Appendix 7.1

Revision of the Boundaries of Selected Aquifers

The sections below describe the details and justifications for changing the boundaries of the Blaine, Bone Spring-Victorio Peak, Edwards (Balcones Fault Zone), Igneous, Lipan, Ogallala, Pecos Valley (formerly Cenozoic Pecos Alluvium), Seymour, and Trinity aquifers. Figure numbers refer to figures in Chapter 7, except for one figure in the discussion of the Igneous Aquifer that is included in this appendix.

Blaine Aquifer

The Blaine Aquifer is a minor aquifer near the Texas Panhandle that consists of the shale, gypsum, anhydrite, salt, and dolomite beds of the Blaine Formation. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, as defined by wells and water quality (total dissolved solids less than 10,000 milligrams per liter). However, a recent internal review shows that additional wells exist in the Blaine Formation to the south of the previous aquifer delineation. These additional wells and the growing relevance of desalination as a water-producing technology have caused TWDB to revisit the boundary.

The new boundary for the Blaine Aquifer (Figure 7.3) is based on water well information, such as well yields, water levels, and water quality, and the digital Geological Atlas of Texas (USGS and TWDB, 2006). The subsurface extent of the aquifer, west of the exposure of the Blaine Formation, includes wells that produce groundwater with total dissolved solids of 10,000 milligrams per liter or less. The subsurface boundary of the Blaine Aquifer to the east includes all wells that draw water from the aquifer regardless of water quality.

More research is needed for the counties in the southern part of the aquifer, especially since desalinating brackish water from the aquifer is a possibility in this area (LBG-Guyton Associates, 2003). More research is also needed on the location of the 10,000-milligrams-per-liter line defining the western subsurface boundary of the aquifer since it is unclear what information was used by TWC (1989) to support the location of this boundary.

Bone Spring-Victorio Peak Aquifer

The Bone Spring-Victorio Peak Aquifer is a minor aquifer in Far West Texas that consists of the Bone Spring and Victorio Peak limestones. Ashworth and Flores (1991) defined the boundary, the same one shown in the 2002 State Water Plan, by the irrigable land overlying the Bone Spring and Victorio Peak limestones, the location of a dominant fault to the south, and the edge of the Salt Basin to the east. However, recent studies have shown that the aquifer has a broader hydrologic connection to the surrounding area than this boundary:

- The same formations that make up the current delineation of the Bone Spring-Victorio Peak Aquifer extend over a much broader area (Mullican and Mace, 2001).
- The Dell Valley area receives groundwater flow not only from the north but also from the west (Mayer, 1995; Mayer and Sharp, 1998).
- A numerical groundwater flow model of the aquifer being developed by El Paso Water Utilities includes a larger area to capture the full hydrologic system (Hutchison, 2002, 2006).

Based on this information, George and others (2005) remapped the extent of the Bone Spring-Victorio Peak Aquifer with the intent of including all of the groundwater that flows into the Dell City area and basing the boundary on geologic and hydrogeologic information instead of the extent of irrigable lands (Figure 7.4). The new boundary is defined on the east by the centerline of the Salt Basin—the original, predevelopment discharge area for the groundwater flow system (Boyd and Kreitler, 1986). The southern boundary follows the Bitterwell Break out of the Salt Basin (Goetz, 1977), a normal fault that reportedly corresponds to a groundwater divide (Nielson and Sharp, 1985; Boyd and Kreitler, 1986). The southern boundary follows the Bitterwell Break in the east and the Babb Flexure, a structural hinge or bend in the rocks, in the west (King, 1965). Because the mapped extent of the Babb Flexure does not reach the state line, the boundary follows a groundwater flow line to the state line based on the water level map of Mayer (1995) and Mayer and Sharp (1998). The northern extent of the aquifer in Texas is then defined by the state line with New Mexico.

