Groundwater Flow Model of the Kinney County Area

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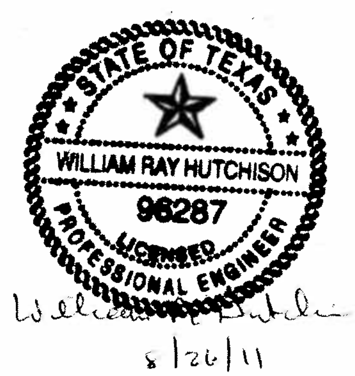
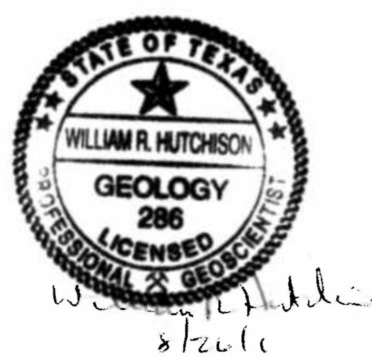
Texas Water Development Board

August 26, 2011





William R. Hutchison is the Division Director of the Groundwater Resources Division and is responsible for oversight of work performed by Jerry Shi and Marius Jigmond under his direct supervision. The seals appearing on this document were authorized by William R. Hutchison, P.E. 96287, P.G. 286, on August 26, 2011.

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EXECUTIVE SUMMARY

ES 1.0 Introduction and Purpose for Groundwater Flow Model

Kinney County Groundwater Conservation District requested an evaluation of its groundwater resources and the effects of potential groundwater withdrawal at wells on springs and river flows. Specifically, the county was interested in maintaining reasonable flows at the three largest springs (Las Moras, Mud, and Pinto springs) under potential future groundwater use conditions.

Prior to this modeling effort, Texas Water Development Board (TWDB) developed two groundwater flow models: one for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2004; Young and Others, 2009) and the other for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer (Lindgren and others, 2004). However, neither model covered the entire Kinney County. In 2008, Wade and Tu from TWDB reviewed both existing MODFLOW models and concluded that neither model could meet the requests from the Kinney County Groundwater Conservation District. As a result, TWDB developed this new groundwater flow model to address groundwater issues concerning the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers that underlie Kinney County.

ES 2.0 Model Overview

The new model, developed using the U.S. Geologic Survey (USGS) MODFLOW-2000 code (Harbaugh and Others, 2000), covered Kinney and its surrounding counties with a refined hydrogeologic framework. The model contained one steady-state stress period (Stress Period 1) that was intended to initiate a transient simulation, and fifty-six transient annual stress periods. The transient stress periods covered the years 1950 through 2005. Model boundaries were also reviewed against observed data and modified, as necessary, in comparison with existing models. A FORTRAN pre-processor was developed to estimate net groundwater recharge distribution based on a revised method originally developed by Maxey and Eakin (1949). Groundwater pumping in Kinney County was also revised to be consistent with groundwater withdrawal data provided by the Kinney County Groundwater Conservation District in June 2010.

ES 3.0 Model Calibration and Results

The calibration of this groundwater model involved adjusting certain model parameters, within a reasonable range, to match the simulated to measured values of groundwater elevation and spring flow. A calibrated groundwater flow model is a tool that can be used to test hypothesis and future conditions. This process is also called prediction. A calibrated model can improve reliability of the prediction.

The new flow model was calibrated to 1,824 water levels measured at wells and 432 flux values measured at springs. Secondarily, the model was also qualitatively evaluated against calculated recharge values to the unconfined aquifers due to precipitation and river leakage in the northern portion of Kinney County and the Nueces River basin. In addition, the model was compared with regional groundwater flow patterns and discharge to rivers. The model calibration was performed using parameter estimation code (PEST), an industry-standard inverse modeling software package (Watermark Numerical Computing, 2004), and by trial-and-error. The model calibration was expedited by incorporating pre- and post-processors developed by TWDB. All calibration parameters indicated that the new flow model was well calibrated to the observed data.

ES 4.0 Sensitivity Analysis

After the calibration, the model was used to assess the sensitivity of spring flows at Las Moras, Mud, and Pinto springs, due to countywide groundwater withdrawal within Kinney County. The sensitivity analysis involved decreasing or increasing the pumping rates at wells located within Kinney County. The sensitivity analysis indicated that increasing groundwater withdrawal at wells within Kinney County would reduce the spring flows at Las Moras, Mud, and Pinto springs. During years experiencing below average recharge conditions, significant groundwater withdrawal may cause the springs to cease flowing at the land surface.

ES 5.0 Model Limitations

Numerical models require some assumptions and have some limitations. These limitations are usually associated with the purpose for the groundwater flow model, our extent of understanding the aquifer(s), the quantity and quality of data needed to constrain parameters in the groundwater flow model, and assumptions made during model development.

Several input parameters for the model are based on limited information. These include groundwater recharge, river level, hydraulic conductivity, and specific storage. During the model sensitivity analysis, spring flows at Las Moras, Mud, and Pinto springs were largely influenced, among other factors, by regional groundwater flow from Edwards County and river leakage. As a result, uncertainty of the input parameters and impacts of regional groundwater and surface water may have been carried over during the model calibration and the sensitivity analysis. It should also be noted that a regional scale model should not be used for determining local scale concerns, such as well spacing or the response of water levels in a single well.

ES 6.0 Summary and Conclusions

The Texas Water Development Board (TWDB) developed a MODFLOW-2000 groundwater flow model for Kinney County. This new groundwater flow model covers an area of 150 miles by 150 miles, with Kinney County at the center of the model domain. For the years 1950 through 2005, the transient model was well calibrated to the water levels collected at wells and flows measured at springs. At the same time, focus was given to the three largest springs in Kinney County: Las Moras, Mud, and Pinto springs. In that regard, the calibrated model reflected the flows at the three springs quite well. The calibrated model also compared well with river leakage in the northern portion of Kinney County as well as the regional groundwater flow pattern.

After the calibration, the model was used to test the sensitivity of countywide groundwater withdrawal at wells on spring flows in Kinney County. The sensitivity analysis indicated that increasing groundwater withdrawal might reduce the spring flows at Las Moras, Mud, and Pinto springs. As a result, these springs may cease flowing during dry climatic years when groundwater usage typically increases.

1.0 INTRODUCTION AND PURPOSE FOR GROUNDWATER FLOW MODEL

Kinney County Groundwater Conservation District requested an evaluation of its groundwater resources and the effects of potential groundwater withdrawal at wells on springs and river flows. Specifically, the county was interested in maintaining reasonable flows at the three largest springs (Las Moras, Mud, and Pinto springs) under future potential groundwater use conditions.

In 2004, Texas Water Development Board (TWDB) developed a three-dimensional MODFLOW (McDonald and Harbaugh, 1988) model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2004). This model was re-calibrated by Young and Others (2009). This MODFLOW model contained three numerical layers, of which only two layers were active, and covered approximately half of the northern portion of Kinney County.

In 2004, a separate MODFLOW model was also developed for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer (Lindgren and others, 2004). This single layer model covered the northeastern portion of Kinney County.

In 2008, Wade and Tu from TWDB reviewed both MODFLOW models developed in 2004 and concluded that:

- the water budgets from the two models do not compare well,
- recharge and other budget components from the San Antonio Segment of the Edwards (Balcones Fault Zone) Aquifer model seem high,
- both model reports cited that data for Kinney County was sparse and the models were not well calibrated in the area, and
- neither MODFLOW models should be used by the Kinney County Groundwater Conservation District.

As a result, it was deemed necessary to develop a new model to include all of Kinney County so that the specific requests from the Kinney County Groundwater Conservation District could be addressed.

This technical report summarizes the development, construction, calibration, and sensitivity analysis of the new groundwater flow model. This groundwater flow model was developed using the U. S. Geologic Survey (USGS) 3-dimensional numerical code, MODFLOW-2000 (Harbaugh and Others, 2000), Version 1.19.01 released in 2010.

2.0 MODEL OVERVIEW

The Kinney County groundwater flow model was constructed using data from existing models and additional sources. The new model covered Kinney County and its surrounding counties, and contained refined hydrogeologic framework. Model boundaries were also reviewed against observed data and modified, as necessary, in comparison with existing models. A FORTRAN pre-processort was developed to estimate net groundwater recharge distribution based on a revised method originally developed by Maxey and Eakin (1949). Groundwater pumping in Kinney County was also revised to be consistent with groundwater withdrawal data provided by the Kinney County Groundwater Conservation District in June 2010.

The new groundwater flow model was calibrated to measured water levels at wells and flux values at springs. The model was also evaluated against calculated values of groundwater recharge to the unconfined aquifers due to precipitation and river leakage in the northern portion of Kinney County by Mace and Anaya (2004). A similar comparison was also performed against the groundwater recharge values to the Edwards Aquifer in the Nueces River basin estimated by the U.S.G.S (Edwards Aquifer Authority, 2009). In addition, the model was qualitatively calibrated to regional groundwater flow patterns and discharge to rivers. During the model calibration, hydraulic conductivity, recharge, specific storage, and boundary conditions (both head and conductance) were adjusted using parameter estimation (PEST), an industry-standard inverse modeling software package (Watermark Numerical Computing, 2004), and by trial-and-error. The model calibration was expedited by incorporating pre- and post-processors in the model batch file. Post-processing programs were also developed to further process the model-generated results to produce hydrographs. The flow budget was calculated using the USGS code, ZONEBUDGET (Version 3.01).

The Kinney County groundwater flow model input and output packages were included in a name file. The MODFLOW-2000 code initiates a model run by calling this name file. The MODFLOW-2000 input packages are listed in Table 1. The output packages are presented in Table 2.

TABLE 1. SUMMARY OF MODEL INPUT PACKAGES.

Packages	**Input Files**
Basic (BAS6)	KC-5.bas
Discretization (DIS)	KC-5.dis
Layer-Property Flow (LPF)	KC-5.lpf
Well (WEL)	KC-5.wel
Drain (DRN)	KC-5.drn
River (RIV)	KC-5.riv
General Head (GHB)	KC-5.ghb
Recharge (RCH)	KC-5.rch
Variable Constant Head (CHD)	KC-5.chd
Output Control (OC)	KC-5.oc
Geometric Multigrid Solver (GMG)	KC-5.gmg

TABLE 2. SUMMARY OF MODEL OUTPUT FILES.

Packages	**Output Files**
GLOBAL (GLO)	KC-5.glo
LIST (LST)	KC-5.lst
Cell-by-Cell Budgets (CBB)	KC-5.cbb
Heads (HDS)	KC-5.hds
Drawdown (DDN)	KC-5.ddn

2.1 Basic (BAS6) Package

The Basic Package specifies the status of each cell (active or inactive), the assigned head for inactive cells (-999), and specifications of starting heads. Inactive cells were used for areas where a specific hydrogeologic unit was absent in the related numerical model layer. For instance, model cells of model layer 1 in Kinney County were assigned a value of zero because the Carrizo-Wilcox hydrogeologic unit does not exist in Kinney County. In addition, previous studies indicated that brackish groundwater existed south and southeast of Kinney County. The brackish groundwater/fresh groundwater interface appears to be relatively stable. Thus, inactive cells were also assigned at the brackish groundwater zones. The location of the brackish groundwater zones are described in the next section.

2.2 Discretization (DIS) Package

The Discretization Package defines the spatial and temporal discretization of the model, including the numbers of layers/rows/columns/stress periods, horizontal dimensions of model cells, the top of model layer 1, bottoms of all model layers, and length/state of each stress period.

The MODFLOW-2000 model contains four numerical layers with 300 uniform rows and 300 uniform columns per layer, resulting in a row/column spacing of 2,640 feet (0.5 miles). The model domain covers an area of 150 miles by 150 miles with Kinney County approximately located at the center (Figure 1). The four numerical layers represent four hydrogeologic units (from top to bottom): Carrizo-Wilcox, Upper Cretaceous, Edwards, and Trinity. The layer top and bottom were defined using dataset generated from previous investigations and interpolations. Figures 2 through 5 show the distribution of each unit and inactive areas. Again, the inactive cells represent missing hydrogeologic units, hydrogeologic units beyond groundwater divide, and brackish groundwater. Two cross sections across Kinney County are also presented on Figures 6 and 7, with their locations shown on Figure 1.

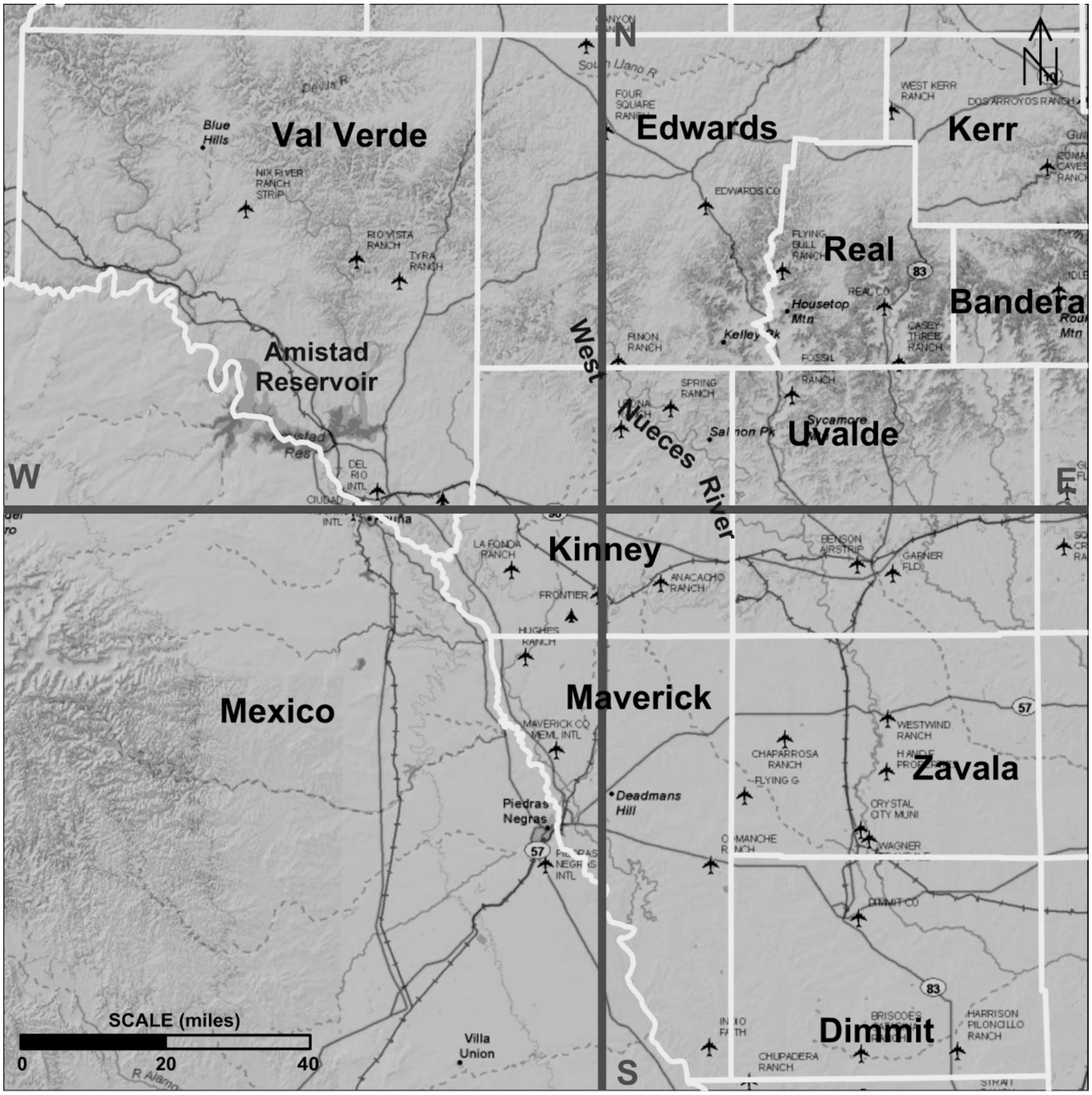


FIGURE 1. MODEL DOMAIN AND LOCATIONS OF CROSS SECTIONS.

FIGURE 2. DISTRIBUTION OF HYDROGEOLOGIC UNITS AND INACTIVE AREAS IN MODEL LAYER 1.

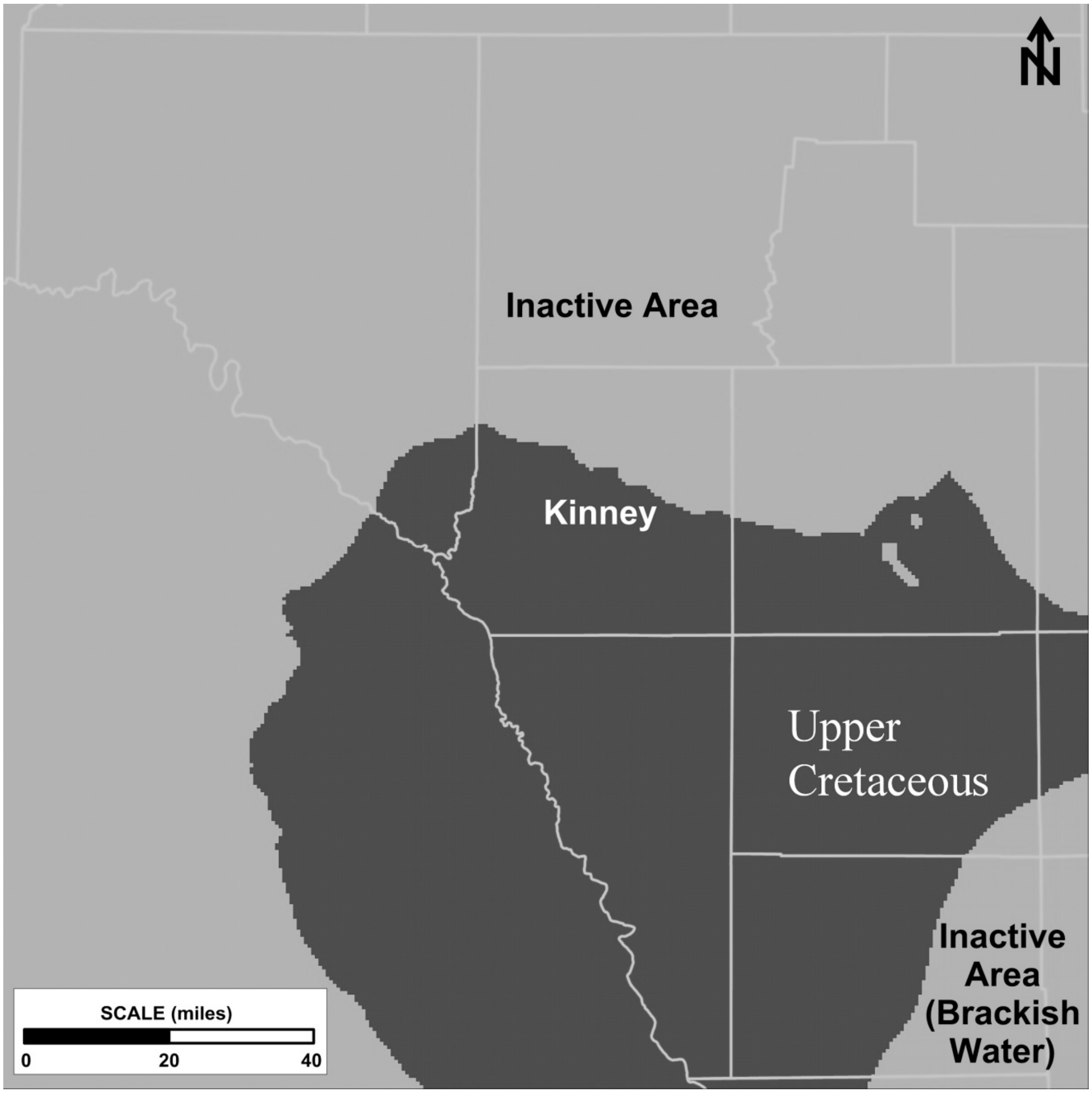


FIGURE 3. DISTRIBUTION OF HYDROGEOLOGIC UNITS AND INACTIVE AREAS IN MODEL LAYER 2.

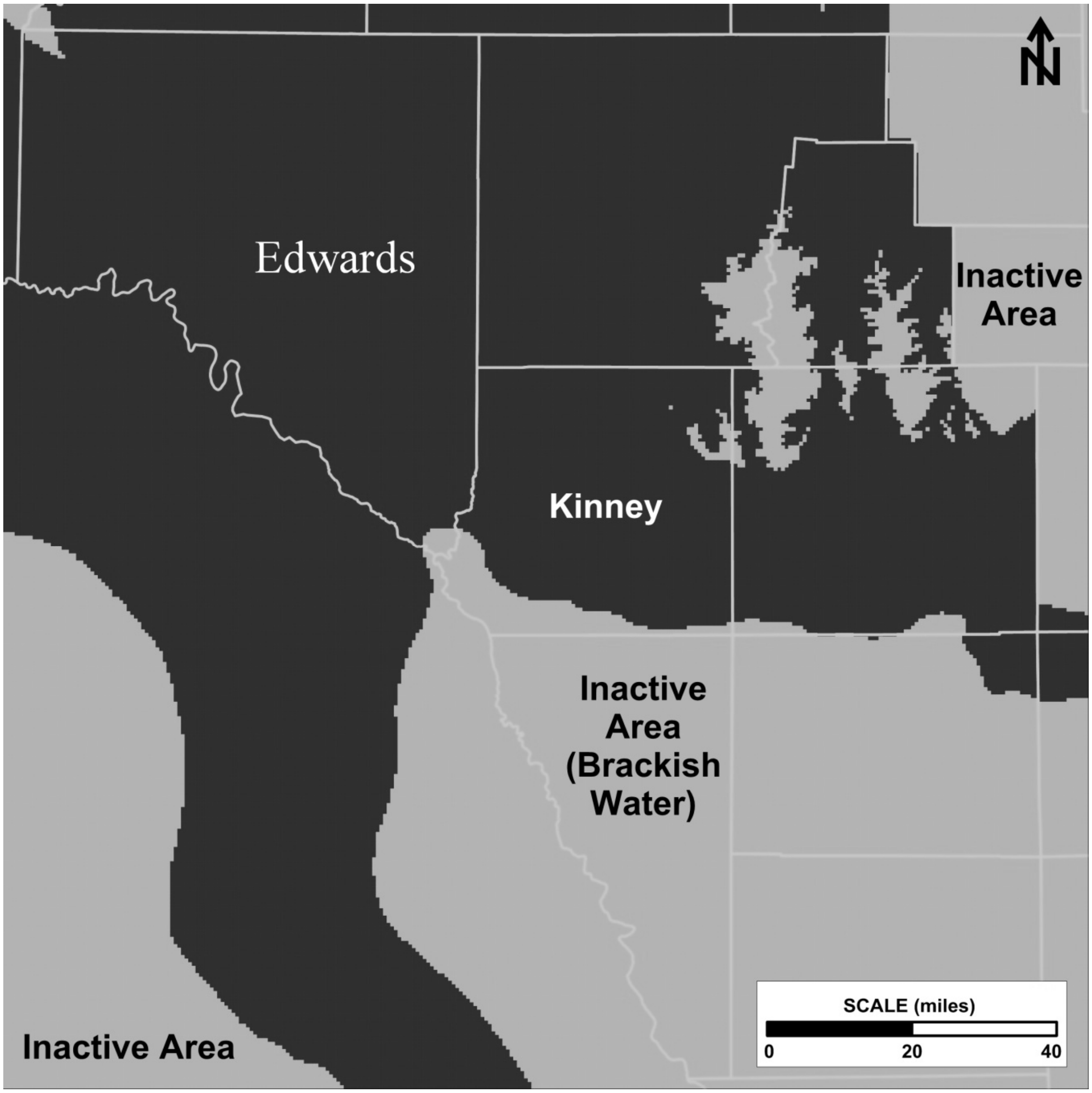


FIGURE 4. DISTRIBUTION OF HYDROGEOLOGIC UNITS AND INACTIVE AREAS IN MODEL LAYER 3.

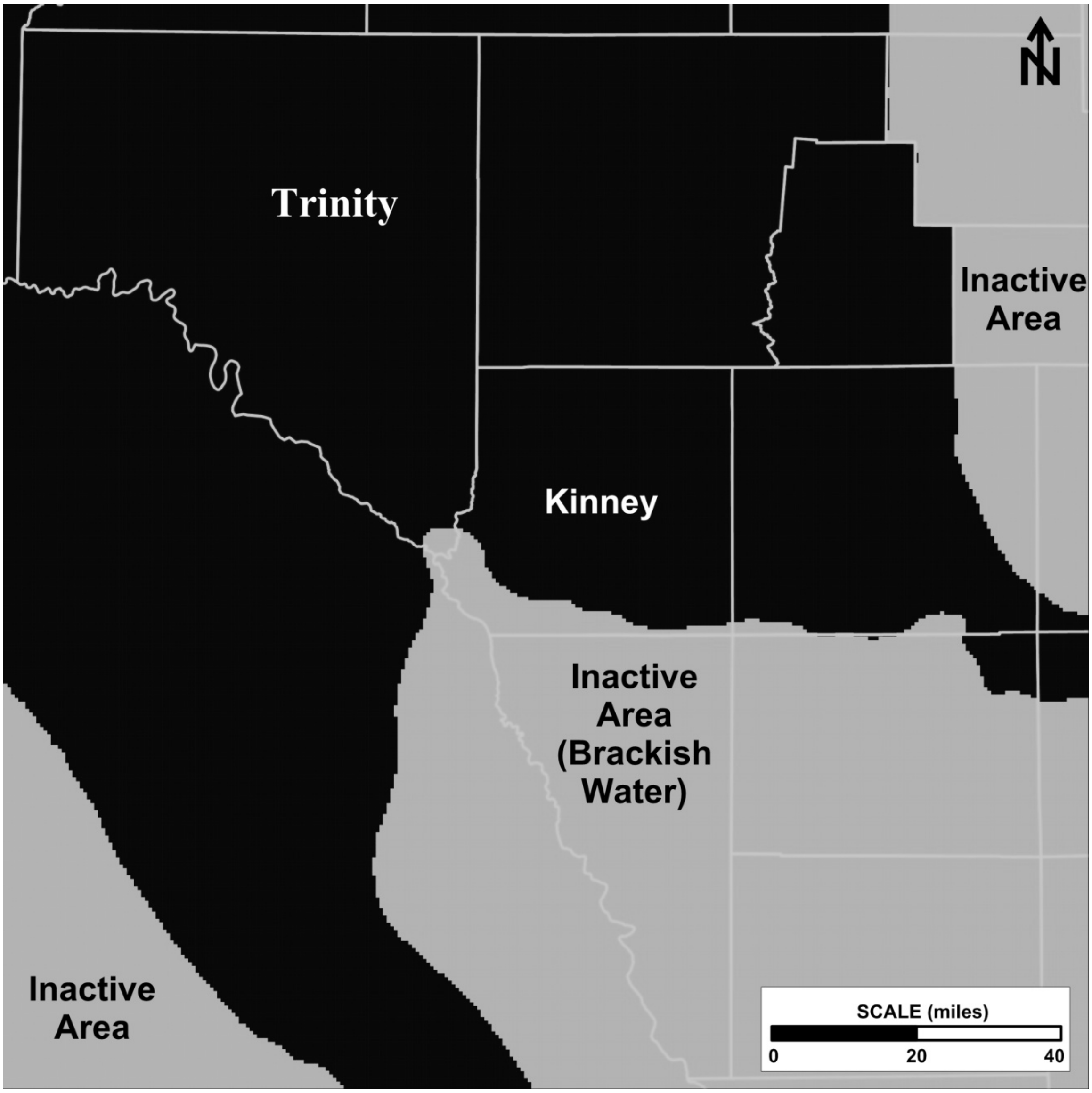


FIGURE 5. DISTRIBUTION OF HYDROGEOLOGIC UNITS AND INACTIVE AREAS IN MODEL LAYER 4.

The temporal discretization includes one steady-state stress period (stress period 1) and fifty six transient stress periods (stress periods 2 through 57). Each transient stress period is one year (365 days) long with one time step and represents the timeframe of 1950 through 2005. The steady state period is used to produce initial head conditions for the transient stress periods, and is not intended to represent actual "pre-development" conditions.

2.3 Layer-Property Flow (LPF) Package

The Layer-Property Flow Package contains the flags of layer type, cell-by-cell flow output, hydraulic conductivity and anisotropy, and storativity/specific storage. The horizontal hydraulic conductivity (Kx) values for each layer are read from a separate file which is defined using a unique file number in the MODFLOW-2000 name file. In this model, the layer type was set to zero for all layers, which assumes a constant transmissivity condition throughout the simulation. As a result of this specification, the only storage value required is the specific storage (Ss). By assuming a constant transmissivity, there are no cells converting to dry during the simulation. In this model, Kx, Ss, and horizontal/vertical anisotropy values are assigned on a cell-to-cell basis. Hydraulic conductivity and anisotropy values are read at the beginning of the simulation to estimate the aquifer transmissivity.

In this model, the Kx values were estimated using pilot points: 52 in model layer 1, 60 in model layer 2, 97 in model layer 3, and 59 in model layer 4. The locations of the pilot points were determined by head/flux targets and areas of interests, with more pilot points in Kinney County. The fifteen Ss zones in the model were approximately defined using the estimated Kx values. During the calibration, the parameter upper and lower bounds were set based on our understanding of the aquifers. Estimates of these parameters were then developed through calibration by PEST. Specific details about the calibration are provided in the Model Calibration and Results Section below. The distributions of horizontal hydraulic conductivity, Kx, are presented on Figures 8 through 11. Geometric means of Kx were calculated based on the pilot points and presented on Table 3. Figures 12 through 15 show the Ss distribution for all four model layers.

2.4 Well (WEL) Package

The Well Package contains groundwater withdrawal information from the aquifers. The pumping data outside of Kinney County were from the TWDB Water Use Survey database and estimates of irrigation use. For stress periods 1 through 9, where pumping data were not available, the pumping data from 1958 were used. Between stress periods 10 and 57, a linear interpolation was used to fill the data gaps if no pumping data were available. In Kinney County, the initial pumping data were from groundwater pumping estimates provided by Kinney County Groundwater Conservation District, with a total permitted value of approximately 64,500 acre-feet per year. During the model calibration, the pumping rates in Kinney County were adjusted between different stress periods. However, the average countywide pumping rate used by the calibrated model, 65,078 acre-feet per year, was consistent with the permitted value, 64,500 acre-feet per year (Table 4), but above the groundwater use survey data. Simulated pumping rates for the whole model and for Kinney County are presented in Table 4.

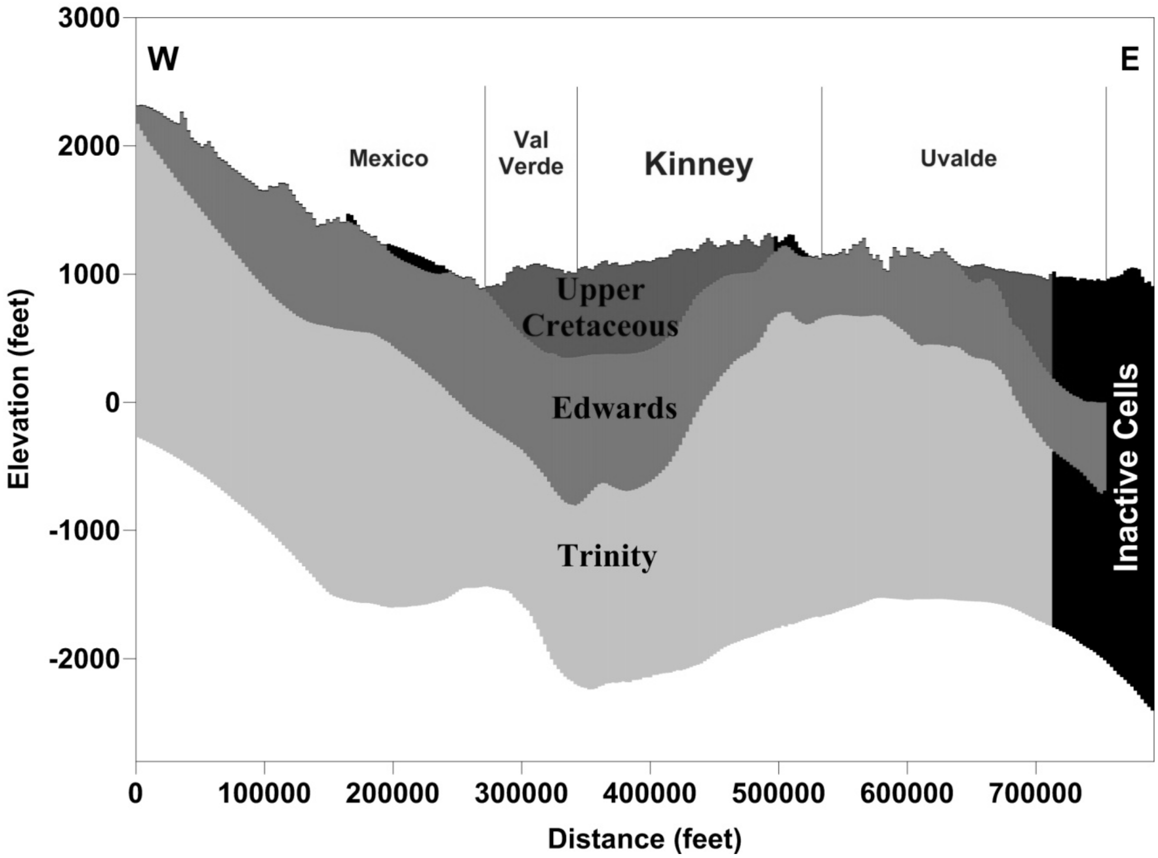


FIGURE 6. HYDROGEOLOGIC UNITS ALONG THE WEST-EAST CROSS SECTION TRANSECT. SEE FIGURE 1 FOR THE LOCATION OF THE CROSS SECTION.

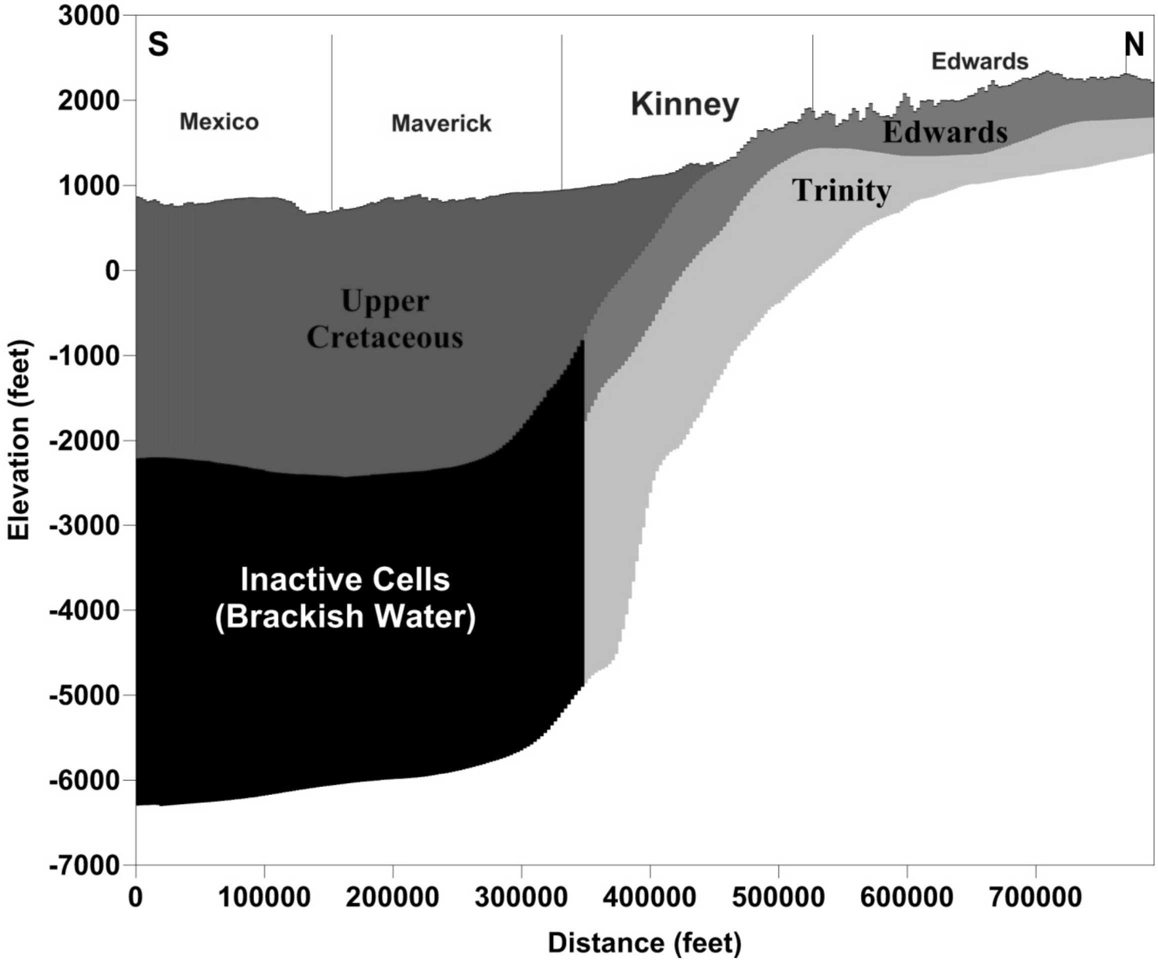


FIGURE 7. HYDROGEOLOGIC UNITS ALONG THE SOUTH-NORTH CROSS SECTION TRANSECT. SEE FIGURE 1 FOR THE LOCATION OF THE CROSS SECTION.

