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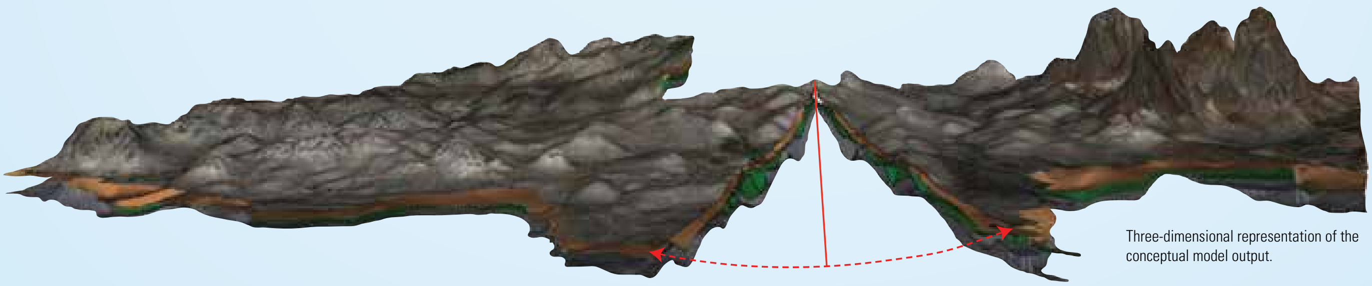
Prepared in cooperation with the Middle Pecos Groundwater Conservation District, Pecos County, City of Fort Stockton, Brewster County, and Pecos County Water Control and Improvement District No. 1

A Conceptual Hydrogeologic Model

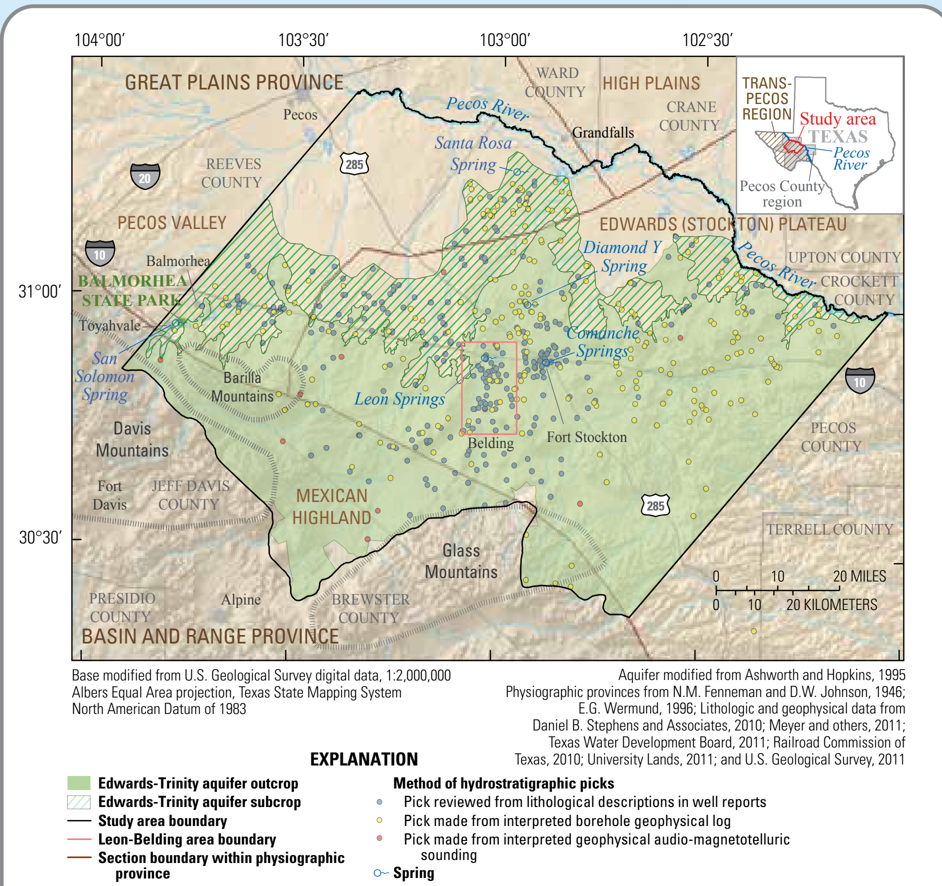
for the Hydrogeologic Framework, Geochemistry, and Groundwater-Flow System of the Edwards-Trinity and Related Aquifers in the Pecos County Region, Texas



Three-dimensional representation of the conceptual model output.