Edwards (Balcones Fault Zone) Aquifer

The Edwards (Balcones Fault Zone) Aquifer is a major aquifer in south central Texas that consists of the Kainer and Person formations (Edwards Group) and overlying Georgetown Formation in the San Marcos platform (Rose, 1972); the Devils River Limestone in the Devils River Trend; and the West Nueces, McKnight, and Salmon Peak formations of Lozo and Smith (1964) in the Maverick Basin. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, as defined by the outcrop, the location of presumed groundwater divides, and the subsurface limit of fresh water (water with total dissolved solids less than 1,000 milligrams per liter), sometimes referred to as the "bad water line." However, studies based on well logs (Schultz, 1993, 1994) and drilling (Waugh, 1993, 2005) for the San Antonio segment of the aquifer suggest a different position for the bad water line than previously thought. Based on these studies, the location of the bad water line is now the same as that recognized by the Edwards Aquifer Authority (Figure 7.5). This line is notably different in Medina and Uvalde counties where the aquifer now extends into Frio County and a small part of Zavala County.

Igneous Aquifer

The Igneous Aquifer is a minor aquifer in Far West Texas that consists of igneous rocks in and around the Davis Mountains. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, by the general location of pumping from igneous rocks in the area. This pumping occurred in three areas: an area around Alpine, an area around Fort Davis, and an area around Marfa.

Although the aquifer extent was limited to areas of pumping, the extent of igneous rocks is much broader. The Region E Planning Group, with a grant from TWDB, supported a study by Ashworth and others (2001) to compile hydrogeologic information on the Igneous Aquifer. As part of that study, Ashworth and others (2001) proposed a new boundary for the aquifer. Recognizing that the boundary of the Igneous Aquifer was larger than had been shown, TWDB requested that a broader boundary be used for developing the groundwater availability model for the Igneous Aquifer. Beach and others (2004a), who developed that model, used a broader boundary to capture presumed natural flow boundaries for the Igneous Aquifer. In addition, in work done for the Texas Commission on Environmental Quality on its Source Water Assessment Project, the U.S. Geological Survey recognized a broader boundary for the Igneous Aquifer. The Region E Planning Group includes the broader boundary in its 2006 Regional Water Plan.

For the revised boundary of the Igneous Aquifer, TWDB considered the boundaries used by the U.S. Geological Survey, Ashworth and others (2001), and Beach and others (2004a) (Figure A7.1). The U.S. Geological Survey boundary roughly coincides with the boundary used for the groundwater availability model, although there are some differences in the west, south, and northeast parts of the aquifer.

The new TWDB boundary for the Igneous Aquifer includes contiguous Tertiary igneous rocks but differs slightly from the boundaries of the U.S. Geological Survey and Beach and others (2004a). TWDB defined the revised boundary to include the majority of wells drawing from Tertiary igneous rocks. Large exposures of pre-Tertiary, mainly Cretaceous, rocks were kept outside of the boundary. The revised boundary excludes the northernmost extension of the U.S. Geological Survey boundary in Culberson County since that area consists of mostly Permian rocks (Figure A7.1) and includes areas of Tertiary rocks that are within the Beach and others (2004a) boundary in the northeast part of the study area (Figure A7.1). TWDB included an area in the southwest part of the proposed boundary because the area appears to contain Tertiary igneous rocks overlain by Quaternary sediments (Figure A7.1). This same area was considered part of the Igneous Aquifer in a recent study by Olson (2004). TWDB excluded a small sliver of Permian and Cretaceous rocks because of the area's small size and to simplify the boundary (Figure A7.1).

Lipan Aquifer

The Lipan Aquifer is a minor aquifer in West Texas under San Angelo that consists of the caliche and gravel deposits of the Leona Formation and the underlying Permian sandstone and limestone formations (San Angelo Sandstone, Choza Formation, Bullwagon Dolomite, Vale Formation, Standpipe Limestone, and Arroyo Formation). Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, by the outcrop area of the Leona Formation and included the hydraulically connected Permian rocks underneath the Leona Formation. However, many wells within the current aquifer extent rely on water from the Permian rocks for supply, and the Permian rocks extend beyond the limits of the Leona Formation. In addition, the groundwater availability model for the Lipan Aquifer, in an effort to follow groundwater flow boundaries, extended beyond the current extent of the aquifer (Beach and others, 2004b).