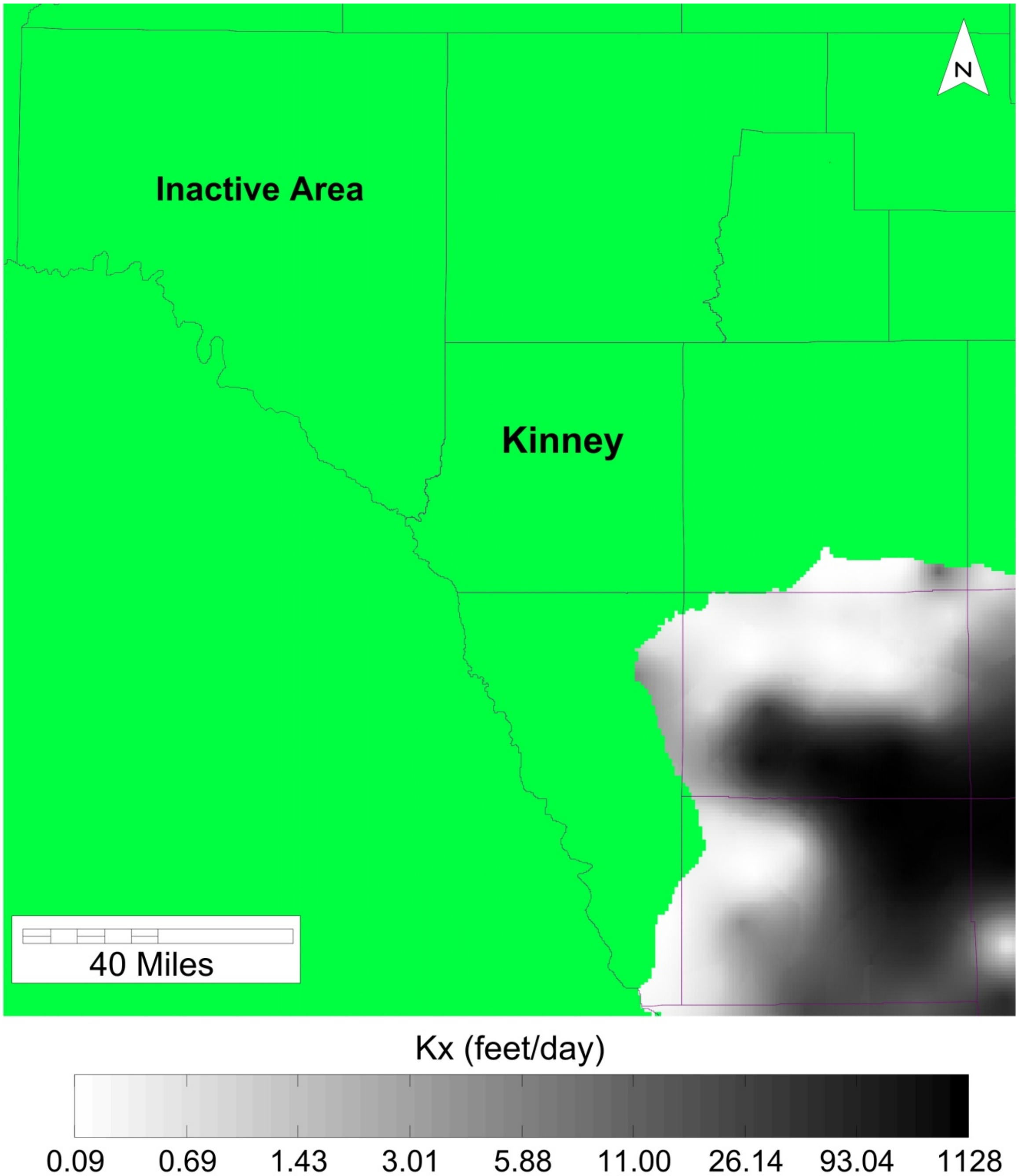


FIGURE 8. DISTRIBUTION OF HYDRAULIC CONDUCTIVITY IN MODEL LAYER 1.

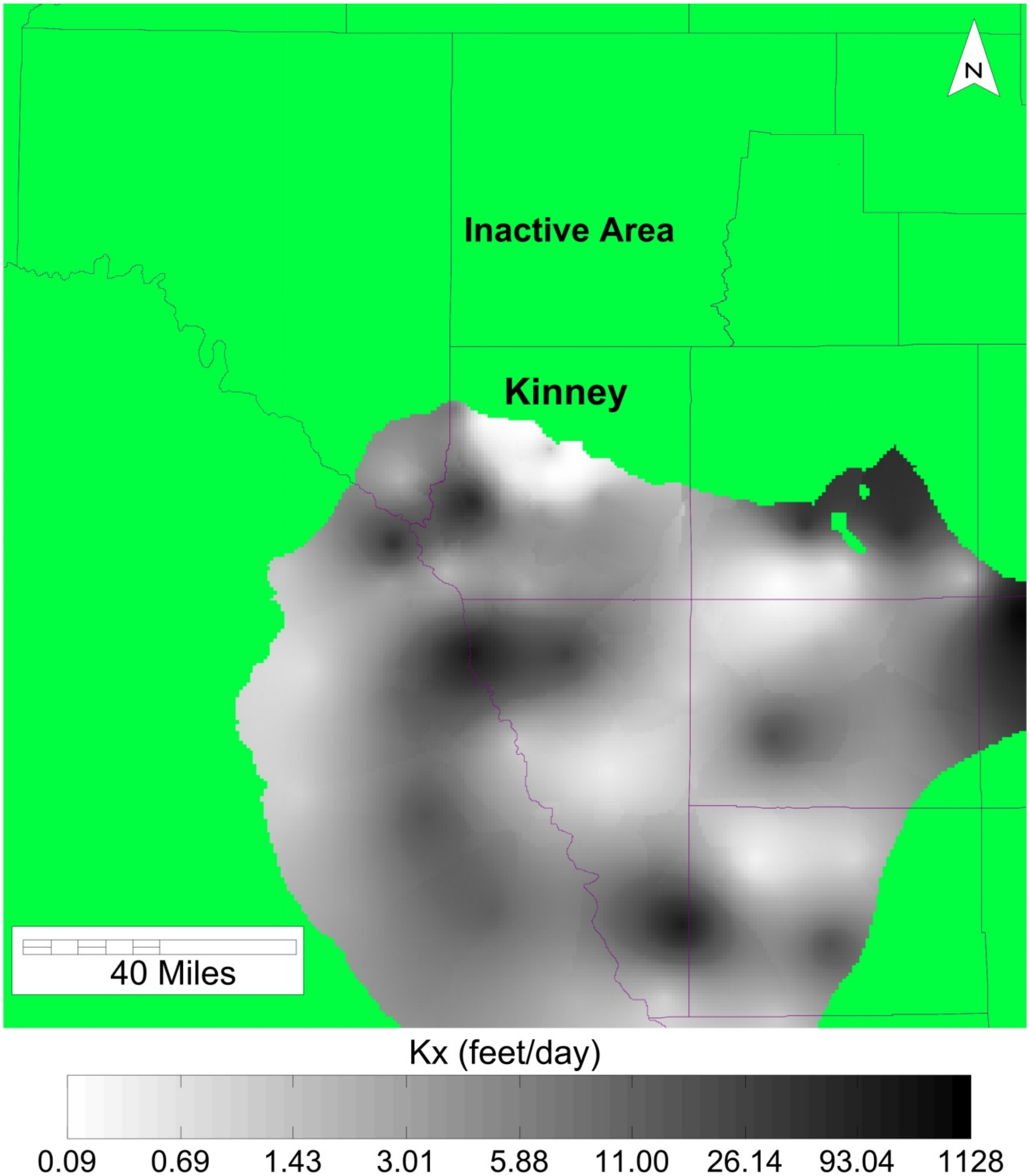


FIGURE 9. DISTRIBUTION OF HYDRAULIC CONDUCTIVITY IN MODEL LAYER 2.

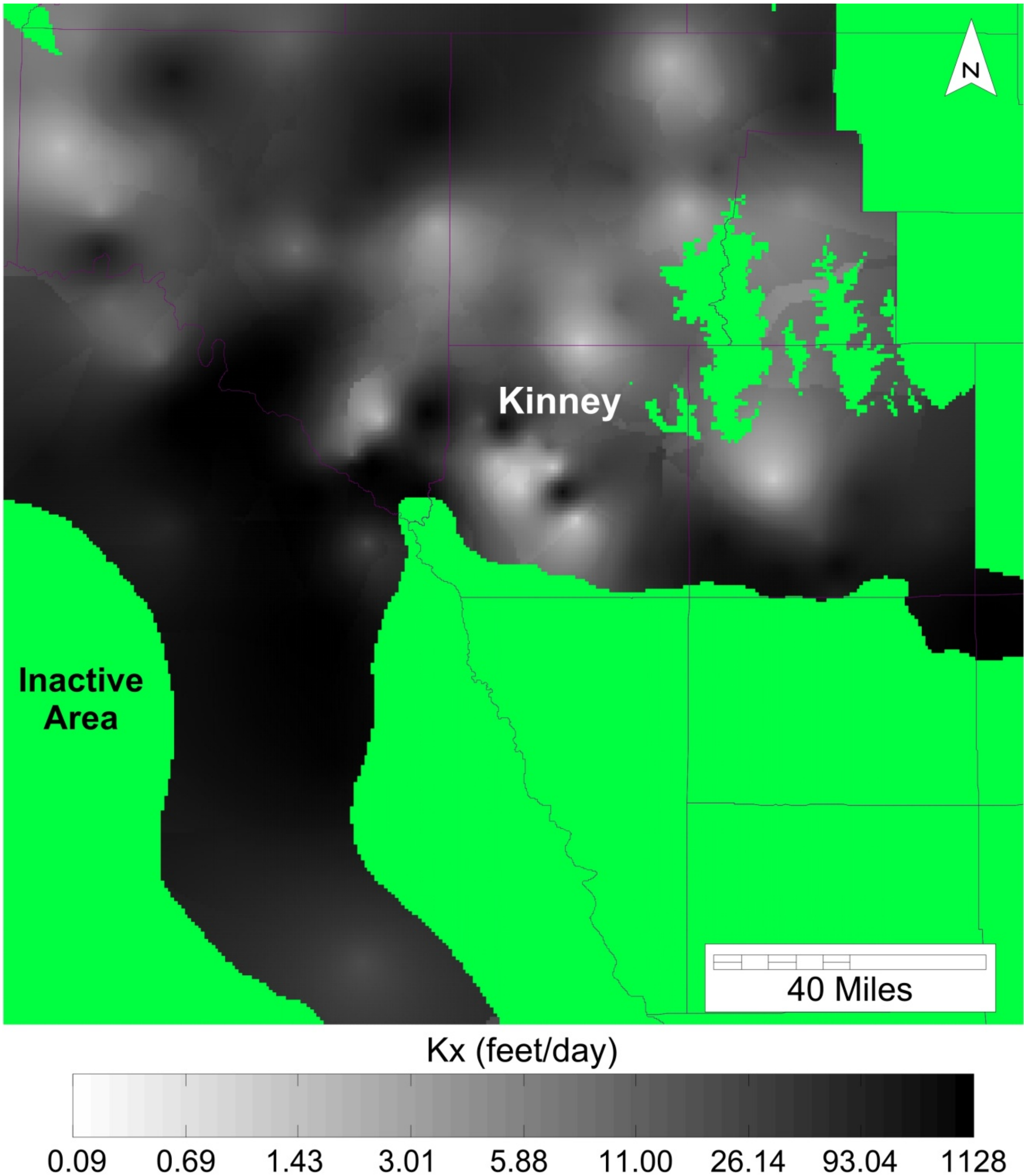


FIGURE 10. DISTRIBUTION OF HYDRAULIC CONDUCTIVITY IN MODEL LAYER 3.

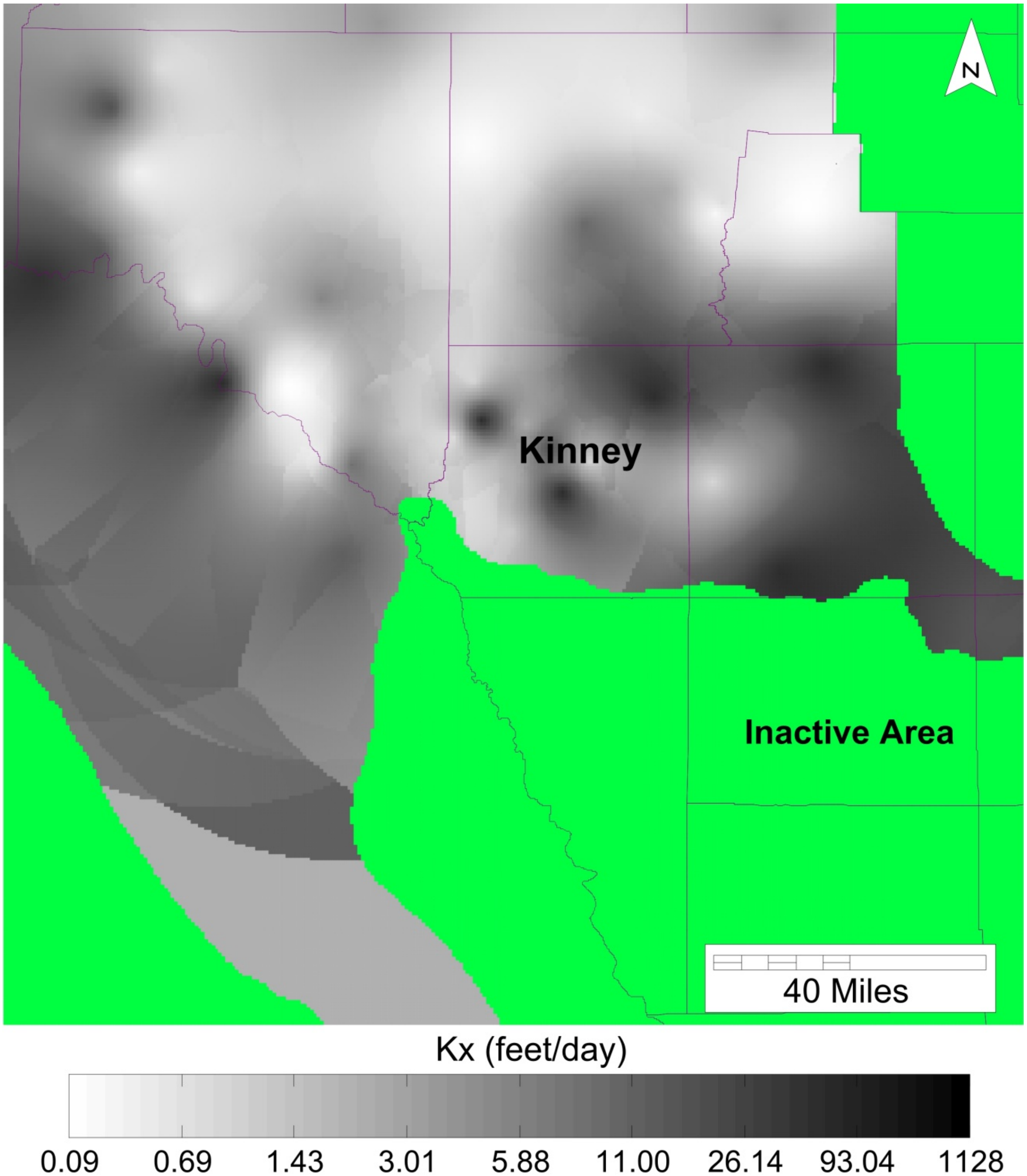


FIGURE 11. DISTRIBUTION OF HYDRAULIC CONDUCTIVITY IN MODEL LAYER 4.

TABLE 3. SUMMARY OF GEOMETRIC MEAN HORIZONTAL HYDRAULIC CONDUCTIVITY (KX).

Layers	Geometric Mean Kx (feet per day)
1	2.64
2	2.64
3	30.15
4	3.06

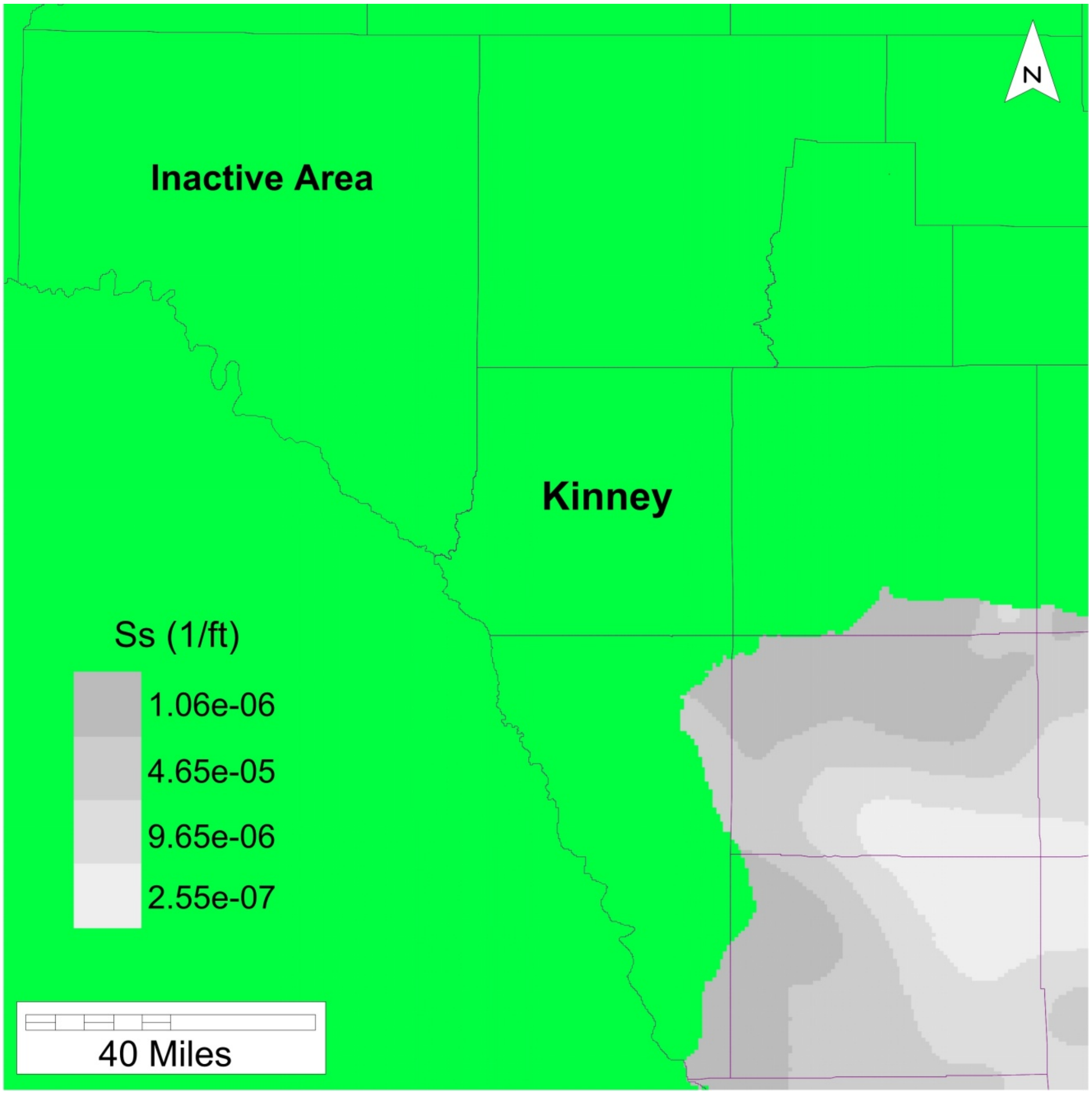


FIGURE 12. DISTRIBUTION OF SPECIFIC STORAGE IN MODEL LAYER 1.

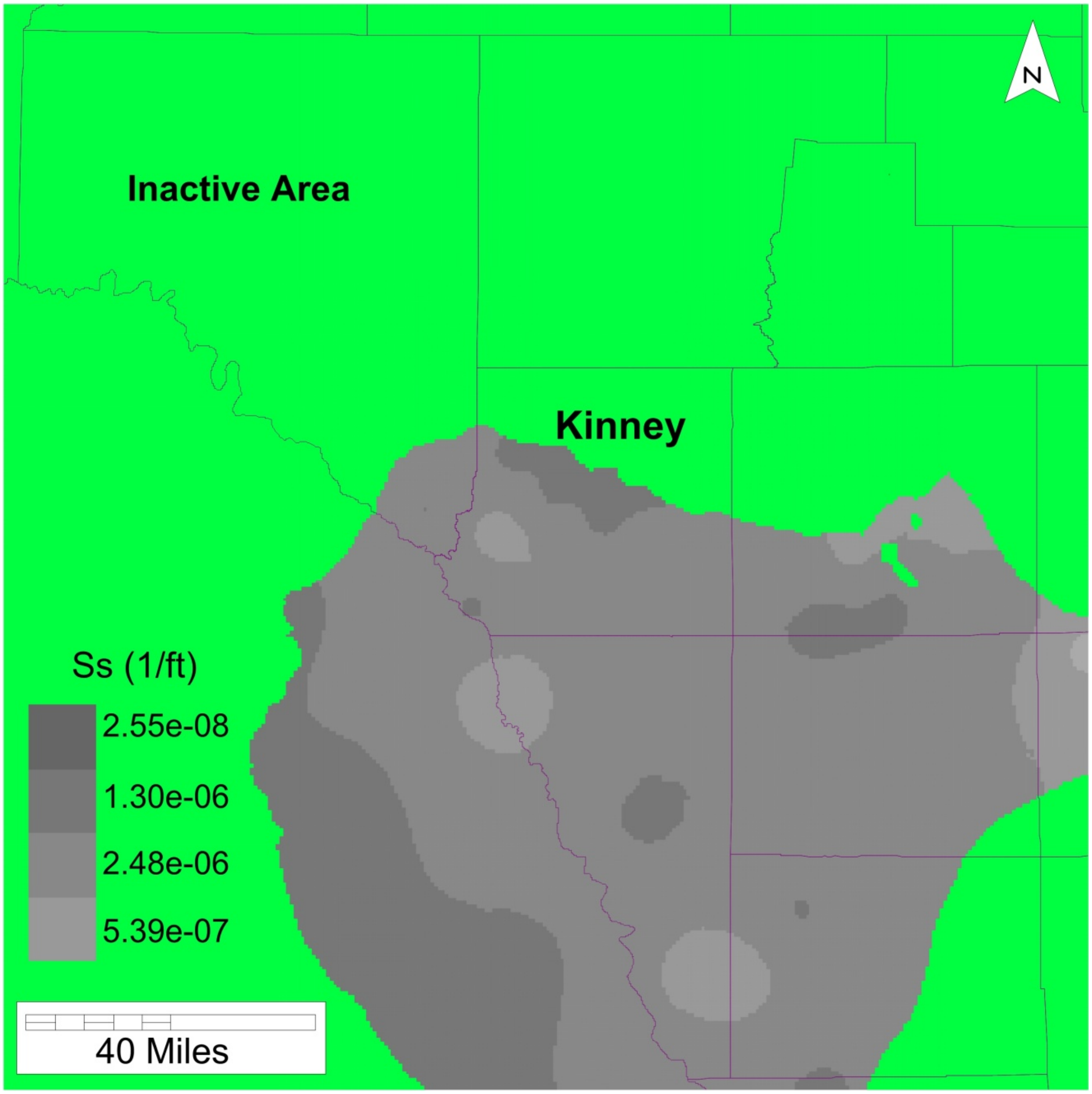


FIGURE 13. DISTRIBUTION OF SPECIFIC STORAGE IN MODEL LAYER 2.

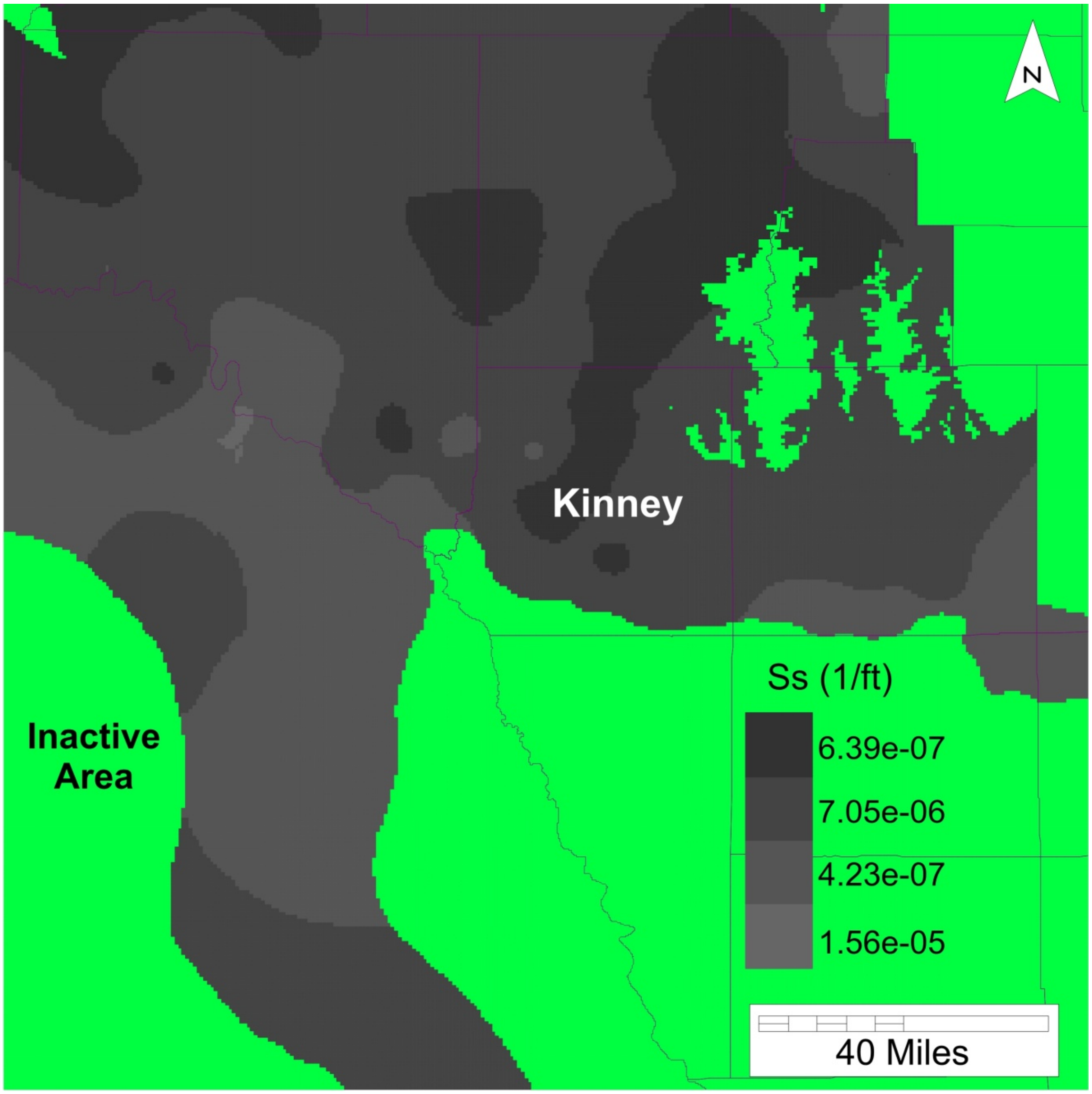


FIGURE 14. DISTRIBUTION OF SPECIFIC STORAGE IN MODEL LAYER 3.

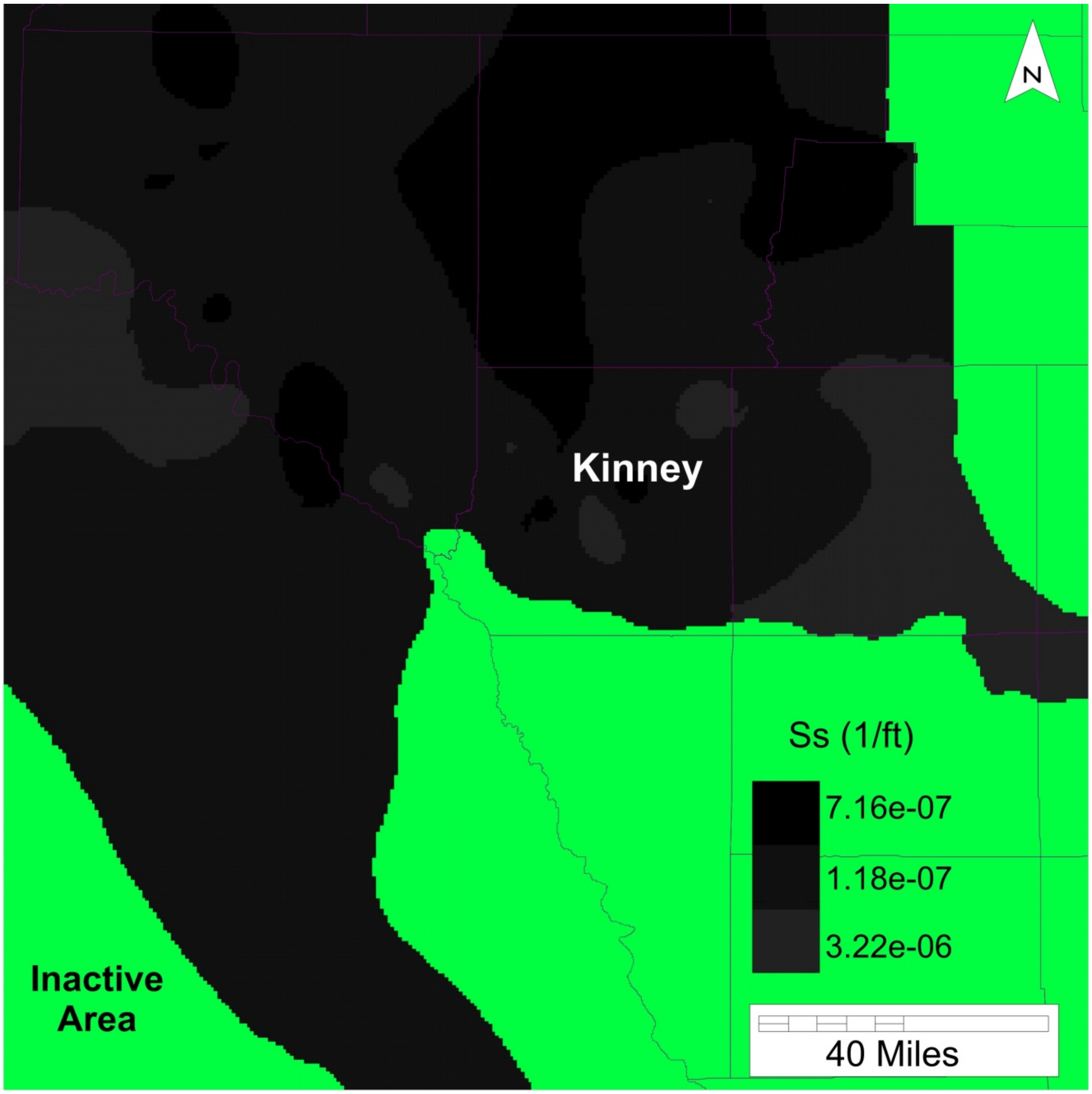


FIGURE 15. DISTRIBUTION OF SPECIFIC STORAGE IN MODEL LAYER 4.

TABLE 4. SUMMARY OF SIMULATED PUMPING RATES IN ACRE-FEET PER YEAR (ACRE-FT/YEAR).

Year	Total pumping rate for whole model (acre-ft/year)	Total pumping rate at Kinney County (acre-ft/year)
Steady State	159,011	53,991
1950	175,012	69,992
1951	173,530	68,510
1952	177,735	72,714
1953	157,236	52,216
1954	175,903	70,883
1955	173,381	68,360
1956	176,377	71,357
1957	164,470	59,450
1958	155,685	50,665
1959	195,857	64,568
1960	214,811	57,241
1961	255,404	71,541
1962	278,269	68,138
1963	308,253	71,830
1964	335,869	73,177
1965	328,780	72,883
1966	304,190	55,062
1967	307,671	65,338
1968	307,024	71,485
1969	284,662	55,917

Year	Total pumping rate for whole model (acre-ft/year)	Total pumping rate at Kinney County (acre-ft/year)
1970	290,646	69,323
1971	267,653	53,766
1972	279,564	73,112
1973	253,794	54,779
1974	266,201	74,621
1975	261,307	70,022
1976	257,287	66,335
1977	263,778	73,121
1978	260,804	70,442
1979	264,672	74,605
1980	261,098	67,928
1981	274,674	64,830
1982	302,016	69,842
1983	318,070	67,377
1984	343,314	71,234
1985	351,217	76,666
1986	252,687	67,156
1987	227,548	73,230
1988	306,298	68,800
1989	320,816	55,318
1990	290,999	54,616
1991	266,759	58,621

Year	Total pumping rate for whole model (acre-ft/year)	Total pumping rate at Kinney County (acre-ft/year)
1992	194,399	67,847
1993	248,428	67,497
1994	225,513	57,444
1995	203,606	59,086
1996	221,272	56,647
1997	188,008	59,276
1998	218,319	56,256
1999	228,605	71,956
2000	179,415	56,836
2001	193,498	52,873
2002	201,111	60,071
2003	180,731	58,845
2004	201,350	70,188
2005	188,132	62,496
Average of 1950 through 2005	244,709	65,078

2.5 Drain (DRN) Package

The MODFLOW-2000 Drain Package was used to simulate groundwater outflows at twenty-two springs. Each spring was simulated using drain cells. Because a spring conduit can penetrate several hydrogeologic units, drain cells were placed in all active model layers to represent a spring. The only exception was Leona Spring, a spring located in the southeastern portion of the model domain. This spring was placed in model layers 1 through 3 because model layer 4 was very deep at the springs location. The locations of the springs are shown on Figure 17b (labeled as the flux targets).

The heads and conductance of the drain cells were adjusted during the model calibration to match the simulated to the measured flow rates, but remained constant through all stress periods. For the same spring, drain cells all had the same head but may have different conductance values for each layer. The simulated heads and conductance values of the springs are summarized in Table 5. Overall flux calibration and hydrographs at three largest springs at Kinney County (Las Moras, Mud, and Pinto springs) are presented in the Model Calibration and Results Section below.

TABLE 5. SUMMARY OF SIMULATED HEADS AND CONDUCTANCE VALUES OF SPRINGS.

Springs	Layer	Simulated head (feet)	Conductance (feet^2 per day)
Las Moras	2	1,056	429,852
	3		16,077
	4		1,000,000
Pinto	2	1,141	1,000,000
	3		938,753
	4		812,093
Mud	2	1,138	119,636
	3		1,000,000
	4		1,000,000
Leona	1	810	392,961
	2		29,939
	3		127,429
Yoas	2	898	2,251
	3		300
	4		1,126
San Felipe	2	952	1,000,000
	3		731,229
	4		125,895

Springs	**Layer**	**Simulated head (feet)**	**Conductance (feet² per day)**
Cienega	3	946	98,768
	4		48,661
Cantu	3	1,015	10,241
	4		61,475
McKee	3	933	27,186
	4		866
Goodenough	3	1,067	1,000,000
	4		1,000,000
Guy Skiles	3	1,193	713
	4		811
YR-54-60-302	3	1,476	108
	4		110
YR-70-01-703/704	3	1,295	1,464
	4		965
YR-70-01-701	3	1,398	404
	4		499
Cade	3	1,850	44
	4		182
Hackberry	3	1,902	101
	4		3,291
Deats	3	1,863	8
	4		8
Tanner	3	1,836	22,790

Springs	Layer	Simulated head (feet)	Conductance (feet^2 per day)
	4		101,755
Seven Hundred	3	1,840	1,000,000
	4		1,000,000
Big Paint	3	1,866	17,768
	4		78
JJ-70-08-801	3	1,936	330
	4		2,713
JJ-70-08-603	3	1,876	572
	4		191

Note: - Simulated values are rounded to integers.

2.6 River (RIV) Package

The River Package was used to simulate the interaction of the aquifer(s) with rivers. The river bottom at a cell was set as the minimum digital elevation model (DEM) value in that cell. Initially, the river levels were assumed two feet above the river bottoms. During the model calibration, the river head for each stress period and conductance throughout the simulation were adjusted to qualitatively match the simulated to the calculated river leakages to the unconfined aquifers located in the northern portion of Kinney County. Table 6 summarizes the river depth changes over the simulation time. The calibrated river conductance values are presented in Table 7. Location of the rivers in the model is shown on Figure 16. The calibration result and river flow budget through time are presented in the Model Calibration and Results Section below.

TABLE 6. SUMMARY OF SIMULATED RIVER DEPTH CHANGES.

Stress period	Year	River depth (feet)
1	Steady State	2
2	1950	0.33
3	1951	0.66
4	1952	1.41

Stress period	Year	River depth (feet)
5	1953	1.60
6	1954	0.86
7	1955	1.21
8	1956	1.49
9	1957	0.90
10	1958	3.15
11	1959	2.35
12	1960	1.83
13	1961	3.43
14	1962	1.31
15	1963	0.56
16	1964	3.54
17	1965	1.19
18	1966	1.66
19	1967	1.90
20	1968	0.42
21	1969	2.36
22	1970	0.28
23	1971	5
24	1972	1.99
25	1973	5
26	1974	0.96
27	1975	0.79

Stress period	Year	River depth (feet)
28	1976	5
29	1977	1.43
30	1978	0.82
31	1979	1.00
32	1980	0.65
33	1981	3.97
34	1982	1.16
35	1983	2.55
36	1984	0.1
37	1985	1.08
38	1986	3.72
39	1987	3.71
40	1988	1.69
41	1989	0.72
42	1990	1.43
43	1991	1.65
44	1992	2.14
45	1993	0.97
46	1994	1.47
47	1995	1.42
48	1996	3.30
49	1997	1.75
50	1998	3.13

Stress period	Year	River depth (feet)
51	1999	3.78
52	2000	1.40
53	2001	2.22
54	2002	2.71
55	2003	2.62
56	2004	3.98
57	2005	4.48
Average (1950 - 2005)		2.00

TABLE 7. SUMMARY OF SIMULATED RIVER CONDUCTANCE VALUES.