The Edwards-Trinity aquifer is a vital groundwater resource for agricultural, industrial, and municipal uses in the Trans-Pecos region of west Texas. A conceptual model of the hydrogeologic framework, geochemistry, and groundwater-flow system in the 4,700 square-mile (mi^2) study area was developed by the U.S. Geological Survey (USGS) in cooperation with the Middle Pecos Groundwater Conservation District, Pecos County, City of Fort Stockton, Brewster County, and Pecos County Water Control and Improvement District No. 1. The model was developed to gain a better understanding of the groundwater system and to establish a scientific foundation for resource-management decisions. Data and information were collected or obtained from various sources to develop the model. Lithologic information obtained from well reports and geophysical data were used to describe the hydrostratigraphy and structural features of the groundwater system, and aquifer-test data were used to estimate aquifer hydraulic properties. Groundwater-quality data were used to evaluate groundwater-flow paths, water and rock interaction, aquifer interaction, and the mixing of water from different sources. Groundwater-level data also were used to evaluate aquifer interaction as well as to develop a potentiometric-surface map, delineate regional groundwater divides, and describe regional groundwater-flow paths.

Several previous studies have been done to compile or collect physical and chemical data, describe the hydrogeologic processes, and develop conceptual and numerical groundwater-flow models of the Edwards-Trinity aquifer in the Trans-Pecos region. Documented methods were used to compile and collect groundwater, surface-water, geochemical, geophysical, and geologic information that subsequently were used to develop this conceptual model.



Location of study area and hydrostratigraphic data used to identify tops and bases (picks) of the hydrostratigraphic contacts in the Pecos County region, Texas.

Hydrogeologic Framework

Hydrostratigraphy

Well reports, borehole geophysical logs, and surface geophysical soundings were evaluated to determine the lithologies, hydrostratigraphic units, and the tops and bases of the hydrostratigraphic units (commonly referred to as the "hydrostratigraphic picks"). The resulting datasets were used to characterize vertical and lateral hydrostratigraphic extents. More than 2,000 data records for wells in or near the study area were obtained from various sources and evaluated for applicability to the study. A total of 662 records were found to contain pertinent data of applicable vertical extent within the study area. Stratigraphic and lithologic descriptions and borehole geophysical logs were obtained from existing reports and were assessed and interpreted to identify the vertical extents of hydrostratigraphic units. After the existing data were compiled, a geospatial analysis was done to identify data gaps and areas of concern. To enhance compiled data and fill in data gaps, where possible, 44 additional borehole geophysical logs, 4 time-domain electromagnetic (TDEM) soundings, and 13 audio-magnetotelluric (AMT) soundings were collected at the site. Three-dimensional surfaces were interpolated to represent the tops and bases of applicable hydrostratigraphic units. These three-dimensional surfaces were then used to assess all hydrostratigraphic contacts and refine contacts as needed.

U.S. Geological Survey borehole geophysical logging truck.

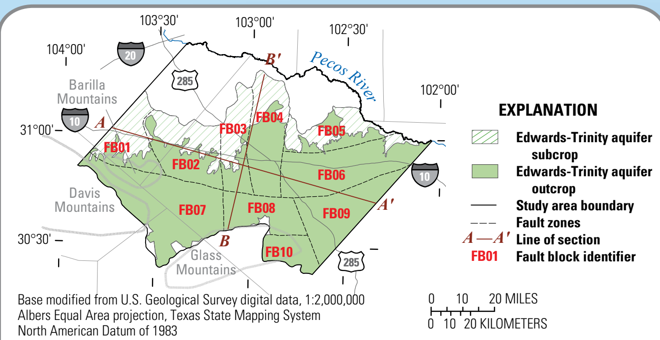
Borehole Geophysics

Borehole geophysical data such as natural gamma, formation resistivity, and caliper are commonly used to identify and characterize stratigraphic units; these data exist for many wells in the study area and were collected during previous scientific investigations and petroleum explorations. A total of 230 borehole geophysical logs—28 from University Lands (2011), 23 from USGS, 51 from the Railroad Commission of Texas, and 128 from Texas Water Development Board (Meyer and others, 2011)—were identified to contain relevant data for the project and were used to generate hydrostratigraphic contacts.