The revised boundary for the Lipan Aquifer includes Quaternary Alluvium outside the present boundary and extends underneath the Edwards-Trinity (Plateau) Aquifer to the south (Figure 7.7). The reason for including Quaternary Alluvium outside the present aquifer boundary is that wells located along the North and Middle Concho rivers to the west are important sources of water in periods of greater rainfall. Also, groundwater from the alluvium in these valleys flows eastward into the Lipan Aquifer as defined in the 2002 State Water Plan (Beach and others, 2004b). By including more alluvium, the Lipan Aquifer coincides with the boundary for the Edwards-Trinity (Plateau) Aquifer to the north, west, and south. To the east the aquifer boundary remains essentially unchanged, occurring at the boundary between the Leona Formation and the Permian Clear Fork Group or Lueders Formation. The boundary to the south is defined by the presumed groundwater divide used in the groundwater availability model (Beach and others, 2004b), which was based on the water level map by Bush and others (1993).

The Lipan Aquifer does not consist of a single rock unit that can be easily traced in outcrop or identified in the subsurface. Instead, the aquifer is made up of seven different formations, mostly covered by alluvium or the Edwards-Trinity (Plateau) Aquifer. Therefore, it is not always clear where the limits of the Lipan Aquifer may be. This poses a problem along the eastern edge of the aquifer where the boundary is covered. The extent of the Lipan Aquifer underneath the Edwards-Trinity (Plateau) Aquifer is unsubstantiated given the small number of wells in this area. Additional well information, perhaps from Lange (1997, 1999) and UCRA (2000), could be used to refine this boundary in the future.

Ogallala Aquifer

The boundary for the Ogallala Aquifer changed when the boundary for the Pecos Valley Aquifer was adjusted (Figure 7.8). Please see the following discussion on the Pecos Valley Aquifer for a description of the change.

Pecos Valley Aquifer (formerly the Cenozoic Pecos Alluvium Aquifer)

The Pecos Valley Aquifer—formerly the Cenozoic Pecos Alluvium Aquifer—is a major aquifer in the Pecos River Basin of West Texas that consists of sand, gravel, and clay deposits. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, as defined by the extent of unconsolidated deposits in the Pecos and Monument Draw troughs. However, recent groundwater availability modeling projects (Anaya and Jones, 2004, and ongoing TWDB work on a model for the Pecos Valley Aquifer) suggest that the boundaries should be revised.

The Pecos Valley Aquifer is composed of the Quaternary alluvial and eolian (windblown) sediments that occur in the Pecos River Valley filling the Pecos and Monument Draw troughs. The boundaries of the aquifer are determined by the occurrence of structural highs along the margins of the aquifer that form barriers to groundwater flow and the pinch out of unconsolidated sediments in the troughs. The base of the aquifer is the top of the geologic units immediately underlying the alluvial/eolian sediments. These geologic units also constitute the Edwards-Trinity (Plateau) Aquifer in the south, the Rustler Formation in the west, and the Dockum Group in the east.

The Pecos Valley Aquifer boundaries differ from those of the Cenozoic Pecos Alluvium Aquifer in two ways. First, the boundary between the Ogallala Aquifer and the Pecos Valley Aquifer is different in Andrews County (Figure 7.8). The new boundary coincides with the surface water divide between the Rio Grande and Colorado River basins. This boundary also coincides with the axis of a structural high, the Central Basin Platform (Howard and Williams, 1972; Ruppel, 1983), and was the official TWDB aquifer boundary prior to 1990 (TWDB, 1984). TWDB revised aquifer boundaries in the late 1980s in response to the completed Texas geologic atlas (Ashworth and Flores, 1991). Prior to 1990, the boundary of the Cenozoic Pecos Alluvium in Andrews County followed the surface water divide. In 1990, Ashworth and Flores (1991) changed the boundary so that it approximately followed the western pinch out of the Ogallala Formation.

