Chapter 9

Cenozoic Pecos Alluvium Aquifer

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Abstract

The Cenozoic Pecos Alluvium aquifer is an unconfined alluvium aquifer located in West Texas. This aquifer is composed of two main basins: the Pecos Trough and Monument Draw Trough. These basins form separate groundwater-flow systems because there is little or no interbasin flow. The Cenozoic Pecos Alluvium aquifer is most important as a source of irrigation water in parts of West Texas. The aquifer is naturally recharged by infiltration of precipitation and interaquifer flow, and natural discharge takes the form of base flow in the Pecos River, as well as evapotranspiration. Groundwater in this aquifer is generally slightly to moderately saline, exceeding drinking-water standards, with dissolved solids generally less than 5,000 mg/L. Groundwater quality is generally better in the Monument Draw Trough than in the Pecos Trough. Explanations for this are related to possibly higher recharge and lower irrigation pumpage rates in the Monument Draw Trough. The Cenozoic Pecos Alluvium aquifer displays effects of pumpage, mainly for irrigation. This pumpage has historically resulted in water-level declines of up to 200 ft, starting in 1940's, and has produced cones of depression in Reeves and Pecos Counties. Since the mid-1970's there has been some recovery owing to declining irrigation. A recent survey indicates that water levels in the Cenozoic Pecos Alluvium aquifer continue to recover in some areas previously impacted by irrigation pumpage. However, there still are areas, especially in Pecos and Ward Counties, where water levels are declining because of irrigation, public supply, and industrial pumpage.

Introduction

The Cenozoic Pecos Alluvium aquifer is located in the upper Pecos River Valley of western Texas (fig. 9-1). This alluvium aquifer underlies parts of Crane, Ector, Loving, Pecos, Reeves, Upton, Ward, and Winkler Counties and extends north into New Mexico. The Cenozoic Pecos Alluvium occurs in a region with an arid climate characterized by average annual precipitation of 10 to 20 inches and high average annual evaporation rates approaching 70 inches (Boghici, 1999). These climatic conditions play an important role in determining the amount of water available for recharge to the aquifer. Climate and crop selection also play a role in determining the water demand for irrigation pumpage. In arid areas and especially during drought periods, irrigation pumpage increases to compensate for the absence of precipitation. This aquifer is of primary importance as a

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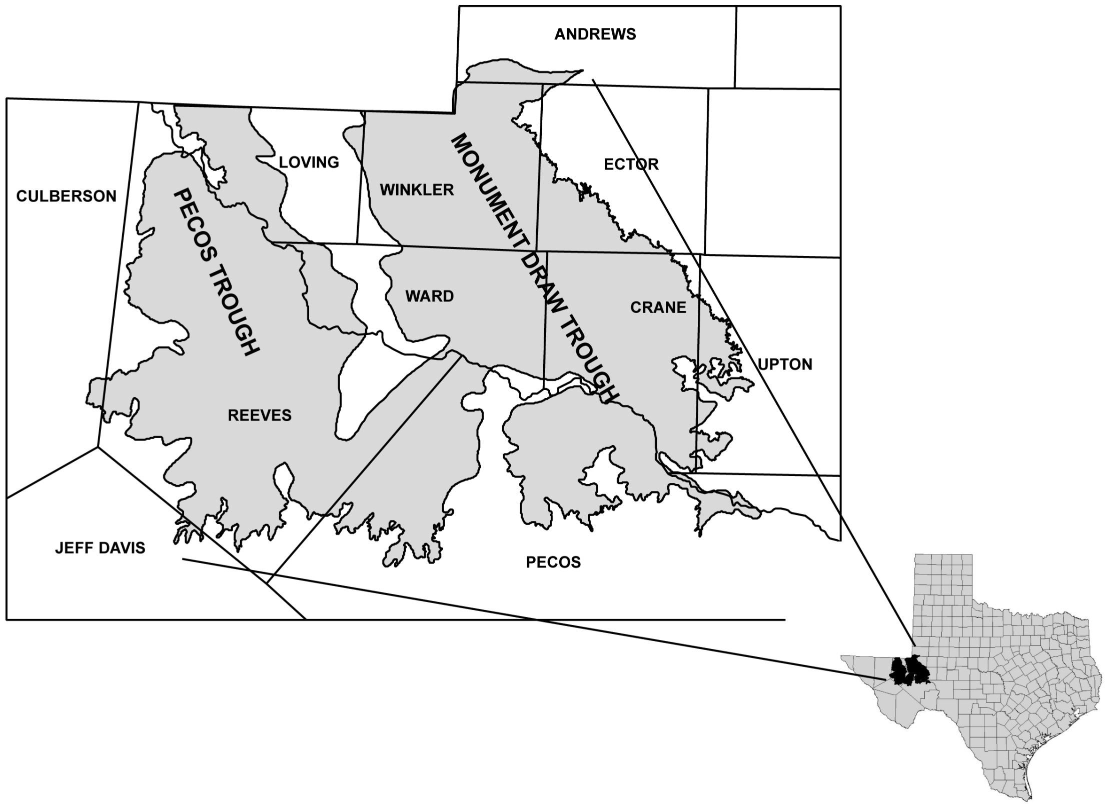
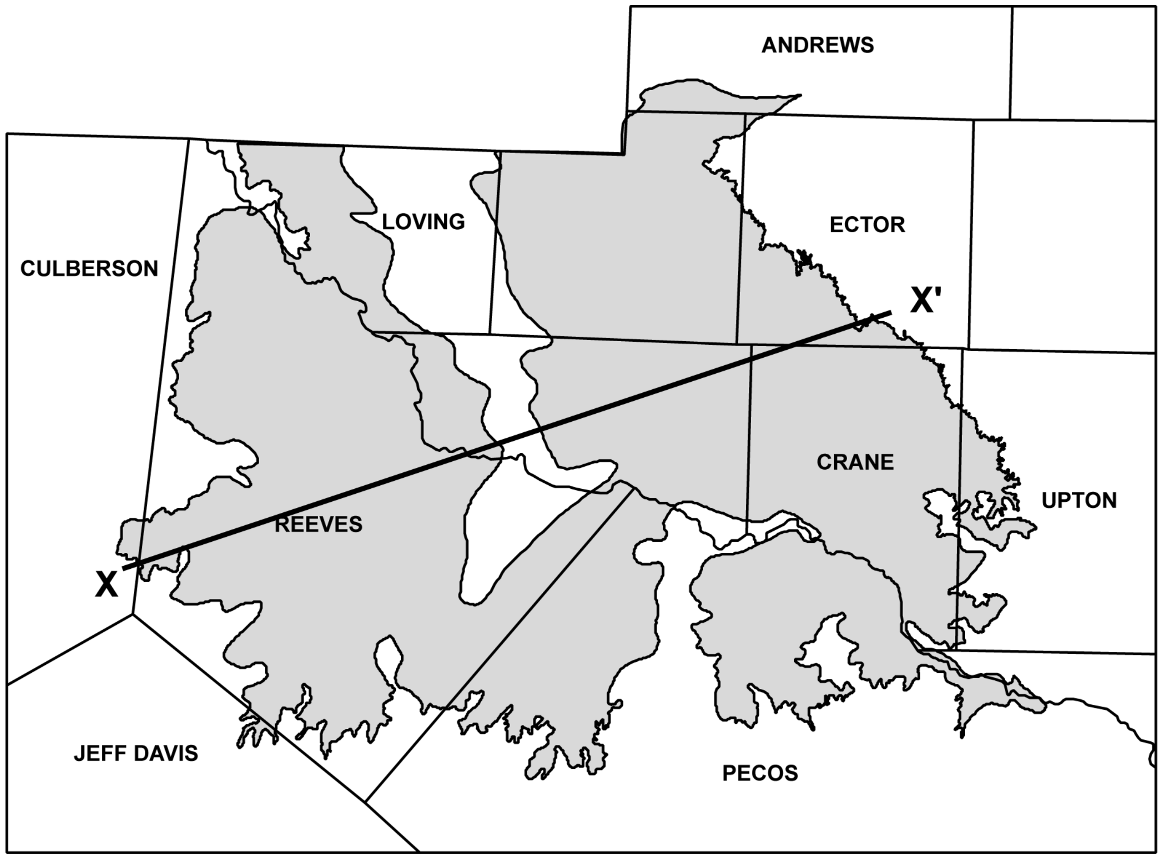


