwater Conservation District was defeated by the voters during a May 8, 2010, election. It is not authorized to hold any subsequent election, and therefore is dissolved.

Sixteen GCDs (76 percent of the total) responded to the survey request. Survey responses were not submitted by:

1. Anderson County Groundwater Conservation District
2. Bee County Groundwater Conservation District
3. Guadalupe County Groundwater Conservation District
4. Live Oak Groundwater Conservation District
5. McMullen County Groundwater Conservation District

The overarching purpose of the survey was to collect information necessary to evaluate the scientific foundation of the management plans, rules and regulations promulgated by these Carrizo-Wilcox Aquifer GCDs.

The 16 responding GCDs had three common responses to the survey question regarding predominant groundwater management and/or protection issues and concerns related to the Carrizo Wilcox Aquifer. These responses can be characterized as concerns regarding (1) availability of water supplies and challenges involved in the establishment of desired future conditions (2) need for continuous improvement of available science for purposes of decision making (3) and perceived lack of regulatory oversight by the RRC regarding oil and gas activities. Allegations are made in some of the surveys that lack of regulatory oversight has contributed to contamination of local groundwater supplies.

Of the 16 GCDs, 7 responded that their districts' primary concern was establishment of desired future conditions that will result in protection and conservation of available groundwater resources in their district. For example, Plum Creek Conservation District (PCCD) stated their primary concern was incorporation of desired future conditions into their management plan and were also concerned that "permitting outside the boundaries of the PCCD that could impact the amount of water that would be available to satisfy local needs in the future". Lost Pines Groundwater Conservation District stated that "it appears that LPGCD has already permitted more than the anticipated total of the MAGs for the district" that were established by Groundwater Management Area 12. Moreover, Lost Pines Groundwater Conservation District noted that export of groundwater resources outside of the district is on the rise and that "13.5 percent of the total pumpage from nonexempt wells was exported from the district." Current and future groundwater production capabilities are of serious concern to three quarters of the districts that responded to the survey.

Of the 16 GCDs, 3 cited a lack of readily available groundwater science resources that could help them make important short-term and long-term decisions. Rusk County GCD stated the need for more technology specifically aimed at monitoring "pumping, spring flow and aquifer volume." Brazos Valley Groundwater Conservation District concerns included establishment of groundwater production limits and development of Depletion Management Zones to "alleviate the depletion stress on the aquifer," which are to be based upon "best available science." Post Oak Savannah Groundwater Conservation District stated "our District has significant concerns with the reliability of the GAM predictions of the groundwater levels in the CW Aquifer". Districts throughout the Carrizo-Wilcox Aquifer expressed uncertainty derived from the availability of accurate local groundwater science and districts ability to forecast future demand.

RRC of Texas (RRC) groundwater management policies and enforcement procedures were a primary concern for 6 of the 16 GCDs. The RRC ability to comprehensively regulate oil and gas exploration, production, and transportation companies is contested because of the perceived inability to effectively regulate groundwater support wells and their inability to eliminate the occurrence of orphan or abandoned wells. Neches and Trinity Valleys Groundwater Conservation District stated concerns regarding *"inadequate oversight by the RRC of oil and gas wells and rig supply wells, including the many old wells within the district, which has presented many potential sources of contamination of groundwater."* GCDs in the eastern region of the Carrizo Wilcox Aquifer, including Panola County Groundwater Conservation District, Plum Creek Conservation District, Neches and Trinity Valleys Groundwater Conservation District, and Rusk County Groundwater Conservation District noted that there are regulatory concerns with the management of oil and gas exploration and the oversight provided by Texas agencies including the RRC and Texas Department of Licensing and Regulation (TDLR). For instance, Rusk County GCD stated *"With each oil/gas exploration well drilled, a water well is drilled to support the operation. Due to lack of staffing, the TDLR does not conduct any construction inspections of these water wells. Our concern is for the illegal practice of screening more than one zone to gain the quantity of water needed. This practice, although not a major problem while the rig is in use, becomes a problem when the well is capped and left idle. The RCGCD purchased a down hole video camera in 2008 and requires inspection of each of these support wells within 180 days of the oil/gas rig leaving the pad. We have inspected over 300 wells and have found that about 11% were screened in more than one zone."* Neches and Trinity Valleys GCD stated *"Inadequate oversight by the RRC of the oil and gas wells and rig supply wells, including the many old wells within the District, which has presented many potential sources of contamination of groundwater."* Panola GCD stated *"lack of regulation by RRC of water wells involved in oil and gas operations and mining."* Plum Creek CD stated *"There are management and regulatory gaps from the RRC that could possibly lead to contamination of the recharge zone. These gaps are from past production practices and casing leaks."* The aforementioned comments were submitted to the Carrizo-Wilcox Aquifer Study GCD survey.

Moreover, Rusk County GCD noted that the recharge zone for the Carrizo Wilcox Aquifer extends beyond the borders of Texas and suggested that a management or regulatory gap could lead to contamination of the recharge zone. Rusk County GCD suggested that this gap should be addressed by the TWDB or some other state entity if it is not currently under study. Rusk County GCD also noted extensive strip mining operations in the recharge area. The strip mining process includes removing 200 to 300 feet of earth to mine the lignite. Once mined, the overburden is then replaced. This mixing of the overburden and removal of the lignite may have an effect on recharge for the Carrizo Wilcox Aquifer. Rusk County GCD noted that this issue should be evaluated in future studies.

1.6 Carrizo-Wilcox GCDs' Enforcement of Substantial Violations

As part of the Study, information was compiled regarding the enforcement of substantial violations of Carrizo-Wilcox GCDs rules. The BEG was asked to *"Evaluate each groundwater conservation district for enforcement of substantial compliance with its rules. Tabulate number of enforcement actions since September 1, 2007. This information will be obtained from the groundwater conservation districts (GCDs) using an online survey.*"

In the survey to the 21 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer, the specific information requested was "*Provide a list of all substantial enforcement actions taken for violations of district rules since September 1, 2007. The district should include in this list the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance*." Enforcement actions that promote current and future compliance with GCD rules are considered positive enforcement actions. Alternatively, enforcement actions where violators simply choose to pay a fine and continue to be in noncompliance are considered by the Study team to be negative enforcement actions. That is, the enforcement approach is not a deterrent to future violations

Of the 16 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer that responded to the survey 13 indicated that they did not pursue either formal or informal enforcement actions for violations of their rules. Three GCDs indicated that they had carried out formal enforcement action under their rules since September 1, 2007. Pineywoods GCD cited nine enforcement actions since September 2007. Eight of the nine violations were resolved through positive enforcement actions. These violations include failing to register a well, well contamination, and well construction without a permit. Fines and fees were assessed by the Pineywoods GCD and paid by the violators. The violations were resolved resulting in compliance with the rules. Neche*s* & Trinity Valley GCD reported two enforcement actions that had been ongoing or resolved since September 1, 2007. In both enforcement actions the Neches & Trinity GCD was able to bring the violators into compliance through the use of the courts and assessing fines. These actions may be considered positive enforcement actions as the violators did not simply elect to pay the fees and continue to violate district rules. Post Oak Savannah GCD made a total of six positive enforcement actions, for which a total of $1,700 in fines was assessed from April 8, 2008 through February 9, 2010. The following Post Oak Savannah GCD rules were violated: one infraction of Rule 7.12, Drilling Permits; two infractions of Rule 7.13, Drilling or Altering a Well; two infractions of Rule 7.3, Records, Reports, and Drillers Logs;, and one infraction of Rule 8.2, Application for Transport Permit. The fines assessed per violator ranged from $100 to $900.

The Interested Parties Survey contained the following parallel request: "*Provide a list of any substantial enforcement actions, regardless of ultimate resolution, taken for violations of district rules since September 1, 2007. In as much detail as possible, include the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance.*" Of the 65 responses to the Interested Party Survey, there were no responses regarding enforcement actions taken by the GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.

2.0 Adequacy of Science Utilized by GCDs during the Development and Adoption of Desired Future Conditions, Management Plans, and Rules

A significant element of the Study was to, *"Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to (1) statutory authority and (2) to any science that was considered during development of the rules. Link individual GCD plan goals, objectives, and performance standards to any science that was considered in their development. Link individual GCD permitting procedures and decisions since September 1, 2007 to any science used in their development."* In order to accomplish this task, we requested specific information from the

GCDs in an online survey.

An evaluation of GCD management plans, rules, and procedures was conducted in order to determine whether they are based on sound scientific principles. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are now available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/ .

We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific rules to both broad or GCD-specific statutory authority and any supporting science that was considered during the development of the management plans and rules. One additional management plan for Anderson County Groundwater Conservation District was obtained from the TWDB, but no rules have been located. A complete set of management plans and rules are available for review online at the Carrizo-Wilcox Aquifer Study website at http://www.beg.utexas.edu/cswr/aquiferstudy/gcd_rules.php/.

2.1 Groundwater Science and Texas Water Law

Eleven of sixteen GCDs provided supporting information to the Study's request for *"electronic copies of any scientific data, reports, or presentations presented to and considered by the district during development of the current management plan."* All 16 GCDs articulated, to varying degrees, their reliance on groundwater science, including information from groundwater availability models that are produced and provided by the Texas Water Development Board. Nine of the 16 GCD's cited the 2007 State Water Plan and applicable regional water plans as a source for science used in developing their management plans.

The history of groundwater science in Texas is long and rich, with substantial contributions made by state agencies such as the Texas Water Development Board (and the predecessor agency, the Texas Board of Water Engineers), the Texas Commission on Environmental Quality (and predecessor agencies), groundwater conservation districts, and federal agencies such as the United States Geological Survey. After the passage of Senate Bill 1 in 1997 by the 75th Texas Legislature, the need for improved, more site-specific groundwater science was realized. This need for improved groundwater science was at least initially the result of (1) the new requirement that GCDs develop and adopt management plans (Texas Water Code, §36.1071), and (2) the regional water planning process requiring water plans be developed for the next 50 years (Texas Water Code, §16.053). As a result of this realization, the 77th Texas Legislature passed Senate Bill 2 in 2001. This legislation, in part, requires that, "*the executive administrator* (of the Texas Water Development Board) *shall obtain or develop groundwater availability models for major and minor aquifers in coordination with groundwater conservation districts and regional water planning groups created under Section 16.053 that overlie the aquifers. Modeling of major aquifers shall be completed not later than October 1, 2004. On completing a groundwater availability model for an aquifer, the executive administrator shall provide the* *model to each groundwater conservation district and each regional water planning group created under Section 16.053 overlying that aquifer*" (Texas Water Code, §16.012(l)). In recognition of the improved groundwater science that would ultimately result from this directive, Texas Water Code, Chapter 36 was also amended to provide guidance to GCDs with regards to one of the primary sources of groundwater science to be considered in developing management plans and rules necessary to achieve the goals adopted in the management plans. Texas Water Code §36.1071(h) states, "*In developing its management plan, the district shall use the groundwater availability modeling information provided by the executive administrator together with any available site-specific information that has been provided by the district to the executive administrator for review and comment before being used in the plan."* Specifically, Texas Water Code §36.1071(e)(3)(E) requires that a GCD management plan contain estimates of "*the annual volume of flow into and out of the district within each aquifer and between aquifers in the district, if a groundwater availability model is available.*" During the joint planning process required by Texas Water Code §36.108(d), the following requirement directing GCDs to consider the TWDB groundwater availability modeling results is included: "*Not later than September 1, 2010, and every five years thereafter, the districts shall consider groundwater availability models and other data or information for the management area and shall establish desired future conditions for the relevant aquifers within the management area….*"

Therefore, it is clear in statute that it is the intent of the Texas Legislature that one of the primary sources of groundwater science to be utilized by GCDs during their development of management plans and their adoption of desired future conditions is to be the groundwater availability models and groundwater science developed and made publically available by the executive administrator of the TWDB. If it is the intent of a GCD to utilize local, site-specific information in the development of a management plan, or in the adoption of desired future conditions, in addition to or in lieu of the groundwater science and groundwater availability models developed and provided by the executive administrator, the GCD must submit and obtain the prior approval of the executive administrator to use this alternative source of information (Texas Water Code §36.1071(h) and §36.108(d).

Our review of the submitted survey questionnaire responses and/or management plans submitted confirms the linkage between sound groundwater science provided by the TWDB to the GCDs for their use in the development of their management plans, as required by Texas Water Code §36.1071. In addition, 5 of 16 responding GCDs cited scientific literature published by the BEG describing the hydrogeology of the Carrizo-Wilcox Aquifer. Six GCDs referenced material utilized in joint planning sessions within their Groundwater Management Areas. Ten GCDs worked with technical consultants to develop their individual GCD management plans and rules.

The GCDs were also asked to submit "*electronic copies of any scientific reports presented to and considered by the district during the development of the current district rule*s." A review of current statute documents that the current sequence of management activities and decision points is (1) adoption of desired future conditions, (2) adoption of a management plan designed to achieve desired future conditions, and (3) adoption of rules designed to achieve the goals of the management plan. Therefore, it is not surprising that for most GCDs, the majority, if not all science developed to address an affected provision included in GCD rules was originally developed during deliberations leading up to the adoption of desired future conditions and management plans. This reality was evidenced by the limited nature of the response by GCDs to the request for information considered during development of rules.

2.2 Linkage Between Sound Scientific Groundwater Principles and GCD Management Plans and Rules

All 16 GCDs that responded to the online survey, either in their direct response or in the text included in their management plan, stated that they utilized sound scientific principles in their adopted management plans. As discussed earlier, this use of sound scientific principles is in large part a result of the direct linkage in statute between the groundwater science produced by the TWDB and requirements for certain elements to be included in GCD management plans. However, the linkage between sound scientific principles and rules adopted by Carrizo-Wilcox GCDs is, for the most part, dependent upon the assumption that necessary science considered during the development of a management plan was adequate for the subsequent development and adoption of rules. To review, one of the objectives of the Study was to, "*Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to …any science that was considered during development of the rules…Link individual GCD permitting procedures and decisions since September 1, 2007 to any science used in their development.*" After an examination of the rules and scientific information provided by the GCDs, the following observations are noted. First, 6 of the 16 GCDs that responded to the Study survey questionnaire provided information regarding the request for scientific information utilized during rule making. Next, of those six GCDs, one GCD clearly articulated the direct linkage between the scientific information that was utilized with the corresponding rule(s) that was subsequently adopted. This district was the Pineywoods GCD. However, it is noted that in the process of adopting rules, decisions made by GCD boards of directors may be based on the cumulative consideration of a number of information sources, such as local studies, regional studies such as regional water plans, and groundwater availability modeling studies, and not just one specific study. Perhaps more importantly, it is also noted that the main focus of scientific efforts from a process perspective is during the adoption of desired future conditions and management plans. The development and adoption of rules is a process designed to achieve the adopted desired future conditions and management plan, and therefore the consideration of science has already occurred earlier in the decision process.

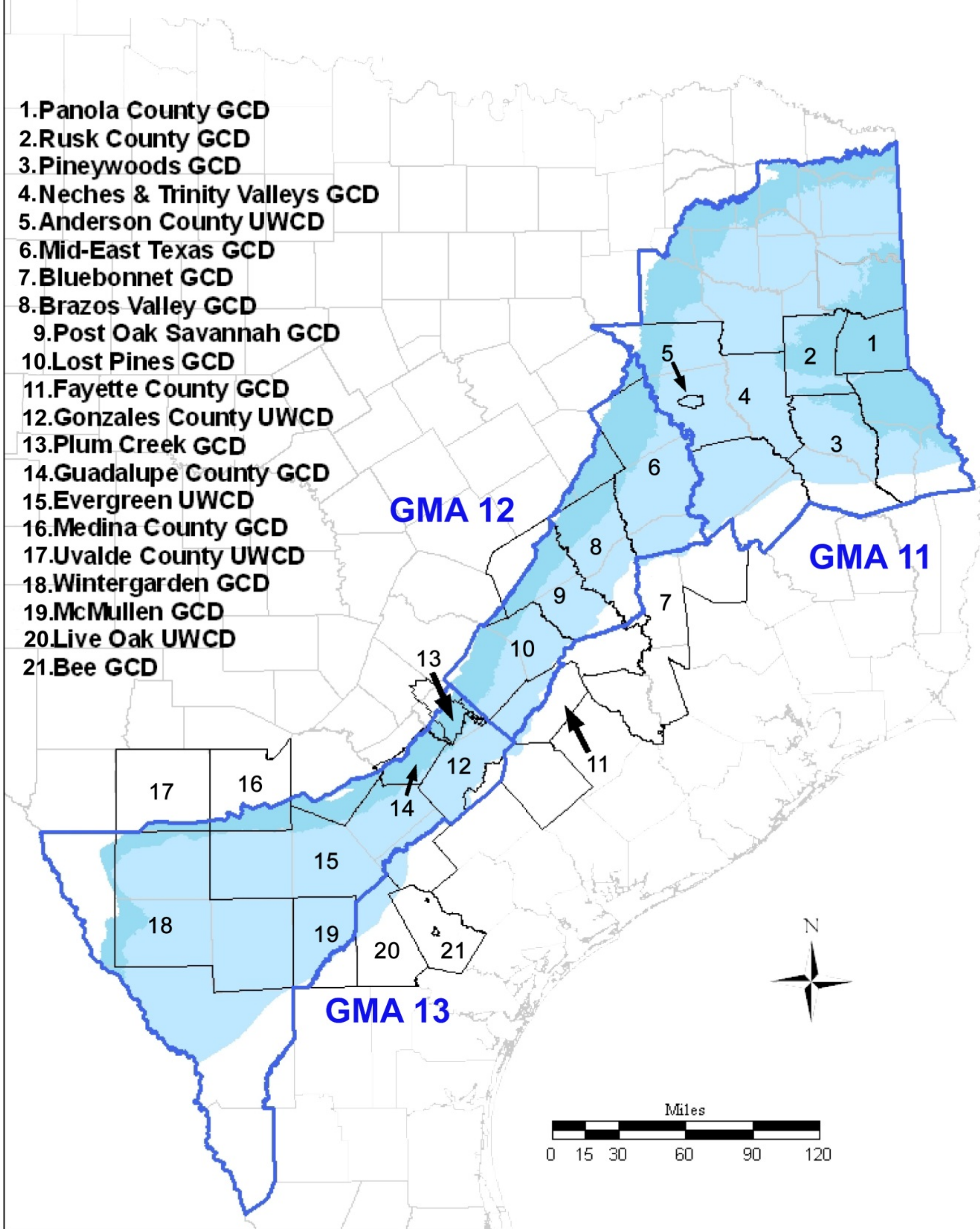
2.3 Linkage Between Sound Scientific Groundwater Principles and Desired Future Conditions

One task included in the Study directed the BEG to "*Review available records from GMAS 11, 12, and 13 and evaluate science behind ultimate Desired Future Conditions (DFCs)* *recommendations*. "The Study was designed to collect this information regarding science considered during the joint-planning process by utilizing the online survey developed specifically for the Study. The BEG was also tasked to "*Evaluate whether the rules adopted by the appropriate GCDs are designed to achieve the probable DFC for each GMA."* Later in this Executive Summary in Section 3.1 and in *Final Summary Report for Task 3* the challenges presented by the various timelines for joint-planning by GCDs in GMAs, and the development and adoption of Regional and State Water Plans are discussed. As was the case with the evaluations presented in *Final Summary Report for Task 3*, ideally, this evaluation would occur after the 2011 Regional Water Plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). At the time of this writing however, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate their adopted DFCs and the resulting estimates of MAG. As such, it is not possible for the purposes of the Study to determine whether the Carrizo-Wilcox GCDs have adopted rules (or management plans) designed to achieve their adopted DFCs. A realistic review of time requirements for this task by the Carrizo-Wilcox GCDs (revise and adoption of rules) suggests that initial efforts to first review and amend the respective management plans and ***then*** adopt revised rules to achieve the applicable DFCs will not be initiated until late 2010—early 2011. Given similar previous efforts, this task by the Carrizo-Wilcox GCDs could take as long as 1 to 2 years to complete, once initiated.

The primary source of information available for evaluation of science used by the three GMAs during their deliberations of potential DFCs was information provided by the representative GCD through the Study's online survey. Information provided by the three GMAs regarding science considered during the first round of joint planning was compiled and reviewed. Additional information was provided after the survey process was completed by Post Oak Savannah GCD and reviewed for the Study.

When the TWDB delineated (by rule, 31 Texas Administrative Code §356.21-23) the boundaries of the groundwater management areas (GMAs) for Texas, as required by Senate Bill 2 (77^{th} Texas Legislature, 2001), all or parts of 58 counties were included in the three GMAs covering the Carrizo-Wilcox Aquifer (Figure 1.1). According to information from the TWDB, there are 18 GCDs within GMAs 11, 12, and 13 (Table 1.2). Three other GCDs with jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the three GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer (see Figure 1.1). These three are the Bluebonnet GCD, Bee GCD, and the Live Oak GCD.

Figure 1.1: Location of Carrizo-Wilcox Aquifer, Groundwater Conservation Districts, and Groundwater Management Areas



In response to the Study survey, the Carrizo-Wilcox GCDs designated as the administrator for GMA 11, 12, and 13 provided information regarding any science considered by the Carrizo-Wilcox GCDs throughout the joint planning process. The details provided through the survey were quite variable. *Final Summary Report for Task 5* provides a detailed summary of the science considered throughout the joint planning process in GMA 11–13, respectively.

Our review of the science considered during the joint planning process for GMAs 11, 12, and 13, based on information provided by the Carrizo-Wilcox GCDs for the Study, has documented that in each GMA, the core science considered in the adoption of DFCs was science developed by the TWDB as part of the GAM Program. The degree to which the results from additional scientific information was considered ranges from no additional substantive information being considered by in GMA 11 to multiple scientific presentations that were local or sub-GMA in scope for GMAs 12 and 13. For example, in GMA 12, results from scientific studies regarding surface water/groundwater interactions were considered as the different possible DFCs were being evaluated. Our review of meeting minutes from GMA 12 documented 11 other presentations by interested stakeholders and consultants. For GMA 13, we documented 12 presentations by the TWDB, the San Antonio Water System and consultants. There were six additional TWDB documents that were mentioned in the meeting minutes of GMA 13, which consisted of GAMs that were conducted and presented to GMA 13.

As was noted in our review of science utilized in t the development of management plans and rules above, the primary source of science utilized by two of the three GMAs (11 and 13) was information derived from the Carrizo-Wilcox Aquifer GAMs. The TWDB provided a number of model simulation results to these two GMAs based on draft DFC requests from the GMAs throughout the DFC process. By design, this was an iterative process, whereby TWDB staff would present model results to the GMAs, and then the GMAs would modify the modeling requests to better understand the potential MAGs that could result from the draft DFCs being considered. Further, there is no record in the meeting minutes from GMA 12 that the TWDB independently presented any GAM results during the joint planning process.

3.0 Evaluation of Desired Future Conditions, Management Plans, Rules, Regional Water Plans, and the Potential for Conflict

3.1 Regional and State Water Plans and Their Potential Conflicts with Carrizo-Wilcox GCD Management Plans

One of the primary focuses of the Study was to "*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans; conduct stakeholder meetings to present the goals and results of the Study, and to identify, tabulate and describe every existing and projected water user group strategy or alternative strategy that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater.*" In the scope of work for the

Study, the use of the phrase "…*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans"* resulted in some unique challenges with respect to the timing of the plans in question. The following are provided to illustrate these challenges:

- The Study was initiated by the Texas Commission on Environmental Quality (TCEQ) with an original deadline for this task of September 1, 2010
- GCDs, through their participation in the joint planning process, were statutorily required (TWC §36.108(d) to adopt Desired Future Conditions (DFCs) and submit them to the TWDB by September 1, 2010
- Regional water planning groups were required by rule (31 TAC §357.5(b)(2)) to submit updated regional water plans to the TWDB for approval by September 1, 2010 (note that a few regions were granted time extensions of approximately one month), and finally,
- The TWDB is statutorily required to submit an updated state water plan reflecting the 2011 regional water plans (that were submitted on September 1, 2010) by January 5, 2012 (TWC §16.051(a)).

This effort was designed to evaluate regional and state water plans and GCD management plans in order to identify conflicts that may exist between the two planning processes. Ideally, this evaluation would occur after the 2011 regional water plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). Due to the very recent submission of DFCs at the time of this writing, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate the adopted DFC.

In order to provide a meaningful evaluation that generally reflects the intent and goal of this task, accommodations were made for the following realities of the various timelines. These include:

- At the time of this analysis (early fall, 2010) the data provided by the TWDB were provisional in nature, in that TWDB staff were still engaged in the final review and approval of regional water plans, and as such, certain water management strategies may have changed.
- It is also understood that the MAGs provided by the TWDB to the BEG for the Study are currently in draft form, pending review and comment from the Carrizo-Wilcox GCDs regarding quantification of exempt use. After exempt use has been established for each county and aquifer, that amount will be deducted from the MAGs utilized in this report. The sum of exempt use and MAG estimates will then represent the total amount of pumping consistent with the adopted DFC. While the MAG estimates may change due to comments from the GCDs, the estimates of total amount of pumping consistent with the DFCs (referred to as MAGs in this report) are not expected to change. This total amount of pumping is what is directly analogous to groundwater availability in the regional water plans. It is expected that the 2016 regional water plans will include this total amount of

pumping (exempt use + MAG). Until exempt use has been quantified, for the purposes of this report only, MAG is equated to total amount of pumping consistent with the DFC.

- With respect to a review of the regional and state water plans, it is recognized that we are currently in the interval between adoption of regional water plans and adoption of a state water plan. As such, the current state water plan is now four years old, and in many cases, inconsistent with recently adopted regional water plans. For the purposes of this report, in order to utilize the most current information and to avoid unnecessary confusion, information regarding currently available supplies and water management strategies from the recently adopted regional water plans was utilized for this analysis. Information from the 2007 State Water Plan was reviewed, but will not be presented in this report.
- In the 2016 regional water plans and the 2017 State Water Plan, the total amount of groundwater available to meet current and future needs can be no more than the MAG for the most recently adopted DFC. The BEG was directed to "*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans"*. What is not defined explicitly during this transitional stage of planning (both regional water planning and joint planning for GCDs) is what constitutes a conflict. For reference, 31 TAC §356.2(a)(6) states a conflict is "*A situation where the managed available groundwater identified in a management plan or the adopted state water plan is not the managed available groundwater based on the desired future conditions set by the groundwater conservation districts in the groundwater management area*." This definition will be universally applicable during the 2016 regional water plans and 2017 State Water Plan. However, due to the timing of submission of DFCs and calculation of MAGs by the TWDB, none of the Carrizo-Wilcox GCDs were able to provide official MAGs in time for inclusion in the 2011 regional water plans. Therefore, technically, no conflict can exist at this time. For the purposes of the Study, we did compare, on a county by county basis, the sum of Carrizo-Wilcox Aquifer availability and water management strategies that rely on the Carrizo-Wilcox Aquifer to the draft estimates of the MAG for the Carrizo-Wilcox Aquifer from the initial round of joint planning that just concluded on September 1, 2010. Therefore, solely for the purposes of this evaluation, a "potential conflict" is defined as "where, on a county-level evaluation, the sum of current water supplies available from the Carrizo-Wilcox Aquifer and water management strategies that rely on groundwater from the Carrizo-Wilcox Aquifer in a county are greater than or exceed the MAG for the same county."

This evaluation was conducted using three different types of data: (1) amount of water supplies currently available from the Carrizo-Wilcox Aquifer based on information contained in the recently adopted 2011 regional water plans, (2) amount of additional water to be obtained from the Carrizo-Wilcox Aquifer recommended as water management strategies in the recently adopted 2011 regional water plans, and (3) draft estimates of MAG from the recently completed joint planning process. Information for 1 and 2 were provided by TWDB Water Resources

Planning and Information staff (email dated October 7, 2010) and MAG estimates were provided by TWDB Water Science and Conservation staff (email dated October 5, 2010).

In order to compare the relevant data, an examination of the different data sources is appropriate. Water supplies available from the Carrizo-Wilcox Aquifer, as reported in the regional water plans on a decadal basis, are defined, in part, in 31TAC §357.7(a)(3) as the "*…existing water supplies legally and physically available to the regional water planning area for use during drought of record….*" In other words, the water supply has to be legally available (i.e., permits obtained) and infrastructure to transport the water to the current or future users has to be in place in order for the water to be counted as a current water supply. If the groundwater cannot be legally produced at this time or the infrastructure is not in place at the time of the plan development, then the groundwater may not be counted as a currently available supply. Any incremental increase in water to meet future water supply needs over what is currently available must be included as a recommended water management strategy in the applicable regional water plan. To include a future supply as a recommended water management strategy, the amount of water must be quantified on a decadal basis in the regional water plan. For the purposes of this evaluation, it is assumed that all water management strategies will be implemented in the amount and time prescribed in the 2011 regional water plans.

For the purposes of this analysis, 64 counties were included in data provided by the TWDB containing information from the 2011 regional water plans and/or estimates of MAG. Table 1.1 contains information on the 64 counties, including the regional water planning area, groundwater management area, and on a decadal basis, (1) the sum of currently available water supplies and water management strategies, (2) the MAG, and (3) the difference between (1) and (2) which is referred to as "*Difference*". Figures 5.1 – 5.3 illustrate the decadal values for (1) and (2) for the years 2010 and 2060, for all counties within the jurisdictional boundaries of a Carrizo-Wilcox GCD. "*Difference*" values noted in Table 1.1 with parentheses (xxx) documents that the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans is greater than the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative for the decade referenced, a potential conflict exists. It is important to note that when the *Difference* is a negative number, this means for that county in that decade, there is insufficient managed available groundwater to implement all water management strategies based on the use of the Carrizo-Wilcox Aquifer in the 2011 regional water plans, while achieving the desired future condition.

Included in Table 1.1 are six counties, Bee, DeWitt, Graves, Live Oak McLennan and Travis, that have either currently available supplies or water management strategies from the Carrizo-Wilcox Aquifer, but for which there is no MAG. This situation may occur under multiple scenarios. For example, water supplies from the Carrizo-Wilcox Aquifer may be either currently imported or being planned for importation into a county, which is most often the case.

Alternatively, as is the case in Travis County (which does not have any Carrizo-Wilcox Aquifer present in the county; a political subdivision, such as the City of Elgin, may be located in two or more counties [in the case of the City of Elgin, Bastrop and Travis counties]). For regional water planning purposes, the source of water supplies or water management strategies is identified on a county by county basis. Therefore, even though the physical source of the groundwater supplies is located in Bastrop County, for regional water planning purposes, Carrizo-Wilcox Aquifer water supplies for the City of Elgin will be included for both counties.

Alternatively, there are two counties within GMA 11; Red River County with a MAG of 0 acre-feet per year and Trinity County with a MAG of 2,215 acre-feet per year, but neither have any currently available supplies or water management strategies from the Carrizo Wilcox Aquifer in the 2011 regional water plans. This situation typically occurs when an aquifer is overlain by another aquifer that is shallower and of superior water quality and quantity such that there is no planned or current use of the aquifer. This is especially true in areas where the freshwater portion of the Carrizo-Wilcox Aquifer is at its most downdip limits. For example, Bee County GCD and Live Oak Underground Water Conservation District both have jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer; however, these GCDs were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer.

There are three counties in GMA 11 - Angelina, Henderson and Van Zandt; seven counties in GMA 12 – Bastrop, Brazos, Burleson, Freestone, Navarro, Uvalde and Williamson; and ten counties in GMA 13 – Atascosa, Dimmitt, Frio, Gonzales, Guadalupe, Karnes, LaSalle, Maverick, Medina and Webb with potential conflicts for at least one decade during the 50 – year planning horizon from 2010 – 2060. Bastrop, Dimmitt, Frio, Guadalupe, LaSalle, Navarro, Webb, and Williamson counties have potential conflicts for all of the decades during the 50-year planning horizon. These potential conflicts range in magnitude from 13 acre-feet per year in Maverick County to 176,615 acre-feet per year in Frio County. Of the 56 counties analyzed that are included as a current supply or water management strategy in the 2011 regional water plans and have an estimate of the MAG from the recently completed joint planning process, 20 have potential conflicts, representing 35 percent of the total. Of these 20 counties with potential conflicts, five are not within the jurisdictional boundaries of a GCD. Van Zandt County has a potential conflict in 2060; Maverick County has potential conflicts in four decades, 2020-2060; Navarro, Webb and Williamson counties are among the counties with potential conflicts in all decades of the 50-year planning horizon. Without a groundwater conservation district, there is no mechanism to implement management activities to achieve the DFC.

Strictly for the counties within the jurisdictional boundaries of a GCD in GMAs 11, 12, and 13, an evaluation was conducted to quantify, on a GMA basis, the sum of the negative, positive, and net values presented in Table 1.1. These values are presented for 2010 and 2060 in Table 1.2. While the net values for GMA 11 and 12 have a net positive value for both 2010 and 2060, it is interesting to note that the net value for GMA 13 is negative, (84,793) acre-feet per year in 2010 and negative (158,902) acre-feet per year in 2060. Based on this analysis, if the estimates of the MAG (the total amount of pumping consistent with the DFC) remain the same in the 2016 regional water plans as it is today, then the volume of water from Carrizo-Wilcox Aquifer recommended to meet future water supply needs will have to be reduced significantly.

Table 1.1: Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year. RWPA: Regional Water Planning Area. GMA: Groundwater Management Area.

RWPA	**GMA**	**County**	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Anderson**	MAG	10,077	10,077	10,077	10,077	10,077	10,077
		Anderson	Supplies + Strategies	9,291	9,393	9,514	9,614	9,614	9,614
			Difference	*786*	*684*	*563*	*463*	*463*	*463*
I	**11**	**Angelina**	MAG	26,414	26,414	26,414	26,414	26,414	26,414
		Angelina	Supplies + Strategies	22,569	22,533	24,339	24,599	26,679	27,051
			Difference	*3,845*	*3,881*	*2,075*	*1,815*	*(265)*	*(637)*
L	**13**	**Atascosa**	MAG	67,949	68,776	70,369	71,947	73,786	75,808
		Atascosa	Supplies + Strategies	67,872	69,043	69,921	69,987	70,051	72,526
			Difference	*77*	*(267)*	*448*	*1,960*	*3,735*	*3,282*
K	**12**	**Bastrop**	MAG	16,866	19,979	20,666	24,833	28,018	28,498
		Bastrop	Supplies + Strategies	21,129	31,489	38,622	46,388	54,275	58,321
			Difference	*(4,263)*	*(11,510)*	*(17,956)*	*(21,555)*	*(26,257)*	*(29,823)*
N	**15&16**	**Bee**	Supplies + Strategies	380	394	394	394	394	394

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
L	**13**	**Bexar**	MAG	26,278	26,278	26,278	26,278	26,278	26,107
		Bexar	Supplies + Strategies	15,916	16,264	12,987	12,993	13,000	13,006
			Difference	*10,362*	*10,014*	*13,291*	*13,285*	*13,278*	*13,101*
D	**11**	**Bowie**	MAG	11,126	8,216	7,976	7,533	7,533	7,083
		Bowie	Supplies + Strategies	4,153	4,296	4,365	4,365	4,194	4,053
			Difference	*6,973*	*3,920*	*3,611*	*3,168*	*3,339*	*3,030*
G	**12**	**Brazos**	MAG	33,925	38,835	44,847	49,421	53,970	57,169
		Brazos	Supplies + Strategies	44,380	44,502	44,386	47,432	47,439	47,434
			Difference	*(10,455)*	*(5,667)*	*461*	*1,989*	*6,531*	*9,735*
G	**12**	**Burleson**	MAG	3,750	23,249	28,047	32,518	36,492	38,701
		Burleson	Supplies + Strategies	4,369	4,369	4,669	27,433	30,053	31,557
			Difference	*(619)*	*18,880*	*23,378*	*5,085*	*6,439*	*7,144*
L	**13**	**Caldwell**	MAG	44,546	44,546	44,137	44,137	43,561	43,561
		Caldwell	Supplies + Strategies	7,706	11,718	18,676	16,902	18,108	20,997
			Difference	*36,840*	*32,828*	*25,461*	*27,235*	*25,453*	*22,564*
D	**11**	**Camp**	MAG	4,041	4,041	4,041	4,041	4,041	4,041
		Camp	Supplies + Strategies	2,071	2,077	2,083	2,088	2,093	2,098
			Difference	*1,970*	*1,964*	*1,958*	*1,953*	*1,948*	*1,943*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Cass**	MAG	3,533	3,533	3,533	3,533	3,533	3,533
		Cass	Supplies + Strategies	3,258	3,294	3,375	3,457	3,527	3,527
			Difference	*275*	*239*	*158*	*76*	*6*	*6*
I	**11**	**Cherokee**	MAG	11,222	11,222	11,222	11,222	11,222	11,222
		Cherokee	Supplies + Strategies	8,774	8,821	8,872	8,927	8,973	9,016
			Difference	*2,448*	*2,401*	*2,350*	*2,295*	*2,249*	*2,206*
L	**15**	**Dewitt**	Supplies + Strategies	71	71	71	71	71	71
L	**13**	**Dimmit**	MAG	3,359	3,359	3,359	3,359	3,359	3,359
		Dimmit	Supplies + Strategies	13,536	13,536	13,536	13,536	13,536	13,536
			Difference	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*
L	**12**	**Falls**	MAG	865	867	875	884	895	895
		Falls	Supplies + Strategies	667	667	667	667	667	667
			Difference	*198*	*200*	*208*	*217*	*228*	*228*
K	**12**	**Fayette**	MAG	1,000	1,000	1,000	1,000	1,000	1,000
		Fayette	Supplies + Strategies	380	453	542	611	690	803
			Difference	*620*	*547*	*458*	*389*	*310*	*197*
11	**D**	**Franklin**	MAG	9,746	9,484	9,484	9,484	9,484	9,484
		Franklin	Supplies + Strategies	1,677	1,651	1,644	1,637	1,617	1,597
			Difference	*8,069*	*7,833*	*7,840*	*7,847*	*7,867*	*7,887*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
12	**C**	**Freestone**	MAG	5,138	5,305	5,317	5,315	5,262	5,259
		Freestone	Supplies + Strategies	5,783	5,223	5,223	5,223	5,223	5,223
			Difference	*(645)*	*82*	*94*	*92*	*39*	*36*
13	**L**	**Frio**	MAG	81,551	79,089	76,734	74,439	72,222	70,030
		Frio	Supplies + Strategies	246,645	246,645	246,645	246,645	246,645	246,645
			Difference	*(165,094)*	*(167,556)*	*(169,911)*	*(172,206)*	*(174,423)*	*(176,615)*
13	**L**	**Gonzales**	MAG	52,483	62,316	70,317	75,791	75,970	75,970
		Gonzales	Supplies + Strategies	15,740	35,648	44,928	55,561	67,821	80,540
			Difference	*36,743*	*26,668*	*25,389*	*20,230*	*8,149*	*(4,570)*
11	**D**	**Gregg**	MAG	7,649	7,649	7,649	7,649	7,649	7,649
		Gregg	Supplies + Strategies	5,621	5,707	5,847	6,281	6,560	7,038
			Difference	*2,028*	*1,942*	*1,802*	*1,368*	*1,089*	*611*
14	**G**	**Grimes**	Supplies + Strategies	236	226	221	217	217	217
13	**L**	**Guadalupe**	MAG	10,241	10,833	11,283	13,021	13,541	14,041
		Guadalupe	Supplies + Strategies	19,832	23,162	25,779	26,384	28,029	29,570
			Difference	*(9,591)*	*(12,329)*	*(14,496)*	*(13,363)*	*(14,488)*	*(15,529)*
11	**D**	**Harrison**	MAG	8,911	8,837	8,786	8,698	8,683	8,639
		Harrison	Supplies + Strategies	5,332	5,786	6,042	6,258	6,601	6,959
			Difference	*3,579*	*3,051*	*2,744*	*2,440*	*2,082*	*1,680*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
11	**C&I**	**Henderson**	MAG	9,253	9,186	9,186	9,186	9,186	9,186
		Henderson	Supplies + Strategies	8,833	9,565	9,567	9,851	9,853	9,895
			Difference	*420*	*(379)*	*(381)*	*(665)*	*(667)*	*(709)*
11	**D**	**Hopkins**	MAG	3,433	3,391	3,391	3,391	3,391	3,391
		Hopkins	Supplies + Strategies	2,227	2,234	2,237	2,238	2,232	2,226
			Difference	*1,206*	*1,157*	*1,154*	*1,153*	*1,159*	*1,165*
I	**11**	**Houston**	MAG	5,356	5,356	5,356	5,356	5,356	5,356
		Houston	Supplies + Strategies	2,272	2,655	2,765	3,397	3,852	4,358
			Difference	*3,084*	*2,701*	*2,591*	*1,959*	*1,504*	*998*
L	**13**	**Karnes**	MAG	1,059	1,117	1,182	1,231	1,259	1,280
		Karnes	Supplies + Strategies	1,141	1,141	1,141	1,141	1,141	1,141
			Difference	*(82)*	*(24)*	*41*	*90*	*118*	*139*
L	**13**	**La Salle**	MAG	6,454	6,454	6,454	6,454	6,454	6,454
		La Salle	Supplies + Strategies	8,013	8,013	8,013	8,013	8,013	8,013
			Difference	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*
G	**12**	**Lee**	MAG	22,259	24,023	23,402	24,624	26,827	27,380
		Lee	Supplies + Strategies	10,584	10,987	10,987	10,988	8,913	12,619
			Difference	*11,675*	*13,036*	*12,415*	*13,636*	*17,914*	*14,761*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
H	**12**	**Leon**	MAG	14,682	14,475	14,647	14,892	15,172	15,196
		Leon	Supplies + Strategies	4,818	5,128	5,334	5,407	5,459	5,558
			Difference	*9,864*	*9,347*	*9,313*	*9,485*	*9,713*	*9,638*
G	**8&12**	**Limestone**	MAG	11,321	11,306	11,436	11,616	11,918	11,918
		Limestone	Supplies + Strategies	7,403	7,591	7,780	7,968	8,157	8,347
			Difference	*3,918*	*3,715*	*3,656*	*3,648*	*3,761*	*3,571*
N	**16**	**Live Oak**	Supplies + Strategies	60	60	60	60	60	60
H	**12**	**Madison**	MAG	2,838	2,859	2,768	2,654	2,552	2,542
		Madison	Supplies + Strategies	1,409	1,493	1,571	1,551	1,518	1,518
			Difference	*1,429*	*1,366*	*1,197*	*1,103*	*1,034*	*1,024*
D	**11**	**Marion**	MAG	2,077	2,077	2,077	2,077	2,077	2,077
		Marion	Supplies + Strategies	1,981	2,001	2,008	2,014	2,020	2,028
			Difference	*96*	*76*	*69*	*63*	*57*	*49*
M	**13**	**Maverick**	MAG	2,043	2,043	2,024	1,677	1,570	1,532
		Maverick	Supplies + Strategies	1,792	2,056	2,058	2,060	2,073	2,444
			Difference	*251*	*(13)*	*(34)*	*(383)*	*(503)*	*(912)*
G	**8**	**McLennan**	Supplies + Strategies	29	29	29	29	29	29

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
N	13	**McMullen**	MAG	1,819	1,819	1,819	1,819	1,819	1,819
		McMullen	Supplies + Strategies	430	438	442	446	450	453
			Difference	*1,389*	*1,381*	*1,377*	*1,373*	*1,369*	*1,366*
L	13	**Medina**	MAG	2,568	2,545	2,533	2,533	2,533	2,533
		Medina	Supplies + Strategies	7,597	7,597	7,597	7,597	7,597	7,597
			Difference	*(5,029)*	*(5,052)*	*(5,064)*	*(5,064)*	*(5,064)*	*(5,064)*
G	12	**Milam**	MAG	38,183	23,923	20,206	19,112	21,359	22,319
		Milam	Supplies + Strategies	13,686	13,686	13,686	12,828	12,941	12,941
			Difference	*24,497*	*10,237*	*6,520*	*6,284*	*8,418*	*9,378*
D	11	**Morris**	MAG	2,616	2,616	2,558	2,558	2,558	2,558
		Morris	Supplies + Strategies	1,381	1,381	1,381	1,381	1,381	1,381
			Difference	*1,235*	*1,235*	*1,177*	*1,177*	*1,177*	*1,177*
I	11	**Nacogdoches**	MAG	21,385	21,385	21,385	21,385	21,385	21,385
		Nacogdoches	Supplies + Strategies	16,375	16,375	16,986	17,258	18,043	18,402
			Difference	*5,010*	*5,010*	*4,399*	*4,127*	*3,342*	*2,983*
C	12	**Navarro**	MAG	15	15	15	15	15	15
		Navarro	Supplies + Strategies	88	88	88	88	88	88
			Difference	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Panola**	MAG	9,097	8,227	8,227	8,069	8,069	8,069
		Panola	Supplies + Strategies	6,609	6,615	6,623	6,631	6,639	6,649
			Difference	*2,488*	*1,612*	*1,604*	*1,438*	*1,430*	*1,420*
D	**11**	**Rains**	MAG	1,703	1,703	1,620	1,620	1,620	1,583
		Rains	Supplies + Strategies	785	809	822	825	823	820
			Difference	*918*	*894*	*798*	*795*	*797*	*763*
D	**11**	**Red River**	MAG	0	0	0	0	0	0
G	**12**	**Robertson**	MAG	44,886	45,435	45,814	46,238	46,582	46,583
		Robertson	Supplies + Strategies	34,552	34,562	34,567	24,349	24,348	24,347
			Difference	*10,334*	*10,873*	*11,247*	*21,889*	*22,234*	*22,236*
I	**11**	**Rusk**	MAG	39,772	42,188	50,336	46,940	48,128	48,119
		Rusk	Supplies + Strategies	11,478	11,459	11,441	11,578	11,555	11,526
			Difference	*28,294*	*30,729*	*38,895*	*35,362*	*36,573*	*36,593*
I	**11**	**Sabine**	MAG	6,866	6,858	6,858	6,858	6,858	6,858
		Sabine	Supplies + Strategies	358	358	358	440	440	440
			Difference	*6,508*	*6,500*	*6,500*	*6,418*	*6,418*	*6,418*
I	**11**	**San Augustine**	MAG	1,781	1,781	1,781	1,781	1,781	1,781
		San Augustine	Supplies + Strategies	677	677	777	827	927	927
			Difference	*1,104*	*1,104*	*1,004*	*954*	*854*	*854*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Shelby**	MAG	12,044	11,217	10,901	10,447	10,311	9,729
		Shelby	Supplies + Strategies	5,304	6,404	7,004	7,004	7,559	7,566
			Difference	*6,740*	*4,813*	*3,897*	*3,443*	*2,752*	*2,163*
D&I	**11**	**Smith**	MAG	33,249	33,249	33,249	33,239	33,225	33,225
		Smith	Supplies + Strategies	26,916	27,212	27,597	28,468	29,910	31,244
			Difference	*6,333*	*6,037*	*5,652*	*4,771*	*3,315*	*1,981*
D	**11**	**Titus**	MAG	10,856	10,321	10,019	9,868	9,638	9,638
		Titus	Supplies + Strategies	5,214	6,379	6,959	7,391	7,628	8,503
			Difference	*5,642*	*3,942*	*3,060*	*2,477*	*2,010*	*1,135*
K	**8,9, &10**	**Travis**	Supplies + Strategies	1,499	1,718	1,901	2,025	2,153	2,300
H&I	**11**	**Trinity**	MAG	2,215	2,215	2,215	2,215	2,215	2,215
D	**11**	**Upshur**	MAG	7,115	7,115	7,115	7,115	7,115	7,115
		Upshur	Supplies + Strategies	6,610	6,697	6,756	6,799	6,835	6,885
			Difference	*505*	*418*	*359*	*316*	*280*	*230*
L	**12**	**Uvalde**	MAG	2,971	1,230	828	828	828	828
		Uvalde	Supplies + Strategies	2,846	2,846	2,846	2,846	2,846	2,846
			Difference	*125*	*(1,616)*	*(2,018)*	*(2,018)*	*(2,018)*	*(2,018)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Van Zandt**	MAG	10,614	10,283	10,283	10,283	10,283	10,051
		Van Zandt	Supplies + Strategies	7,499	8,170	8,645	8,982	9,645	10,292
			Difference	*3,115*	*2,113*	*1,638*	*1,301*	*638*	*(241)*
M	**13**	**Webb**	MAG	916	916	916	916	916	916
		Webb	Supplies + Strategies	3,882	6,824	9,138	9,712	9,711	9,710
			Difference	*(2,966)*	*(5,908)*	*(8,222)*	*(8,796)*	*(8,795)*	*(8,794)*
G	**12**	**Williamson**	MAG	7	7	7	7	7	7
		Williamson	Supplies + Strategies	8,412	8,412	8,412	8,522	8,522	8,522
			Difference	*(8,405)*	*(8,405)*	*(8,405)*	*(8,515)*	*(8,515)*	*(8,515)*
L	**13**	**Wilson**	MAG	35,560	36,986	38,717	40,486	42,531	44,794
		Wilson	Supplies + Strategies	20,823	21,621	24,374	26,297	32,343	33,631
			Difference	*14,737*	*15,365*	*14,343*	*14,189*	*10,188*	*11,163*
D	**11**	**Wood**	MAG	21,716	21,539	21,451	21,408	21,333	21,311
		Wood	Supplies + Strategies	8,930	9,021	9,074	9,083	9,087	9,098
			Difference	*12,786*	*12,518*	*12,377*	*12,325*	*12,246*	*12,213*
L	**13**	**Zavala**	MAG	35,859	35,859	35,521	35,388	35,288	34,969
		Zavala	Supplies + Strategies	23,935	23,935	23,935	23,935	23,935	23,935
			Difference	*11,924*	*11,924*	*11,586*	*11,453*	*11,353*	*11,034*

Table 1.2: Summation of differences between the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans compared to the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative (xxx), for the decade referenced, a potential conflict exists. This comparison is only for counties in GMA 11, 12, and 13 that are within the jurisdictional boundaries of a GCD. All values are in acre-feet per year.

GMA	Difference is (+) 2010	Difference is (-) 2010	Net 2010	Difference is (+) 2060	Difference is (-) 2060	Net 2060
11	43,291	0	43,291	43,665	1,346	42,319
12	58,419	15,982	42,437	74,149	29,823	88,652
13	101,710	186,503	*(84,793)*	49,548	208,450	*(158,902)*
Total	203,420	202,485	935	167,362	239,619	*(27,931)*

The BEG was also directed to evaluate the water management strategies in the regional water plans "*that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater*." Table 1.3 provides summary information on all Carrizo-Wilcox Aquifer water management strategies in the 2011 regional water plans and the counties receiving the supplies. It is important to note that the amount of water represented in Table 1.3 is a subset of the sum of currently available supplies and water management strategies reported in Table 1.1. No water management strategies are planned for implementation prior to 2020. The volume of brackish groundwater recommended as water management strategies in the 2011 regional water plans begins at 12,260 acre-feet per year in 2020 and increases to 37,357 acre-feet per year in 2060. Six counties are scheduled to receive brackish groundwater supplies based on recommended water management strategies in the 2011 regional water plans. These are Bexar, Comal, Guadalupe, Hays, Maverick, and Wilson counties, with the majority going to Bexar County.

Table 1.3: County-level sum of water management strategies in the 2011 regional water plans that are based on the use of brackish groundwater from the Carrizo-Wilcox Aquifer. All values are in acre-feet per year.

County	2010	2020	2030	2040	2050	2060
Bexar	0	12,000	21,750	27,150	27,903	27,903
Comal	0	0	880	880	1,762	1,762
Guadalupe	0	0	1,630	1,630	4,203	4,203
Hays	0	0	336	336	1,728	1,728
Maverick	0	260	260	260	272	641
Wilson	0	0	0	1,120	1,120	1,120
Total	0	12,260	24,856	31,376	36,988	37,357

As part of the Study, the BEG was to "*Determine other long-term impacts of the GCD rules and plans on the entire Carrizo-Wilcox Aquifer, considering projected agricultural, industrial and municipal demands for water from the aquifer.*" In order to evaluate long-term impacts on the Carrizo-Wilcox Aquifer, the primary focus for this evaluation was to review the potential socio-economic impacts of not meeting future water supply needs that are the result of policy decisions made in the joint planning process resulting in the adopted DFCs for the Carrizo-Wilcox Aquifer. Socio-economic impact data developed for this evaluation was provided by the TWDB. This information is required as part of the regional water planning process in Texas. 31 Texas Administrative Code §357.7(a)(4)(A) states, in part, that a Regional Water Plan shall include, "*…The social and economic impact of not meeting these needs shall be evaluated by the regional water planning groups and reported by regional water planning area and river basin. The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs."* A fundamental component of the regional water planning process is the evaluation of what are the socio-economic impacts at the regional, county, and sector (municipal, manufacturing, mining, etc.) level, of not meeting future water supply needs. During this evaluation, several impacts are modeled and quantified, including social impacts such as population, school enrollment, and economic impacts such as regional income, state and local business taxes, and the number of full and part time jobs. These evaluations are modeled for the major water use sectors; municipal, agricultural, livestock, steam-electric power generation, and mining. One of the outputs from the socio-economic impact analysis that is included in all Regional Water Plans is the total monetary losses per acre foot of water need that is not met by a water management strategy. In other words, what is the monetary impact to a water use sector if future water supply needs are not met?

The water supply shortages that may result as a consequence of the adopted DFCs in GMAs 11, 12, and 13 were quantified in the *Summary Report for Task 3* and are included as Table 1.1 above. Readers are encouraged to refer to this report for a full explanation of methodologies utilized. It is important to note that it is not possible to determine which water use sector would be impacted by the "potential conflicts" if the 2016 Regional Water Plans are not able to develop additional water management strategies to meet these needs. Therefore, if the *potential conflicts* are not resolved, the economic impacts will be dependent upon which water use sector(s) has the unmet need. For example, the total monetary losses per acre foot of water needs in 2020 for Bastrop County ranges from $125 for irrigation use to $4,277 for municipal use. Therefore, if all unmet needs are realized by the irrigation water use sector in Bastrop County, and the unmet need is 4,263 acre-feet in 2010 (see table 1.4), then the economic impact as expressed by the total monetary loss is estimated to be $532,875. However, if the unmet needs are evenly divided between the irrigation water use sector and the municipal water use sector, then the total monetary loss for 2010 would be $9,382,863 ([2,131.5 acre-feet × $125 for irrigation water use sector] + [2,131.5 × $4,277 for municipal water use sector]). Practically speaking, however, if a repeat of drought of record conditions were to occur, it is very difficult to make categorical projections of which water use sector will be asked or expected to realize what portion of the shortage. For example, would manufacturers or power generators be asked to cut back on production, or would businesses and homes be expected to reduce water use in order to meet total demands? These types of modeling assumptions have a very significant impact on the final analysis of total monetary loss, and are clearly beyond the scope of the Study.

Table 1.4: Socio-economic impacts results from 2011 Regional Water Plans (* denotes county that did not have any water supply needs during the 50-year planning horizon; therefore, no monetary losses have been calculated).

Region C		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Freestone	Steam-electric	$0	$0	$0	$0	$24,617	$24,617
Freestone	Municipal	$0	$40,561	$40,569	$23,452	$17,637	$15,461
Navarro	Steam-electric	$0	$98,083	$98,083	$98,083	$98,083	$98,083
Navarro	Municipal	$0	$1,766	$1,620	$1,699	$3,084	$5,845
Navarro	Manufacturing	$0	$81,977	$81,967	$82,005	$163,979	$163,974
Region D		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Van Zandt	Municipal	$941	$957	$1,011	$1,459	$8,131	$18,473
Region G		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brazos	Municipal	$119	$2,221	$3,170	$8,637	$9,389	$10,770
Williamson	Municipal	$6,205	$10,545	$15,826	$23,391	$30,033	$31,340
Williamson	Manufacturing	$107,880	$107,880	$107,880	$107,880	$107,880	$107,880
Williamson	Mining	$24,139	$24,139	$24,139	$24,139	$24,139	$24,139
Region I		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Angelina	Livestock	$0	$0	$0	$60,362	$60,362	$60,362
Angelina	Steam-electric	$72,631	$72,631	$72,631	$72,631	$72,631	$72,631
Angelina	Mining	$76,776	$82,394	$0	$0	$0	$0
Angelina	Manufacturing	$12,474	$24,942	$24,941	$49,883	$49,883	$49,883
Angelina	Municipal	$5,067	$18,406	$18,297	$18,020	$30,419	$23,349
Henderson	Livestock	$0	$60,362	$60,362	$60,362	$60,362	$60,362
Henderson	Steam-electric	$0	$0	$160,127	$160,127	$160,127	$160,127
Henderson	Municipal	$2,456	$10,609	$8,808	$12,159	$19,747	$24,469
Region K		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bastrop	Municipal	$576	$4,277	$7,214	$11,737	$14,765	$21,624
Bastrop	Irrigation	$125	$125	$125	$125	$125	$125
Bastrop	Manufacturing	$63,229	$63,229	$63,229	$63,229	$63,229	$126,458
Bastrop	Steam-electric	$0	$0	$0	$27,719	$27,719	$27,719

Table 1.4 (continued): Socio-economic impacts results from 2011 Regional Water Plans.

Region L		Total Monetary Losses Per Acre-Foot of Water Supply Need					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Atascosa	Municipal	$6,578	$8,445	$6,869	$7,037	$7,842	$9,232
Atascosa	Irrigation	$194	$194	$194	$194	$194	$194
Atascosa	Steam-electric	$7,760	$0	$0	$0	$7,760	$7,760
Dimmit	Needs Satisfied	*	*	*	*	*	*
Frio	Needs Satisfied	*	*	*	*	*	*
Gonzales	Needs Satisfied	*	*	*	*	*	*
Guadalupe	Municipal	$11,780	$13,865	$18,150	$32,188	$30,322	$25,502
Karnes	Municipal	$9,011	$18,867	$28,839	$31,147	$32,065	$34,289
La Salle	Needs Satisfied	*	*	*	*	*	*
Medina	Municipal	$9,493	$7,342	$7,545	$10,195	$10,721	$10,845
Medina	Irrigation	$174	$174	$174	$174	$174	$0
Uvalde	Municipal	$14,089	$14,139	$14,180	$14,202	$14,220	$14,247
Region M		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Maverick	Municipal	$833	$1,285	$1,622	$5,772	$6,348	$7,040
Maverick	Irrigation	$397	$200	$200	$200	$200	$200
Webb	Municipal	$899	$1,387	$5,941	$12,445	$14,410	$23,944
Webb	Irrigation	$293	$293	$293	$293	$293	$293
Webb	Steam-electric	$0	$0	$0	$0	$9,645	$9,645

3.2 Review and Characterization of Carrizo-Wilcox GCD Management Plans

As part of the Study the BEG was directed to, *"Characterize Groundwater Conservation District (GCD) plans with respect to their ability to conserve and protect the aquifer. Compare each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility."* We compared each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/. The remaining five GCD management plans and rules were acquired from the Texas Water Development Board (TWDB) and from district websites. We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific plans, rules, and procedures that support the GCDs' ability to conserve and protect the Carrizo-Wilcox Aquifer. One additional management plan for

Anderson County Underground Water Conservation District was obtained from the TWDB, but no rules were available.

Programs developed by Carrizo-Wilcox GCDs to conserve and protect the groundwater resources under their jurisdiction vary greatly, from simple to complex, from narrow to broad in scope, and from passive to aggressive. During our review, the compatibility of programs designed to conserve and protect groundwater resources within groundwater management areas, between neighboring Carrizo-Wilcox GCDs, and between Carrizo-Wilcox GCDs and adjacent counties that are not under the jurisdiction of a GCD were evaluated. Solely based on a review of groundwater management plans and rules, no compatibility issues were identified within groundwater management areas and between existing Carrizo-Wilcox GCDs. However, there will always be the potential for conflict and incompatibility between adjacent counties where one county is within a GCD and a neighboring county is not. Progressive conservation of groundwater resources through programs developed and implemented in a GCD management plan can and has led to economic development shifting to neighboring counties that are not in a GCD. Potential incompatibility may also occur between existing, adjacent Carrizo-Wilcox GCDs that have significantly different approaches to permitting strategies, for example. However, compatibility issues resulting from disparate permitting strategies are not discernable solely from a review of management plans.

According to Section 36.1071 of the Texas Water Code (TWC), GCDs are to *"…develop a comprehensive management plan which addresses the following management goals, as applicable."* Therefore, we reviewed seven of the eight management goals required for a management plan, excluding the management goal requiring a GCD to establish their desired future conditions of aquifers within their jurisdictional boundaries because they have only very recently been adopted and management plans have not been amended to implement adopted desired future conditions at this point in time.

The following management goals were reviewed:

1. Providing the most efficient use of groundwater (TWC §36.1071(a)(1));
2. Controlling and preventing waste of groundwater (TWC §36.1071(a)(2));
3. Controlling and preventing subsidence (TWC §36.1071(a)(3));
4. Addressing conjunctive surface water management issues (TWC §36.1071(a)(4));
5. Addressing natural resource issues (TWC §36.1071(a)(5));
6. Addressing drought conditions (TWC §36.1071(a)(6));
7. Addressing conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, or brush control, where appropriate and cost effective (TWC §36.1071(a)(7)).

In order to accomplish this task, the BEG requested specific information from the GCDs in the survey developed for the Study. According to the Survey results, 15 of the 16 GCDS responded to the request to "*Summarize significant programs included in the District's management plan specifically designed to conserve and protect the Carrizo Wilcox Aquifer."* Six of the GCDs, including Panola County GCD, Rusk County GCD, Fayette County GCD, Gonzales County GCD, Post Oak Savannah GCD, and Brazos GCD provided summaries of programs included in their management plans that have been designed to conserve and protect the Carrizo-Wilcox Aquifer. Other districts responded to the Survey with more abbreviated descriptions of programs designed to preserve and protect that Carrizo-Wilcox Aquifer. Each of the GCDs independently developed management plans to address conservation and protection of the aquifer. The GCDs methodologies and metrics were broad and varied in how they addressed the need to conserve and protect the Carrizo-Wilcox Aquifer within their respective jurisdictions.

All 21 GCDs addressed the management goal, *"providing the most efficient use of groundwater,"* in their management plans. The nature and scope of management objectives and performance standards varied greatly among the 21 Carrizo-Wilcox GCDs. A complete matrix of management goals, objectives, and performance standards currently included in the 21 Carrizo-Wilcox GCD management plans is included in ***Final Summary Report for Task 3*** produced for the Study. Approaches to providing the most efficient use of groundwater, if achieved, within the GCDs were varied, largely because of diverse regional socio-economic and developmental pressures and environmental concerns represented in the three different groundwater management areas and 21 GCDs. The Carrizo-Wilcox GCDs have established objectives and performance standards that are geared towards influencing the public's perception and consumption practices through education, collection of basic groundwater data for use during development of policy or regulations, and taking physical steps to regulate groundwater consumption via establishment of well permitting, registration, and metering programs. These soft and hard policy measures have been developed by the individual Carrizo-Wilcox GCD Boards of Directors to satisfy the management goal requirement to provide for the most efficient use of groundwater. The phrase "most efficient use" has clearly been viewed differently within the various Carrizo-Wilcox GCDs. Landowners and boards of directors in East Texas may perceive the use of groundwater in surface ponds as economically beneficial and efficient whereas landowners in South-Central Texas may find that development and transport of groundwater resources to metropolitan areas to be the most efficient use of their groundwater resources.

All 21 Carrizo-Wilcox GCD's addressed the goal "*controlling and preventing waste of groundwater*" in their respective management plans. The Carrizo-Wilcox GCDs, as would be expected due to varied local conditions, have adopted different methods of addressing the management of groundwater resources in order to prevent and control the waste of groundwater.

Eighteen of the 21 Carrizo-Wilcox GCDs explicitly stated in their management plans that controlling and preventing subsidence is not applicable to their districts due to the geologic and hydrogeologic profile of the region. Two other districts characterized and stated why their GCD was not managing subsidence within their respective GCD. Only the Anderson County UWCD included an objective and standard for this goal, but upon review, its relationship to controlling subsidence was not established.

Of the 21 management plans, 14 Carrizo-Wilcox GCD have established management objectives and performance standards to address goal 4 *"conjunctive surface water management issues."* Of the 14 Carrizo-Wilcox GCD's, 5 state they will achieve this goal by attending meetings of regional water authority's, such as the Brazos River Authority, Guadalupe-Blanco River Authority, and the Nueces River Authority. Further, eight of the GCD's have elected to attend regional water planning meetings with the appropriate regional water planning group. Of the 21 Carrizo-Wilcox GCDs management plans, 8 reviewed stated that goal 4 related to conjunctive surface water management issues was not applicable to their jurisdiction: Four Carrizo-Wilcox GCDs included management objectives and performance standards that went beyond meeting with regional water planning groups and river authority's to address goal 4. The degree of intergovernmental cooperation at the local and regional level varies by GCD.

In summary, participation in governing local groundwater and surface water resources is varied. Groundwater resources and surface water resources interaction differs regionally because of different hydrological and hydrogeological interactions in the environment. From this review, it is apparent that regional water planning groups and river authorities are the focal point for the coordination of groundwater and surface water issues for Carrizo-Wilcox GCDs.

Of 21 Carrizo Wilcox GCDs, 14 included management objectives and performance standards for goal 5, "*addressing natural resource issues*." Seven districts elected not to include any management objectives or performance standards addressing natural resource issues.

Natural resource issues that could be monitored cooperatively by Carrizo-Wilcox GCDs and the RRC including the regulation and plugging of abandoned oil and gas wells, well construction of oil and gas production wells and related Class 2 disposal wells, and the documentation and monitoring of active pipelines, inactive pipelines, and other pipelines that may pose a threat to the quality of Carrizo-Wilcox Aquifer groundwater resources were not addressed as frequently as possible in the management plans reviewed for the Study.

However, the 18 other Carrizo-Wilcox GCDs elected not to address the contamination monitoring through cooperation with the RRC on oil and gas activity within their respective jurisdictions under goal 5 "*addressing natural resource issues.*" Other opportunities for addressing natural resource issues that were not included in the management plans reviewed include: (1) monitoring of point source or non-point-source pollution that may be of concern for natural resources within their jurisdiction, (2) natural sources of groundwater contamination, and (3) opportunities such as partnering with the TCEQ's Groundwater Planning and Assessment Team, which provides "support and coordination of interagency efforts toward preventing and managing contamination of groundwater by pesticides," or the Texas Groundwater Protection Committee. Texas Water Code §5.236 requires the TCEQ to provide notice to local officials regarding groundwater contamination which may affect drinking water supplies in their area. Notification is provided to county judges and public health officials to supply information on groundwater impacts to drinking water supplies within the county. However, the Carrizo-Wilcox GCDs did not include management objectives or performance standards recognizing or utilizing this source of information from state agencies and committees regarding groundwater contamination. Eighty percent of the management objectives and performance standards focused on water quantity concerns and not water quality concerns.

All Carrizo-Wilcox GCDs included management objectives and performance standards for goal 6, *"Addressing Drought Conditions."* Each Carrizo-Wilcox GCD elected to address drought conditions through establishing a Drought Contingency Plan, monitoring the Palmer Drought Severity Index, or to maintain updates with the Drought Preparedness Council Situation Report. GCDs have created rules that trigger conservation by water users in their jurisdictions. Largely, Carrizo-Wilcox GCD boards of directors and general managers are responsible for implementing plans and notifying residents of the water conservation measures established by the individual districts. Thirteen out of 21 Carrizo-Wilcox GCDs stated that they would monitor the Palmer Drought Severity Index; however, several districts did not include detailed management objectives and performance standards necessary to determine whether or not the goal is being achieved. Precipitation and climate vary from east to west in the state as do the hydrologic and hydrogeological characteristics. Generally prolonged droughts in Texas are perceived as a threat to the environment, human welfare, and to the economy of the state. According to our evaluation, six of the Carrizo-Wilcox GCD's called for development of Drought Contingency Plans or Drought Management Strategy Plans when "addressing drought conditions". Our review of the GCD management plans suggests that more may have to be done at the local level of government to ensure that strategic groundwater resources important to the environment and economy are more adequately monitored during drought conditions. Another observation is that certain Carrizo-Wilcox GCD management plans could benefit from the utilization of more than just one well as a drought monitor well, considering that some GCDs have expansive jurisdictions. Drought conditions impact groundwater resources differently from region to region and this is recognized from this review.

All 21 GCDs addressed goal 7 "*Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control, Where Appropriate and Cost-Effective."* We found that the Carrizo-Wilcox GCDs are not, as would be expected, uniformly addressing this goal due to the varied conditions and aquifer characteristics in regions from northeast to southwest. Overall, recharge enhancement and brush management were not generally supported objectives of the Carrizo-Wilcox GCDs. Only a few districts specifically stated they would participate in rain harvesting or precipitation modification programs.

4.0 Evaluation and Critique of the State's Groundwater Availability Models for the Carrizo-Wilcox Aquifer

The BEG examined and critiqued the Groundwater Availability Models (GAMs) to

(a) Assess model runs of representative pumpage scenarios in the northern, central, and southern Carrizo Wilcox aquifer

(b) Estimate spatial and temporal variability of recharge and modeling of recharge

(c) Evaluate sources of water for pumpage (outcrop zone [increased recharge, reduced discharge], confined zone [change in aquifer storage, increased recharge from overlying Queen City Sparta), and timescales for impacts of pumpage on outcrop and Queen City Sparta aquifer.

The current Queen City Sparta Groundwater Availability Models (QCSP GAMs) include the Carrizo-Wilcox Aquifer. It was built upon the original Carrizo-Wilcox GAM (Dutton et al., 2003) by adding the Queen City and Sparta Aquifers and it superseded the original Carrizo-Wilcox GAM. A simplified cross section of the Carrizo-Wilcox Aquifer and the conceptual groundwater flow model for the Queen City and Sparta GAM can be find in the main text (Figure 8.1 and 8.2). In this text, we refer QCSP GAM as "Carrizo-Wilcox Queen City Sparta GAMs" or simply GAMs.

A general critique of the GAMs was conducted. The value of the GAMs in the process of establishing desired future conditions was recognized. Important factors to consider in future updates of the GAMs include role of faults in flow system because barrier faults significantly reduce water availability for future pumpage, importance of groundwater-surface water interactions, improved recharge estimates, incorporating the Yegua Jackson Aquifer and Brazos River Alluvium Aquifer into the Carrizo-Wilcox Queen City/Sparta GAM, refining the groundwater pumping database, linking steady state and transient models, including groundwater quality, and incorporating new information into the Carrizo-Wilcox Queen City Sparta GAMs. One of the critical issues with respect to the conceptual model is whether the central Carrizo Wilcox GAM should include **faults** as barriers to flow and evaluation of the location of such faults. Universal application of faults as barriers in the Central Carrizo Wilcox Queen City Sparta GAM significantly impedes horizontal flow. Modeling analysis indicates that the impact of these faults may be more important in predicting future drawdown than it was for transient calibration. Current stresses to the system from pumping are too low to evaluate the impacts of these faults on horizontal flow in the system. Future Carrizo-Wilcox GAMs should consider models with and without faults to provide bounding estimates on groundwater availability. **Groundwater-surface water interactions** are also an important component of the Carrizo-Wilcox Queen City Sparta GAM. Because pumpage captures groundwater discharge to streams, it is important that simulations of groundwater–surface-water interactions are realistic and reliable. Although current GAMs simulate groundwater-surface water interactions, incorporating an additional shallow layer into the Carrizo-Wilcox Queen City Sparta GAM may improve simulations of these interactions and allow an improved approximation of the potential to reduce baseflow discharge to streams and capture of surface water by future pumpage. Evaluating impacts of pumpage on stream baseflow is extremely important for future environmental flows. **Recharge** is a critical parameter for GAMs. The impact of grid resolution on recharge estimates in the models also needs to be considered. Recharge rates are important for model calibration because they help to constrain the hydraulic conductivity field (Kelley et al., 2004). Field studies should be conducted to better quantify groundwater recharge to the aquifer. Improvements in the **groundwater pumping** database are very important and should include reevaluation of groundwater production in Brazos and Robertson Counties (by Bryan College Station, TAMU and industrial commercial pumping). Because most of the pumping in the aquifer in GMA 12 is in the Simsboro Formation, additional information should be collected or any existing data used to better describe the thickness and hydraulic conductivity distribution of this unit. The current Carrizo-Wilcox GAM within the Queen City Sparta GAMs uses the predevelopment period for the **steady state** simulation; however, the **transient simulation** does not begin until 1980. Groundwater pumping expanded significantly between predevelopment and 1980, and this expansion is not captured in the GAMs. Two different approaches could be used to address this problem: (1) begin the transient simulation in the 1920s and 1930s and simulate the expansion of pumpage from that time similar to that of the original Carrizo Wilcox GAM (Dutton et al., 2003) or (2) use 1980s data to simulate steady state conditions if the aquifer was relatively stable at that time. These different options should be considered. Future revisions of the GAMs should incorporate any basic data collected in the aquifers since the GAMs were developed. Such information should include structure data and hydraulic properties, including hydraulic conductivity and storativity, and calibration data, including hydraulic heads and stream gain/loss data. While TWDB collects data on these parameters throughout the aquifer, the GCDs are also collecting substantial quantities of data that should be incorporated into TWDB databases. Detailed pumping tests and water level data from mines in the region, including the Sandow Mine, Walnut Creek Mine, and others, should be evaluated and fully used in the GAMs. **Uncertainties** in conceptual models, input parameters, such as recharge and ET and hydraulic parameters, should be considered in GAM modeling. Uncertainties in the conceptual models could be considered through bounding calculations, e.g. models with and without faults in the Central Carrizo Wilcox Aquifer. Model sensitivity analyses should be used to guide future data collection in areas where the GAM is sensitive to different parameters. It is important that stakeholders and others are aware of uncertainties in GAM data and calibration and do not try to use the GAMs beyond the level at which the data can support them. **Groundwater quality** was not simulated by the GAMs; however, groundwater quality is a critical aspect of groundwater availability. The GAM program should consider expanding simulations to explicitly simulate groundwater quality. **Postaudits** can be done at this stage to test the reliability of GAM predictions. The Carrizo-Wilcox GAM was calibrated from 1980 through 1999. As stated earlier, new information has been collected since then. Postaudits involve using the existing GAM structure and new boundary conditions to assess how model output compares with new available target information. It should be recognized that these enhancements of the GAMs will require additional data collection beyond what is currently being collected.

(a) GAM runs of representative pumpage scenarios for GMA 11, 12, and 13 were based on the desired future conditions obtained from TWDB staff. GAMs for establishing DFCs were run by TWDB staff for GMAs 11 and 13 and by consultants for GMA12. Mean drawdowns corresponding to DFCs for the GMA regions are as follows:

Simsboro: GMA 12: ~100 to 300 ft

Middle Wilcox: GMA 11: 15 ft and GMA 13: ~ 25 ft

Carrizo: GMA 11: 38 ft; GMA 12: ~ 60 ft, GMA 13: 31 ft

(b) Spatial and temporal variations in groundwater recharge were reevaluated for the GAMs. Recharge rates were estimated using a variety of different approaches. Recharge rates based on groundwater chloride data from the TWDB database range from 0.4 in/yr (2 percent of precipitation) in the semiarid southern part to 4.0 in/yr (8% of precipitation) in the humid northern part of the aquifer. Point recharge rates based on unsaturated zone chloride data in the central Carrizo Wilcox Aquifer are spatially variable (0.7 to 1.6 in/yr) but generally consistent with those based on groundwater chloride data. Recharge rates based on unsaturated zone modeling results range from 0.4 in/yr (2 percent of precipitation) in the southern part to 5.1 in/yr (10 percent of precipitation) in the northern part of the aquifer.

(c) Impacts of pumpage on water resources depend on the source of water for pumpage. Prior to groundwater development, groundwater recharge to the aquifer equaled groundwater discharge through streams, evapotranspiration (ET), and deep recharge to the confined portion of the aquifer. Water for pumpage associated with groundwater development can be derived from various sources, including aquifer storage, increased recharge, and/or decreased discharge. The transient GAM model indicates that after decades of pumping (1999) groundwater storage represents a significant fraction of total pumpage. Total cross-formational flow is reversed in all portions of the aquifer from the overlying Queen City Aquifer. Analysis of sources of water for pumpage related to the desired future conditions for 2060 shows that aquifer storage contributes 44 to 58 percent of pumpage. Cross-formational flow contributes 40 percent of pumpage in GMA 13 because most pumpage is from the Carrizo Aquifer, which is adjacent to the overlying Queen City Aquifer. In contrast, pumpage in GMA 12 is mostly from the Simsboro Aquifer and is separated from the Queen City Aquifer by the Carrizo Aquifer; therefore, cross-formational flow is much less (19 percent). Low cross-formational flow in GMA 11 (19 percent) may be related to generally low pumpage in the Carrizo Aquifer. Understanding the sources of pumpage is important for determining the impacts of pumpage on the flow system. Temporal variability in water sources for pumpage shows that aquifer storage contributions decrease from 100 percent to

~50 percent over the 50-yr modeling period, whereas contributions from cross-formational flow, streams, and ET increase through time. It will be important to design monitoring programs to evaluate these changes through time.

5.0 Assessment of Anthropogenic Contamination in the Recharge Area of the Carrizo-Wilcox Aquifer and Potential Pollution of the Aquifer

The distribution of contaminants was evaluated primarily from the TWDB database. The main objective of the TWDB monitoring program is to evaluate regional variations in groundwater quality, and the monitoring program is not designed to assess local contamination. Water quality in the Carrizo-Wilcox Aquifer outcrop (unconfined) area from the TWDB groundwater quality database was evaluated for compliance with U.S. Environmental Protection Agency (EPA) Maximum Contamination Level (MCL) concentrations, including 17 primary and 11 secondary inorganic and radioactive constituents. Given the analysis of the TWDB groundwater quality database, there are no widespread violations of any of the primary MCL constituents, with only 27 individual violations for all primary MCL constituents. The most significant violation is for nitrate-N, which accounts for 19 of the primary MCL exceedances. These nitrate exceedances are found largely in domestic and irrigation wells and are most likely related to septic tank and fertilizer applications. The number of secondary MCL exceedances ranges from ~200 to 350 for various elements. These exceedances are dominated by TDS, chloride, sulfate, iron, and manganese. The percentage of wells that exceeded the TDS MCL is much greater in the southern (62%) than in the central or northern Carrizo Wilcox Aquifer (25 and 27%), and median TDS concentrations are also greatest in the southern region (587 mg/L) relative to the central and northern regions (331 and 325 mg/L). Iron and manganese MCL exceedances are also widespread. Median iron concentrations range from 79 to 133 ug/L. These exceedances may be related to lignite distribution. Occurrence of pH values outside the 6.5 to 8.5 range are greatest in the north and may cause problems of scaling and corrosion.

There are 147 documented groundwater contamination cases from the TCEQ database and 23 documented cases from the RRC data in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 Draft Groundwater Quality Portion of the Water Quality Inventory of the State of Texas, required by EPA according to Section 305B of the Clean Water Act. The most common contaminants reported include gasoline and diesel related to petroleum storage tanks. Additional contaminants include volatile organic compounds (such as benzene, toluene, ethylbenzene, xylene, and BTEX), chlorinated solvents, TCE, TPH, creosote, heavy metals, chloride, and arsenic. These contaminants are generally related to local sources and do not represent widespread impacts on the aquifer.