Surface Geophysics

Of the TDEM and AMT soundings collected in the study area, all of the TDEM soundings and four of the AMT soundings were near wells from which borehole geophysical logs were collected by the USGS. These locations were used to verify results between well data and surface geophysical soundings. Hydrostratigraphic contacts (picks) from surface soundings were used to supplement and enhance the compiled data set. Surface geophysical inverse modeling results were interpreted with layered-earth electrical scenarios in which each layer represents a separate electrical layer. These electrical layers then were associated with geologic layers. The layered-earth electrical scenarios for the AMT soundings were interpreted based on electrical changes in the modeling results.

Time-domain electromagnetic surface geophysical sounding collection.



Location of fault zones and fault blocks within the study area delineated based on the interpretation of multiple cross sections of interpolated hydrostratigraphic contacts.

Fault Interpretation

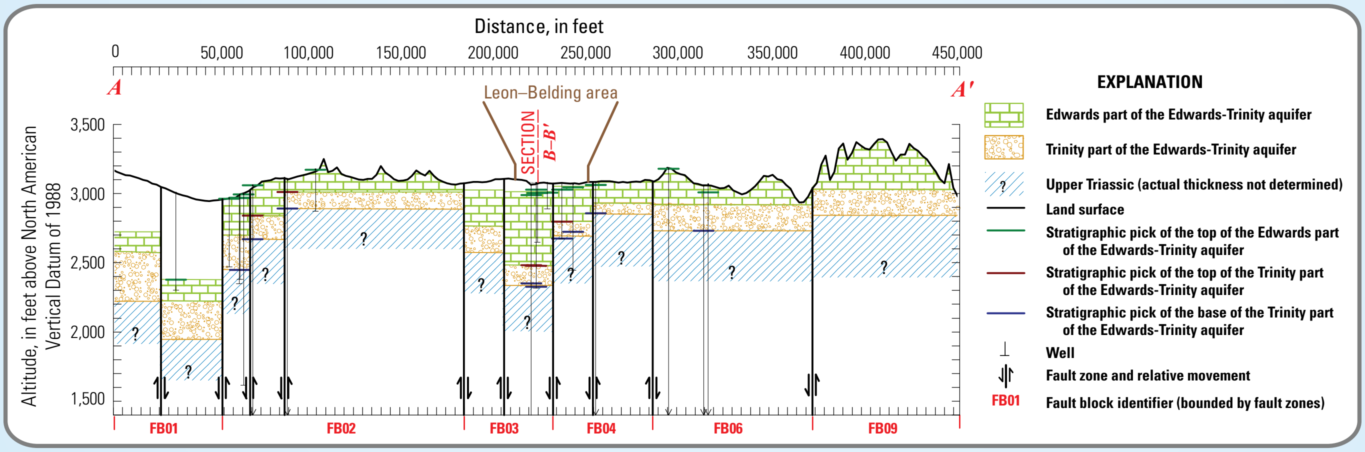
Faults in the study area likely formed as growth and collapse features as sediments were deposited along the margins of more resistant rocks and structures, such as the Glass Mountains, and as sediments collapsed into the voids created by the dissolution of Permian-age evaporite deposits. Fault zones were delineated based on the interpretation of cross sections of the interpolated top and base surfaces of the Edwards-Trinity aquifer units and are similar to faults delineated previously for the underlying Rustler aquifer (INTERRA Incorporated, 2011). Each fault zone represents a series of parallel and transverse faults that result in an overall displacement between two adjacent fault blocks.

Stratigraphic Surface Construction

After the geophysical logs and soundings were compiled and interpreted and the tops and bases of hydrostratigraphic units (picks) were determined, grids were created for each surface using kriging interpolation techniques. Modeling software was used to create the three-dimensional hydrostratigraphic surfaces. Preliminary grids were then used to identify outliers and areas requiring review. Throughout the process, the identified tops and bases of hydrostratigraphic units were reviewed and revised as needed to better conform to the available data.

