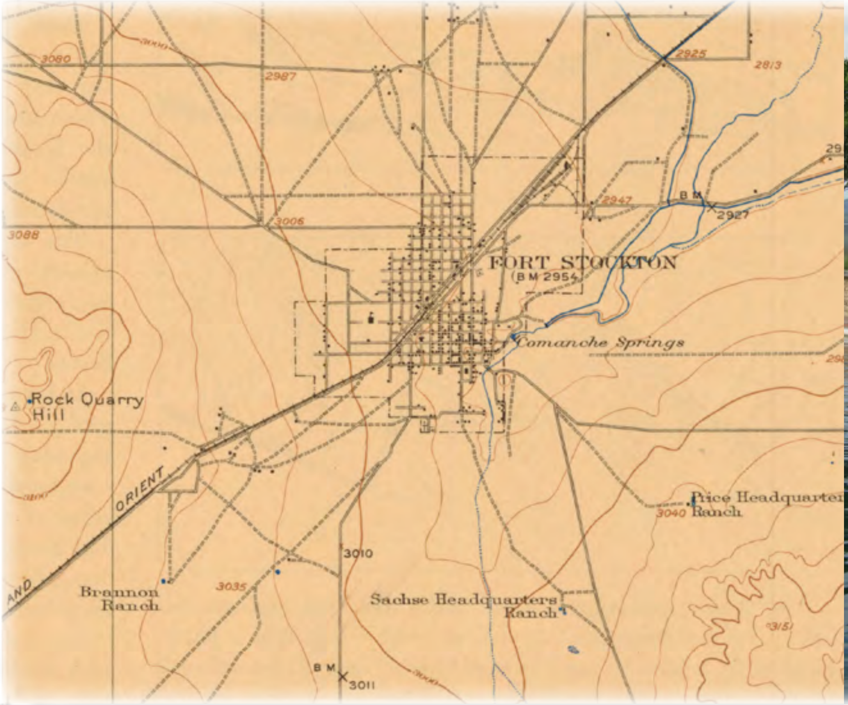
Prepared in cooperation with the Middle Pecos Groundwater Conservation District, Pecos County, City of Fort Stockton, Brewster County, and Pecos County Water Control and Improvement District No. 1

Data Collection and Compilation for a Geodatabase of Groundwater, Surface-Water, Water-Quality, Geophysical, and Geologic Data, Pecos County Region, Texas, 1930–2011



Data Series 678

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U.S. Geological Survey

Cover left. The historical topographic map is a closeup of the City of Fort Stockton, Pecos County, Texas, Fort Stockton quadrangle (U.S. Geological Survey, 1923, scale 1:62,500). The map also shows Comanche Springs, which is one of the sampling sites in this study.

Cover right. Water-quality sampling by U.S. Geological Survey, San Solomon Springs, Balmorhea, Texas (photograph by T. L. Sample, U.S. Geological Survey).

Data Collection and Compilation for a Geodatabase of Groundwater, Surface-Water, Water-Quality, Geophysical, and Geologic Data, Pecos County Region, Texas, 1930–2011

By Daniel K. Pearson, Johnathan R. Bumgarner, Natalie A. Houston,
Gregory P. Stanton, Andrew P. Teeple, and Jonathan V. Thomas

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Data Series 678

U.S. Department of the Interior
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83)

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Data Collection and Compilation for a Geodatabase of Groundwater, Surface-Water, Water-Quality, Geophysical, and Geologic Data, Pecos County Region, Texas, 1930–2011

By Daniel K. Pearson, Johnathan R. Bumgarner, Natalie A. Houston, Gregory P. Stanton,
Andrew P. Teeple, and Jonathan V. Thomas

Abstract

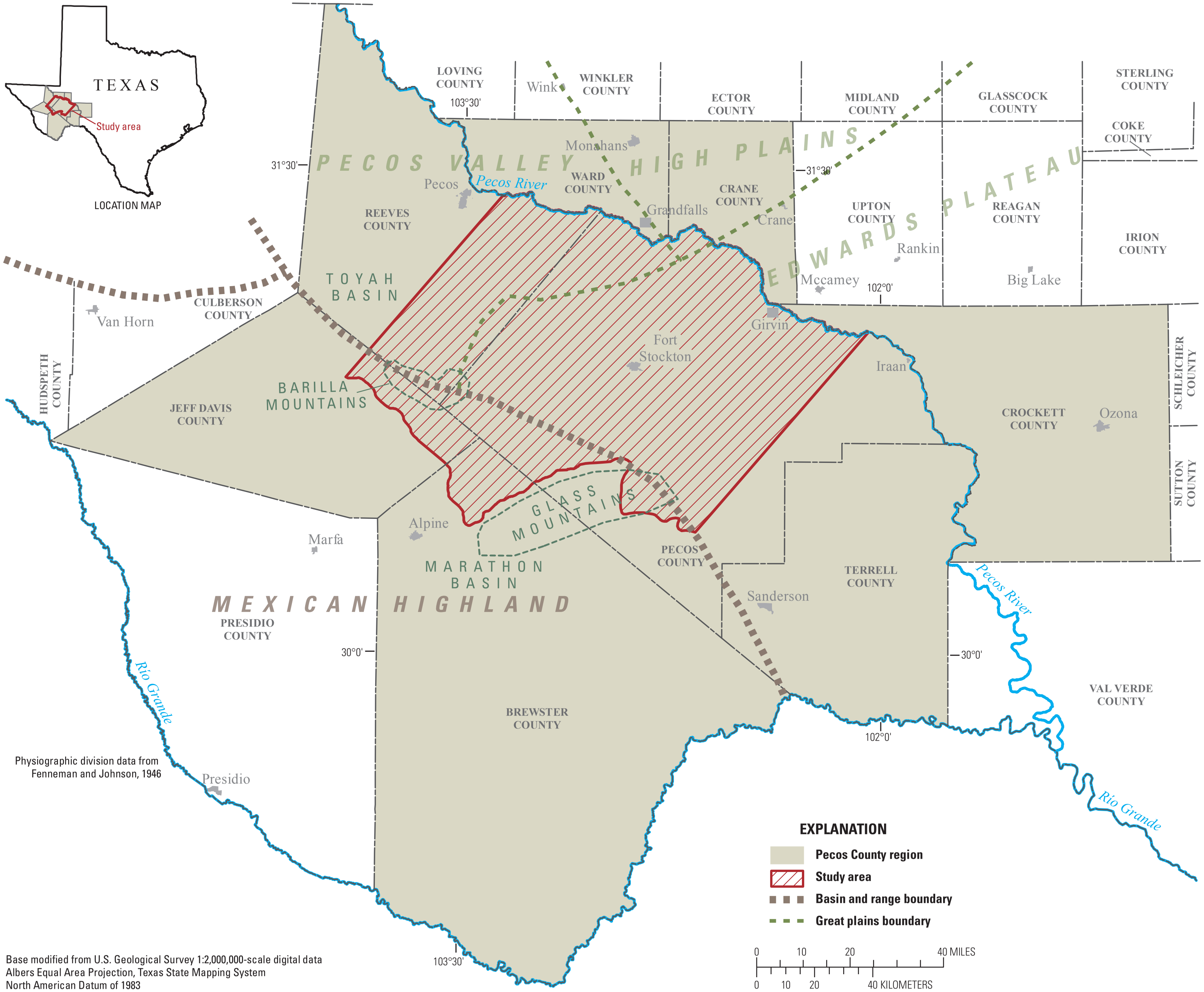
The U.S. Geological Survey, in cooperation with Middle Pecos Groundwater Conservation District, Pecos County, City of Fort Stockton, Brewster County, and Pecos County Water Control and Improvement District No. 1, compiled groundwater, surface-water, water-quality, geophysical, and geologic data for site locations in the Pecos County region, Texas, and developed a geodatabase to facilitate use of this information. Data were compiled for an approximately 4,700 square mile area of the Pecos County region, Texas. The geodatabase contains data from 8,242 sampling locations; it was designed to organize and store field-collected geochemical and geophysical data, as well as digital database resources from the U.S. Geological Survey, Middle Pecos Groundwater Conservation District, Texas Water Development Board, Texas Commission on Environmental Quality, and numerous other State and local databases. The geodatabase combines these disparate database resources into a simple data model. Site locations are geospatially enabled and stored in a geodatabase feature class for cartographic visualization and spatial analysis within a Geographic Information System. The sampling locations are related to hydrogeologic information through the use of geodatabase relationship classes. The geodatabase relationship classes provide the ability to perform complex spatial and data-driven queries to explore data stored in the geodatabase.

Introduction

The U.S. Geological Survey (USGS), in cooperation with the Middle Pecos Groundwater Conservation District (MPGCD), Pecos County, City of Fort Stockton (COFS), Brewster County, and Pecos County Water Control and Improvement District No. 1, developed a geodatabase of available groundwater, surface-water, water-quality, geophysical, and geologic data for site locations in the Pecos County region, Texas (fig. 1). Digital data resources from existing databases and previous publications were identified and assessed for inclusion into the geodatabase based on data quality and completeness. Data were gathered from various Federal, State, and local databases including USGS, MPGCD, COFS, Texas Water Development Board (TWDB), Texas Commission on Environmental Quality (TCEQ), Texas Railroad Commission (TXRRC), U.S Environmental Protection Agency (USEPA), and the University of Texas Land System (UTLD). In addition to downloadable data sources, geochemical and geophysical data collected by the USGS during 2009–11 were included into the geodatabase. The geodatabase contains data from 8,242 sampling locations (sites) in the study area. Data from groundwater, surface-water, and water-quality sampling sites are included. Geophysical data and driller log files were compiled for 626 of the groundwater sites, along with the geologic data associated with those logs.

Purpose and Scope

This report documents data collection, compilation, and geodatabase design for a geodatabase of groundwater, surface-water, water-quality, geophysical, and geologic data collected from more than 8,000 sampling locations in the Pecos County region, Texas. Data were compiled from existing digital databases, previously published reports, and USGS field-collected data. The geodatabase compiled for this report will be used by the cooperating agencies as a data clearinghouse for obtaining groundwater, surface-water, water-quality, geophysical, and geologic data. Following a description of the study area, the methodologies used for field-collected data acquisition and the compilation of existing digital database resources and previously published reports in the geodatabase are described. The geodatabase compilation processes section includes an explanation of the geodatabase design, data input steps, and quality-assurance controls. The geodatabase provides detailed information regarding site locations and associated groundwater, surface-water, water-quality, geophysical, and geologic information.



Physiographic division data from Fenneman and Johnson, 1946

Base modified from U.S. Geological Survey 1:2,000,000-scale digital data
Albers Equal Area Projection, Texas State Mapping System
North American Datum of 1983

Figure 1. Location of study area and Pecos County region, Texas, 2011.

Description of Study Area

The study area (fig. 1) includes the western part of the MPGCD management area (Pecos County) and extends beyond Pecos County to include the extent of the field-collected data gathered for this project. The study area was modified from the TWDB Groundwater Availability Model (GAM) of the Edwards-Trinity and Pecos Valley aquifers extent (Anaya and Jones, 2009). The northeastern boundary of the project study area was set at the Pecos River, while the southeastern and northwestern boundaries were aligned to the data cells of the GAM model and set to the extent of the geodatabase contents. The southwestern boundary was modified using the “active” part of the GAM model as a template for editing the final study area boundary. Geospatial data were compiled for the Pecos County region of West Texas including parts of Pecos, Reeves, Jeff Davis, Brewster, Terrell, Crane, Ward and Crockett Counties.

The study area is located in the Pecos Valley, Edwards Plateau, and High Plains sections of the Great Plains Physiographic Province and the Mexican Highland section of the Basin and Range Province (Fenneman and Johnson, 1946; fig. 1). West of the Pecos River, the Edwards Plateau section of the Great Plains Physiographic Province (Fenneman and Johnson, 1946) is defined by the boundary of the major geographic features in the area: (1) the Pecos River; (2) the Toyah Basin; (3) the Marathon Basin, characterized by ridges and isolated buttes and mesas; (4) the Glass Mountains; and (5) the Barilla Mountains (Small and Ozuna, 1993, fig. 1).

Hydrogeologic Setting

The geologic setting contributed to the formation of two major and four minor aquifers in the study area. The major aquifers include the Pecos Valley and the Edwards-Trinity, and the minor aquifers include the Igneous, the Dockum, the Rustler, and the Capitan Reef Complex (also called the Capitan Reef) aquifers (table 1, fig. 2). The Pecos Valley aquifer is composed of Cenozoic-age alluvium consisting of unconsolidated silt, sand, gravel and clay (Small and Ozuna, 1993). In the northern part of the study area the Pecos Valley aquifer uncomformably overlies the Cretaceous-age Edwards-Trinity aquifers, Triassic-age Dockum aquifer, and Permian-age Rustler aquifer. The Igneous aquifer is a minor aquifer that is composed of Tertiary-age volcanic and volcaniclastic rocks. Located southwest of the study area, the Igneous aquifer uncomformably overlies the Cretaceous-age Edwards-Trinity aquifer. The Edwards-Trinity aquifer is composed of lower Cretaceous-age rocks of limestone, marl, and clay of the Washita Group; limestone of the Fredericksburg Group; and sand, limestone, and shale of the Trinity group (table 1). The Edwards part of the aquifer is composed of rocks of the Washita and Fredericksburg Groups, which locally are referred to as the Edwards and Sixshooter Groups (Brand and DeFord, 1958; Small and Ozuna, 1993; Smith and others, 2000). The Fort Lancaster Formation, the Burt Ranch Member, and the Fort Terrett Formation make up the Edwards Group and occur in the eastern part of the study area (Rose, 1972; Smith and Brown, 1983; Small and Ozuna, 1993). The Boracho Formation, the University Mesa Marl, which is a facies change equivalent of the Boracho Formation, and the Finlay Formation make up the Sixshooter Group and occur in the western part of Pecos County (Brand and DeFord, 1958; Small and Ozuna, 1993; Smith and others, 2000). The Buda Limestone, which overlies the Boracho Formation, is present east of Fort Stockton. Regionally, the Buda Limestone, the Fort Lancaster Formation, and the Burt Ranch Member form the Washita Group. The Fort Terrett Formation forms the Fredericksburg Group. The Trinity group is composed of the Maxon Sand, the Glen Rose Formation, and the Basal Cretaceous Sand (Anaya and Jones, 2009). The individual formations in the Trinity Group are not separated for the purposes of this report. Locally the Trinity Group is known as the Trinity Sands (Small and Ozuna, 1993; Rees and Buckner, 1980).

The Dockum aquifer is a minor aquifer and is composed of Triassic-age rocks of shale, sand, sandstone, and conglomerate of the Dockum Group (Bradley and Kalaswad, 2003). The stratigraphic nomenclature of the Dockum Group has been updated and regionalized in the literature as better information became available (Lehman, 1994a,b; Bradley and Kalaswad, 2003). In Pecos County, a sand unit within the Dockum aquifer is recognizable in some geophysical logs, but the individual formations of the Dockum Group are not separated for the purposes of this report. Locally, the Dockum aquifer is also known as the Santa Rosa aquifer (Small and Ozuna, 1993).

The Rustler and Capitan Reef aquifers are minor aquifers composed of Permian-age rocks. The Rustler aquifer is composed of mostly dolomite, anhydrite, and some limestone of the Rustler Formation. A basal unit consists of sand, conglomerate, and some shale (Small and Ozuna, 1993; LBG-Guyton, 2003). The Capitan Reef aquifer consists of reef, fore-reef, and back-reef facies of dolomite and limestone of the older Capitan Limestone.

Table 1. Hydrostratigraphic section in the Pecos County region, Texas.

[Water-yielding properties: yields (gallons per minutes) - small less than 50, moderate 50 to 500, large is more than 500; Classification of water dissolved-solids concentration (milligrams per liter) - fresh less than 1,000, slightly saline 1,000 to 3,000, moderately saline 3,000 to 10,000]

<table>
<tr><th>Era</th><th>System</th><th colspan="2">Series or group</th><th colspan="5">Stratigraphic unit</th><th colspan="4">Approximate maximum thickness (feet)</th></tr>
<tr><td rowspan="2">Cenozoic</td><td>Quaternary and Tertiary</td><td colspan="2"></td><td colspan="5">Alluvium</td><td colspan="4">1,150</td></tr>
<tr><td>Tertiary</td><td colspan="2"></td><td colspan="5">Volcanic Rocks, Undivided</td><td colspan="4">1,000+</td></tr>
<tr><td rowspan="12">Mesozoic</td><td rowspan="10">Cretaceous</td><td rowspan="2">Gulfian Series</td><td rowspan="2">Terlingua Group</td><td colspan="5" rowspan="2">Boquillas Formation</td><td colspan="4">250</td></tr>
<tr><td colspan="2">Western Pecos County</td><td colspan="2">Eastern Pecos County</td></tr>
<tr><td rowspan="8">Comanchean Series</td><td rowspan="4">Washita Group</td><td colspan="3">Western Pecos County</td><td colspan="2">Eastern Pecos County</td><td colspan="2" rowspan="2">100</td><td colspan="2" rowspan="2">200</td></tr>
<tr><td rowspan="4">Sixshooter Group*</td><td colspan="4">Buda Limestone</td></tr>
<tr><td colspan="2">Boracho Formation*</td><td rowspan="3">Edwards Group**</td><td>Fort Lancaster Formation***</td><td colspan="2" rowspan="2">410</td><td colspan="2" rowspan="2">350</td></tr>
<tr><td colspan="2">University Mesa Marl***</td><td>Burt Ranch Member**</td></tr>
<tr><td>Fredericksburg Group</td><td colspan="2">Finlay Formation*</td><td>Fort Terrett Formation**</td><td colspan="2">165</td><td colspan="2">200</td></tr>
<tr><td rowspan="3">Trinity Group</td><td colspan="2" rowspan="3">Trinity Sands</td><td colspan="3">Maxon Sands****</td><td colspan="4">300****</td></tr>
<tr><td colspan="3">Glen Rose Formation****</td><td colspan="4">200+****</td></tr>
<tr><td colspan="3">“Basal” Sand****</td><td colspan="4">100****</td></tr>
<tr><td rowspan="2">Triassic</td><td colspan="2" rowspan="2">Dockum Group</td><td colspan="5">Middle</td><td colspan="4">600</td></tr>
<tr><td colspan="5">Lower</td><td colspan="4">70</td></tr>
<tr><td rowspan="9">Paleozoic</td><td rowspan="8">Permian</td><td colspan="2" rowspan="5">Ochoan Series</td><td colspan="5">Dewey Lake Red Beds</td><td colspan="4">600</td></tr>
<tr><td colspan="2">Southern Pecos County</td><td colspan="3">Northern Pecos County</td><td colspan="2">Southern Pecos County</td><td colspan="2">Northern Pecos County</td></tr>
<tr><td colspan="2" rowspan="3">Tessey Limestone</td><td colspan="3">Rustler Formation</td><td colspan="2" rowspan="3">1,050</td><td colspan="2">450</td></tr>
<tr><td colspan="3">Salado Formation</td><td colspan="2">2,200</td></tr>
<tr><td colspan="3">Castile Formation</td><td colspan="2">2,300</td></tr>
<tr><td rowspan="2">Guadalupian Series</td><td rowspan="2">Whitehorse Group</td><td colspan="2">Gilliam Limestone</td><td colspan="2">Capitan Limestone</td><td>Guadalupian Formations; undivided</td><td>870</td><td colspan="2">1,650</td><td>1,900</td></tr>
<tr><td colspan="5">Lower Guadalupian Formations; undivided</td><td colspan="4">2,000</td></tr>
<tr><td colspan="2"></td><td colspan="5">Lower Permian Formations; undivided</td><td colspan="4">10,000</td></tr>
<tr><td>Pennsylvanian</td><td colspan="2"></td><td colspan="5">Pennsylvanian Formations; undivided</td><td colspan="4">6,000</td></tr>
</table>