Reach number	Layer	Simulated conductance (feet²per day)	Note
11	1	0.25	
13	1	0.34	
112	1	223	
113	1	2,511	
114	1	146	
116	1	31.2	
117	1	25.4	
21	2	0.46	
22	2	0.06	
23	2	50,000	

Reach number	Layer	Simulated conductance (feet^{2}per day)	Note
24	2	3.54	
25	2	40,353	
26	2	5,303	
213	2	23,652	
214	2	50,000	
215	2	42.7	
216	2	50,000	
217	2	49,986	
31	3	48,422	
32	3	20,583	
36	3	481.3	
37	3	23,006	
38	3	28,826	
39	3	50,000	
310	3	145.4	
311	3	59.3	
315	3	50,000	
316	3	13,064	
317	3	7,893	
318	3	298.4	
666	3	16,853	At unconfined aquifer in northern Kinney County
42	4	50,000	

Reach number	Layer	Simulated conductance (feet^{2}per day)	Note
410	4	90.2	
415	4	41,960	
417	4	129.2	
418	4	24.5	
666	4	16,853	At unconfined aquifer in northern Kinney County

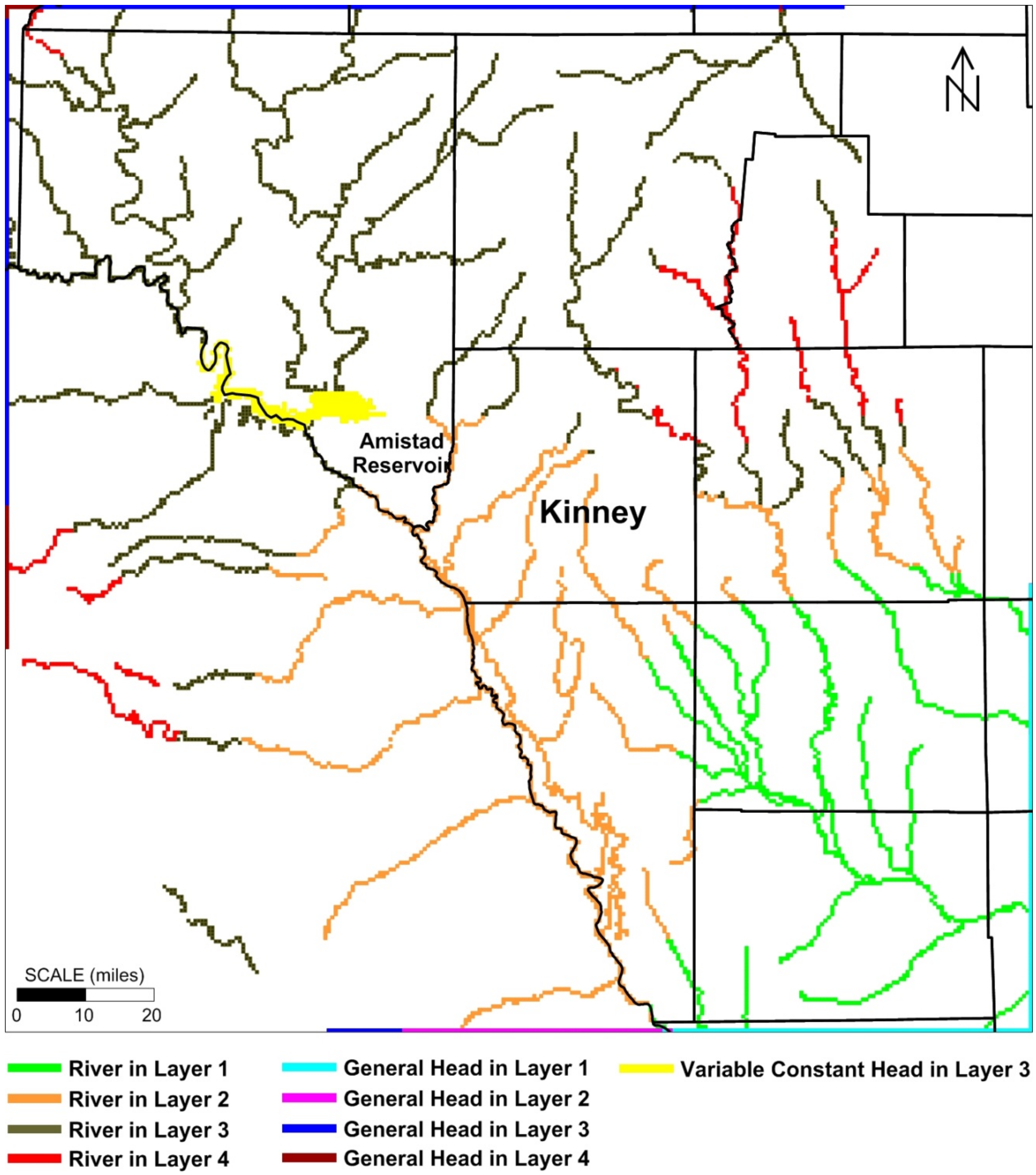


FIGURE 16. LOCATION OF RIVER, GENERAL HEAD, AND VARIABLE CONSTANT HEAD BOUNDARIES.

2.7 General Head Boundary (GHB) Package

The General Head Boundary (GHB) Package is used to allow flow into or out of a model based on the difference between the head value in a cell and the specified general head boundary value and the hydraulic properties that determine how easily flow can occur. In this model, the general head boundary was used at active cells in all four model layers along the model domain perimeter. Initially, the general head boundary was imported from the two existing models (as described above) at correlated cells and layers. Where existing data were not available, the general head boundary was defined by interpretation of river levels, reference to ground surface, and aquifer properties. The general head boundary head and conductance values were later adjusted to improve the model calibration. The calibrated conductance values of the general head boundaries are presented in Table 8. The location of the general head boundary is shown on Figure 16.

TABLE 8. SUMMARY OF GENERAL HEAD CONDUCTANCE VALUES.

Reach Number	Layer	Simulated conductance (feet^{2}per day)	Reach Number	Layer	Simulated conductance (feet^{2}per day)
11	1	13,910	39	3	87.4
12	1	9,094	40	3	10.4
13	1	23,908	41	3	1.68
14	1	50,000	42	3	1.15
15	1	50,000	43	3	0.58
16	1	0.48	44	3	11.6
17	1	0.53	45	3	42.9
18	1	0.45	46	3	305.9
19	1	0.03	51	4	0.06
21	2	50,000	52	4	1,691
22	2	0.03	53	4	8.85
31	3	239.8	54	4	8.27
32	3	0.03	55	4	1.26
33	3	0.92	56	4	0.29
34	3	2.29	57	4	0.26
35	3	3,317	58	4	306.1
36	3	13,523	59	4	107.5

Reach Number	Layer	Simulated conductance (feet^{2}per day)	Reach Number	Layer	Simulated conductance (feet^{2}per day)
37	3	50,000	60	4	1,218
38	3	25,253	61	4	0.19

2.8 Recharge (RCH) Package

The Recharge Package is used to simulate inflow to an aquifer due to precipitation on the outcrop areas of the aquifer. In this model, the Recharge Package contains recharge rate (feet per day) on a cell-by-cell basis. The recharge values were applied to the uppermost active cells during simulations.

The Recharge Package was generated using a revised algorithm developed by Maxey and Eakin (1949). A pre-processor written in FORTRAN was used to implement this algorithm. The pre-processor reads in data from three files representing recharge zones, annual precipitation factors (Table 9), and recharge parameters (Table 10), respectively. The recharge zone file contains location (i.e. row and column), elevation, and average annual precipitation of the upper-most active model cells. The annual precipitation factor file contains the variation factors of annual precipitation relative to the average conditions. The recharge parameter file contains annual precipitation and elevation thresholds, base recharge rates, contribution of precipitation to groundwater recharge, and a damping factor. The recharge parameters were all defined by user and adjusted during the model calibration. The pre-processor then performed the followings: (1) calculating rainfall (Equation 2.1), (2) calculating recharge (Equation 2.2), and (3) writing a MODFLOW recharge package file.

$$\text{Rainfall} = \text{AAP} \times (\text{pfac} + ((1 - \text{pfac}) \times \text{damp})) \qquad (2.1)$$

where:

Rainfall = Annual precipitation for specific stress period
AAP = Average annual precipitation
pfac = Precipitation factor
damp = Overall dampening factor

$$\text{Recharge} = \text{Rainfall} \times \text{rfac} \qquad (2.2)$$

where:

Recharge = Recharge expressed in feet per day
Rainfall = Annual precipitation for specific stress period
rfac = Recharge factor

The precipitation factor indicates annual precipitation relative to average annual precipitation. The recharge factor indicates the fraction of annual precipitation that recharges the aquifer.

After preliminary simulation runs, it was determined that the original recharge rates may be relatively high. As a result, the recharge rates were reduced by 50 percent in the calibrated model. The recharge rates varied spatially and temporally, with an overall average of approximately 2.1 inches per year across the whole model domain and 2.4 inches per year in Kinney County. Based on the low flow data collected at the West Nueces River, Mace and Anaya (2004) estimated that precipitation contributed approximately 65,800 acre-feet per year to the unconfined aquifers located in the northern portion of Kinney County. Given the recharge area of 491 miles^2, the average recharge rate for the aquifers in the northern portion of Kinney County can be calculated as 2.5 inches per year. Thus, the calibrated model reproduced the groundwater recharge these aquifers quite well.

The recharge water budget and calibration result are presented in the Model Calibration and Results Section below.

TABLE 9. SUMMARY OF ANNUAL PRECIPITATION FACTORS.

Year	Annual precipitation (inches per year)	Change relative to steady state	Year	Annual precipitation (inches peryear)	Change relative to steady state
Steady State	17.45	1			
1950	25.76	1.48	1978	19.6	1.12
1951	11.01	0.63	1979	16.58	0.95
1952	8.73	0.5	1980	13.15	0.75
1953	10.64	0.61	1981	25.08	1.44
1954	17.58	1.01	1982	13.84	0.79
1955	17.41	1	1983	15.34	0.88
1956	5.81	0.33	1984	37.04	2.12
1957	28.82	1.65	1985	16.47	0.94
1958	28.42	1.63	1986	20.69	1.19

Year	Annual precipitation (inches per year)	Change relative to steady state	Year	Annual precipitation (inches peryear)	Change relative to steady state
1959	20.94	1.2	1987	14.12	0.81
1960	17.33	0.99	1988	13.1	0.75
1961	11.98	0.69	1989	13.2	0.76
1962	10.54	0.6	1990	27.18	1.56
1963	12.31	0.71	1991	21.16	1.21
1964	18.94	1.09	1992	23.14	1.33
1965	17.29	0.99	1993	12.07	0.69
1966	20.65	1.18	1994	17.6	1.01
1967	15.77	0.9	1995	17.73	1.02
1968	17.77	1.02	1996	15.46	0.89
1969	23.28	1.33	1997	22.37	1.28
1970	14.76	0.85	1998	20.31	1.16
1971	20.74	1.19	1999	15.88	0.91
1972	12.02	0.69	2000	20.98	1.2
1973	14.41	0.83	2001	13.97	0.8
1974	11.82	0.68	2002	15.07	0.86
1975	18.57	1.06	2003	20.32	1.16
1976	29.73	1.7	2004	23.64	1.36
1977	15.42	0.88	2005	16.32	0.94

TABLE 10. SUMMARY OF RECHARGE PARAMETERS.

Name	Percentage I	Percentage II	Percentage III
Base precipitation (inches per year)	2	9.53	11.97
Percentage	0.066	0.203	0.205
Base recharge (fee per day)	0	0	0
Minimum elevation (feet)	0		
Dampening factor	0.285		

2.9 Variable Constant Head (CHD) Package

The variable Constant Head Package was used to simulate the Amistad Reservoir located along the border between Val Verde County and Mexico. The reservoir was filled in 1969 following the construction of Amistad Dam. Consequently, the CHD Package was included in stress periods 20 (i.e. 1969) through 57 (i.e. 2005). The River Package was used at the reservoir site for stress periods 1 through 19. During the model calibration, the head values of the constant head cells were adjusted relative to the initial elevation by adding the river depth values (see Table 6). The initial reservoir l elevation, 1,103 feet, was an average based on long-term measurements. The location of the variable constant head boundary is shown on Figure 16.

2.10 Output Control (OC) Package

The MODFLOW-2000 Output Control Package specifies when to save head, drawdown, and budget output during the model run. It is a standard file required for all MODFLOW models. The output control file for this model was set up to output head, drawdown, and budget information at the end of each stress period.

2.11 Geometric Multigrid (GMG) Solver Package

MODFLOW requires the use of a solver to solve the finite difference equations that govern groundwater flow in the aquifers. This MODFLOW-2000 model uses the Geometric Multigrid (GMG) solver developed by Wilson and Naff (2004). The solver uses 0.01 feet head change and 1 foot residual convergence criteria. Evaluation of mass balance for each stress period and cumulative discrepancy between total inflows and outflows indicated negligible numerical errors with this solver setup.

3.0 MODEL CALIBRATION AND RESULTS

3.1 Calibration Procedure

The calibration of a groundwater model involves adjusting certain model parameters, within a reasonable range, to match the simulated to measured values. A calibrated groundwater flow model is a tool that can be used to test hypothesis and future conditions. This process is also called prediction. A calibrated model can improve reliability of the prediction.

The primary targets for the calibration were water levels measured at wells (i.e. head targets) and fluxes measured at springs (i.e. flux targets). There are 1,824 head targets from 507 wells and 432 flux targets from 22 springs (Figures 17a and 17b). Secondarily, the model was also qualitatively evaluated against calculated recharge values to the unconfined aquifers due to precipitation and river leakage for the aquifers located in northern Kinney County. These calculated recharges are either directly from or estimated based on the value from Mace and Anaya (2004). Their recharge value due to precipitation, 65,800 acre-feet per year, was based on base flow at the West Nueces River. This value was later revised to 62,700 acre-feet per year after review of the recharge area using geographic information system (GIS) software (Anaya, 2007). Based on river loss, Mace and Anaya (2004) also estimated a direct recharge of 4,000 acre-feet per year from the West Nueces River to the unconfined portion of the aquifer located in northern Kinney County. By assuming the same leakage rate per unit length for other rivers, the total river leakage to the unconfined aquifers was estimated to be 6,667 acre-feet per year in northern Kinney County.

Similar to Mace and Anaya (2004, 2007), the U.S.G.S. has estimated the annual groundwater recharge to the Edwards Aquifer in the Nueces River basin since 1934 (Edwards Aquifer Authority, 2009). The Nueces River basin covers the northern Kinney County and other areas. Based on the annual recharge data estimated by the U.S.G.S., TWDB calculated an average groundwater recharge of approximately 132,000 acre-feet per year to the Edwards Aquifer in the Nueces River basin between 1950 and 2005. This value was not used to calibrate the model, in part, because much of the Nueces River basin was outside Kinney County. However, simulated recharge to the same region was compared with this value after the model calibration.

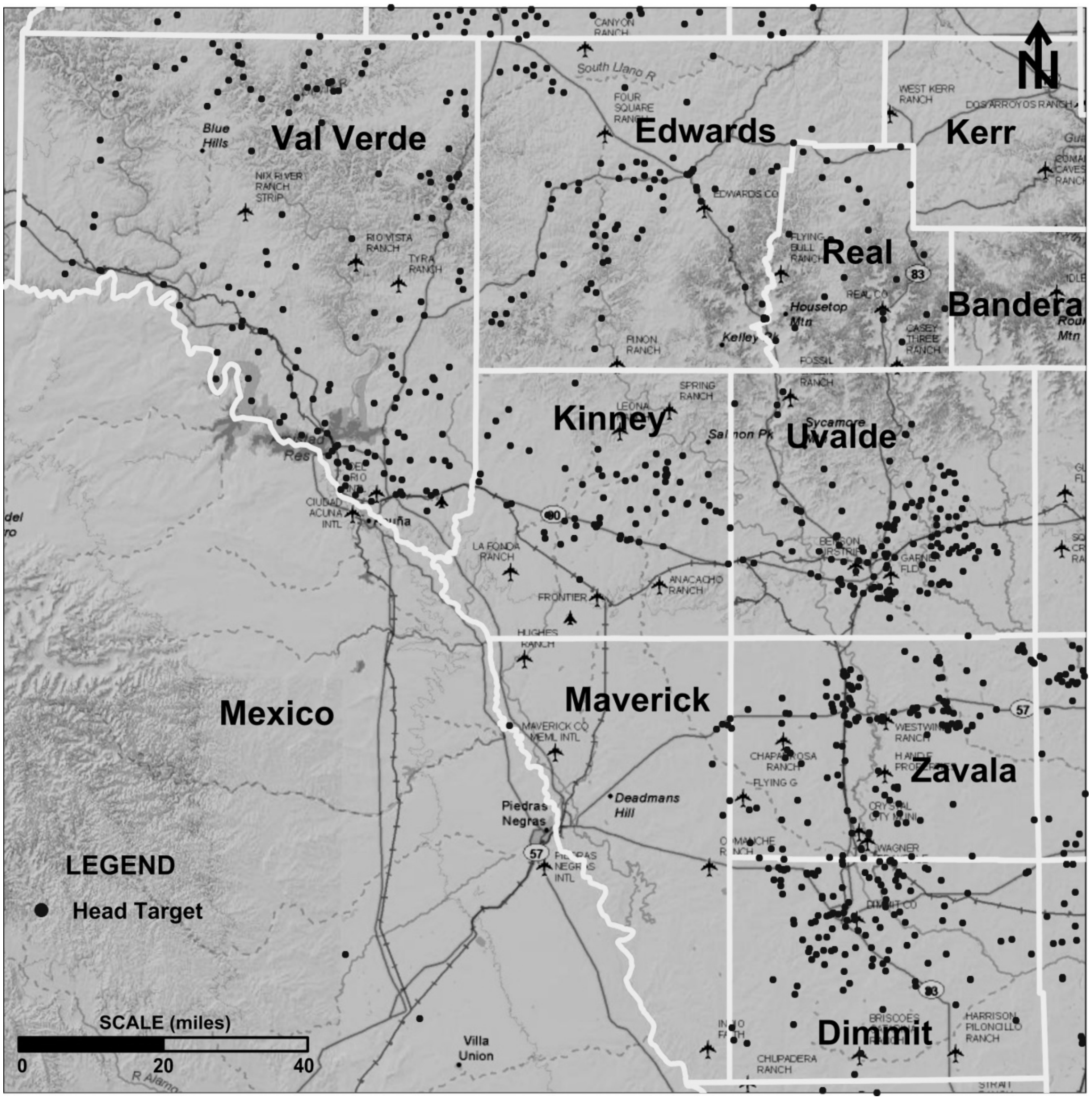
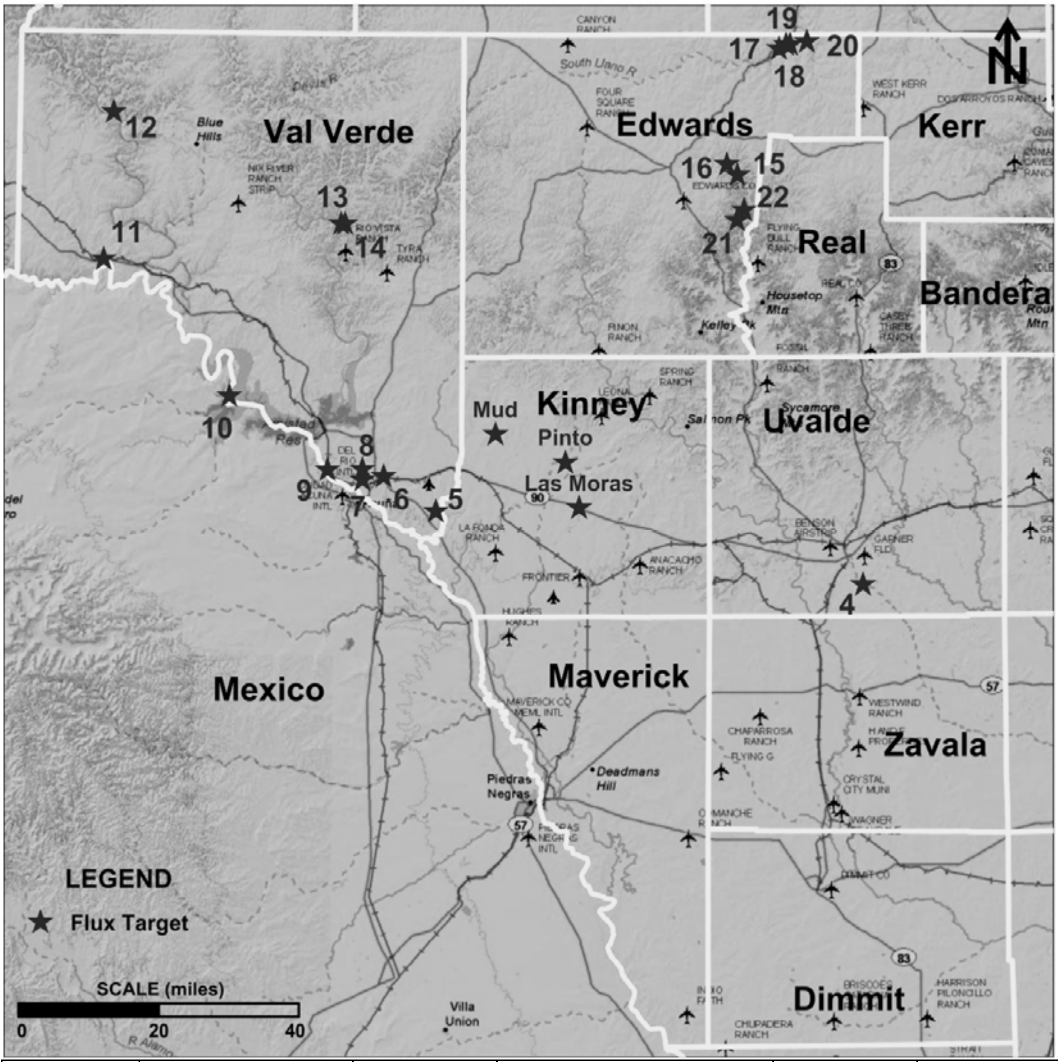


FIGURE 17A. DISTRIBUTION OF HEAD TARGETS.



Number	Spring	Number	Spring	Number	Spring
4	Leona	11	Guy Skiles	17	Deats
5	Yoas	12	YR-54-60-302	18	Tanner
6	San Felipe	13	YR-70-01-703/704	19	Seven Hundred
7	Cienega	14	YR-70-01-701	20	Big Paint
8	Cantu	15	Cade	21	JJ-70-08-801
9	McKee	16	Hackberry	22	JJ-70-08-603
10	Goodenough				

FIGURE 17B. DISTRIBUTION OF FLUX (SPRING) TARGETS.

During the model calibration, the following parameters were adjusted: hydraulic conductivity, anisotropy, specific storage, drain head and conductance, river head and conductance, general head boundary head and conductance, recharge, and constant head boundary head. The model was calibrated using a combination of parameter estimation program PEST (Watermark Numerical Computing, 2004) and trial-and-error. The parameter values and model results achieved through PEST runs were first inspected to determine if they were reasonable. In cases where unreasonable results were found, a trial-and-error method was used to determine a more appropriate range of possible parameter values to produce more reasonable results. This process was repeated until the model matched the measured or calculated values and generated reasonable flow fields consistent with the conceptual understanding of the regional groundwater flows.

3.2 Model Simulated versus Measured Heads

Figure 18 shows the model simulated versus measured heads and related statistic analysis summary. Head calibration and related statistic analysis summary based on wells in Kinney County was presented on Figure 19. Details of measured and simulated heads are included in Table A1 of Appendix A. Please note that wells in model layer 1 are not included because they are located downgradient and are not expected to influence the groundwater flow at Kinney County.

As shown on Figures 18 and 19, the model was well calibrated to the measured water levels collected at wells, with both ratios of head residual (simulated head minus measured head) standard deviations over ranges of measured heads less than 10 percent.

In addition, four wells with the most measured heads in Kinney County were also selected to compare the simulated heads with the measured heads. The hydrographs of these wells with their locations are presented on Figures 20 through 24. In general, the model reproduced the head fluctuation measured at these wells.

Previous studies, such as Bennett and Sayre (1962), indicated that a groundwater divide extended from north to south near Brackettville in Kinney County. East of the divide, the groundwater flowed to southeast and east. West of the divide, the groundwater flowed to southwest. To evaluate if the calibrated model reproduced this regional groundwater flow pattern, the simulated head contour maps with predicted flow directions in model layer 3 for the years of 1950 (stress period 2), 1978 (stress period 30), and 2005 (stress period 57) are presented on Figures 25a, 25b, and 25c. These figures show that the simulated groundwater flows are consistent with the observed regional flow pattern.

In summary, the comparison between the simulated and measured heads suggests that the calibration is reasonable and is consistent with the intended use of the model.

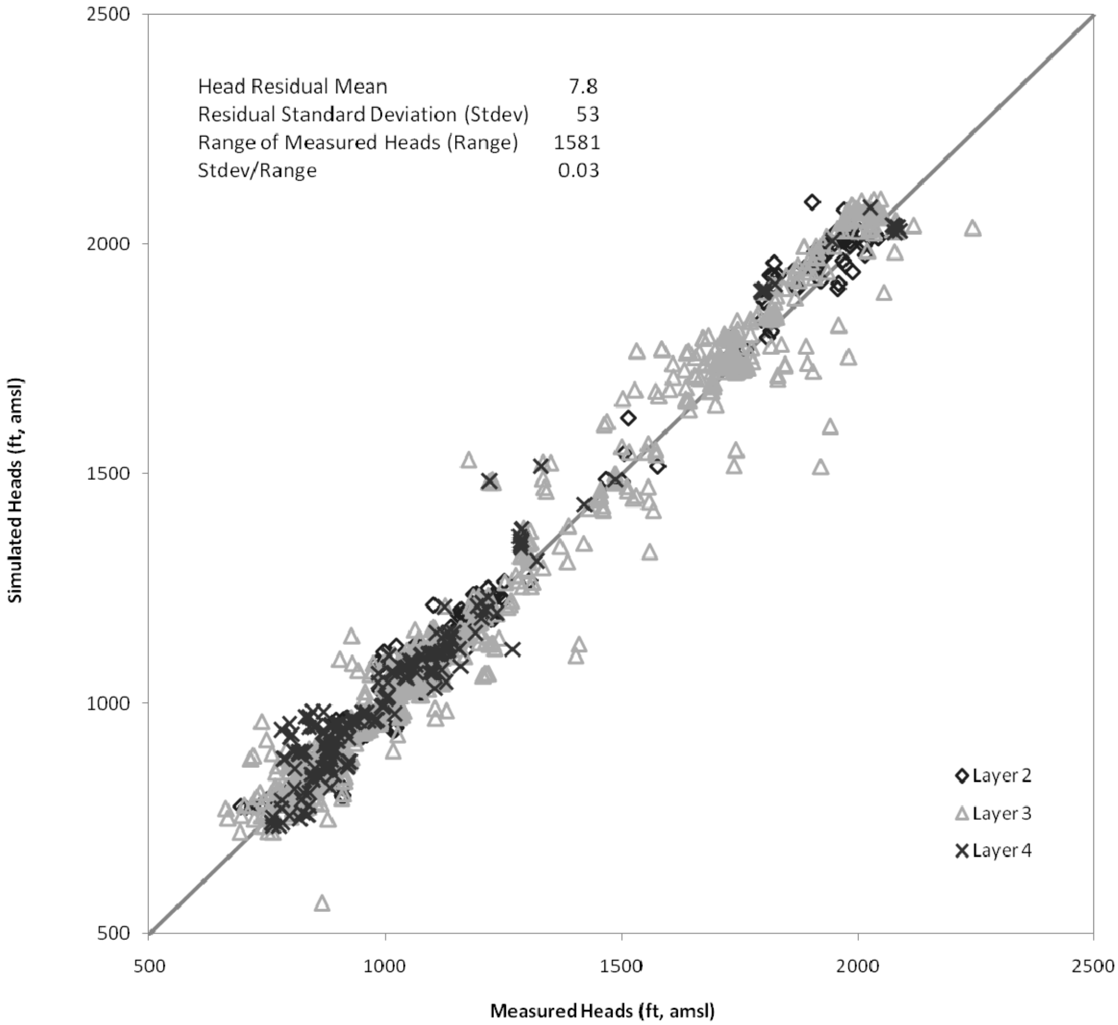


FIGURE 18. OVERALL HEAD CALIBRATION PLOT AND STATISTIC ANALYSIS SUMMARY FOR LAYERS 2 THROUGH 4.

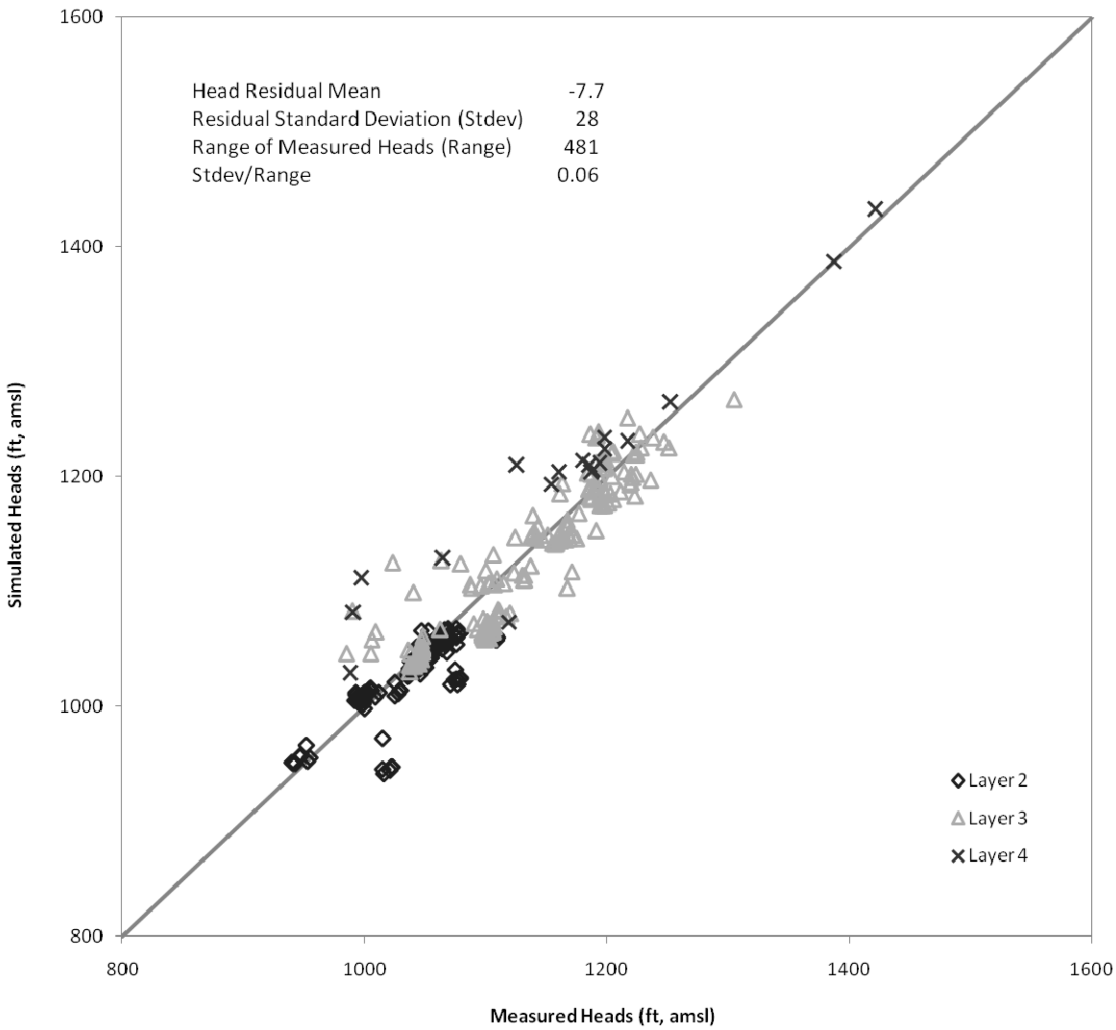


FIGURE 19. HEAD CALIBRATION PLOT AND STATISTIC ANALYSIS SUMMARY FOR KINNEY COUNTY FOR LAYERS 2 THROUGH 4.

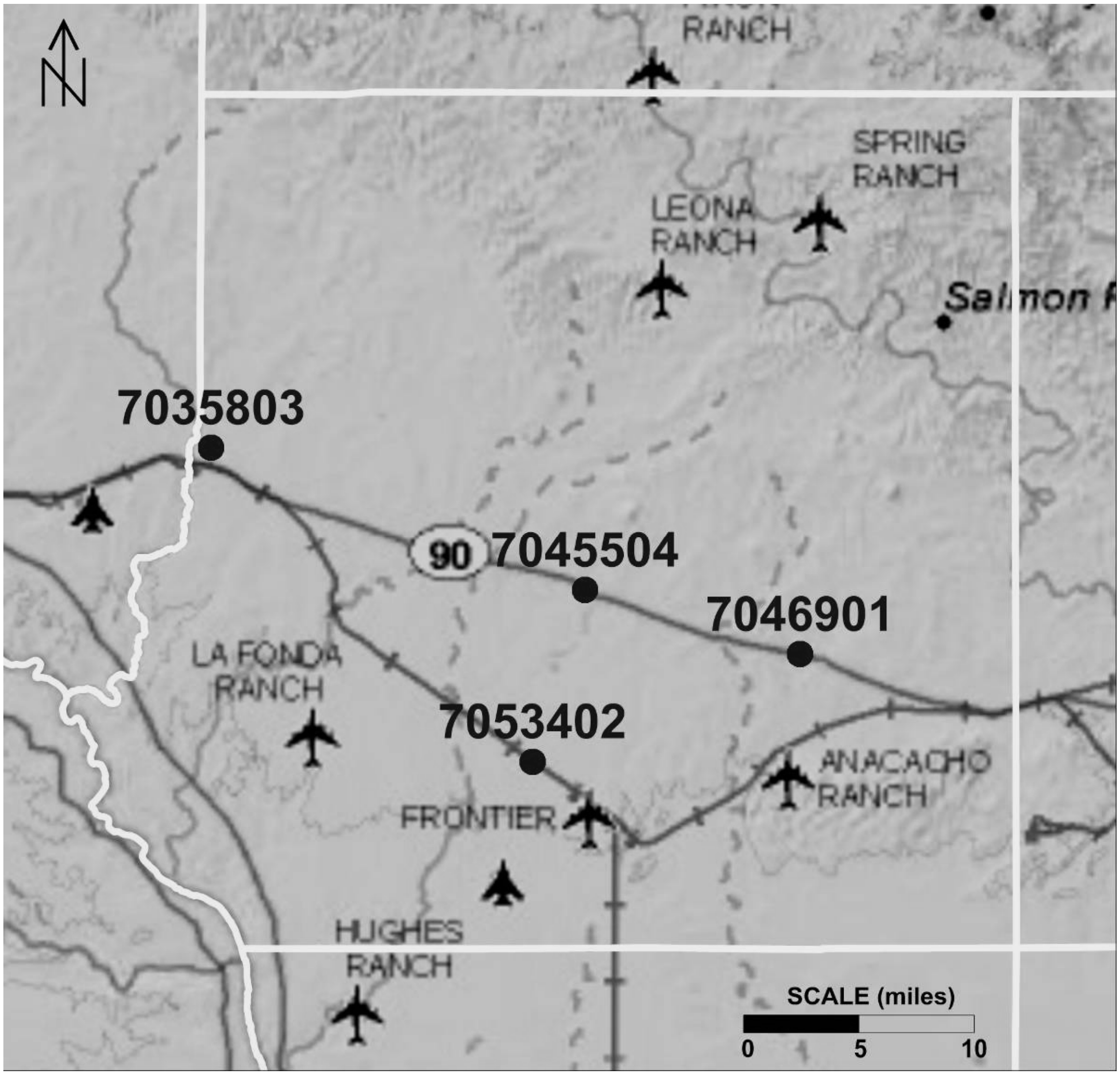


FIGURE 20. LOCATIONS OF SELECTED HEAD TARGET WELLS IN KINNEY COUNTY.

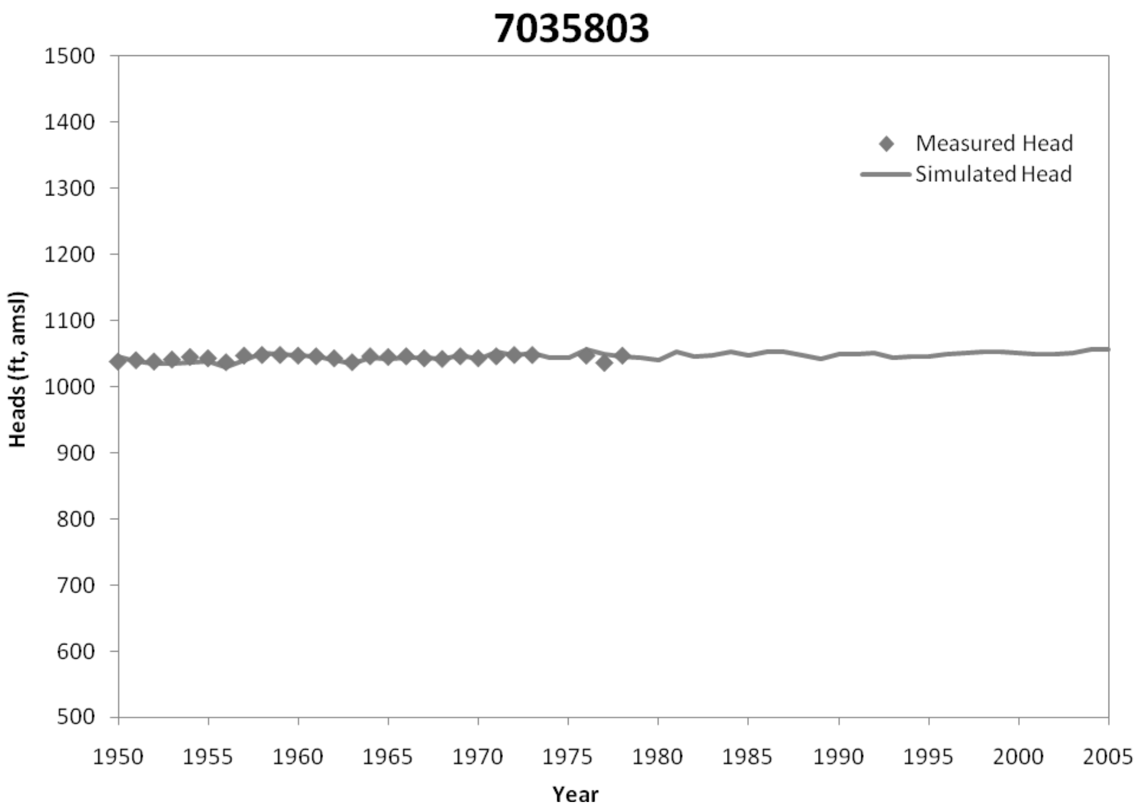


FIGURE 21. SIMULATED AND MEASURED HEADS AT WELL 7035803 LOCATED IN KINNEY COUNTY (WELL LOCATION SHOWN IN FIGURE 20).

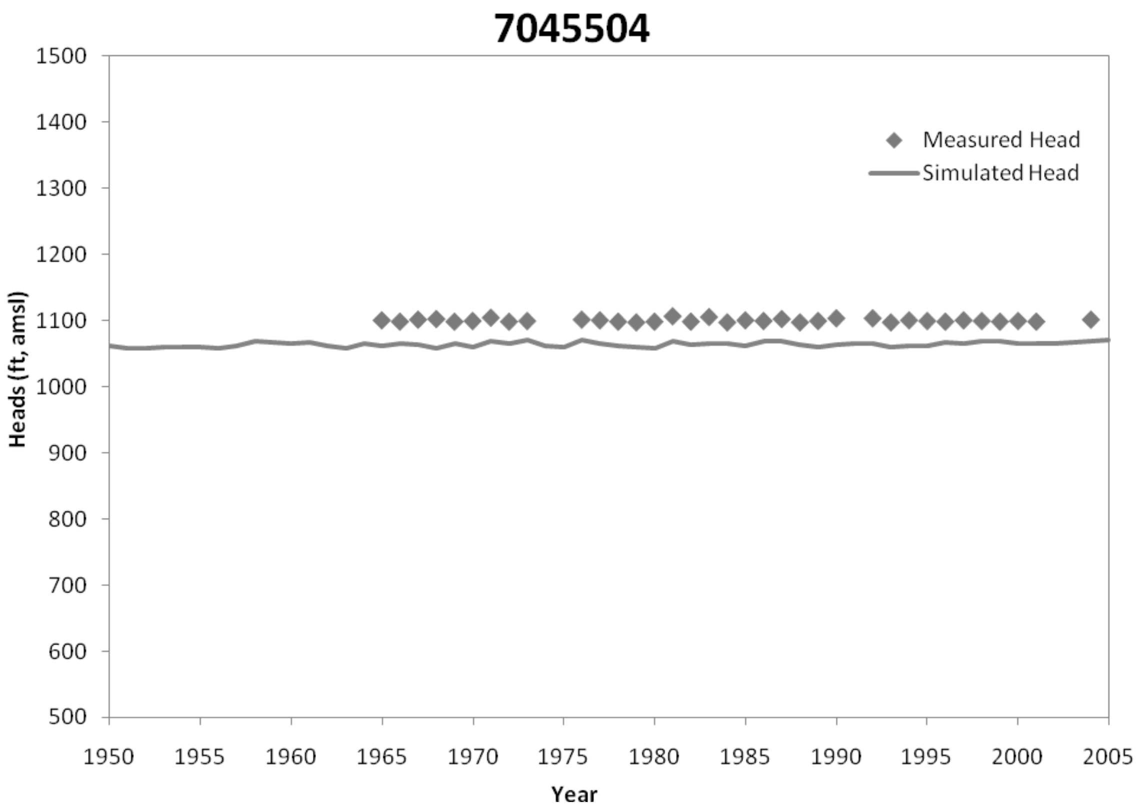


FIGURE 22. SIMULATED AND MEASURED HEADS AT WELL 7045504 LOCATED IN KINNEY COUNTY (WELL LOCATION SHOWN IN FIGURE 20).

