GAM run 09-001

by Richard Smith, P.G.

Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-0877
February 17, 2009

EXECUTIVE SUMMARY:

Groundwater Management Area 1 requested a groundwater availability model run to determine if retaining three different volumes of groundwater after 50 fifty years of pumping in the Ogallala Aquifer in three predetermined geographical subdivisions in Groundwater Management Area 1 (Figure 1) was feasible. They requested 40 percent retention of the starting point volume after fifty years in subdivision 1, 80 percent retention in subdivision 2, and 50 percent retention in subdivision 3. We ran the northern segment of the Ogallala Aquifer groundwater availability model in order to evaluate the three different proposed desired future conditions for the Ogallala Aquifer within Groundwater Management Area 1. The southern segment of the Ogallala Aquifer was run for Potter, Randall, and Armstrong counties and reported in the supplement to GAM run 08-16 (Smith, 2008b). These numbers have not changed. We applied annual pumping based on individual cell volumes for each grid cell. After calculating the total volume in each grid cell and adding the recharge, we calculated the pumping rate for each cell that would result in the retention of the desired percent of the volume at the end of fifty years as specified in the request. The results were used to generate a new well file for the model of the northern portion of the Ogallala Aquifer in Groundwater Management Area 1. Pumping rates varied according to aquifer thickness. By 2060, large parts of Dallam, Hartley, and Moore counties and smaller part Sherman County become “dry”. Carson, Gray, and Hutchinson counties also include dry cells by this time. However, the model simulation did achieve the desired future conditions as described in the request.

REQUESTOR:

Mr. Steve Walthour with the North Plains Groundwater Conservation District on behalf of Groundwater Management Area 1.

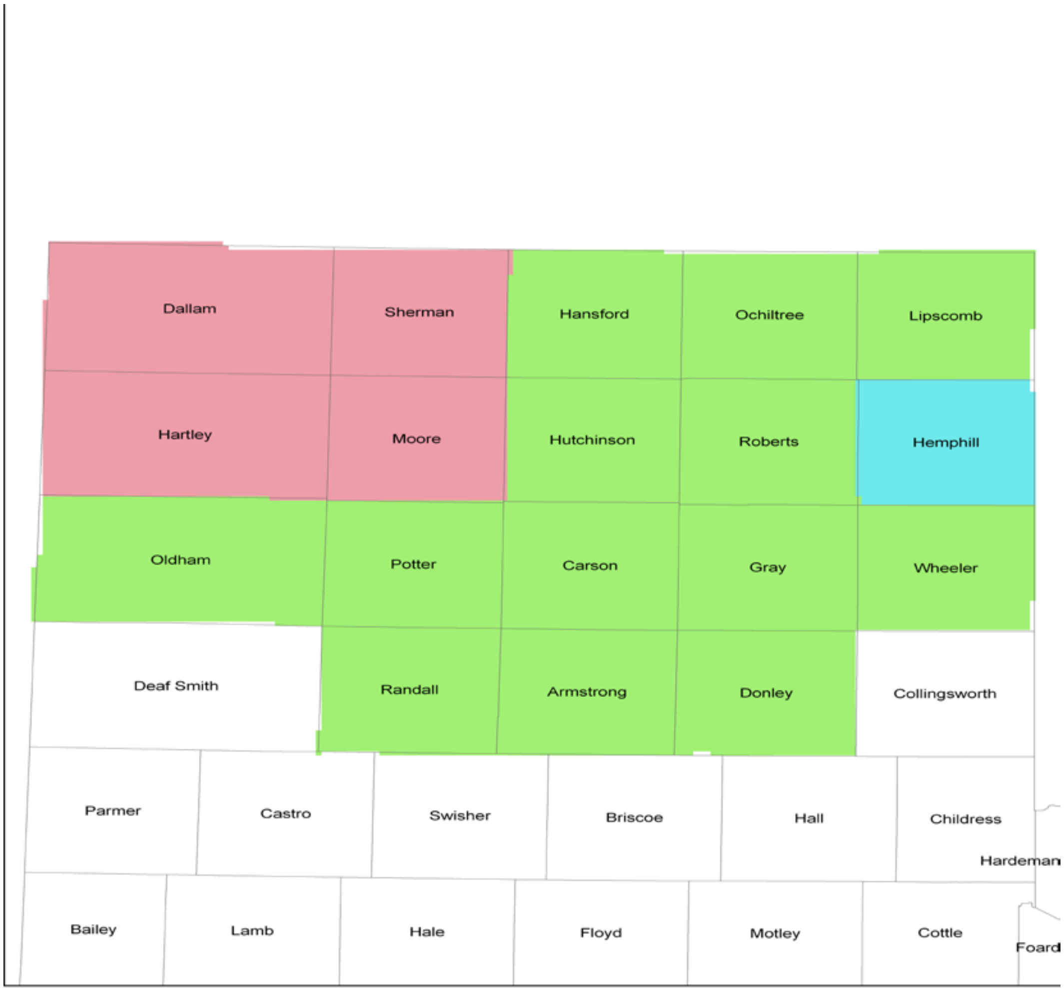

Figure 1**. Subdivisions requested by the groundwater conservation districts in Groundwater Management Area 1. Pink counties are Subdivision 1, the blue county is Subdivision 2 and green counties are Subdivision 3**

DESCRIPTION OF REQUEST:

The groundwater conservation districts in Groundwater Management Area 1 requested a groundwater availability model run to determine if retaining different volumes of groundwater after fifty years of pumping in the Ogallala Aquifer in three subdivisions of the groundwater management area (Figure 1) was feasible. The three subdivisions are as follows:

- Subdivision 1 is comprised of Dallam, Hartley, Moore, and Sherman counties;
- Subdivision 2 is comprised of Hemphill County; and
- Subdivision 3 is comprised of Hutchinson, Hansford, Lipscomb, Ochiltree, Armstrong, Carson, Donley, Gray, Oldham, Potter, Randall, Roberts, and Wheeler counties.

The districts requested that the Texas Water Development Board (TWDB) provide the draft managed available groundwater estimates in the management area based upon the draft desired future condition of the Ogallala Aquifer for each subdivision as follows:

- Subdivision 1 is to achieve at least 40 percent of the 2006 total aquifer storage remaining in 2060. The TWDB shall calculate the amount of managed available groundwater for the 50 year period with an initial amount of available groundwater set at 1,331,500 acre-feet for the first year. This starting point will decrease at a fixed percent throughout the 50 years to achieve the desired future condition of the Ogallala Aquifer goal for the subdivision.
- Subdivision 2 is to have at least 80 percent of the total aquifer storage remaining in 2060. The annual pumping volume will be 55,000 acre-feet without change through the fifty year simulation period.
- Subdivision 3 is to have at least 50 percent of the baseline total aquifer storage remaining in 2060. TWDB shall estimate the managed available groundwater volume by reducing the total aquifer storage by no more than 1.25 percent annually.

Based on the pumping rates established in GAM Run 07-31 (Smith, 2007) the districts requested that the area-wide pumping rates be applied to the northern and southern segments of the Ogallala Aquifer groundwater availability models for a fifty year period with 2006 as the baseline year.

METHODS:

To address the request, we did the following steps:

- We selected a stress period in the northern portion of the Ogallala Aquifer groundwater availability model which best approximated water-level information and volume information supplied by the North Plains Groundwater Conservation District. The District's 2006 information corresponds to stress period 55 in the model which became the base year.
- Initial pumping rates were calculated on a cell-by-cell basis, based on either the volume or maximum percent declines described in the request above plus the average recharge. We then annually decreased pumping by a set percent rate to achieve the desired final volumes of water as described in the request above.
- The pumping rates per grid cell were used to create a new well file which was then used as input to the model.
- The model was run to simulate projections for fifty years.
- Water levels for the base year and final year of the simulation, as well as the base of the aquifer and hydraulic properties, were exported from the model to ArcGIS® to compare and analyze the volume remaining in the aquifer.
- Saturated thickness maps were constructed on a decadal basis starting with 2010 and extending to 2060.

The model was then zoned by county. Pumpage was extracted from the model to develop a table of the managed available groundwater for each county.

PARAMETERS AND ASSUMPTIONS:

- We used version 2.01 of the groundwater availability model for the northern part of the Ogallala Aquifer (Dutton, 2004) and version 1.01 of the groundwater availability model for the southern part of the Ogallala Aquifer (Blandford and others, 2003),
- See Dutton and others (2001) and Dutton (2004) for assumptions and limitations of the model for the northern part of the Ogallala Aquifer. Root mean squared error for this model is 53 feet. This error has more of an effect on model results where the aquifer is thin.
- See Blandford and others (2003) for assumptions and limitations of the model for the southern part of the Ogallala Aquifer. Root mean squared error for this model is 47 feet. This error will have more of an effect on model results where the aquifer is thin.
- Recharge was reappraised in the updated model of the northern part of the Ogallala Aquifer (Dutton, 2004).
- Average recharge used in both of the models was based on a percentage of precipitation for the 1950 through 1990 period of record. Since this includes the 1950s drought of record, the average recharge used for this analysis is considered a conservative estimate.
- For Oldham, Randall, Potter, and Armstrong counties, which are partially included in both the northern and southern parts of the Ogallala Aquifer groundwater availability models, we will combine the results of the volume calculation from each model to get full county totals. At this time this report only includes the results from the groundwater availability model for the northern portion of the Ogallala Aquifer. It should be noted that we will use the volume calculated from each model for that segment of the county covered as the starting point for the annual pumping rate calculation which would result in a fifty percent decline over a fifty year period.
- It should be noted that The Rita Blanca Aquifer is part of the layer representing the Ogallala Aquifer in western Dallam and Hartley counties.

RESULTS:

Table 1 gives the starting and the final volumes for each of the three subdivisions calculated from the model at the end of the 50 year simulation. The rates of water-level decline, and the percentage decrease in pumping compared with the previous stress period, were adjusted to achieve the desired future condition of the Ogallala Aquifer requested for each subdivision. The starting pumpage was 1.98 percent of the initial volume in Subdivision 1, 55,000 acre-feet per year in Subdivision 2, and 1.25 percent in Subdivision 3. It should be noted that recharge was added back into the initial value which accounts for a larger initial available groundwater value than a simple 1.98 percent or 1.25 percent of the starting volume.

Table 2 shows the different zones tabulated from the model runs. They are summed to achieve county values within a groundwater conservation district. All numbers are expressed in acre-feet per year. Tables 3 and 4 show the tabulated results for Subdivisions 1, 2, and 3. Recharge was added back into each pumping value for each stress period in Subdivisions 1 and 3. The 55,000 acre-feet per year in Subdivision 2 was maintained throughout the 50-year simulation. The declines are different since the starting volumes and the final requested volumes are different for each subdivision.

Figures 2 to 19 show the saturated thickness of the northern portion of the Ogallala Aquifer by decade from 2010 through 2060. Large swaths of the western counties (Dallam, Hartley, Moore and Sherman), go dry by 2060 while the eastern and south central counties maintain large areas of saturated thickness at that time.

REFERENCES:

Dutton, A., 2004, Adjustments of parameters to improve the calibration of the Og-N model of the Ogallala aquifer, Panhandle Water Planning Area: Bureau of Economic Geology, The University of Texas at Austin, 9 p

Blandford, T.N., Blazer, D.J., Calhoun, K.C., Dutton, A.R., Naing, T., Reedy, R.C., and Scanlon, B.R., 2003, Groundwater availability of the southern Ogallala aquifer in Texas and New Mexico—Numerical Simulations Through 2050: Final Report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 158 p.

Dutton, A., Reedy, R., and Mace, R., 2001, Saturated thickness of the Ogallala aquifer in the Panhandle Water Planning Area—Simulation of 2000 through 2050 Withdrawal Projections: prepared for the Panhandle Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 54 p.

Smith, R, 2007, GAM Run 07-31, Texas Water Development Board, 23 p.

Smith, R, 2008a, GAM Run 08-16, Texas Water Development Board, 30 p.

Smith, R, 2008b, Supplement to GAM Run 08-16, Texas Water Development Board, 7 p.

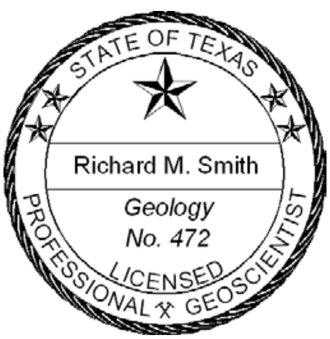

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Table 1: Volumes within each Subdivision with decline rates and final percentages.

