TCEQ Carrizo-Wilcox Study

Project 582-8-75374-119

Summary Report for completion of Task 7

Table of Contents

List of Tables

List of Figures

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Summary Report for completion of Task 7

1.0 Executive Summary

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 Railroad Commission of Texas (RCT) are also provided.

Water quality in the Carrizo-Wilcox Aquifer outcrop (unconfined) area from the TWDB 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 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.

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 the 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 low levels of cropland in the outcrop area of the Carrizo Wilcox Aquifer and the presence of reducing conditions, as evidenced by high levels of iron and manganese in many regions. The remainder represents 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.

Violations of many of the secondary MCL constituents, generally related to indicators of overall water quality including median TDS, chloride, and sulfate concentrations, generally show increasing concentrations from north to south. Median iron and manganese concentrations also increase from north to south, whereas the occurrence of pH values outside the 6.5 to 8.5 range tends to decrease in this direction.

There are 147 documented groundwater contamination cases from the TCEQ database and 23 documented cases from the RCT data in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 TCEQ State of Texas water quality inventory. 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.

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 south part of the aquifer, which was attributed to cross-formational leakage into the aquifer. Reductions in chloride with depth were attributed to increasing salinity of meteoric water since glacial times and enhanced evapotranspiration with a drier climate in the Holocene. 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.

Potential pollution of the aquifer was evaluated from the online survey conducted as part of this study and assessment of potential sources of contamination. 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.

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 addressed 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 RCT's groundwater-management policies and enforcement procedures. RCT's ability 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.

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 aquifers. 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.

Carrizo groundwater 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. 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. Reductions in chloride with depth are attributed to 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 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 the area. 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. (2003) point 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 et al. (1979) and Fogg et al. (2003) 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) have 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 for 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 1, 2, and 3, respectively. The spatial distribution of each MCL listed in the tables is shown in Figures 1 thru 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 4), suggesting primarily septic tank and fertilizer sources of nitrate (Table 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 water quality, including median TDS, chloride, and sulfate concentrations that are generally highest in the south. The number of MCL exceedances for chloride, sulfate, and TDS are highest in the south. 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 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.

The number of MCL exceedances for iron and manganese is greatest in the north, most likely related to lignite occurrence in this region. However, median iron and manganese concentrations are also highest in the south. 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 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.

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 Railroad Commission of Texas Data

Regulatory agencies, including TCEQ and the RCT, 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 RCT data in the outcrop area of the Carrizo Wilcox Aquifer in the 2010 TCEQ State of Texas water quality inventory (Table 5, Figure 29). Contamination cases under the jurisdiction of the TCEQ are generally identified through regulatory compliance monitoring, whereas cases under the jurisdiction of the RCT 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 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 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 RCT 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 should enhance cross formational flow from confining units into the aquifers and may degrade groundwater quality. In the following section we briefly discuss hydraulic fracturing (fracing) activities related to shale-gas production as a potential source of contamination. 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.

3.1 Oil and Gas Activities

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 freshwater. 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 29). The IHS database revealed ~30,000 stimulated wells statewide in the 2005–2010 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 1980's and 1990's, respectively, using fracing technology (Figure 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 1990's 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 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.

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 RCT's groundwater management policies and enforcement procedures were a primary concern for 6 of the 16 groundwater conservation districts. The RCT'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 RCT 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 note that there are regulatory concerns with the management of oil and gas exploration and the oversight provided by Texas agencies including the RCT and 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 Railroad Commission of water wells involved in oil and gas operations and mining.” Plum Creek CD stated “There are Management and regulatory gaps from the Railroad Commission 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 removing 200 to 300 ft 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. This issue should be evaluated in future studies.

Table 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 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 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 4. Well types for Carrizo-Wilcox aquifer outcrop wells with NO_3-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

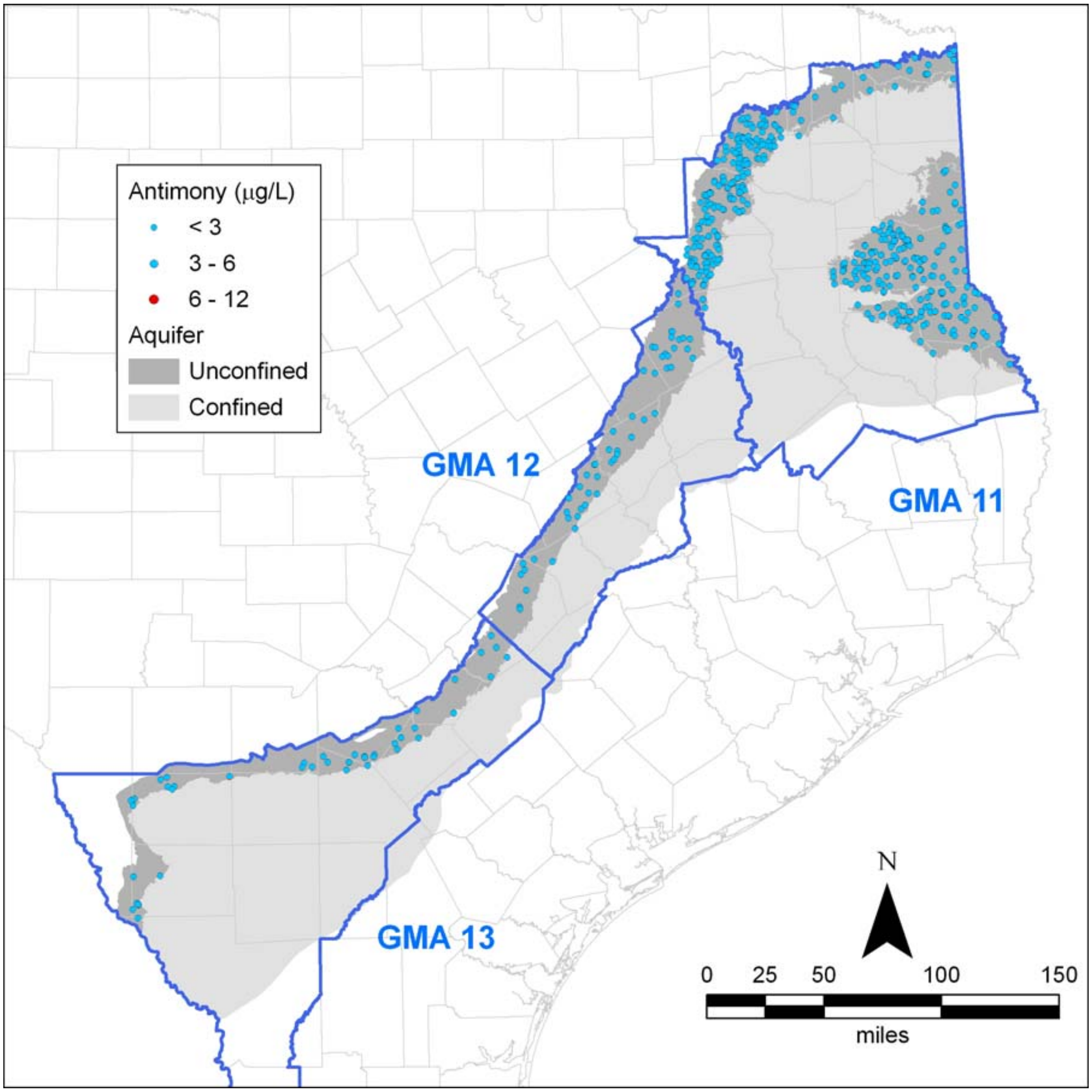

Figure 1. Spatial distribution of antimony (Sb) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

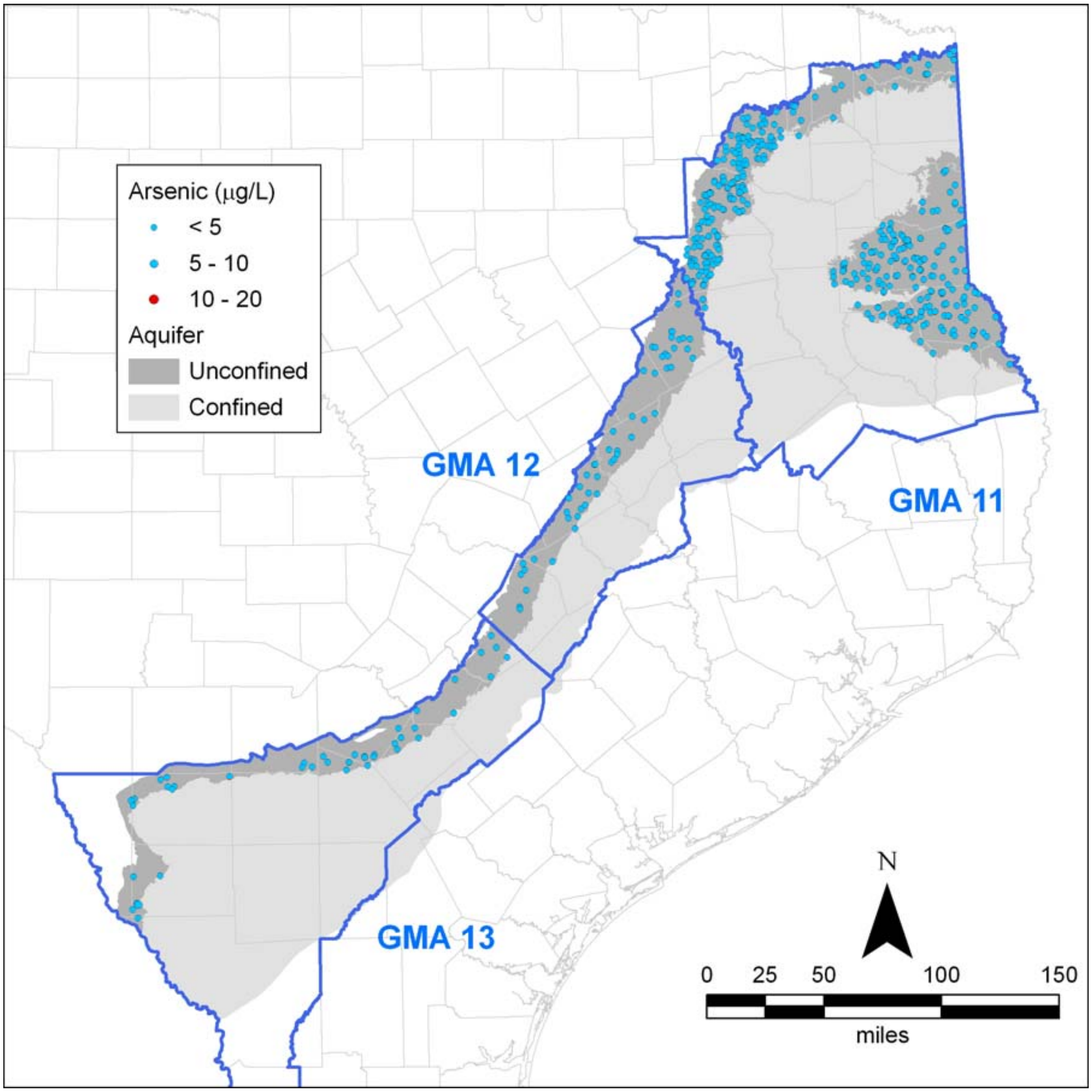

Figure 2. Spatial distribution of arsenic (As) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

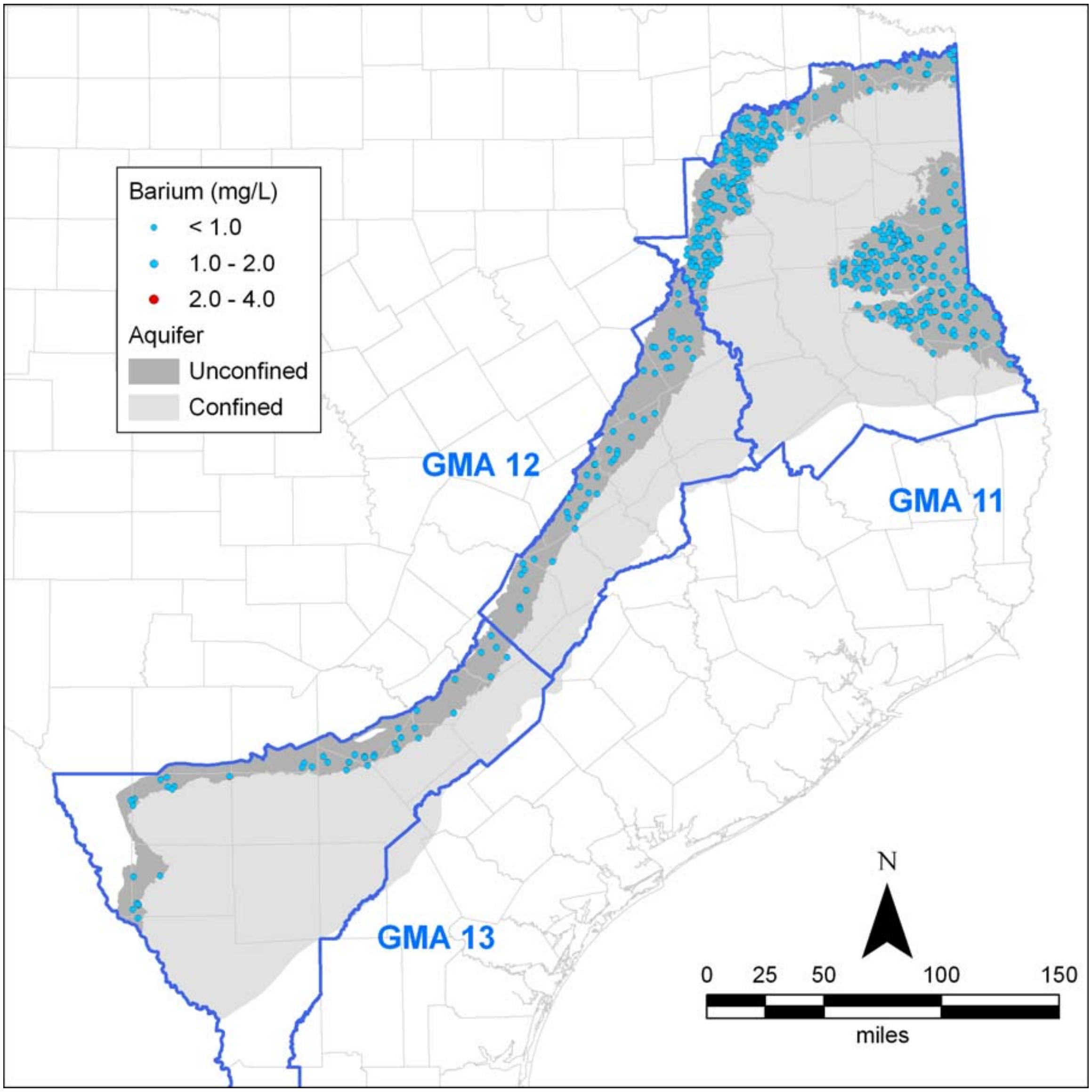

Figure 3. Spatial distribution of barium (Ba) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