Figure 9-1: The Cenozoic Pecos Alluvium aquifer is located in the upper Pecos River valley of western Texas. This alluvium aquifer underlies parts of Crane, Ector, Loving, Pecos, Reeves, Upton, Ward, and Winkler Counties and extends north into New Mexico.

source of irrigation water, especially in Reeves and northwestern Pecos Counties (Ashworth and Hopkins, 1995; TWDB, 1997). Some groundwater from this aquifer is also exported to the City of Odessa by the Colorado River Municipal Water District (TWDB, 1997).

Geology and Hydrogeology

The Cenozoic Pecos Alluvium aquifer is composed of Tertiary- and Quaternary-age alluvium up to 1,500 ft thick. This alluvium unconformably overlies older Permian, Triassic- and Cretaceous-age rocks (fig. 9-2; White, 1971). The alluvium is mostly composed of unconsolidated or poorly cemented clay, sand, gravel and caliche (White, 1971). North of the Pecos River, the alluvium is overlain in places by windblown sand deposited in dunes. This windblown sand was derived from the Pleistocene Blackwater Draw Formation, an older, extensive eolian deposit that crops out east of the region (White, 1971; Muhs and Holliday, 2001). The sand dunes are composed of fine quartz



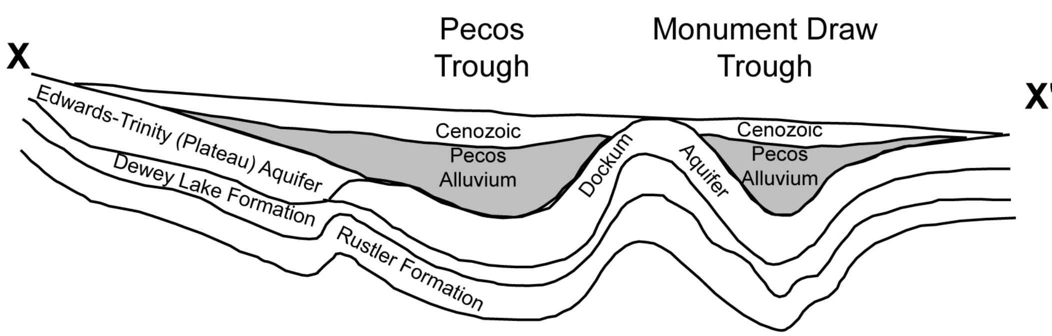


Figure 9-2: The Cenozoic Pecos Alluvium aquifer is composed of Tertiary and Quaternary age alluvium, up to 1,500 feet thick, that unconformably overlies older Permian, Triassic and Cretaceous age rocks. Modified from Ashworth and Hopkins (1995).