The other boundary change extends the aquifer to include parts of Loving, Winkler, Ward, Pecos, and Crane counties where the alluvium is thin. Adding these previously excluded areas allows for more realistic interaction between the Pecos Valley Aquifer and the Pecos River in groundwater flow models (Figure 7.8). In addition, the new aquifer boundary better represents the geology as indicated by the 1:250,000 maps of the Geologic Atlas of Texas (Eifler and Barnes, 1976; Eifler and others, 1976; Anderson and others, 1982).

TWDB also changed the name from the Cenozoic Pecos Alluvium Aquifer to the Pecos Valley Aquifer. "Cenozoic" was removed because it is now recognized that it is not advisable to attach a time-stratigraphic name (such as "Cenozoic") to an aquifer name (Hansen, 1991). "Alluvium" was removed because the aquifer consists of both alluvial and eolian deposits. TWDB added "Valley" to provide a geographic reference to the name.

Seymour Aquifer

The Seymour Aquifer is a major aquifer in North Texas that consists of gravel, conglomerate, sand, and silty clay beds of the Seymour Formation, the Lingos Formation, and younger alluvial deposits. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, as defined by surface extent of alluvium, well development, and usage. However, initial analysis and a recent groundwater availability modeling project (Ewing and others, 2004) suggests that not all of the previously delineated Seymour Aquifer holds water.

Aware of reports that not all of the mapped Seymour Aquifer held water, TWDB reviewed well information to determine which parts of the aquifer hold water and which parts do not. This review was done prior to developing the groundwater availability model for the Seymour Aquifer. In the process of developing the model, additional changes were made to the aquifer's extent. Therefore, TWDB has changed the boundary so that only those sediments that are known to hold groundwater are part of the Seymour Aquifer (Figure 7.9).

Trinity Aquifer

The Trinity Aquifer is a major aquifer in Central and north central Texas that consists of sand, limestone, silty clay, and conglomerate. Ashworth and Flores (1991) described the boundary, the same one shown in the 2002 State Water Plan, as defined by all water-bearing basal Cretaceous units. The Trinity Aquifer extends beneath the Edwards (Balcones Fault Zone) Aquifer ending in the subsurface toward the west in eastern Uvalde County. This subsurface boundary in Uvalde County appears to coincide with the Sabinal River and, therefore, has a great amount of sinuosity and detail.

Groundwater in the Trinity Aquifer in Uvalde County presumably flows beneath the Edwards (Balcones Fault Zone) Aquifer toward the south, in the same direction of the Sabinal River, which is probably why TWDB chose the river as the subsurface boundary of the aquifer. However, the boundary—as shown in Ashworth and Hopkins (1995)—has much greater detail than what is known about the groundwater flow line. Therefore, TWDB has smoothed the shape of this line to better reflect the knowledge of its position (Figure 7.10).

The position of this line in Uvalde County is somewhat arbitrary and open to interpretation. Although not shown on current maps, the water-bearing rocks of the Trinity Group also exist underneath the Edwards (Balcones Fault Zone) Aquifer in the rest of Uvalde County and the eastern part of Kinney County. One reason these water-bearing rocks are not included as part of an aquifer is because this area is where the Trinity, Edwards (Balcones Fault Zone), and Edwards-Trinity (Plateau) aquifers converge, and it is unclear which aquifer these rocks should be assigned to. Another reason is that there have not been any studies on the limit of the aquifer in these parts of Uvalde and Kinney counties similar to what was done in Bexar County (Duffin, 1974).

References

Anaya, R., and Jones, I.C., 2004, Groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifer systems, Texas: Texas Water Development Board, unpublished report, 208 p.

Anderson, J.E., Jr., Brown, J.B., Gries, J.C., Lovejoy, E.M.P., McKalips, D., and Barnes, V.E., 1982, Fort Stockton sheet: Bureau of Economic Geology, Geologic Atlas of Texas, Charles Laurence Baker Memorial Edition, scale 1:250,000, 1 sheet.