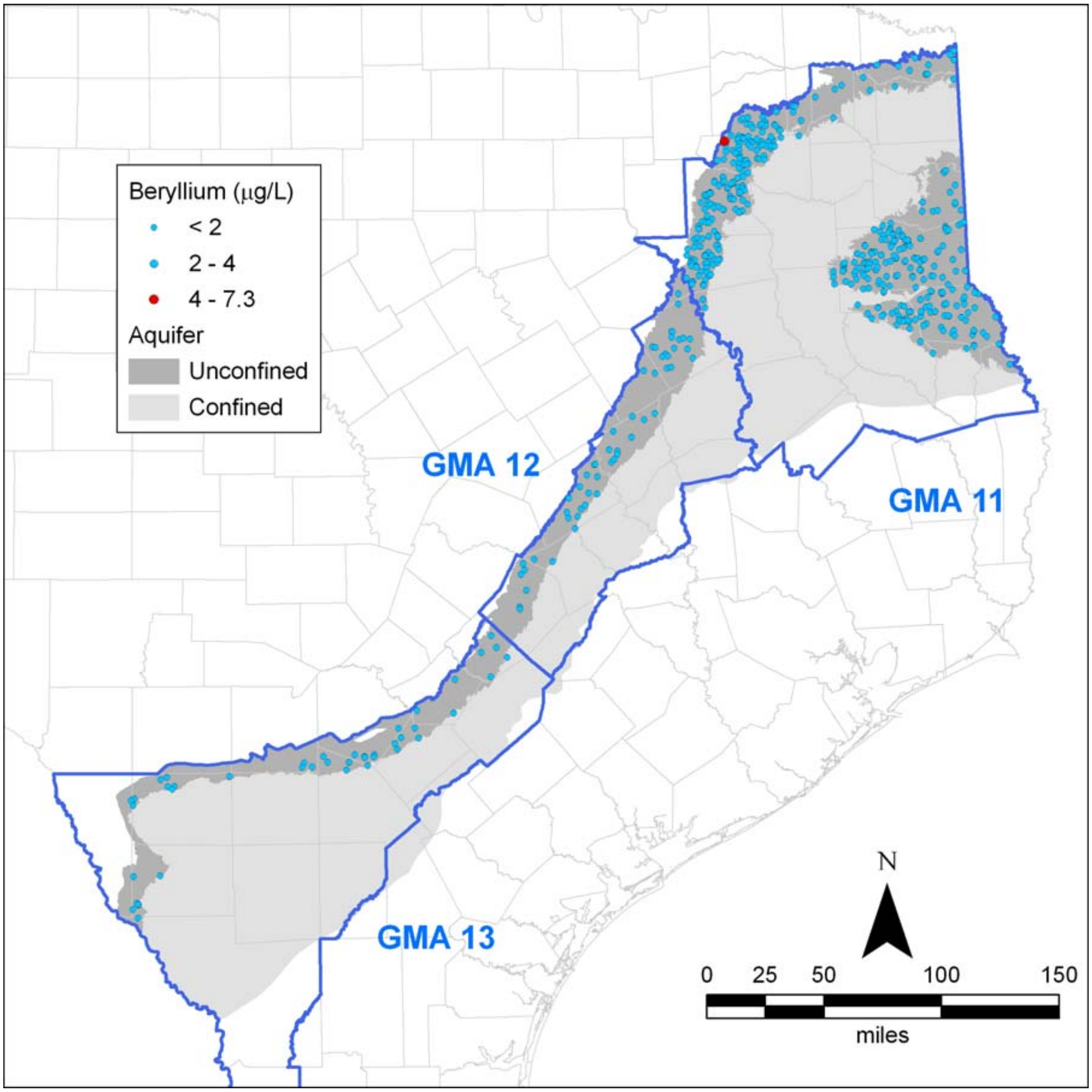

Figure 4. Spatial distribution of beryllium (Be) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

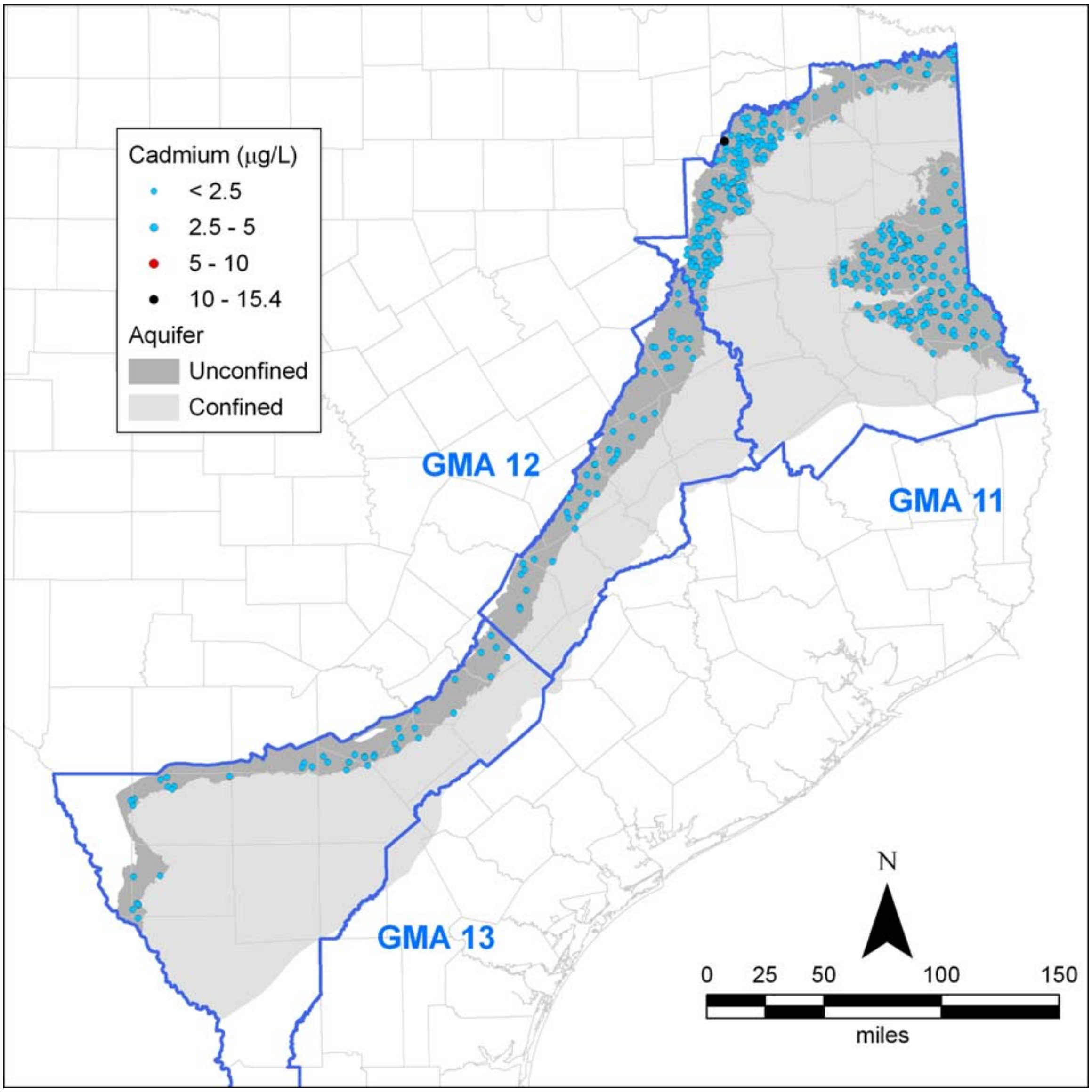

Figure 5. Spatial distribution of cadmium (Cd) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

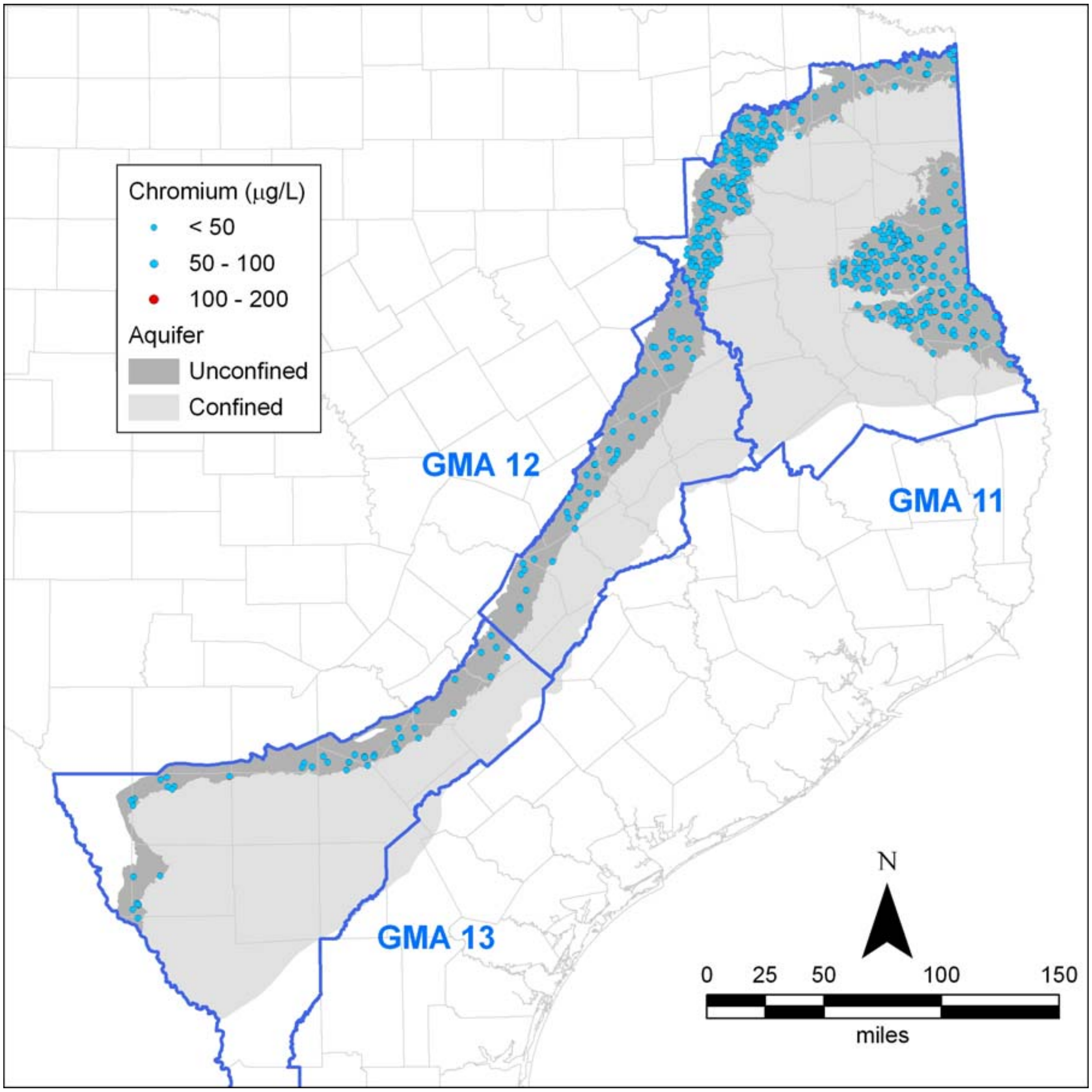

Figure 6. Spatial distribution of chromium (Cr) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

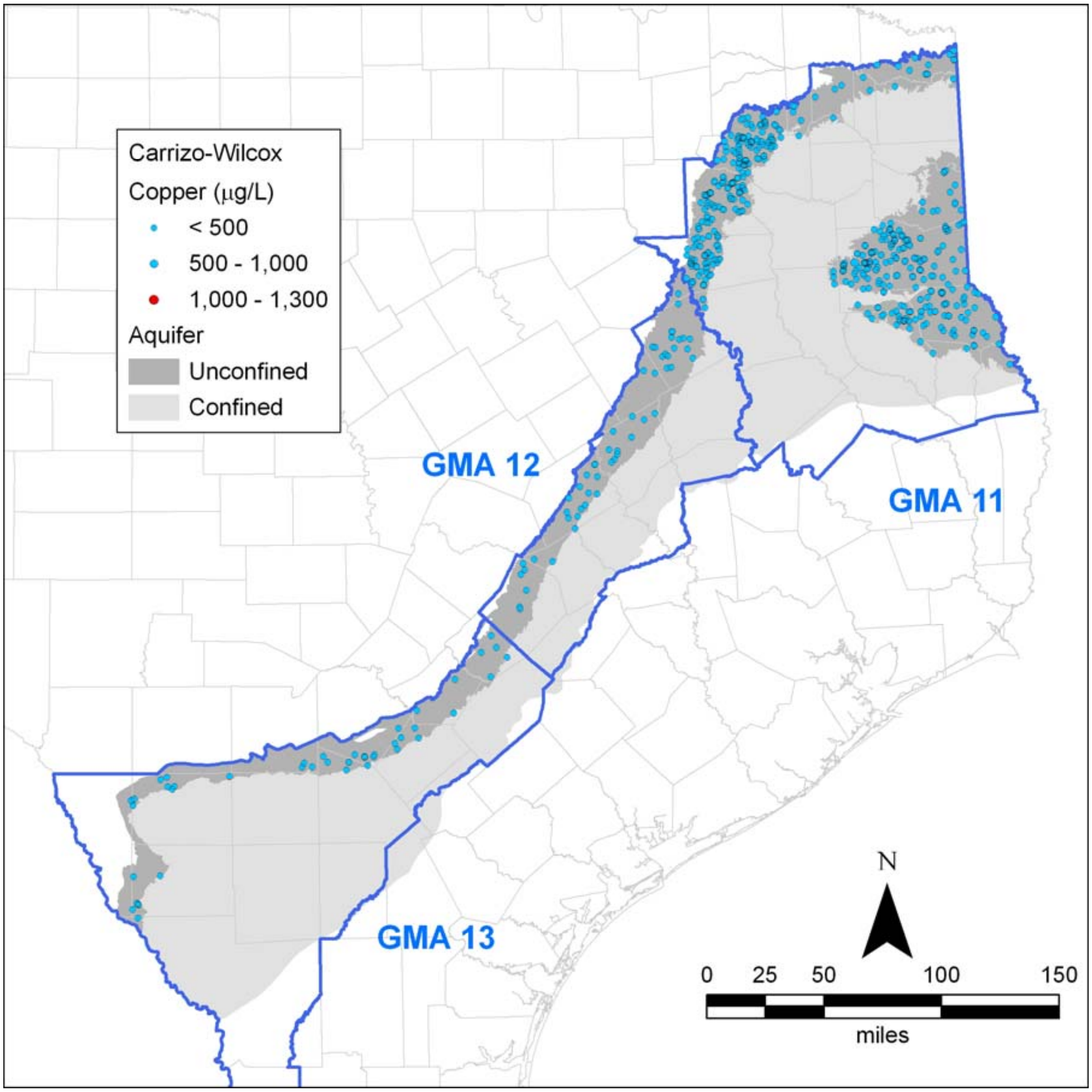

Figure 7. Spatial distribution of copper (Cu) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