We reviewed previous studies of groundwater quality in the aquifer that focused mostly on regional evolution of groundwater chemistry from oxidizing acidic water in the recharge zone to reducing basic water in the confined zone in the East Texas Basin. Poor-quality water in the unconfined aquifer was attributed to wells in Calvert Bluff muddy sediments. Groundwater generally evolved from calcium-rich water to sodium-rich water, attributed to cation exchange on clays. Highest salinity was found in the southern part of the aquifer, which was attributed to cross-formational leakage into the aquifer. Lignite and lignite mining can also impact groundwater quality. Leaching of mine spoils may generate moderately brackish waters (<10,000 mg/L) that could degrade groundwater quality near a mine. Although the primary lignite host, the Eocene Wilcox Group, is a major aquifer, lignite and groundwater resources in the Wilcox Group generally occur at different stratigraphic intervals and geographic locations, reducing potential contamination. There are no reported cases of groundwater contamination from the surface mining group of the RRC.

Potential pollution of the aquifer was evaluated from an online survey conducted as part of this study. Most groups did not submit any response to this question, many responded negatively, and a few pointed to some issues, such as the need to plug old oil wells, inconsistencies in rules among groundwater conservation districts, and importance of developing regulations to protect the recharge zone of the aquifer. Lignite mining was listed as a potential cause of groundwater pollution in the aquifer because of removal of the filtering capacity of lignite and replacement with mine spoils; however, others have suggested a relationship between lignite deposits and kidney disease and/or renal pelvic cancer with a syndrome termed Balkan Endemic Nephropathy (BEN). There is no reported case of groundwater contamination from the surface mining group of the RRC.

The distribution of fracing wells in the Carrizo Wilcox outcrop area was evaluated as a potential source of groundwater contamination. The EPA is currently conducting a study on potential groundwater contamination from fracing operations. Projected increases in groundwater pumpage in the confined part of the Carrizo Wilcox Aquifer should enhance flow from surrounding confining units, such as the Hooper and Calvert Bluff units, which could degrade groundwater quality, depending on the quality of groundwater in the confining units. The likelihood of this cross-formational flow into the aquifer degrading groundwater quality should be evaluated in future studies.

The main management or protection regulatory gap identified through the online survey was concern expressed by 6 of the 16 groundwater conservation districts related to the groundwater-management policies and enforcement procedures of the RRC. The ability of the RRC to effectively regulate hydrocarbon production companies and their well operations is contested owing to its perceived inability to effectively regulate groundwater support wells or to eliminate the occurrence of abandoned wells. Whereas water quality of Public Water Supply wells is regulated by TCEQ, these regulations are restricted to water quality at entry points and do not assess raw water quality. The Texas Groundwater Protection Committee identified the lack of oversight of water quality of private wells as a major regulatory gap that should be addressed in the future.

Summary Report for Task 1a and Elements of Task 1b: Predominant Management or Protection Issues and Concerns from Stakeholders Regarding the Carrizo-Wilcox Aquifer

1.0 Introduction

This summary report prepared by the Bureau of Economic Geology (BEG) is submitted to fulfill requirements of Task 1a and partial requirements of Task 1b of the TCEQ Carrizo-Wilcox Study, Project 582-8-75374-119. Specifically, this report describes (1) the final stakeholder group identified as part of the TCEQ Carrizo-Wilcox Study (the Study), (2) surveys developed to solicit input from interested parties, including groundwater conservation districts (GCDs) with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, regarding predominant management or protection issues and concerns related to the Carrizo-Wilcox Aquifer, and (3) a summary and representative detailed responses to the survey questionnaires. While this summary report contains survey responses from the GCD's survey regarding predominant groundwater management and/or protection issues and concerns, the complete responses to the survey questionnaires are available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/

2.0 Final Stakeholder List

A significant component of Task 1a was focused on identifying, contacting, and soliciting feedback from targeted interest groups and individuals directly or indirectly involved with the Carrizo-Wilcox Aquifer. In order to compile and contact potential stakeholders of the Carrizo-Wilcox Aquifer, the following efforts were completed.

- A project website was created at http://www.beg.utexas.edu/cswr/aquiferstudy/ that contained a link inviting individuals and interested groups to sign up as a stakeholder.
- State agencies, trade and professional organizations such as Texas Alliance of Groundwater Districts, Texas Water Conservation Association, Texas Rural Water Association, and Texas Section American Water Works Association were contacted with requests to post links on the organization's websites advertising the Study and the request for stakeholders to participate.
- A list of water user groups with contact information from the 2006 and draft 2011 regional water plans for all regional water planning groups currently using or planning to use the Carrizo-Wilcox Aquifer at any point in the 50-year planning horizon were obtained from the TWDB.
- A list of water users of the Carrizo-Wilcox Aquifer and their contact information that have submitted a water use survey was obtained from the TWDB.
- A variety of sources were used to compile a complete list of all GCDs with jurisdictional responsibilities over the Carrizo-Wilcox Aquifer, including current contact information.

- Sign up lists from a 2009 Carrizo-Wilcox Aquifer Symposium held at Texas A&M University were obtained from the TWDB.

The final stakeholder list contains 517 names, the majority of which include email contact information (see separate electronic attachment). This stakeholder list has been and will continue to be used throughout the course of the Study to disseminate results, findings, and information on future meetings.

3.0 Carrizo-Wilcox Study Online Survey Questionnaires

The primary process for soliciting comments from stakeholders of the Carrizo-Wilcox Aquifer was through online surveys developed specifically for this Study. Two separate survey questionnaires were developed to solicit focused information from interested parties and from GCDs. Draft surveys were presented to TCEQ staff for review prior to their release. These surveys are presented below.

3.1 Interested Parties Survey Questionnaire

Following is the complete Carrizo-Wilcox Aquifer Interested Parties Survey Questionnaire that was posted online.

1. What is the name of your interested organization, if applicable?
2. What is the mailing address for your interested party?
3. What is the phone number for your interested party?
4. What is the email address for the interested party?
5. Provide a brief description of any predominant groundwater management or protection issues and concerns related to the Carrizo-Wilcox Aquifer.
6. Please provide a list, with sufficient detail to allow for an availability analysis, of any new or alternative water management strategies that are being considered for future implementation that may impact groundwater availability in the Carrizo-Wilcox Aquifer, but are not currently in the regional and state water plans.
7. Are you aware of any compatibility issues that have already been documented or that may occur as a result of the implementation of any district's management plan? If yes, please describe the nature of the compatibility issue.
8. Provide a list of any substantial enforcement actions, regardless of ultimate resolution, taken for violations of district rules since September 1, 2007. In as much detail as possible, include the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance.
9. Are you aware of the presence of anthropogenic contaminants in the recharge zone or the

production zones of the Carrizo-Wilcox Aquifer? If so, please describe the nature of the contamination (i.e.- contaminant, location, possible sources and supporting analytical data, if available).

10. Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current or potential aquifer contamination.

3.2 Carrizo-Wilcox Aquifer Groundwater Conservation District Survey Questionnaire

Following is the complete Carrizo-Wilcox Aquifer Groundwater Conservation District Survey Questionnaire that was posted online.

1. What is the name of your groundwater conservation district?
2. Who is the primary point of contact, and what is his or her title?
3. What is the physical address of the district's headquarters?
4. What is the mailing address for the district's headquarters?
5. What is the phone number?
6. What is the primary contact email address?
7. On what date was the groundwater conservation district established by the legislature or TCEQ?
8. What is the date of the confirmation election, if applicable?
9. By what method was the district created? (special law, petition, other)
10. If the district's boundaries are based on something other than county boundaries please provide a map of the district's boundaries. (Adobe PDF format preferred)
11. If the district's jurisdictional boundaries are based on political boundaries, please describe what boundaries are included in the district.
12. Provide a brief description of any predominant groundwater management and/or protection issues and concerns related to the Carrizo-Wilcox Aquifer.
13. Provide an electronic copy of the district's current adopted management plan. (Word format preferred)
14. Provide an electronic copy of the district's current adopted rules. (Word format preferred)
15. Provide an electronic copy of any written procedures or guidelines for operational purposes that have been developed and adopted by the district. (Word format preferred)
16. Provide electronic copies of any scientific data, reports, or presentations presented to and considered by the district during development of the current management plan. Include

board of directors meeting minutes for any meeting in which the science in question was discussed. (Microsoft Office formats preferred)

17. Provide electronic copies of any scientific reports presented to and considered by the district during the development of the current district rules. Include in this information request electronic copies (Word format preferred) of district board of directors meeting minutes for any meeting during which the science identified was discussed.

18. Provide electronic copies (Word format preferred) of any scientific reports presented to and considered by the district during the development of any procedures that have been adopted by the district. Include in this information request electronic copies (Word format preferred) of district board of directors meeting minutes for any meeting during which the science identified was discussed.

19. Provide a list of all substantial enforcement actions taken for violations of district rules since September 1, 2007. The district should include in this list the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance. (Word format preferred)

20. Provide a list, with sufficient detail to allow for a groundwater availability analysis, any new or alternative water management strategies that are being considered for future implementation that may impact groundwater availability in the Carrizo-Wilcox Aquifer, but are not currently in the regional and state water plans.

21. Summarize significant programs included in the district's management plan specifically designed to conserve and protect the Carrizo-Wilcox Aquifer.

22. Has the district identified any compatibility issues that have already been documented or that may occur as a result of implementation of the district's current management plan and an adjacent district's management plan? If yes, please describe nature of compatibility issue.

23. Within GMA 11, 12, and 13, each groundwater conservation district that has been selected to serve as the administrator for the GMA process is asked to provide electronic copies of minutes from any meetings that have taken place since the beginning of the joint planning process during which scientific data and/or studies have been considered during the development of desired future condition recommendations. Provide electronic copies of any scientific data or presentations considered and identified in the minutes (Word format preferred).

24. Are you aware of the presence of anthropogenic contaminants in the recharge zone or the production zones of the Carrizo-Wilcox Aquifer? If so, please describe the nature of the contamination (i.e.- contaminant, location, possible sources and supporting analytical data, if available).

25. Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current or potential aquifer contamination.

4.0 Summary and Representative Responses to Carrizo-Wilcox Aquifer Study Survey Questionnaire

There are a variety of stakeholders within the Carrizo-Wilcox Aquifer, representing numerous interests such as municipalities, regional water suppliers, environmental interests, private property owners, agriculture, industry, and locally governed GCDs. All identified interests were invited to participate in the Study by responding to surveys developed to collect information regarding the Carrizo-Wilcox Aquifer and any predominant groundwater management and protection concerns. The following sections summarize selected responses to the survey questionnaires. For the complete set of responses, the reader is referred to the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/

4.1 Interested Parties' Responses

There were 65 unique responses received, either directly to the BEG (via email or other correspondence) or through the online Carrizo-Wilcox Aquifer Interested Parties Survey Questionnaire. Questions 1-4 were included to solicit contact information in the event that follow up questions were determined to be warranted.

Question 5 requests that the interested party *"Provide a brief description of any predominant groundwater management or protection issues and concerns related to the Carrizo-Wilcox Aquifer."* This was the question for which almost all responses were focused. Generally, the responses can be divided into four broad categories:

- Wholesale and retail water providers concerned about the future of groundwater management in the Carrizo-Wilcox Aquifer
- Environmental interests concerned with inadequate focus on environmental protection during adoption of desired future conditions, management plans, and rules by Carrizo-Wilcox GCDs
- Citizens concerned about property rights being violated by the Lost Pines Groundwater Conservation District
- Citizens in Gonzales County concerned about their ability to sell their groundwater due to actions by the Gonzales County Groundwater Conservation District

Wholesale and retail water providers survey comments focused on a number of issues related to their ability to continue to provide water supplies to their current and future customers. For example, San Antonio Water System and Schertz Seguin Local Government Corporation commented on difficulties they experienced during water supply project implementation due to inconsistencies in the permitting process from one district to another and their inability to obtain long-term commitments for water supply permits. San Antonio Water System commented regarding the variability in local groundwater conservation district philosophies and rules that "*This regulatory inconsistency adds unnecessary difficulty to both long-term planning for water supply projects, as well as planning for the aquifer on a hydrologic basis.*" Canyon Regional Water Authority commented that the "crisis" in management of the Carrizo-Wilcox Aquifer is not based on actual hydrologic data. Specifically, Canyon Regional Water Authority commented that, "*Over the past several years, public awareness of groundwater issues and concerns over the availability of future supplies has grown dramatically. Fueling much of the anxiety is a fear of the impending "drying up" of Texas' aquifers. However, the common perception that we are recklessly "mining" groundwater and that future generations will be left with meager and dwindling supplies is unfounded. On the contrary, the large amount of available hydrogeologic data indicates that the Carrizo-Wilcox aquifers are vast and largely underdeveloped resources that contain enough water to supply all of Central and South Texas' needs for centuries.*"

The City of Bryan submitted two sets of comments to the Study. The following is a portion of the comments submitted by the City of Bryan along with recommendations:

"…When Senate Bill 2 passed in 2001, the Texas Water Development Board was directed to 'designate groundwater management areas covering all major and minor aquifers in the state…Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources. To the extent feasible, the groundwater management area shall coincide with the boundaries of a groundwater reservoir or a subdivision of a groundwater reservoir'. (Sec. 35.004, Senate Bill 2, 77th Texas Legislature).

In response to this directive, the Texas Water Development Board designated 16 groundwater management areas, based almost exclusively on the boundaries of major and minor aquifers throughout the state. Recognizing the natural hydrologic divide effect that the Colorado and Trinity rivers have on groundwater flow in this critical groundwater resource, the Carrizo-Wilcox Aquifer, which covers all or parts of more than 60 counties in Texas, was divided into three groundwater management areas.

It is noteworthy to reflect on the directive from the Texas Legislature in 2001, 'Each groundwater management area shall be designated with the objective of providing the most suitable area for the management of the groundwater resources'. If the Carrizo-Wilcox Aquifer is to be managed as effectively as possible in order to ensure that it remains a high quality, cost-effective, reliable water supply for the citizens of Texas, including the City of Bryan, then the most effective form of groundwater management should be utilized. However, the Carrizo-Wilcox Aquifer is currently managed, in part by 24 groundwater conservation districts, and in other areas, still has no management.*(*- reader's note - for this study, it has been determined that there are 21 confirmed GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.)

Therefore, the City of Bryan requests;

- *Continued legislative review to ensure hydrologically-based management of the Carrizo-Wilcox Aquifer,*
- *Continued legislative support for financial resources necessary to develop, update, and maintain science necessary to make sound policy and regulatory decisions, and*
- *Legislative review regarding ownership of groundwater as it relates to investments made by political subdivisions, such as the City of Bryan, to ensure that these investments will not be negatively harmed by any adopted desired future conditions or regulatory methods developed and adopted by groundwater conservation districts."*

The Brazos River Authority, a large wholesale water supplier over a significant portion of the Carrizo-Wilcox Aquifer expressed concerns regarding (1) groundwater conservation district's that treat local use differently than nonlocal use in permitting, (2) that current regulations encourage "use it or lose it" mentality, i.e., current district rules give no incentive to keep water in place, (3) district rules do not address conjunctive use with any specificity and in practice work against the concept, (4) permits give no assurance to continued access to the water in the "out" years, and (5) differences in groundwater management philosophies of adjacent GCDs managing and regulating essentially the same supply of water will result in recurring problems and conflicts with no clear solutions.

Environmental Stewardship submitted comments regarding concerns that the groundwater management area joint planning process and individual GCDs need to adequately capture the need to sustain spring flows and base flows to streams and rivers as a component of establishing desired future conditions. Environmental Stewardship's primary conclusion is that the groundwater management area process and GCDs have a duty and obligation to include rivers, streams and springs in the adopted desired future conditions of the Carrizo-Wilcox Aquifer.

Thirty five comment letters (form letters) were received from landowners who are concerned that their property rights are being violated through the actions of the Lost Pines Groundwater Conservation District. This letter states that the moratorium placed on groundwater permits in the Lost Pines Groundwater Conservation District is preventing the citizens from selling their water to the Guadalupe-Blanco River Authority for future water supplies. The letter is reproduced below in its entirety.

"As a constituent landowner in Texas, I am writing to let you know I feel my property rights are being violated. The Lost Pines Groundwater Conservation District (LPGCD) is blocking my rights to sell my ground water. The Rule of Capture has been in effect in the State of Texas since 1904. Although tested more than once, the Texas State Supreme Court has upheld this law in every case. The legislative creation of groundwater conservation districts has, because of the actions and policy of our local district, taken away my rights to my water, and has given it to the

District. The District is not bound to either its constituents or science. "Life" terms for board members, and appointee vs. elected official status, gives board members free rein to act on political motivation and personal bias, with no accountability to anyone. Across the state, districts are "hoarding" resources that are the property rights of landowners. The Carrizo Wilcox aquifer has more than enough water to meet the projected demands in our district for decades beyond the 50-year planning period. The Guadalupe Blanco Water Authority has signed a letter of intent to purchase much needed municipal water supplies from my land, water that I have a legal right to sell. In addition, the project would generate considerable revenues for our county. The Lost Pines Groundwater Conservation District is attempting to block this sale. The District has placed a moratorium on issuing any permits for water to be exported outside the district pending the setting of Desired Future Conditions (DFC's) by the TWDB. The neighboring district, Post Oak Savannah Groundwater Conservation District, does not have a moratorium and is still issuing permits regardless of the DFC's. The district has denied the landowners the right to participate or comment on rules, reservations, or any action that could impact landowners by refusing to post all meetings, except their regularly scheduled monthly meetings, and denying attendance in any meeting met with less than a forum. Therefore, the LPGCD is interfering with the free market system and placing all landowners within the District at a disadvantage because of denying due process."

Thirteen comments were received from a group of landowners and board members of Gonzales-Carrizo Management, Inc. This is a group of landowners who organized and arranged to lease groundwater to Texas Water Alliance—a division of the San Jose Water Company. These survey responders state that they own property in eastern Gonzales County. This set of comments states, "*Our main concern is being able to lease our water rights. We want parity (for our eastern side of the county) with the western side of the county, with regard to the number of allocable acre feet that we are allowed to lease*."

Question 6 asks the interested party to *"Provide a list, with sufficient detail to allow for an availability analysis, of any new or alternative water management strategies that are being considered for future implementation that may impact groundwater availability in the Carrizo-Wilcox Aquifer, but are not currently in the regional and state water plans."* Two responses were received to this request for information. First, the Schertz-Seguin Local Government Corporation submitted a preliminary project description for expansion of the existing Schertz-Seguin Local Government Corporation Project well fields in Gonzales and Guadalupe counties to include wells and/or well fields in Wilson County to provide a project yield of 10,000 acre feet per year by the year 2020. Second, Environmental Stewardship submitted a substantial set of comments and information that supported the process of establishing desired future conditions. Environmental Stewardship has been involved in the joint planning process leading to the establishments of desired future conditions, and is supporting the need to ensure sustainable management of the groundwater resources including the protection of spring flow and base flow into streams and rivers from the Carrizo-Wilcox Aquifer. Due to the volume of information submitted by Environmental Stewardship, the reader is encouraged to review the complete set of comments and information submitted by Environmental Stewardship on this survey request at the Study website. Canyon Regional Water Authority submitted a lengthy commentary under this question, titled *Observations on the Regulation of the Carrizo-Wilcox Aquifer in Central and South Central Texas*. However, the content of this commentary was determined to not be related to this question. It is included in its entirety on the Study website link for survey responses.

Question 7 from the Interested Parties Survey asked *"Are you aware of any compatibility issues that have already been documented or that may occur as a result of the implementation of any district's management plan? If yes, please describe the nature of the compatibility issue."* Six "yes" responses addressing Question 7 were received, all but one of which were from either wholesale or retail water suppliers. The main concerns raised were (1) conflicts between GCDs over different approaches to the issuance of production permits and in their interpretation and application of Chapter 36 requirements, (2) conflicts between regional water planning groups and GCDs in that the regional water planning groups have incorporated water supplies from the Carrizo-Wilcox Aquifer in volumes that are reported to be in excess of what the Carrizo-Wilcox Aquifer ecosystem can sustain, (3) that GCDs through the groundwater management area joint planning process should submit desired future conditions that are based on preferred hydrogeologic parameters and not geographically specific production amounts, which will allow TWDB to calculate a managed available groundwater estimate for the GCDs to manage, and (4) absence of required coordination between GCDs and regional water planning groups will lead to significant uncertainty about the reliability of water management strategies in the regional water plans. There were 12 "no" responses.

Question 8 requests the responder to *"Provide a list of any substantial enforcement actions, regardless of ultimate resolution, taken for violations of district rules since September 1, 2007. In as much detail as possible, include the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance."* Question 9 asks *"Are you aware of the presence of anthropogenic contaminants in the recharge zone or the production zones of the Carrizo-Wilcox Aquifer? If so, please describe the nature of the contamination (i.e.- contaminant, location, possible sources and supporting analytical data, if available)."* Of the 65 responses to the Interested Party Survey Questionnaire, no respondent answered question 8. Seventeen respondents answered question 9 with "no," "none," or "not aware of any."

Question 10 asks *"Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current or potential aquifer contamination."* Fourteen respondents answered this question with a negative response. There were three responses to this question regarding management or regulatory gaps. The Schertz-Seguin Local Government Corporation reported that "… there are numerous wells in the Carrizo Formation. Some are old wells that were originally used for irrigation of crops.

There are also numerous oil wells that have been converted to water wells. Some of these wells are deteriorated and should be plugged but landowners are reluctant to assume financial responsibility for maintaining wells that are no longer in use." Bexar Metropolitan Water District pointed to possible management or regulatory gaps because of the many different GCDs and their rules and the lack of consistency between them. The absence of any interstate and bi-national management of the aquifer could lead to potential future contamination of the aquifer. The City of Bryan reported that they were unaware of what regulatory controls are in place to manage the recharge zone. The City of Bryan went on to suggest that the recharge zone should be considered a sensitive area to protect these areas from sources of contamination such as from manufacturing or commercial industries. Forty-eight respondents did not answer this question.

Finally, a few other comments were received regarding the need for the Study and other issues that were not specific to the questions posed in the survey. These comments are included in the online database.

4.2 Carrizo-Wilcox Aquifer Groundwater Conservation Districts Responses

For the purposes of this Study, 21 confirmed GCDs are recognized as having statutory responsibilities regarding the management and conservation of groundwater resources in the Carrizo-Wilcox Aquifer. The 21 GCDs are:

1. Anderson County Groundwater Conservation District
2. Bee Groundwater Conservation District
3. Bluebonnet Groundwater Conservation District
4. Brazos Valley Groundwater Conservation District
5. Evergreen Underground Water Conservation District
6. Fayette County Groundwater Conservation District
7. Gonzales County Underground Water Conservation District
8. Guadalupe County Groundwater Conservation District
9. Live Oak Underground Water Conservation District
10. Lost Pines Groundwater Conservation District
11. McMullen Groundwater Conservation District
12. Medina County Groundwater Conservation District
13. Mid-East Texas Groundwater Conservation District
14. Neches and Trinity Valleys Groundwater Conservation District
15. Panola County Groundwater Conservation District

16. Pineywoods Groundwater Conservation District
17. Plum Creek Conservation District which is a WC&ID
18. Post Oak Savannah Groundwater Conservation District
19. Rusk County Groundwater Conservation District
20. Uvalde County Underground Water Conservation District
21. Wintergarden Groundwater Conservation District

The confirmation election for the Harrison County Groundwater Conservation District was defeated by the voters during a May 8, 2010, election. It is not authorized to hold any subsequent election, and therefore is dissolved.

Sixteen GCDs (76 percent of the total) responded to the survey request. Survey responses were not submitted by:

1. Anderson County Groundwater Conservation District
2. Bee County Groundwater Conservation District
3. Guadalupe County Groundwater Conservation District
4. Live Oak Groundwater Conservation District
5. McMullen County Groundwater Conservation District

The overarching purpose of the survey was to evaluate the scientific foundation of the management plans, rules and regulations promulgated by these Carrizo-Wilcox Aquifer GCDs.

The 16 GCDs had three common responses to the survey question regarding predominant groundwater management and/or protection issues and concerns related to the Carrizo Wilcox Aquifer. These responses can be characterized as concerns regarding (1) availability of water supplies and challenges involved in the establishment of desired future conditions (2) need for continuous improvement of available science for purposes of decision making (3) and perceived lack of regulatory oversight by the RRC regarding oil and gas activities. Allegations are made in some of the surveys that lack of regulatory oversight has contributed to contamination of local groundwater supplies.

Seven of the 16 GCDs responded that their districts primary concern was establishment of desired future conditions that will result in protection and conservation of available groundwater resources in their district. For example, Plum Creek Conservation District (PCCD) stated their primary concern was incorporation of desired future conditions into their management plan and that "permitting outside the boundaries of the PCCD that could impact the amount of water that would be available to satisfy local needs in the future." Lost Pines Groundwater Conservation District stated that "it appears that LPGCD has already permitted more than the anticipated total of the MAGs for the district" that were established by Groundwater Management Area 12.

Moreover, Lost Pines Groundwater Conservation District noted that export of groundwater resources outside of the district is on the rise and that "13.5 percent of the total pumpage from nonexempt wells was exported from the district." Current and future groundwater production capabilities are of serious concern to three quarters of the districts that responded to the survey.

Three of the 16 GCDs cited a lack of readily available groundwater science resources that could help them make important short-term and long-term decisions. Rusk County GCD stated the need for more technology specifically aimed at monitoring "pumping, spring flow and aquifer volume." Brazos Valley Groundwater Conservation District concerns included establishment of groundwater production limits and development of Depletion Management Zones to "alleviate the depletion stress on the aquifer", which are to be based upon "best available science." Post Oak Savannah Groundwater Conservation District stated "our District has significant concerns with the reliability of the GAM predictions of the groundwater levels in the CW Aquifer". Districts throughout the Carrizo-Wilcox Aquifer expressed uncertainty derived from the availability of accurate local groundwater science and districts ability to forecast future demand.

RRC's (RRC) groundwater management policies and enforcement procedures were a primary concern for 6 of the 16 GCDs. The RRC ability to comprehensively regulate oil and gas exploration, production, and transportation companies is contested because of the perceived inability to effectively regulate groundwater support wells and their inability to eliminate the occurrence of orphan or abandoned wells. Neches and Trinity Valleys Groundwater Conservation District stated concerns regarding *"inadequate oversight by the RCT of oil and gas wells and rig supply wells, including the many old wells within the district, which has presented many potential sources of contamination of groundwater."* GCDs in the eastern region of the Carrizo Wilcox Aquifer, including Panola County Groundwater Conservation District, Plum Creek Conservation District, Neches and Trinity Valleys Groundwater Conservation District, and Rusk County Groundwater Conservation District noted that there are regulatory concerns with the management of oil and gas exploration and the oversight provided by Texas agencies including the RRC and Texas Department of Licensing and Regulation (TDLR). For instance, Rusk County GCD stated *"With each oil/gas exploration well drilled, a water well is drilled to support the operation. Due to lack of staffing, the TDLR does not conduct any construction inspections of these water wells. Our concern is for the illegal practice of screening more than one zone to gain the quantity of water needed. This practice, although not a major problem while the rig is in use, becomes a problem when the well is capped and left idle. The RCGCD purchased a down hole video camera in 2008 and requires inspection of each of these support wells within 180 days of the oil/gas rig leaving the pad. We have inspected over 300 wells and have found that about 11% were screened in more than one zone."* Neches and Trinity Valleys GCD stated *"Inadequate oversight by the RRC of the oil and gas wells and rig supply wells, including the many old wells within the District, which has presented many potential sources of contamination of groundwater."* Panola GCD stated *"lack of regulation by RRC of water wells involved in oil and gas operations and mining."* Plum Creek CD stated *"There are management* *and regulatory gaps from the RRC that could possible lead to contamination of the recharge zone. These gaps are from past production practices and casing leaks."* The aforementioned comments were submitted to the Carrizo-Wilcox Aquifer Study GCD survey.

Moreover, Rusk County GCD noted that the recharge zone for the Carrizo Wilcox Aquifer extends beyond the borders of Texas and suggested that a management or regulatory gap could lead to contamination of the recharge zone. Rusk County GCD suggested that this gap should be addressed by the TWDB or some other state entity if it is not currently under study. Rusk County GCD also noted extensive strip mining operations in the recharge area. The strip mining process includes removing 200 to 300 feet of earth to mine the lignite. Once mined, the overburden is then replaced. This mixing of the overburden and removal of the lignite may have an effect on recharge for the Carrizo Wilcox Aquifer. Rusk County GCD noted that this issue should be evaluated in future studies.

Attachment: Electronic copy of Carrizo-Wilcox Study stakeholders list.

Summary Report for Task 1b: Review of Carrizo-Wilcox Groundwater Conservation District (GCD) Management Plans, Rules, and Procedures Adopted by GCDs to Determine Whether They are Based on Sound Scientific Principles

1.0 Introduction

This summary report prepared by the Bureau of Economic Geology (BEG) is submitted to fulfill remaining requirements of Task 1b of the TCEQ Carrizo-Wilcox Study (the Study), Project 582-8-75374-119. Task 1b directs the BEG to, *"Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to (1) statutory authority and (2) to any science that was considered during development of the rules. Link individual GCD plan goals, objectives, and performance standards to any science that was considered in their development. Link individual GCD permitting procedures and decisions since September 1, 2007, to any science used in their development."* In order to accomplish this subtask, the BEG requested specific information from the GCDs in an online survey developed for the Study. The requests were as follows (a subset of total online survey):

- *Number 16 - Provide electronic copies of any scientific data, reports, or presentations presented to and considered by the district during development of the current management plan. Include board of directors meeting minutes for any meeting in which the science in question was discussed.*
- *Number17 - Provide electronic copies of any scientific reports presented to and considered by the district during the development of the current district rules. Include in this information request electronic copies of district board of directors meeting minutes for any meeting during which the science identified was discussed.*
- *Number 18 - Provide electronic copies of any scientific reports presented to and considered by the district during the development of any procedures that have been adopted by the district. Include in this information request electronic copies of district board of directors meeting minutes for any meeting during which the science identified was discussed.*

This summary report is our evaluation of GCD management plans, rules, and procedures in order to determine if they are based on sound scientific principles. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are now available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/.

We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific rules to both broad or GCD-specific statutory authority and any supporting science that was considered during the development of the management plans and rules. One additional management plan for Anderson County Groundwater Conservation District was obtained from the TWDB, but no rules have been located.

2.0 GCD Rules and Statutory Authority

Our review of the rules promulgated by the GCDs indicates that the statutory basis of rulemaking by the Carrizo-Wilcox GCDs originates from Chapter 36 of the Texas Water Code, specifically, §36.101 which authorizes GCDs to create and enforce rules. Specific activities for which GCDs may develop and adopt rules are described throughout Chapter 36 of the Texas Water Code. In addition, Texas Water Code §36.1071 specifically provides that a GCD shall adopt rules to implement the management plans. No GCDs identified any unique rule-making authority in their responses to the Study survey questionnaire beyond those contained in Chapter 36 of the Texas Water Code. Since not all of the management plans and rules were submitted through the online survey, and in order to facilitate a more complete analysis, we obtained missing management plans and rules with the assistance of staff at the Texas Water Development Board and by accessing the nonrespondent GCD websites for publically available copies. A complete set of management plans and rules are available for review online at the Carrizo-Wilcox Aquifer Study website at http://www.beg.utexas.edu/cswr/aquiferstudy/gcd_rules.php/.

3.0 Groundwater Science and Texas Water Law

Eleven of sixteen GCDs provided supporting information to the Study's request for *"electronic copies of any scientific data, reports, or presentations presented to and considered by the district during development of the current management plan."* All 16 GCDs articulated, to varying degrees, their reliance on groundwater science, including information from groundwater availability models that are produced and provided by the Texas Water Development Board. Nine of the 16 GCD's cited the 2007 State Water Plan and applicable regional water plans as a source for science used in developing their management plans.

The history of groundwater science in Texas is long and rich, with substantial contributions made by state agencies such as the Texas Water Development Board (and the predecessor agency, the Texas Board of Water Engineers), the Texas Commission on Environmental Quality (and predecessor agencies), groundwater conservation districts, and federal agencies such as the United States Geological Survey. After the passage of Senate Bill 1 in 1997 by the 75th Texas Legislature, the need for improved, more site-specific groundwater science was realized. This need for improved groundwater science was at least initially the result of (1) the new requirement that GCDs develop and adopt management plans (Texas Water Code, §36.1071), and (2) the regional water planning process requiring water plans be developed for the next 50 years (Texas Water Code, §16.053). As a result of this realization, the 77th Texas Legislature passed Senate Bill 2 in 2001. This legislation, in part, requires that, "*the executive administrator* (of the Texas Water Development Board) *shall obtain or develop groundwater availability models for major and minor aquifers in coordination with groundwater conservation districts and regional water planning groups created under Section 16.053 that overlie the aquifers. Modeling of major aquifers shall be completed not later than October 1, 2004. On completing a groundwater availability model for an aquifer, the executive administrator shall provide the model to each groundwater conservation district and each regional water planning group created under Section 16.053 overlying that aquifer*" (Texas Water Code, §16.012(l)). In recognition of the improved groundwater science that would ultimately result from this directive, Texas Water Code, Chapter 36 was also amended to provide guidance to GCDs with regards to one of the primary sources of groundwater science to be considered in developing management plans and rules necessary to achieve the goals adopted in the management plans. Texas Water Code §36.1071(h) states, "*In developing its management plan, the district shall use the groundwater availability modeling information provided by the executive administrator together with any available site-specific information that has been provided by the district to the executive administrator for review and comment before being used in the plan."* Specifically, Texas Water Code §36.1071(e)(3)(E) requires that a GCD management plan contain estimates of "*the annual volume of flow into and out of the district within each aquifer and between aquifers in the district, if a groundwater availability model is available.*" During the joint planning process required by Texas Water Code §36.108(d), the following requirement directing GCDs to consider the TWDB groundwater availability modeling results is included: "*Not later than September 1, 2010, and every five years thereafter, the districts shall consider groundwater availability models and other data or information for the management area and shall establish desired future conditions for the relevant aquifers within the management area….*"

Therefore, it is clear in statute that it is the intent of the Texas Legislature that one of the primary sources of groundwater science to be utilized by GCDs during their development of management plans and their adoption of desired future conditions is to be the groundwater availability models and groundwater science developed and made publically available by the executive administrator of the Texas Water Development Board. If it is the intent of a GCD to utilize local, site-specific information in the development of a management plan, or in the adoption of desired future conditions, in addition to or in lieu of the groundwater science and groundwater availability models developed and provided by the executive administrator, the GCD must submit and obtain the prior approval of the executive administrator to use this alternative source of information (Texas Water Code §36.1071(h) and §36.108(d).

Our review of the submitted survey questionnaire responses and/or management plans submitted confirms the linkage between sound groundwater science provided by the Texas Water Development Board to the GCDs for their use in the development of their management plans, as required by Texas Water Code §36.1071. In addition, 5 of 16 responding GCDs cited scientific literature published by the BEG describing the hydrogeology of the Carrizo-Wilcox Aquifer. Six

GCDs referenced material utilized in joint planning sessions within their Groundwater Management Areas. Ten GCDs worked with technical consultants to develop their individual GCD management plans and rules.

The Survey also asked GCDs to submit "*electronic copies of any scientific reports presented to and considered by the district during the development of the current district rule*s." A review of current statute documents that the current sequence of management activities and decision points is (1) adoption of desired future conditions, (2) adoption of a management plan designed to achieve desired future conditions, and (3) adoption of rules designed to achieve the goals of the management plan. Therefore, it is not surprising that for most GCDs, the majority, if not all science developed to address an affected provision included in GCD rules was originally developed during deliberations leading up to the adoption of desired future conditions and management plans. This reality was evidenced by the limited nature of the response by GCDs to the request for information considered during development of rules.

4.0 Linkage between Sound Scientific Groundwater Principles and GCD Management Plans and Rules

All 16 GCDs that responded to the online survey, either in their direct response or in the text included in their management plan, stated that they utilized sound scientific principles in their adopted management plans. As discussed earlier, this use of sound scientific principles is in large part a result of the direct linkage in statute between the groundwater science produced by the TWDB and requirements for certain elements to be included in GCD management plans. However, the linkage between sound scientific principles and rules adopted by Carrizo-Wilcox GCDs is, for the most part, dependent upon the assumption that necessary science considered during the development of a management plan was adequate for the subsequent development and adoption of rules. To review, one of the objectives of the Study was to, "*Examine rules, plans and procedures adopted by each groundwater conservation district (GCD) to determine if they are based on sound scientific principles. This information will be obtained from the GCDs using an online survey. Link individual GCD rules to …any science that was considered during development of the rules…Link individual GCD permitting procedures and decisions since September 1, 2007 to any science used in their development."* After an examination of the rules and scientific information provided by the GCDs, the following observations are noted. First, 6 of the 16 GCDs that responded to the Study survey questionnaire provided information regarding the request for scientific information utilized during rule making. Next, of those six GCDs, one GCD clearly articulated the direct linkage between the scientific information that was utilized with the corresponding rule(s) that was subsequently adopted. This district was the Pineywoods GCD. However, it is noted that in the process of adopting rules, decisions made by GCD boards of directors may be based on the cumulative consideration of a number of information sources, such as local studies, regional studies such as regional water plans, and groundwater availability modeling studies, and not just one specific study. Perhaps more importantly, it is also noted that the main focus of scientific efforts from a process perspective is during the adoption of desired future conditions and management plans. The development and adoption of rules is a process designed to achieve the adopted desired future conditions and management plan, and therefore the consideration of science has already occurred earlier in the decision process.

The following summaries are provided to better articulate this point.

Bluebonnet GCD submitted a list of approximately 16 scientific publications, not all of which were related to the Carrizo-Wilcox Aquifer. There was no supporting information or meeting minutes submitted that articulated how any of this information was considered, if at all, by the board of directors during rule-making activities.

Pineywoods GCD submitted copies of board meeting minutes and two presentations that were considered during the rule making process. One of these presentations provided a link between the scientific reasoning and adoption of District *Rule 14* that enables the Pineywoods GCD to regulate the transfer of groundwater outside of the district. The Pineywoods GCD adopted *Rule 14* based upon regional water planning demand projections, groundwater availability modeling estimates, and population projections for the region. In the materials provided, the Pineywoods GCD ultimately decided to establish a transfer rule that safe guards the region's water supply future and potential socioeconomic development. The rule's purpose states:

"In recognition of the fact that the transfer of groundwater resources from the District for use outside of the District impacts residents and property owners of the District differently than use within the District, and in order to manage and conserve groundwater resources within the District, and provide reasonable protection of the public health and welfare of residents and property owners of the District, a ground water transfer permit is required to produce groundwater from within the District's boundaries and to transfer such groundwater for use outside the District."

Gonzales County Underground Water Conservation District (UWCD) submitted six reports in response to the Study's request for scientific information that was utilized during their rule making procedures. The reports submitted are as follows:

- *South Central Carrizo System Groundwater Model*, presented by the San Antonio Water System and HDR Inc.
- *Technical Comparison of Southern and Central Carrizo-Wilcox Groundwater Availability Models (GAMs) in Overlap Area*, presented by the San Antonio Water System and HDR Inc.
- *Ground Water Velocity*, presented by the Center for Water Supply Studies Texas A&M University-Corpus Christi
- *Comparison between the South Central Carrizo System Groundwater (SCCS) Model and the Southern Queen City and Sparta Aquifer (QSCW) GAM*, presented by URS

- *Status of Joint Planning in Groundwater Management Areas*, presented by the Texas Water Development Board
- *Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer*, presented by Intera and Parsons

Though the studies provided by the Gonzales County UWCD are relevant and supported by sound scientific principles, we were unable to discern where the science submitted was specifically linked to the rules of the Gonzales County UWCD. Further, based upon review of meeting minutes submitted, it was documented that these presentations were made to the board of directors.

Rusk County GCD provided a variety of information and datasets that have been assembled relevant to the groundwater resources of Rusk County. However, this information was not cited by the board of directors in any meeting minutes during development of rules. It is noted that the district's well monitoring activities were utilized in implementing the District's Drought Contingency Plan.

Fayette County GCD submitted several scientific reports and exhibits produced by Daniel B. Stephens & Associates, Inc., including a hydrogeologic study of the various aquifers within the region and various district maps produced by the Thornhill Group, Inc. Further, after review of the Fayette County GCD's board meeting minutes provided in response to the Study survey questionnaire, rule-making and amending of the rules were often discussed. A review of meeting minutes documented several instances where development of the rules was addressed.

Plum Creek Conservation District provided seven DVDs with numerous articles of information that supported the board of director's decision making process during the development of management plan and rules. It is clear from information contained on the DVDs provided that the PCCD did go through a deliberate process to ensure that sound scientific principles were considered during their decision-making process.

Summary Report for Task 2: Groundwater Conservation District Enforcement of Substantial Compliance with Rules Regarding the Carrizo-Wilcox Aquifer

1.0 Introduction and Background

This is a report to summarize information regarding district enforcement of substantial compliance with district rules regarding groundwater management over the Carrizo-Wilcox Aquifer. There are 21 groundwater conservation districts (GCDs) that have jurisdictional authority over the management and conservation of the Carrizo-Wilcox Aquifer.

Throughout the report, italicized text indicates language lifted directly from the surveys developed and utilized for this Carrizo-Wilcox Aquifer Study (the Study).

1.1 Online Survey

Task 2 of the Study directs the Bureau of Economic Geology (BEG) to:

> *"Evaluate each groundwater conservation district for enforcement of substantial compliance with its rules. Tabulate number of enforcement actions since September 1, 2007. This information will be obtained from the groundwater conservation districts (GCDs) using an online survey.*"

The BEG developed two online surveys: one for GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer, and another for parties identified as having an interest in the management of the Carrizo-Wilcox Aquifer (Interested Parties Survey).

Of the 21 GCDs with jurisdictional authority over the management and conservation of the Carrizo-Wilcox Aquifer, 16 responded to the survey (Table 4.1). Thirteen of the 16 indicated that they did not pursue either formal or informal enforcement actions for violations of their rules. Three GCDs indicated that they had carried out formal enforcement action under their rules since September 1, 2007.

In the survey to the 21 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer, the specific information request stated:

> "*#19. Provide a list of all substantial enforcement actions taken for violations of district rules since September 1, 2007. The district should include in this list the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance*."

Table 4.1: The 21 GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.

#	Groundwater Conservation Districts	Groundwater Conservation Districts That Responded to Survey
1	*Anderson County GCD*	*Bluebonnet GCD*
2	*Bee County GCD*	*Brazos Valley GCD*
3	*Bluebonnet GCD*	*Evergreen UWCD*
4	*Brazos Valley GCD*	*Fayette County GCD*
5	*Evergreen UWCD*	*Gonzales County UWCD*
6	*Fayette County GCD*	*Lost Pines GCD*
7	*Gonzales County UWCD*	*Medina County GCD*
8	*Guadalupe County GCD*	*Mid-East Texas GCD*
9	*Live Oak UWCD*	*Neches &Trinity Valleys GCD*
10	*Lost Pines GCD*	*Panola County GCD*
11	*McMullen County GCD*	*Pineywoods GCD*
12	*Medina County GCD*	*Plum Creek GCD*
13	*Mid-East Texas GCD*	*Post Oak Savannah GCD*
14	*Neches & Trinity Valleys GCD*	*Rusk County GCD*
15	*Panola County GCD*	*Uvalde County UWCD*
16	*Pineywoods GCD*	*Wintergarden GCD*
17	*Plum Creek GCD*	
18	*Post Oak Savannah GCD*	
19	*Rusk County GCD*	
20	*Uvalde UWCD*	
21	*Wintergarden GCD*	

The Interested Parties Survey contained a similar request:

> "#5. *Provide a list of any substantial enforcement actions, regardless of ultimate resolution, taken for violations of district rules since September 1, 2007. In as much detail as possible, include the dates, nature of violations, citation to rules violated, enforcement actions taken by the district, resolution actions taken by violators, and dates of compliance."*

A variety of stakeholders responded to the survey including 49 concerned citizens and landowners. Further, 11 other entities responded to the survey including: the Gonzales-Carrizo Management, Inc. landowners association, the Plum Creek Group, the City of Bryan, the San Antonio Water System, Aqua Water Supply Corporation, Bexar Metropolitan Water District, Environmental Stewardship, the Brazos River Authority, the Schertz-Seguin Local Government Corporation, the Canyon Regional Water Authority, and the Lavaca County GCD.

Only respondent information provided through these two surveys are included in this report.

1.2 GCD Rules and Regulations

GCDs are authorized through their enabling legislation to promulgate rules and regulations necessary to manage and conserve groundwater resources within their jurisdictional boundaries. Moreover, GCDs are provided the ability to construct policies and rules that may aid the GCD in meeting goals established in the GCD's management plan. GCDs are directed by statute to develop rules and regulations that will facilitate compliance with broader policy goals within their jurisdictional boundaries.

Enforcement actions that promote current and future compliance with GCD rules are considered positive enforcement actions. Alternatively, enforcement actions where violators simply choose to pay a fine and continue to be in noncompliance are considered by the Study team to be negative enforcement actions. That is, the enforcement approach is not a deterrent to future violations The following section details positive and negative enforcement actions identified as part of the Study.

2.0 Survey Responses from Carrizo-Wilcox GCDs

There are 21 confirmed GCDs with jurisdictional responsibilities for the Carrizo-Wilcox Aquifer. Of the 21 GCDs, 16 submitted at least partial responses to the GCD survey questionnaire developed for the Study. Six GCDs included a response to the survey request "*to provide a list of all substantial enforcement actions taken for violations of district rules since September 1, 2007*." Three *of the six* GCD's stated that they had carried out formal enforcement actions since September 1, 2007.

Pineywoods Groundwater Conservation District cited nine enforcement actions since September 2007. Eight of the nine violations were resolved through positive enforcement actions. Table 4.2 details violations including: failing to register a well, well contamination, and well construction without a permit. Fines and fees were assessed by the Pineywoods GCD and paid by the violators. The violations were resolved resulting in compliance with the rules.

Table 4.2: Violations from the Pineywoods Groundwater Conservation District

Date	Violations	Rules Violated	Enforcement Actions	Violators Actions
7/10/07	*Jeanine Butler* Deteriorated Well	TOC§1901.255	Notice of Violation	Compliance, Well Capp
5/20/08	*Melrose* No Permit	Water Code§36.001 (8)(B)(E), 1.1(s), 2(a)(b)(	Notice of Violation	Compliance, Permit Fee Paid & Permits Renewed
1/8/09	*ETTL Engineering* No Permit	District Rule 3.1 TAC§76.700(1)	Notice of Violation	Compliance
1/22/09	*Keithville,* Drilling Without Permit	District Rule 3.1 TAC§76.700(1)	Notice of Violation	Compliance
1/30/09	*Smithers,* Drilling Without Permit	District Rule 3.1, 3.4, 5.1, 6(a)(b) TAC§76.700(1)	Notice of Violation Board action penalties	Compliance, Penalties Paid $2,750.00
4/24/09	*Cotton Thompson* No Permit	District Rule 3.1Water C §36.115(a), §36.119(a)	Notice of Violation	Compliance
8/5/09	*Emmett Luman,* Possible Contamination	District Rule 3.1, 3.4, 5.1 6(a)(b) TAC§76.700(1)	Notice of Violation	Compliance
1/4/10	*Jimmy Cordova* Rehabilitation of Well Without Registering	District Rule 3.1Water C §36.115(a), §36.119(a)	Notice of Violation	Compliance
1/28/10	*Kenneth Mechell* Contamination	TAC§76.1000(a)(4)	Notice of Violation	Ongoing

Neches & Trinity Valley Groundwater Conservation District reported two enforcement actions that had been ongoing or resolved since September 1, 2007. In both enforcement actions the Neches & Trinity GCD was able to bring the violators into compliance through the use of the courts and assessing fines. These actions may be considered positive enforcement actions as the violators did not simply elect to pay the fees and continue to violate district rules.

In the first enforcement, the Neches & Trinity Valley GCD reported that:

> "*Lakeshore Utilities Co. had drilled two wells without drilling permits and had not submitted operating permit applications or quarterly pumping report. They also had not paid any fees due to these violations. In February 2008 Lakeshore agreed to a settlement agreement to pay District legal fees and all back pumping fees. They had previously completed the drilling and operating permit applications and begun reporting and paying for current pumping. The settlement was reached out of court.*"

In the second enforcement action, the Neches & Trinity Valley ***GCD reported***:

> *"Eagles Bluff County Club (AKA Lake Palestine Associates, LP) was operating a well when the District began operating in 2003 and did not register the well, obtain an operating permit, nor submit quarterly pumping reports and pay the required fees. A settlement agreement was reached in December 2008 with Lake Palestine Associates, LP agreeing to pay back pumping fees and District legal expenses. They had previously submitted an operating permit application and began submitting quarterly pumping reports and paying current pumping fees."*

Post Oak Savannah Groundwater Conservation District made a total of six positive enforcement actions, for which a total of $1,700 in fines was assessed from April 8, 2008, through February 9, 2010. The following Post Oak Savannah GCD rules were violated: one infraction of Rule 7.12, Drilling Permits; two infractions of Rule 7.13, Drilling or Altering a Well; two infractions of Rule 7.3, Records, Reports, and Drillers Logs;, and one infraction of Rule 8.2, Application for Transport Permit. The fines assessed per violator ranged from $100 to $900. Table 4.2, below, is reproduced in its entirety from materials submitted by Post Oak Savannah GCD, and details the five various violators and six infractions of the rules. One violation was from the oil and gas sector and all other violators were from the commercial and residential water supply sector.

Table 4.3: Summary of Post Oak Savannah Groundwater Conservation District Enforcement Actions

1.) April 8, 2008 – Chucks Oilfield Service - Violation of District Rules – Producing groundwater from a nonexempt well without a permit from the District. Fine $250.00
The owners of Chuck's Oil Field Service, upon notice from the District, immediately filed permit applications to become compliant with District Rules and paid all fees associated with the amounts of water which had been produced as well as application fees and the fine. Chuck's also became compliant with all other Rules of the District as directed by the Board. **RULE 7.12. DRILLING PERMITS.** 1.) A landowner, well owner, or any other person acting on their behalf, must obtain a drilling permit before a new nonexempt well may be drilled, equipped, or completed. Such permit must also be obtained before re-drilling, replacing or altering a new or existing well that is not exempt under Rule 7.10(2)(a)(b) or (c). Except as otherwise provided in these rules, wells that are to be used for domestic use, or for poultry or livestock purposes, and that are located on a tract of land that is less than ten acres in size, including wells that will be equipped so as not to be able to produce more than 25,000 gallons per day (GPD), must comply with the requirements set forth in these rules.
2.) April 15, 2009 – Siegert Water Wells – Violation of District Rules – Drilling exempt water wells for oil and gas use (Chapter 36.117, TWC) without filing appropriate reports to the District. Fine $900.00
Upon notice from the District Siegert filed all necessary reports and became compliant with all Rules. **RULE 7.3. RECORDS, REPORTS, AND DRILLER'S LOGS.** The driller of a well shall keep an accurate driller's log for each new well. The driller shall file a copy of each log and a report detailing the drilling, equipping, and completing of the new well with the District within 60 days after the date the new well is completed. The report shall include all information submitted by the driller to any agency of the State of Texas.
3.) July 14, 2009 – James Eugene Luce - Violation of District Rules – Drilling a well without a license and registration and failure to file reports to the District. Fine $200.00
The District required Mr. Luce to file all necessary reports with the District and then to plug the well. The reports were filed and the well was duly plugged, and the fine was paid within 60 days.

RULE 7.13. DRILLING OR ALTERING A WELL. No person may drill a new nonexempt well without first obtaining a drilling permit from the District. A new well described in Rule 7.10(1) must obtain a drilling permit and be registered.

RULE 7.3. RECORDS, REPORTS, AND DRILLER'S LOGS. The driller of a well shall keep an accurate driller's log for each new well. The driller shall file a copy of each log and a report detailing the drilling, equipping, and completing of the new well with the District within 60 days after the date the new well is completed. The report shall include all information submitted by the driller to any agency of the State of Texas.

4.) August 6, 2009 – Brien Water Wells – Violation of District Rules – installing pump in existing well without well owner obtaining a permit – Fine $100.00

Brien Water Wells, after putting a pump in an existing water well, prior to property owner obtaining a permit, filed all necessary reports with the District and then assisted the District in obtaining compliance from the property owner to permit the well. The fine was paid and compliance achieved within 30 days.

RULE 7.13. DRILLING OR ALTERING A WELL. No person may increase the production rate or the size of a nonexempt well or well pump to exceed the production rate, well or well pump size authorized in the permit, and no person may increase the production rate or size of a well or well pump of a well that is exempt under Rule 7.10(1)(a) or (b), or Rule 7.10(2)(a) to increase the production capacity of the well to more than25,000 GPD, without first applying for and obtaining a permit from the District.

5.) February 9, 2010 – Blue Water Systems – Violation of Permit – Fine $250.00

Upon notice from the District that Blue Water Systems (BWS) was not compliant with the Rules and terms of their permit, BWS forwarded to the District the necessary documents and amended their contracts with their customers to become compliant with the Rules and requirements and paid the fine within 60 days.

RULE 8.2. APPLICATION FOR TRANSPORT PERMIT. If the water is to be resold to others, provide a description of the applicant's service area, metering, leak detection and repair program for its water storage, delivery and distribution system, drought or emergency water management plan, and information on each subsequent customer's water demands, including population and customer data, water use data, water supply system data, alternative water supply, water conservation measures and goals, conjunctive use, and the means for implementation and enforcement of all applicable rules, plans, and goals.

GCDs are authorized to implement rules including the assessment of fees and levying legal charges against violators. However, 13 of the 16 GCDs that responded to the Study's survey questionnaire reported that they had neither formal enforcement actions nor informal enforcement actions (informal enforcement actions being GCD actions such as communications from GCD staff to a potential violator that a problem exists and if no corrective action is taken, the potential violation will be taken to the Board of Directors for formal enforcement action).

For instance, **Rusk County Groundwater Conservation District** stated that:

> "*There have been no enforcement actions taken for violations of district rules. When developed, the rules were reviewed with all local entities involved, TWDB, TCEQ, TDLR, and RRC of Texas. Because of this collective approach, applicability of our rules has been reinforced through occasional communication between local entities and State enforcement agencies. This cooperative effort has led to positive acceptance by all parties of our rules. The District has also been successful in working with violators to ensure compliance, suspending the need to enter into formal enforcement procedures."*

Brazos Valley Groundwater Conservation District and ***Fayette County Groundwater Conservation District*** reported that:

> "*The District has followed up on many complaints and violations for alleged waste, illegal drilling of a well, drilling of a well in violation of spacing requirements, producing over permitted amount, and abandoned wells; but to date, communications (written and oral) with the District's board, staff and attorney have resolved the issues without having to pursue formal enforcement measures. As all of the issues were resolved, the District does not consider these occurrences "substantial violations."*"

3.0 Survey Responses from Interested Parties

Of the 65 responses to the Interested Party Survey, there were no responses regarding enforcement actions taken by the GCDs with jurisdictional authority over the Carrizo-Wilcox Aquifer.

4.0 Conclusions

Twenty-one GCDs have jurisdictional authority over the management and conservation of the Carrizo-Wilcox Aquifer. Of those 21, three GCDs or less than 15 percent of the 21 GCDs, reported substantial enforcement actions stemming from violations of groundwater conservation district rules. All enforcement actions were instances of positive enforcement (intentionally punitive), as there were no instances of negative enforcement reported as part of this Study. Based on a review of other documentation submitted as part of the Carrizo-Wilcox Aquifer Study such as GCD Board meeting minutes, it appears that there have been numerous violations of rules within certain GCDs, but in all but one case, based on the meeting minutes, it appears that violations were resolved informally.

Summary Report for Task 3: Regional and State Water Plans and Their Potential Conflicts with Carrizo-Wilcox Groundwater Conservation District (GCD) Management Plans

1.0 Introduction and Background

Task 3 of the Carrizo-Wilcox Aquifer Study (the Study) directs the Bureau of Economic Geology (BEG) to "*Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD* (Groundwater Conservation District) *plans; conduct stakeholder meetings to present the goals and results of the Study, and to identify, tabulate and describe every existing and projected water user group strategy or alternative strategy that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater."*

In the scope of work for the Study, the use of the phrase "… *Evaluate current regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans"* resulted in some unique challenges with respect to the timing of the plans in question. The following are provided to illustrate these challenges:

- The Study was initiated by the Texas Commission on Environmental Quality (TCEQ) with an original deadline for Task 3 of September 1, 2010
- Groundwater conservation districts, through their participation in the joint planning process, were statutorily required (TWC §36.108(d) to adopt Desired Future Conditions (DFCs) and submit them to the Texas Water Development Board (TWDB) by September 1, 2010
- Regional water planning groups were required by rule (31 TAC §357.5(b)(2)) to submit updated regional water plans to the TWDB for approval by September 1, 2010 (note that a few regions were granted time extensions of approximately one month), and finally,
- The TWDB is statutorily required to submit an updated state water plan reflecting the 2011 regional water plans (that were submitted on September 1, 2010) to the Governor, Lieutenant Governor, Speaker of the House, and to the Chairs of the Natural Resource Committees by January 5, 2012 (TWC §16.051(a)).

Task 3 was designed to evaluate regional and state water plans and GCD management plans in order to identify conflicts that may exist between the two planning processes. Ideally, this evaluation would occur after the 2011 regional water plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). Due to the very recent submission of DFCs at the time of this writing, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate the adopted DFC.

In order to provide a meaningful evaluation that generally reflects the intent and goal of Task 3, accommodations were made for the following realities of the various timelines. These include

- Delivery of this report was delayed by approximately two months in order to allow the TWDB to process applicable data in the 2011 regional water plans pertaining to currently available supplies and water management strategies that utilize the Carrizo-Wilcox Aquifer.
- It is understood that the data provided by the TWDB are provisional in nature, in that TWDB staff are currently engaged in the final review and approval of regional water plans, and as such, certain water management strategies may need to be revised prior to final approval of the regional water plans by the TWDB.
- It is also understood that the MAGs provided by the TWDB to the BEG for the Study are currently in draft form, pending review and comment from the Carrizo-Wilcox GCDs regarding quantification of exempt use. After exempt use has been established for each county and aquifer, that amount will be deducted from the MAGs utilized in this report. The sum of exempt use and MAG estimates will then represent the total amount of pumping consistent with the adopted DFC. While the MAG estimates may change due to comments from the GCDs, the estimates of total amount of pumping consistent with the DFCs (referred to as MAGs in this report) are not expected to change. This total amount of pumping is what is directly analogous to groundwater availability in the regional water plans. It is expected that the 2016 regional water plans will include this total amount of pumping (which includes exempt use + the MAG). Until exempt use has been quantified, <u>for the purposes of this report only</u>, MAG equals the total amount of pumping consistent with the DFC.
- With respect to a review of the regional and state water plans, it is recognized that we are currently in the interval between adoption of regional water plans and adoption of a state water plan. As such, the current state water plan is now four years old, and in many cases, inconsistent with recently adopted regional water plans. For the purposes of this report, in order to utilize the most current information and to avoid unnecessary confusion, information regarding currently available supplies and water management strategies from the recently adopted regional water plans was utilized for this analysis. Information from the 2007 State Water Plan was reviewed, but will not be presented in this report.
- In the 2016 regional water plans and the 2017 State Water Plan, the total amount of groundwater available to meet current and future needs can be no more than the MAG for the most recently adopted DFC. This task (Task 3) asks the BEG to "*Evaluate <u>current</u> regional and state water plans and all Carrizo-Wilcox aquifer related strategies for conflicts with GCD plans*". What is not defined explicitly during this transitional stage of planning (both regional water planning and joint planning for GCDs) is what constitutes a conflict. For reference, 31 TAC §356.2(a)(6) states a conflict is "*A situation where the managed available groundwater identified in a management plan or the adopted state water plan is not the managed available groundwater based on the desired future*

conditions set by the groundwater conservation districts in the groundwater management area." This definition will be universally applicable during the 2016 regional water plans and 2017 State Water Plan. However, due to the timing of submission of DFCs and calculation of MAGs by the TWDB, none of the Carrizo-Wilcox GCDs were able to provide official MAGs in time for inclusion in the 2011 regional water plans. Therefore, technically, no conflict can exist at this time. For the purposes of Task 3, we did compare, on a county by county basis, the sum of Carrizo-Wilcox Aquifer availability and water management strategies that rely on the Carrizo-Wilcox Aquifer to the draft estimates of MAG for the Carrizo-Wilcox Aquifer from the initial round of joint planning that just concluded on September 1, 2010. Therefore, solely for the purposes of this evaluation, a "potential conflict" is defined as "where, on a county-level evaluation, the sum of current water supplies available from the Carrizo-Wilcox Aquifer and water management strategies that rely on groundwater from the Carrizo-Wilcox Aquifer in a county are greater than or exceed the MAG for the same county."

2.0 Methodology

This Summary Report was prepared using three different types of data; (1) amount of water supplies currently available from the Carrizo-Wilcox Aquifer based on information contained in the recently adopted 2011 regional water plans, (2) amount of additional water to be obtained from the Carrizo-Wilcox Aquifer recommended as water management strategies in the recently adopted regional water plans, and (3) draft estimates of MAG from the recently completed joint planning process. Information for (1) and (2) were provided by TWDB Water Resources Planning and Information staff (email dated October 7, 2010) and MAG estimates were provide by TWDB Water Science and Conservation staff (email dated October 5, 2010).

In order to compare the relevant data, an examination of the different data sources is appropriate. Water supplies available from the Carrizo-Wilcox Aquifer, as reported in the regional water plans on a decadal basis, are defined, in part, in 31TAC §357.7(a)(3) as the "*... existing water supplies legally and physically available to the regional water planning area for use during drought of record....*" In other words, the water supply has to be legally available (i.e., permits obtained) and infrastructure to transport the water to the current or future users has to be in place in order for the water to be counted as a current water supply. If the groundwater cannot be legally produced at this time or the infrastructure is not in place at the time of the plan development, then the groundwater may not be counted as a currently available supply. Any incremental increase in water to meet future water supply needs over what is currently available must be included as a recommended water management strategy in the applicable regional water plan. To include a future supply as a recommended water management strategy, the amount of water must be quantified on a decadal basis in the regional water plan. For the purposes of this evaluation, it is assumed that all water management strategies will be implemented in the amount and time prescribed in the 2011 regional water plans.

3.0 Results

For the purposes of this analysis, 64 counties were included in data provided by the TWDB containing information from the 2011 regional water plans and/or estimates of MAG. Table 5.1 contains information on the 64 counties, including the regional water planning area, groundwater management area, and on a decadal basis, (1) the sum of currently available water supplies and water management strategies, (2) the MAG, and (3) the difference between (1) and (2), which is referred to as "*Difference*." Figures 5.1–5.3 illustrate the decadal values for (1) and (2) for the years 2010 and 2060, for all counties within the jurisdictional boundaries of a Carrizo-Wilcox GCD.

"*Difference*" values noted in Table 5.1 with parentheses (xxx) documents that the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans is greater than the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative for the decade referenced, a potential conflict exists. It is important to note that when the *Difference* is a negative number, which means for that county in that decade, there is insufficient managed available groundwater to implement all water management strategies based on the use of the Carrizo-Wilcox Aquifer in the 2011 regional water plans, while achieving the desired future condition.

Included in Table 5.1 are six counties, Bee, DeWitt, Graves, Live Oak McLennan and Travis, that included either currently available supplies or water management strategies from the Carrizo-Wilcox Aquifer, but for which there is no MAG. This situation may occur under multiple situations. For example, water supplies from the Carrizo-Wilcox Aquifer may be either currently or being planned for importation into a county, which is most often the case. Alternatively, as is the case in Travis County (which does not have any Carrizo-Wilcox Aquifer present in the county, a political subdivision, such as the City of Elgin, may be located in two or more counties (In the case of the City of Elgin, Bastrop and Travis counties) . For regional water planning purposes, the source of water supplies or water management strategies is identified on a county by county basis. Therefore, Carrizo-Wilcox Aquifer water supplies for the City of Elgin, In the case of Elgin will be included for both counties.

Alternatively, there are two counties within GMA 11; Red River County with a MAG of 0 and Trinity County with a MAG of 2,215 acre-feet per year, but neither have any currently available supplies or water management strategies from the Carrizo Wilcox Aquifer in the 2011 regional water plans. This situation is typically results when an aquifer is overlain by another aquifer that is shallower and of superior water quality and quantity such that there is no planned or current use of the aquifer. This is especially true in areas where the freshwater portion of the Carrizo-Wilcox Aquifer is at its most downdip limits. For example, Bee County GCD and Live Oak Underground Water Conservation District both have jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer, however these GCDs were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer.

There are 3 counties in GMA 11—Angelina, Henderson and Van Zandt; 7 counties in GMA 12—Bastrop, Brazos, Burleson, Freestone, Navarro, Uvalde and Williamson; and 10 counties in GMA 13—Atascosa, Dimmitt, Frio, Gonzales, Guadalupe, Karnes, LaSalle, Maverick, Medina and Webb; with potential conflicts for at least one decade during the 50-year planning horizon from 2010–2060. Bastrop, Dimmitt, Frio, Guadalupe, LaSalle, Navarro, Webb and Williamson have potential conflicts for all of the decades during the 50-year planning horizon. These potential conflicts range in magnitude from 13 acre-feet per year in Maverick County to 176,615 acre-feet per year in Frio County.

Of the 56 counties analyzed that are included as a current supply or water management strategy in the 2011 regional water plans and have an estimate of MAG from the recently completed joint planning process, 20 have potential conflicts, representing 35 percent of the total. Of these 20 counties with potential conflicts, five are not within the jurisdictional boundaries of a GCD - Van Zandt County has a potential conflict in 2060; Maverick County has potential conflicts in four decades, 2020–2060; Navarro, Webb and Williamson counties are among the counties with potential conflicts in all decades of the 50-year planning horizon. Absent a groundwater conservation district, there is no mechanism to implement management activities to achieve the DFC.

Strictly for the counties within the jurisdictional boundaries of a GCD in GMAs 11, 12, and 13, an evaluation was conducted to quantify, on a GMA basis, the sum of the negative, positive, and net values presented in Table 5.1. These values are presented for 2010 and 2060 in Table 5.2. While the net values for GMA 11 and 12 have a net positive value for both 2010 and 2060, it is interesting to note that the net value for GMA 13 is negative, (84,793) acre-feet per year in 2010 and negative (158,902) in 2060. Given this analysis, if the estimates of MAG (the total amount of pumping consistent with the DFC) remain the same in the 2016 regional water plans as it is today, then the volume of water from Carrizo-Wilcox Aquifer recommended to meet future water supply needs will have to be reduced significantly.

Task 3 also directed the BEG to evaluate the water management strategies in the regional water plans "*that is presently or is likely to impact groundwater use from the Carrizo-Wilcox Aquifer including but not limited to strategies for the use of brackish groundwater*." Table 5.3 provides summary information on all Carrizo-Wilcox Aquifer water management strategies in the 2011 regional water plans and the counties receiving the supplies. It is important to note that the amount of water represented in Table 5.3 is a subset of the sum of currently available supplies and water management strategies reported in Table 5.1. No water management strategies are planned for implementation prior to 2020. The volume of brackish groundwater recommended as water management strategies in the 2011 regional water plans begins at 12,260 acre-feet per year in 2020 and increases to 37,357 acre-feet per year in 2060. Six counties are scheduled to receive brackish groundwater supplies on the basis of recommended water management strategies in the 2011 regional water plans. These are Bexar, Comal, Guadalupe, Hays, Maverick, and Wilson counties, with the majority going to Bexar County.

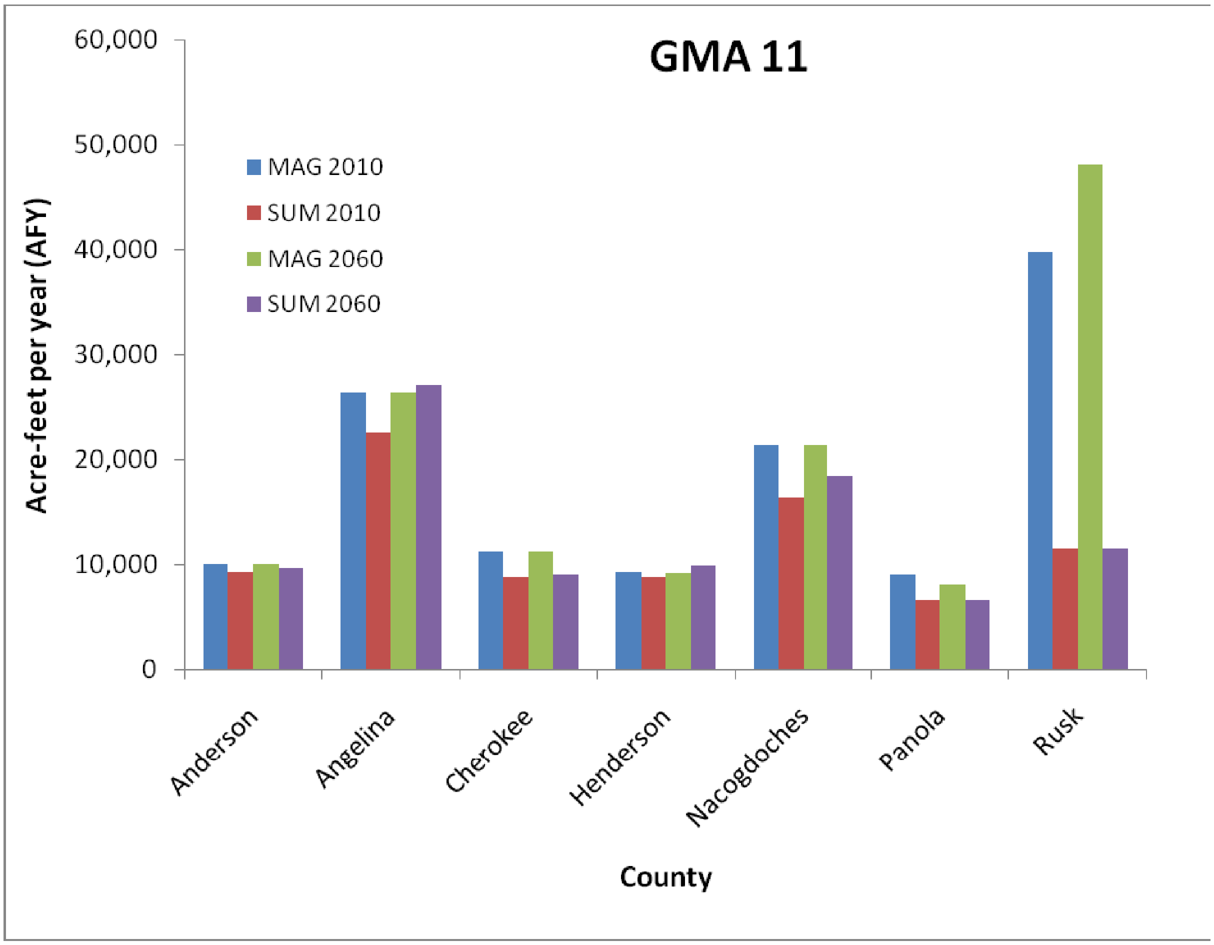


Figure 5.1: GMA 11 comparison of sum of currently available water supplies and water management strategies included in the 2011 regional water plans to the estimates of MAG resulting from the recently completed joint planning process for counties inside a GCD.

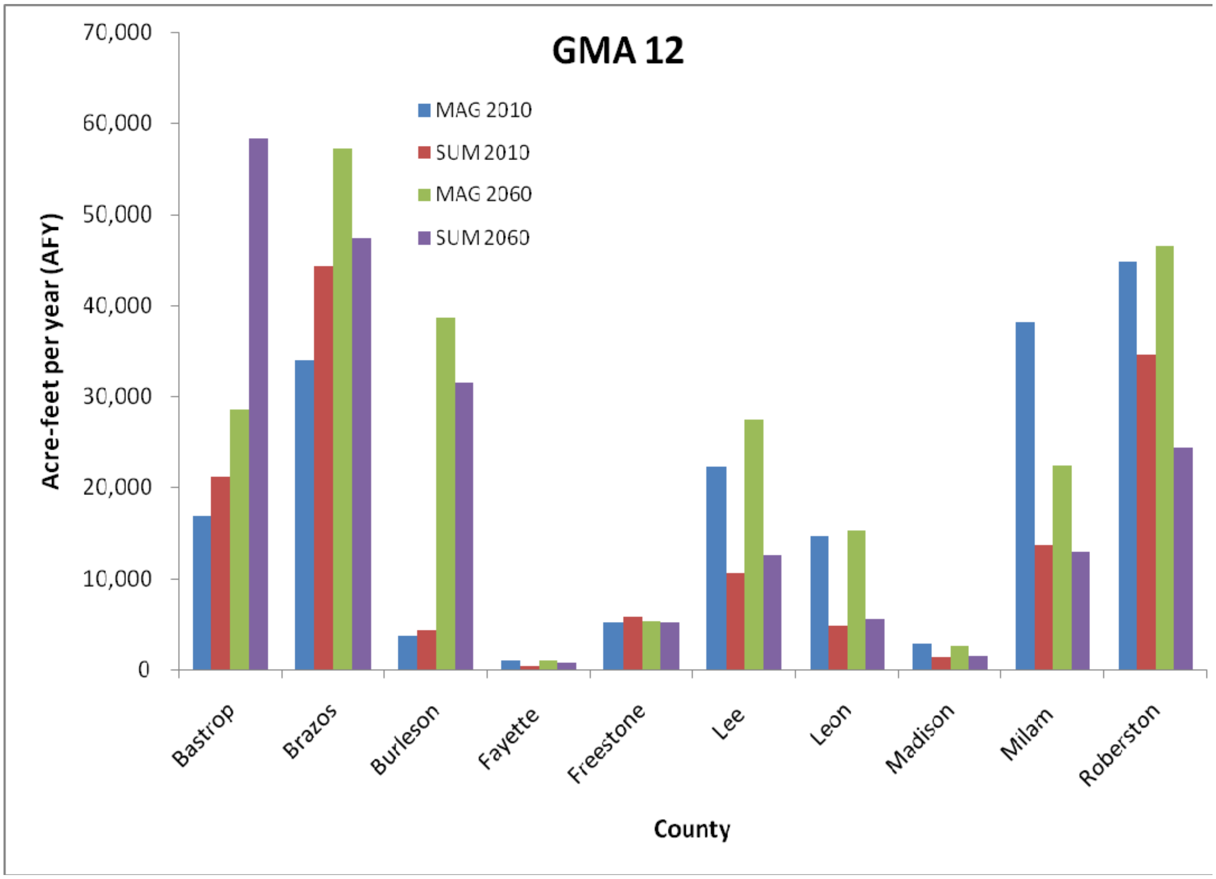


Figure 5.2: GMA 12 comparison of sum of currently available water supplies and water management strategies included in the 2011 regional water plans to the estimates of MAG resulting from the recently completed joint planning process for counties inside a GCD.

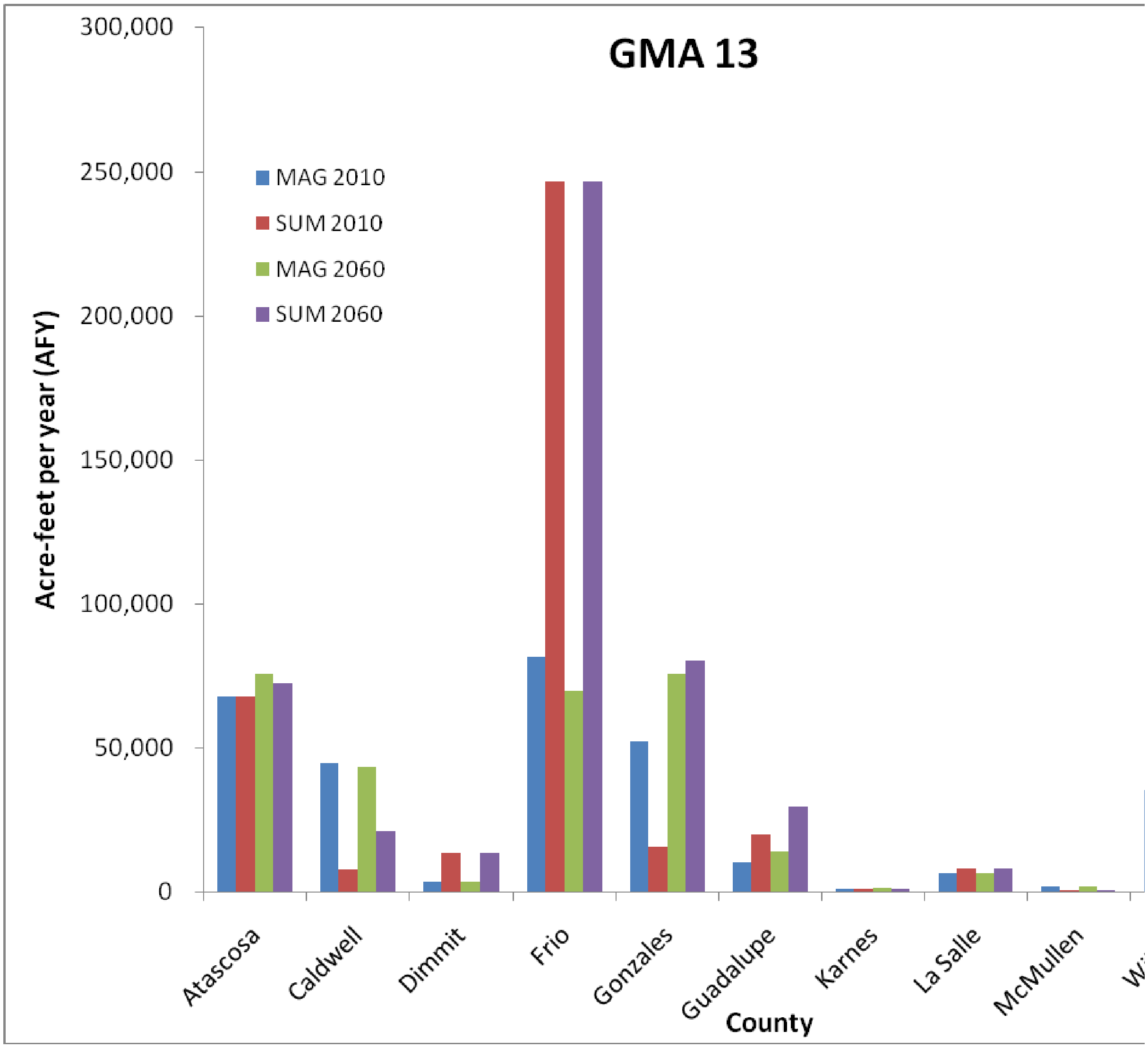


Figure 5.3: GMA 13 comparison of sum of currently available water supplies and water management strategies included in the 2011 regional water plans to the estimates of MAG resulting from the recently completed joint planning process for counties inside a GCDs.