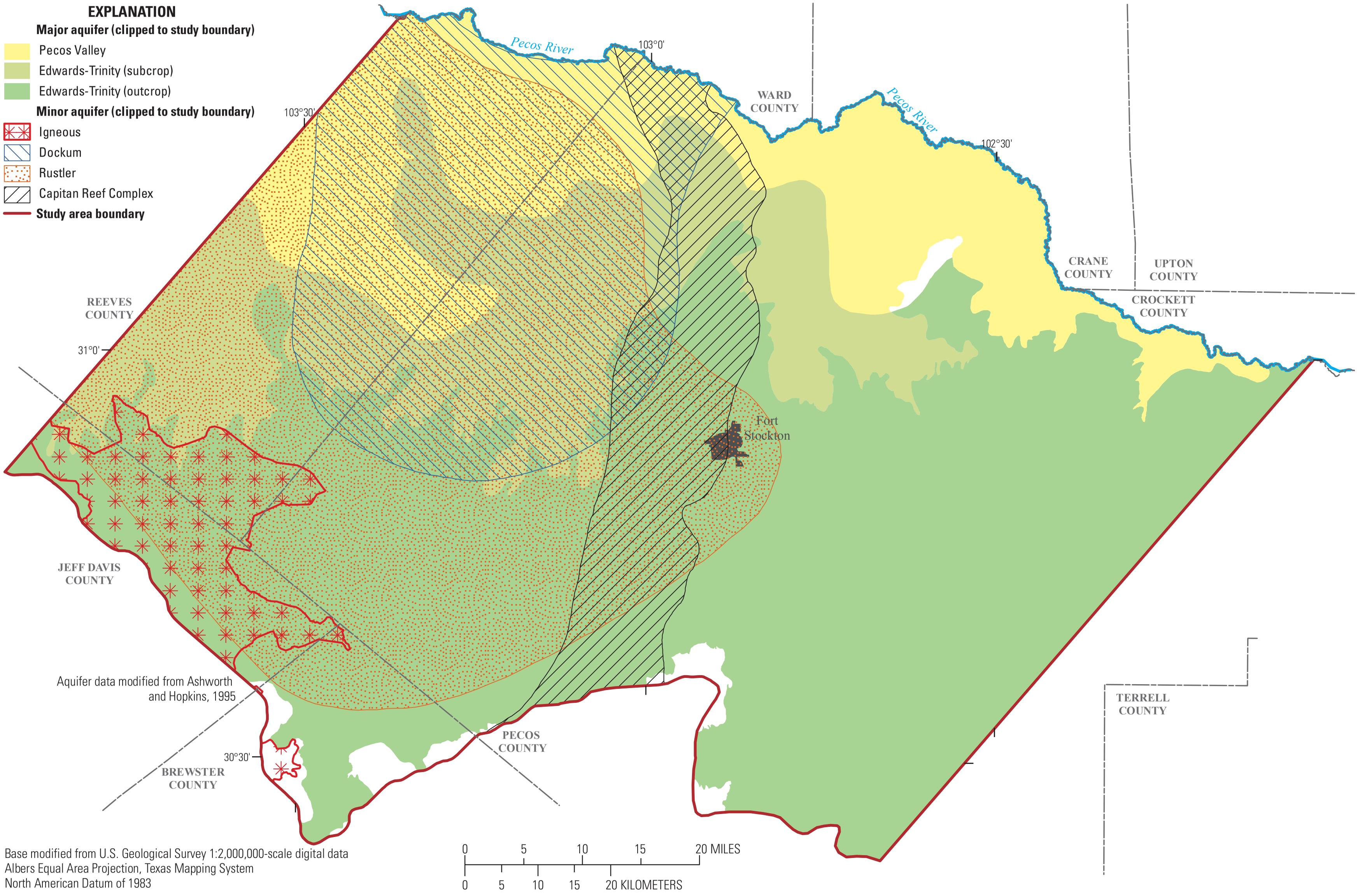
* — Brand and DeFord, 1968

** — Rose, 1972

*** — Smith and Brown, 1983

**** — Rees and Buckner, 1980

<table>
<tr><th colspan="3">Character of rocks</th><th colspan="2">Water yielding properties</th><th>Hydrostratigrphic unit</th></tr>
<tr><td colspan="3">Unconsolidated silt, sand, gravel, clay, boulders, caliche, gypsum, and conglomerate</td><td colspan="2">Yields range from small to large quantities of fresh to moderately saline water</td><td>Pecos Valley</td></tr>
<tr><td colspan="3">Lavas, pyroclastic tuffs, volcanic ash, tuff breccias, fragmental breccias, agglomerates; few thin beds of conglomerates, sandstones, and freshwater limestones</td><td colspan="2">Yields small quantities of freshwater</td><td>Igneous</td></tr>
<tr><td colspan="3">Brown to red flaggy limestone interbedded with shale</td><td colspan="2">Not known to yield water</td><td></td></tr>
<tr><td colspan="3">Soft nodular limestone, marl, and thin-bedded hard granular limesone</td><td colspan="2">Does not yield water in most of the study area; however, may yield small quantities in Reeves County</td><td rowspan="5">Edwards-Trinity</td></tr>
<tr><td colspan="3">Hard massive limestone, thin-bedded limestone, and soft nodular limestone with some clay</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Soft nodular limestone, marl, and hard massive ledge-forming limestone</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Massive ledge-forming limestone and soft nodular limestone</td><td colspan="2">Yields small quantities of fresh to moderately saline water</td></tr>
<tr><td colspan="3">Crossbedded, fine- to coarse-grained, poorly to well-cemented quartz sand with some silt, shale, and limestone</td><td colspan="2">Yields small to moderate quantities of fresh to slightly saline water</td></tr>
<tr><td colspan="3">Reddish-brown to gray coarse-grained sandstone</td><td colspan="2">Yields small to moderate quantities of fresh to slightly saline water</td><td>Dockum</td></tr>
<tr><td colspan="3">Red shale and siltstone</td><td colspan="2">Not known to yield water</td><td rowspan="3"></td></tr>
<tr><td colspan="3">Sand, shale, gypsum, and anhydrite</td><td colspan="2">Not known to yield water</td></tr>
<tr><td colspan="2">Southern Pecos County</td><td>Northern Pecos County</td><td>Southern Pecos County</td><td>Northern Pecos County</td></tr>
<tr><td colspan="2" rowspan="3">Limestone and dolomite</td><td>Red shale, sandstone, anhydrite, dolomite, limestone, conglomerate, and halite</td><td rowspan="3">Not known to yield water</td><td>Yields small to large quantities of slightly to moderately saline water</td><td>Rustler</td></tr>
<tr><td>Mostly halite, with anhydrite and some dolomite</td><td>Not known to yield water</td><td rowspan="2"></td></tr>
<tr><td>Mostly calcareous anhydrite, with halite and associated salts and some limestone</td><td>Not known to yield water</td></tr>
<tr><td>Limestone, dolomite, and sandstone</td><td>Limestone, dolomite, and reef talus</td><td>Dolomite, limestone, anhydrite, shale, and sandstone</td><td>Yields freshwater to a few wells in the Glass Moutains</td><td>Yields moderate to large quantities of moderately saline water</td><td>Capitan Reef</td></tr>
<tr><td colspan="3">Dolomite, dolomitic limestone, limestone, and siliceous shale</td><td colspan="2">Yields small to large quantities of moderately saline water</td><td rowspan="3"></td></tr>
<tr><td colspan="3">Shale, siliceous shale, limestone, dolomitic limestone, sandstone, and basal conglomerate</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Limestone, sand, sandstone, shale chert, and conglomerate</td><td colspan="2">Yields small quantities of water</td></tr>
</table>



Aquifer data modified from Ashworth and Hopkins, 1995

Base modified from U.S. Geological Survey 1:2,000,000-scale digital data
Albers Equal Area Projection, Texas Mapping System
North American Datum of 1983

Figure 2. Extent of the major aquifers (Pecos Valley, Edwards-Trinity [subcrop], and Edwards-Trinity [outcrop]) and minor aquifers (Igneous, Dockum, Rustler, and Capitan Reef Complex), Pecos County region, Texas, 2011.

Methods

The geodatabase contains data gathered in support of this project using two different data collection strategies. First, new (data collected during the study period) geochemical and geophysical data were collected in the field in 2009, 2010, and 2011 by USGS. Second, existing data from Federal, State and local agencies that manage and store groundwater, surface-water, water-quality, geophysical, and geology information were gathered and compiled into the geodatabase. These data were downloaded using internet portal, through direct connect with the native database using secured access, or gathered from published reports or other hardcopy sources.

Water-Quality Methods

Geochemical data were collected in 2010 and 2011 at 44 data-collection sites (fig. 3, table 2). Final results were reviewed for completeness and accuracy and, with the exception of data for one constituent, uploaded to the USGS National Water Information System (NWIS) for warehousing (U.S. Geological Survey, 2011a). Helium–4 (^{4}He) data were the only data collected that are not available from NWIS; these data are presented in table 3.

Water-Quality Sample Collection

Geochemical samples were collected in 2010–11 from 38 wells screened in the Pecos Valley, Edwards-Trinity, Dockum, Rustler, and Capitan Reef aquifers, from 4 springs, and from 2 Pecos River surface-water sites (fig. 3, table 2) (Wilde and others, variously dated). Almost all of the data can be accessed using the USGS NWIS at http://waterdata.usgs.gov (U.S. Geological Survey, 2011a). Those data that were not uploaded to the USGS NWIS web are included herein. Physicochemical properties (water temperature, dissolved oxygen, specific conductance, pH, turbidity, and alkalinity), barometric pressure, and depth to water were measured in the field at the time of sample collection. All samples were analyzed for major ions, nutrients, trace elements, and isotopes (hydrogen [hydrogen–2/hydrogen–1 (^{2}H/^{1}H)], oxygen [oxygen–18/oxygen–16 (^{18}O/^{16}O)], and strontium [strontium–87/strontium–86 (^{87}Sr/^{86}Sr)]). Samples collected from select sites were analyzed for pesticide compounds, tritium (^{3}H), dissolved gases, and ^{4}He.

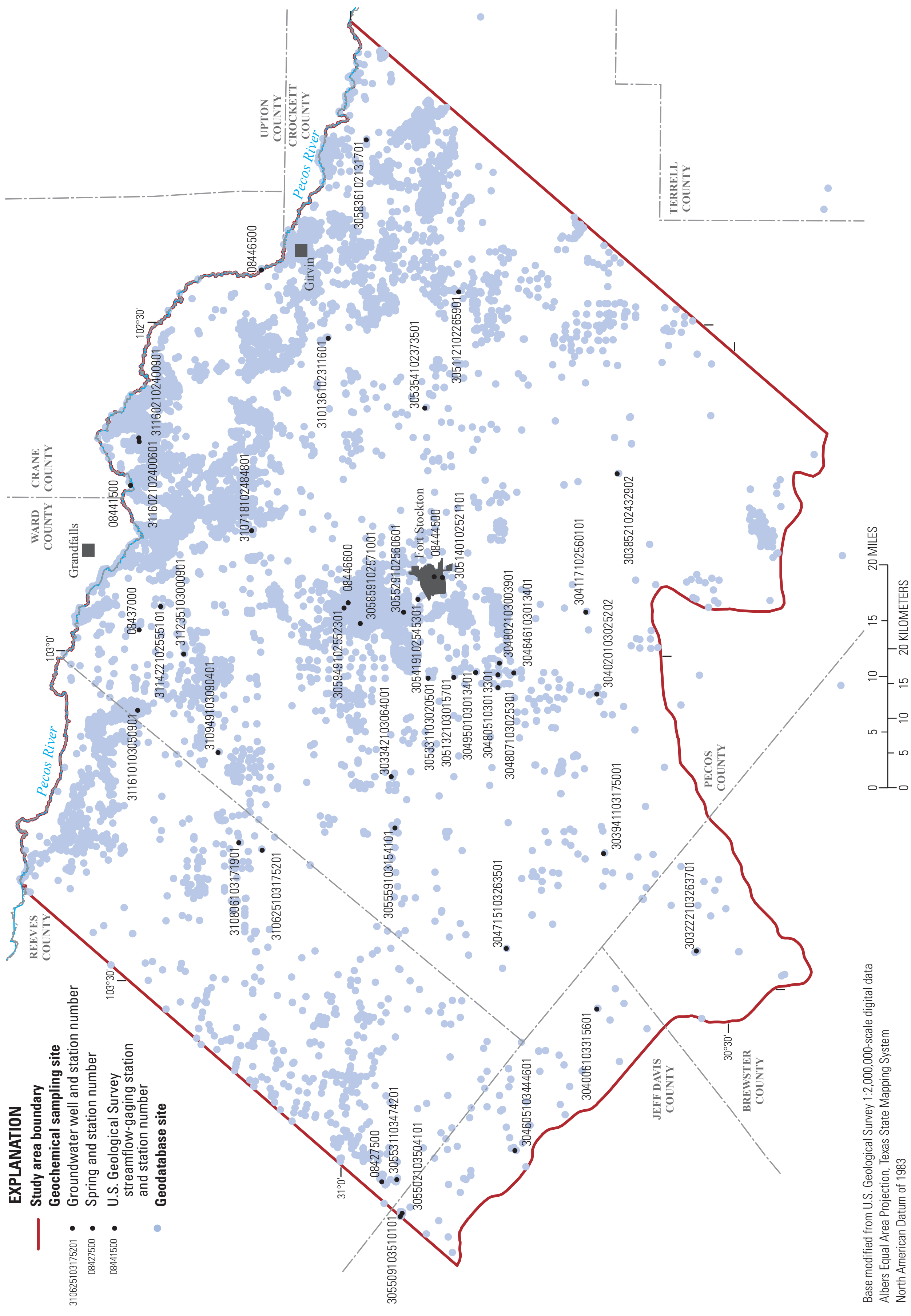
Groundwater Sampling

Groundwater samples were collected using procedures described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated), the USGS Chlorofluorocarbon Laboratory, Reston, Virginia (U.S. Geological Survey, 2011b), and the USGS Stable Isotope Laboratory in Reston, Va. (U.S. Geological Survey, 2011c). Groundwater-quality samples, physicochemical properties, and water-level data were collected once from each site (fig. 3) during 2010–11. Water levels in wells were measured manually at the time of sampling, when possible, by using an electric tape or steel tape.

Observation wells were pumped using an electric, portable, submersible, positive displacement pump (Grundfos Redi–flo2, Redi–flo–3) constructed of stainless steel and Teflon. Water was pumped from domestic and municipal wells using existing pumps, and samples were collected at the wellhead prior to installation of any pressure tanks or filtering or other treatment devices. Prior to any treatment, a connection was made for purging and sampling by using a brass connector with compression fitting to refrigeration-grade copper tubing.

Prior to sample collection, one to three casing volumes were purged from the well, depending on well type, either observation or supply. For wells that are continuously pumped (or pumped regularly every few hours) such as those used for public supply, domestic supply, or industrial purposes, purging less than three casing volumes is permissible (U.S. Geological Survey, variously dated, chapter A4). The purge procedure removes stagnant water in the well, reduces chemical artifacts of well installation or well construction materials, or mitigates effects of infrequent pumping. After purging was complete, the physicochemical properties dissolved oxygen, pH, specific conductance, and water temperature were measured until readings were stable (Wilde, variously dated). Once readings stabilized, water samples were collected through Teflon tubing in new, precleaned bottles. Water samples were collected and processed onsite to minimize changes to the water-sample chemistry or contamination from the atmosphere. To prevent degradation of water samples and maintain the initial concentration of compounds between the time of sample collection and laboratory analyses, samples were preserved with the appropriate acid (when required) or chilled to 4 degrees Celsius (^{o}C) according to the laboratory protocols and shipped overnight to the analyzing laboratories.

At each site after sample completion, sampling equipment was cleaned according to established protocols prior to use at the next site (Wilde, 2004). All samples were stored on ice in coolers following collection and during shipping. Samples were shipped overnight to the analyzing laboratories.



Base modified from U.S. Geological Survey 1:2,000,000-scale digital data
Albers Equal Area Projection, Texas State Mapping System
North American Datum of 1983

Figure 3. Site locations of field-collected geochemical data, Pecos County region, Texas, 2010–11.

Table 2. Geochemical data-collection sites in the Pecos County region, Texas, 2010–11.

[USGS, U.S. Geological Survey; dd, decimal degrees; --, not applicable]

USGS station number	Station name or State well number	Latitude (dd)	Longitude (dd)	Site type	Contributing aquifer
08427500	San Solomon Springs	30.94292	-103.78824	Spring	--
08437000	Santa Rosa Spring	31.26743	-102.95828	Spring	--
08441500	Pecos River below Grandfalls, Tex.	31.28348	-102.74265	Stream	--
08444500	Comanche Springs	30.88628	-102.87495	Spring	--
08446500	Pecos River near Girvin, Tex.	31.11320	-102.41764	Stream	--
08446600	Diamond Y Springs	31.00190	-102.92358	Spring	--
302955103451101	PS-52-34-303	30.49860	-103.75300	Well	Igneous
303222103263701	BK-52-29-8xx (Brewster County ET Well)	30.53950	-103.44346	Well	Edwards-Trinity
303342103064001	US-52-07-502	30.93779	-103.18711	Well	Edwards-Trinity
303852102432902	US-53-19-7xx (PC QW)	30.64799	-102.72470	Well	Rustler
303941103175001	US-52-22-8xx (Farm Well 3)	30.66139	-103.29720	Well	Edwards-Trinity
304006103315601	PS-52-20-601	30.66827	-103.53216	Well	Edwards-Trinity
304020103025202	US-52-24-501	30.67295	-103.05601	Well	Rustler
304117102560101	US-53-17-501	30.68806	-102.93361	Well	Edwards-Trinity
304605103444601	PS-52-11-702	30.77100	-103.74800	Well	Igneous
304646103013401	US-52-16-910	30.77931	-103.02615	Well	Edwards-Trinity
304715103263501	US-52-13-801	30.78740	-103.44343	Well	Edwards-Trinity
304802103003901	US-52-16-611	30.80088	-103.01110	Well	Edwards-Trinity
304805103013301	US-52-16-609	30.80129	-103.02618	Well	Rustler
304807103025301	US-52-16-504	30.80241	-103.04844	Well	Capitan Reef
305112102265901	US-53-13-208	30.85341	-102.44965	Well	Dockum
305132103015701	US-52-16-3xx (S-21)	30.85899	-103.03244	Well	Edwards-Trinity
305140102521101	US-53-09-306	30.87393	-102.88229	Well	Edwards-Trinity
305331103020501	US-52-08-909	30.89210	-103.03516	Well	Edwards-Trinity
305354102373501	US-53-03-9xx	30.89825	-102.62647	Well	Edwards-Trinity
305419102545301	US-53-01-907	30.90560	-102.91610	Well	Edwards-Trinity
305502103504101	PS-52-02-404	30.91737	-103.84518	Well	Pecos Valley
305509103510101	PS-52-02-4xx (Balmerea)	30.91911	-103.85027	Well	Edwards-Trinity
305529102560601	US-53-01-5xx (Apache 3)	30.92470	-102.93490	Well	Rustler
305531103474201	WD-52-02-507	30.92539	-103.79511	Well	Edwards-Trinity
305559103154101	US-52-06-603	30.93305	-103.26194	Well	Dockum
305836102131701	US-53-07-105	30.97667	-102.22139	Well	Edwards-Trinity
305859102571001	US-53-01-210	30.98293	-102.95271	Well	Edwards-Trinity
305949102552301	US-53-01-208	30.99718	-102.92291	Well	Dockum
310136102311601	US-45-60-903	31.02670	-102.52102	Well	Edwards-Trinity
310625103175201	WD-46-62-201	31.10685	-103.29777	Well	Pecos Valley
310718102484801	US-45-58-2xx	31.12162	-102.81354	Well	Edwards-Trinity
310806103171901	WD-46-54-901	31.13502	-103.28796	Well	Rustler
310949103090401	US-46-55-9xx (Weatherby Ranch)	31.16341	-103.15103	Well	Dockum
311235103000901	US-46-56-309	31.20974	-103.00262	Well	Edwards-Trinity
311422102555101	US-45-49-203	31.23974	-102.93097	Well	Capitan Reef
311602102400601	US-45-43-807	31.26942	-102.67609	Well	Pecos Valley
311602102400901	US-45-43-8xx (PA 1)	31.26934	-102.68214	Well	Pecos Valley
311610103050901	US-46-48-701	31.26959	-103.08683	Well	Dockum

Table 3. Helium-4 measured in groundwater samples collected in the Pecos County region, Texas, 2010–11.

[USGS, U.S. Geological Survey; cc/g, cubic centimeter per gram; H_2O, water; STP, standard temperature and pressure]

USGS station number	Date	Sample start time	Helium-4 (cc/g of H_2O at STP x 10^{-9})
305509103510101	9/1/2010	16:00	81
311602102400901	8/17/2010	21:00	164
302955103451101	9/2/2010	11:00	55
304715103263501	8/28/2010	14:00	230
305140102521101	8/10/2010	17:00	261
305502103504101	8/15/2010	19:00	53
304006103315601	6/23/2011	11:00	3,877
305531103474201	6/22/2011	11:00	573
304605103444601	6/22/2011	14:00	68

Surface-Water Sampling

Streamflow velocities at the Pecos River surface-water sites were below 1.5 feet per second (ft/s) and, therefore, samples were collected using the multi-vertical grab sampling method (U.S. Geological Survey, variously dated). A sample was collected at each site using a 1-liter Teflon bottle with a 5/16- inch (in.) nozzle. The grab sample was then composited in a Teflon churn and dispensed into appropriate containers.

At each site after sample completion, sampling equipment was cleaned according to established protocols prior to use at the next site (Wilde, 2004). All samples were stored on ice in coolers following collection and during shipping. Samples were shipped overnight to the analyzing laboratories.

Spring Sampling

Spring water was sampled as close to a spring orifice as possible. Otherwise, spring water was sampled from the bottom of the pool or nearest to the primary discharge location based on anecdotal evidence. Spring-water samples were collected using a peristaltic pump and flexible Teflon diaphragm head by immersing Teflon tubing below the water surface into or near the spring orifice, avoiding contact with the atmosphere and standing surface water. San Solomon Springs (8427500) was sampled from the main discharge point. Comanche Springs (08444500) was sampled at the Government Spring discharge point, which is the primary discharge orifice of the springs. A spring orifice could not be located at the Diamond Y Springs (08446600) or Santa Rosa Spring (08437000) sites, so the samples were taken from the spring pools.

At each site after sample completion, sampling equipment was cleaned according to established protocols prior to use at the next site (Wilde, 2004). All samples were stored on ice in coolers following collection and during shipping. Samples were shipped overnight to the analyzing laboratories.

Analytical Methods

Samples collected and analyzed for major ions, nutrients, trace elements, and pesticide compounds were analyzed by the USGS National Water Quality Laboratory (NWQL), Denver, Colorado, using published methods. Methods for major ions are published in Fishman and Friedman (1989), Fishman (1993), and American Public Health Association (1998). Nutrients methods are published in Patton and Kryskalla (2003) and Fishman (1993). Trace element methods are published in Fishman and Friedman (1989), Garbarino and others (2006), and Garbarino (1999). Pesticide compound methods are published in Zaugg and others (1995), Lindley and others (1996), Madsen and others, (2003), and Sandstrom and others (2001). Samples for analysis of oxygen and hydrogen isotopes were analyzed at the USGS Stable Isotope Laboratory in Reston, Va. $^{18}O/^{16}O$ analytical methods are described in Révész and Coplen (2008a) and $^{2}H/^{1}H$ methods are described in Révész and Coplen (2008b). Samples for analysis of strontium isotopes were analyzed at the Menlo Park Isotope Laboratory in Menlo Park, California. Samples for the analysis of tritium were shipped to the Menlo Park Tritium Laboratory in Menlo Park, Calif. Analytical methods for ^{3}H are documented in Ostlund and Warner (1962) and Thatcher and others (1977). Samples for the analysis of dissolved gases and 4–helium were shipped to the USGS Dissolved Gas Laboratory in Reston, Va., and analyzed by methods described in Busenberg and others (1993) and Busenberg and others (2001). Samples for the analysis of 3–helium were analyzed by the Noble Gas Laboratory of

Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, using methods described in Schlosser and others (1988).

The USGS uses two reporting conventions for the analytical data from the National Water Quality Laboratory, the laboratory reporting level (LRL) and the long-term method detection level (LT-MDL). The LRL is two times the LT-MDL, and concentrations measured between the LRL and LT-MDL are reported as estimated concentrations (Childress and others, 1999).

Geochemical Quality Assurance

Quality-control data were collected to assess the precision and accuracy of sample-collection procedures and laboratory analyses (U.S. Geological Survey, variously dated). Quality-control samples consisted of two equipment blank samples, four field blank samples, four sequential replicate samples, and environmental matrix-spike samples.

Equipment blanks were collected annually in a controlled environment to determine if the cleaning procedures for sample containers and the equipment for sample collection and sample processing were sufficient to produce contaminant-free samples. Field blank samples were collected and processed at a sampling site prior to environmental samples to ensure equipment cleaning conducted in the field between sites was adequate, and that the collection, processing, or transporting procedures in the field did not contaminate the samples.

Equipment blank results indicate the sampling equipment did not introduce appreciable amounts of the constituents of interest to the samples and, with a few exceptions, equipment blank results were less than the reporting limits (table 4). Field blank results indicate the sample collection and handling procedures did not introduce appreciable contamination of the constituents of interest to the environmental samples, with a few exceptions, and provided another indication that representative samples were collected. Analytes detected in the field blanks included ammonia, barium, calcium, chloride, cobalt, copper, fluoride, lead, magnesium, manganese, molybdenum, nickel, sodium, strontium, sulfate, thallium, total nitrogen, and zinc (table 4). Because most of the concentrations measured in the field blanks were low, with a few exceptions, the environmental results do not show a bias except for some of the metal concentrations measured in the field blank samples collected on August 28, 2010, and the lead concentrations in some of the blank samples. The detected copper concentration of 1.5 µg/L was greater than the measured copper concentrations in 23 of the environmental samples. The detected filtered lead concentrations of 0.24 µg/L and 0.23 µg/L were greater than the measured lead concentrations in 21 of the environmental samples. The detected molybdenum concentration of 0.77 µg/L was greater than the measured molybdenum concentrations in five of the environmental samples. The detected nickel concentration of 0.48 µg/L was greater than the measured nickel concentrations in 19 of the environmental samples. The detected zinc concentration of 3.8 µg/L was greater than the measured zinc concentrations in 11 of the environmental samples. All of these detections of concern were measured in the field blank collected on August 28, 2010, except the lead concentration of 0.24 µg/L, which was measured in the field blank collected on August 12, 2010, and the filtered ammonia concentration of 0.011, which was measured in the field blank collected on June 22, 2011.

The cause of the low-level contamination of several metals in the field blank collected on August 28, 2010, and the detected concentrations of lead in three of the field blanks collected on August 12, 18, and 28, 2010, is currently (February 2012) unknown. The corresponding metals data from samples associated with these blanks were censored in the database.