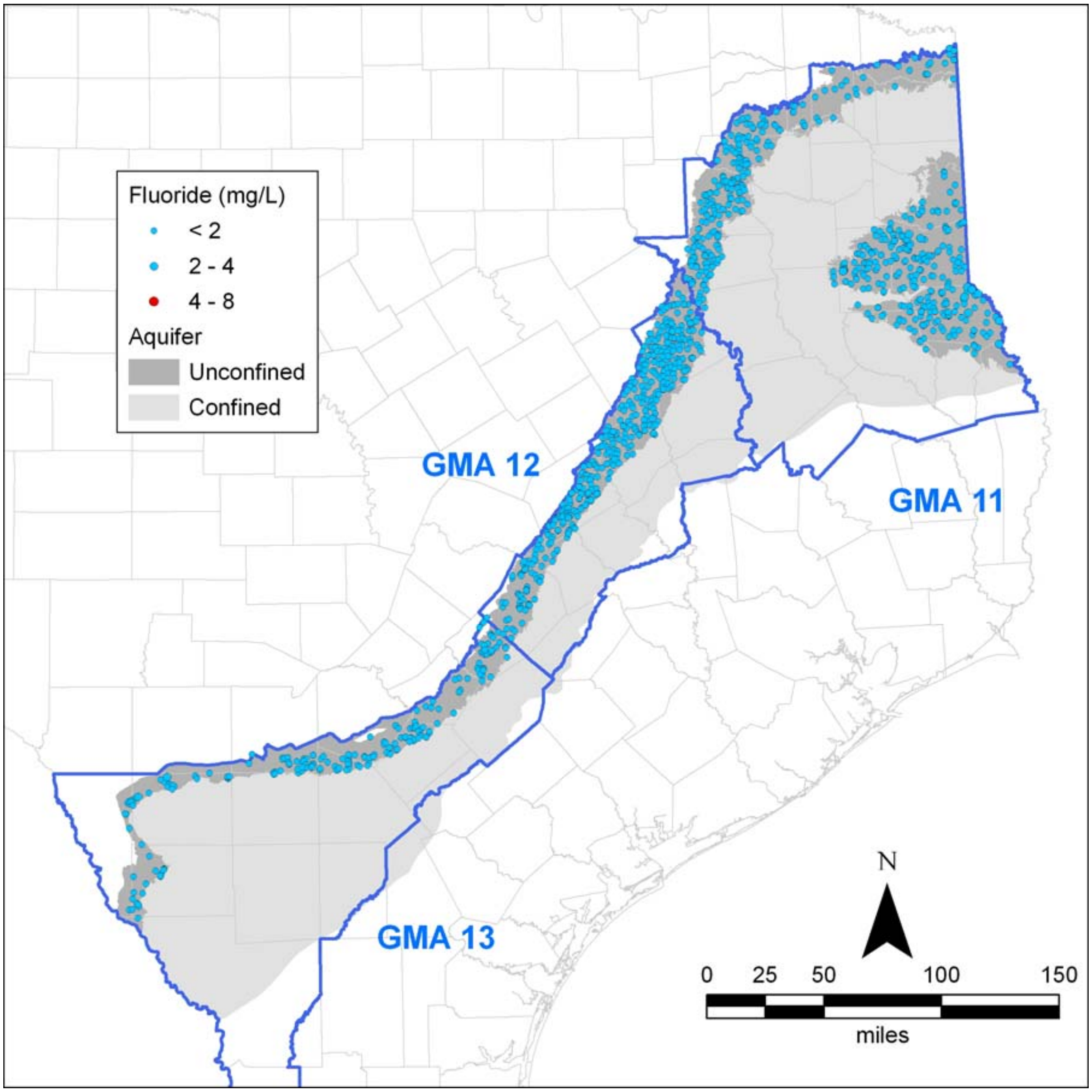

Figure 8. Spatial distribution of fluoride (F) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

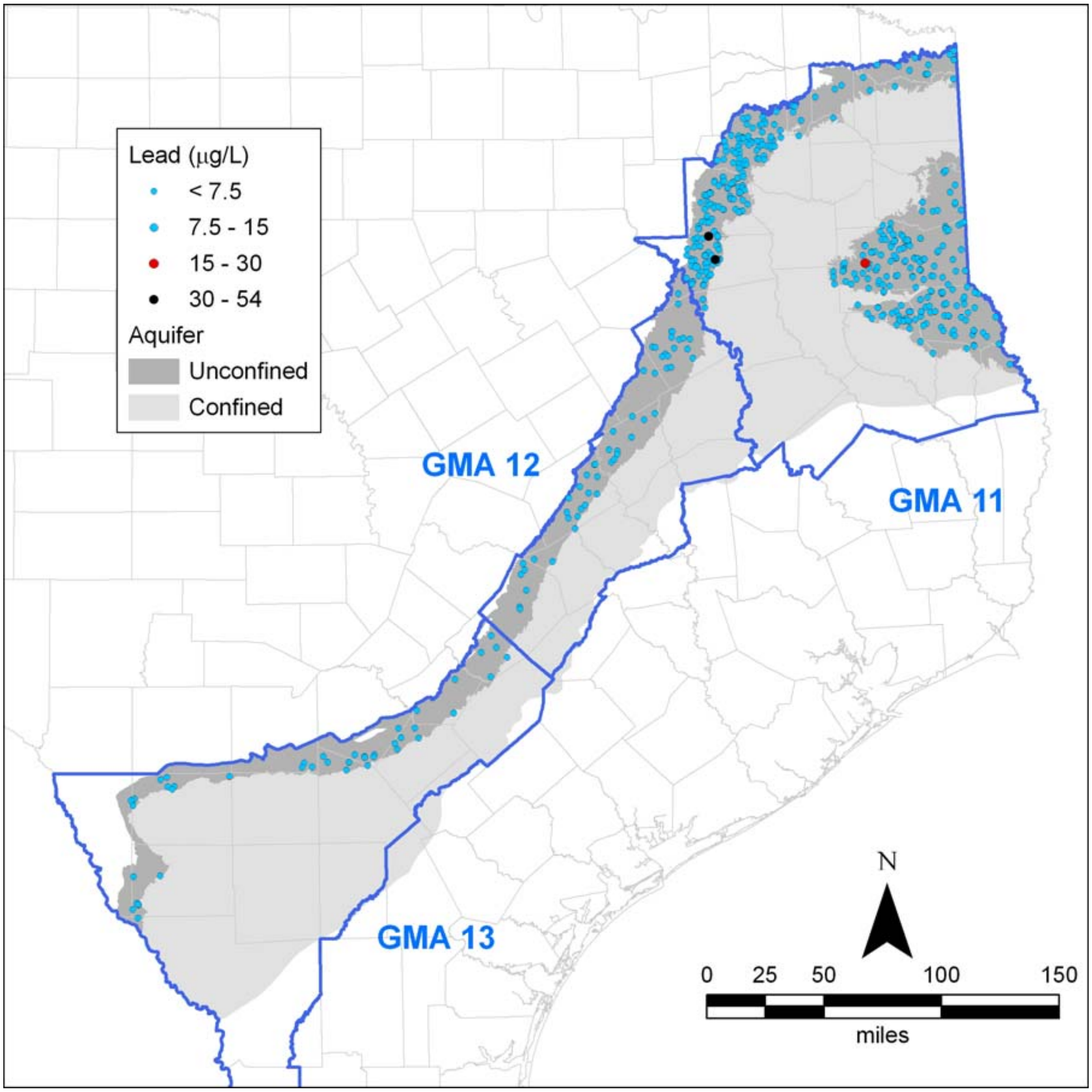

Figure 9. Spatial distribution of lead (Pb) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

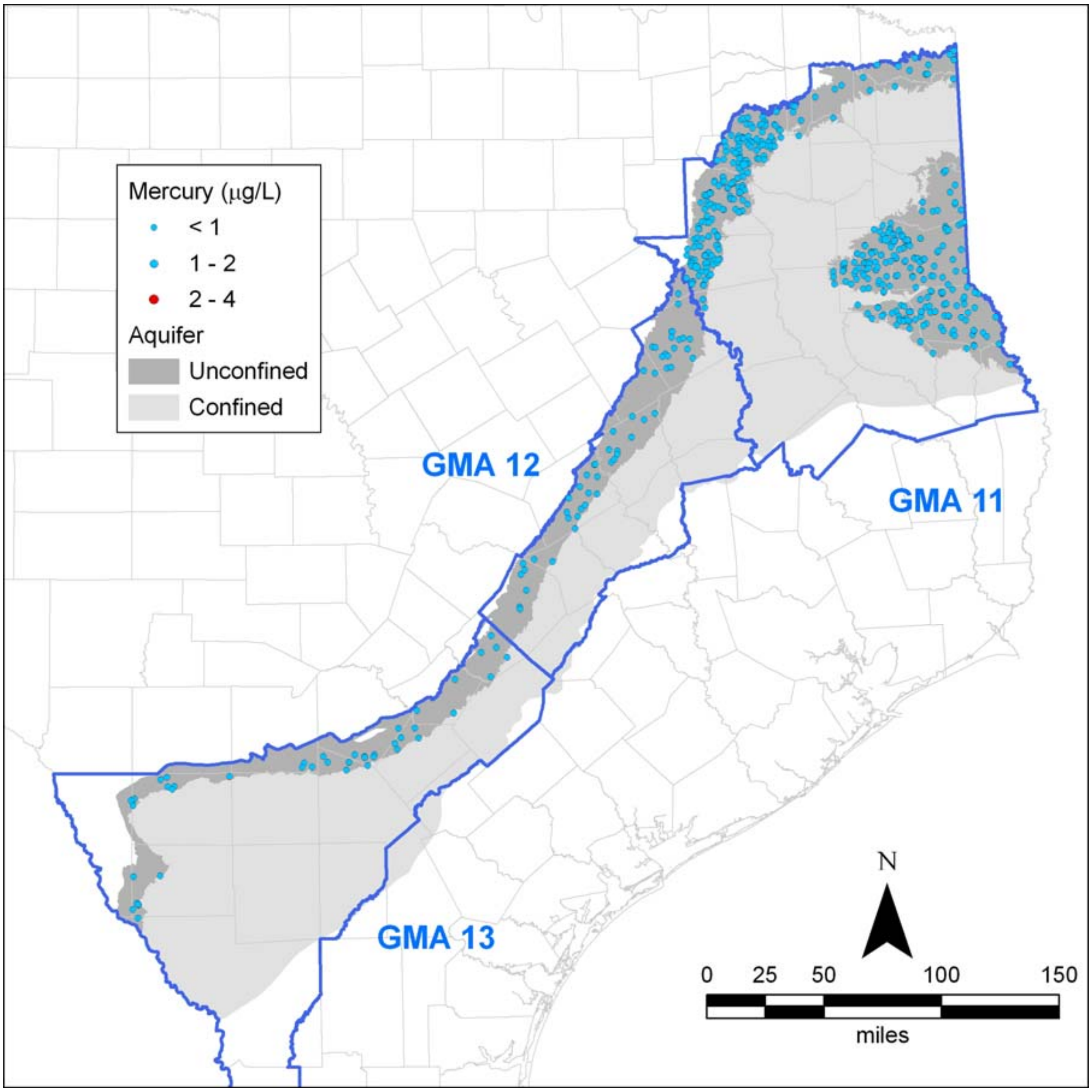

Figure 10. Spatial distribution of mercury (Hg) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