Table 5.1: Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year. RWPA: Regional Water Planning Area. GMA: Groundwater Management Area.

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Anderson**	MAG	10,077	10,077	10,077	10,077	10,077	10,077
		Anderson	Supplies + Strategies	9,291	9,393	9,514	9,614	9,614	9,614
			Difference	*786*	*684*	*563*	*463*	*463*	*463*
I	**11**	**Angelina**	MAG	26,414	26,414	26,414	26,414	26,414	26,414
		Angelina	Supplies + Strategies	22,569	22,533	24,339	24,599	26,679	27,051
			Difference	*3,845*	*3,881*	*2,075*	*1,815*	*(265)*	*(637)*
L	**13**	**Atascosa**	MAG	67,949	68,776	70,369	71,947	73,786	75,808
		Atascosa	Supplies + Strategies	67,872	69,043	69,921	69,987	70,051	72,526
			Difference	*77*	*(267)*	*448*	*1,960*	*3,735*	*3,282*
K	**12**	**Bastrop**	MAG	16,866	19,979	20,666	24,833	28,018	28,498
		Bastrop	Supplies + Strategies	21,129	31,489	38,622	46,388	54,275	58,321
			Difference	*(4,263)*	*(11,510)*	*(17,956)*	*(21,555)*	*(26,257)*	*(29,823)*
N	**15&16**	**Bee**	Supplies + Strategies	380	394	394	394	394	394

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
L	**13**	**Bexar**	MAG	26,278	26,278	26,278	26,278	26,278	26,107
		Bexar	Supplies + Strategies	15,916	16,264	12,987	12,993	13,000	13,006
			Difference	*10,362*	*10,014*	*13,291*	*13,285*	*13,278*	*13,101*
D	**11**	**Bowie**	MAG	11,126	8,216	7,976	7,533	7,533	7,083
		Bowie	Supplies + Strategies	4,153	4,296	4,365	4,365	4,194	4,053
			Difference	*6,973*	*3,920*	*3,611*	*3,168*	*3,339*	*3,030*
G	**12**	**Brazos**	MAG	33,925	38,835	44,847	49,421	53,970	57,169
		Brazos	Supplies + Strategies	44,380	44,502	44,386	47,432	47,439	47,434
			Difference	*(10,455)*	*(5,667)*	*461*	*1,989*	*6,531*	*9,735*
G	**12**	**Burleson**	MAG	3,750	23,249	28,047	32,518	36,492	38,701
		Burleson	Supplies + Strategies	4,369	4,369	4,669	27,433	30,053	31,557
			Difference	*(619)*	*18,880*	*23,378*	*5,085*	*6,439*	*7,144*
L	**13**	**Caldwell**	MAG	44,546	44,546	44,137	44,137	43,561	43,561
		Caldwell	Supplies + Strategies	7,706	11,718	18,676	16,902	18,108	20,997
			Difference	*36,840*	*32,828*	*25,461*	*27,235*	*25,453*	*22,564*
D	**11**	**Camp**	MAG	4,041	4,041	4,041	4,041	4,041	4,041
		Camp	Supplies + Strategies	2,071	2,077	2,083	2,088	2,093	2,098
			Difference	*1,970*	*1,964*	*1,958*	*1,953*	*1,948*	*1,943*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Cass**	MAG	3,533	3,533	3,533	3,533	3,533	3,533
		Cass	Supplies + Strategies	3,258	3,294	3,375	3,457	3,527	3,527
			Difference	*275*	*239*	*158*	*76*	*6*	*6*
I	**11**	**Cherokee**	MAG	11,222	11,222	11,222	11,222	11,222	11,222
		Cherokee	Supplies + Strategies	8,774	8,821	8,872	8,927	8,973	9,016
			Difference	*2,448*	*2,401*	*2,350*	*2,295*	*2,249*	*2,206*
L	**15**	**Dewitt**	Supplies + Strategies	71	71	71	71	71	71
L	**13**	**Dimmit**	MAG	3,359	3,359	3,359	3,359	3,359	3,359
		Dimmit	Supplies + Strategies	13,536	13,536	13,536	13,536	13,536	13,536
			Difference	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*	*(10,177)*
L	**12**	**Falls**	MAG	865	867	875	884	895	895
		Falls	Supplies + Strategies	667	667	667	667	667	667
			Difference	*198*	*200*	*208*	*217*	*228*	*228*
K	**12**	**Fayette**	MAG	1,000	1,000	1,000	1,000	1,000	1,000
		Fayette	Supplies + Strategies	380	453	542	611	690	803
			Difference	*620*	*547*	*458*	*389*	*310*	*197*
11	**D**	**Franklin**	MAG	9,746	9,484	9,484	9,484	9,484	9,484
		Franklin	Supplies + Strategies	1,677	1,651	1,644	1,637	1,617	1,597
			Difference	*8,069*	*7,833*	*7,840*	*7,847*	*7,867*	*7,887*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
12	**C**	**Freestone**	MAG	5,138	5,305	5,317	5,315	5,262	5,259
		Freestone	Supplies + Strategies	5,783	5,223	5,223	5,223	5,223	5,223
			Difference	*(645)*	*82*	*94*	*92*	*39*	*36*
13	**L**	**Frio**	MAG	81,551	79,089	76,734	74,439	72,222	70,030
		Frio	Supplies + Strategies	246,645	246,645	246,645	246,645	246,645	246,645
			Difference	*(165,094)*	*(167,556)*	*(169,911)*	*(172,206)*	*(174,423)*	*(176,615)*
13	**L**	**Gonzales**	MAG	52,483	62,316	70,317	75,791	75,970	75,970
		Gonzales	Supplies + Strategies	15,740	35,648	44,928	55,561	67,821	80,540
			Difference	*36,743*	*26,668*	*25,389*	*20,230*	*8,149*	*(4,570)*
11	**D**	**Gregg**	MAG	7,649	7,649	7,649	7,649	7,649	7,649
		Gregg	Supplies + Strategies	5,621	5,707	5,847	6,281	6,560	7,038
			Difference	*2,028*	*1,942*	*1,802*	*1,368*	*1,089*	*611*
14	**G**	**Grimes**	Supplies + Strategies	236	226	221	217	217	217
13	**L**	**Guadalupe**	MAG	10,241	10,833	11,283	13,021	13,541	14,041
		Guadalupe	Supplies + Strategies	19,832	23,162	25,779	26,384	28,029	29,570
			Difference	*(9,591)*	*(12,329)*	*(14,496)*	*(13,363)*	*(14,488)*	*(15,529)*
11	**D**	**Harrison**	MAG	8,911	8,837	8,786	8,698	8,683	8,639
		Harrison	Supplies + Strategies	5,332	5,786	6,042	6,258	6,601	6,959
			Difference	*3,579*	*3,051*	*2,744*	*2,440*	*2,082*	*1,680*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
11	**C&I**	**Henderson**	MAG	9,253	9,186	9,186	9,186	9,186	9,186
		Henderson	Supplies + Strategies	8,833	9,565	9,567	9,851	9,853	9,895
			Difference	*420*	*(379)*	*(381)*	*(665)*	*(667)*	*(709)*
11	**D**	**Hopkins**	MAG	3,433	3,391	3,391	3,391	3,391	3,391
		Hopkins	Supplies + Strategies	2,227	2,234	2,237	2,238	2,232	2,226
			Difference	*1,206*	*1,157*	*1,154*	*1,153*	*1,159*	*1,165*
I	**11**	**Houston**	MAG	5,356	5,356	5,356	5,356	5,356	5,356
		Houston	Supplies + Strategies	2,272	2,655	2,765	3,397	3,852	4,358
			Difference	*3,084*	*2,701*	*2,591*	*1,959*	*1,504*	*998*
L	**13**	**Karnes**	MAG	1,059	1,117	1,182	1,231	1,259	1,280
		Karnes	Supplies + Strategies	1,141	1,141	1,141	1,141	1,141	1,141
			Difference	*(82)*	*(24)*	*41*	*90*	*118*	*139*
L	**13**	**La Salle**	MAG	6,454	6,454	6,454	6,454	6,454	6,454
		La Salle	Supplies + Strategies	8,013	8,013	8,013	8,013	8,013	8,013
			Difference	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*	*(1,559)*
G	**12**	**Lee**	MAG	22,259	24,023	23,402	24,624	26,827	27,380
		Lee	Supplies + Strategies	10,584	10,987	10,987	10,988	8,913	12,619
			Difference	*11,675*	*13,036*	*12,415*	*13,636*	*17,914*	*14,761*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
H	**12**	**Leon**	MAG	14,682	14,475	14,647	14,892	15,172	15,196
		Leon	Supplies + Strategies	4,818	5,128	5,334	5,407	5,459	5,558
			Difference	*9,864*	*9,347*	*9,313*	*9,485*	*9,713*	*9,638*
G	**8&12**	**Limestone**	MAG	11,321	11,306	11,436	11,616	11,918	11,918
		Limestone	Supplies + Strategies	7,403	7,591	7,780	7,968	8,157	8,347
			Difference	*3,918*	*3,715*	*3,656*	*3,648*	*3,761*	*3,571*
N	**16**	**Live Oak**	Supplies + Strategies	60	60	60	60	60	60
H	**12**	**Madison**	MAG	2,838	2,859	2,768	2,654	2,552	2,542
		Madison	Supplies + Strategies	1,409	1,493	1,571	1,551	1,518	1,518
			Difference	*1,429*	*1,366*	*1,197*	*1,103*	*1,034*	*1,024*
D	**11**	**Marion**	MAG	2,077	2,077	2,077	2,077	2,077	2,077
		Marion	Supplies + Strategies	1,981	2,001	2,008	2,014	2,020	2,028
			Difference	*96*	*76*	*69*	*63*	*57*	*49*
M	**13**	**Maverick**	MAG	2,043	2,043	2,024	1,677	1,570	1,532
		Maverick	Supplies + Strategies	1,792	2,056	2,058	2,060	2,073	2,444
			Difference	*251*	*(13)*	*(34)*	*(383)*	*(503)*	*(912)*
G	**8**	**McLennan**	Supplies + Strategies	29	29	29	29	29	29

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
N	**13**	**McMullen**	MAG	1,819	1,819	1,819	1,819	1,819	1,819
		McMullen	Supplies + Strategies	430	438	442	446	450	453
			Difference	*1,389*	*1,381*	*1,377*	*1,373*	*1,369*	*1,366*
L	**13**	**Medina**	MAG	2,568	2,545	2,533	2,533	2,533	2,533
		Medina	Supplies + Strategies	7,597	7,597	7,597	7,597	7,597	7,597
			Difference	*(5,029)*	*(5,052)*	*(5,064)*	*(5,064)*	*(5,064)*	*(5,064)*
G	**12**	**Milam**	MAG	38,183	23,923	20,206	19,112	21,359	22,319
		Milam	Supplies + Strategies	13,686	13,686	13,686	12,828	12,941	12,941
			Difference	*24,497*	*10,237*	*6,520*	*6,284*	*8,418*	*9,378*
D	**11**	**Morris**	MAG	2,616	2,616	2,558	2,558	2,558	2,558
		Morris	Supplies + Strategies	1,381	1,381	1,381	1,381	1,381	1,381
			Difference	*1,235*	*1,235*	*1,177*	*1,177*	*1,177*	*1,177*
I	**11**	**Nacogdoches**	MAG	21,385	21,385	21,385	21,385	21,385	21,385
		Nacogdoches	Supplies + Strategies	16,375	16,375	16,986	17,258	18,043	18,402
			Difference	*5,010*	*5,010*	*4,399*	*4,127*	*3,342*	*2,983*
C	**12**	**Navarro**	MAG	15	15	15	15	15	15
		Navarro	Supplies + Strategies	88	88	88	88	88	88
			Difference	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*	*(73)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Panola**	MAG	9,097	8,227	8,227	8,069	8,069	8,069
		Panola	Supplies + Strategies	6,609	6,615	6,623	6,631	6,639	6,649
			Difference	*2,488*	*1,612*	*1,604*	*1,438*	*1,430*	*1,420*
D	**11**	**Rains**	MAG	1,703	1,703	1,620	1,620	1,620	1,583
		Rains	Supplies + Strategies	785	809	822	825	823	820
			Difference	*918*	*894*	*798*	*795*	*797*	*763*
D	**11**	**Red River**	MAG	0	0	0	0	0	0
G	**12**	**Robertson**	MAG	44,886	45,435	45,814	46,238	46,582	46,583
		Robertson	Supplies + Strategies	34,552	34,562	34,567	24,349	24,348	24,347
			Difference	*10,334*	*10,873*	*11,247*	*21,889*	*22,234*	*22,236*
I	**11**	**Rusk**	MAG	39,772	42,188	50,336	46,940	48,128	48,119
		Rusk	Supplies + Strategies	11,478	11,459	11,441	11,578	11,555	11,526
			Difference	*28,294*	*30,729*	*38,895*	*35,362*	*36,573*	*36,593*
I	**11**	**Sabine**	MAG	6,866	6,858	6,858	6,858	6,858	6,858
		Sabine	Supplies + Strategies	358	358	358	440	440	440
			Difference	*6,508*	*6,500*	*6,500*	*6,418*	*6,418*	*6,418*
I	**11**	**San Augustine**	MAG	1,781	1,781	1,781	1,781	1,781	1,781
		San Augustine	Supplies + Strategies	677	677	777	827	927	927
			Difference	*1,104*	*1,104*	*1,004*	*954*	*854*	*854*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
I	**11**	**Shelby**	MAG	12,044	11,217	10,901	10,447	10,311	9,729
		Shelby	Supplies + Strategies	5,304	6,404	7,004	7,004	7,559	7,566
			Difference	*6,740*	*4,813*	*3,897*	*3,443*	*2,752*	*2,163*
D&I	**11**	**Smith**	MAG	33,249	33,249	33,249	33,239	33,225	33,225
		Smith	Supplies + Strategies	26,916	27,212	27,597	28,468	29,910	31,244
			Difference	*6,333*	*6,037*	*5,652*	*4,771*	*3,315*	*1,981*
D	**11**	**Titus**	MAG	10,856	10,321	10,019	9,868	9,638	9,638
		Titus	Supplies + Strategies	5,214	6,379	6,959	7,391	7,628	8,503
			Difference	*5,642*	*3,942*	*3,060*	*2,477*	*2,010*	*1,135*
K	**8,9, &10**	**Travis**	Supplies + Strategies	1,499	1,718	1,901	2,025	2,153	2,300
H&I	**11**	**Trinity**	MAG	2,215	2,215	2,215	2,215	2,215	2,215
D	**11**	**Upshur**	MAG	7,115	7,115	7,115	7,115	7,115	7,115
		Upshur	Supplies + Strategies	6,610	6,697	6,756	6,799	6,835	6,885
			Difference	*505*	*418*	*359*	*316*	*280*	*230*
L	**12**	**Uvalde**	MAG	2,971	1,230	828	828	828	828
		Uvalde	Supplies + Strategies	2,846	2,846	2,846	2,846	2,846	2,846
			Difference	*125*	*(1,616)*	*(2,018)*	*(2,018)*	*(2,018)*	*(2,018)*

RWPA	GMA	County	Calculations	2010	2020	2030	2040	2050	2060
D	**11**	**Van Zandt**	MAG	10,614	10,283	10,283	10,283	10,283	10,051
		Van Zandt	Supplies + Strategies	7,499	8,170	8,645	8,982	9,645	10,292
			Difference	*3,115*	*2,113*	*1,638*	*1,301*	*638*	*(241)*
M	**13**	**Webb**	MAG	916	916	916	916	916	916
		Webb	Supplies + Strategies	3,882	6,824	9,138	9,712	9,711	9,710
			Difference	*(2,966)*	*(5,908)*	*(8,222)*	*(8,796)*	*(8,795)*	*(8,794)*
G	**12**	**Williamson**	MAG	7	7	7	7	7	7
		Williamson	Supplies + Strategies	8,412	8,412	8,412	8,522	8,522	8,522
			Difference	*(8,405)*	*(8,405)*	*(8,405)*	*(8,515)*	*(8,515)*	*(8,515)*
L	**13**	**Wilson**	MAG	35,560	36,986	38,717	40,486	42,531	44,794
		Wilson	Supplies + Strategies	20,823	21,621	24,374	26,297	32,343	33,631
			Difference	*14,737*	*15,365*	*14,343*	*14,189*	*10,188*	*11,163*
D	**11**	**Wood**	MAG	21,716	21,539	21,451	21,408	21,333	21,311
		Wood	Supplies + Strategies	8,930	9,021	9,074	9,083	9,087	9,098
			Difference	*12,786*	*12,518*	*12,377*	*12,325*	*12,246*	*12,213*
L	**13**	**Zavala**	MAG	35,859	35,859	35,521	35,388	35,288	34,969
		Zavala	Supplies + Strategies	23,935	23,935	23,935	23,935	23,935	23,935
			Difference	*11,924*	*11,924*	*11,586*	*11,453*	*11,353*	*11,034*

Table 5.2: Summation of differences between the sum of currently available supplies and water management strategies for the Carrizo-Wilcox Aquifer in the county and decade referenced in the 2011 regional water plans compared to the total amount of pumping consistent with the DFC (or for the purposes of this report as discussed earlier, the MAG). In these cases where the *Difference* value is negative (xxx), for the decade referenced, a potential conflict exists. This comparison is only for counties in GMA 11, 12, and 13 that are within the jurisdictional boundaries of a GCD. All values are in acre-feet per year.

GMA	Difference is (+) 2010	Difference is (-) 2010	Net 2010	Difference is (+) 2060	Difference is (-) 2060	Net 2060
11	43,291	0	43,291	43,665	1,346	42,319
12	58,419	15,982	42,437	74,149	29,823	88,652
13	101,710	186,503	*(84,793)*	49,548	208,450	*(158,902)*
Total	203,420	202,485	935	167,362	239,619	*(27,931)*

Table 5.3: County-level sum of water management strategies in the 2011 regional water plans that are based on the use of brackish groundwater from the Carrizo-Wilcox Aquifer. All values are in acre-feet per year.

County	2010	2020	2030	2040	2050	2060
Bexar	0	12,000	21,750	27,150	27,903	27,903
Comal	0	0	880	880	1,762	1,762
Guadalupe	0	0	1,630	1,630	4,203	4,203
Hays	0	0	336	336	1,728	1,728
Maverick	0	260	260	260	272	641
Wilson	0	0	0	1,120	1,120	1,120
Total	0	12,260	24,856	31,376	36,988	37,357

Summary Report for Task 4: Characterize GCD Plans with Respect to Their Ability to Conserve and Protect the Aquifer, and Compare Each GCD's Plans, Rules and Procedures with Those of Each Adjacent GCD for Compatibility.

1.0 Introduction and Background

This summary report prepared by the Bureau of Economic Geology (BEG) is submitted to fulfill requirements of Task 4 of the Texas Commission on Environmental Quality (TCEQ) Carrizo-Wilcox Aquifer Study (the Study), Project 582-8-75374-119. Task 4 directs the BEG to, *"Characterize Groundwater Conservation District (GCD) plans with respect to their ability to conserve and protect the aquifer. Compare each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility."*

This summary report evaluates GCD management plans, rules, and procedures in order to characterize GCD plans with respect to their ability to conserve and protect the aquifer. We compared each GCD's plans, rules and procedures with those of each adjacent GCD for compatibility. The complete responses provided by the 16 GCDs that submitted requested information to the Study's survey questionnaire are now available for review at the Carrizo-Wilcox Aquifer Study webpage at http://www.beg.utexas.edu/cswr/aquiferstudy/. The remaining five GCD management plans and rules were acquired from the Texas Water Development Board (TWDB) and from district websites.

We reviewed 20 complete sets of management plans and rules in order to evaluate and link specific plans, rules, and procedures that support the GCDs' ability to conserve and protect the Carrizo-Wilcox Aquifer. One additional management plan for Anderson County Underground Water Conservation District was obtained from the TWDB, but no rules were available.

Programs developed by Carrizo-Wilcox GCDs to conserve and protect the groundwater resources under their jurisdiction vary greatly, from simple to complex, from narrow to broad in scope, and from passive to aggressive. During our review, the compatibility of programs designed to conserve and protect groundwater resources within groundwater management areas, between neighboring Carrizo-Wilcox GCDs, and between Carrizo-Wilcox GCDs and adjacent counties that are not under the jurisdiction of a GCD were evaluated. Solely based on a review of groundwater management plans and rules, no compatibility issues were identified within groundwater management areas and between existing Carrizo-Wilcox GCDs. However, there will always be the potential for conflict and incompatibility between adjacent counties where one county is within a GCD and a neighboring county is not. Progressive conservation of groundwater resources through programs developed and implemented in a GCD management plan can and has led to economic development shifting to neighboring counties that are not in a

GCD. Potential incompatibility may also occur between existing, adjacent Carrizo-Wilcox GCDs that have significantly different approaches to permitting strategies, for example. However, compatibility issues resulting from disparate permitting strategies are not discernable solely from a review of management plans.

2.0 GCD Management Plans and Rules Supporting Conservation and Protection Programs

According to Section 36.1071 of the Texas Water Code (TWC), GCDs are to develop and implement groundwater management plans, *"... develop a comprehensive management plan which addresses the following management goals, as applicable."* Therefore, we reviewed seven of the eight management goals required for a management plan, excluding the management goal requiring a GCD to establish their desired future conditions of aquifers within their jurisdictional boundaries because they have only very recently been adopted and management plans have not been amended to implement adopted desired future conditions at this point in time.

The following management goals were reviewed:

1. Providing the most efficient use of groundwater (TWC §36.1071(a)(1));
2. Controlling and preventing waste of groundwater (TWC §36.1071(a)(2));
3. Controlling and preventing subsidence (TWC §36.1071(a)(3));
4. Addressing conjunctive surface water management issues (TWC §36.1071(a)(4));
5. Addressing natural resource issues (TWC §36.1071(a)(5));
6. Addressing drought conditions (TWC §36.1071(a)(6));
7. Addressing conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, or brush control, where appropriate and cost-effective (TWC §36.1071(a)(7)).

In order to accomplish this task, the BEG requested specific information from the GCDs in an online survey developed for the Study. The requests were as follows (a subset of total online survey):

- *Number 13 - Provide an electronic copy of the District's current adopted management plan.*
- *Number 14 - Provide an electronic copy of the District's current adopted rules.*
- *Number 15 - Provide an electronic copy of any written procedures or guidelines for operational purposes that have been developed and adopted by the District.*
- *Number 21 - Summarize significant programs included in the District's management plan specifically designed to conserve and protect the Carrizo Wilcox Aquifer.*

According to the Survey results, 15 of the 16 GCDS addressed question 21 which requested each district to "*Summarize significant programs included in the District's management plan specifically designed to conserve and protect the Carrizo Wilcox Aquifer."* Six of the GCDs, including Panola County GCD, Rusk County GCD, Fayette County GCD, Gonzales County GCD, Post Oak Savannah GCD, and Brazos GCD provided summaries of programs included in their management plans that have been designed to conserve and protect the Carrizo-Wilcox Aquifer. Other districts responded to the Survey with more abbreviated descriptions of programs designed to preserve and protect that Carrizo-Wilcox Aquifer. For example, Lost Pines GCD stated *"The District's Management Plan is self-explanatory. In addition, though, LPGCD engages in public education through presentations at elementary schools within the District, county commissioners' courts, various civic associations, Bastrop and Lee counties' Emergency Management Services, the WSCS, and environmental groups such as Lee County Wildlife Association, Bastrop County Audubon Society. To the extent possible, all requests for presentations are honored."* Medina County GCD stated that. *"Well level monitoring; annual use reports for all nonexempt wells; and production limits of 2 acre feet"* as the programs implemented by the District to conserve and protect the Carrizo-Wilcox Aquifer. Wintergarden GCD stated *"Series of well monitors monitoring water levels."* Plum Creek CD stated "*Many of our management goals: 10.1 efficient use of groundwater, 10.2 controlling and preventing waste of groundwater, 10.4 conjunctive use of surface and groundwater, 10.6, natural resource issues, 10.7 conservation, and 10.8 mitigation are all important and are designed to conserve and protect the Carrizo-Wilcox Aquifer. Significant, as far as resource allocation, is the monitoring well observation program in which we have already budgeted for 4 In-situ 24/7 units and will probably have to purchase more in the future*." Each of the Districts independently developed management plans to address conservation and protection of the aquifer. The Districts methodologies and metrics were broad and varied in how they addressed the need to conserve and protect the Carrizo-Wilcox Aquifer within their respective jurisdictions.

2.1 Providing the Most Efficient Use of Groundwater

All 21 GCDs addressed the management goal, *"providing the most efficient use of groundwater,"* in their management plans. The nature and scope of management objectives and performance standards varied greatly among the 21 Carrizo-Wilcox GCD's throughout Groundwater Management Areas 11, 12, and 13. Appendix 1 is a complete matrix of management goals, objectives, and performance standards currently included in the 21 Carrizo-Wilcox GCD management plans. Approaches to providing the most efficient use of groundwater, if achieved, within the GCDs were varied, largely because of diverse regional socio-economic and developmental pressures and environmental concerns represented in the three different groundwater management areas and 21 GCDs.

The Carrizo-Wilcox GCDs have established objectives and performance standards that are geared towards influencing the public's perception and consumption practices through education, collection of basic groundwater data for use during development of policy or regulations, and taking physical steps to regulate groundwater consumption via establishment of well permitting, registration, and metering programs. These soft and hard policy measures have been developed by the individual Carrizo-Wilcox GCD Boards of Directors to satisfy the management goal requirement to provide for the most efficient use of groundwater. For example, the Uvalde County GCD listed two management objectives and companion performance standards. The Uvalde County GCD Management Plan states that, "*Each year the District will make available educational brochures to the public promoting and explaining conservation methods and concepts, on at least one occasion,"* and the companion performance standard stating, *"The District will make educational material available at least one time per year through service organizations, and on a continuing basis at the District Office."* The second management objective stated, *"Each year, the District will provide informative speakers to school and civic groups to raise public awareness of practices that ensure the efficient use of groundwater,"* and the companion performance standard stating *"Each year, the District will make at least two public speaking appearances to promote efficient use of groundwater."*

The Rusk County GCD Management Plan includes a management objective that, if achieved, would *"Establish a Groundwater Database for all water wells in the District. The database shall include information relating to well location, production volume, and other information deemed necessary by the District to enable effective monitoring of groundwater in Rusk County,"* and a companion performance standard that states the District will, *"Document all new and existing wells by 2010. Tracking method—each year the number of new and existing groundwater wells added to the database will be presented in the Annual Report submitted to the Board of Directors of the District."* Some GCDs clearly have more comprehensive management objectives and performance standards than other GCDs. For instance, the Evergreen GCD listed four management objectives that included monitoring the "*volume of water produced from nine irrigation wells and make note of the crops irrigated by the wells to promote water conservation in irrigation practices*," and stated that "*Each month the District will monitor the volume of water produced by 35 municipal and rural water suppliers in the District."* The Evergreen GCD also references other metrics for achieving this management goal, such as requesting production data from *"the operators of 800 agricultural irrigation wells in the District*." The phrase "most efficient use" has clearly been viewed differently within the various Carrizo-Wilcox GCDs. Land owners and Boards of Directors in East Texas may perceive the use of groundwater in surface ponds as economically beneficial and efficient whereas landowners in South-Central Texas may find that development and transport of groundwater resources to metropolitan areas to be the most efficient use of their groundwater resources.

Table 6.1 is a compilation of all management objectives and performance standards included in the Carrizo-Wilcox GCD management plans providing the most efficient use of groundwater.

Table 6.1: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans providing the most efficient use of groundwater.

MOB= Management Objective PS=Performance Standard

#	
1	**Anderson Groundwater Conservation District** **MOB:** The District will begin a process to register all wells within the District's jurisdiction. **PS:** Each year, beginning in FY09, the number of new and existing wells registered with the District will be presented in the District's annual report
2	**Bee Groundwater Conservation District** **MOB:** Each year the District will provide education materials concerning the efficient use of groundwater. **PS:** Provide educational materials to at least one school annually
3	**Bluebonnet Groundwater Conservation District** **MOB:** Each year, the District will require all new exempt or nonexempt wells that are constructed within the boundaries of the District to be registered with the District in accordance with the District rules. **PS:** Each Year the number of exempt and nonexempt wells registered by the District for the year will be incorporated into the Annual Report submitted to the Board of Directors of the District.
4	**Brazos Valley Groundwater Conservation District** **MOB:** Require all existing and new nonexempt wells constructed within the boundaries of the District to be permitted by the District and operated in accordance with District Rules. In addition, the District will encourage all exempt wells constructed within the District boundaries to be registered with the District. **PS:** The number of exempt and permitted wells registered within the District will be reported annually in the District's Annual Report submitted to the Board of Directors of the District. **MOB:** Regulate the production of groundwater by permitting wells within the District's boundaries based on beneficial use and in accordance with District Rules. Each year the District will accept and process applications for the permitted use of groundwater in the District, in accordance with the permitting process established by District Rules. The District will regulate the production of groundwater from permitted wells by verification of pumpage volumes using meters, if meters are required under the District Rule and/or permit for the wells. **PS:** The number and type of applications made for the permitted use of groundwater in the District, the number and type of permits issued by the District, and the amount of groundwater permitted, will be included in the Annual Report given to the Board of Directors. The actual annual pumpage from each metered well within the District will be reported annually and compared to the amount permitted for that well. This information

	will be included in the District's Annual Report submitted to the Board of Directors of the District. **MOB:** Conduct ongoing monitoring of the aquifers underlying the District and the current groundwater production within the District, and then assess the available groundwater that can be produced from each aquifer within the District after sufficient data are collected and evaluated. Using this data and information developed for GMA-12 the District will re-evaluate availability goals as necessary and will permit wells in accordance with the appropriate production goals. **PS:** The District will conduct the appropriate studies to identify the issues and criteria needed to address groundwater management needs within the District's boundaries. Groundwater availability goals will take into consideration the GMA-12 Planning and research of the hydro-geologic and geologic characteristics of the aquifers, which may include, but not necessarily be limited to, the amount of water use, water quality, and water level declines. A progress report on the work of the District regarding the groundwater availability will be written annually, as substantial additional data are developed. The progress report will be included in the annual report to the District Board of Directors.
5	**Evergreen Underground Water Conservation District** **MOB:** Each month the District will monitor the volume of water produced from nine irrigation wells and make note of the crops irrigated by the wells to promote water conservation in irrigation practices. **PS:** A table of the monthly meter readings from the nine irrigation wells and a discussion of the irrigation application rates for each type of crop irrigated by the nine wells monitored by the District will be included in the Annual Report on District Activities made to the Board of Directors each year. **MOB:** Each month the District will monitor the volume of water produced 35 municipal and Rural water suppliers in the District. **PS:** A table showing the monthly production volumes reported to the District by the Municipal and Rural water suppliers in the District will be included in the Annual Report on District Activities made to the Board of Directors each year. **MOB:** Each year the District will request production reports from the operators 800 agricultural irrigation wells in the District. **PS:** A copy of the request for production reports sent to the operators of agricultural irrigation wells will be included in the Annual Report on District Activities made to the Board of Directors each year. A table showing the production volumes reported to the District from the agricultural irrigation well operators in the District will be included in the Annual Report on District Activities made to the Board of Directors each year. **MOB:** Each month the District will measure the water levels in 45 water wells and will measure the water level of an additional 126 wells on an annual basis each year. **PS:** A table showing the monthly and a table showing the annual water level measurements made by the District will be included in the Annual Report on District Activities made to the Board of Directors each year.

6 Fayette County Groundwater Conservation District

MOB: *Establish a Water Level Monitoring Program*: Establish a water level monitoring network by first, identifying the wells to be monitored, and secondly, by annually measuring the depth to water in those wells; record all measurements and/or observations; enter all measurements into District's computer data base; file specific locations of wells in the District's filing system. Establish a baseline by using existing wells, preferably those for which the District already has some historical data, in all major and minor aquifers where wells are available.

PS: Annually report to the Board of Directors on:

♦ The percent of water level monitoring wells for which measurements were recorded each year.
♦ The number of data records entered into District's data base each year.
♦ The number of wells in the water level measurement network each year.
♦ The number of wells added to the network, if required, each year.

MOB: *Set and Enforce Maximum Allowable Production Limits*: Annually, the District will investigate all reports filed by District constituents, on forms provided by the District, regarding pumpage of groundwater in excess of the maximum production allowable under the District's rules. Investigation of each occurrence shall occur within 30 days of receiving the report. Each case will be remedied in accordance with District rules.

PS: Annually report to the Board of Directors on:

♦ The number of reports investigated each year.
♦ The average amount of time taken to investigate reports each year.
♦ The number of incidences where violations occurred and violators were required to change operations to be in compliance with District rules each year.

MOB: *Implement Well Permitting Process:* Issue water well drilling permits for the drilling and completion of nonexempt water wells in the District within 30 days of application, or as soon thereafter as possible. Randomly inspect new well drilling sites to be assured that the District's completion and spacing standards are met. Send written notification to the well owner if the well fails to meet standards within 30 days of inspection. The Board will vote on final approval of the permit at the next scheduled meeting and insure that well completion standards have been met.

PS: Annually report to the Board of Directors on:

♦ The number of permits issued each year in Fayette County.
♦ The number of on-site inspections performed of all wells for which District staff have reason to question compliance with District rules.
♦ The number of permits field checked each year.
♦ The number of letters mailed to permit applicants requesting applicant to provide additional information or make changes to comply with District rules.
♦ The number of these letters which result in changes to comply with District rules and the number of cases still open at year-end.

7	**MOB:** The District will register at least 20 exempt wells annually and will compile 100 percent of the data in a database within 30 working days. **PS:** Record the date and number of exempt wells registered annually, the percentage of exempt wells that were entered into the database, and the number of days before the data was entered. **MOB:** The District will measure water levels in 20 wells three times a year in western

	Gonzales County within the same 60 day period and will compile 100 percent of the water level data into a database within 30 working days. **PS:** Record the date and number of wells measured, the percent of collected water level data that was entered into the database and the number of days before the data was entered. **MOB:** The District will measure water levels in 20 wells three times a year in eastern Gonzales County within the same 60 day period and will compile 100 percent of the water level data into a database within 30 working days. **PS:** Record the date and number of wells measured, the percent of collected water level data that was entered into the database and the number of days before the data was entered. **MOB:** The District will meet with the cities of Gonzales, Nixon, Smiley and Waelder, at least once a year, to inform the cities on water availability for economic development. The District will provide input on 100 percent of requests for information within 30 days of the request. **PS:** Record the date and number of meetings with each city. Record number of requests for information from each city, the number of responses to each city, and the number of days required to respond to each request for information. **MOB:** The District will attend all Groundwater Management Area (GMA) 13 meetings annually. The District will provide input on 100 percent of the requests for information within 30 days. **PS:** Record the number of GMA meetings posted annually, the number of GMA 13 meetings attended annually, the number of requests for information made by GMA 13, the number of responses to requests for information by GMA 13, the number of days required for each response to GMA 13 requests for information. **MOB:** The District will meet with the Gonzales Area Development Corporation (GADC), at least once a year, to inform the GADC on water availability for economic development. The District will provide input on 100 percent of requests for information within 30 days of the request. **PS:** Record the date and number of meetings with the GADC. Record the number of requests for information from the GADC, the number of responses given to the GADC, and the number of days required to respond to each request for information. **MOB:** The District will gather water production data from at least 4 public water suppliers annually and will compile 100 percent of these figures into a database of groundwater usage within 30 working days of receipt in order to better project the needs of the District. **PS:** Record the number of public suppliers from which water production data was collected annually, the percent of collected water production data that was entered into the database, and the number of days before the data was entered. **MOB:** The District will gather water production data from at least 10 irrigation wells and 5 livestock production facilities annually and will compile 100 percent of these figures into a database of groundwater usage within 30 working days of receipt in order to project future water use. **PS:** Record the number of irrigation wells and number livestock production facilities from which water production data was collected annually, the percent of collected water

	production data that was entered into the database, and the number of days before the data was entered.
8	**Guadalupe County Groundwater Conservation District** **MOB:** District will establish a Carrizo-Wilcox aquifer water-level observation well program with a minimum of nine (9) observation wells. The nine observation wells will be measured twice annually, in January and September. **PS:** Number of times the wells are measured per year. The water level database will be maintained by the District office.
9	**Live Oak Underground Water Conservation District** **MOB:** School education: (a) Provide speakers to address water topics. (b) Distribute water resource education packets for use in the classroom. **PS:** Contact teacher or principle of 1 school annually. **MOB:** Farm education: (a) Provide speakers to address water topics at farm meetings (b) Distribute water resource education packets to farm leaders and farmers **PS:** Contact 1 farm group annually. **MOB:** Home Education: (a) Provide speakers to address water topics (b) Distribute water resource education packets to community people **PS:** Contact 1 civic group annually.
10	**Lost Pines Groundwater Conservation District** **MOB:** To inform the residents of Bastrop and Lee counties about the efficient use of groundwater. Such information may be related to irrigation efficiency, transmission losses, xeriscaping, or any other related subject deemed appropriate by the LPGCD board. The information on efficient use of groundwater may be disseminated in conjunction with information on controlling and preventing waste of groundwater and/or water conservation. **PS:** At least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on efficient use of groundwater. The article on efficient use of groundwater may be published in conjunction with an article on controlling and preventing waste of groundwater and/or water conservation. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
11	**McMullen Groundwater Conservation District** **MOB:** Each year the District will provide education materials concerning the efficient use of groundwater **PS:** Provide educational materials to at least one school annually.
12	**Medina County Groundwater Conservation District** **MOB:** Each year, the District will provide informative speakers to schools and civic groups to raise public awareness of practices which ensure the efficient use of groundwater. **PS:** The District will make at least two public speaking appearances to promote the efficient use groundwater per year.
13	**Mid-East Groundwater Conservation District** **MOB:** The District will at least once annually conduct at least one program to provide public information and education to promote the efficient use of groundwater. Such programs may include newspaper publication, open meetings, handout brochures and

	mail-out brochures. **PS:** The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
14	**Neches & Trinity Valleys Groundwater Conservation District** **MOB:** Each year the District will require the registration of all new wells drilled within the District's jurisdiction and the District will require a permit for drilling all nonexempt wells. **PS:** At all regularly scheduled Board meetings, the General Manager reports to the Board of Directors on the number of new wells registered with the District and the number of permit applications received and approved for new wells within the District.
15	**Panola County Groundwater Conservation District** **MOB:** Beginning in 2008, the District will require the registration of all wells within the District's boundaries each year. **PS:** The number of new and existing wells registered with the District will be provided in the Annual Report for each fiscal year. **MOB:** The District will require permits for all nonexempt groundwater use within District boundaries pursuant to the District Rules each year. **PS:** The District will accept and process applications for permits for all nonexempt groundwater use pursuant to the permitting process described in the District Rules each year. The Annual Report for each fiscal year will contain a summary of the number of applications for the permitted use of groundwater and the number and type of permits issued.
16	**Pineywoods Groundwater Conservation District** **MOB:** Each year, beginning in FY2002, the District will require the registration of all new wells drilled within the District's jurisdiction and the District will require a permit for all nonexempt wells, new and existing. **PS:** Each month at regularly scheduled meetings the General Manager reports to the District Board of Directors the number of new and existing wells registered with the District and the number of applications received for new wells within the District.
17	**Plum Creek Conservation District** **MOB:** 1. The District will establish the PCCD Aquifer Water Level Observation Well Program with at least 6 observation wells located according to management zones within the District, and measure those wells at least once quarterly. 2. The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program. 3. The District will use its best efforts to obtain information on water being produced from areas in Caldwell County that are outside the boundaries of the District. 4. The District will use its best efforts to obtain information on groundwater being produced from groundwater aquifers in counties surrounding the District as well as in areas close to the District that are not in groundwater districts to develop information about impacts of such production on groundwater in the District.

	PS: Establish the PCCD Aquifer Water Level Observation Well Program and its criteria, and begin quarterly measurements of at least 6 of the observation wells within one year following the adoption and certification of this plan. 2. Water levels at these observation wells will be measured a minimum of once quarterly. 3. PCCD representatives will circulate at least one publication and notice speaking appearances each year. 4. PCCD representatives will attend and participate in GMA meetings appropriate to the District's regulatory authority. 5. PCCD will periodically seek information from nearby groundwater districts not in the same GMA but drawing from the same aquifers regulated by the District.
18	**Post Oak Savannah Groundwater Conservation District** **MOB:** The District will establish the POSGCD Aquifer Water Level Observation Well Program with at least 10 observation wells located according to management zones within the District, and measure those wells at least once annually. **PS:** Establish the POSGCD Aquifer Water Level Observation Well Program and its criteria, and begin measurements of at least 10 of the observation wells within one year following the adoption and certification of this plan. Number of observation wells measured annually by the District. Water levels at these observation wells will be measured a minimum of once annually. **MOB:** The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program. **PS:** The number of publications and speaking appearances by the District each year under the District's Public Education Program.
19	**Rusk County Groundwater Conservation District** **MOB:** The District will require all new exempt or nonexempt wells that are constructed within the boundaries of the District to be registered with the District in accordance with the District rules. **PS:** Issue permits within 20 days of application. Each Year the number of exempt and nonexempt wells registered by the District for the year and a list of any permits that were not issued within 20 days with the cause and corrective action taken, will be incorporated into the Annual Report submitted to the Board of Directors of the District. **MOB:** Establish a Groundwater Database for all water wells in the District. The database shall include information relating to well location, production volume, and other information deemed necessary by the District to enable effective monitoring of groundwater in Rusk County. **PS:** Document all new and existing wells by 2010. Each Year the number of new and existing groundwater wells added to the database will be presented in the Annual Report submitted to the Board of Directors of the District. **MOB:** Provide Public Education Opportunities. **PS:** Disseminate educational information regarding the hydro-geologic cycle and status of aquifers through at least two articles in Rusk County newspapers, posting on the District internet website, and as needed responses to public inquiries. The Annual Report to the

	Board of Directors of the District will reflect educational achievements through newspaper articles, the number of hits on the Districts website, and the number of responses to public inquiries annually.
20	**MOB:** Each year the District will make available educational brochures to the public promoting and explaining conservation methods and concepts, on at least one occasion. **PS:** The District will make educational material available at least one time per year through service organizations, and on a continuing basis at the District Office. **MOB:** Each year, the District will provide informative speakers to school and civic groups to raise public awareness of practices that ensure the efficient use of groundwater. **PS:** Each year, the District will make at least two public speaking appearances to promote the efficient use of groundwater.
21	**Wintergarden Groundwater Conservation District** **MOB:** District will continue monitoring and recording data from the five (5) Carrizo Aquifer well/monitors. **PS:** The District will assimilate data from the aquifer water level monitors and present to the Board monthly.

2.2 Controlling and Preventing Waste of Groundwater

All 21 Carrizo-Wilcox GCD's addressed the goal "*controlling and preventing waste of groundwater*" in their respective management plans. The Carrizo-Wilcox GCDs throughout the three groundwater management areas, as would be expected due to varied local conditions, have adopted different methods of addressing the management of groundwater resources in order to prevent and control the waste of groundwater. For example, Evergreen UWCD stated their management objectives was *"Each year the District will conduct an on-site investigation of any reports of waste of groundwater within two working days of the time of the receipt of the report to the District."* and the coinciding performance standard "*A discussion on the waste of the groundwater observed by the District each year, including the number of reports of the waste of groundwater received by the District and the Districts response to the report will be included in the Annual Report on District Activities made to the Board of Directors each year."*

The Fayette County GCD cited five objectives under "*Management Strategies to Protect and Enhance the Quantity and Quality of Useable Groundwater by Controlling and Preventing Contamination and Waste."* The Fayette County GCD management objectives include "*Establish a Water Quality Monitoring Program,*" "*Assume Proper Closing, Destruction, or Reequipping of Wells', "Encourage Plugging of Abandoned wells," "Control and Prevention of Water", and "Produce and Disseminate Quarterly Newsletter."*

Table 6.2 is a compilation of all management objectives and performance standards included in the Carrizo-Wilcox GCD management plans for controlling and preventing the waste of groundwater.

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Table 6.2: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans for controlling and preventing the waste of groundwater.

MOB= Management Objective PS=Performance Standard

1	**Anderson UCWD** **MOB:** Each year the District will disseminate educational information on eliminating and reducing the wasteful use of groundwater focusing on water quality protection. This may be accomplished annually by two of the following methods: a. Conduct an annual contest on water quality protection b. Compile literature packets for distribution to schools in Anderson County c. Conduct classroom presentations d. Sponsor an educational program/curriculum e. Post information on the District's website f. Provide newspaper articles for publication g. Publish District newsletter h. Conduct public presentations i. Set up displays at public events j. Distribute brochures/literature **PS:** The annual report will include a summary of the District activities during the year to disseminate educational information on eliminating and reducing the wasteful use of groundwater focusing on water quality protection.
2	**Bee Groundwater Conservation District** **MOB:** Measure water levels from the land surface on strategic wells on an annual basis and report waste to the District Board. **PS:** Report to the District Board annually the number of water level measurements. **PS:** The District will investigate all reports of waste of groundwater within five working days. The number of reports of waste as well as the investigation findings will be reported to the District Board in the annual report.
3	**Bluebonnet Groundwater Conservation District** **MOB:** Each year, the District will make an evaluation of the District Rules to determine whether any amendments are recommended to decrease the amount of waste of groundwater within the District. **PS:** The District will include a discussion of the annual evaluation of the District Rules and the determination of whether any amendments to the rules are recommended to prevent the waste of groundwater in the Annual Report of the District provided to the Board of Directors. **MOB:** Each year, the District will provide information to the public on eliminating and reducing wasteful practices in the use of groundwater posting information or a link to information on groundwater waste reduction on the District’s website. **PS:** Each year, a copy of the information provided on groundwater waste reduction on the District’s website will be included in the District’s Annual Report provided to the District Board of Directors.
4	**Brazos Valley Groundwater Conservation District** **MOB:** Apply a water use fee to the permitted use of groundwater in the District to

	encourage conservation-oriented use of the groundwater resources to eliminate or reduce waste. **PS:** Each year the District will apply a water use fee to the nonexempt permitted use of groundwater produced within the District pursuant to District rules. The amount of fees generated and the amount of water produced for each type of permitted use will be a part of the Annual Report presented to the District Board of Directors. **MOB:** Evaluate District rules annually to determine whether any amendments are necessary to decrease the amount of waste within the District. **PS:** The District will include a discussion of the annual evaluation of the District rules, and the determination of whether any amendments to the rules are necessary to prevent the waste of groundwater in the Annual Report of the District provided to the Board of Directors. **MOB:** Provide information to the public and the schools within the District on the wise use of water to eliminate and reduce wasteful practices. **PS:** The District will include a page on the Districts web-site devoted to the wise use of water and providing tips to help eliminate and reduce wasteful use of groundwater annually. The District will provide information to local school Districts including providing book covers to encourage wise use of water.
5	**Evergreen Underground Water Conservation District** **MOB:** Each year the District will conduct an on-site investigation of any reports of waste of groundwater within two working days of the time of the receipt of the report to the District. **PS:** A discussion of the waste of groundwater observed by the District each year, including the number of reports of the waste of groundwater received by the District and the District response to the report will be included in the Annual Report on District Activities made to the Board of Directors each year.
6	**Fayette County Groundwater Conservation District** **MOB:** The District will investigate all identified wasteful practices within a reasonable number of working days of identification or complaint received, depending upon the magnitude of the wasteful practice. **PS:** Annually report to the Board of Directors on: ♦ the number of wasteful practices identified and the average number of days District personnel took to respond or investigate after identification or complaint received. ♦ the actions taken to resolve the identification or complaint received.
7	**Gonzales Underground Water Conservation District** **MOB:** The District will collect samples for water quality data in 20 wells annually at locations throughout the District during the same period every year and will compile 100 percent of this data into a water quality database within 30 working days of receipt. In selecting wells the District will emphasize the wells at or near the zone of bad water or potential pollution sources based on best available data. **PS:** The District will collect samples for water quality data in 20 wells annually at locations throughout the District during the same period every year and will compile 100 percent of this data into a water quality database within 30 working days of receipt. In selecting wells the District will emphasize the wells at or near the zone of bad water or potential pollution sources based on best available data. **MOB:** The District will monitor new facilities and activities on the recharge zones of the

	Carrizo/Wilcox, Queen City and Sparta aquifers on at least an annual basis for point source and non-point-source pollution and compile 100 percent of this data into a pollution database within 30 working days from completion of the survey. **PS:** Record the date and results of visual survey of all recharge zones for point source and nonpoint source activities and facilities, the percent of available information that was entered into the database, and the number of days before the data was entered. **MOB:** The District will meet with the RRC at least once annually and coordinate its efforts with this agency in locating abandoned or deteriorated oil wells. The District will act on local complaints of abandoned or deteriorated oil wells within 30 days and compile 100 percent of the complaints and resulting District action in a database. **PS:** Record the date and number of meetings with the RRC annually. Record the date and number of complaints filed with the District annually, the time required to respond to each complaint, and the percentage of complaints entered into the database.
8	**Guadalupe County Groundwater Conservation District** **MOB:** The District will once a year provide public information on closure of abandoned water wells and uncontrolled flowing wells through articles in local newspapers or the District's newsletter and website. **PS:** Number of times a year the District will address the proper closure of abandoned water wells and uncontrolled flowing wells in the local newspaper or the District's newsletter and website.
9	**Live Oak Groundwater Conservation District** **MOB: NA** **PS:NA**
10	**Lost Pines Groundwater Conservation District** **MOB:** To inform the residents of Bastrop and Lee counties about the waste of groundwater. Such information may be related to leaky or poorly functioning plumbing, transmission losses, xeriscaping, or any other related subject deemed appropriate by the LPGCD Board. The information on waste of groundwater may be disseminated in conjunction with information on efficient use of groundwater and/or water conservation. **PS:** At least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on waste of groundwater. The article on waste of groundwater may be published in conjunction with an article on efficient use of groundwater and/or water conservation. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
11	**McMullen Groundwater Conservation District** **MOB:** Measure water levels from the land surface on strategic wells on an annual basis and report waste to the District Board. **PS:** (a) Report to the District Board annually the number of water level measurements. (b) The District will investigate all reports of waste of groundwater within five working days. The number of reports of waste as well as the investigation findings will be reported to the District Board in the annual report.
12	**Medina County Groundwater Conservation District** **MOB:** Each year the District will provide at least one public service announcement concerning waste, which is prohibited under the District rule, to the newspapers and to

	the general public on at least six occasions. **PS:**(a) The District will furnish at least six newspaper articles and/or public service announcements on an annual basis. (b) The District will investigate all written reports of waste of groundwater within 24 hours.
13	**Mid-East Texas Groundwater Conservation District** **MOB:** The District will at least annually conduct at least one program to provide public information and education of the prevention of the waste of groundwater. Such programs may include newspaper publications, open meetings, handout brochures and mail-out brochures. **PS:** The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
14	**Neches & Trinity Valleys Groundwater Conservation District** **MOB:** 100 percent of complete permit applications will be reviewed by the District within 90 days to ensure all procedures are followed to control and prevent the waste of groundwater. The District will report annually to the Board the number of permit application requests that met the District's rules and requirements for approval within 90 days of the receipt of the completed application. **PS:** 1. Number of permits issued each year by the District for new nonexempt wells in compliance with District rules and procedures. 2. Percent of completed applications reviewed within 90 days of receipt of application. **MOB:** The District will maintain procedures for the receipt of well permit applications. Annual reports will be made to the Board on the number and type of well permits approved. If no applications are received by the District during a reporting period, this will annually be reported to the Board. **PS:** The procedures for the receipt of well permit applications will be maintained in District files. An annual report will be made by the District to the Board on the number and type of well permits approved. If no well permit applications are filed and completed during the year, this will be reported to the Board.
15	**Panola County Groundwater Conservation District** **MOB:** The District will provide information on an annual basis to the public on the elimination, reduction, and prevention of the waste of groundwater and information focused on water quality protection each year. The District will use one of the following methods to provide information to the public at least once during each fiscal year: a. distribute literature packets or brochures within Panola County and the surrounding areas; b. provide public presentations on groundwater and water issues, including waste prevention; c. sponsor an educational program/course; d. provide information on the District's website; e. submit newspaper articles to local paper for publication; f. present displays at local public events; or g. become involved in the distribution of information, such as brochures, in schools in Panola County.

	PS: The District's Annual Report will include a summary of the District's efforts during the fiscal year to provide educational information to the public on the elimination, reduction and prevention of the waste of groundwater. **MOB:** The District will make an annual evaluation of its Rules to determine whether any amendments are necessary to facilitate prevention of waste of the groundwater within District boundaries. **PS:** The District's Annual Report will include a summary of the evaluation of the District Rules and will provide a recommendation as to whether any amendments to the Rules are needed to facilitate prevention of waste.
16	**Pineywoods Groundwater Conservation District** **MOB:** Determine waste as defined in the Rules of the District and the Water Code and respond to reports of waste within 4 days. **PS:** Annually review all reported sources of waste, and if corrective actions were taken when warranted. A summary that includes the number of reports of waste and the number of days the District took to respond to each report of waste will be included in the annual report to the District Board of Directors.
17	**Plum Creek Conservation District** **MOB:** The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure. **PS:** A number of publications and speaking appearances by the District each year.
18	**Post Oak Savannah Groundwater Conservation District** **MOB:** The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program. The District will also offer at least one grant, during years when the District's revenues remain at a level sufficient to fund the program, to sponsor the attendance of students at summer camps/seminars that place emphasis on the conservation of water resources. **PS:** The number of publications and speaking appearances by the District each year, and the number of grants offered and students actually accepting and attending an educational summer camp or seminar.
19	**Rusk County Groundwater Conservation District** **MOB:** Public Education **PS:** The District will provide educational leadership to the citizens of the District concerning this subject through at least one printed publication per year, public speaking at least once per year at service organizations or public schools, and wasteful practices posted on the Districts internet website. Each Year the number of publications and speaking appearances by the District each year will be presented in the Annual Report submitted to the Board of Directors of the District. **MOB:** Identify wasteful practices. **PS:** a) Write and adopt rules to regulate wasteful practices by December 2008. b) Track Water Quality Issues. c) Initiate a District wide program to identify the location of all abandoned wells by January 2010. d) Develop and adopt guidelines, setting forth the period of time allowed, for abandoned well owners to insure voluntary compliance with

	Texas Water Code well plugging requirements by January 2010. a) Report unplugged abandoned water wells to the well owners and Board within thirty (30) days of discovery. b) Hold public hearing on proposed rules to regulate wasteful practices by December 2008. c) Report achievements in the District's Annual Report. d) Provide TECQ and TWDB an annual status report on unplugged abandoned water wells beginning in 2010.
20	**Uvalde County Underground Water Conservation District** **MOB:** Each year the District will provide education materials concerning waste, which is prohibited under the District rule, to the newspapers and to the general public on at least six occasions. **PS:** (a) The District will provide to a newspaper of general circulation within the District at least six newspaper articles and/or public service announcements on an annual basis, including those that may be posted on the District's Website. (b) The District will investigate all written reports of waste of groundwater within five working days from the date the report is filed with the District.
21	**Wintergarden Groundwater Conservation District** **MOB:** The District will at least on two (2) occasions each year provide public information on water conservation and waste prevention through public speaking appearances at public schools, and civic organizations or newspaper articles. **PS:** A. The number of speaking appearances made by the District each year. B. The number of newspaper articles published by the District each year.

2.3 Controlling and Preventing Subsidence

Of the 21 Carrizo-Wilcox GCDs, 18 explicitly stated in their management plans that controlling and preventing subsidence is not applicable to their districts due to the geologic and hydrogeologic profile of the region. Two other districts characterized and stated why their district was not managing subsidence within their respective GCD. Plum Creek CD stated *"Subsidence is unlikely to occur in the Plum Creek Conservation District. The District historically has not experienced any subsidence. Accordingly, the District's Plan does not contain any "Management Objective" or related "Performance Standards" to address the issue of non-existent subsidence. Alluvium is poorly consolidated, but generally too thin to experience measurable (if any) subsidence due to groundwater withdrawals."* Uvalde County GCD stated "*The geologic framework of the District Area precludes any significant subsidence from occurring. This management goal is not applicable to the operations of the District."* Only the Anderson County UWCD has established a management objective and performance standard for the subsidence goal. However, the Anderson County UWCD management objective states that "*Each year, the District will manage the withdrawal of groundwater*," and the coinciding performance standard stated "*Each year, attendance at GMA 11 meetings by a representative of the District will be reflected in the District's annual report and will include the number of meetings attended and the dates."*. Therefore while there is a management objective listed within this management goal, the applicability to subsidence is vague at best.

2.4 Addressing Conjunctive Surface Water Management Issues

Of the 21 Carrizo-Wilcox GCD management plans, 14 have established management objectives and performance standards to address goal 4 *"conjunctive surface water management issues."* Of the 14 Carrizo-Wilcox GCD's, 5 state they will achieve this goal by attending meetings of regional water authority's, such as the Brazos River Authority, Guadalupe-Blanco River Authority, and the Nueces River Authority. Further, eight of the GCD's have elected to attend regional water planning meetings with the appropriate regional water planning group. Of the 21 Carrizo-Wilcox GCDs management plans, 8 reviewed stated that goal 4 related to conjunctive surface water management issues was not applicable to their jurisdiction: Bee GCD, Fayette County GCD, Lost Pines GCD, McMullen GCD, Mid-East Texas, Neches & Trinity Valley's GCD, Pineywoods GCD, and Uvalde County UWCD. For instance, Bee GCD stated *"It is the opinion of the District that the Conjunctive Surface Water goal is not an issue in the District."* Further, Uvalde County UWCD and McMullen GCD stated *"Except as provided in Chapter 36 of the Texas Water Code, the District has no jurisdiction over surface water. The District shall consider the effects of surface water resources as required by Section 36.113 and other state law."*

Four Carrizo-Wilcox GCDs included management objectives and performance standards that went beyond meeting with regional water planning groups and river authority's to address goal 4. The degree of intergovernmental cooperation at the local and regional level varies by GCD. For example, Rusk County GCD's management objective stated *"The District will actively participate with Municipal and County Governments to encourage the development of additional surface water sources for Rusk County,"* and the coinciding performance standard stated *"Selected board members will attend at least one planning meeting per year with municipal and county government groups addressing surface water options. Each Year, the progress made by Municipal and County Governments will be submitted to the Board of Directors in the Annual Report on advancements made toward increasing surface water availability and reduction of demand on the aquifers in the county."* The second Rusk County GCD management objective for this goal stated the district would *"Coordinate conjunctive surface water issues with the East Texas Regional Water Planning Group,"* and the coinciding performance standard stated *"The District will participate in the regional planning process by attending at least 50% of the East Texas Regional Water Planning Group meetings per year. A report will be made by the board's* *representative at each board meeting of the Rusk County Groundwater Conservation District, updating the Board on conjunctive surface water issues being discussed by the ETRWPG."*

The management objectives and performance standards set forth by certain Carrizo-Wilcox GCDs may also be representative of a particular districts definition of conjunctive use. According to the Texas Administrative Code §356.2(a)(7) conjunctive use issues are *"Issues relating to the combined use of groundwater and surface water sources that optimize the beneficial characteristics of each source."* For example, the Evergreen UWCD management objective for this goal stated that **"***Each year the District will use the Southern Carrizo-Wilcox Groundwater Availability Model to predict the potential effects of different groundwater pumping scenarios on both groundwater and surface water. In addition, each year the District will arrange to meet with the appropriate surface water management entities"* and the coinciding performance standard stated *"A summary of the discussion(s) with the surface water management entities for status on surface water conditions will be relayed in a memorandum to the Board of Directors each year."*

The Live Oak UWCD management plan listed the following management objectives that support developing a more comprehensive understanding of how local groundwater and surface water resources interact via well and stream monitoring programs.

1. Attend meeting with surface water entities in the district, to include but not limited to; conjunctive use, emergency response, and drought contingency planning

2. Evaluate existing historical data and data derived from new monitoring programs to enhance understanding of aquifer/surface-water relationships

3. Evaluate impact of surface-water usage on groundwater resources within the District as needed. Provide comments regarding surface-water rights requests for those requests effecting the groundwater resources of the district

4. Coordinate with other entities on regional planning efforts

One performance standard was included for the four management objectives listed above, *"District representative will attend 1 meeting with surface water entities annually. District representative will attend 1 meeting concerning regional water planning annually. Coordinate with other entities on regional planning efforts."* Intergovernmental cooperation appears to be an important element of this plan for the management of local and trans-boundary water resources.

The Medina County GCD management objectives stated *"The District will attend 50% of the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface water management entities within the District"* and the coinciding performance standard states *" The District will attend at least 50% of the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface* *water management entities within the District. The District will report these activities annual in the District annual report to the Board of Directors."*

In summary, participation in governing local groundwater and surface water resources is varied. Groundwater resources and surface water resources interaction differs regionally because of different hydrological and hydrogeological interactions in the environment. From this review, it is apparent that regional water planning groups and river authorities are the focal point for the coordination of groundwater and surface water issues for Carrizo-Wilcox GCDs.

Table 6.3 is a compilation of all management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing conjunctive surface water management issues.

Table 6.3: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing conjunctive surface water management issues.

MOB= Management Objective PS=Performance Standard

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1	**Anderson UWCD** **PS:** Each year, the District will participate in the regional planning process by attending at least one meeting of the regional water-planning group per fiscal year. **MOB**: Each year, attendance at Region I meetings by a representative of the District will be reflected in the District's annual report and will include the number of meetings attended and the dates.
2	**Bluebonnet Groundwater Conservation District** **PS**: Each year, the District will participate in the regional planning process by being represented at the Region G and Region H Regional Water Planning Group meetings. **MOB**: The attendance of a District representative to at least 50 percent of the Region G and Region H Regional Water Planning Group meetings will be noted in the Annual Report presented to the District Board of Directors.
3	**Brazos County GCD:** **MOB:** Encourage the use of surface water supplies where available, to meet the needs of specific user groups within the District. **PS:** The District will participate in the Region G - Regional Water Planning process by attending at least one RWPG meeting annually and will encourage the development of surface water supplies where appropriate. This activity will be noted in the Annual Report presented to the District Board of Directors.
4	**Evergreen UWCD** **MOB:** Each year the District will use the Southern Carrizo-Wilcox Groundwater Availability Model to predict the potential effects of different groundwater pumping scenarios on both groundwater and surface water. In addition, each year the District will arrange to meet with the appropriate surface water management entities.

	PS: A summary of the discussion(s) with the surface water management entities for status on surface water conditions will be relayed in a memorandum to the Board of Directors each year.
5	**Gonzales County UWCD** **MOB:** The District will meet with the staff of the Guadalupe Blanco River Authority, at least once a year, to share information updates about conjunctive use potential. **PS:** Record the date and number of meetings with GBRA representatives annually
6	**Guadalupe GCD** **MOB:** Each year the District will confer at least on one occasion with the Guadalupe-Blanco River Authority (GBRA) on cooperative opportunities for conjunctive resource management. **PS:** Number of meetings per year with GBRA on conjunctive resource management. A memo to document the meeting will be on file in the District's office.
7	**Live Oak UWCD** **MOB: 1)**Attend meeting with surface water entities in the district, to include but not limited to; conjunctive use, emergency response, drought contingency planning **2)** Evaluate existing historical data and data derived from new monitoring programs to enhance understanding of aquifer/surface-water relationships **3)** Evaluate the impact of surface-water usage on groundwater resources within the District as needed. Provide comments regarding surface-water rights requests for those requests effecting the groundwater resources of the district**.** Coordinate with other entities on regional planning efforts. **PS:** District representative will attend 1 meeting with surface water entities annually. District representative will attend 1 meeting concerning regional water planning annually.
8	**Medina County GCD** **MOB:** The District will attend 50% 0f the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface water management entities within the District. **PS:** The District will attend at least 50% of the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface water management entities within the District. The District will report these activities annual in the District annual report to the Board of Directors. 1. Attend meeting with surface water entities in the district, to include but not limited to; conjunctive use, emergency response, drought contingency planning 2. Evaluate existing historical data and data derived from new monitoring programs to enhance understanding of aquifer/surface-water relationships 3. Evaluate the impact of surface-water usage on groundwater resources within the District as needed. Provide comments regarding surface-water rights requests for those requests effecting the groundwater resources of the district Coordinate with other entities on regional planning efforts.
9	**Panola County GCD** **MOB**: The attendance at any Region I meeting by a representative of the District will be

	included in the District's Annual Report and will indicate the dates of attendance. **PS:** The District will participate in the regional planning process by sending a representative to attend at least one meeting of the East Texas Regional Water Planning Group (Region I) each fiscal year.
10	**Plum Creek GCD** **MOB**: Each year the District will confer at least once with the Guadalupe-Blanco River Authority (GBRA) and other local political subdivisions and water and wastewater utilities on cooperative opportunities for conjunctive resource management. **PS:** The number of conferences with the GBRA, other political subdivisions and water and wastewater utilities, on conjunctive resource management each year. The District will continue to monitor progress of the Plum Creek Watershed Project.
11	**Post Oak Savannah GCD** **MOB:** Each year the District will confer at least once with the Brazos River Authority (BRA) on cooperative opportunities for conjunctive resource management. **PS:** The number of conferences with the BRA on conjunctive resource management each year.
12	**Rusk County GCD** **MOB:** The District will actively participate with Municipal and County Governments to encourage the development of additional surface water sources for Rusk County. **PS:** Selected board members will attend at least one planning meeting per year with municipal and county government groups addressing surface water options. Each Year, the progress made by Municipal and County Governments will be submitted to the Board of Directors in the Annual Report on advancements made toward increasing surface water availability and reduction of demand on the aquifers in the county. **MOB:** Coordinate conjunctive surface water issues with the East Texas Regional Water Planning Group. **PS:** The District will participate in the regional planning process by attending at least 50% of the East Texas Regional Water Planning Group meetings per year. A report will be made by the board's representative at each board meeting of the Rusk County Groundwater Conservation District, updating the Board on conjunctive surface water issues being discussed by the ETRWPG.
13	**Wintergarden GCD** **MOB:** Each year the District will confer at least on one occasion with the Nueces River Authority on cooperative opportunities for conjunctive resource management. **PS:** The number of conferences on conjunctive resource management opportunities held with Nueces River Authority each year.

2.5 Addressing Natural Resource Issues

Fourteen of 21 Carrizo Wilcox GCDs included management objectives and performance standards for goal 5, "*addressing natural resource issues*." Seven districts elected not to include any management objectives or performance standards addressing natural resource issues. For example, Mid-East Texas GCD stated *"There are no known natural resource issues in the District that have an impact on the groundwater quantity or quality at this time. Therefore, this goal is not applicable to the District at this time,"* Similarly, Rusk County GCD stated *"The District has no documented occurrences of endangered or threatened species dependent upon groundwater resources. However, the District will coordinate with the Texas Commission on Environmental Quality (TCEQ) on water quality issues."*

Gonzales UWCD, Post Oak Savannah GCD, and Plum Creek CD made reference to communicating with the RRC in their management objectives and performance standards under the natural resources goal of their management plans.

Natural resource issues that could be monitored cooperatively by Carrizo-Wilcox GCDs and the RRC including the regulation and plugging of abandoned oil and gas wells, well construction of oil and gas production wells and related Class 2 disposal wells, and the documentation and monitoring of active pipelines, inactive pipelines, and other pipelines that may pose a threat to the quality of Carrizo-Wilcox Aquifer groundwater resources were not addressed as frequently as possible in the management plans reviewed for the Study.

One example of cooperation is the following Gonzales UWCD management objective that states *"The District will meet with the local RRC engineering technician at least once annually to review oil well permits and oil related activity that could endanger the aquifers."* Another example is the Plum Creek CD management objective that states *"Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production or waste and disposal operations associated with oil and gas production on groundwater availability and quality, as well as the impact of groundwater production on the production of oil and gas in the District. 2. Also, during each year the District will evaluate all permit applications for new production injection or disposal wells permitted by the RRC, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District."*

A Post Oak Savannah GCD management objective states *"Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production on groundwater availability, as well as the impact of groundwater production on the production of oil and gas in the District."*

However, the 18 other Carrizo-Wilcox GCDs elected not to address the contamination monitoring through cooperation with the RRC on oil and gas activity within their respective jurisdictions under goal 5 "*addressing natural resource issues*".

Other opportunities for addressing natural resource issues that were not included in the management plans reviewed include: (1) monitoring of point source or non-point-source pollution that may be of concern for natural resources within their jurisdiction, (2) natural sources of groundwater contamination, and (3) opportunities such as partnering with the TCEQ's Groundwater Planning and Assessment Team which provides "support and coordination of interagency efforts toward preventing and managing contamination of groundwater by pesticides," or the Texas Groundwater Protection Committee.

According to the August 2010 Texas Groundwater Protection Committee's *Joint Groundwater Monitoring and Contamination Report-2009* the *"(Texas)RCT has jurisdiction over discharges or spills associated with the transportation of crude oil prior to refining of the oil, and of natural gas prior to its use in a manufacturing process or as a residential or industrial fuel. As a result, discharges or spills from crude oil or natural gas pipelines are under the jurisdiction of the RCT. However, discharges or spills from pipelines transporting refined products such as gasoline, diesel, or other fuel oils fall under the regulatory jurisdiction of the TCEQ, and the Spill Prevention and Control Rules should be followed. As specified under the State of Texas Oil and Hazardous Substances Spill Contingency Plan, the TCEQ serves as the lead agency in directing and approving the response for the discharge or spill of a harmful quantity of crude oil (defined as five or more barrels discharged or spilled on the ground or any quantity discharged or spilled into water) during highway or rail transportation"* (Texas Groundwater Protection Committee, 2010).

Texas Water Code §5.236 requires the TCEQ to provide notice to local officials regarding groundwater contamination which may affect drinking water supplies in their area. Notification is provided to county judges and public health officials to supply information on groundwater impacts to drinking water supplies within the county. However, the Carrizo-Wilcox GCDs did not include management objectives or performance standards recognizing or utilizing this source of information from state agencies and committees regarding groundwater contamination.

Eighty percent of the management objectives and performance standards focused on water quantity concerns and not water quality concerns. In many instances well depth and well technology protect Carrizo-Wilcox Aquifer water quality from contamination. The possibility for contamination is always present; however, and the groundwater resource should be protected accordingly. For example, Evergreen UWCD management objective stated "*Each year the District will sample at least 40 water wells in the District for chemical analysis of water quality*" and the coinciding performance standard stated "*A table giving the results of the chemical analyses of the water quality samples taken by the District each year will be included in the Annual Report on District Activities made to the Board of Directors. A discussion of whether any instances of groundwater contamination or issues of concern were noted in the water quality sample analyses will be included in the Annual Report on District Activities made to the Board of Directors*." Information gathered by the Evergreen GCD will be helpful for interagency cooperation to evaluate and possibly eliminate or regulate anthropogenic pollution factors within the District.

A few Carrizo-Wilcox GCDs adopted management objectives and performance standards that comprehensively address natural resource issues within their jurisdictions on an annual basis. For example, the Lost Pines GCD management objective stating "*To provide information to the public about the status of groundwater use, availability, and water levels and a description of natural resource issues, e.g., mining, out of District transport of groundwater, protection of endangered species, or the spread of phreatophytic vegetation, that impact the use and availability of groundwater or which are affected by the use and availability of groundwater,*" and the coinciding management objective stated "*At least annually, the General Manager shall prepare a report for the LPGCD board on the status of groundwater use, availability, and water levels within the District and a description of natural resource issues. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. To the extent practical, the LPGCD also will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.*"

Table 6.4 is a compilation of all management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing natural resource issues.

Table 6.4: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing natural resource issues.

MOB= Management Objective PS=Performance Standard

#	
1	**Anderson Underground Water Conservation District** **MOB:** Each year, the District will require permits for all nonexempt use of groundwater in the District as defined in the District rules, in accordance with adopted procedures. **PS:** Each year, a summary of the number of applications for the drilling of nonexempt wells, the number of applications for the permitted use of groundwater and the disposition of the applications will be presented in the District's annual report.
2	**Bluebonnet Groundwater Conservation District** **Bee Groundwater Conservation District** **MOB:** The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge. **PS:** A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
3	**Brazos Valley Groundwater Conservation District** **MOB:** Determine if there are any natural spring flows within the District that may be impacted by increased groundwater pumping. **PS:** Annually monitor water levels in at least 2 wells near natural spring flows, if found, for potential impact from groundwater production. Prepare an annual assessment statement and include in annual report to the District Board of Directors.
4	**Evergreen Underground Water Conservation District** **MOB:** Each year the District will sample at least 40 water wells in the District for

	chemical analysis of water quality. **PS:** A table giving the results of the chemical analyses of the water quality samples taken by the District each year will be included in the Annual Report on District Activities made to the Board of Directors. A discussion of whether any instances of groundwater contamination or issues of concern were noted in the water quality sample analyses will be included in the Annual Report on District Activities made to the Board of Directors.
5	**Gonzales Underground Water Conservation District** **MOB:** The District will meet with Natural Resources Conservation Service representatives to exchange information on wells and water levels at least once annually. **PS:** Record the date and number of meetings with the Natural Resource Conservation Service representatives annually. **MOB:** The District will meet with the local RRC engineering technician at least once annually to review oil well permits and oil related activity that could endanger the aquifers. **PS:** Record the date and number of meetings with the RRC engineering technician annually
6	**Guadalupe County Groundwater Conservation District** **MOB:** Each year the District will evaluate all proposed new wells prior to drilling. Information submitted by the applicant will be evaluated in order assess water level impacts within the District. **PS:** A monthly report to the Board will be made on the results of all water level impact studies and number of wells evaluated each month.
7	**Lost Pines Groundwater Conservation District** **MOB:** To provide information to the public about the status of groundwater use, availability, and water levels and a description of natural resource issues, e.g., mining, out of District transport of groundwater, protection of endangered species, or the spread of phreatophytic vegetation, that impact the use and availability of groundwater or which are affected by the use and availability of groundwater. **PS:** At least annually, the General Manager shall prepare a report for the LPGCD board on the status of groundwater use, availability, and water levels within the District and a description of natural resource issues. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. To the extent practical, the LPGCD also will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
8	**McMullen Groundwater Conservation District** **MOB:** The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge. **PS:** A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
9	**Medina County Groundwater Conservation District** **MOB:** Each year the District will work with various interest groups and appropriate agencies, such as the San Antonio River Authority, to provide information on aquifer storage and recovery projects and will require permits for all aquifer storage and

	recovery projects. **PS:** The District will require permits for all aquifer and storage projects within the District and report the number of applications submitted annually. The District will provide one article to a newspaper of general circulation in the District regarding the San Antonio River Authority's Aquifer Storage and Recovery project.
10	**Panola County Groundwater Conservation District** **MOB:** The District will monitor water-levels within District boundaries on an annual basis by measuring the water level of at least 5 wells. **PS:** The District's Annual Report will include a description of the number of wells measured and the monitoring results of the measured well for each year.
11	**Plum Creek Conservation District** **MOB:** 1. Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production or waste and disposal operations associated with oil and gas production on groundwater availability and quality, as well as the impact of groundwater production on the production of oil and gas in the District. 2. Also, during each year the District will evaluate all permit applications for new production injection or disposal wells permitted by the RRC, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District. **PS:** 1. The number of conferences with a representative of the Texas RRC each year; 2. The addition of available RRC well data to the District's database; 3. Monthly reports to the PCCD Board of Directors on the number of new well permit applications filed, and the possible impacts of those new wells on the groundwater resources in the District; and 4. Annual reports to the Board about consumption and use of groundwater for commercial purposes, including irrigation uses and enhanced oil and gas production when information is available.
12	**Post Oak Savannah Groundwater Conservation District** **MOB:** Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production on groundwater availability, as well as the impact of groundwater production on the production of oil and gas in the District. **PS:** The number of conferences with a representative of the Texas RRC each year. **MOB:** Also, during each year the District will evaluate all permit applications for new wells, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District. **PS:** Monthly reports to the POSGCD Board of Directors on the number of new well permit applications filed, and the possible impacts of those new wells on the groundwater resources in the District.
13	**Uvalde County Groundwater Conservation District** **MOB:** Each year the District will cooperate with interested parties and appropriate agencies to develop additional information on aquifer recharge and weather modification projects. **PS:**(a) The District will establish terms for all aquifer recharge, transportation, or storage project permits. The District shall take into consideration all applicable factors

	and requirements of the District's rules and state law. (b) The District will make all information available to the District on such projects available to the general public and to permit applicants annually. (c) The District shall require owners or operators of all aquifer pumping, recharge, transportation, or storage projects affecting the district to obtain a permit amendment if the use, volume of groundwater pumped, location of, or means of transportation, recharge, or storage changes from the manner in which it was originally permitted. **MOB:** The District will require issuance of a well construction permit, or preregistration of exempt wells not requiring a construction permit, prior to the drilling of all new wells for all aquifers under the District's jurisdiction. **PS:** All well construction permits in compliance with the District rules will be issued within 20 days. Well construction permits not in compliance with the rules, as determined by the General Manager, will be considered at the next regular board meeting, but within 90 days of the General Manager's determination of the application's compliance with District rules.
14	**Wintergarden Groundwater Conservation District** **MOB:** Each year the District will insure that all new wells permitted for construction within the District, comply with the District construction standards through monitoring of the State of Texas water well report required to be provided to the District by water well drillers. **PS:** The number of newly permitted water wells within the District monitored for compliance will be reported to the Board annually.

2.6 Addressing Drought Conditions

All Carrizo-Wilcox GCDs included management objectives and performance standards for goal 6, *"Addressing Drought Conditions."* Each GCD elected to address drought conditions through establishing a Drought Contingency Plan, monitoring the Palmer Drought Severity Index, or to maintain updates with the Drought Preparedness Council Situation Report. Districts have created rules that trigger conservation by water users in their jurisdictions. Largely, Carrizo-Wilcox GCD boards of directors and general managers are responsible for implementing plans and notifying residents of the water conservation measures established by the individual districts. Thirteen out of 21 Carrizo-Wilcox GCDs stated that they would monitor the Palmer Drought Severity Index; however, several districts did not include detailed management objectives and performance standards necessary to determine whether or not the goal is being achieved.

For instance, Anderson County UWCD District management objective stated *"Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report posted on the Texas Water"* and the coinciding performance standard stated *"Each year, the downloaded PDSI maps and Situation Reports will be included in the District Annual Report to the Board of Directors"*. Brazos Valley GCD went beyond monitoring the Palmer Drought Severity Index (PDSI) and stated that the District would *"Require 100 percent of water producers that are required by the state of Texas to have drought contingency plans, to submit those plans to the District when applying for a permit for well production from the District."* Further, the coinciding performance standard stated "*Review 100 percent of the drought contingency plans submitted as a result of permit requirements whenever a severe drought condition is reached as determined by the PDSI. The number of drought contingency plans required to be submitted by water producers to the District as part of the well permitting process and the number of drought contingency plans actually submitted to the District will be reports in the annual report to the District Board of Directors."* Though methodologies vary, districts have committed to monitoring drought conditions and report the findings at least annually to the public. One observation is that more timely dissemination of current drought information to district residents would be a beneficial service for the districts to provide.

