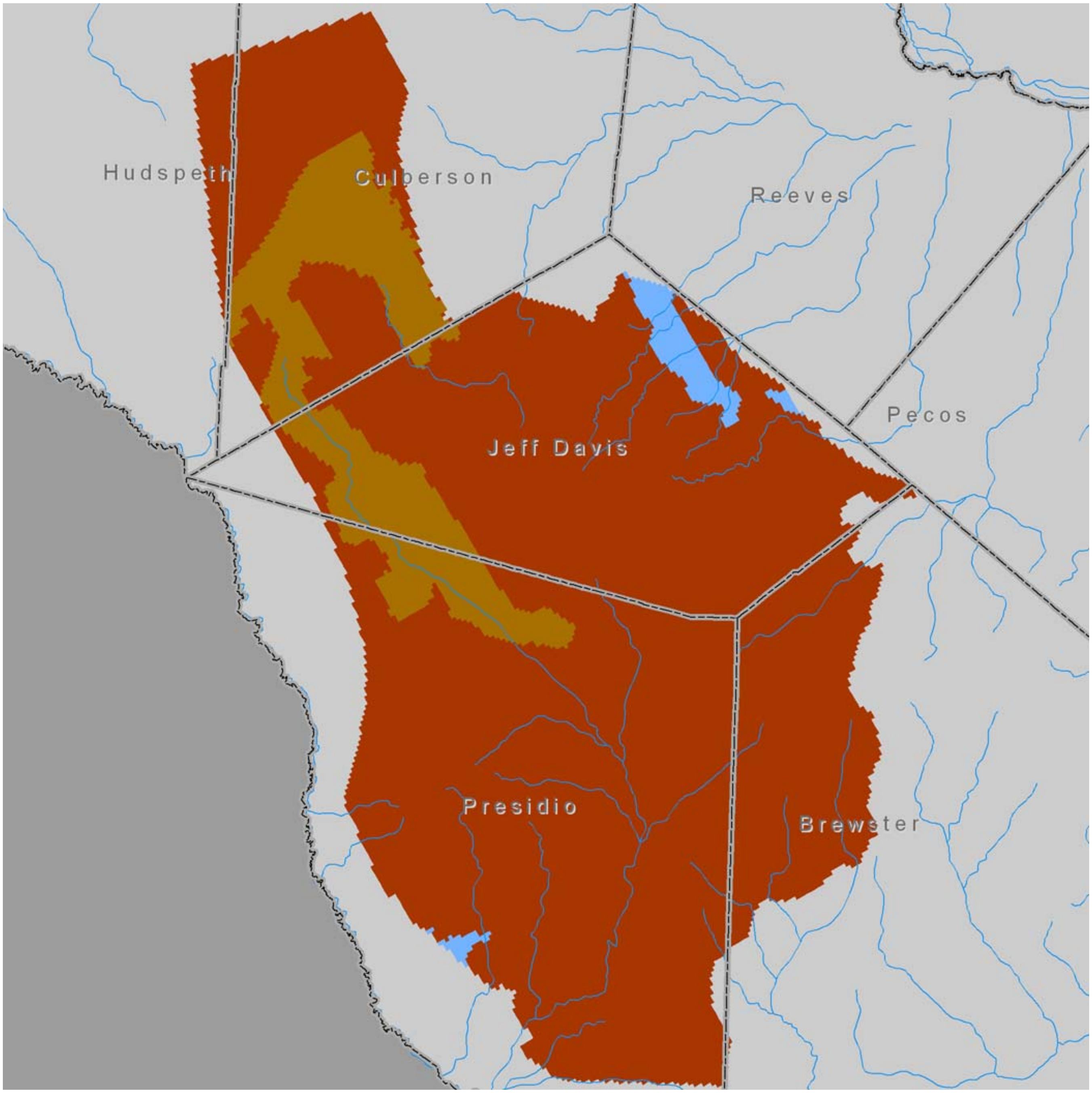

QuickReference

for the Groundwater Availability Model

of the Igneous and parts of West Texas Bolsons Aquifers

QuickReference for the Groundwater Availability Model of the Igneous and parts of West Texas Bolsons Aquifers

September 18, 2009

Purpose: This reference guide is intended to assist people with using the GAM. It is primarily intended for people with experience in hydrogeology, groundwater modeling, MODFLOW, the TWDB GAM program, and the Igneous and parts of West Texas Bolsons aquifers. For more information on these subjects, please refer to the appropriate groundwater textbook, or modeling reference.

This GAM is appropriate for regional evaluations of groundwater conditions in the Igneous and parts of West Texas Bolsons aquifers. It is not intended for site-specific use, such as small well fields or individual wells. For details on how the Igneous and parts of West Texas Bolsons aquifers GAM was developed, calibrated, and for limitations of this model, please refer to the Igneous and parts of West Texas Bolsons aquifers GAM report (Beach and others, 2004).

Unique or noteworthy aspects of this GAM are marked in bold and highlighted in red in this document.

Igneous and parts of West Texas Bolsons GAM report reference:

Beach, J. A., Ashworth, J. B., Finch, Jr., S. T., Chastain-Howley, A., Calhoun, K., Urbanczyk, K. M., Sharp, J. M., and Olson, J., 2004, 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 to the Texas Water Development Board, 208 p.

Please forward any comments, corrections, or suggestions to Wade Oliver at the Texas Water Development Board (wade.oliver@twdb.state.tx.us).

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1. Updates to this QuickReference Guide

December 1, 2006—Original version of this QuickReference guide.

September 18, 2009—Updated contact information for comments, corrections, and suggestions.

2. Versions of the Model

December 1, 2006—Version 1.01—Initial GAM constructed by LBG-Guyton Associates. The initial model was provided in PMWin and standard MODFLOW-96 model files. This version was imported into Groundwater Vistas with no changes to the original model files.

3. Notes on Running the Model

- There are no problems or special considerations for running the original model version (Version 1.01). Both the historic and predictive models take less than 5 minutes to run on a Dell PWS470 with a 3 GHz processor and 1 GB of RAM with Microsoft Windows XP.
- *Dry Cells*- Dry cells may occur in layer 1 starting along the margins of the layer where the bolsons typically pinch out and in layer 2 around the margins of the layer where the Igneous aquifer pinches out. Dry cells occur in areas where the areas where the aquifer would be expected to go dry or where the saturated thickness is so small that the overall flow is insignificant.

4. Model Summary

300 Rows—Grid-spacing = **2,640 feet**

180 Columns—Grid-spacing = **2,640 feet**

3 Layers

- Layer 1—Salt Basin Bolson, which includes Wild Horse, Michigan, Lobo, and Ryan Flats (Figure 1)
- Layer 2—Igneous Aquifer (Figure 2)
- Layer 3—Underlying Cretaceous and Permian Units (Figure 3)

The uppermost active layers in the model area are shown in Figure 4.

Units—feet and days

Coordinate System or Projection—The model was developed in the GAM projection (shown below).