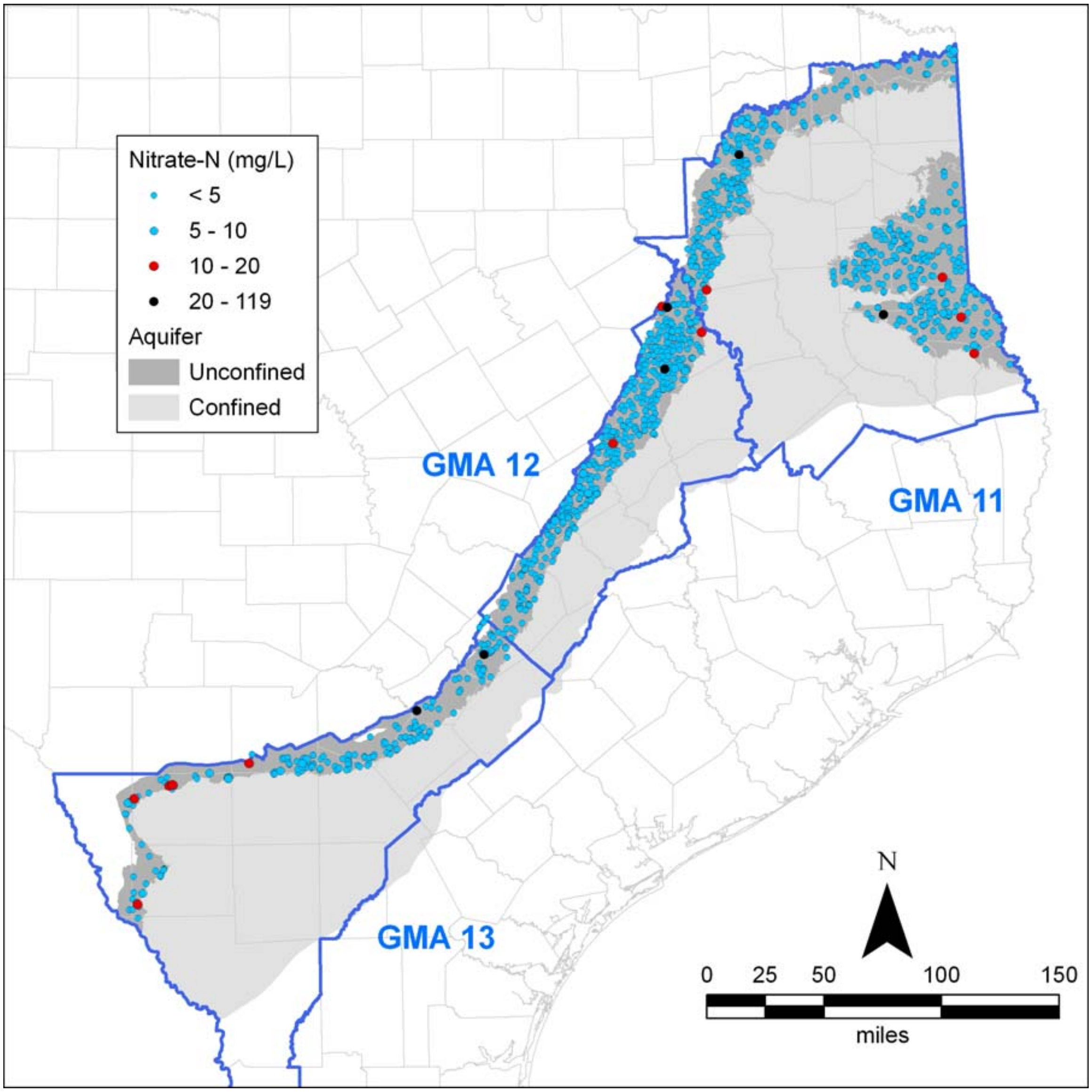

Figure 11. Spatial distribution of nitrate-N (NO_3-N) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

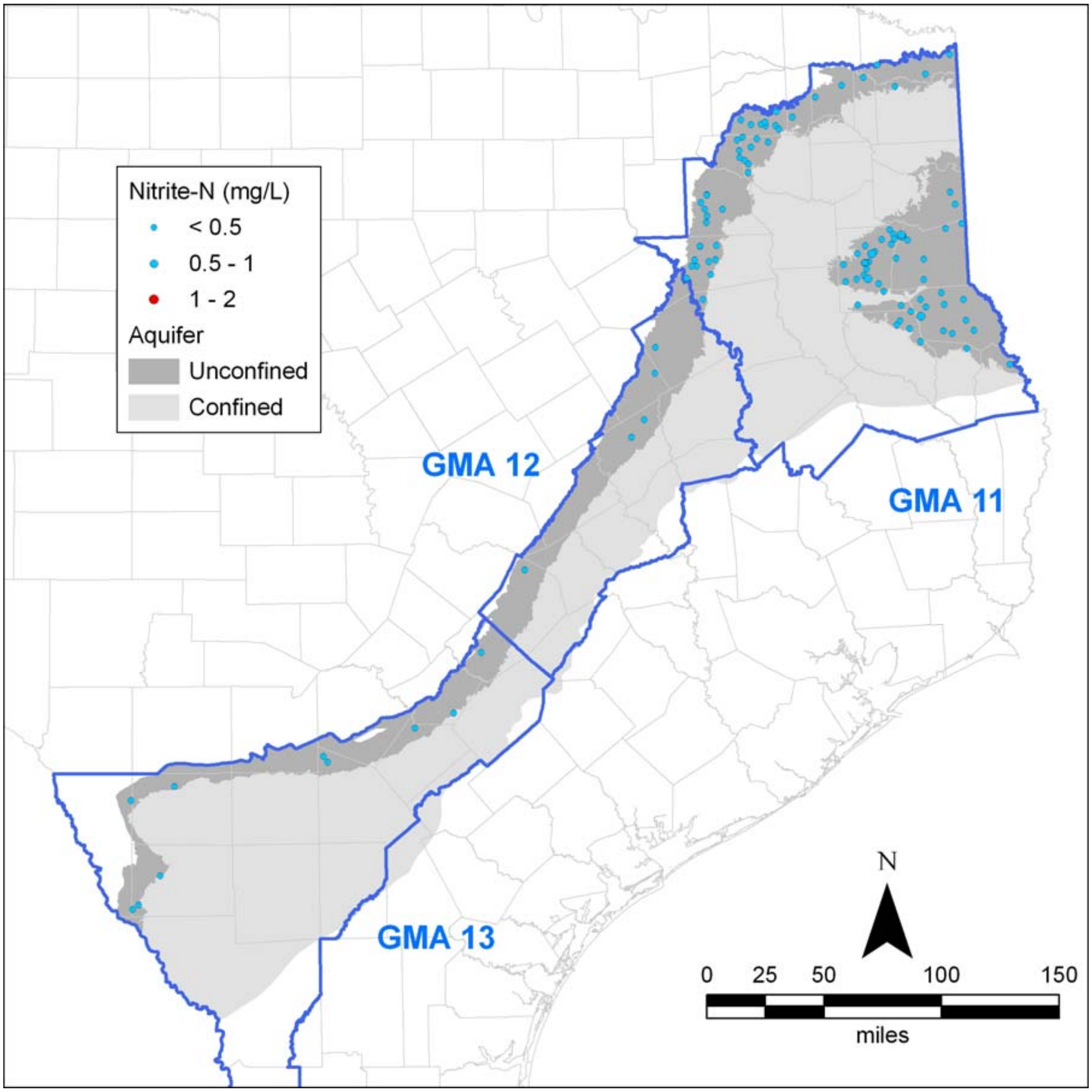

Figure 12. Spatial distribution of nitrite-N (NO_2-N) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

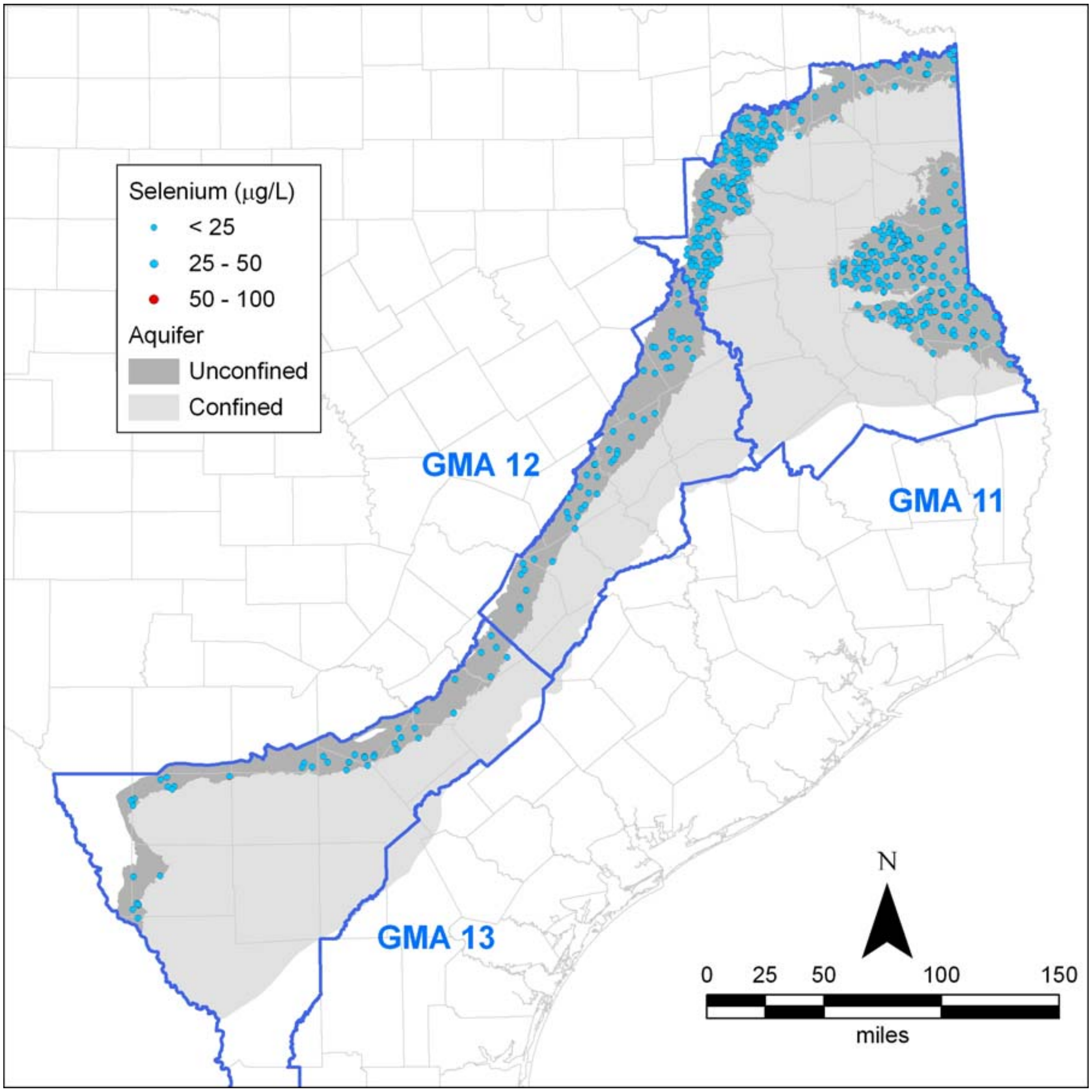

Figure 13. Spatial distribution of selenium (Se) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

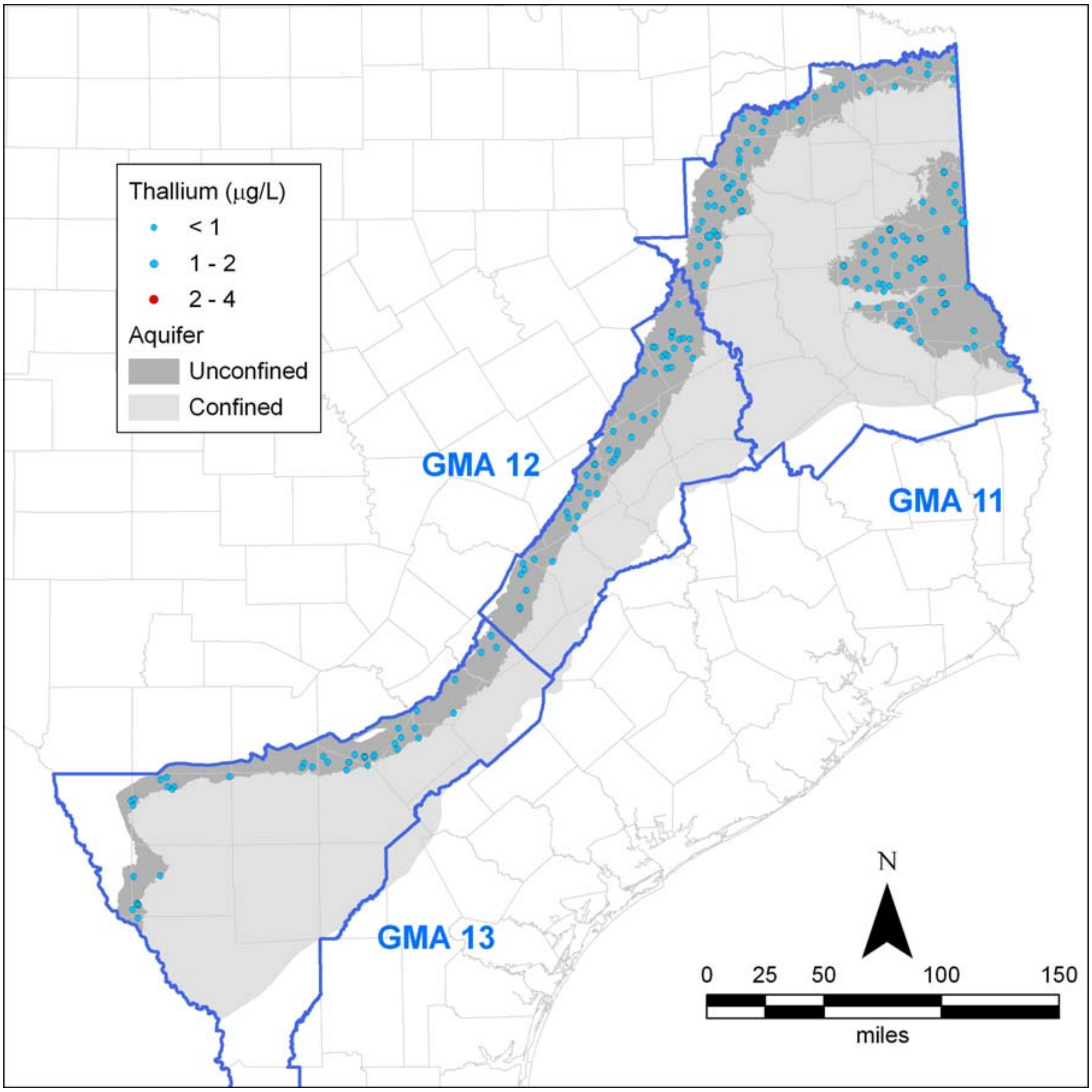

Figure 14. Spatial distribution of thallium (Tl) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