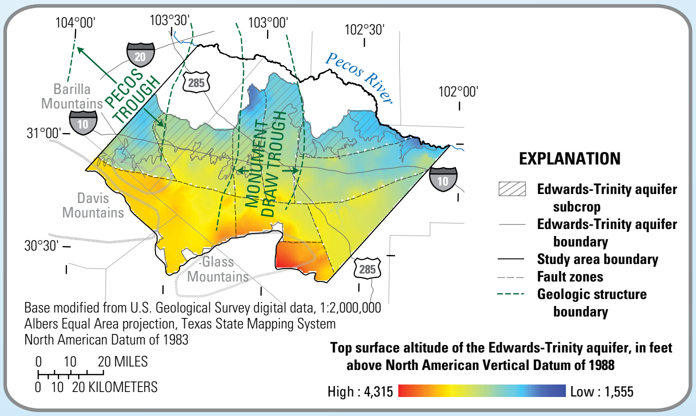
Hydrostratigraphic Layers

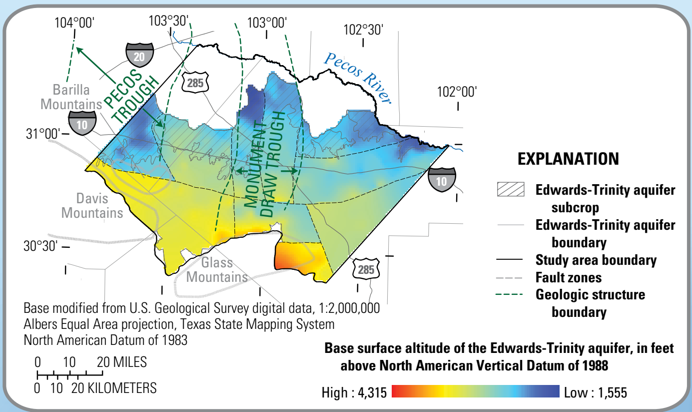
Cross Sections



Top of the Edwards-Trinity Aquifer

The altitude of the top of the Edwards-Trinity aquifer, which is, in general, the top of the Edwards part of the aquifer (upper Cretaceous), closely matched those of the land-surface altitudes throughout most of the study area. The altitude of the top surface of the Edwards-Trinity aquifer was highest in the southern part of the study area near the Glass Mountains (about 4,310 feet). The altitude decreased to the northeast, and the lowest altitude near the northeastern edge of the study area at the Pecos River was about 2,250 feet. The Edwards-Trinity aquifer dipped more sharply than the slope of the land surface in two locations, Monument Draw trough and the Pecos trough. All altitudes were measured in feet above North American Vertical Datum of 1988.



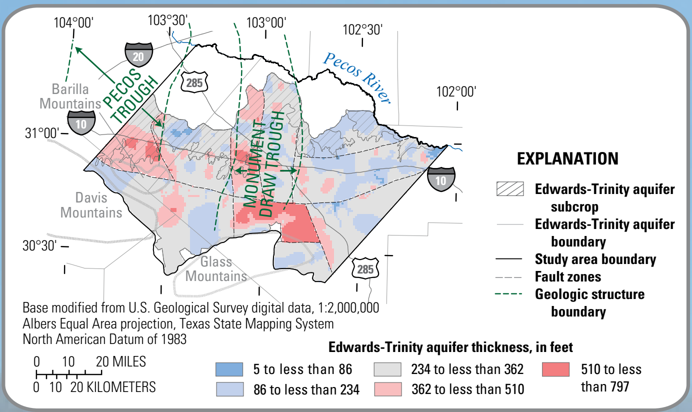


Base of the Edwards-Trinity Aquifer

The spatial trends observed for the base surface of the Edwards-Trinity aquifer were similar to those observed for the top of the Edwards-Trinity aquifer. The highest altitude of the base of the Edwards-Trinity aquifer was in the southern part of the study area near the Glass Mountains (about 4,110 feet). Similar to the top of the Edwards-Trinity aquifer, the altitude of the base of the Edwards-Trinity aquifer decreased to the northeast, which is consistent with findings by Barker and Ardis (1992). The lowest altitude for the base of the Edwards-Trinity aquifer was in the north-central part of the study area in the Monument Draw trough (about 1,550 feet).