Projection: Albers Equal Area Conic
Units: feet
Datum: NAD83
Spheroid: GRS80
1st Std. Parallel: 27 30 00 (27.50000)
2nd Std. Parallel: 35 00 00 (35.00000)
Central Meridian: -100 00 00 (-100.00000)
Latitude of Projection: 31 15 00 (31.25000)
False Easting: 4921250.00000 (US survey feet)
False Northing: 19685000.00000 (US survey feet)

Model Grid Origin (GAM Coordinates)—X=3,593,650; Y=18,997,700 (to lower left of model grid (i.e. Row 300, Column 1)

Model Grid Rotation—30 degrees

Steady-State Model—Included as the first stress period in the transient model. The steady-state stress period is 10,000,000 days in length and represents pre-1950's aquifer conditions.

Transient Calibration-Verification Model—52 stress periods (pre-1950–2000)—Note: The final stress period represents the year 2000 (Table 1).

MODFLOW Version—MODFLOW-96

Aquifer Parameters—Aquifer parameters for each of the model layers are summarized in Table 2. Distributions of horizontal and vertical hydraulic conductivities are shown in Figures 5, 6, and 7 for Layers 1, 2, and 3, respectively.

Table 1. Historic (transient calibration-verification) model stress periods.

Stress Period	Length (days)	Time Period	Stress Period	Length (days)	Time Period
1	10,000,000	Pre-1950	27	365.25	1975
2	365.25	1950	28	365.25	1976
3	365.25	1951	29	365.25	1977
4	365.25	1952	30	365.25	1978
5	365.25	1953	31	365.25	1979
6	365.25	1954	32	365.25	1980
7	365.25	1955	33	365.25	1981
8	365.25	1956	34	365.25	1982
9	365.25	1957	35	365.25	1983
10	365.25	1958	36	365.25	1984
11	365.25	1959	37	365.25	1985
12	365.25	1960	38	365.25	1986
13	365.25	1961	39	365.25	1987
14	365.25	1962	40	365.25	1988
15	365.25	1963	41	365.25	1989
16	365.25	1964	42	365.25	1990
17	365.25	1965	43	365.25	1991
18	365.25	1966	44	365.25	1992
19	365.25	1967	45	365.25	1993
20	365.25	1968	46	365.25	1994
21	365.25	1969	47	365.25	1995
22	365.25	1970	48	365.25	1996
23	365.25	1971	49	365.25	1997
24	365.25	1972	50	365.25	1998
25	365.25	1973	51	365.25	1999
26	365.25	1974	52	365.25	2000

Table 2. Aquifer properties.

Layer	Horizontal Hydraulic Conductivity (feet/day)	Vertical Hydraulic Conductivity (feet/day)	Specific Yield	Storativity
1	4–50	0.0001–0.35	0.06	--
2	0.2–1	0.00008–0.1	0.01	$3x10^{-5}$
3	0.1–1	0.0005–0.1	0.01	$3x10^{-5}$

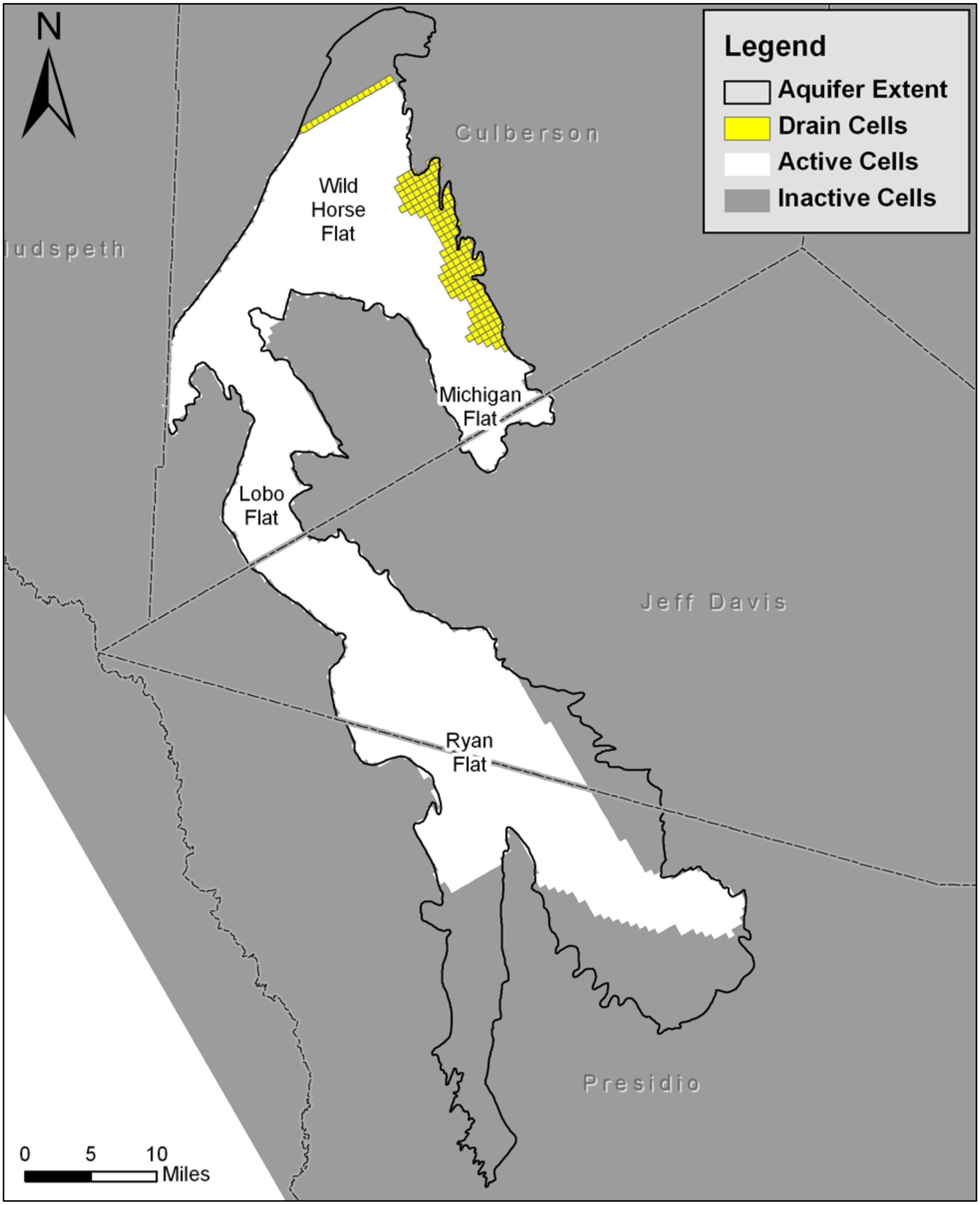

Figure 1. Active cells and boundary conditions in Layer 1.