Ashworth, J.B., Chastain-Howley, A., Urbanczyk, K.M., Standen, A.R., and Darling, B. K., 2001, Igneous aquifer system of Brewster, Jeff Davis, and Presidio counties, Texas: Contract report prepared for the Far West Texas Regional Water Planning Group, 47 p.

Ashworth, J.B., and Flores, R.R., 1991, Delineation criteria for the major and minor aquifer maps of Texas: Texas Water Development Board Limited Publication 212, 27 p.

Ashworth, J.B., and Hopkins, J., 1995, Minor and major aquifers of Texas: Texas Water Development Board Report 345, 66 p.

Beach, J.A., Ashworth, J.B., Finch, S.T., Jr., Chastain-Howley, A., Calhoun, K., Urbanczyk, K.M., Sharp, J.M., and Olson, J., 2004a, Groundwater availability model for the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat and Lobo Flat) aquifers: Contract report prepared for the Texas Water Development Board by LBG-Guyton and Associates (prime contractor), variously paginated.

Beach, J.A., Burton, S., and Kolarik, B., 2004b, Groundwater availability model for the Lipan Aquifer in Texas: Contract report prepared for the Texas Water Development Board by LBG-Guyton and Associates, variously paginated.

Boyd, F.M., and Kreitler, C.W., 1986, Hydrogeology of a gypsum playa, northern Salt Basin, Texas: El Paso Geological Society, Guidebook 18, p. 170–183.

Bush, P.W., Ardis, A.F., and Wynn, K.H., 1993, Historical potentiometric surface of the Edwards-Trinity Aquifer System and contiguous hydraulically connected units, West-Central Texas: U.S. Geological Survey, Water-Resources Investigations Report 92-4055, 3 maps.

Duffin, G., 1974, Subsurface saline water resources in the San Antonio area, Texas: Texas Water Development Board Open File Report, 23 p.

Eifler, G.K., Jr., Reeves, C.C., Jr., and Barnes, V.E., 1976, Hobbs sheet: Bureau of Economic Geology, Geologic Atlas of Texas, William Battle Phillips Memorial Edition, scale 1:250,000, 1 sheet.

Eifler, G.K., and Barnes, V.E., 1976, Pecos sheet: Bureau of Economic Geology, Geologic Atlas of Texas, Johan August Udden Memorial Edition, scale 1:250,000, 1 sheet.

Ewing, J.E., Jones, T.L., Pickens, J.F., Chastain-Howley, A., Dean, K.E., and Spear, A.A., 2004, Groundwater availability model for the Seymour Aquifer: Contract report to the Texas Water Development Board by Intera, Inc. (prime contractor), variously paginated.

George, P., Mace, R.E., and Mullican, W.F., III, 2005, The hydrogeology of Hudspeth County, Texas: Texas Water Development Board Report 364, 95 p.

Goetz, L.K., 1977, Quaternary faulting in Salt Basin grabens, West Texas: Unpublished M.A. thesis, The University of Texas at Austin, 136 p.

Hansen, W.R., 1991, Suggestions to authors of the reports of the United States Geologic Survey, seventh edition: U.S. Government Printing Office, 289 p.

Howard, A.D., and Williams, J.W., 1972, Physiography *in* Geologic atlas of the Rocky Mountain region, United States of America: Rocky Mountain Association of Geologists, Denver, Colorado, p. 29–31.

Hutchison, W.R., 2002, Development of a preliminary groundwater flow model for the Dell City area, Texas: Association of Engineering Geologists/American Institute of Professional Geologists Annual Meeting—Gambling with Geologic Hazards and Dealing with Sustainability, September 26, 2002, Reno, Nevada.

Hutchison, W.R., 2006, Groundwater management in El Paso, Texas: Ph.D. Dissertation, The University of Texas at El Paso, 345 p.

King, P.B., 1965, Geology of the Sierra Diablo region, Texas: U.S. Geological Survey Professional Paper 480, 185 p.