Thickness of the Edwards-Trinity Aquifer

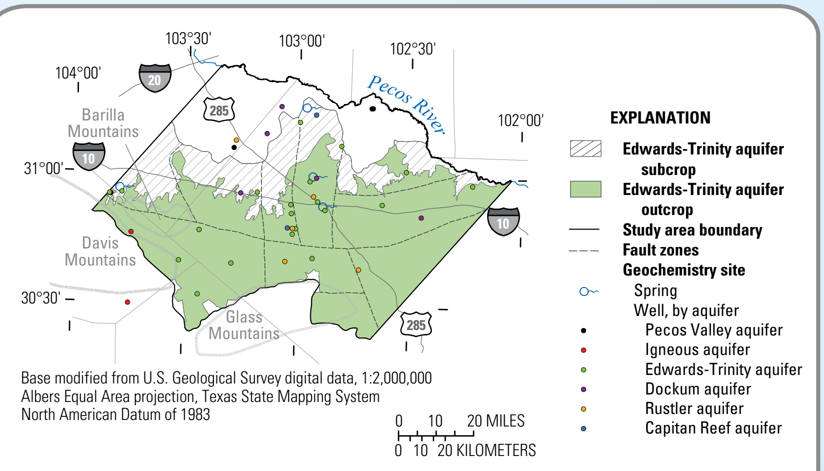
Thickness of the Edwards-Trinity aquifer in the study area was calculated as the difference in altitudes between its top and base. About 50 percent of the aquifer was between 234 and 362 feet thick, about 25 percent was less than 234 feet thick, and about 25 percent was more than 362 feet thick. The minimum thickness was 5 feet and the maximum thickness was about 797 feet. Some of the thinnest sections of the Edwards-Trinity aquifer were in the eastern part of the study area, near the northwestern slope of the Glass Mountains, and near the northeastern slope of the Davis Mountains. It was determined that the aquifer was often thickest in the central part of the study area in the Monument Draw trough and at the western edge of the study area in the Pecos trough.



Geochemistry

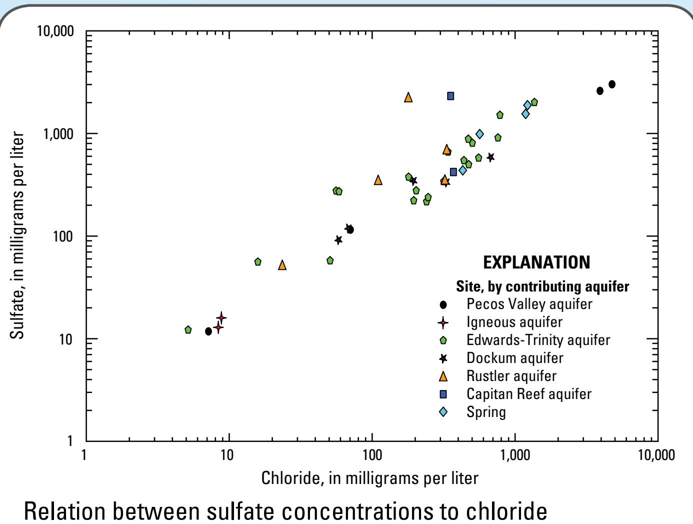
Geochemical Results

Analyses of geochemical and isotopic samples provided insights into the chemical characteristics of water from different sources and different aquifers. Chemical characteristics of water from different sources were used to qualitatively asses the aquifer interaction, groundwater-flow paths, water-rock interaction, mixing of water from different sources, and to identify likely source waters and geochemical endmembers. Geochemical properties that were evaluated included specific conductance, hydrochemical facies, sulfate and chloride concentrations, silica concentrations, stable isotopes of oxygen and hydrogen, strontium isotopes, environmental tracers, and concentrations of organic compounds and nutrients.



Location of groundwater-well and spring sites for geochemical data collection.

Geochemical and isotopic results indicate groundwater in the system likely is dominated by mineralized, regional groundwater flow that probably recharged during the cooler, wetter climates of the Pleistocene with variable contributions of recent, local recharge. The mixing of water from multiple sources combined with water-rock interaction with various rock types, including siliciclastic, carbonate, evaporite, and igneous rocks, contributed to a groundwater chemistry that was complex between and within aquifer units.



Relation between sulfate concentrations to chloride concentrations for samples collected from groundwater and spring sites.

Water-quality sampling by the U.S. Geological Survey, San Solomon Springs, Texas.

Geochemical Endmembers

Four endmembers were identified to use as part of the qualitative groundwater-flow and mixing analysis. The endmembers represented: (1) mineralized groundwater that likely recharged northwest of the study area during the Pleistocene and is flowing through the Edwards-Trinity aquifer along regional groundwater-flow paths; (2) dilute, recent recharge from the Barilla and Davis Mountains with a composition indicative of interaction with igneous rocks; (3) dilute, recent recharge from the Glass Mountains with a composition indicative of interaction with carbonate rocks; and (4) mineralized water that is likely a mixture of recharge under recent and Pleistocene climatic conditions and is flowing through the Edwards-Trinity aquifer along regional groundwater-flow paths east of the Monument Draw trough.