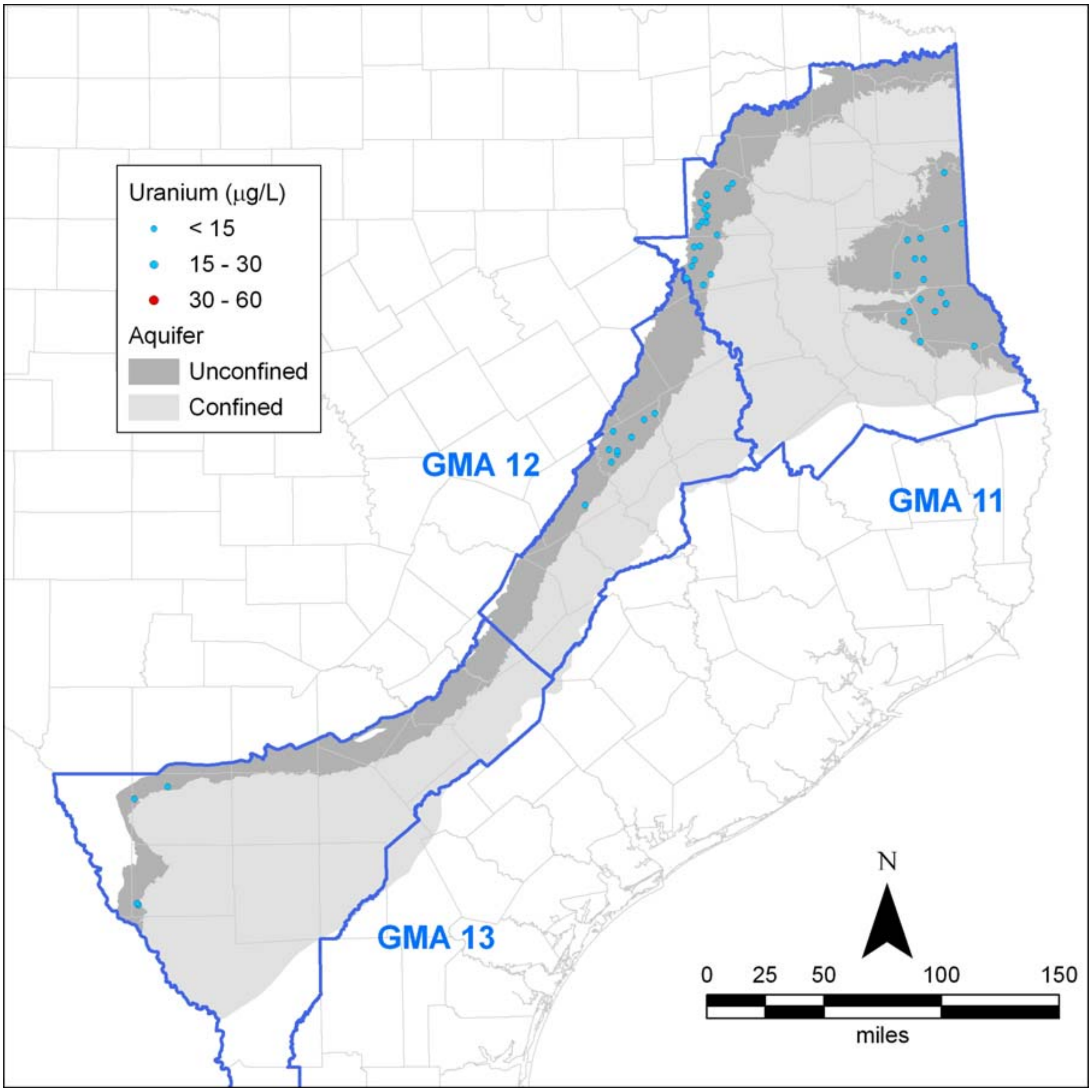

Figure 15. Spatial distribution of uranium (U) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

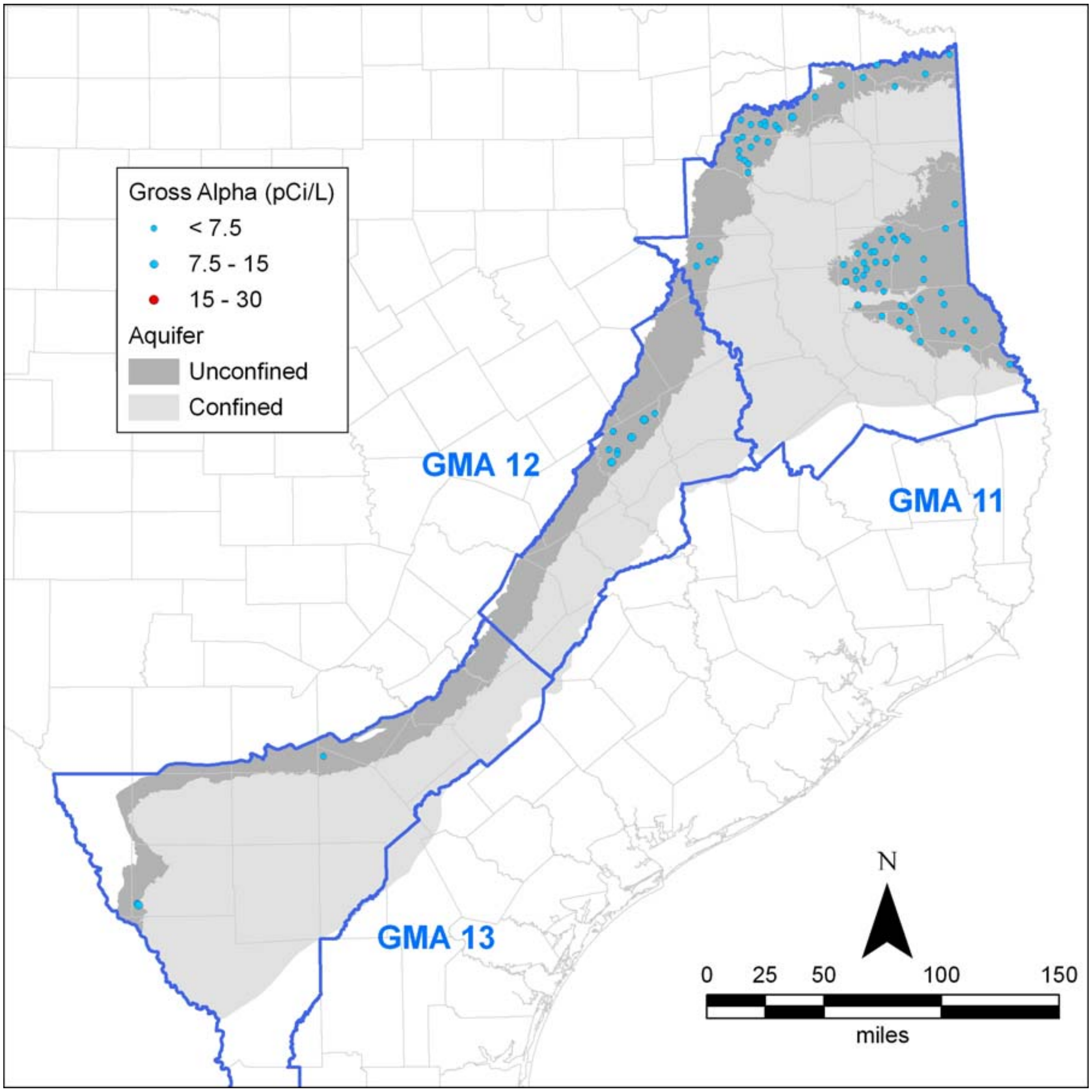

Figure 16. Spatial distribution of gross alpha (α) radiation in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

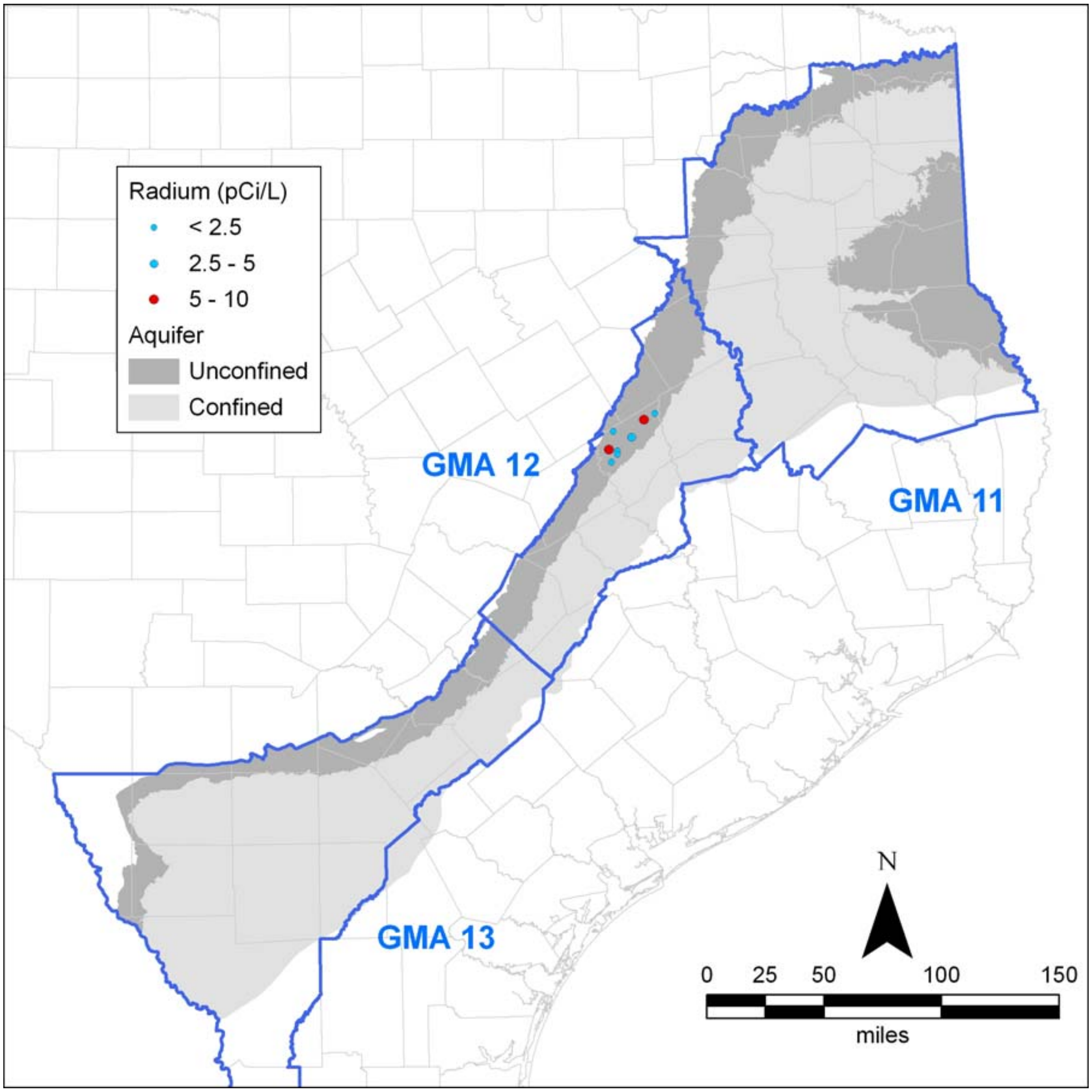

Figure 17. Spatial distribution of radium (Ra) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

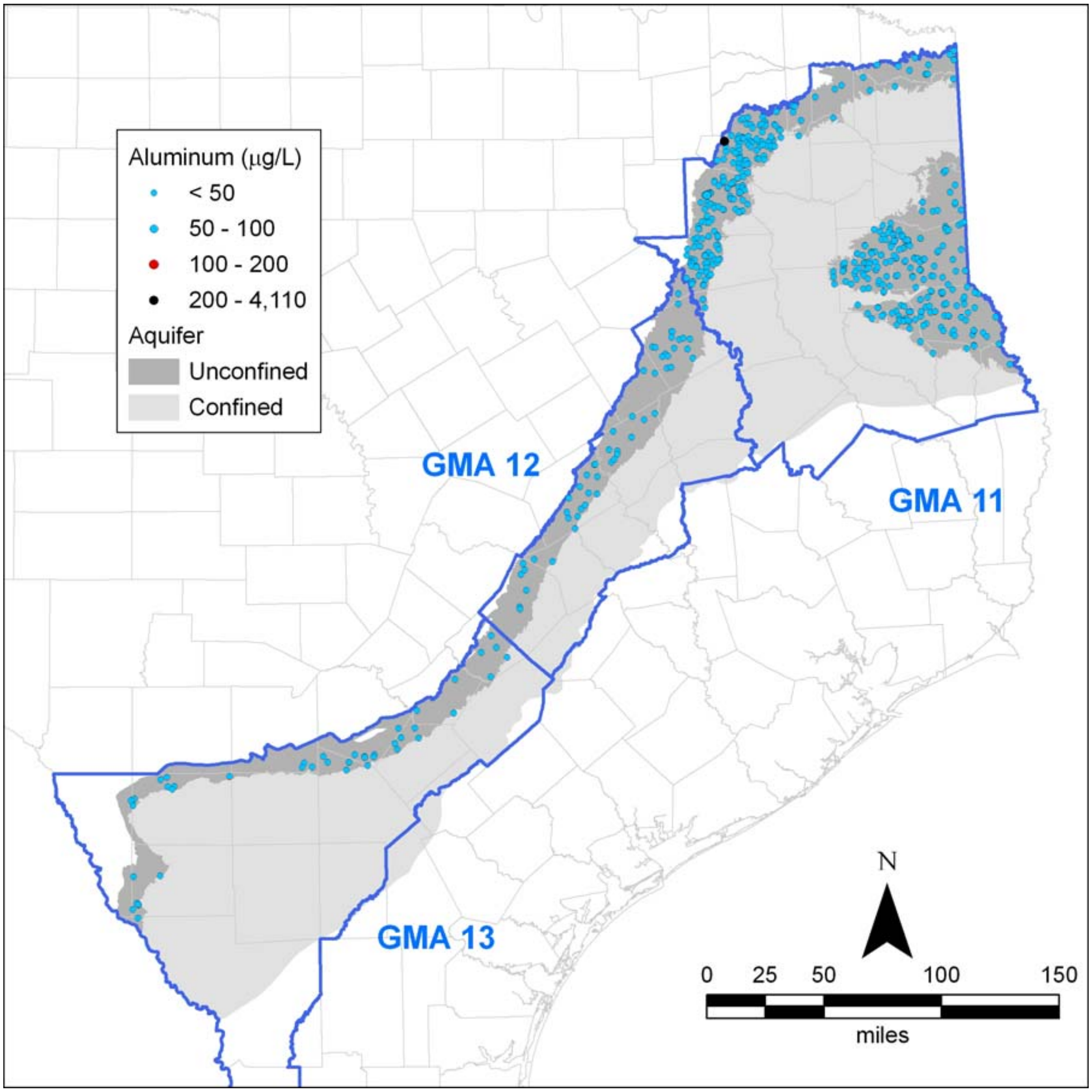

Figure 18. Spatial distribution of aluminum (Al) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