Lange, A.J., 1997, Hydrogeology and water quality of the Lipan Aquifer: Lipan-Kickapoo Water Conservation District, 56 p.

Lange, A.J., 1999, Water levels and water quality of the Lipan Aquifer: Lipan-Kickapoo Water Conservation District, 64 p.

LBG-Guyton Associates, 2003, Brackish groundwater manual for Texas regional water planning groups: Contract report prepared for the Texas Water Development Board, 188 p.

Leggatt, E.R., 1957, Geology and ground-water resources of Tarrant County, Texas: Texas Board of Water Engineers Bulletin 5709, 187 p.

Lozo, F.E., Jr., and Smith, C.I., 1964, Revision of Comanche Cretaceous stratigraphic nomenclature, southern Edwards Plateau, southwest Texas: Gulf Coast Association of Geological Societies Transactions, v. 14, p. 285–306.

Mayer, J.R., 1995, The role of fractures in regional groundwater flow—Field evidence and model results from the basin and range of Texas and New Mexico: Unpublished Ph.D. dissertation, The University of Texas at Austin, 221 p.

Mayer, J.M., and Sharp, J.M., Jr., 1998, Fracture control of regional ground-water flow in a carbonate aquifer in a semi-arid region: Geological Society of America Bulletin, v. 110, p. 269–283.

Mullican, W.F., III, and Mace, R.E., 2001, The Diablo Plateau Aquifer *in* Mace, R.E., Mullican, W.F., III, and Angle, E.A., eds., Aquifers of West Texas: Texas Water Development Board Report 356, p. 257–267.

Olson, J., 2004, The Igneous aquifers of West Texas: Unpublished report sent to the Texas Water Development Board, 45 p.

Nielson, P.D., and Sharp, J.M., 1985, Tectonic controls on the hydrogeology of the Salt Basin, Trans-Pecos Texas *in* Dickerson, P.W., and Muehlberger, W.R., eds., Structure and tectonics of Trans-Pecos Texas: West Texas Geological Society Publication 85-81, p. 231–234.

Rose, P.R., 1972, Edwards Group, surface and subsurface, central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 74, 198 p.

Ruppel, S.C., 1983, Facies and depositional setting of Mississippian rocks in the Palo Duro-Hardeman Basin area *in* Shaw, R.L., and Poulan, B.J., eds., Permian Basin cores—A core workshop: Permian Basin Section of the Society of Economic Paleontologists and Mineralogists Core Workshop No. 2, p. 47–68.

Schultz, A.L., 1993, Defining the Edwards Aquifer freshwater/saline-water interface with geophysical logs and measured data (San Antonio to Kyle, Texas): Edwards Underground Water District Report 93-06, 81 p.

Schultz, A.L., 1994, 1994 review and update of the position of the Edwards Aquifer freshwater/saline-water interface from Uvalde to Kyle, Texas: Edwards Underground Water District Report 94-05, 31 p.

TWC (Texas Water Commission), 1989, Ground-water quality of Texas—An overview of natural and man-affected conditions: Texas Water Commission Report 89-01, 197 p.

TWDB (Texas Water Development Board), 1984, Water for Texas—A comprehensive plan for the future: Texas Water Development Board Document Number GP-4-1, 81 p.

UCRA (Upper Colorado River Authority), 2000, High levels of nitrates in ground water within the Lipan Aquifer, Tom Green and Concho counties and the effects on surface water quality: Upper Colorado River Authority Clean Rivers Program Special Study, http://www.lcra.org/crp/crpconcho_study.html.

USGS (U.S. Geological Survey) and TWDB (Texas Water Development Board), 2006, Digital geologic atlas of Texas: Austin, TX, U.S. Geological Survey and Texas Water Development Board, Arc shapefiles, available through the Texas Natural Resources Information System, Austin, TX.

Waugh, J.R., 1993, South Medina County observation well project: Edwards Underground Water District Report 93-11.

Waugh, J.R., 2005, San Antonio Water System saline water study: The Fountainhead, Texas Ground Water Association, 4th issue, p. 3, 10–11.