Sequential replicate samples were collected to measure the variation in results originating from sampling and analytical methods. Sequential replicate sample results are included in table 5. Inorganic constituent replicates were collected with a new, preconditioned capsule filter. Capsule filters were replaced prior to collecting the sequential replicate in case of filter loading, which might reduce the effective pore size of the filter (Horowitz and others, 1996).

Replicate samples were compared with associated environmental samples to assess the variability of the measured concentrations by computing the relative percent difference (RPD) for each constituent with equation 1:

$$RPD = |C1 - C2|/((C1 + C2)/2) \times 100, \qquad (1)$$

where

C1 is constituent concentration, in milligrams per liter, from the environmental sample; and

C2 is constituent concentration, in milligrams per liter, from the replicate sample.

RPDs of 10 percent or less indicate good agreement between the paired results if the concentrations are sufficiently large compared to their associated LRL (Oden and others, 2011). An RPD was not computed for a replicated constituent if the paired results were censored as estimated or less than their associated LRL.

There was generally good agreement between the environmental and replicate samples with a few exceptions. Several of the replicate metal concentrations measured on January 25, 2011, and June 23, 2011, were greater than 10 percent different (table 5). All but one of these samples with greater than 10 percent differences were detected at or near the detection limit so that small variability in the analysis caused large RPDs. The one exception was the detected lead concentration in the June 23, 2011, sample and, because of issues with lead concentrations in the blanks, these were already censored. The causes of the greater than 10 percent differences between some of the environmental and replicate samples are unknown.

Table 4. Results of major ion, trace element, and nutrient analyses from equipment blanks and field blanks collected in association with geochemical samples collected in the Pecos County region, Texas, 2010–11.

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; E, estimated; M, presence verified but not quantified; U, analyzed for but not detected at a concentration equal to or greater than the long-term method detection level]

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Calcium, water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Bromide, water, filtered (mg/L)	Chloride, water, filtered (mg/L)	Fluoride, water, filtered (mg/L)	Hydrogen sulfide, water, unfiltered (mg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	<0.04	<0.016	<0.06	<0.10	<0.02	<0.12	<0.08	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<.04	<.016	<.06	<.10	<.02	<.12	<.08	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.04	<.016	<.06	<.10	<.02	<.12	<.08	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	.11	.026	<.06	E.10	<.02	.14	E.05	U
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	.03	<.008	<.02	<.06	<.01	<.06	<.04	--

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Silica, water, filtered as SiO_2 (mg/L)	Sulfate, water, filtered (mg/L)	Ammonia plus organic nitrogen, water, filtered as nitrogen (mg/L)	Ammonia plus organic nitrogen, water, unfiltered as nitrogen (mg/L)	Ammonia, water, filtered as NH_4 (mg/L)	Ammonia, water, filtered as nitrogen (mg/L)	Ammonia, water, unfiltered as NH_4 (mg/L)	Ammonia, water, unfiltered as nitrogen (mg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	<0.06	<0.18	<0.10	--	--	--	<0.052	<0.04
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	E0.07	--	--	<.052	<.04
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<.06	<.18	--	--	<0.026	<0.020	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.06	<.18	--	--	<.026	<.020	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.06	E.12	--	--	<.026	<.020	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.03	<.09	--	--	.014	.011	--	--

UUSGS station number	Station name or State well number	Date	Sample start time	Sample type	Nitrate plus nitrite, water, filtered as nitrogen (mg/L)	Nitrate, water, filtered (mg/L)	Nitrate, water, filtered as nitrogen (mg/L)	Nitrite, water, filtered (mg/L)	Nitrite, water, filtered (mg/L) as nitrogen	Organic nitrogen, water, filtered (mg/L)	Organic nitrogen, water, unfiltered (mg/L)	Orthophosphate, water, filtered (mg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	<0.04	--	--	--	--	--	--	<0.025
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	<.04	<0.177	<0.040	<0.007	<0.002	--	<0.07	.080
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<.04	<.177	<.040	<.007	<.002	<0.10	--	<.025
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.04	<.177	<.040	<.007	<.002	<.10	--	<.025
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.04	<.177	<.040	<.007	<.002	<.10	--	<.025
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.02	<.089	<.020	<.003	<.001	<.04	--	<.012

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Orthophos-phate, water, filtered as phosphorus (mg/L)	Phosphorus, water, filtered as phosphorus (mg/L)	Phosphorus, water, unfiltered as phosphorus (mg/L)	Total nitrogen (nitrate + nitrite + ammonia + organic-N), water, filtered, analytically determined (mg/L)	Total nitrogen, water, filtered (mg/L)	Total nitrogen, water, unfiltered (mg/L)	Aluminum, water, filtered (µg/L)	Barium, water, filtered (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	<0.008	<0.006	--	--	<0.14	--	<3.4	<0.14
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	.026	E.03	E0.03	--	--	<0.11	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<.008	--	--	<0.10	--	--	<3.4	<.14
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.008	--	--	<.10	--	--	<3.4	<.14
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.008	--	--	E.10	--	--	<3.4	M
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.004	--	--	<.05	--	--	339	<.07

Table 4. Results of major ion, trace element, and nutrient analyses from equipment blanks and field blanks collected in association with geochemical samples collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; E, estimated; M, presence verified but not quantified; U, analyzed for but not detected at a concentration equal to or greater than the long-term method detection level]

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Beryllium, water, filtered (µg/L)	Cadmium, water, filtered (µg/L)	Chromium, water, filtered (µg/L)	Cobalt, water, filtered (µg/L)	Copper, water, filtered (µg/L)	Copper, water, unfiltered, recoverable (µg/L)	Iron, water, filtered (µg/L)	Lead, water, filtered (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	<0.02	<0.12	--	<1.0	--	<6	<0.03
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	<1.4	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<0.01	<.02	<.12	<0.01	<1.0	--	<6	.24
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.01	<.02	<.12	<.01	E.92	--	<6	.10
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.01	<.02	<.12	.02	1.5	--	<6	.23
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.01	<.02	<.06	.35	<.50	--	<3	.05

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Lead, water, unfiltered, recoverable (µg/L)	Lithium, water, filtered (µg/L)	Manganese, water, filtered (µg/L)	Molybdenum, water, filtered (µg/L)	Nickel, water, filtered (µg/L)	Silver, water, filtered (µg/L)	Strontium, water, filtered (µg/L)	Thallium, water, filtered (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	<0.3	--	<0.12	<0.01	<0.40	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	<0.06	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	<0.4	<.3	<0.03	<.12	<.01	<.40	E0.02
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	<.4	<.3	.05	E.08	<.01	<.40	<.02
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	<.4	E.2	.77	.48	<.01	.53	<.02
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	--	<.2	.7	<.01	<.09	<.01	<.20	<.01

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Vanadium, water, filtered (µg/L)	Zinc, water, filtered (µg/L)	Zinc, water, unfiltered, recoverable (µg/L)	Antimony, water, filtered (µg/L)	Arsenic, water, filtered (µg/L)	Boron, water, filtered (µg/L)	Selenium, water, filtered (µg/L)	1-Naphthol, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	<2.8	--	--	<0.04	<3	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	<2.0	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<0.16	<2.8	--	<0.05	<.04	<3	<0.04	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.16	<2.8	--	<.05	<.04	<3	<.04	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.16	3.8	--	<.05	<.04	<3	<.04	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.08	<1.4	--	.03	<.02	<3	<.03	<0.036

USGS station number	Station name or State well number	Date	Sample start time	Sample type	2,6-Diethylaniline, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	2-Chloro-2′, 6′-diethylacetanilide, water, filtered, recoverable (µg/L)	2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable (µg/L)	2-Ethyl-6-methylaniline, water, filtered, recoverable (µg/L)	3,4-Dichloroaniline, water, filtered, recoverable (µg/L)	3,5-Dichloroaniline, water, filtered, recoverable (µg/L)	4-Chloro-2-methylphenol, water, filtered, recoverable (µg/L)	Acetochlor, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.006	<0.010	<0.006	<0.010	<0.004	<0.004	<0.005	<0.010

Table 4. Results of major ion, trace element, and nutrient analyses from equipment blanks and field blanks collected in association with geochemical samples collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; E, estimated; M, presence verified but not quantified; U, analyzed for but not detected at a concentration equal to or greater than the long-term method detection level]

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Alachlor, water, filtered, recoverable (µg/L)	alpha-Endosulfan, water, filtered, recoverable (µg/L)	Atrazine, water, filtered, recoverable (µg/L)	Azinphos-methyl oxygen analog, water, filtered, recoverable (µg/L)	Azinphos-methyl, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Benfluralin, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Carbaryl, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Carbofuran, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.008	<0.006	<0.008	<0.04	<0.120	<0.014	<0.060	<0.060

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Chlorpyrifos oxygen analog, water, filtered, recoverable (µg/L)	Chlorpyrifos, water, filtered, recoverable (µg/L)	cis-Permethrin, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	cis-Propiconazole, water, filtered, recoverable (µg/L)	Cyanazine, water, filtered, recoverable (µg/L)	Cyfluthrin, water, filtered, recoverable (µg/L)	Cypermethrin, water, filtered, recoverable (µg/L)	DCPA, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.06	<0.004	<0.010	<0.008	<0.022	<0.016	<0.020	<0.008

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Desulfinylfipronil amide, water, filtered, recoverable (µg/L)	Desulfinylfipronil, water, filtered, recoverable (µg/L)	Diazinon, water, filtered, recoverable (µg/L)	Dichlorvos, water, filtered, recoverable (µg/L)	Dicrotophos, water, filtered, recoverable (µg/L)	Dieldrin, water, filtered, recoverable (µg/L)	Dimethoate, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Disulfoton sulfone, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.029	<0.012	<0.006	<0.04	<0.08	<0.008	<0.006	<0.01

Table 4. Results of major ion, trace element, and nutrient analyses from equipment blanks and field blanks collected in association with geochemical samples collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; E, estimated; M, presence verified but not quantified; U, analyzed for but not detected at a concentration equal to or greater than the long-term method detection level]

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Disulfoton, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Endosulfan sulfate, water, filtered, recoverable (µg/L)	EPTC, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Ethion monoxon, water, filtered, recoverable (µg/L)	Ethion, water, filtered, recoverable (µg/L)	Ethoprop, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Fenamiphos sulfone, water, filtered, recoverable (µg/L)	Fenamiphos sulfoxide, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.04	<0.016	<0.006	<0.02	<0.008	<0.016	<0.054	<0.08

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Fenamiphos, water, filtered, recoverable (µg/L)	Fipronil sulfide, water, filtered, recoverable (µg/L)	Fipronil sulfone, water, filtered, recoverable (µg/L)	Fipronil, water, filtered, recoverable (µg/L)	Fonofos, water, filtered, recoverable (µg/L)	Hexazinone, water, filtered, recoverable (µg/L)	Iprodione, water, filtered, recoverable (µg/L)	Isofenphos, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.03	<0.012	<0.024	<0.018	<0.005	<0.008	<0.014	<0.006

USGS station number	Station name or State well number	Date	Sample start time	Sample type	lambda-Cyhalothrin, water, filtered, recoverable (µg/L)	Malaoxon, water, filtered, recoverable (µg/L)	Malathion, water, filtered, recoverable (µg/L)	Metalaxyl, water, filtered, recoverable (µg/L)	Methidathion, water, filtered, recoverable (µg/L)	Methyl paraoxon, water, filtered, recoverable (µg/L)	Methyl parathion, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Metolachlor, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.010	<0.022	<0.016	<0.014	<0.012	<0.01	<0.008	<0.020

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Metribuzin, water, filtered, recoverable (µg/L)	Molinate, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Myclobutanil, water, filtered, recoverable (µg/L)	Oxyfluorfen, water, filtered, recoverable (µg/L)	Pendimethalin, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Phorate oxygen analog, water, filtered, recoverable (µg/L)	Phorate, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Phosmet oxygen analog, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.012	<0.004	<0.010	<0.006	<0.012	<0.03	<0.020	<0.05

Table 4. Results of major ion, trace element, and nutrient analyses from equipment blanks and field blanks collected in association with geochemical samples collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than; E, estimated; M, presence verified but not quantified; U, analyzed for but not detected at a concentration equal to or greater than the long-term method detection level]

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Phosmet, water, filtered, recoverable (µg/L)	Prometon, water, filtered, recoverable (µg/L)	Prometryn, water, filtered, recoverable (µg/L)	Propanil, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Propargite, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Simazine, water, filtered, recoverable (µg/L)	Tebuthiuron, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Tefluthrin, water, filtered, recoverable (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.140	<0.012	<0.006	<0.010	<0.02	<0.006	<0.03	<0.010

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Terbufos oxygen analog sulfone, water, filtered, recoverable (µg/L)	Terbufos, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Terbuthylazine, water, filtered, recoverable (µg/L)	Thiobencarb, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	trans-Propiconazole, water, filtered, recoverable (µg/L)	Tribuphos, water, filtered, recoverable (µg/L)	Trifluralin, water, filtered (0.7 micron glass fiber filter), recoverable (µg/L)	Organic carbon, water, unfiltered (mg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--	--	--	--	--	--	--	E0.3
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--	--	--	--	--	--	--	<.6
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	--	--	--	--	--	--	--	--
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	--	--	--	--	--	--	--	--
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	--	--	--	--	--	--	--	--
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<0.04	<0.02	<0.01	<0.016	<0.01	<0.018	<0.018	--

USGS station number	Station name or State well number	Date	Sample start time	Sample type	Uranium (natural), water, filtered (µg/L)
302009097405901	Austin Field Headquarters	03-15-2010	14:00	Equipment blank	--
302009097405901	Austin Field Headquarters	04-05-2010	12:30	Equipment blank	--
311610103050901	US-46-48-701	08-12-2010	10:05	Field blank	<0.01
304805103013301	US-52-16-609	08-18-2010	15:05	Field blank	<.01
304715103263501	US-52-13-801	08-28-2010	13:05	Field blank	<.01
305531103474201	WD-52-02-507	06-22-2011	10:00	Field blank	<.004

Table 5. Relative percent differences between sequential replicate and environmental samples analyzed for major ions, trace elements, and elemental isotopes collected in the Pecos County region, Texas, 2010–11.

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; NTRU, Nephelometric Turbidity Ratio Unit; <, concentration was less than laboratory reporting level; --, RPD not calculated because the concentration for one or both samples in the pair was less than the laboratory reporting level]

USGS station number	Date	Constituent	Sequential replicate result	Environmental result	Relative percent differences
08437000	1/25/2011	Alkalinity, water, filtered inflection-point titration method (incremental titration method), field (mg/L as calcium carbonate)	254.0	232.0	9.05
08437000	1/25/2011	Aluminum, water, filtered (µg/L)	5.6	<5.1	--
08437000	1/25/2011	Ammonia, water, filtered (µg/L)	.057	.060	5.13
08437000	1/25/2011	Arsenic, water, filtered (µg/L)	1.7	1.7	0
08437000	1/25/2011	Barium, water, filtered (µg/L)	20	20	0
08437000	1/25/2011	Beryllium, water, filtered (µg/L)	.04	.04	0
08437000	1/25/2011	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	309	283	8.78
08437000	1/25/2011	Boron, water, filtered (µg/L)	1,010	1,020	0.99
08437000	1/25/2011	Bromide, water, filtered (mg/L)	2.33	2.37	1.70
08437000	1/25/2011	Cadmium, water, filtered (µg/L)	.10	.05	66.67
08437000	1/25/2011	Calcium, water, filtered (mg/L)	447	462	3.30
08437000	1/25/2011	Carbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	.3	.2	40.00
08437000	1/25/2011	Chloride, water, filtered (mg/L)	1,180	1,180	0
08437000	1/25/2011	Chromium, water, filtered (µg/L)	.40	.43	7.23
08437000	1/25/2011	Cobalt, water, filtered (µg/L)	.46	.36	24.39
08437000	1/25/2011	Delta deuterium, water, unfiltered (per mil)	-46.70	-47.00	-0.64
08437000	1/25/2011	Delta oxygen-18, water, unfiltered (per mil)	-6.57	-6.56	-0.15
08437000	1/25/2011	Dissolved solids dried at 180 degrees Celsius, water, filtered (mg/L)	4,530	4,520	0.22
08437000	1/25/2011	Fluoride, water, filtered (mg/L)	1.70	1.72	1.17
08437000	1/25/2011	Iron, water, filtered (µg/L)	15	<13	--
08437000	1/25/2011	Lead, water, filtered (µg/L)	0.11	<0.04	--
08437000	1/25/2011	Lithium, water, filtered (µg/L)	280	279	0.36
08437000	1/25/2011	Magnesium, water, filtered (mg/L)	176	180	2.25
08437000	1/25/2011	Manganese, water, filtered (µg/L)	12.8	12.5	2.37
08437000	1/25/2011	Molybdenum, water, filtered (µg/L)	13.7	13.7	0
08437000	1/25/2011	Nickel, water, filtered (µg/L)	2.0	1.9	5.13
08437000	1/25/2011	Nitrite, water, filtered (µg/L)	.02	.02	0
08437000	1/25/2011	Nitrate plus Nitrite, water, filtered (mg/L)	2.97	2.95	0.68
08437000	1/25/2011	Orthophosphate, water, filtered (mg/L as phosphorus)	.02	.02	0
08437000	1/25/2011	Potassium, water, filtered (mg/L)	21.1	21.6	2.34
08437000	1/25/2011	Selenium, water, filtered (µg/L)	5.4	5.6	3.64
08437000	1/25/2011	Silica, water, filtered (mg/L as SiO_2)	32.4	32.8	1.23
08437000	1/25/2011	Silver, water, filtered (µg/L)	<.01	.02	--
08437000	1/25/2011	Sodium, water, filtered (mg/L)	688	696	1.16
08437000	1/25/2011	Strontium, water, filtered (µg/L)	8,760	9,060	3.37
08437000	1/25/2011	Sulfate, water, filtered (mg/L)	1,550	1,550	0

Table 5. Relative percent differences between sequential replicate and environmental samples analyzed for major ions, trace elements, and elemental isotopes collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; NTRU, Nephelometric Turbidity Ratio Unit; <, concentration was less than laboratory reporting level; --, RPD not calculated because the concentration for one or both samples in the pair was less than the laboratory reporting level]

USGS station number	Date	Constituent	Sequential replicate result	Environmental result	Relative percent differences
08437000	1/25/2011	Thallium, water, filtered (µg/L)	0.28	0.26	7.41
08437000	1/25/2011	Total nitrogen, water, filtered (mg/L)	3.09	3.16	2.24
08437000	1/25/2011	Tritium, water, unfiltered (pCi/L)	1.9	1.8	5.41
08437000	1/25/2011	Uranium (natural), water, filtered (µg/L)	21.0	21.1	0.48
08437000	1/25/2011	Vanadium, water, filtered (µg/L)	6.3	6.5	3.13
304006103315601	6/23/2011	Alkalinity, water, filtered inflection-point titration method (incremental titration method), field (mg/L as calcium carbonate)	330	336	1.80
304006103315601	6/23/2011	Ammonia, water, filtered (µg/L)	.781	.780	0.13
304006103315601	6/23/2011	Antimony, water, filtered (µg/L)	<.03	.13	--
304006103315601	6/23/2011	Arsenic, water, filtered (µg/L)	3.1	3.0	3.28
304006103315601	6/23/2011	Barium, water, filtered (µg/L)	40	40	0
304006103315601	6/23/2011	Beryllium, water, filtered (µg/L)	.02	.02	0
304006103315601	6/23/2011	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	401	409	1.98
304006103315601	6/23/2011	Boron, water, filtered (µg/L)	1,120	1,110	0.90
304006103315601	6/23/2011	Cadmium, water, filtered (µg/L)	.03	.03	0
304006103315601	6/23/2011	Calcium, water, filtered (mg/L)	26.8	27.0	0.74
304006103315601	6/23/2011	Carbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	.7	.6	15.38
304006103315601	6/23/2011	Chloride, water, filtered (mg/L)	57.1	58.6	2.59
304006103315601	6/23/2011	Cobalt, water, filtered (µg/L)	.07	<0.02	--
304006103315601	6/23/2011	Dissolved solids dried at 180 degrees Celsius, water, filtered (mg/L)	869	859	1.16
304006103315601	6/23/2011	Fluoride, water, filtered (mg/L)	1.22	1.23	0.82
304006103315601	6/23/2011	Iron, water, filtered (µg/L)	66	65	1.53
304006103315601	6/23/2011	Lead, water, filtered (µg/L)	.02	1.21	193.50
304006103315601	6/23/2011	Lithium, water, filtered (µg/L)	198	199	0.50
304006103315601	6/23/2011	Magnesium, water, filtered (mg/L)	4.39	4.38	0.23
304006103315601	6/23/2011	Manganese, water, filtered (µg/L)	15.9	16.1	1.25
304006103315601	6/23/2011	Molybdenum, water, filtered (µg/L)	12.5	12.5	0
304006103315601	6/23/2011	Orthophosphate, water, filtered (mg/L as phosphorus)	.019	.019	0
304006103315601	6/23/2011	Potassium, water, filtered (mg/L)	7.25	7.43	2.45
304006103315601	6/23/2011	Selenium, water, filtered (µg/L)	.06	.06	0
304006103315601	6/23/2011	Silica, water, filtered (mg/L as SiO_2)	20.7	21.1	1.91
304006103315601	6/23/2011	Sodium, water, filtered (mg/L)	266	265	0.38
304006103315601	6/23/2011	Strontium, water, filtered (µg/L)	1,020	1,030	0.98
304006103315601	6/23/2011	Sulfate, water, filtered (mg/L)	271	271	0
304006103315601	6/23/2011	Total nitrogen, water, filtered (mg/L)	.85	.86	1.17
304006103315601	6/23/2011	Uranium (natural), water, filtered (µg/L)	22.4	22.4	0
304006103315601	6/23/2011	Vanadium, water, filtered (µg/L)	.19	.21	10.00

Table 5. Relative percent differences between sequential replicate and environmental samples analyzed for major ions, trace elements, and elemental isotopes collected in the Pecos County region, Texas, 2010–11.—Continued

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; NTRU, Nephelometric Turbidity Ratio Unit; <, concentration was less than laboratory reporting level; --, RPD not calculated because the concentration for one or both samples in the pair was less than the laboratory reporting level]