Precipitation and climate vary from east to west in the state as do the hydrologic and hydrogeological characteristics. Generally prolonged droughts in Texas are perceived as a threat to the environment, human welfare, and to the economy of the state. According to our evaluation, six of the Carrizo-Wilcox GCD's called for development of Drought Contingency Plans or Drought Management Strategy Plans when "addressing drought conditions", including Brazos Valley GCD, Neches & Trinity Valleys GCD, Pineywoods GCD, Plum Creek CD, Post Oak Savannah GCD and Rusk County GCD. Drought Contingency Plans are designed to be the preferred course of action to fulfill the need of each district. For instance, the Guadalupe County GCD established a *"Drought Management Plan to cope with the effects of water supply deficits due to climatic or other conditions will be adopted by the Board after notice and hearing. In developing the contingency plan, the District will consider the economic effect of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydrogeologic conditions of the aquifers within the District and the appropriate conditions under which to implement the contingency plan."* Therefore, after a thorough review of the District management plans it appears that more may have to be done at the local level of government to ensure that strategic groundwater resources important to the environment and economy are more adequately monitored during drought conditions. For example, Fayette County GCD management objective stated *"The annual amount of groundwater permitted by the District for withdrawal from the portion of the aquifers located within the District may be curtailed during periods of extreme drought in the recharge zones of the aquifers or because of other conditions that cause significant declines in groundwater surface elevations. Such curtailment may be triggered by the District's Board based on the groundwater elevation measured in the District's monitoring well(s)"* and the coinciding performance standard stated *"The District shall monitor at least one well each year. Annually report to the Board of Directors the number of measurements obtained from the water level monitoring network. A summary report of the water level measurement results and an* *analysis of any situations that may require curtailment of groundwater withdrawal will be included in the report."*

Another observation is that certain Carrizo-Wilcox GCD management plans could benefit from the utilization of more than just one well as a drought monitor well, considering that some districts have expansive jurisdictions. Further, districts including Gonzales Underground Water Conservation District state that "*The General Manager will access the National Weather Service–Climate Prediction Center website*

(http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml) monthly to determine the Palmer Drought Severity Index and will submit a report to the Board of Directors monthly. The District will, 100 percent of the time when under extreme drought conditions, as defined by the Palmer Drought Severity Index, provide information to and coordinate with local water users and water managers regarding drought response activities." Lost Pines GCD management objective stated that "*Drought conditions are to be addressed on an ongoing basis by tracking rainfall records available from nearby weather stations as compared to hydrographs for LPGCD monitoring wells. At least once per month, the General Manager will update rainfall and water level records maintained by the LPGCD. Based on GAM modeling and an understanding of the outcrop areas of the principal aquifers – Simsboro, Carrizo, Queen City, and Sparta – in the LPGCD, recharge appears to be relatively constant under the current climatic regime and little affected by drought conditions. It is anticipated, though that drought conditions will result in increased pumpage and decreased natural discharge, thereby affecting water levels in the aquifers."* Lost Pines GCD's performance standard is a positive example of the amount of transparency and reporting of drought conditions to the public. The District's performance standard stated "*At least annually, the General Manager shall prepare a report for the LPGCD board on precipitation amounts as compared to water levels within the District and a description of apparent trends. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. The summary may be published in conjunction with the publication of the summary of natural resource issues. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.*" Public information and awareness of drought conditions is an important step to managing groundwater resources in times of need.

Carrizo-Wilcox GCDs are addressing drought conditions by varied means. From Live Oak GCD participation in the South Texas Weather Modification Program and attendance of the South Texas Weather Modification Association to Neches & Trinity Valleys GCD's multi-pronged approach to addressing drought conditions. Simply stated, drought conditions impact groundwater resources differently from region to region and this is recognized from this review.

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	Table 6.5: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing drought conditions. **MOB= Management Objective PS=Performance Standard**
1	**Anderson County Groundwater Conservation District** **MOB:** Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report posted on the Texas Water. **PS:** Each year, the downloaded PDSI maps and Situation Reports will be included in the District Annual Report to the Board of Directors.
2	**Bluebonnet Groundwater Conservation District** **MOB:** Each month, the District will download available drought information, for the counties in the District, from available websites on the internet. **PS:** Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing for the Board of Directors. The downloaded maps, reports and information will be included with copies of the quarterly briefings, in the District Annual Report to the Board of Directors.
3	**Bee Groundwater Conservation District** **MOB:** The District will monitor the Palmer Drought Severity Index (PDSI). **PS:** A report of the Palmer Drought Severity Index will be presented to the District board on an annual basis.
4	**Brazos Valley Groundwater Conservation District** **MOB:** A report of the Palmer Drought Severity Index will be presented to the District board on an annual basis. **PS:** The District will make an assessment of drought conditions in the District and will prepare an annual briefing to the Board of Directors. **MOB:** Require 100 percent of water producers that are required by the state of Texas to have drought contingency plans, to submit those plans to the District when applying for a permit for well production from the District. **PS:** Review 100 percent of the drought contingency plans submitted as a result of permit requirements whenever a severe drought condition is reached as determined by the PDSI. The number of drought contingency plans required to be submitted by water producers to the District as part of the well permitting process and the number of drought contingency plans actually submitted to the District will be reports in the annual report to the District Board of Directors. **MOB:** Develop a District drought contingency plan. The target goal for developing the plan is June 2010. The drought contingency plan will be reviewed for effectiveness and needed updates once annually. **PS:** A report summarizing the findings of the annual review of the District drought contingency plan will be included in the annual report of the District Board of Directors.
5	**Evergreen Groundwater Conservation District** **MOB:** Each month, the District will download at least one updated Palmer Drought Severity Index (PDSI) map posted on the National Weather Service - Climate Prediction

	Center website (http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml) and check for the periodic updates to the Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Department of Public Safety website (http://www.txdps.state.tx.us/dem/sitrepindex.html). **PS:** Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the quarterly briefing in the District Annual Report to the Board of Directors.
6	**Fayette Groundwater Conservation District** **MOB:** ***Curtailment of Groundwater Withdrawal:*** The annual amount of groundwater permitted by the District for withdrawal from the portion of the aquifers located within the District may be curtailed during periods of extreme drought in the recharge zones of the aquifers or because of other conditions that cause significant declines in groundwater surface elevations. Such curtailment may be triggered by the District's Board based on the groundwater elevation measured in the District's monitoring well(s). **PS:** The District shall monitor at least one well each year. Annually report to the Board of Directors the number of measurements obtained from the water level monitoring network. A summary report of the water level measurement results and an analysis of any situations that may require curtailment of groundwater withdrawal will be included in the report.
7	**Gonzales Underground Water Conservation District** **MOB:** The General Manager will access the National Weather Service – Climate Prediction Center website (http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml) monthly to determine the Palmer Drought Severity Index and will submit a report to the Board of Directors monthly. The District will, 100 percent of the time when under extreme drought conditions, as defined by the Palmer Drought Severity Index, provide information to and coordinate with local water users and water managers regarding drought response activities. **PS:** Record the date and number of monthly reports made to the District Board of Directors. Record the date and number of times when the District was under extreme drought conditions and the number of times letters were sent to public water suppliers.
8	**Guadalupe County Groundwater Conservation District** **MOB:** The District developed and adopted a Drought Management Plan in 2007. The District will obtain the Palmers Drought Severity Index (PDSI), as per the District's Drought Management Plan. **PS:** Number of reports made to the board each year on the PDSI.
9	**Live Oak Groundwater Conservation District** **MOB:** 1) Participate in the South Texas Weather Modification Program. 2) Evaluate the performance of the weather modification program. **PS:** District representative will attend 1 meeting of the South Texas Weather Modification Assn. Annually.
10	**Lost Pines Groundwater Conservation District** **MOB:** Drought conditions are to be addressed on an ongoing basis by tracking rainfall records available from nearby weather stations as compared to hydrographs for LPGCD

	monitoring wells. At least once per month, the General Manager will update rainfall and water level records maintained by the LPGCD. Based on GAM modeling and an understanding of the outcrop areas of the principal aquifers—Simsboro, Carrizo, Queen City, and Sparta—in the LPGCD, recharge appears to be relatively constant under the current climatic regime and little affected by drought conditions. It is anticipated, though that drought conditions will result in increased pumpage and decreased natural discharge, thereby affecting water levels in the aquifers. **PS:** At least annually, the General Manager shall prepare a report for the LPGCD board on precipitation amounts as compared to water levels within the District and a description of apparent trends. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. The summary may be published in conjunction with the publication of the summary of natural resource issues. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
11	**McMullen Groundwater Conservation District** **MOB:** The District will monitor the Palmer Drought Severity Index (PDSI). **PS:** A report of the Palmer Drought Severity Index will be presented to the District board on an annual basis.
12	**Medina County Groundwater Conservation District** **MOB:** Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Water Information Network Website www.txwin.net. **PS:** Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the quarterly briefing in the District Annual Report to the Board of Directors.
13	**Mid-East Groundwater Conservation District** **MOB:** The District shall call for the most efficient use of groundwater by all users in the District to maintain sufficient groundwater aquifer resources during periods of drought and for future resources by preventing waste and by regulation of users, if necessary to prevent depletion of the aquifers. The District will review the Texas Palmer Drought Index and the Texas Drought Preparedness Report, and monitor the District's production figures annually. **PS:** The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
14	**Neches & Trinity Valleys Groundwater Conservation District** **MOB:** The Board has adopted a contingency plan to cope with the effects of water supply shortages due to climatic or other conditions. The plan is reviewed at least annually by the Board. In developing the contingency plan, the District considered the economic effects of conservation measures upon all water resource user groups, the

	local implications of the degree and effect of changes in water storage conditions, the unique hydro-geologic conditions of the aquifer and the appropriate conditions under which to implement the contingency plan. During extreme drought conditions within the District as measured by the Palmer Drought Index, all efforts will be made to see that all municipalities and public water supply companies follow their drought contingency plans. During extreme drought conditions that materially affects the aquifer levels, the District staff will closely monitor the aquifer levels through establishment of a District monitoring plan of static levels in selected monitoring wells or by obtaining well water levels from selected water supply companies who have such data available to ensure that adequate quantities of water are available to the District and will coordinate with the Region C and I Water Planning Groups. **PS:** A drought contingency plan developed by the District and approved by the Board will be reviewed by the Board every year and revised as necessary. During extreme drought conditions within the District, efforts will be made through contact by District staff to see that municipalities and public water supply companies follow their drought contingency plans.
15	**Panola County Groundwater Conservation District** **MOB:** The District will download at least one updated Palmer Drought Severity Index ("PDSI") map each month and will check for the regular updates to the Drought Preparedness Council Situation Report ("Situation Report") posted on the following website: http://www.txdps.state.tx.us/dem/sitrepindex.html. **PS:** The District will include the 12 monthly downloaded PDSI maps and Situation Reports in the Annual Report for each fiscal year.
16	**Pineywoods Groundwater Conservation District** **MOB:** The District shall call for the most efficient use of groundwater by all users in the District to maintain sufficient groundwater aquifer resources during periods of drought and for future resources by preventing waste and by regulation of users, if necessary, to prevent depletion of the aquifers. To work closely with groundwater users and provide assistance where it is possible to control customer usage as it is outlined in their Drought Contingency Plans. **PS:** Periodically review the Texas Palmer Drought Index and the Texas Drought Preparedness Report, and monitor production figures quarterly. A summary of any drought conditions will be given to the Board of Directors in the annual report along with any recommendations and make necessary changes, as needed.
17	**Plum Creek Conservation District** **MOB:** The District will develop and adopt a Drought Management Strategy Plan for groundwater under the authority of the District within five years of the adoption and certification of this plan, and thereafter review it annually, and revise it if necessary. The plan will be implemented when specified conditions require. After its adoption, the Board will periodically review and update the Plan based upon the availability of additional scientific data collected by or presented to the Board. **PS:** 1. Development and adoption of a Drought Management Strategy Plan within 5 years of the adoption and certification of this plan. 2. Review all of the conditions and requirements specified in the Drought Management Strategy

	Plan that would trigger implementation on an annual basis. 3. Determine the necessity of a program to monitor rainfall for timing of effects on groundwater availability during droughts.
18	**Post Oak Savannah Groundwater Conservation District** **MOB:** The District will develop and adopt a Drought Management Strategy Plan within five years of the adoption and certification of this plan, review it annually, and revise it if necessary. The plan will be implemented when specified conditions require. **PS:** Development and adoption of a Drought Management Strategy Plan within five years of the adoption and certification of this plan.
19	**Rusk County Groundwater Conservation District** **MOB:** The District will develop and adopt a Drought Contingency Plan for the Rusk County Groundwater Conservation District within one year of the adoption and certification of this plan, review it annually, and revise it if necessary. **PS:** A contingency plan to cope with the effects of water supply shortages due to climatic or other conditions will be developed by the District and will be adopted by the Board after notice and hearing. In developing the contingency plan, the District will consider the economic effects of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydro geologic conditions of the aquifer and the appropriate conditions under which to implement the contingency plan. (a) Development and adoption of a Drought Contingency Plan within one year of the adoption and certification of this plan. (b) The Annual Report to the Board of Directors of the District will reflect any implementations of the Drought Contingency Plan in that year. The report will include an appraisal of the plans effectiveness and suggestions for revisions to the plan.
20	**Uvalde County Groundwater Conservation District** **MOB:** Each year the District will provide education materials concerning waste, which is prohibited under the District rule, to the newspapers and to the general public on at least six occasions **PS:** (a) The District will provide to a newspaper of general circulation within the District at least six newspaper articles and/or public service announcements on an annual basis, including those that may be posted on the District's Website. (b) The District will investigate all written reports of waste of groundwater within five working days from the date the report is filed with the District.
21	**Wintergarden Groundwater Conservation District** **MOB:** Each month the District will download the Palmer Drought Severity Index (PDSI) map and check the updates to the Drought Preparedness Council Situation Report posted on the Texas Water Information Network website www.txwin.net. **PS:** As required, the staff will assess the status of drought in the District and when needed, prepare a briefing with maps and situation reports for the Board of Directors. Monthly downloads will be filed for future use.

2.7 Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control, Where Appropriate and Cost Effective

All 21 GCDs addressed goal 7 "*Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control, Where Appropriate and Cost-Effective."*

We found that the Carrizo-Wilcox GCDs are not uniformly addressing this goal due to the varied conditions and aquifer characteristics in regions from northeast to southwest. For instance, according to the Pineywoods GCD, "*A small part of the northeast portion of Nacogdoches County is the outcrop of the Carrizo-Wilcox aquifer. This area of the county is rural and is the only recharge site for the Carrizo-Wilcox in the District. The main recharge areas lie in counties in the north and east of the Pineywoods GCD. From the information contained in the above report, the District has determined that for the reasons listed, recharge, natural or artificial, including precipitation enhancement, rainwater harvesting or brush control is not an appropriate management goal of the District at this time."* The Brazos Valley GCD stated their management objective was to *"Determine if there are any natural spring flows within the District that may be impacted by increased groundwater pumping*" and the coinciding performance standard stated **"***Annually monitor water levels in at least 2 wells near natural spring flows, if found, for potential impact from groundwater production. Prepare an annual assessment statement and include in annual report to the District Board of Directors."* The Neches & Trinity Valleys Groundwater Conservation District management objective stated **"***Each year, on four or more occasions, the District will disseminate educational information relating to conservation practices for the efficient use of water resource,"* and the coinciding performance standard stated *"Number of occasions, annually, the District disseminated educational information relating to the conservation practices for the efficient use of water resources."*

To present the diversity of these objectives presented in the management plans Table 6.6 was created to document the management objectives and performance standards. On a whole recharge enhancement and brush management were not generally supported objectives of the Carrizo-Wilcox GCDs. Only a few districts specifically stated they would participate in rain harvesting or precipitation modification programs.

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Table 6.6: Management objectives and performance standards included in the Carrizo-Wilcox GCD management plans addressing conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, or brush control, where appropriate and cost-effective.

MOB= Management Objective PS=Performance Standard

1	**Anderson County Underground Water Conservation District** **MOB:** Each year, the District will require permits for all nonexempt use of groundwater in the District as defined in the District rules, in accordance with adopted procedures. **PS:** Each year, the downloaded PDSI maps and Situation Reports will be included in the

	District Annual Report to the Board of Directors.
2	**Bluebonnet Groundwater Conservation District** **MOB:** Conservation- The District will post an article or a link to an article annually, regarding water conservation on the District website www.bluebonnetgroundwater.org . **PS:** A copy of the article linked or posted on the District website regarding water conservation will be included in the Annual Report to the Board of Directors. **MOB:** Rainwater Harvesting- The District will post an article or a link to an article annually, regarding rainwater harvesting on the District website. **PS:** A copy of the article posted on the District website regarding rainwater harvesting will be included in the Annual Report to the Board of Directors.
3	**Bee Groundwater Conservation District** **MOB:** The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge. **PS:** A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
4	**Brazos Valley Groundwater Conservation District** **MOB:** Determine if there are any natural spring flows within the District that may be impacted by increased groundwater pumping. **PS:** Annually monitor water levels in at least 2 wells near natural spring flows, if found, for potential impact from groundwater production. Prepare an annual assessment statement and include in annual report to the District Board of Directors.
5	**Evergreen Underground Water Conservation District** **MOB:** Each year the District will sample at least 40 water wells in the District for chemical analysis of water quality. **PS:** A table giving the results of the chemical analyses of the water quality samples taken by the District each year will be included in the Annual Report on District Activities made to the Board of Directors. A discussion of whether any instances of groundwater contamination or issues of concern were noted in the water quality sample analyses will be included in the Annual Report on District Activities made to the Board of Directors
6	**Fayette County Groundwater Conservation District** **MOB:** The District will develop and sponsor a water conservation education curriculum, available upon request for all schools within the District. The District will utilize the methodologies listed under Goal 5 in order to raise public awareness of the necessity and importance of a water conservation program. **PS:** Annually report to the Board of Directors on: ♦ the number of schools where water conservation education curriculums are presented each year. ♦ the number of water conservation articles presented to the public via the various methodologies outlined in Goal 5. Promote and/or implement groundwater banking, recharge projects, rainwater harvesting and aquifer storage and recovery projects, where appropriate and cost-effective, to address areas with declining groundwater levels. Promotion of these projects may be accomplished through articles published in at least one of the District's quarterly newsletters.
7	**Gonzales Underground Water Conservation District** **MOB:** The District will meet with Natural Resources Conservation Service representatives

	to exchange information on wells and water levels at least once annually. **PS:** Record the date and number of meetings with the Natural Resources Conservation Service representatives annually. **MOB:** The District will meet with the local RRC engineering technician at least once annually to review oil well permits and oil related activity that could endanger the aquifers. **PS:** Record the date and number of meetings with the RRC engineering technician annually.
8	**Guadalupe County Groundwater Conservation District** **MOB:** Each year the District will evaluate all proposed new wells prior to drilling. Information submitted by the applicant will be evaluated in order assess water level impacts within the District. **PS:** A monthly report to the Board will be made on the results of all water level impact studies and number of wells evaluated each month
9	**Live Oak Groundwater Conservation District** **MOB:** Participate in the South Texas Weather Modification Program **MOB:** Evaluate the performance of the weather modification program **PS:** District representative will attend 1 meeting of the South Texas Weather Modification Assn. annually
10	**Lost Pines Groundwater Conservation District** **MOB:** To provide information to the public about the status of groundwater use, availability, and water levels and a description of natural resource issues, e.g., mining, out of District transport of groundwater, protection of endangered species, or the spread of phreatophytic vegetation, that impact the use and availability of groundwater or which are affected by the use and availability of groundwater. **PS:** At least annually, the General Manager shall prepare a report for the LPGCD board on precipitation amounts as compared to water levels within the District and a description of apparent trends. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. The summary may be published in conjunction with the publication of the summary of natural resource issues. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
11	**McMullen Groundwater Conservation District** **MOB:** The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge. **PS:** A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
12	**Medina County Groundwater Conservation District** **MOB:** The District will annually submit an article regarding water conservation for publication to at least one newspaper of general circulation in Medina County. **PS:** A copy of the article submitted by the District for publication to a newspaper of general circulation in Medina County regarding water conservation will be included in the Annual Report to the Board of Directors.
13	**Mid-East Groundwater Conservation District**

	MOB: The District will at least annually conduct a least one program to provide public information and education to promote the conservation of water. Such programs may include newspaper publication, open meetings, handout brochures and mail-out brochures. **PS:** The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
14	**Neches & Trinity Valleys Groundwater Conservation District** **MOB:** Each year, on four or more occasions, the District will disseminate educational information relating to conservation practices for the efficient use of water resources. **PS:** Number of occasions, annually, the District disseminated educational information relating to the conservation practices for the efficient use of water resources.
15	**Panola County Groundwater Conservation District** **MOB:** The District will promote conservation at least once during each fiscal year by one of the following methods: a. distribute literature packets or brochures; b. conduct public presentations; c. sponsor an educational program/curriculum; d. provide information on the District's website; e. submit newspaper articles to local newspaper for publication; f. present displays at local public events; g. annually conduct a local contest on water conservation; or h. conduct classroom presentations on conservation. **PS:** The District's Annual Report will provide a summary of the District efforts and a copy of any information provided by the District to the public during the previous fiscal year to promote conservation. **MOB:** The District will provide information relating to recharge enhancement on the District website at least one time each fiscal year. **PS:** Each year, the District's Annual Report will include a copy of the information that has been provided on the District website relating to recharge enhancement. **MOB:** The District will advocate rainwater harvesting each year by providing updated information about rainwater harvesting on the District website at least once each fiscal year. **PS:** The Annual Report for the District will include a copy of the information on rainwater harvesting which has been provided on the District website within the previous fiscal year.
16	**Pineywoods Groundwater Conservation District** Management Goal: Prevent unnecessary waste of the groundwater and encourage **MOB:** Maintain a constant review of all projects to ensure that they are using the best available technology. Publish a newsletter at least quarterly and include some educational information to promote conservation. Provide public education at any opportunity to promote conservation. **PS:** Annually review all projects to determine if they are using best available technology and if educational materials are benefiting the conservation program. This review will be included in the annual report to the Board of Directors.
17	**Plum Creek Conservation District** **MOB:** 1. Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production or waste and disposal operations associated with oil and gas production on groundwater availability and quality, as well as the impact of groundwater production on the production of oil and gas in the District. 2. Also, during each year the District will evaluate all permit applications for new

	production injection or disposal wells permitted by the RRC, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District. **PS:** 1. The number of conferences with a representative of the Texas RRC each year; 2. The addition of available RRC well data to the District's database; 3. Monthly reports to the PCCD Board of Directors on the number of new well permit applications filed, and the possible impacts of those new wells on the groundwater resources in the District; and 4. Annual reports to the Board about consumption and use of groundwater for commercial purposes, including irrigation uses and enhanced oil and gas production when information is available.
18	**Post Oak Savannah Groundwater Conservation District** **MOB:** The District will develop and adopt a Drought Management Strategy Plan within five years of the adoption and certification of this plan, review it annually, and revise it if necessary. The plan will be implemented when specified conditions require. **PS:** Development and adoption of a Drought Management Strategy Plan within five years of the adoption and certification of this plan.
19	**Rusk County Groundwater Conservation District** **MOB:** Public education on groundwater conservation. **PS:** The District will issue at least two articles per year in Rusk County newspapers and on the District internet website regarding water conservation issues applicable to the residence of Rusk County. Tracking Method: Copies of the articles posted on the District website regarding groundwater conservation will be included in the Annual Report to the Board of Directors.
20	**Uvalde County Underground Water Conservation District** **MOB:** The District will annually submit an article regarding water conservation for publication to at least one newspaper of general circulation in Uvalde County. **PS:** A copy of the article submitted by the District for publication to a newspaper of general circulation in Uvalde County regarding water conservation will be included in the Annual Report to the Board of Directors.
21	**Wintergarden Groundwater Conservation District** **MOB:** Each year the District will insure that all new wells permitted for construction within the District, comply with the District construction standards through monitoring of the State of Texas water well report required to be provided to the District by water well drillers. **PS:** The number of newly permitted water wells within the District monitored for compliance will be reported to the Board annually.

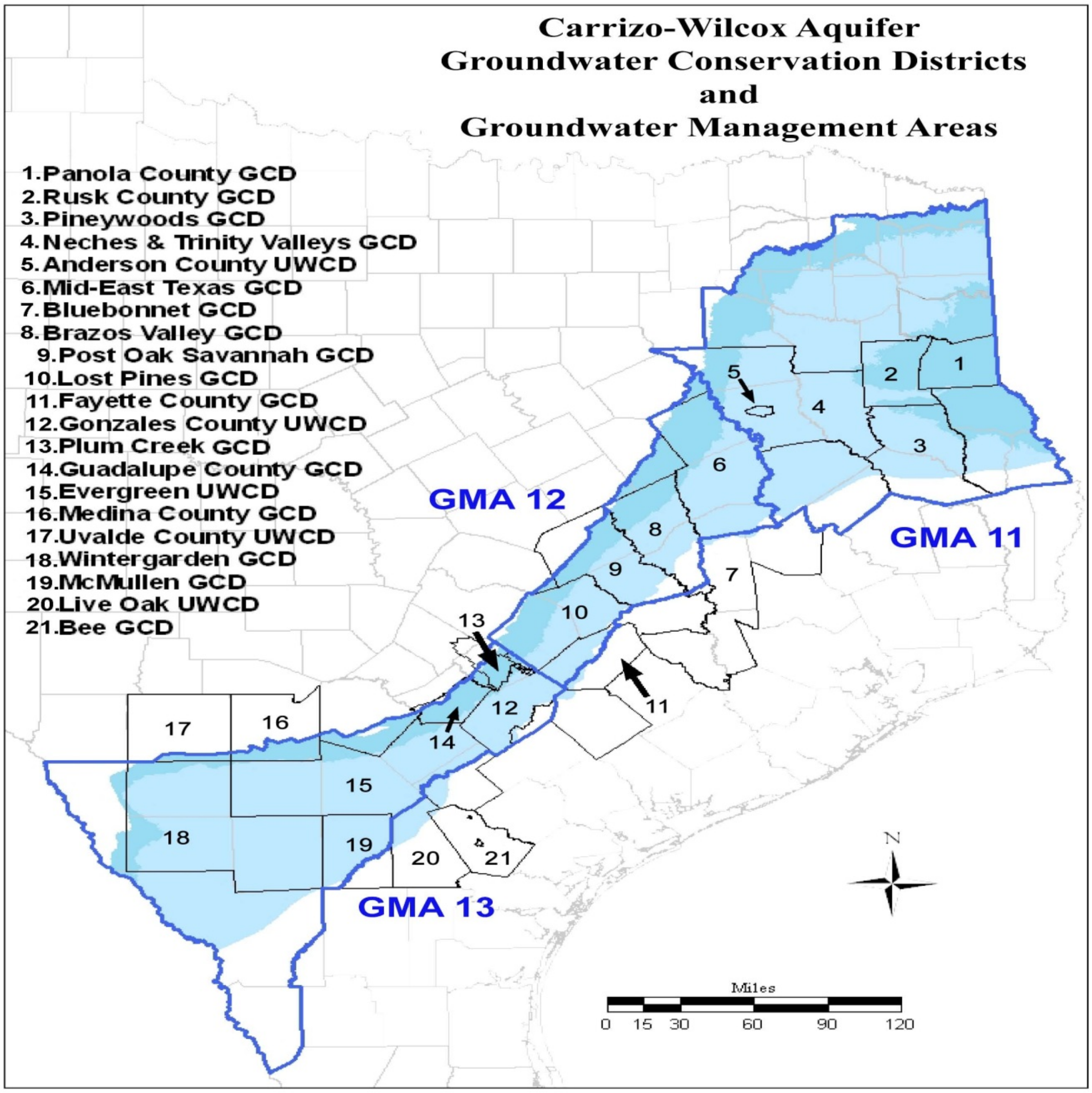


Figure 6.1: Carrizo-Wilcox Aquifer Groundwater Conservation Districts and Groundwater Management Areas.

Appendices

Appendix 1: Anderson Groundwater Conservation District

#	Goal	Management Plan Objectives	Performance Standard
A1	**Providing the most efficient use of groundwater**	The District will begin a process to register all wells within the District's jurisdiction.	Each year, beginning in FY09, the number of new and existing wells registered with the District will be presented in the District's annual report
A2	**Controlling and preventing waste of groundwater**	Each year the District will disseminate educational information on eliminating and reducing the wasteful use of groundwater focusing on water quality protection. This may be accomplished annually by two of the following methods: a. Conduct an annual contest on water quality protection b. Compile literature packets for distribution to schools in Anderson County c. Conduct classroom presentations d. Sponsor an educational program/curriculum e. Post information on the District's website f. Provide newspaper articles for publication g. Publish District newsletter h. Conduct public presentations i. Set up displays at public events j. Distribute brochures/literature	The annual report will include a summary of the District activities during the year to disseminate educational information on eliminating and reducing the wasteful use of groundwater focusing on water quality protection.
A3	**Addressing conjunctive surface water management issues**	Each year, the District will participate in the regional planning process by attending at least one meeting of the regional water-planning group per fiscal year.	Each year, attendance at Region I meetings by a representative of the District will be reflected in the District's annual report and will include the number of meetings attended and the dates.

B1	**Controlling and preventing subsidence**	Each year, the District will manage the withdrawal of groundwater.	Each year, attendance at GMA 11 meetings by a representative of the District will be reflected in the District's annual report and will include the number of meetings attended and the dates.
B2	**Addressing natural resource issues which impact the use and availability of groundwater, and which are impacted by the use of groundwater**	Each year, the District will require permits for all nonexempt use of groundwater in the District as defined in the District rules, in accordance with adopted procedures.	Each year, a summary of the number of applications for the drilling of nonexempt wells, the number of applications for the permitted use of groundwater and the disposition of the applications will be presented in the District's annual report
C1	**Addressing drought conditions**	Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report posted on the Texas Water.	Each year, the downloaded PDSI maps and Situation Reports will be included in the District Annual Report to the Board of Directors.
D1	**Addressing conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, or brush control, where appropriate and cost effective**	Each year, the District will promote conservation by one of the following methods: a. Conduct an annual contest on water conservation b. Distribute conservation literature packets to schools in Anderson County c. Conduct classroom conservation presentations d. Sponsor and educational conservation program/curriculum e. Post conservation information on the District's website f. Provide a newspaper article on conservation for publication g. Publish an article on conservation in the District newsletter h. Conduct a public conservation presentation	Each year, the annual report will include a copy of the information on rainwater harvesting that is provided on the District's website.

		i. Set up a conservation display at a public event j. Distribute conservation brochures/literature to the public Each year, the District will provide information relating to recharge enhancement and brush control on the District's website. Performance Standard: Each year, the District annual report will include a copy of the information that has been provided on the District's website relating to recharge enhancement and brush control	
E1	**Addressing in a quantitative manner the desired future conditions of the groundwater resources**	This category of management goal is not applicable to the District because the desired future condition of the groundwater resources in GMA 11 has not been defined. The District intends to coordinate with other groundwater conservation districts in GMA 11 to define the desired future conditions of the aquifers, as required by TWC 36.108. The District also intends to review and evaluate the GAM simulation results and other available data by September 1, 2010 to determine if revisions are needed regarding the total aquifer storage and groundwater availability.	

Appendix 1: Bee Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Providing the most efficient use of groundwater**	Each year the District will provide education materials concerning the efficient use of groundwater.	Provide educational materials to at least one school annually
B1	**Controlling and preventing waste of groundwater**	Measure water levels from the land surface on strategic wells on an annual basis and report waste to the District Board.	(a) Report to the District Board annually the number of water level measurements. (b) The District will investigate all reports of waste of groundwater within five working days. The number of reports of waste as well as the investigation findings will be reported to the District Board in the annual report.
C1	**Natural resource issues**	The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge.	A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
D1	**Drought conditions**	The District will monitor the Palmer Drought Severity Index (PDSI).	A report of the Palmer Drought Severity Index will be presented to the District board on an annual basis.
E1	**Conservation**	Each year the District will make educational material to the public promoting conservation methods and concepts.	The District will make at least one educational brochure available per year through service organizations, and on a continuing basis at the District office.
F1	**Precipitation enhancement**	The District will participate in the South Texas Weather Modification Program.	A district representative will attend a meeting of the South Texas Weather Modification Assn. annually.

Appendix 1: Bluebonnet Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A 1	**Providing for the most efficient use of groundwater in the district**	Each year, the District will require all new exempt or nonexempt wells that are constructed within the boundaries of the District to be registered with the District in accordance with the District rules.	Each Year the number of exempt and nonexempt wells registered by the District for the year will be incorporated into the Annual Report submitted to the Board of Directors of the District.
B 1	**Controlling and preventing the waste of groundwater in the district**	Each year, the District will make an evaluation of the District Rules to determine whether any amendments are recommended to decrease the amount of waste of groundwater within the District.	The District will include a discussion of the annual evaluation of the District Rules and the determination of whether any amendments to the rules are recommended to prevent the waste of groundwater in the Annual Report of the District provided to the Board of Directors.
B 2		Each year, the District will provide information to the public on eliminating and reducing wasteful practices in the use of groundwater posting information or a link to information on groundwater waste reduction on the District's website.	Each year, a copy of the information provided on groundwater waste reduction on the District's website will be included in the District's Annual Report provided to the District Board of Directors.
C 1	**Conjunctive surface water management issues**	year, the District will participate in the regional planning process by being represented at the Region G and Region H Regional Water Planning Group meetings.	The attendance of a District representative to at least 50 percent of the Region G and Region H Regional Water Planning Group meetings will be noted in the Annual Report presented to the District Board of Directors.

D 1	**Addressing drought conditions**	Each month, the District will download available drought information, for the counties in the District, from available websites on the internet.	Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing for the Board of Directors. The downloaded maps, reports and information will be included with copies of the quarterly briefings, in the District Annual Report to the Board of Directors.
E 1	**Addressing conservation**	The District will post an article or a link to an article annually, regarding water conservation on the District website www.bluebonnetgroundwater.org .	A copy of the article linked or posted on the District website regarding water conservation will be included in the Annual Report to the Board of Directors.
F 1	**Rainwater harvesting**	The District will post an article or a link to an article annually, regarding rainwater harvesting on the District website www.bluebonnetgroundwater.org.	A copy of the article posted on the District website regarding rainwater harvesting will be included in the Annual Report to the Board of Directors.

Appendix 1: Brazos Valley Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Implement Strategies Providing For the Most Efficient Use of Groundwater**	Require all existing and new nonexempt wells constructed within the boundaries of the District to be permitted by the District and operated in accordance with District Rules. In addition, the District will encourage all exempt wells constructed within the District boundaries to be registered with the District.	The number of exempt and permitted wells registered within the District will be reported annually in the District's Annual Report submitted to the Board of Directors of the District.
A2		Regulate the production of groundwater by permitting wells within the District's boundaries based on beneficial use and in accordance with District Rules. Each year the District will accept and process applications for the permitted use of groundwater in the District, in accordance with the permitting process established by District Rules. The District will regulate the production of groundwater from permitted wells by verification of pumpage volumes using meters, if meters are required under the District Rule and/or permit for the wells.	The number and type of applications made for the permitted use of groundwater in the District, the number and type of permits issued by the District, and the amount of groundwater permitted, will be included in the Annual Report given to the Board of Directors. The actual annual pumpage from each metered well within the District will be reported annually and compared to the amount permitted for that well. This information will be included in the District's Annual Report submitted to the Board of Directors of the District.
A3		Conduct ongoing monitoring of the aquifers underlying the District and the current groundwater production within the District, and then assess the available groundwater that can be produced from each aquifer within the District after sufficient data are collected and evaluated. Using this data and information developed for GMA-12 the District will re-evaluate availability goals as necessary and will permit wells in accordance with the appropriate production goals.	The District will conduct the appropriate studies to identify the issues and criteria needed to address groundwater management needs within the District's boundaries. Groundwater availability goals will take into consideration the GMA-12 Planning and research of the hydro-geologic and geologic characteristics of the aquifers, which may include, but not necessarily be limited to, the amount of water use, water quality, and water

			level declines. A progress report on the work of the District regarding the groundwater availability will be written annually, as substantial additional data are developed. The progress report will be included in the annual report to the District Board of Directors.
B1	**Implement Strategies to Control and Prevent Waste of Groundwater:**	Apply a water use fee to the permitted use of groundwater in the District to encourage conservation-oriented use of the groundwater resources to eliminate or reduce waste.	Each year the District will apply a water use fee to the nonexempt permitted use of groundwater produced within the District pursuant to District rules. The amount of fees generated and the amount of water produced for each type of permitted use will be a part of the Annual Report presented to the District Board of Directors.
B2		Evaluate District rules annually to determine whether any amendments are necessary to decrease the amount of waste within the District.	The District will include a discussion of the annual evaluation of the District rules, and the determination of whether any amendments to the rules are necessary to prevent the waste of groundwater in the Annual Report of the District provided to the Board of Directors.
B3		Provide information to the public and the schools within the District on the wise use of water to eliminate and reduce wasteful practices.	The District will include a page on the Districts web-site devoted to the wise use of water and providing tips to help eliminate and reduce wasteful use of groundwater annually. The District will provide information to local school Districts including providing book covers to encourage wise use of water.
C1	**Implement Strategies to Address Conjunctive Surface Water Management Issues:**	Encourage the use of surface water supplies where available, to meet the needs of specific user groups within the District.	The District will participate in the Region G - Regional Water Planning process by attending at least one RWPG meeting annually and will encourage the development of surface water supplies where appropriate. This activity will be noted in the Annual Report presented to the District Board of Directors.

D1	**Implement Strategies to Address Natural Resource Issues which Impact the Use and Availability of groundwater, and which are Impacted by the Use of Groundwater**	Determine if there are any natural spring flows within the District that may be impacted by increased groundwater pumping.	Annually monitor water levels in at least 2 wells near natural spring flows, if found, for potential impact from groundwater production. Prepare an annual assessment statement and include in annual report to the District Board of Directors.
E1	**Implement Strategies to Address Drought Conditions:**	A District staff member will download at least one Palmer Drought Severity Index (PDSI) map monthly. The Palmer Drought Severity Index map will be used to monitor drought conditions and notify permit holders of severe drought conditions when the PDSI is at 3.0 or below (Severe Drought) for more than 2 consecutive months.	The District will make an assessment of drought conditions in the District and will prepare an annual briefing to the Board of Directors.
E2		Require 100 percent of water producers that are required by the state of Texas to have drought contingency plans, to submit those plans to the District when applying for a permit for well production from the District.	Review 100 percent of the drought contingency plans submitted as a result of permit requirements whenever a severe drought condition is reached as determined by the PDSI. The number of drought contingency plans required to be submitted by water producers to the District as part of the well permitting process and the number of drought contingency plans actually submitted to the District will be reports in the annual report to the District Board of Directors.
E3		Develop a District drought contingency plan. The target goal for developing the plan is June 2010. The drought contingency plan will be reviewed for effectiveness and needed updates once annually.	A report summarizing the findings of the annual review of the District drought contingency plan will be included in the annual report of the District Board of Directors.
F1	**Implement Strategies to Promote Water Conservation:**	Require 100 percent of the water producers requesting a permit for water production within the District to submit a water conservation plan unless one is already on file with the District at the time	Review 100 percent of the water conservation plans submitted as a result of permit requirements to ensure compliance with permit conditions. The number of water

		of the permit application, or agree to comply with the District's adopted Water Conservation guidelines.	conservation plans required to be submitted by water producer to the District as part of the well permitting process and the number of water conservation plans actually submitted to the District will be reported in the annual report to the District Board of Directors. If the a water producer chooses to agree to follow the District's adopted Water Conservation guidelines in lieu of submitting a Water Conservation Plan, then that number will be indicated in the annual report to the District Board of Directors.
F2		Develop a system for measurement and evaluation of groundwater supplies.	Water level monitoring wells will be identified for and the Brazos River Alluvium, the Yegua-Jackson, Sparta, Queen City, Carrizo, Calvert Bluff, Simsboro and Hooper aquifers at least 2 wells per aquifer will be monitored on an annual basis to track changes in static water levels.
F3		Assist in obtaining grant funds for the implementation of water conservation methods. Work with the appropriate state and federal agencies to facilitate bringing grant funds to various groups within the District boundaries to develop and implement water conservation methods. The District will meet with at least one state or federal agency annually in order to discuss bringing water conservation methods grant funds into the District.	The number of meetings held annually with at least one state or federal agency and the number of grants for water conservation methods applied for and obtained will be included in the annual report to the District Board of Directors.
G1	**Implement Strategies to Protect Water Quality:**	Develop baseline water quality data and a system for continued evaluation of groundwater quality.	Develop general understanding of water quality within aquifers in the District based on TCEQ and TWDB data. Develop response plan for potential water quality issues.

G2		Require all water producers that are required by the TCEQ to have well vulnerability studies prior to constructing a well, to provide evidence of the study to the District prior to construction of a well within the District.	Review all vulnerability studies submitted as result of permit requirements to help ensure water quality protection.
G3		Provide information to the public and the schools within the District on the importance of protecting water quality.	The District will include a page on the Districts web-site devoted to water quality issues and will provide information to water producers on wellhead protection programs.
H1	**Desired Future Conditions**	The desired future conditions of the groundwater within the District have not yet been established in accordance with Chapter 36.108 of the Texas Water Code. The District is actively participating in the joint planning process and the development of desired future conditions for the parts of the aquifers within the District. Therefore, this goal is not applicable to the District at this time.	

Appendix 1: Evergreen Underground Water Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A 1	**ADDRESSING THE EFFICIENT USE OF GROUNDWATER**	Each month the District will monitor the volume of water produced from nine irrigation wells and make note of the crops irrigated by the wells to promote water conservation in irrigation practices.	A table of the monthly meter readings from the nine irrigation wells and a discussion of the irrigation application rates for each type of crop irrigated by the nine wells monitored by the District will be included in the Annual Report on District Activities made to the Board of Directors each year.
A 2		Each month the District will monitor the volume of water produced 35 municipal and Rural water suppliers in the District.	A table showing the monthly production volumes reported to the District by the Municipal and Rural water suppliers in the District will be included in the Annual Report on District Activities made to the Board of Directors each year.
A 3		Each year the District will request production reports from the operators 800 agricultural irrigation wells in the District.	A copy of the request for production reports sent to the operators of agricultural irrigation wells will be included in the Annual Report on District Activities made to the Board of Directors each year. A table showing the production volumes reported to the District from the agricultural irrigation well operators in the District will be included in the Annual Report on District Activities made to the Board of Directors each year.
A 4		Each month the District will measure the water levels in 45 water wells and will measure the water level of an additional 126 wells on an annual basis each year.	A table showing the monthly and a table showing the annual water level measurements made by the District will be included in the Annual Report on District Activities made to the Board of Directors each year.
B 1	**ADDRESSING THE CONTROL AND PREVENTION OF THE WASTE OF GROUNDWATER**	Each year the District will conduct an on-site investigation of any reports of waste of groundwater within two working days of the time of the receipt of the report to the District.	A discussion of the waste of groundwater observed by the District each year, including the number of reports of the waste of groundwater received by the District and the District response to the report will be included in the Annual Report on District Activities made to the Board of Directors each year.
C 1	**ADDRESS THE CONJUNCTIVE USE**	Each year the District will use the Southern Carrizo-Wilcox Groundwater	A summary of the discussion(s) with the surface water management entities for status on surface water conditions will

	OF SURFACE AND GROUNDWATER	Availability Model to predict the potential effects of different groundwater pumping scenarios on both groundwater and surface water. In addition, each year the District will arrange to meet with the appropriate surface water management entities.	be relayed in a memorandum to the Board of Directors each year.
D 1	**Addressing natural resource issues which impact the use and availability of groundwater, and which are impacted by the use of groundwater**	Each year the District will sample at least 40 water wells in the District for chemical analysis of water quality.	A table giving the results of the chemical analyses of the water quality samples taken by the District each year will be included in the Annual Report on District Activities made to the Board of Directors. A discussion of whether any instances of groundwater contamination or issues of concern were noted in the water quality sample analyses will be included in the Annual Report on District Activities made to the Board of Directors.
E 1	**Addressing conservation**	Each year, the District will submit an article for publication regarding water conservation to one newspaper of general circulation in the District.	A copy of the article regarding water conservation submitted by the District for publication to a newspaper of general circulation in the District will be included in the Annual Report to the Board of Directors.
E 2		Each year, the District will include an informative flier on water conservation with at least one mail-out distributed in the normal course of business to groundwater use permit holders in the District.	The Annual Report to the Board of Directors will include a copy of the informative flier regarding water conservation that was distributed to groundwater use permit holders in the District and the number of fliers distributed.
F 1	**Addressing drought conditions**	Each month, the District will download at least one updated Palmer Drought Severity Index (PDSI) map posted on the National Weather Service - Climate Prediction Center website (http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml) and check for the periodic updates to the	Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the quarterly briefing in the District Annual Report to the Board of Directors.

		Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Department of Public Safety website (http://www.txdps.state.tx.us/dem/sitrepindex.html).	
G 1	**Addressing in a quantitative manner the desired future conditions**	The development of DFCs is also considered to be a goal for each GCD, in accordance with chapter 36 of the water code. Since coordination with GMA 13 and GMA 15 is ongoing but not yet complete, the district has determined this goal to not be applicable at this time.	

Appendix 1: Fayette Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Management Strategies to Protect and Enhance the Quantity of Useable Groundwater by Encouraging the Most Efficient Use**	***Establish a Water Level Monitoring Program***: Establish a water level monitoring network by first, identifying the wells to be monitored, and secondly, by annually measuring the depth to water in those wells; record all measurements and/or observations; enter all measurements into District's computer data base; file specific locations of wells in the District's filing system. Establish a baseline by using existing wells, preferably those for which the District already has some historical data, in all major and minor aquifers where wells are available.	Annually report to the Board of Directors on: ♦ the percent of water level monitoring wells for which measurements were recorded each year. ♦ the number of data records entered into District's data base each year. ♦ the number of wells in the water level measurement network each year. ♦ the number of wells added to the network, if required, each year.
A2		***Set and Enforce Maximum Allowable Production Limits***: Annually, the District will investigate all reports filed by District constituents, on forms provided by the District, regarding pumpage of groundwater in excess of the maximum production allowable under the District's rules. Investigation of each occurrence shall occur within 30 days of receiving the report. Each case will be remedied in accordance with District rules.	Annually report to the Board of Directors on: ♦ the number of reports investigated each year. ♦ the average amount of time taken to investigate reports each year. ♦ the number of incidences where violations occurred and violators were required to change operations to be in compliance with District rules each year.
A3		***Implement Well Permitting Process:*** Issue water well drilling permits for the drilling and completion of nonexempt water wells in the District within 30 days of application, or as soon thereafter as possible. Randomly inspect new well drilling sites to be assured that the District's completion and spacing standards are met. Send written notification to the well owner if the well	Annually report to the Board of Directors on: ♦ the number of permits issued each year in Fayette County. ♦ The number of on-site inspections performed of all wells for which District staff have reason to question compliance with District rules. ♦ the number of permits field checked each

		fails to meet standards within 30 days of inspection. The Board will vote on final approval of the permit at the next scheduled meeting and insure that well completion standards have been met.	year. ♦ the number of letters mailed to permit applicants requesting applicant to provide additional information or make changes to comply with District rules. ♦ the number of these letters which result in changes to comply with District rules and the number of cases still open at year-end.
B1	**Management Strategies to Protect and Enhance the Quantity and Quality of Useable Groundwater by Controlling and Preventing Contamination and Waste**	***Establish a Water Quality Monitoring Program***: The District staff will obtain water quality samples for analysis from wells within the monitoring network in order to track water quality changes in the District, and will resample a representative group of the wells sampled the previous year. The results of the tests will be published and entered in to the District's computer data base, and will be made available to the public.	Annually report to the Board of Directors on: ♦ the number of samples collected and analyzed each year ♦ the percent of previously sampled wells that were sampled in the current testing year. ♦ the number of analyses entered into District's computer data base each year.
B2		***Assure Proper Closing, Destruction, or Re-Equipping of Wells:*** The District staff will inspect all sites reported as being open or improperly covered in a timely manner and follow through to assure proper closing or repair.	Annually report to the Board of Directors on: ♦ the number of open, improperly covered, or deteriorated wells reported and inspected each year. ♦ the number of letters of notification of an open hole or deteriorated well mailed to well owners and/or operators each year. ♦ the number of wells the District required to be closed each year.
B3		***Encourage Plugging of Abandoned Wells:*** Field inspect each reported well abandoned or replaced, and assure proper closing under Water Well Drillers' Rules or that the well is re-equipped in accordance with District rules.	Annually report to the Board of Directors on: ♦ the number of reported wells abandoned or replaced each year. ♦ the number of reported wells destroyed and noted on the topographic map each year.

			♦ the number of reported wells re-equipped in accordance with the District's rules each year.
B4		***Control and Prevention of Water Waste:*** The District will investigate all identified wasteful practices within a reasonable number of working days of identification or complaint received, depending upon the magnitude of the wasteful practice.	Annually report to the Board of Directors on: ♦ the number of wasteful practices identified and the average number of days District personnel took to respond or investigate after identification or complaint received. ♦ the actions taken to resolve the identification or complaint received.
C1	**Management Strategies Under Drought Conditions**	***Curtailment of Groundwater Withdrawal:*** The annual amount of groundwater permitted by the District for withdrawal from the portion of the aquifers located within the District may be curtailed during periods of extreme drought in the recharge zones of the aquifers or because of other conditions that cause significant declines in groundwater surface elevations. Such curtailment may be triggered by the District's Board based on the groundwater elevation measured in the District's monitoring well(s).	The District shall monitor at least one well each year. Annually report to the Board of Directors the number of measurements obtained from the water level monitoring network. A summary report of the water level measurement results and an analysis of any situations that may require curtailment of groundwater withdrawal will be included in the report.
D1	**Promote Water Conservation**	***Emphasize Water Conservation Program:*** The District will develop and sponsor a water conservation education curriculum, available upon request for all schools within the District. The District will utilize the methodologies listed under Goal 5 in order to raise public awareness of the necessity and importance of a water conservation program.	Annually report to the Board of Directors on: ♦ the number of schools where water conservation education curriculums are presented each year. ♦ the number of water conservation articles presented to the public via the various methodologies outlined in Goal 5. 4.1.b. Promote and/or implement groundwater banking, recharge projects, rainwater harvesting and aquifer storage and recovery projects, where appropriate and cost-effective, to address areas with declining groundwater

			levels. Promotion of these projects may be accomplished through articles published in at least one of the District's quarterly newsletters.
E1	**Implementation of Public Relations and Educational Programs to Assist in Accomplishing Goals 1 through 4**	***Produce and Disseminate Quarterly Newsletter:*** Each year, 4 quarterly newsletters are produced for distribution to District constituents who request a free subscription, and other interested parties. Articles will strive to discuss methods to enhance and protect the quantity of usable quality ground water within the District.	Annually document number of newsletters published. Annually document the circulation of the newsletter during that year.
E2		***Provide News Releases to District Media:*** Each year, news releases discussing methods to enhance, conserve and protect the quantity of usable quality ground water are written and distributed to all print and electronic media within the District. This may also include radio public service announcements discussing methods to enhance, conserve and protect the groundwater.	Annually document number of news releases prepared and distributed to local and regional media detailing methods to enhance and protect the quantity and quality of usable ground water within the District.
E3		***Provide Public Information Boards at District Office:*** Each year, the District makes well information, technical reports, brochures, and other printed information available to the public in the District office	Annually document the number of publications made available to the public via the information boards. Annually document the number of the items printed and/or photocopied for public distribution.
E4		***Provide Public Information Displays at Fairs/Meetings:*** Each year, the District will place informative displays at regional fairs, farm shows, and professional meetings to address the protection and enhancement of usable quality groundwater in the District.	Annually document the number of the displays placed at regional fairs, farm shows, and professional meetings within the District's service area.
E5		***Offer Public Information Access via Internet:*** The District will make information about water	Annually document the number of "hits" the District website receives.

		and water conservation available to the public via its home page on the Internet. This information will be continuously updated.	
E6		***Provide Classroom Presentations:*** Upon request by instructors, District staff or Board members will assist area classrooms in presenting information about ground water quality, quantity, and water conservation to public school students. The District will make films and videos on a wide-range of water-related subjects available through the District office. Eventually, the District will develop a conservation education program and its accompanying curriculum in public and/or private schools within its service area.	Annually document the number of classroom presentations made or classroom and audio-visual materials provided. Annually document the names of participating schools and any feedback from students/teachers.
F1	**Desired Future Conditions of the Aquifers within the Boundaries of the Fayette County Groundwater Conservation District**	***Desired Future Conditions:*** The Fayette County Groundwater Conservation District actively participates in developing the desired future conditions for the aquifers within the District's boundaries and within the boundaries of Groundwater Management Areas (GMAs) 12 and 15. The desired future conditions for the aquifers within GMAs 12 and 15 have not yet been established. Consequently, there are no Managed Available Groundwater estimates available to include in this Management Plan at this time. Therefore, this goal is not applicable to the District at this time. Once the desired future conditions are established, an estimate of the managed available groundwater will be determined. The District will amend the management plan at that time.	

Appendix 1: Gonzales Underground Water Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A 1	**Providing the Most Efficient Use of Groundwater**	The District will register at least 20 exempt wells annually and will compile 100 percent of the data in a database within 30 working days.	Record the date and number of exempt wells registered annually, the percentage of exempt wells that were entered into the database, and the number of days before the data was entered.
A 2		The District will measure water levels in 20 wells three times a year in western Gonzales County within the same 60 day period and will compile 100 percent of the water level data into a database within 30 working days.	Record the date and number of wells measured, the percent of collected water level data that was entered into the database, and the number of days before the data was entered.
A 3		The District will measure water levels in 20 wells three times a year in eastern Gonzales County within the same 60 day period and will compile 100 percent of the water level data into a database within 30 working days.	Record the date and number of wells measured, the percent of collected water level data that was entered into the database, and the number of days before the data was entered.
A 4		The District will meet with the cities of Gonzales, Nixon, Smiley and Waelder, at least once a year, to inform the cities on water availability for economic development. The District will provide input on 100 percent of requests for information within 30 days of the request.	Record the date and number of meetings with each city. Record number of requests for information from each city, the number of responses to each city, and the number of days required to respond to each request for information.
A 5		The District will attend all Groundwater Management Area (GMA) 13 meetings annually. The District will provide input on 100 percent of the requests for information within 30 days.	Record the number of GMA meetings posted annually, the number of GMA 13 meetings attended annually, the number of requests for information made by GMA 13, the number of responses to requests for information by GMA 13, the number of days required for each response to GMA 13 requests

			for information.
A 6		The District will meet with the Gonzales Area Development Corporation (GADC), at least once a year, to inform the GADC on water availability for economic development. The District will provide input on 100 percent of requests for information within 30 days of the request.	Record the date and number of meetings with the GADC. Record the number of requests for information from the GADC, the number of responses given to the GADC, and the number of days required to respond to each request for information.
A 7		The District will gather water production data from at least 4 public water suppliers annually and will compile 100 percent of these figures into a database of groundwater usage within 30 working days of receipt in order to better project the needs of the District.	Record the number of public suppliers from which water production data was collected annually, the percent of collected water production data that was entered into the database, and the number of days before the data was entered.
A 8		The District will gather water production data from at least 10 irrigation wells and 5 livestock production facilities annually and will compile 100 percent of these figures into a database of groundwater usage within 30 working days of receipt in order to project future water use.	Record the number of irrigation wells and number livestock production facilities from which water production data was collected annually, the percent of collected water production data that was entered into the database, and the number of days before the data was entered.
B 1	**Controlling and Preventing Waste of Groundwater**	The District will collect samples for water quality data in 20 wells annually at locations throughout the District during the same period every year and will compile 100 percent of this data into a water quality database within 30 working days of receipt. In selecting wells the District will emphasize the wells at or near the zone of bad water or potential pollution sources based on best available data.	Record the date and number of wells sampled annually, the location of the wells sampled, the percent of water quality data that was entered into the database, and the number of days before the data was entered.
B 1		The District will monitor new facilities and activities on the recharge zones of the Carrizo/Wilcox, Queen City and Sparta aquifers on	Record the date and results of visual survey of all recharge zones for point source and non-point-source activities and facilities,

		at least an annual basis for point source and non-point-source pollution and compile 100 percent of this data into a pollution database within 30 working days from completion of the survey.	the percent of available information that was entered into the database, and the number of days before the data was entered.
B 3		The District will meet with the RRC at least once annually and coordinate its efforts with this agency in locating abandoned or deteriorated oil wells. The District will act on local complaints of abandoned or deteriorated oil wells within 30 days and compile 100 percent of the complaints and resulting District action in a database.	Record the date and number of meetings with the RRC annually. Record the date and number of complaints filed with the District annually, the time required to respond to each complaint, and the percentage of complaints entered into the database.
C 1	**Conjunctive Surface Water Management**	The District will meet with the staff of the Guadalupe Blanco River Authority, at least once a year, to share information updates about conjunctive use potential.	Record the date and number of meetings with GBRA representatives annually.
D 1	**Addressing Natural Resource Issues**	The District will meet with Natural Resources Conservation Service representatives to exchange information on wells and water levels at least once annually.	Record the date and number of meetings with the Natural Resources Conservation Service representatives annually.
D 2		The District will meet with the local RRC engineering technician at least once annually to review oil well permits and oil related activity that could endanger the aquifers.	Record the date and number of meetings with the RRC engineering technician annually.
E 1	**Addressing Drought Conditions**	The General Manager will access the National Weather Service – Climate Prediction Center website (http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml) monthly to determine the Palmer Drought Severity Index and will submit a report to the Board of Directors monthly. The District will, 100 percent of the time when under extreme drought conditions, as	Record the date and number of monthly reports made to the District Board of Directors. Record the date and number of times when the District was under extreme drought conditions and the number of times letters were sent to public water suppliers.

		defined by the Palmer Drought Severity Index, provide information to and coordinate with local water users and water managers regarding drought response activities.	
F 1	**Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, Brush Control**	The District will publish an information article in a publication of wide circulation in the District, at least annually, describing conservation measures that can be taken by water users within the District.	Record date and number of conservation articles published annually.
F 2		The District will publish an information article in a publication of wide circulation in the District, at least annually, describing recharge enhancement measures.	Record date and number of recharge enhancement articles published annually.
F 3		The District will publish an information article in a publication of wide circulation in the District, at least annually, describing rainwater harvesting measures that can be taken by water users within the District.	Record date and number of rain water harvesting articles published annually.
F 4		The District will publish an information article in a publication of wide circulation in the District, at least annually, describing current precipitation enhancement measures.	Record date and number of precipitation enhancement articles published annually.
F 5		The District will publish an information article in a publication of wide circulation in the District, at least annually, describing brush control measures that can be used by landowners within the District.	Record date and number of brush control articles published annually.
G 1	**Transportation of Water from the District**	The District will obtain monthly usage reports from individuals or entities that transport groundwater out of the District and will compile 100 percent of this data into a database within 30 working days of receipt.	Record the date and number of usage reports received from each individual or entity that transports groundwater out of the District, the percent of usage data that was entered into the database each month, and the number of days before the data was entered each month.

Appendix 1: Guadalupe County Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	***Efficient Use of Groundwater***	District will establish a Carrizo-Wilcox aquifer water-level observation well program with a minimum of nine (9) observation wells. The nine observation wells will be measured twice annually, in January and September.	Number of times the wells are measured per year. The water level database will be maintained by the District office.
B1	***Controlling & Preventing Waste of Groundwater***	The District will once a year provide public information on closure of abandoned water wells and uncontrolled flowing wells through articles in local newspapers or the District's newsletter and website.	Number of times a year the District will address the proper closure of abandoned water wells and uncontrolled flowing wells in the local newspaper or the District's newsletter and website.
C1	***Conjunctive Use of Surface and Groundwater***	Each year the District will confer at least on one occasion with the Guadalupe-Blanco River Authority (GBRA) on cooperative opportunities for conjunctive resource management.	Number of meetings per year with GBRA on conjunctive resource management. A memo to document the meeting will be on file in the District's office.
D1	***Address Natural Resource Issues that Impact the Use and Availability of Groundwater***	Each year the District will evaluate all proposed new wells prior to drilling. Information submitted by the applicant will be evaluated in order assess water level impacts within the District.	A monthly report to the Board will be made on the results of all water level impact studies and number of wells evaluated each month.
E1	***Develop a Management Strategy to Address Drought Conditions***	District representative will attend 1 meeting of the South Texas Weather Modification Assn. Annually	Number of reports made to the board each year on the PDSI.
F1	***Conservation of Groundwater***	The District once a year will provide public information on water conservation, recharge enhancement, rainwater harvesting, precipitation enhancement, and brush control through articles published in local newspapers or the District's newsletter and website.	Number of articles published in local newspapers or the District's newsletter and website each year. The articles will be on a five year rotating basis, so that at least one topic is covered each year.
G1	***Accurate Measurement of Rainfall***	The District has established a rainfall measurement system in the Guadalupe County Carrizo-Wilcox recharge area to obtain specific data on annual rainfall	The rainfall data will be saved and made public, and used in making management decisions. Data from the seven rainfall

		amounts.	gauges will be reported to the Board each month. Number of times the data is reported to the board each year.
H1	***Desired Future Conditions***	The desired future conditions of the groundwater within the District have not yet been established in accordance with Chapter 36.108 of the Texas Water Code. The District is actively participating in the joint planning process and the development of a desired future condition for the portion of the aquifer within the District and the GMA area	
I1	***Methodology***	The District Manager will prepare an annual report on the District performances in achieving the management goals. The annual report will be presented to the Board of Directors during the first quarter of the calendar year. The report will include the number of instances each management activity was engaged in during the year. The annual report will be maintained on file at the District Office and made available to the public upon adoption by the Board.	

Appendix 1: Live Oak Underground Water Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	***Collection and maintenance of data on water quantity and quality***	a. Take measurements of depth to water level below the land surface on strategic wells on annual basis b. Take water samples for chemical analysis on strategic on an annual basis c. Reports annually, water quality and quantity data	Measure depth of water on one well annually measure chemical analysis of four wells annually.
A2		Measurement of pollution sources as wells: a. Identify wells that are polluted and take appropriate action b. Identify sources of pollution and take appropriate action c. Provide information to the public about wells that are polluted and the sources of pollution	Investigate 100% of complaints of well pollution annually
B1	***Efficient use of groundwater***	School education: a. Provide speakers to address water topics b. Distribute water resource education packets for use in the classroom	Contact teacher or principle of one school annually
B2		Farm education: a. Provide speakers to address water topics at farm meetings b. Distribute water resource education packets to farm leaders and farmers	Contact one farm group annually
B3		Home Education: a. Provide speakers to address water topics b. Distribute water resource education packets to community people	Contact one civic group annually

C1	***Conjunctive water management issues***	4. Attend meeting with surface water entities in the district, to include but not limited to; conjunctive use, emergency response, drought contingency planning 5. Evaluate existing historical data and data derived from new monitoring programs to enhance understanding of aquifer/surface-water relationships 6. Evaluate the impact of surface-water usage on groundwater resources within the District as needed. Provide comments regarding surface-water rights requests for those requests effecting the groundwater resources of the district 7. Coordinate with other entities on regional planning efforts	District representative will attend 1 meeting with surface water entities annually. District representative will attend one meeting concerning regional water planning annually
D1	***Drought Conditions***	1. Participate in the South Texas Weather Modification Program 2. Evaluate the performance of the weather modification program	District representative will attend one meeting of the South Texas Weather Modification Assn. Annually
E1	***Conservation***	1. Provide Information to area residents about water conservation 2. Provide information to agriculture users about water conservation	Provide water conservation pamphlet to one district resident annually

Appendix 1: Lost Pines Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Provide the most efficient use of groundwater.**	To inform the residents of Bastrop and Lee counties about the efficient use of groundwater. Such information may be related to irrigation efficiency, transmission losses, xeriscaping, or any other related subject deemed appropriate by the LPGCD board. The information on efficient use of groundwater may be disseminated in conjunction with information on controlling and preventing waste of groundwater and/or water conservation.	At least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on efficient use of groundwater. The article on efficient use of groundwater may be published in conjunction with an article on controlling and preventing waste of groundwater and/or water conservation. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
B1	**Controlling and preventing waste of groundwater.**	To inform the residents of Bastrop and Lee counties about the waste of groundwater. Such information may be related to leaky or poorly functioning plumbing, transmission losses, xeriscaping, or any other related subject deemed appropriate by the LPGCD Board. The information on waste of groundwater may be disseminated in conjunction with information on efficient use of groundwater and/or water conservation.	At least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on waste of groundwater. The article on waste of groundwater may be published in conjunction with an article on efficient use of groundwater and/or water conservation. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
C1	**Address natural resource issues that impact the use and availability of ground- water and which are impacted by the use of groundwater.**	To provide information to the public about the status of groundwater use, availability, and water levels and a description of natural resource issues, e.g., mining, out of District transport of groundwater, protection of endangered species, or the spread of phreatophytic vegetation, that impact the use and availability of groundwater or which	At least annually, the General Manager shall prepare a report for the LPGCD board on the status of groundwater use, availability, and water levels within the District and a description of natural resource issues. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to

		are affected by the use and availability of groundwater.	the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. To the extent practical, the LPGCD also will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
D1	**Address drought conditions.**	Drought conditions are to be addressed on an ongoing basis by tracking rainfall records available from nearby weather stations as compared to hydrographs for LPGCD monitoring wells. At least once per month, the General Manager will update rainfall and water level records maintained by the LPGCD. Based on GAM modeling and an understanding of the outcrop areas of the principal aquifers – Simsboro, Carrizo, Queen City, and Sparta – in the LPGCD, recharge appears to be relatively constant under the current climatic regime and little affected by drought conditions. It is anticipated, though that drought conditions will result in increased pumpage and decreased natural discharge, thereby affecting water levels in the aquifers.	At least annually, the General Manager shall prepare a report for the LPGCD board on precipitation amounts as compared to water levels within the District and a description of apparent trends. Once this report is reviewed and accepted by the LPGCD Board, it shall be made available to the public at the District's office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. The summary may be published in conjunction with the publication of the summary of natural resource issues. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
E1	**Address conservation of groundwater resources.**	To educate the public within the District concerning water conservation. One or more articles related to advances in plumbing fixtures that conserve water and comparative cost savings of installing such fixtures, xeriscaping, or any other related subject deemed appropriate by the LPGCD board will be prepared for publication.	At least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on conservation of groundwater. The article on water conservation may be published in conjunction with an article on efficient use of groundwater and controlling and preventing waste of

			groundwater. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.
F1	**Public Education**	To inform the public about any and all matters related to the occurrence, distribution, behavior, and use of groundwater. To a degree, this management objective overlaps with all the required goals and management objectives described above; however, the focus of this management objective is on children.	At least once each year in each county of the LPGCD, the General Manager, assisted by other staff and consultants, as necessary, will present a program dealing with the above matters at a public school. The particular timing and age-level of such a program will be coordinated with the local school systems.
G1	**Drilling Permits**	To review and evaluate all applications for drilling permits for exempt and nonexempt wells, not otherwise excluded and not existing prior to the date the District rules became effective.	At least once per year, notify all known water-well drillers operating in the District of the requirement for the prospective non-excluded well owner to obtain a drilling permit and the requirement that the driller insure that no new non-excluded well is drilled in the District without a permit. In addition, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article related to the requirement to obtain drilling permits for non-excluded wells. Such an article may be combined with articles on other subjects published by the District.
H1	**Register all wells within the LPGCD boundaries**	To register all exempt wells drilled since the LPGCD Rules became effective and attempt to register all pre-existing exempt wells.	Registration of newly drilled exempt wells is accomplished by refunding the drilling permit fee upon submittal of completion reports, well logs, and well registration materials. The number of newly drilled wells will be documented in the annual report by the General Manager and in the LPGCD's database. Registration of preexisting exempt

			wells is a more difficult issue, because registration of such wells is voluntary. Nevertheless, at least annually, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop and Lee counties an article on registration of exempt wells. The article on registration of exempt wells may be published in conjunction with an article on controlling and preventing waste of groundwater, water use efficiency, and/or water conservation. In addition, the General Manager or his designated representative will note the existence of unregistered wells, spot the location of such wells on a map as best possible, and visit with the landowner, if possible, to encourage registration of the wells. Documentation of attempts to encourage registration of wells that were in existence prior to the effective date of the LPGCD Rules will be though notes made and kept on file at the District offices.
I1	**Operating Permits**	To review and evaluate all applications for operating permits for nonexempt wells, not otherwise excluded, within the LPGCD. In addition, the LPGCD will notify operating permit holders of the need to renew their operating permit at least sixty days prior to expiration.	At least once per year, notify all known water-well drillers and pump installers operating in the District of the requirement for the owner of a nonexempt well, not otherwise excluded, to obtain an operating permit and the requirement that the driller and/or pump installer insure that no nonexempt well, not otherwise excluded, is placed into service within the District without an operating permit. In addition, the General Manager shall cause to be published in one or more newspapers of general circulation in Bastrop

			and Lee counties an article related to the requirement to obtain operating permits for nonexempt wells, not otherwise excluded. Such an article may be combined with articles on other subjects published by the District.
J1	**Transfer Permits**	To review and evaluate all applications for transfer permits. Notify holders of transfer permits of the need to renew their transfer permit prior to expiration.	To complete administrative review of all permit applications and schedule for LPGCD consideration within sixty days of receipt.
K1	**Timely Processing of All Drilling Permits, Operating Permits and Transfer Permits**	To complete administrative review of all permit applications and schedule for LPGCD consideration within sixty days of receipt	On an annual basis track the dates on which applications are received, the dates on which administrative review is completed, and the date on which the board considered applications. For any permit application taking longer than sixty days to process, record a brief comment in the files as to the reason for the delay. Provide an annual summary of the permit application tracking to the LPGCD board. Upon review and approval of the report, make it available for public review at the District office.
L1	**Maintain a Database**	To maintain a database of each drilling permit and registration of an exempt well, each drilling and operating permit for a non- exempt well, and each transfer permit. The LPGCD's intent is to be able to generate plots of the locations of each registered and permitted well, available completion information for the well, and to compute distances between the wells based on the most detailed coordinates in the data base.	The database will be constantly changing and evolving, as new data are acquired and entered into the database and as new or updated software and hardware become available. The overall performance standard is; Does it do what the LPGCD needs done? The measurable standard is an annual report prepared by the General Manager to the Board describing changes made to the structure and the content of the database and containing recommendations for additional changes and improvements. Once reviewed and accepted by the Board it shall be made available to the

			public at the LPGCD’s office. In addition, the General Manager will cause a summary of the annual report to be published in one or more newspapers of general circulation in Bastrop and Lee counties. The summary may be published in conjunction with the publication of the summary of natural resource issues and drought conditions. In addition, to the extent practical, the LPGCD will sponsor or co-sponsor workshops open to the public that address this issue and similar issues.

Appendix 1: McMullen Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Providing the most efficient use of groundwater**	Each year the District will provide education materials concerning the efficient use of groundwater.	Provide educational materials to at least one school annually.
B1	**Controlling and preventing waste of groundwater**	Measure water levels from the land surface on strategic wells on an annual basis and report waste to the District Board.	(a) Report to the District Board annually the number of water level measurements. (b) The District will investigate all reports of waste of groundwater within five working days. The number of reports of waste as well as the investigation findings will be reported to the District Board in the annual report.
C1	**Natural Resource Issues**	The District will cooperate with other interested parties and appropriate agencies to develop additional information on aquifer recharge.	A representative of the District will attend a meeting annually with interested parties and appropriate agencies.
D1	**Drought Conditions**	The District will monitor the Palmer Drought Severity Index (PDSI).	A report of the Palmer Drought Severity Index will be presented to the District board on an annual basis.
E1	**Conservation**	Each year the District will make available educational material to the public promoting conservation methods and concepts. The District will make at least one educational brochure available per year through service organizations, and on a continuing basis at the District office.	
F1	**Precipitation Enhancement**	The District will participate in the South Texas Weather Modification Program.	A district representative will attend a meeting of the South Texas Weather Modification Assn. annually.

Appendix 1: Medina County Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**To Control and Prevent the Waste of Groundwater**	Each year the District will provide at least one public service announcement concerning waste, which is prohibited under the District rule, to the newspapers and to the general public on at least six occasions.	(a) The District will furnish at least six newspaper articles and/or public service announcements on an annual basis. (b) The District will investigate all written reports of waste of groundwater within 24 hours.
B1	**Addressing Natural Resource Issues that Impact the Use and Availability of Groundwater and Are Impacted by the Use of Groundwater**	Each year the District will work with various interest groups and appropriate agencies, such as the San Antonio River Authority, to provide information on aquifer storage and recovery projects and will require permits for all aquifer storage and recovery projects.	(a) The District will require permits for all aquifer and storage projects within the District and report the number of applications submitted annually. (b) The District will provide one article to a newspaper of general circulation in the District regarding the San Antonio River Authority's Aquifer Storage and Recovery project.
B2		Each year the District will require issuance of a well construction permit prior to drilling all new wells.	Each year all well construction permits in compliance with the District rules will be issued within **15** working days. Well construction permits not in compliance will be considered at the next regular board meeting.
C1	**Providing for the Efficient Use of Groundwater within the District**	Each year, the District will provide informative speakers to schools and civic groups to raise public awareness of practices which ensure the efficient use of groundwater.	The District will make at least 2 public speaking appearances to promote the efficient use groundwater per year.
D1	**Addressing Conjunctive Surface Water Management Issues**	The District will attend 50% 0f the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface water management entities within the District.	The District will attend at least 50% of the regular meetings of the Region L Regional Water Planning Group and coordinate activities when requested by surface water management entities within the District. The District will report these activities annual in the District

			annual report to the Board of Directors.
E1	**Addressing Conservation**	The District will annually submit an article regarding water conservation for publication to at least one newspaper of general circulation in Medina County.	A copy of the article submitted by the District for publication to a newspaper of general circulation in Medina County regarding water conservation will be included in the Annual Report to the Board of Directors.
F1	**Addressing Drought Conditions**	Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Water Information Network Website www.txwin.net.	Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the quarterly briefing in the District Annual Report to the Board of Directors.

Appendix 1: Mid-East Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A 1	**Providing the Most Efficient Use of Groundwater**	The District will at least once annually conduct at least one program to provide public information and education to promote the efficient use of groundwater. Such programs may include newspaper publication, open meetings, handout brochures and mail-out brochures.	The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
B 1	**Controlling and Preventing the Waste of Groundwater.**	The District will at least annually conduct at least one program to provide public information and education of the prevention of the waste of groundwater. Such programs may include newspaper publications, open meetings, handout brochures and mail-out brochures.	The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
C 1	**Addressing Drought Conditions**	The District shall call for the most efficient use of groundwater by all users in the District to maintain sufficient groundwater aquifer resources during periods of drought and for future resources by preventing waste and by regulation of users, if necessary to prevent depletion of the aquifers. The District will review the Texas Palmer Drought Index and the Texas Drought Preparedness Report, and monitor the District's production figures annually.	The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.
D 1	**Conservation**	The District will at least annually conduct a least one program to provide public information and education to promote the conservation of water. Such programs may include newspaper publication, open meetings, handout brochures and mail-out brochures.	The District will document the number of times this activity was completed in the annual report to the Board of Directors and maintain a record of the above for subsequent audits.

Appendix 1: Neches & Trinity Valleys Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Providing for the Most Efficient Use of Groundwater**	Each year the District will require the registration of all new wells drilled within the District's jurisdiction and the District will require a permit for drilling all nonexempt wells.	At all regularly scheduled Board meetings, the General Manager reports to the Board of Directors on the number of new wells registered with the District and the number of permit applications received and approved for new wells within the District.
A2		Each year the District will provide informative speakers to schools, civic groups, social clubs, and other organizations for presentations to inform a minimum of 50 citizens on the activities and programs, the geology and hydrology of groundwater, and the principles of water conservation relating to the best management practices for the efficient use of groundwater.	The number of citizens in attendance annually at District presentations concerning the principals of water conservation relating to the best practices for the efficient use of groundwater.
A3		Each year, on four or more occasions, the District will disseminate educational information relating to the conservation practices for the efficient use of water resources.	Number of occasions, annually, the District disseminated educational information relating to the conservation practices for the efficient use of water resources.
B1	**Controlling and Preventing Waste of Groundwater**	100 percent of complete permit applications will be reviewed by the District within 90 days to ensure all procedures are followed to control and prevent the waste of groundwater. The District will report annually to the Board the number of permit application requests that met the District's rules and requirements for approval within 90 days of the receipt of the completed application.	1. Number of permits issued each year by the District for new nonexempt wells in compliance with District rules and procedures. 2. Percent of completed applications reviewed within 90 days of receipt of application.
B2		The District will maintain procedures for the receipt of well permit applications. Annual reports will be made to the Board on the number and type of well permits approved. If no applications are received by	The procedures for the receipt of well permit applications will be maintained in District files. An annual report will be made by the District to the Board on the number and type of well

		the District during a reporting period, this will annually be reported to the Board.	permits approved. If no well permit applications are filed and completed during the year, this will be reported to the Board.
C1	**Addressing Drought Conditions**	The Board has adopted a contingency plan to cope with the effects of water supply shortages due to climatic or other conditions. The plan is reviewed at least annually by the Board. In developing the contingency plan, the District considered the economic effects of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydro-geologic conditions of the aquifer and the appropriate conditions under which to implement the contingency plan. During extreme drought conditions within the District as measured by the Palmer Drought Index, all efforts will be made to see that all municipalities and public water supply companies follow their drought contingency plans. During extreme drought conditions that materially affects the aquifer levels, the District staff will closely monitor the aquifer levels through establishment of a District monitoring plan of static levels in selected monitoring wells or by obtaining well water levels from selected water supply companies who have such data available to ensure that adequate quantities of water are available to the District and will coordinate with the Region C and I Water Planning Groups.	A drought contingency plan developed by the District and approved by the Board will be reviewed by the Board every year and revised as necessary. During extreme drought conditions within the District, efforts will be made through contact by District staff to see that municipalities and public water supply companies follow their drought contingency plans.
D1	**Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control**	Each year, on four or more occasions, the District will disseminate educational information relating to the conservation practices for the efficient use of water resources.	Number of occasions, annually, the District disseminated educational information relating to the conservation practices for the efficient use of water resources.

Appendix 1: Panola County Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Providing the Most Efficient Use of Groundwater**	Beginning in 2008, the District will require the registration of all wells within the District's boundaries each year.	The number of new and existing wells registered with the District will be provided in the Annual Report for each fiscal year.
A2		The District will require permits for all nonexempt groundwater use within District boundaries pursuant to the District Rules each year.	The District will accept and process applications for permits for all nonexempt groundwater use pursuant to the permitting process described in the District Rules each year. The Annual Report for each fiscal year will contain a summary of the number of applications for the permitted use of groundwater and the number and type of permits issued.
B1	**Preventing Waste of Groundwater**	The District will provide information on an annual basis to the public on the elimination, reduction, and prevention of the waste of groundwater and information focused on water quality protection each year. The District will use one of the following methods to provide information to the public at least once during each fiscal year: a. distribute literature packets or brochures within Panola County and the surrounding areas; b. provide public presentations on groundwater and water issues, including waste prevention; c. sponsor an educational program/course; d. provide information on the District's website; e. submit newspaper articles to local paper for publication; f. present displays at local public events; or g. become involved in the distribution of information, such as brochures, in schools in Panola County.	The District's Annual Report will include a summary of the District's efforts during the fiscal year to provide educational information to the public on the elimination, reduction and prevention of the waste of groundwater.