Subdivision	Initial volumes in acre-feet	Final volumes in acre-feet	Decline rate	Final percentage remaining
1	68,426,375	27,349,643	0.059	39.97 %
2	15,492,740	12,349,626	0.00	79.71 %
3	145,937,684	73,025,835	0.0775	50.04 %

Table 2: Zones within the model

Zone	County	GCD
2	Dallam	North Plains coverage
3	Dallam	No North Plains - non district areas
4	Sherman	North Plains coverage
5	Lipscomb	North Plains coverage
6	Ochiltree	North Plains coverage
7	Hansford	North Plains coverage
8	Roberts	Pan Handle coverage
10	Hartley	North Plains coverage
11	Hartley	No North Plains - non district areas
12	Moore	North Plains coverage
13	Moore	No North Plains - non district areas
14	Hutchinson	North Plains coverage
15	Hutchinson	No North Plains - non district areas
16	Hutchinson	Panhandle coverage
17	Hemphill	Hemphill
19	Carson	Panhandle coverage
20	Carson	Panhandle coverage
21	Gray	Panhandle coverage
23	Potter	Panhandle coverage
25	Wheeler	Panhandle coverage
26	Oldham	No coverage
27	Potter	Panhandle coverage
29	Randall	High Plains coverage
30	Donley	Panhandle coverage
31	Armstrong	Panhandle coverage
33	Randall	No Coverage

Table 3: Managed available groundwater for Subdivision 1 and 2. All numbers are in acre-feet. NPGCD = North Plains Groundwater Conservation District. UWCD = Underground Water Conservation District.

Year	Dallam NPGCD	Dallam No district	Dallam Total	Sherman NPGCD	Lipscomb NPGCD	Ochiltree NPGCD	Hansford NPGCD	Hartley NPGCD	Hartley No district	Hartley Total	Moore NPGCD	Moore No district	Moore Total	Hemphill County UWCD
2010	340,762	100,090	440,852	270,088	246,011	256,701	270,396	363,651	56,230	419,881	207,724	38,012	245,736	54,998
2011	335,522	98,388	433,910	261,845	244,179	254,789	268,381	356,460	54,302	410,762	199,907	36,439	236,346	54,998
2012	329,077	96,502	425,579	254,087	242,359	252,891	266,382	349,677	52,764	402,441	193,111	34,648	227,759	54,998
2013	324,068	94,723	418,791	246,787	240,554	251,006	264,397	343,255	51,590	394,845	186,990	32,933	219,923	54,998
2014	319,769	93,317	413,086	239,921	238,762	249,136	262,428	337,185	50,485	387,670	179,879	31,846	211,725	54,998
2015	313,644	91,194	404,838	233,456	236,983	247,281	260,472	331,710	48,380	380,090	173,928	30,808	204,736	54,998
2016	308,997	89,703	398,700	227,375	235,217	245,438	258,532	326,275	47,162	373,437	167,563	29,814	197,377	54,998
2017	303,254	88,039	391,293	221,654	233,465	243,610	256,606	321,441	45,754	367,195	163,031	27,790	190,821	54,998
2018	296,665	86,208	382,873	216,265	231,726	241,795	254,694	317,123	44,667	361,790	158,046	25,558	183,604	54,998
2019	289,050	84,716	373,766	211,201	229,999	239,993	252,797	312,815	43,393	356,208	153,046	24,970	178,016	54,998
2020	282,300	83,296	365,596	206,430	228,286	238,206	250,913	308,491	41,207	349,698	148,598	23,891	172,489	54,998
2021	274,749	82,187	356,936	201,943	226,585	236,431	249,044	304,409	39,828	344,237	143,894	23,360	167,254	54,998
2022	268,049	81,139	349,188	197,722	224,897	234,670	247,189	300,957	37,803	338,760	139,082	22,846	161,928	54,998
2023	262,097	79,910	342,007	193,748	223,222	232,921	245,347	297,682	36,312	333,994	134,601	22,357	156,958	54,998
2024	255,593	78,969	334,562	189,777	221,559	231,186	243,519	294,659	34,885	329,544	130,069	21,145	151,214	54,998
2025	249,636	78,077	327,713	186,264	219,908	229,464	241,705	292,037	33,036	325,073	126,937	20,203	147,140	54,998
2026	244,054	77,452	321,506	182,956	218,270	227,754	239,904	289,120	32,613	321,733	123,314	19,534	142,848	54,998
2027	236,417	76,644	313,061	179,621	216,644	226,057	238,117	286,016	31,547	317,563	119,786	18,157	137,943	54,998
2028	231,761	76,094	307,855	176,696	215,030	224,373	236,343	283,397	29,199	312,596	116,573	16,322	132,895	54,998
2029	227,068	75,144	302,212	173,727	213,428	222,702	234,582	281,130	28,215	309,345	113,603	15,233	128,836	54,998
2030	221,796	74,234	296,030	171,137	211,838	221,042	232,835	278,545	26,389	304,934	110,539	14,634	125,173	54,998
2031	215,965	73,055	289,020	168,700	210,259	219,396	231,100	275,795	26,121	301,916	108,234	13,816	122,050	54,998
2032	208,981	72,331	281,312	166,408	208,693	217,761	229,378	273,891	25,021	298,912	105,513	13,255	118,768	54,998
2033	205,437	71,424	276,861	164,250	207,138	216,139	227,670	272,145	23,749	295,894	103,224	11,776	115,000	54,998
2034	198,258	70,032	268,290	162,221	205,595	214,529	225,973	270,442	22,502	292,944	101,292	11,248	112,540	54,998

Table 3 cont: Managed available groundwater for Subdivision 1 and 2. All numbers are in acre-feet. NPGCD = North Plains Groundwater Conservation District and UWCD = Underground Water Conservation District.

Year	Dallam NPGCD	Dallam No district	Dallam Total	Sherman NPGCD	Lipscomb NPGCD	Ochiltree NPGCD	Hansford NPGCD	Hartley NPGCD	Hartley No district	Hartley Total	Moore NPGCD	Moore No district	Moore Total	Hemphill County UWCD
2035	193,918	69,382	263,300	160,309	204,063	212,930	224,290	268,523	21,497	290,020	99,511	10,720	110,231	54,998
2036	189,222	69,056	258,278	158,511	202,543	211,344	222,619	266,991	19,893	286,884	97,752	10,283	108,035	54,998
2037	179,598	67,330	246,928	156,822	201,034	209,770	220,930	265,450	19,334	284,784	96,163	9,327	105,490	54,998
2038	174,743	67,043	241,786	155,228	199,537	208,207	219,284	263,943	18,368	282,311	94,698	8,818	103,516	54,998
2039	169,865	65,965	235,830	153,728	198,050	206,656	217,651	262,847	17,845	280,692	93,584	8,323	101,907	54,998
2040	162,878	64,905	227,783	152,122	196,574	205,116	216,029	261,512	16,915	278,427	92,109	7,459	99,568	54,998
2041	157,635	63,252	220,887	150,797	195,110	203,588	214,420	260,348	16,221	276,569	91,062	6,768	97,830	54,998
2042	152,322	62,116	214,438	149,551	193,656	202,071	212,822	259,302	15,927	275,229	89,923	6,392	96,315	54,998
2043	145,064	61,714	206,778	148,183	192,214	200,566	211,237	258,245	15,449	273,694	87,973	6,140	94,113	54,998
2044	138,958	61,214	200,172	147,080	190,782	199,071	209,663	256,318	14,970	271,288	86,714	5,435	92,149	54,998
2045	133,041	59,761	192,802	146,041	189,360	197,589	208,101	255,067	13,888	268,955	85,864	5,417	91,281	54,998
2046	128,222	59,091	187,313	145,063	187,949	196,116	206,551	253,777	13,631	267,408	84,784	5,401	90,185	54,998
2047	123,350	58,242	181,592	144,144	186,549	194,655	205,012	252,291	12,583	264,874	83,780	4,947	88,727	54,998
2048	117,528	57,292	174,820	143,281	185,160	193,205	203,485	250,872	12,152	263,024	81,841	4,711	86,552	54,938
2049	113,907	55,665	169,572	142,346	183,780	191,766	201,969	249,965	11,726	261,691	80,745	4,699	85,444	54,938
2050	107,576	54,547	162,123	141,468	182,411	190,337	200,464	248,677	11,487	260,164	79,056	3,823	82,879	54,938
2051	103,546	53,133	156,679	140,559	181,052	188,871	198,813	247,499	11,259	258,758	78,079	3,593	81,672	54,938
2052	100,696	51,917	152,613	139,885	179,703	187,428	197,332	246,820	10,645	257,465	77,138	3,144	80,282	54,938
2053	98,039	50,521	148,560	138,948	178,364	186,032	195,789	245,799	10,239	256,038	76,074	3,137	79,211	54,938
2054	96,396	48,709	145,105	138,164	177,036	184,646	194,264	244,504	10,022	254,526	74,967	3,131	78,098	54,938
2055	91,864	48,313	140,177	137,493	175,717	183,270	192,682	243,004	9,250	252,254	74,377	3,125	77,502	54,938
2056	87,478	47,124	134,602	136,964	174,408	181,840	191,177	242,624	8,669	251,293	73,734	2,771	76,505	54,938
2057	85,067	45,942	131,009	136,468	173,108	180,485	189,376	241,067	8,356	249,423	72,564	2,767	75,331	54,938
2058	82,901	45,070	127,971	135,448	171,819	179,141	187,893	239,156	7,967	247,123	71,487	2,763	74,250	54,938
2059	79,775	43,651	123,426	135,009	170,474	177,806	186,493	237,500	7,950	245,450	70,911	2,540	73,451	54,938
2060	77,560	42,422	119,982	134,488	169,204	176,481	184,990	235,389	7,750	243,139	70,194	2,406	72,600	54,938

Table 4: Managed available groundwater for Subdivision 3. All numbers are in acre-feet. NPGCD = North Plains Groundwater Conservation District, UWCD = Underground Water Conservation District, PGCD= Panhandle Groundwater Conservation District, and HPUWCD = High Plains Underground Water Conservation District. Note: this table only represents the portion of the Ogallala Aquifer located in the northern segment of the Ogallala Aquifer groundwater availability model for Oldham, Randall, Potter, and Armstrong counties.

Year	Hutchinson NPGCD	Hutchinson No district	Hutchinson PGCD	Hutchinson Total	Roberts PGCD	Carson PGCD	Gray PGCD	Potter PGCD	Wheeler PGCD	Oldham No district	Donley PGCD	Armstrong PGCD	Randall HPUWCD	Randall No district
2010	54,174	82,509	13,715	150,398	367,090	190,230	180,604	35,950	110,041	5,289	88,024	47,395	6,830	12,171
2011	53,770	81,895	13,613	149,278	364,355	188,813	179,259	35,683	109,222	5,250	87,369	47,041	6,779	12,080
2012	53,370	81,284	13,512	148,166	361,641	187,407	177,923	35,417	108,408	5,211	86,718	46,691	6,728	11,990
2013	52,972	80,679	13,411	147,062	358,946	186,010	176,598	35,153	107,600	5,172	86,072	46,343	6,678	11,901
2014	52,578	80,078	13,311	145,967	356,272	184,625	175,282	34,891	106,799	5,133	85,430	45,998	6,629	11,812
2015	52,186	79,481	13,212	144,879	353,618	183,249	173,976	34,631	106,003	5,095	84,794	45,655	6,579	11,724
2016	51,797	78,889	13,113	143,799	350,984	181,884	172,680	34,373	105,213	5,057	84,162	45,315	6,530	11,637
2017	51,411	78,301	13,016	142,728	348,369	180,529	171,394	34,117	104,429	5,019	83,535	44,977	6,481	11,550
2018	51,028	77,718	12,919	141,665	345,773	179,184	170,117	33,863	103,651	4,982	82,913	44,642	6,433	11,464
2019	50,648	77,139	12,823	140,610	343,197	177,849	168,849	33,611	102,879	4,945	82,295	44,310	6,385	11,379
2020	50,271	76,564	12,727	139,562	340,641	176,524	167,591	33,360	102,113	4,908	81,682	43,980	6,338	11,294
2021	49,896	75,994	12,632	138,522	338,103	175,209	166,343	33,112	101,352	4,871	81,074	43,652	6,291	11,210
2022	49,524	75,428	12,538	137,490	335,584	173,904	165,104	32,865	100,597	4,835	80,470	43,327	6,244	11,126
2023	49,156	74,866	12,445	136,467	333,084	172,608	163,874	32,620	99,848	4,799	79,870	43,004	6,197	11,043
2024	48,789	74,308	12,352	135,449	330,602	171,322	162,653	32,377	99,104	4,763	79,275	42,684	6,151	10,961
2025	48,426	73,754	12,260	134,440	328,139	170,046	161,441	32,136	98,365	4,728	78,685	42,366	6,105	10,879
2026	48,065	73,205	12,169	133,439	325,695	168,779	160,238	31,896	97,633	4,693	78,098	42,050	6,060	10,798
2027	47,707	72,660	12,078	132,445	323,268	167,522	159,044	31,659	96,905	4,658	77,516	41,737	6,014	10,718
2028	47,352	72,118	11,988	131,458	320,860	166,274	157,860	31,423	96,183	4,623	76,939	41,426	5,970	10,638
2029	46,999	71,581	11,899	130,479	318,470	165,035	156,684	31,189	95,467	4,589	76,366	41,117	5,925	10,559
2030	46,649	71,048	11,810	129,507	316,097	163,805	155,516	30,957	94,755	4,554	75,797	40,811	5,881	10,480
2031	46,301	70,518	11,722	128,541	313,742	162,585	154,358	30,726	94,049	4,520	75,232	40,507	5,837	10,402
2032	45,956	69,993	11,635	127,584	311,405	161,374	153,208	30,497	93,349	4,487	74,672	40,205	5,794	10,325
2033	45,614	69,472	11,548	126,634	309,085	160,171	152,066	30,270	92,653	4,453	74,115	39,906	5,751	10,248
2034	45,274	68,954	11,462	125,690	306,782	158,978	150,933	30,044	91,963	4,420	73,563	39,608	5,708	10,171