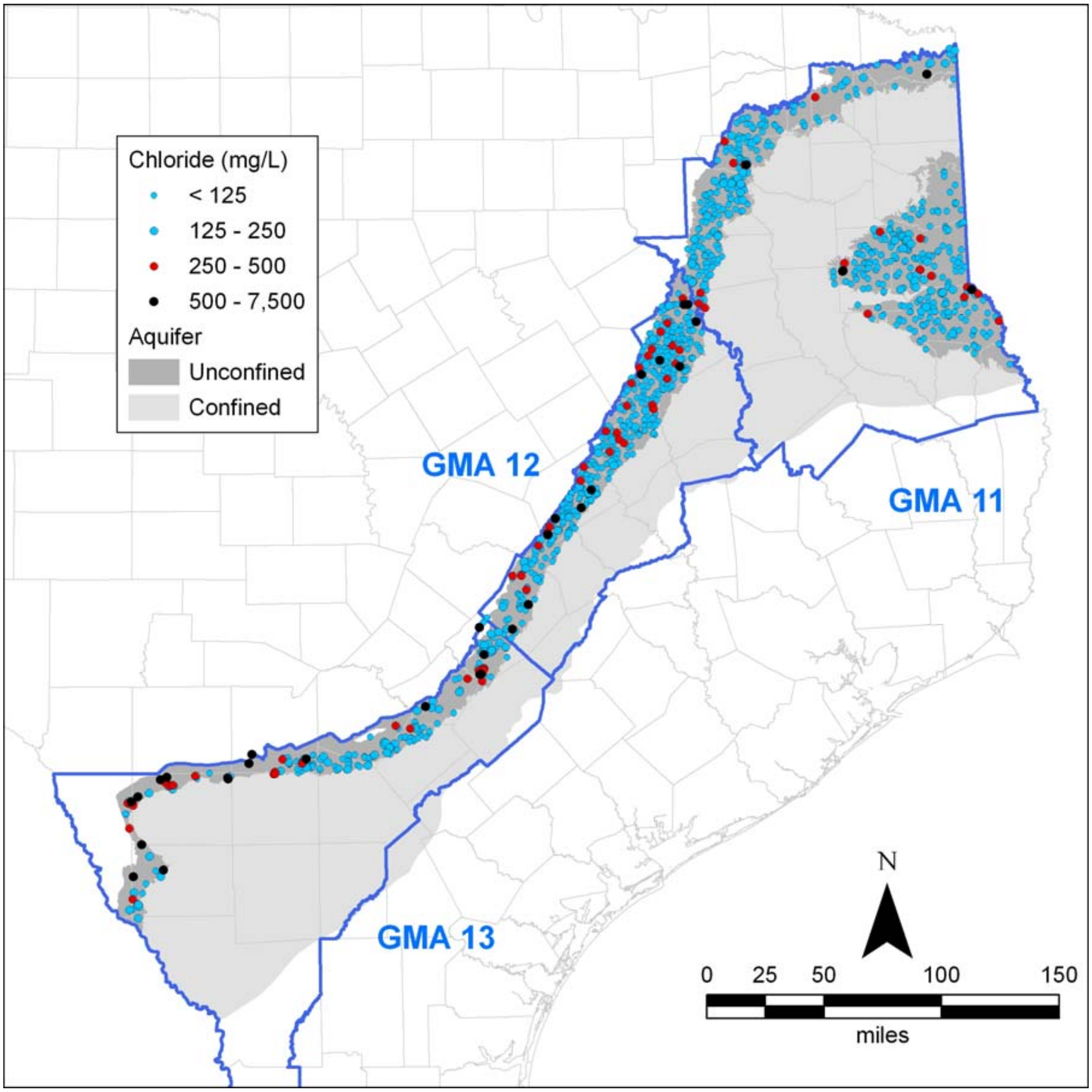

Figure 19. Spatial distribution of chloride (Cl) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

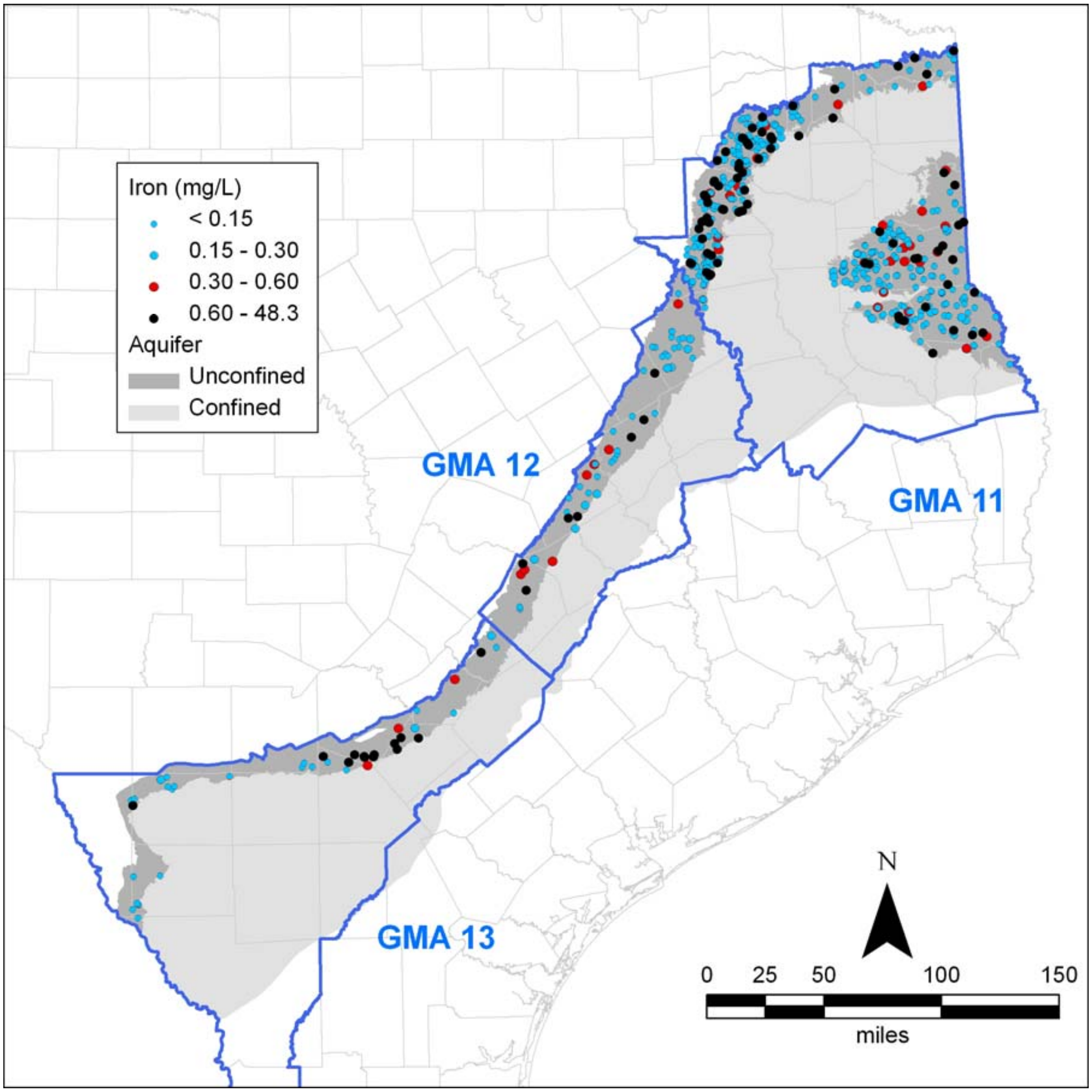

Figure 20. Spatial distribution of iron (Fe) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

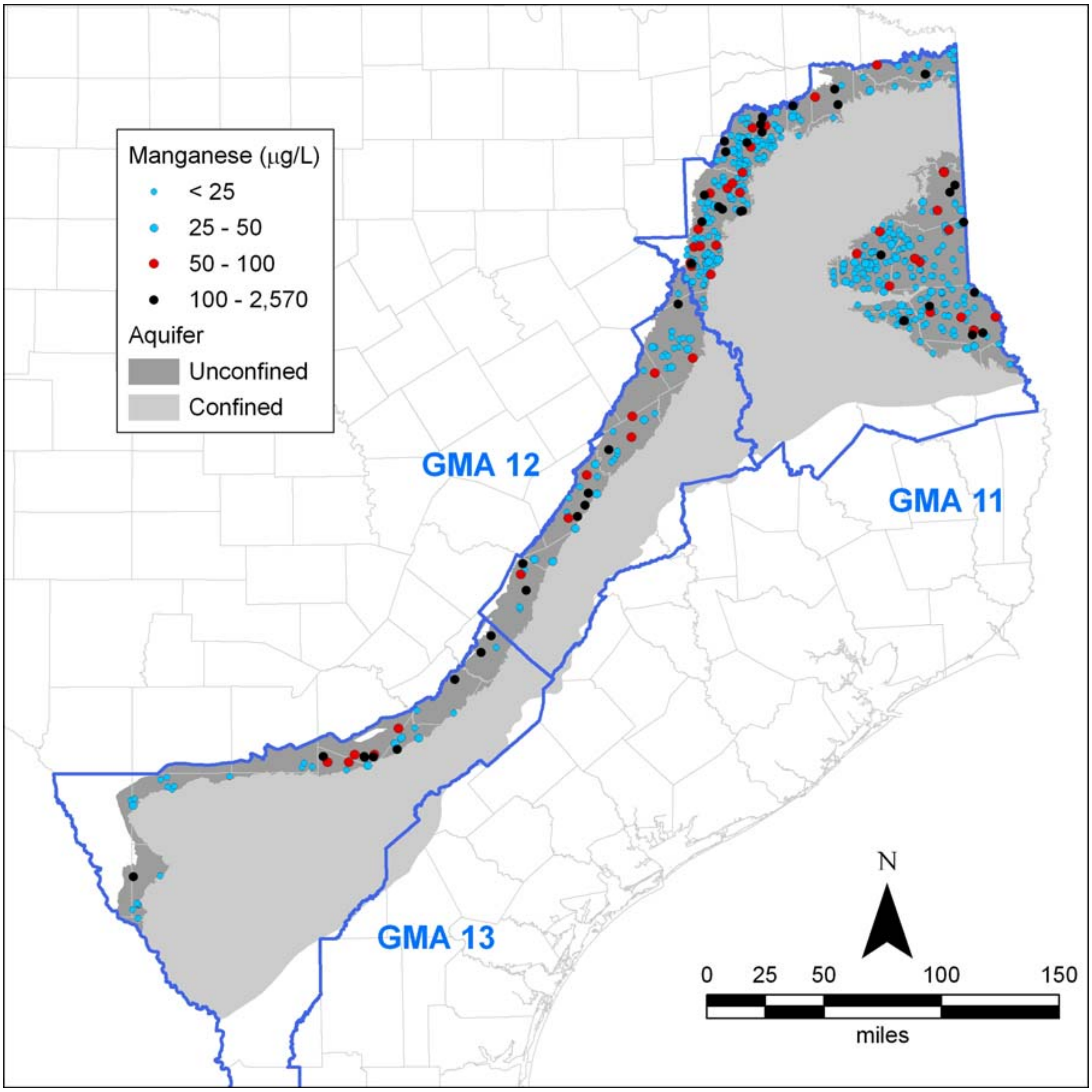

Figure 21. Spatial distribution of manganese (Mn) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

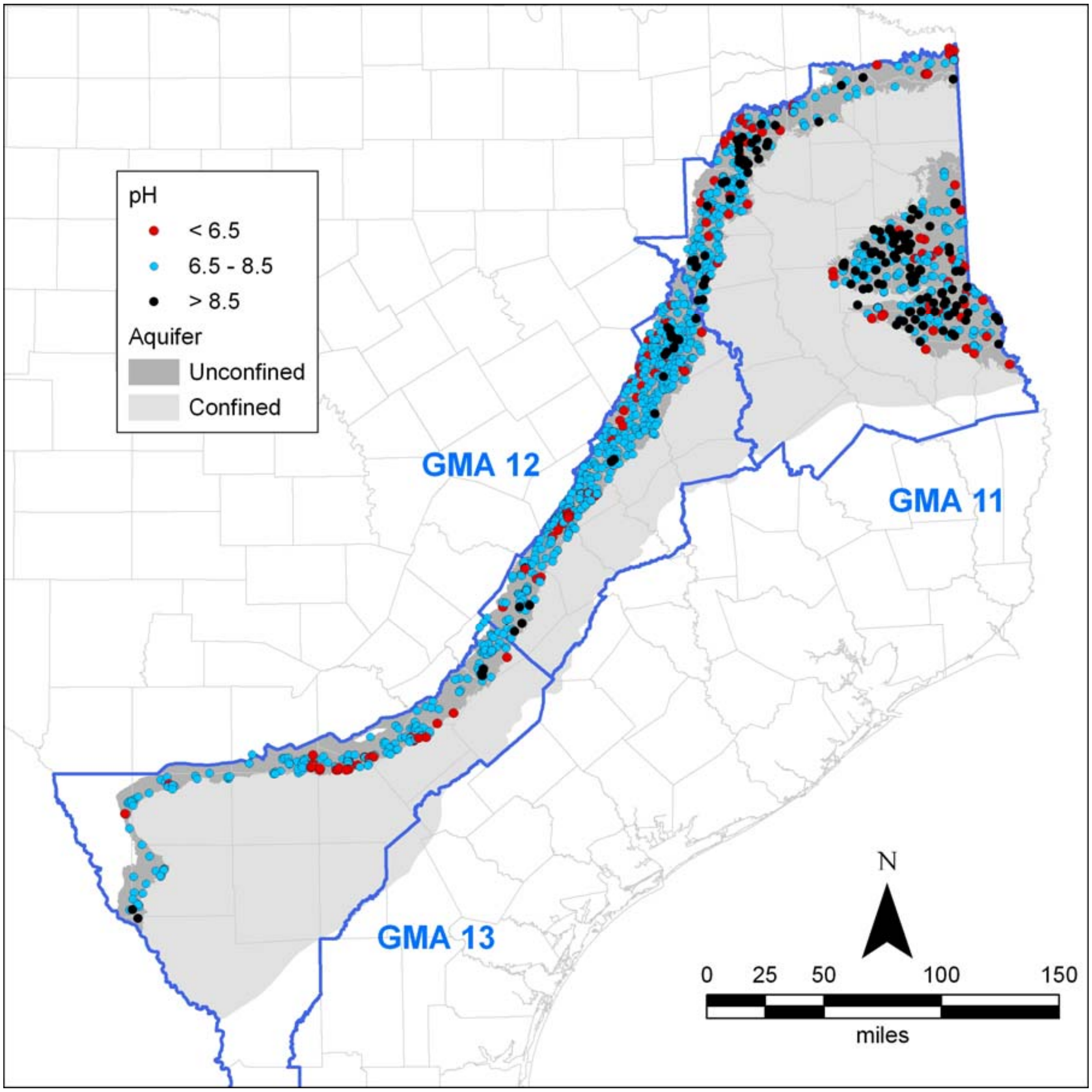

Figure 22. Spatial distribution of pH in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