B2		The District will make an annual evaluation of its Rules to determine whether any amendments are necessary to facilitate prevention of waste of the groundwater within District boundaries.	The District's Annual Report will include a summary of the evaluation of the District Rules and will provide a recommendation as to whether any amendments to the Rules are needed to facilitate prevention of waste.
C1	**Addressing Conjunctive Surface Water Management Issues**	The District will participate in the regional planning process by sending a representative to attend at least one meeting of the East Texas Regional Water Planning Group (Region I) each fiscal year.	The attendance at any Region I meeting by a representative of the District will be included in the District's Annual Report and will indicate the dates of attendance.
D1	**Addressing Natural Resource Issues**	The District will monitor water-levels within District boundaries on an annual basis by measuring the water level of at least 5 wells.	The District's Annual Report will include a description of the number of wells measured and the monitoring results of the measured well for each year.
E1	**Addressing Drought Conditions**	The District will download at least one updated Palmer Drought Severity Index ("PDSI") map each month and will check for the regular updates to the Drought Preparedness Council Situation Report ("Situation Report") posted on the following website: http://www.txdps.state.tx.us/dem/sitrepindex.html.	The District will include the 12 monthly downloaded PDSI maps and Situation Reports in the Annual Report for each fiscal year.
F1	**Addressing Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, or Brush Control, Where Appropriate and Cost Effective**	The District will promote conservation at least once during each fiscal year by one of the following methods: a. distribute literature packets or brochures; b. conduct public presentations; c. sponsor an educational program/curriculum; d. provide information on the District's website; e. submit newspaper articles to local newspaper for publication; f. present displays at local public events; g. annually conduct a local contest on water conservation; or h. conduct classroom presentations on conservation.	The District's Annual Report will provide a summary of the District efforts and a copy of any information provided by the District to the public during the previous fiscal year to promote conservation.

F2		The District will provide information relating to recharge enhancement on the District website at least one time each fiscal year.	Each year, the District's Annual Report will include a copy of the information that has been provided on the District website relating to recharge enhancement.
F3		The District will advocate rainwater harvesting each year by providing updated information about rainwater harvesting on the District website at least once each fiscal year.	The Annual Report for the District will include a copy of the information on rainwater harvesting which has been provided on the District website within the previous fiscal year.

Appendix 1: Pineywoods Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Groundwater Quality Protection Measures**	Maintain a constant awareness of activities which may be or become a threat to the quality of groundwater and be prepared to adopt rules, resolutions, orders and/or directives to address the issue.	Annually review the Minutes of Board Meetings to determine if all water quality issues considered by the Board were addressed. This review will be included in the annual report to the Board of Directors.
B1	**Waste**	Determine waste as defined in the Rules of the District and the Water Code and respond to reports of waste within 4 days.	Annually review all reported sources of waste, and if corrective actions were taken when warranted. A summary that includes the number of reports of waste and the number of days the District took to respond to each report of waste will be included in the annual report to the District Board of Directors.
C1	**Providing for the Most Efficient Use of Groundwater**	Each year, beginning in FY2002, the District will require the registration of all new wells drilled within the District's jurisdiction and the District will require a permit for all nonexempt wells, new and existing.	Each month at regularly scheduled meetings the General Manager reports to the District Board of Directors the number of new and existing wells registered with the District and the number of applications received for new wells within the District.
D1	**Drought Conditions**	The District shall call for the most efficient use of groundwater by all users in the District to maintain sufficient groundwater aquifer resources during periods of drought and for future resources by preventing waste and by regulation of users, if necessary, to prevent depletion of the aquifers. To work closely with groundwater users and provide assistance where it is possible to control customer usage as it is outlined in their Drought Contingency Plans.	Periodically review the Texas Palmer Drought Index and the Texas Drought Preparedness Report, and monitor production figures quarterly. A summary of any drought conditions will be given to the Board of Directors in the annual report along with any recommendations and make necessary changes, as needed.

E1	**Water Conservation Programs**	Maintain a constant review of all projects to ensure that they are using the best available technology. Publish a newsletter at least quarterly and include some educational information to promote conservation. Provide public education at any opportunity to promote conservation.	Annually review all projects to determine if they are using best available technology and if educational materials are benefiting the conservation program. This review will be included in the annual report to the Board of Directors.
F1	**Information**	Publish current information and or reports in the newsletter and other local news media as they become available.	Annually verify that each edition of the newsletter contains current information and or reports about water conservation and waste prevention. This review will be included in the annual report to the Board of Directors.
G1	**Education**	Inform people about the benefits, goals, programs, duties and responsibilities of the District.	Annually review programs the District has provided or helped to provide which inform people about the goals, programs, duties and responsibilities of the District**,** and determine if more is needed and can be done to promote the District and its benefits. This review will be included in the annual report to the Board of Directors.
G2		Inform the cities and rural areas of the District about the benefits of providing conservation education to the schools through the newsletters and other correspondence.	Periodically review school education programs that cities and rural areas have begun. This review will be included in the annual report to the Board of Directors.

Appendix 1: Plum Creek Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Efficient Use of Groundwater**	1. The District will establish the PCCD Aquifer Water Level Observation Well Program with at least 6 observation wells located according to management zones within the District, and measure those wells at least once quarterly. 2. The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program. 3. The District will use its best efforts to obtain information on water being produced from areas in Caldwell County that are outside the boundaries of the District. 4. The District will use its best efforts to obtain information on groundwater being produced from groundwater aquifers in counties surrounding the District as well as in areas close to the District that are not in groundwater districts to develop information about impacts of such production on groundwater in the District.	1. Establish the PCCD Aquifer Water Level Observation Well Program and its criteria, and begin quarterly measurements of at least 6 of the observation wells within one year following the adoption and certification of this plan. 2. Water levels at these observation wells will be measured a minimum of once quarterly. 3. PCCD representatives will circulate at least one publication and notice speaking appearances each year. 4. PCCD representatives will attend and participate in GMA meetings appropriate to the District's regulatory authority. 5. PCCD will periodically seek information from nearby groundwater districts not in the same GMA but drawing from the same aquifers regulated by the District.

B1	**Controlling and Preventing Waste of Groundwater**	The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure.	A number of publications and speaking appearances by the District each year.
C1	**Control and Prevent Subsidence**	Subsidence is unlikely to occur in the Plum Creek Conservation District. The District historically has not experienced any subsidence. Accordingly, the District's Plan does not contain any "Management Objective" or related "Performance Standards" to address the issue of non-existent subsidence. Alluvium is poorly consolidated, but generally too thin to experience measurable (if any) subsidence due to groundwater withdrawals.	
D1	**Conjunctive Use of Surface and Groundwater**	Each year the District will confer at least once with the Guadalupe-Blanco River Authority (GBRA) and other local political subdivisions and water and wastewater utilities on cooperative opportunities for conjunctive resource management.	1. The number of conferences with the GBRA, other political subdivisions and water and wastewater utilities, on conjunctive resource management each year. 2. The District will continue to monitor progress of the Plum Creek Watershed Project.
E1	**Develop a Management Strategy to Address Drought Conditions**	The District will develop and adopt a Drought Management Strategy Plan for groundwater under the authority of the District within five years of the adoption and certification of this plan, and thereafter review it annually, and revise it if necessary. The plan will be implemented when specified conditions require. After its adoption, the Board will periodically review and update the Plan based upon the availability of additional scientific	1. Development and adoption of a Drought Management Strategy Plan within five years of the adoption and certification of this plan. 2. Review all of the conditions and requirements specified in the Drought Management Strategy Plan that would trigger implementation on an annual basis. 3. Determine the necessity of a program to monitor rainfall for timing of effects on groundwater

		data collected by or presented to the Board.	availability during droughts.
F1	**Address Natural Resource Issues that Impact the Use and Availability of Groundwater and Which are Impacted by the Use of Groundwater**	1. Each year the District will confer at least once with a representative of the Texas Railroad Commission (RRC) on the impact of oil and gas production or waste and disposal operations associated with oil and gas production on groundwater availability and quality, as well as the impact of groundwater production on the production of oil and gas in the District. 2. Also, during each year the District will evaluate all permit applications for new production injection or disposal wells permitted by the RRC, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District.	1. The number of conferences with a representative of the Texas RRC each year; 2. The addition of available RRC well data to the District's database; 3. Monthly reports to the PCCD Board of Directors on the number of new well permit applications filed, and the possible impacts of those new wells on the groundwater resources in the District; and 4. Annual reports to the Board about consumption and use of groundwater for commercial purposes, including irrigation uses and enhanced oil and gas production when information is available.
G1	**Conservation of Groundwater Including Rainwater Harvesting, Brush Control, and/or Recharge Enhancement of Groundwater Resources in the District**	1. The District will provide educational leadership to citizens within the District concerning this subject. The educational efforts will be through at least one printed publication, such as a brochure produced either by the District or produced by others and made available by the District. Each of the following topics will be addressed in the publications: A. Conservation B. Rainwater Harvesting C. Brush Control 2. The District will encourage and support projects and programs to conserve and/or preserve groundwater, and/or enhance	1. A number of publications by the District each year. 2. The District staff will complete its investigation of the feasibility of using Brush Control to enhance recharge within the District and report its findings and recommendations to the Board. **3.** The staff will consider recommendations from and report to the Board on any recommendations of the Plum Creek Watershed Project upon completion of the Project.

		groundwater recharge by annually. 3. The District will evaluate the feasibility using Brush Control to enhance recharge within the District. 4. The District will continue to sponsor and monitor development of the Plum Creek Watershed Project.	
H1	**Mitigation & Desired Future Conditions of Groundwater Resources**	1. Once the Desired Future Conditions of Groundwater Resources in the District have been established, the staff will then assess the need and benefit of adopting a mitigation plan for the District on an annual basis, with the first study to be completed within one year of the adoption and certification of this plan. Upon determining the need for a mitigation plan, the District will prepare a draft plan, seek public comment, hold appropriate hearings and adopt a plan for mitigation within one year of the assessment that finds a need for a mitigation plan. The plan will be reviewed on an annual basis thereafter. Possible practices for mitigation within the District would include producers funding projects that are included in a natural or artificial recharge plan adopted under the following paragraph 11, establishing fees to fund infrastructure in areas of the District in which groundwater was but is no longer readily available, and producers contracting to provide water to such areas at or near their cost.	Review of groundwater resources in the District in comparison with the Desired Future Conditions of those resources once they are established and preparation of a recommendation for any mitigation actions within six (6) months following establishment of desired future conditions.
I1	**Precipitation Enhancement**	The District will assess the need and opportunity for precipitation enhancement in the District at	Annual evaluation and reports to the Board about the status of ongoing studies of the possibility

		least once every five years, with the first study to be completed within five years of the adoption and certification of this plan. Upon determining the need for precipitation enhancement, the District will adopt a plan for precipitation enhancement within two years of the assessment for the need for precipitation enhancement. The District will review that plan on an annual basis. Possible practices for precipitation enhancement in the District would be cloud seeding.	of precipitation enhancement actions within the District to increase groundwater resources available in the District.
J1	**Natural or Artificial Recharge Enhancement of Groundwater Within the District**	The District will gather data to further the scientific understanding of recharge of the groundwater supplies within the District. The District will then assess the need and opportunity for recharge enhancement in the District at least once every five years, with the first study to be completed within five years of the adoption and certification of this plan. Upon determining the need for recharge the District will adopt a plan for natural and/or artificial recharge within two years of the assessment for the need of that recharge. The plan will be reviewed on an annual basis. Possible practices for recharge in the District would be Brush Management or construction of surface ponds in key recharge areas.	1. Develop data relating to recharge, purifying and groundwater levels in the District. 2. Annually report to the Board on recharge data.

Appendix 1: Post Oak Savannah Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Efficient Use of Groundwater**	The District will establish the POSGCD Aquifer Water Level Observation Well Program with at least 10 observation wells located according to management zones within the District, and measure those wells at least once annually.	Establish the POSGCD Aquifer Water Level Observation Well Program and its criteria, and begin measurements of at least 10 of the observation wells within one year following the adoption and certification of this plan. Number of observation wells measured annually by the District. Water levels at these observation wells will be measured a minimum of once annually.
A2		The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program.	The number of publications and speaking appearances by the District each year under the District's Public Education Program.
B1	**Controlling and Preventing Waste of Groundwater**	The District will provide educational leadership to citizens within the District concerning this subject. The activity will be accomplished annually through at least one printed publication, such as a brochure, and public speaking at service organizations and public schools as provided for in the District's Public Education Program. The District will also offer at least one grant, during years when the District's revenues remain at a level sufficient to fund the program, to sponsor the attendance of students at summer camps/seminars that place emphasis on the conservation of water resources.	The number of publications and speaking appearances by the District each year, and the number of grants offered and students actually accepting and attending an educational summer camp or seminar.
C1	**Conservation of Groundwater Including**	The District will provide educational leadership to citizens within the District concerning this	The number of publications and speaking appearances by the District each year under the

	Rainwater Harvesting, Precipitation Enhancement, Brush Control, and/or Recharge Enhancement of Groundwater Resources in the District	subject. The educational efforts will be through at least one printed publication, such as a brochure, and at least one public speaking program at a service organization and/or public school as provided for in the District's Public Education Program. Each of the following topics will be addressed in that program: A. Conservation B. Rainwater Harvesting C. Brush Control	District's Public Education Program.
C2		The District will offer to sponsor the attendance of at least one student at summer camps/seminars that place emphasis on the conservation of groundwater, groundwater recharge enhancement, or precipitation enhancement of water resources. The District will encourage and support projects and programs to conserve and/or preserve groundwater, and/or enhance groundwater recharge by annually funding the District's Groundwater Conservation and Enhancement Grant Program, during years when the District's revenues remain at a level sufficient to fund the program. The objective of this program is to obtain the active participation and cooperation of local water utilities in the funding and successful completion of programs and projects that will result in the conservation of groundwater and the protection or enhancement of the aquifers in the District. The qualifying water conservation projects and programs will include, as appropriate, projects that: result in the conservation of groundwater, reduce	The number of students sponsored to attend a summer camp/seminar emphasizing the conservation of water. Annual funding, when applicable, for the District's Groundwater Conservation and Enhancement Grant Program, and the number of projects and programs reviewed, approved, and funded under that program.

		the loss or waste of groundwater, recharge enhancement, rainwater harvesting, precipitation enhancement, brush control, or any combination thereof. The District's objective is to benefit the existing and future users of groundwater in the District by providing for the more efficient use of water, increasing recharge to aquifers, reducing waste, limiting groundwater level declines, and maintaining or increasing the amount of groundwater available, by awarding at least one grant under the program in each county annually.	
C3		The District will implement the POSGCD Well Closure Program. The objective of the well closure program is to obtain the closure and plugging of derelict and abandoned wells in a manner that is consistent with state law, for the protection of the aquifers, the environment, and the public safety. The District will conduct a program to identify, inspect, categorize and cause abandoned and derelict water, oil and gas wells to be closed and plugged, by annually funding the program or segments or phases of the program appropriate to be funded in such fiscal year. The District will fund the closure of at least one abandoned well during years when the District's revenues remain at a level sufficient to fund the program.	Annual funding, when applicable, for the District's Well Closure Program, and the number of wells closed and plugged as a result of the Well Closure Program.
E1	**Conjunctive Use of Surface and Groundwater**	Each year the District will confer at least once with the Brazos River Authority (BRA) on cooperative opportunities for conjunctive resource management.	The number of conferences with the BRA on conjunctive resource management each year.

F1	**Develop a Management Strategy to Address Drought Conditions**	The District will develop and adopt a Drought Management Strategy Plan within five years of the adoption and certification of this plan, review it annually, and revise it if necessary. The plan will be implemented when specified conditions require.	Development and adoption of a Drought Management Strategy Plan within five years of the adoption and certification of this plan.
G1	**Address Natural Resource Issues That Impact the Use and Availability of Groundwater and Which are Impacted by the Use of Groundwater**	Each year the District will confer at least once with a representative of the RRC (RRC) on the impact of oil and gas production on groundwater availability, as well as the impact of groundwater production on the production of oil and gas in the District.	The number of conferences with a representative of the Texas RRC each year.
G2		Also, during each year the District will evaluate all permit applications for new wells, if any are filed, and the information submitted by the applicants on those wells prior to drilling, in order to assess the impact of these wells on the groundwater resources in the District.	Monthly reports to the POSGCD Board of Directors on the number of new well permit applications filed, and the possible impacts of those new wells on the groundwater resources in the District.
H1	**Mitigation**	The District will assess the need and benefit of adopting a mitigation plan for the District on an annual basis, with the first study to be completed within one year of the adoption and certification of this plan. Upon determining the need for a mitigation plan, the District will prepare a draft plan, seek public comment, hold appropriate hearings and adopt a plan for mitigation within one year of the assessment that finds a need for a mitigation plan. The plan will be reviewed on an annual basis thereafter. Possible practices for mitigation within the District would include producers funding projects that are included in a natural or artificial	

		recharge plan adopted under the following paragraph 11, establishing fees to fund infrastructure in areas of the District in which groundwater was but is no longer readily available, and producers contracting to provide water to such areas at or near their cost.	
I1	**Precipitation Enhancement**	The District will assess the need and opportunity for precipitation enhancement in the District at least once every five years, with the first study to be completed within five years of the adoption and certification of this plan. Upon determining the need for precipitation enhancement, the District will adopt a plan for precipitation enhancement within two years of the assessment for the need for precipitation enhancement. The District will review that plan on an annual basis. Possible practices for precipitation enhancement in the District would be cloud seeding.	
J1	**Natural or Artificial Recharge Enhancement of Groundwater Within the District**	The District will assess the need and opportunity for recharge enhancement in the District at least once every five years, with the first study to be completed within five years of the adoption and certification of this plan. Upon determining the need for recharge the District will adopt a plan for natural and/or artificial recharge within two years of the assessment for the need of that recharge. The plan will be reviewed on an annual basis. Possible practices for recharge in the District would be Brush Management or construction of surface ponds in key recharge areas.	

Appendix 1: Rusk County Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Efficient Use of Groundwater**	The District will require all new exempt or non-exempt wells that are constructed within the boundaries of the District to be registered with the District in accordance with the District rules.	Issue permits within 20 days of application. Each Year the number of exempt and nonexempt wells registered by the District for the year and a list of any permits that were not issued within 20 days with the cause and corrective action taken, will be incorporated into the Annual Report submitted to the Board of Directors of the District.
A2		Establish a Groundwater Database for all water wells in the District. The database shall include information relating to well location, production volume, and other information deemed necessary by the District to enable effective monitoring of groundwater in Rusk County.	Document all new and existing wells by 2010. Each Year the number of new and existing groundwater wells added to the database will be presented in the Annual Report submitted to the Board of Directors of the District.
A3		Provide Public Education Opportunities.	Disseminate educational information regarding the hydro-geologic cycle and status of aquifers through at least two articles in Rusk County newspapers, posting on the District internet website, and as needed responses to public inquiries. The Annual Report to the Board of Directors of the District will reflect educational achievements through newspaper articles, the number of hits on the Districts website, and the number of responses to public inquiries annually.
B1	**Minimize Waste of Groundwater**	Public Education	The District will provide educational leadership to the citizens of the District concerning this subject through at least one printed publication per year, public speaking at least once per year at service organizations or public schools, and wasteful practices posted on the Districts internet website. Each Year the number of publications and speaking appearances by the District each year will be presented in the Annual Report submitted to the

			Board of Directors of the District
B2		Identify wasteful practices.	a) Write and adopt rules to regulate wasteful practices by December 2008. b) Track Water Quality Issues. c) Initiate a District wide program to identify the location of all abandoned wells by January 2010. d) Develop and adopt guidelines, setting forth the period of time allowed, for abandoned well owners to insure voluntary compliance with Texas Water Code well plugging requirements by January 2010. e) Report unplugged abandoned water wells to the well owners and Board within thirty (30) days of discovery. a) Hold public hearing on proposed rules to regulate wasteful practices by December 2008. b) Report achievements in the District's Annual Report. c) Provide TECQ and TWDB an annual status report on unplugged abandoned water wells beginning in 2010.
C1	**Conjunctive Surface Water Management Issues.**	The District will actively participate with Municipal and County Governments to encourage the development of additional surface water sources for Rusk County.	Selected board members will attend at least one planning meeting per year with municipal and county government groups addressing surface water options. Each Year, the progress made by Municipal and County Governments will be submitted to the Board of Directors in the Annual Report on advancements made toward increasing surface water availability and reduction of demand on the aquifers in the county.
C2		Coordinate conjunctive surface water issues with the East Texas Regional Water Planning Group.	The District will participate in the regional planning process by attending at least 50% of the East Texas Regional Water Planning Group meetings per year. A report will be made by the board's representative at each board meeting of the Rusk County

			Groundwater Conservation District, updating the Board on conjunctive surface water issues being discussed by the ETRWPG.
D1	**Addressing Drought Conditions**	The District will develop and adopt a Drought Contingency Plan for the Rusk County Groundwater Conservation District within one year of the adoption and certification of this plan, review it annually, and revise it if necessary.	A contingency plan to cope with the effects of water supply shortages due to climatic or other conditions will be developed by the District and will be adopted by the Board after notice and hearing. In developing the contingency plan, the District will consider the economic effects of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydro geologic conditions of the aquifer and the appropriate conditions under which to implement the contingency plan. a) Development and adoption of a Drought Contingency Plan within one year of the adoption and certification of this plan. b) The Annual Report to the Board of Directors of the District will reflect any implementations of the Drought Contingency Plan in that year. The report will include an appraisal of the plans effectiveness and suggestions for revisions to the plan.
E1	**Addressing Conservation**	Public education on groundwater conservation.	The District will issue at least two articles per year in Rusk County newspapers and on the District internet website regarding water conservation issues applicable to the residence of Rusk County. Copies of the articles posted on the District website regarding groundwater conservation will be included in the Annual Report to the Board of Directors.
F1	**Total Usable Amount of Groundwater**	The total usable amount of groundwater for the Carrizo-Wilcox Aquifer located in Rusk County shall be "Near Sustainability," which is a	The RCGCD has contracted with Hydrex Environmental to increase the aquifer monitoring program from 15 sites within the county to

		reasonable and attainable goal for the residents of Rusk and the surrounding counties. Near Sustainability is defined as allowing up to an average drawdown of the aquifer between 2010 and 2050 not to exceed 10 feet. This objective is based on the Texas Water Development Board's (TWDB) Groundwater Availability Model (GAM) and other applicable and available data analyzed by LBG-Guyton Associates and Hydrex Environmental, using the best available science. The District recognizes that the GAM is a model and may be based on inaccurate and/or out of date assumptions. The district reserves the right to adjust its total usable amount of groundwater based on new data, as it is available. By allowing up to an average drawdown of up to 10 feet, the aquifer will sustain increased groundwater withdrawal of up to 10,000 af/yr. Currently, the estimated amount of groundwater pumped within Rusk County annually is 7,963 acre-feet.	approximately 100 sites. Aquifer levels will be monitored at least quarterly for all additional sites. Aquifer levels will be evaluated against recorded precipitation within the county. If the average drawdown of the aquifer in Rusk County exceeds 8 feet for more than two consecutive months the District will implement the Drought Contingency Plan (DCP). The DCP will be lifted after the average aquifer level drawdown is less than 8 Feet for two consecutive months. If the average drawdown of the aquifer in Rusk County exceeds 10 feet for more than two consecutive months, issuance of nonexempt permits will be halted until the average aquifer drawdown is less than 8 feet for two consecutive months. a) Establish additional aquifer level monitoring sites by the end of 2008. b) Set the average aquifer level for the County from the data gathered by January 2010. c) Publish the data gathered on the districts website quarterly beginning in 2009. d) Share this data with the TWDB annually. e) Report average quarterly aquifer levels in the annual report to the Board of Directors.

Appendix 1: Uvalde County Groundwater Conservation District			
#	Goal	Management Plan Objectives	Performance Standard
A1	**To Control and Prevent the Waste of Groundwater**	Each year the District will provide education materials concerning waste, which is prohibited under the District rule, to the newspapers and to the general public on at least six occasions	(a) The District will provide to a newspaper of general circulation within the District at least six newspaper articles and/or public service announcements on an annual basis, including those that may be posted on the District's Website. (b) The District will investigate all written reports of waste of groundwater within five working days from the date the report is filed with the District.
B1	**Addressing Natural Resource Issues that Impact the Use and Availability of Groundwater and Are Impacted by the Use of Groundwater**	Each year the District will cooperate with interested parties and appropriate agencies to develop additional information on aquifer recharge and weather modification projects.	(a) The District will establish terms for all aquifer recharge, transportation, or storage project permits. The District shall take into consideration all applicable factors and requirements of the District's rules and state law. (b) The District will make all information available to the District on such projects available to the general public and to permit applicants annually. (c) The District shall require owners or operators of all aquifer pumping, recharge, transportation, or storage projects affecting the district to obtain a permit amendment if the use, volume of groundwater pumped, location of, or means of transportation, recharge, or storage changes from the manner in which it was

			originally permitted.
B2		The District will require issuance of a well construction permit, or preregistration of exempt wells not requiring a construction permit, prior to the drilling of all new wells for all aquifers under the District's jurisdiction.	All well construction permits in compliance with the District rules will be issued within 20 days. Well construction permits not in compliance with the rules, as determined by the General Manager, will be considered at the next regular board meeting, but within 90 days of the General Manager's determination of the application's compliance with District rules.
C1	**Providing for the Efficient Use of Groundwater within the District**	Each year the District will make available educational brochures to the public promoting and explaining conservation methods and concepts, on at least one occasion.	The District will make educational material available at least one time per year through service organizations, and on a continuing basis at the District Office.
C2		Each year, the District will provide informative speakers to school and civic groups to raise public awareness of practices that ensure the efficient use of groundwater.	Each year, the District will make at least two public speaking appearances to promote the efficient use of groundwater.
D1	**The Control and Prevention of Subsidence**	The geologic framework of the District Area precludes any significant subsidence from occurring. This management goal is not applicable to the operations of the District.	
E1	**Addressing Conjunctive Surface Water Management Issues**	Except as provided in Chapter 36 of the Texas Water Code, the District has no jurisdiction over surface water. The District shall consider the effects of surface water resources as required by Section 36.113 and other state law.	
F1	**Addressing Conservation**	The District will annually submit an article regarding water conservation for publication to at least one newspaper of general circulation in	A copy of the article submitted by the District for publication to a newspaper of general circulation in Uvalde County regarding water

		Uvalde County.	conservation will be included in the Annual Report to the Board of Directors.
G1	**Addressing Drought Conditions**	Each month, the District will download the updated Palmer Drought Severity Index (PDSI) map and check for the periodic updates to the Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Water Information Network website www.txwin.net.	Quarterly, the District will make an assessment of the status of drought in the District and prepare a quarterly briefing to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the quarterly briefing in the District Annual Report to the Board of Directors.

Appendix 1: Wintergarden Groundwater Conservation District			
#	**Goal**	**Management Plan Objectives**	**Performance Standard**
A1	**Efficient Use of Ground Water**	District will continue monitoring and recording data from the five (5) Carrizo Aquifer well/monitors.	The District will assimilate data from the aquifer water level monitors and present to the Board monthly.
B1	**Controlling and Preventing Waste of Groundwater**	The District will at least on two (2) occasions each year provide public information on water conservation and waste prevention through public speaking appearances at public schools, and civic organizations or newspaper articles.	A. The number of speaking appearances made by the District each year. B. The number of newspaper articles published by the District each year.
C1	**Address Conjunctive Surface Water Management Issues**	Each year the District will confer at least on one occasion with the Nueces River Authority on cooperative opportunities for conjunctive resource management.	The number of conferences on conjunctive resource management opportunities held with Nueces River Authority each year.
D1	**Address Natural Resource Issues that Impact the Use and Availability of Groundwater**	Each year the District will insure that all new wells permitted for construction within the District, comply with the District construction standards through monitoring of the State of Texas water well report required to be provided to the District by water well drillers.	The number of newly permitted water wells within the District monitored for compliance will be reported to the Board annually.
D2	**Address Natural Resource Issues that Impact the Use and Availability of Groundwater**	Each year the District will insure that all new wells permitted for construction within the District, comply with the District construction standards through monitoring of the State of Texas water well report required to be provided to the District by water well drillers.	The number of newly permitted water wells within the District monitored for compliance will be reported to the Board annually.
E1	**Conservation, Recharge Enhancement, Rainwater Harvesting, Precipitation Enhancement, Brush Control, Where Appropriate and**	The District, in partnership with the Texas A & M Research Center, Uvalde, Texas, will maintain and provide a Weather Station centrally located in the District.	Hourly and average daily temperatures are available as a Precision Irrigation Network online at http://uvalde.tamu.edu/pet/ to prescribe daily irrigated crops use/need for precipitation.

	Effective		
E2		The District will monitor existing recharge structure and evaluate how natural or artificial recharge may be increased for the groundwater resources within the District via the existing structure and/or new sites.	The number of recharge sites monitored will be at least one site annually. The number of acre feet of captured rainwater in the recharge pit will be documented and reported to the Board of Directors annually.
E3		The District will participate in and manage the Southwest Texas Rain Enhancement Association cloud seeding project for eight months of each calendar year with five counties (Dimmit, La Salle, Uvalde, Webb, and Zavala Counties) in the target area. The project will be for precipitation increase and groundwater conservation. The project is also involved in hail suppression.	The Southwest Texas Rain Enhancement Association annual report will be provided to the Board as well as anyone interested by January 31 of the following year. The day-to-day (each mission) reports are also available next day to the Board of Directors and any interested individual.
E4		Brush Control – Recharge Enhancement and Conservation Project in partnership with the Texas A & M Research Center, Uvalde, Texas, in La Salle County.	Four (4) sites consisting of a control (no treatment – root plowed) freshly treated site – 5-year post treated, and 15-year post treated sites will be instrumented and data collected biweekly as to moisture depth and penetration and retention in relation to woody vegetation. Periodic updates will be forwarded to the Board of Directors and kept on file along with an annual report at the close of the project year. At the end of the project, data will be published in a scientific, peer-reviewed journal.
F1	**Drought Contingency Plan**	Each month the District will download the Palmer Drought Severity Index (PDSI) map and check the updates to the Drought Preparedness Council Situation Report posted on the Texas Water Information Network website www.txwin.net.	As required, the staff will assess the status of drought in the District and when needed, prepare a briefing with maps and situation reports for the Board of Directors. Monthly downloads will be filed for future use.
G1	**Desired Future Condition**	The District in conjunction with neighboring districts within our Groundwater Management Area will utilize the planning committee to develop the Desired Future Conditions of the aquifer.	This goal is not applicable to the District at the time of plan adoption.

Summary Report for Task 5: Science Utilized in the Groundwater Management Area (GMA) Joint Planning Process Utilized by Carrizo-Wilcox Groundwater Conservation District (GCD), the Appropriateness of Current GCD Rules to Achieve Desired Future Conditions (DFCs) and Other Long-term Impacts

1.0 Introduction and Background

Task 5 of the Carrizo-Wilcox Aquifer Study (the Study) directs the Bureau of Economic Geology (BEG) to "*Review available records from GMAS 11, 12, and 13 and evaluate science behind ultimate Desired Future Conditions (DFCs) recommendations*. " The Study was designed to collect this information regarding science considered during the joint-planning process by utilizing the online survey developed specifically for the Study.

The BEG was also tasked to "*Evaluate whether the rules adopted by the appropriate GCDs are designed to achieve the probable DFC for each GMA."* In a separate report produced for the Study, (*Summary Report for Task 3*) the challenges presented by the various timelines for joint-planning by GCDs in GMAs, and the development and adoption of Regional and State Water Plans were discussed. As was the case with Task 3, ideally, this evaluation for the Study would occur after the 2011 Regional Water Plans were adopted ***and*** all Carrizo-Wilcox GCDs had amended their respective management plans to reflect adopted DFCs and estimates of Managed Available Groundwater (MAG). At the time of this writing however, all estimates of MAG are still in draft form and the Carrizo-Wilcox GCDs have not had sufficient time to amend their management plans to integrate their adopted DFCs and the resulting estimates of MAG. As such, it is not possible for the purposes of the Study to determine whether the Carrizo-Wilcox GCDs have adopted rules (or management plans) designed to achieve their adopted DFCs. A realistic review of time requirements for this task by the Carrizo-Wilcox GCDs (revise and adoption of rules) suggests that initial efforts to first review and amend the respective management plans and ***then*** adopt revised rules to achieve the applicable DFCs will not be initiated until late 2010 – early 2011. Based on similar previous efforts, this task by the Carrizo-Wilcox GCDs could take as long as one to two years to complete, once initiated.

Finally, the BEG was to "*Determine other long-term impacts of the GCD rules and plans on the entire Carrizo-Wilcox Aquifer, considering projected agricultural, industrial and municipal demands for water from the aquifer.*" In order to evaluate long-term impacts on the Carrizo-Wilcox Aquifer, the primary focus for this evaluation was to review the potential socio-economic impacts of not meeting future water supply needs that are the result of policy decisions made in the joint planning process resulting in the adopted DFCs for the Carrizo-Wilcox Aquifer.

As was the case with the *Summary Report for Task 3*, the following statements are reiterated so as to allow the reader an understanding of the provisional nature of much of the data presented in this report:

- It is understood that regional water planning data provided by the Texas Water Development Board (TWDB) are provisional in nature, in that TWDB staff are currently (at the time of this writing) engaged in the final review and approval of Regional Water Plans, and as such, certain water management strategies may need to be revised prior to final approval of the Regional Water Plans by the TWDB. However, it is not anticipated that revision necessary to water management strategies that are based on groundwater sources will need to be substantively revised. (Note—all regional water plans have now been adopted as of December 16, 2010. However, public access to the regional water planning database to confirm provisional data utilized in the Study will not be available according to TWDB staff until early 2011).
- It is also understood that the MAGs provided by the TWDB to the BEG for the Study are currently in draft form, pending review and comment from the Carrizo-Wilcox GCDs regarding quantification of exempt use. After exempt use has been established for each county and aquifer, that amount will be deducted from the draft MAGs utilized in this report. The sum of exempt use and MAG estimates will then represent the total amount of pumping consistent with the adopted DFC. While the MAG estimates may change due to comments from the GCDs, the estimates of total amount of pumping consistent with the DFCs (referred to as MAGs in this report) are not expected to change. This total amount of pumping is what is directly analogous to groundwater availability in the Regional Water Plans. It is expected that the 2016 Regional Water Plans will include this total amount of pumping (which includes exempt use + the MAG). Until exempt use has been quantified, ***<u>for the purposes of this report only</u>***, MAG equals the total amount of pumping consistent with the DFC.
- With respect to a review of the Regional and State Water Plans, it is recognized that we are currently in the interval between adoption of Regional Water Plans and adoption of a State Water Plan. As such, the current State Water Plan is now four years old, and in many cases, inconsistent with recently adopted Regional Water Plans. For the purposes of this report, in order to utilize the most current information and to avoid unnecessary confusion, information regarding currently available supplies and water management strategies from the recently adopted 2011 Regional Water Plans was utilized for this analysis. Information from the 2007 State Water Plan was reviewed, but will not be presented in this report.
- In the 2016 Regional Water Plans and the 2017 State Water Plan, the total amount of groundwater available to meet current and future needs can be no more than the MAG for the most recently adopted DFC. This task (Task 5) asks the BEG ***<u>to "Determine other long-term impact</u>****s of the GCD rules and plans on the entire Carrizo-Wilcox Aquifer, considering projected agricultural, industrial and municipal demands for water from the aquifer"*. In order to conduct this evaluation of long-term impacts, information developed in the *Summary Report for Task 3* was utilized. *Summary Report for Task 3* was primarily focused on the identification and quantification of *<u>conflicts</u>* between DFCs adopted in the joint-planning process *<u>and</u>* the sum of

currently available supplies and water management strategies from the recently adopted 2011 Regional Water Plans. As was discussed in this report, what is not defined explicitly during this transitional stage of planning (*both regional water planning and joint planning for GCDs) is what constitutes a conflict. For reference, 31 TAC §356.2(a)(6) states a conflict is "A situation where the managed available groundwater identified in a management plan or the adopted State Water Plan is not the managed available groundwater based on the desired future conditions set by the groundwater conservation districts in the groundwater management area." T*his definition will be universally applicable during *th*e 2016 Regional Water Plans and 2017 State Water Plan. However, due to the timing of submission of DFCs and calculation of MAGs by the TWDB, none of the Carrizo-Wilcox GCDs were able to provide official MAGs in time for inclusion in the 2011 Regional Water Plans. Therefore, technically, no conflict can exist at this time. For the purposes of Task 3, we did compare, on a county b*y county basis, the sum of Carrizo-Wilcox Aquifer availability and water management strategies that rely on the Carrizo-Wilcox Aquifer to the draft estimates of MAG for the Carrizo-Wilcox Aquifer from the initial round of joint planning that just concluded on September 1, 201*0. Therefore, solely for the purposes of the Study, a "potential conflict" is defined as "where, on a county-level evaluation, the sum of current water supplies available from the Carrizo-Wilcox Aquifer and water management strategies that rely on groundwater from the Carrizo-Wilcox Aquifer in a county are greater than or exceed the MAG for the same county."

2.0 Methodology

The primary source of information available for evaluation of science used by the three GMAs during their deliberations of potential DFCs was information provided by the representative GCD through the Study's online survey. As part of the online survey, the following question was asked:

Question 23 – Within GMA 11, 12, and 13, each groundwater conservation district that has been selected to serve as the administrator for the GMA process is asked to provide electronic copies of minutes from any meetings that have taken place since the beginning of the joint planning process during which scientific data and/or studies have been considered during the development of desired future condition recommendations. Provide electronic copies of any scientific data or presentations considered and identified in the minutes.

Information provided by the three GMAs regarding science considered during the first round of joint planning was compiled and reviewed. Additional information was provided after the survey process was completed by Post Oak Savannah GCD and reviewed for the Study.

In order to evaluate the impacts of GCD rules and plans on the entire Carrizo-Wilcox Aquifer, considering projected agricultural, industrial and municipal demands for water from the aquifer, information developed for the *Summary Report for Task 3* quantifying "potential conflicts" was correlated with socio-economic impact analysis developed for the 2011 Regional Water Plans. In the *Summary Report for Task 3*, an evaluation of the Regional and State Water Plans and MAGs resulting from the DFCs adopted by the Carrizo-Wilcox GCDs during the recently completed joint planning process was conducted in order to identify *potential conflicts* that may exist between the two planning processes. Solely for the purposes of this Study, a *potential conflict* is defined as "where, on a county-level evaluation, the sum of current water supplies available from the Carrizo-Wilcox Aquifer and water management strategies that rely on groundwater from the Carrizo-Wilcox Aquifer in a county are greater than or exceed the MAG for the same county." For a more complete description of assumptions and methodology utilized in this evaluation, the reader is referred to the *Summary Report for Task 3* that was prepared as part of the Study.

Socio-economic impact data developed for this evaluation was provided by the TWDB. This information is required as part of the regional water planning process in Texas. 31 Texas Administrative Code §357.7(a)(4)(A) states, in part, that a Regional Water Plan shall include, "*… The social and economic impact of not meeting these needs shall be evaluated by the regional water planning groups and reported by regional water planning area and river basin. The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs."* Information provided by the executive administrator to all of the regional water planning groups with water supplies utilized from the Carrizo-Wilcox Aquifer was utilized for this evaluation.

3.0 Results

The Carrizo-Wilcox Aquifer is present over more surface area than any other aquifer within Texas. According to the Texas State Water Plan, *Water for Texas – 2007*, the Carrizo Wilcox Aquifer covers all or parts of 66 counties in Texas, reaching from the Texas – Arkansas – Louisiana border in the northeast to Mexico in the south (Figure 7.1). The area, when combined, (the outcrop and subsurface extent) of the Carrizo-Wilcox Aquifer is approximately 36,595 square miles in aerial extent, which is 80 square miles larger than the surface area of largest producing aquifer in Texas, the Ogallala Aquifer, with a surface area of 36,515 square miles (*Water for Texas – 2007*).

When the TWDB delineated (by rule, 31 Texas Administrative Code §356.21-23) the boundaries of the groundwater management areas (GMAs) for Texas, as required by Senate Bill 2 (77^{th} Texas Legislature, 2001), all or parts of 58 counties were included in the three GMAs covering the Carrizo-Wilcox Aquifer (Table 7.1, Figure 7.1). According to information from the TWDB, there are 18 GCDs within GMAs 11, 12, and 13 (Table 7.2). Three other GCDs with jurisdictional boundaries that include at least some area within the boundaries of the Carrizo-Wilcox Aquifer were included in other GMAs, due primarily to the relatively minor amount of Carrizo-Wilcox Aquifer resources within the three GCDs as compared to the primary aquifer for those GCDs, which in this case is the Gulf Coast Aquifer (see Figure 7.1). These three are the Bluebonnet GCD, Bee GCD, and the Live Oak GCD.

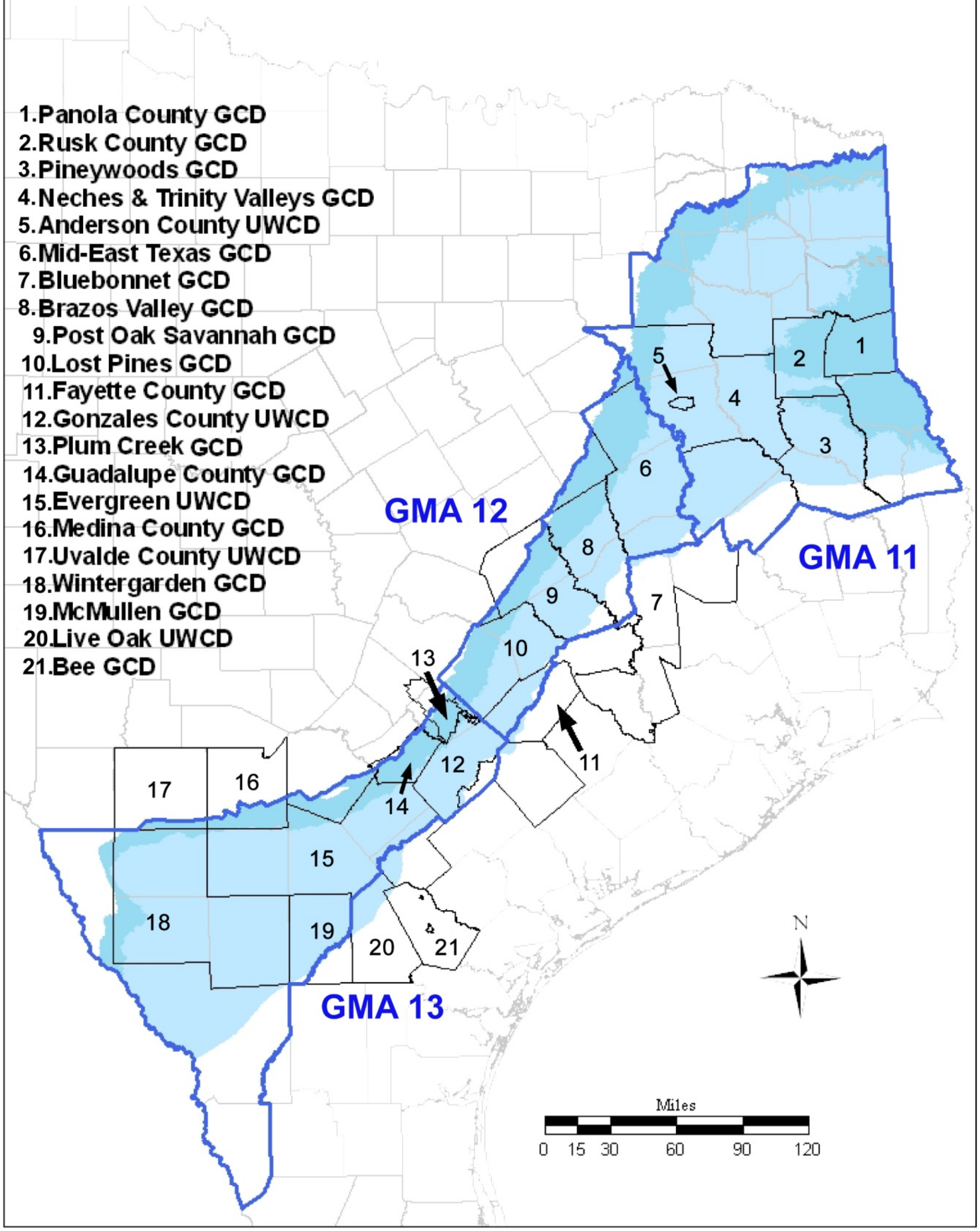
Table 7.1: Carrizo-Wilcox Aquifer Groundwater Management Areas and counties included (either in whole or in part).

GMA 11 (27 Counties)	***GMA 12 (14 Counties)***	***GMA 13 (17 Counties)***
Anderson	Bastrop	Atascosa
Angelina	Brazos	Bexar
Bowie	Burleson	Caldwell
Camp	Falls	Dimmit
Cass	Fayette	Frio
Cherokee	Freestone	Gonzales
Franklin	Lee	Guadalupe
Gregg	Leon	Karnes
Harrison	Limestone	La Salle
Henderson	Madison	Maverick
Hopkins	Milam	McMullen
Houston	Navarro	Medina
Marion	Robertson	Uvalde
Morris	Williamson	Webb
Nacogdoches		Wilson
Panola		Zapata
Rains		Zavala
Rusk		
Sabine		
San Augustine		
Shelby		
Smith		
Titus		
Trinity		
Upshur		
Van Zandt		
Wood		

Table 7.2: Carrizo-Wilcox Aquifer Groundwater Management Areas, Groundwater Conservation Districts, and constituent counties.

GMA 11	GMA 12	GMA 13
Anderson County GCD	**Brazos Valley GCD**	**Evergreen UWCD**
Anderson	Robertson	Atascosa
Neches & Trinity	Brazos	Frio
GCD	**Fayette County GCD**	Karnes
Anderson	Fayette	Wilson
Cherokee	Burleson	**McMullen County GCD**
Henderson	**Lost Pines GCD**	McMullen
Panola County GC	Lee	**Medina County GCD**
Panola	Bastrop	Medina
Pineywoods GCD	**Mid-East Texas GCD**	**Gonzales County UWCD**
Angelina	Freestone	Gonzales
Nacogdoches	Leon	**Guadalupe County GCD**
Rusk County GCD	Madison	Guadalupe
Rusk	**Post Oak Savannah GCD**	**Plum Creek GCD**
	Burleson	Caldwell
	Milam	**Uvalde UWCD**
		Uvalde
		Wintergarden GCD
		Dimmit
		La Salle
		Zavala

Figure 7.1: Location of Carrizo-Wilcox Aquifer, Groundwater Conservation Districts, and Groundwater Management Areas



In response to the survey questionnaire developed for the Study, the Carrizo-Wilcox GCD designated as the administrator for GMA 11, 12, and 13 provided information regarding any science considered by the Carrizo-Wilcox GCDs throughout the joint planning process. The detail provided through the survey on this question was quite variable. Tables 7.3–7.5 provide a summary of the science considered throughout the joint planning process in GMA 11–13, respectively.

Table 7.3: Information submitted by GMA 11 regarding science considered during the recently completed joint planning process.

Date	Description (*Italics indicate a presentation was included with meeting minutes).*
5/25/2006	Rima Petrossian, TWDB, made presentation on joint planning under TWC 36.108
6/22/2006	Len Luscomb, Rusk County GCD, discussion of Martin Lake impacts to the DFC's of GMA 11.
7/27/2006	Dr. MacDonald, Stephen F. Austin University: ARC GIS utility presentation.
7/27/2006	Len Luscomb, Rusk County GCD: Again raised issue of Martin Lake impacts to the GMA 11 DFC's.
6/25/2007	Len Luscomb, Rusk County GCD, made recommendation regarding approach to obtain best available data for monitoring all counties in GMA-11 (including unprotected counties).
11/29/2007	Shirley Wade, TWDB, made presentation on results from Groundwater Availability Model (GAM) Run 07-20 for GMA 11.
11/29/2007	Len Luscomb, Rusk County GCD, made recommendation to adopt a DFC of near sustainability for the Carrizo-Wilcox Aquifer, allowing a 10 foot drawdown.
10/15/2008	Roy Rodgers, Neches & Trinity Valleys GCD, made recommendation regarding possible action on exempt well pumping in determining MAG.
5/19/2009	Len Luscomb, Rusk County, made recommendation regarding possible action on exempt well pumping in determining MAG.
10/20/2009	Dr. William Hutchinson, TWDB, made presentation on GAM Run 08-23.
10/20/2009	Len Luscomb, Rusk County GCD, made recommendation to set initial DFCs for the Carrizo-Wilcox Aquifer in GMA 11
11/24/2009	David Alford, Pineywoods GCD, led discussion of setting a DFC.
11/24/2009	Dr. William Hutchinson, TWDB, presented additional analysis of GAM Run 08-23

Table 7.4 : Information submitted by GMA 12 regarding science considered during the recently completed joint planning process.

Date	Description (*Italics indicate a presentation was included with meeting minutes.)*
1/26/2006	***Larry French, URS, Process Necessary to Identify the Desired Future Conditions of the Aquifers in GMA12***
4/27/2006	Robert Gresham, Mid-East Texas GCD, Presentation on DFC for Groundwater.
4/27/2006	Rodney Willis, Fayette County GCD, Presentation on DFC for Groundwater.
4/27/2006	Larry French, URS for Post Oak Savannah GCD, Presentation on DFC for Groundwater.
4/27/2006	Robert Kier, Lost Pines GCD, Presentation on DFC for Groundwater.
4/27/2006	John Seifert, Brazos Valley GCD, Presentation on DFC for Groundwater.
10/30/2006	Discussion of HB 1763 and Dialogue on Desired Future Conditions.
12/12/2006	***Larry French, URS, Proposed Initial DFC Statement for GMA 12 Planning***
03/01/2007	Member GCD's review LBG- Guyton, GAM information
03/01/2007	***James Beach, LBG-Guyton, Carrizo-Wilcox GAMs for GMA12 and GMA-1.***
05/10/2007	***Dan Opdyke, Texas Parks & Wildlife, Possible Impact of GMA 12 GAM***
05/10/2007	***LBG-Guyton, GAM Run Considerations***
10/30/2008	***Steve Box, Environmental Stewardship, Groundwater & Surface Water Crossroads.***
10/30/2008	Frank Limer, Russ Johnson, Mike Thornhill, Stacy Reeves, Ends Ops LP & Brazos River Alliance, Property Owner Rights and How DFC's adopted by GMA 12 would affect
10/30/2008	***David Dunn, HDR Engineers, Impact of large groundwater withdrawals on the economies of Brazos and Robertson Counties.***
10/30/2008	***Dan Opdyke, Texas Parks and Wildlife, A Groundwater Perspective on Surface Water Resources for GMA 12.***
10/30/2008	Ridge Kaiser, R.W. Hardin, Stakeholder Comments regarding DFC & MAG Process.
10/30/2008	Frank Limer, Russ Johnson, Mike Thornhill, Stacy Reeves, Ends Ops LP & Brazos River Alliance, Property Owner Rights and How DFC's Adopted by GMA 12 Would Affect Those Rights.
6/24/2009	Matt Uliana, Mid-East Texas GCD, Presentation on DFC for Groundwater.
6/24/2009	David Van Dresar, Fayette County GCD, Presentation on DFC for Groundwater.
Saunders	***Steve Young, Post Oak Savannah GCD, Presentation on DFC for Groundwater.***

6/24/2009	Robert Kier, Lost Pines GCD, Presentation on DFC for Groundwater.
6/24/2009	John Seifert, Brazos Valley GCD, Presentation on DFC for Groundwater.
6/24/2009	Meeting Minutes Indicate that the LBG-Guyton and URS were selected as Consultants
6/24/2009	***Environmental Stewardship, Protection of Rivers, Streams, and Springs through DFC.***
6/24/2009	***Geoffrey P. Saunders, LCRA, Low-Flow Gain-Loss Study of the Colorado River in Bastrop County, Texas.***
6/24/2009	Response to Comments from the GMA-12 Stakeholder Meeting on October 30, 2008.
6/24/2009	Primary Estimates of Desired Future Conditions for Brazos Valley Groundwater Conservation District.
8/28/2009	***James Beach, LBG Guyton, History of Groundwater Management.***
8/28/2009	John Seifort, Brazos Valley GCD, Presentation on Estimated Groundwater Use in GMA 12.
8/28/2009	Predicted Changes in Groundwater Levels.

Table 7.5: Information submitted by GMA 13 regarding science considered during the recently completed joint planning process.

Date	**Presentations** *Italics indicate a presentation was included with meeting minutes.*
1/11/2006	***Robert Bradley, TWDB, Groundwater Availability Modeling***
3/22/2006	***Robert Bradley, TWDB, Groundwater Availability Modeling***
3/2/2007	***Robert Bradley, TWDB, Groundwater Availability Modeling***
11/20/2007	***Andrew Donnelly, TWDB, Discussion of DFC of the Aquifers of GMA 13.***
1/9/2008	***Andrew Donnelly, TWDB, Discussion of DFC of the Aquifers of GMA 13.***
3/31/2008	Groundwater Management Area 13 Stakeholder Group Report
9/26/2008	***San Antonio Water System, Recommended Desired Future Conditions (DFC) for GMA-13***
10/15/2008	***Sarah Backhouse, Shirley Wade, TWDB, GAM MODELS***
8/13/2009	***Sarah Backhouse, Shirley Wade, TWDB, GAM MODELS***
9/19/2009	***Charles Kreitler, LBG-Guyton, Presentation on the Desired Future Conditions***
9/19/2009	***Shirley Wade, TWDB, Groundwater Budgets, Inflows, Outflows, and Storage Changes.***
2/19/2010	***Dr. William Hutchinson, Texas Water Development Board, Groundwater Available Model***
4/9/2010	***Resolution to Adopt Scenario 4 with a 23' drawdown across GMA 13.***
	Additional Texas Water Development Board Documents
9/29/2008	Shirley Wade, TWDB, DRAFT GAM RUN 08-43
1/22/2008	Peter George, et al , TWDB, Desired Future Conditions and Aquifer Slivers in GMAs

4/24/2008	Texas Water Development Board, Appendix for GAM RUN 07-17
8/29/2008	Shirley Wade, Texas Water Development Board, GAM RUN 08-41
9/16/2008	Shirley Wade, Texas Water Development Board, Amended GAM RUN 08-41
9/25/2008	Shirley Wade, Texas Water Development Board, Amended GAM RUN 08-41; 08-42;08-43
7/7/2009	Andrew Donnelly, Texas Water Development Board, GAM RUN 06-29

Our review of the science considered during the joint planning process for GMAs 11, 12, and 13, based on information provided by the Carrizo-Wilcox GCDs for the Study, has documented that in each GMA, the core science considered in the adoption of DFCs was science developed by the TWDB as part of the GAM Program. The degree to which the results from additional scientific information was considered ranges from no additional substantive information being considered by in GMA 11 to multiple scientific presentations that were local or sub-GMA in scope for GMAs 12 and 13. For example, in GMA 12, results from scientific studies regarding surface water/groundwater interactions were considered as the different possible DFCs were being evaluated. Our review of meeting minutes from GMA 12 documented 11 other presentations by interested stakeholders and consultants including: Environmental Defense Fund, Environmental Stewardship, LBG-Guyton, City of Bryan, Lower Colorado River Authority, HDR Engineers, Texas Parks and Wildlife, and URS. Also, there were multiple occasions when stakeholders submitted letters to GMA 12 for consideration during the DFC process including: Ends Ops. LP., Brazos River Alliance, and private property owners.

On January 26, 2006, for example, Larry French, Senior Hydrogeologist for URS, submitted a letter detailing the process necessary to identify the desired future conditions for the aquifers in GMA 12. On December 12th 2006, Larry French, Senior Hydrogeologist for URS, submitted a technical memorandum and listed the Draft DFC's for all of all segments of the Carrizo-Wilcox Aquifer. As the DFC process continued comments and presentations were received concerning the impact of establishing a DFC for the GMA 12 Carrizo-Wilcox GCDs. During March and May of 2007, LBG-Guyton provided groundwater availability models to GMA 12 for review. Texas Parks and Wildlife Department, Environmental Stewardship, the Lower Colorado River Authority, and Environmental Defense Fund presented information detailing the relationship between surface water and groundwater in the region and the impact that groundwater production has on the regions hydrogeology.

Though multiple comments and presentations were heard by the Board of GMA12, there were materials from for only five of the presentations prepared by the GMA 12 consultants submitted to the Study for review.

For GMA 13, we documented 12 presentations by the TWDB, the San Antonio Water System and by LBG-Guyton. There were six additional TWDB documents that were mentioned in the meeting minutes of GMA 13, which consisted of GAMs that were conducted and presented to GMA 13.

As part of the Study in Task 1, the BEG was asked to review and evaluate the adequacy of science utilized by Carrizo-Wilcox GCDs in the development of management plans and rules. The results of this review and evaluation are presented in the *Summary Report for Task 1b*. Based on the review contained in the *Summary Report for Task 1b*, the following conclusion was made, "*Therefore, it is clear in statute that it is the intent of the Texas Legislature that one of the primary sources of groundwater science to be utilized by GCDs during their development of management plans and their adoption of desired future conditions is to be the groundwater availability models and groundwater science developed and made publically available by the executive administrator of the Texas Water Development Board.*"

The evaluation for this report leads to a similar conclusion. Based on information provided through the survey for the Study, the primary source of science utilized by two of the three GMAs (11 and 13) was information derived from the three Carrizo-Wilcox GAMs. The TWDB provided a number of model simulation results to these two GMAs based on draft DFC requests from the GMAs throughout the DFC process. By design, this was an iterative process, whereby TWDB staff would present model results to the GMAs, and then the GMAs would modify the modeling requests to better understand the potential MAGs that could result from the draft DFCs being considered. Further, there is no record in the meeting minutes from GMA 12 that the TWDB independently presented any GAM results during the joint planning process.

In summary, with respect to our review and evaluation of science considered during the joint planning process and the adoption of DFCs, based on information provided by the three GMAs, one of the primary sources of science considered in GMA 11 and 13 was information provided by TWDB staff. In the survey developed for the Study, GCDs serving as administrator during the joint planning process for each of the three GMAs were asked, *"…to provide electronic copies of minutes from any meetings that have taken place since the beginning of the joint planning process during which scientific data and/or studies have been considered during the development of desired future condition recommendations. Provide electronic copies of any scientific data or presentations considered and identified in the minutes.*" Meeting minutes were provided by the responsible Carrizo-Wilcox GCDs, and presentations identified in the meeting minutes are listed in Tables 7.3–7.5. In some instances, a copy of a PowerPoint presentation was attached with the meeting minutes. However, no electronic copies of any scientific data considered by the Carrizo-Wilcox GCDs during the joint planning process were submitted in the survey. While a PowerPoint presentation can be an effective means of communicating the results of a scientific study, the reality is that a PowerPoint presentation is rarely adequate to fully document the nature and scope of the science considered in a decision-making process such as the joint planning process. Our conclusion from this review is that one of the primary sources of science considered in the joint planning process was information from the TWDB, especially information from the three GAMs that have been developed for the Carrizo-Wilcox Aquifer.

A fundamental component of the regional water planning process is the evaluation of what are the socio-economic impacts at the regional, county, and sector (municipal, manufacturing, mining, etc.) level, of not meeting future water supply needs. During this evaluation, several impacts are modeled and quantified, including social impacts such as population, school enrollment, and economic impacts such as regional income, state and local business taxes, and the number of full and part time jobs. These evaluations are modeled for the major water use sectors; municipal, agricultural, livestock, steam-electric power generation, and mining. One of the outputs from the socio-economic impact analysis that is included in all Regional Water Plans is the total monetary losses per acre foot of water need that is not met by a water management strategy. In other words, what is the monetary impact to a water use sector if future water supply needs are not met?

The water supply shortages that may result as a consequence of the adopted DFCs in GMAs 11, 12, and 13, were quantified in the *Summary Report for Task 3*. Readers are encouraged to refer to this report for a full explanation of methodologies and results. However, due to the nature of the evaluation process required to understand the potential socio-economic impacts of the adopted DFCs, Table 7.6 (Table 5.1 in *Summary Report on Task 3*) is reproduced in this report for those counties for which a "potential conflict" has been quantified. Solely for the purpose of the Study, these potential conflicts are a result of the amount of groundwater from the Carrizo-Wilcox Aquifer for current water supplies plus water management strategies included in the recently adopted 2011 Regional Water Plans being greater at some point in the 50-year planning horizon than the MAG for the Carrizo-Wilcox Aquifer for the county in question. Next, monetary losses per acre-foot of water supply need for the 20 counties was derived from the socio-economic impact analysis conducted by the TWDB as part of the regional water planning process. These results, by regional water planning group, by county, by water use sector, and by decade are presented in Table 7.7.

It is important to note that it is not possible to determine which water use sector would be impacted by the "potential conflicts" if the 2016 Regional Water Plans are not able to develop additional water management strategies to meet these needs. Therefore, if the *potential conflicts* are not resolved, the economic impacts will be dependent upon which water use sector(s) has the unmet need. For example, the total monetary losses per acre foot of water needs in 2020 for Bastrop County ranges from $125 for irrigation use to $4,277 for municipal use. Therefore, if all unmet needs are realized by the irrigation water use sector in Bastrop County, and the unmet need is 4,263 acre-feet in 2010 (see Table 7.6), then the economic impact as expressed by the total monetary loss is estimated to be $532,875. However, if the unmet needs are evenly divided between the irrigation water use sector and the municipal water use sector, then the total monetary loss for 2010 would be $9,382,863 ((2,131.5 acre-feet x $125 for irrigation water use sector) + (2,131.5x$4,277 for municipal water use sector)). Practically speaking however, if a repeat of drought of record conditions were to occur, it is very difficult to make categorical projections of which water use sector will be asked or expected to realize what portion of the shortage. For example, would manufacturers or power generators be asked to cut back on production, or would businesses and homes be expected to reduce water use in order to meet total demands? These types of modeling assumptions have a very significant impact on the final analysis of total monetary loss, and are clearly beyond the scope of the Study.

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
I	**11**	**Angelina**	MAG	26,414	26,414	26,414	26,414	26,414	26,414
		Angelina	Supplies + Strategies	22,569	22,533	24,339	24,599	26,679	27,051
			Difference	***3,845***	***3,881***	***2,075***	***1,815***	***(265)***	***(637)***
L	**13**	**Atascosa**	MAG	67,949	68,776	70,369	71,947	73,786	75,808
		Atascosa	Supplies + Strategies	67,872	69,043	69,921	69,987	70,051	72,526
			Difference	***77***	***(267)***	***448***	***1,960***	***3,735***	***3,282***
K	**12**	**Bastrop**	MAG	16,866	19,979	20,666	24,833	28,018	28,498
		Bastrop	Supplies + Strategies	21,129	31,489	38,622	46,388	54,275	58,321
			Difference	***(4,263)***	***(11,510)***	***(17,956)***	***(21,555)***	***(26,257)***	***(29,823)***
G	**12**	**Brazos**	MAG	33,925	38,835	44,847	49,421	53,970	57,169
		Brazos	Supplies + Strategies	44,380	44,502	44,386	47,432	47,439	47,434

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
			Difference	***(10,455)***	***(5,667)***	***461***	***1,989***	***6,531***	***9,735***
G	**12**	**Burleson**	MAG	3,750	23,249	28,047	32,518	36,492	38,701
		Burleson	Supplies + Strategies	4,369	4,369	4,669	27,433	30,053	31,557
			Difference	***(619)***	***18,880***	***23,378***	***5,085***	***6,439***	***7,144***
L	**13**	**Dimmit**	MAG	3,359	3,359	3,359	3,359	3,359	3,359
		Dimmit	Supplies + Strategies	13,536	13,536	13,536	13,536	13,536	13,536
			Difference	***(10,177)***	***(10,177)***	***(10,177)***	***(10,177)***	***(10,177)***	***(10,177)***
12	**C**	**Freestone**	MAG	5,138	5,305	5,317	5,315	5,262	5,259
		Freestone	Supplies + Strategies	5,783	5,223	5,223	5,223	5,223	5,223
			Difference	***(645)***	***82***	***94***	***92***	***39***	***36***

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
13	**L**	**Frio**	MAG	81,551	79,089	76,734	74,439	72,222	70,030
		Frio	Supplies + Strategies	246,645	246,645	246,645	246,645	246,645	246,645
			Difference	***(165,094)***	***(167,556)***	***(169,911)***	***(172,206)***	***(174,423)***	***(176,615)***
13	**L**	**Gonzales**	MAG	52,483	62,316	70,317	75,791	75,970	75,970
		Gonzales	Supplies + Strategies	15,740	35,648	44,928	55,561	67,821	80,540
			Difference	***36,743***	***26,668***	***25,389***	***20,230***	***8,149***	***(4,570)***
13	**L**	**Guadalupe**	MAG	10,241	10,833	11,283	13,021	13,541	14,041
		Guadalupe	Supplies + Strategies	19,832	23,162	25,779	26,384	28,029	29,570
			Difference	***(9,591)***	***(12,329)***	***(14,496)***	***(13,363)***	***(14,488)***	***(15,529)***
11	**C&I**	**Henderson**	MAG	9,253	9,186	9,186	9,186	9,186	9,186
		Henderson	Supplies + Strategies	8,833	9,565	9,567	9,851	9,853	9,895
			Difference	***420***	***(379)***	***(381)***	***(665)***	***(667)***	***(709)***

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
L	**13**	**Karnes**	MAG	1,059	1,117	1,182	1,231	1,259	1,280
		Karnes	Supplies + Strategies	1,141	1,141	1,141	1,141	1,141	1,141
			Difference	***(82)***	***(24)***	***41***	***90***	***118***	***139***
L	**13**	**La Salle**	MAG	6,454	6,454	6,454	6,454	6,454	6,454
		La Salle	Supplies + Strategies	8,013	8,013	8,013	8,013	8,013	8,013
			Difference	***(1,559)***	***(1,559)***	***(1,559)***	***(1,559)***	***(1,559)***	***(1,559)***
M	**13**	**Maverick**	MAG	2,043	2,043	2,024	1,677	1,570	1,532
		Maverick	Supplies + Strategies	1,792	2,056	2,058	2,060	2,073	2,444
			Difference	***251***	***(13)***	***(34)***	***(383)***	***(503)***	***(912)***
L	**13**	**Medina**	MAG	2,568	2,545	2,533	2,533	2,533	2,533
		Medina	Supplies + Strategies	7,597	7,597	7,597	7,597	7,597	7,597

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
			Difference	***(5,029)***	***(5,052)***	***(5,064)***	***(5,064)***	***(5,064)***	***(5,064)***
C	**12**	**Navarro**	MAG	15	15	15	15	15	15
		Navarro	Supplies + Strategies	88	88	88	88	88	88
			Difference	***(73)***	***(73)***	***(73)***	***(73)***	***(73)***	***(73)***
L	**12**	**Uvalde**	MAG	2,971	1,230	828	828	828	828
		Uvalde	Supplies + Strategies	2,846	2,846	2,846	2,846	2,846	2,846
			Difference	***125***	***(1,616)***	***(2,018)***	***(2,018)***	***(2,018)***	***(2,018)***
D	**11**	**Van Zandt**	MAG	10,614	10,283	10,283	10,283	10,283	10,051
		Van Zandt	Supplies + Strategies	7,499	8,170	8,645	8,982	9,645	10,292
			Difference	***3,115***	***2,113***	***1,638***	***1,301***	***638***	***(241)***
M	**13**	**Webb**	MAG	916	916	916	916	916	916

Table 7.6 (Part of Table 5.1: Summary Report for Task 3): Comparison of draft estimates of MAG from first round of joint planning with sum of currently available supplies and water management strategies recommended in recently adopted 2011 regional water plans. Due to the absence of quantified values for exempt use at this time, for the purposes of this report only, the values for MAG equal the total amount of pumping consistent with the adopted DFC. A potential conflict, as defined in the Study, exists when the sum of currently available supplies and water management strategies is greater than the MAG for any decade during the 50-year planning horizon. These instances are illustrated in this table in parentheses (xxxx), i.e. negative numbers. All values are in acre-feet per year.

Regional Water Planning Area (RWPA)	**Groundwater Management Area (GMA)**	**County**	**Calculations**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
		Webb	Supplies + Strategies	3,882	6,824	9,138	9,712	9,711	9,710
			Difference	***(2,966)***	***(5,908)***	***(8,222)***	***(8,796)***	***(8,795)***	***(8,794)***
G	**12**	**Williamson**	MAG	7	7	7	7	7	7
		Williamson	Supplies + Strategies	8,412	8,412	8,412	8,522	8,522	8,522
			Difference	***(8,405)***	***(8,405)***	***(8,405)***	***(8,515)***	***(8,515)***	***(8,515)***

Table 7.7: Socio-economic impacts results from 2011 Regional Water Plans (* - denotes county that did not have any water supply needs during the 50-year planning horizon, therefore, no monetary losses have been calculated).

Region C		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Freestone	Steam-electric	$0	$0	$0	$0	$24,617	$24,617
Freestone	Municipal	$0	$40,561	$40,569	$23,452	$17,637	$15,461
Navarro	Steam-electric	$0	$98,083	$98,083	$98,083	$98,083	$98,083
Navarro	Municipal	$0	$1,766	$1,620	$1,699	$3,084	$5,845
Navarro	Manufacturing	$0	$81,977	$81,967	$82,005	$163,979	$163,974
Region D							
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Van Zandt	Municipal	$941	$957	$1,011	$1,459	$8,131	$18,473
Region G							
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brazos	Municipal	$119	$2,221	$3,170	$8,637	$9,389	$10,770
Williamson	Municipal	$6,205	$10,545	$15,826	$23,391	$30,033	$31,340
Williamson	Manufacturing	$107,880	$107,880	$107,880	$107,880	$107,880	$107,880
Williamson	Mining	$24,139	$24,139	$24,139	$24,139	$24,139	$24,139
Region I							
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Angelina	Livestock	$0	$0	$0	$60,362	$60,362	$60,362
Angelina	Steam-electric	$72,631	$72,631	$72,631	$72,631	$72,631	$72,631
Angelina	Mining	$76,776	$82,394	$0	$0	$0	$0
Angelina	Manufacturing	$12,474	$24,942	$24,941	$49,883	$49,883	$49,883
Angelina	Municipal	$5,067	$18,406	$18,297	$18,020	$30,419	$23,349
Henderson	Livestock	$0	$60,362	$60,362	$60,362	$60,362	$60,362
Henderson	Steam-electric	$0	$0	$160,127	$160,127	$160,127	$160,127
Henderson	Municipal	$2,456	$10,609	$8,808	$12,159	$19,747	$24,469
Region K							
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bastrop	Municipal	$576	$4,277	$7,214	$11,737	$14,765	$21,624
Bastrop	Irrigation	$125	$125	$125	$125	$125	$125
Bastrop	Manufacturing	$63,229	$63,229	$63,229	$63,229	$63,229	$126,458
Bastrop	Steam-electric	$0	$0	$0	$27,719	$27,719	$27,719

Region L		**Total Monetary Losses Per Acre-Foot of Water Supply Need**					
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Atascosa	Municipal	$6,578	$8,445	$6,869	$7,037	$7,842	$9,232
Atascosa	Irrigation	$194	$194	$194	$194	$194	$194
Atascosa	Steam-electric	$7,760	$0	$0	$0	$7,760	$7,760

Dimmit	Needs Satisfied	*	*	*	*	*	*
Frio	Needs Satisfied	*	*	*	*	*	*

Table 7.7 (Continued): Socio-economic impacts results from 2011 Regional Water Plans.

Gonzales	Needs Satisfied	*	*	*	*	*	*
Guadalupe	Municipal	$11,780	$13,865	$18,150	$32,188	$30,322	$25,502
Karnes	Municipal	$9,011	$18,867	$28,839	$31,147	$32,065	$34,289
La Salle	Needs Satisfied	*	*	*	*	*	*
Medina	Municipal	$9,493	$7,342	$7,545	$10,195	$10,721	$10,845
Medina	Irrigation	$174	$174	$174	$174	$174	$0
Uvalde	Municipal	$14,089	$14,139	$14,180	$14,202	$14,220	$14,247
Region M							
County	**Sector**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Maverick	Municipal	$833	$1,285	$1,622	$5,772	$6,348	$7,040
Maverick	Irrigation	$397	$200	$200	$200	$200	$200
Webb	Municipal	$899	$1,387	$5,941	$12,445	$14,410	$23,944
Webb	Irrigation	$293	$293	$293	$293	$293	$293
Webb	Steam-electric	$0	$0	$0	$0	$9,645	$9,645

Summary Report for Task 6: Evaluation and Critique of the State's Groundwater Availability Models for the Carrizo-Wilcox Aquifer

1.0 Introduction and Background

This summary report prepared by the Bureau of Economic Geology (BEG) is submitted to fulfill requirements of Task 6 of the Texas Commission on Environmental Quality (TCEQ) Carrizo-Wilcox Aquifer Study (the Study), Project 582-8-75374-119. Task 6 directs the BEG to examine and critique Groundwater Availability Models (GAMs) to:

(a) Assess model runs of representative pumpage scenarios in the northern, central, and southern Carrizo Wilcox Aquifer

(b) Estimate spatial and temporal variability of recharge and modeling of recharge

(c) Evaluate sources of water for pumpage (outcrop zone [increased recharge, reduced discharge], confined zone [change in aquifer storage, increased recharge from overlying Queen City Sparta), timescales for impacts of pumpage on outcrop and Queen City Sparta Aquifer.

The current Queen City Sparta Groundwater Availability Models (QCSP GAMs) include the Carrizo-Wilcox Aquifer. It was built upon the original Carrizo-Wilcox GAM (Dutton et al., 2003) by adding the Queen City and Sparta Aquifers and it superseded the original Carrizo-Wilcox GAM. A simplified cross section of the Carrizo-Wilcox Aquifer is shown in Figure 8.1 and the conceptual groundwater flow model for the Queen City and Sparta GAM is shown in Figure 8.2. In this text, we refer QCSP GAM as "Carrizo-Wilcox Queen City Sparta GAMs" or simply GAMs.