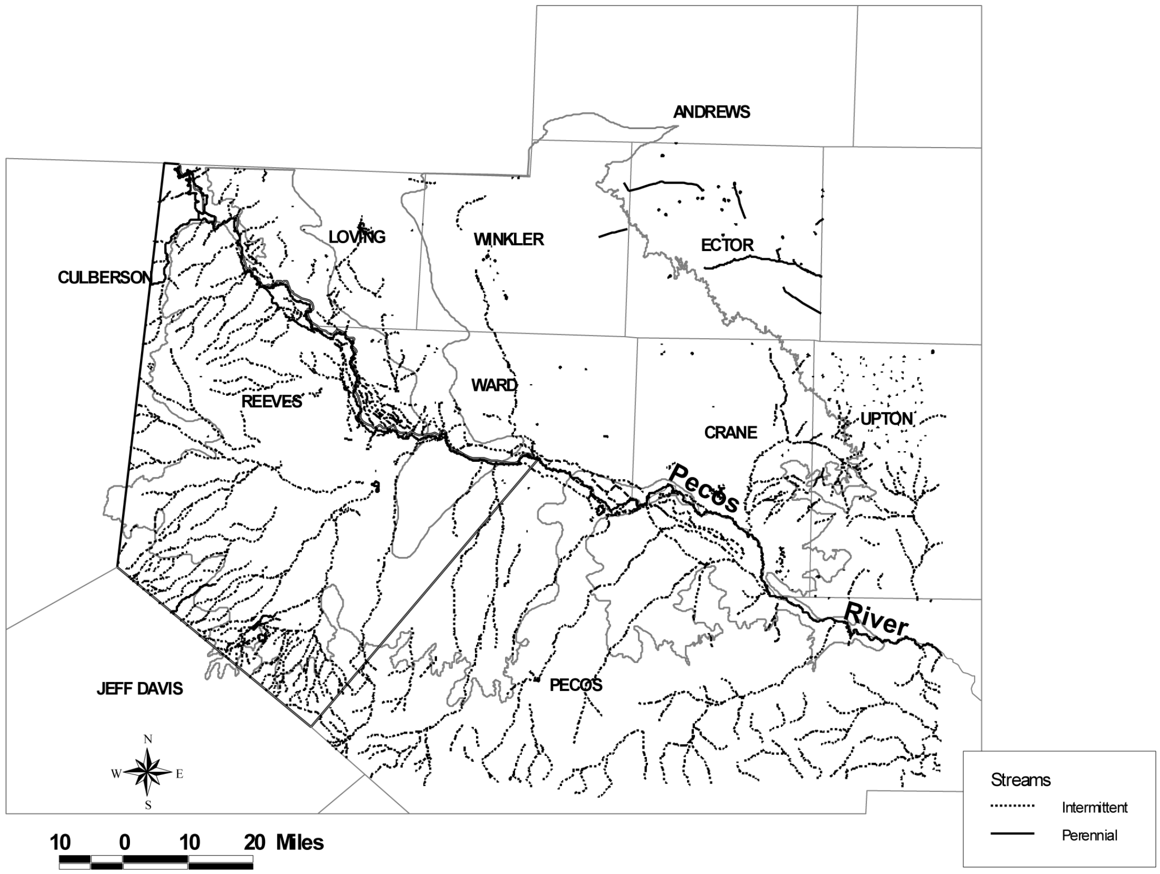


Figure 9-3: Excluding the Pecos River, there are few perennial streams flowing over the Cenozoic Pecos Alluvium aquifer. The high infiltration rates over the eastern part of the aquifer are responsible for the lack of either perennial or intermittent streams over that part of the aquifer.

sand, up to 250 ft thick (Garza and Wesselman, 1959; White, 1971). These dunes are potentially important sites for recharge (White, 1971). This is indicated by the fact that, excluding the Pecos River, there are few perennial streams north of the Pecos River because storm water quickly infiltrates into the dune sand (fig. 9-3; Garza and Wesselman, 1959; Ogilbee and others, 1962).

The Cenozoic Pecos Alluvium aquifer is unconfined, although clay beds may locally produce artesian conditions (Ashworth and Hopkins, 1995). This alluvium aquifer overlies, and in some places is hydrologically connected to, underlying aquifers. These aquifers include (1) the Edwards-Trinity (Plateau) aquifer in Pecos and Reeves Counties; (2) the Dockum Group in Ward and Winkler Counties; and (3) the Tertiary volcanics in Reeves County (Ashworth and Hopkins, 1995). Areas where groundwater is perched on clay beds that occur above the main water table have been identified near the City of

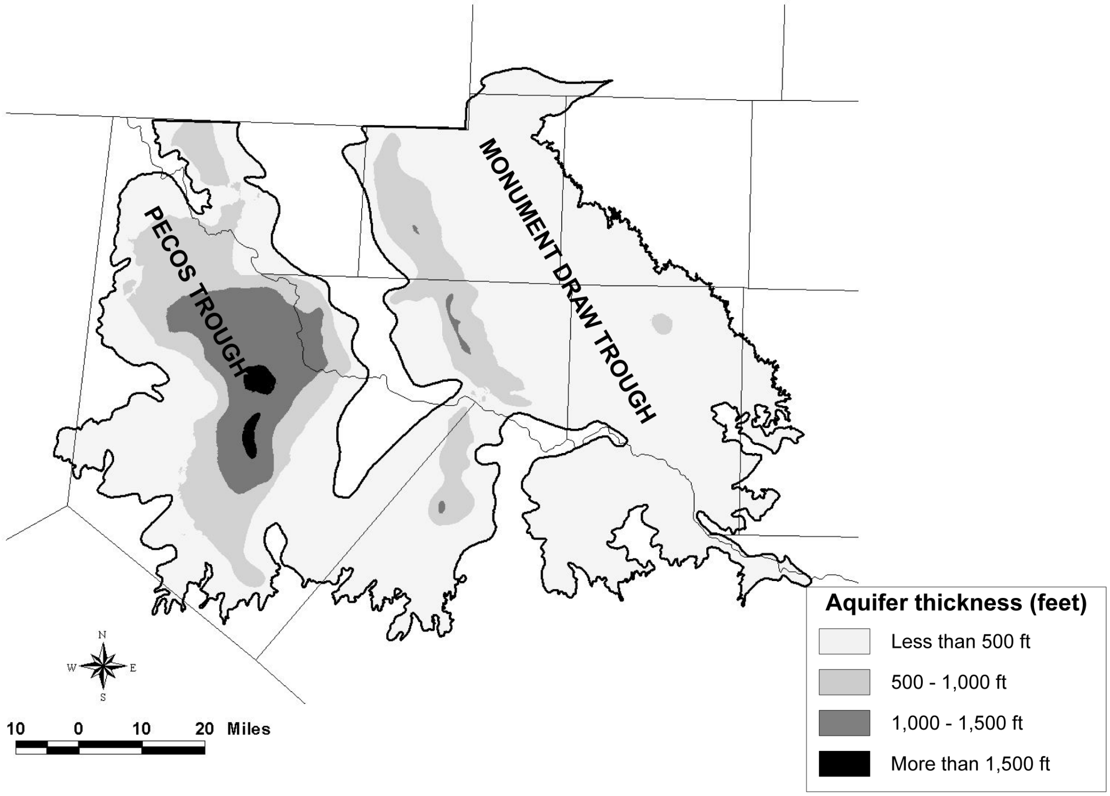


Figure 9-4: The Cenozoic Pecos Alluvium aquifer is composed of two main alluvium-filled troughs. These troughs were formed by subsidence that took place due to dissolution of underlying evaporites.

Pecos (Boghici, 1998; 1999). Well yields in the Cenozoic Pecos Alluvium aquifer are generally moderate to high (Ashworth and Hopkins, 1995). In the Pecos River Valley, depths to groundwater are 10 to 20 ft, increasing to about 50 ft away from the river (Boghici, 1998; 1999). Depths to groundwater are much greater in cones of depression adjacent to wells.