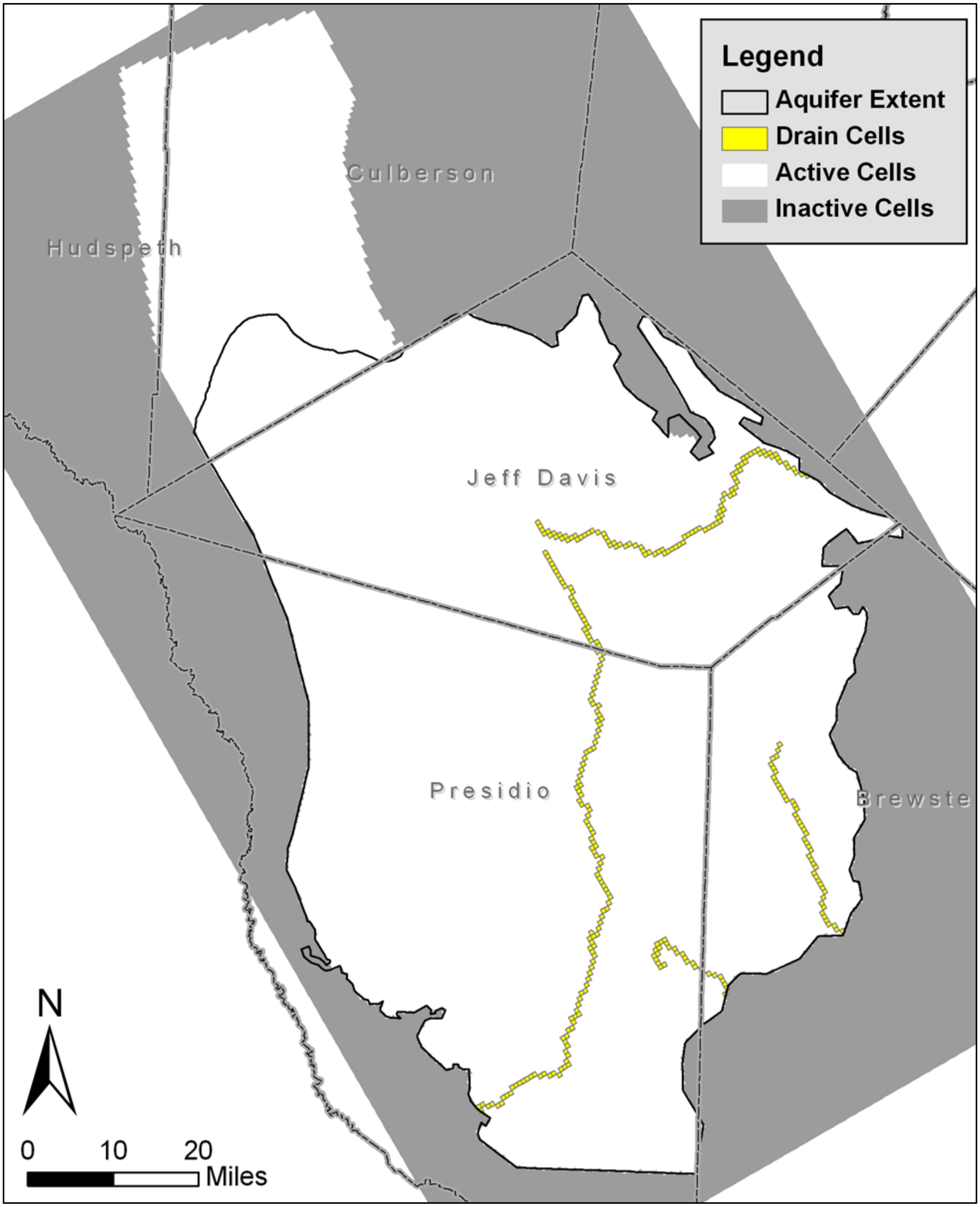

Figure 2. Active cells and boundary conditions in Layer 2.

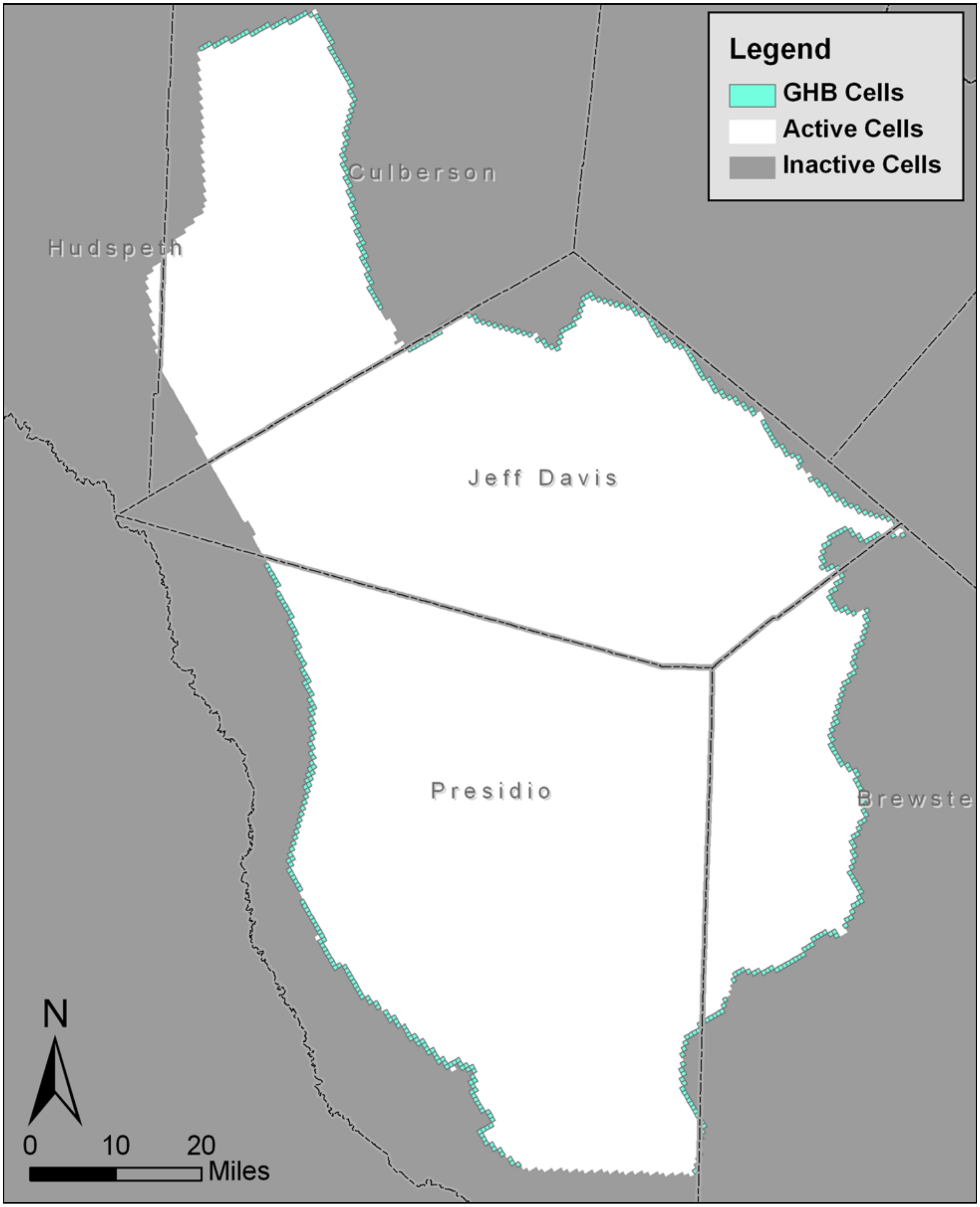

Figure 3. Active cells and boundary conditions in Layer 3.