Groundwater-Flow System

Groundwater Recharge

Four principal sources of recharge to the Edwards-Trinity aquifer were identified: (1) regional groundwater flow in the Edwards-Trinity aquifer that originated as recharge northwest of the study area and enters the study area near the western corner; (2) runoff from the Barilla, Davis, and Glass Mountains that percolates through underlying rocks and into the gravels along the slopes of the mountains; (3) return flow from irrigation; and (4) upwelling from deeper aquifers. Although some of the groundwater appears to have recharged under conditions similar to the current climate, the only samples collected from the Edwards-Trinity aquifer that likely recharged during the last 60 years were collected from wells in mountain recharge areas and in areas receiving agricultural return flow.

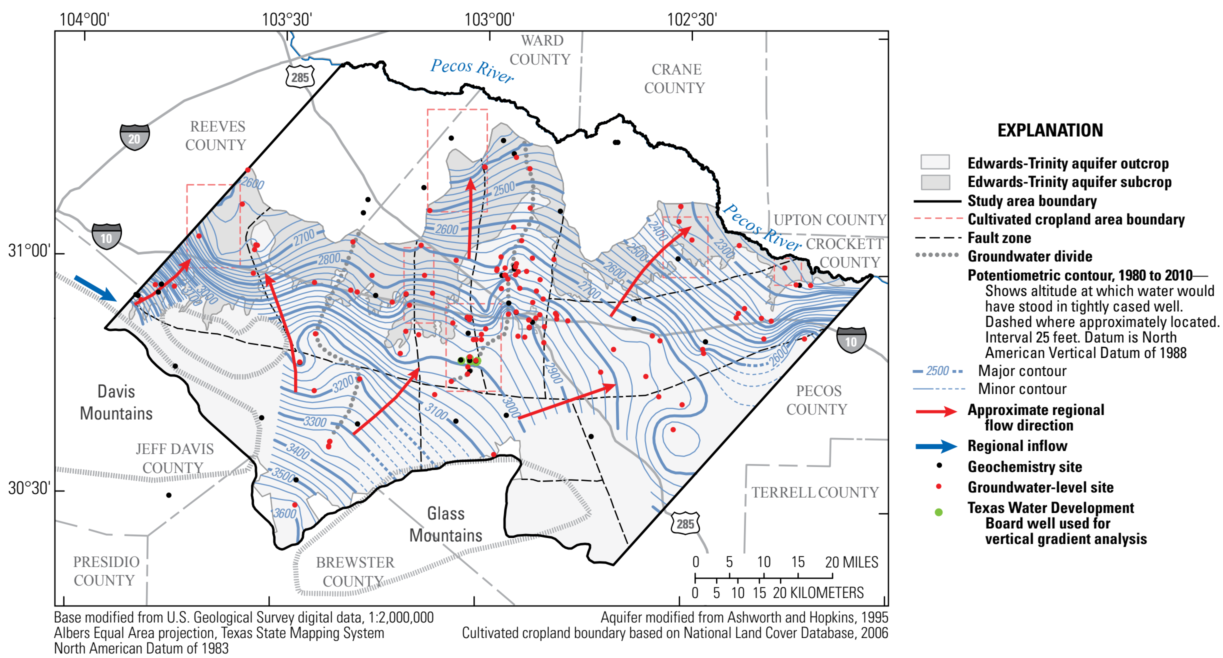
Transmissivity

Transmissivity values calculated and estimated from historical aquifer-test data ranged from 1,500 to 1,216,000 gallons per day per foot. The highest transmissivity values were measured in the Monument Draw trough area, which is also one of the thickest parts of the Edwards-Trinity aquifer and is in a faulted area. The lowest values were measured in the eastern part of the study area, near some of the thinnest parts of the aquifer. Hydraulic conductivity values generally showed the same trends as the transmissivity values.

U.S. Geological Survey pump hoist truck and water-quality trailer.