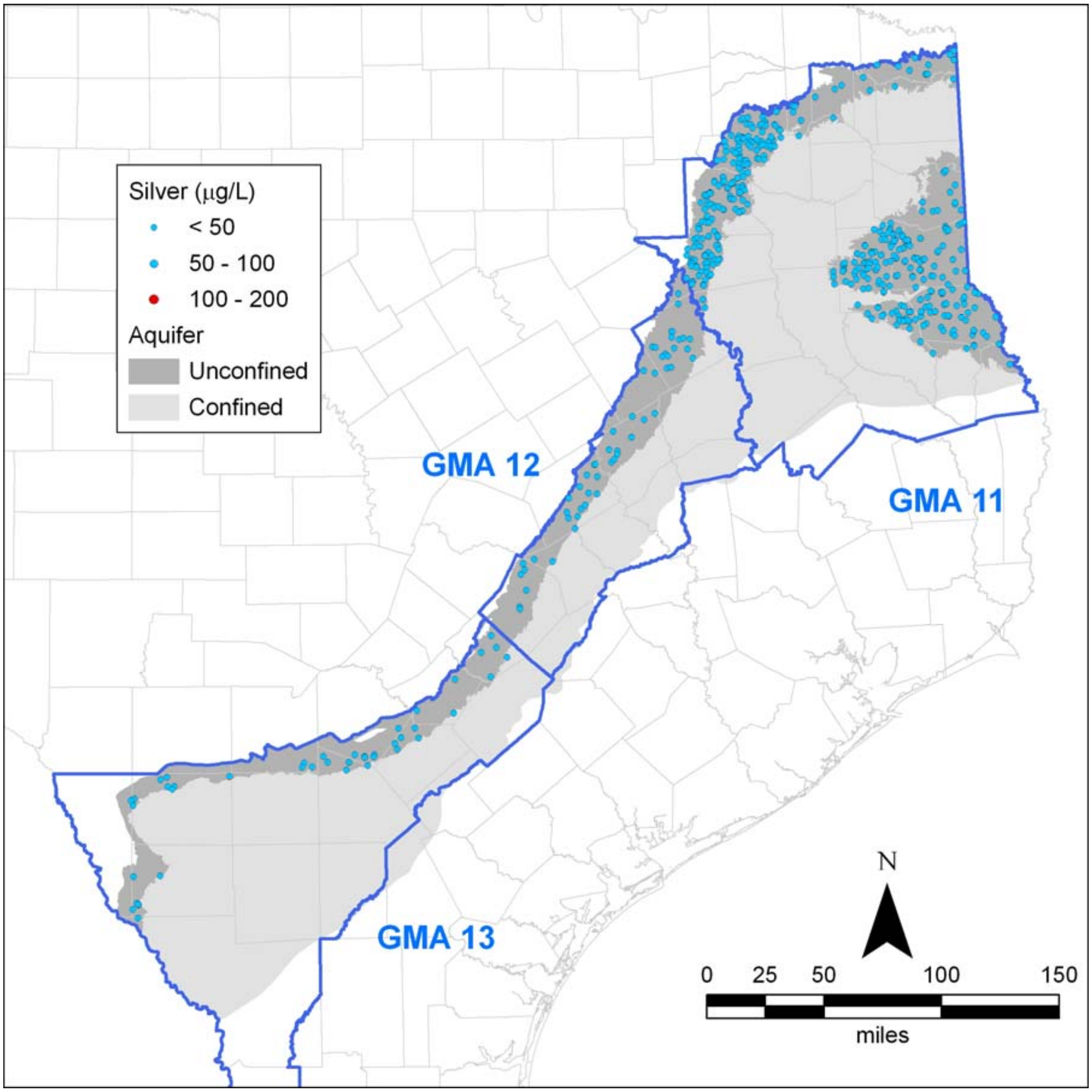

Figure 23. Spatial distribution of silver (Ag) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

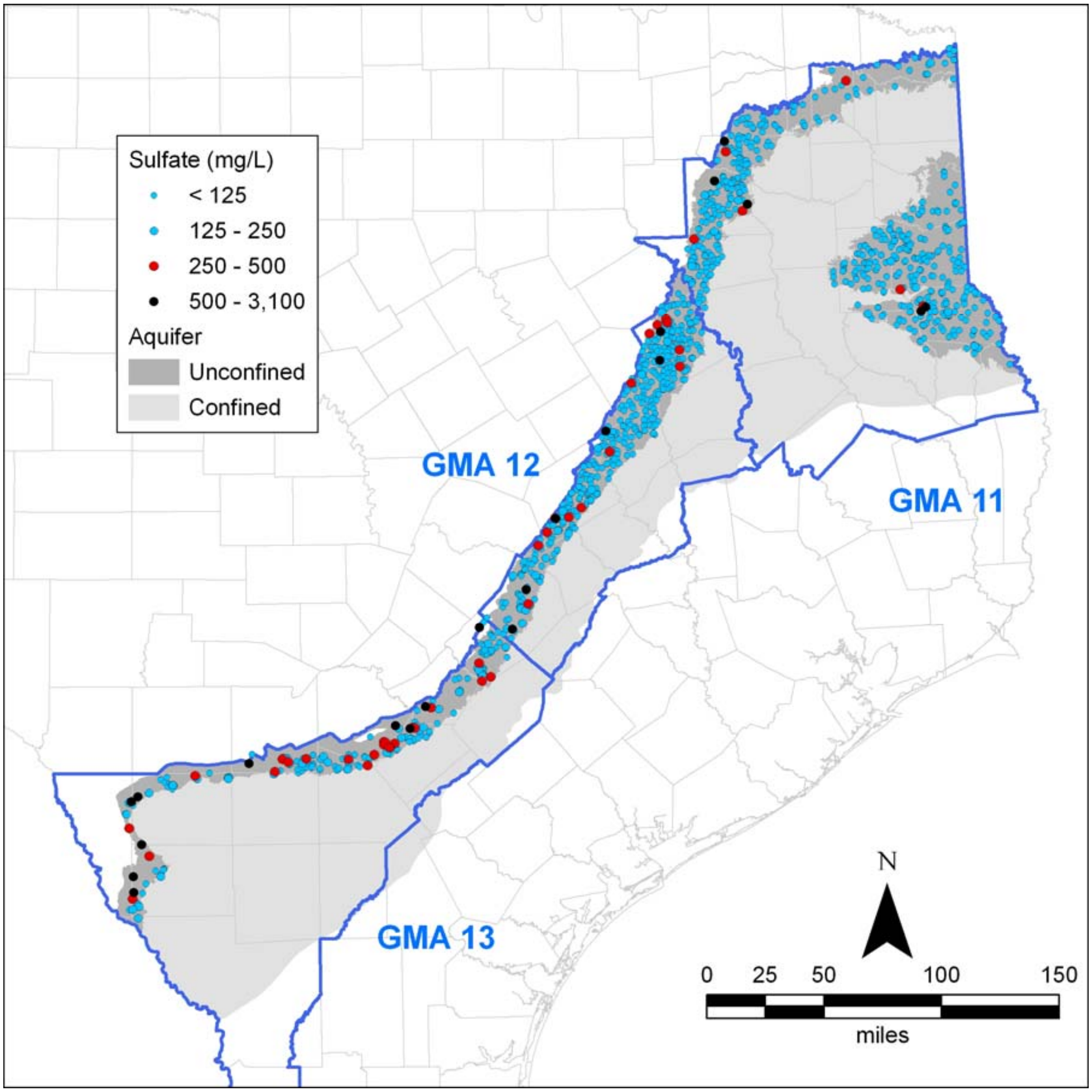

Figure 24. Spatial distribution of sulfate (SO4) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

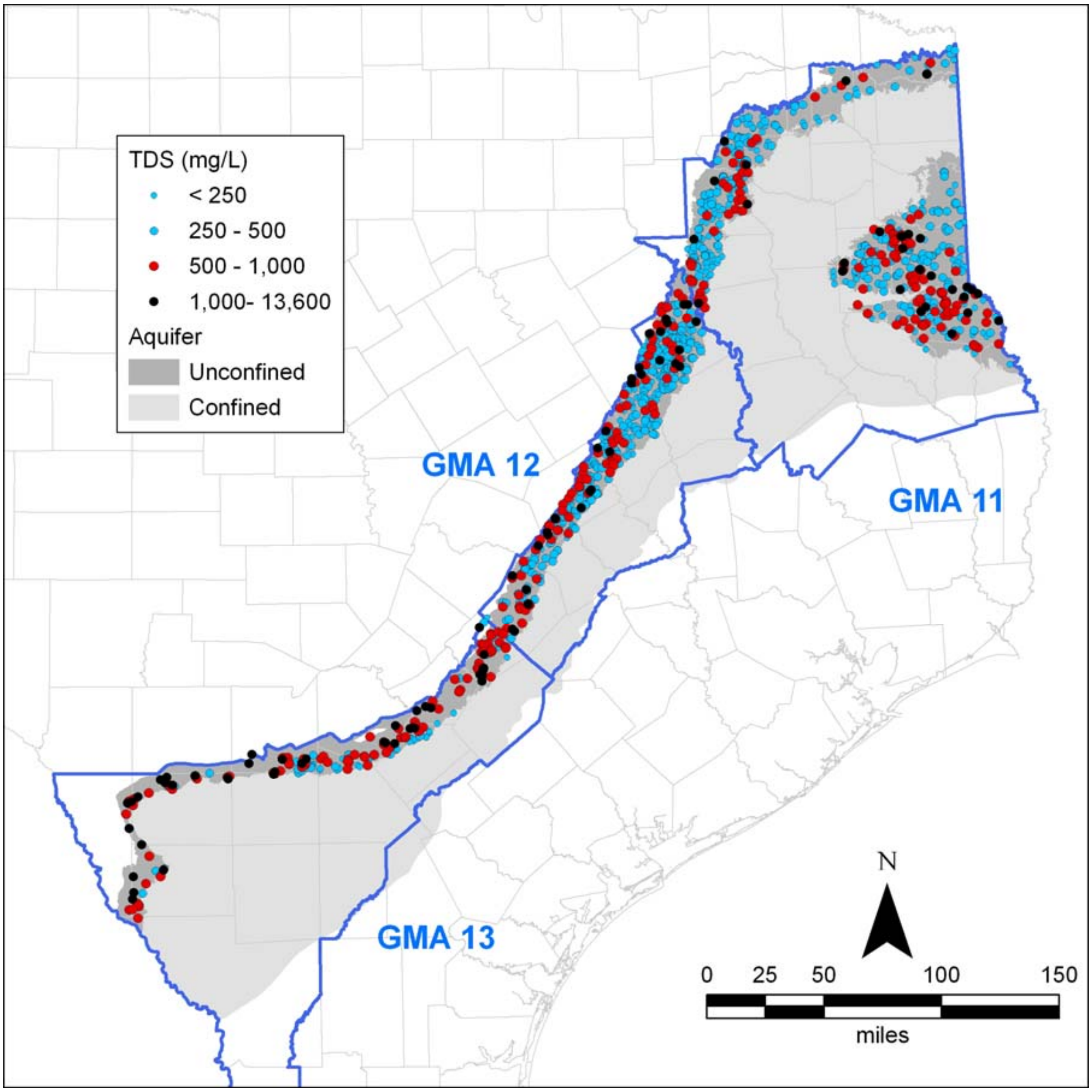

Figure 25. Spatial distribution of total dissolved solids (TDS) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

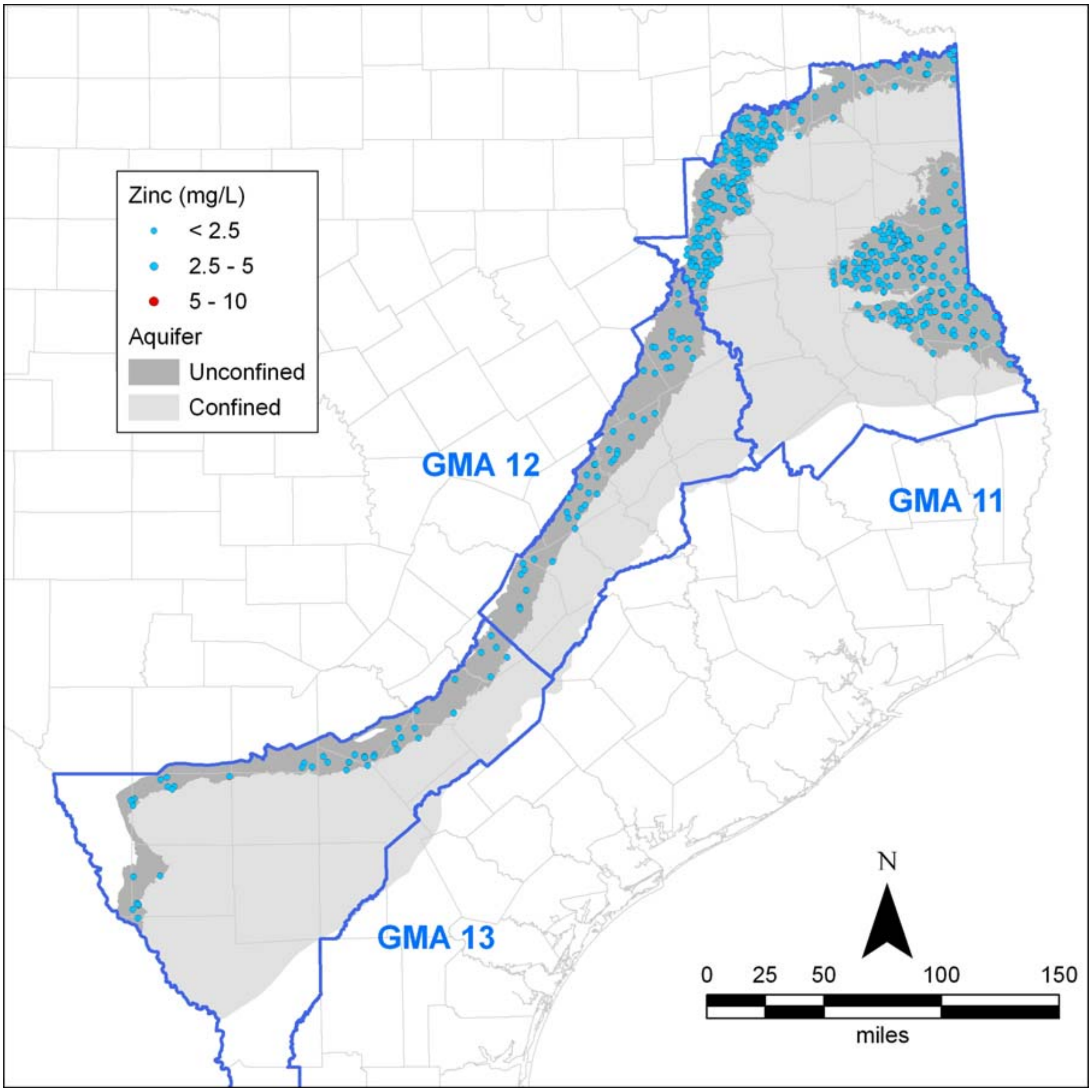

Figure 26. Spatial distribution of zinc (Zn) in groundwater wells located in the Carrizo-Wilcox aquifer outcrop (unconfined) area.