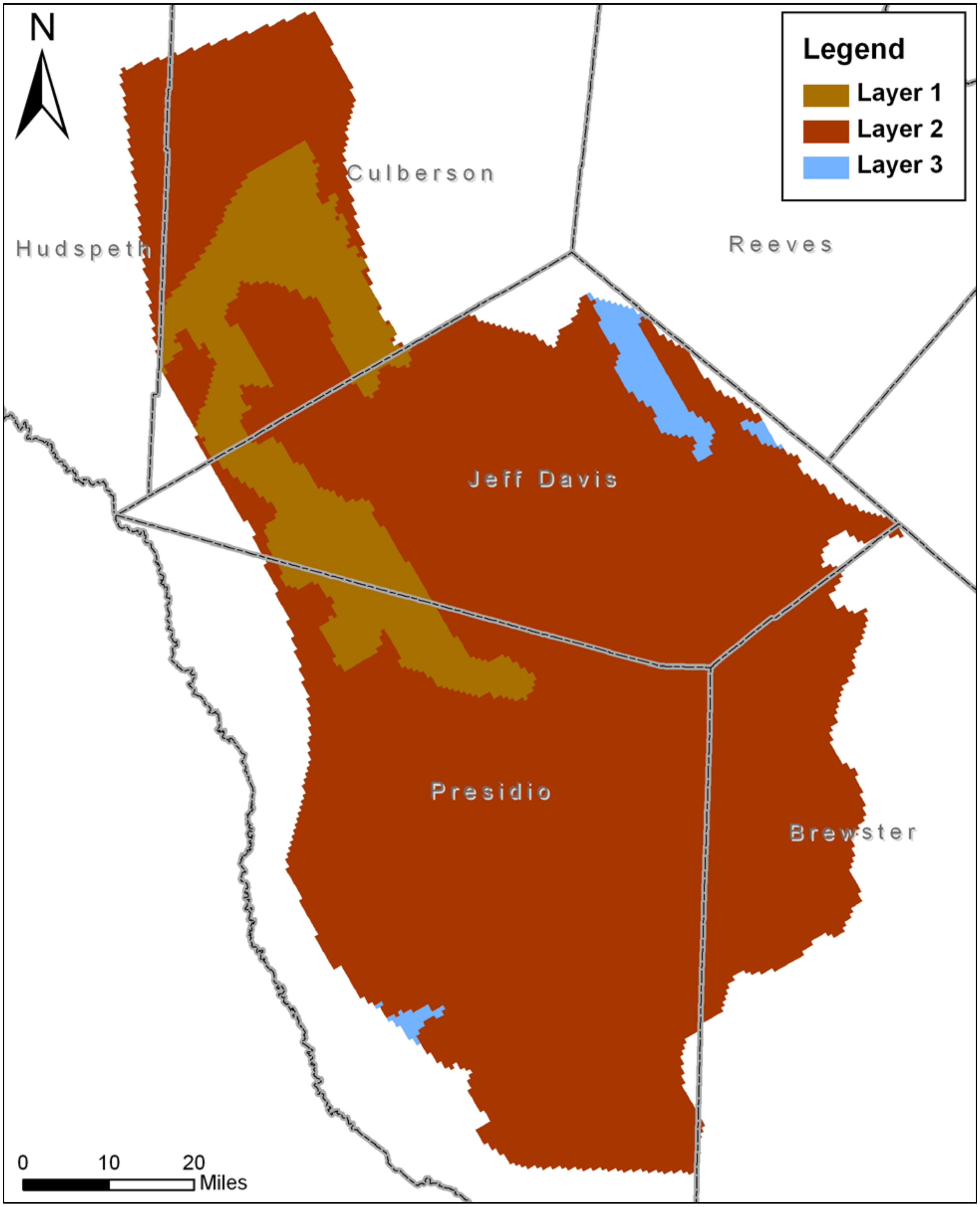

Figure 4. Uppermost active cells in the model.