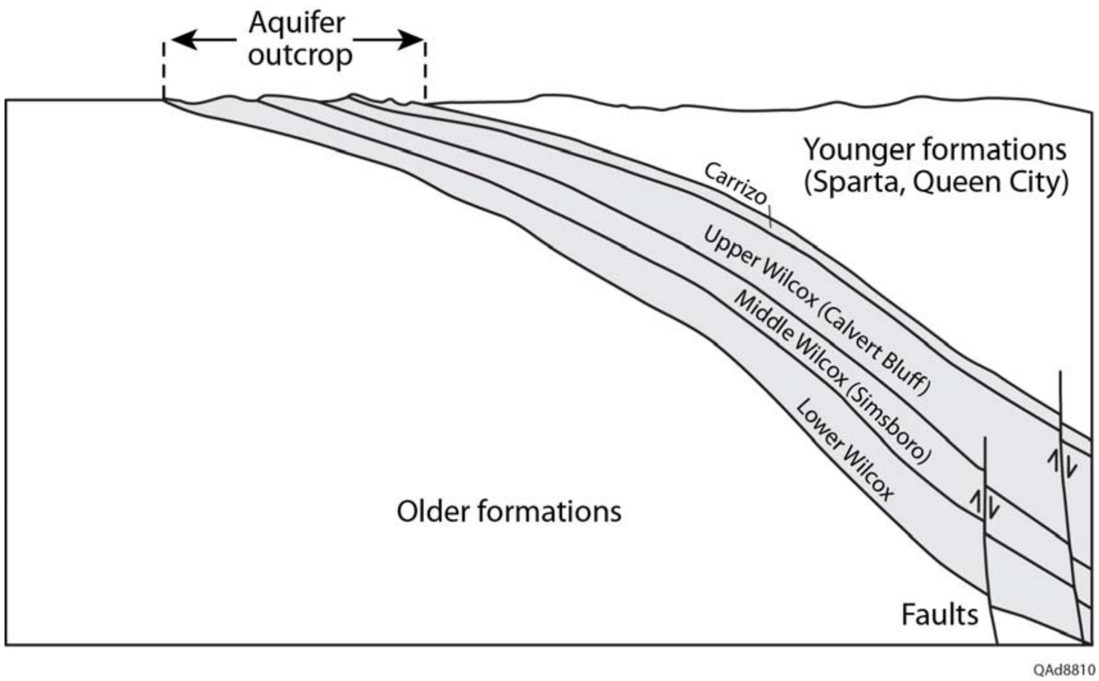


Figure 8.1. Simplified cross-section of the Carrizo-Wilcox Aquifer (Modified from Kelley et al. (2004))

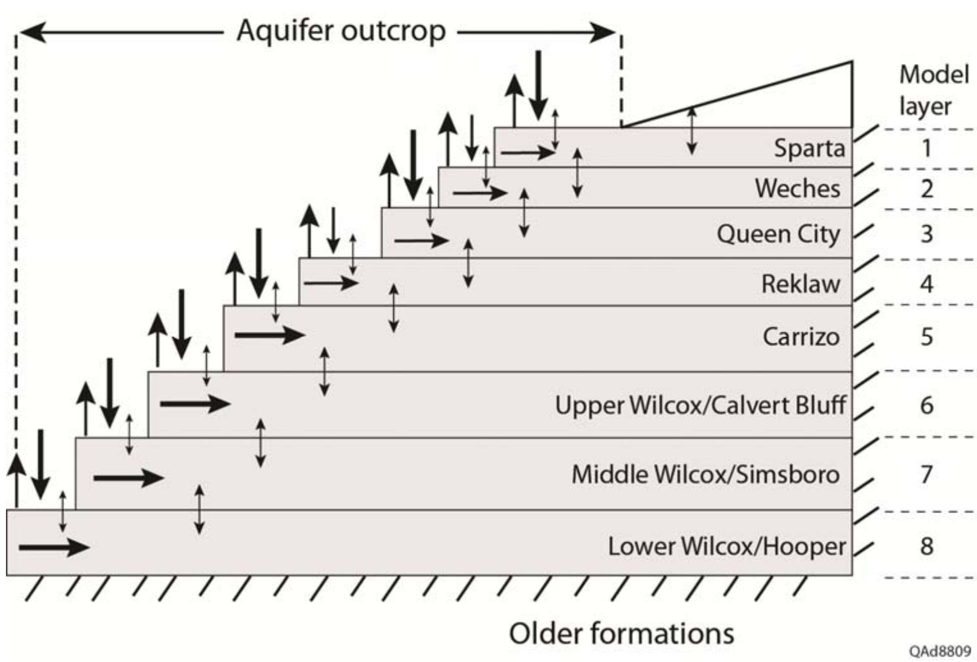


Figure 8.2. The conceptual groundwater flow model for the Queen City Sparta GAM **(**adopted from Kelley et al. (2004))

A general critique of the GAMs was conducted. The value of the GAMs in the process of establishing desired future conditions was recognized. Important factors to consider in future updates of the GAMs include: role of faults in the flow system because barrier faults significantly reduce water availability for future pumpage, importance of groundwater-surface water interactions, improved recharge estimates, incorporating the Yegua Jackson Aquifers and the Brazos Valley Alluvium aquifer into the Carrizo Wilcox Queen City Sparta GAM, refining the groundwater pumping database, linking steady state and transient models, including groundwater quality, and incorporating new information into the GAMs. One of the critical issues with respect to the conceptual model is whether the central Carrizo Wilcox model should include **faults** as barriers to flow and evaluation of the location of such faults. Universal application of faults as barriers in the Central Carrizo Wilcox Queen City Sparta GAM significantly impedes horizontal flow. Modeling analysis indicates that the impact of these faults may be more important in predicting future drawdown than it was for transient calibration. Current stresses to the system from pumping are too low to evaluate the impacts of these faults on horizontal flow in the system. Future GAMs should consider models with and without faults to provide bounding estimates on groundwater availability. **Groundwater–surface-water interactions** are also an important component of the GAM. Because pumpage captures groundwater discharge to streams, it is important that simulations of groundwater–surface-water interactions are realistic and reliable. Although current GAMs simulate groundwater-surface water interactions, incorporating an additional shallow layer into the Carrizo-Wilcox Queen City Sparta GAM may improve simulations of these interactions and allow an improved approximation of the potential to reduce baseflow discharge to streams and capture of surface water by future pumpage. Evaluating impacts of pumpage on stream baseflow is extremely important for future environmental flows. **Recharge** is a critical parameter for groundwater availability models. The impact of grid resolution on recharge estimates in the models also needs to be considered. Recharge rates are important for model calibration because they help to constrain the hydraulic conductivity field (Kelley et al., 2004). Field studies should be conducted to better quantify groundwater recharge to the aquifer. Improvements in the **groundwater pumping** database are very important and should include reevaluation of groundwater production in Brazos and Robertson Counties (by Bryan College Station, TAMU and industrial commercial pumping). Because most of the pumping in the aquifer is in the Simsboro Formation in GMA 12, additional information should be collected or any existing data used to better describe the thickness and hydraulic conductivity distribution of this unit. The current Carrizo Wilcox model within the Queen City Sparta GAMs uses the predevelopment period for the **steady state** simulation; however, the **transient simulation** does not begin until 1980. Groundwater pumping expanded significantly between predevelopment and 1980, and this expansion is not captured in the GAMs. Two different approaches could be used to address this problem: (1) begin the transient simulation in the 1920s and 1930s and simulate the expansion of pumpage from that time similar to the original Carrizo Wilcox GAM (Dutton et al., 2003) or (2) use 1980s data to simulate steady state conditions if the aquifer were relatively stable at that time. These different options should be considered. Future revisions of the GAMs should incorporate any basic data collected in the aquifers since the GAMs were developed. Such information should include structure data and hydraulic properties, including hydraulic conductivity and storativity, and calibration data, including hydraulic heads and stream gain/loss data. While the Texas Water Development Board (TWDB) collects data on these parameters throughout the aquifer, the Groundwater Conservation Districts are also collecting substantial quantities of data that should be incorporated into TWDB databases. Detailed pumping tests and water level data from mines in the region, including the Sandow Mine, Walnut Creek Mine, and others, should be evaluated and fully used in the GAMs. **Uncertainties** in conceptual models and input parameters, such as recharge and ET, and hydraulic parameters, should be considered in GAM modeling. Uncertainties in the conceptual models could be considered through bounding calculations, e.g. models with and without faults in the Central Carrizo Wilcox Aquifer. Model-sensitivity analyses should be used to guide future data collection in areas where the model is sensitive to different parameters. It is important that stakeholders and others are aware of uncertainties in model data and calibration and do not try to use the models beyond the level at which the data can support them. **Groundwater quality** was not simulated by the GAMs; however, groundwater quality is a critical aspect of groundwater availability. The GAM program should consider expanding simulations to include groundwater quality. **Postaudits** can be done at this stage to test the reliability of model predictions. The Carrizo-Wilcox Queen City Sparta GAM was calibrated from 1980 through 1999. As stated earlier, new information has been collected since then. Postaudits involve using the existing GAM structure and new boundary conditions to assess how model output compares with new available target information. It should be recognized that these enhancements of the GAMs will require additional data collection beyond what is currently being collected.

(a) Model runs of representative pumpage scenarios for GMA 11, 12, and 13 were based on the desired future conditions obtained from TWDB staff. Models for establishing DFCs were run by TWDB staff for GMAs 11 and 13 and by consultants for GMA 12. Mean drawdowns corresponding to DFCs for the GMA regions are as follows:

Simsboro: GMA 12: ~100 to 300 ft

Middle Wilcox: GMA 11: 15 ft and GMA 13: ~ 25 ft

Carrizo: GMA 11: 38 ft; GMA 12: ~ 60 ft, GMA 13: 31 ft

(b) Spatial and temporal variations in groundwater recharge were reevaluated for the Groundwater Availability Models. Recharge rates were estimated using a variety of different approaches. Recharge rates based on groundwater chloride data from the TWDB database range from 0.4 in/yr (2% of precipitation) in the semiarid southern part to 4.0 in/yr (8% of precipitation) in the humid northern part of the aquifer. Point recharge rates based on unsaturated zone chloride data in the central Carrizo Wilcox aquifer are spatially variable (0.7–1.6 in/yr) but generally consistent with those based on groundwater chloride data. Recharge rates based on unsaturated zone modeling results range from 0.4 in/yr (2% of precipitation) in the southern part to 5.1 in/yr (10% of precipitation) in the northern part of the aquifer.

(c) Impacts of pumpage on water resources depend on the source of water for pumpage. Prior to groundwater development, groundwater recharge to the aquifer equaled groundwater discharge through streams, evapotranspiration (ET), and deep recharge to the confined portion of the aquifer. Water for pumpage associated with groundwater development can be derived from various sources, including aquifer storage, increased recharge, and/or decreased discharge. The transient GAM model indicates that after decades of pumping (1999), groundwater storage represents a significant fraction of total pumpage. Total cross-formational flow is reversed in all portions of the aquifer from the overlying Queen City Aquifer. Analysis of sources of water for pumpage related to the desired future conditions for 2060 shows that aquifer storage contributes 44 to 58% of pumpage. Cross-formational flow contributes 40% of pumpage in GMA 13 because most pumpage is from the Carrizo Aquifer, which is adjacent to the overlying Queen City Aquifer. In contrast, pumpage in GMA 12 is mostly from the Simsboro Aquifer and separated from the Queen City Aquifer by the Carrizo Aquifer, resulting in low cross-formational flow (19%). Low cross-formational flow in GMA 11 (19%) may be related to generally low overall pumpage in the Carrizo Aquifer. Understanding the sources of pumpage is important for determining impacts of pumpage on the flow system. Temporal variability in water sources for pumpage shows that aquifer storage contributions decrease from 100% to ~50% over the 50-yr modeling period, whereas contributions from cross-formational flow, streams, and ET increase through time. It will be important to design monitoring programs to evaluate these changes through time.

2.0 Critique of Groundwater Availability Models and Recommendations for Future Revisions

The current Carrizo-Wilcox Queen City Sparta GAMs are extremely useful for analyzing regional groundwater flow in the Carrizo Wilcox Aquifer and have been instrumental in assessing compatibility and physical possibility of the proposed desired future conditions. Several factors need to be considered in the next update of the GAMs, including the conceptual model, model structure, data inputs, parameter values, uncertainty analyses, groundwater quality, and postaudits. Aspects of the conceptual model that need to be considered include simulation of faults, groundwater recharge, and groundwater–surface-water interactions. Many of the model limitations described in Kelley et al. (2004) for the Carrizo Wilcox Queen City Sparta GAM apply to the Carrizo Wilcox aquifer and were reviewed when developing the following critique.

One of the critical issues with respect to the conceptual model is whether the central Carrizo Wilcox model should include **faults** as barriers to flow and evaluation of the location of such faults. Universal application of faults as barriers in the Central Carrizo Wilcox Queen City Sparta GAM significantly impedes horizontal flow. The hydraulic conductivity values used for these faults are generally not supported by data. Modeling analysis indicates that the impact of these faults may be more important in predicting future drawdown than it was for transient calibration. Current stresses to the system from pumping are too low to evaluate the impacts of these faults on horizontal flow in the system. Therefore, additional studies need to be conducted to assess these faults, particularly those near the outcrop zone to determine whether they are acting as flow barriers. Well log information should be examined to quantify offsets across the faults and the potential for flow across the faults, considering the geology on either side of the faults. Any existing data from pumping tests should be evaluated to assess how the faults function in the system. Future GAMs should consider models with and without faults to provide bounding estimates on groundwater availability. The sensitivity of the model output to the faults should be evaluated. Monitoring approaches to quantify impacts of faults should be devised as the aquifer is increasingly developed and stresses to the system increase.

Groundwater–surface water interactions are also an important component of the GAM. Because pumpage captures groundwater discharge to streams, it is important that simulations of groundwater–surface water interactions are realistic and reliable. Although current GAMs simulate groundwater-surface water interactions, the current grid resolution of the models, particularly the vertical resolution, may limit the ability of the GAMs to reliably simulate groundwater–surface water interactions. Incorporating an additional shallow layer into the model may improve simulations of these interactions and allow an improved approximation of the potential to reduce baseflow discharge to streams and capture surface water. Stream gain/loss studies are extremely limited, and additional studies should be conducted to provide information to calibrate the GAMs. Groundwater evapotranspiration (ET) adjacent to streams should also be quantified because it provides a source of water for future pumpage, but may be at the expense of vegetation reliant on that water.

Recharge is a critical parameter for groundwater availability models. Recharge in the GAMs was varied with precipitation, soil texture, and topography. There is limited information on recharge rates for the Carrizo Wilcox Aquifer. The impact of grid resolution on recharge estimates in the models also needs to be considered. Restriction of recharge rates in the northern Carrizo Wilcox Queen City Sparta GAM to 2 inches per year, relative to independent estimates from groundwater data of up to 4.5 inches per year, is attributed to limitations of the coarse grid resolution in the model. The 1-mile grid space does not allow simulation of small streams discharging from the system; therefore, the simulated recharge should be considered an effective recharge that takes into account the inability to simulate high-resolution discharge from the system. Recharge rates are important for model calibration because they help to constrain the hydraulic conductivity field (Kelley et al., 2004). Field studies should be conducted to better quantify groundwater recharge to the aquifer.

The **model structure** should consider incorporating the Yegua Jackson Aquifers and the Brazos River Alluvium aquifer into the Carrizo Wilcox Queen City Sparta GAMs, expanding the GAM models vertically. This change will allow interactions among aquifers to be more fully evaluated.

Groundwater pumping is a critical input to the model, and uncertainties in pumping should be considered in the simulations. Kelley et al. (2004) emphasized the importance of refining the pumping data with regard to location and volume to improve the reliability of the GAMs. Specific examples include reevaluation of groundwater production in Brazos and Robertson Counties (by Bryan College Station, TAMU and industrial commercial pumping) and modeling to mimic observations both in the downdip portion of the Simsboro, where there has been drawdown near the well fields, and near the outcrop, where there has been limited drawdown. Because most of the pumping in the aquifer in GMA 12 is in the Simsboro Formation, additional information should be collected or any existing data used to better describe the thickness and hydraulic conductivity distribution of this unit. Information on pumping test data and sandstone thickness should be evaluated to develop predictive relationships between these two parameters.

Steady State and Transient Models: The current Carrizo Wilcox model within the Queen City Sparta GAMs uses the predevelopment period for the steady state simulation; however, the transient simulation does not begin until 1980. Groundwater pumping expanded significantly between predevelopment and 1980, and this expansion is not captured in the GAMs. The aquifer may be in a long-term transient in response to pumpage when the transient simulation begins in 1980, and this transient would not be reflected in the GAMs. Two different approaches could be used to address this problem: (1) begin the transient simulation in the 1920s and 1930s and simulate the expansion of pumpage from that time similar to the original Carrizo Wilcox GAM or (2) use 1980s data to simulate steady state conditions if the aquifer were relatively stable at that time. These different options should be considered.

New Information: The future revision of the GAM should incorporate any basic data collected in the aquifers since the GAMs were developed. Such information should include structure data and hydraulic properties, including hydraulic conductivity and storativity, and calibration data, including hydraulic heads and stream gain/loss data. While TWDB collects data on these parameters throughout the aquifer, the Groundwater Conservation Districts are also collecting substantial quantities of data that should be incorporated into TWDB databases. Detailed pumping tests and water level data from mines in the region, including the Sandow Mine, Walnut Creek Mine, and others, should be evaluated and fully used in the GAMs. Data in the northeast part of the model in Limestone, Freestone, and Leon Counties should be reviewed, with particular focus on the region in the vicinity of the Limestone Station Mine, where pumping from the Calvert Bluff Aquifer has occurred for the past few decades.

GAMS to date have focused on the physical flow system; however, the recent request for Statements of Qualifications from the TWDB will result in work with groundwater chemistry and isotopes, which will be used to constrain the conceptual models of the flow system and should lead to significant improvements in the GAMs.

Uncertainties should be considered in the GAM modeling. Uncertainties in the conceptual models could be considered through bounding calculations, e.g. models with and without faults in the Central Carrizo Wilcox Aquifer. Uncertainties in input parameters, such as recharge and ET, are difficult to quantify. Information on hydraulic parameters may be insufficient to conduct a rigorous uncertainty analysis. Model sensitivity analyses should be used to guide future data collection in areas where the model is sensitive to different parameters. It is important that stakeholders and others are aware of uncertainties in model data and calibration and do not try to use the models beyond the level at which the data can support them.

Groundwater quality was not simulated by the GAMs; however, groundwater quality is a critical aspect of groundwater availability. Although existing GAMs include flow in brackish groundwater zone, the GAM program should consider expanding simulations to explicitly simulate groundwater quality.

Postaudits can be done at this stage to test the reliability of model predictions. The Carrizo-Wilcox Queen City Sparta GAM was calibrated from 1980 through 1999. As stated earlier, new information has been collected since then. Postaudits involve using existing GAM structure and new boundary conditions to assess how model output compares with new available target information.

3.0 Assessment of Model Runs of Representative Pumpage Scenarios in the Northern, Central, and Southern Carrizo Wilcox Aquifer

The most representative model runs for the Carrizo Wilcox Aquifer are those developed for desired future conditions. These are described in the following section and are based on submissions from the GMA regions to the TWDB.

GMA 11 Desired Future Conditions

Pumpage and drawdown related to the Desired Future Conditions for GMA 11 were described by Oliver (2010a) and Shi and Oliver (2010). The members of GMA 11 submitted pumping requests to the TWDB. TWDB staff then ran the groundwater availability model for the northern portion of the Carrizo Wilcox Aquifer and determined the mean drawdown on the basis of the submitted pumpage for the 51-yr predictive period from 2010 through 2060. The resultant average drawdown for the Carrizo Wilcox, Queen City, and Sparta Aquifers is 17 ft. Recharge rates for the simulation were based on average precipitation from 1961 through 1990. Pumping in the Carrizo Wilcox, Queen City, and Sparta Aquifers was provided by the members of GMA 11. Pumping for the last year of the groundwater availability model (1999) was adjusted in each county to match the requested pumping for desired future conditions. Decreases in pumping were implemented by reducing pumping in each cell by a uniform factor to preserve the original pumping distribution. Increases in pumping were uniformly distributed among cells that had pumping in 1999, which corresponded to the last year of the historical calibration period. The total pumping from the Carrizo Wilcox Aquifer that achieves desired future conditions ranges from 275,000 af/yr in 2010 to 264,000 af/yr in 2060. Figure 8.3 and Table 8.1 show the amount of pumping by county in 2060. Pumping is greatest in Angelina, Nacogdoches, Rusk, Smith, and

Wood Counties. Table 8.2 shows the desired future conditions adopted by members of Groundwater Management Area 11. The corresponding drawdown in the Carrizo Wilcox Aquifer is greatest in Gregg, Henderson, Smith, Upshur, and Wood Counties.

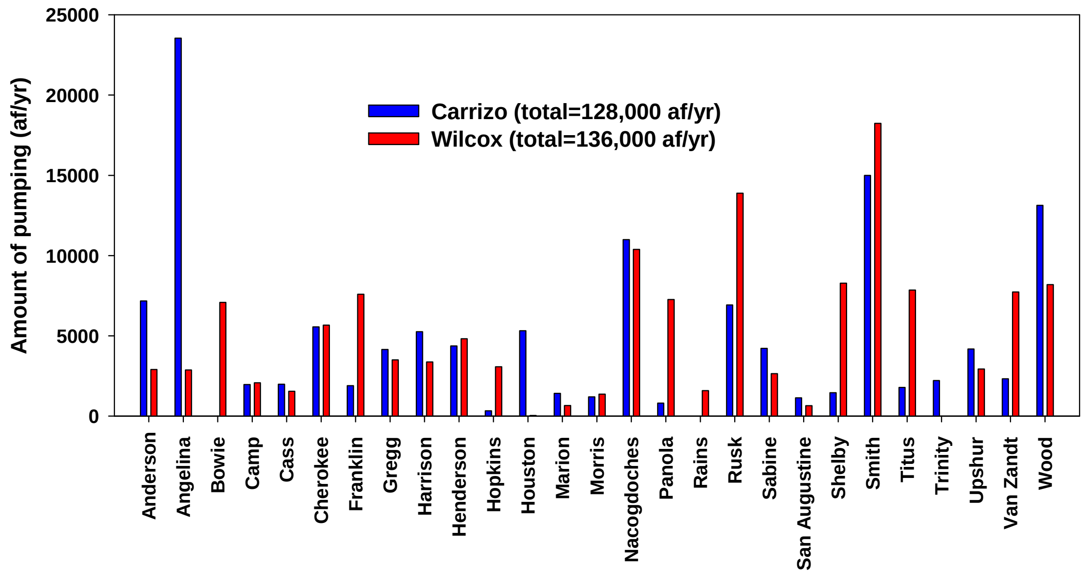


Figure 8.3: Carrizo-Wilcox pumping by county in 2060 in GMA 11 area from desired future condition model run.

Table 8.1: Carrizo-Wilcox pumping by county in 2060 in GMA 11 area from desired future condition model run.

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Wilcox Total	Total
Anderson (ACUWCD)	282	107	15	7	129	411
Anderson (NTVGCD)	6,896	2,169	336	267	2,772	9,668
Angelina	23,540	2,874	0	0	2,874	26,414
Bowie	na	1,542	5,541	0	7,083	7,083
Camp	1,963	1,110	968	0	2,078	4,041
Cass	1,989	882	663	0	1,545	3,534
Cherokee	5,556	5,647	19	0	5,666	11,222
Franklin	1,895	1,257	6,332	0	7,589	9,484
Gregg	4,153	2,380	1,116	0	3,496	7,649
Harrison	5,262	1,746	1,627	4	3,377	8,639
Henderson	4,365	1,837	1,364	1,619	4,820	9,185
Hopkins	325	203	2,864	0	3,067	3,392
Houston	5,317	38	0	0	38	5,355
Marion	1,420	425	232	0	657	2,077
Morris	1,193	404	961	0	1,365	2,558
Nacogdoches	11,000	9,707	678	0	10,385	21,385

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Wilcox Total	Total
Panola	810	770	5,764	725	7,259	8,069
Rains	na	506	1,001	76	1,583	1,583
Rusk	6,927	5,156	8,731	0	13,887	20,814
Sabine	4,221	1,695	471	471	2,637	6,858
San Augustine	1,130	645	5	0	650	1,780
Shelby	1,451	3,316	4,855	106	8,277	9,728
Smith	14,987	13,673	4,566	0	18,239	33,226
Titus	1,791	1,905	5,941	0	7,846	9,637
Trinity	2,215	0	0	0	0	2,215
Upshur	4,182	2,321	612	0	2,933	7,115
Van Zandt	2,322	1,541	4,129	2,059	7,729	10,051
Wood	13,124	5,906	2,281	0	8,187	21,311
Total	128,316	69,762	61,071	5,334	136,167	264,483

Table 8.2: Desired future conditions adopted by members of GMA 11 in terms of average drawdown in feet.

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Overall
Anderson (ACUWCD)	35	26	12	5	15
Anderson (NTVGCD)	36	26	11	4	16
Angelina	42	5	-18	-3	11
Bowie	na	21	0	0	1
Camp	18	17	39	0	19
Cass	10	7	7	0	8
Cherokee	32	32	15	10	18
Franklin	-3	7	19	0	11
Gregg	42	49	56	79	35
Harrison	24	13	5	4	9
Henderson	41	32	27	15	23
Hopkins	-12	-15	-28	0	-26
Houston	35	12	2	-2	8
Marion	21	15	15	0	16
Morris	29	25	23	0	21
Nacogdoches	14	11	-10	-6	4
Panola	11	2	1	4	2
Rains	na	7	-10	-5	-8
Rusk	6	6	23	21	12
Sabine	24	13	6	5	10
San Augustine	20	9	-3	-2	3
Shelby	23	-3	3	1	1
Smith	103	118	92	76	68
Titus	31	14	5	0	9
Trinity	33	-3	-7	-1	6
Upshur	56	66	66	97	44
Van Zandt	31	13	17	11	14
Wood	110	83	55	114	59
Total	38	26	15	11	17

GMA 12 Desired Future Conditions

Pumpage and drawdown related to the desired future conditions for GMA 12 were described by Oliver (2010b). The Groundwater Conservation Districts in GMA 12 had several consultants develop desired future conditions for the Carrizo Wilcox Aquifer. The Groundwater Availability Model for the Carrizo Wilcox, Queen City, and Sparta Aquifers was run with the GMA 12 7B pumpage file. An independent analysis was performed by the TWDB to confirm that desired future conditions are physically possible and that the proposed pumping achieves desired future conditions. Estimated total pumpage from the Carrizo Wilcox Aquifer that achieves desired future conditions increases from 196,000 af/yr in 2010 to 257,000 af/yr in 2060. Figure 8.4 and Table 8.3 show the amount of pumping in 2060 by county. Pumpage is highest in Brazos County and decreases in the following order: Robertson, Burleson, Bastrop, and Lee Counties. Most of the pumpage is concentrated in the Simsboro Aquifer. Drawdown is also greatest in the Simsboro Aquifer in those GCDs whose member counties have high pumpage, ranging from 115 to 300 ft. In contrast, drawdown is much lower in the Carrizo Aquifer in these Groundwater Conservation Districts (47–65 ft). (Table 8.4)

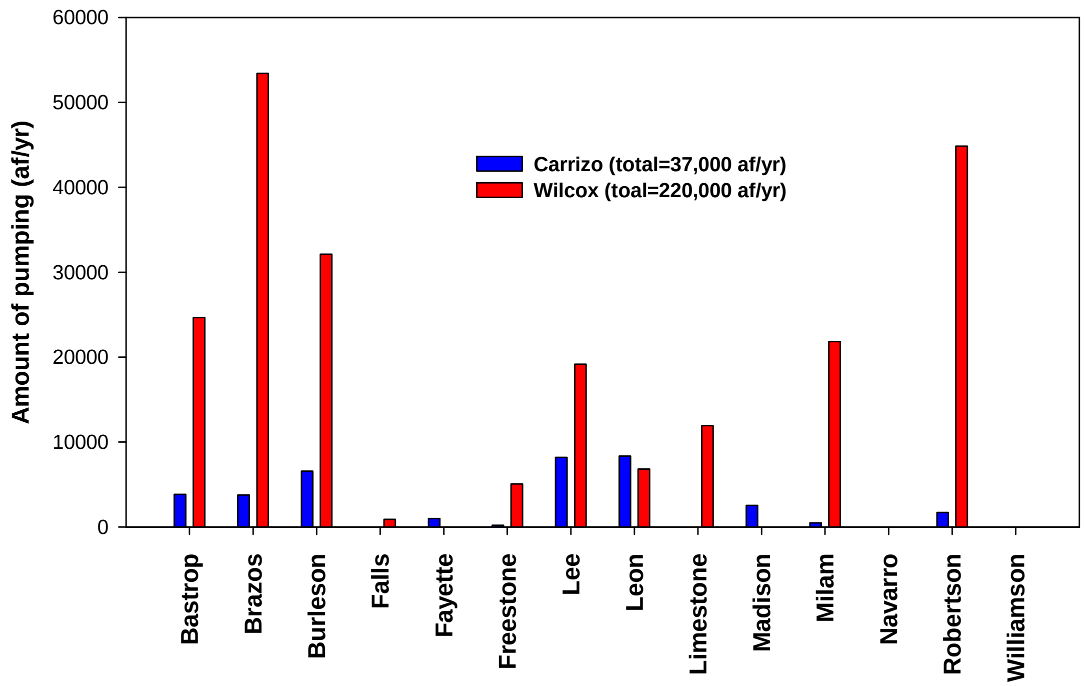


Figure 8.4: Carrizo-Wilcox pumping by county in 2060 in GMA 12 area from desired future condition model run.

Table 8.3: Carrizo-Wilcox pumping by county in 2060 in GMA 12 area from desired future condition model run.

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Wilcox Total	Total
Bastrop	3,845	3,685	18,423	2,545	24,653	28,498
Brazos	3,766	0	53,403	0	53,403	57,169
Burleson	6,578	91	30,409	1,623	32,123	38,701
Falls	na	na	146	749	895	895
Fayette	1,000	0	0	0	0	1,000
Freestone	190	707	3,535	827	5,069	5,259
Lee	8,207	300	18,826	47	19,173	27,380
Leon	8,356	3,205	3,635	0	6,840	15,196
Limestone	na	235	10,187	1,496	11,918	11,918
Madison	2,542	0	0	0	0	2,542
Milam	481	947	18,092	2,799	21,838	22,319
Navarro	na	0	4	11	15	15
Robertson	1,730	1,755	42,782	316	44,853	46,583
Williamson	na	0	2	5	7	7
Total	36,695	10,925	199,444	10,418	220,787	257,482

Table 8.4: Desired future condition adopted by members of GMA 12 in terms of average drawdown in feet.

GCD or County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox
Brazos Valley	47	106	270	170
Fayette County	60	na	na	na
Lost Pines	47	99	237	129
Mid-East Texas	55	70	115	95
Post Oak Savannah	65	140	300	180
Falls County	na	na	0	20
Limestone County	na	9	43	40
Navarro County	na	0	1	1
Williamson County	na	-10	50	55

<u>GMA 13 Desired Future Conditions</u>

Members of GMA 13 submitted pumping amounts and distributions to the TWDB, which represented the base case (1). Three additional pumping scenarios were considered, with additional pumping in (2) Gonzales County, (3) Caldwell County, and a combination of scenarios 2 and 3. The four model scenarios were run with pumping scaled by 70 to 130% in 10% increments. TWDB staff then ran the GAM for the southern portion of the Carrizo Wilcox, Queen City, and Sparta Aquifers and determined the average drawdown on the basis of the submitted pumpage for the 61-yr predictive period from 2000 to 2060. The simulations used average recharge, ET, and initial streamflows based on historic calibration runs for 1981 through 1999. The pumping associated with scenario four was selected as the final.

The estimated total pumpage that results in the desired future conditions for GMA 13 ranges from 376,000 acre-feet per year in 2010 to 404,000 acre feet per year in 2060. Figure 8.5 and Table 8.5 show the amount of pumping in 2060 by county. Most (68%) of the pumping is in the Carrizo Aquifer. The average drawdown in the Carrizo-Wilcox, Queen City, and Sparta Aquifers is 23 ft (Table 8.6). Average drawdown is low to moderate in the Queen City (7 ft) and Sparta (9 ft) Aquifers but is higher in the Carrizo (31 ft) and Wilcox (31 ft) Aquifers.

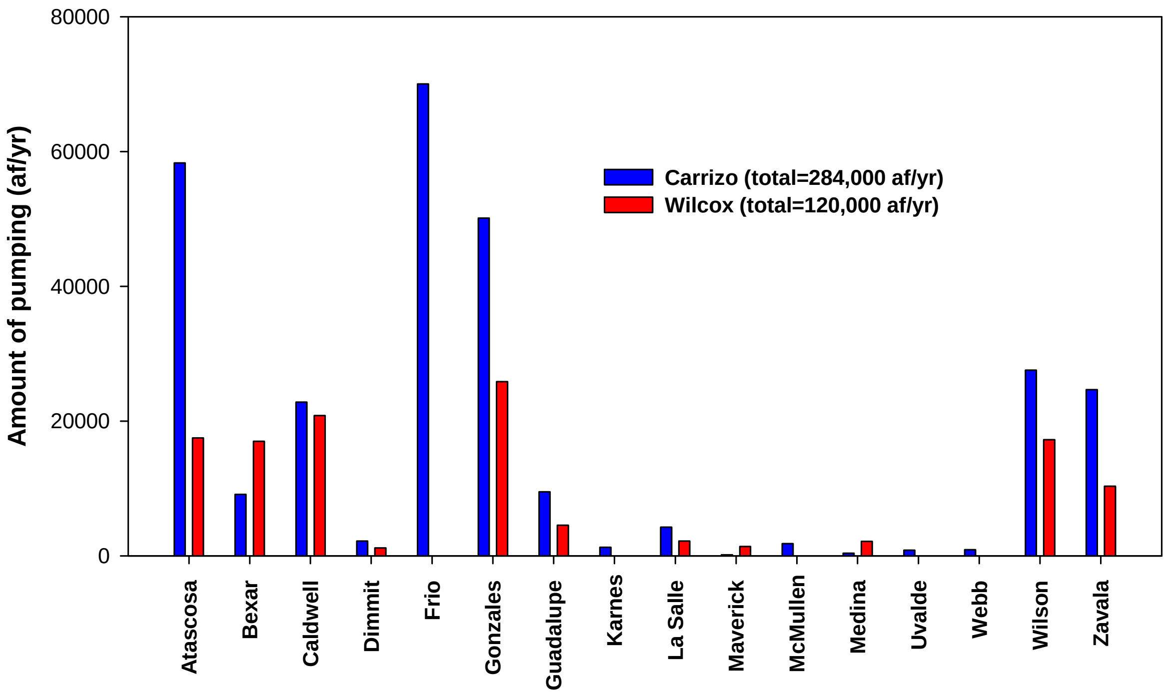


Figure 8.5: Carrizo-Wilcox pumping by county in 2060 in GMA 13 area from desired future condition model run.

Table 8.5: Carrizo-Wilcox pumping by county in 2060 in GMA 13 area from desired future condition model run.

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Wilcox Total	Total
Atascosa	58,308	250	250	17,000	17,500	75,808
Bexar	9,107	0	0	17,000	17,000	26,107
Caldwell	22,809	0	7,372	13,441	20,813	43,622
Dimmit	2,188	991	142	38	1,171	3,359
Frio	70,030	0	0	0	0	70,030
Gonzales	50,121	0	9,577	16,272	25,849	75,970
Guadalupe	9,500	0	2,994	1,549	4,543	14,043
Karnes	1,280	0	0	0	0	1,280
La Salle	4,263	1,952	189	50	2,191	6,454
Maverick	143	136	259	992	1,387	1,530
McMullen	1,819	0	0	0	0	1,819
Medina	400	0	1,248	886	2,134	2,534
Uvalde	828	0	0	0	0	828
Webb	896	13	6	1	20	916
Wilson	27,549	125	121	17,000	17,246	44,795
Zavala	24,649	6,316	3,676	328	10,320	34,969
Total	283,890	9,783	25,834	84,557	120,174	404,064

Table 8.6: Desired future condition adopted by members of GMA 13 in terms of average drawdown in feet.

County	Carrizo	Upper Wilcox	Middle Wilcox	Lower Wilcox	Wilcox Overall	Overall
Atascosa	74	74	85	145	102	62
Bexar	64	48	37	136	94	90
Caldwell	97	93	52	65	64	63
Dimmit	-17	-17	-22	-18	-19	-15
Frio	39	38	31	35	35	24
Gonzales	94	94	88	82	88	65
Guadalupe	54	52	20	31	30	32
Karnes	85	85	61	88	78	57
La Salle	12	12	-1	-9	1	6
Maverick	-8	-12	-11	-3	-7	-7
McMullen	45	44	12	9	22	29
Medina	29	29	28	28	28	28
Uvalde	1	0	12	30	22	19
Webb	-4	-3	-1	-3	-2	-4
Wilson	75	75	78	153	102	68
Zavala	2	0	-5	-3	-3	-5
Overall	31	31	25	38	31	23

4.0 Estimation of Spatial and Temporal Variability of Recharge and Modeling of Recharge

Groundwater recharge is a critical parameter for managing water resources of aquifers. Recharge is generally defined as addition of water to an aquifer, mostly derived from the land surface.

4.1 Previous Studies

Variations in recharge caused by pumpage during postdevelopment have been described in many previous studies, as reviewed in Kelley et al. (2004). In the southern Carrizo Wilcox Aquifer, under predevelopment conditions, prior to 1900, western streams such as the Nueces and Frio Rivers were likely gaining streams, given historical occurrence of flowing wells. By 1904 there were 30 artesian wells in the Carrizo Springs area alone, with average flows from 40 to 300 gpm. The Dimmit County area was famous for spring-fed creeks that supported travelers and wildlife from early times. Within 40 yr of drilling the first well, virtually all of the springs and creeks they fed were dry. By 1910, farmers in some areas had to pump their wells (http://www.historicdistrict.com/Genealogy/Dimmit/dimmit.htm). Hamlin (1988) reported that, prior to significant production (before 1900), Carrizo wells flowed at elevations up to 700 ft amsl. By the 1930s, flowing wells were limited to elevations below 500 ft amsl, and by 1972, only certain wells flowed at elevations below 360 ft amsl. In the eastern portion of the southern Carrizo Wilcox Aquifer, flowing Carrizo wells still exist in areas such as Gonzales County.

A transient groundwater model developed by LBG Guyton HDR (1998) was used to evaluate impacts of groundwater development on the flow system from 1942 through 1994. The simulation results showed gain/loss for each major river in the model study area from 1942 through 1994 on a 10-year moving average basis. Simulation results indicate that the San Marcos and Guadalupe Rivers were gaining streams from 1942 through 1994, gaining less than 100 af/yr/mi of outcrop from 1980 through 1994. The San Antonio River changed from strongly gaining (over 400 af/yr/mi) to losing in the 1960s more than 400 af/yr/mi of outcrop by 1990. The change from gaining to losing occurred in the late 1960s. The Atascosa River also changed from gaining to losing in the early 1970s to becoming slightly losing (less than 50 af/yr/mi) from 1980 through 1994. Cibolo Creek also changed from gaining 200 af/yr/mi in the 1940s to losing up to 100 af/yr/mi in the late 1970s through 1994. Their analysis predicted that San Miguel Creek, the Nueces River, and the Frio River were losing streams throughout their analysis period (1942–1994). Their results predicted that the Nueces and Frio Rivers lose, on average, approximately 500 af/yr/mi of outcrop.

Model simulation results are supported by gain/loss studies conducted in various streams and reviewed by Slade et al. (2002). Gain/loss studies indicated that the Nueces River was losing on the basis of studies conducted from 1925 through 1933 and in 1940. Cibolo Creek was found to be gaining along a 62-mi length in September 1949 at a rate of 163 af/yr/mi. Medina Creek was found to be losing in May 1925 at a gain/loss rate of -42 af/yr/mi.

4.2 Materials and Methods

4.3 Site Description

The Carrizo Wilcox Aquifer is typical of coastal plain dipping aquifers that have a generally narrow, unconfined outcrop section and a large confined section (Figure 8.6). The aquifer extends from the Rio Grande in South Texas to East Texas. For groundwater modeling purposes, the Carrizo Wilcox Aquifer has been subdivided into southern (Rio Grande to surface-water divide between Guadalupe and Colorado Rivers), central (San Antonio River to part of East Texas Basin), and northern (surface-water divide between Trinity and Brazos Rivers to Red River in Louisiana and Arkansas) sections. The geology of the Carrizo Wilcox Aquifer was described in detail by Deeds et al. (2009). In the Central Carrizo Wilcox Aquifer, the geology consists of the following formations, from oldest to youngest: Hooper, Simsboro, Calvert Bluff, and Carrizo Formations. The Hooper and Calvert Bluff Formations are semiconfining units, and the Simsboro and Carrizo Formations are aquifers. In most of the footprint of the southern and northern models, the Simsboro Formation cannot be distinguished, and the Wilcox Formation is subdivided into the lower, middle, and upper Wilcox. The Carrizo Wilcox Aquifer is overlain by the Queen City Aquifer, separated by the Reklaw Formation, which is a confining unit.

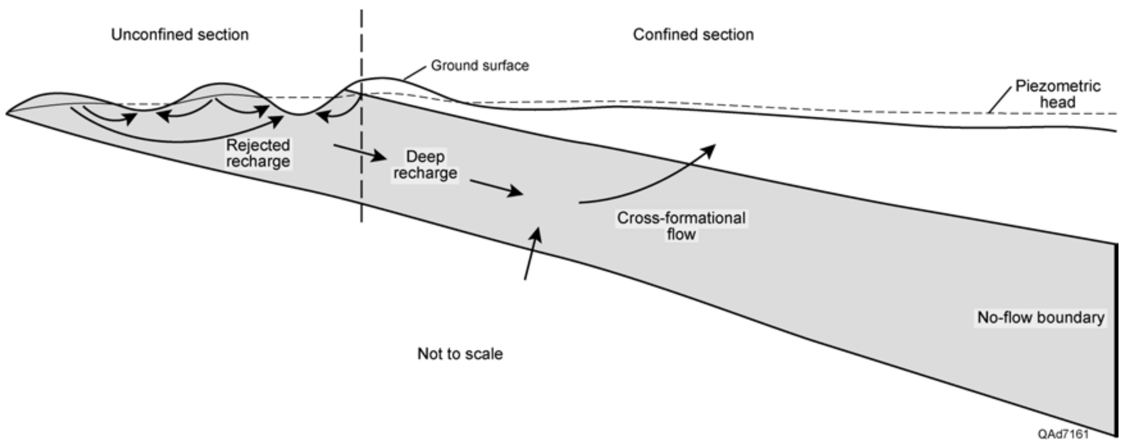


Figure 8.6: Conceptual diagram of groundwater flow components under natural (predevelopment) conditions in the Carrizo-Wilcox Aquifer.

Previous studies indicate that there is more recharge through the predominantly sandy Simsboro Formation and other sandy sections of the Carrizo and Wilcox formations than through the clay-rich Hooper, Calvert Bluff, and Reklaw Formations. Hydrologic properties of the soils developed on these formations reflect the dominant texture of the underlying formations (Figure 8.7).

Land use/land cover varies widely in the outcrop areas (Figure 8.8). Natural vegetation, open water, and wetlands combined constitute from 48 to 78% of the land surface. From south to north, natural vegetation generally transitions from predominantly shrublands and grasslands (57%) to forests (43%), whereas the percentage of open water and wetland areas increases greatly (Table 8.7, Figure 8.8). The dominant agricultural land use in all areas is pasture or hay, which generally increase from the south to the north. Cultivated croplands occupy only a minor percentage of outcrop areas.

Mean annual precipitation from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) precipitation data set shows precipitation increasing from a low of 20.7 inches in the far south to a high of 55.9 inches in the Sabine Uplift area, based upon 1971through 2000 data (www.prism.oregonstate.edu). The mean annual net pan-evaporation depth in the study area ranges from a low of 38.3 inches per year in the north portion of the study area to a high of 65.9 inches per year in the south of the study area. In general, pan-evaporation rate exceeds mean annual precipitation, except in the far north portion of the aquifer. The greatest rainfall deficit with regard to pan-evaporation rate occurs in the south portion of the study area and equals ~48 in/yr.

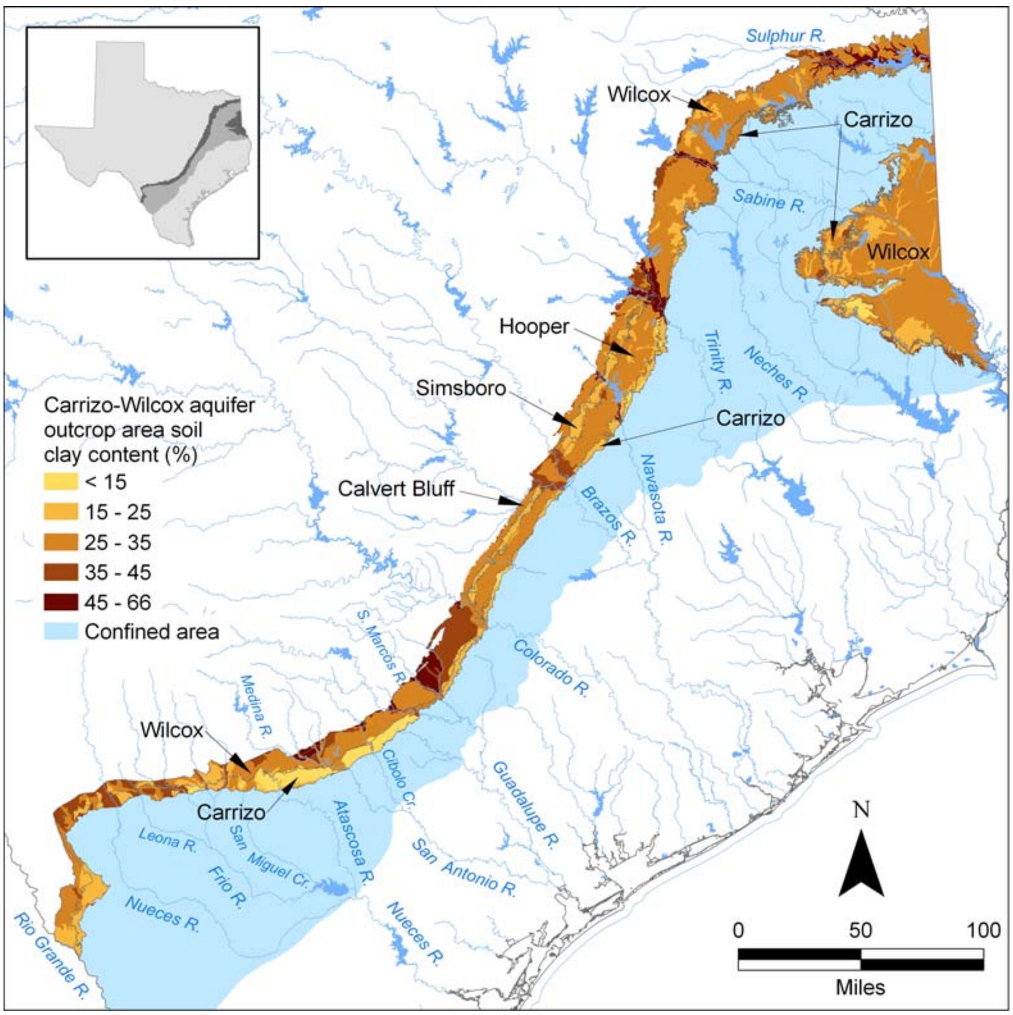


Figure 8.7: Soil clay content in the Carrizo Wilcox Aquifer outcrop areas and extent of the aquifer confined zone. Formation names are indicated for the southern, central, and northern areas. Major rivers and reservoirs are also shown. Soil-clay content derived from the State Soil Geographic (STATSGO) database (USDA, 1994).

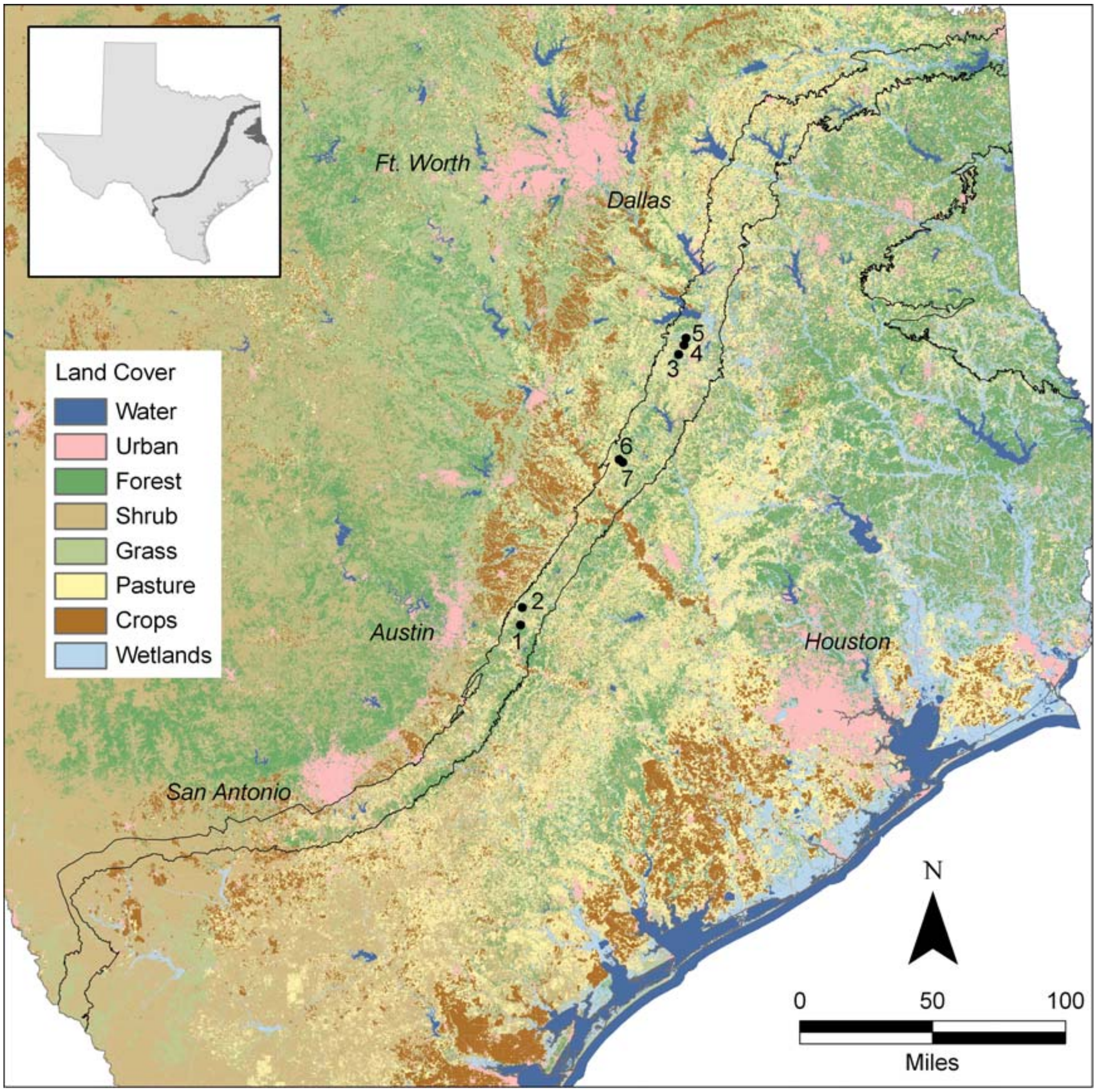


Figure 8.8: Land cover map and unsaturated zone borehole locations (NLCD, 2001; USGS, 2007.) The outcrop area of the Carrizo Wilcox Aquifer is delineated.

4.4 Recharge Estimation Methods

A variety of approaches were used to estimate groundwater recharge. The chloride mass balance approach was applied to unsaturated zone soil water samples from the central Carrizo Wilcox Aquifer and to groundwater chloride data from the TWDB database (www.twdb.state.tx.us) from the entire aquifer. Tritium was also measured in groundwater samples in the central Carrizo Wilcox Aquifer as a qualitative indicator of recharge. Carbon-14 data from previous studies (Pearson and White, 1967; Castro and Goblet, 2003) were also used to estimate deep recharge from the unconfined to the confined portion of the aquifer. Unsaturated zone and groundwater modeling was also used to assess groundwater recharge in the aquifer.

Table 8.7: General land use by region in Carrizo Wilcox Aquifer outcrop areas.

Region	Area (mi^2)	Urban/ Developed (%)	Crops (%)	Pasture/ Hay (%)	Shrubland/ Grassland (%)	Forest (%)	Water/ Wetlands (%)
South of Colorado River	2,815	6	5	14	57	15	3
Colorado to Trinity Rivers	2,468	6	3	32	22	26	11
North of Trinity River	2,631	8	3	40	6	24	18
Sabine Uplift	3,332	6	0	16	14	43	22
Combined	11,247	6	3	25	25	28	14

Note: percentages are rounded.
Source: National Land Cover Database (NLCD, 2001; USGS 2007)
mi^2 = square miles

4.4.1 Chloride Mass Balance Approach

A total of seven boreholes in three different locations were drilled in the outcrop area of the Simsboro Formation in the central Carrizo Wilcox Aquifer: Bastrop and Lee Counties, Robertson County, and Freestone County (Figure 8.8). Soil samples from these boreholes were analyzed for water extractable chloride concentrations, and groundwater was analyzed for tritium. Cores were collected using a hollow-stem auger with a CME Mobile 75 drilling rig. Cores were taken continuously with depth until auger refusal or until the water table was encountered. No drilling fluid was used to avoid contamination of samples.

Soil samples were leached by adding double de-ionized water to oven-dried sediment samples in a 1:1 ratio by weight. Samples were then placed on a reciprocal shaker for 4 hr and centrifuged at 7000 rpm for 20 min and filtered through 0.45 µm filter, and the supernatant was extracted. Water-extractable concentrations of chloride were measured by ion chromatography at the New Mexico Bureau of Mines. Water-extractable chloride concentrations are expressed on a mass basis as mg ion per kg of dry soil and were calculated by multiplying ion concentrations in the supernatant by the extraction ratio (g water/g soil). Ion concentrations expressed as mg ion per L of soil pore water were calculated by dividing concentrations in mg/kg by gravimetric water content and multiplying by water density. Gravimetric water content was measured in the laboratory at the BEG by oven drying samples at 105°C for 24 to 72 hr. Groundwater samples were collected from all seven test holes for tritium, which were analyzed using gas proportional counting with enrichment at the University of Miami Tritium Laboratory (http://www.rsmas.miami.edu/groups/tritium/).

Total recharge was estimated using a mass balance approach based on chloride (chloride mass balance, CMB) (Allison and Hughes, 1983). According to the mass balance approach, chloride input from precipitation (P) balances chloride output in recharge:

$$P \times Cl_P = R \times Cl_{UZ} = R \times Cl_{GW}; \qquad R = \frac{P \times Cl_P}{Cl_{UZ}} = \frac{P \times Cl_P}{Cl_{GW}} \tag{1}$$

where Cl_P, $Cl_{UZ,}$ and Cl_{GW} are chloride concentrations in precipitation, unsaturated zone pore water, and groundwater, respectively. Concentrations of chloride in precipitation were obtained from the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/). Chloride concentrations in precipitation were doubled to account for dry fallout, which is consistent with total chloride fallout based on prebomb $^{36}Cl/Cl$ ratios at Amarillo (Scanlon and Goldsmith, 1997). Recharge was estimated using chloride concentrations in soil water from samples for each borehole, and depth-weighted average recharge rates were calculated. Regional recharge was also estimated using groundwater chloride concentrations for 1128 sampled wells from the TWDB database (www.twdb.state.tx.us). The wells used are completed solely in the Carrizo-Wilcox Aquifer and are located either in the outcrop or within 5 mi downdip of the outcrop. The wells were grouped into nine zones representing the range of climatic conditions across the outcrop of the aquifer. Because it is difficult to envision any large-scale process other than recharge that would reduce groundwater chloride concentrations and several processes can add chloride to the system (i.e., land use change, contamination, cross-formational flow, etc.), the 25th-percentile groundwater chloride concentrations for each zone were used to estimate regional recharge rates.

The time required to accumulate chloride in the unsaturated zone was calculated by dividing the cumulative total mass of chloride from the land surface or the base of the root zone to the depth of interest by the chloride input:

$$t = \frac{\int_0^z \theta \times Cl_{uz} \, dz}{P \times Cl_P} \tag{2}$$

where θ is average water content in the unsaturated zone. Deep recharge was also calculated from a transect of ^{14}C ages in Atascosa County (Pearson and White, 1967). The ^{14}C ages (age) along the flow path were used to calculate water velocities on the basis of distance from outcrop (L). The velocities (v) were then used with an assumed unit width perpendicular to the flow direction and an estimated average porosity (n) and average aquifer thickness (b) to calculate average water flux into the confined aquifer. These recharge estimates are considered upper bounds on recharge from the outcrop because cumulative cross-formational loss/gain of water from overlying and underlying aquifers is ignored. Deep recharge (R_d) can then be expressed in terms of outcrop unit area by distributing the annual water flux over the width of the outcrop zone (w), which is equivalent to the recharge zone:

$$R_d = \frac{v \times n \times b}{w} \quad \text{with} \quad v = L/age \tag{3}$$

4.4.2 Unsaturated Zone Modeling

Regional recharge was also estimated using the relationship between recharge and precipitation developed from unsaturated zone modeling by Keese et al. (2005). These recharge estimates were developed for various scenarios, including sandy, nonvegetated soils and vegetated, texturally variable soils. Power-law expressions were developed for these different conditions:

$$R = 1.956e^{-2}P^{1.484} \text{ (bare, sandy soil)} \tag{4}$$

$$R = 3.242e^{-9}P^{3.407} \text{ (vegetated, texturally variable soil)} \tag{5}$$

Bare, sandy soil provides an estimate of maximum recharge as a function of precipitation, whereas vegetated, texturally variable soil provides the most realistic scenario that should represent current conditions. The relationship was developed using mean annual precipitation from 1961 through 1990.

5.0 Results and Discussion

5.1 Recharge Estimates Using the Chloride Mass Balance Approach

Regional total recharge rates based on groundwater chloride data range from 0.4 in/yr in the south to 4.0 in/yr in the north (Figure 8.9, Table 8.8). The 25th percentile of groundwater chloride concentrations was used in the recharge estimation, and these chloride concentrations range from 49 mg/L in the south to ~8 mg/L in the north. Mean annual precipitation ranges from 24 inches per year in the south to 51 inches per year in the north. Recharge rates range from 2 to 9% of mean annual precipitation. These recharge estimates are considered representative of the aquifer units rather than the confining units.

Recharge rates were also estimated from soil water chloride concentrations in the central Carrizo Wilcox Aquifer region (Figure 8.9, Table 8.9). Recharge rates range from 0.7 to 1.6 in/yr, representing 2 to 5% of mean annual precipitation. The recharge rates from these field studies are generally consistent with regional recharge rates from groundwater chloride data. There is no systematic variation in recharge rates within this region. The lowest recharge was calculated for a profile in a forest (borehole 5), which has a bulge-shaped profile, with peak chloride concentration of 120 mg/L at 1.8 m depth. However, there may be no recharge in this setting as chloride is accumulating. This is the only profile drilled in a forest setting; all other profiles were drilled in pasture settings. Some profiles have vertical variations in chloride concentrations and corresponding recharge rates. For example, recharge in the upper 12 m of the borehole 1 profile is 1.4 in/yr, whereas below this zone recharge is much less (0.4 in/yr). These variations with depth may be related to land use changes; however, detailed information on land use history is not available for these sites. The chloride accumulation times represented by the chloride data based on equation 6 range from 32 to 78 yr, with the exception of borehole 1, which has an accumulation time of 245 yr.

Table 8.8: Recharge rates by zones based on chloride mass balance analysis of groundwater chloride concentrations.

Region	Zone	Number of Wells	Outcrop Area (mi^2)	Precip. (in/yr)	Cl_P (mg/L)	Cl_{GW} (mg/L)	Rech. (in/yr)	Rech. (af/yr)	Rech. (in/yr)	Rech. (af/yr)
South	1	124	1,223	24.4	0.82	49	0.4 (2)	26,500	0.9 (3)	131,000
	2	73	648	30.9	1.18	37	1.0 (3)	34,300		
	3	48	944	36.1	1.14	30	1.4 (4)	69,800		
Central	4	95	812	36.3	0.98	29	1.2 (3)	52,800	1.8 (5)	241,000
	5	165	1,657	40.5	0.78	15	2.1 (5)	188,000		
North	6	124	936	42.8	0.68	7.9	3.7 (9)	183,000	3.6 (7)	1,160,000
	7	83	789	45.4	0.62	11	2.5 (6)	107,000		
	8	58	906	49.6	0.60	9.0	3.3 (7)	158,000		
	9	358	3,332	51.3	0.70	9.0	4.0 (8)	711,000		

Note: Zones and well locations are shown in Figure 8.9. Precipitation represents the 1971 through 2000 mean. Precipitation chloride concentrations were multiplied by two to account for dry fallout. Groundwater chloride concentration represents the 25th percentile of zone well population. Values in parentheses represent percentages of annual precipitation. Recharge values in af/yr units calculated by multiplying recharge by outcrop area. Mean area-weighted recharge rates are provided for groups of zones that correspond approximately to the modeled zones.

Table 8.9: Unsaturated zone borehole information and recharge rates based on chloride mass balance and groundwater tritium levels.

Borehole	Total Depth (ft)	Depth to Water Table (ft)	Precipitation (in/yr)	Cl_P (mg/L)	Cl_{UZ} (mg/L)	Recharge (in/yr)	Age (yr)	Tritium (TU)
1	103.8	74.8	35.6	1.02	71.6	0.7 (2)	245	0.76
2	53.3	43.3	35.4	1.02	42.6	1.6 (5)	70	3.25
3	53.7	41.3	42.0	0.74	37.2	0.9 (2)	78	3.30
4	38.8	24.8	41.8	0.74	20.5	1.6 (4)	32	3.57
5	18.5	10.5	41.5	0.74	37.6	0.4 (1)	48	3.43
6	48.6	37.4	38.4	0.84	27.9	1.3 (3)	64	3.05
7	78.5	76.7	38.5	0.84	27.7	1.4 (4)	75	1.10

Note: Borehole locations are shown in Figure 8.8. Precipitation represents the 1971 through 2000 mean. Precipitation chloride concentrations were multiplied by two to account for dry fallout. Values in parentheses represent percentages of annual precipitation.

Groundwater tritium concentrations range from 0.76 to 3.6 TU (Table 8.9) Tritium levels were greater than the detection limit (~0.2 TU) and indicate that a component of water was recharged after about 1950. However, quantitative recharge rates cannot be estimated from tritium data alone.

Deep recharge to the Carrizo Aquifer was estimated from carbon-14 ages by Pearson and White (1967) and Castro et al. (2000) using an estimated average aquifer thickness of 100 m, porosity of 35%, and outcrop width of 10 km. Estimated deep recharge rates range from 0.1 to 0.4 in/yr (Table 8.10).

Table 8.10: Carbon-14 age, uncertainty, and recharge rate for wells in Atascosa County in the southern portion of the Carrizo-Wilcox Aquifer.

Sample ID	**Age** (yr)	**Uncertainty** (yr)	**Distance** (mi)	**Velocity** (ft/yr)	**Mean Deep Recharge** (in/yr)	**Minimum Deep Recharge** (in/yr)	**Maximum Deep Recharge** (in/yr)
Tx-01[a]	9,500	3,000	11.9	6.6	0.28	0.21	0.40
Tx-24[a]	17,400	3,000	10.8	3.3	0.14	0.12	0.17
Tx-92[b]	3,750	700	2.0	2.8	0.12	0.10	0.14
Tx-93[b]	6,300	11,500	11.0	9.2	0.39	0.14	-0.47
Tx-94[b]	14,500	1,050	18.0	6.6	0.28	0.26	0.30

Note: Sample ID values from original references. Average recharge rates are based on ^{14}C ages. Minimum and maximum recharge rates are based on ^{14}C age uncertainty.

[a] Castro et al. (2000)
[b] Pearson and White (1967)

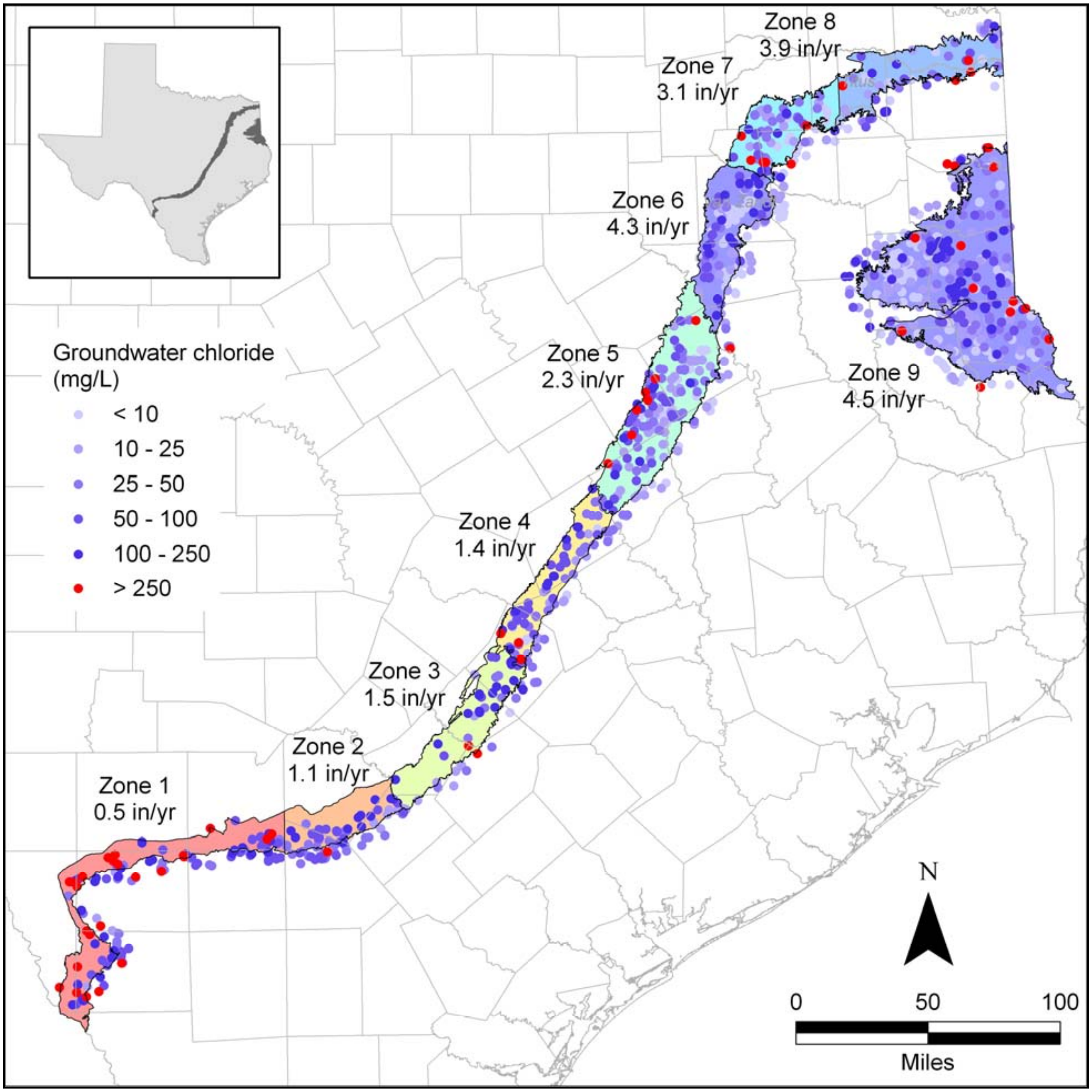


Figure 8.9: Groundwater chloride concentrations and chloride mass balance recharge rates for nine zones in the Carrizo-Wilcox outcrop area. Points represent groundwater wells located inside and within 5 mi downdip of the outcrop area. Chloride mass balance recharge rates are based on 25^{th}-percentile chloride concentrations for wells in each zone.

5.2 Recharge Estimates from Unsaturated Zone Modeling Results

Maximum recharge rates developed using the relationships between precipitation and recharge for bare, sandy soils from unsaturated zone modeling (equation 8) range from 11 in/yr (44% of mean annual precipitation) in the southern part of the aquifer to 32 in/yr (63% of mean annual precipitation) in the northern part. These rates represent the maximum, diffuse recharge rates as a function of climate forcing because vegetation ET and soil textural variability are not included;

however, the rates are so high that they do little to constrain actual recharge rates. Recharge rates for vegetated, texturally variable soils were much lower than those based on bare, sandy soils (0.4 to 5.1 in/yr) representing 2 to 10% of mean annual precipitation. These recharge rates compare favorably with regional recharge estimates based on groundwater chloride data (Figure 8.6).

5.3 Recharge Estimates from Groundwater Models

5.3.1 Steady State Predevelopment Model

The steady state predevelopment model provides valuable information on aquifer recharge and discharge that can potentially be captured by pumpage during postdevelopment. The water budget for each of the three models was obtained from Kelley et al. (2004), and the combined budget for the entire aquifer was obtained from Deeds et al. (2009). The budget for the entire aquifer differs from that of the combined individual models (southern, central, and northern) because of the overlap in each of the individual models. Total recharge increases from 114,000 af/yr in the southern model to 251,000 af/yr in the central model and to 590,000 af/yr in the northern model; however, when these recharge rates are normalized by the area of the outcrop of the aquifer, the increases are not as marked (0.75 in/yr, southern model, and 1.1 in/yr in both central and northern models) (Table 8.8). Most (54 to 66%) of the recharge discharges as streams and springs. The ratio of losing stream inflow to gaining stream outflow decreases from the southern to northern (16%, 10%, and 2%, respectively) models, consistent with the observation of some losing sections but still overall gaining streams in the southern area and overwhelming gaining streams in the northern area. The proportion of total recharge that discharges as ET increases from 6% in the southern, 27% in the central, and 46% in the northern aquifer models. Subtracting discharge in the outcrop (streams, springs, ET) from total recharge results in deep recharge that ranges from 34% in the southern, 6% in the central, and 0% in the northern aquifer models. Therefore, although total volumetric recharge increases from the southern to the northern aquifer models, deep recharge decreases from the southern to the northern aquifer models.

The relatively low quantities of deep recharge in the northern model is attributed to shallower water tables and large-scale discharge to perennial streams in the northern aquifer model that serve to reject much of the increased recharge in the more humid climate in this region (Kelley et al., this volume). Deep recharge is balanced by slow upward cross-formational flow, cumulatively accounting for all deep recharge and upward flow from underlying aquifers. The far downdip boundary is, for the most part, closed, although Dutton et al. (2006) showed that there may be a small updip component of flow from the geopressured zone. The GAM models provide regional average water budgets for the different aquifers and may deviate markedly from averages at the county or finer scale. In summary, predevelopment conditions are characterized by discharge mostly as streams (~60%) and a combination of groundwater ET (more significant in the north, 46%) and cross-formational flow (more important in the south, 34%) (Table 8.11).

Table 8.11: Steady state simulation results for the south, central, north, and combined model regions.

	Component and volume or depth							
	Recharge		Streams		Evapotranspiration		Deep recharge	
Region	(af/yr)	(in/yr)	(af/yr)	(in/yr)	(af/yr)	(in/yr)	(af/yr)	(in/yr)
South	114,000	0.75	68,000	0.45 (60)	6,600	0.04 (6)	39,100	0.26 (34)
Central	251,000	1.1	166,000	0.70 (66)	68,000	0.29 (27)	16,300	0.07 (6)
North	590,000	1.1	317,000	0.59 (54)	275,000	0.51 (46)	<2,000	<0.01 (0)
Combined	778,000						47,000	

Note: Values in (in/yr) units represent flow values (af/yr) divided by outcrop area. Values in parentheses represent percentages of total flow.

The simulated water balance for predevelopment provides information on the amount of water that can be captured by well pumpage in the postdevelopment stage. The simulated total discharge provides an upper bound on the volume of groundwater that can be pumped from the system during aquifer development; however, pumping at such a level would eliminate baseflow to streams and possibly groundwater ET, which would not be desirable. An understanding of the water requirements for instream flows (NRC, 2005) and for riparian ET could be used to constrain permissible pumpage levels during postdevelopment.

The predevelopment model is calibrated using hydraulic-head data and baseflow discharge to streams. Solution of the model calibration is not unique. Similar calibration results could be obtained with higher recharge, as long as groundwater ET is also increased. Although the difference between such models may not be important for steady state calibration, they can substantially impact transient simulations. Higher recharge and ET will result in more water being available for pumpage during transient simulations because groundwater ET can be captured by pumpage.

6.0 Summary

Total recharge rates based on groundwater chloride range from 0.4 in/yr (2% of precipitation) in the semiarid southern part to 4.0 in/yr (8% of precipitation) in the humid northern part of the aquifer. Point recharge rates based on unsaturated zone chloride data in the central Carrizo Wilcox Aquifer are spatially variable (0.7 to 1.6 in/yr) but generally consistent with those based on groundwater chloride. The presence of tritium (0.76 to 3.57 TU) in the central Carrizo Wilcox Aquifer outcrop area indicates young (post-1950) ages and provides evidence of recent recharge. Upper bounds on deep recharge to the confined part of the southern Carrizo Wilcox Aquifer range from 0.1 to 0.4 in/yr, according to ^{14}C transects in Atascosa County. Total recharge rates based on unsaturated zone modeling results range from 0.4 in/yr (2% of precipitation) in the southern part to 5.1 in/yr (10% of precipitation) in the northern part of the aquifer. Under steady state conditions, recharge equals discharge, and model results indicate that recharge ranges from 0.75 in/yr in the southern part and 1.1 in/yr in both the central and northern parts of the Carrizo Wilcox Aquifer.

7.0 Sources of Water for Pumpage and Timescales of Pumpage Impacts

During predevelopment groundwater recharge (R_0) is equal to groundwater discharge (D_0).

$$R_0 = D_0 \; . \qquad (1)$$

Groundwater pumpage during postdevelopment disturbs this equilibrium between recharge and discharge. The water balance equation can be described as

$$(R_0 + \Delta R_0) - (D_0 + \Delta D_0) - Pu = \Delta S, \qquad (2)$$

where ΔR_0 and ΔD_0 are change in recharge and discharge that can be caused by pumpage (Pu) and ΔS is change in aquifer storage. If a new steady state is established under pumping conditions, there is no further change in groundwater storage and $\Delta S = 0$. In such a case, groundwater pumpage is considered sustainable and is derived from an increase in recharge or a decrease in discharge, which is termed *capture* (Sophocleous, 1998).

$$Pu_s = \Delta R_0 + \Delta D_0 \qquad (3)$$

Initially all water abstracted through pumpage is derived from groundwater storage. With continued pumpage, water is derived less and less from groundwater storage but comes from other sources, such as increased recharge and/or decreased discharge. In an unconfined aquifer, water can be captured by intercepting groundwater discharge to streams, changing streams from gaining to losing, and/or reducing groundwater ET from riparian zones near streams. In a confined aquifer, water can be captured by increasing recharge from an overlying unconfined aquifer through cross-formational flow, which will correspond to capture from the unconfined aquifer as described earlier and can result in a reversal of the flow direction if water in the confined aquifer was previously flowing to the unconfined aquifer. Transient simulations are used to quantify the amount and timing of these transitions. The initial decline in groundwater storage caused by pumpage generates a vertical head gradient, ultimately reversing cross-formational flow and capturing this discharge mechanism and possibly draining water from overlying adjacent aquifers. Pumpage from the Carrizo Aquifer impacts the overlying Queen City Aquifer and will ultimately impact the Queen City recharge zone also. Groundwater from the Queen City Aquifer is slowly drawn into the Reklaw Aquitard, whereas some groundwater from the aquitard moves into the Carrizo Aquifer. At the same time, increased hydraulic gradients downdip from the Carrizo Wilcox outcrop zone increase the fraction of deep recharge resulting from a combination of decreased discharge, decreased groundwater storage in both the unconfined and confined zones, and downdip migration of the unconfined/confined boundary.

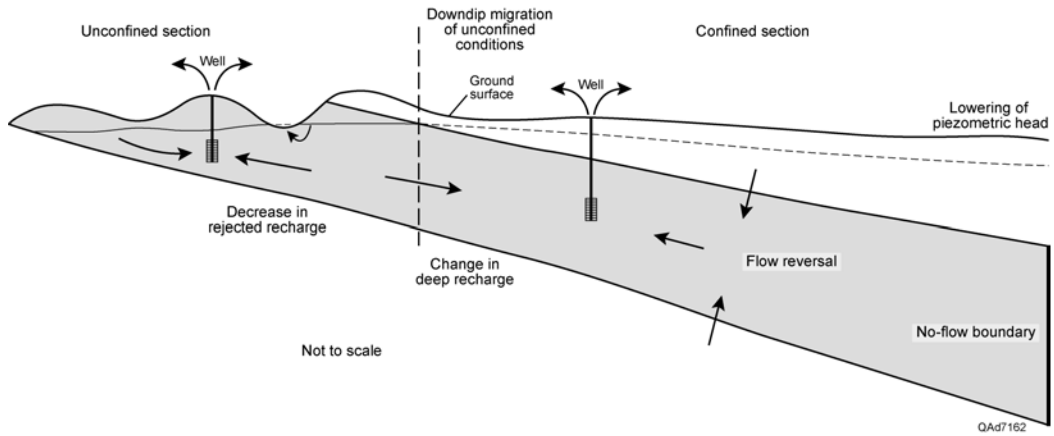


Figure 8.10: Conceptual model representing sources of water for pumping in the unconfined and confined aquifer and sources.

The water budget for the transient model for the Carrizo Wilcox Aquifer within the Queen City and Sparta GAM was evaluated to assess sources of groundwater pumpage, as described. Model calibration is based on matching simulated and measured groundwater-level hydrographs over the transient simulation period. The transient simulation results indicate that by 1999 groundwater abstractions through pumpage represent increasing fractions of total flow from northern (33%), central (54%), and southern (91%) parts of the aquifer (Table 8.12). Pumpage in the southern part of the aquifer is primarily for irrigation in the Winter Garden region, whereas pumpage in the central and northern parts of the aquifer is primarily for municipal purposes. The remaining outflows from the system include discharge to streams and springs and groundwater ET, both of which increase in percentage of total outflow from south to north. The water budget for the transient simulation is balanced by change in groundwater storage, recharge, and cross-formational flow.

Table 8.12: Transient simulation results (1999) in the south, central, and north regions.

Region	Recharge	Storage change	Cross-formation flow	Total inflow	Wells	Streams	ET	Lateral flow
South	69	181	57	307	-279 (91%)	-22	-2	-3
Central	157	187	18	362	-197 (54%)	-126	-39	0
North	357	61	45	463	-154 (33%)	-219	-85	-4

Note: Values in parentheses represent percentages of total flow.

Analysis of sources of water for pumpage in 1999 indicates that after decades of development (1999) and increasing pumpage, the change in groundwater storage (that is, decline in water table and piezometric head) represents a significant fraction of total pumpage (50–72%). Ultimately this fraction should tend to zero; however, currently, the aquifer cannot reach a new steady state (that is, no change in groundwater storage) because pumping continues to increase. Total cross-formational flow is reversed in all portions of the aquifer from the overlying Queen City Aquifer. The reversal of cross-formational flow should not be confused with the fact that, locally, some water moves upward through the confining layer, but it is more than balanced by water being drawn into cones of depression caused by pumpage. Cross-formational flow also provides a significant contribution to pumpage (13–28%). The remaining water for pumpage is derived from reduced discharge in the outcrop, including reduced baseflow discharge (7–16%) to streams and groundwater ET (0– 6%).

Table 8.13: Transient simulation results (1999) for source of well pumpage in the south, central, and north regions.

Region	Pumpage	Storage	Streams	ET	Cross-formation Flow	Lateral Flow
South	-279	182 (65%)	18 (7%)	0.1 (0%)	78 (28%)	0.8 (0%)
Central	-197	99 (50%)	32 (16%)	12 (6%)	34 (17%)	20 (10%)
North	-154	112 (72%)	14 (9%)	6 (4%)	21 (13%)	1 (1%)

A similar analysis was also done related to the desired future conditions of 2060 for the three GMAs (Table 8.14 and Figure 8.11). This analysis shows that aquifer storage contributes 44 to 58% of pumpage. Cross-formational flow contributes 40% of pumpage in GMA 13, which is attributed to most pumpage in this region from the Carrizo Aquifer, adjacent to the overlying Queen City Aquifer. In contrast, pumpage in the other GMAs from the Carrizo Aquifer is much less, resulting in much lower cross-formational flow from the Queen City Sparta Aquifer (19%). Capture of baseflow to streams ranges from 13 to 27% and may be very important because of impacts on environmental flows; however, these baseflow reductions need to be evaluated relative to total stream flow under drought conditions. Capture of groundwater ET ranges from 0 to 37% of pumpage and is negligible in GMA 13 because ET is not a significant discharge mechanism and, therefore, cannot be captured by pumpage. Understanding the sources of pumpage determines the impacts of pumpage on the flow system.

Table 8.14: Sources of water for pumping in 2060 from desired future condition simulations using QCSP/CW GAMs.