Table 4 cont: Managed available groundwater for Subdivision 3. All numbers are in acre-feet. NPGCD = North Plains Groundwater Conservation District, UWCD = Underground Water Conservation District, PGCD= Panhandle Groundwater Conservation District, and HPUWCD = High Plains Underground Water Conservation District. Note: this table only represents the portion of the Ogallala Aquifer located in the northern segment of the Ogallala Aquifer groundwater availability model for Oldham, Randall, Potter, and Armstrong counties.

Year	Hutchinson NPGCD	Hutchinson No district	Hutchinson PGCD	Hutchinson Total	Roberts PGCD	Carson PGCD	Gray PGCD	Potter PGCD	Wheeler PGCD	Oldham No district	Donley PGCD	Armstrong PGCD	Randall HPUWCD	Randall No district
2035	44,937	68,440	11,377	124,754	304,497	157,794	149,809	29,820	91,278	4,387	73,015	39,313	5,665	10,096
2036	44,602	67,930	11,292	123,824	302,228	156,618	148,693	29,598	90,598	4,354	72,471	39,020	5,623	10,020
2037	44,270	67,424	11,208	122,902	299,976	155,451	147,585	29,378	89,923	4,322	71,931	38,730	5,581	9,946
2038	43,940	66,922	11,124	121,986	297,742	154,293	146,486	29,159	89,253	4,290	71,395	38,441	5,540	9,872
2039	43,612	66,423	11,041	121,076	295,523	153,144	145,394	28,942	88,588	4,258	70,864	38,155	5,498	9,798
2040	43,288	65,929	10,959	120,176	293,322	152,003	144,311	28,726	87,928	4,226	70,336	37,870	5,457	9,725
2041	42,965	65,437	10,877	119,279	291,136	150,870	143,236	28,512	87,273	4,195	69,812	37,588	5,417	9,653
2042	42,604	64,950	10,796	118,350	288,968	149,747	142,169	28,300	86,623	4,163	69,291	37,308	5,376	9,581
2043	42,286	64,466	10,716	117,468	286,815	148,631	141,110	28,089	85,978	4,132	68,775	37,030	5,336	9,509
2044	41,971	63,986	10,636	116,593	284,678	147,524	139,923	27,880	85,337	4,102	68,263	36,754	5,297	9,438
2045	41,659	63,509	10,557	115,725	282,557	146,425	138,880	27,672	84,701	4,071	67,754	36,481	5,257	9,368
2046	41,301	63,036	10,478	114,815	280,452	145,334	137,846	27,466	84,070	4,041	67,250	36,209	5,218	9,298
2047	40,955	62,566	10,400	113,921	278,363	144,251	136,819	27,261	83,444	4,011	66,749	35,939	5,179	9,229
2048	40,650	62,100	10,323	113,073	276,289	143,176	135,799	27,058	82,822	3,981	66,251	35,671	5,140	9,160
2049	40,347	61,638	10,246	112,231	274,231	142,110	134,788	26,856	82,205	3,951	65,758	35,406	5,102	9,092
2050	40,012	61,178	10,169	111,359	272,187	141,051	133,783	26,656	81,593	3,922	65,268	35,142	5,064	9,024
2051	39,635	60,723	10,094	110,452	270,160	140,000	132,787	26,458	80,937	3,892	64,782	34,880	5,026	8,957
2052	39,340	60,270	10,018	109,628	268,147	138,957	131,798	26,261	80,278	3,863	64,299	34,620	4,989	8,890
2053	38,991	59,821	9,944	108,756	266,149	137,922	130,816	26,065	79,680	3,835	63,820	34,362	4,952	8,824
2054	38,700	59,375	9,870	107,945	264,166	136,894	129,841	25,845	79,086	3,806	63,344	34,057	4,915	8,758
2055	38,365	58,933	9,796	107,094	262,198	135,874	128,820	25,618	78,497	3,778	62,873	33,758	4,878	8,693
2056	37,957	58,494	9,723	106,174	260,245	134,862	127,860	25,428	77,912	3,750	62,404	33,506	4,842	8,628
2057	37,674	58,058	9,651	105,383	258,306	133,857	126,908	25,238	77,332	3,722	61,939	33,257	4,806	8,564
2058	37,289	57,626	9,579	104,494	256,382	132,860	125,962	25,032	76,755	3,694	61,478	33,009	4,770	8,500
2059	37,011	57,196	9,508	103,715	254,472	131,870	125,024	24,845	76,184	3,666	61,020	32,763	4,735	8,437
2060	36,735	56,770	9,437	102,942	252,576	130,888	124,092	24,660	75,616	3,639	60,565	32,519	4,699	8,374

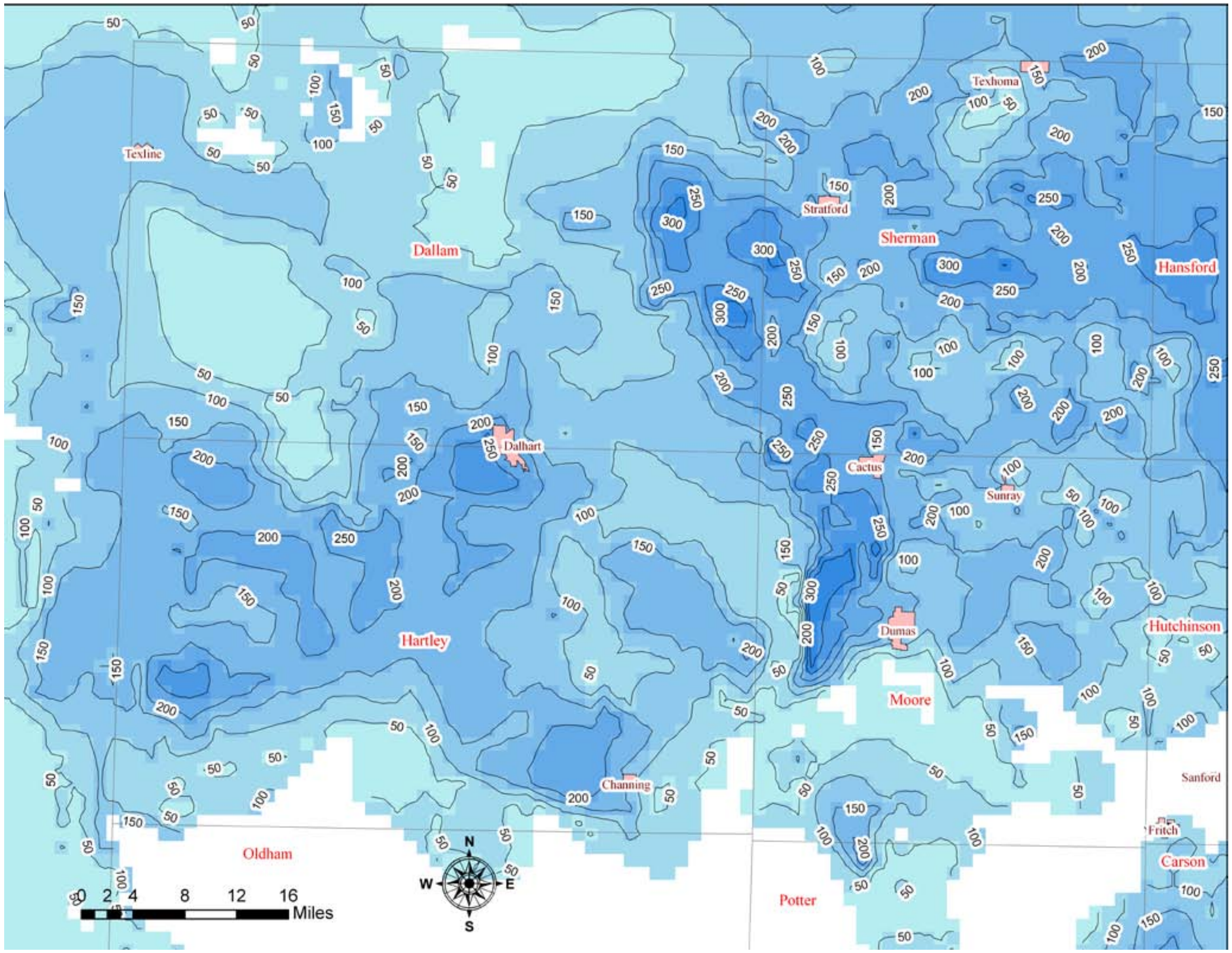

Figure 2: Baseline year showing saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

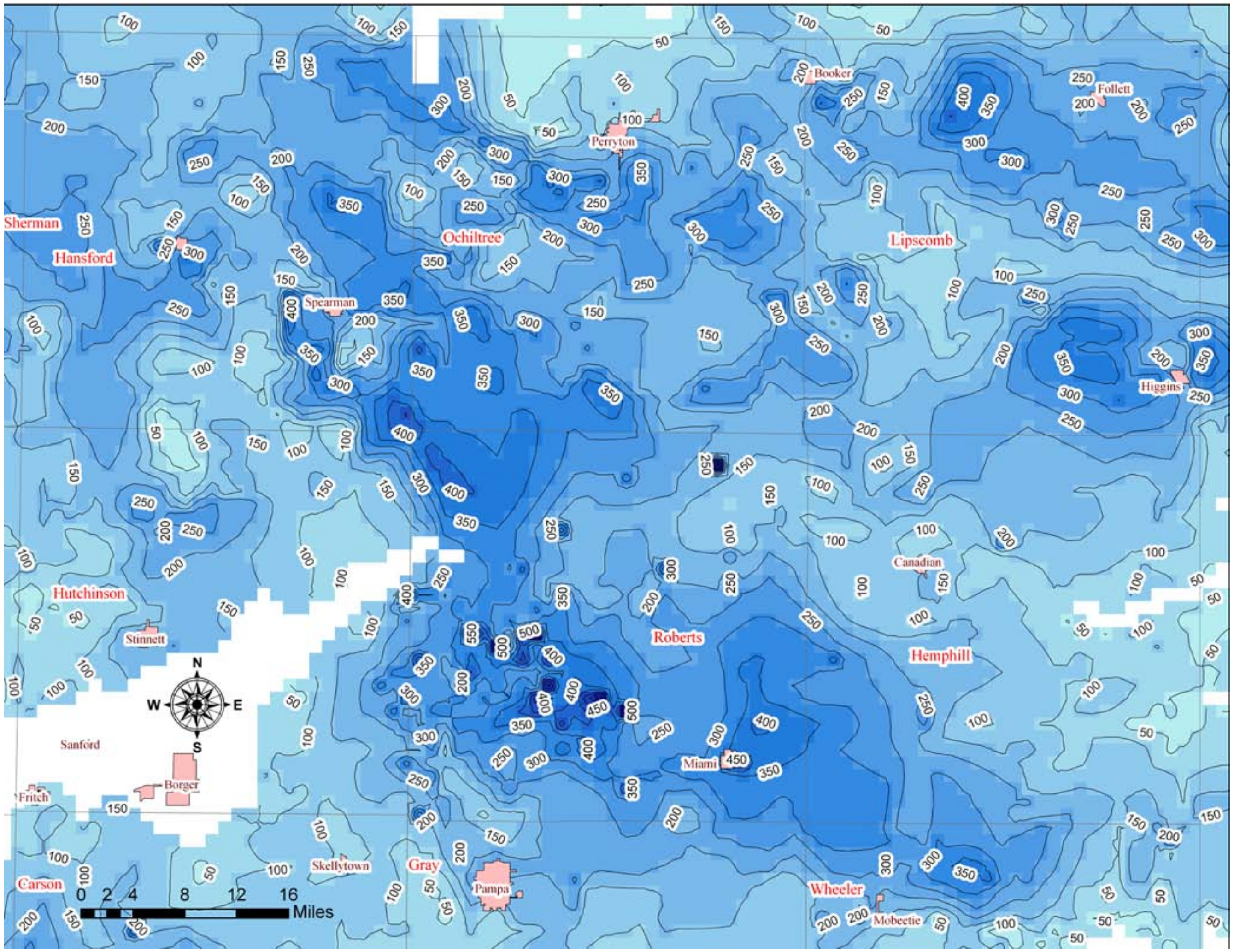

Figure 3: Baseline year showing saturated thickness on the eastern side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