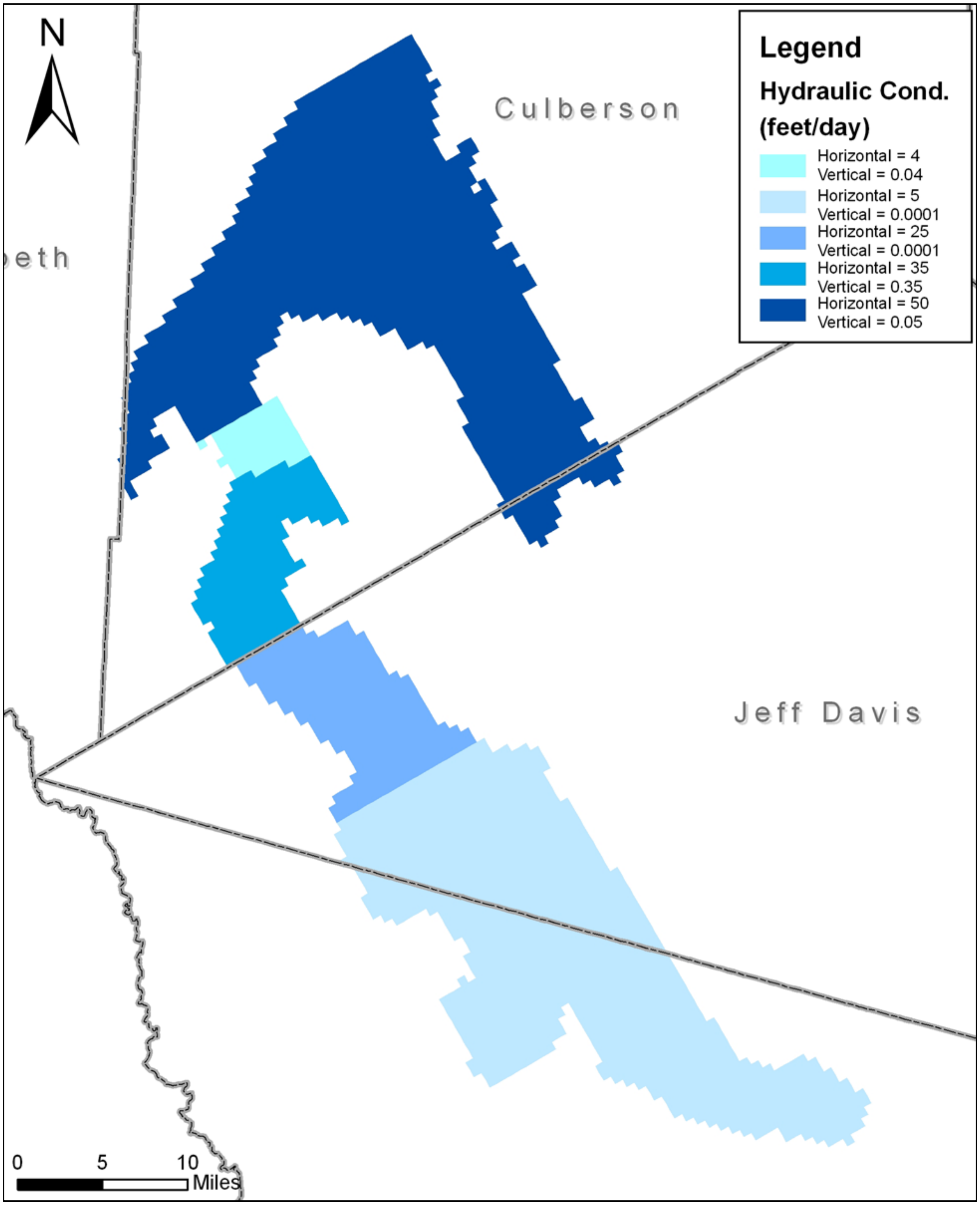

Figure 5. Calibrated horizontal and vertical hydraulic conductivities in Layer 1.

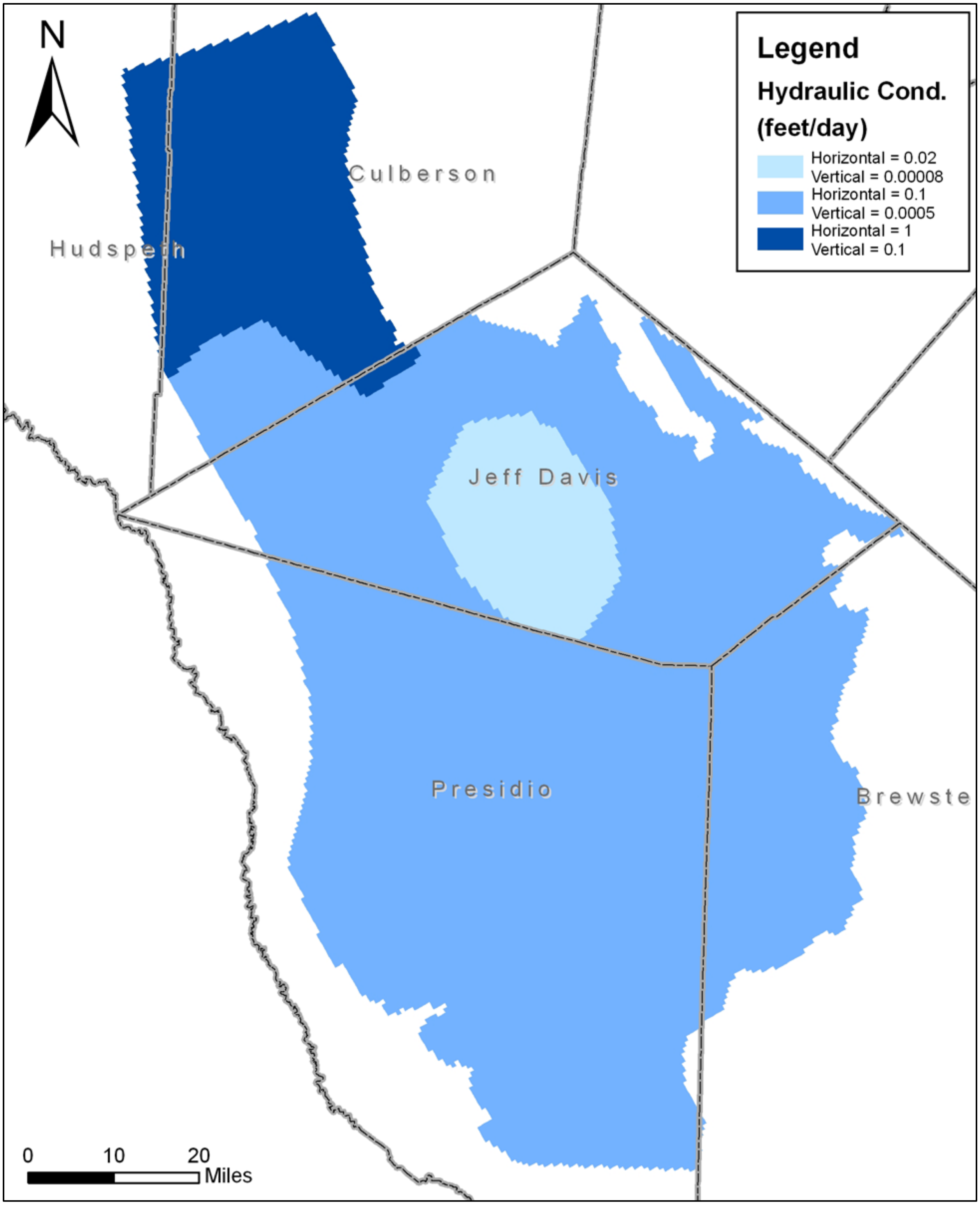

Figure 6. Calibrated horizontal and vertical hydraulic conductivities in Layer 2.