Regions	Pumpage	Storage	Streams	ET	Cross-Formational Flow
GMA11	-264	153 (58%)	35 (13%)	24 (9%)	52 (19%)
GMA12	-257	113 (44%)	69 (27%)	26 (10%)	49 (19%)
GMA13	-403	176 (44%)	64 (16%)	0.3 (0%)	162 (40%)

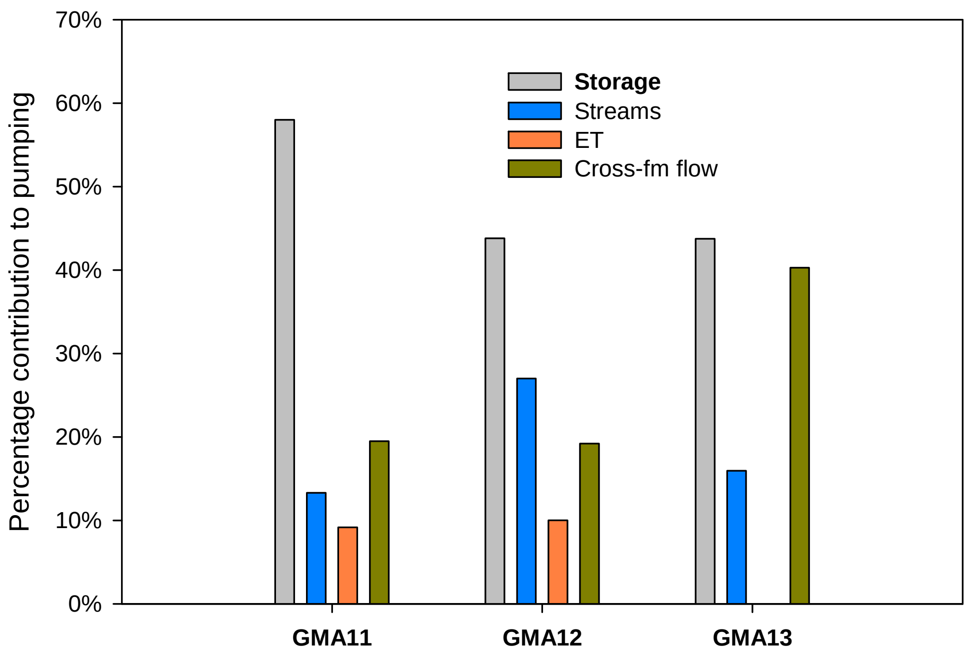
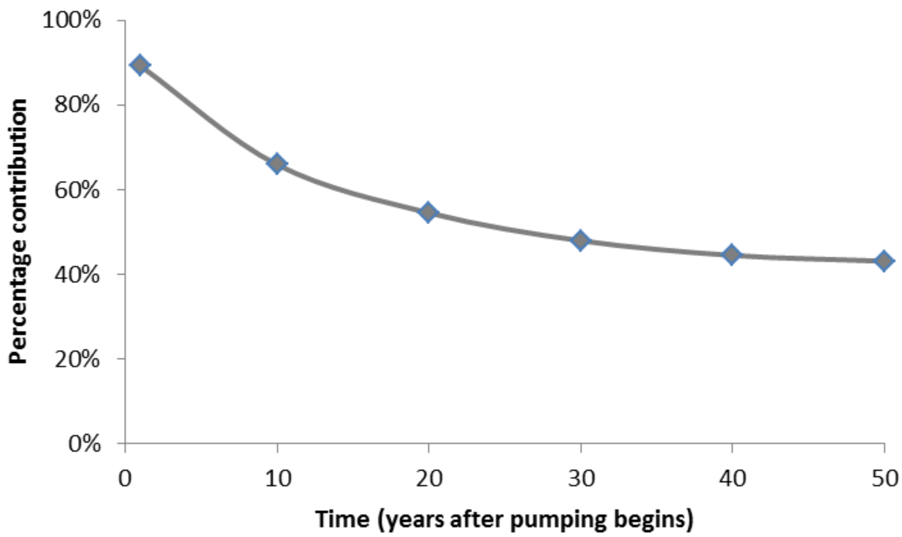


Figure 8.11: Sources of water for pumping in 2060 in three GMA areas.

8.0 Timescales of Impacts of Pumpage

It is important to understand the timescales of impacts of pumpage for water resources management. The management timescale for planning is ~50 yr. In many situations the impacts of pumpage may not be seen for decades; however, if the impacts are not considered ahead of time, their effects may be irreversible.

An analysis was conducted to evaluate temporal variability in how storage, cross-formational flow, streams, and ET contribute to pumping in the Carrizo-Wilcox aquifer using the Central Carrizo Wilcox Queen City Sparta GAM. The contribution of storage to pumpage decreases rapidly initially and then levels off (Figure 8.12a). In contrast, the contribution of cross-formational flow, streams, and ET increases through time. Although cross-formational flow and ET increase rapidly initially and then level off, stream flow contribution increases more gradually through time. Figure 8.12b shows that ET and cross-formational flow contributions level off over time, whereas stream capture continues to increase. Impacts of groundwater pumpage on environmental flows may be critical in the future, and it will be important to design monitoring programs to evaluate these changes through time.



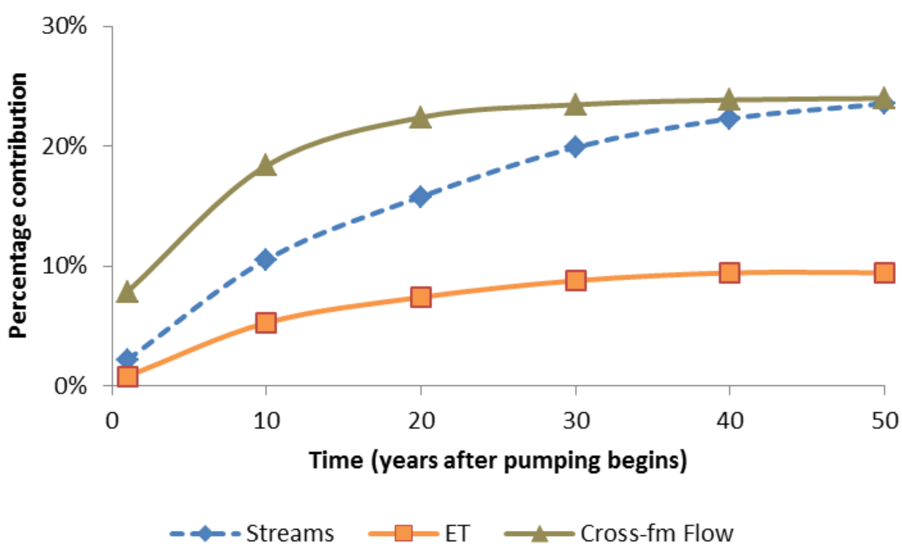


Figure 8.12: a, Storage contribution to pumping in Carrizo-Wilcox aquifer over time; b, streams, ET and cross-formational flow contribution to pumping in Carrizo-Wilcox aquifer over time.

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Summary Report for Task 7: Assessment of Anthropogenic Contamination in the Recharge Area of the Carrizo-Wilcox Aquifer and Potential Pollution of the Aquifer

1.0 Introduction and Background

This summary report prepared by the Bureau of Economic Geology (BEG) is submitted to fulfill requirements of Task 7 of the Texas Commission on Environmental Quality (TCEQ) Carrizo-Wilcox Aquifer Study (the Study), Project 582-8-75374-119. Task 7 directs the BEG to *"**Determine whether the presence of anthropogenic contaminants in the recharge area of the aquifer and the potential pollution of the aquifer are issues that should be addressed and, if so, by whom. Assess distribution of contaminants from available databases from TCEQ PWS and TWDB. Identify any management or protection regulatory gaps**."*

The distribution of contaminants was evaluated primarily from the Texas Water Development Board (TWDB) database. The main objective of the TWDB monitoring program is to evaluate regional variations in groundwater quality, and the monitoring program is not designed to assess local contamination. Groundwater contamination cases reported by the Texas Groundwater Protection Committee from the TCEQ and RRC of Texas (RRC) are also provided.

Water quality in the Carrizo-Wilcox Aquifer outcrop (unconfined) area from the TWDB groundwater quality database was evaluated for compliance with U.S. Environmental Protection Agency (EPA) Maximum Contamination Level (MCL) concentrations, including 17 primary and 11 secondary inorganic and radioactive constituents. Data were derived for wells that are listed as (1) being solely completed in the Carrizo-Wilcox Aquifer, (2) having geographic coordinate locations that place the well within the outcrop area as defined by the aquifer GIS coverage published by TWDB, and (3) having balanced water quality analyses with a sample date of 1969 or later as of May 2010.

There are no widespread violations of any of the primary MCL constituents, with only 27 individual violations for all primary MCL constituents. The most significant violation is for nitrate-N, which accounts for 19 of the primary MCL exceedances. These nitrate exceedances are found largely in domestic and irrigation wells and are most likely related to septic tank and fertilizer applications. The low levels of nitrate contamination are attributed to the limited area of cropland in the outcrop area of the Carrizo Wilcox Aquifer and the widespread occurrence of reducing conditions, as evidenced by high levels of iron and manganese in many regions. The remaining primary MCL violations include three violations for lead (all in GMA 11), one each for beryllium and cadmium (also in GMA 11), and one for gross alpha radiation (in GMA 13). In addition, radium (combined Ra-226 and Ra-228) activity was measured for eight wells in GMA 12, two of which had values exceeding the MCL. Several of the primary MCL constituents have only a limited number of analyses in one or more of the GMA regions, including mercury, nitrite-N, uranium, radium, and gross alpha. With the exception of nitrite, these constituents are considered natural in origin and related to the original depositional environment of the sediments in the Carrizo Wilcox Aquifer.

The number of secondary MCL exceedances ranges from ~200 to 350 for various elements. These exceedances are dominated by TDS, chloride, sulfate, iron, and manganese. The percentage of wells that exceeded the TDS MCL is much greater in the southern (62%) than in the central or northern Carrizo Wilcox Aquifer (25 and 27%), and median TDS concentrations are also greatest in the southern (587 mg/L) region relative to the central and northern regions (331 and 325 mg/L). Iron and manganese MCL exceedances are also widespread. Median iron concentrations range from 79 to 133 μγ/L. These exceedances may be related to lignite distribution. Occurrence of pH values outside the 6.5 to 8.5 range are greatest in the north and may cause problems of scaling and corrosion.

There are 147 documented groundwater contamination cases from the TCEQ database and 23 documented cases from the RRC database in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 Draft Groundwater Quality Portion of the Water Quality Inventory of the State of Texas, required by EPA according to Section 305B of the Clean Water Act. The most common contaminants reported include gasoline and diesel related to petroleum storage tanks. Additional contaminants include volatile organic compounds (such as benzene, toluene, ethylbenzene, xylene, and BTEX), chlorinated solvents, TCE, TPH, creosote, heavy metals, chloride, and arsenic. These contaminants are generally related to local sources and do not represent widespread contamination of the aquifer.

We reviewed previous studies of groundwater quality in the aquifer that focused mostly on regional evolution of groundwater chemistry from oxidizing acidic water in the recharge zone to reducing basic water in the confined zone in the East Texas Basin. Poor-quality water in the unconfined aquifer was attributed to wells in Calvert Bluff muddy sediments. Groundwater generally evolved from calcium-rich water to sodium-rich water, attributed to cation exchange on clays. Highest salinity was found in the southern part of the aquifer, which was attributed to cross-formational leakage into the aquifer. Lignite and lignite mining can also impact groundwater quality. Leaching of mine spoils may generate moderately brackish waters (<10,000 mg/L) that could degrade groundwater quality near a mine. Although the primary lignite host, the Eocene Wilcox Group, is a major aquifer, lignite and groundwater resources in the Wilcox Group generally occur at different stratigraphic intervals and geographic locations, reducing potential contamination. There are no reported cases of groundwater contamination from the surface mining group of the RRC.

Potential pollution of the aquifer was evaluated from an online survey conducted as part of this study. Most groups did not submit any response to this question, many responded negatively, and a few pointed to some issues, such as the need to plug old oil wells, inconsistencies in rules among groundwater conservation districts, and importance of developing regulations to protect the recharge zone of the aquifer. Lignite mining was listed as a potential cause of groundwater pollution in the aquifer because of removal of the filtering capacity of lignite and replacement with mine spoils; however, others suggested a relationship between lignite deposits and kidney disease and/or renal pelvic cancer with a syndrome termed Balkan Endemic Nephropathy (BEN). And yet there is no reported case of groundwater contamination from the surface mining group of the RRC.

The distribution of fracing wells in the Carrizo Wilcox outcrop area was evaluated as a potential source of groundwater contamination. EPA is currently conducting a study on potential groundwater contamination from fracing operations. Projected increases in groundwater pumpage in the confined part of the Carrizo Wilcox Aquifer should enhance flow from surrounding confining units, such as the Hooper and Calvert Bluff units, which could degrade groundwater quality, depending on the quality of groundwater in the confining units. The likelihood of this cross-formational flow into the aquifer degrading groundwater quality should be evaluated in future studies.

The main management or protection regulatory gap identified through the online survey was concern expressed by 6 of the 16 groundwater conservation districts related to the groundwater-management policies and enforcement procedures of the RRC. The ability of the RRC to effectively regulate hydrocarbon production companies and their well operations is contested owing to its perceived inability to effectively regulate groundwater support wells or to eliminate the occurrence of abandoned wells. Whereas water quality of public water supply wells is regulated by TCEQ, these regulations are restricted to water quality at entry points and do not assess raw water quality. The Texas Groundwater Protection Committee identified the lack of oversight of water quality of private wells as a major regulatory gap that should be addressed in the future.

2.0 Determine Whether the Presence of Anthropogenic Contaminants in the Recharge Area of the Aquifer is an Issue that Should be Addressed and, if so, by Whom. Assess Distribution of Contaminants from Available Databases from TCEQ PWS and TWDB

2.1 Previous Studies Related to Groundwater Quality in the Carrizo Wilcox Aquifer

The groundwater quality of the Carrizo Wilcox Aquifer has been evaluated in many previous studies. One of the earliest studies was conducted by Henry and Basciano (1979) and Henry et al. (1980), describing the hydrology and water quality of the Wilcox Group with respect to lignite development in East Texas. The study focuses on the general water quality evolution from calcium bicarbonate to sodium bicarbonate waters attributed to cation exchange on clays. The origin of high TDS is attributed to shallow wells, mostly <100 ft, in predominantly finer grained Calvert Bluff sediments. Leaching of soluble chloride compounds in muds is the dominant source of salts. Reductions in chloride with depth are attributed to deeper wells penetrating cleaner sands within the Calvert Bluff and Simsboro Formations with more fresh water. High sulfate concentrations may also be attributed to pyrite oxidation in shallow muddy parts of the Calvert Bluff Formation.

Hydraulics and hydrochemical facies of Eocene aquifers in the East Texas Basin were also characterized by Fogg and Kreitler (1982). General trends in the geochemical environment range from an oxidizing acidic water in recharge zones to a reducing basic water in confined zones. Some shallow (<100 ft) wells near oil fields in the outcrop zone were reported to contain high chloride and may be contaminated with brines. Generally high chloride in shallow water and lower chloride in deeper waters in the confined section are similar to the findings by Henry et al. (1980) and are attributed to higher chloride in muddier sediments in the Wilcox Aquifer relative to lower chloride in cleaner sands in the Carrizo Aquifer. In contrast, the Carrizo Wilcox Aquifer in Gregg County shows increasing chloride with depth, which is attributed to the East Texas oil and gas field in Gregg and Rusk Counties. The oil and gas field is one of the largest in the western hemisphere. Hydrocarbons may have accumulated as a result of regional flow of deep basinal fluids toward the field and discharge of these fluids into shallower aquifers. The cation component of the water type generally evolves from Ca-Mg-Na water in the recharge zones to Na water in the confined section as a result of dissolution of calcite followed by cation exchange of Ca for Na with clays. Ca concentrations decrease with depth. The anion component evolves from Cl-SO_4-HCO_3 in recharge zones to HCO_3-Cl-SO_4 in the confined section through dissolution of calcite. Chloride concentrations tend to be higher at shallower depth in the Wilcox (not Carrizo) and may be related to connate waters in less permeable zones. In the recharge zone pH is low (<8) and increases with depth (>8) as bicarbonate increases, indicating a closed system with respect to CO_2.

Hamlin (1988) described depositional and groundwater flow systems of the Carrizo-Upper Wilcox Aquifer in South Texas. Chemical evolution of groundwater is controlled by the chemistry of recharging meteoric and in situ connate waters, mineral and organic constituents in the soil and aquifer, and geochemical constraints. Low TDS in the northeast part of the study area is attributed to clean quartz sand and higher recharge from precipitation. Higher TDS in the central and southwest zones are attributed to lower recharge and lithologic heterogeneity. Samples from some outcrop and shallow artesian wells in this region had anomalously high TDS (>1,000 mg/L) that may be related to badly cased wells or leakage into the Carrizo Aquifer from more saline groundwater in the lower Wilcox muddy facies. In the central and southwest zones, TDS decreases with depth to ~1,000 to 1,200 ft, largely resulting from high chloride and sulfate in some shallow wells. The Carrizo downdip salinity boundary generally coincides with the transition between alluvial facies and marine-dominated facies in the Carrizo-Upper Wilcox interval across most of the Rio Grande Embayment. Depth of burial affects compaction and expulsion of formation water. Original sedimentary environments control salinity of syndepositionally included waters. Faults enhance upward discharge and groundwater mixing.

Groundwater in the Carrizo-Wilcox Aquifer in South Texas has high chemical variability but becomes dominated by sodium bicarbonate water with depth and distance along flow paths related to dissolution of calcium bicarbonate combined with cation exchange in clays (Hamlin, 1988). In the southwest, where sandstone percent is lowest and mud-bank overbank facies are highest, chloride and sulfate are high. Bicarbonate and pH increase with distance along the flow path as carbonic acid is consumed (closed system). The pH increases with bicarbonate and stabilizes at 8.0 to 8.6. Increasing bicarbonate at greater depth is attributed to methane fermentation related to hydrocarbons and carbonic acid generated in the deep basin, which migrates up into the Carrizo meteoric system, along with expulsing formation water. Cross-formational leakage of relatively saline water into the Carrizo Aquifer is greatest in the southwest zone, where groundwater-head decline is mostly related to irrigation pumpage. A possible explanation for reductions in chloride with depth is variations in the chlorinity of meteoric recharge through time. Radiocarbon dating indicates that low-chloride water (<25 mg/L) corresponds to groundwater that is 25,000 to 15,000 yr old, intermediate chlorinity (25–50 mg/L) corresponds to 15,000- to 5,000-yr-old groundwater, and highest chlorinity (>50 mg/L) is found in shallow groundwater <5,000 yr old. Rising sea level ~25,000 yr ago toward the end of the late Wisconsinan glacial stage corresponded to a shoreline at least 100 mi farther east of Atascosa County than it is today. The Holocene transgression brought the shoreline nearer to the Carrizo recharge area, increasing chloride concentrations in precipitation and recharge. Climate change also varied evapotranspiration and concentration of salts in the soil profile and recharge water. More humid conditions toward the end of the last glaciation corresponded to low ET rates and lower chloride concentrations. Increasing aridity during the Holocene also increased chloride concentrations through evapotranspiration. Sulfate concentrations in Carrizo groundwater are related to aquifer lithology and iron sulfides and organic material. Oxidation of pyrite adds sulfate to the groundwater. Ferrous sulfides, such as pyrite, are common in muddy, organic-rich overbank facies but are less abundant in channel sandstones. The southwest zone has the highest sulfate concentrations.

In summary, shallow young Carrizo groundwater in South Texas has low TDS and variable chemical compositions. With time and distance down flow, TDS increases, but composition becomes less variable. Shallow groundwater contains calcium, sodium, bicarbonate, and sulfate, whereas deeper groundwater is dominated by sodium and bicarbonate. Evolution of water is related to calcium carbonate dissolution and cation exchange on clays, resulting in sodium and bicarbonate increasing and calcium decreasing downgradient. Dissolution of soluble chlorides releases chloride into solution, but most chloride is introduced through cross-formational flow and in meteoric recharge. Chloride is a major constituent only in the southwest part of this region. Oxidation of iron sulfides releases sulfate into solution, which is significant in relatively shallow groundwater locally in the southwest zone.

Boghici (2009) evaluated chemical analyses of 331 groundwater samples collected by TWDB between 2005 and 2006 and noted that groundwater quality was generally good, although there were some MCL exceedances for nitrate, lead, fluoride, chloride, sulfate, iron, manganese, and TDS. Groundwater salinity generally did not change over time in the northern and central

Carrizo Wilcox Aquifer but increased slightly (mostly ≤100 mg/L) in the southern zone, with the exception of Zavala, Dimmit, and Frio Counties, where larger changes were found. Groundwater ages increased progressively along flow paths from recharge areas to downdip areas, and most groundwater originated from meteoric sources.

The occurrence of lignite in a major fresh-water aquifer, the Eocene Wilcox Group, could result in groundwater quality problems. However, as Fogg et al. (1982) pointed out, major groundwater and lignite resources in the Wilcox Group generally occur at different stratigraphic intervals and locations, reducing contamination potential of the aquifer. Both Henry and Basciano (1979) and Fogg et al. (1982) recognized that lignites occur primarily in low-permeability, muddy, interchannel sediments, reducing groundwater discharge into mines or groundwater pollution in shallow mines (<200 ft). At that time, eight shallow lignite mines had few groundwater quality problems. Deeper mines have a higher probability of intersecting Wilcox sands and could contaminate aquifers. Another issue related to lignite is the proposed linkage between lignite deposits and kidney disease and/or renal pelvic cancer with a syndrome termed Balkan Endemic Nephropathy (BEN) (Branning, 2010). Branning (2010) determined that there is a positive statistical correlation between the proportion of people using Carrizo-Wilcox water and the number of beds in dialysis clinics in east Texas counties. While not conclusive, this relationship indicates that organic compounds in Carrizo-Wilcox groundwater may be a contributing factor to kidney disease in the area.

2.2 Evaluation of Groundwater Quality on the Basis of TWDB Data

The following assessment of the distribution of contaminants from the TWDB database addresses the presence of anthropogenic contaminants in the recharge area of the Carrizo Wilcox Aquifer. Note that the purpose of the TWDB groundwater quality sampling program is "to monitor changes in the quality of groundwater over time and to establish as accurately as possible the baseline quality of groundwater occurring naturally in the state's aquifers." (http://www.twdb.state.tx.us/GwRD/HEMON/GMSA.asp). Therefore, this analysis of groundwater quality will evaluate the regional distribution of groundwater quality and cannot be used to assess local contamination. Data from the TCEQ database were not included in the assessment because the focus of the analysis was on raw water and not treated water in public water systems.

Water quality in the Carrizo-Wilcox Aquifer outcrop (unconfined) area was evaluated for compliance with U.S. Environmental Protection Agency (EPA) Maximum Contamination Level (MCL) concentrations, including 17 primary and 11 secondary inorganic and radioactive constituents. Data were derived from the TWDB groundwater database for wells that are listed as (1) being solely completed in the Carrizo-Wilcox Aquifer, (2) having geographic coordinate locations that place the well within the outcrop area as defined by the aquifer GIS coverage published by TWDB, and (3) having balanced water quality analyses with a sample date of 1969 or later as of May 2010. We did not evaluate the TCEQ PWS database because many of the samples from entry points include treatment and blending that would not reflect water quality in the aquifer.

The most recent sample for a given well was used and resulted in water quality information for 1,293 wells. Analyses for MCL parameters that are either commonly measured (pH) or that are commonly present in mg/L concentrations (including chloride, sulfate, TDS, fluoride, and nitrate) are available for all or most of the wells analyzed. Analyses for MCL parameters that are commonly present in μg/L concentrations (including trace metals and radioactive parameters) are available for a subset of the wells. Results published in the database that represent detection limits (i.e., "less than" values) that are greater than the MCL for a given constituent were eliminated from this analysis.

Concentrations are summarized for Groundwater Management Areas (GMA) 11, 12, and 13 in Tables 9.1, 9.2, and 9.3, respectively. The spatial distribution of each MCL listed in the tables is shown in Figures 9.1 through 9.26.

Primary MCL constituents

There are no widespread violations of any of the primary MCL constituents, with only 27 individual violations for all constituents. The most significant violation is for nitrate-N, which accounts for 19 of these. Approximately 75% of wells with nitrate exceedances of the MCL were domestic and irrigation wells (Table 9.4), suggesting primarily septic tank and fertilizer sources of nitrate (Table 9.4). Remaining exceedances of MCLs represent three violations for lead (all in GMA 11), one each for beryllium and cadmium (also in GMA 11), and one for gross alpha radiation (in GMA 13). In addition, radium (combined Ra-226 and Ra-228) activity was measured for eight wells in GMA 12, two of which had values higher than the MCL. Several of the primary MCL constituents have only a small number of analyses in one or more of the GMA regions, including mercury, nitrite-N, uranium, radium, and gross alpha.

Secondary MCL constituents

Violations of many of the secondary MCL constituents are widespread and generally related to indicators of overall groundwater quality. The number of secondary MCL exceedances ranges from ~200 to 350 for various elements. These exceedances are dominated by TDS, chloride, sulfate, iron, and manganese. The percentage of wells that exceeded the TDS MCL is much greater in the southern (62%) region of the Carrizo Wilcox Aquifer than in the central or northern (25 and 27%) regions, and median TDS concentrations are also greatest in the southern (587 mg/L) region relative to the central and northern regions (331 and 325 mg/L). Chloride concentrations tend to decrease with well depth to ~300 to 400 ft, particularly in GMA 12 and 13, and concentrations remain fairly uniform with greater well depth (Figure 9.27). TDS concentrations show similar trends, decreasing to depths of 300 to 400 ft and increasing at greater depths, mostly likely reflecting increased bicarbonate concentrations.

Iron and manganese MCL exceedances are also widespread. Median iron concentrations range from 79 to 133 ug/L. These exceedances may be related to lignite distribution. It is difficult to assess the regional distribution of iron and manganese concentrations because of large differences in the number of groundwater samples analyzed for these elements among the regions. Median iron concentrations range from 79 to 133 ug/L. Although the largest number of iron and manganese exceedances are found in the northern region, the percentage of exceedances is less in the north (23%) than in the south (42%). However, the sample number is much less in the south (43) than in the north (458). Increasing the number of samples by extending the analysis to include wells in the confined zone results in similar percentage exceedances as found in the outcrop zone (24% in north versus 41% in south), supporting the percentage differences in the outcrop. Median iron and manganese concentrations are also highest in the south. These iron and manganese exceedances may be related to lignite distribution; however, further study is required to assess this. Log values of iron and manganese concentrations are positively correlated (r=0.53 to 0.66) in each of the GMAs, using only analyses for which concentrations for both constituents were above detection limits (i.e., no less than n=177) (Figure 9.28). Using the overall data set, 67 wells (57%) exceed the MCL for iron (300 μg/L), and 81 wells (69%) exceed the MCL for manganese (50 μg/L). No information is available on redox potential or dissolved oxygen concentrations for these samples in the TWDB database. Only limited information is available for nitrite concentrations (112 analyses), which would indicate reducing conditions. Most (80) samples show undetectable (<0.01 mg/L NO_2-N) levels of nitrite, with most nitrite detections occurring in the Sabine Uplift region.

Occurrence of pH outside the secondary EPA MCL range of 6.5 and 8.5 is much greater in the north (19 to 23%) than in the central (4 to 7%) and south (3 to 12%) Carrizo Wilcox Aquifer. These pH values outside the range in the north may be related to scaling and corrosion problems in groundwater in this region.

Section 2.1 on previous studies provides information that can be used for an understanding of the regional distribution of many inorganic chemical constituents.

2.3 Groundwater Contamination Based on Data from the Texas Commission on Environmental Quality and the RRC

Regulatory agencies, including TCEQ and the RRC, require or conduct monitoring to ensure compliance with guidelines and regulations for protection of groundwater from contamination. There are 147 documented groundwater contamination cases from the TCEQ database and 23 documented cases from the RRC data in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 TCEQ State of Texas water quality inventory (Table 9.5, Figure 9.29). Contamination cases under the jurisdiction of the TCEQ are generally identified through regulatory compliance monitoring, whereas cases under the jurisdiction of the RRC are identified mostly from special studies, investigations in response to complaints, or ambient groundwater quality monitoring activities. The most common contaminants reported include gasoline and diesel related to petroleum storage tanks. Additional contaminants include volatile organic compounds (such as benzene, toluene, ethylbenzene, xylene, and BTEX), chlorinated solvents, TCE, TPH, creosote, heavy metals, chloride, and arsenic.

2.4 Responses Concerning Groundwater Contamination from Online Survey

The following question was posed to the groundwater conservation districts (GCDs) "Are you aware of the presence of anthropogenic contaminations in the recharge zone or the production zone of the Carrizo Wilcox Aquifer?" A total of four GCDs responded. Mid-East Texas GCD listed eight specific groundwater contamination cases in the Carrizo Wilcox recharge zone in Freestone County detailed in the *Joint Groundwater Monitoring and Contamination Report*, 2008. Plum Creek Conservation District provided an in-depth report on groundwater nitrate contamination in Caldwell County. One of the wells exceeding the EPA MCL corresponds to a well shown in Figure 9.11 in the outcrop area; however, many of the other wells on this map are outside the outcrop area of the Carrizo Wilcox Aquifer. Plum Creek Conservation District also presented a report on oil and gas activity in and around Caldwell County, showing ~3,000 oil and gas wells and 41 new wells in 2008 and 72 injection wells and 1 new injection well in 2008. The RRC TCEQ Salt Water Minimization Program for plugging abandoned, unplugged, or improperly plugged wells was described. It was noted that ~419 orphan wells (no activity within 12 mo) are in the region and 17 have been approved for plugging. Post Oak Savannah GCD noted anthropogenic contamination near Rockdale as a result of the operation of a power plant and smelter. Rusk County GCD also noted potential contamination related to electric generation operation on Martin Lake from lignite coal and has been monitoring mercury levels in active wells near the plant; however, no contamination has been found to date.

3.0 Determine Whether Potential Pollution of the Aquifer is an Issue that Should be Addressed and, if so, by Whom

Potential pollution of the aquifer may result from a number of activities. Increased groundwater production from the confined portion of the aquifer will induce water movement from surrounding confining layers, including the Hooper and Calvert Bluff units. The quality of groundwater in these confining units will determine whether flow from these units will degrade groundwater quality. This issue should be evaluated in future studies. Groundwater quality is currently not incorporated into the TWDB Groundwater Availability Modeling (GAM) program; however, water quality impacts water availability. Recent requests for statements of qualifications from TWDB are related to use of groundwater quality to refine the conceptual flow models of major aquifers. Future GAMs should consider modeling groundwater quality as an integral part of the program.

In the following section we briefly discuss hydraulic fracturing (fracing) activities related to shale-gas production as a potential source of contamination.

3.1 Potential Pollution of Aquifer Related to Hydraulic Fracturing

The previous studies section and Section 4 on management and regulatory gaps describe contamination issues related to oil and gas activity. The following discussion focuses on fracing wells or hydraulic fracturing of wells for gas production, which was brought up during stakeholder meetings. Fracing poses a potential threat to groundwater quality because, although frac fluids are ~99% water, chemical additives, including acids, antibacterial agents, gelling agents, surfactants, and pH adjusting agents could impact groundwater quality. Frac fluids are injected under high pressure, which could enhance potential contamination if the pressure causes cracking of cement and well casings of wells are poorly constructed. Potential pathways of contaminants include surface spills (road accident, defective pipeline, leaky storage pond or container, etc.) or faulty surface casing contaminating shallow aquifers. Although faults and fractures could also provide pathways for frac fluids, these pathways are unlikely to have a direct connection all the way to the fresh water. Both the frac fluid before injection and the flowback/produced water after the frac job could jeopardize water resources, despite precautions by operators.

The past decade has seen a tremendous growth in wells completed and stimulated with an expanded approach of hydraulic fracturing in Texas (Figure 9.29). The IHS database revealed ~30,000 stimulated wells statewide in the 2005 through 2010 period. Reservoirs, especially gas reservoirs, with low permeability (<<1 md), so-called tight gas reservoirs or tight sands, cannot produce gas without developing a fracture network, and they have traditionally been stimulated with relatively small volumes of water (<500,000 gal) applied to vertical wells. Water and additives combine to make a gel to keep the proppant, which consists of small sand grains, suspended in a fluid in suspension. The mixture is injected under pressure high enough to create new fractures or rejuvenate older fractures. The proppant grains then keep the fractures open when the pressure subsides and allow gas production. Examples of tight sands in the footprint of the Carrizo Wilcox Aquifer are the Cotton Valley and Travis Peak Formations in East Texas and the Olmos Formation in South Texas, which have been producing gas since the 1980s and 1990s, respectively, using fracing technology (Figure 9.29). Two important developments have been related to hydraulic fracturing in the past few years: (1) advances in horizontal drilling and (2) frac fluid composition. Horizontal wells contact more rock than vertical wells and are thus more advantageous, particularly if they are deep. The end of the 1990s saw development of slick water fracs, in which less proppant and no gel were injected, but higher pressure and higher flow rates were used. The combination of these two factors was pioneered in the Fort Worth Basin in the Barnett Shale. Laterals or horizontal sections of these wells can be 5,000 ft long, and fracing such long intervals consumes large amounts of water. A representative value would be 4 million gal per well, but it can be much higher.

The footprint of the Carrizo Wilcox Aquifer includes two shale-gas plays: the Haynesville/Bossier Shales at the Texas-Louisiana state line and the Eagle Ford and Pearsall Shales at the Mexican border (Figure 9.30). Typical well depths range from 10,000 to 14,000 ft in the Haynesville/Bossier Shales and ~7,000 to 12,000 ft in the Eagle Ford Shale in South Texas. As of the end of 2010, most of the activity had been in the Eagle Ford play, primarily because it contains oil, currently more valuable than gas. In 2008, ~30,000 acre-feet of water (surface water and groundwater) was used across Texas, more than half in the Barnett Shale; however, the quantity of water is expected to increase as more operators move into these new plays. Although this level of pumping may have local impacts, 30,000 acre-feet represents less than 1% of total groundwater pumping in Texas. EPA is currently conducting a study to confirm the origin of the few reported cases of contamination related to shale-gas development in the U.S.

3.3 Agencies for Assessing Potential Pollution of the Aquifer

Currently TCEQ is responsible for groundwater quality in Public Water Supply systems and the RRC is responsible for groundwater quality related to oil and gas activities. Many of the Groundwater Conservation Districts are also conducting monitoring of groundwater quality. Regional groundwater quality is evaluated by the TWDB. Assessment of potential pollution impacts on the aquifer should follow current guidelines: pollution of PWS systems by TCEQ, pollution related to oil and gas by RRC, and regional water quality by TWDB. Evaluation of specific groundwater quality issues could be examined using studies funded by these agencies to universities or consultants, such as assessments of impacts of water from confining units on regional groundwater quality, evaluation of lignite mining on local groundwater quality, or analysis of potential impacts of fracing on groundwater quality. As discussed in the next section, one of the regulatory gaps is assessment of groundwater quality of private well owners. The legislature should designate some group to be responsible for this, such as Groundwater Conservation Districts, TCEQ, or TWDB.

4.0 Identify Any Management or Protection Regulatory Gaps

Management and protection regulatory gaps were assessed through the online survey. Results from the online survey are reported in Task 1b and are presented in this section for completeness. The following question was posed in the survey. "Are you aware of management gaps or regulatory gaps that have led to or could lead to contamination of the recharge zone or production areas of the Carrizo-Wilcox Aquifer? If so, please describe the management or regulatory gaps related to past, current, or potential aquifer contamination." Fourteen respondents answered this question with a negative response. Three responded to the question regarding management or regulatory gaps. The Schertz-Seguin Local Government Corporation reported that "…there are numerous wells in the Carrizo Formation. Some are old wells that were originally used for irrigation of crops. There are also numerous oil wells that have been converted to water wells. Some of these wells are deteriorated and should be plugged but landowners are reluctant to assume financial responsibility for maintaining wells that are no longer in use." Bexar Metropolitan Water District pointed to possible management or regulatory gaps because of the many different groundwater conservation districts and their rules and the lack of consistency between them. Bexar Metropolitan Water District further stated there was an "absence of any interstate or binational management of the aquifer could lead to potential future contamination of the aquifer." The City of Bryan reported being unaware of what regulatory controls are in place to manage the recharge zone. The City of Bryan went on to suggest that the recharge zone should be considered a sensitive area to protect these areas from sources of contamination, such as from manufacturing or commercial industries. Forty-eight respondents did not answer this question.

The groundwater management policies and enforcement procedures of the RRC were a primary concern for 6 of the 16 groundwater conservation districts. The RRC's ability to effectively regulate hydrocarbon production companies and their well operations is contested because of the perceived inability to effectively regulate groundwater support wells and their inability to eliminate the occurrence of orphan or abandoned wells. Neches and Trinity Valleys Groundwater Conservation District stated concerns regarding "inadequate oversight by the RRC of the oil and gas wells and rig supply wells, including the many old wells within the district, which has presented many potential sources of contamination of groundwater." Districts in the eastern region of the Carrizo Wilcox Aquifer, including Panola County Groundwater Conservation District, Plum Creek Conservation District, and Neches and Trinity Valleys Groundwater Conservation District, have noted that there are regulatory concerns with the management of oil and gas exploration and the oversight provided by Texas agencies including the RRC and Texas Department of Licensing and Regulation (TDLR). For instance, Rusk County GCD stated "With each oil/gas exploration well drilled, a water well is drilled to support the operation. Due to lack of staffing, the TDLR does not conduct any construction inspections of these water wells. Our concern is for the illegal practice of screening more than one zone to gain the quantity of water needed. This practice, although not a major problem while the rig is in use, becomes a problem when the well is capped and left idle. The RCGCD purchased a downhole video camera in 2008 and requires inspection of each of these support wells within 180 days of the oil/gas rig leaving the pad. We have inspected over 300 wells and have found that about 11% were screened in more than one zone." Neches and Trinity Valleys GCD stated "Inadequate oversight by the RRC of the oil and gas wells and rig supply wells, including the many old wells within the District, which has presented many potential sources of contamination of groundwater." Panola GCD stated "lack of regulation by RRC of water wells involved in oil and gas operations and mining." Plum Creek CD stated "There are Management and regulatory gaps from the RRC that could possible lead to contamination of the recharge zone. These gaps are from past production practices and casing leaks." The aforementioned comments were submitted to the Carrizo-Wilcox Aquifer Study groundwater conservation district survey.

Moreover, Rusk County noted that the recharge zone for the Carrizo Wilcox Aquifer extends beyond the borders of Texas and suggested that a management or regulatory gap could lead to contamination of the recharge zone. They suggested that this gap should be addressed by the TWDB or some other state entity if it is not currently under study. Rusk County also noted extensive strip mining operations in the recharge area. The strip mining process includes removal of 200 to 300 ft of earth to mine the lignite. Mixing of the overburden and removal of the lignite may affect recharge and groundwater quality in the Carrizo Wilcox Aquifer. However, there are no reported cases of groundwater contamination from the surface mining group in the RRC related to lignite mining.

Another regulatory gap is the lack of oversight of groundwater quality in private wells. In addition, regulation of public water supply wells is restricted to water quality at the entry points and does not include evaluation of raw groundwater quality. The Texas Groundwater Protection Committee identified the lack of regulation of water quality in private wells as an important gap; however, there is no mandate from the legislature or from federal agencies to oversee water quality in private wells.

Table 9.1: Water quality summary for wells completed in the Carrizo-Wilcox Aquifer outcrop area in Groundwater Management Area 11.

Name (symbol)	*Concentration*			*Sample*			
	MCL	*Median*	*Unit*	*Median Date*	*Total*	*# >MCL*	*% >MCL*
Primary MCL							
Antimony (Sb)	6	< 1	µg/L	2002	130	0	0.0
Arsenic (As)	10	< 2	µg/L	1998	198	0	0.0
Barium (Ba)	2	0.032	mg/L	2002	192	0	0.0
Beryllium (Be)	4	< 1	µg/L	2002	131	1	0.8
Cadmium (Cd)	5	< 1	µg/L	1998	197	1	0.5
Chromium (Cr)	100	4	µg/L	1998	198	0	0.0
Copper (Cu)	1.3	< 0.004	mg/L	1998	197	0	0.0
Fluoride (F)	4	0.2	mg/L	1986	566	0	0.0
Lead (Pb)	15	< 1	µg/L	1998	199	3	1.5
Mercury (Hg)	2	< 0.2	µg/L	1993	119	0	0.0
Nitrate-N (NO_3-N)	10	< 0.05	mg/L	1986	541	6	1.1
Nitrite-N (NO_2-N)	1	< 0.01	mg/L	1993	97	0	0.0
Selenium (Se)	50	< 2	µg/L	1998	197	0	0.0
Thallium (Tl)	2	< 1	µg/L	2005	112	0	0.0
Uranium (U)	30	< 1	µg/L	2009	37	0	0.0
Gross alpha	15	< 2	pCi/L	1993	84	0	0.0
Radium (Ra)	5	–	pCi/L	–	–	–	–
Secondary MCL							
Aluminum (Al)	50	< 4	µg/L	2002	149	3	2.0
Chloride (Cl)	250	28	mg/L	1986	571	22	3.9
Copper (Cu)	1	< 0.004	mg/L	1998	197	0	0.0
Fluoride (F)	2	0.2	mg/L	1986	566	13	2.3
Iron (Fe)	300	80	µg/L	1986	458	103	22.5
Manganese (Mn)	50	< 20	µg/L	1991	302	58	19.2
pH	<6.5	8.1	–	1986	571	62	10.9
pH	>8.5	8.1	–	1986	571	139	24.3
Silver (Ag)	100	< 4	µg/L	1993	131	0	0.0
Sulfate (SO_4)	250	10	mg/L	1986	565	11	1.9
TDS	500	325	mg/L	1986	571	152	26.6
Zinc (Zn)	5	0.012	mg/L	1998	197	0	0.0

Name (Symbol): MCL constituent name and chemical symbol, *MCL*: MCL concentration, *Median*: median concentration for wells in GMA, *Unit*: concentration units, *Median Date*: median year of samples, *Total*: number of sampled wells, *# >MCL*: number of wells with constituent concentration greater than the MCL value, *% >MCL*: percentage of wells with constituent concentration greater than the MCL value.

Table 9.2: Water quality summary for wells completed in the Carrizo-Wilcox Aquifer outcrop area in Groundwater Management Area 12.

Name (symbol)	*Concentration*			*Sample*			
	MCL	*Median*	*Unit*	*Median Date*	*Total*	*# >MCL*	*% >MCL*
Primary MCL							
Antimony (Sb)	6	< 1	µg/L	2006	50	0	0.0
Arsenic (As)	10	< 2	µg/L	2006	50	0	0.0
Barium (Ba)	2	0.1	mg/L	2006	50	0	0.0
Beryllium (Be)	4	< 1	µg/L	2006	50	0	0.0
Cadmium (Cd)	5	< 1	µg/L	2006	50	0	0.0
Chromium (Cr)	100	2	µg/L	2006	50	0	0.0
Copper (Cu)	1.3	< 0.001	mg/L	2006	50	0	0.0
Fluoride (F)	4	0.2	mg/L	1986	487	0	0.0
Lead (Pb)	15	< 1	µg/L	2006	50	0	0.0
Mercury (Hg)	2	< 0.2	µg/L	2009	9	0	0.0
Nitrate-N (NO_3-N)	10	< 0.09	mg/L	1986	451	5	1.1
Nitrite-N (NO_2-N)	1	< 0.01	mg/L	1993	5	0	0.0
Selenium (Se)	50	< 4	µg/L	2006	50	0	0.0
Thallium (Tl)	2	< 1	µg/L	2006	50	0	0.0
Uranium (U)	30	< 1	µg/L	2009	9	0	0.0
Gross alpha	15	5	pCi/L	2009	11	0	0.0
Radium (Ra)	5	<1.5	pCi/L	2009	8	2	25.0
Secondary MCL							
Aluminum (Al)	50	< 4	µg/L	2006	50	0	0.0
Chloride (Cl)	250	41	mg/L	1986	493	20	4.1
Copper (Cu)	1	<0.001	mg/L	2006	50	0	0.0
Fluoride (F)	2	0.2	mg/L	1986	487	0	0.0
Iron (Fe)	300	79	µg/L	2005	51	14	27.5
Manganese (Mn)	50	24	µg/L	2005	51	14	27.5
pH	< 6.5	7.6	–	1986	490	33	6.7
pH	> 8.5	7.6	–	1986	490	20	4.1
Silver (Ag)	100	< 1	µg/L	2009	10	0	0.0
Sulfate (SO_4)	250	23	mg/L	1986	493	20	4.1
TDS	500	331	mg/L	1986	493	124	25.2
Zinc (Zn)	5	0.008	mg/L	2006	50	0	0.0

Name (Symbol): MCL constituent name and chemical symbol, *MCL*: MCL concentration, *Median*: median concentration for wells in GMA, *Unit*: concentration units, *Median Date*: median year of samples, *Total*: number of sampled wells, *# >MCL*: number of wells with constituent concentration greater than the MCL value, *% >MCL*: percentage of wells with constituent concentration greater than the MCL value.

Table 9.3: Water quality summary for wells completed in the Carrizo-Wilcox Aquifer outcrop area in Groundwater Management Area 13.

Name (symbol)	*Concentration*			*Sample*			
	MCL	*Median*	*Units*	*Median Date*	*Total*	*# >MCL*	*% >MCL*
Primary MCL							
Antimony (Sb)	6	< 1	µg/L	2006	43	0	0.0
Arsenic (As)	10	< 2	µg/L	2006	43	0	0.0
Barium (Ba)	2	0.083	mg/L	2006	43	0	0.0
Beryllium (Be)	4	< 1	µg/L	2006	43	0	0.0
Cadmium (Cd)	5	< 1	µg/L	2006	43	0	0.0
Chromium (Cr)	100	< 1	µg/L	2006	43	0	0.0
Copper (Cu)	1.3	< 0.001	mg/L	2006	43	0	0.0
Fluoride (F)	4	0.3	mg/L	1986	227	0	0.0
Lead (Pb)	15	< 1	µg/L	2006	43	0	0.0
Mercury (Hg)	2	<0.2	µg/L	2009	5	0	0.0
Nitrate-N (NO_3-N)	10	<0.09	mg/L	1986	228	8	3.5
Nitrite-N (NO_2-N)	1	<0.01	mg/L	1990	10	0	0.0
Selenium (Se)	50	< 4	µg/L	2006	43	0	0.0
Thallium (Tl)	2	< 1	µg/L	2006	43	0	0.0
Uranium (U)	30	4	µg/L	2009	5	0	0.0
Gross alpha	15	6	pCi/L	2009	5	1	20.0
Radium (Ra)	5	–	pCi/L	–	–	–	–
Secondary MCL							
Aluminum (Al)	50	< 4	µg/L	2006	43	0	0.0
Chloride (Cl)	250	109	mg/L	1986	229	42	18.3
Copper (Cu)	1	<0.001	mg/L	2006	43	0	0.0
Fluoride (F)	2	0.3	mg/L	1986	227	2	0.9
Iron (Fe)	300	133	µg/L	2006	43	18	41.9
Manganese (Mn)	50	18	µg/L	2006	43	14	32.6
pH	< 6.5	7.3	–	1986	227	28	12.3
pH	> 8.5	7.3	–	1986	227	7	3.1
Silver (Ag)	100	< 1	µg/L	2009	5	0	0.0
Sulfate (SO_4)	250	79	mg/L	1986	229	33	14.4
TDS	500	587	mg/L	1986	229	143	62.4
Zinc (Zn)	5	0.01	mg/L	2006	43	0	0.0

Name (Symbol): MCL constituent name and chemical symbol, *MCL*: MCL concentration, *Median*: median concentration for wells in GMA, *Unit*: concentration units, *Median Date*: median year of samples, *Total*: number of sampled wells, *# >MCL*: number of wells with constituent concentration greater than the MCL value, *% >MCL*: percentage of wells with constituent concentration greater than the MCL value.

Table 9.4: Well types for Carrizo-Wilcox Aquifer outcrop wells with NO3-N >MCL (10 mg/L).

Region	Total	# > MCL	% > MCL	Domestic	Stock	Irrigation	Unused	Med. Depth (ft)
Combined	1220	19	1.6	9	2	5	3	45
GMA 11	541	6	1.1	2	2	1	1	44
GMA 12	451	5	1.1	4	0	0	1	26
GMA 13	228	8	3.5	3	0	4	1	162

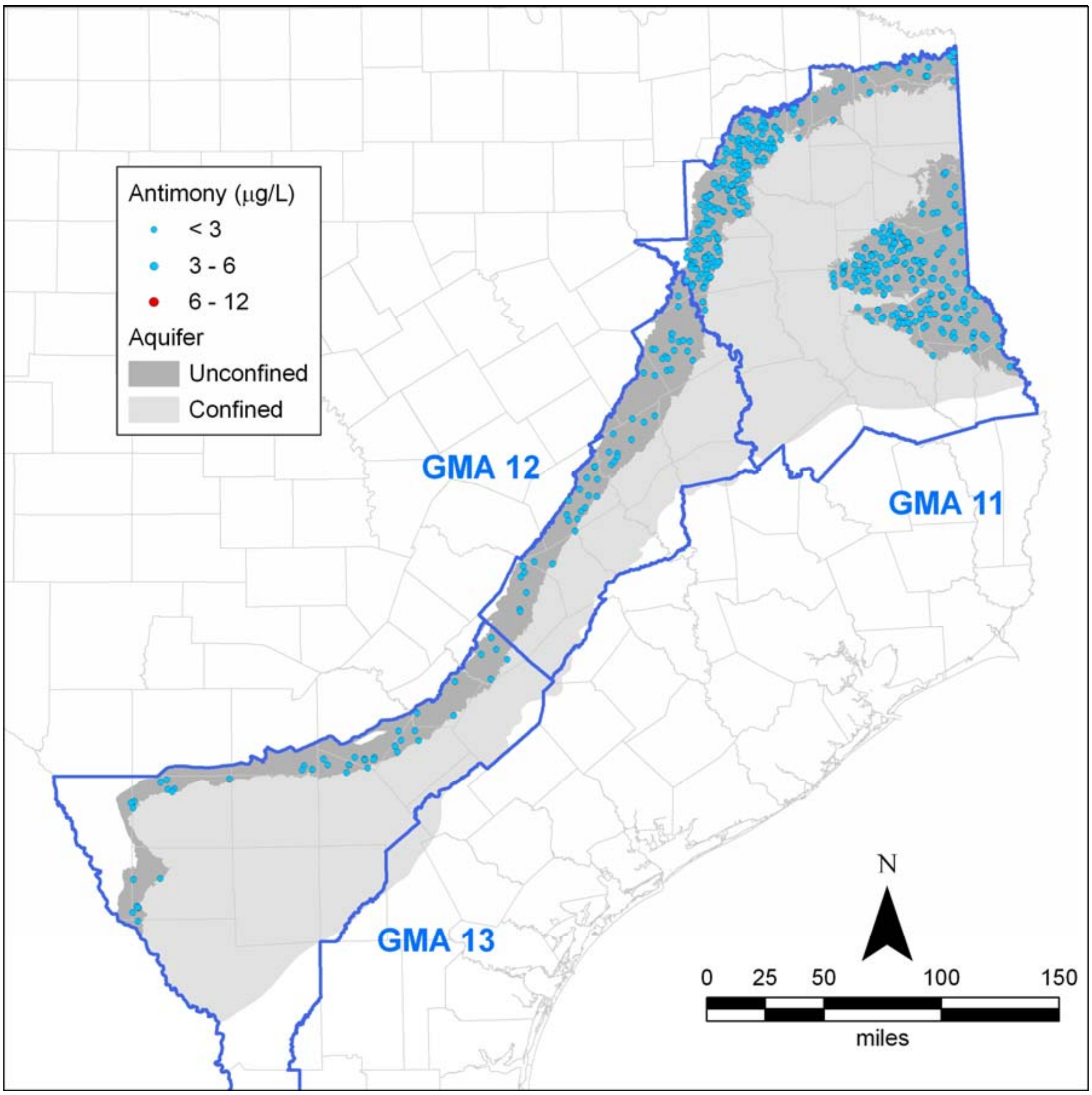

Figure 9.1: Spatial distribution of antimony (Sb) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

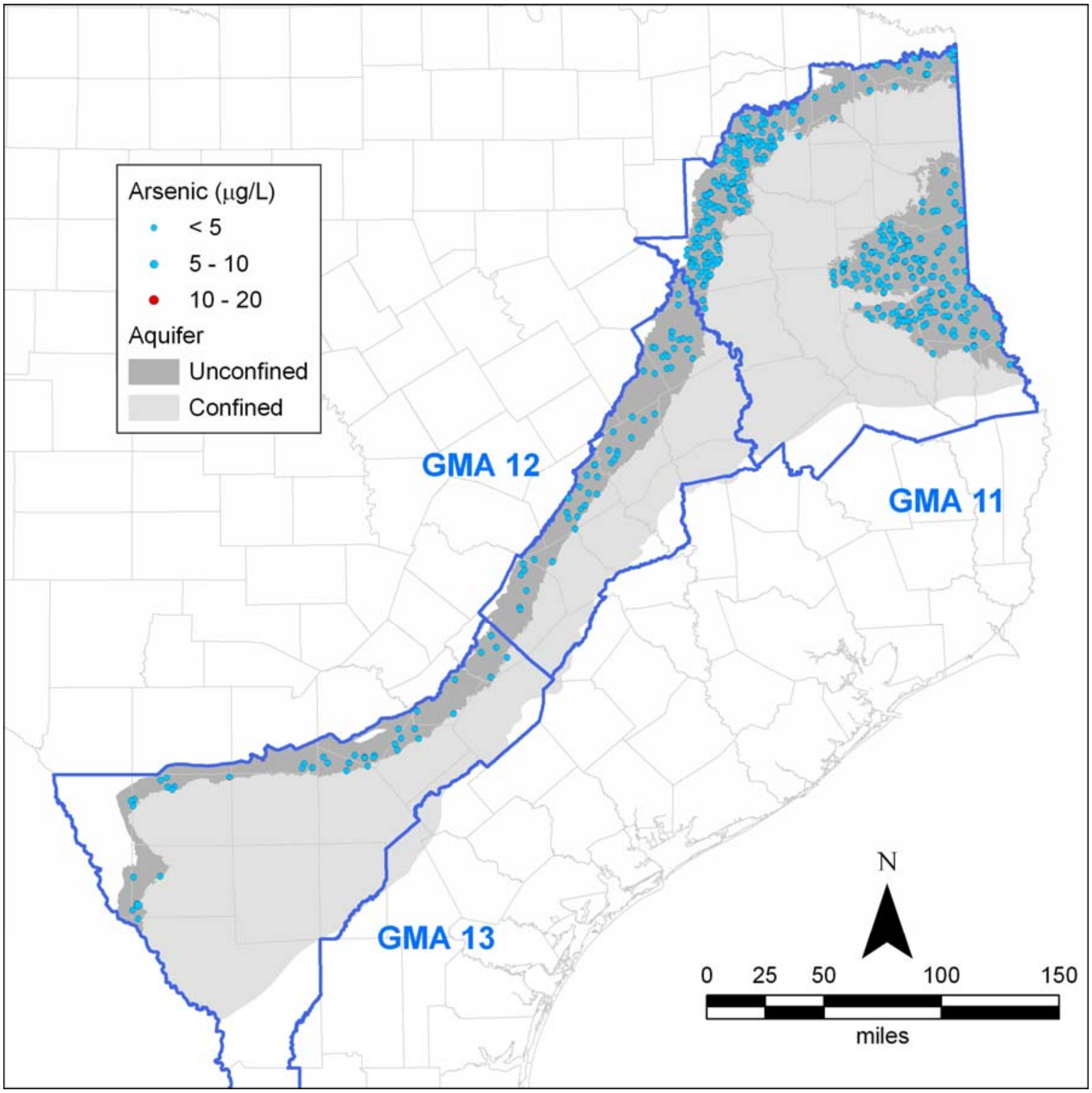

Figure 9.2: Spatial distribution of arsenic (As) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

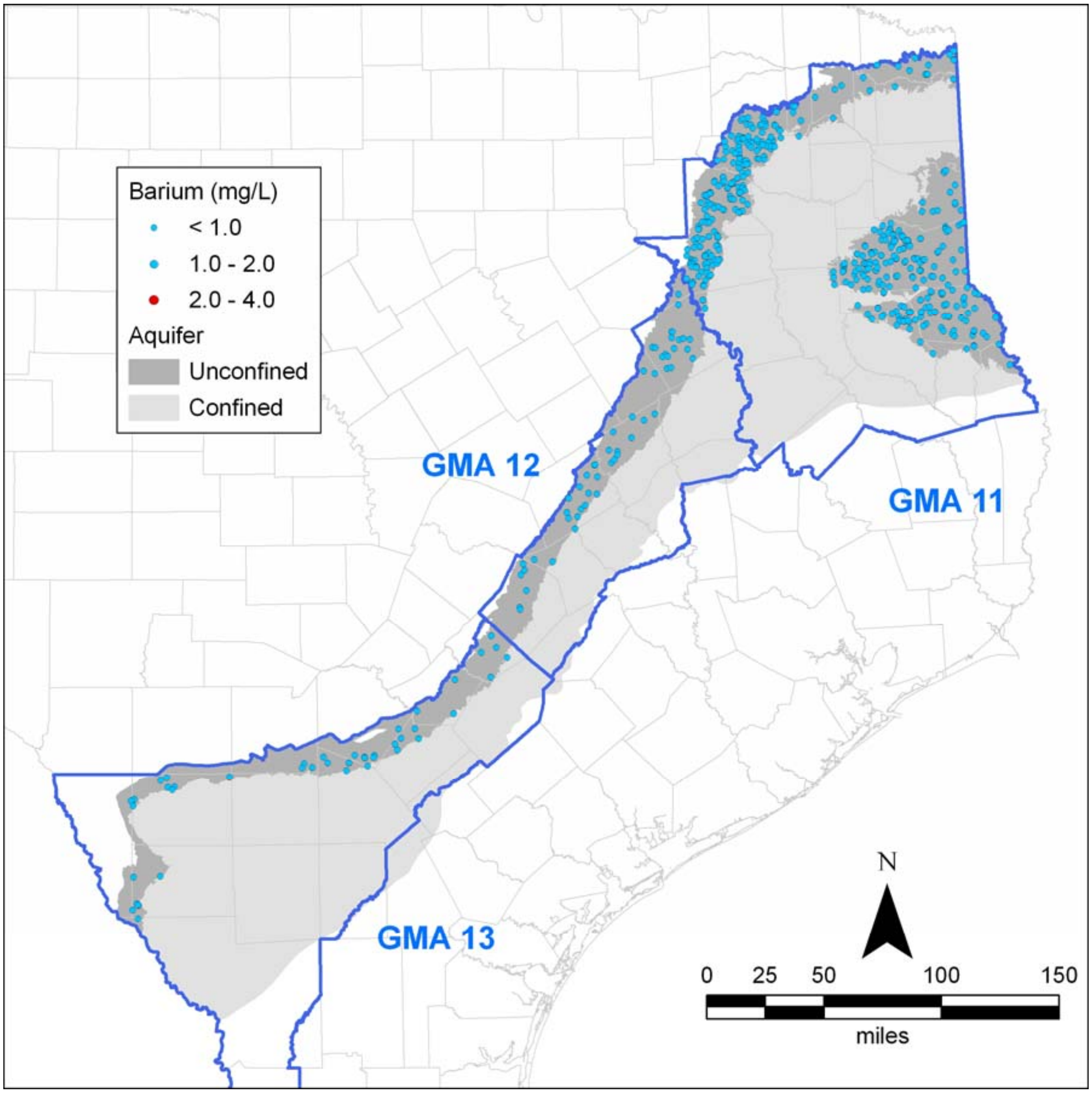

Figure 9.3: Spatial distribution of barium (Ba) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

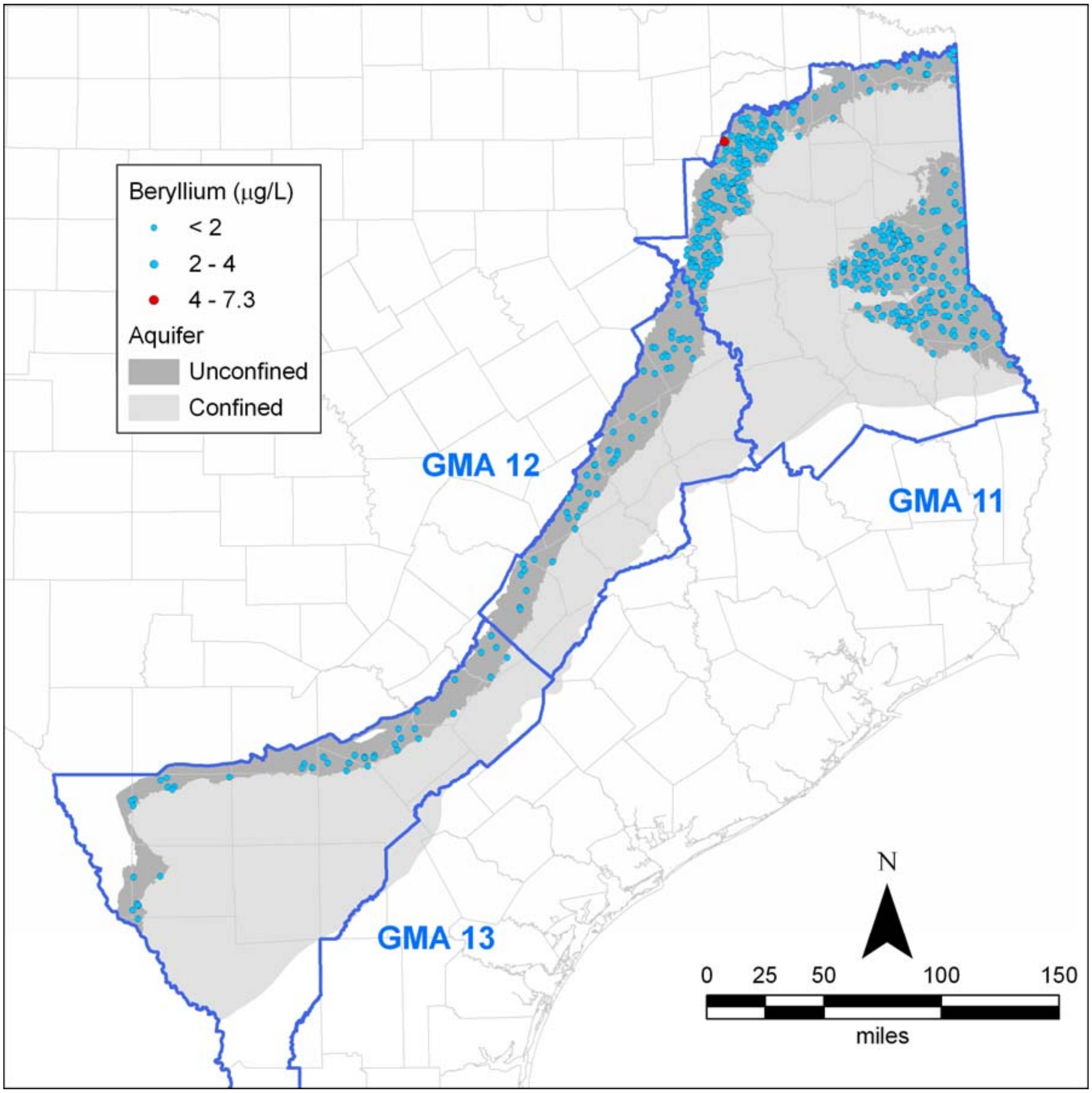

Figure 9.4: Spatial distribution of beryllium (Be) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

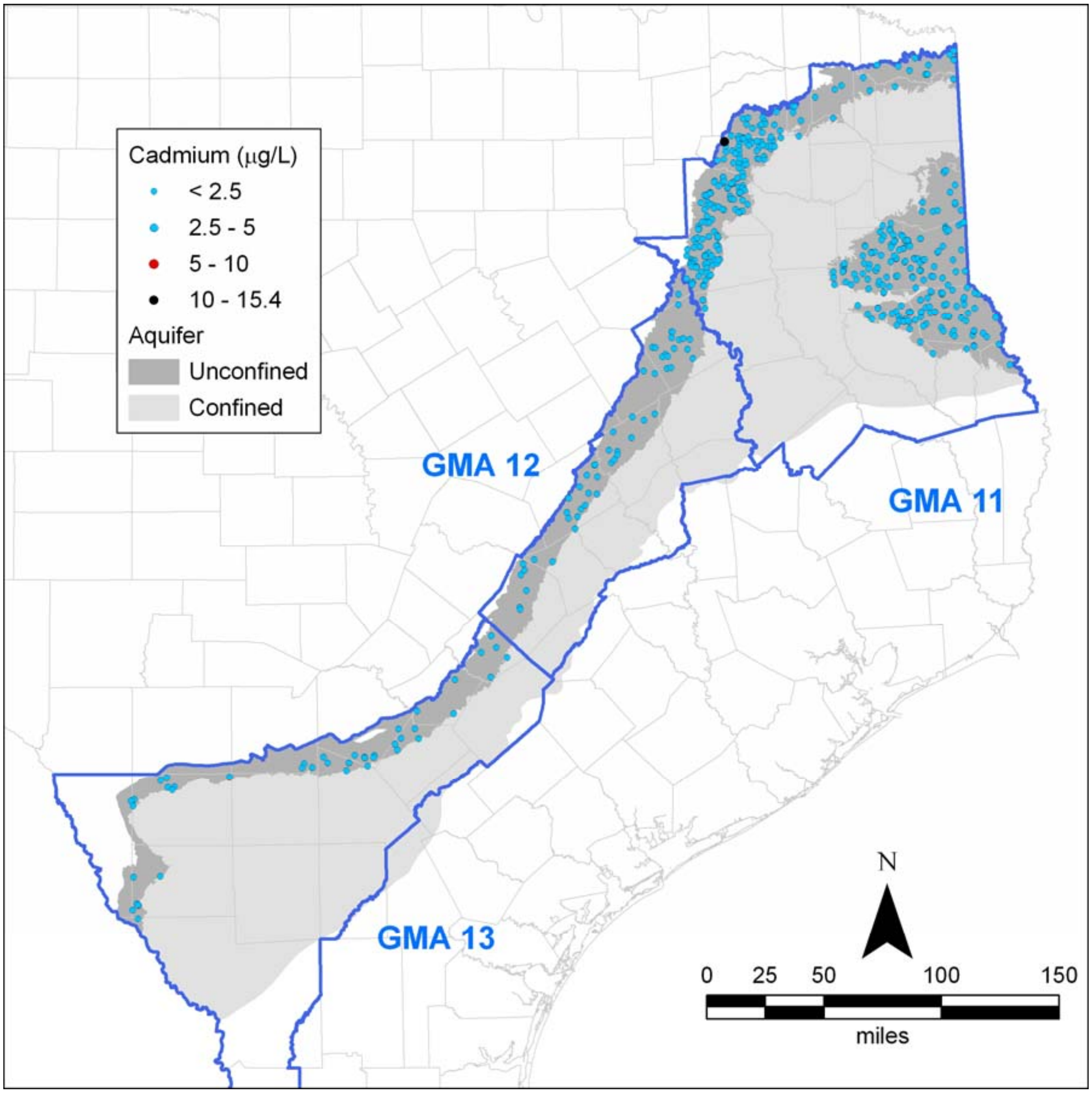

Figure 9.5: Spatial distribution of cadmium (Cd) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

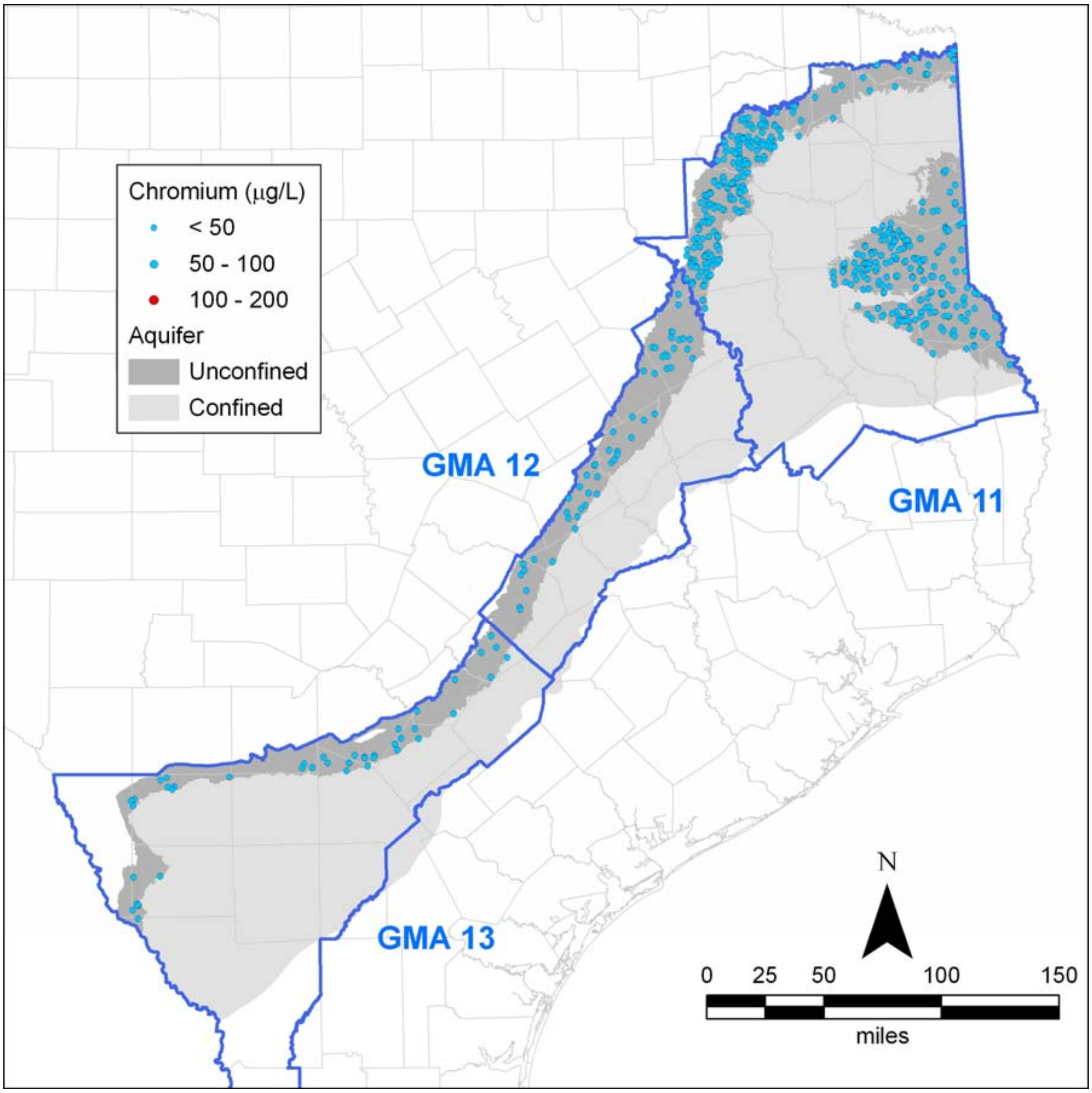

Figure 9.6: Spatial distribution of chromium (Cr) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

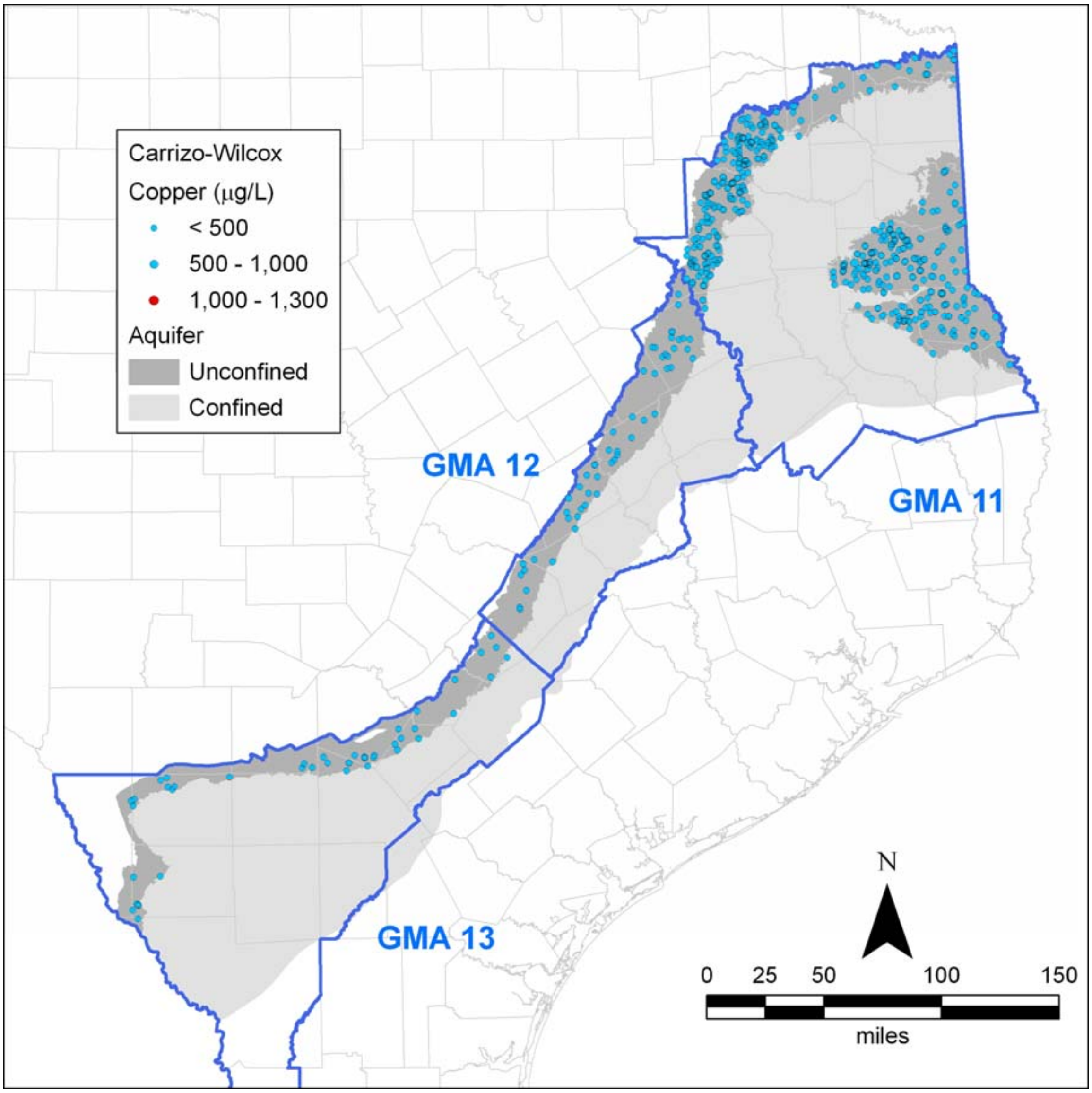

Figure 9.7: Spatial distribution of copper (Cu) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

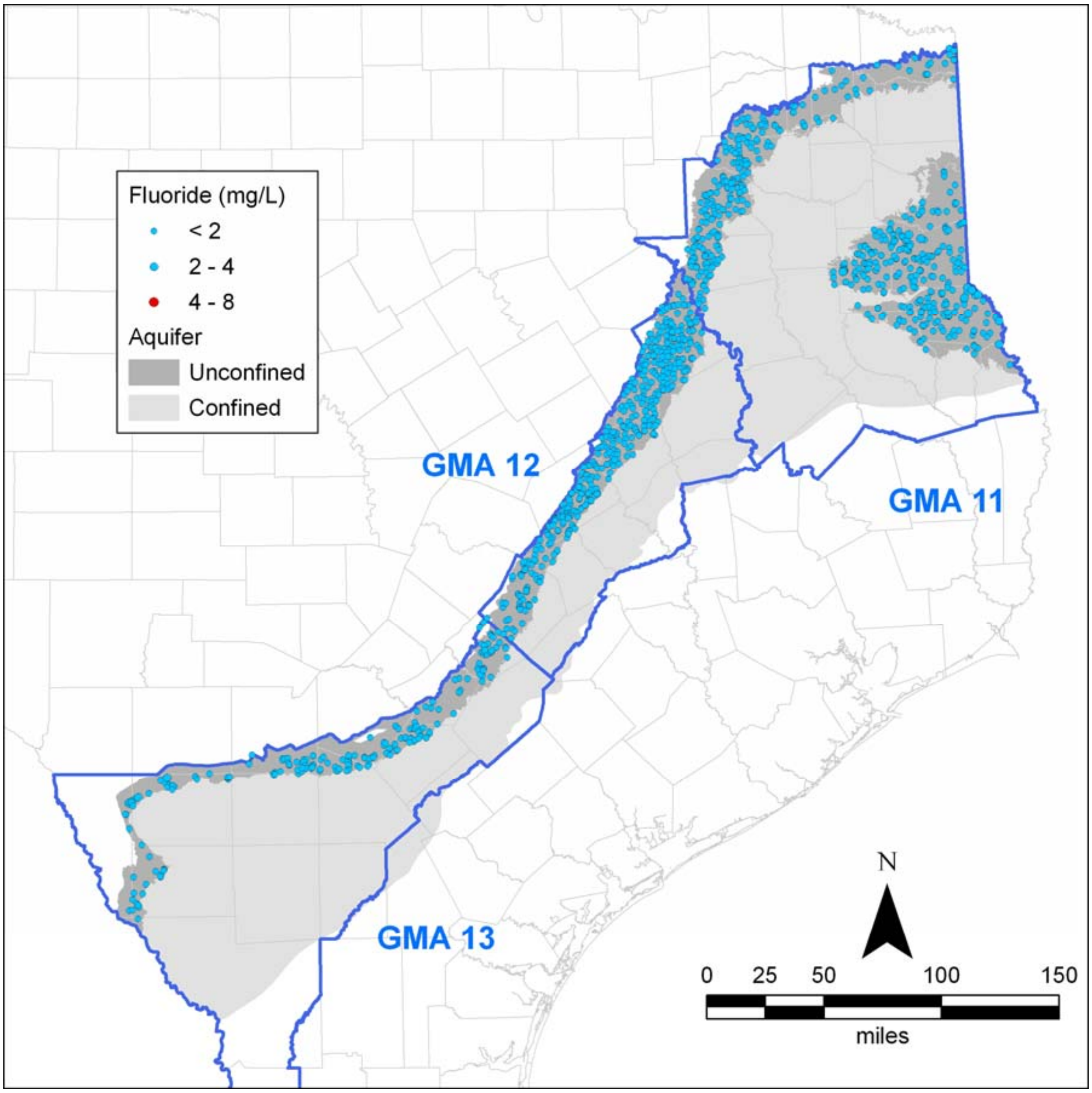

Figure 9.8: Spatial distribution of fluoride (F) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