USGS station number	Date	Constituent	Sequential replicate result	Environmental result	Relative percent differences
304006103315601	6/23/2011	Zinc, water, filtered (µg/L)	2.6	3.0	14.29
305331103020501	8/17/2010	Alkalinity, water, filtered inflection-point titration method (incremental titration method), field (mg/L as calcium carbonate)	230	235	2.15
305331103020501	8/17/2010	Arsenic, water, filtered (µg/L)	.60	.56	6.90
305331103020501	8/17/2010	Barium, water, filtered (µg/L)	15	16	6.45
305331103020501	8/17/2010	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	280	286	2.12
305331103020501	8/17/2010	Boron, water, filtered (µg/L)	388.8	396.4	1.94
305331103020501	8/17/2010	Bromide, water, filtered (mg/L)	1.06	1.05	0.95
305331103020501	8/17/2010	Calcium, water, filtered (mg/L)	275	278	1.08
305331103020501	8/17/2010	Carbonate, water, filtered, inflection-point titration method (incremental titration method), field (mg/L)	.2	.2	0
305331103020501	8/17/2010	Chloride, water, filtered (mg/L)	760	758	0.26
305331103020501	8/17/2010	Cobalt, water, filtered (µg/L)	.11	.11	0
305331103020501	8/17/2010	Delta deuterium, water, unfiltered (per mil)	-50.50	-52.30	-3.50
305331103020501	8/17/2010	Delta oxygen-18, water, unfiltered (per mil)	-7.41	-7.47	-0.81
305331103020501	8/17/2010	Dissolved solids dried at 180 degrees Celsius, water, filtered (mg/L)	2,770	2,770	0
305331103020501	8/17/2010	Fluoride, water, filtered (mg/L)	1.31	1.30	0.77
305331103020501	8/17/2010	Lead, water, filtered (µg/L)	.19	.19	0
305331103020501	8/17/2010	Lithium, water, filtered (µg/L)	130	133	2.28
305331103020501	8/17/2010	Magnesium, water, filtered (mg/L)	107	109	1.85
305331103020501	8/17/2010	Molybdenum, water, filtered (µg/L)	14.2	14.5	2.09
305331103020501	8/17/2010	Nickel, water, filtered (µg/L)	.88	.83	5.85
305331103020501	8/17/2010	Nitrate plus Nitrite, water, filtered (mg/L)	1.63	1.61	1.23
305331103020501	8/17/2010	Orthophosphate, water, filtered (mg/L as phosphorus)	.016	.018	11.76
305331103020501	8/17/2010	Potassium, water, filtered (mg/L)	15.0	15.2	1.32
305331103020501	8/17/2010	Selenium, water, filtered (µg/L)	3.6	3.7	2.74
305331103020501	8/17/2010	Silica, water, filtered (mg/L as SiO_2)	23.4	23.3	0.43
305331103020501	8/17/2010	Sodium, water, filtered (mg/L)	418	421	0.72
305331103020501	8/17/2010	Strontium, water, filtered (µg/L)	5,490	5,330	2.96
305331103020501	8/17/2010	Sulfate, water, filtered (mg/L)	912	908	0.44
305331103020501	8/17/2010	Thallium, water, filtered (µg/L)	.87	.87	0
305331103020501	8/17/2010	Total nitrogen, water, filtered (mg/L)	1.61	1.61	0
305331103020501	8/17/2010	Tritium, water, unfiltered (pCi/L)	1.5	1.3	14.29
305331103020501	8/17/2010	Uranium (natural), water, filtered (µg/L)	8.76	8.90	1.59
305331103020501	8/17/2010	Vanadium, water, filtered (µg/L)	1.8	1.9	5.41
305509103510101	9/1/2010	Delta deuterium, water, unfiltered (per mil)	-11.70	-11.50	-1.72
305509103510101	9/1/2010	Delta oxygen-18, water, unfiltered (per mil)	-0.52	-0.61	-15.93

Field spikes are used to assess bias and variability from degradation of organic constituent concentrations during sample processing, storage, and analysis. Field spikes are environmental replicate samples into which a known volume and concentration of target analytes are added. Analytical recoveries of the spiked target compounds are expressed as percentages of expected (theoretical) concentrations. Computed field-spike recoveries (equation 2) are compared to theoretical and laboratory recoveries to evaluate matrix interferences or degradation of organic compounds:

$$\text{Recovery} = [(C_{\text{spiked}} - C_{\text{unspiked}}) \div C_{\text{expected}}] \times 100, \qquad (2)$$

where

C_{spiked} is the measured concentration of analyte in the spiked environmental sample, in micrograms per liter;

C_{unspiked} is the measured concentration of analyte in the unspiked environmental sample, in micrograms per liter;

C_{expected} is the theoretical concentration of analyte in the spiked environmental sample, in micrograms per liter, and is computed as

$$C_{\text{expected}} = C_{\text{solution}} \times V_{\text{spike}} \div V_{\text{sample,}} \qquad (3)$$

where

C_{solution} is concentration of analyte in spiked environmental solution, in micrograms per liter;

V_{spike} is volume of spike added to environmental sample, in milliliters; and

V_{sample} is volume of environmental sample, in liters.

A mixture of target analytes was added to a replicate environmental sample (site 305419102545301 collected on August 6, 2010). The calculated spike recoveries in this report were compared to time-series graph of groundwater spike recoveries in appendix 3 of Martin and Eberle (2011). In 2010, the spike recoveries in this report are within the range of spike recoveries shown by Martin and Eberle, indicating no bias in the results. For target analytes not included, the spiked recoveries of reagent water by the NWQL were reviewed for method performance, with methods appearing to be operating normally (U.S. Geological Survey, 2012).

Geophysical Methods

Surface and borehole geophysical data were collected throughout the study area from 2009 to 2011 to supplement compiled historical data and to minimize data gaps. Time-domain electromagnetic (TDEM) soundings were collected at 4 locations (fig. 4, table 6) and audio-magnetotelluric (AMT) soundings were collected at 13 locations (fig. 4, table 7) and borehole geophysical logs were collected at 44 locations (fig. 4, table 8). Site locations and associated information can be accessed using the USGS NWIS (U.S. Geological Survey, 2011a) and archived geophysical database.

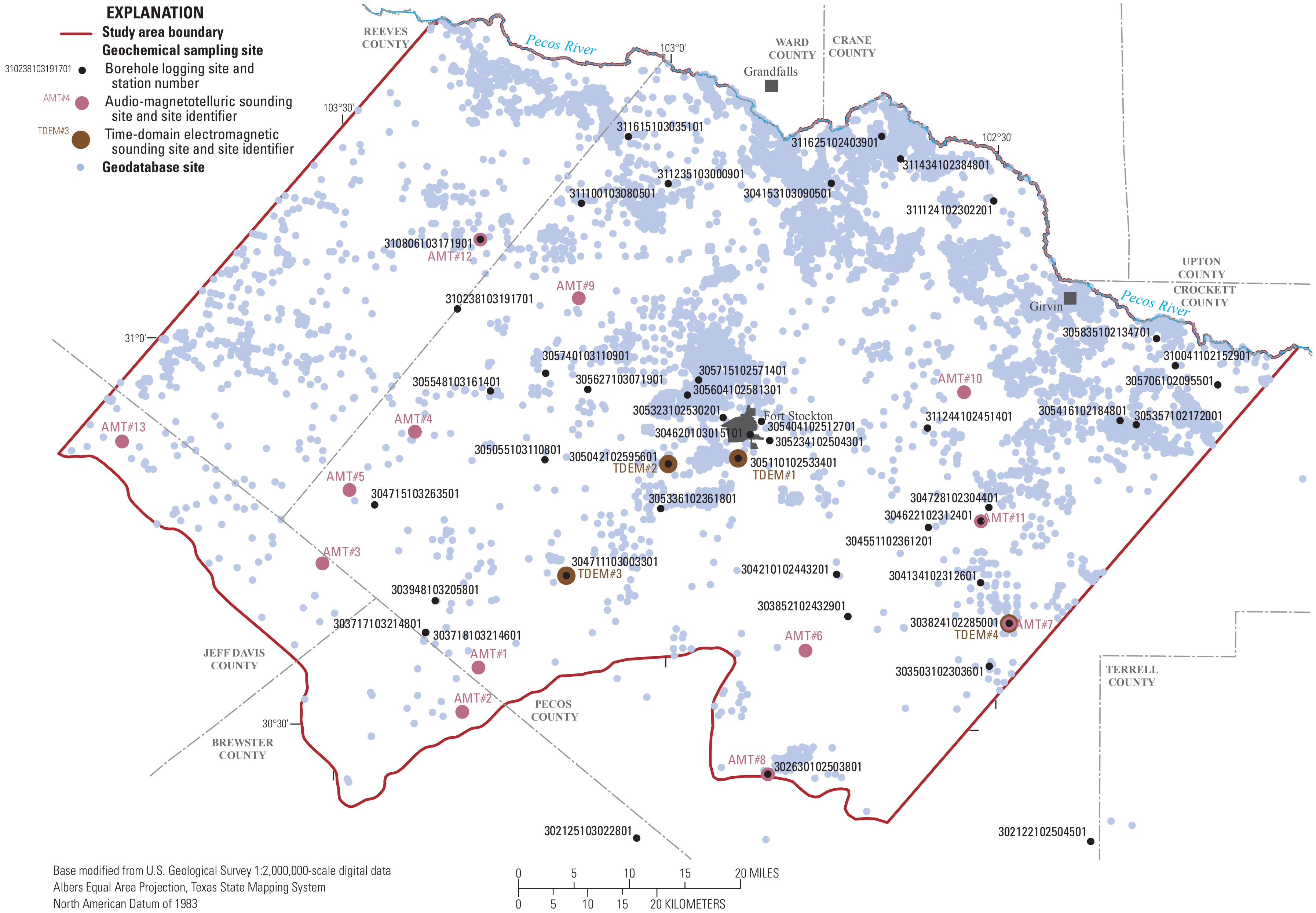
Surface Geophysical Methods

Surface geophysical resistivity methods can be used to detect changes in the electrical properties of the subsurface (Zohdy and others, 1974). The electrical properties of soil and rock are determined by water content, porosity, clay content and mineralogy, and conductivity (or reciprocal of electrical resistivity) of the pore water (Lucius and others, 2007). Resistivity measurements can be used to construct graphical images of the spatial distribution of electrical properties of the subsurface which, in turn, can be used to identify stratigraphic units and describe subsurface hydrogeology. The two surface geophysical methods used to evaluate the subsurface stratigraphy and hydrogeology in the study area were TDEM and AMT. Comprehensive descriptions of the theory and application of surface geophysical resistivity methods, as well as tables of the electrical properties of earth materials, are presented in Keller and Frischknecht (1966) and Lucius and others (2007).

Time-Domain Electromagnetic Soundings

Four TDEM soundings were collected at four different sites using the Geonics Protem 47 and 57 systems (Geonics Limited, 2006a,b). Each of the locations were near wells that had borehole geophysical logs collected by the USGS. Locations were selected so that the TDEM could be compared to the borehole geophysical logs to determine if this geophysical method would yield information to fill in data gaps associated with these sites.

The Geonics Protem 47 and 57 systems (hereinafter referred to as Protem 47 and 57, respectively) were used to collect TDEM soundings at each site. The Protem 47 and 57 use a multiturn receiver (Rx) coil to measure electromagnetic fields in the center of the transmitter (Tx) loop. The effective area of the receiver relates to the sensitivity of the Rx coil. The 100 square meter (m^2) Rx coil of the Protem 57 is able to measure smaller voltages than the 31.4-m^2 coil of the Protem 47. At each sounding, an integration time of 15 seconds (s) was used to measure six different data sets (the compilation of these data sets is referred to as a stack). The mean value of all the soundings collected over the integration time is stored. The values stored in the stack are averaged to ensure data quality and repeatability, and averaging is done prior to the inversion step, which is explained in the inverse modeling section of this report.



Base modified from U.S. Geological Survey 1:2,000,000-scale digital data
Albers Equal Area Projection, Texas State Mapping System
North American Datum of 1983

Figure 4. Site locations of field-collected geophysical data, including borehole logging and surface geophysical sites, Pecos County region, Texas, 2009–11.

Table 6. Time-domain electromagnetic geophysical sounding sites, Pecos County region, Texas, 2009-11

[TDEM, time-domain electromagnetic; USGS, U.S. Geological Survey; dd, decimal degrees]

Sounding identification number	USGS station number	State well number	Latitude (dd)	Longitude (dd)
TDEM#1	305110102533401	US-53-09-301	30.85286	-102.89278
TDEM#2	305042102595601	US-53-09-106	30.84509	-102.99899
TDEM#3	304711103003301	US-52-16-909	30.69795	-103.15138
TDEM#4	303824102285001	US-53-21-703	30.64000	-102.48052

Table 7. Audio magnetotelluric geophysical sounding sites, Pecos County region, Texas, 2009-11.

[AMT, audio magnetotelluric; USGS, U.S.Geological Survey; dd, decimal degrees; --, sounding not collected at/near well site]

Sounding identification number	USGS station number	State well number	Latitude (dd)	Longitude (dd)
AMT#1	--	--	30.57745	-103.28333
AMT#2	--	--	30.51932	-103.30687
AMT#3	--	--	30.71023	-103.52157
AMT#4	--	--	30.88350	-103.38389
AMT#5	--	--	30.80659	-103.48194
AMT#6	--	--	30.60335	-102.78842
AMT#7	303824102285001	US-53-21-703	30.64000	-102.48052
AMT#8	302630102503801	US-53-34-401	30.44176	-102.84396
AMT#9	--	--	31.06002	-103.13731
AMT#10	--	--	30.94134	-102.55057
AMT#11	304622102312401	US-53-12-901	30.77304	-102.52379
AMT#12	310806103171901	WD-46-54-901	31.13502	-103.28796
AMT#13	--	--	30.86516	-103.82792

Table 8. Borehole geophysical data-collection sites, Pecos County region, Texas, 2009-11.

[USGS, U.S. Geological Survey; dd, decimal degrees]

USGS station number	State well number	Latitude (dd)	Longitude (dd)
302122102504501	US-53-42-101	30.356	-102.8458611
302125103022801	BK-52-48-301	30.357	-103.0411306
302630102503801	US-53-34-401	30.4417611	-102.8439611
303503102303601	US-53-28-303	30.5842111	-102.5100694
303717103214801	US-52-30-107	30.62143889	-103.3638306
303718103214601	US-52-30-108	30.62181944	-103.3632389
303824102285001	US-53-21-703	30.64	-102.4805194
303852102432901	US-53-19-701	30.6479	-102.7247111
303948103205801	52-22-7xx	30.66344444	-103.3494444
304134102312601	US-53-20-603	30.69278889	-102.5239889
304153103090501	US-52-23-604	30.69795	-103.1513806
304210102443201	53-19-4xx	30.70269444	-102.7422778
304551102361201	US-53-12-701	30.76448056	-102.6038694
304620103015101	US-53-02-7xx (COFS 6)	30.7721	-103.0308
304622102312401	US-53-12-901	30.77303889	-102.5237889
304711103003301	US-52-16-909	30.78641944	-103.0093194
304715103263501	US-52-13-801	30.7874	-103.4434306
304728102304401	US-53-12-902	30.79098056	-102.5121611
305042102595601	US-53-09-106	30.84508889	-102.9989889
305055103110801	52-15-2xx	30.84863889	-103.1856667
305110102533401	US-53-09-301	30.8528611	-102.8927806
305234102504301	US-53-02-708	30.87618056	-102.8452111
305323102530201	US-53-01-908	30.88951944	-102.8839694
305336102361801	US-53-04-701	30.89363889	-102.6054
305357102172001	US-53-06-901	30.89923056	-102.2891194
305404102512701	US-53-02-710	30.9012	-102.8577
305416102184801	US-53-06-803	30.90458056	-102.3132694
305548103161401	US-52-06-604	30.9302	-103.2706
305604102581301	US-53-01-4xx (Apache 4)	30.93455	-102.9703
305627103071901	US-52-08-402	30.94075	-103.122
305706102095501	US-53-07-601	30.95175	-102.1653611
305715102571401	US-53-01-503	30.9542611	-102.9538194
305740103110901	US-52-07-201	30.9612	-103.1860806
305835102134701	US-53-07-106	30.9765	-102.2297694
310041102152901	US-45-62-901	31.0115611	-102.25855
310238103191701	US-46-62-801	31.0440111	-103.3213889
310806103171901	WD-46-54-901	31.13501944	-103.2879611
311100103080501	US-46-55-603	31.1834611	-103.1347389
311124102302201	US-45-52-602	31.19008056	-102.5065389
311235103000901	US-46-56-309	31.20973889	-103.0026194
311244102451401	US-45-50-302	31.21208889	-102.7539694
311434102384801	US-45-51-306	31.24468056	-102.6493
311615103035101	US-46-48-805	31.2708111	-103.0641611
311625102403901	US-45-43-806	31.27378889	-102.6778389

For each TDEM sounding collected, the voltages measured from the eddy currents were averaged and evaluated statistically by using preprocessing scripts (Joe Vrabel, U.S. Geological Survey, written commun., 2010). These scripts use the raw field data (voltage data) to calculate the uncertainty of each time gate (measured voltage values at discreet intervals of time increasing after shutoff of the current) independently. After calculating the standard deviation of the voltage, the user can specify limits to trim the data set (remove outliers prior to inverse modeling). For this study, the data were initially filtered by using the mean of the six stacks collected. Outliers were evaluated by the program and any data that were more than 10 percent above or below other data points were removed. The averages of each time gate were saved as processed data files to be used in the inversion software (Interpex Limited, 1996).

Audiomagnetotelluric Soundings

A total of 13 AMT soundings was collected and processed within the study area using the Stratagem EH4 electrical conductivity imaging system developed by Geometrics, Inc. and Electromagnetic Instruments, Inc. (Geometrics, 2012), and in accordance with techniques described by Asch and Sweetkind (2010). Of the 13 soundings collected, 4 of these soundings were collected near wells that had borehole geophysical logs collected by the USGS. These locations were selected so that the AMT soundings could be compared to the borehole geophysical logs, which aid in the interpretation of the AMT soundings. The remaining nine sounding locations were selected in areas where little or no other compiled data were located.

The Stratagem EH4 system was used to collect AMT data for each sounding location. The Stratagem EH4 system measures perpendicular arrays of electrical and magnetic fields labeled as X and Y directions within a range of 10 hertz (Hz) to 100 kilohertz (kHz) (Asch and Sweetkind, 2010). The electric field was measured by four stainless-steel electrodes placed into the earth with a 25-meter dipole (two electrodes separated by 25 meters) in the X direction and a 25-meter dipole in the Y direction. A fifth electrode was used as a ground. The ambient magnetic field was measured with two induction magnetometer coils that were placed more than 3 meters away from the electrode dipoles and are placed level in a small trench and then covered with dirt to ensure there is no movement of the coil. The controlled source transmitter was a 400-watt transmitter to supplement the received electromagnetic signal in the frequency range from 900 Hz to 23,000 Hz. The X and Y directions were chosen on a site by site basis with the X and Y directions being approximately 45 degrees from visible anthropogenic sources (Geometrics, 2007).

Time-series datasets were analyzed and selected based on the optimal signal-to-noise ratio before calculations were performed on the datasets. The measured AMT time-series datasets at each location were converted to the frequency domain and processed to determine a two-dimensional (2D) impedance tensor of apparent resistivity and phase (Asch and Sweetkind, 2010). Poor quality (noisy) data were filtered out in the time-series datasets before the conversion was made and in the spectral and resistivity datasets after conversion. Apparent resistivity is the approximate ratio of the magnitude of the electric field to the magnitude of the magnetic field for a given frequency (Asch and Sweetkind, 2010). The impedance tensor was rotated to an angle that closely represented a 2D earth at each sounding location. This allows for the separation of the TE and TM modes, which can be used to identify lateral variation across the sounding site.

Data were exported from Imagem, the Stratagem data acquisition program, into two files: a cross-power data file, which contained spectral conversion of the data and a magnetotelluric (MT) impedance data file, which contained the apparent resistivity and phase conversion of the data (Geometrics, 2007). These files were used during the 2D inversion modeling process.

Inverse Modeling of Surface Geophysical Results

Apparent resistivity represents the resistivity of a completely uniform (homogenous and isotropic) subsurface (Keller and Frischknecht, 1966). Inverse modeling is the process of creating an estimate of the true distribution of subsurface resistivity (derived from the actual heterogeneous, anisotropic rocks) from the measured apparent resistivity (modeled as homogeneous, isotropic rocks). To estimate the resistivity of nonuniform earth material, inverse modeling software is used. The IX1Dv3 program, developed by Interpex Limited (1996), was used for inverse modeling of the TDEM soundings. The AMT sounding data were inverted using selected inversion algorithms within the Geotools MT software package used to process AMT and MT data (Geotools, 1998).

For this report, root mean square errors (RMSE) of 10 percent or less were generally considered acceptable, and RMSEs of 5 percent were generally considered good. The inverse modeling results of the TDEM data collected throughout the area had RMSEs of less than 4 percent for all soundings collected (appendix 1). The TDEM results were not able to resolve the depths needed to make geologic picks, so AMT was used to obtain deeper information.

The inverse modeling results of the AMT data collected throughout the area had acceptable errors between the measured field data and the calculated model data (appendix 2). There were two locations (AMT07 and AMT13, fig. 4) where anthropogenic noise distorted the signal sufficiently such that a poor inversion result was obtained. Four of the AMT soundings were located near wells from which geophysical logs were obtained, allowing the data quality to be assessed using borehole geophysical results.

Borehole Geophysical Methods

Borehole geophysical data such as natural gamma, formation resistivity, and caliper are commonly used to characterize and identify stratigraphic units (Keys, 1997). Many of these data had been collected in some wells in the study area as parts of previous studies and petroleum exploration (Small, and Ozuna, 1993; Smith and others, 2000). Conventional borehole geophysical log data such as natural gamma, formation resistivity, fluid resistivity, temperature, and caliper were collected in 44 wells where additional geophysical data were most critical to supplement existing data. In addition to the conventional borehole geophysical methods, advanced borehole geophysical measurements of vertical flow (magnitude and direction), in the borehole were collected in six representative wells using the Electromagnetic (EM) flowmeter. These data can be evaluated to determine the relation of flow to the hydrostratigraphic units in each well. All borehole geophysical data were collected using a Century Geophysical Corporation System VI logging system conveyed by a 0.25-in. diameter 4-conductor wireline or a Mount Sopris Instruments Matrix logging system conveyed by a 0.1875-in. diameter single conductor wireline. Limitations, calibration procedures, and algorithms of the geophysical probes are available from the manufacturers (Century Geophysical Corporation, 2012; Mount Sopris Instruments, 2012).

Electromagnetic Induction Logs

Electromagnetic induction probes measure conductivity in air- or water-filled holes and perform well in open holes or polyvinyl chloride (PVC) cased holes. The measurement of conductivity commonly is reciprocated to provide logs with curves of resistivity and conductivity (Keys, 1997). Conductivity is affected by the salinity of borehole and formation fluids and the type of lithology encountered. Generally, pure carbonates, sands, and gravels have lower conductivity, thus higher resistivity, than clays or shales (Keys, 1997). A Century Geophysical Corporation 9510 or a Geonics EM39 induction conductivity probe was calibrated and was used to the manufacturer’s specifications (Century Geophysical Corporation, written commun., 2011; Mount Sopris Instruments, written commun., 2011). The EM induction conductivity measurements (commonly sensitive to metallic conductive objects) were affected at depths corresponding with metal objects such as centralizers and stainless steel screens.

Natural Gamma Logs

Natural gamma logs provide a record of gamma radiation detected at depth in a borehole. Fine-grained sediments that contain abundant clay tend to be more radioactive than quartz-grain sandstones or carbonates (Keys, 1997). The natural gamma log was run in conjunction with the fluid resistivity log and was recorded in natural gamma counts per second simultaneously as the induction log was recorded in both cased and open boreholes. A Century Geophysical Corporation 8044 multiparameter probe or a Mount Sopris Instruments 2PGA–1000 natural gamma probe with a sodium iodide detector was calibrated and was used to the manufacturer’s specifications. The natural gamma and induction logs collectively can be useful in identifying lithologies and contact depths of the strata penetrated in the borehole.

Electric Logs

Electric logs use a series of electrodes mounted on the downhole probe and a surface electrode in the ground to measure potential (or voltage) that varies with the electrical properties of fluids and rock materials. Electric logs require an uncased, fluid-filled hole to allow the current to flow into the formation. Electric logs include the following electrical methods measured in boreholes: normal resistivity, lateral resistivity, spontaneous potential, and single-point resistance. A Century Geophysical Corporation model 8044 multiparameter E-log probe was used to measure normal resistivity, lateral resistivity, spontaneous potential, and single-point resistance. These geophysical methods are explained in detail in Keys (1990, 1997).