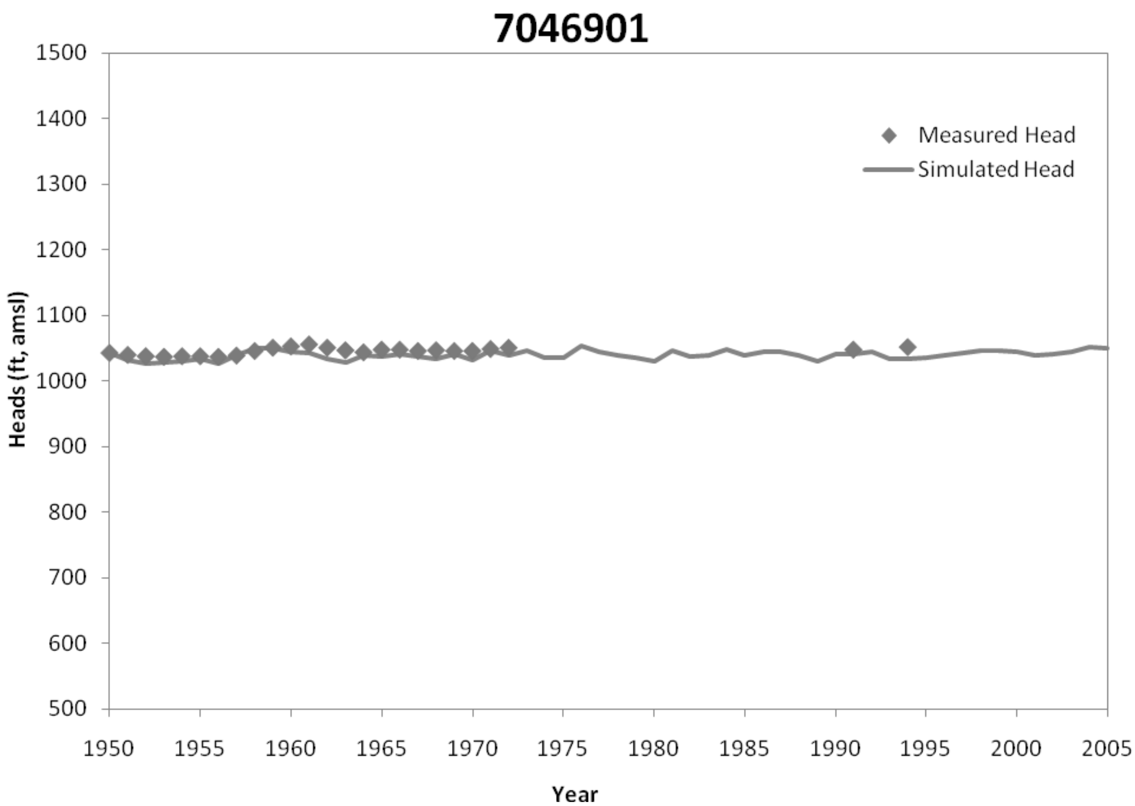


FIGURE 23. SIMULATED AND MEASURED HEADS AT WELL 7046901 LOCATED IN KINNEY COUNTY (WELL LOCATION SHOWN IN FIGURE 20).

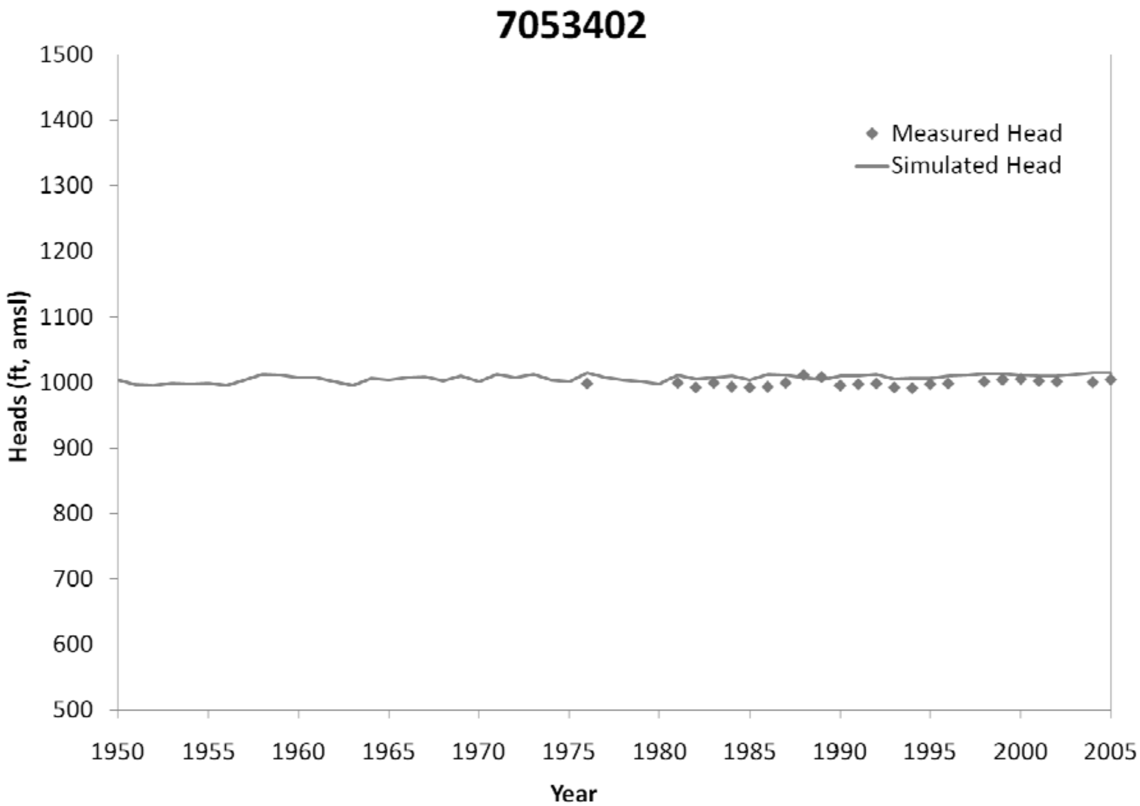


FIGURE 24. SIMULATED AND MEASURED HEADS AT WELL 7053402 LOCATED IN KINNEY COUNTY (WELL LOCATION DHOWN IN FIGURE 20).

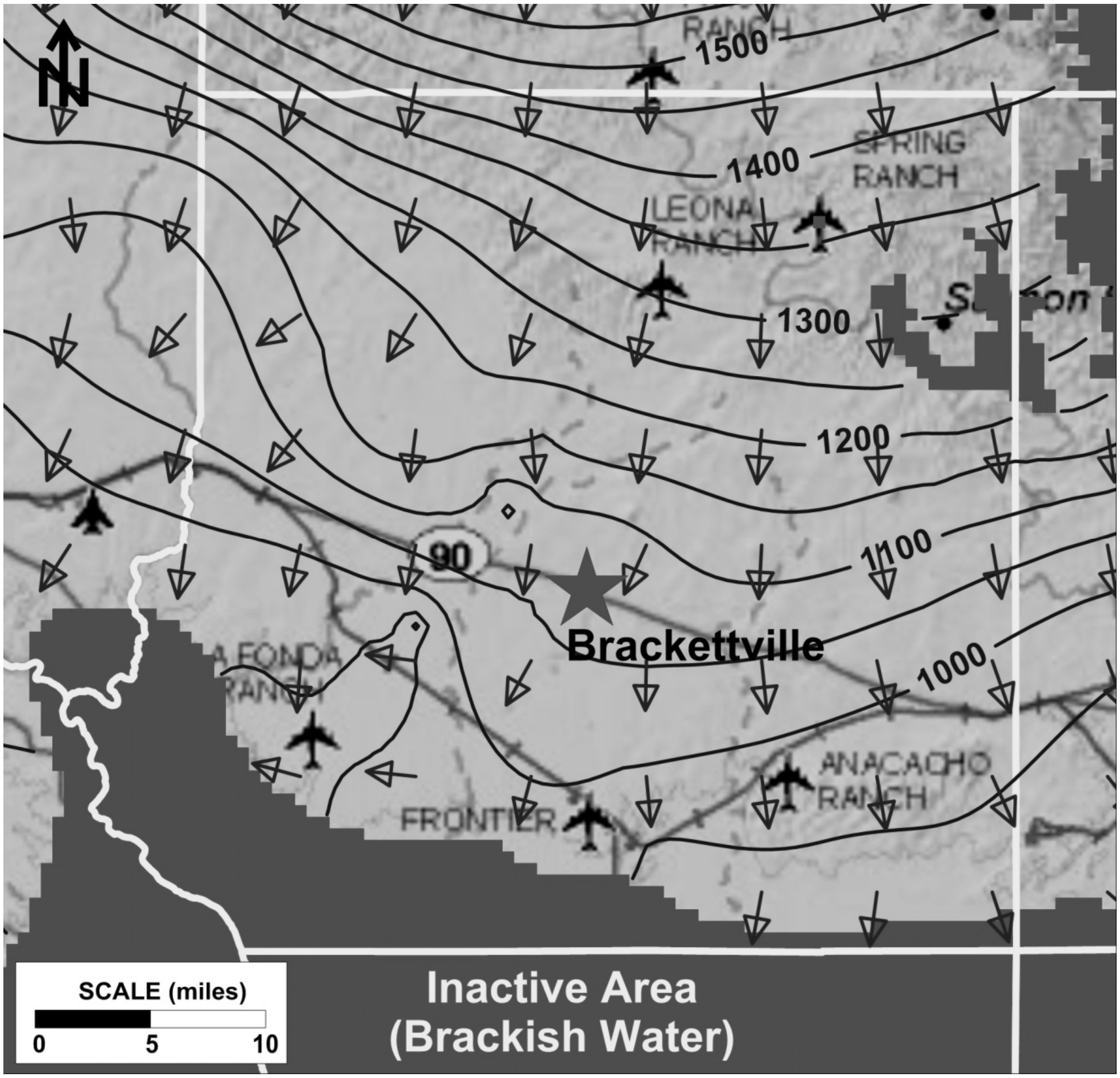


FIGURE 25A. SIMULATED GROUNDWATER HEADS AND FLOW DIRECTION IN MODEL LAYER 3 IN KINNEY COUNTY (1950).

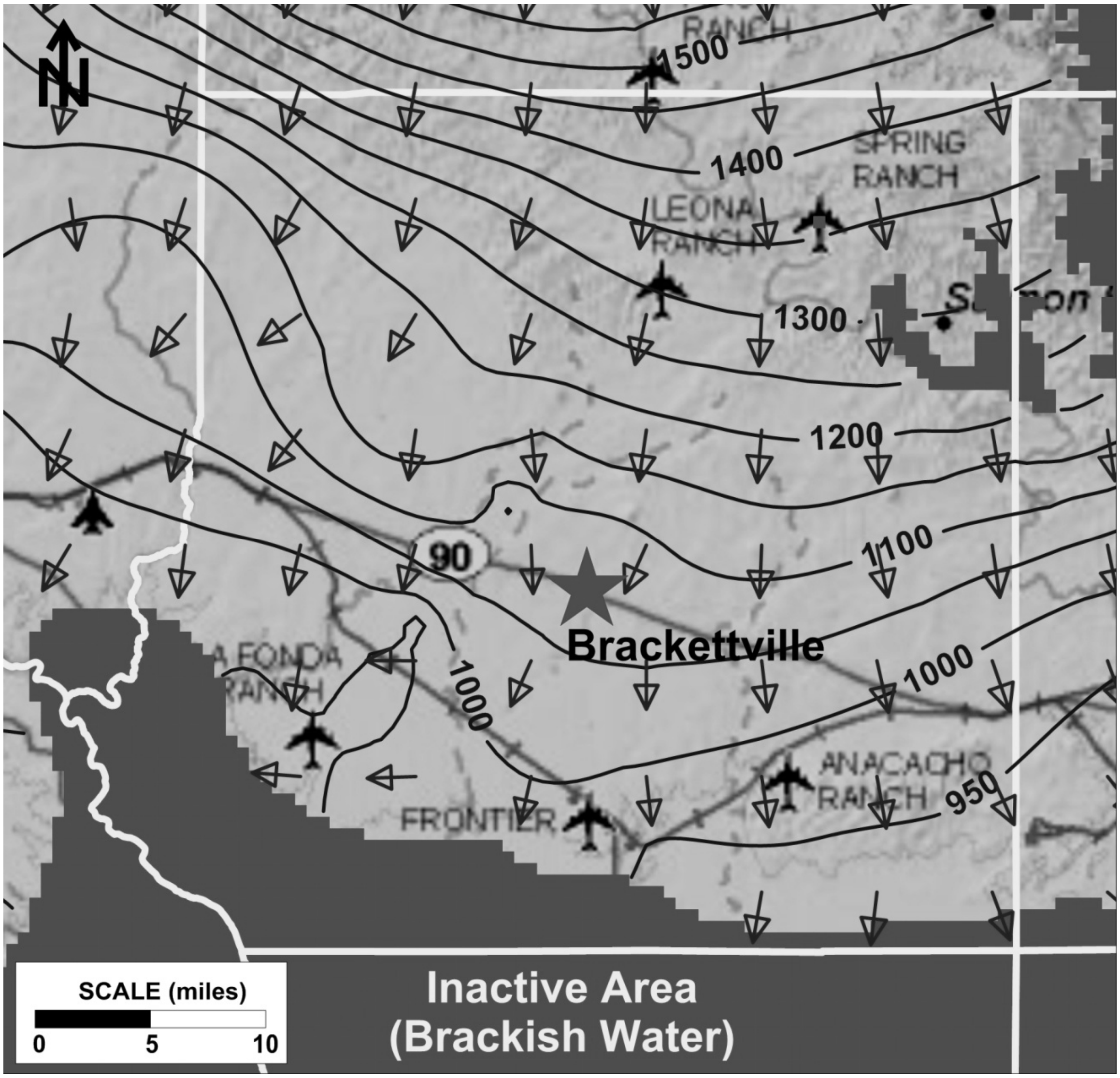


FIGURE 25B. SIMULATED GROUNDWATER HEADS AND FLOW DIRECTION IN MODEL LAYER 3 IN KINNEY COUNTY (1978).

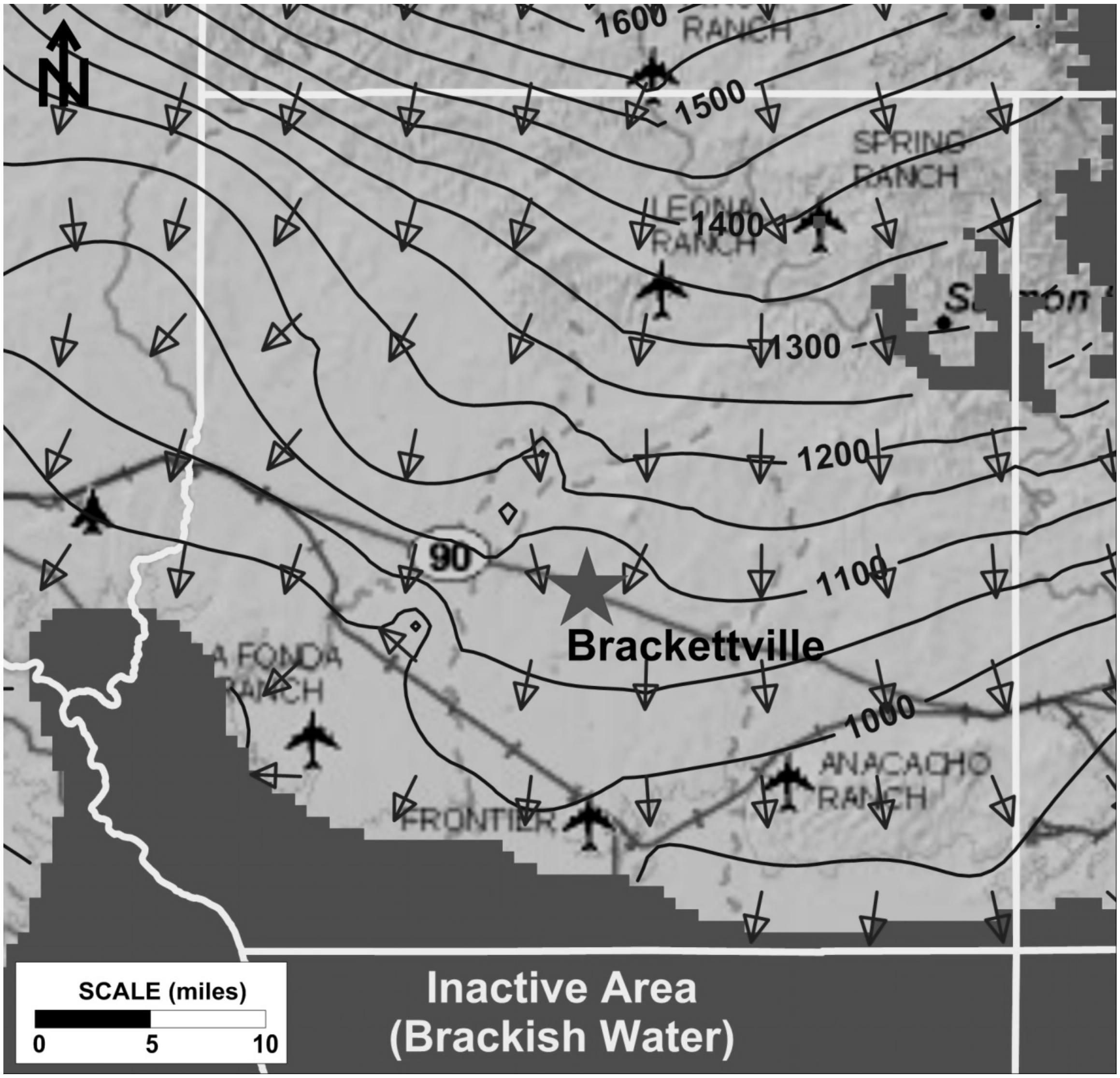


FIGURE 25C. SIMULATED GROUNDWATER HEADS AND FLOW DIRECTION IN MODEL LAYER 3 IN KINNEY COUNTY (2005).

3.3 Model Simulated versus Measured Fluxes

In addition to the head calibration at wells, the model was further calibrated to the measured fluxes at twenty-two springs. The overall calibration plot and related statistic analysis summary are shown on Figure 26. Details of measured and simulated fluxes at springs are included in Table B1 of Appendix B. The calibration results indicated that the model was also well calibrated to the measured fluxes at springs, with the ratio of flux residual (simulated flux minus measured flux) standard deviation over range of measured fluxes less than 10 percent (Figure 26).

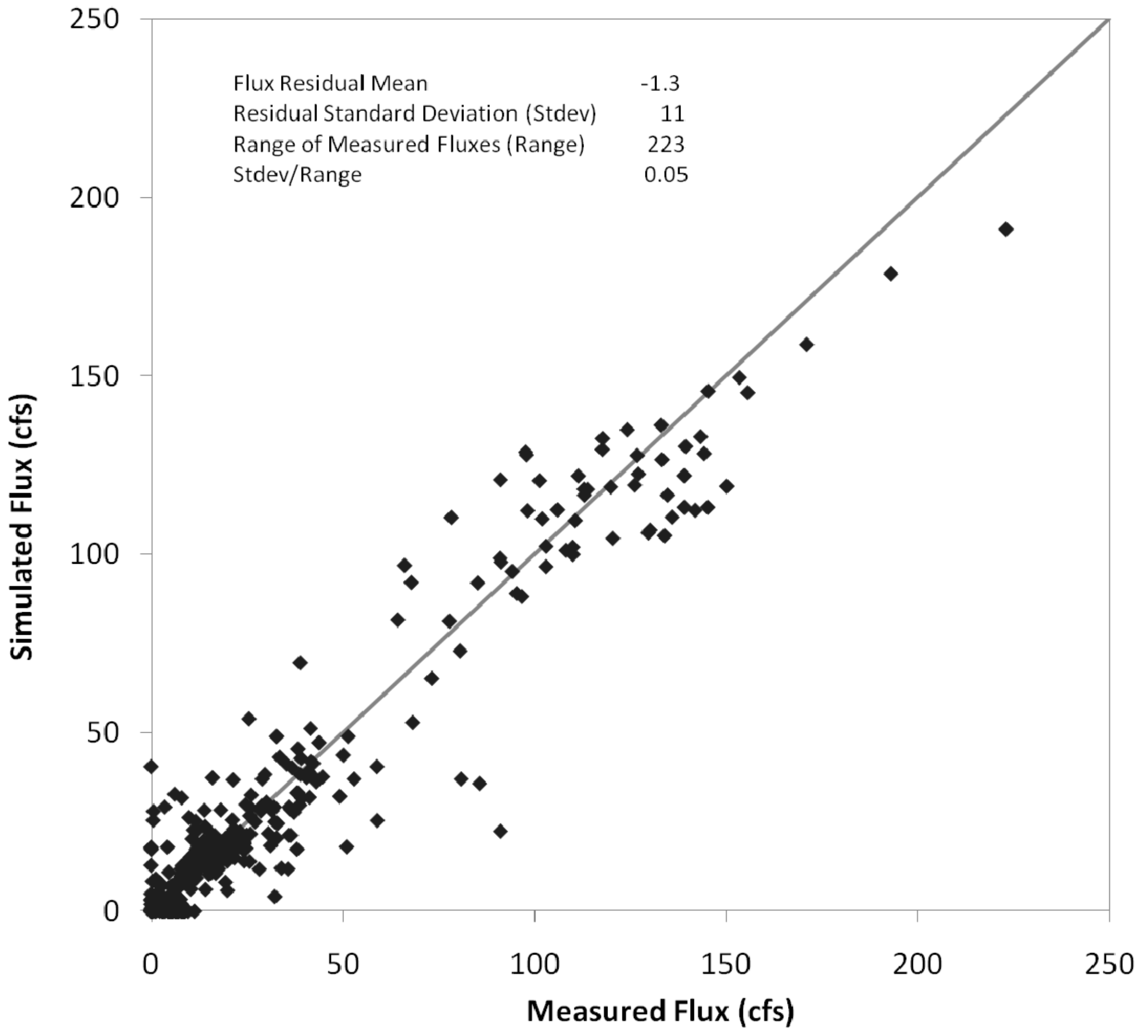


FIGURE 26. FLUX CALIBRATION PLOT AND STATISTIC ANALYSIS SUMMARY. FLUXES ARE REPORTED IN CUBIC FEET PER SECOND (CFS).

To evaluate how the model reproduced the fluxes at three largest springs in Kinney County, hydrographs for Las Moras, Mud, and Pinto springs with their locations were presented on Figures 27 through 30. In general, the model reproduced the flux fluctuation measured at these springs.

In summary, the comparison between the simulated and measured spring fluxes in Kinney County suggests that the calibration is reasonable and is consistent with the intended use of the model.

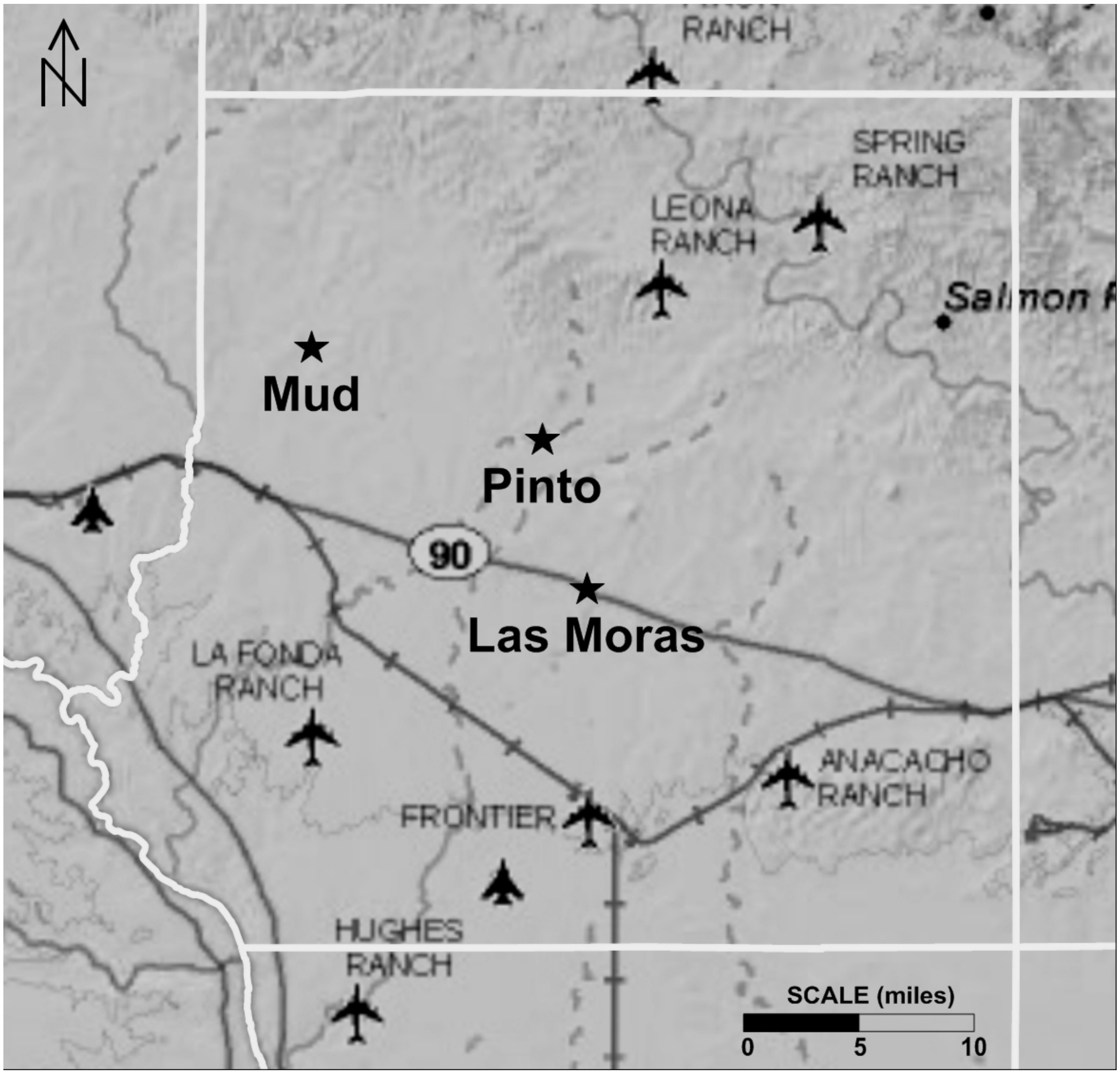


FIGURE 27. LOCATIONS OF MAJOR SPRINGS IN KINNEY COUNTY.

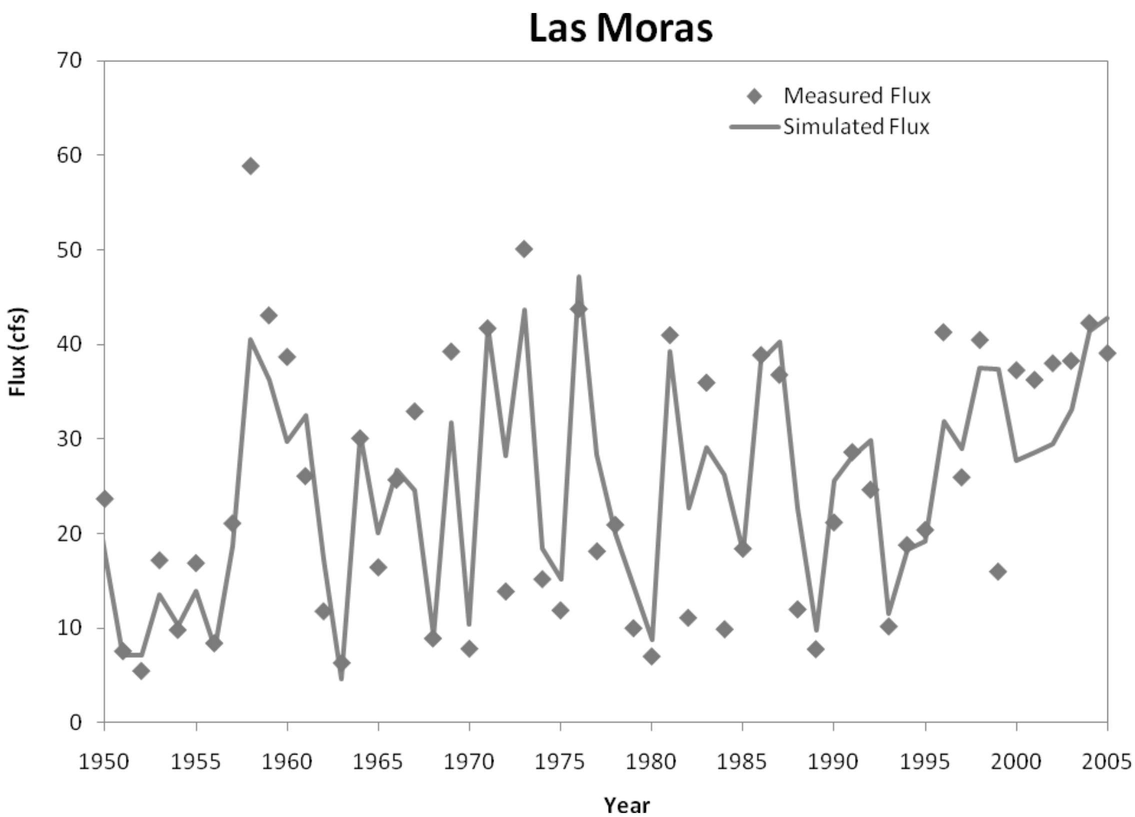


FIGURE 28. SIMULATED AND MEASURED FLUXES AT LAS MORAS SPRINGS IN KINNEY COUNTY (SPRING LOCATION SHOWN ON FIGURE 27). FLUXES ARE REPORTED IN CUBIC FEET PER SECOND (CFS).

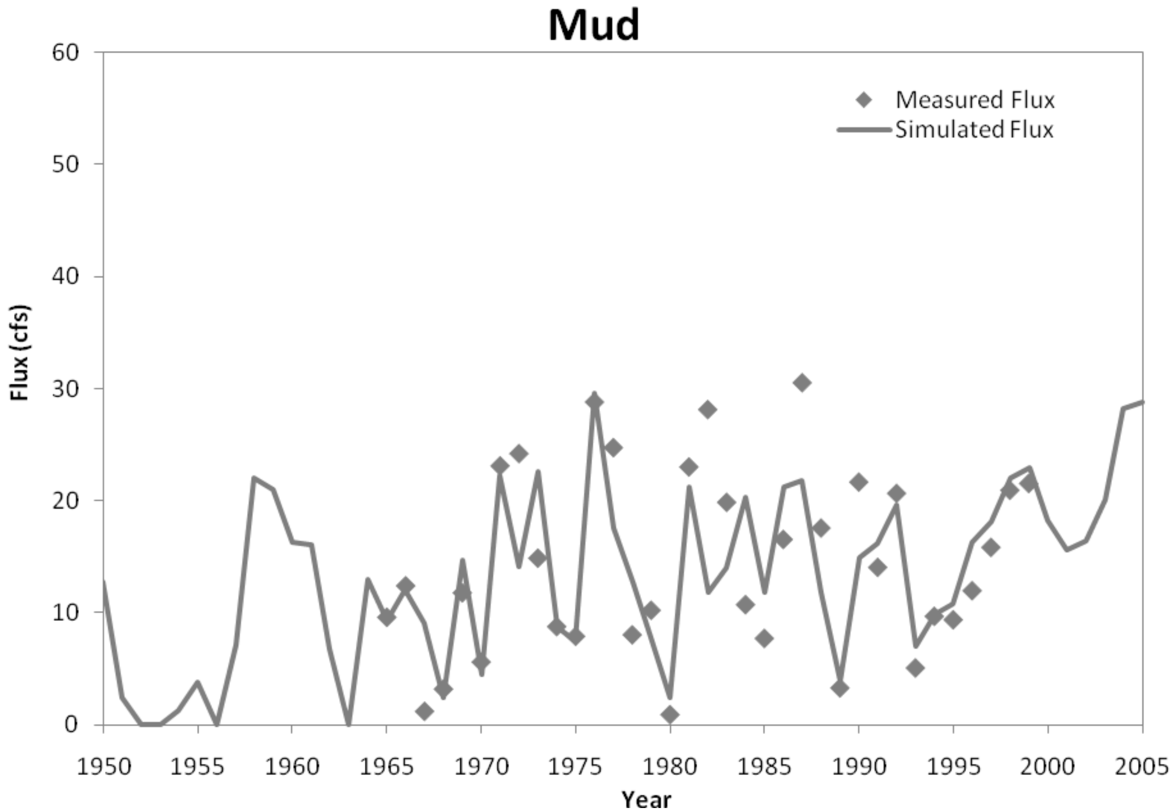


FIGURE 29. SIMULATED AND MEASURED FLUXES AT MUD SPRINGS IN KINNEY COUNTY (SPRING LOCATION SHOWN ON FIGURE 27). FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

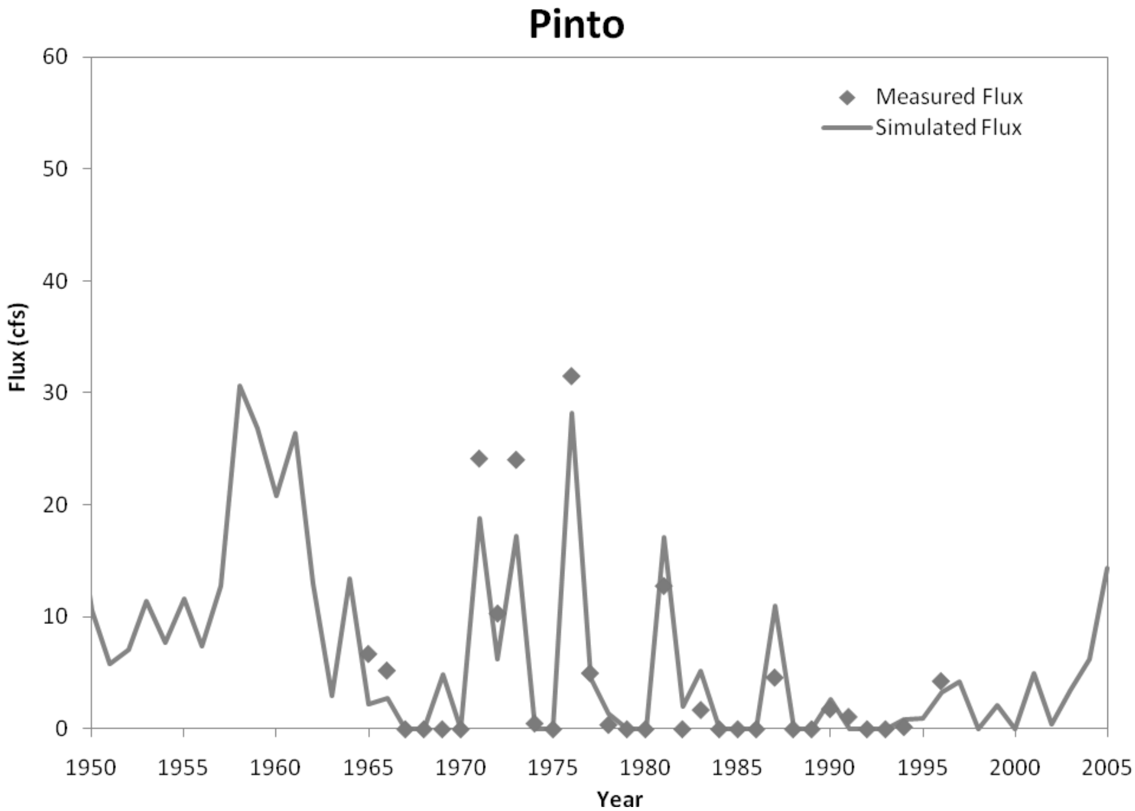


FIGURE 30. SIMULATED AND MEASURED FLUXES AT PINTO SPRINGS IN KINNEY COUNTY (SPRING LOCATION SHOWN ON FIGURE 27). FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

3.4 Model Simulated versus Calculated Discharges in Northern Kinney County and Nueces River Basin

As described above, simulated discharges to the unconfined aquifers due to precipitation and river leakage were also evaluated against the calculated values in northern Kinney County (Figures 31 and 32). As shown on Figure 31, the model almost exactly simulated the average groundwater recharge to the unconfined aquifers due to precipitation. The model also reproduced the river leakage quite well with an average of 6,824 acre-feet per year versus the estimated value of 6,667 acre-feet per year (Figure 32).

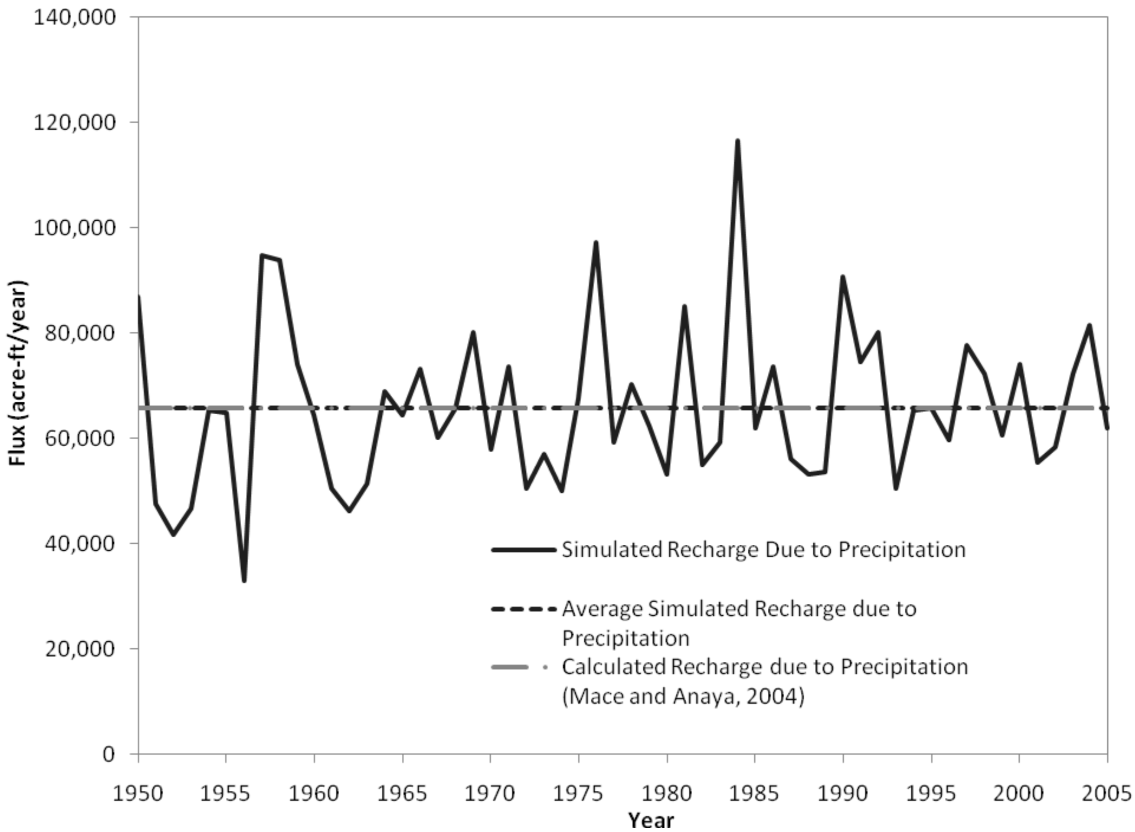


FIGURE 31. SIMULATED AND CALCULATED RECHARGES TO THE UNCONFINED AQUIFER DUE TO PRECIPITATION IN THE NORTHERN PORTION OF KINNEY COUNTY.