The Cenozoic Pecos Alluvium aquifer consists of two main basins or troughs: the Pecos Trough to west and the Monument Draw Trough in east (fig. 9-4). These are composed of alluvial sediments deposited in two major depressions during the Cenozoic Era (Ashworth, 1990). These troughs formed because of dissolution of underlying evaporites (rock salt, anhydrite, gypsum), especially but not exclusively in the Salado and Castile Formations (table 9-1). This dissolution resulted in the formation of the troughs due to subsidence of overlying rocks of the Rustler Formation, Dockum Group, and younger rocks (Ashworth, 1990).

Table 9-1: Stratigraphic units that comprise the aquifers of Loving, Pecos, Reeves, Ward and Winkler Counties.

<table>
<tr><th>Era</th><th>System</th><th colspan="2">Series/Group</th><th>Stratigraphic Unit</th></tr>
<tr><td>Cenozoic</td><td>Quaternary</td><td colspan="2"></td><td>Cenozoic Pecos Alluvium</td></tr>
<tr><td rowspan="6">Mesozoic</td><td>Tertiary</td><td colspan="2"></td><td>Volcanic Rocks</td></tr>
<tr><td rowspan="4">Cretaceous</td><td colspan="2">Gulf</td><td>undifferentiated</td></tr>
<tr><td rowspan="3">Comanche</td><td>Washita</td><td rowspan="2">undifferentiated</td></tr>
<tr><td>Fredericksburg</td></tr>
<tr><td>Trinity</td><td>undifferentiated</td></tr>
<tr><td>Triassic</td><td colspan="2">Dockum</td><td>undifferentiated</td></tr>
<tr><td rowspan="5">Paleozoic</td><td rowspan="5">Permian</td><td colspan="2" rowspan="4">Ochoan</td><td>Dewey Lake Red Beds</td></tr>
<tr><td>Rustler Formation</td></tr>
<tr><td>Salado Formation</td></tr>
<tr><td>Castile Formation</td></tr>
<tr><td colspan="2">Guadalupian</td><td>Capitan Reef Complex</td></tr>
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Recharge to the Cenozoic Pecos Alluvium aquifer takes the form of infiltration of precipitation, seepage from ephemeral streams, and interaquifer flow, as well as irrigation return-flow (Ashworth, 1990). Most natural recharge is episodic, associated with heavy rainfall (Ashworth, 1990). Recharge is only likely to occur during long-duration rainfall events or periods of frequent smaller rainfall events; otherwise the water is lost to evapotranspiration (Ashworth, 1990). Recharge only occurs after soil moisture is high enough to overcome the effects of surface tension that would otherwise adhere the water to sand grains. High soil moisture allows water to infiltrate through to the water table (Ashworth, 1990). The most favorable sites for natural recharge of precipitation are the dune sands that overlie the Monument Draw Trough (fig. 9-5; Richey and others, 1985). These sand dunes are highly permeable and in some places sparsely vegetated (White, 1971). High permeability and sparse vegetation result in rapid infiltration of precipitation because together they minimize losses to evapotranspiration (White, 1971). It is possible that due to the occurrence of these highly permeable sand dunes, recharge rates may be higher to the Monument Draw Trough than to the Pecos Trough. Recharge due to infiltration from ephemeral streams is also episodic, requiring sufficient precipitation to generate runoff through these streams.

Interaquifer flow primarily enters the Cenozoic Pecos Alluvium aquifer in the south and west, where the aquifer is hydrologically connected to Permian (Rustler Formation), Cretaceous (Edwards-Trinity aquifer), and Tertiary volcanics aquifers (Ashworth, 1990). Seepage from irrigation canals and irrigation return-flow also contributes water to the aquifer. Estimates of losses due to seepage from irrigation canals range from 30 to 72 percent (Ashworth, 1990). These high loss rates can be attributed to the high-permeability sandy soils that overlie parts of the aquifer. Overall, irrigation return-flow is estimated to be 20 percent of applied irrigation water (Ashworth, 1990).

Natural discharge from the Cenozoic Pecos Alluvium aquifer takes the form of evapotranspiration adjacent to the Pecos River and discharge into the Pecos River (White, 1971). Evapotranspiration losses are greatest in lowlands adjacent to the river and other areas where the water table is close to land surface. These losses primarily take the form of uptake by vegetation (e.g., saltcedar and mesquite) that are abundant in these areas (White, 1971). Water uptake by vegetation can be substantial. For example, estimated transpiration rates for saltcedar, juniper, mesquite, cattail, and shrubs are 2 to 20, about 2, 1 to 2, 4 to 10, and 1 to 2 acre-ft/acre/yr, respectively (Gatewood and others, 1950; McDonald and Hughes, 1968; Van Hylckama, 1970; Weeks and others, 1987; Devitt and others, 1997; Ansley and others, 1998; Dugas and others, 1998).

Water Quality

Groundwater quality in the Cenozoic Pecos Alluvium aquifer is variable. Dissolved solids in Cenozoic Pecos Alluvium groundwater range from 300 mg/L to more than 5,000 mg/L (Ashworth and Hopkins, 1995). Groundwater quality is generally better in the Monument Draw Trough portion of the aquifer than in the Pecos Trough (fig. 9-6). Groundwater in the Pecos Trough is generally slightly to moderately saline, while groundwater in Monument Draw Trough varies from fresh to moderately saline. In the Monument Draw Trough, more saline groundwater tends to occur on the western side of the trough adjacent to the Pecos River in parts of Winkler, Ward, and Pecos Counties. The lowest dissolved solids (< 500 mg/L) in the aquifer are generally associated with dune sands. Groundwater quality generally deteriorates with depth, although the most saline groundwater in the Cenozoic Pecos Alluvium aquifer actually occurs in shallow wells (fig. 9-7).