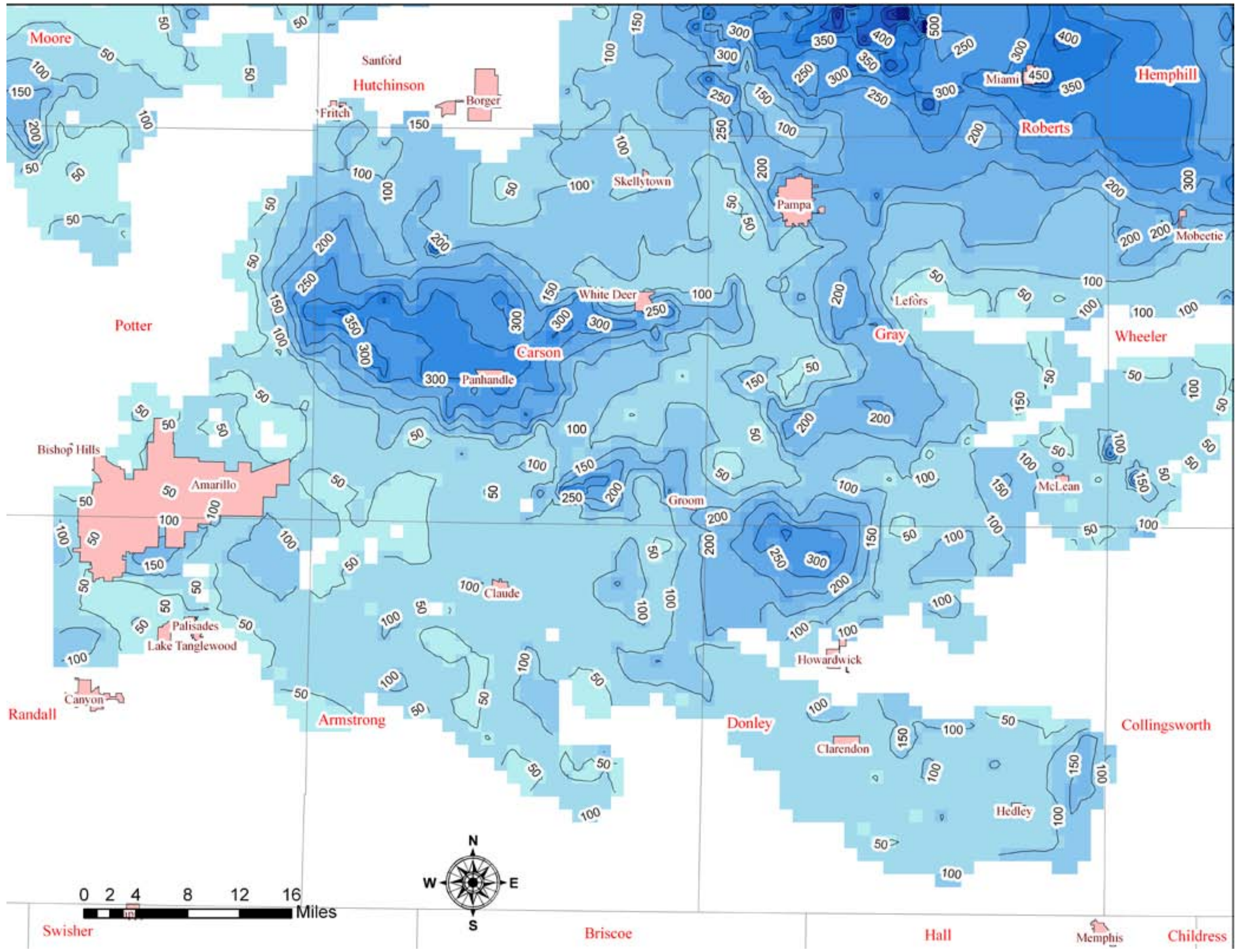

Figure 4: Baseline year showing saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

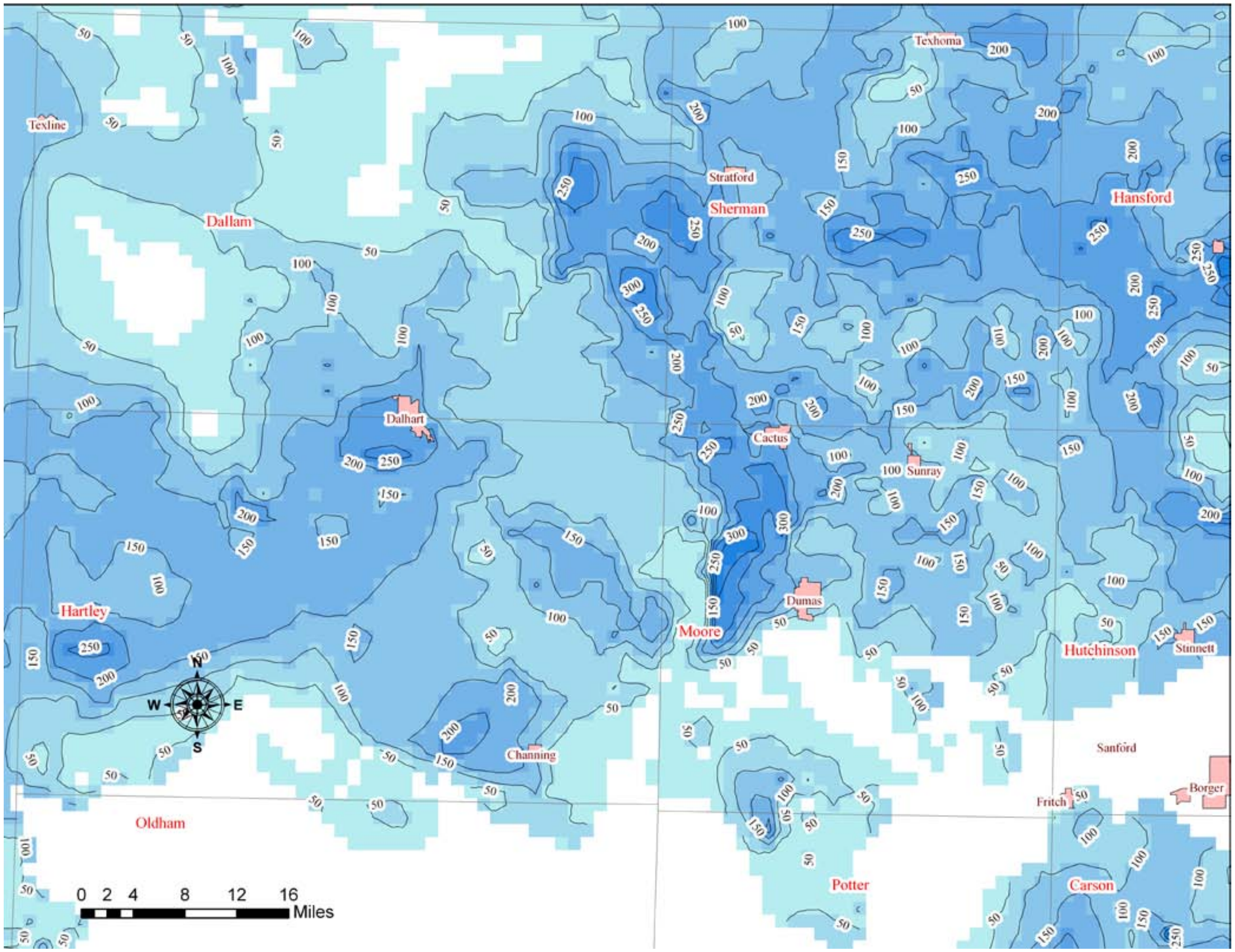

Figure 5: 2020 saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

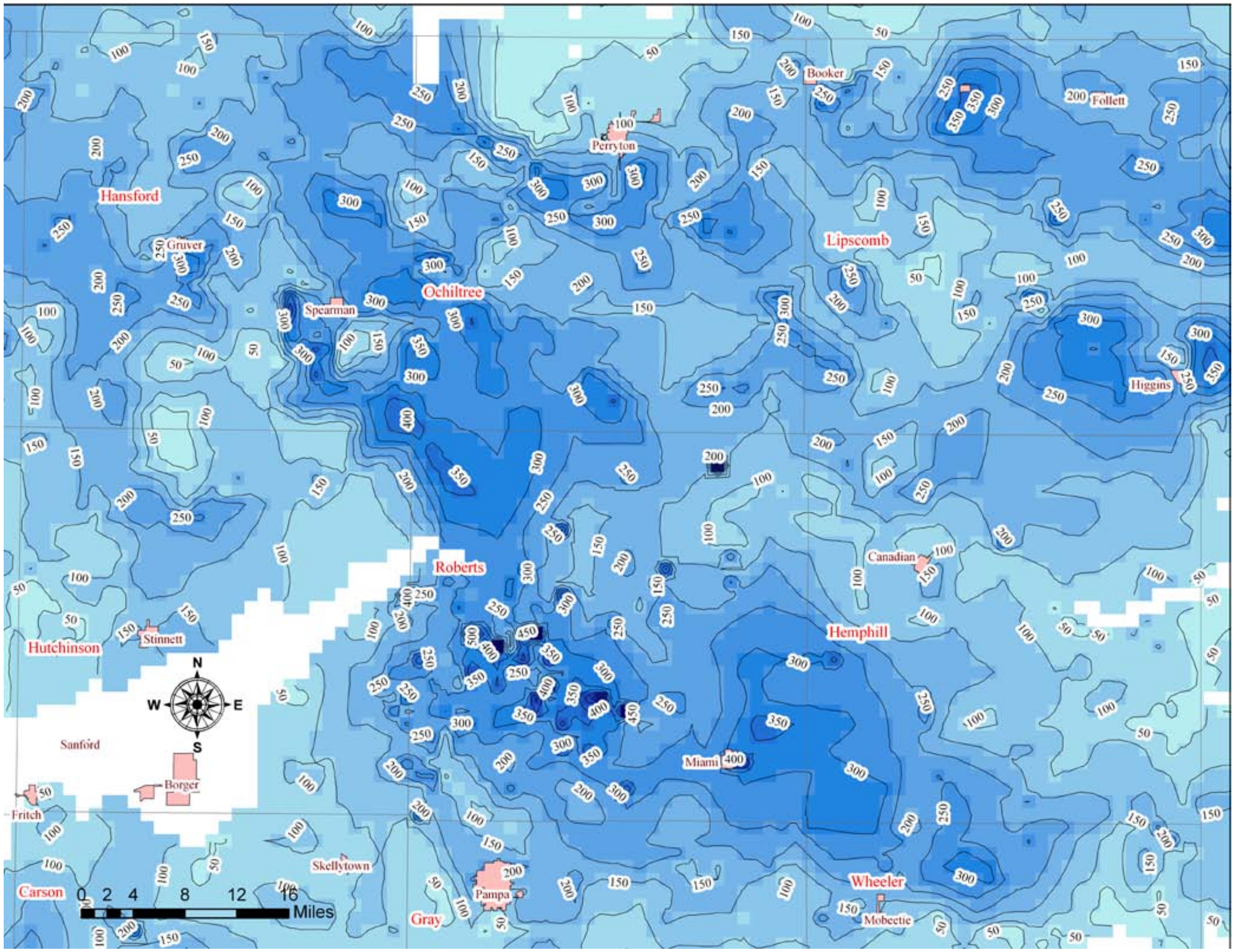

Figure 6: 2020 saturated thickness on the eastern side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