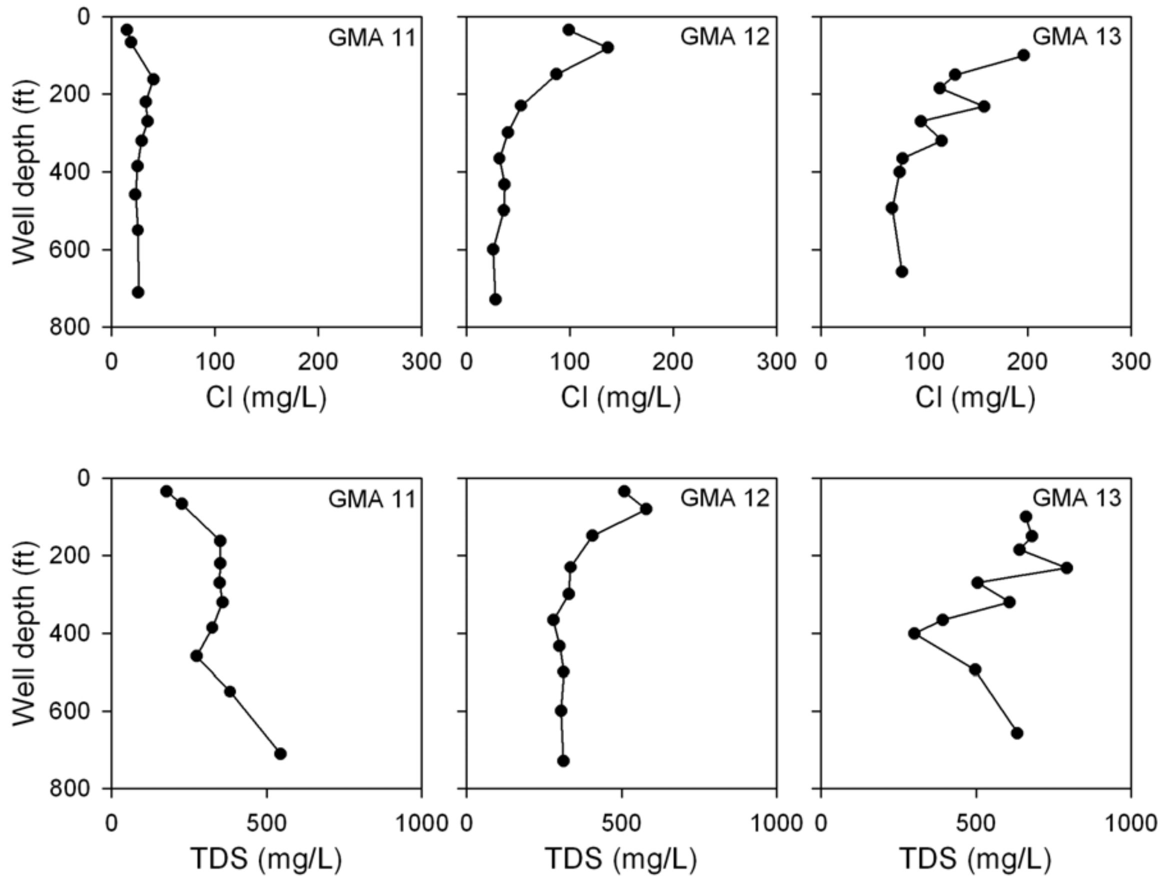

Figure 27. Variation in groundwater chloride and TDS with depth in the outcrop zone of the Carrizo Wilcox Aquifer in GMAs 11, 12, and 13. Concentrations represent median values per median decile of depth.

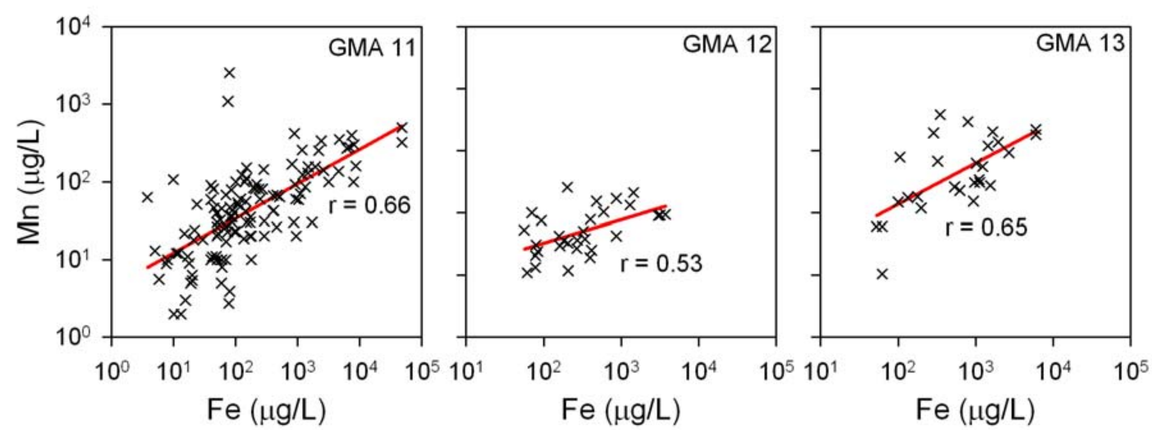

Figure 28. Correlations between manganese and iron in outcrop wells in GMAs 11, 12, and 13 in the Carrizo Wilcox Aquifer. Concentrations represent median values per median decile of depth.

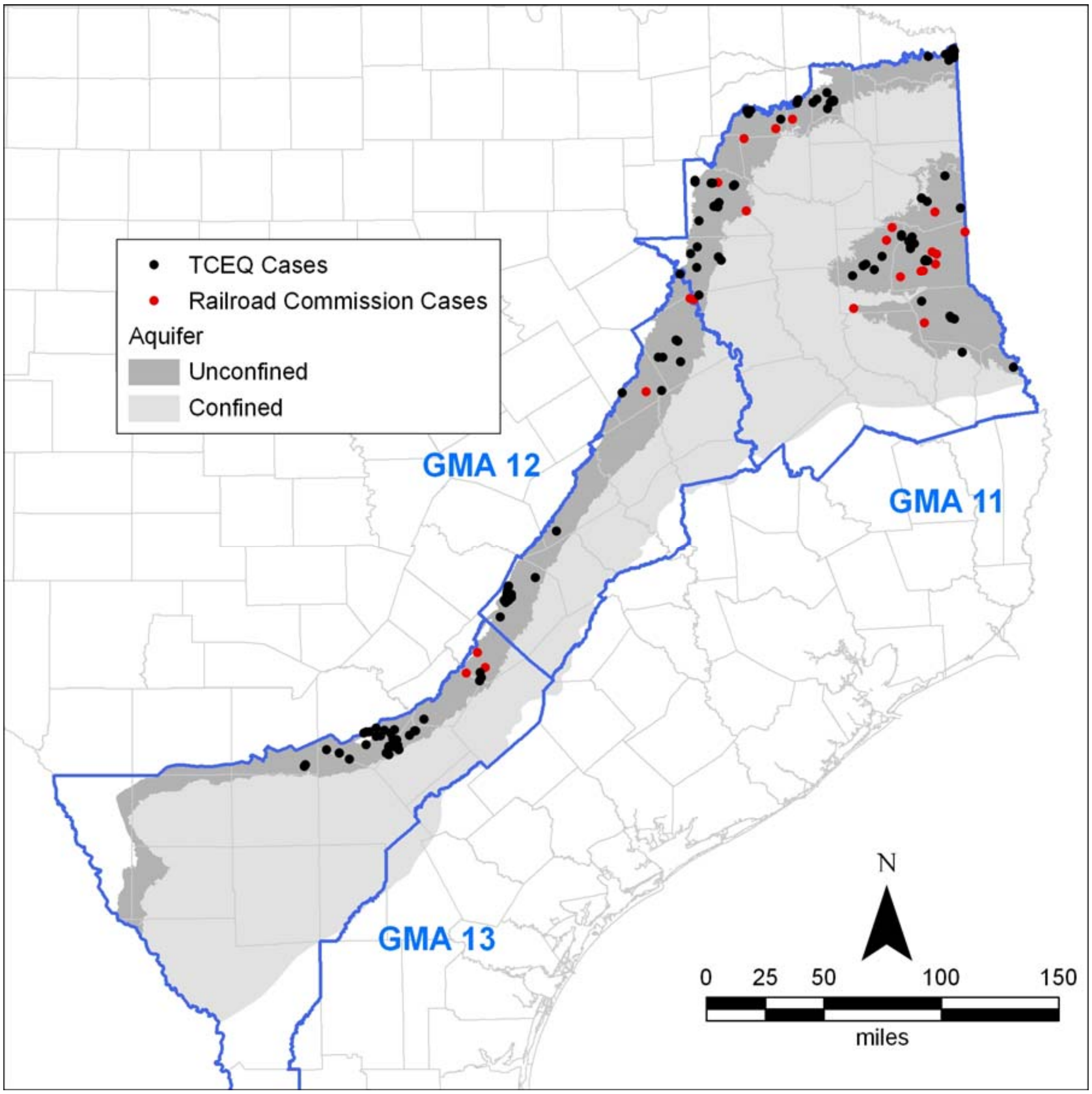

Figure 29. Distribution of contamination cases based on TCEQ and Railroad Commission of Texas data in the outcrop of the Carrizo Wilcox Aquifer. Data are from the Texas Groundwater Protection Committee Joint Groundwater Monitoring and Contamination Report (TGPC, 2010).

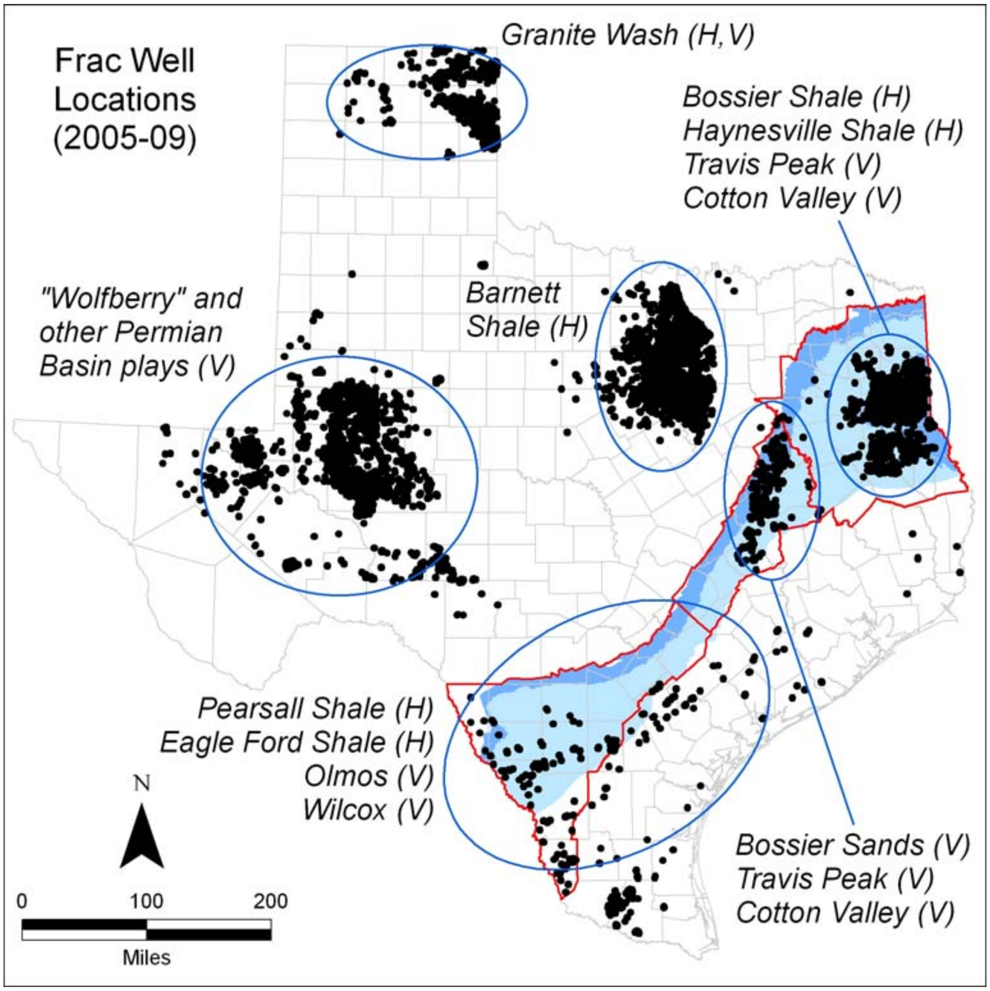

Figure 30. Distribution of fracing wells in Texas and footprint of the Carrizo Wilcox aquifer, ~30,000 wells in the 2005–2009 period. Gas shales include the Bossier Shale, Haynesville Shale in northeast Carrizo Wilcox, and Pearsall Shale and Eagle Ford Shale in the southwest Carrizo Wilcox. The only 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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