Saline groundwater that occurs in this aquifer is mostly the result of natural processes. However, poor water quality may result from anthropogenic activity in some areas (Ashworth and Hopkins, 1995). Groundwater quality in the Cenozoic Pecos Alluvium is influenced by several factors: (1) the presence of evaporite beds, (2) evaporation, (3) recharge of irrigation return-flow, (4) pumpage, and (5) past oil-field practices. The presence of evaporite beds in the Rustler Formation, especially underlying northern and

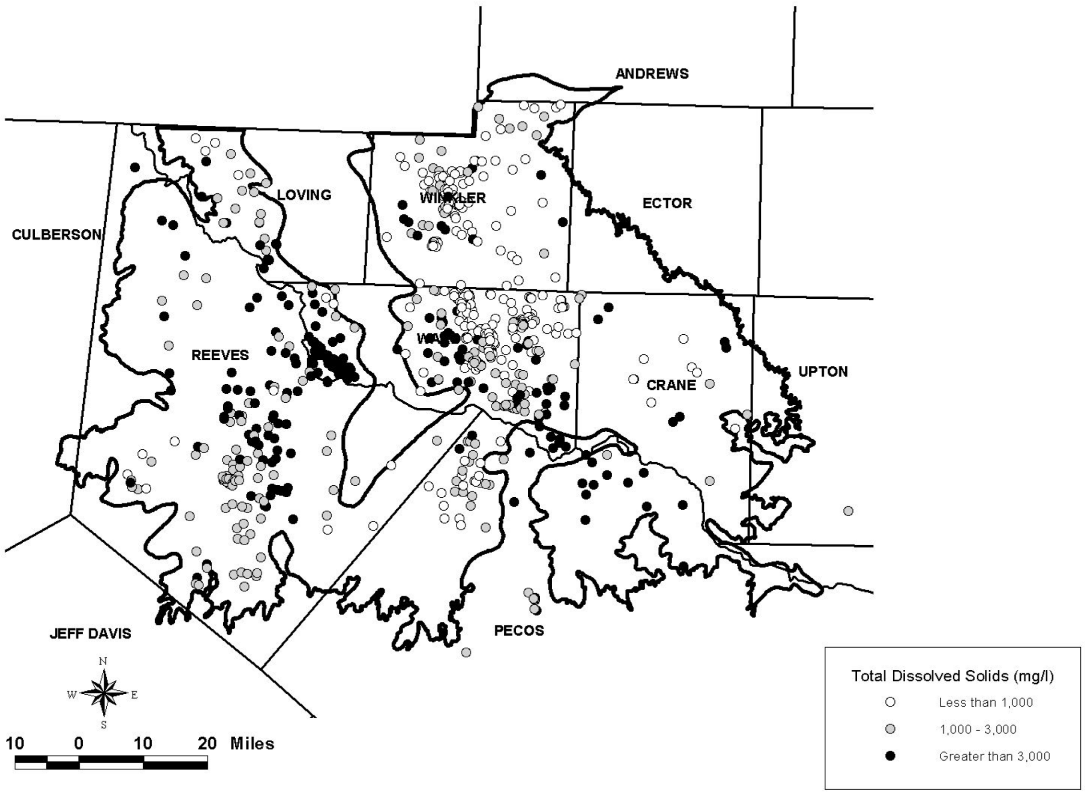

Figure 9-6: Total dissolved solids in Cenozoic Pecos Alluvium aquifer groundwater. Groundwater salinity tends to be greatest west of, and along the Pecos River. The lowest groundwater salinities are associated with the sand dunes that occur in the eastern part of the aquifer.

western parts of Pecos Trough, produces elevated sulfate in the groundwater owing to interaquifer flow (Ashworth, 1990). Shallow saline groundwater occurs in the Pecos

River Valley. This salinity can be attributed partially to evaporation in areas where the water table is shallow. Saline groundwater may also result from activities related to agriculture. Salinity may result from recharge of irrigation return-flow, especially in Reeves County, or encroachment of saline groundwater related to heavy pumpage (Ashworth, 1990). Irrigation return-flow may become saline because of evaporation at land surface or dissolution of salts accumulated in the soil. In some areas, nitrate derived from fertilizers may impact groundwater quality (Ashworth, 1990). In these areas, fertilizer nitrogen is leached from the soil by infiltrating precipitation or irrigation return-flow. Groundwater salinity may increase because heavy pumpage draws in more saline groundwater that occurs at depth. Locally, saline groundwater occurs because of oil-field brine, especially in Winkler and Loving Counties (Ashworth, 1990). Most of this