Groundwater Flow

Groundwater-level altitudes (which were used to generate a potentiometric-surface map of the Edwards-Trinity aquifer) ranged from about 2,300 to about 3,300 feet and generally decreased from southwest to northeast. Regional groundwater flow is from areas of recharge in the south and southwest to the north and northeast. Groundwater generally flows north into the down-dip extent of the Edwards-Trinity aquifer or east out of the study area. Regional groundwater flow entering the study area from the northwest naturally discharges from springs or turns northward to flow into the Pecos trough where it discharges into the Pecos Valley or Dockum aquifers at the down-dip extent of the Edwards-Trinity aquifer. Recharge from the Barilla and Davis Mountains also predominantly flows toward the Pecos trough and most likely naturally discharges to other aquifers in the groundwater system. Groundwater flow in the Edwards-Trinity aquifer in the Monument Draw trough originated as recharge in the Glass Mountains, agricultural return flow, or upwelling groundwater from lower units. Edwards-Trinity aquifer water generally flows north and northeast in the Monument Draw trough and naturally discharges from springs or to other aquifers in the groundwater system at the down-dip extent. Groundwater in the eastern part of the study area likely originated in the Glass Mountains, generally flows northeast, and flows out of the study area to the east or naturally discharges from springs or to other aquifers in the groundwater system at the down-dip extent or to the Pecos River.



Groundwater flow and potentiometric-surface map of the Edwards-Trinity aquifer developed using geochemical data and the average winter (November through April) groundwater-level data for 1980–2010.

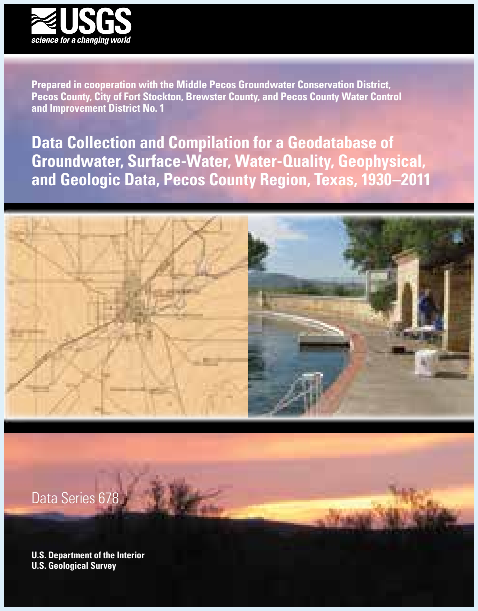
This fact sheet is based on the following USGS reports:

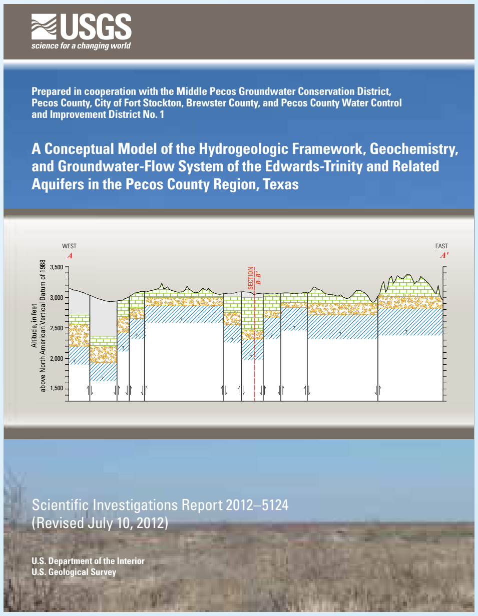
Pearson, D.K., Bumgarner, J.R., Houston, N.A., Stanton, G.P., Teeple, A.P., and Thomas, J.V., 2012, Data collection and compilation for a geodatabase of groundwater, surface-water, water-quality, geophysical, and geologic data, Pecos County region, Texas, 1930–2011; U.S. Geological Survey Data Series 678, 67 p.

http://pubs.er.usgs.gov/publication/ds678

Bumgarner, J.R., Stanton, G.P., Teeple, A.P., Thomas, J.V., Houston, N.A., Payne, J.D., and Musgrove, MaryLynn, 2012, A conceptual model of the hydrogeologic framework, geochemistry, and groundwater-flow system of the Edwards-Trinity and related aquifers in the Pecos County region, Texas: U.S. Geological Survey Scientific Investigations Report 2012–5124, 74 p.

http://pubs.er.usgs.gov/publication/sir20125124





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Barker, R.A., and Ardis, A.F., 1992, Configuration of the base of the Edwards-Trinity aquifer and hydrogeology of the underlying pre-Cretaceous rocks, west-central Texas: U.S. Geological Survey Water-Resources Investigations Report 91–4071, 25 p., 1 pl.

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