Caliper Logs

Caliper logs provide a measurement of the diameter of the borehole and are useful in determining changes in borehole diameter that can be related to drilling techniques, cavernous formations, lithology, and well construction. The Century Geophysical Corporation model 7074 and the Mount Sopris Instruments 2PCA–1000, three-arm caliper probes were used in this study and recorded an average diameter measured by the three arms. The Century Geophysical Corporation 7074 probe was run in the short or long arm configurations (depending on hole diameter) for boreholes from 2 to 24 and 2 to 36 inches in diameter, respectively (Century Geophysical Corporation, 2012). The Mount Sopris Instruments 2PCA–1000 can be used in boreholes from 2 to 17 inches in diameter (Mount Sopris Instruments, 2012). Other limitations and algorithms of the geophysical probes can be found at Century Geophysical Corporation (2012) and Mount Sopris Instruments (2012). The caliper logs were collected using the Century Geophysical Corporation System IV or Mount Sopris Instruments Matrix logging systems. The caliper was calibrated by performing a two-point calibration on short sections of pipe (rings) where diameters were larger and smaller than the borehole sizes that were expected to be encountered.

Fluid Resistivity and Temperature Logs

Fluid resistivity logs provide a record of the capacity of the borehole fluid to conduct electrical current (Keys, 1990). Changes in fluid resistivity are measured by ring electrodes inside a housing that allows borehole fluid to flow through it. When feasible, fluid resistivity logs were run as the first logging run to record the ambient conditions before other probes have passed through the borehole and have vertically mixed the borehole fluid. Curve deflections on the fluid resistivity log can indicate horizontal or vertical flow, stratification of borehole fluid, or screened intervals in cased wells. The fluid resistivity values also can be used in calculations with other logs. Fluid resistivity and the reciprocal (fluid conductivity) are shown on the logs in this study for comparison to specific-conductance values collected at springs (appendix 1).

The fluid conductivity values contained in the logs for this study are the values recorded at the ambient borehole temperature and are not corrected to a standard temperature. A Century Geophysical Corporation model 8044 multiparameter E-log probe or a Mount Sopris Instruments model 2PFA–1000 probe was used to log fluid resistivity in uncased (open) boreholes and cased wells. Calibration of the fluid resistivity logging probes was done with solutions of known conductivity in a two-point calibration. Temperature logs record the temperature of the borehole fluid that the logging probe passes through as it is raised or lowered in the borehole. A Century Geophysical Corporation model 8044 multiparameter E-log probe or a Mount Sopris Instruments model 2PFA–1000 probe was used to log fluid temperature in uncased (open) boreholes and cased wells. All temperature logs were collected as the probe was lowered in the borehole to maximize the flow into the sensor housing at the bottom of the Century Geophysical Corporation model 8044 logging probe. Temperature logs can provide useful information on the movement of water through a water-well borehole, including the location of depth intervals that produce or accept water (Keys, 1990).

Optical Borehole Imaging

The optical borehole imager (OBI) is an oriented logging device that can provide a high-resolution, 360-degree image or “cylindrical picture” of the circumference of the borehole that can be used to evaluate secondary porosity features such as fractures and solution openings. The OBI uses a digital scanning camera and conical mirror, which records a 360-degree image of the borehole wall showing the texture, color, and fractures in air-filled or clear fluid-filled boreholes (Hearst and others, 2000). A cylindrical light ring between the camera and mirror illuminates the part of the borehole wall being imaged. An Advanced Logic Technology optical borehole imager or OBI40 was used to collect optical images of the surface wall of open and cased wells in both air and clear water (Advanced Logic Technology, 2012). The utility and analytical methods of optical imaging are explained in Keys (1997) and Hearst and others (2000).

Acoustic Borehole Imaging

The acoustic borehole imager (ABI) is an oriented logging device that can provide a high-resolution, 360-degree image or cylindrical acoustic image of the circumference of the borehole that can be used to evaluate secondary porosity features such as fractures and solution openings. Acoustic borehole imaging tools generate an image of the borehole wall by transmitting ultrasonic pulses from a rotating sensor and recording the amplitude and traveltime of the signals reflected at the interface between the borehole fluid and borehole wall. Because of the need for sound waves to be transmitted to and from the borehole wall and rock formation, ABI tools can only be used in fluid-filled holes. An Advanced Logic Technology acoustic borehole imager or ABI40 was used to collect acoustic borehole images. These are multiecho systems that measure multiple echoes of amplitude and traveltime. The ABI image shows the borehole-fracture intersection by scattering acoustic energy and enabling the defined orientation and fracture aperture to be used to calculate the strike and dip of planar features such as fractures and bedding planes (Hearst and others, 2000; Keys, 1997; Paillet, 1991).

Electromagnetic Flowmeter

The EM flowmeter measures the vertical flow rate and direction in a borehole using the principal of Faraday’s Law of EM Induction (Century Geophysical Corporation, written commun., 2006). The EM flowmeter probe consists of an electromagnet and two electrodes 180 degrees apart and oriented 90 degrees to the magnetic field inside a hollow cylinder or tube. The voltage induced by a conductor moving at right angles through the magnetic field is directly proportional to the velocity of the conductor (water) through the field (Century Geophysical Corporation, written commun., 2006). Generally, when using the tool to measure low-velocity flow, rubber diverters direct the water flow through the tube, which is open at both ends, instead of around the tool. Because the diameter of the tube and voltage response is calibrated, the volume of flow is instantaneously recorded. The direction of water flow is determined by the polarity of the response; upward flow is positive and downward flow is negative. If there are vertical hydraulic head gradients within the aquifer adjacent to the borehole, then the ambient flow profile is subtracted from the flow profile during steady pumping to yield the estimated relative interval transmissivity (Paillet, 2001).

Geophysical Data Quality Assurance and Formats

All logs collected during 2009–11 were collected according to the American Society of Testing and Materials (ASTM) borehole geophysical standard procedures: (1) ASTM Standard Guide for Planning and Conducting Borehole Geophysical Logging - D5753-05 (American Society of Testing and Materials, 2010), (2) ASTM Standard Guide for Conducting Borehole Geophysical Logging Mechanical Caliper - D6167 – 97 (American Society of Testing and Materials, 2004), and (3) ASTM Standard Guide for Conducting Borehole Geophysical Logging Electromagnetic Induction - D6726 – 01 (American Society of Testing and Materials, 2007). All logs were collected in digital format and were recorded in the proprietary format of the data acquisition equipment used to collect the logs. These proprietary data formats were converted to and stored as Log American Standard Code for Information Interchange (ASCII) Standard (Canadian Well Logging Society, 2011) tabular data and presented as chart logs in a portable document format (PDF) file (appendix 2). All surface geophysical data were collected in accordance with ASTM Standard Guide for Selecting Surface Geophysical Methods - D6429 (American Society of Testing and Materials, 1999).

Geodatabase Compilation

Groundwater, surface-water, water-quality, geophysical, and geologic information were downloaded from existing database resources hosted by various Federal, State, and local agencies. The geodatabase comprises data accessed and downloaded from enterprise database resources that warehouse environmental data, such as USGS NWIS, USEPA Modernized Storage and Retrieval Repository (STORET), TWDB Groundwater Database, TCEQ Surface Water Quality Information System (SWQMIS), and others.

The USGS groundwater, surface-water, and water-quality data were obtained from NWIS and include measurements taken as part of routine sampling and project-specific sampling in the Texas Water Science Centers (U.S. Geological Survey, 2011a). In addition, field-collected geochemical and geophysical data reported in the sections above were included with the downloaded data obtained from NWIS. The USEPA data were obtained from the Modern STORET and include mostly surface water-quality data supplied by State and local agencies (U.S. Environmental Protection Agency, 2011). Data from the TWDB Groundwater Database include well information, water quality, and water levels reported to TWDB from Federal, State, and local entities (Texas Water Development Board, 2011). The TCEQ SWQMIS data were obtained using direct connection with the database (Texas Commission on Environmental Quality, 2011). This information includes mostly surface-water information focused on water quality for sites throughout Texas. Local database resources were used from the City of Fort Stockton and Middle Pecos Groundwater Conservation District. Additional data were mined from published reports and other hardcopy data resources in the geodatabase. In most cases, these data were acquired directly from the source agency and accessed through the publishing agency’s website or online libraries. Appendix 3 provides detail about the database resources used in the final geodatabase product.

Many of the data resources compiled into the geodatabase came from databases or other digital files with vastly different file formats, contents, structure, and function. The compilation process included a qualitative and quantitative analysis of each individual data source to identify relevant, authoritative data to include in the geodatabase. Data were extracted from the native data source using custom queries and export functions, and then loaded into the geodatabase using import functions and structured query language (SQL) code. This process incorporates data from many disparate databases into a single compilation and may result in duplicate records in the geodatabase because of redundant data reported between unique databases.

The first step of this process was to compile all geographic site locations from independent database resources into a single master site file for the geodatabase. Site locations were provided in a compatible geospatial data format (geodatabase feature class or shapefile format) or latitude/longitude coordinates were identified in the tabular information. The final master site file was then related to the groundwater, surface-water, water-quality, geophysical, and geologic data stored in data tables in the geodatabase. Groundwater levels and geologic data were combined into a single table for all available sources, while groundwater, surface-water, and water-quality data were stored in separate tables in the geodatabase and organized by source agency.

Geodatabase Design

A geodatabase is a spatially enabled database that contains spatial and tabular data and allows users to associate tabular data with physical and spatial components (Shah and Houston, 2007). It is capable of handling volumes of data efficiently through the use of a relational database management system. The geodatabase can be explored interactively using a GIS or accessed through traditional database queries. Using a GIS, the spatial data can be viewed in combination with other relevant geospatial data layers (aerial imagery, surface geology, administrative boundaries, and so forth) to analyze distribution patterns, data gaps, spatial relationships, and to create cartographic representations of the geodatabase contents.

The geodatabase is comprised of database objects: feature classes, relationship classes, and attribute tables. Feature classes store geospatial data objects of similar geometry type (point, line, or polygon). A collection of feature classes are stored and managed in a feature dataset, which uses a single, defined geographic or projected coordinate system for all data stored within the database object. Relationship classes link geospatial data stored in the feature classes with related tabular information stored in attribute tables. Relationship classes allow the end user to query data by establishing connections between geospatial data stored in the feature classes with related tabular information stored within the geodatabase attribute tables (Zeiler, 1999). The geodatabase designed for this study was based on an Environmental Systems Research Institute (ESRI) ArcGIS 10.0 personal geodatabase platform. ArcGIS personal geodatabases store database information as Microsoft Access (97–2003) files (Zeiler, 1999).

Figure 5 shows the simplified geodatabase model used for this project. Figure elements are shaded to highlight the distinction between data sources, data elements used to store geographic information and those used to store related tabular information. Compiling data, entering data into the geodatabase, ensuring data quality, and documenting the associated metadata were the primary steps in creating the geodatabase.

Data Input

Digital data were imported and select hardcopy data were entered manually into the geodatabase. Data were extracted from the native data resources using custom queries and basic data export functions and then were loaded into the geodatabase using import functions and SQL code within Microsoft Access. Whenever possible, SQL code was used to automate the creation of tables within the geodatabase and to load data into specified database elements within the geodatabase. Traditional geodatabase import/export functions within ArcGIS were used for the final compilation for geospatial components. The Microsoft Access table and query design wizards also were used for data input. In addition, ESRI ArcCatalog was used to create tables and upload data into the geodatabase attribute tables using the "Simple Data Loader." This efficient tool allows the end-user to load both spatial and tabular data, stored in various native data formats, into a geodatabase feature class or attribute table.

Geodatabase Data Quality Assurance

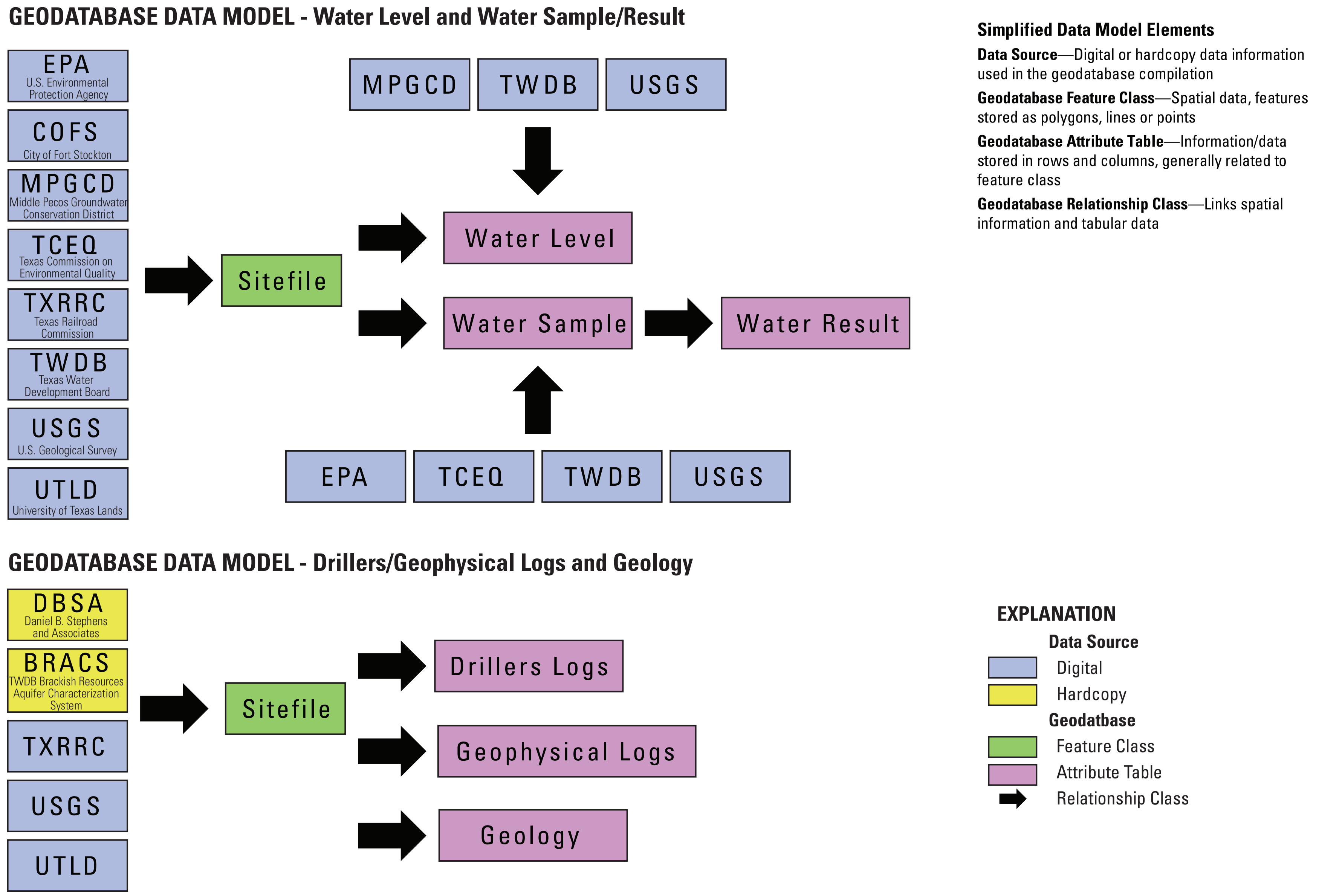
Database schemas and data formats from the various source agencies are incongruent, so the final database schema was simplified to capture only essential information needed for the geodatabase. Using database imports functions and SQL code, the disparate data were loaded into the generalized schema for geographic locations (sitefile) and attribute tables that store water-level and water-quality data. Simple cross-checks were performed to ensure the number of records from the native data resources were consistent with the number of records imported into the geodatabase after loading.

In some cases, data from one source agency were reported in one or more of the unique database sources used in this project. For example, some of water-level altitudes collected by the USGS and stored in NWIS were also stored in the TWDB Groundwater Database. Based on the design of the geodatabase, native database resources uploaded into the geodatabase reside in independent attribute tables and are linked to the sitefile through relationship classes linked by the unique identifier for each record. The design of the geodatabase operates under the assumption that data might be duplicated between source agencies.

Additional quality assurance methods can be applied after querying the geodatabase to ensure a higher level of data quality. This may include a search for duplicate geographic site locations using a tolerance established by the end-user. Shah and Maltby (2010) used a 30-meter horizontal buffer to identify site locations near each other and then used additional fields (for example, source agency) to eliminate duplicate information where possible. Additionally, tabular information can be reviewed post-query using a combination of key fields, such as source agency, date/time, site type, parameter name or result values, to help identify potential duplicates. While these steps can help eliminate duplicate data, the possibility that duplicate data exist in the post-query results is still high based on the inability to precisely identify all duplicate data because of data rounding, incongruent database schemas, and other data handling errors present in each database resource.

Metadata

Federal Geographic Data Committee (FGDC) compliant metadata were created for each spatial data layer in the geodatabase. Metadata describe the "who, what, when, where, why, and how" for each spatial data layer. FGDC metadata include data categories such as title, abstract, publication date, and sourcing information. In addition, the metadata record describes the geographic setting for each spatial data layer, including the geographic or projected coordinate system and vertical/horizontal datum. Lastly, the metadata record describes the attribute label definitions and domain values for fields in the attribute table of the spatial data layer. A detailed listing of metadata contents can be found at *http://www.fgdc.gov/metadata* (Federal Geographic Data Committee, 2012). The metadata record for the sitefile feature class can be found in appendix 4.



Simplified Data Model Elements

Data Source—Digital or hardcopy data information used in the geodatabase compilation

Geodatabase Feature Class—Spatial data, features stored as polygons, lines or points

Geodatabase Attribute Table—Information/data stored in rows and columns, generally related to feature class

Geodatabase Relationship Class—Links spatial information and tabular data

Figure 5. Simplified geodatabase data model for hydrogeologic data for the Pecos County region, Texas, 2011.

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Glossary

Acronyms and terms used throughout the report

ABI	acoustic borehole imager
AMT	audio-magnetotelluric
ASCII	American Standard Code for Information Interchange
ASTM	American Society of Testing and Materials
COFS	City of Fort Stockton
EM	electromagnetic
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
GAM	groundwater availability model
GIS	geographic information system
LRL	laboratory reporting level
MPGCD	Middle Pecos Groundwater Conservation District
MT	magnetotelluric
NWIS	National Water Information System
OBI	optical borehole imager
Ohm	Unit of measure of electrical resistance (International System)
Ohm-meters	Unit by which resistivity is measured; it is derived from the following equation:

$$R = rA/L$$

where

R is resistivity, in ohm-meters;
r is resistance measured, in ohms;
A is cross-sectional area, in meters squared; and
L is length of the resistor, in meters.

PDF	Portable Document Format
RMSE	root mean square error
RPD	relative percent difference
SQL	Structured Query Language
STORET	Storage and Retrieval Repository
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TDEM	time-domain electromagnetic
TE	transverse electric
TM	transverse magnetic
TWDB	Texas Water Development Board
TXRRC	Texas Railroad Commission
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UTLD	University of Texas System Lands

Appendix 1. Time-Domain Electromagnetic Resistivity from Field Measurements as a Function of Time and Inverse Modeling Results (Smooth and Layered-Earth Models)

Measured apparent resistivity data as a function of time are presented in appendix 1. Apparent resistivity values are calculated from the raw voltage values measured for each sounding, When plotted in time, these apparent resistivity values yield a decay curve representing the subsurface electrical stratigraphy. Data points that deviated appreciably (in the judgment of the authors) from the decay curve (and, therefore, represented suspect data) were deleted before inverse modeling. Appendix 1 includes the decay curve for each sounding as well as the inverse modeling results calculated from the curve.

A smooth inverse model (a multilayered model that holds the depth values fixed and allows the resistivities to vary during inversion) was then fit to the data using Occam's inversion principle (Constable and others, 1987). The inversion process uses a series of iterations to create a model that closely fits the data. Iterations were continued until the root mean square error (RMSE) between measured and calculated apparent resistivity changed less than 0.1 percent between iterations. To better represent the electrical stratigraphy of each sounding, layered-earth models were then generated. The layered-earth models are simplified to represent geologic units with depth. Throughout the area, the layered-earth models range from 4 to 6 layers, depending on observed inflections in the apparent resistivity decay curve and smooth model inversions. Graphs of the smooth and layered-earth models for each sounding site are in appendix 1. The graphs show the raw apparent resistivity data and the inversion results. The smooth (green line), layered-earth (red line), and error or bounds of layered equivalent models (grey shaded area around depth profiles) are shown in the plots.

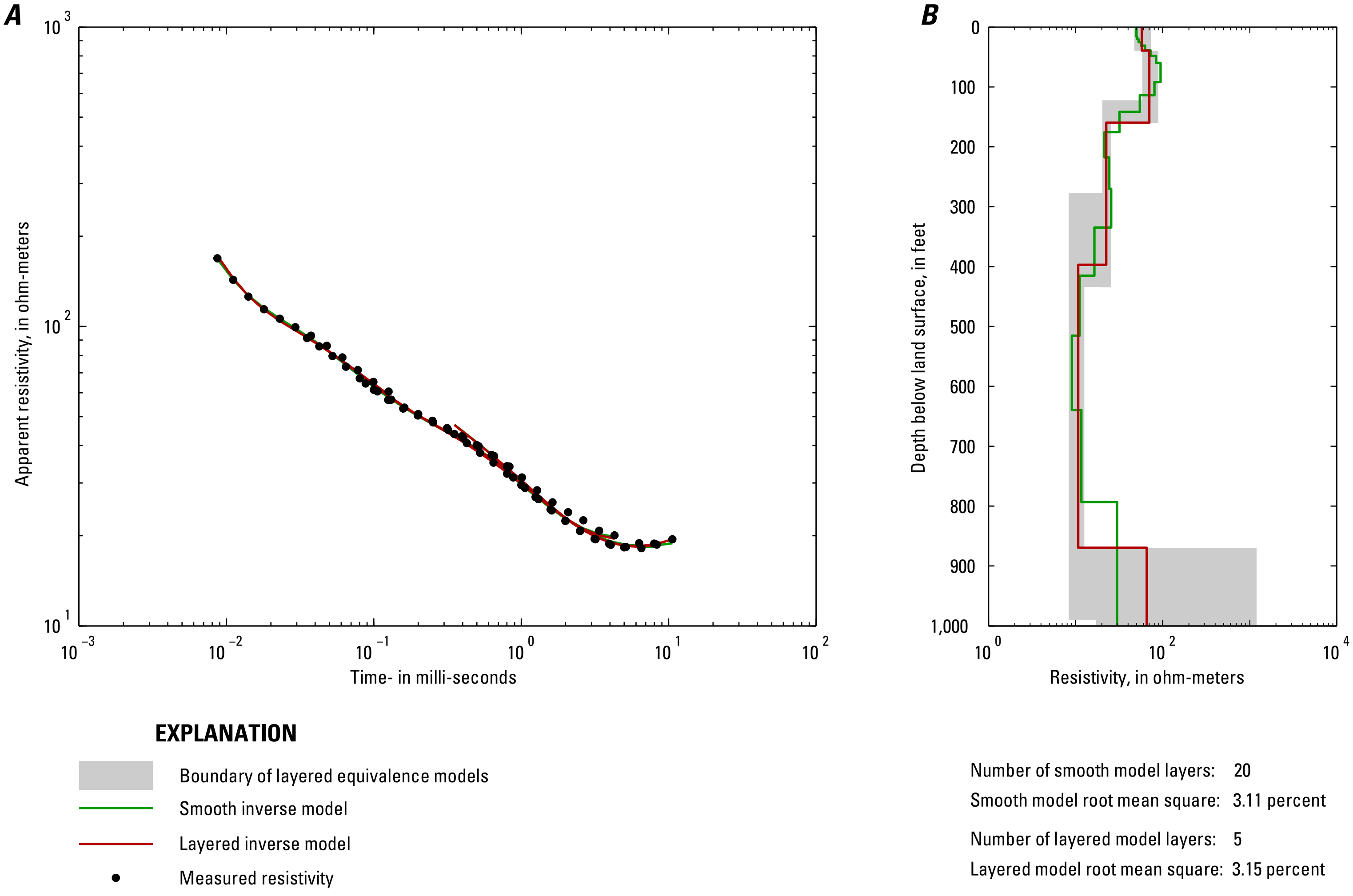


Figure 1.1 Sounding site TDEM#1, Pecos County, Texas. *A*, 80-meter time-domain electromagnetic sounding data (apparent resistivity from field measurements) as a function of time. *B*, 80-meter layered and equivalent inverse modeling results (models of true resistivity as a function of depth).