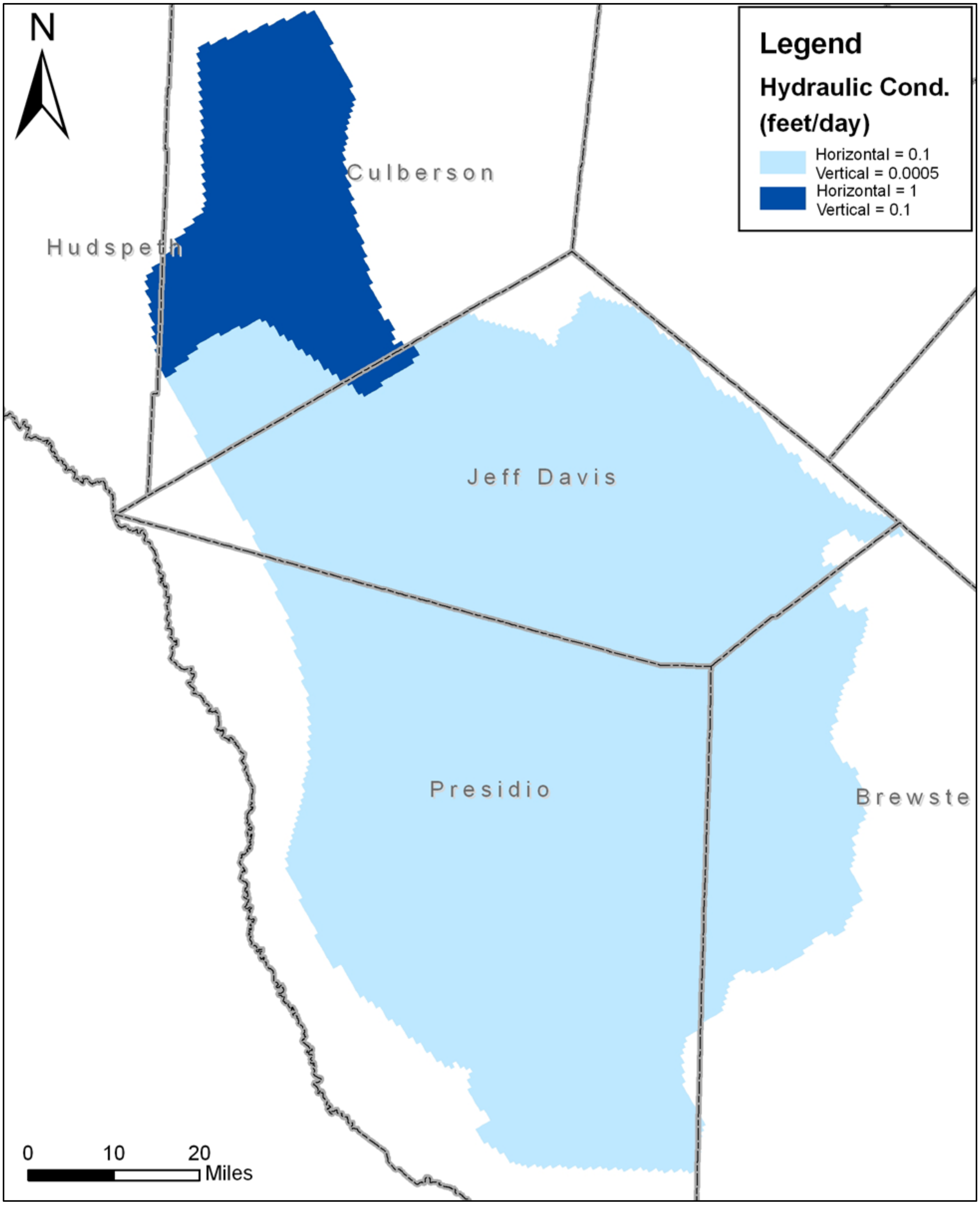

Figure 7. Calibrated horizontal and vertical hydraulic conductivities in Layer 3.

5. MODFLOW Packages used in the GAM

- **Basic (BAS) Package—**Standard MODFLOW package required in all models.

- **Block-Centered Flow (BCF) Package—**Standard MODFLOW package required in all models.

- **Output Control (OC)—**Standard MODFLOW package required in all models.

- **Well (WEL) Package—**The GAM uses the MODFLOW well package to represent rural domestic, municipal, industrial, irrigation, and livestock pumpage. Pumpage included in each county in the GAM in the transient calibration-verification time period is summarized in Appendix A.

- **Recharge (RCH) Package—The GAM uses the recharge package to model both recharge from alluvial fans/stream beds and precipitation. It is assumed that precipitation recharge to the Salt Basin Bolson aquifer is zero, and therefore all recharge included in the recharge package to Layer 1 is along mountain fronts from alluvial fans and stream bed infiltration. Recharge applied with the recharge package to the Igneous aquifer (Layer 2) is from precipitation recharge as well as alluvial fan/stream bed recharge in Presidio County.** Distribution of steady-state recharge rates are shown in Figure 8. Transient values were created by multiplying the steady-state rates by a factor directly correlated to precipitation at the Mount Locke precipitation gage. The factors used to create the transient recharge rates are summarized in Table 3.

  Drought-of-Record- The drought-of-record for this GAM has been defined as a seven-year time period from 1951 to 1957.

- **Strongly Implicit Procedure (SIP) Solver Package—**The GAM uses the SIP solver.

- **Drain (DRN) Package—**The GAM uses drains to simulate discharge to streams and springs. Drains are included in both the Salt Basin Bolson aquifer and Igneous aquifer layers of the model (Figures 1 and 2). In the Salt Basin Bolson (Layer 1) the drains are located at the northern end of the aquifer and are present to account for northward groundwater flow from the bolson aquifer to Balmorhea Springs. Drains are included in the Igneous Aquifer (Layer 2) to represent loss of groundwater to springs and streams. The total number of drain cells included in each layer of the model is summarized in Table 4.

- **General-Head Boundary (GHB) Package—**The GAM uses GHBs to simulate cross-formational flow into and out of Layer 3, which represents the Cretaceous and Permian units underlying the Igneous aquifer (Figure 3). The heads for the

GHBs were based on estimated heads from the Igneous aquifer and then adjusted downward based on a conceptual model that assumes downward movement from the Igneous to lower units. The total number of GHB cells included in each layer of the model is summarized in Table 4.

- **Evapotranspiration (EVT) Package—**The GAM uses the MODFLOW evapotranspiration package to simulate discharge of water to evaporation and transpiration. The EVT package assumes a uniform extinction depth of 10 feet and a uniform ET rate of 10 inches per year. All of the steady-state ET parameters were used in each of the transient stress periods.

Table 3. Factors used to create historic recharge rates.

Year	Recharge Factor	Year	Recharge Factor	Year	Recharge Factor
pre-1950	0	1967	0.974	1984	1.768
1950	0.887	1968	1.478	1985	0.966
1951	0.720	1969	0.736	1986	1.448
1952	0.715	1970	1.041	1987	1.010
1953	0.438	1971	0.641	1988	0.891
1954	0.914	1972	1.144	1989	0.661
1955	0.935	1973	0.830	1990	1.493
1956	0.633	1974	1.348	1991	1.316
1957	0.921	1975	1.020	1992	1.118
1958	1.282	1976	1.370	1993	0.927
1959	0.626	1977	0.886	1994	0.710
1960	1.234	1978	1.473	1995	0.772
1961	0.708	1979	0.886	1996	0.893
1962	1.037	1980	0.907	1997	1.129
1963	0.853	1981	1.407	1998	0.558
1964	0.729	1982	0.833	1999	0.878
1965	0.844	1983	0.780	2000	0.710
1966	1.314				

Table 4. Number of drain and GHB cells included in the GAM.