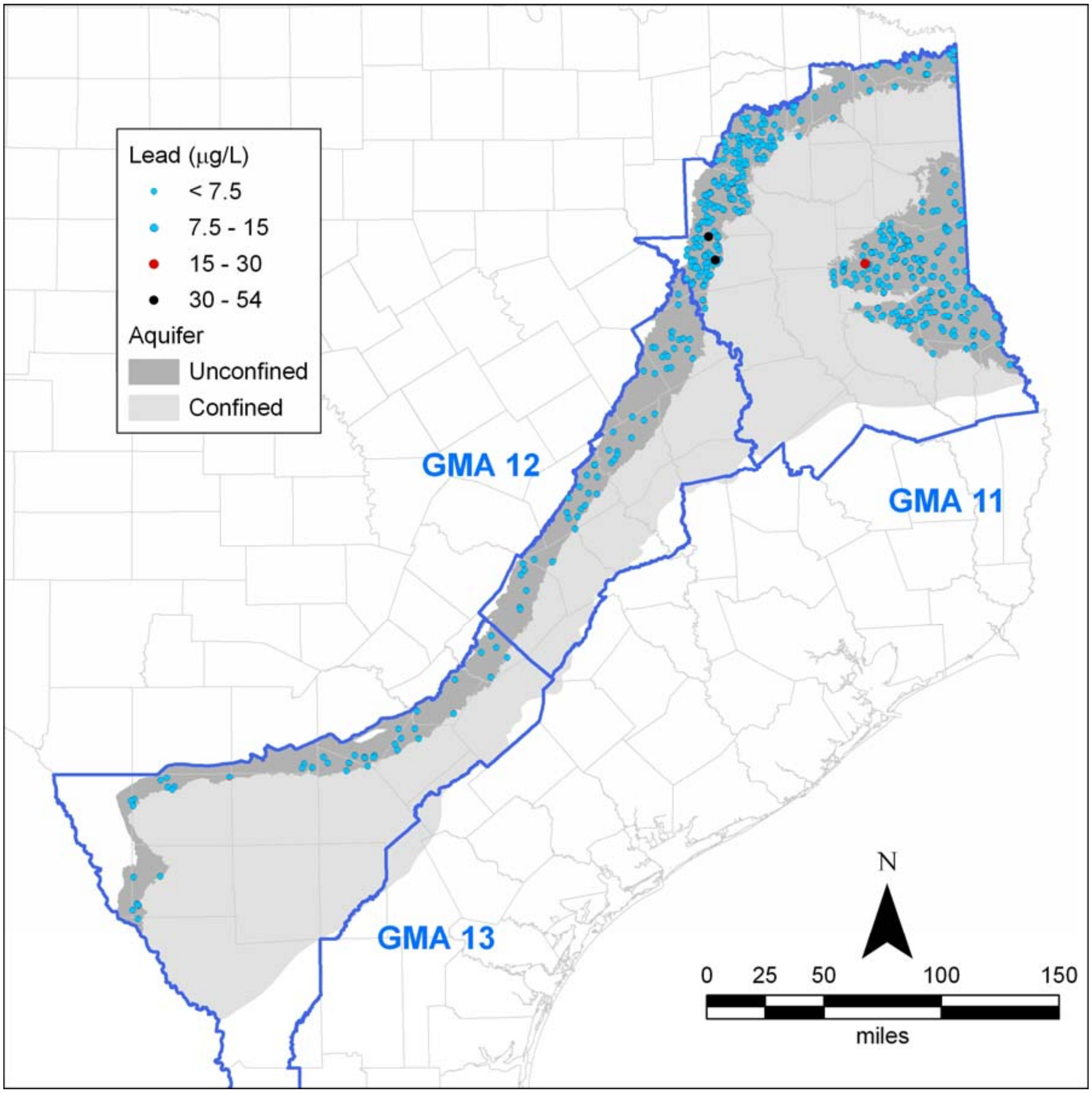

Figure 9.9: Spatial distribution of lead (Pb) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

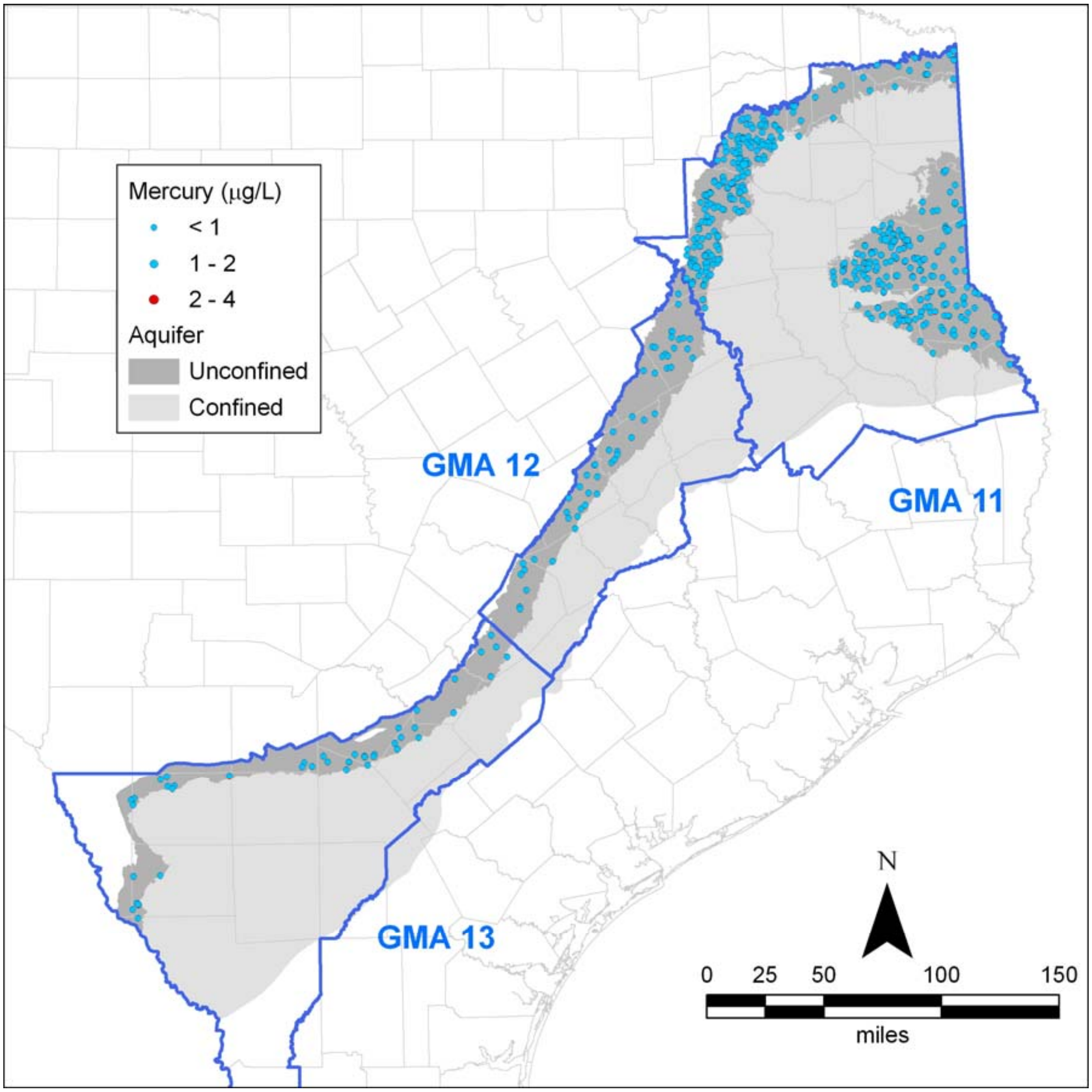

Figure 9.10: Spatial distribution of mercury (Hg) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

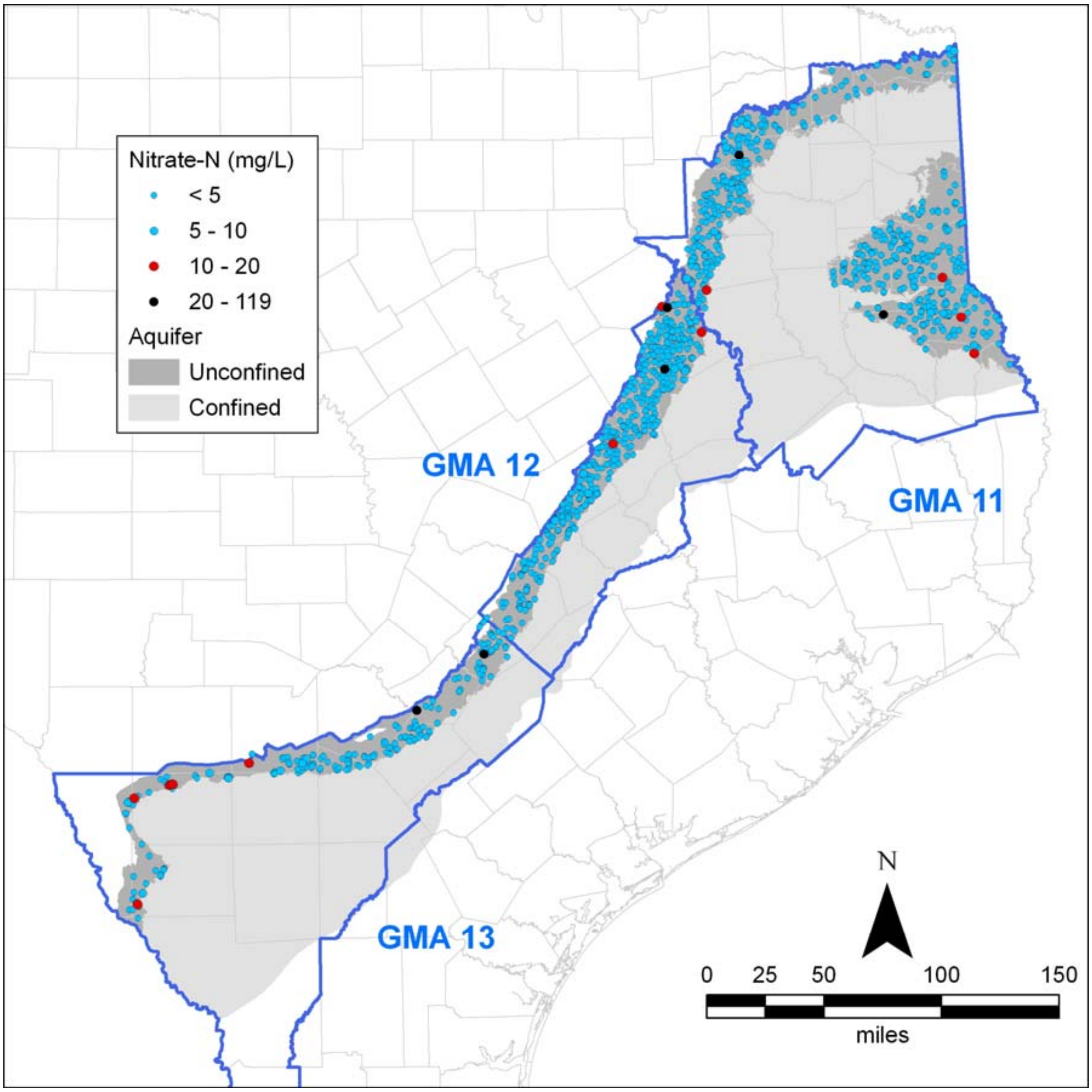

Figure 9.11: Spatial distribution of nitrate-N (NO3-N) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

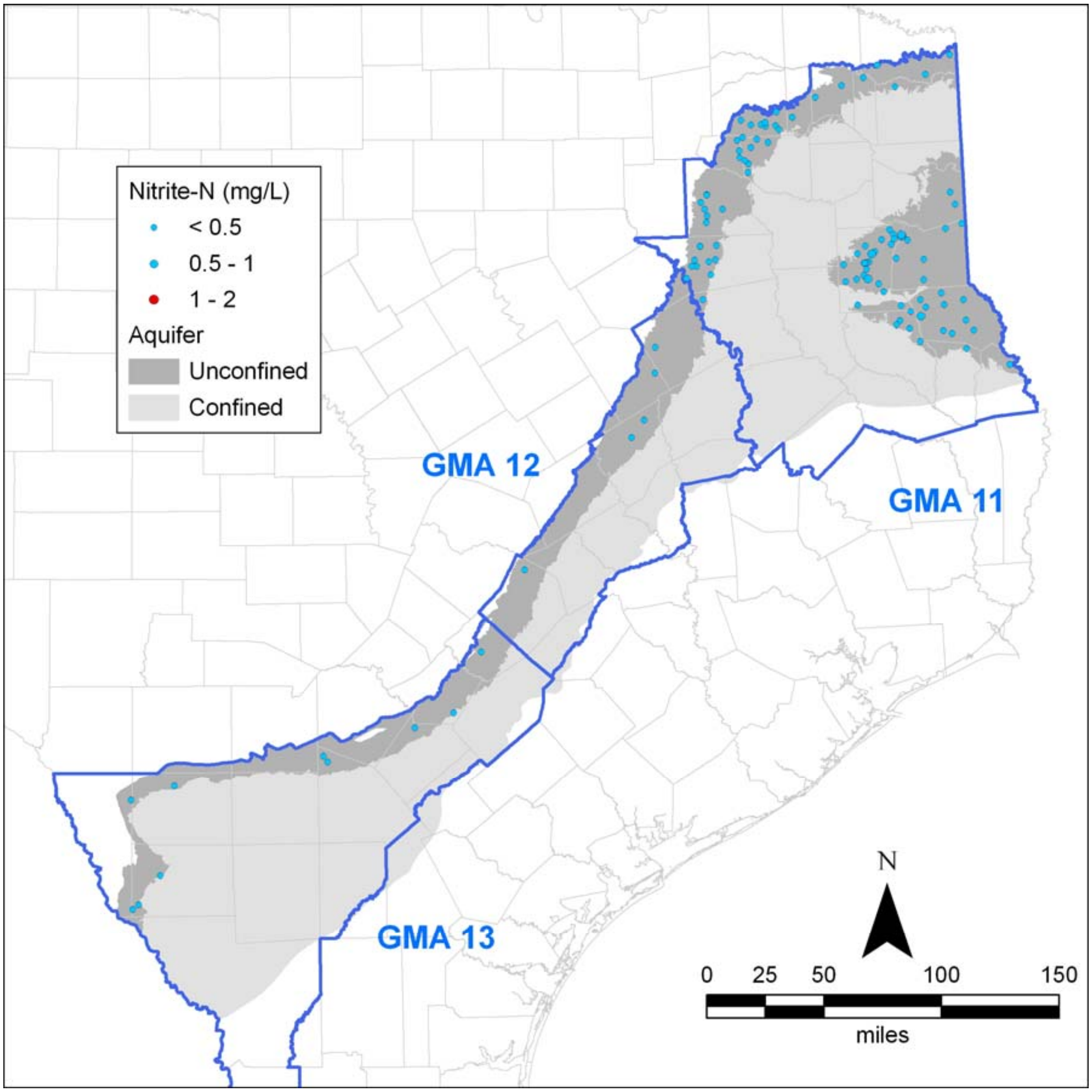

Figure 9.12: Spatial distribution of nitrite-N (NO2-N) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

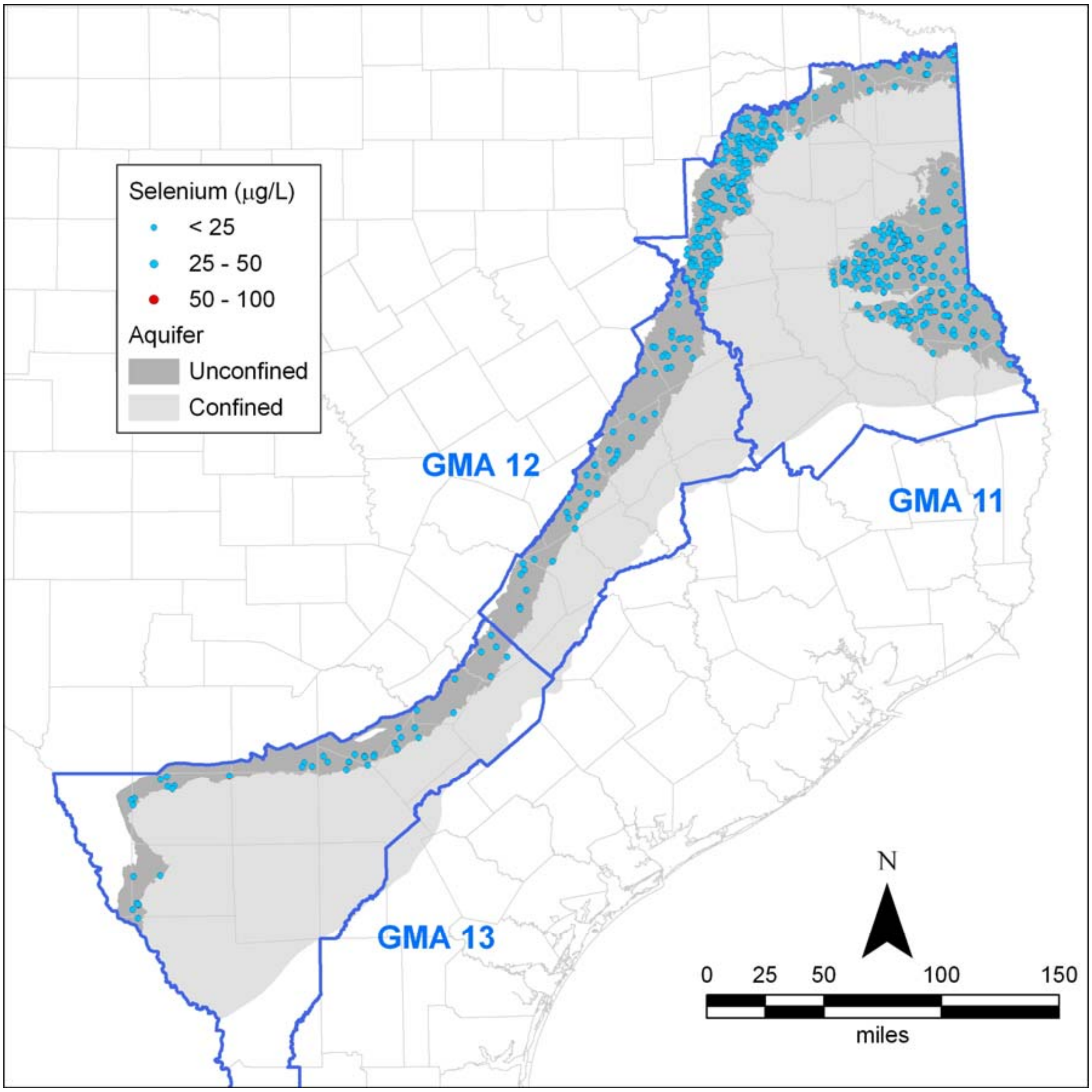

Figure 9.13: Spatial distribution of selenium (Se) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

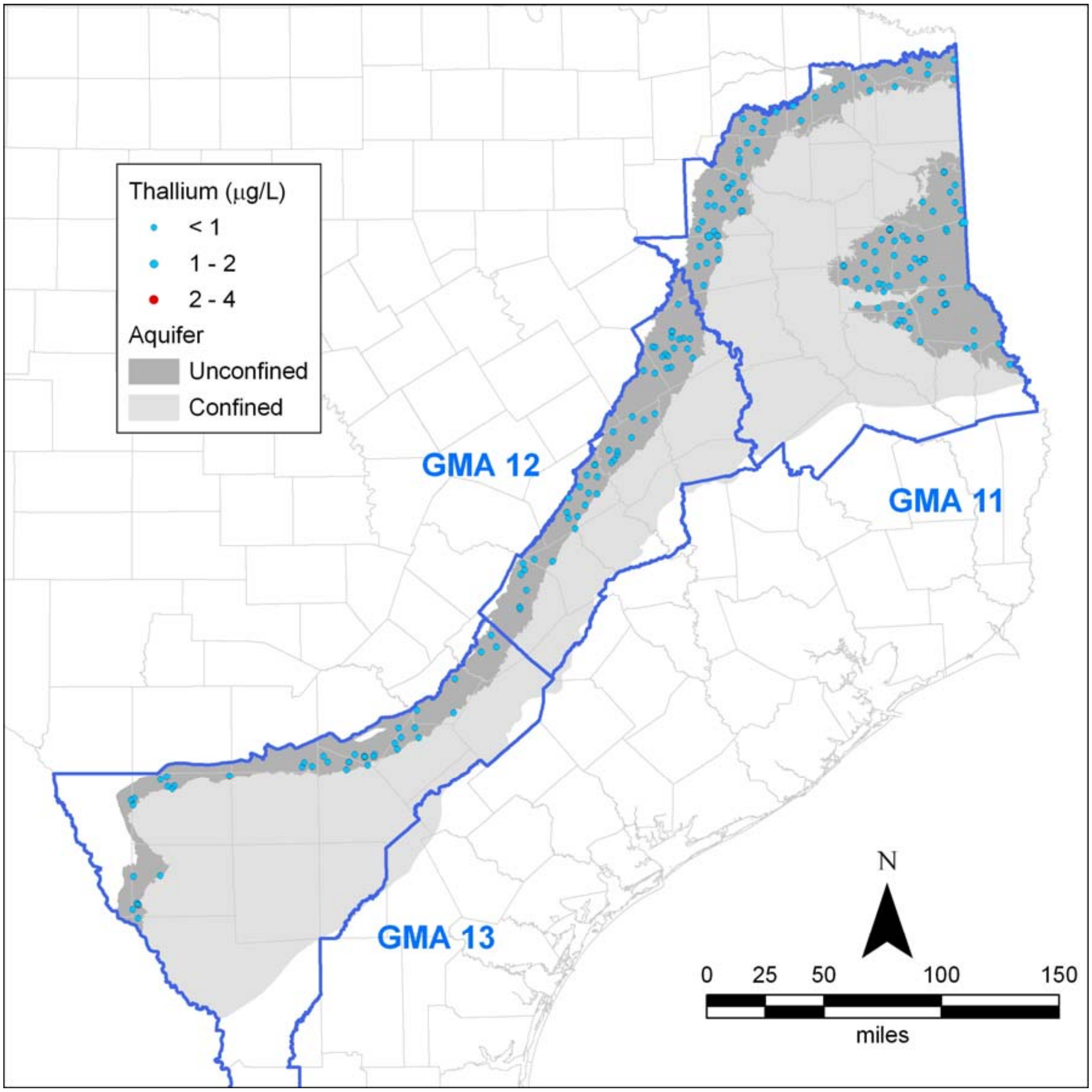

Figure 9.14: Spatial distribution of thallium (Tl) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

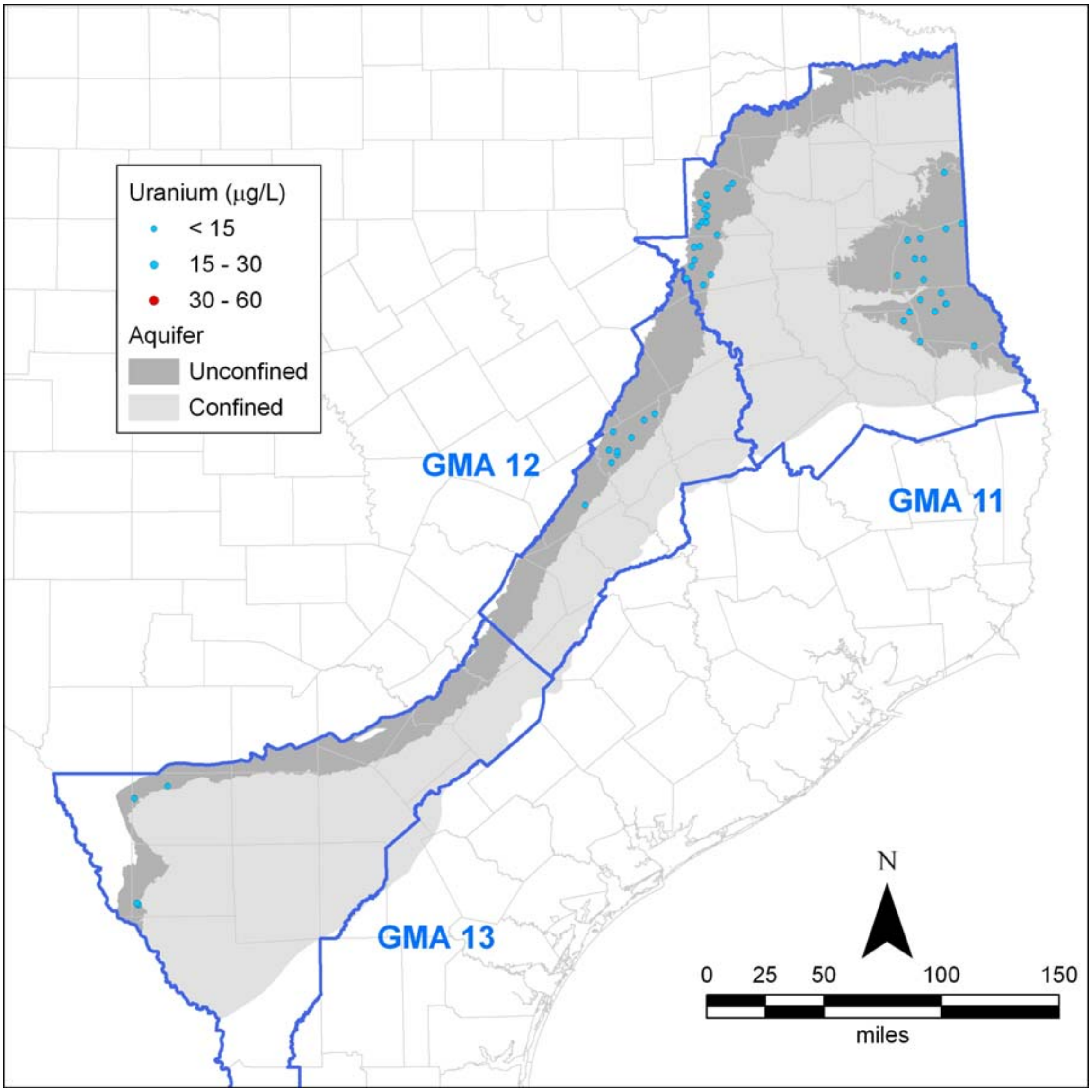

Figure 9.15: Spatial distribution of uranium (U) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

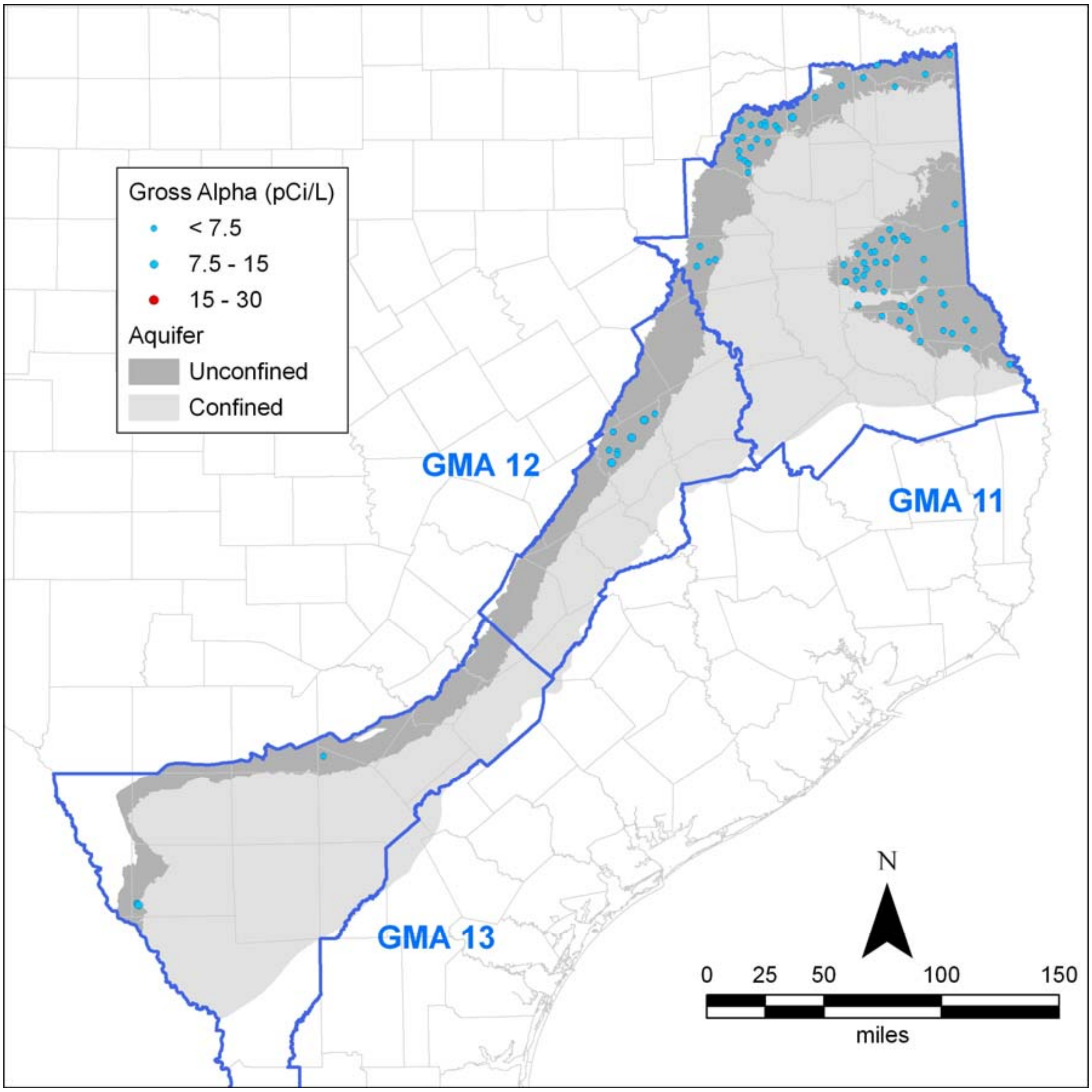

Figure 9.16: Spatial distribution of gross alpha (□) radiation in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

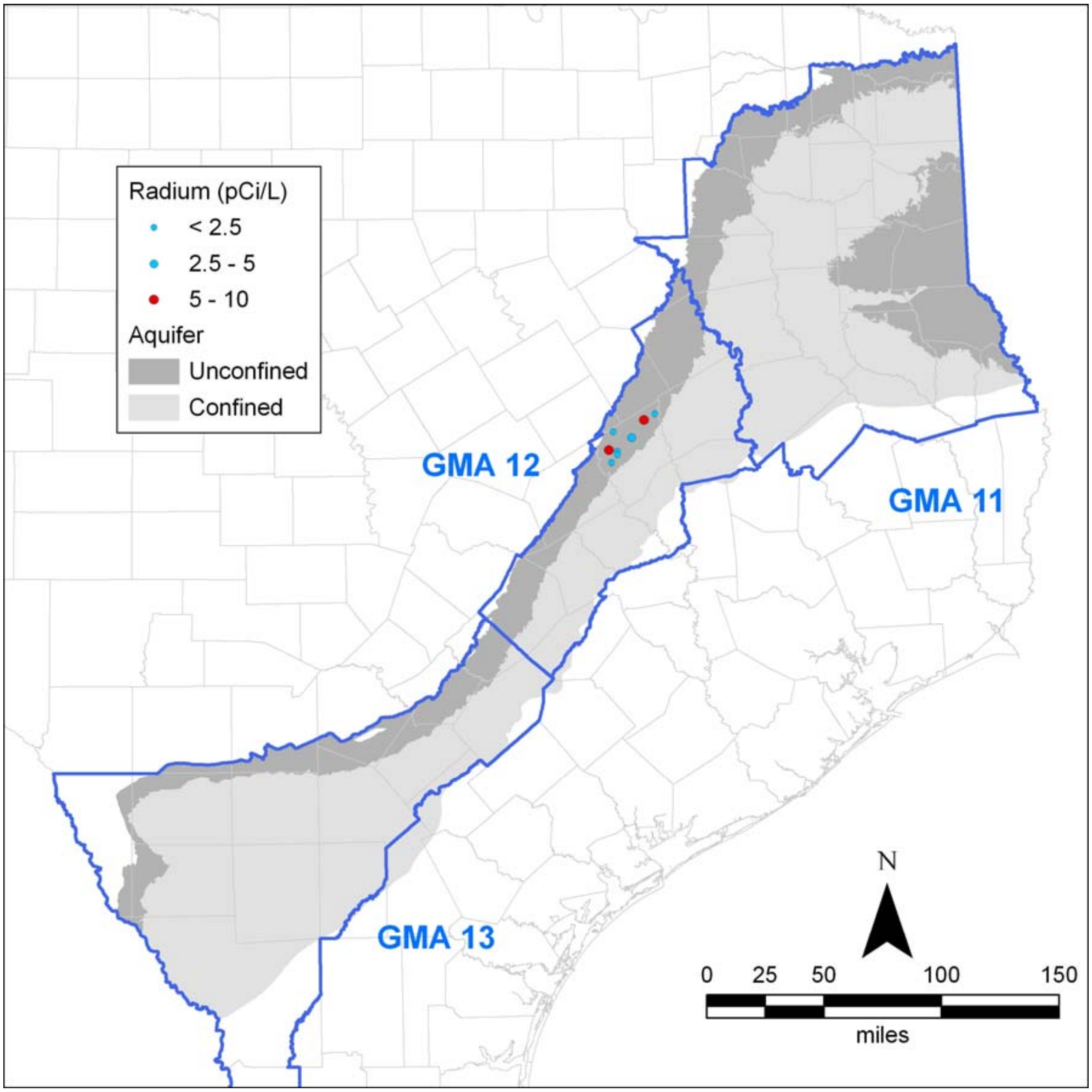

Figure 9.17: Spatial distribution of radium (Ra) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

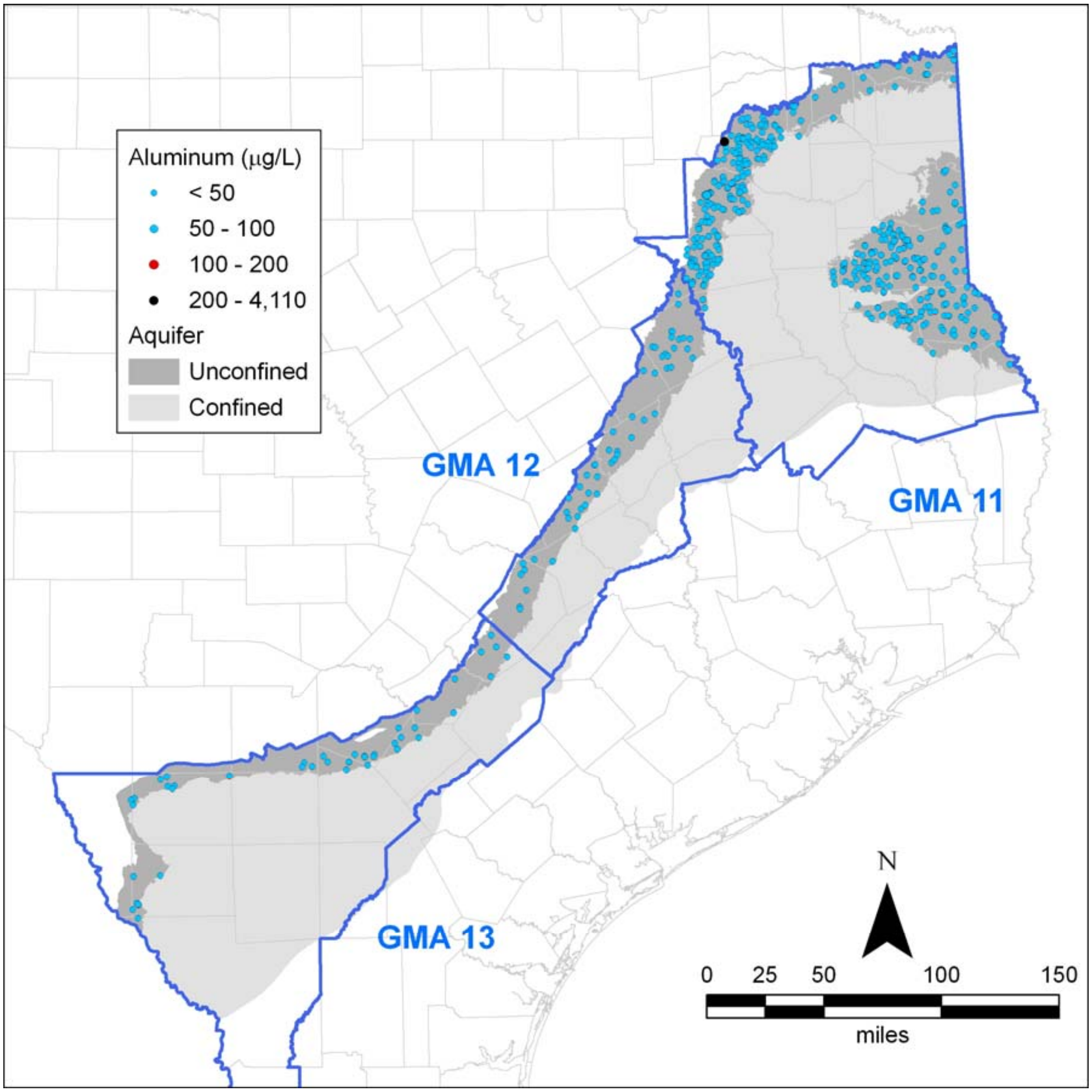

Figure 9.18: Spatial distribution of aluminum (Al) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

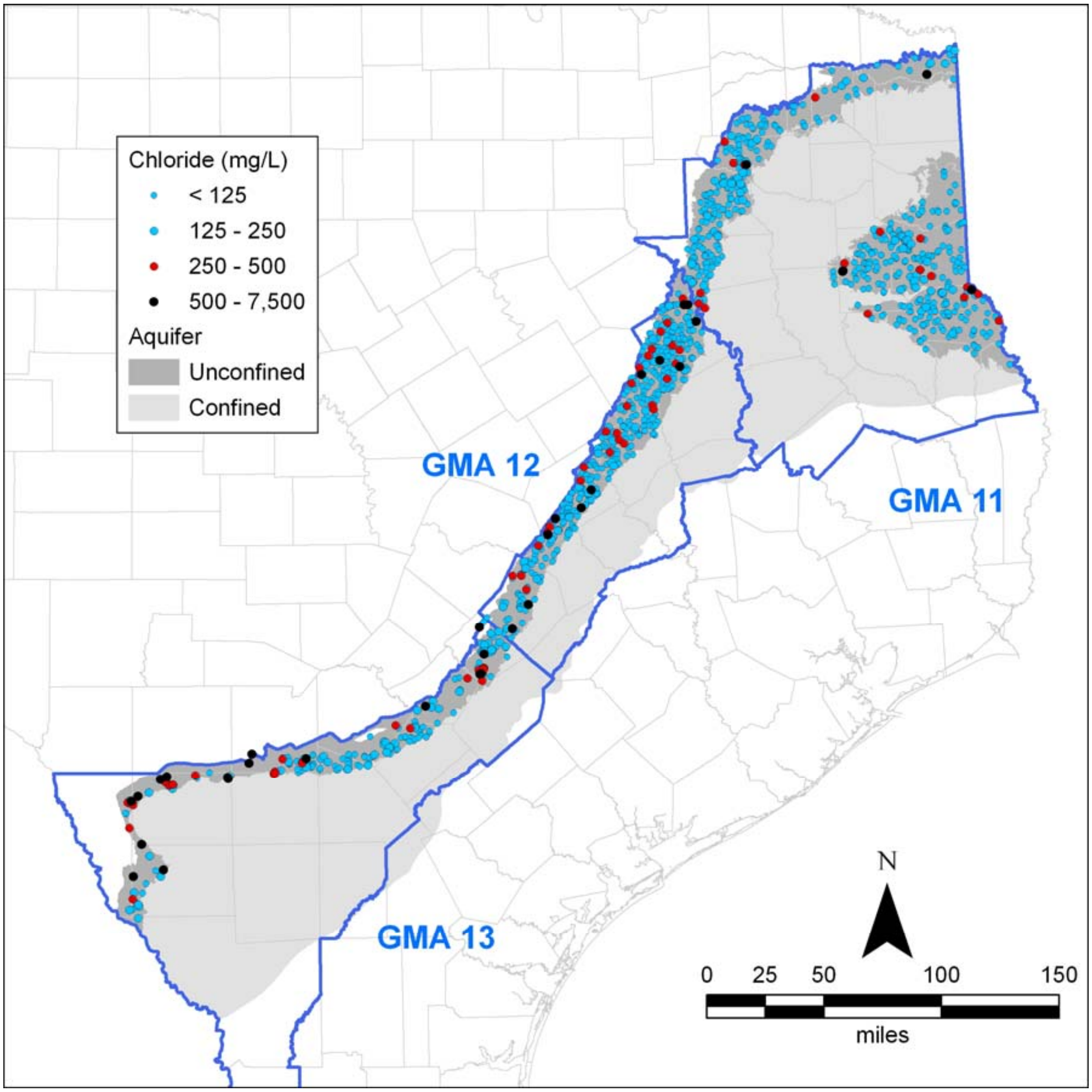

Figure 9.19: Spatial distribution of chloride (Cl) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

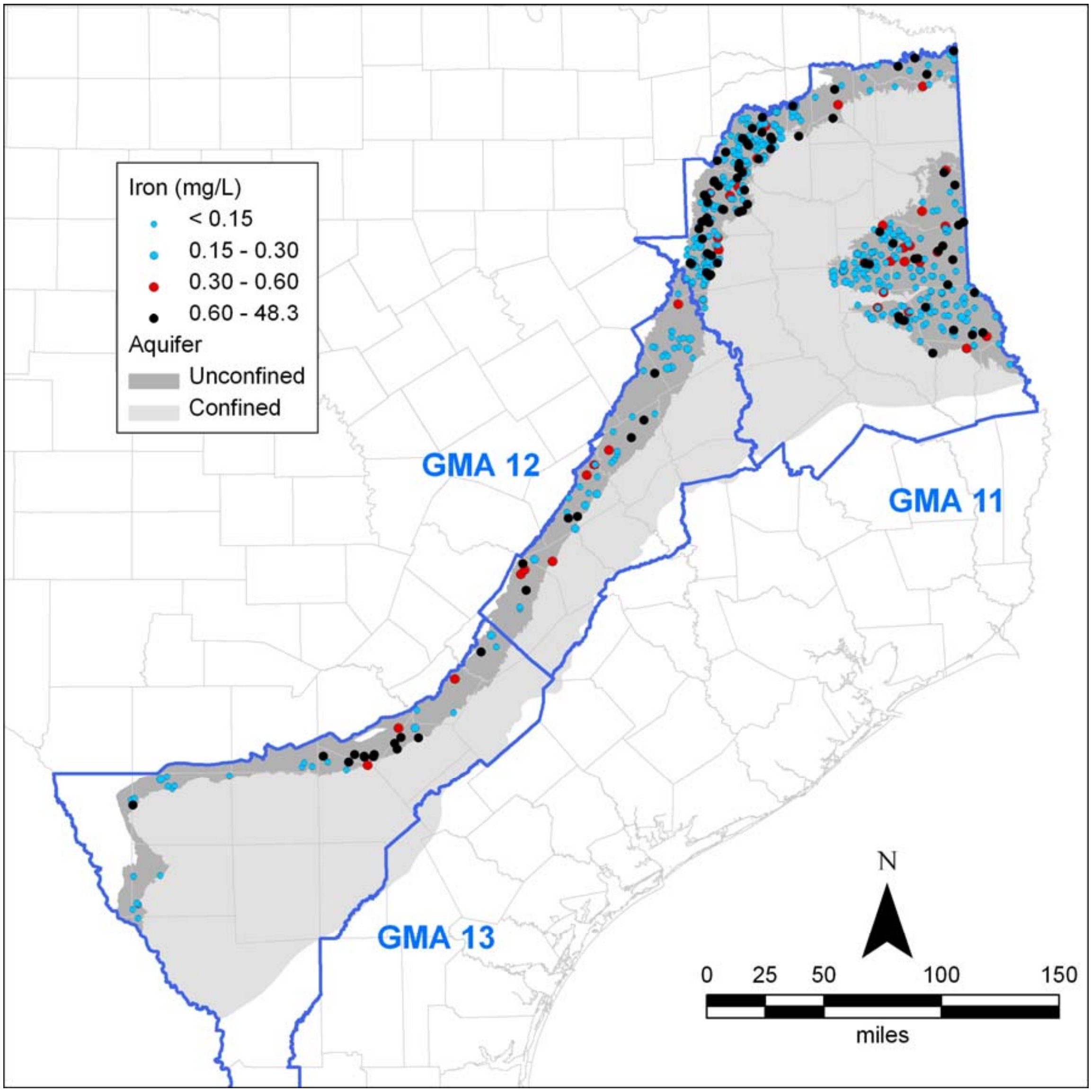

Figure 9.20: Spatial distribution of iron (Fe) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

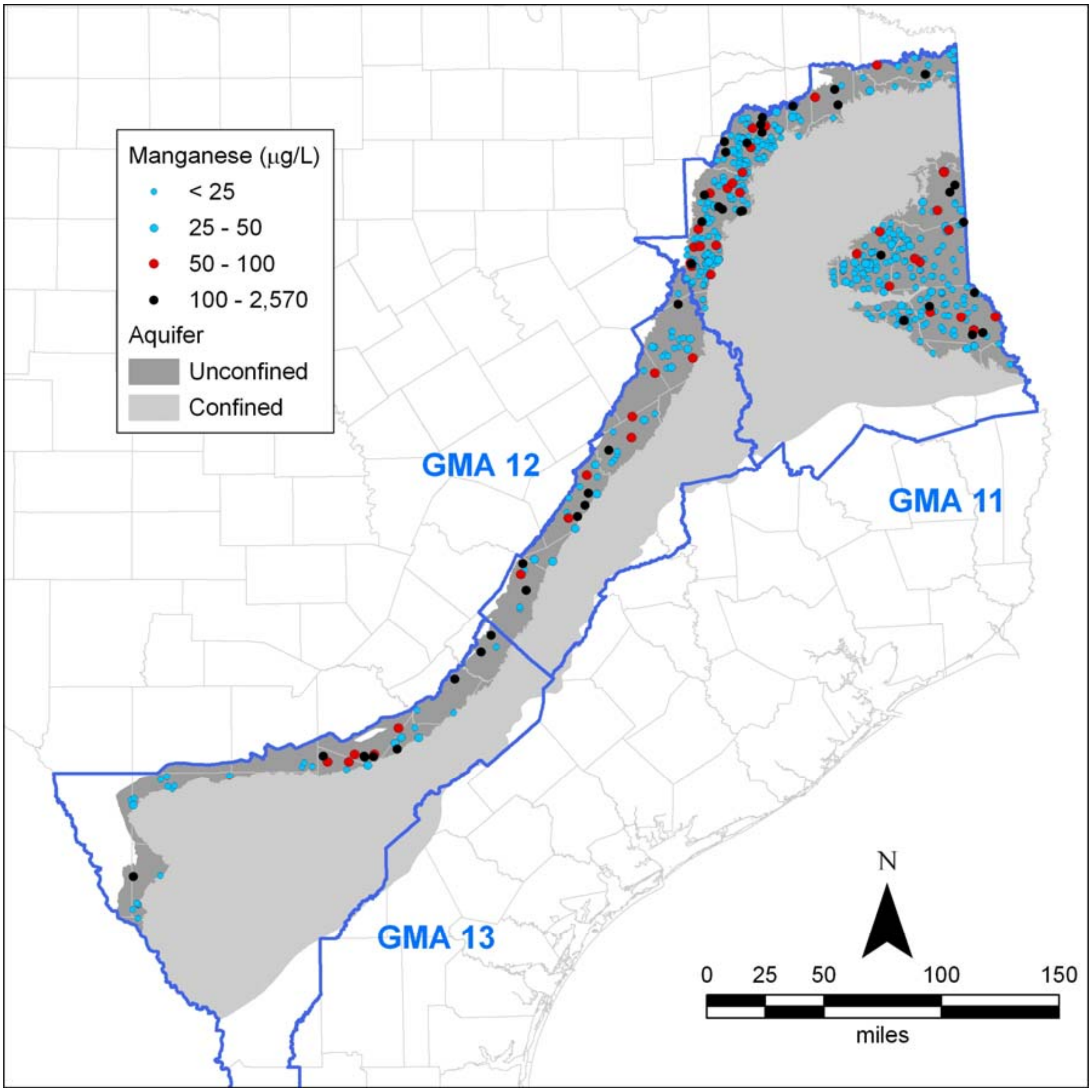

Figure 9.21: Spatial distribution of manganese (Mn) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

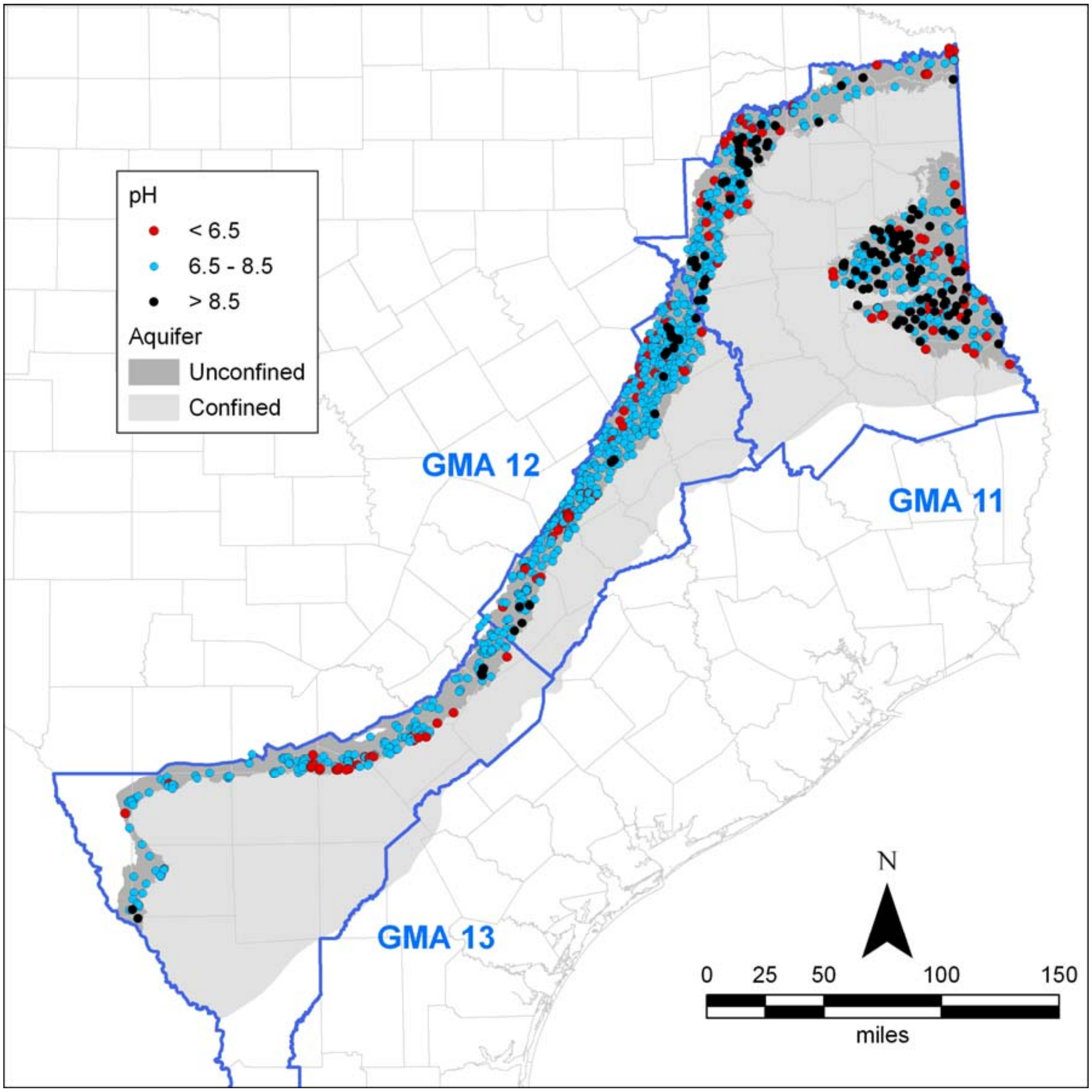

Figure 9.22: Spatial distribution of pH in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

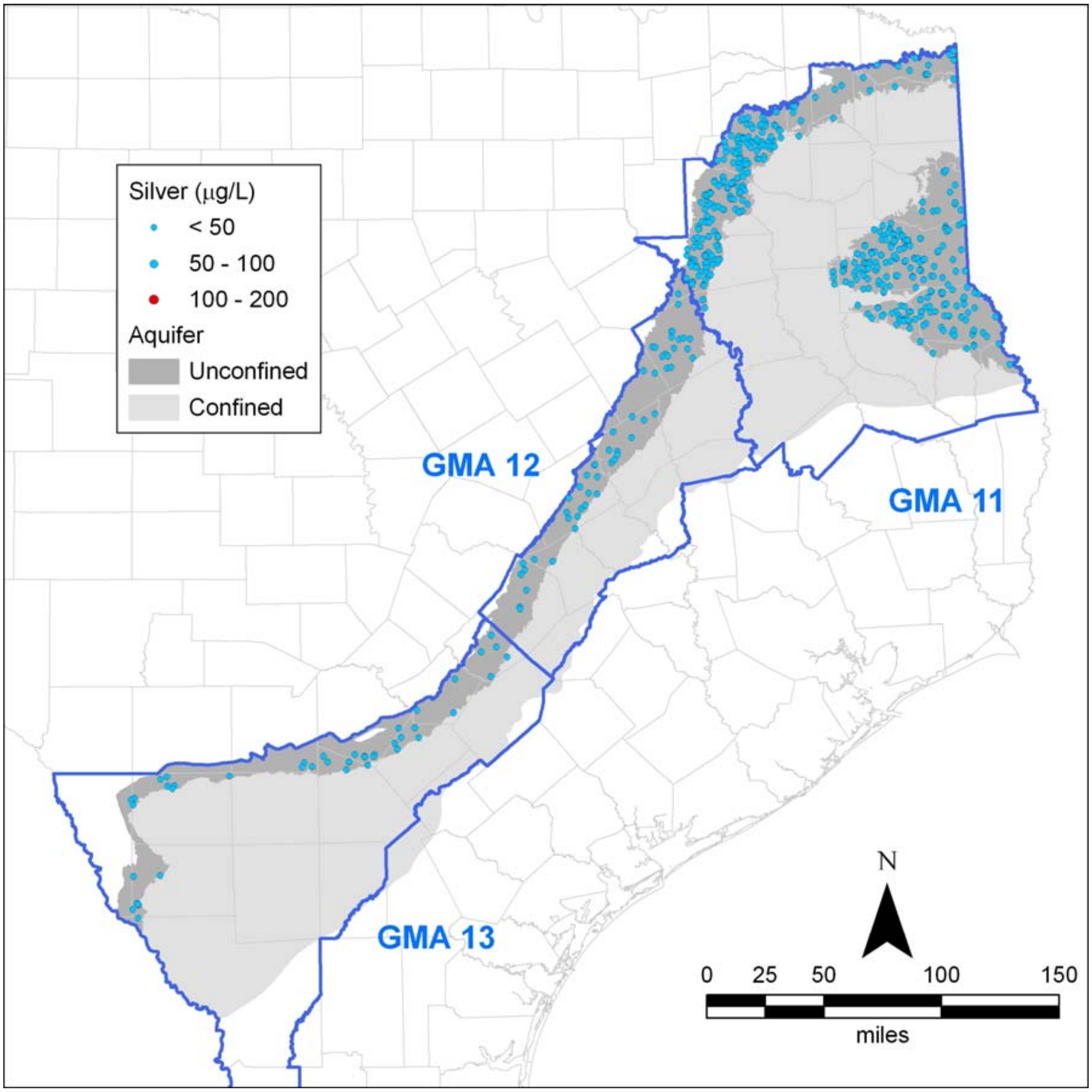

Figure 9.23: Spatial distribution of silver (Ag) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

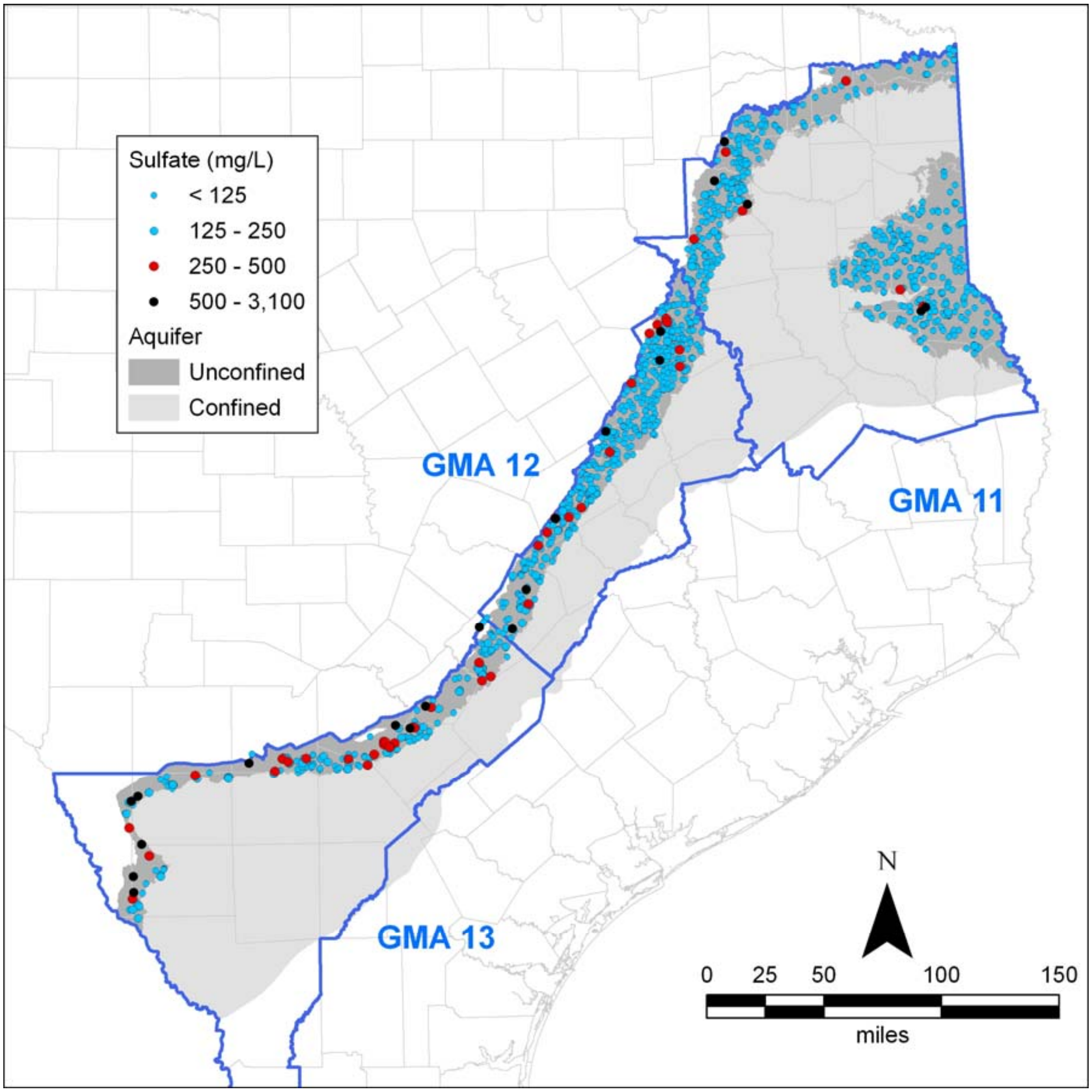

Figure 9.24: Spatial distribution of sulfate (SO4) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

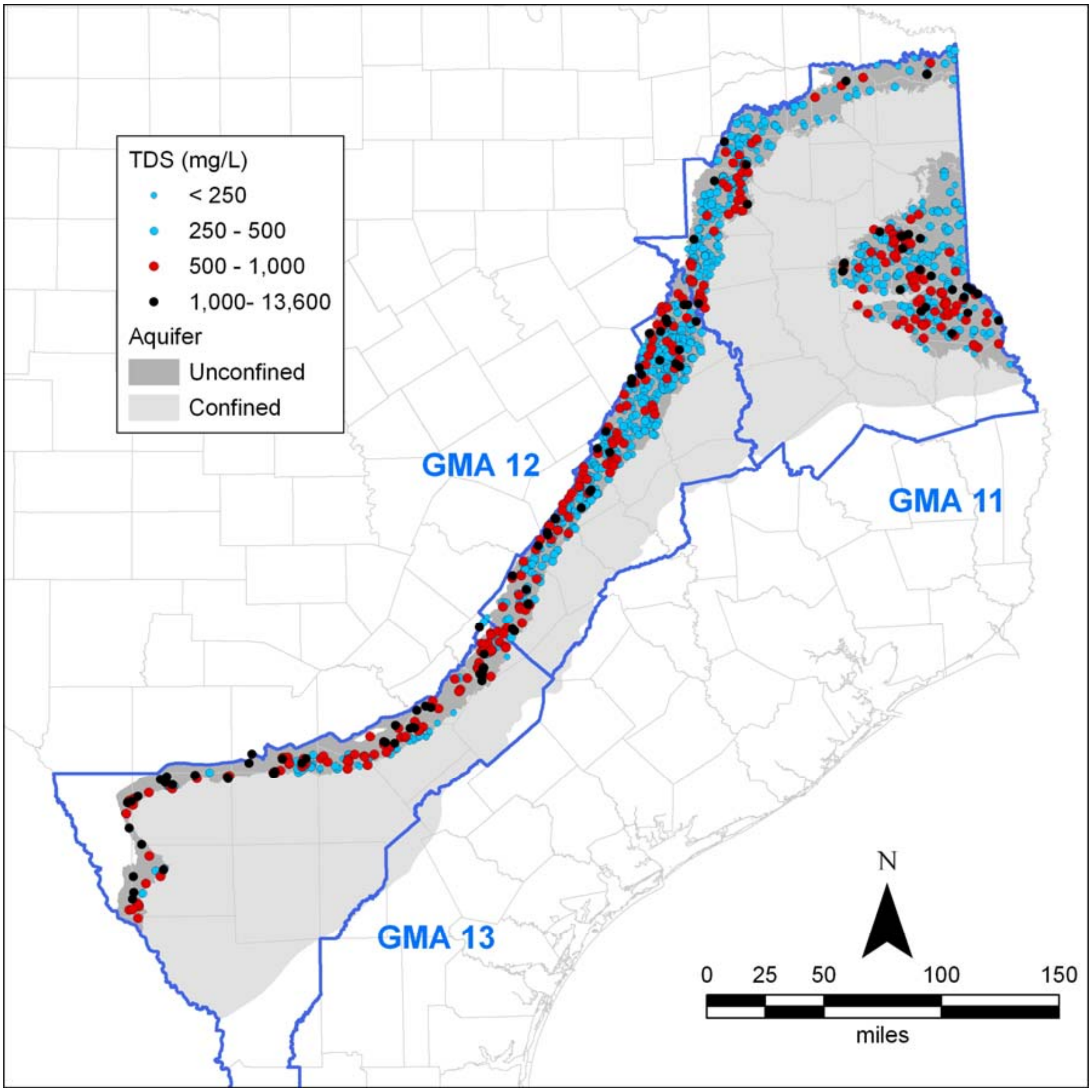

Figure 9.25: Spatial distribution of total dissolved solids (TDS) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

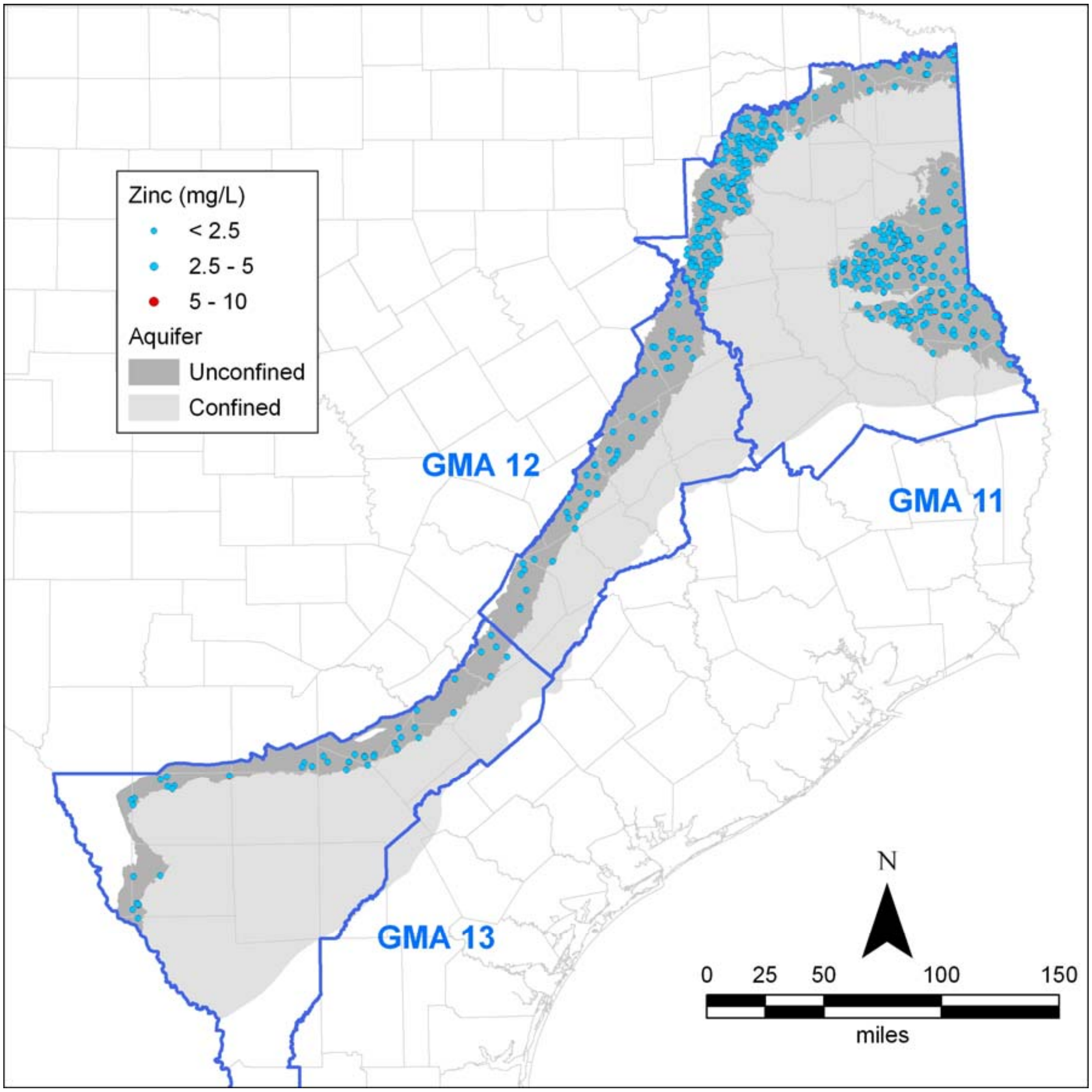

Figure 9.26: Spatial distribution of zinc (Zn) in groundwater wells located in the Carrizo-Wilcox Aquifer outcrop (unconfined) area.

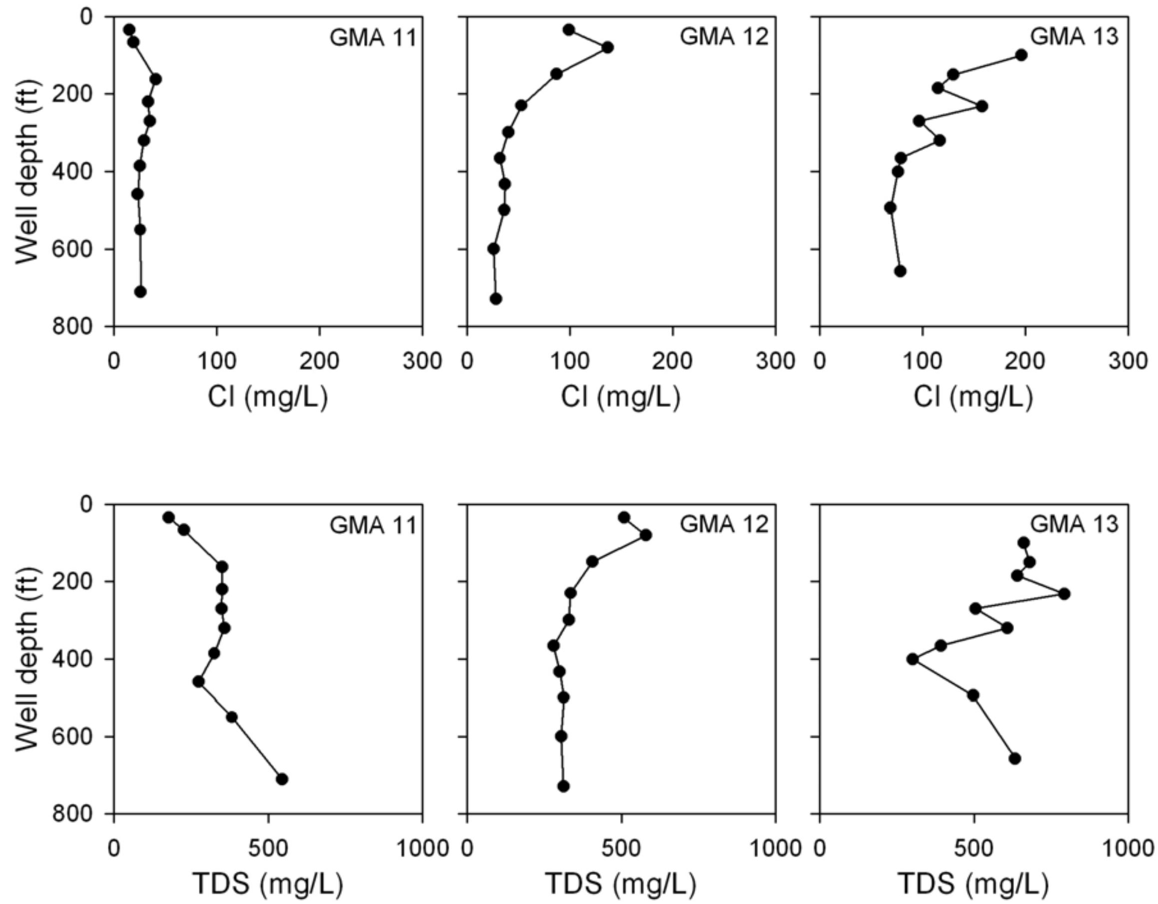

Figure 9.27: Variation in groundwater chloride and TDS with depth in the outcrop zone of the Carrizo Wilcox Aquifer in GMAs 11, 12, and 13. Concentrations represent median values per median decile of depth.

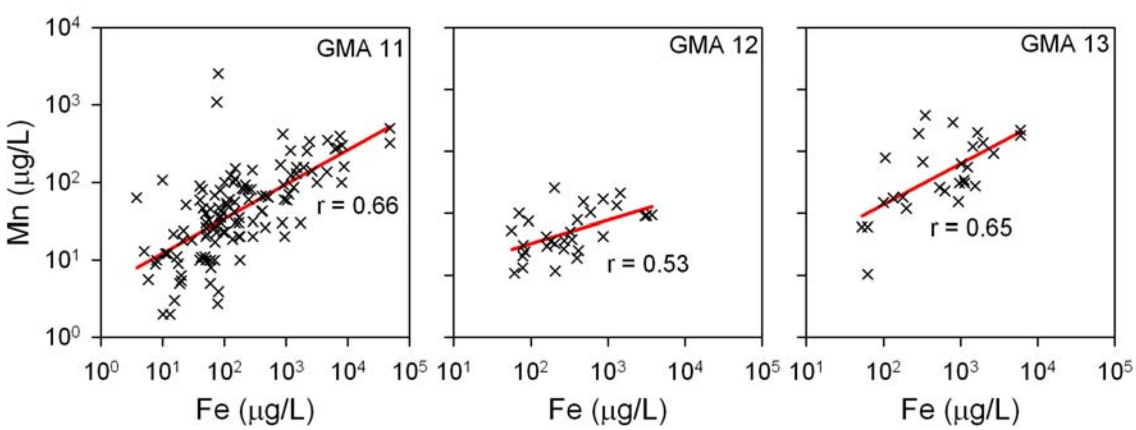

Figure 9.28: Correlations between manganese and iron in outcrop wells in GMAs 11, 12, and 13 in the Carrizo Wilcox Aquifer. Concentrations represent median values per median decile of depth.

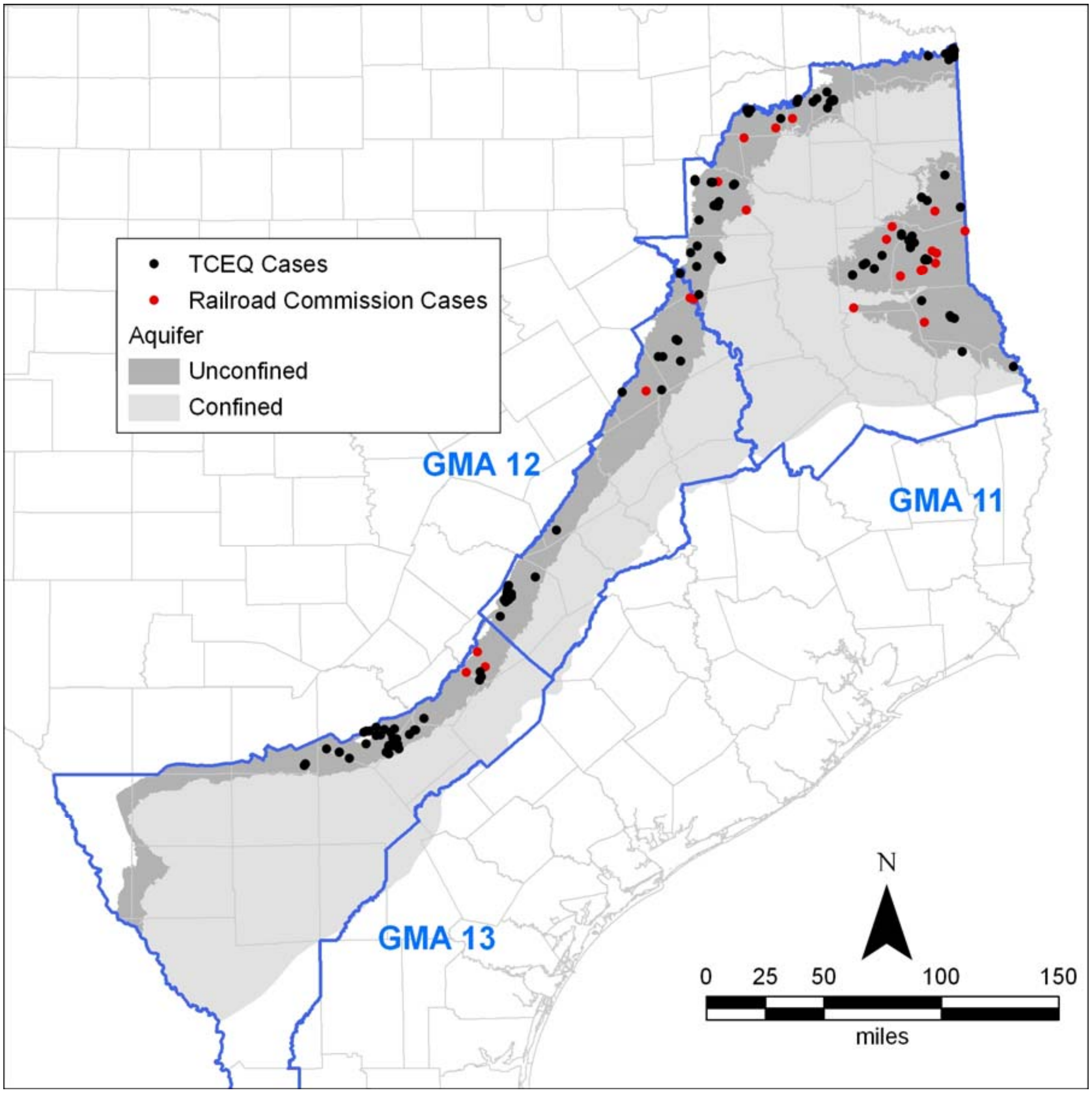

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Figure 9.29: Distribution of contamination cases based on TCEQ and RRC data in the outcrop of Carrizo Wilcox Aquifer. Data are from the Texas Groundwater Protection Committee Joint Groundwater Monitoring and Contamination Report (TGPC, 2010).

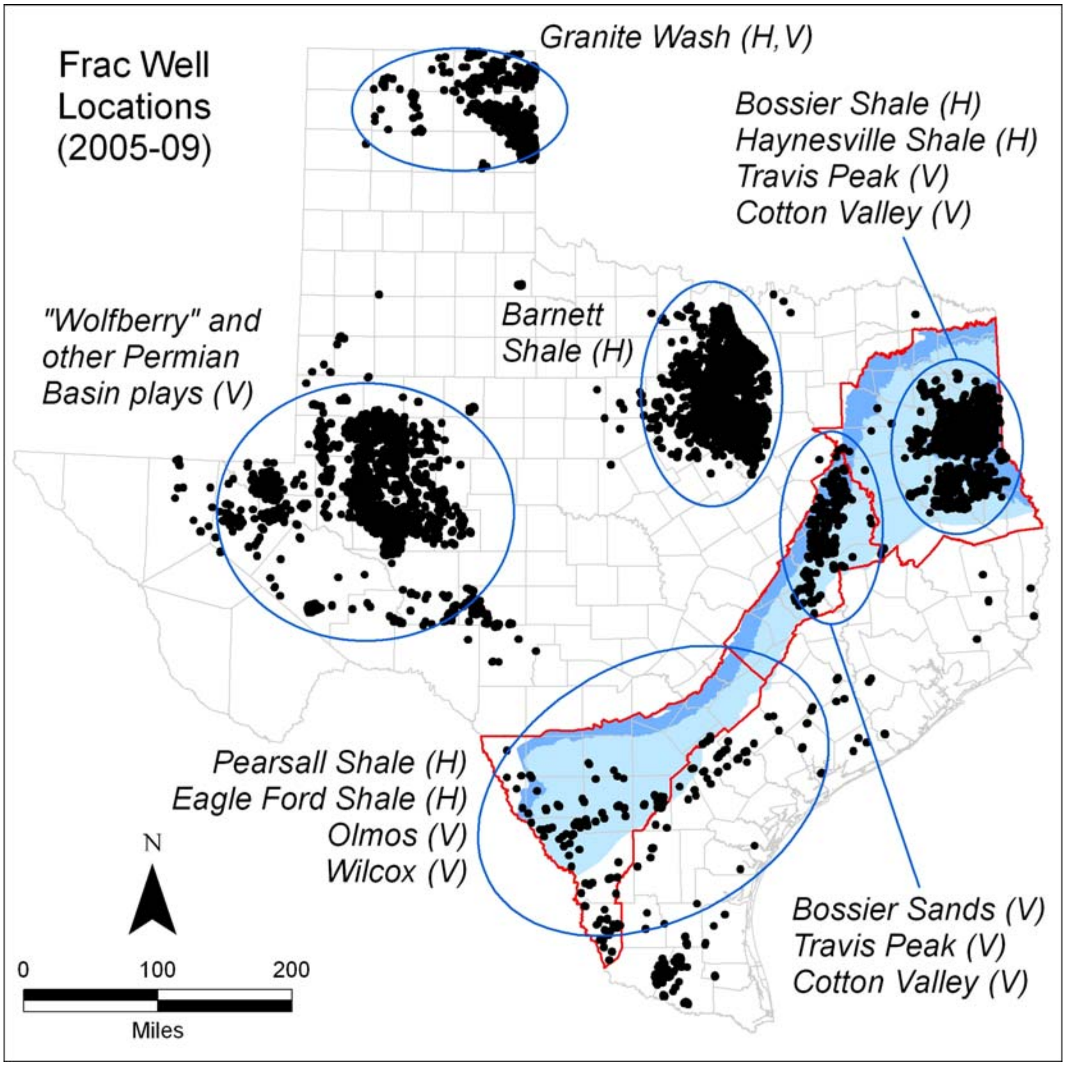

Figure 9.30: Distribution of fracing wells in Texas and footprint of the Carrizo Wilcox Aquifer, ~30,000 wells in the 2005–2009 period. Gas shales include the Bossier Shale, Haynesville Shale in northeast Carrizo Wilcox Aquifer, and Pearsall Shale and Eagle Ford Shale in the southwest Carrizo Wilcox Aquifer. The only other shale gas in Texas is the Barnett Shale. The other units are tight gas systems. H and V refer to horizontal and vertical wells used for fracing. Source of data for fracing wells is IHS database.

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