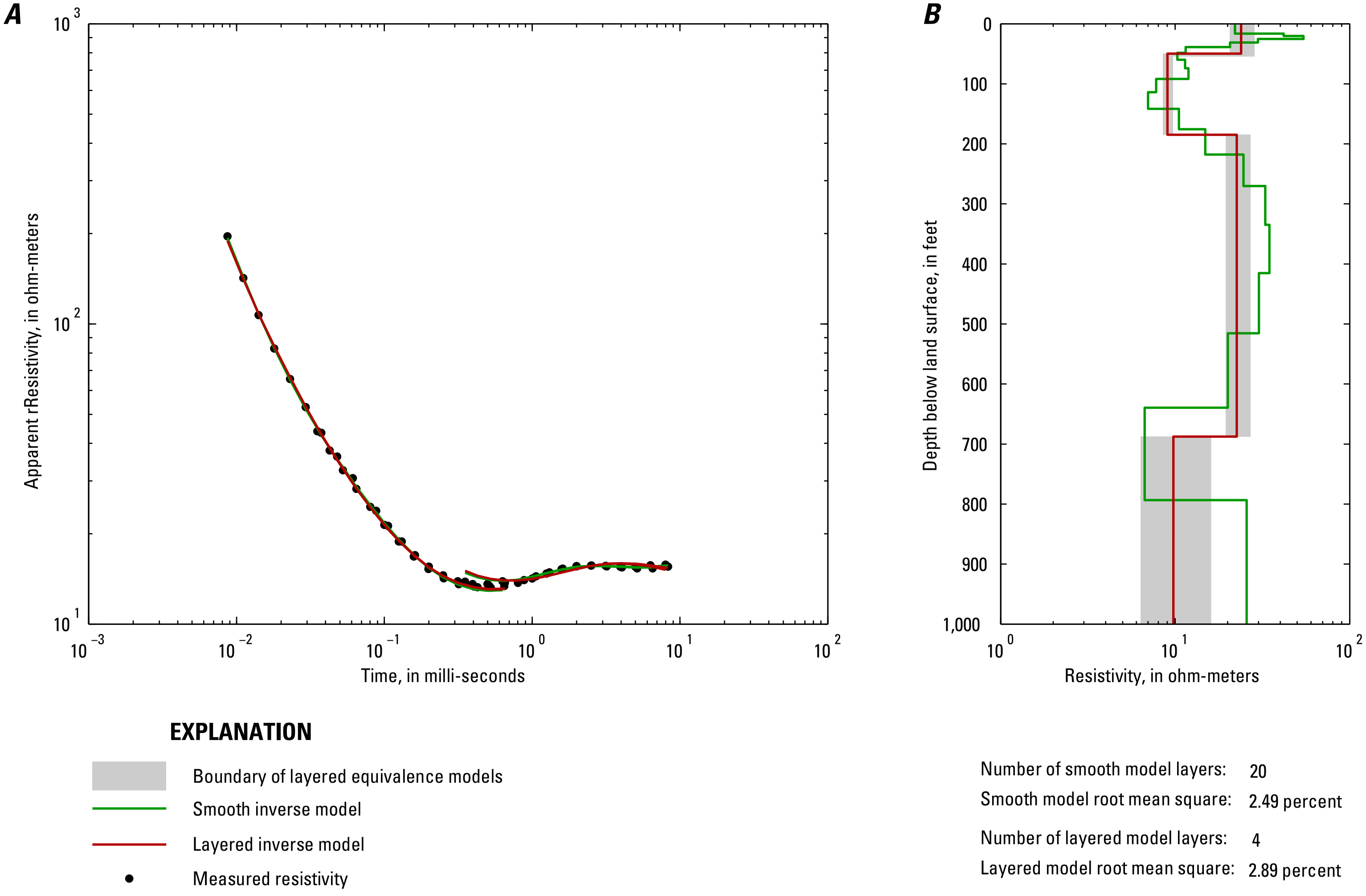


Figure 1.2 Sounding site TDEM#2, Pecos County, Texas. *A*, 80-meter time-domain electromagnetic sounding data (apparent resistivity from field measurements) as a function of time. *B*, 80-meter layered and equivalent inverse modeling results (models of true resistivity as a function of depth).

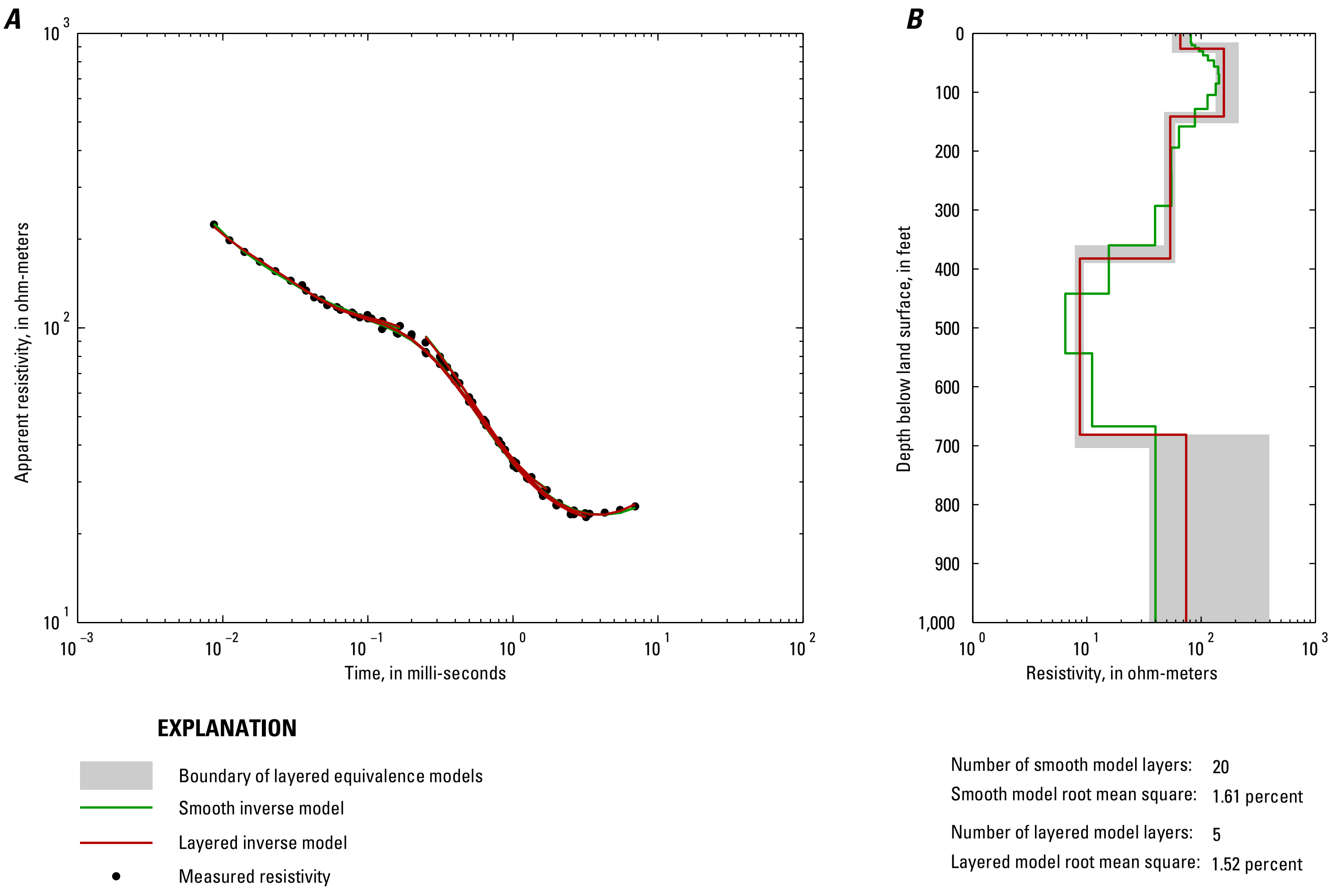
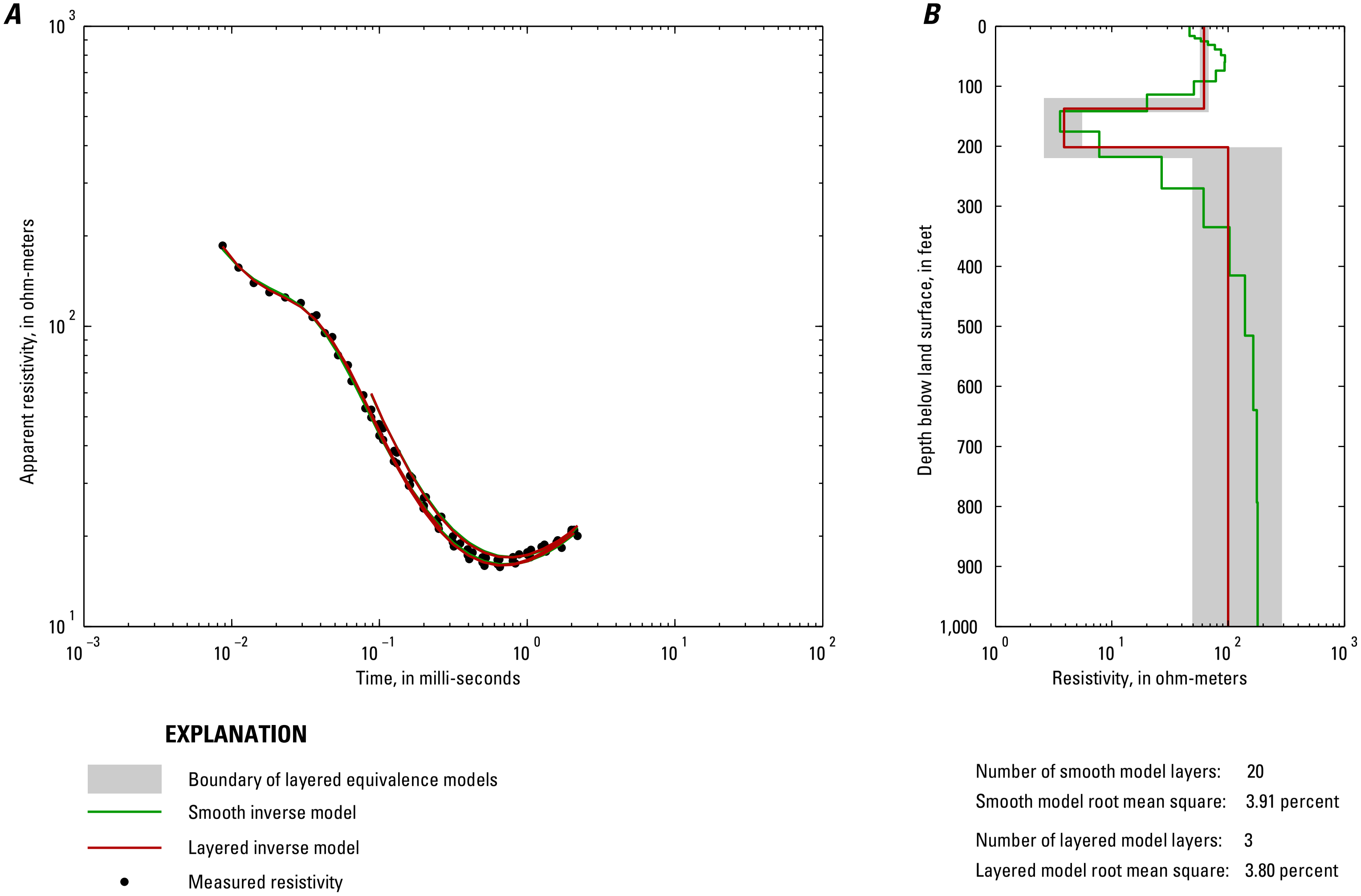


Figure 1.3 Sounding site TDEM#3, Pecos County, Texas. *A*, 80-meter time-domain electromagnetic sounding data (apparent resistivity from field measurements) as a function of time. *B*, 80-meter layered and equivalent inverse modeling results (models of true resistivity as a function of depth).



Number of smooth model layers:	20
Smooth model root mean square:	3.91 percent
Number of layered model layers:	3
Layered model root mean square:	3.80 percent

Figure 1.4 Sounding site TDEM#4, Pecos County, Texas. *A*, 80-meter time-domain electromagnetic sounding data (apparent resistivity from field measurements) as a function of time. *B*, 80-meter layered and equivalent inverse modeling results (models of true resistivity as a function of depth).

Appendix 2. Inverse Modeling Results of Audio-Magnetotelluric Soundings as a Function of Resistivity and Depth

Inverse modeling of the best fit for the transverse magnetic (TM) curve for the audio-magnetotelluric (AMT) sounding data is the best choice when approximating a three-dimensional structure beneath a centrally located point as demonstrated by Wannamaker and others (1984). However, the depths to the base of electrical units in the model may not be well constrained because TM data are relatively insensitive to the depth extent of a subsurface body (Eberhart-Phillips and others, 1995). Using a mixed mode analysis (modeling the mixed mode analysis of transverse magnetic and transverse electric response [TMTE] mode) can aid in the interpretation of elongated geologic structures from the modeling results.

The AMT sounding data were inverted using the computer algorithm RLM2DI (Mackie and others, 1997; Rodi and Mackie, 2001) from Geotools MT (Geotools, 1998). The forward modeling computer algorithm PW2D (Wannamaker and others, 1987) then used the inversion results from RLM2DI as the initial input model to perform a sensitivity analysis on the conductive units. The RLM2DI algorithm uses Maxwell's equations governing magnetotellurics within a finite-difference network to calculate the forward model and minimizes the objective function using a nonlinear conjugate gradient optimization approach for the inverse modeling results (Asch and Sweetkind, 2010). The PW2D algorithm simulates transverse electric and magnetic fields using a linear basis for each finite element. RLM2DI ran approximately 25 iterations in order to reduce the root mean square error (RMSE) to a reasonable value between the measured field data and the calculated data. PW2D ran the necessary number of iterations of forward modeling for a sensitivity analysis of conductive units based on how complex the inversion results were from RLM2DI. Graphs of the AMT inversion results for each sounding site (figs. 2.1–2.13) show modeled resistivity with warmer colors (red, orange, and yellow) representing higher values and cooler colors (green, blue, and violet) representing lower values measured in ohm-meters. The graphs show the inversion results for the TMTE mode for all sounding locations. For sites where there appeared to be a three-dimensional change, the TM and transverse electric (TE) modes were separated in order to get a better understanding of what is present at that site.

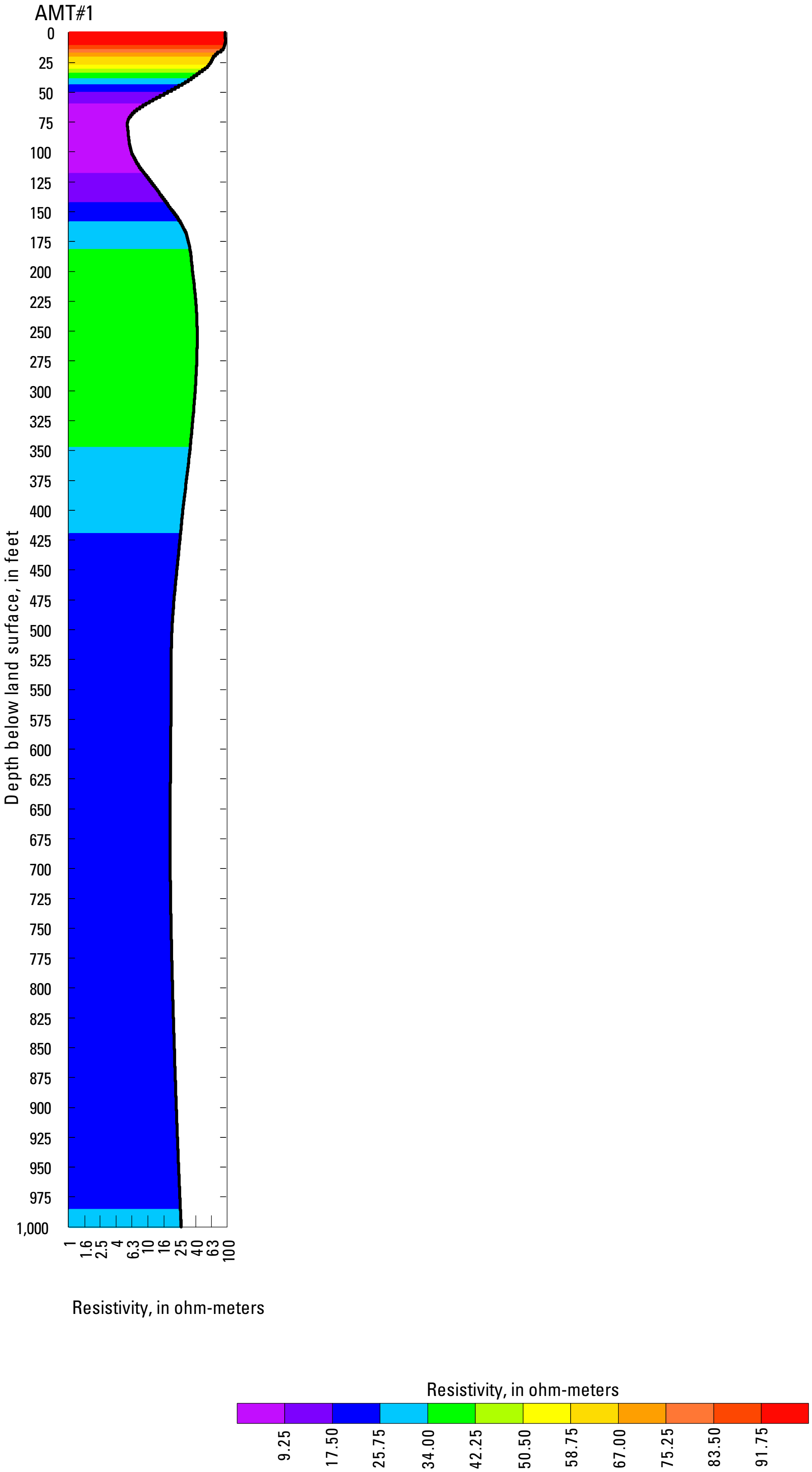


Figure 2.1 Sounding site AMT#1, Pecos County, Texas. Resistivity of mixed mode transverse magnetic and transverse electric responses.

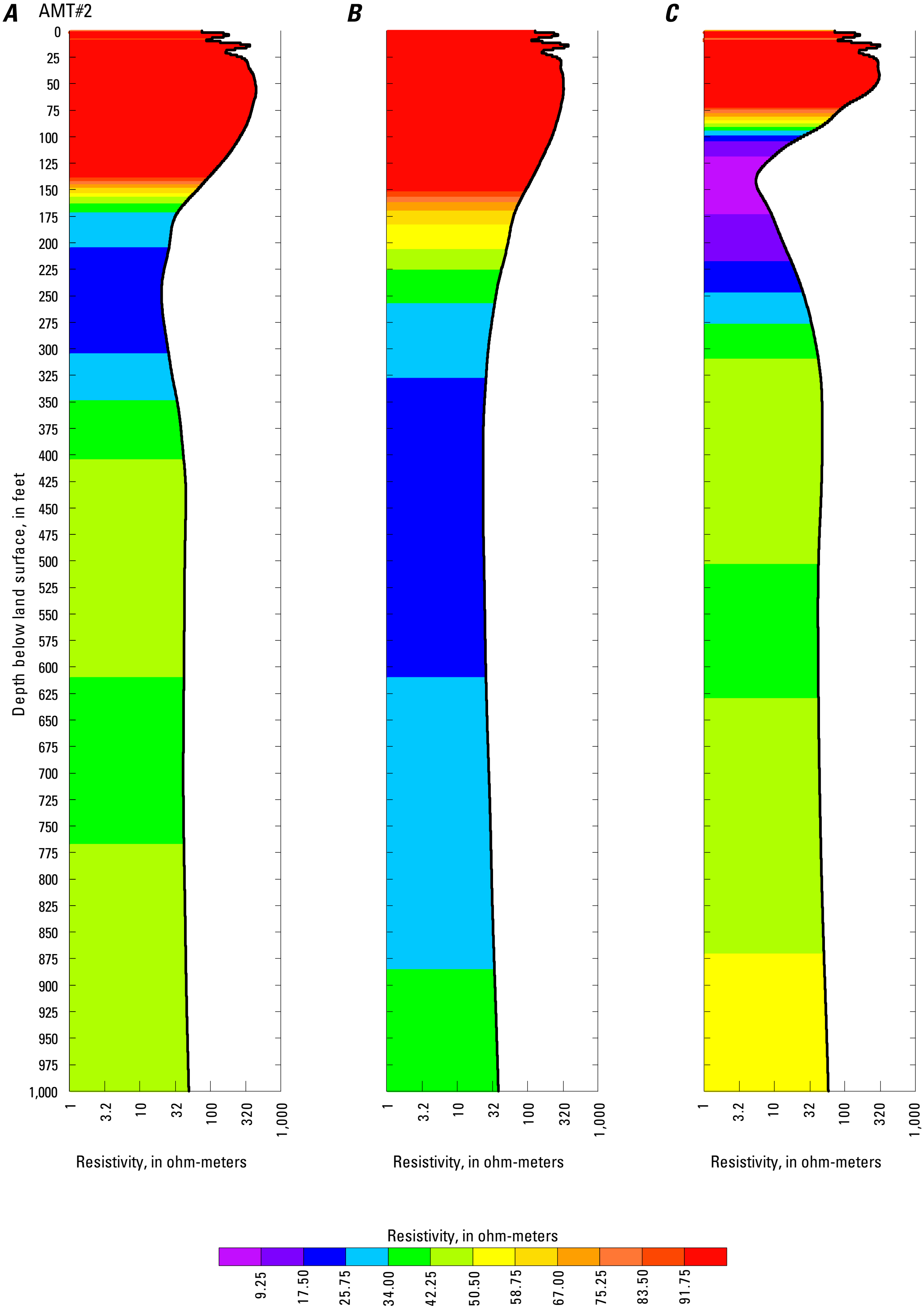


Figure 2.2 Sounding site AMT#2, Brewster County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