	Drains	GHBs
Total	478	569
Layer 1	164	0
Layer 2	314	0
Layer 3	569	0

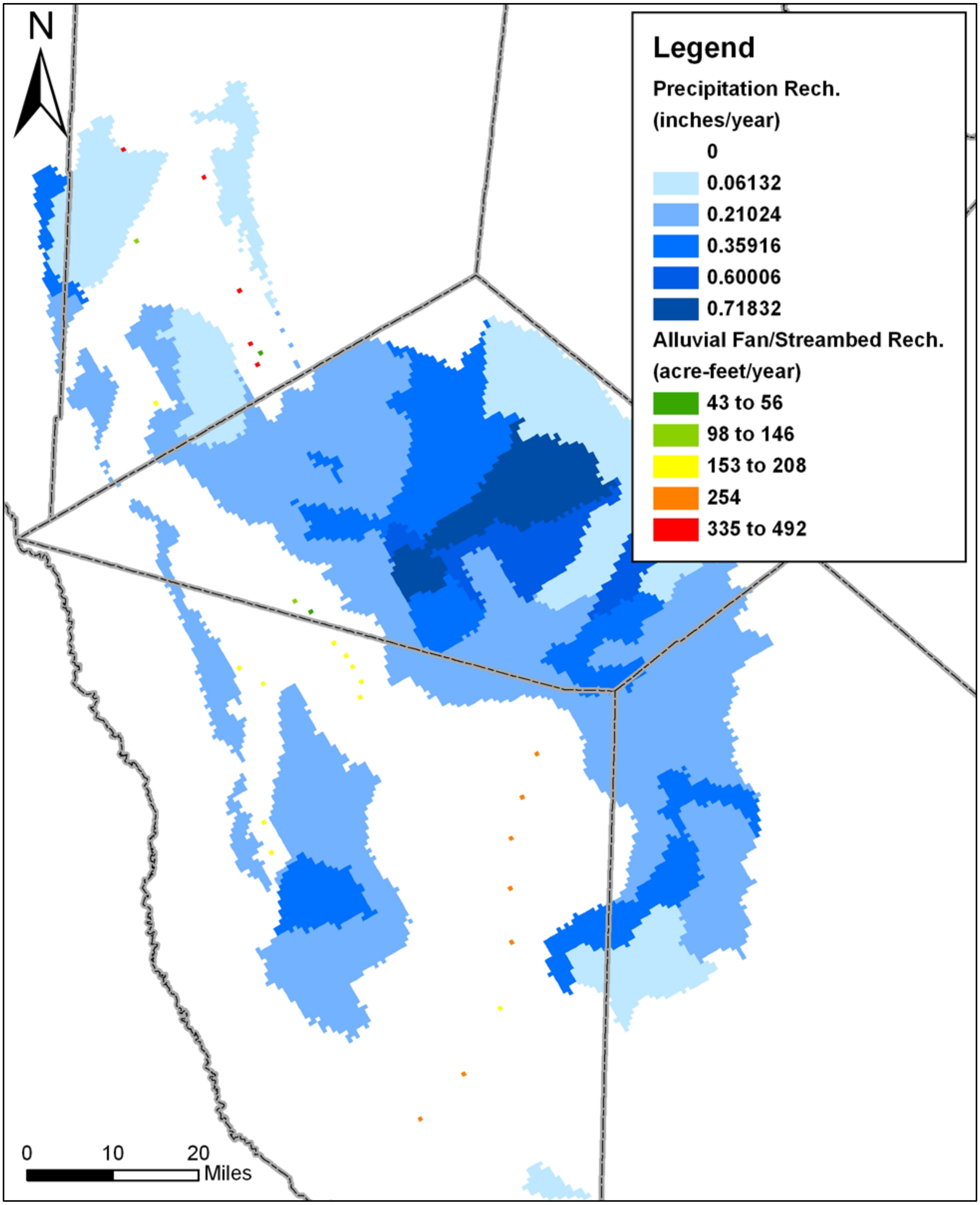

Figure 8. Steady-state recharge rates.

Appendix A

Summary of Estimated Historic Pumpage

Table A-1. Historic pumpage included in the GAM for all aquifers (in acre-feet per year).

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
pre-1950	0	0	0	0	0	0
1950	20,981	2	18,458	763	786	972
1951	19,843	2	16,824	1,138	907	972
1952	22,554	2	19,039	1,512	1,028	972
1953	25,651	2	21,640	1,887	1,148	973
1954	26,952	2	22,446	2,261	1,269	973
1955	30,441	2	24,194	2,636	2,116	1,493
1956	31,547	2	24,612	3,011	2,266	1,656
1957	33,345	2	25,924	3,385	2,445	1,588
1958	35,461	2	27,685	3,760	2,487	1,527
1959	36,477	2	28,269	3,654	2,804	1,747
1960	36,994	2	28,312	3,549	3,193	1,939
1961	36,782	2	28,336	3,446	3,152	1,845
1962	36,582	2	28,346	3,343	3,037	1,853
1963	36,545	2	28,358	3,240	2,983	1,962
1964	36,727	2	28,417	3,137	3,001	2,170
1965	38,408	2	28,382	4,747	3,150	2,127
1966	37,765	2	28,348	4,237	3,073	2,105
1967	37,096	2	28,143	3,727	3,155	2,067
1968	35,808	2	27,418	3,217	3,103	2,067
1969	36,449	2	28,051	2,708	3,433	2,255
1970	37,753	2	29,075	2,530	4,010	2,135
1971	36,971	2	27,501	2,350	4,990	2,127
1972	37,052	2	26,847	2,207	5,861	2,135
1973	46,289	2	35,388	2,000	6,826	2,073
1974	52,565	2	40,893	1,732	7,532	2,406
1975	51,081	2	39,827	1,865	7,395	1,991
1976	50,071	2	38,764	2,045	7,294	1,966
1977	49,279	2	37,738	2,252	7,376	1,910
1978	47,017	2	27,858	10,453	6,985	1,719
1979	53,252	2	26,254	18,693	6,630	1,673
1980	60,290	1	25,046	26,975	6,364	1,904
1981	51,402	1	23,753	20,911	5,265	1,471
1982	43,995	1	22,534	15,022	4,599	1,839
1983	36,233	1	21,351	9,115	3,748	2,017
1984	29,169	1	21,405	3,202	2,839	1,723
1985	27,811	1	20,116	2,984	2,850	1,860
1986	26,663	1	18,675	3,937	2,181	1,869
1987	24,082	1	18,271	2,946	1,321	1,543
1988	25,685	1	16,714	5,025	2,266	1,679
1989	22,739	1	15,462	2,595	3,025	1,655

Table A-1. Continued.

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
1990	18,728	1	10,520	3,868	2,748	1,591
1991	15,956	1	10,143	3,135	1,162	1,515
1992	18,475	1	11,763	3,326	1,938	1,447
1993	11,548	1	6,984	1,086	1,826	1,650
1994	11,970	1	7,079	1,113	2,095	1,682
1995	11,970	1	7,081	1,068	2,171	1,650
1996	12,242	1	7,503	1,041	2,116	1,582
1997	13,572	1	7,912	1,093	2,700	1,866
1998	19,548	1	13,266	1,426	2,821	2,034
1999	36,552	1	30,343	1,386	2,771	2,051
2000	36,282	1	30,320	1,129	2,782	2,051

Table A-2. Historic pumpage included in the GAM for the Salt Basin Bolson (Layer 1) (in acre-feet per year).