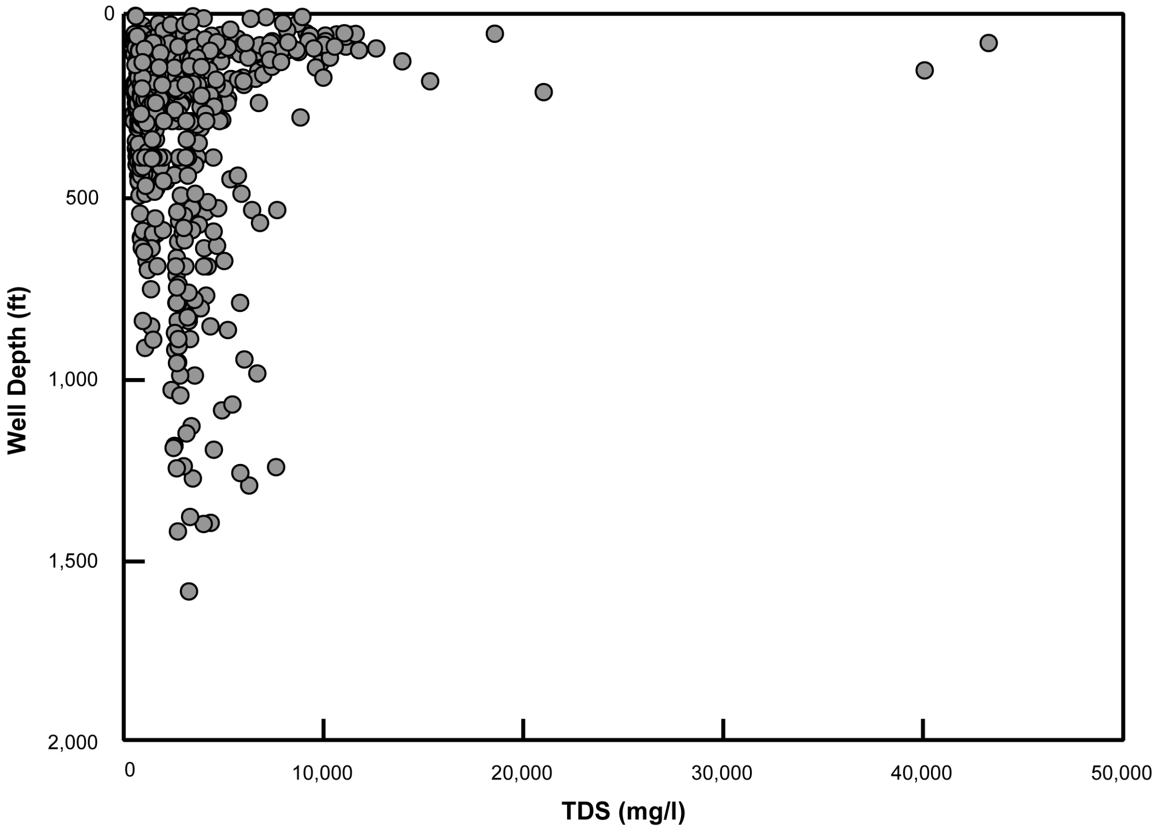

Figure 9-7: Total dissolved solids (TDS) in Cenozoic Pecos Alluvium aquifer groundwater generally increase with depth. In some areas, saline occurs in shallow groundwater due to the effects of evaporation or influxes of saline irrigation return-flow.

contamination is related to past disposal of large quantities of brine in unlined pits or improperly cased oil wells (Ashworth, 1990).

Water levels

Groundwater in the Cenozoic Pecos Alluvium aquifer generally flows toward the Pecos River, except where pumpage forms cones of depression (fig. 9-8; Boghici, 1998; 1999). This situation suggests that there is probably no groundwater flow between the two main troughs. Therefore, it can be concluded that they are separate groundwater flow systems.

This aquifer has experienced historic water-level declines of more than 200 ft in parts of south-central Reeves and northwest Pecos Counties. One of the results of this water-level decline has been reduced base flow to the Pecos River. The water-level variations over time in the aquifer have been associated with varying intensity of irrigation pumpage (Ashworth and Hopkins, 1995). Irrigation farming developed in Reeves and Pecos

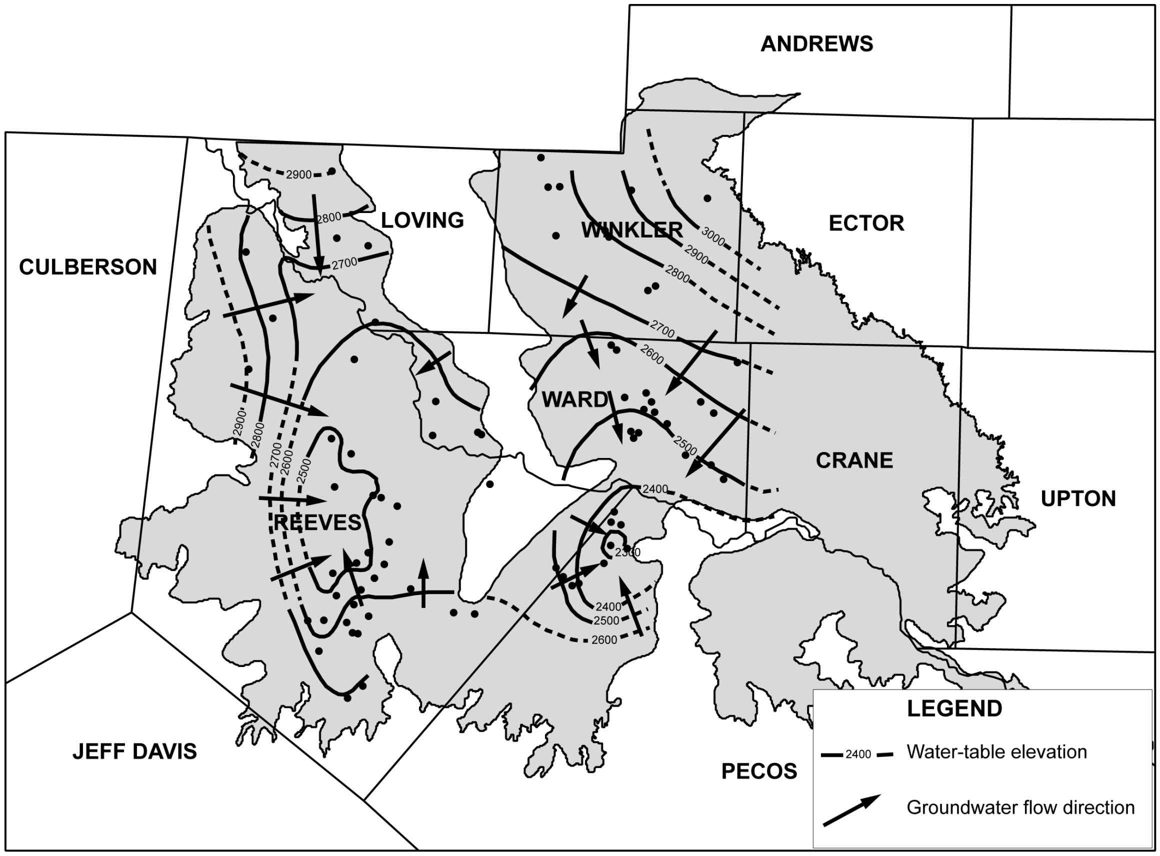

Figure 9-8: Water-level elevations in the Cenozoic Pecos Alluvium aquifer, 1998 (modified from Boghici, 1999).

Counties in the 1940's peaked in the 1950's and began declining in the mid-1970's (TWDB, 1997). In Reeves County, the number of irrigation wells increased tenfold, from 35 to 355, between 1940 and 1950 (Hood and Knowles, 1952).