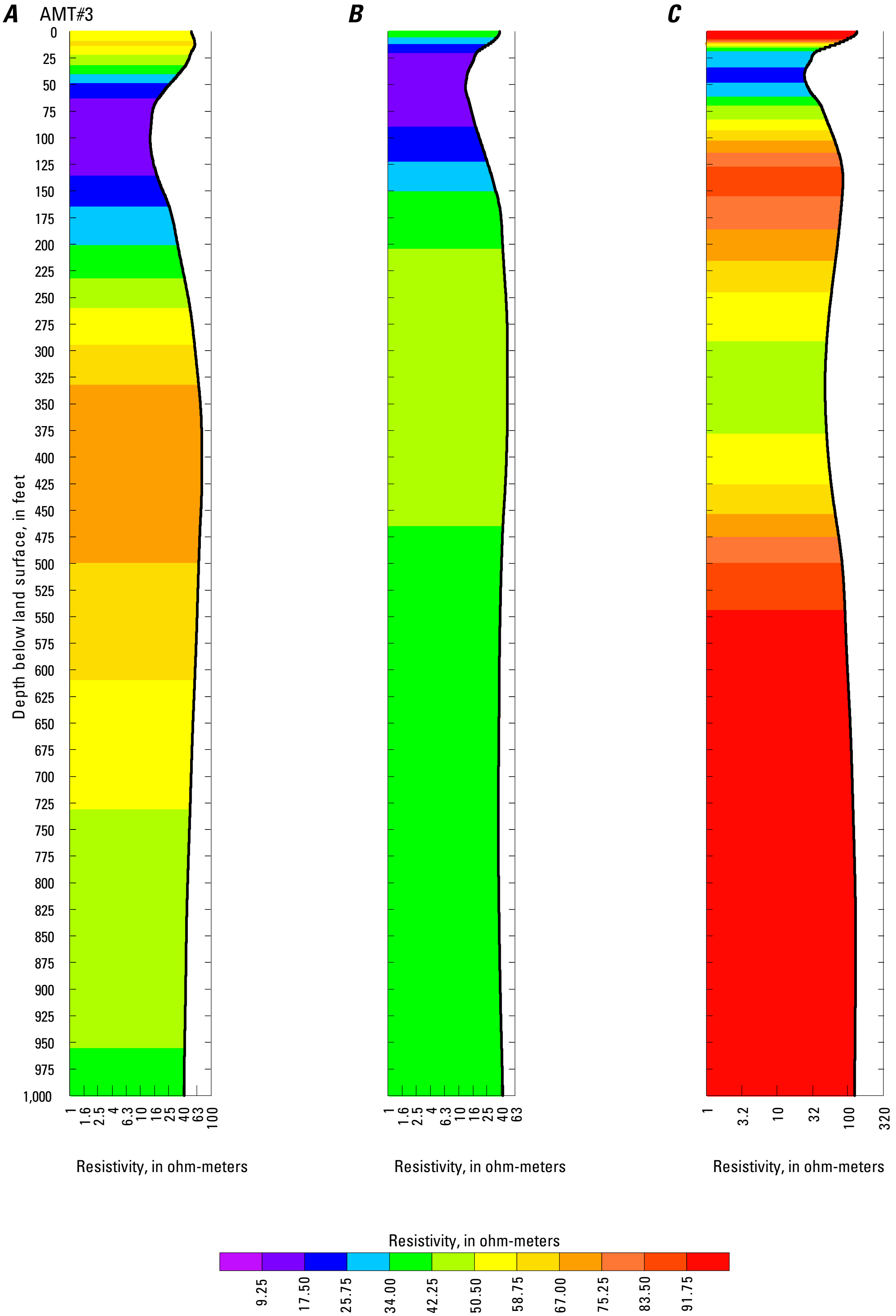


Figure 2.3 Sounding site AMT#3, Jeff Davis County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

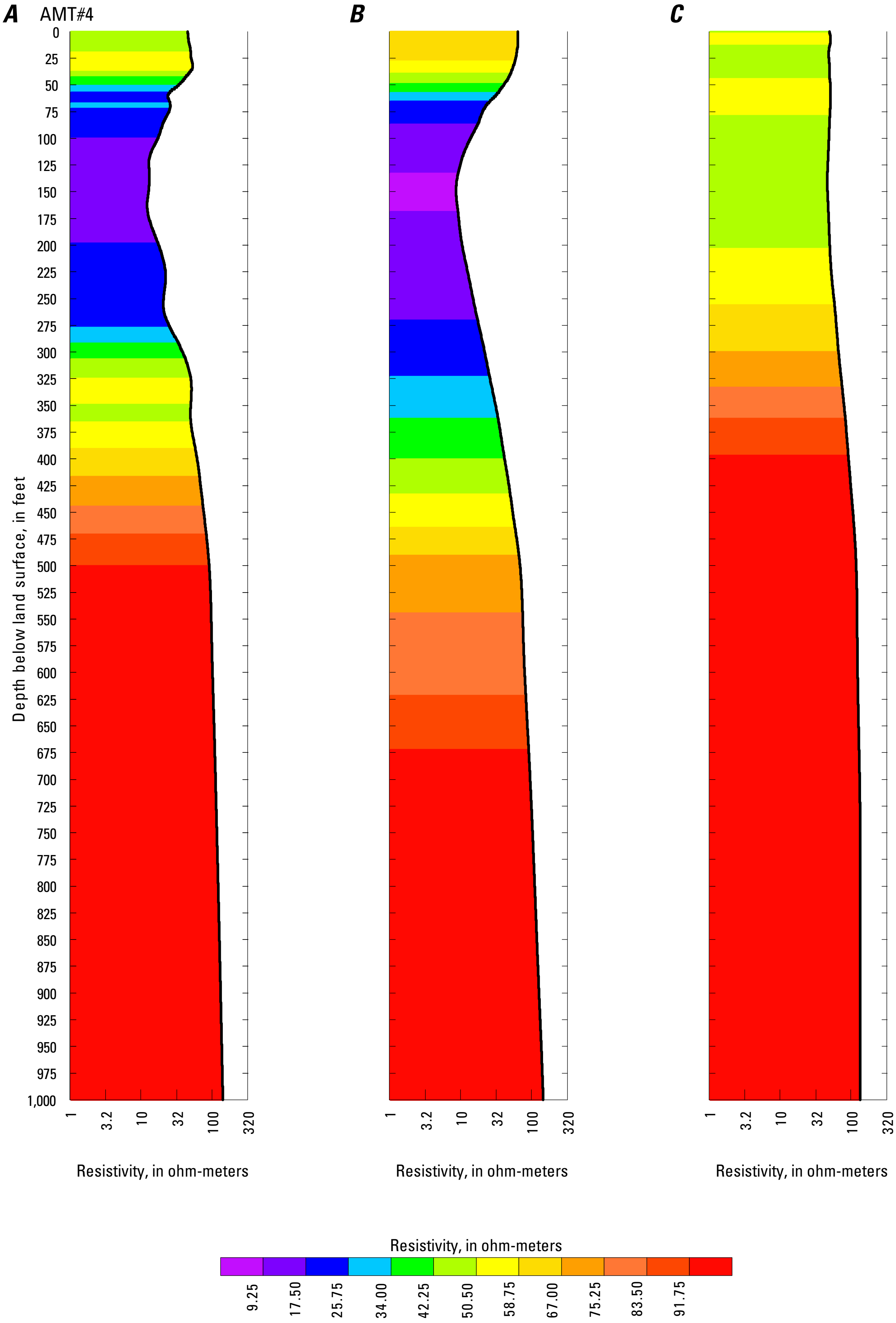


Figure 2.4 Sounding site AMT#4, Pecos County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

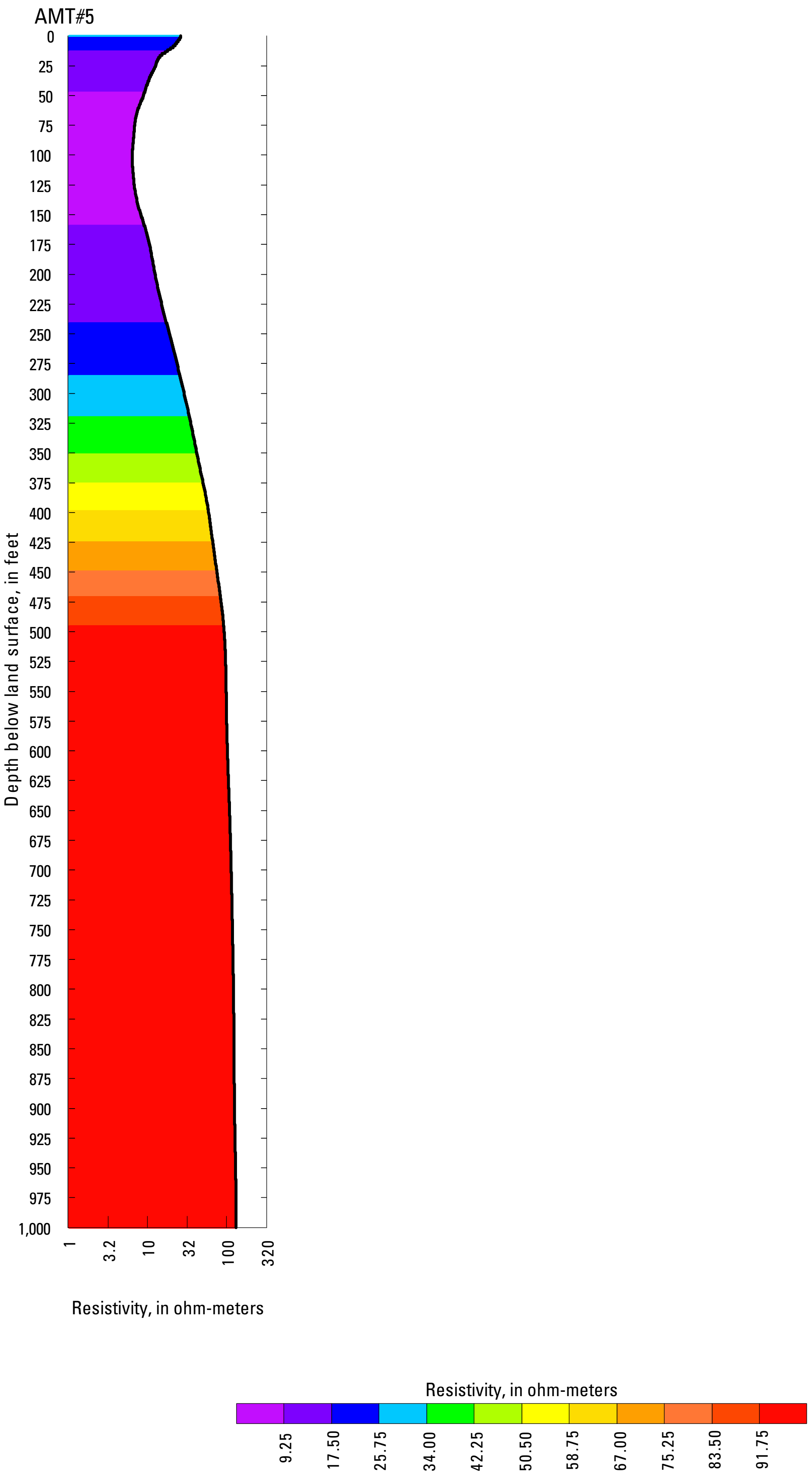


Figure 2.5 Sounding site AMT#5, Pecos County, Texas. Resistivity of mixed mode transverse magnetic and transverse electric responses.

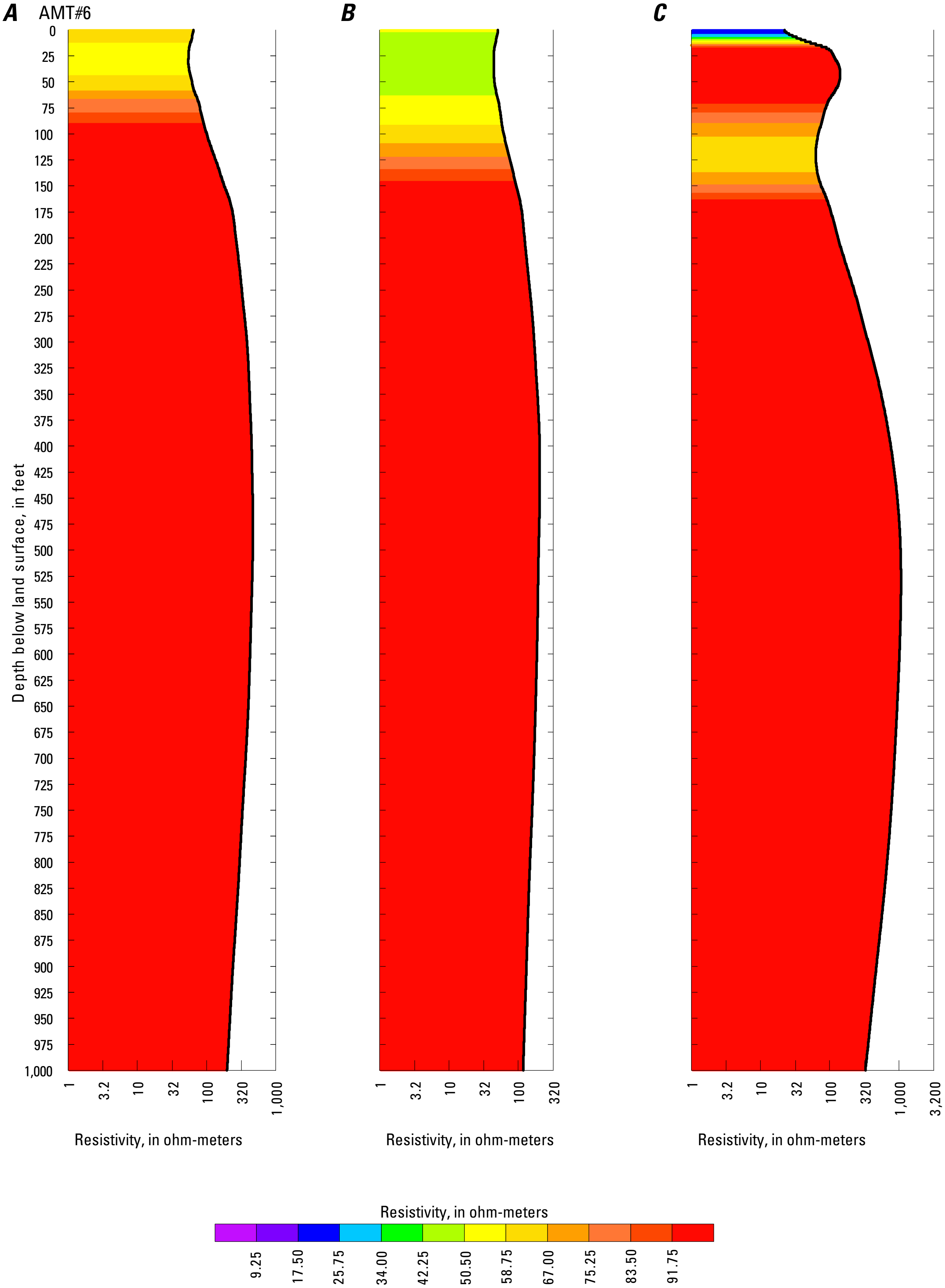


Figure 2.6 Sounding site AMT#6, Pecos County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

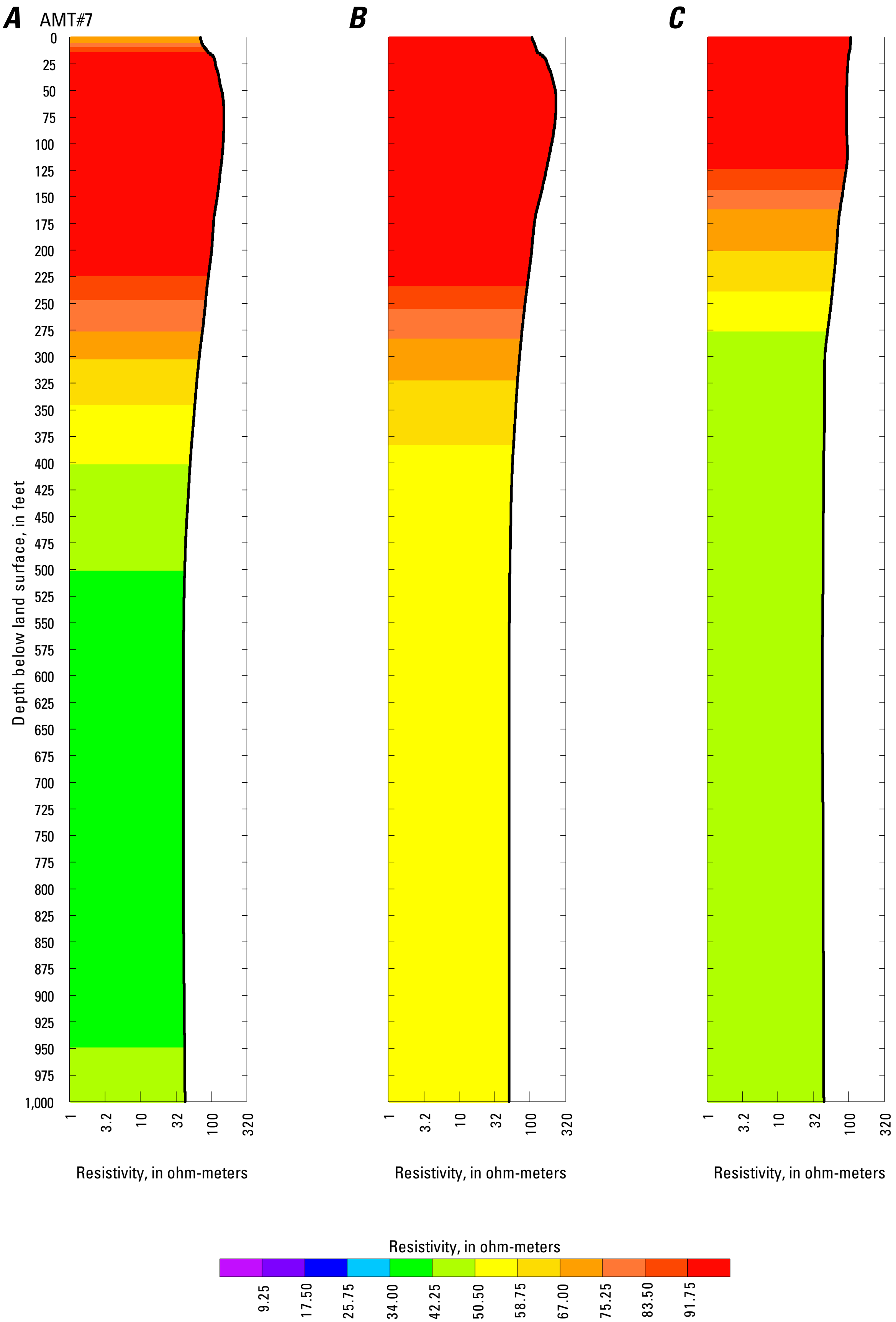


Figure 2.7 Sounding site AMT#7, Pecos County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

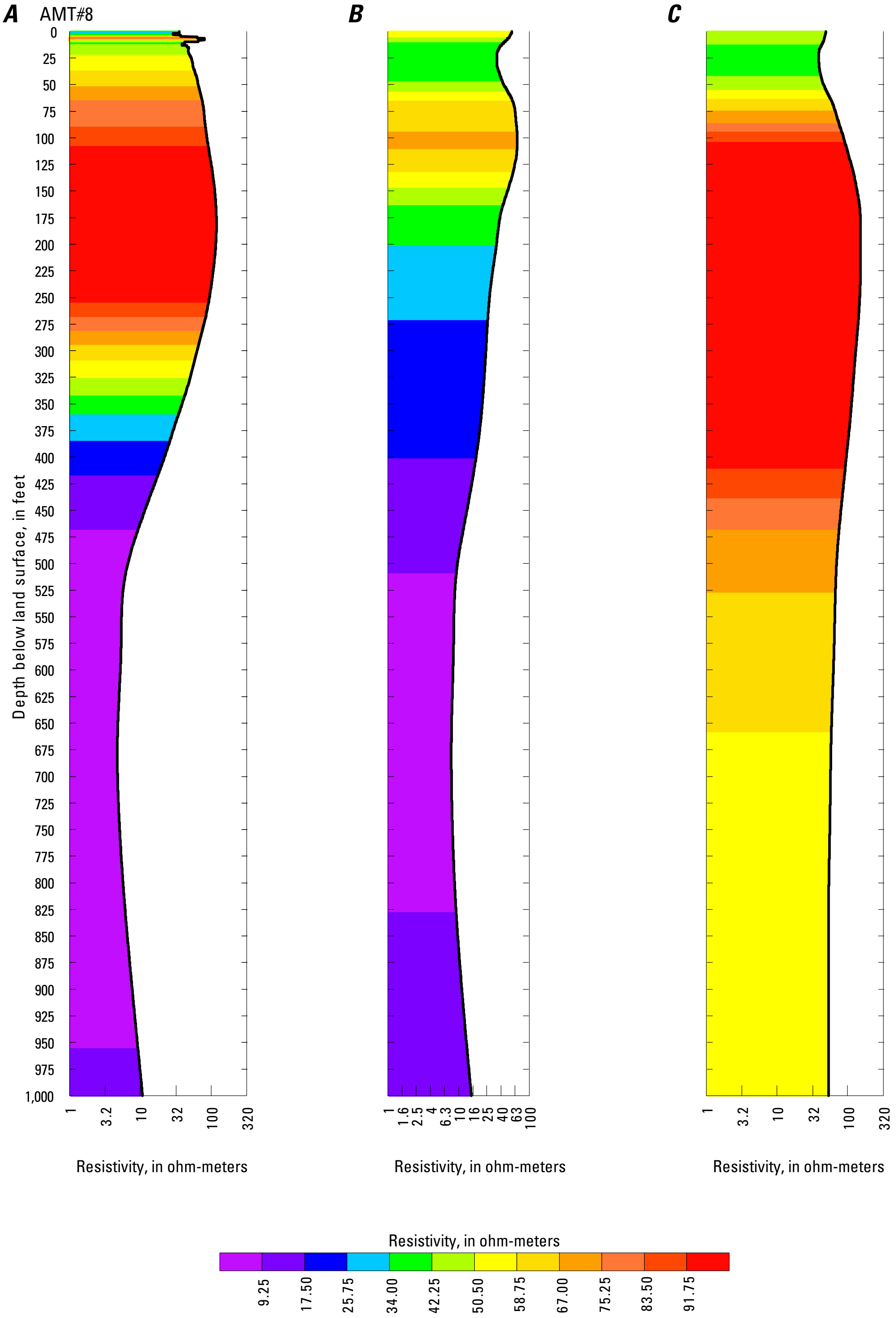


Figure 2.8 Sounding site AMT#8, Pecos County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