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
pre-1950	0	0	0	0	0	0
1950	18,663	0	18,456	153	55	0
1951	17,397	0	16,822	457	117	0
1952	19,978	0	19,037	762	180	0
1953	22,947	0	21,638	1,066	243	0
1954	24,120	0	22,444	1,371	305	0
1955	26,235	0	24,191	1,675	368	0
1956	27,020	0	24,610	1,980	431	0
1957	28,700	0	25,922	2,285	494	0
1958	30,828	0	27,682	2,589	556	0
1959	31,490	0	28,267	2,505	719	0
1960	31,611	0	28,310	2,420	881	0
1961	31,478	0	28,334	2,337	806	0
1962	31,330	0	28,344	2,254	732	0
1963	31,183	0	28,356	2,171	657	0
1964	31,085	0	28,415	2,088	582	0
1965	32,405	0	28,379	3,392	634	0
1966	32,010	0	28,346	2,979	686	0
1967	31,444	0	28,141	2,566	738	0
1968	30,358	0	27,416	2,153	789	0
1969	30,630	0	28,048	1,740	841	0
1970	32,416	0	29,073	1,541	1,803	0
1971	31,605	0	27,499	1,343	2,764	0
1972	31,713	0	26,844	1,144	3,725	0
1973	41,017	0	35,385	946	4,687	0
1974	47,285	0	40,890	747	5,648	0
1975	46,398	0	39,824	910	5,663	0
1976	45,512	0	38,761	1,073	5,679	0
1977	44,665	0	37,736	1,236	5,694	0
1978	41,550	0	27,853	8,494	5,204	0
1979	46,712	0	26,247	15,751	4,714	0
1980	52,269	0	25,035	23,009	4,225	0
1981	44,981	0	23,743	17,776	3,462	0
1982	37,774	0	22,525	12,550	2,700	0
1983	30,608	0	21,343	7,328	1,938	0
1984	24,679	0	21,397	2,107	1,176	0
1985	23,250	0	20,107	1,892	1,252	0
1986	22,274	0	18,668	2,811	795	0
1987	20,535	0	18,259	2,077	198	0
1988	21,403	0	16,702	3,845	856	0
1989	18,492	0	15,450	1,534	1,508	0

Table A-2. Continued.

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
1990	14,711	0	10,509	2,697	1,505	0
1991	12,371	0	10,132	2,060	179	0
1992	14,838	0	11,755	2,229	853	0
1993	7,913	0	6,978	248	688	0
1994	7,672	0	7,073	150	449	0
1995	7,722	0	7,076	142	505	0
1996	8,142	0	7,497	134	511	0
1997	8,831	0	7,906	129	797	0
1998	14,186	0	13,260	129	797	0
1999	31,263	0	30,337	129	797	0
2000	31,239	0	30,314	129	797	0

Table A-3. Historic pumpage included in the GAM for the Igneous Aquifer (Layer 2) (in acre-feet per year).

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
pre-1950	0	0	0	0	0	0
1950	2,169	2	0	464	731	971
1951	2,283	2	0	519	790	972
1952	2,396	2	0	574	848	972
1953	2,510	2	0	630	906	973
1954	2,624	2	0	685	964	973
1955	3,983	2	0	740	1,748	1,492
1956	4,289	2	0	795	1,835	1,656
1957	4,392	2	0	850	1,951	1,588
1958	4,366	2	0	906	1,931	1,527
1959	4,724	2	0	889	2,086	1,747
1960	5,125	2	0	873	2,312	1,938
1961	5,050	2	0	857	2,346	1,845
1962	5,002	2	0	842	2,305	1,853
1963	5,116	2	0	826	2,326	1,962
1964	5,401	2	0	811	2,418	2,169
1965	5,696	2	0	1,051	2,516	2,127
1966	5,469	2	0	975	2,388	2,105
1967	5,386	2	0	899	2,418	2,067
1968	5,205	2	0	823	2,314	2,067
1969	5,595	2	0	746	2,592	2,255
1970	5,120	2	0	775	2,207	2,135
1971	5,156	2	0	801	2,226	2,127
1972	5,136	2	0	863	2,135	2,135
1973	5,076	2	0	862	2,139	2,072
1974	5,134	2	0	843	1,884	2,405
1975	4,538	2	0	813	1,731	1,991
1976	4,414	2	0	831	1,615	1,966
1977	4,469	2	0	874	1,683	1,910
1978	5,325	2	0	1,823	1,781	1,719
1979	6,401	2	0	2,810	1,916	1,673
1980	7,883	1	0	3,839	2,139	1,904
1981	6,294	1	0	3,019	1,803	1,471
1982	6,102	1	0	2,363	1,899	1,839
1983	5,513	1	0	1,684	1,810	2,017
1984	4,385	1	0	997	1,663	1,723
1985	4,450	1	0	991	1,599	1,859
1986	4,302	1	0	1,047	1,386	1,869
1987	3,472	1	0	805	1,123	1,543
1988	4,198	1	0	1,108	1,410	1,679
1989	4,125	1	0	952	1,517	1,655

Table A-3. Continued.

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
1990	3,896	1	0	1,061	1,243	1,591
1991	3,476	1	0	977	982	1,515
1992	3,533	1	0	1,000	1,085	1,447
1993	3,541	1	0	752	1,139	1,650
1994	4,209	1	0	880	1,646	1,682
1995	4,170	1	0	853	1,666	1,650
1996	4,023	1	0	835	1,604	1,582
1997	4,666	1	0	896	1,903	1,866
1998	5,288	1	0	1,229	2,024	2,034
1999	5,215	1	0	1,189	1,974	2,051
2000	4,969	1	0	932	1,985	2,051

Table A-4. Historic pumpage included in the GAM for the Cretaceous and Permian Units (Layer 3) (in acre-feet per year).

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
pre-1950	0	0	0	0	0	0
1950	149	0	2	147	0	0
1951	164	0	2	162	0	0
1952	179	0	2	176	0	0
1953	193	0	2	191	0	0
1954	208	0	2	206	0	0
1955	223	0	2	221	0	0
1956	238	0	2	235	0	0
1957	252	0	2	250	0	0
1958	267	0	2	265	0	0
1959	263	0	2	260	0	0
1960	258	0	2	256	0	0
1961	254	0	2	251	0	0
1962	250	0	2	247	0	0
1963	246	0	2	243	0	0
1964	241	0	2	239	0	0
1965	306	0	2	304	0	0
1966	286	0	2	283	0	0
1967	265	0	2	263	0	0
1968	245	0	2	242	0	0
1969	224	0	2	221	0	0
1970	217	0	3	214	0	0
1971	210	0	3	207	0	0
1972	203	0	3	200	0	0
1973	196	0	3	193	0	0
1974	145	0	3	142	0	0
1975	145	0	3	142	0	0
1976	145	0	3	142	0	0
1977	145	0	2	142	0	0
1978	142	0	5	137	0	0
1979	140	0	8	132	0	0
1980	137	0	10	127	0	0
1981	127	0	10	117	0	0
1982	119	0	9	109	0	0
1983	112	0	9	103	0	0
1984	106	0	8	98	0	0
1985	111	0	9	102	0	0
1986	86	0	7	79	0	0
1987	75	0	11	64	0	0
1988	84	0	12	72	0	0
1989	121	0	12	109	0	0

Table A-4. Continued.

Year	Total	Other	Culberson	Jeff Davis	Presidio	Brewster
1990	121	0	11	109	0	0
1991	109	0	11	98	0	0
1992	105	0	7	97	0	0
1993	93	0	7	86	0	0
1994	89	0	6	83	0	0
1995	78	0	5	73	0	0
1996	77	0	5	71	0	0
1997	74	0	6	68	0	0
1998	74	0	6	68	0	0
1999	74	0	6	68	0	0
2000	74	0	6	68	0	0