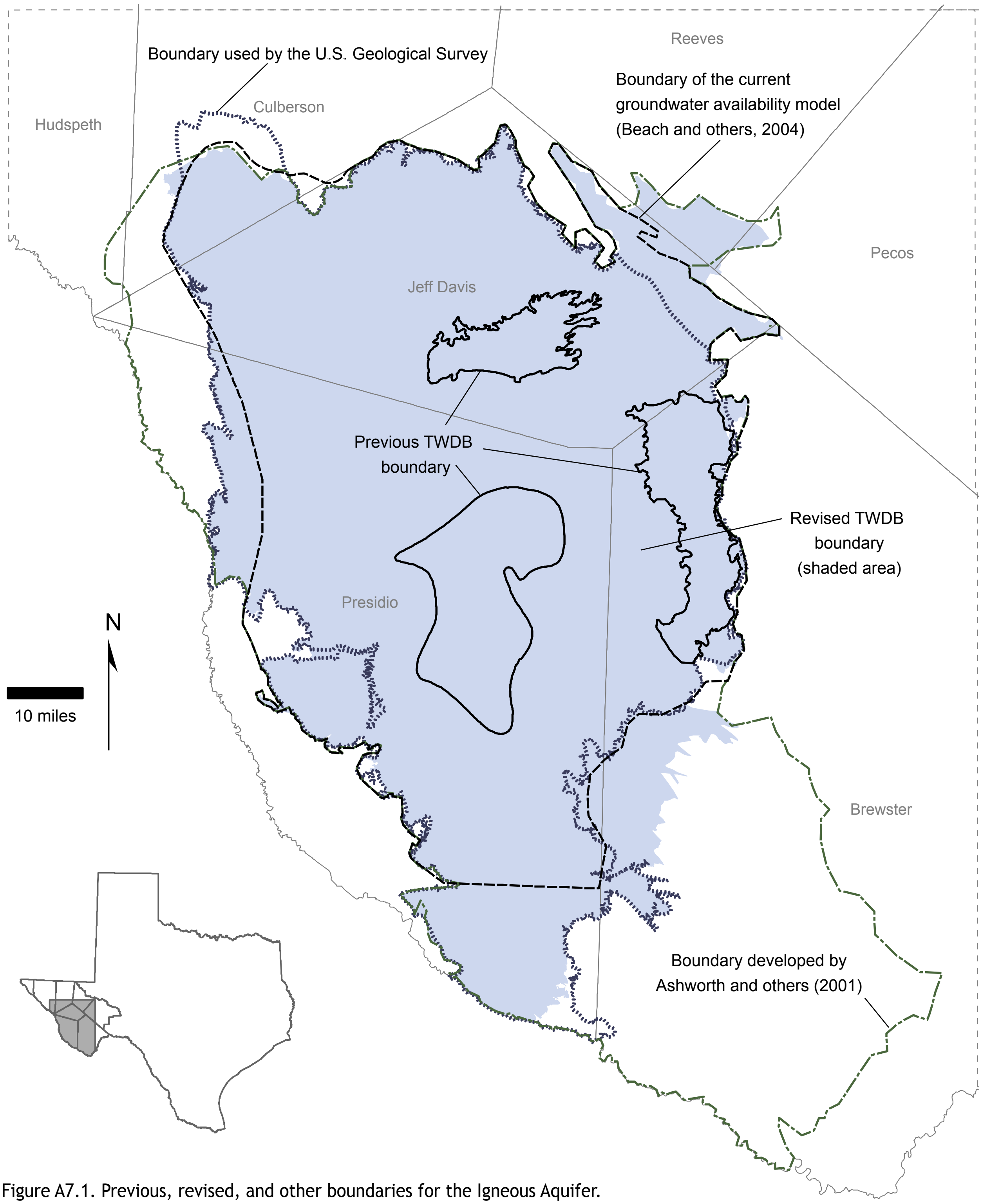

Figure A7.1. Previous, revised, and other boundaries for the Igneous Aquifer.