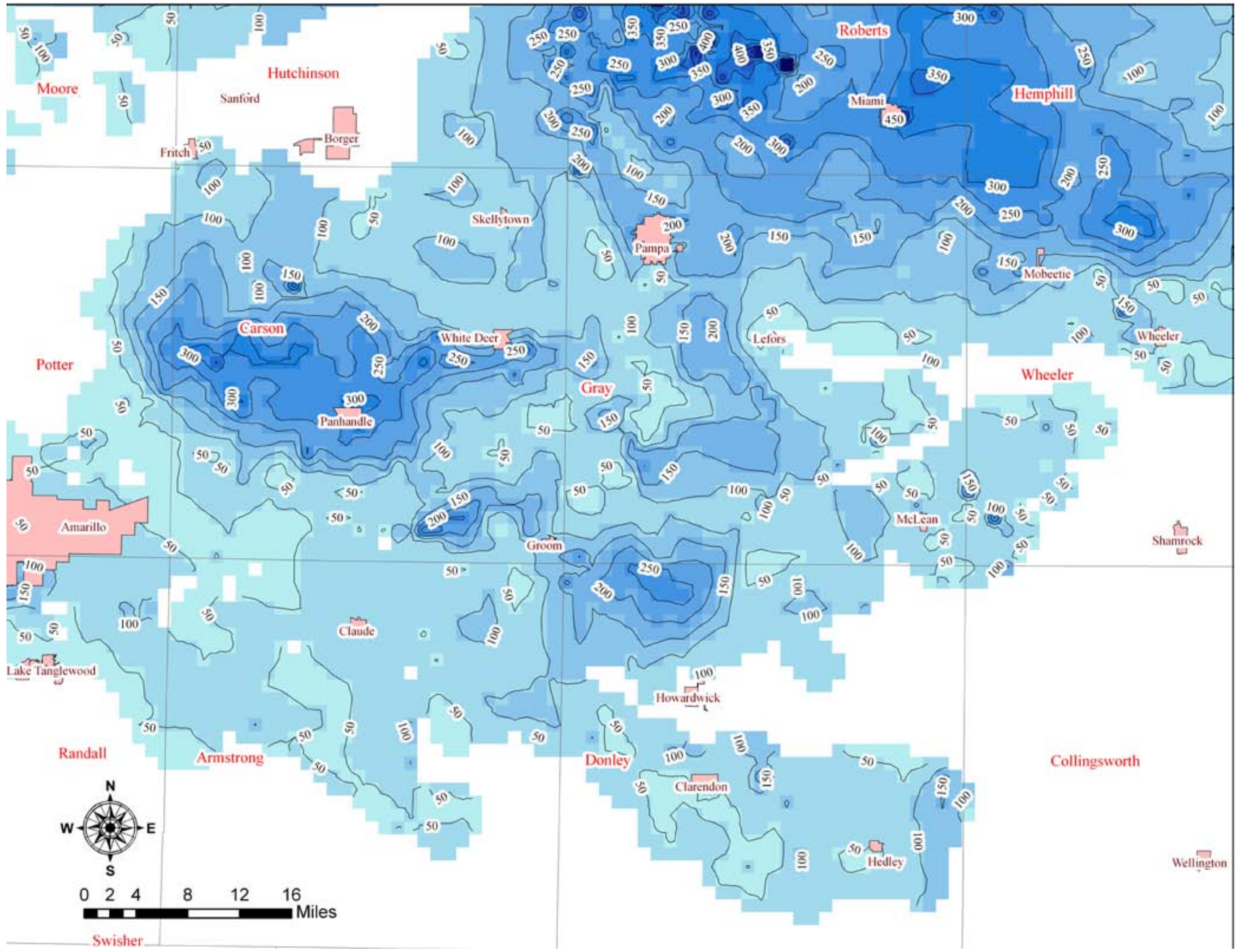

Figure 7: 2020 saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

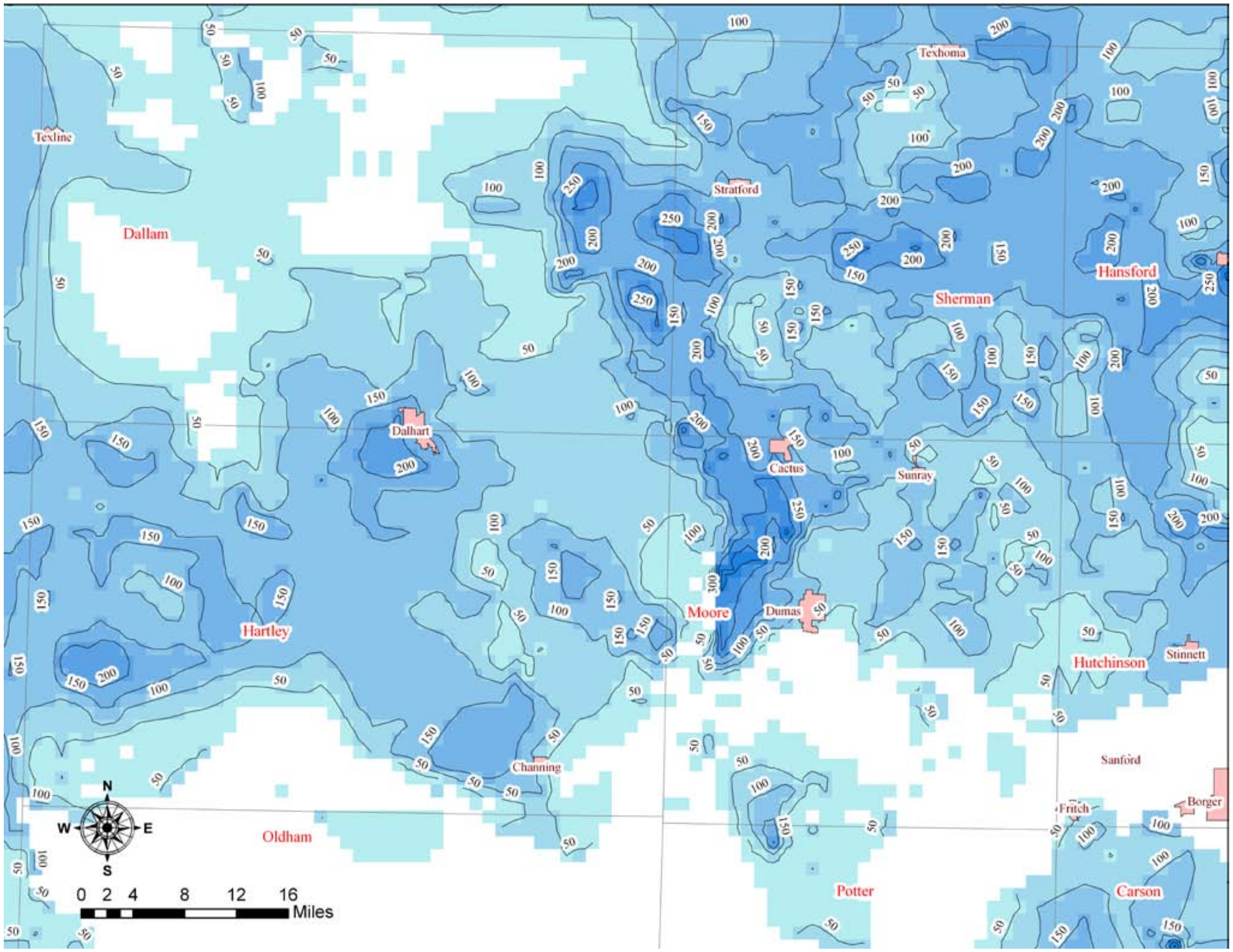

Figure 8: 2030 saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

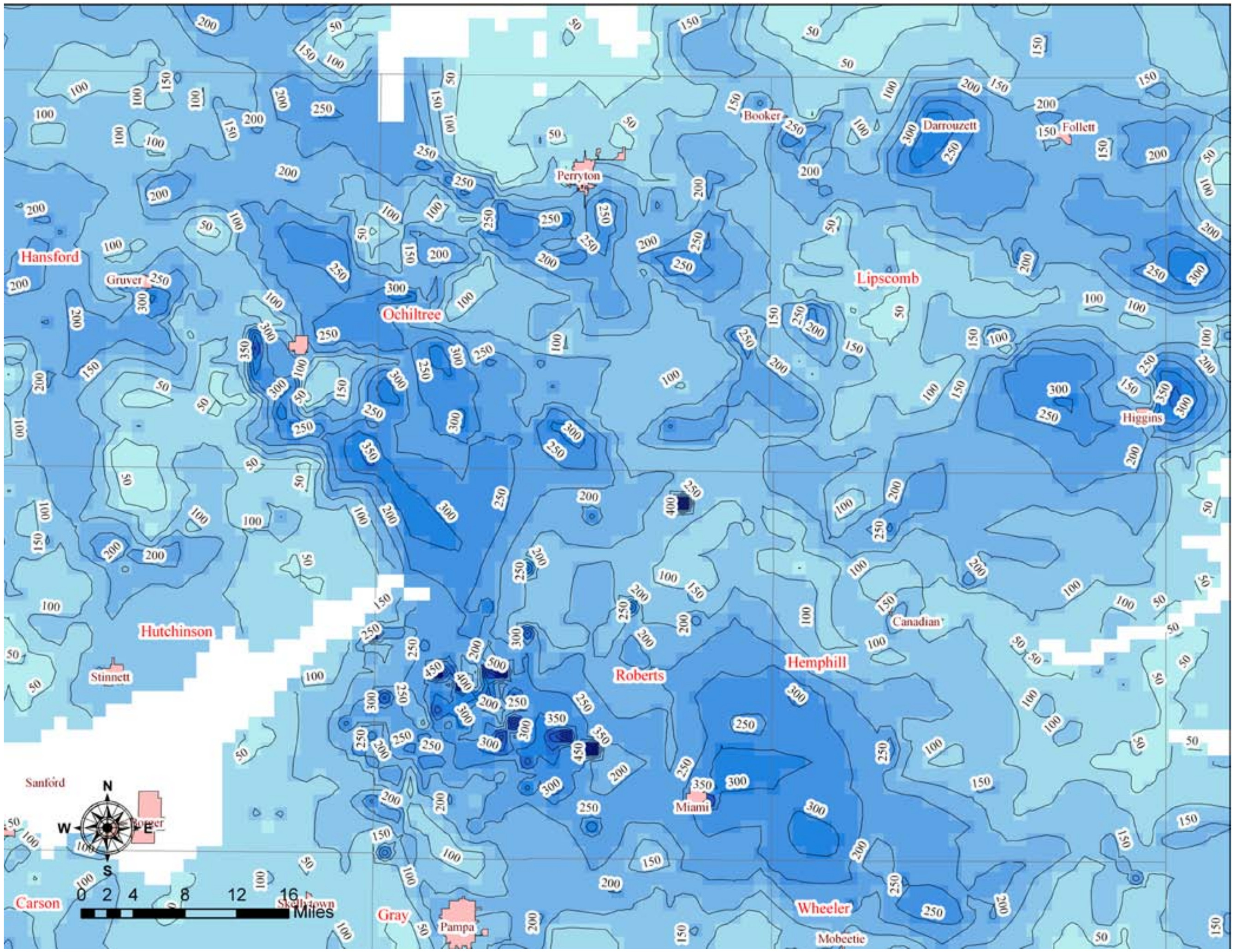

Figure 9: 2030 saturated thickness on the eastern side of the Northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