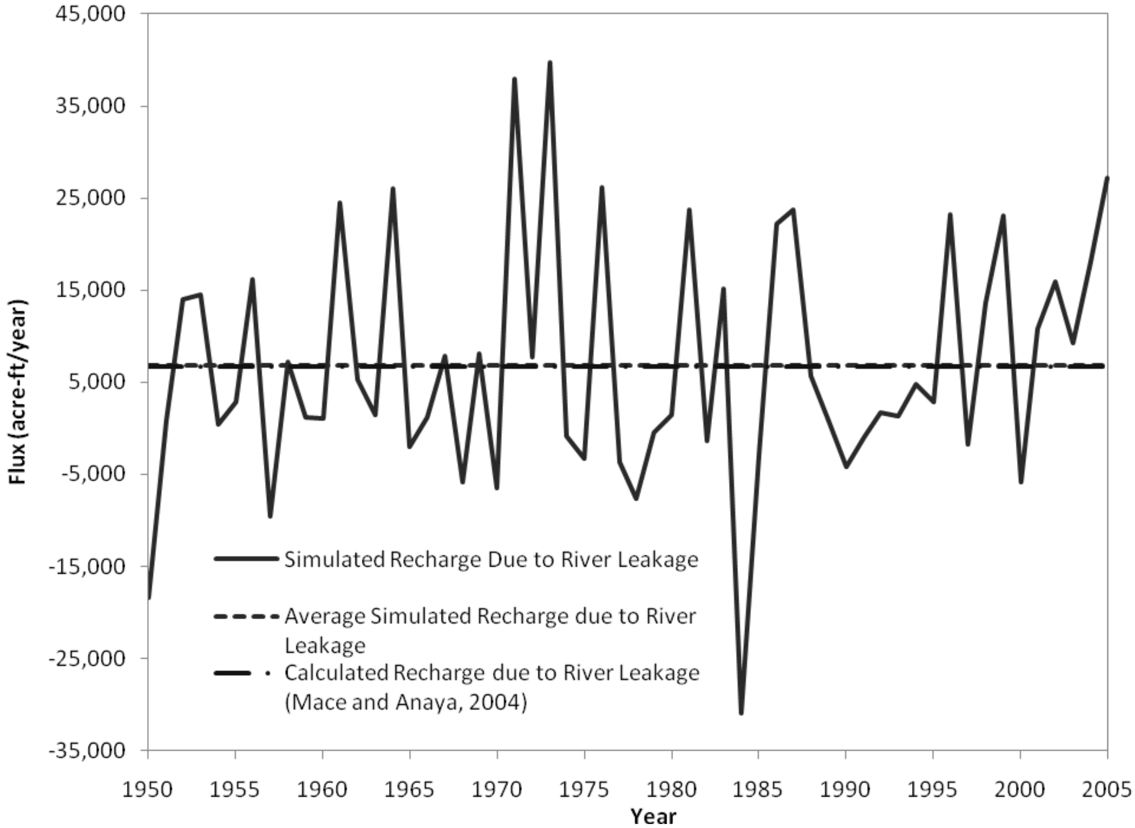


FIGURE 32. SIMULATED AND CALCULATED RECHARGES TO THE UNCONFINED AQUIFER DUE TO RIVER LEAKAGE IN THE NORTHERN PORTION OF KINNEY COUNTY.

For the Nueces River basin, the U.S.G.S. has been monitoring the groundwater recharge to the Edwards Aquifer outcrop area due to precipitation and river leakage since 1934 (Edwards Aquifer Authority, 2009). According to the email from Mr. George Ozuna of the U.S.G.S. Texas Water Science Center dated January 21, 2011, the U.S.G.S. estimated the groundwater recharge to the Edwards recharge zone (i.e. outcrop area) based on surface runoff in the catchment area of the Nueces/West Nueces River basins.

To evaluate the calibrated model, the same flow components to the Edwards Aquifer outcrop area from the calibrated model were combined and compared with the U.S.G.S. values. The results are presented in Table 11.

TABLE 11. COMPARISON OF GROUNDWATER RECHARGE TO EDWARDS OUTCROP IN NUECES RIVER BASIN BETWEEN ESTIMATES BY U.S.G.S. AND CALIBRATED MODEL.

Year	USGS (acre-feet/year)	Calibrated Model (acre-feet/year)		
		Recharge to Edwards Outcrop due to River Leakage	Recharge to Edwards Outcrop due to Precipitation	Total Recharge to Edwards Outcrop
1950	41,500	2,047	51,840	53,887
1951	18,300	18,143	28,395	46,538
1952	27,900	39,267	24,809	64,076
1953	21,400	42,726	27,844	70,570
1954	61,300	22,399	38,879	61,278
1955	128,000	30,346	38,603	68,949
1956	15,600	42,398	20,006	62,404
1957	108,600	18,030	56,531	74,561
1958	266,700	58,586	55,981	114,566
1959	109,600	43,692	44,121	87,813
1960	88,700	36,845	38,326	75,171
1961	85,200	72,831	30,050	102,882
1962	47,400	32,118	27,568	59,686
1963	39,700	16,785	30,603	47,388
1964	126,100	78,328	41,085	119,413
1965	97,900	28,235	38,326	66,561
1966	169,200	37,664	43,567	81,231
1967	82,200	44,777	35,842	80,619
1968	130,800	11,163	39,153	50,316

Year	USGS (acre-feet/year)	Calibrated Model (acre-feet/year)		
		Recharge to Edwards Outcrop due to River Leakage	Recharge to Edwards Outcrop due to Precipitation	Total Recharge to Edwards Outcrop
1969	119,700	51,808	47,703	99,511
1970	112,600	7,496	34,464	41,960
1971	263,400	102,393	43,842	146,235
1972	108,400	44,147	30,050	74,197
1973	190,600	99,807	33,912	133,720
1974	91,100	22,017	29,775	51,792
1975	71,800	19,080	40,257	59,336
1976	150,700	89,218	57,911	147,129
1977	102,900	28,170	35,292	63,462
1978	69,800	17,063	41,909	58,972
1979	128,400	24,635	37,223	61,858
1980	58,600	18,573	31,705	50,278
1981	205,000	80,159	50,737	130,896
1982	19,400	26,915	32,809	59,724
1983	79,200	57,683	35,292	92,975
1984	32,400	-5,630	69,492	63,862
1985	105,900	27,344	36,946	64,291
1986	188,400	77,433	43,842	121,275
1987	308,500	76,331	33,361	109,691
1988	59,200	38,460	31,705	70,165
1989	52,600	20,573	31,981	52,554

Year	USGS (acre-feet/year)	Calibrated Model (acre-feet/year)		
		Recharge to Edwards Outcrop due to River Leakage	Recharge to Edwards Outcrop due to Precipitation	Total Recharge to Edwards Outcrop
1990	479,300	31,676	54,048	85,724
1991	325,200	36,500	44,395	80,894
1992	234,100	42,497	47,703	90,200
1993	32,600	25,136	30,050	55,186
1994	124,600	35,786	38,879	74,665
1995	107,100	33,567	39,153	72,719
1996	130,000	71,666	35,569	107,235
1997	176,900	34,091	46,325	80,416
1998	141,500	61,980	43,015	104,995
1999	101,400	74,351	36,118	110,469
2000	238,400	24,937	44,121	69,059
2001	297,500	47,907	33,085	80,991
2002	83,600	57,775	34,740	92,515
2003	149,800	51,740	43,015	94,755
2004	481,900	71,498	48,529	120,027
2005	105,500	79,543	36,946	116,489
Average	132,038	42,513	39,240	81,752

The combined groundwater recharges to the Edwards outcrop area within the Nueces/West Nueces River basins due to river leakage and precipitation are also presented on Figure 33. As shown on Figure 33, the calibrated model reproduced similar variation pattern of the total groundwater recharge as estimated by the U.S.G.S. under relatively low recharge conditions, but does not match the high peaks estimated by the U.S.G.S. Also note that the model estimates recharge increase and decrease similar to the U.S.G.S estimates.

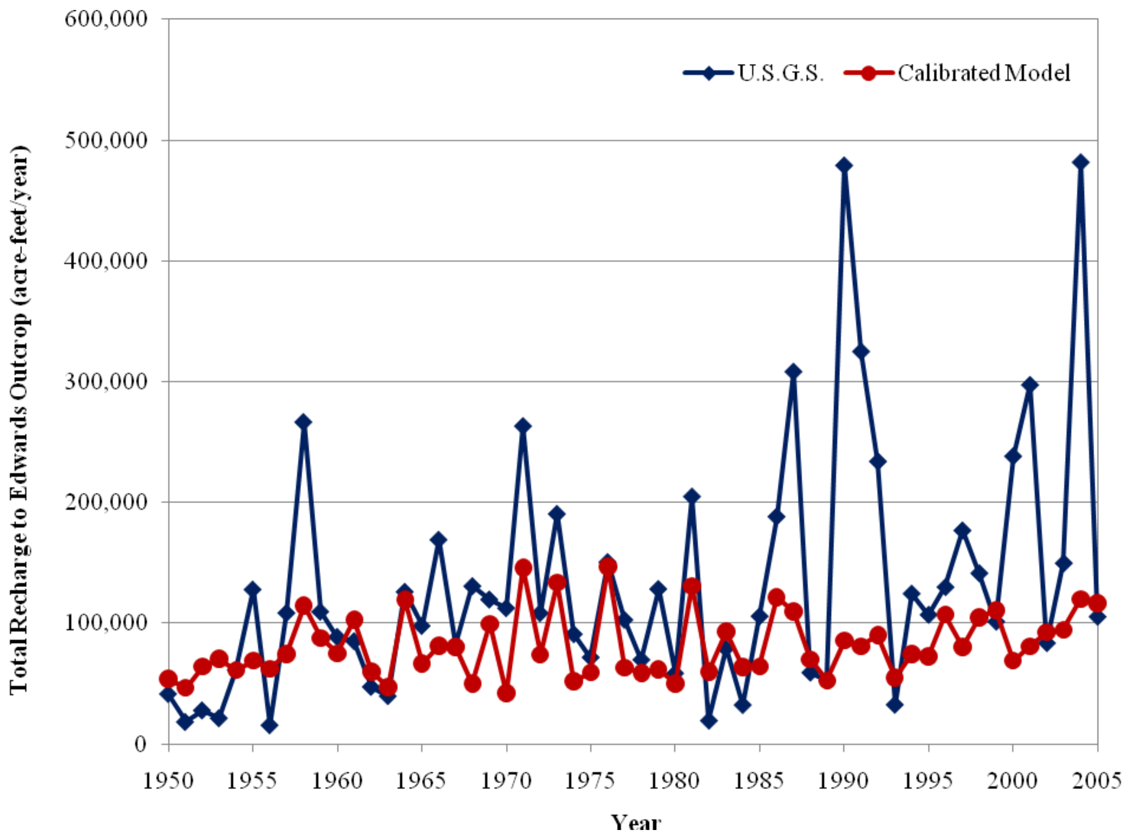


FIGURE 33. GROUNDWATER RECHARGES TO EDWARDS OUTCROP AREA DUE TO RIVER LEAKAGE AND PRECIPITATION.

3.5 Model Simulated Water Budgets

Evaluation of the simulated water budget further helps to verify if the model reproduces the regional groundwater flows consistent with our conceptual understanding of the regional geology, hydrogeology, surface water hydrology, and regional weather conditions.

Groundwater budgets or groundwater inventories are developed by quantifying all inflows to a system, all outflows from a system, and the system storage change over a specified period of time. Literature on the development of groundwater budgets dates back to at least the 1930s with the work of Meinzer (1932). Tolman (1937) noted that, at the time, methods to develop groundwater budgets had not reached the accuracy necessary to be accepted by all investigators. This was largely due to extensive data collection requirements and the lengthy time needed to observe the range of hydraulic conditions.

Bredehoeft (2002) reviewed the evolution of analysis of groundwater systems. The earliest methods in the 1940s and 1950s revolved around the analysis of flow to a single well.

Understanding groundwater flow on an aquifer or basin scale became possible with the analog model in the 1950s. Improvements in computer technology in the 1960s and 1970s led to the development of digital computer models or numerical models of groundwater flow. By 1980, Bredehoeft (2002) reported that numerical models had replaced analog models in the investigations of aquifer dynamics. The principle objective of such models is to understand the impacts of pumping on the system.

A groundwater system in near steady-state (or near equilibrium) prior to development (prior to groundwater pumping for irrigation or other human use) is shown on Figure 34. In this condition, groundwater inflow equals groundwater outflow and no change in storage occurs over time.

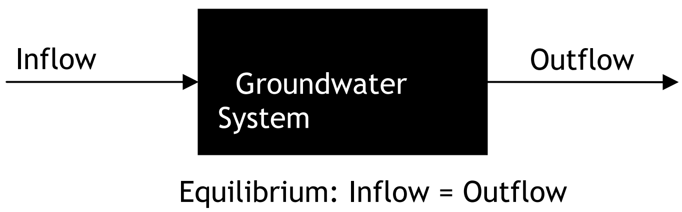


FIGURE 34. GROUNDWATER SYSTEM PRIOR TO DEVELOPMENT (AFTER ALLEY AND OTHERS, 1999).

Pumping of wells results in three "impacts" to the equilibrium system: 1) storage decline (manifested in the form of lowered groundwater levels), 2) induced flow (generally manifested by increased surface water recharge), and 3) captured natural outflow (generally manifested in decreased springflows).

The initial response to pumping is a lowering of the groundwater level or a "cone of depression" around the well, which results in a decline in storage. The cone of depression deepens and extends radially with time. As the cone of depression expands, it causes groundwater to move toward the well thereby increasing the inflow to the area around the well.

The cone of depression can also cause a decrease of natural groundwater outflow from the area adjacent to the well and acts to "capture" this natural outflow. If the cone of depression causes water levels to decline in an area of shallow groundwater, evapotranspiration is reduced and the pumping is said to capture the evapotranspiration. At some point, the induced inflow and captured outflow (collectively the capture of the well) can cause the cone of depression to stabilize or equilibrate.

Figure 35 illustrates the case of a groundwater system after pumping begins. Note that the groundwater storage is decreased, inflow is increased, and outflow is decreased in response to the pumping. The inflow does not equal the total outflow (natural outflow plus pumping). The system is not in equilibrium and groundwater storage is decreasing.

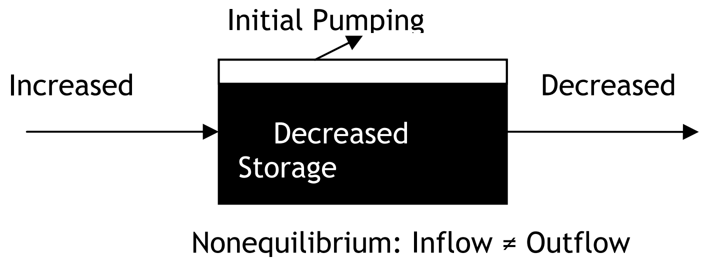


FIGURE 35. GROUNDWATER SYSTEM AFTER INITIAL PUMPING (AFTER ALLEY AND OTHERS, 1999).

If the hydraulic conductivity is sufficiently large and the initial pumping rate is relatively constant, the inflow and natural outflow will adjust to a new near steady-state condition in response to the pumping. Groundwater storage is decreased from the predevelopment level. This reduction in storage is the result of the new near steady-state condition of the system because the location and the nature of the outflow have changed (i.e. pumping wells). Figure 36 presents a diagram of this new near steady-state or new equilibrium condition.

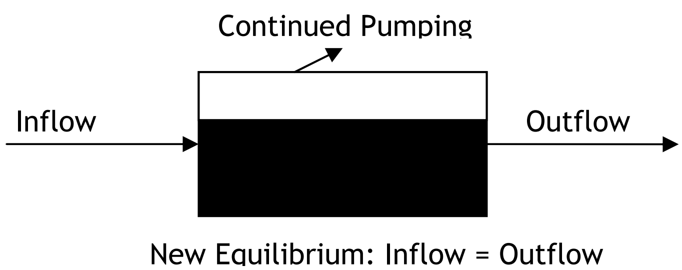


FIGURE 36. GROUNDWATER SYSTEM UNDER CONTINUED PUMPING-NEW EQUILIBRIUM CONDITION (AFTER ALLEY AND OTHERS, 1999).

If pumping were to increase after this new near steady-state condition was established, the system inflow increases again, the natural outflow decreases again, and groundwater storage is further decreased. Figure 37 depicts this condition.

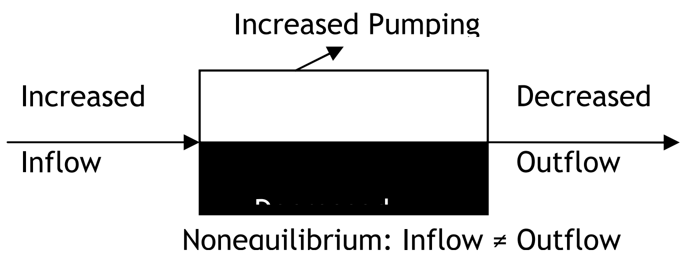


FIGURE 37. GROUNDWATER SYSTEM UNDER ADDITIONAL INCREMENT OF INCREASED PUMPING (AFTER ALLEY AND OTHERS, 1999).

In response to this new increase in pumping, inflow would continue to increase, outflow would continue to decrease, and storage would continue to decrease as the system is equilibrating. If the pumping is relatively constant, it is possible for a groundwater basin to exhibit stable groundwater levels at a lower level than had been previously observed. Stable groundwater levels are an indication that a new near steady-state condition has been reached.

Pumping can increase to the point where no new near steady-state condition is possible. In this condition, inflow can be induced no further and/or natural outflow can be decreased no further. From an outflow perspective, this condition would be reached once all springs have ceased to flow (no more springflow to "capture") or the water table has declined to the point that shallow groundwater evapotranspiration has ceased.

In summary, groundwater pumping dynamically alters the direction and magnitude of hydraulic gradients, induces inflow, decreases natural discharge from the system (e.g springflows, evapotranspiration) and affects fluxes between hydraulically connected aquifer systems. Bredehoeft (2002) noted that understanding the dynamic response of a groundwater system under pumping stress distills down to understanding the rate and nature of "capture" attributable to pumping, which is the sum of the change in recharge and the change in discharge caused by pumping. A calibrated numerical groundwater model of a region is an ideal tool in meeting the objective of understanding capture. Output from the model includes estimates of the various components of the water budget.

The overall water budget for this groundwater flow model includes the following components: reservoir, rivers, general heads, recharge, springs, pumpage, and storage change. Inflow and outflow components represent those contributing groundwater to or taking groundwater away from the aquifers in the model domain, respectively. As shown in Table 12, the groundwater in the model domain is mainly from recharge due to precipitation and, to a lesser degree, from the Amistad Reservoir leakage. The outflow components comprise of (in descending order): leakage to rivers, flow to surrounding aquifers, discharge to springs, and groundwater withdrawal at wells.

For Kinney County, the simulated water budget from the calibrated model is presented in Table 13. In comparison with the whole model domain, the groundwater flow from recharge due to precipitation and Edwards County were predicted to dominate the inflow to Kinney County. The calibrated model also predicted that discharge to rivers, pumping wells, and Uvalde County controlled the groundwater outflow. Discharges to other surrounding counties and springs were moderate.

TABLE 12. SUMMARY OF OVERALL ANNUAL AVERAGE GROUNDWATER BUDGET FOR THE MODEL.

Flow components		1950-1959	1960-1967	1968-1979	1980-1989	1990-1999	2000-2005
Inflow	Recharge	2,151,728	2,019,633	2,231,540	2,257,917	2,361,415	2,279,816
	Reservoir	0	0	734,751	732,670	724,472	684,225
	Total Inflow	2,151,728	2,019,633	2,966,291	2,990,587	3,085,887	2,964,041
Outflow	Rivers	1,268,869	1,137,093	1,732,708	1,789,641	1,767,959	1,621,329
	Surrounding Aquifers	459,933	447,837	466,053	462,167	487,180	548,684
	Springs	228,957	262,776	479,217	473,051	479,677	521,135
	Pumpage	172,518	291,656	271,449	295,774	228,591	190,706
	Total Outflow	2,130,277	2,139,362	2,949,427	3,020,633	2,963,407	2,881,854
Total Inflow - Total Outflow		21,451	-119,729	16,864	-30,046	122,480	82,187
Storage change		21,450	-119,730	16,864	-30,047	122,480	82,187

Note: - All flows are in acre-ft/year.

TABLE 13. SUMMARY OF ANNUAL AVERAGE GROUNDWATER BUDGET FOR KINNEY COUNTY (MODEL LAYERS 2 TO 4).

Flow components		1950-1959	1960-1967	1968-1979	1980-1989	1990-1999	2000-2005
Inflow	Recharge	171,113	158,027	174,065	176,263	183,963	177,527
	Edwards County	138,124	140,566	139,829	140,854	142,335	143,322
	Mexico	22,263	22,753	24,220	24,486	24,466	24,975
	Total Inflow	331,500	321,346	338,114	341,603	350,764	345,824
Outflow	Rivers	124,605	111,648	128,501	132,479	139,663	128,280
	Pumpage	64,871	66,901	67,294	68,238	60,924	60,218
	Uvalde County	53,134	53,843	54,384	55,527	54,906	53,529
	Maverick County	33,671	33,989	33,712	33,363	33,714	34,224
	Springs	27,152	31,659	33,429	31,172	31,836	43,420
	Val Verde County	25,957	27,246	22,632	21,411	22,695	23,253
	Total Outflow	329,390	325,286	339,952	342,190	343,738	342,924
Total Inflow - Total Outflow		2,110	-3,940	-1,838	-587	7,026	2,900
Storage change		2,110	-3,941	-1,838	-588	7,026	2,900

Note: - All flows are in acre-ft/year.

3.6 Correlation between Pumpage and Recharge

In general, pumpage is negatively correlated to precipitation in this region, i.e. groundwater withdrawal at wells is usually higher in dry years than in wet years. Since groundwater recharge is positively related to precipitation, pumpage may then be negatively correlated to the groundwater recharge. To evaluate this, the simulated total pumping rates versus total groundwater recharge rates in Kinney County are plotted on Figure 38, with correlation analysis result presented in Table 14. As expected, the calibrated model re-produced this negative correlation.

TABLE 14. CORRELATION BETWEEN SIMULATED PUMPAGE AND RECHARGE.

Components	Pumpage	Recharge
Pumpage	1	-0.25
Recharge	-0.25	1

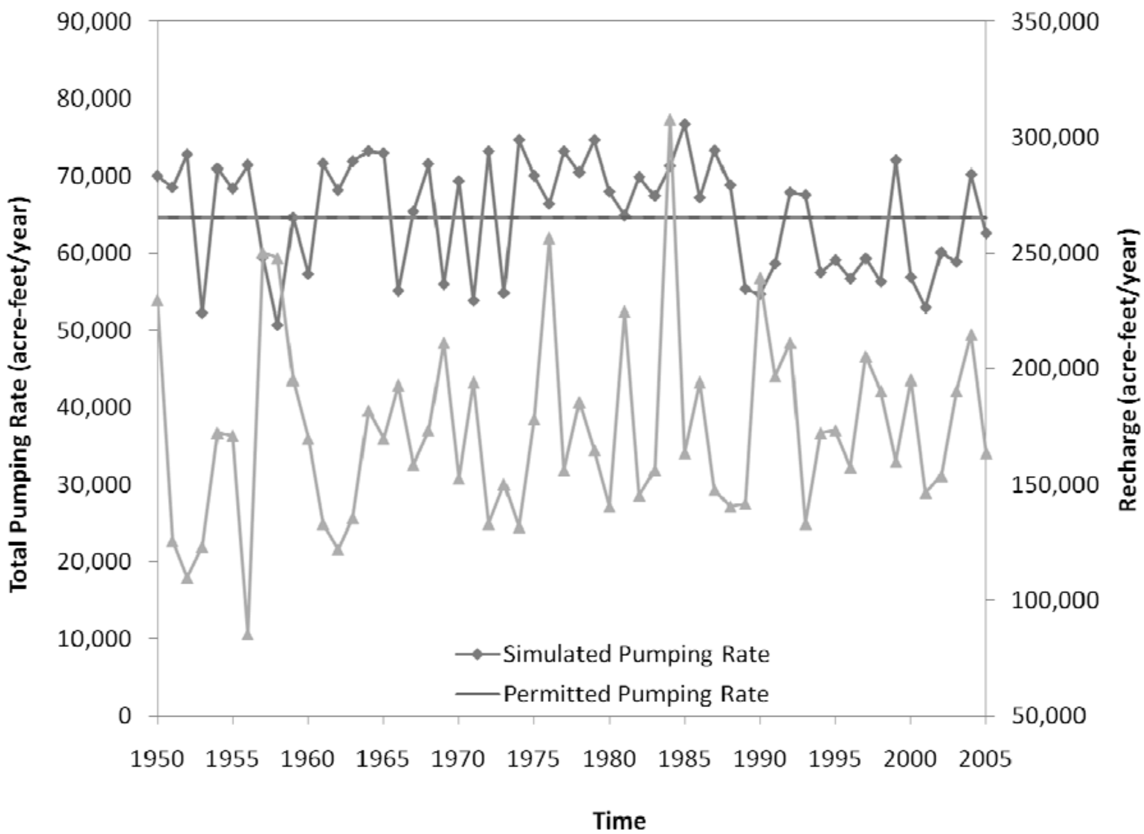


FIGURE 38. CORRELATION BETWEEN GROUNDWATER WITHDRAWAL AT WELLS AND RECHARGE DUE TO PRECIPITATION.

4.0 SENSITIVITY ANALYSIS

Sensitivity analysis was performed after the model calibration was accomplished. The purpose of the sensitivity analysis was to test how county-wide groundwater pumping would affect the model calibration and groundwater discharge at the springs in Kinney County.

4.1 Procedure of Sensitivity Analysis

The sensitivity analysis includes adjusting the pumping in Kinney County in the calibrated model by the following factors: 0.2, 0.5, 1.5, and 2.0. For each sensitivity analysis, statistics of head and flux calibration results as well as spring flow hydrographs are presented with, for comparison purpose, the results from the calibrated model. The results are summarized in the following section.

4.2 Results of Sensitivity Analysis

In summary, decreasing or increasing groundwater pumping rates within the tested range in Kinney County was predicted to have impacts on the head/flux residuals especially for targets in Kinney County (Tables 14 through 16). Greater impacts may be observed at the spring flows in Kinney County. As shown in Figures 39 through 41, the spring flows may be reduced by more than 50 percent when groundwater pumping doubled in Kinney County. During dry climatic years, this increasing well withdrawal may cause the springs to cease flowing.

TABLE 15. SUMMARY OF OVERALL HEAD STATISTICS FROM SENSITIVITY ANALYSIS.

Statistics	Relative change of pumping in Kinney County to calibrated model				
	x 0.2	x 0.5	x 1.0	x 1.5	x 2.0
Residual mean	9.10	8.67	7.79	6.59	4.60
Residual standard deviation (SD)	52.86	52.98	53.37	54.14	55.79
Range of measured (Range)	1581	1581	1581	1581	1581
SD/Range	0.03	0.03	0.03	0.03	0.04

Note:
- Residual (feet) = Simulated Head – Measured Head
- Head residual calculation excludes targets in model layer 1.

TABLE 16. SUMMARY OF HEAD STATISTICS FROM SENSITIVITY ANALYSIS IN KINNEY COUNTY.

Statistics	**Relative change of pumping in Kinney County to calibrated model**				
	x 0.2	**x 0.5**	**x 1.0**	**x 1.5**	**x 2.0**
Residual mean	-1.55	-3.61	-7.73	-13.30	-22.59
Residual standard deviation (SD)	25.45	25.78	27.67	31.61	38.76
Range of measured (Range)	481	481	481	481	481
SD/Range	0.05	0.05	0.06	0.07	0.08

Note: - Residual (feet) = Simulated Head – Measured Head

- Head residual calculation excludes targets in model layer 1.

TABLE 17. SUMMARY OF OVERALL FLUX STATISTICS FROM SENSITIVITY ANALYSIS.

Statistics	**Relative change of pumping in Kinney County to calibrated model**				
	x 0.2	**x 0.5**	**x 1.0**	**x 1.5**	**x 2.0**
Residual mean	1.74	0.61	-1.28	-3.16	-4.82
Residual standard deviation (SD)	12.25	11.33	10.54	10.81	11.94
Range of measured (Range)	222.98	222.98	222.98	222.98	222.98
SD/Range	0.05	0.05	0.05	0.05	0.05

Notes: - Residual (cfs) = Simulated Flux – Measured Flux

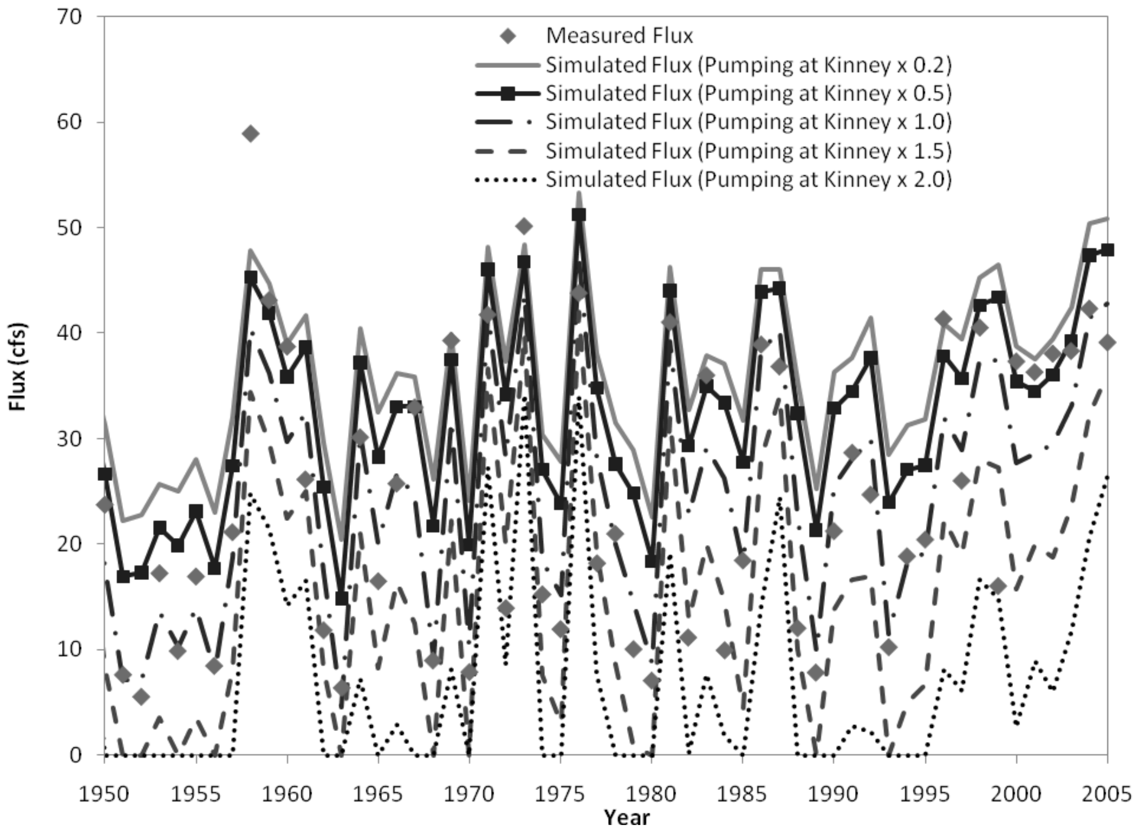


FIGURE 39. IMPACTS OF COUNTYWIDE GROUNDWATER PUMPING ON SPRING FLOW AT LAS MORAS SPRINGS.

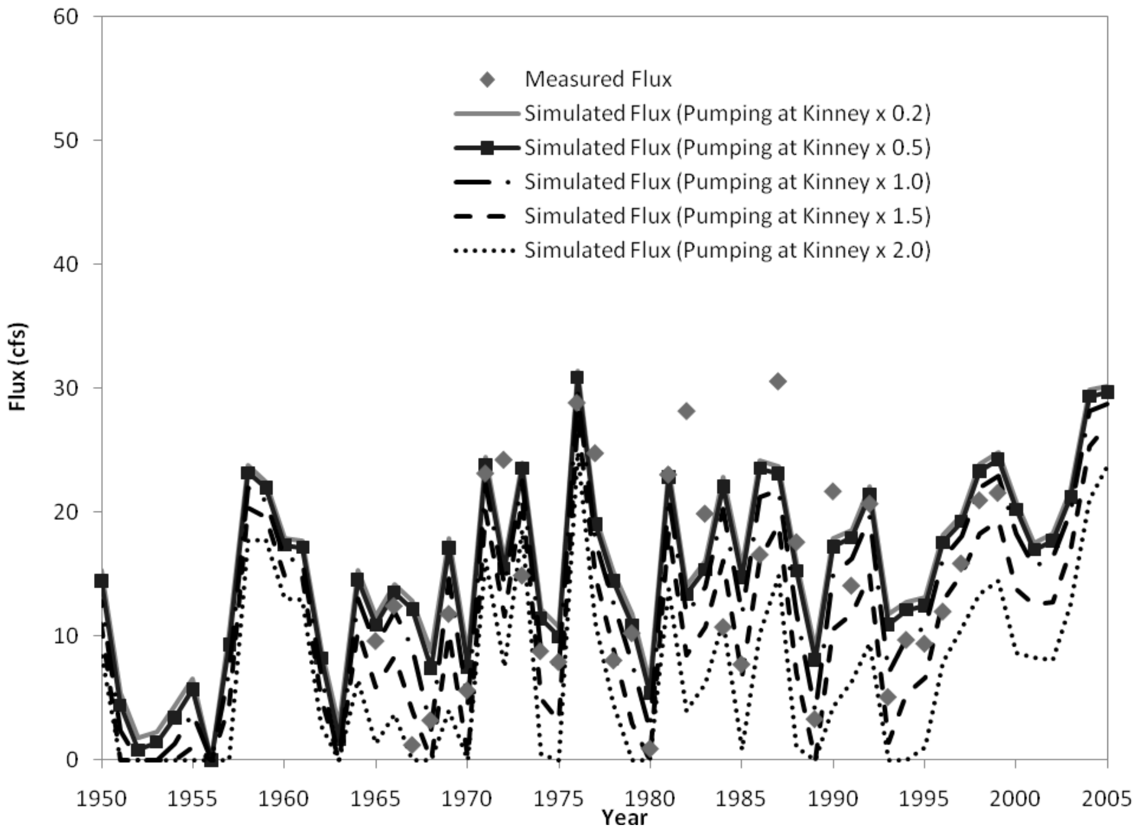


FIGURE 40. IMPACTS OF COUNTYWIDE GROUNDWATER PUMPING ON SPRING FLOW AT MUD SPRINGS.

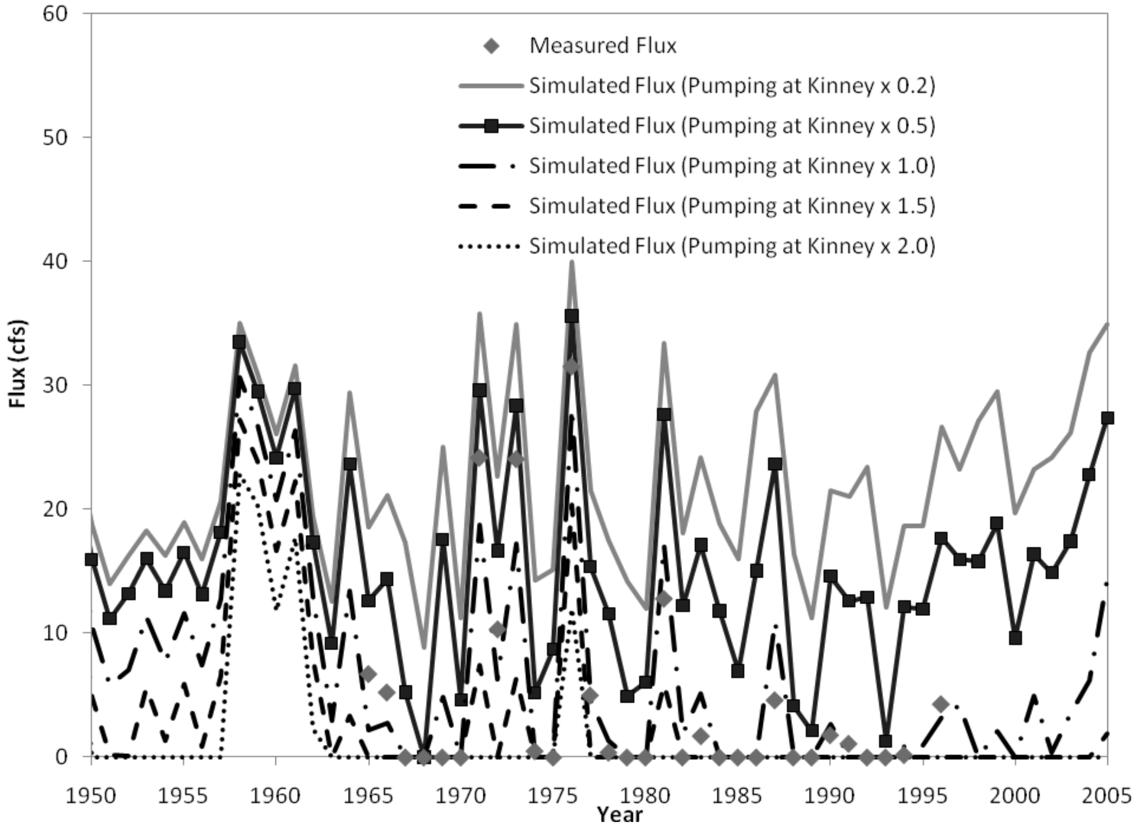


FIGURE 41. IMPACTS OF COUNTYWIDE GROUNDWATER PUMPING ON SPRING FLOW AT PINTO SPRINGS.