Water levels in the aquifer have responded to changes in irrigation pumpage rates (fig. 9-9). Water levels dropped sharply in the late 1940's and early 1950's in response to the development of irrigation farming and leveled off in the 1960's. Water levels began to recover in the mid-1970's owing to decreased irrigation pumpage (Ashworth and Hopkins, 1995). In the main irrigated areas, water levels also exhibit seasonal fluctuations related to seasonal irrigation cycles (Ashworth, 1990). Groundwater levels drop during summer months when irrigation demand is greatest and recover slightly during the winter when little or no irrigation is taking place. Water-level declines have been greatest in the major irrigation areas of Reeves and northern Pecos Counties (fig. 9-8 and 10). Two major cones of depression have formed in irrigated areas along State Highway 17 in Reeves County and the Coyanosa irrigation area of Reeves and Pecos Counties (fig. 9-8; Boghici, 1998; 1999). Irrigation pumpage has been less intense in the

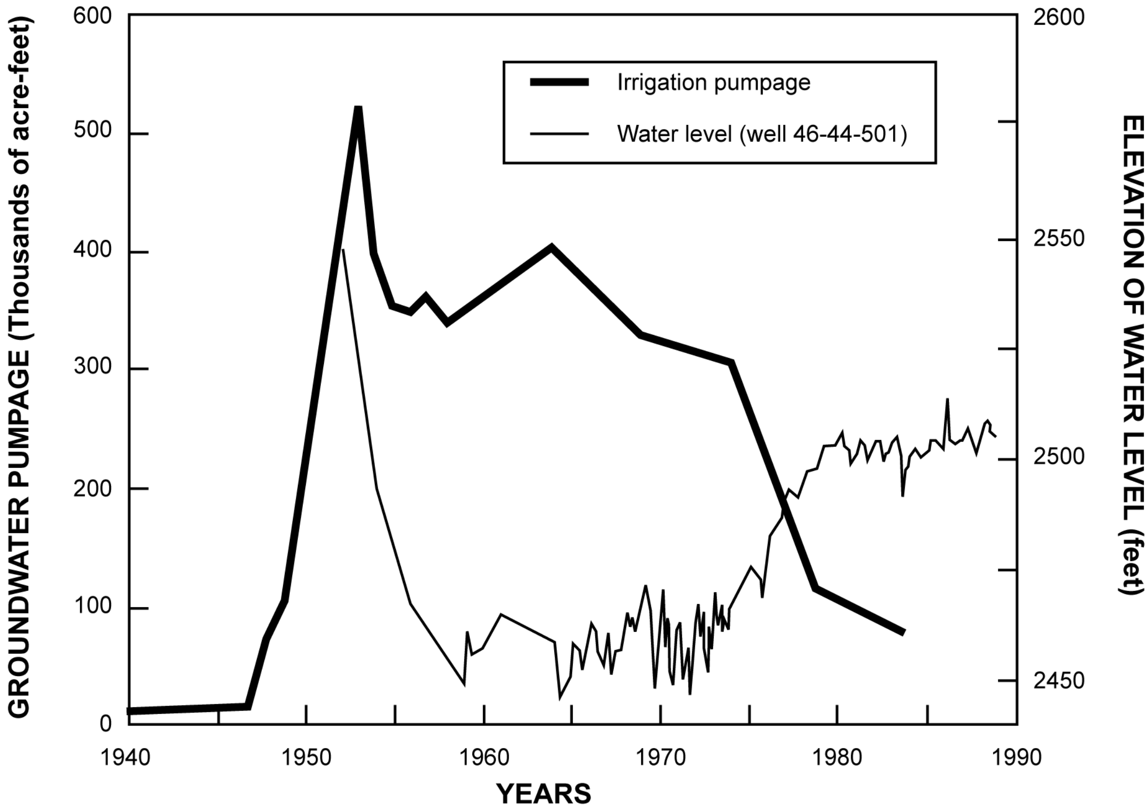

Figure 9-9: Irrigation pumpage from the Cenozoic Pecos Alluvium aquifer in Reeves County and associated groundwater-level responses (modified from Ashworth, 1990).

Monument Draw Trough than the Pecos Trough. Therefore, water-level declines have been less of a problem north of the Pecos River (Ashworth, 1990).

In the 1990's, groundwater levels rose in parts of Reeves County that had previously been heavily impacted by irrigation pumpage. However, water-level declines have been observed in other parts of the aquifer (fig. 9-11; Boghici, 1999). Rising water levels have been observed along State Highway 17, the main irrigation area in Reeves County, while water-level declines have been observed in the Coyanosa area of Reeves and Pecos Counties and in eastern Ward County south of Monahans (Boghici, 1998; 1999). Unlike the water-level declines in Reeves and Pecos Counties that are attributable to continued irrigation, the water-level declines in Ward County are associated with pumpage related to public supply and industrial uses (Boghici, 1998, 1999).