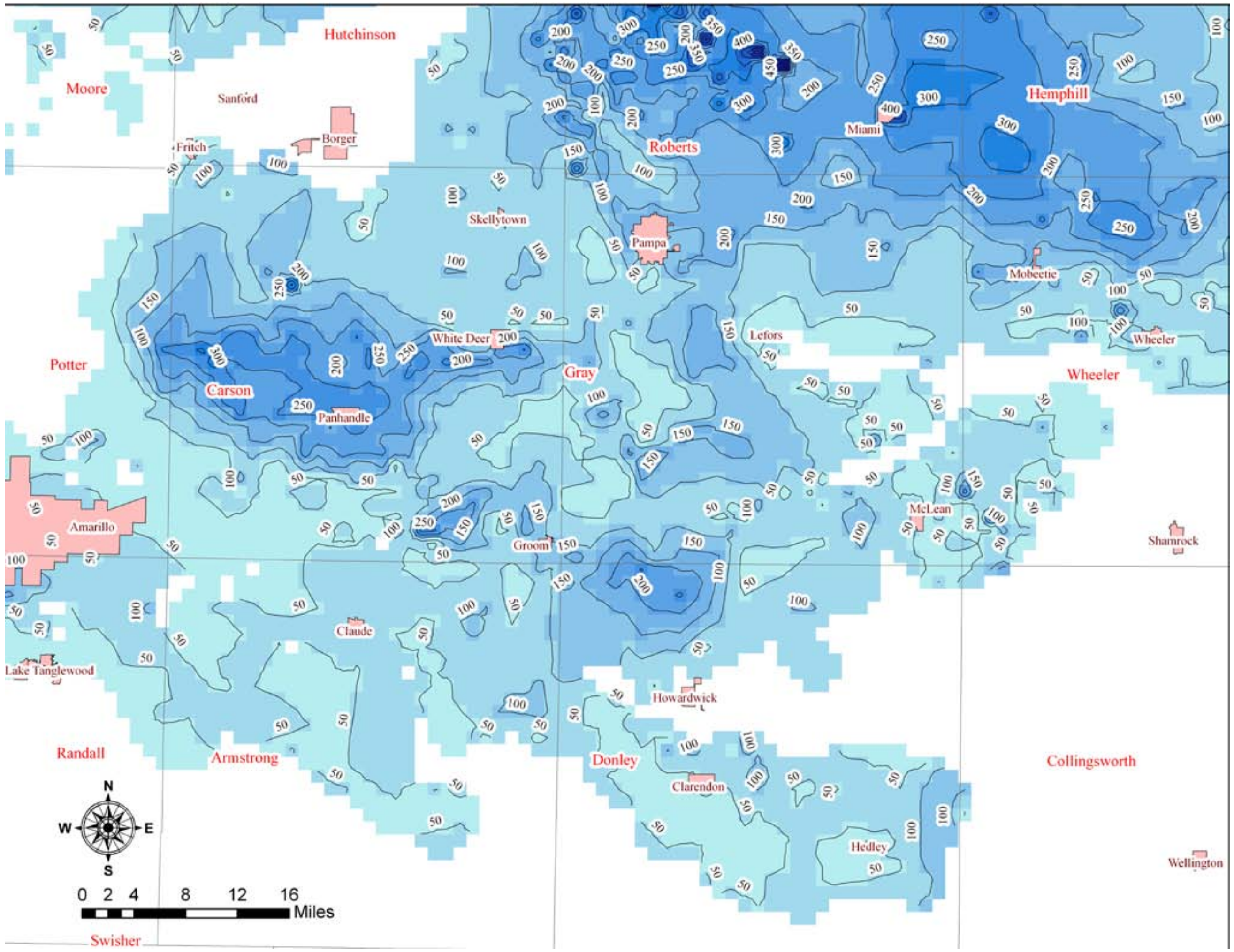

Figure 10: 2030 saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

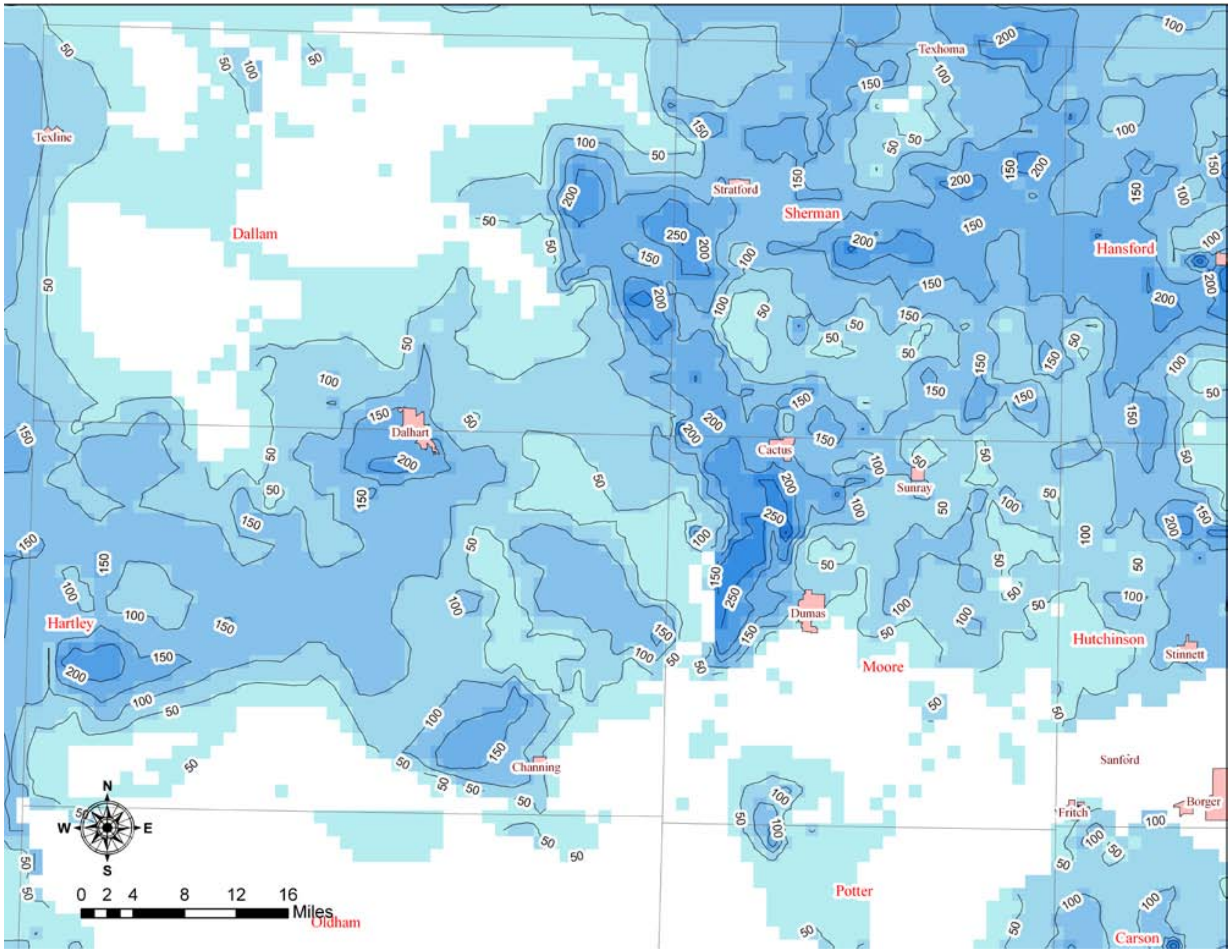

Figure 11: 2040 saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

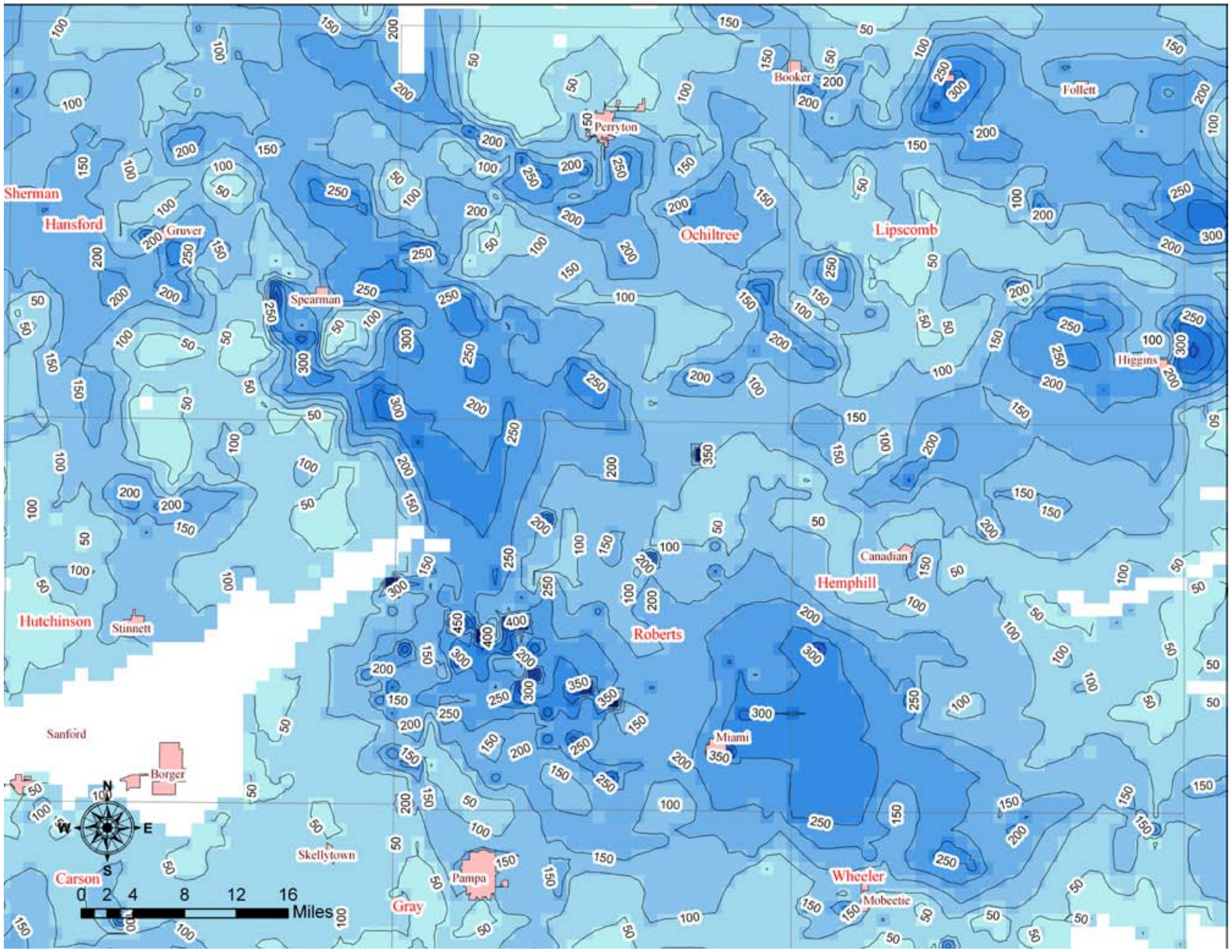

Figure 12: 2040 saturated thickness on the eastern side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