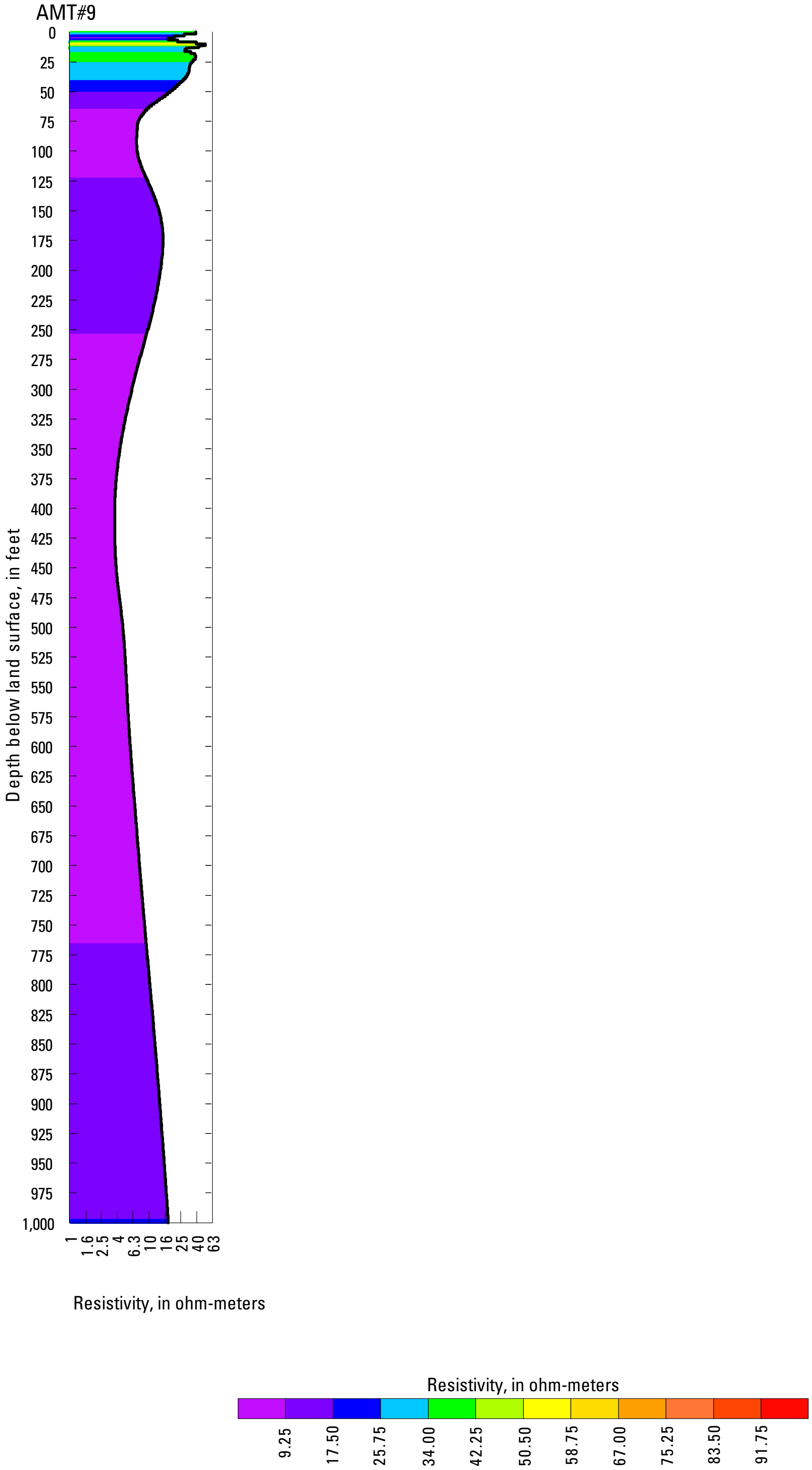
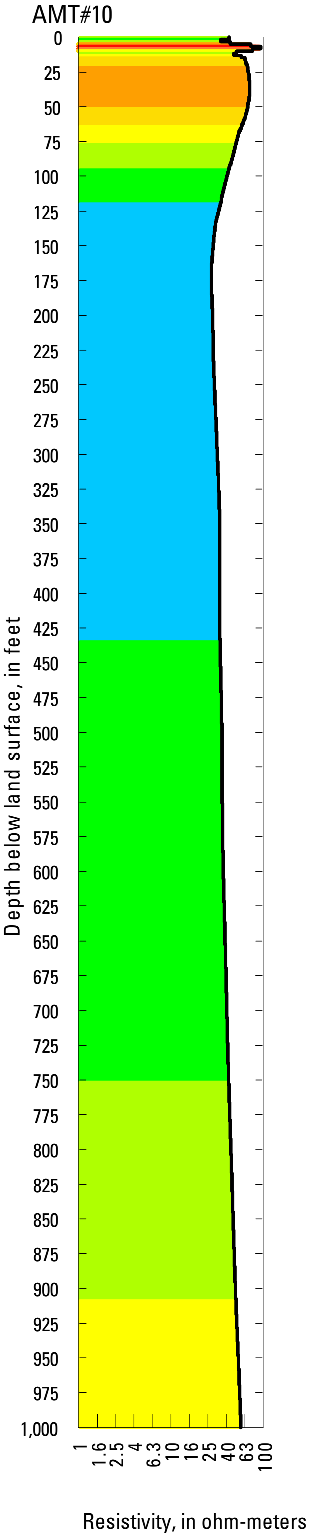


Figure 2.9 Sounding site AMT#9, Pecos County, Texas. Resistivity of mixed mode transverse magnetic and transverse electric responses.



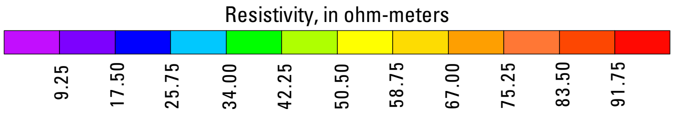


Figure 2.10 Sounding site AMT#10, Pecos County, Texas. Resistivity of mixed mode transverse magnetic and transverse electric responses.

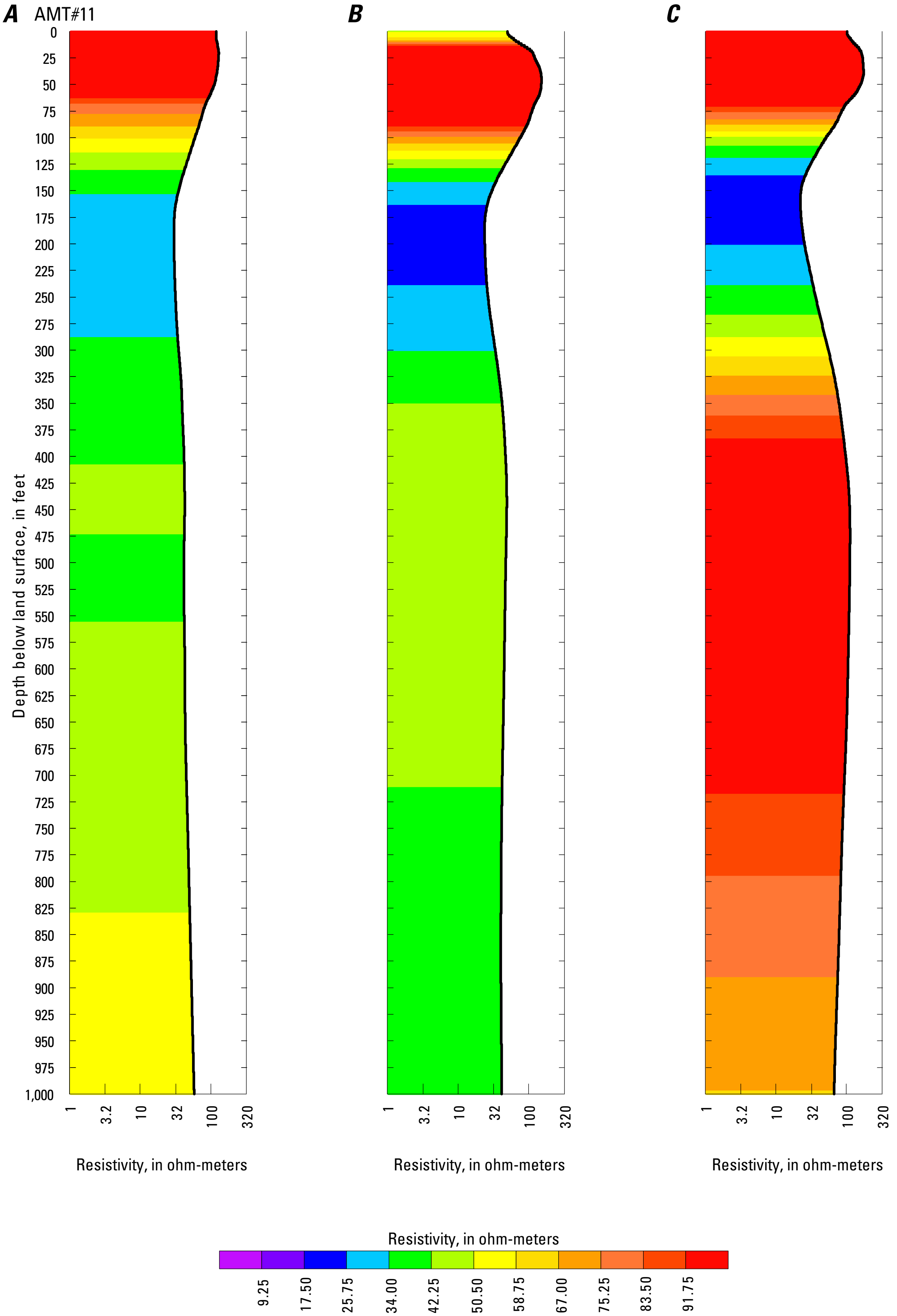


Figure 2.11 Sounding site AMT#11, Pecos County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

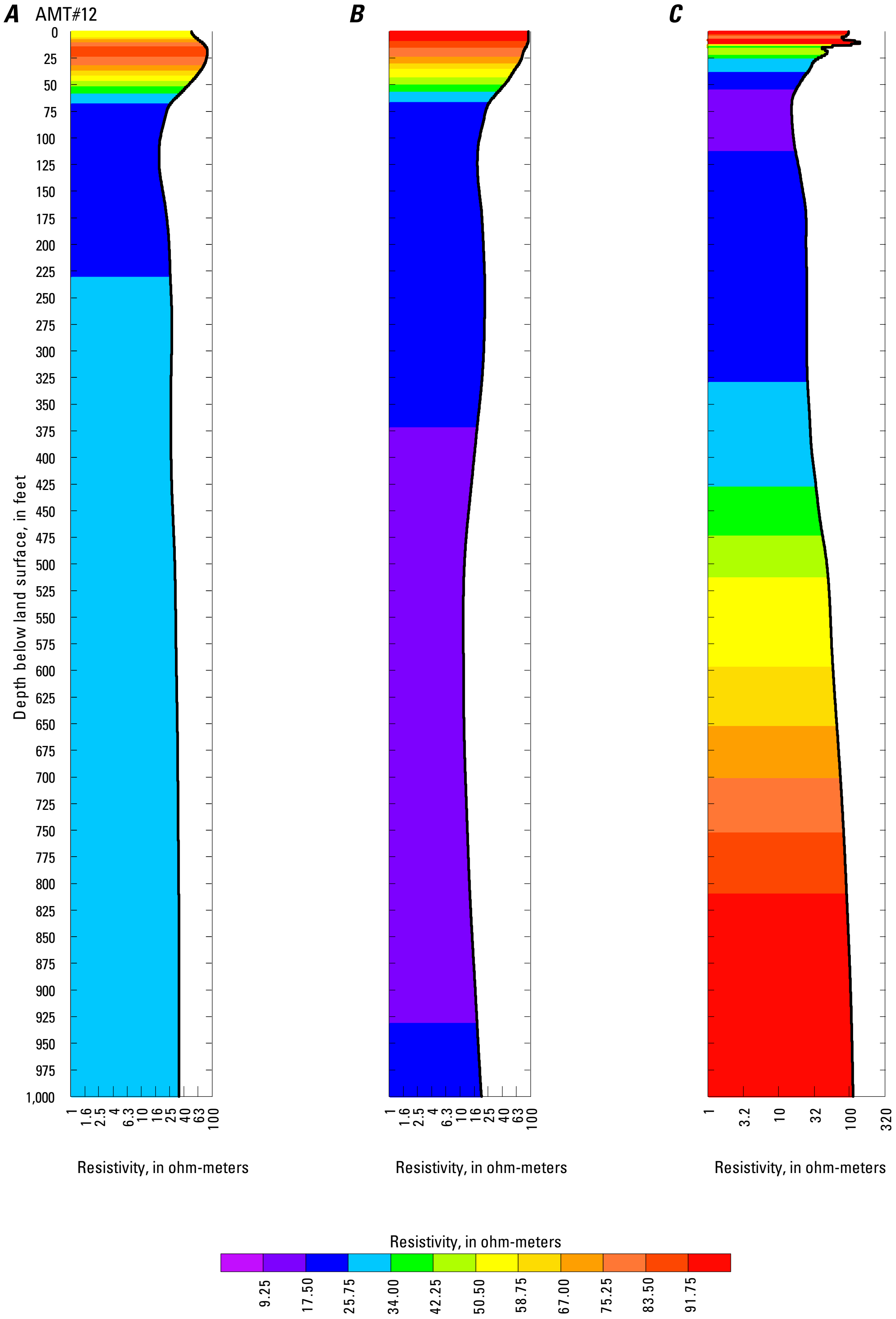


Figure 2.12 Sounding site AMT#12, Reeves County, Texas. *A*, Resistivity of mixed mode transverse magnetic and transverse electric responses. *B*, Resistivity of transverse electric response. *C*, Resistivity of transverse magnetic response.

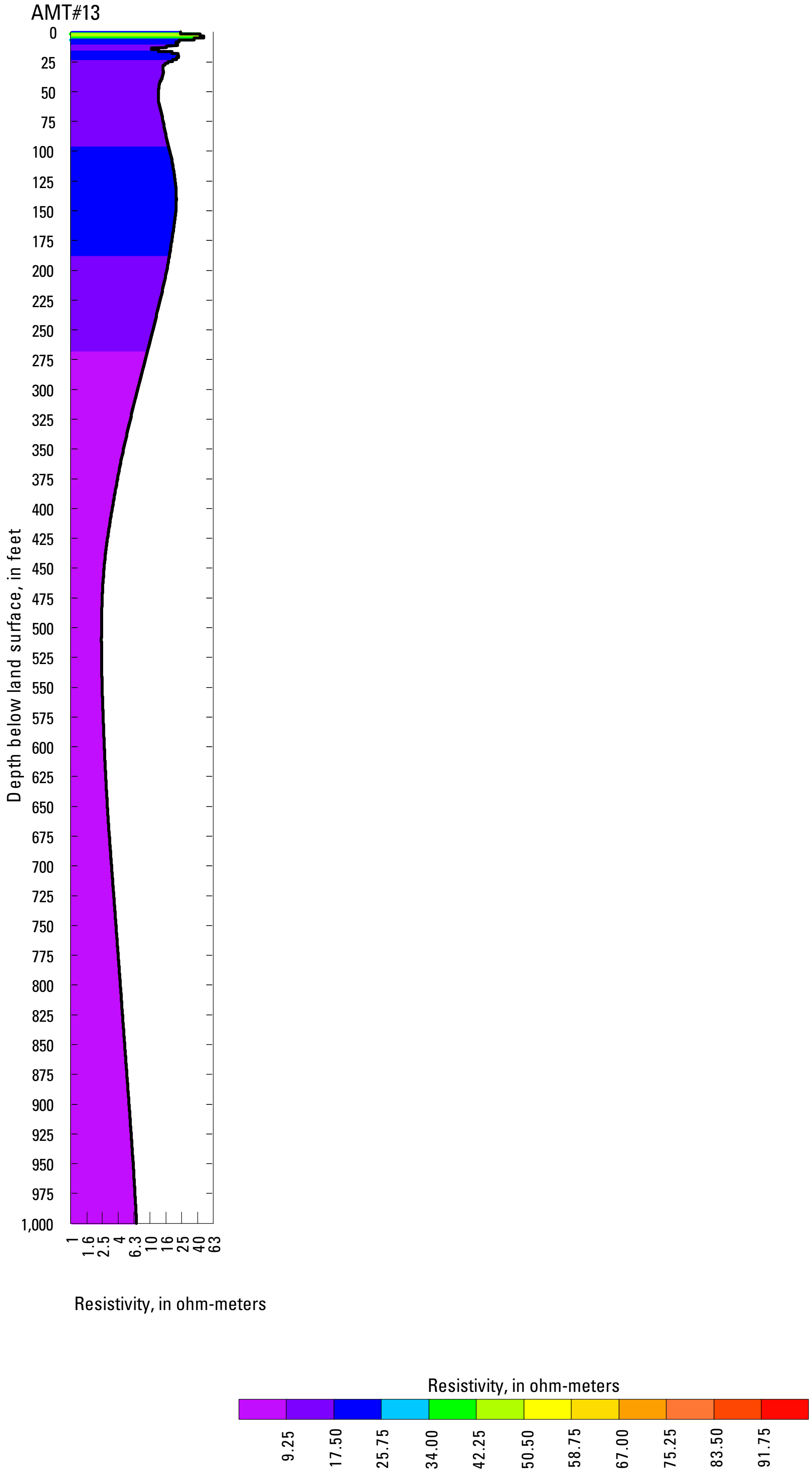


Figure 2.13 Sounding site AMT#13, Jeff Davis County, Texas. Resistivity of mixed mode transverse magnetic and transverse elctric responses.

Appendix 3. Digital Database Resources

Source: U.S. Environmental Protection Agency STORET Modern
Processing: Created sample table. Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: Downloadable data- http://www.epa.gov/storet/
Water-Quality Date Range: 8/15/1996 – 6/15/2011
Number of sites: 7

Source: Middle Pecos Groundwater Conservation District
Processing: Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: File transfer protocol or other direct access
Water-Quality Date Range: no data available
Number of Sites: 33

Source: Texas Commission on Environmental Quality , Surface Water Quality Information System
Processing: Created sample table. Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: File transfer protocol or other direct access
Water-Quality Date Range: 9/5/1968 – 8/24/1992
Number of Sites: 13

Source: Texas Railroad Commission
Processing: Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: Downloadable data- http://www.rrc.state.tx.us/data/online/oilgasrecords.php
(Texas Railroad Commission, 2011)
Water-Quality Date Range: no data available
Number of Sites: 6220

Source: Texas Water Development Board Groundwater Database (GWDB)
Processing: Created sample table. Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: Downloadable data- http://www.twdb.state.tx.us/groundwater/data/gwdbrpt.asp
Water-Quality Date Range: 10/2/1930–4/30/2009
Number of Sites: 1065

Source: U.S. Geological Survey, National Water Information System
Processing: Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: File transfer protocol or other direct access
Water-Quality Date Range: 4/7/1932–6/23/2011
Number of Sites: 81

Source: University of Texas System Lands
Processing: Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: Downloadable data- http://www.utlands.utsystem.edu/WellSearchInfo.aspx
(University of Texas System Lands, 2011)
Water-Quality Date Range: no data available
Number of Sites: 823

Source: City of Fort Stockton Well Locations (Domestic and Municipal)
Processing: Created unique site identifier by prefixing site_id assigned by sourcing agency with site_abv.
Data Origination: File transfer protocol or other direct access
Water-Quality Date Range: no data available
Number of Sites: 281

Source: Daniel B. Stephens and Associates (Capitan Reef Study)
Processing: Data compiled from digital media included previously published geologic formation picks
Data Origination: File transfer protocol or other direct access
Water-Quality Date Range: no data available
Number of Sites: 153

Source: Texas Water Development Board Brackish Resources Aquifer Characterization System
Processing: Data compiled from digital media included previously published geologic formation picks
Data Origination: File transfer protocol or other direct access (Meyer and others, 2011)
Water-Quality Date Range: no data available
Number of Sites: 153

Appendix 4. Federal Geographic Data Committee-Compliant Metadata Record

Identification_Information
Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: 20111101
Title: Data Collection and Compilation for a Geodatabase, Pecos County Region, Texas, 1930–2011
Region, Texas, 2011
Geospatial_Data_Presentation_Form: vector digital data

Description:

Abstract: The U.S. Geological Survey, 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, developed a geodatabase of available groundwater, surface-water, water-quality, geophysical, and geology data for site locations in the Pecos County region, Texas. Data were compiled for an approximately 4,700 square mile area of the Pecos County region, Texas. The geodatabase, designed to warehouse field-collected geochemical and geophysical data, as well as digital database resources from the U.S. Geological Survey, Middle Pecos Groundwater Conservation District, Texas Water Development Board, Texas Commission on Environmental Quality, and numerous other State and local databases, contains 8,242 unique sampling locations. The geodatabase was used to combine these disparate database resources into a simple data model. Site locations are geospatially-enabled and stored in a geodatabase feature class for general mapping purposes and more rigorous spatial analysis. The sampling locations are related to the hydrogeologic information through the use of geodatabase relationship classes. The geodatabase relationship classes provide the ability to perform complex spatial and data-driven queries to explore data stored in the geodatabase.

Purpose: The purpose of this report is to provide information on data acquisition and geodatabase compilation of hydrogeologic data, Pecos County region, Texas. Groundwater, surface-water, water-quality, geophysical, and geologic information for more than 8,000 sampling locations were compiled from various digital data sources in the study area. Digital data sources were gathered from existing databases, previously published reports, and field-collected data.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2011
Currentness_Reference: 1930–2011
Status:
Progress: On-going
Maintenance_and_Update_Frequency: None Planned
Spatial_Domain:
Bounding_Coordinate:
West_Bounding_Coordinate: -103.903888
East_Bounding_Coordinate: -101.816520
North_Bounding_Coordinate: 31.420552
South_Bounding_Coordinate: 30.356220

Keywords:
Theme:
Theme_Keyword: hydrogeology
Theme_Keyword: groundwater
Theme_Keyword: surface water
Theme_Keyword: water quality
Theme_Keyword: geology
Place:
Place_Keyword: Pecos County region
Place_Keyword: Trans-Pecos
Place_Keyword: Pecos County
Place_Keyword: Reeves County
Place_Keyword: Jeff Davis County
Place_Keyword: Brewster County
Place_Keyword: Terrell County
Place_Keyword: Crane County
Place_Keyword: Ward County
Place_Keyword: Crockett County

Use_Constraints: These data are for informational purposes only. These data have not received Bureau approval and as such are provisional and subject to revision. The data are released on the condition that neither the U.S. Geological Survey, its cooperators, nor the U.S. Government may be held liable for any damages resulting from its authorized or unauthorized use. Although these data have been processed successfully on a computer system at the U.S. Geological Survey, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty.
Native_Data_Set_Environment: Microsoft Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcGIS 10.0.0.2414

Data_Quality_Information:
Lineage:
Process_Step:
Process_Description: Geographic locations of groundwater well sites, oil/gas well sites and surface-water sites were gathered from various Federal, State, and local databases. These data were compiled into a simplified feature class that maintains information related to: source agency, site identifier, unique identifier, site code (type), and site name.
Process_Date: 20111101

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 8242

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution: 0.000000
Longitude_Resolution: 0.000000
Geographic_Coordinate_Units: Decimal degrees

Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

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Attribute_Label: OBJECTID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: SHAPE
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: source_nm
Attribute_Definition: Source name.
Attribute:
Attribute_Label: source_abv
Attribute_Definition: Source abbreviation.
Attribute:
Attribute_Label: site_id
Attribute_Definition: Native source identifier.
Attribute:
Attribute_Label: unique_id
Attribute_Definition: Unique identifier is combination of source_abv and site_id fields.
Attribute:
Attribute_Label: site_cd
Attribute_Definition: Site code.

Attribute:
Attribute_Label: site_nm
Attribute_Definition: Site name.

Distribution_Information:
Resource_Description: Downloadable Data
Metadata_Reference_Information:
Metadata_Date: 20111101
Metadata_Contact:
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Contact_Person: Public Information Officer
Contact_Address:
Address_Type: mailing and physical address
Address: 1505 Ferguson Lane
City: Austin
State_or_Province: Texas
Postal_Code: 78754
Country: USA
Contact_Voice_Telephone: 512–927–3500
Contact_Facsimile_Telephone: 512–927–3590
Contact_Electronic_Mail_Address: gs-w-txpublic-info@usgs.gov
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Metadata_Standard_Version: FGDC–STD–001–1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Profile_Name: ESRI Metadata Profile

Prepared by the USGS Lafayette Publishing Service Center

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