5.0 MODEL LIMITATIONS

Numerical groundwater flow models are approximations of aquifer systems (Anderson and Woessner, 2002). Similar to analytical models, numerical models require some assumptions and have some limitations. These limitations are usually associated with the purpose for the groundwater flow model, our extent of understanding the aquifer(s), the quantity and quality of data needed to constrain parameters in the groundwater flow model, and assumptions made during model development.

Several input parameters for the model are based on limited information. These include groundwater recharge, river level, hydraulic conductivity, and specific storage. During the model sensitivity analysis, we noted that the spring flows at Las Moras, Mud, and Pinto springs were largely influenced, among other factors, by regional groundwater flow from Edwards County and river leakage. As a result, uncertainty of the input parameters and impacts of regional groundwater and surface water may have been carried over during the model calibration and the sensitivity analysis. It should also be noted that a regional scale model should not be used for determining local scale concerns, such as well spacing or the response of water levels in a single well.

6.0 SUMMARY AND CONCLUSIONS

The Texas Water Development Board (TWDB) developed this MODFLOW-2000 groundwater flow model for the Kinney County area. This new groundwater flow model covers an area of 150 miles by 150 miles, with Kinney County at the center of the model domain. The transient model was calibrated from 1950 to 2005 to the water levels collected at wells and flows measured at springs. At the same time, focus was given to the three largest springs in Kinney County: Las Moras, Mud, and Pinto springs. In that regard, the calibrated model reflected the flows at the three springs quite well. The calibrated model was also compared well with the river leakage in the northern portion of Kinney County as well as the regional groundwater flow pattern.

After the calibration, the model was used to test the sensitivity of countywide groundwater withdrawal at wells on spring flows in Kinney County. The sensitivity analysis indicated that increasing groundwater withdrawal might reduce the spring flows at Las Moras, Mud, and Pinto springs. As a result, these springs may cease flowing during dry climatic years when groundwater usage typically increases.

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Appendix A:
Simulated Heads and Measured Heads at Wells

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6941702	2	2	931	950	19
6944403	2	2	910	817	-93
6949301	2	2	873	887	14
6950505	2	2	863	854	-9
7042106	2	2	919	969	50
7044101	2	2	1075	1032	-43
7044601	2	2	1060	1054	-6
7045402	2	2	1067	1053	-14
7045404	2	2	1057	1053	-4
7045502	2	2	1109	1062	-47
7046702	2	2	1069	1068	-1
7046801	2	2	1047	1066	19
7046901	2	2	1042	1043	1
7056101	2	2	952	963	11
7056102	2	2	952	966	14
7056201	2	2	946	951	5
6935804	2	3	985	960	-25
6941701	2	3	909	933	24
6941701	2	3	908	933	25

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943404	2	3	847	877	30
6943404	2	3	844	877	33
6944705	2	3	750	791	41
6950302	2	3	862	851	-11
6950304	2	3	856	847	-9
6950410	2	3	870	870	0
6950609	2	3	861	846	-15
7026601	2	3	1103	1123	20
7034101	2	3	1020	1067	47
7035802	2	3	1048	1061	13
7035803	2	3	1038	1046	8
7037201	2	3	1227	1237	10
7037601	2	3	1187	1191	4
7038501	2	3	1238	1234	-4
7038601	2	3	1217	1251	34
7038602	2	3	1305	1267	-38
7038701	2	3	1161	1185	24
7038702	2	3	1198	1187	-11
7038801	2	3	1185	1189	4
7038901	2	3	1191	1212	21

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7038905	2	3	1163	1194	31
7038906	2	3	1139	1166	27
7045302	2	3	1171	1117	-54
7045602	2	3	1099	1068	-31
7046101	2	3	1100	1118	18
7046201	2	3	1106	1132	26
7046302	2	3	1079	1124	45
7046501	2	3	1040	1099	59
7047102	2	3	1063	1127	64
7047103	2	3	1124	1147	23
7047201	2	3	1023	1125	102
7047301	2	3	990	1083	93
7047501	2	3	1062	1067	5
7130201	2	3	982	1089	107
6935601	2	4	895	964	69
7039401	2	4	1252	1265	13
7039702	2	4	1154	1193	39
7039901	2	4	1160	1204	44
7043302	2	4	988	1029	41
7047101	2	4	1064	1129	65

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7047302	2	4	990	1082	92
7047303	2	4	997	1112	115
6944403	3	2	910	801	-109
6950505	3	2	850	844	-6
7042106	3	2	915	966	51
7044101	3	2	1074	1023	-51
7044601	3	2	1056	1045	-11
7045402	3	2	1068	1047	-21
7045404	3	2	1056	1047	-9
7045502	3	2	1109	1058	-51
7046702	3	2	1070	1061	-9
7046801	3	2	1048	1055	7
7046901	3	2	1039	1031	-8
7056101	3	2	947	952	5
7056102	3	2	947	956	9
7056201	3	2	938	941	3
6935804	3	3	969	940	-29
6944705	3	3	733	777	44
6950302	3	3	847.5	840	-7.5
7012702	3	3	1514	1621	107

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7035803	3	3	1040	1038	-2
7037201	3	3	1224	1221	-3
7037601	3	3	1187	1180	-7
7038601	3	3	1186	1237	51
7038906	3	3	1140	1152	12
7045602	3	3	1099	1064	-35
7114901	3	3	1229	1184	-45
7114501	3	4	1102	1214	112
6941702	4	2	909	936	27
6944403	4	2	909	799	-110
6950505	4	2	839	841	2
7042106	4	2	911	965	54
7044601	4	2	1053	1056	3
7044602	4	2	1016	941	-75
7044901	4	2	1025	1009	-16
7044906	4	2	1015	945	-70
7045402	4	2	1068	1055	-13
7045404	4	2	1056	1049	-7
7045502	4	2	1108	1058	-50
7045703	4	2	1048	1038	-10

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7046702	4	2	1067	1060	-7
7046801	4	2	1043	1052	9
7046901	4	2	1037	1027	-10
7056101	4	2	942	948	6
7056102	4	2	940	951	11
7056201	4	2	934	937	3
6935804	4	3	960	932	-28
6941701	4	3	893	920	27
6944705	4	3	719	775	56
6950302	4	3	835.5	839	3.5
7019302	4	3	1505	1544	39
7019303	4	3	1576	1516	-60
7019304	4	3	1501	1482	-19
7019305	4	3	1467	1487	20
7035803	4	3	1038	1035	-3
7036201	4	3	1167	1162	-5
7037201	4	3	1224	1221	-3
7038601	4	3	1191	1234	43
7038702	4	3	1194	1175	-19
7038904	4	3	1187	1202	15

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7038906	4	3	1138	1148	10
7038907	4	3	1219	1193	-26
6941702	5	2	910	937	27
6944403	5	2	909	800	-109
6950505	5	2	836	841	5
7042106	5	2	920	965	45
7044101	5	2	1079	1024	-55
7044601	5	2	1053	1066	13
7044602	5	2	1015	972	-43
7044901	5	2	1025	1021	-4
7045402	5	2	1068	1066	-2
7045404	5	2	1056	1056	0
7045502	5	2	1109	1060	-49
7045703	5	2	1048	1044	-4
7046702	5	2	1069	1062	-7
7046801	5	2	1049	1054	5
7046901	5	2	1036	1028	-8
7056101	5	2	953	949	-4
7056102	5	2	953	952	-1
7056201	5	2	946	937	-9

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5456402	5	3	1743	1724	-19
5456501	5	3	1757	1729	-28
5456502	5	3	1734	1751	17
5456601	5	3	1723	1751	28
5456602	5	3	1707	1738	31
5541801	5	3	1818	1837	19
5549102	5	3	1732	1794	62
5562704	5	3	1933	1996	63
5562801	5	3	1962	2004	42
5562802	5	3	1964	2006	42
5562803	5	3	2016	2002	-14
5562902	5	3	1969	2011	42
5562903	5	3	2042	2013	-29
5562904	5	3	1970	2007	37
5563803	5	3	1983	2026	43
6941701	5	3	908	921	13
6943910	5	3	832	788	-44
6943914	5	3	834	793	-41
6950302	5	3	832	840	8
7004302	5	3	1921	1919	-2

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7004305	5	3	1959	1913	-46
7004601	5	3	1957	1902	-55
7005104	5	3	1988	1938	-50
7005105	5	3	1906	1956	50
7005107	5	3	1904	1951	47
7005601	5	3	1822	1958	136
7005801	5	3	1820	1909	89
7005802	5	3	1814	1931	117
7005901	5	3	1870	1905	35
7005901	5	3	1869	1905	36
7005902	5	3	1831	1931	100
7006201	5	3	1950	2000	50
7006301	5	3	1970	2005	35
7006601	5	3	1982	1995	13
7006703	5	3	1863	1940	77
7006801	5	3	1887	1948	61
7006804	5	3	1820	1930	110
7007204	5	3	1981	2019	38
7007205	5	3	1981	2016	35
7007207	5	3	1982	2005	23

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7012204	5	3	1816	1809	-7
7013106	5	3	1808	1796	-12
7013204	5	3	1797	1882	85
7013303	5	3	1801	1873	72
7013306	5	3	1796	1833	37
7013503	5	3	1762	1768	6
7013801	5	3	1736	1753	17
7013802	5	3	1746	1741	-5
7035803	5	3	1041	1035	-6
7037201	5	3	1228	1225	-3
7037601	5	3	1189	1187	-2
7038601	5	3	1192	1236	44
7038702	5	3	1205	1180	-25
7038906	5	3	1139	1150	11
7038907	5	3	1220	1195	-25
7045602	5	3	1099	1066	-33
6941702	6	2	919	938	19
6944403	6	2	909	796	-113
6950505	6	2	839	841	2
7041304	6	2	944	953	9

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7042106	6	2	921	966	45
7044101	6	2	1076	1024	-52
7044601	6	2	1060	1055	-5
7044601	6	2	1061	1055	-6
7044602	6	2	1021	944	-77
7044901	6	2	1028	1011	-17
7045402	6	2	1076	1054	-22
7045404	6	2	1064	1050	-14
7045502	6	2	1109	1059	-50
7045703	6	2	1052	1040	-12
7046702	6	2	1075	1062	-13
7046801	6	2	1056	1056	0
7046901	6	2	1037	1031	-6
7056101	6	2	956	951	-5
7056102	6	2	955	955	0
7056201	6	2	950	939	-11
5547901	6	3	1903	2090	187
5552101	6	3	1905	1945	40
5552102	6	3	1916	1951	35
5552201	6	3	1968	1963	-5

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5552202	6	3	1917	1957	40
5552302	6	3	1927	1975	48
5552601	6	3	1922	1968	46
5552602	6	3	1932	1976	44
5552603	6	3	1908	1982	74
5554403	6	3	1953	2025	72
5555704	6	3	1971	2073	102
5562701	6	3	1932	1996	64
5562702	6	3	1914	1989	75
5562903	6	3	2042	2013	-29
5563401	6	3	1973	2027	54
5563707	6	3	1985	2026	41
5563805	6	3	1983	2033	50
5564901	6	3	2012	1995	-17
5564902	6	3	2015	1975	-40
5657201	6	3	2002	2028	26
5657402	6	3	2006	2024	18
5657601	6	3	2023	2034	11
6935804	6	3	951	928	-23
6941101	6	3	1005	1017	12

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6941701	6	3	896	921	25
6942810	6	3	827	870	43
6943911	6	3	788	806	18
6944705	6	3	704	773	69
6950302	6	3	833.5	837	3.5
7005901	6	3	1871	1902	31
7007301	6	3	1974	2016	42
7035803	6	3	1045	1037	-8
7037201	6	3	1251	1225	-26
7037601	6	3	1194	1184	-10
7038601	6	3	1193	1239	46
7038907	6	3	1221	1199	-22
7041101	6	3	937	931	-6
7042205	6	3	989	984	-5
7045602	6	3	1100	1065	-35
6941903	6	4	870	903	33
6944403	7	2	908	800	-108
6950505	7	2	833	842	9
6950505	7	2	838	842	4
7041304	7	2	943	953	10

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7041304	7	2	943	953	10
7042106	7	2	925	967	42
7042106	7	2	916	967	51
7044101	7	2	1079	1025	-54
7044602	7	2	1022	947	-75
7044602	7	2	1023	947	-76
7044901	7	2	1029	1014	-15
7044901	7	2	1030	1014	-16
7045402	7	2	1076	1060	-16
7045404	7	2	1062	1053	-9
7045502	7	2	1110	1060	-50
7045703	7	2	1052	1042	-10
7046702	7	2	1079	1064	-15
7046702	7	2	1077	1064	-13
7046801	7	2	1060	1058	-2
7046901	7	2	1037	1033	-4
7056101	7	2	948	953	5
7056102	7	2	947	957	10
7056201	7	2	942	941	-1
5456402	7	3	1748	1726	-22

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5456501	7	3	1760	1730	-30
5456502	7	3	1737	1752	15
5456602	7	3	1712	1738	26
5456603	7	3	1707	1736	29
5541801	7	3	1820	1839	19
5549102	7	3	1733	1794	61
6935804	7	3	941	932	-9
6941101	7	3	1007	1019	12
6941701	7	3	890	924	34
6943911	7	3	777	810	33
6943914	7	3	831	793	-38
6944705	7	3	694	776	82
6950302	7	3	834	839	5
6950406	7	3	842	860	18
7008702	7	3	1973	1954	-19
7035803	7	3	1043	1039	-4
7036201	7	3	1177	1168	-9
7037201	7	3	1247	1230	-17
7037601	7	3	1192	1189	-3
7038702	7	3	1223	1183	-40

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7038906	7	3	1143	1156	13
7038907	7	3	1224	1202	-22
7038907	7	3	1220	1202	-18
7042205	7	3	984	985	1
7045602	7	3	1101	1067	-34
6933601	7	4	1231	1121	-110
6933601	7	4	1231	1121	-110
6933901	7	4	1119	1056	-63
6935901	7	4	720	887	167
6941903	7	4	869	905	36
6941702	8	2	909	935	26
6944403	8	2	907	795	-112
6944809	8	2	878	749	-129
6950903	8	2	828	821	-7
6951406	8	2	814	815	1
7044101	8	2	1071	1019	-52
7044101	8	2	1077	1019	-58
7045402	8	2	1068	1056	-12
7045402	8	2	1067	1056	-11
7045404	8	2	1056	1049	-7

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7045404	8	2	1056	1049	-7
7045502	8	2	1109	1058	-51
7045502	8	2	1109	1058	-51
7046801	8	2	1049	1052	3
7046801	8	2	1047	1052	5
7046901	8	2	1036	1026	-10
7056101	8	2	945	946	1
7056102	8	2	943	950	7
7056102	8	2	941	950	9
7056201	8	2	934	935	1
5456402	8	3	1741	1720	-21
5456501	8	3	1756	1725	-31
5456601	8	3	1722	1746	24
5456602	8	3	1708	1735	27
5549102	8	3	1727	1791	64
6935804	8	3	931	925	-6
6941101	8	3	997	1017	20
6941701	8	3	865	919	54
6942101	8	3	928	970	42
6942603	8	3	803	870	67

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6942604	8	3	797	880	83
6942909	8	3	826	848	22
6943106	8	3	845	896	51
6943204	8	3	793	865	72
6943406	8	3	772	865	93
6943911	8	3	773	806	33
6944705	8	3	662	772	110
6950204	8	3	819	852	33
6950302	8	3	814.5	836	21.5
6950305	8	3	811	829	18
6950306	8	3	804	831	27
6950406	8	3	823	857	34
6950507	8	3	819	848	29
6950902	8	3	841	823	-18
7035803	8	3	1037	1030	-7
7036201	8	3	1168	1158	-10
7036201	8	3	1166	1158	-8
7037201	8	3	1224	1219	-5
7037201	8	3	1222	1219	-3
7037601	8	3	1186	1182	-4

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7037601	8	3	1186	1182	-4
7038702	8	3	1198	1175	-23
7038702	8	3	1196	1175	-21
7038906	8	3	1137	1147	10
7038906	8	3	1141	1147	6
7042205	8	3	977	978	1
7045602	8	3	1097	1064	-33
7045602	8	3	1097	1064	-33
6933901	8	4	1119	1050	-69
6935901	8	4	714	880	166
6941903	8	4	838	902	64
6952401	8	4	666	751	85
7016901	8	4	1176	1531	355
6941702	9	2	926	945	19
6944403	9	2	911	804	-107
6950405	9	2	858	867	9
6950505	9	2	841	845	4
6950611	9	2	841	835	-6
6951701	9	2	827	824	-3
7046401	9	2	1076	1068	-8

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7046901	9	2	1038	1039	1
7056101	9	2	959	958	-1
7056101	9	2	955	958	3
7056201	9	2	955	946	-9
5456402	9	3	1756	1728	-28
5456501	9	3	1765	1732	-33
5456502	9	3	1743	1754	11
5456601	9	3	1733	1754	21
5456602	9	3	1724	1739	15
5456603	9	3	1718	1738	20
5541801	9	3	1828	1841	13
5549102	9	3	1747	1794	47
6935804	9	3	956	938	-18
6941101	9	3	1008	1021	13
6941202	9	3	1008	1018	10
6941701	9	3	917	928	11
6942603	9	3	828	877	49
6942604	9	3	822	887	65
6942712	9	3	868	914	46
6942805	9	3	868	869	1

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943106	9	3	868	905	37
6943204	9	3	819	875	56
6943404	9	3	813	863	50
6943406	9	3	797	872	75
6943911	9	3	815	813	-2
6943914	9	3	855	796	-59
6944705	9	3	701	779	78
6944705	9	3	717	779	62
6950204	9	3	845	858	13
6950302	9	3	840.5	842	1.5
6950305	9	3	826	835	9
6950306	9	3	828	837	9
6950406	9	3	848	863	15
6950507	9	3	844	855	11
6950601	9	3	841	841	0
6950612	9	3	828	827	-1
6950901	9	3	843	833	-10
6951407	9	3	837	825	-12
7035803	9	3	1047	1041	-6
7042205	9	3	987	987	0

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7045401	9	3	1106	1065	-41
6933901	9	4	1120	1061	-59
6935901	9	4	760	892	132
6941903	9	4	870	909	39
6943202	9	4	834	889	55
6952401	9	4	695	757	62
6941702	10	2	958	959	1
6944403	10	2	913	840	-73
6950505	10	2	861	863	2
7046901	10	2	1045	1051	6
7056201	10	2	959	958	-1
6935804	10	3	1033	978	-55
6941101	10	3	1012	1030	18
6941202	10	3	1008	1023	15
6941701	10	3	933	941	8
6943911	10	3	881	851	-30
6944805	10	3	762	789	27
6944805	10	3	742	789	47
6950302	10	3	865.5	867	1.5
6950306	10	3	858	864	6

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7035803	10	3	1048	1051	3
7042205	10	3	995	993	-2
7045401	10	3	1120	1081	-39
6933901	10	4	1125	1119	-6
6941903	10	4	905	925	20
6943202	10	4	872	930	58
6952401	10	4	772	784	12
6941702	11	2	962	958	-4
6941702	11	2	961	958	-3
6944403	11	2	915	842	-73
6950505	11	2	872	865	-7
7046901	11	2	1050	1049	-1
7056101	11	2	975	969	-6
7056201	11	2	968	958	-10
5455101	11	3	1673	1795	122
5456402	11	3	1755	1734	-21
5456501	11	3	1764	1738	-26
5456502	11	3	1742	1759	17
5456601	11	3	1731	1759	28
5456602	11	3	1720	1743	23

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5456603	11	3	1715	1744	29
5541801	11	3	1826	1849	23
5549102	11	3	1742	1799	57
6935804	11	3	1038	984	-54
6935804	11	3	1037	984	-53
6941101	11	3	1011	1028	17
6941101	11	3	1011	1028	17
6941701	11	3	936	941	5
6943911	11	3	862	852	-10
6943911	11	3	859	852	-7
6950302	11	3	876	868	-8
6950306	11	3	875	866	-9
7035803	11	3	1048	1050	2
7042205	11	3	996	992	-4
7045401	11	3	1117	1078	-39
7045401	11	3	1111	1078	-33
6933901	11	4	1124	1116	-8
6941903	11	4	908	925	17
6943202	11	4	905	935	30
6944403	12	2	914	832	-82

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6944403	12	2	913	832	-81
6950505	12	2	873	860	-13
7046901	12	2	1052	1044	-8
7056101	12	2	971	965	-6
7056201	12	2	966	953	-13
6941701	12	3	933	936	3
6941701	12	3	933	936	3
6943404	12	3	868	893	25
6943404	12	3	869	893	24
6944805	12	3	772	780	8
6950302	12	3	877	862	-15
6950306	12	3	876	859	-17
7035803	12	3	1047	1047	0
7038901	12	3	1199	1215	16
7042205	12	3	993	990	-3
6933901	12	4	1122	1100	-22
6941903	12	4	908	920	12
6943202	12	4	920	925	5
7115202	12	4	1420	1349	-71
6950403	13	2	872	873	1

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6950505	13	2	874	863	-11
7046901	13	2	1055	1042	-13
7056101	13	2	970	964	-6
7056201	13	2	965	952	-13
6943405	13	3	874	908	34
6943914	13	3	874	830	-44
6944805	13	3	779	788	9
6944805	13	3	776	788	12
6950204	13	3	883	879	-4
6950302	13	3	878	868	-10
6950306	13	3	878	866	-12
6950408	13	3	885	881	-4
6951401	13	3	857	841	-16
6951401	13	3	859	841	-18
7035803	13	3	1046	1046	0
7038901	13	3	1198	1215	17
7042205	13	3	993	990	-3
7140302	13	3	956.6667	1026	69.33333
6933901	13	4	1122	1122	0
6941903	13	4	908	925	17

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943202	13	4	930	934	4
6950403	14	2	866	862	-4
6950505	14	2	868	851	-17
7046901	14	2	1050	1034	-16
7056101	14	2	960	956	-4
7056201	14	2	955	944	-11
5456402	14	3	1748	1726	-22
5456501	14	3	1760	1730	-30
5456601	14	3	1724	1752	28
5456602	14	3	1714	1738	24
5541801	14	3	1821	1840	19
5549102	14	3	1737	1794	57
6943405	14	3	860	882	22
6943405	14	3	859	882	23
6943914	14	3	759	806	47
6950204	14	3	873	864	-9
6950302	14	3	870	850	-20
6950306	14	3	868	846	-22
6950408	14	3	879	871	-8
7035803	14	3	1043	1040	-3

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7038901	14	3	1184	1203	19
7042205	14	3	982	985	3
6933901	14	4	1122	1077	-45
6941903	14	4	894	912	18
6941903	14	4	892	912	20
6943202	14	4	906	904	-2
6951602	14	4	837	793	-44
6950403	15	2	859	849	-10
6950505	15	2	861	837	-24
7046901	15	2	1046	1028	-18
7056101	15	2	955	948	-7
7056201	15	2	949	937	-12
5456402	15	3	1744	1722	-22
5456501	15	3	1758	1726	-32
5456601	15	3	1724	1747	23
5456602	15	3	1710	1734	24
5456603	15	3	1705	1731	26
5549102	15	3	1732	1791	59
6943914	15	3	823	783	-40
6950204	15	3	864	849	-15

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6950302	15	3	861.5	833	-28.5
6950306	15	3	857	827	-30
6950408	15	3	871	859	-12
6951401	15	3	854	810	-44
6951401	15	3	853	810	-43
7033903	15	3	1030	970	-60
7034401	15	3	1021	997	-24
7035803	15	3	1037	1036	-1
7038901	15	3	1191	1194	3
7042205	15	3	977	982	5
7111603	15	3	1158	1157	-1
7122602	15	3	1403	1105	-298
7131902	15	3	942	1072	130
7140302	15	3	956	1014	58
6933901	15	4	1121	1044	-77
6943202	15	4	881	876	-5
6950403	16	2	862	862	0
6950505	16	2	859	851	-8
6950505	16	2	860	851	-9
7034801	16	2	1007	991	-16

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7046901	16	2	1043	1039	-4
7056201	16	2	954	948	-6
7056201	16	2	954	948	-6
5456402	16	3	1749	1733	-16
5456501	16	3	1763	1738	-25
5456502	16	3	1740	1759	19
5456601	16	3	1729	1759	30
5456602	16	3	1715	1743	28
5456603	16	3	1712	1744	32
5541801	16	3	1825	1848	23
5549102	16	3	1740	1800	60
6943914	16	3	807	810	3
6950204	16	3	865	864	-1
6950204	16	3	867.5	864	-3.5
6950302	16	3	859.5	853	-6.5
6950306	16	3	854	848	-6
6950306	16	3	855	848	-7
6950408	16	3	874	871	-3
7017901	16	3	928	1148	220
7017902	16	3	1098	1137	39

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7017902	16	3	1097	1137	40
7025301	16	3	1213	1136	-77
7025502	16	3	1003	1096	93
7033301	16	3	1023	1067	44
7033901	16	3	977	968	-9
7034101	16	3	1040	1062	22
7034301	16	3	1031	1068	37
7035201	16	3	1115	1107	-8
7035803	16	3	1046	1044	-2
7038901	16	3	1196	1213	17
7042205	16	3	992	989	-3
7111601	16	3	1102	1166	64
7111603	16	3	1159	1163	4
7132101	16	3	1057	1099	42
7132802	16	3	973	1071	98
6933901	16	4	1121	1103	-18
6943202	16	4	873	907	34
7017201	16	4	1206	1194	-12
7113801	16	4	1071	1144	73
7115501	16	4	1299	1289	-10

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7122801	16	4	903	1097	194
7123102	16	4	1198	1133	-65
7123302	16	4	1100	1144	44
7131401	16	4	974	1088	114
7132501	16	4	1028	1092	64
6950403	17	2	864	856	-8
7046901	17	2	1047	1038	-9
5456402	17	3	1748	1728	-20
5456501	17	3	1760	1732	-28
5456601	17	3	1725	1753	28
5456602	17	3	1712	1739	27
5456603	17	3	1707	1738	31
5541801	17	3	1820	1842	22
5548302	17	3	2023	2051	28
5548501	17	3	2000	2055	55
5549102	17	3	1734	1794	60
6950302	17	3	865.5	842	-23.5
7017401	17	3	1136	1126	-10
7025502	17	3	999	1093	94
7033901	17	3	971	967	-4

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034101	17	3	1032	1061	29
7034301	17	3	1027	1066	39
7034501	17	3	1055	1033	-22
7035201	17	3	1096	1105	9
7035803	17	3	1045	1042	-3
7038901	17	3	1194	1208	14
7042205	17	3	988	987	-1
7045401	17	3	1102	1067	-35
7045504	17	3	1101	1063	-38
7045504	17	3	1099	1063	-36
7132802	17	3	967	1064	97
6933901	17	4	1121	1069	-52
6943202	17	4	875	890	15
6952401	17	4	738	756	18
7116402	17	4	1280	1268	-12
6950403	18	2	864	857	-7
7046901	18	2	1047	1040	-7
7056201	18	2	951	947	-4
5456402	18	3	1743	1729	-14
5456501	18	3	1758	1733	-25

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5456502	18	3	1733	1755	22
5456601	18	3	1723	1755	32
5456602	18	3	1710	1740	30
5456603	18	3	1705	1739	34
5541801	18	3	1817	1843	26
5549102	18	3	1721	1796	75
6950302	18	3	867	843	-24
6952201	18	3	742	734	-8
7025502	18	3	1001	1094	93
7033602	18	3	962	991	29
7034101	18	3	1035	1064	29
7034301	18	3	1028	1068	40
7034501	18	3	1056	1035	-21
7034601	18	3	1020.5	1051	30.5
7035201	18	3	1102	1107	5
7035803	18	3	1046	1044	-2
7038901	18	3	1198	1211	13
7042205	18	3	989	988	-1
7045401	18	3	1106	1074	-32
7103701	18	3	1186	1233	47

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6933901	18	4	1123	1075	-48
6933901	18	4	1123	1075	-48
6943202	18	4	888	892	4
7131101	18	4	930	1088	158
6950101	19	2	876	876	0
6950202	19	2	862	858	-4
6950403	19	2	862	857	-5
6951406	19	2	815	822	7
7034702	19	2	971	973	2
7046901	19	2	1045	1038	-7
7056201	19	2	955	945	-10
5452602	19	3	1830	1707	-123
5453201	19	3	1675	1737	62
5453301	19	3	1846	1735	-111
5454601	19	3	1710	1734	24
5456402	19	3	1743	1729	-14
5456501	19	3	1757	1733	-24
5456502	19	3	1732	1754	22
5456601	19	3	1722	1754	32
5456602	19	3	1709	1740	31

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5456603	19	3	1704	1739	35
5460803	19	3	1512	1463	-49
5541801	19	3	1815	1843	28
5543401	19	3	1908	1928	20
5549102	19	3	1718	1796	78
6950302	19	3	863.5	844	-19.5
6952201	19	3	739	734	-5
7018901	19	3	1126	1213	87
7025502	19	3	1001	1094	93
7026203	19	3	1062	1161	99
7033704	19	3	968	945	-23
7034101	19	3	1026	1061	35
7034301	19	3	1022	1067	45
7034501	19	3	1051	1034	-17
7035201	19	3	1087	1106	19
7035803	19	3	1043	1043	0
7038901	19	3	1198	1207	9
7042205	19	3	982	988	6
7045401	19	3	1106	1074	-32
7045504	19	3	1102	1064	-38

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7112502	19	3	1114	1149	35
7112502	19	3	1114	1149	35
7112503	19	3	1162	1149	-13
7112503	19	3	1204	1149	-55
5454502	19	4	1653	1715	62
6935602	19	4	1129	985	-144
6943202	19	4	888	892	4
7026204	19	4	1104	1163	59
7124701	19	4	1046	1100	54
6950403	20	2	869	848	-21
7034801	20	2	1008	990	-18
7034901	20	2	1034	992	-42
7046901	20	2	1046	1033	-13
7056201	20	2	952	940	-12
5446801	20	3	1816	1778	-38
5448701	20	3	1684	1800	116
5448801	20	3	1745	1834	89
5453302	20	3	1893	1741	-152
5454301	20	3	1642	1767	125
5454302	20	3	1690	1754	64

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5454601	20	3	1710	1722	12
5454802	20	3	1694	1690	-4
5456101	20	3	1698	1768	70
5456402	20	3	1737	1724	-13
5456501	20	3	1755	1728	-27
5456502	20	3	1733	1750	17
5456503	20	3	1703	1750	47
5456601	20	3	1722	1750	28
5456602	20	3	1708	1736	28
5456603	20	3	1702	1733	31
5456702	20	3	1665	1708	43
5460502	20	3	1573	1542	-31
5541303	20	3	1797	1896	99
5541801	20	3	1817	1837	20
5542301	20	3	1863	1926	63
5542501	20	3	1828	1887	59
5542601	20	3	1843	1904	61
5542701	20	3	1824	1875	51
5543102	20	3	1869	1943	74
5543103	20	3	1888	1948	60

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5543301	20	3	1900	1973	73
5543401	20	3	1875	1921	46
5543402	20	3	1848	1931	83
5543503	20	3	1896	1939	43
5543603	20	3	1902	1961	59
5544202	20	3	1912	1996	84
5544205	20	3	1949	1996	47
5544401	20	3	1913	1971	58
5544402	20	3	1913	1985	72
5544403	20	3	1912	1974	62
5544502	20	3	1925	2001	76
5544504	20	3	1885	1995	110
5545204	20	3	1957	2034	77
5546104	20	3	1971	2054	83
5546201	20	3	1979	2061	82
5546203	20	3	1980	2062	82
5547201	20	3	2008	2068	60
5547402	20	3	1994	2078	84
5549102	20	3	1728	1791	63
5549106	20	3	1746	1777	31

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5550601	20	3	1807	1840	33
5550901	20	3	1773	1831	58
5551402	20	3	1823	1855	32
5551701	20	3	1785	1842	57
5551702	20	3	1772	1837	65
5557802	20	3	1502	1664	162
5558601	20	3	1724	1795	71
5558802	20	3	1777	1745	-32
5558803	20	3	1905	1723	-182
5558901	20	3	1656	1754	98
5559701	20	3	1585	1772	187
5559702	20	3	1585	1772	187
5559703	20	3	1532	1768	236
5563802	20	3	2243	2036	-207
6943903	20	3	853	786	-67
6950302	20	3	873	831	-42
6951502	20	3	816.5	785	-31.5
6951603	20	3	803	771	-32
6952201	20	3	761	721	-40
6952201	20	3	692	721	29

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7002201	20	3	1633	1726	93
7002302	20	3	1608	1740	132
7002303	20	3	1609	1711	102
7002401	20	3	1469	1614	145
7002501	20	3	1699	1651	-48
7002603	20	3	1656	1712	56
7002901	20	3	1578	1670	92
7003102	20	3	1637	1764	127
7003401	20	3	1838	1782	-56
7010801	20	3	1370	1342	-28
7011401	20	3	1463	1608	145
7011402	20	3	1500	1559	59
7011701	20	3	1350	1524	174
7018201	20	3	1385	1309	-76
7025502	20	3	1048.5	1105	56.5
7025603	20	3	1046	1116	70
7026401	20	3	1100	1132	32
7026501	20	3	1103	1130	27
7033704	20	3	968	956	-12
7034101	20	3	1026	1086	60

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034301	20	3	1020	1066	46
7034401	20	3	1021	1007	-14
7034501	20	3	1051	1034	-17
7034602	20	3	1039	1047	8
7035201	20	3	1088	1103	15
7035803	20	3	1042	1042	0
7036101	20	3	1157	1141	-16
7038901	20	3	1194	1198	4
7038901	20	3	1194	1198	4
7042205	20	3	981	988	7
7042206	20	3	990	982	-8
7045401	20	3	1100	1059	-41
7045504	20	3	1103	1059	-44
7045504	20	3	1099	1059	-40
7104701	20	3	1258	1210	-48
7140101	20	3	1050	1103	53
7140201	20	3	1043	1103	60
7140202	20	3	1134	1103	-31
7140303	20	3	1060	1083	23
7140603	20	3	1027	1018	-9

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7140604	20	3	998	1018	20
5446802	20	4	1664	1765	101
5446901	20	4	1671	1796	125
5544503	20	4	1886	1995	109
6943202	20	4	913	873	-40
6943603	20	4	799	795	-4
6944701	20	4	763	758	-5
6944701	20	4	746	758	12
6944703	20	4	769	749	-20
6944703	20	4	722.5	749	26.5
6944704	20	4	802	761	-41
6944704	20	4	802	761	-41
6944803	20	4	761	738	-23
6944803	20	4	756.5	738	-18.5
6951602	20	4	831.67	774	-57.67
6952401	20	4	759	744	-15
7026204	20	4	1097	1162	65
6950403	21	2	870	858	-12
6950403	21	2	869	858	-11
7046901	21	2	1045	1041	-4

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7056201	21	2	957	948	-9
5452601	21	3	1572	1680	108
5452602	21	3	1830	1715	-115
5453201	21	3	1675	1742	67
5453301	21	3	1846	1739	-107
5455403	21	3	1690	1742	52
5455903	21	3	1601	1684	83
5456402	21	3	1738	1732	-6
5456501	21	3	1758	1736	-22
5456502	21	3	1737	1757	20
5456503	21	3	1707	1757	50
5456601	21	3	1725	1757	32
5456602	21	3	1711	1742	31
5456603	21	3	1705	1742	37
5460502	21	3	1572	1553	-19
5460803	21	3	1511	1473	-38
5464203	21	3	1636	1688	52
5541801	21	3	1817	1846	29
5549102	21	3	1735	1798	63
5657501	21	3	2006	2055	49

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5657601	21	3	2026	2066	40
5658701	21	3	2041	2072	31
5659401	21	3	2023	2070	47
6901901	21	3	2020	1986	-34
6902202	21	3	2039	2062	23
6902204	21	3	2001	2072	71
6902401	21	3	2054	2063	9
6902801	21	3	2078	1983	-95
6903202	21	3	2055	2057	2
6903801	21	3	2055	1895	-160
6911402	21	3	1890	1778	-112
6919301	21	3	1921	1516	-405
6944402	21	3	767	817	50
6950302	21	3	873.5	846	-27.5
7017301	21	3	1217	1236	19
7017401	21	3	1138	1137	-1
7025502	21	3	1073	1109	36
7025603	21	3	1081	1122	41
7025605	21	3	1092	1126	34
7026401	21	3	1138	1139	1

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7033101	21	3	1058	1075	17
7033402	21	3	1001	1029	28
7033403	21	3	1032	1017	-15
7033702	21	3	957	942	-15
7033704	21	3	978	960	-18
7033903	21	3	1034	987	-47
7034101	21	3	1050	1091	41
7034301	21	3	1040	1073	33
7034501	21	3	1064	1040	-24
7035201	21	3	1109	1111	2
7035803	21	3	1046	1048	2
7036101	21	3	1164	1146	-18
7042205	21	3	994	993	-1
7045401	21	3	1110	1079	-31
7104402	21	3	1307	1255	-52
7104701	21	3	1263	1216	-47
7107601	21	3	1453	1453	0
7115702	21	3	1213	1208	-5
7122602	21	3	1410	1130	-280
7123401	21	3	1225	1132	-93

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7123802	21	3	1115	1116	1
7131901	21	3	1018	1107	89
7132101	21	3	1092	1115	23
7132302	21	3	1054	1112	58
7132401	21	3	1056	1110	54
7132601	21	3	1074	1111	37
7140101	21	3	1074	1105	31
7140201	21	3	1066	1105	39
7140202	21	3	1159	1106	-53
7140601	21	3	1090	1032	-58
7140602	21	3	1056	1073	17
7140604	21	3	1013	1022	9
7140902	21	3	875	923	48
5455405	21	4	1773	1757	-16
5455801	21	4	1691	1722	31
5541802	21	4	1746	1814	68
5657901	21	4	2027	2065	38
5658602	21	4	2033	2067	34
6909901	21	4	1941	1604	-337
6910401	21	4	1980	1755	-225

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943202	21	4	910	896	-14
7113801	21	4	1073	1139	66
7115501	21	4	1298	1293	-5
7115701	21	4	1236	1196	-40
7121301	21	4	1018	1103	85
7123504	21	4	1220	1129	-91
7131301	21	4	1089	1112	23
7131401	21	4	1070	1106	36
7132501	21	4	1055	1110	55
7046901	22	2	1045	1032	-13
7056201	22	2	952	938	-14
5456402	22	3	1740	1723	-17
5456501	22	3	1759	1727	-32
5456502	22	3	1732	1749	17
5456601	22	3	1722	1749	27
5456602	22	3	1707	1735	28
5541801	22	3	1816	1836	20
5549102	22	3	1728	1791	63
6941103	22	3	1048	1041	-7
6941203	22	3	1003	1001	-2

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6942101	22	3	948	953	5
6950302	22	3	873	830	-43
7025502	22	3	1074	1105	31
7025603	22	3	1074	1118	44
7026401	22	3	1113	1134	21
7033704	22	3	976	957	-19
7034101	22	3	1040	1087	47
7034301	22	3	1031	1067	36
7034501	22	3	1054	1035	-19
7035803	22	3	1043	1042	-1
7036101	22	3	1158	1142	-16
7038901	22	3	1194	1198	4
7041209	22	3	920	947	27
7042205	22	3	989	988	-1
7045401	22	3	1099	1058	-41
7045504	22	3	1100	1059	-41
6918302	22	4	1567	1421	-146
6918303	22	4	1336	1471	135
6925401	22	4	1333	1296	-37
6935101	22	4	1217	1066	-151