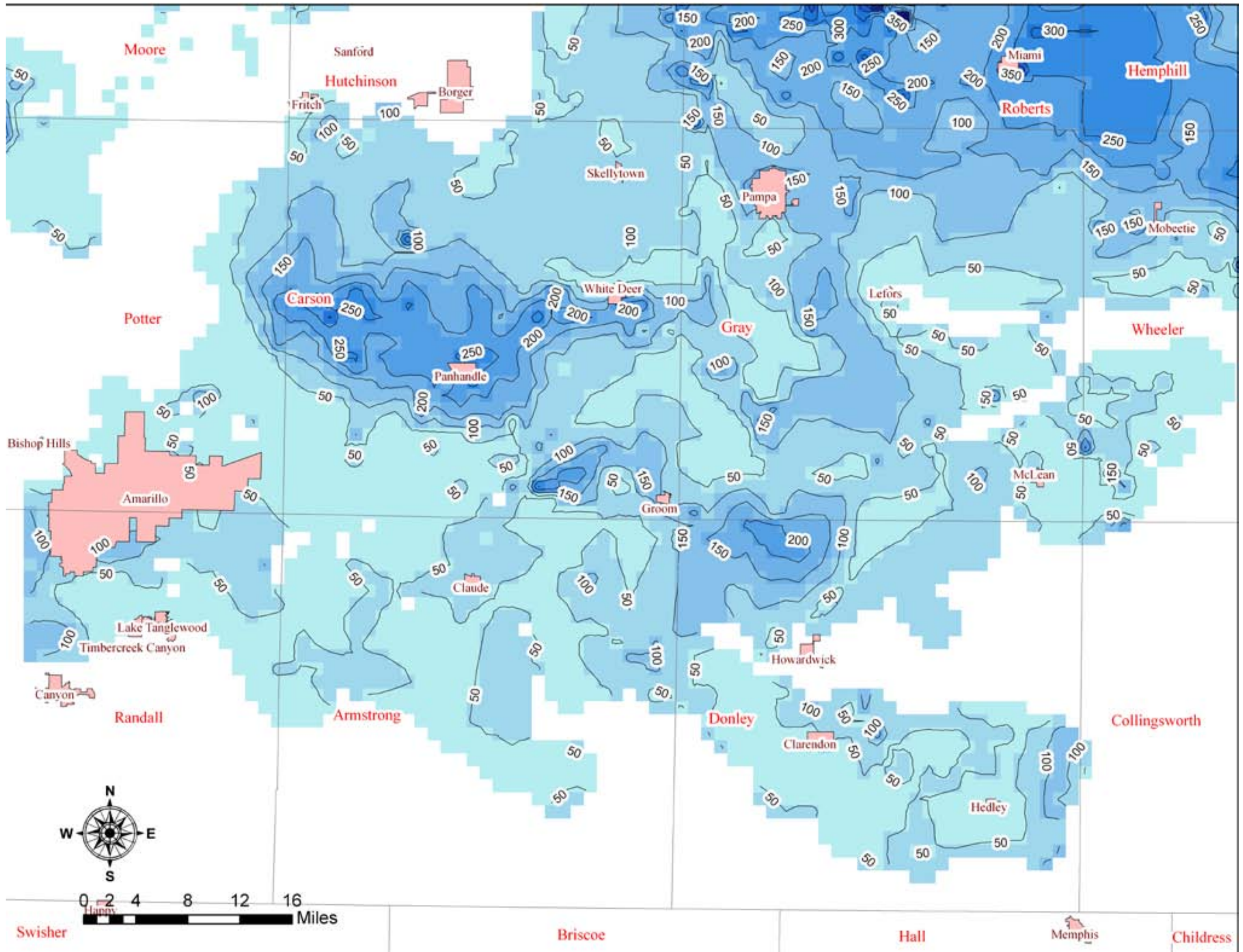

Figure 13: 2040 saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

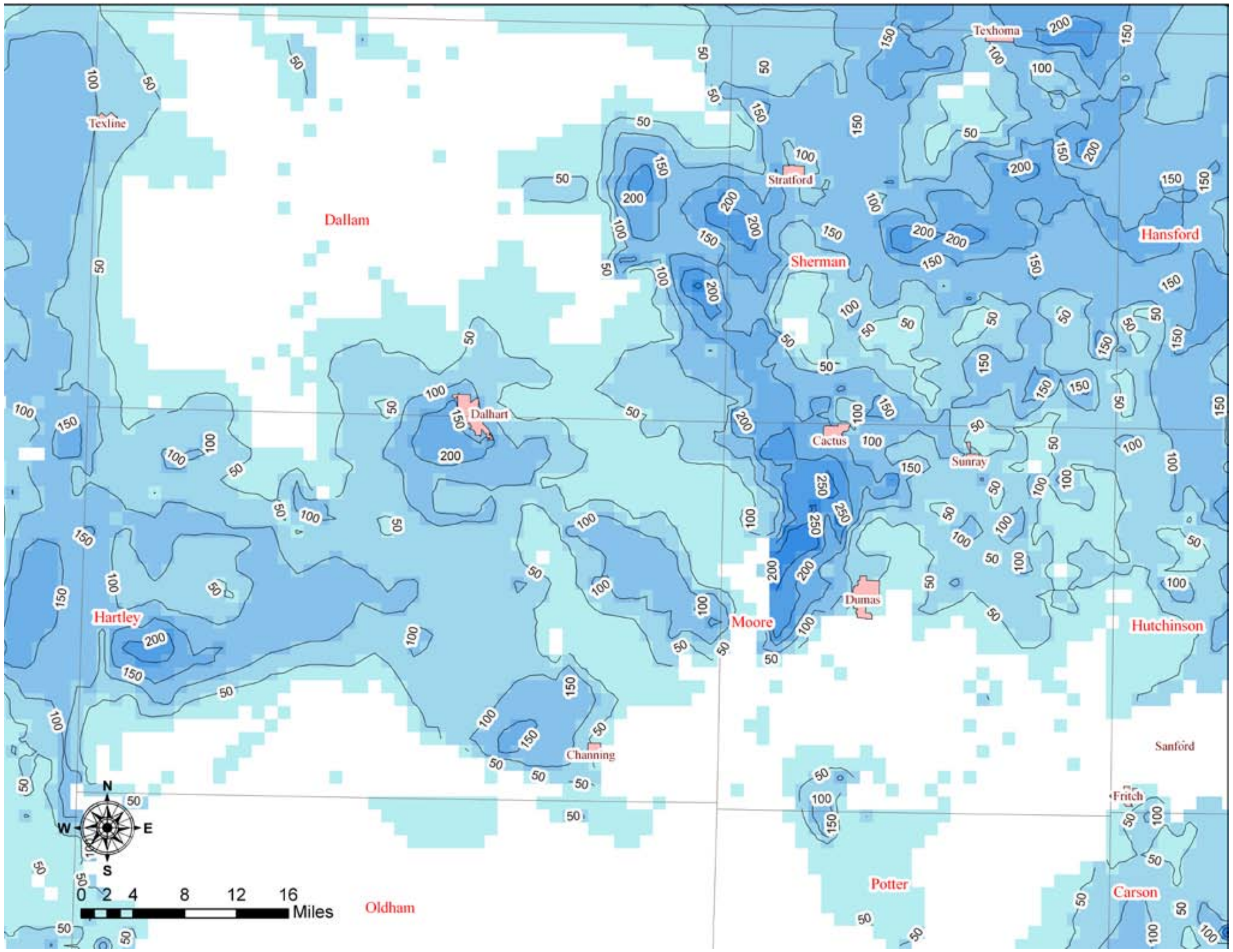

Figure 14: 2050 saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

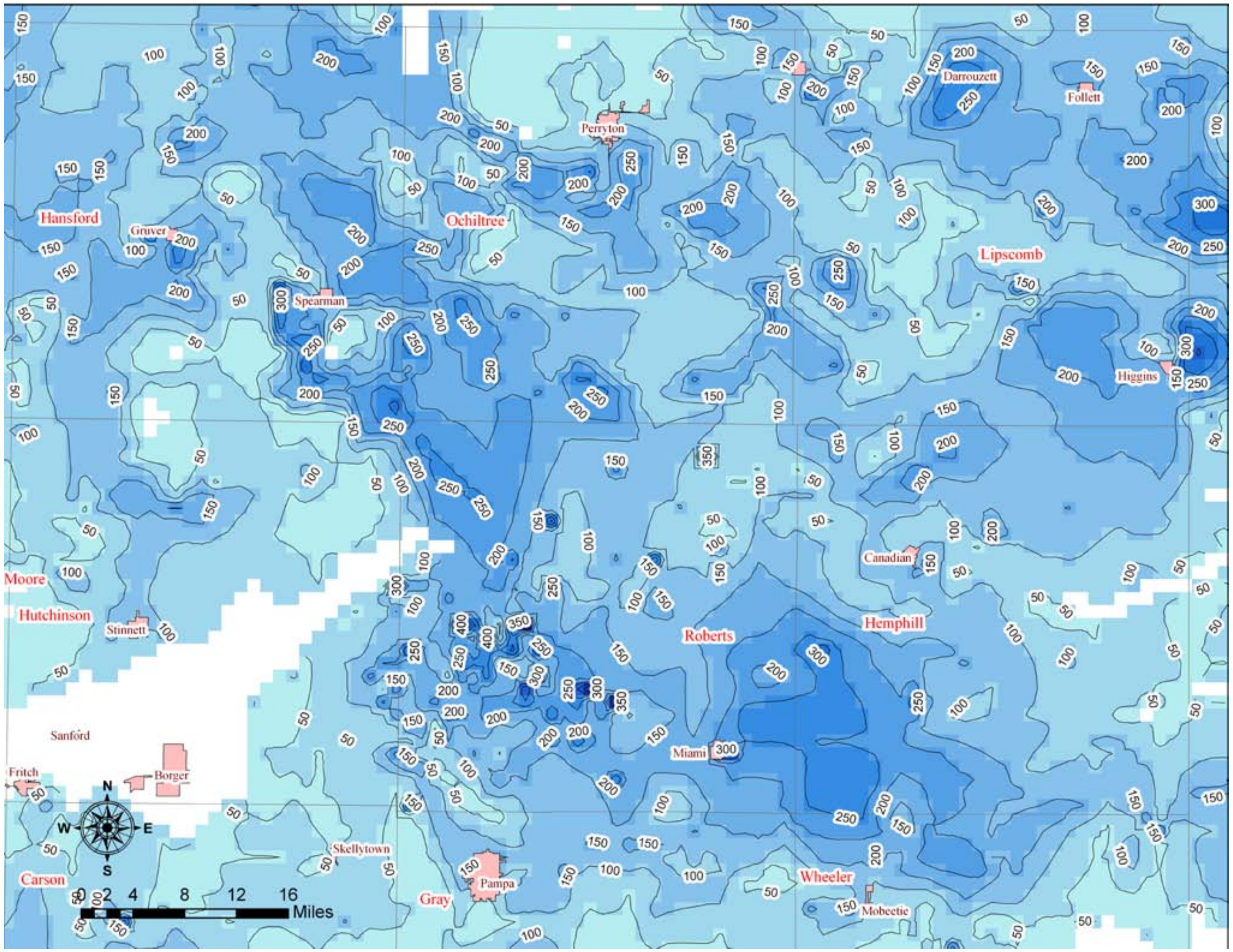

Figure 15: 2050 saturated thickness on the eastern side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