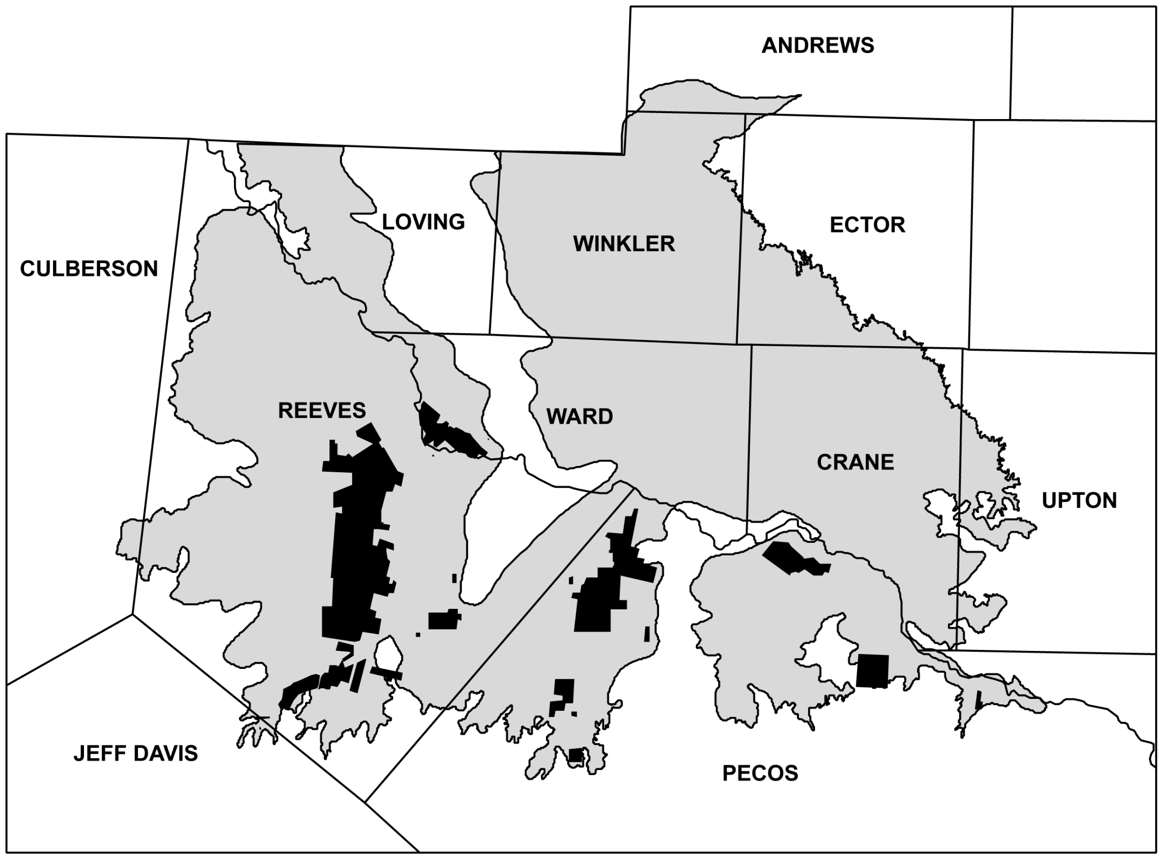

Figure 9-10: Irrigated farmland overlying the Cenozoic Pecos Alluvium aquifer. Based on 1994 survey of irrigation in Texas.

Summary

The Cenozoic Pecos Alluvium aquifer is an unconfined alluvial aquifer. This aquifer is naturally recharged by infiltration of precipitation, seepage from ephemeral streams, and interaquifer flow from underlying aquifers. Discharge from the aquifer primarily takes the form of evapotranspiration where the water table is shallow, base flow to the Pecos River, and by pumpage primarily related to irrigation.

Cenozoic Pecos Alluvium groundwater is characterized by dissolved solids concentrations that are generally less than 5,000 mg/L. Groundwater salinity is generally lower east of the Pecos River than to the west. Groundwater salinity is mainly related to natural or pumpage-related inflows of saline groundwater, evaporation from the aquifer, saline irrigation return-flow, and local oil-field brine contamination. The lowest salinity is associated with sand dunes and may thus be recharge related. Recharge of precipitation, characterized by low dissolved solids, will potentially reduce groundwater dissolved solids by dilution.

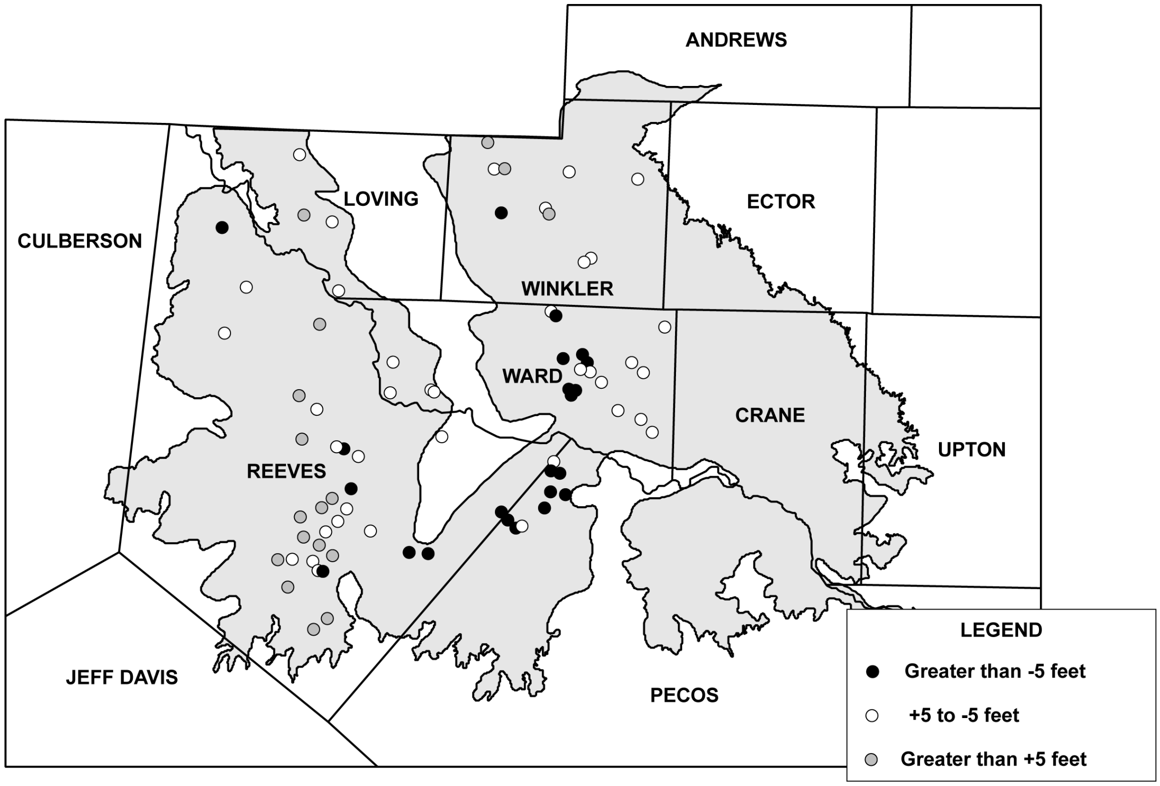

Figure 9-11: Cenozoic Pecos Alluvium aquifer groundwater-level changes between 1989 and 1998 (modified from Boghici, 1999).

The Cenozoic Pecos Alluvium aquifer is divided into two parts: the Pecos Trough and the Monument Draw Trough. These troughs form separate groundwater flow systems. The Monument Draw Trough displays the potential for higher recharge rates than the Pecos Trough because of the presence of permeable dune sands. The better groundwater quality in the Monument Trough can be attributable to many factors, such as higher recharge of precipitation, less irrigation, and less inflow of saline groundwater from underlying rock units.

Starting in the 1940's, irrigation pumpage resulted in water-level declines of up to 200 ft in parts of the Cenozoic Pecos Alluvium aquifer. This water-level decline has primarily taken place in the major agricultural areas of Reeves and Pecos Counties. Decreased irrigation pumpage starting in the mid-1970's has resulted in water-level recovery in some parts of the aquifer. A recent survey indicates rising water levels in some parts of Reeves County that had previously been heavily impacted by irrigation pumpage. However, water levels continue to decline in other areas, especially in Pecos and Ward Counties because continued irrigation pumpage, as well as public supply and industrial pumpage.

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