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6935102	22	4	1211	1066	-145
6935201	22	4	1206	1061	-145
6935602	22	4	1106	968	-138
6943202	22	4	922	871	-51
7032401	22	4	1559	1331	-228
7032601	22	4	1275	1279	4
7032901	22	4	1253	1264	11
6944804	23	2	770	809	39
6950403	23	2	872	871	-1
7046901	23	2	1048	1046	-2
7056201	23	2	969	954	-15
5456402	23	3	1746	1737	-9
5456501	23	3	1764	1742	-22
5456502	23	3	1742	1762	20
5456602	23	3	1720	1746	26
5541801	23	3	1825	1854	29
5549102	23	3	1717	1804	87
6935804	23	3	1035	975	-60
6942601	23	3	875	917	42
6943106	23	3	937	946	9

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943301	23	3	852	908	56
6943910	23	3	801	824	23
6944402	23	3	768	851	83
6949302	23	3	897	903	6
6950302	23	3	877	868	-9
7025502	23	3	1089	1111	22
7025603	23	3	1100	1124	24
7026401	23	3	1144	1142	-2
7033504	23	3	994	1038	44
7033704	23	3	984	963	-21
7034101	23	3	1062	1094	32
7034301	23	3	1047	1078	31
7034501	23	3	1070	1044	-26
7035201	23	3	1123	1116	-7
7035803	23	3	1046	1052	6
7036101	23	3	1172	1149	-23
7038901	23	3	1205	1222	17
7041209	23	3	920	954	34
7042205	23	3	999	996	-3
7045401	23	3	1111	1083	-28

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7045504	23	3	1105	1070	-35
6943103	23	4	899	924	25
6943202	23	4	925	931	6
6943603	23	4	796	852	56
6944701	23	4	734	807	73
6944703	23	4	727	797	70
6944704	23	4	810	808	-2
6950403	24	2	872	866	-6
7046901	24	2	1050	1040	-10
7056201	24	2	965	949	-16
5456402	24	3	1755	1730	-25
5456501	24	3	1765	1734	-31
5456502	24	3	1743	1755	12
5456601	24	3	1724	1755	31
5456602	24	3	1723	1741	18
5456603	24	3	1716	1740	24
5541801	24	3	1815	1845	30
5549102	24	3	1726	1797	71
6950302	24	3	877	856	-21
6951301	24	3	824	801	-23

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7025502	24	3	1113	1108	-5
7025603	24	3	1119	1120	1
7026401	24	3	1151	1138	-13
7033704	24	3	988	960	-28
7034101	24	3	1079	1089	10
7034301	24	3	1061	1072	11
7034501	24	3	1076	1039	-37
7035201	24	3	1132	1110	-22
7035201	24	3	1131	1110	-21
7035803	24	3	1048	1047	-1
7036101	24	3	1175	1146	-29
7038901	24	3	1195	1211	16
7038901	24	3	1195	1211	16
7041209	24	3	919	950	31
7042205	24	3	1006	991	-15
7045401	24	3	1101	1074	-27
7045504	24	3	1099	1065	-34
7045504	24	3	1100	1065	-35
7045603	24	3	1090	1072	-18
6943202	24	4	936	914	-22

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6944806	24	4	764	750	-14
7024601	24	4	1460	1424	-36
6950403	25	2	874	878	4
7056201	25	2	967	956	-11
6942709	25	3	903	934	31
6942709	25	3	903	934	31
6950302	25	3	882	878	-4
7025502	25	3	1118	1111	-7
7025603	25	3	1122	1123	1
7026401	25	3	1141	1141	0
7026401	25	3	1141	1141	0
7033704	25	3	987	963	-24
7034101	25	3	1077	1093	16
7034301	25	3	1058	1077	19
7034501	25	3	1069	1043	-26
7035803	25	3	1048	1052	4
7036101	25	3	1168	1150	-18
7041209	25	3	919	954	35
7042205	25	3	1003	995	-8
7045401	25	3	1110	1084	-26

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6943202	25	4	947	949	2
6943915	25	4	876	852	-24
7038902	25	4	1198	1224	26
6950403	26	2	874	865	-9
6950403	26	2	874	865	-9
7056201	26	2	963	946	-17
5456402	26	3	1758	1727	-31
5456501	26	3	1767	1730	-37
5456502	26	3	1745	1752	7
5456601	26	3	1734	1752	18
5456602	26	3	1726	1738	12
5541801	26	3	1824	1840	16
5544702	26	3	1913	1972	59
5547402	26	3	1979	2074	95
5548601	26	3	2000	2029	29
5549102	26	3	1740	1793	53
5561902	26	3	1933	2016	83
5563803	26	3	1982	2050	68
5657601	26	3	2023	2032	9
5659401	26	3	2024	2036	12

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6902202	26	3	2034	2025	-9
6942709	26	3	905	910	5
6942907	26	3	881	875	-6
6950302	26	3	881	853	-28
6961526	26	3	866	567	-299
7006301	26	3	1966	2030	64
7012501	26	3	1775	1774	-1
7012701	26	3	1528	1683	155
7021301	26	3	1690	1680	-10
7021801	26	3	1516	1548	32
7025502	26	3	1126	1106	-20
7025502	26	3	1127	1106	-21
7025603	26	3	1133	1119	-14
7033704	26	3	988	958	-30
7034101	26	3	1077	1088	11
7034301	26	3	1055	1070	15
7034501	26	3	1063	1037	-26
7035201	26	3	1103	1107	4
7036101	26	3	1161	1144	-17
7041209	26	3	920	949	29

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7042205	26	3	1001	990	-11
7045401	26	3	1100	1066	-34
7045401	26	3	1099	1066	-33
7045505	26	3	1097	1062	-35
5658602	26	4	2030	2033	3
6901702	26	4	1867	1882	15
6917101	26	4	1558	1440	-118
6918303	26	4	1340	1462	122
6919401	26	4	1302.667	1314	11.33333
6920101	26	4	1738	1518	-220
7016802	26	4	1642	1640	-2
7024301	26	4	1487	1481	-6
7024302	26	4	1486	1500	14
7024303	26	4	1228	1482	254
7024601	26	4	1461	1421	-40
7038902	26	4	1188	1206	18
7053402	27	2	999	1002	3
6942709	27	3	900	898	-2
6950302	27	3	880	842	-38
7025603	27	3	1139	1119	-20

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7026401	27	3	1155	1136	-19
7033704	27	3	983.5	958	-25.5
7034101	27	3	1077	1088	11
7034301	27	3	1057	1069	12
7034501	27	3	1066	1037	-29
7035201	27	3	1107	1106	-1
7041209	27	3	920	949	29
7042205	27	3	1001	989	-12
6919401	27	4	1302	1319	17
7038902	27	4	1187	1204	17
6950403	28	2	877	880	3
7056201	28	2	974	962	-12
5460502	28	3	1556	1566	10
6950302	28	3	885	880	-5
7025603	28	3	1145	1129	-16
7026401	28	3	1175	1148	-27
7033501	28	3	1018	1050	32
7033704	28	3	989	965	-24
7034101	28	3	1086	1097	11
7034301	28	3	1066	1084	18

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034501	28	3	1076	1049	-27
7034602	28	3	1048	1064	16
7035201	28	3	1137	1122	-15
7035803	28	3	1047	1057	10
7041209	28	3	920	956	36
7042205	28	3	1006	999	-7
7045504	28	3	1102	1071	-31
7104402	28	3	1311	1265	-46
7104701	28	3	1266	1224	-42
7107601	28	3	1455	1465	10
7112502	28	3	1132	1154	22
7132401	28	3	1122	1115	-7
7140201	28	3	1116	1108	-8
6919401	28	4	1306.5	1376	69.5
7038902	28	4	1198	1234	36
6950403	29	2	875	871	-4
7056201	29	2	966	953	-13
5460502	29	3	1552	1548	-4
6950302	29	3	883	861	-22
7025502	29	3	1129	1108	-21

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7025502	29	3	1129	1108	-21
7025603	29	3	1136	1123	-13
7025603	29	3	1115	1123	8
7026401	29	3	1160	1142	-18
7026401	29	3	1157	1142	-15
7033501	29	3	1013	1045	32
7033501	29	3	1008	1045	37
7033704	29	3	988	960	-28
7033704	29	3	984	960	-24
7034101	29	3	1084	1091	7
7034101	29	3	1083	1091	8
7034301	29	3	1066	1076	10
7034301	29	3	1065	1076	11
7034501	29	3	1076	1042	-34
7034501	29	3	1075	1042	-33
7034602	29	3	1044	1056	12
7034602	29	3	1044	1056	12
7035201	29	3	1132	1114	-18
7035201	29	3	1130	1114	-16
7035803	29	3	1036	1049	13

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7035803	29	3	1047	1049	2
7041209	29	3	921	951	30
7041209	29	3	921	951	30
7042205	29	3	1005	993	-12
7045504	29	3	1101	1065	-36
7045504	29	3	1099	1065	-34
7104402	29	3	1289	1255	-34
7107601	29	3	1452	1454	2
7112502	29	3	1130	1149	19
7132401	29	3	1120	1109	-11
7140201	29	3	1110	1104	-6
6919401	29	4	1307	1352	45
6950101	30	2	891	882	-9
6950202	30	2	882.5	864	-18.5
6950403	30	2	871.5	863	-8.5
7056201	30	2	960	949	-11
6950302	30	3	878	849	-29
7037805	30	3	1167	1103	-64
7042205	30	3	1004	991	-13
7112502	30	3	1136	1148	12

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7132401	30	3	1120	1108	-12
7140201	30	3	1119	1104	-15
6919401	30	4	1304	1348	44
6950101	31	2	892	875	-17
6950101	31	2	890	875	-15
6950202	31	2	885	857	-28
6950202	31	2	883	857	-26
6950403	31	2	872	857	-15
6950403	31	2	872	857	-15
6951406	31	2	846	821	-25
7056201	31	2	956.5	944	-12.5
6943804	31	3	864	826	-38
6943804	31	3	870	826	-44
6950302	31	3	879	842	-37
7040901	31	3	1078	1088	10
7042205	31	3	999	990	-9
7045504	31	3	1098	1061	-37
7112502	31	3	1132	1147	15
7112502	31	3	1132	1147	15
7132401	31	3	1121	1108	-13

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7132401	31	3	1121	1108	-13
7140201	31	3	1113	1104	-9
7140201	31	3	1112	1104	-8
6919401	31	4	1299.5	1331	31.5
6935602	31	4	1105	990	-115
7053402	32	2	1000	998	-2
6950302	32	3	871	828	-43
6951117	32	3	850	822	-28
7025502	32	3	1119	1105	-14
7033704	32	3	978	957	-21
7033704	32	3	980	957	-23
7042205	32	3	990	988	-2
7042205	32	3	991	988	-3
7045504	32	3	1099	1059	-40
7132401	32	3	1116	1107	-9
7140201	32	3	1107	1104	-3
6919401	32	4	1303	1308	5
141065	33	2	1240.218	1143	-97.218
141088	33	2	1197.565	1158	-39.565
7053402	33	2	993	1011	18

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6942402	33	3	907	939	32
6942715	33	3	905	939	34
6950302	33	3	882	858	-24
7045504	33	3	1107	1069	-38
6919401	33	4	1303	1349	46
7053402	34	2	1000	1005	5
6950302	34	3	877	841	-36
7025502	34	3	1128	1107	-21
7025603	34	3	1130	1120	-10
7026401	34	3	1146	1138	-8
7033704	34	3	982	959	-23
7034301	34	3	1059	1072	13
7034501	34	3	1070	1039	-31
7034602	34	3	1043	1052	9
7036101	34	3	1147	1145	-2
7041209	34	3	918	950	32
7042205	34	3	996	991	-5
7045401	34	3	1101	1069	-32
7045504	34	3	1099	1063	-36
7132401	34	3	1117	1108	-9

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7140201	34	3	1108	1104	-4
6919401	34	4	1300.5	1326	25.5
7038902	34	4	1185	1210	25
7053402	35	2	994	1008	14
6950302	35	3	873	844	-29
7025502	35	3	1122	1108	-14
7025603	35	3	1126	1121	-5
7026401	35	3	1144	1139	-5
7033704	35	3	981	960	-21
7034301	35	3	1058	1073	15
7034501	35	3	1070	1040	-30
7034602	35	3	1052	1053	1
7045504	35	3	1106	1066	-40
7132401	35	3	1114	1111	-3
7140201	35	3	1102	1106	4
6919401	35	4	1304	1322	18
6950403	36	2	861	853	-8
7053402	36	2	993	1010	17
6950208	36	3	865	858	-7
6950302	36	3	861	832	-29

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7036101	36	3	1160	1148	-12
7045504	36	3	1098	1065	-33
6919401	36	4	1292.5	1382	89.5
6950101	37	2	892	862	-30
6950101	37	2	891	862	-29
6950202	37	2	881	841	-40
6950202	37	2	881	841	-40
6950403	37	2	871	845	-26
6950403	37	2	871	845	-26
7053402	37	2	994	1005	11
7056201	37	2	962	943	-19
7056201	37	2	961	943	-18
7604722	37	2	738	961	223
6943307	37	3	776	814	38
6943804	37	3	798.5	806	7.5
6943804	37	3	816	806	-10
6944203	37	3	778	795	17
6950302	37	3	877	826	-51
7045504	37	3	1101	1062	-39
7045504	37	3	1100	1062	-38

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6919401	37	4	1292	1343	51
6951406	38	2	847	828	-19
7053402	38	2	1000	1012	12
5548601	38	3	1996	2070	74
5657601	38	3	2008	2094	86
6902202	38	3	2048	2098	50
6950302	38	3	877.5	851	-26.5
7012501	38	3	1772	1804	32
7021301	38	3	1690	1699	9
7033501	38	3	1004	1045	41
7034703	38	3	969	971	2
5658602	38	4	2033	2097	64
6901702	38	4	1872	1954	82
6917101	38	4	1556	1472	-84
6918303	38	4	1333	1525	192
6919401	38	4	1294	1352	58
7016802	38	4	1642	1660	18
7024301	38	4	1487	1491	4
7024303	38	4	1226	1487	261
7024601	38	4	1460	1431	-29

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6951406	39	2	847.5	837	-10.5
7053402	39	2	1012	1012	0
6950302	39	3	887	861	-26
7036101	39	3	1151	1149	-2
7045504	39	3	1103	1069	-34
6919401	39	4	1296	1342	46
6951406	40	2	846	825	-21
7053402	40	2	1009	1008	-1
6950302	40	3	879	845	-34
7026401	40	3	1153	1140	-13
7033704	40	3	982	959	-23
7033704	40	3	982	959	-23
7034101	40	3	1080	1090	10
7034301	40	3	1059	1073	14
7034602	40	3	1041	1053	12
7036101	40	3	1166	1145	-21
7041209	40	3	916	950	34
7042205	40	3	996	992	-4
7045504	40	3	1098	1063	-35
6919401	40	4	1290	1326	36

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6919401	40	4	1290	1326	36
6951406	41	2	844	809	-35
7053402	41	2	996	1004	8
6950302	41	3	867	825	-42
7025502	41	3	1123	1106	-17
7026401	41	3	1144	1135	-9
7026401	41	3	1137	1135	-2
7033302	41	3	1116	1104	-12
7033501	41	3	1011	1041	30
7034101	41	3	1069	1087	18
7034301	41	3	1047	1068	21
7034301	41	3	1046	1068	22
7034602	41	3	1038	1049	11
7036101	41	3	1155	1142	-13
7041209	41	3	917	948	31
7042205	41	3	987	989	2
7042205	41	3	985	989	4
7045504	41	3	1100	1059	-41
7107601	41	3	1449	1445	-4
7112502	41	3	1115	1146	31

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7140201	41	3	1107	1104	-3
7140201	41	3	1104	1104	0
6911303	41	4	1959	1824	-135
6950101	42	2	887	866	-21
6950202	42	2	875	845	-30
6950511	42	2	876	845	-31
6951406	42	2	845	813	-32
7046901	42	2	1047	1041	-6
7053402	42	2	998	1010	12
5548601	42	3	2003	2070	67
5563702	42	3	1995	2069	74
6941101	42	3	1008	1022	14
6941502	42	3	973	976	3
6941701	42	3	932	926	-6
6942601	42	3	872	866	-6
6942709	42	3	888	889	1
6943910	42	3	837	776	-61
6944402	42	3	762	792	30
6950302	42	3	873	831	-42
6950306	42	3	873	826	-47

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6952201	42	3	751	722	-29
6952402	42	3	758	748	-10
7006301	42	3	1967	2045	78
7021301	42	3	1691	1695	4
7033501	42	3	1015	1045	30
7034101	42	3	1069	1092	23
7036101	42	3	1169	1146	-23
7037402	42	3	1199	1184	-15
7038701	42	3	1211	1187	-24
7040901	42	3	1076	1089	13
7045401	42	3	1103	1072	-31
7045504	42	3	1104	1064	-40
7047501	42	3	1009	1065	56
7107601	42	3	1455	1451	-4
7112502	42	3	1134	1148	14
6943202	42	4	925	876	-49
6944703	42	4	757	749	-8
6951602	42	4	830	775	-55
7016802	42	4	1636	1663	27
7024301	42	4	1486	1488	2

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7024303	42	4	1224	1484	260
7038902	42	4	1180	1214	34
6950101	43	2	888	870	-18
6950202	43	2	876	850	-26
6951406	43	2	845	816	-29
7053402	43	2	999	1010	11
5548601	43	3	2002	2069	67
5641401	43	3	2080	2047	-33
6943607	43	3	767	820	53
6950302	43	3	872.5	835	-37.5
7006301	43	3	1970	2051	81
7021301	43	3	1689	1696	7
7033302	43	3	1125	1105	-20
7033501	43	3	1024	1043	19
7033704	43	3	985	960	-25
7034101	43	3	1077	1092	15
7034301	43	3	1056	1076	20
7040901	43	3	1076	1089	13
7042205	43	3	1000	993	-7
7107601	43	3	1450	1451	1

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7112502	43	3	1136	1149	13
6919401	43	4	1291.5	1341	49.5
7024301	43	4	1484	1487	3
6950101	44	2	898	883	-15
6950202	44	2	892	866	-26
6951406	44	2	847	828	-19
7053402	44	2	993	1012	19
5548601	44	3	2001	2075	74
5641401	44	3	2080	2052	-28
6943607	44	3	844	845	1
6950302	44	3	885	849	-36
7021301	44	3	1695	1698	3
7033302	44	3	1126	1105	-21
7033501	44	3	1022	1044	22
7033704	44	3	987	961	-26
7034101	44	3	1082	1093	11
7034301	44	3	1061	1078	17
7034602	44	3	1045	1058	13
7040901	44	3	1076	1090	14
7041209	44	3	916	952	36

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7042205	44	3	1002	995	-7
7045504	44	3	1104	1066	-38
7107601	44	3	1454	1455	1
7112502	44	3	1135	1150	15
7140201	44	3	1114	1105	-9
6919401	44	4	1291	1355	64
7016802	44	4	1636	1660	24
7024301	44	4	1486	1489	3
7024303	44	4	1223	1485	262
6950101	45	2	890	869	-21
6950202	45	2	882	850	-32
6951406	45	2	844	816	-28
7053402	45	2	992	1005	13
5563702	45	3	2032	2043	11
5657601	45	3	2015	2071	56
6942709	45	3	897	893	-4
6943607	45	3	803.5	820	16.5
6950302	45	3	877.5	834	-43.5
6950302	45	3	877	834	-43
7021301	45	3	1685	1679	-6

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7025502	45	3	1124	1106	-18
7033302	45	3	1119	1104	-15
7033501	45	3	1016	1040	24
7033704	45	3	985	958	-27
7034101	45	3	1073	1088	15
7034301	45	3	1052	1070	18
7034602	45	3	1040	1051	11
7041209	45	3	913	949	36
7042205	45	3	998	990	-8
7045504	45	3	1098	1060	-38
7107601	45	3	1453	1446	-7
7112502	45	3	1134	1147	13
7140201	45	3	1106	1104	-2
5445603	45	4	1824	1908	84
5658602	45	4	2028	2074	46
6917101	45	4	1524	1447	-77
6919401	45	4	1286	1321	35
6919401	45	4	1286	1321	35
6936402	45	4	1016	898	-118
6943409	45	4	878.5	869	-9.5

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7024301	45	4	1487	1482	-5
7024303	45	4	1222	1482	260
7029101	45	4	1387	1387	0
6950101	46	2	890	870	-20
6950202	46	2	881	850	-31
7046901	46	2	1051	1034	-17
7053402	46	2	998	1006	8
5641401	46	3	2087	2031	-56
5657601	46	3	2013	2068	55
6902202	46	3	2046	2069	23
6935804	46	3	1026	933	-93
6941101	46	3	1008	1021	13
6942601	46	3	868	872	4
6943607	46	3	789.5	821	31.5
6943910	46	3	864	783	-81
6944402	46	3	789	802	13
6950306	46	3	877	831	-46
6952402	46	3	800	753	-47
7033302	46	3	1107	1104	-3
7033501	46	3	998	1041	43

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034101	46	3	1061	1089	28
7034301	46	3	1043	1071	28
7034602	46	3	1040	1052	12
7036101	46	3	1161	1144	-17
7038701	46	3	1201	1177	-24
7041209	46	3	918	950	32
7042205	46	3	992	991	-1
7042205	46	3	992	991	-1
7045401	46	3	1106	1071	-35
7045504	46	3	1101	1062	-39
7045504	46	3	1100	1062	-38
7047501	46	3	1006	1058	52
7107601	46	3	1452	1448	-4
7112502	46	3	1133	1148	15
5445603	46	4	1824	1909	85
5658602	46	4	2027	2071	44
6917101	46	4	1531	1453	-78
6918303	46	4	1333	1490	157
6920101	46	4	1742	1553	-189
6943202	46	4	928	883	-45

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6951602	46	4	829	780	-49
7024301	46	4	1485	1484	-1
7024303	46	4	1219	1483	264
7024601	46	4	1430	1425	-5
7053402	47	2	999	1006	7
5564801	47	3	1935	1940	5
5641401	47	3	2073	2032	-41
6950302	47	3	874	837	-37
7034101	47	3	1060	1089	29
7045504	47	3	1099	1062	-37
5445603	47	4	1824	1909	85
6919401	47	4	1286	1323	37
6936402	47	4	790.5	902	111.5
6943409	47	4	870.5	872	1.5
5563803	48	3	1986	2085	99
5641401	48	3	2082	2028	-54
6950302	48	3	867.5	852	-15.5
7013301	48	3	1789	1849	60
7025502	48	3	1095	1109	14
7034101	48	3	1044	1091	47

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034301	48	3	1034	1074	40
7034301	48	3	1036	1074	38
7034602	48	3	1046	1055	9
7041209	48	3	917	952	35
7041209	48	3	918	952	34
7042205	48	3	988	993	5
7042205	48	3	990	993	3
7123502	48	3	1228	1131	-97
5445603	48	4	1818	1910	92
6919401	48	4	1288.5	1324	35.5
6936402	48	4	748	922	174
6943409	48	4	857.5	895	37.5
7053402	49	2	1002	1011	9
5551304	49	3	1870	1940	70
5563803	49	3	1988	2084	96
5641401	49	3	2118	2041	-77
5657601	49	3	2018	2078	60
6950302	49	3	877.5	852	-25.5
7021301	49	3	1688	1696	8
7025502	49	3	1101	1109	8

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034101	49	3	1052	1092	40
7034301	49	3	1040	1076	36
7034602	49	3	1041	1057	16
7036101	49	3	1163	1147	-16
7041209	49	3	918	951	33
7042205	49	3	993	994	1
7045504	49	3	1101	1065	-36
7045504	49	3	1100	1065	-35
7140201	49	3	1075	1105	30
5445603	49	4	1824	1912	88
5658602	49	4	2026	2080	54
6918303	49	4	1329	1516	187
6919401	49	4	1286	1347	61
6927801	49	4	1269	1118	-151
6936402	49	4	799	928	129
6936402	49	4	797.5	928	130.5
6943409	49	4	877	896	19
6943409	49	4	876	896	20
7024301	49	4	1486	1487	1
7024303	49	4	1220	1484	264

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7053402	50	2	1005	1014	9
6950302	50	3	880.5	861	-19.5
6919401	50	4	1289	1356	67
6951406	51	2	844.5	846	1.5
7053402	51	2	1006	1014	8
6942709	51	3	902	930	28
6943607	51	3	787	879	92
6943607	51	3	784	879	95
6944902	51	3	762	752	-10
6950302	51	3	879	869	-10
7025502	51	3	1099	1110	11
7033704	51	3	980	962	-18
7034101	51	3	1058	1093	35
7034301	51	3	1046	1079	33
7034602	51	3	1043	1059	16
7041209	51	3	919	953	34
7042205	51	3	997	996	-1
7045504	51	3	1099	1068	-31
7045504	51	3	1100	1068	-32
7123802	51	3	1133	1118	-15

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5445502	51	4	1795	1898	103
6919401	51	4	1285	1354	69
6935401	51	4	1159	1081	-78
6935602	51	4	1104	1033	-71
6936402	51	4	797	956	159
6943409	51	4	878.5	925	46.5
6950101	52	2	889	892	3
6951406	52	2	845	838	-7
7053402	52	2	1003	1012	9
5641401	52	3	2073	2041	-32
6935804	52	3	1019	977	-42
6942601	52	3	874	910	36
6942709	52	3	897.5	919	21.5
6942709	52	3	899	919	20
6943910	52	3	883	816	-67
6944902	52	3	759	740	-19
6950302	52	3	872.5	857	-15.5
6950306	52	3	876	858	-18
7025502	52	3	1090	1108	18
7033704	52	3	977	960	-17

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034101	52	3	1051	1092	41
7034301	52	3	1042	1077	35
7034602	52	3	1041	1057	16
7041209	52	3	919	951	32
7042205	52	3	992	994	2
7042205	52	3	993	994	1
7123802	52	3	1132	1114	-18
5445502	52	4	1801	1899	98
6919401	52	4	1284	1363	79
6936402	52	4	779.5	943	163.5
6943202	52	4	923	925	2
6943409	52	4	869	908	39
6944703	52	4	781	789	8
6951602	52	4	839	805	-34
6951406	53	2	846	834	-12
7053402	53	2	1002	1010	8
5641401	53	3	2088	2029	-59
6944902	53	3	762	733	-29
6944902	53	3	774.5	733	-41.5
6950302	53	3	876.3333	855	-21.3333

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7025502	53	3	1095	1108	13
7033302	53	3	1078	1105	27
7033508	53	3	986	1065	79
7033704	53	3	978	960	-18
7034101	53	3	1052	1091	39
7034301	53	3	1039	1074	35
7034602	53	3	1045	1055	10
7041209	53	3	918	951	33
7045504	53	3	1099	1065	-34
7112502	53	3	1125	1149	24
7123802	53	3	1126	1115	-11
5445502	53	4	1797	1895	98
6919401	53	4	1285	1343	58
6936402	53	4	802.5	933	130.5
6943409	53	4	877	901	24
7038603	53	4	1217	1231	14
7038902	53	4	1194	1212	18
7038908	53	4	1125	1210	85
6949201	54	2	893	900	7
7046706	54	2	1066	1067	1

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
5641401	54	3	2078	2025	-53
6950302	54	3	883	857	-26
6952202	54	3	819	749	-70
7025502	54	3	1092	1109	17
7033302	54	3	1077	1106	29
7033704	54	3	966	961	-5
7034301	54	3	1041	1075	34
7037501	54	3	1204	1200	-4
7037902	54	3	1203	1185	-18
7041209	54	3	917	952	35
7042205	54	3	995	993	-2
7042205	54	3	995	993	-2
7046705	54	3	1093	1067	-26
7112502	54	3	1125	1150	25
7123802	54	3	1125	1116	-9
5445502	54	4	1799	1895	96
6919401	54	4	1286.5	1338	51.5
7053402	55	2	1001	1012	11
5641401	55	3	2084	2036	-48
6944902	55	3	782	741	-41

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6950302	55	3	880	862	-18
6952202	55	3	797	756	-41
6952404	55	3	780	772	-8
7025502	55	3	1097	1109	12
7033704	55	3	944	961	17
7033704	55	3	978	961	-17
7034301	55	3	1037	1078	41
7041209	55	3	921	953	32
7041209	55	3	920	953	33
7042205	55	3	993	995	2
7045504	55	3	1102	1067	-35
7123802	55	3	1134	1116	-18
5445502	55	4	1796	1898	102
6919401	55	4	1285.5	1353	67.5
7053402	56	2	1005	1016	11
6943912	56	3	891	845	-46
6944902	56	3	825	762	-63
6950302	56	3	884.5	878	-6.5
6950302	56	3	885	878	-7
6952202	56	3	838.5	777	-61.5

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6952404	56	3	822	790	-32
7025502	56	3	1119	1112	-7
7025603	56	3	1132	1128	-4
7033302	56	3	1090	1107	17
7033508	56	3	1018	1068	50
7033705	56	3	854	951	97
7034301	56	3	1052	1084	32
7037501	56	3	1204	1220	16
7037902	56	3	1214	1204	-10
7046705	56	3	1098	1076	-22
7048401	56	3	1005	1046	41
7112502	56	3	1134	1153	19
7123802	56	3	1156	1119	-37
7140201	56	3	1110	1107	-3
5445502	56	4	1803	1902	99
6919401	56	4	1289	1380	91
6935602	56	4	1128	1047	-81
6951606	56	4	827	805	-22
7029101	56	4	1421	1433	12
7045601	56	4	1119	1073	-46

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7115501	56	4	1321	1310	-11
7122801	56	4	1008	1105	97
7131401	56	4	1114	1107	-7
6944403	57	2	924	873	-51
6944403	57	2	923	873	-50
6944407	57	2	920	864	-56
6944407	57	2	920	864	-56
6944507	57	2	920	861	-59
6944507	57	2	919	861	-58
6949201	57	2	885	910	25
7053402	57	2	1004	1015	11
5641401	57	3	2078	2039	-39
6936703	57	3	839	971	132
6936703	57	3	831	971	140
6936704	57	3	916	939	23
6936704	57	3	908	939	31
6936708	57	3	848	948	100
6936708	57	3	839	948	109
6942603	57	3	887	953	66
6942909	57	3	887	917	30

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6942909	57	3	886	917	31
6942913	57	3	887	917	30
6942913	57	3	886	917	31
6943109	57	3	960	979	19
6943109	57	3	952	979	27
6943204	57	3	935	958	23
6943204	57	3	931	958	27
6943410	57	3	889	950	61
6943410	57	3	885	950	65
6943501	57	3	872	938	66
6943501	57	3	867	938	71
6943606	57	3	829	895	66
6943606	57	3	822	895	73
6943804	57	3	879	894	15
6943804	57	3	880	894	14
6943912	57	3	880	857	-23
6943917	57	3	851	858	7
6943917	57	3	877	858	-19
6944204	57	3	817	890	73
6944204	57	3	819	890	71

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6944404	57	3	817	895	78
6944404	57	3	805	895	90
6944901	57	3	836	757	-79
6944901	57	3	835	757	-78
6950302	57	3	881	885	4
6950401	57	3	875	891	16
6951202	57	3	872	861	-11
6951202	57	3	868	861	-7
6951301	57	3	859	841	-18
6951301	57	3	861	841	-20
7017401	57	3	1141	1143	2
7025603	57	3	1135	1127	-8
7026102	57	3	1144	1155	11
7027901	57	3	1191	1153	-38
7028401	57	3	1236	1197	-39
7033302	57	3	1118	1107	-11
7033508	57	3	1011	1068	57
7033704	57	3	983	964	-19
7033704	57	3	980	964	-16
7034301	57	3	1065	1083	18

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
7034301	57	3	1064	1083	19
7041209	57	3	921	955	34
7045504	57	3	1101	1070	-31
7048401	57	3	985	1046	61
7112502	57	3	1108	1154	46
7123802	57	3	1155	1119	-36
7140201	57	3	1106	1108	2
5641202	57	4	1946	2007	61
6919401	57	4	1287	1377	90
6936707	57	4	870	982	112
6936707	57	4	847	982	135
6942901	57	4	887	902	15
6942901	57	4	887	902	15
6942902	57	4	887	902	15
6942902	57	4	886	902	16
6943102	57	4	932	968	36
6943102	57	4	929	968	39
6943205	57	4	902	956	54
6943205	57	4	895	956	61
6950309	57	4	886	897	11

TABLE A1. SUMMARY OF MODEL SIMULATED HEADS AND MEASURED HEADS AT WELLS. HEAD VALUES REPORT IN FEET ABOVE MEAN SEA LEVEL (FEET AML).

Well name	Stress Period	Model layer	Measured head (feet, amsl)	Simulated head (feet, amsl)	Residual (simulated head - measured head, feet)
6950309	57	4	886	897	11
6951606	57	4	807	814	7
6951705	57	4	809	858	49
7122801	57	4	1007	1105	98
7131401	57	4	1111	1108	-3

Appendix B:
Simulated Fluxes and Measured Fluxes at Springs

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Las Moras	13.5	23.71	17.76	-5.94
Las Moras	698.5	7.58	7.11	-0.47
Las Moras	1050.5	5.49	7.16	1.67
Las Moras	1415.5	17.19	13.55	-3.65
Las Moras	1480.5	9.83	10.29	0.46
Las Moras	1836.5	16.90	13.92	-2.98
Las Moras	2531.5	8.43	7.9	-0.52
Las Moras	2909.5	21.10	18.69	-2.41
Las Moras	3259.5	58.90	40.48	-18.42
Las Moras	3629.5	43.11	36.23	-6.87
Las Moras	3993.5	38.69	29.72	-8.98
Las Moras	4350.5	26.09	32.52	6.42
Las Moras	4727.5	11.80	17.32	5.52
Las Moras	5078.5	6.33	4.57	-1.77
Las Moras	5465.5	30.11	30.53	0.43
Las Moras	5814.5	16.46	20.05	3.6
Las Moras	6187.5	25.71	26.72	1.01
Las Moras	6550.5	32.94	24.55	-8.39
Las Moras	6921.5	8.92	9.17	0.24

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Las Moras	7283.5	39.27	31.68	-7.6
Las Moras	7647.5	7.85	10.44	2.6
Las Moras	8018.5	41.72	41.87	0.14
Las Moras	8382.5	13.89	28.24	14.34
Las Moras	8739.5	50.11	43.69	-6.43
Las Moras	9104.5	15.21	18.43	3.23
Las Moras	9474.5	11.91	15.14	3.24
Las Moras	9846.5	43.78	47.2	3.42
Las Moras	10209.5	18.15	28.33	10.18
Las Moras	10573.5	20.94	19.94	-1.01
Las Moras	10937.5	10.01	14.48	4.47
Las Moras	11301.5	7.02	8.71	1.68
Las Moras	11665.5	41.01	39.22	-1.79
Las Moras	12042.5	11.11	22.76	11.65
Las Moras	12402.5	35.97	29.16	-6.82
Las Moras	12764.5	9.90	26.23	16.33
Las Moras	13128.5	18.42	18.08	-0.34
Las Moras	13502.5	38.89	38.32	-0.58
Las Moras	13857.5	36.82	40.21	3.4
Las Moras	14227.5	12.00	22.65	10.65

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Las Moras	14591.5	7.78	9.83	2.04
Las Moras	14955.5	21.21	25.53	4.33
Las Moras	15319.5	28.63	28.06	-0.58
Las Moras	15683.5	24.66	29.89	5.23
Las Moras	16054.5	10.19	11.49	1.29
Las Moras	16418.5	18.80	18.31	-0.5
Las Moras	16446.5	20.41	19.19	-1.21
Las Moras	17146.5	41.32	31.9	-9.42
Las Moras	17510.5	25.98	28.96	2.98
Las Moras	17874.5	40.50	37.45	-3.05
Las Moras	18244.5	15.99	37.39	21.39
Las Moras	18609.5	37.31	27.68	-9.62
Las Moras	18973.5	36.28	28.58	-7.7
Las Moras	19345.5	38.05	33.14	-4.9
Las Moras	19701.5	38.29	33.14	-5.15
Las Moras	20059.5	42.30	41.42	-0.88
Las Moras	20409.5	39.09	42.77	3.67
Leona	353.5	0.60	27.96	27.36
Leona	2908.5	0.00	17.9	17.9
Leona	3261.5	0.00	40.51	40.51

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Leona	3630.5	33.50	43.13	9.63
Leona	3961.5	28.99	37.03	8.03
Leona	4349.5	35.30	41.2	5.9
Leona	4728.5	11.60	25.18	13.58
Leona	5078.5	0.38	8.37	8
Leona	5116.5	0.56	25.44	24.89
Leona	5819.5	0.04	17.31	17.26
Leona	6197.5	4.26	17.97	13.7
Leona	6547.5	0.00	17.77	17.77
Leona	6936.5	18.00	19.56	1.56
Leona	7276.5	23.71	19.56	-4.14
Leona	7654.5	19.89	5.8	-14.1
Leona	8004.5	29.70	38.31	8.61
Leona	8399.5	32.69	48.96	16.26
Leona	8738.5	51.40	48.96	-2.44
Leona	9130.5	51.00	18.04	-32.96
Leona	9494.5	41.59	51.16	9.56
Leona	9861.5	80.91	37.04	-43.86
Leona	10201.5	52.94	37.04	-15.91
Leona	10551.5	27.10	25.07	-2.03

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Leona	10925.5	38.05	17.35	-20.7
Leona	11303.5	14.21	6.09	-8.11
Leona	11678.5	49.20	32.17	-17.03
Leona	12024.5	31.15	18.36	-12.79
Leona	12386.5	18.00	19.43	1.43
Leona	12765.5	0.00	12.85	12.85
Leona	13134.5	32.25	4.08	-28.17
Leona	13492.5	32.29	25.04	-7.26
Leona	13821.5	85.70	35.76	-49.94
Leona	13885.5	91.10	22.39	-68.71
Leona	14593.5	6.51	3.49	-3.02
Leona	14961.5	19.40	8.1	-11.3
Leona	15319.5	14.61	11.97	-2.63
Leona	15662.5	59.01	25.39	-33.61
Leona	16054.5	33.94	12.05	-21.9
Leona	16413.5	35.75	11.83	-23.92
Leona	16785.5	25.69	13.91	-11.79
Leona	17156.5	3.57	29.16	25.59
Leona	17517.5	32.09	29.16	-2.94
Leona	17869.5	42.51	37.55	-4.95

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Leona	18202.5	38.29	45.44	7.14
Leona	18605.5	21.41	36.79	15.39
Leona	18966.5	8.01	31.77	23.77
Leona	19340.5	6.13	32.77	26.64
Leona	19693.5	44.69	37.65	-7.05
Leona	20058.5	68.20	52.86	-15.34
Big Paint	1827.5	18.15	15.13	-3.03
Cade	1827.5	0.33	0.19	-0.14
Cantu	4358.5	2.88	0	-2.88
Cantu	4718.5	0.00	0	0
Cantu	5083.5	0.00	0	0
Cantu	5449.5	3.10	0	-3.1
Cantu	5826.5	2.25	0	-2.26
Cantu	6191.5	2.97	0	-2.96
Cantu	6544.5	0.00	0	0
Cantu	6910.5	1.25	0	-1.24
Cantu	7297.5	5.20	0	-5.2
Cantu	7645.5	3.68	0	-3.69
Cantu	8011.5	6.69	0	-6.68
Cantu	8389.5	8.34	0	-8.34