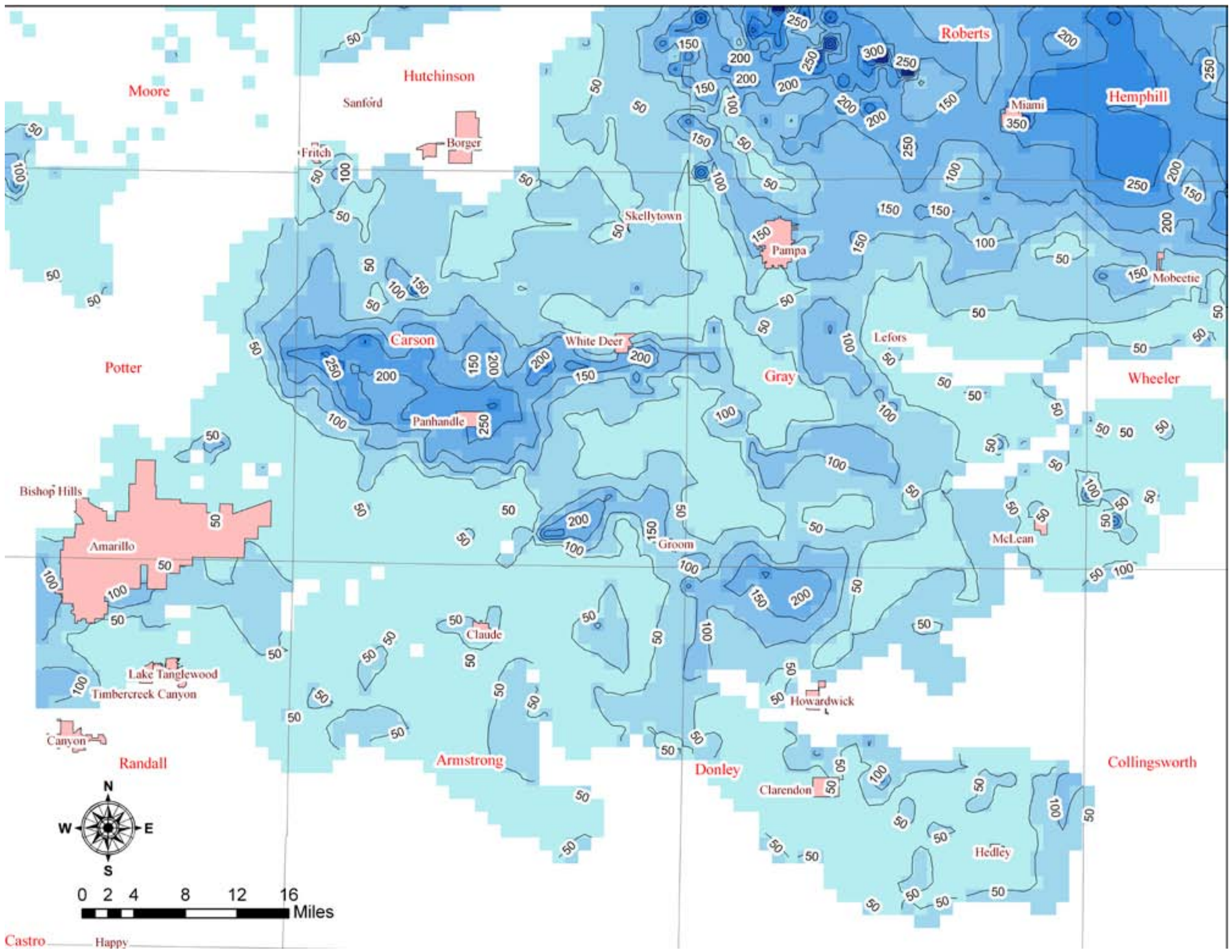

Figure 16: 2050 saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

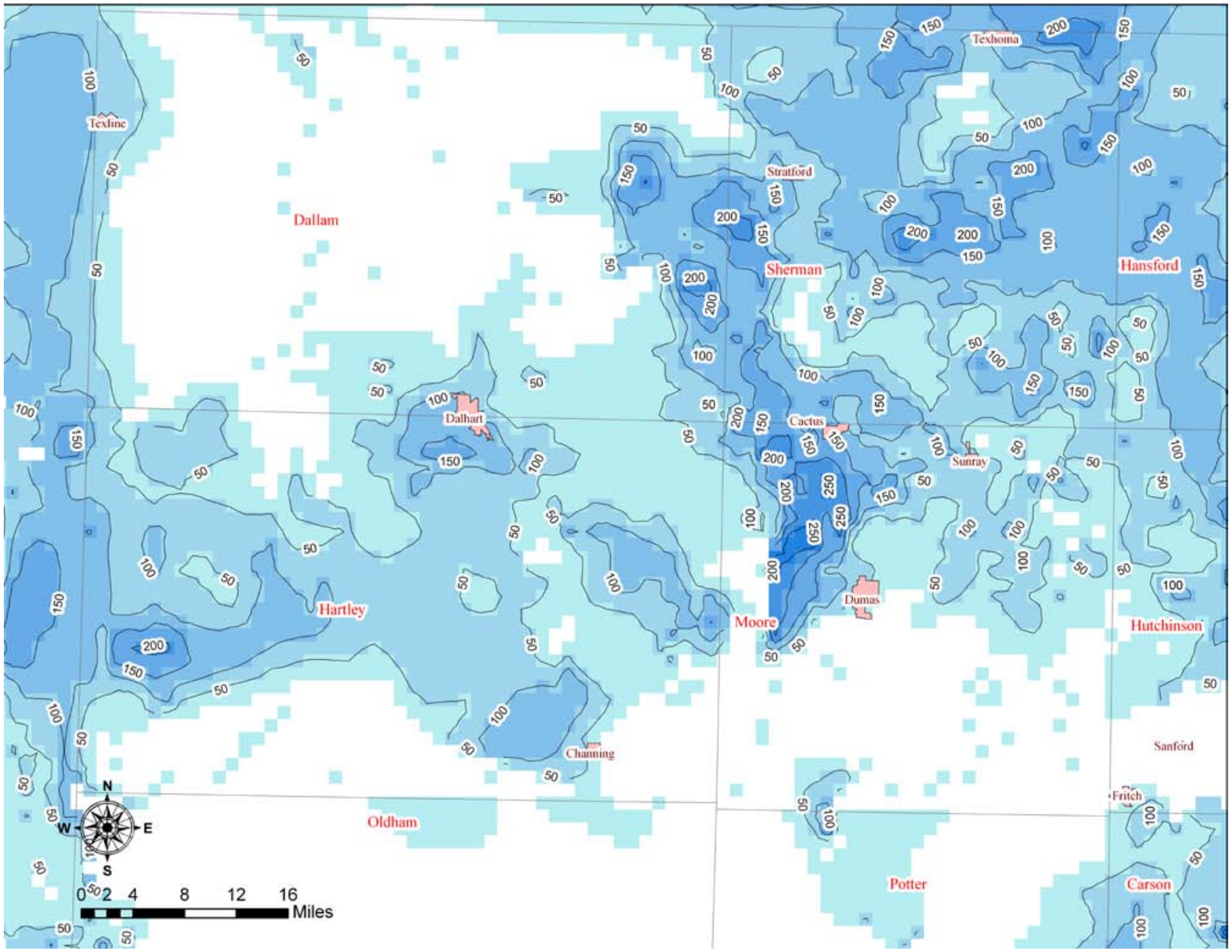

Figure 17: 2060 saturated thickness on the western side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

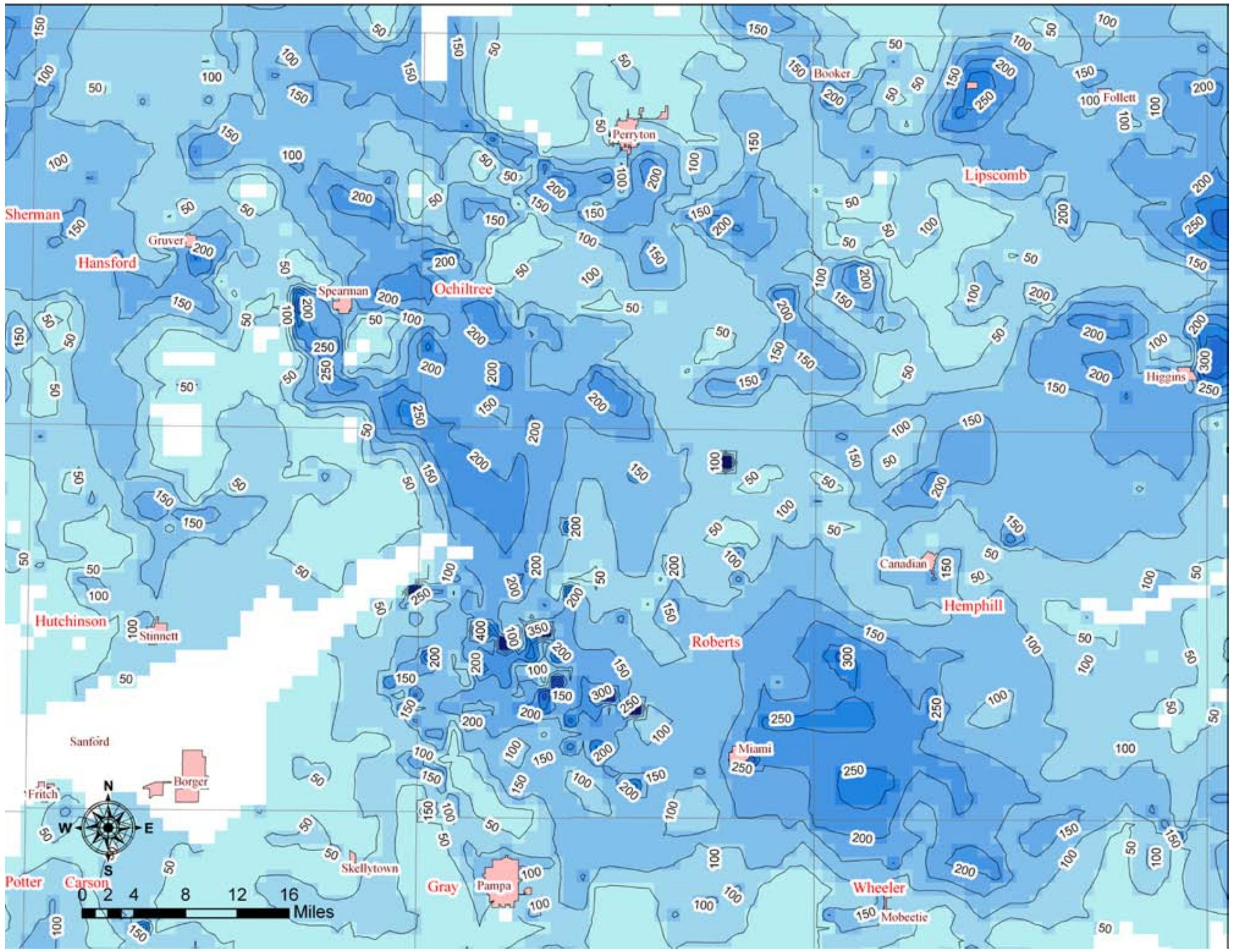

Figure 18: 2060 saturated thickness on the eastern side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.

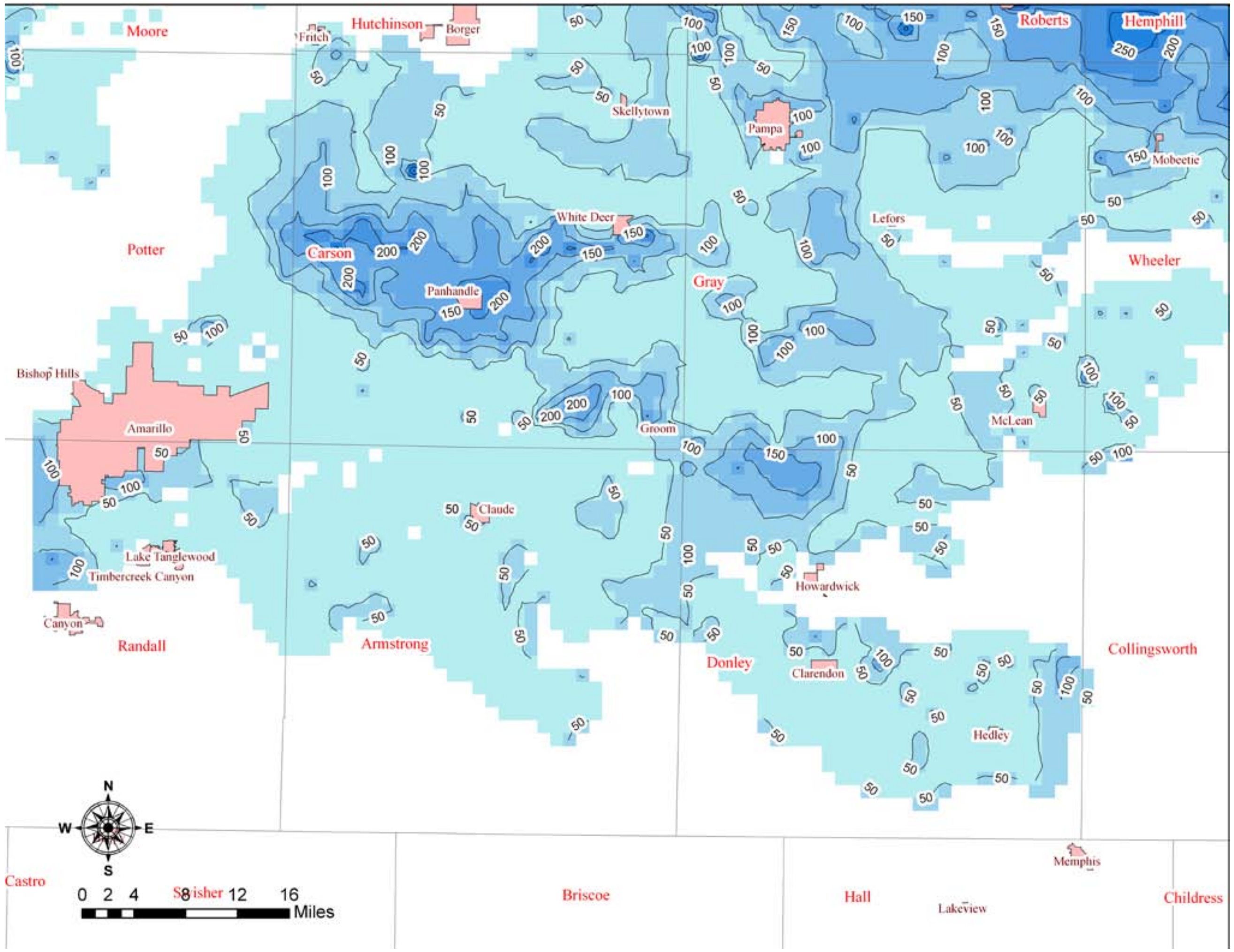

Figure 19: 2060 saturated thickness on the south central side of the northern portion of the Ogallala Aquifer. White cells are inactive and/or outside the boundary of the model.