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Cantu	8745.5	6.42	0	-6.43
Cantu	9124.5	7.74	0	-7.74
Cantu	9491.5	7.02	0	-7.03
Cantu	9832.5	8.83	0	-8.83
Cantu	10223.5	8.05	0	-8.04
Cantu	10579.5	7.20	0	-7.21
Cantu	10930.5	6.65	0	-6.65
Cantu	11293.5	4.95	0	-4.94
Cantu	11658.5	8.59	0	-8.58
Cantu	12036.5	8.39	0	-8.39
Cantu	12394.5	6.78	0	-6.77
Cantu	12769.5	4.68	0	-4.69
Cantu	13119.5	5.49	0	-5.49
Cantu	13484.5	6.15	0	-6.16
Cantu	13849.5	8.21	0	-8.2
Cantu	14245.5	9.68	0	-9.68
Cantu	14609.5	5.42	0	-5.41
Cantu	14949.5	8.16	0	-8.17
Cantu	15310.5	7.07	0	-7.06
Cantu	15676.5	8.83	0	-8.83

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Cantu	16041.5	5.24	0	-5.24
Cantu	16406.5	4.46	0	-4.45
Cantu	16772.5	2.92	0	-2.92
Cantu	17137.5	3.39	0	-3.38
Cantu	17502.5	5.42	0	-5.43
Cantu	17867.5	6.62	0	-6.62
Cantu	18232.5	6.40	0	-6.41
Cantu	18598.5	4.79	0	-4.79
Cantu	18963.5	5.64	0	-5.65
Cantu	19328.5	5.42	0	-5.41
Cantu	19693.5	4.59	0	-4.59
Cantu	20085.5	8.52	0	-8.53
Cantu	20424.5	11.28	0	-11.29
Cienega	5828.5	2.52	6.8	4.28
Cienega	6193.5	2.32	7.98	5.67
Cienega	6558.5	2.12	7.53	5.41
Cienega	6924.5	1.05	8.61	7.57
Cienega	7289.5	13.85	12.96	-0.88
Cienega	7654.5	9.41	8.82	-0.6
Cienega	8019.5	13.27	16.8	3.52

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Cienega	8385.5	16.55	12.1	-4.45
Cienega	8750.5	16.68	16.53	-0.16
Cienega	9115.5	16.86	10.57	-6.28
Cienega	9480.5	15.05	10.32	-4.73
Cienega	9846.5	19.04	19.37	0.33
Cienega	10211.5	17.37	12.95	-4.43
Cienega	10576.5	17.19	11.56	-5.63
Cienega	10941.5	15.68	10.66	-5.02
Cienega	11307.5	11.82	9.31	-2.51
Cienega	11672.5	15.90	16.81	0.92
Cienega	12037.5	16.23	11.48	-4.76
Cienega	12402.5	14.74	12.97	-1.76
Cienega	12768.5	11.04	14.08	3.03
Cienega	13133.5	12.18	11.71	-0.47
Cienega	13498.5	11.15	16.12	4.97
Cienega	13863.5	16.57	15.79	-0.79
Cienega	14229.5	16.10	12.19	-3.92
Cienega	14594.5	9.88	9.89	0.02
Cienega	14959.5	12.00	13.5	1.5
Cienega	15324.5	14.76	13.14	-1.63

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Cienega	15690.5	15.86	14.52	-1.34
Cienega	16055.5	11.51	10.39	-1.12
Cienega	16420.5	12.00	11.4	-0.59
Cienega	16785.5	8.70	11.52	2.83
Cienega	17151.5	9.39	13.95	4.57
Cienega	17516.5	11.66	13.65	1.98
Cienega	17881.5	10.21	15.14	4.93
Cienega	18246.5	11.35	15.52	4.16
Cienega	18612.5	10.95	13.01	2.07
Cienega	18977.5	11.24	13.2	1.97
Cienega	19342.5	12.13	14.01	1.88
Cienega	19707.5	12.58	15.16	2.58
Cienega	20073.5	15.99	18.45	2.45
Cienega	20438.5	15.90	18.59	2.7
Deats	731.5	0.00	0.02	0.02
Deats	1097.5	0.00	0.02	0.02
Deats	1462.5	0.00	0.02	0.02
Deats	1827.5	0.00	0.02	0.02
Goodenough	335.5	97.70	128.58	30.89
Goodenough	700.5	77.81	81.2	3.4

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Goodenough	1066.5	80.59	72.89	-7.7
Goodenough	1431.5	85.19	91.94	6.75
Goodenough	1796.5	102.98	96.48	-6.51
Goodenough	2161.5	98.19	112.16	13.97
Goodenough	2527.5	73.19	65.2	-7.99
Goodenough	2892.5	91.10	120.82	29.73
Goodenough	3257.5	222.98	190.97	-32.01
Goodenough	3622.5	192.99	178.52	-14.46
Goodenough	3653.5	170.98	158.69	-12.3
Guy_Skiles	6575.5	0.00	0	-0.01
Hackberry	1462.5	5.75	1.24	-4.51
JJ-70-08-603	1827.5	0.11	0	-0.11
JJ-70-08-801	1827.5	0.22	0	-0.22
McKee	4356.5	1.81	1.24	-0.56
McKee	4718.5	0.00	0.16	0.16
McKee	5083.5	0.00	0.03	0.03
McKee	5470.5	3.79	1.25	-2.54
McKee	5828.5	1.65	0.38	-1.27
McKee	6189.5	0.47	0.63	0.16
McKee	6544.5	0.00	0.6	0.6

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
McKee	6910.5	1.78	1.61	-0.17
McKee	7304.5	6.20	1.67	-4.54
McKee	7640.5	6.11	1.67	-4.43
McKee	8005.5	7.07	3.52	-3.54
McKee	8371.5	7.07	2.41	-4.65
McKee	8736.5	6.36	3.49	-2.87
McKee	9131.5	7.85	1.96	-5.9
McKee	9466.5	6.71	1.96	-4.75
McKee	9832.5	7.07	3.87	-3.19
McKee	10216.5	6.60	2.43	-4.16
McKee	10592.5	7.85	2.03	-5.82
McKee	10944.5	7.89	2.03	-5.87
McKee	11305.5	5.89	1.75	-4.13
McKee	11658.5	7.69	3.31	-4.39
McKee	12023.5	6.49	2.16	-4.33
McKee	12388.5	4.95	2.57	-2.37
McKee	12754.5	4.62	2.34	-2.27
McKee	13139.5	4.82	2.14	-2.68
McKee	13484.5	3.52	3.2	-0.33
McKee	13849.5	3.19	3.17	-0.01

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
McKee	14245.5	1.61	1.87	0.26
McKee	14602.5	1.40	2.45	1.05
McKee	14945.5	1.25	2.45	1.21
McKee	15310.5	4.71	2.46	-2.25
McKee	15676.5	5.13	2.72	-2.4
McKee	16041.5	4.95	1.99	-2.95
McKee	16427.5	3.41	2.2	-1.22
McKee	16771.5	3.01	2.2	-0.82
McKee	17160.5	2.85	2.56	-0.3
McKee	17502.5	2.48	2.56	0.09
McKee	17867.5	2.88	3.01	0.14
McKee	18232.5	2.61	3.2	0.59
McKee	18612.5	2.27	2.49	0.21
McKee	18984.5	2.01	2.72	0.71
McKee	19328.5	2.03	2.72	0.7
McKee	19693.5	1.96	2.86	0.9
McKee	20077.5	4.79	3.64	-1.16
McKee	20424.5	5.04	3.64	-1.4
Mud	5827.5	9.61	9.25	-0.37
Mud	6187.5	12.44	12.01	-0.43

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Mud	6556.5	1.20	9.05	7.84
Mud	6921.5	3.19	2.42	-0.78
Mud	7283.5	11.82	14.68	2.87
Mud	7647.5	5.62	4.53	-1.09
Mud	8018.5	23.17	22.26	-0.91
Mud	8382.5	24.26	14.06	-10.21
Mud	8739.5	14.92	22.56	7.65
Mud	9104.5	8.79	8.74	-0.05
Mud	9474.5	7.92	7.42	-0.5
Mud	9846.5	28.88	29.56	0.68
Mud	10209.5	24.80	17.6	-7.2
Mud	10573.5	8.05	12.73	4.68
Mud	10937.5	10.26	7.78	-2.47
Mud	11301.5	0.91	2.45	1.54
Mud	11665.5	23.06	21.18	-1.89
Mud	12042.5	28.21	11.77	-16.44
Mud	12402.5	19.91	14.02	-5.89
Mud	12764.5	10.75	20.27	9.52
Mud	13128.5	7.74	11.82	4.09
Mud	13492.5	16.59	21.2	4.61

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Mud	13857.5	30.62	21.75	-8.86
Mud	14227.5	17.62	11.87	-5.74
Mud	14591.5	3.30	3.94	0.64
Mud	14955.5	21.72	14.96	-6.76
Mud	15319.5	14.09	16.23	2.14
Mud	15683.5	20.72	19.59	-1.12
Mud	16054.5	5.08	7.03	1.94
Mud	16418.5	9.70	9.83	0.12
Mud	16446.5	9.41	10.74	1.34
Mud	17146.5	12.00	16.23	4.23
Mud	17510.5	15.88	18.1	2.22
Mud	17874.5	20.98	22	1.01
Mud	18210.5	21.59	22.98	1.39
Pinto	5827.5	6.71	2.21	-4.51
Pinto	6187.5	5.24	2.72	-2.52
Pinto	6556.5	0.00	0	0
Pinto	6921.5	0.00	0	0
Pinto	7283.5	0.00	4.88	4.88
Pinto	7647.5	0.00	0	0
Pinto	8018.5	24.15	18.78	-5.38

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Pinto	8382.5	10.33	6.23	-4.1
Pinto	8739.5	24.04	17.21	-6.84
Pinto	9104.5	0.51	0	-0.51
Pinto	9474.5	0.00	0	0
Pinto	9846.5	31.51	28.17	-3.35
Pinto	10209.5	5.00	4.55	-0.45
Pinto	10573.5	0.38	1.32	0.93
Pinto	10937.5	0.00	0	0
Pinto	11301.5	0.00	0	0
Pinto	11665.5	12.80	17.14	4.35
Pinto	12042.5	0.00	1.94	1.94
Pinto	12402.5	1.72	5.14	3.42
Pinto	12764.5	0.00	0.01	0.01
Pinto	13128.5	0.00	0	0
Pinto	13492.5	0.00	0	0
Pinto	13857.5	4.62	10.93	6.32
Pinto	14227.5	0.00	0	0
Pinto	14591.5	0.00	0	0
Pinto	14955.5	1.81	2.66	0.86
Pinto	15319.5	1.09	0	-1.1

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Pinto	15683.5	0.00	0	0
Pinto	16054.5	0.00	0	0
Pinto	16418.5	0.20	0.85	0.65
Pinto	17146.5	4.28	3.21	-1.08
San_Felipe	2497.5	25.49	53.87	28.37
San_Felipe	2874.5	96.70	88.11	-8.58
San_Felipe	3258.5	113.00	116.5	3.51
San_Felipe	3601.5	101.98	109.87	7.88
San_Felipe	3993.5	109.99	99.9	-10.09
San_Felipe	4353.5	103.01	102.21	-0.8
San_Felipe	4718.5	64.34	81.57	17.23
San_Felipe	5083.5	38.87	69.55	30.68
San_Felipe	5449.5	108.16	101.06	-7.09
San_Felipe	5814.5	95.34	88.97	-6.36
San_Felipe	6179.5	94.18	95.14	0.96
San_Felipe	6544.5	67.86	92.06	24.2
San_Felipe	6910.5	66.10	96.83	30.74
San_Felipe	7275.5	113.87	118.14	4.28
San_Felipe	7640.5	91.21	97.77	6.55
San_Felipe	8005.5	124.19	134.85	10.66

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
San_Felipe	8371.5	145.18	113.1	-32.08
San_Felipe	8736.5	143.30	132.91	-10.39
San_Felipe	9101.5	129.68	105.97	-23.71
San_Felipe	9466.5	133.94	105.17	-28.76
San_Felipe	9832.5	153.43	149.44	-4
San_Felipe	10197.5	150.13	119	-31.12
San_Felipe	10562.5	141.90	112.27	-29.62
San_Felipe	10927.5	130.15	106.72	-23.42
San_Felipe	11293.5	91.01	98.85	7.85
San_Felipe	11658.5	133.05	136.12	3.07
San_Felipe	12023.5	135.88	110.36	-25.52
San_Felipe	12388.5	134.65	116.51	-18.14
San_Felipe	12754.5	97.92	127.79	29.87
San_Felipe	13119.5	105.95	112.4	6.44
San_Felipe	13484.5	117.77	132.42	14.66
San_Felipe	13849.5	139.38	130.15	-9.24
San_Felipe	14215.5	139.07	113.1	-25.97
San_Felipe	14580.5	109.96	101.95	-8.01
San_Felipe	14945.5	139.02	121.97	-17.06
San_Felipe	15310.5	126.13	119.31	-6.82

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
San_Felipe	15676.5	133.25	126.46	-6.78
San_Felipe	16041.5	120.42	104.42	-16
San_Felipe	16406.5	110.61	109.4	-1.21
San_Felipe	16771.5	78.28	110.27	31.99
San_Felipe	17137.5	101.29	120.58	19.29
San_Felipe	17502.5	111.41	121.89	10.47
San_Felipe	17867.5	126.78	127.62	0.83
San_Felipe	18232.5	144.24	128.15	-16.08
San_Felipe	18598.5	112.93	118.18	5.26
San_Felipe	18963.5	119.89	118.8	-1.09
San_Felipe	19328.5	127.09	122.42	-4.67
San_Felipe	19693.5	117.68	129.31	11.63
San_Felipe	20059.5	145.29	145.64	0.36
San_Felipe	20424.5	155.59	145.2	-10.4
Seven_Hundred	3313.5	36.51	21.23	-15.27
Seven_Hundred	4398.5	21.70	16.76	-4.94
Seven_Hundred	4756.5	15.90	16.25	0.35
Seven_Hundred	5127.5	16.50	17.72	1.22
Seven_Hundred	5491.5	15.70	17.85	2.15
Seven_Hundred	6213.5	19.20	18.13	-1.07

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Seven_Hundred	6584.5	12.20	18.26	6.06
Seven_Hundred	6948.5	13.69	19.8	6.1
Seven_Hundred	7319.5	19.29	18.34	-0.96
Seven_Hundred	7683.5	18.60	19.46	0.86
Seven_Hundred	8425.5	20.70	17.61	-3.09
Seven_Hundred	8781.5	20.49	16.63	-3.87
Seven_Hundred	9160.5	22.06	17.76	-4.29
Seven_Hundred	9504.5	24.91	21.31	-3.59
Seven_Hundred	9881.5	24.24	19.36	-4.89
Seven_Hundred	10239.5	20.81	19.57	-1.23
Seven_Hundred	10600.5	17.75	18.88	1.13
Seven_Hundred	11694.5	24.31	18.89	-5.41
Seven_Hundred	12059.5	17.31	18.64	1.34
Seven_Hundred	12442.5	14.09	23.73	9.63
Seven_Hundred	12809.5	21.01	21.11	0.11
Seven_Hundred	13907.5	22.50	18.56	-3.94
Seven_Hundred	14264.5	20.61	17.87	-2.73
Seven_Hundred	14620.5	16.30	20.99	4.69
Seven_Hundred	15300.5	20.49	20.96	0.46
Seven_Hundred	15348.5	25.89	21.62	-4.28

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Seven_Hundred	16046.5	18.00	19.12	1.12
Seven_Hundred	16446.5	19.69	19.4	-0.3
Seven_Hundred	16812.5	13.29	18.95	5.65
Seven_Hundred	17518.5	19.40	20.37	0.97
Seven_Hundred	17869.5	22.30	20.6	-1.7
Seven_Hundred	18217.5	20.41	19.73	-0.67
Seven_Hundred	18601.5	32.69	20.47	-12.23
Seven_Hundred	18973.5	19.60	19.09	-0.51
Seven_Hundred	19323.5	23.19	18.73	-4.47
Seven_Hundred	19702.5	15.10	19.81	4.71
Seven_Hundred	20071.5	35.90	21.25	-14.65
Tanner	13907.5	15.90	12.64	-3.26
Tanner	14264.5	10.70	12.21	1.51
Tanner	14620.5	9.99	14.22	4.22
Tanner	15348.5	17.60	14.61	-2.99
Tanner	16046.5	12.20	13	0.8
Tanner	16446.5	11.80	13.19	1.39
Tanner	16812.5	10.79	12.91	2.11
Tanner	17518.5	13.40	13.82	0.42
Tanner	17869.5	14.90	13.97	-0.93

TABLE B1. SUMMARY OF SIMULATED FLUXES AND MEASURED FLUXES AT SPRINGS. FLUXES REPORTED IN CUBIC FEET PER SECOND (CFS).

Springs	Elapsed time (days)	Measured flux (cfs)	Simulated flux (cfs)	Residual (simulated flux - measured flux, cfs)
Tanner	18217.5	11.71	13.4	1.7
Tanner	18601.5	15.90	13.87	-2.03
Tanner	18973.5	13.29	12.99	-0.31
Tanner	19323.5	14.09	12.76	-1.34
Tanner	19702.5	12.40	13.45	1.05
Tanner	20071.5	16.10	14.38	-1.72
Yoas	1827.5	0.00	3.25	3.25
Yoas	2192.5	0.00	3	3
Yoas	6575.5	0.11	3.36	3.25
YR-54-60-302	6941.5	1.92	0.35	-1.56
YR-70-01-701	6941.5	0.22	0	-0.22
YR-70-01-703	6941.5	2.01	1.79	-0.22
YR-70-01-704	5845.5	2.01	1.77	-0.24

Appendix C:
Glossary List

acre-foot (acre-ft) - the volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.

anisotropy - the condition of having different values of hydraulic conductivity (in particular) in different directions in geologic materials. This is especially apparent in fractured bedrock or layered sediment.

aquifer - a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.

aquifer (confined) - soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer (not necessarily flowing well).

aquifer (unconfined) - an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.

base flow - sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced stream flows. Natural base flow is sustained largely by ground-water discharges.

boundary condition - a mathematical statement specifying the dependent variable at the boundaries of the modeled domain which contain the equations of the mathematical model. Examples are specified head, specified flux, or mixed boundaries.

calibrated model - a model for which all residuals between calibration targets and corresponding model outputs, or statistics computed from residuals, are less than pre-set acceptable values.

calibration - the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observations of the groundwater flow system, which includes both measured hydraulic head and flux.

calibration target - measured, observed, calculated, or estimated hydraulic heads or groundwater flow rates that a model must reproduce, at lease approximately, to be considered calibrated.

cell - a distinct one-two-or three dimensional model unit representing a discrete portion of a physical system with uniform properties assigned to it.

code (computer program) - the assembly of numerical techniques, bookkeeping, and control language that represents the model from acceptance of input data and instructions to delivery of output. Examples: MODFLOW, BIOSCREEN, MT3d, etc.

conceptual model - an interpretation of the characteristics and dynamics of an aquifer system which is based on an examination of all available hydrogeological data for a modeled area. This includes the external configuration of the system, location and rates of recharge and discharge, location and hydraulic characteristics of natural boundaries, and the directions of groundwater flow throughout the aquifer system.

cone of depression - a depression of the potentiometric surface that develops around a well which is being pumped.

constant head boundary – a MODFLOW boundary condition used to simulate a hydraulic feature (such as lake or reservoir) where hydraulic head remains the same over the time period considered. Constant head boundary could receive from or discharge to groundwater.

cubic feet per second (cfs) - a rate of the flow, in streams and rivers, for example. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second.

discharge - the volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

discretization - the process of subdividing the continuous model and/or time domain into discrete segments or cells. Algebraic equations which approximate the governing flow and/or transport equations are written for each segment or cell.

drain boundary - a MODFLOW boundary condition used to simulate a hydraulic feature (such as agriculture drain) which only receives groundwater.

drawdown - a lowering of the ground-water surface caused by pumping.

evaporation - the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces.

evapotranspiration - the sum of evaporation and transpiration.

finite difference method (FDM) - a discretization technique for solving a partial differential equation (PDE) by (1) replacing the continuous domain of interest by a finite number of regular-spaced mesh-or grid-points (i.e., nodes) representing volume-averaged sub-domain properties; and (2) by approximating the derivatives of the PDE for each of these points using finite differences; the resulting set of linear or nonlinear algebraic equations is solved using direct or interactive matrix solving techniques.

flux - the volume of fluid crossing a unit cross-sectional surface area per unit time.

general head boundary – a generic MODFLOW boundary condition used to simulate groundwater flow between model domain and a constant head hydraulic source outside the model domain.

groundwater - part of the subsurface water that is in the saturated zone.

groundwater recharge - inflow of water to a groundwater aquifer from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

groundwater basin - a groundwater system that has defined boundaries and may include more than one aquifer of permeable materials, which are capable of furnishing a significant water supply.

groundwater discharge - the water released from the zone of saturation; also the volume of water released.

groundwater flow - the movement of water in the zone of saturation.

groundwater flow model - an application of mathematical model to represent a regional or site-specific groundwater flow system.

groundwater modeling code - the computer code used in groundwater modeling to represent a non unique, simplified mathematical description of the physical framework, geometry, active processes, and boundary conditions present in a reference subsurface hydrologic system.

hydraulic conductivity - a constant of proportionality which relates the rate of groundwater flow to the hydraulic head gradient. It is a property of the porous media (intrinsic permeability) and the density and viscosity of the water moving through the porous media. It is defined as the volume of water at the existing kinematic viscosity that will move in unit time under unit hydraulic gradient through a unit area measured at right angles to the direction of low. Estimated by, in order of preference, aquifer tests, slug tests, grain size analysis.

hydraulic gradient - the change in total hydraulic head per unit distance of flow at a given point and in the direction of groundwater flow.

hydraulic head - the height above a datum plane (such as sea level) of the column of water than can be supported by the hydraulic pressure at a given point in a groundwater system. For a well, the hydraulic head is equal to the distance between the water level in the well and the datum plane.

hydraulic properties - properties of sediment and rock that govern the entrance of water and the capacity to hold, transmit and deliver water, e.g. porosity, effective porosity, specific retention, permeability and direction of maximum and minimum permeability. Synonymous with hydrologic properties.

hydrogeologic unit - geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids.

infiltration - flow of water from the land surface into the subsurface.

initial conditions - the specified values for the dependent variable (hydraulic head or solute concentration) at the beginning of the model simulation.

inverse method - a method of calibrating a groundwater flow model using a computer code to systematically vary inputs or input parameters to minimize residuals or residual statistics.

irrigation - the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall.

leakage - the flow of water from one hydrogeologic unit to another. The leakage may be natural, as through semi-impervious confining layer, or human made, as through an uncased tank.

model - an assembly of concepts in the form of mathematical equations that portray an understanding of a natural phenomenon.

model construction - the process of transforming the conceptual model into a parameterized mathematical form; as parameterization requires assumptions regarding spatial and temporal discretization, model construction requires a-priori selection of computer code.

modeling - the process of formulating a model of a system of process.

m**odel input** - the constitutive coefficients, system parameters, forcing terms, auxiliary conditions and program control parameters required to apply a computer code to a particular problem.

MODFLOW – a computer code developed by the U.S.Geological Survey to simulate groundwater flow.

MODFLOW-2000 – a version of MODFLOW released in 2000.

no-flow boundary – a model boundary which is a specified flux boundary where the assigned flux is equal to zero.

numerical model - in subsurface fluid flow modeling, a mathematical model that uses numerical methods to solve the governing equations of the applicable problem.

numerical layer - a layer in a numerical model representing a hydrogeologic unit.

output - in subsurface fluid flow modeling, all information that is produced by the computer code.

parameter - any of a set of physical properties which determine the characteristics or behavior of a system.

peak flow - the maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

pre/post-processing - using computer programs to assist in preparing data sets for use with generic simulation codes; may include parameter allocation, control parameter selection, and data file formatting.

precipitation - rain, snow, hail, sleet, dew, and frost.

recharge - water added to an aquifer. For instance, rainfall that seeps into the ground.

reservoir - a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

residual - the difference between the model-computed and field-measured values of a variable, such as hydraulic head or groundwater flow rate, at a specific time and location.

river - a natural stream of water of considerable volume, larger than a brook or creek.

river basin: the total area drained by a river and its tributaries.

river boundary - a MODFLOW boundary condition used to simulate the interaction between a hydraulic feature (such as river) and groundwater. The river boundary could gain water from or lose water to an aquifer.

runoff - part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff.

sensitivity analysis - a procedure based on systematic variation of model input values (1) to identify those model input elements that cause the most significant variations in model output; and (2) to quantitatively evaluate the impact of uncertainty in model input on the degree of calibration and on the model's predictive capability.

simulation - in groundwater modeling, one complete execution of a groundwater modeling computer program, including input and output. Simulation is sometimes also used broadly to refer to the process of modeling in general.

specific storage - the volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.

specific yield - the quantity of water released due to gravity drainage from unit volume of water table or unconfined aquifer.

specified flux boundary - a model boundary condition in which the groundwater flux or mass flux is specified; also called fixed or prescribed flux, or Neumann boundary condition.

spring - area where there is a concentrated discharge of ground water that flows at the ground surface.

steady state condition - a condition in which system inputs and outputs are in equilibrium so that there is no net change in the system with time.

storage coefficient - the volume of water an aquifer releases from or takes into storage per unit surface are of the aquifer per unit change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness. For an unconfined aquifer, the storage coefficient is approximately equal to specific yield.

storativity - see storage coefficient.

transient condition - a condition in which system inputs and outputs are not in equilibrium so that there is a net change in the system with time.

transmissibility (groundwater) - the capacity of a rock or sediment to transmit water under pressure.

transpiration - the loss of water vapor from plants.

water budget (mass balance) - an inventory of the difference source and sinks of water in a hydrogeologic system. In a well-posed model, the sources and sinks should balance.

water table - the top of the water surface in the saturated part of an aquifer.

Appendix D:
Responses to Stakeholder Comments

EXECUTIVE SUMMARY

No comments.

INTRODUCTION AND PURPOSE FOR GROUNDWATER FLOW MODEL

No comments.

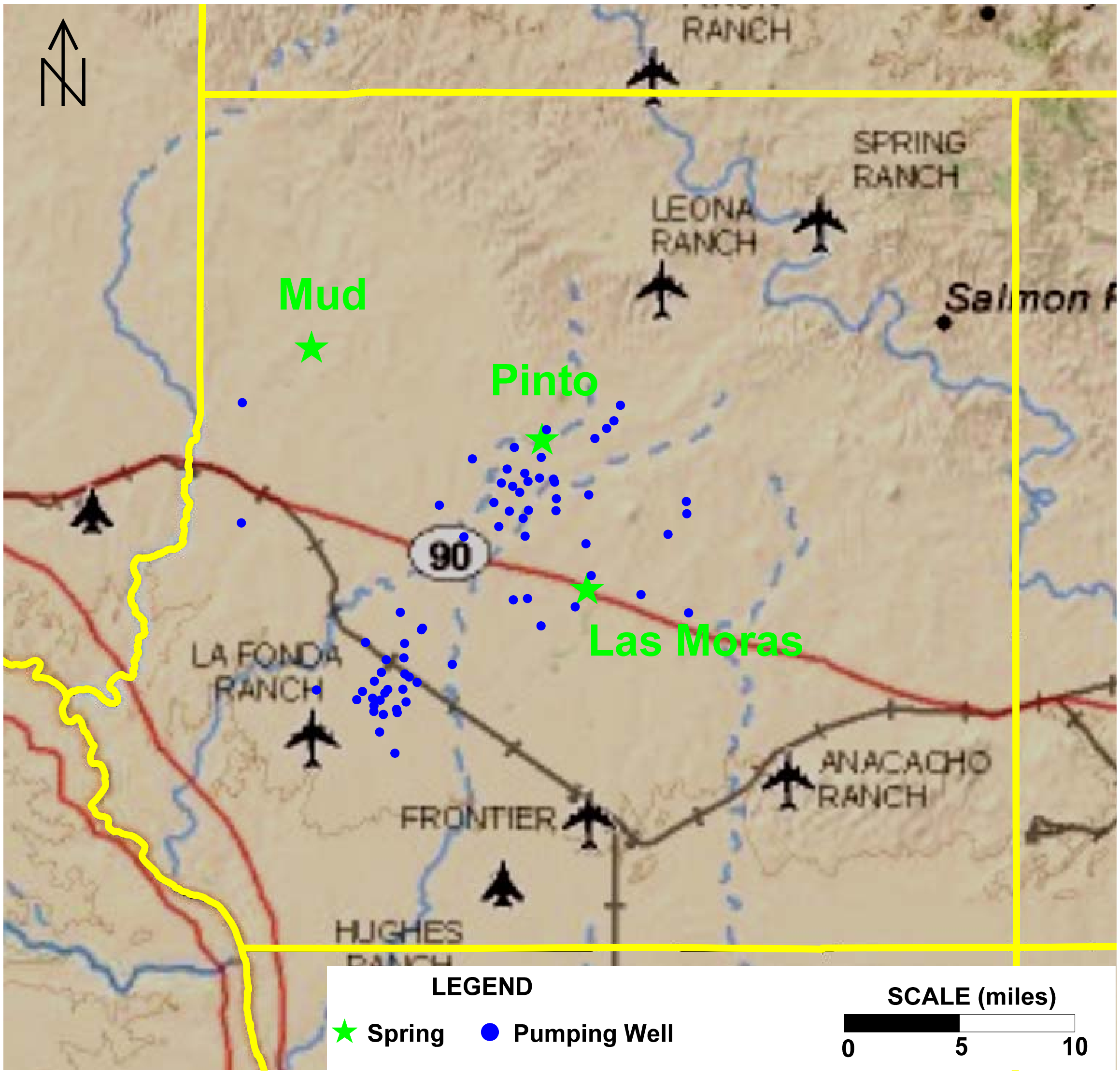
MODEL OVERVIEW AND PACKAGES

Comment 1: Stakeholder is concerned with the model grid interval and its impacts on the model application to evaluate spring flows at Las Moras, Mud and Pinto Springs. The stakeholder suggests that a finer grid interval should have been used based on the recommendation in "Groundwater Availability Model for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium Aquifer Systems, Texas, GAM Report" by Roberto Anaya and Ian Jones (2004).

Response: The Kinney County regional groundwater flow model was intended to evaluate the spring flows at Las Moras, Mud and Pinto Springs under potential desired future conditions. As such, the model was designed to evaluate spring flows under alternative county-wide pumping scenarios. The Kinney County model grid interval satisfies this need. As described in the Kinney County model report, this regional groundwater flow model was NOT meant to evaluate local-scale issues. To evaluate impacts of groundwater pumping close to springs or wells, the model grid would need to be refined and additional data including, but not limited to, geology, hydrogeology, hydrology, and groundwater withdrawal may be required. The finer grid interval, 1,320 feet, on Pages 64 and 65 of the Anaya and Jones (2004) report was proposed for the Cenozoic Pecos Alluvium aquifer located in West Texas where ground relief is relatively high.

Comment 2: Stakeholder claims that locations of individual pumping wells are not specified in the Kinney County groundwater flow model, which will affect its application on predicting spring flows under pumping conditions at Kinney County.

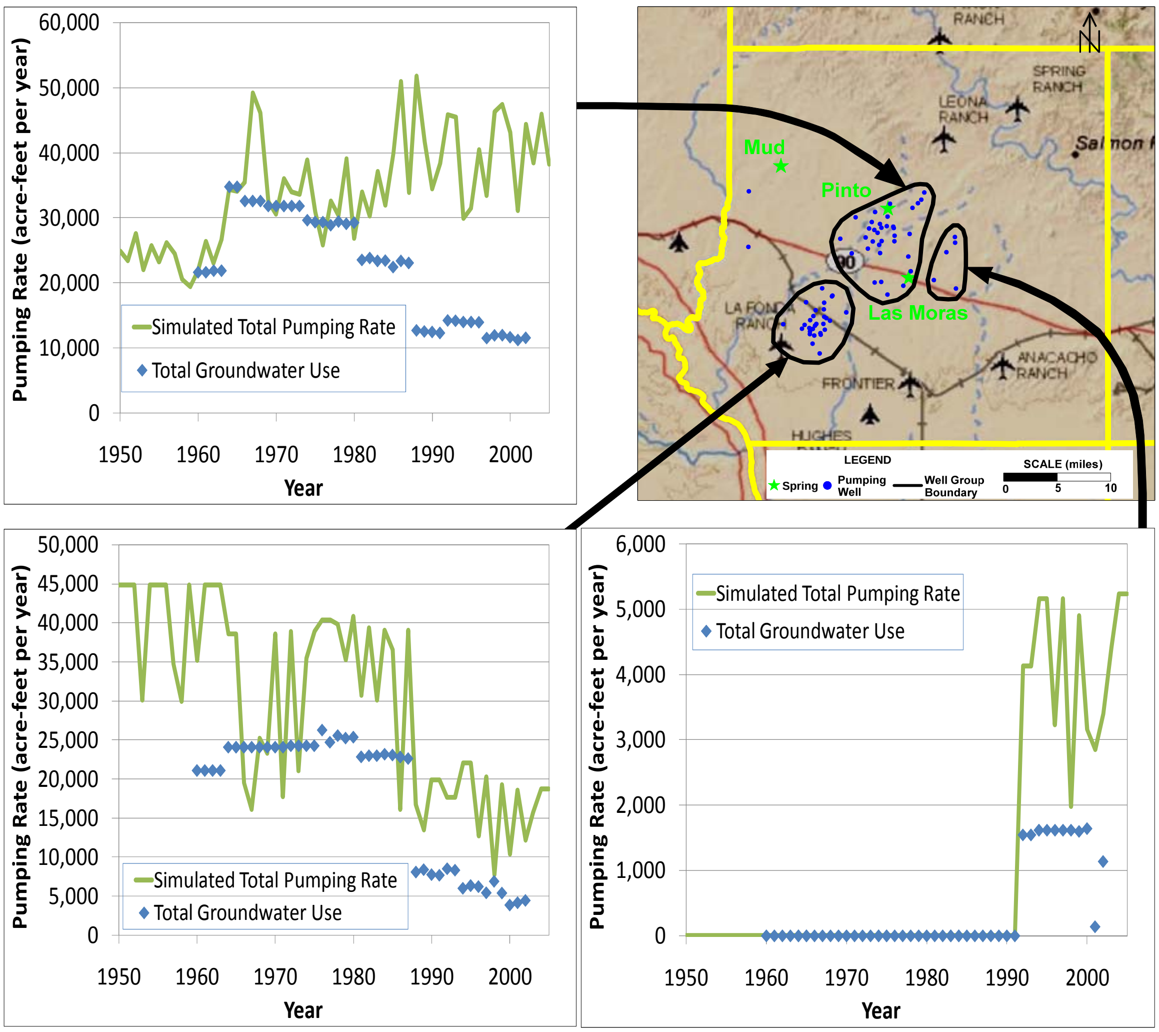
Response: Locations of individual pumping wells in Kinney County are explicitly defined in the Kinney County regional groundwater flow model using the permit data provided by the Kinney County Groundwater Conservation District. The locations of these groundwater pumping wells are presented on the figure below.



MODEL CALIBRATION AND RESULTS

Comment 3: Stakeholder claims that the average pumping rate of 65,078 acre-feet per year used by the model is under-estimated in comparison with the total usable amount of groundwater in the county documented in the Kinney County Groundwater Conservation District's management plans in 2003 and 2008.

Response: The Kinney County regional groundwater flow model is calibrated in reference to the historic groundwater pumping. As stated in the report, initial estimates of historic pumping amounts and locations were provided by the Kinney County Groundwater Conservation District in 2010. The final calibrated total pumping rate at Kinney County is close to the total groundwater pumping permit. This statement will be included in the revised model report. Note that the permit data are not always equal to the groundwater use data. For comparison purpose, the pumping wells are divided to three clusters, with simulated total pumping rate and groundwater use presented on the figure below for each cluster.



The figure above indicates that the Kinney County groundwater flow model does not under-estimate the groundwater withdrawal at Kinney County. This is especially true near Las Moras and Pinto Springs since 1980.

Finally, it should be noted that the comment refers to the total “usable amount of groundwater”. It must be emphasized that a potential amount of pumping is quite distinct from a historic amount of pumping. Historic pumping is needed to calibrate the model. A potential future increases in pumping is a concept that can be explored in predictive simulation of the model, but not in the calibration of the model.

SENSITIVITY ANALYSIS

Comment 4: Stakeholder claims that, based on the Kinney County Groundwater Conservation District Groundwater Management Plan (2008), the combined groundwater uses should be over 100,000 acre-feet per year. The stakeholder further states that the Pinto Springs would have been dry from 1985 to 2005, as indicated by the model sensitivity analysis, with a county-wide total pumping rate of approximately 100,000 acre-feet per year.

Response: First, the combined pumping rate, 100,000 acre-feet per year, includes existing and pending permits. Groundwater permits are not the same as groundwater uses. Thus, the combined pumping rate, 100,000 acre-feet per year, is not the groundwater use in Kinney County. As described in the model report, the sensitivity analysis is to test how sensitive the spring flows are to the potential groundwater pumping scenarios at Kinney County. The total pumping rates used in the sensitivity analysis has nothing to do with the groundwater use, either. In fact, the groundwater use data provided by the Kinney County Groundwater Conservation District indicates a much lower groundwater withdrawal than 100,000 acre-feet per year from 1985 to 2005 (see the figure under Response to Comment 3). In addition, the spring flows simulated by the calibrated model are consistent with the measured spring fluxes.

MODEL LIMITATIONS

No comments.

SUMMARY AND CONCLUSIONS

No comments.

REFERENCES

No comments.

APPENDIX A - Simulated Heads and Measured Heads at Wells

No comments.

APPENDIX B - Simulated Fluxes and Measured Fluxes at Springs

No comments.

LIST OF FIGURES

No comments.

LIST OF TABLES

No comments.

The following comments are not related to a specific section of the model report:

Comment 5: Stakeholder suggests that a glossary section should be added to include definitions of certain technical terms used in the model report to help non-technical readers to understand the technical issues presented in the model report.

Response: The model report will be revised to include a glossary section as Appendix C.

Comment 6: Stakeholder claims that the potential desired future condition (i.e. 77,000 acre-feet per year groundwater pumping based on the Kinney County regional groundwater model study) which may be adopted by the Kinney County Groundwater Conservation District cannot be achieved given the settlement combined with existing and pending uses.

Response: The desired future pumping rate, 77,000 acre-feet per year, at Kinney County was based on the model task run (GAM Task 10-027). This task model run indicates that the flow at the Las Moras Springs will be protected with a county-wide groundwater pumping rate of approximately 77,000 acre-feet per year. This value has nothing to do with settlement, existing or pending permits. Again, groundwater permit is not the same as groundwater use.