Groundwater Availability Model of West Texas Bolsons (Presidio and Redford) Aquifer

By Shirley C. Wade, Ph.D., P.G.,
and Marius Jigmond
Texas Water Development Board
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Groundwater Availability Model of West Texas Bolsons (Presidio and Redford) Aquifer

By Shirley C.Wade, Ph.D., P.G.,
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EXECUTIVE SUMMARY

As part of the Texas Water Development Board's Groundwater Availability Modeling Program we have completed a groundwater flow model of the Presidio and Redford Bolsons (of the West Texas Bolsons Aquifer). The model will provide a groundwater management tool for the Presidio County Underground Water Conservation District, Groundwater Management Area 4, and the Far West Texas Regional Water Planning Group.

We developed the model using the U.S. Geological Survey code MODFLOW-2000. The model includes three layers of quarter mile grid cells representing three units (from top to bottom): (1) river alluvium, (2) bolson deposits, and (3) underlying older rocks. Recharge to the aquifer is modeled using the MODFLOW Recharge Package as a percentage of rainfall with a cutoff minimum rainfall and a dampening factor to account for travel time in the unsaturated zone. We implemented the method using cell-by-cell distributed rainfall estimates for each stress period. Interaction with the Rio Grande, Rio Conchos and riparian evapotranspiration are modeled using the MODFLOW River Package. We modeled spring discharge using the MODFLOW Drain Package and we used the MODFLOW Well Package for groundwater pumping. Most of the model boundaries are assumed to be no-flow representing possible groundwater divides. We used a general head boundary along three reaches to simulate interaction with regional groundwater flow.

The MODFLOW Well Package contains groundwater withdrawal information for municipal, domestic, irrigation, and livestock use. We compiled groundwater use estimates in the United States for distributed and point sources and we estimated

groundwater use in Mexico based on an online permit database from the Mexico National Water Commission. Because of inherent uncertainty in pumping estimates, we adjusted pumping within plus or minus 50 percent during calibration for distributed pumping in the United States, point municipal pumping in the United States, and point pumping in Mexico. During calibration, parameters for recharge, hydraulic properties, and boundary conditions were adjusted to match over 500 water level targets collected from 1948 through 2008. Calibration was assisted using PEST: a model-independent, industry-standard, parameter estimation code. The standard head error for the calibration for all layers is 63 feet or 5.2 percent of the range in head elevations.

In the model, groundwater enters the aquifer system from two sources: recharge due to precipitation and regional inflow from the general head boundaries. Groundwater leaves the system via outflow as (in descending order of flow magnitude): net leakage to rivers and evapotranspiration, pumping, and discharge to springs. Modeled groundwater flow directions in layer one indicate the groundwater flow is principally southeastward along the Rio Grande. In layer two the modeled groundwater flows from the edges of the bolsons towards the river and southeastward along the river axis. At the center of the bolsons the groundwater flow is net upward toward the Rio Grande alluvium in layer one. In layer three on the eastern side of the river the flow is towards the center of the basin and on the northwestern portion of the model (north of Rio Conchos and west of Rio Grande) the flow is southeast toward the Rio Conchos. South of the Rio Conchos the flow is toward the Rio Grande. In the center of the basin the flow is generally upward into the overlying bolsons in layer two. A few diversions from the general trend are caused by local gradients due to pumping.

Sensitivity analysis results indicate that the model is most sensitive to recharge and horizontal hydraulic conductivity and it is moderately sensitive to pumping wells and river conductance.

Model users should consider several limitations when using this model. To a certain extent this model is interpretive rather than being a fully predictive model because of the limited historical stresses on the aquifer, limited amount of measured water levels, and limited hydraulic property data, particularly for the Mexico portion of the model. In addition, because of the lack of historical stresses, it was not possible to fully calibrate the storage coefficient. Also, the use of a constant transmissivity in the model requires that model users carefully evaluate whether it is appropriate to assume that water level drawdown is insignificant relative to the total aquifer thickness.

1.0 INTRODUCTION AND PURPOSE FOR GROUNDWATER FLOW MODEL

The Presidio and Redford Bolsons (of the West Texas Bolsons Aquifer) are important sources of drinking water in the southwest parts of Presidio County and the adjoining parts of the Mexican State of Chihuahua (Groat, 1972). The bolsons which underlie the Rio Grande valley on the southwest edge of Presidio County in Far West Texas (Figure 1) are also used for irrigation and livestock water supplies. Because of the low population density in the area, the bolsons have seen limited groundwater development in the past. However, Presidio County's population is projected to increase more than 50 percent by 2060 (TWDB, 2007) with an expected increase in groundwater development in the future. The Presidio County Underground Water Conservation District, Groundwater Management Area 4 (Figure 2), and the Far West Texas Regional Water Planning Group (Figure 3) all would benefit from having a modeling tool to help them evaluate the groundwater resources of the area. Groundwater models are useful tools for understanding aquifers and for predicting the effects of future water management strategies. As part of the Texas Water Development Board's Groundwater Availability Modeling Program we have developed a groundwater availability model for the Presidio and Redford Bolsons. The purpose of the program is to provide reliable and timely information on groundwater availability to the citizens of Texas to ensure adequate supplies or recognize inadequate supplies over a 50-year planning period. Our process includes stakeholder input and results in standardized, thoroughly documented and publicly available numerical groundwater flow models and support information.

Following standard modeling protocols (Anderson and Woessner, 1992), we first developed a conceptual model of the groundwater system by gathering data on the hydrology and geology of the study area and identifying hydrostratigraphic units and model boundaries for the groundwater flow system. From 2004 through 2005 water level and geochemistry data were collected from the study area. Data from earlier sampling and water level programs were also assembled and reviewed. In addition information from previous hydrogeology and water resource studies was reviewed to help define the water balance components such as recharge, evapotranspiration, spring discharge, groundwater pumping, and surface water-groundwater interactions. Groundwater flow properties derived from aquifer tests and other hydrologic and modeling studies of the area were also analyzed. Finally, historical water levels, springflows, and estimated stream baseflows were compiled to use as calibration targets. A report summarizing the conceptual model was released in 2011 (Wade and others, 2011). This report documents the final phase of the project; to construct and calibrate a numerical groundwater flow model based on the conceptual model and hydrogeology data.

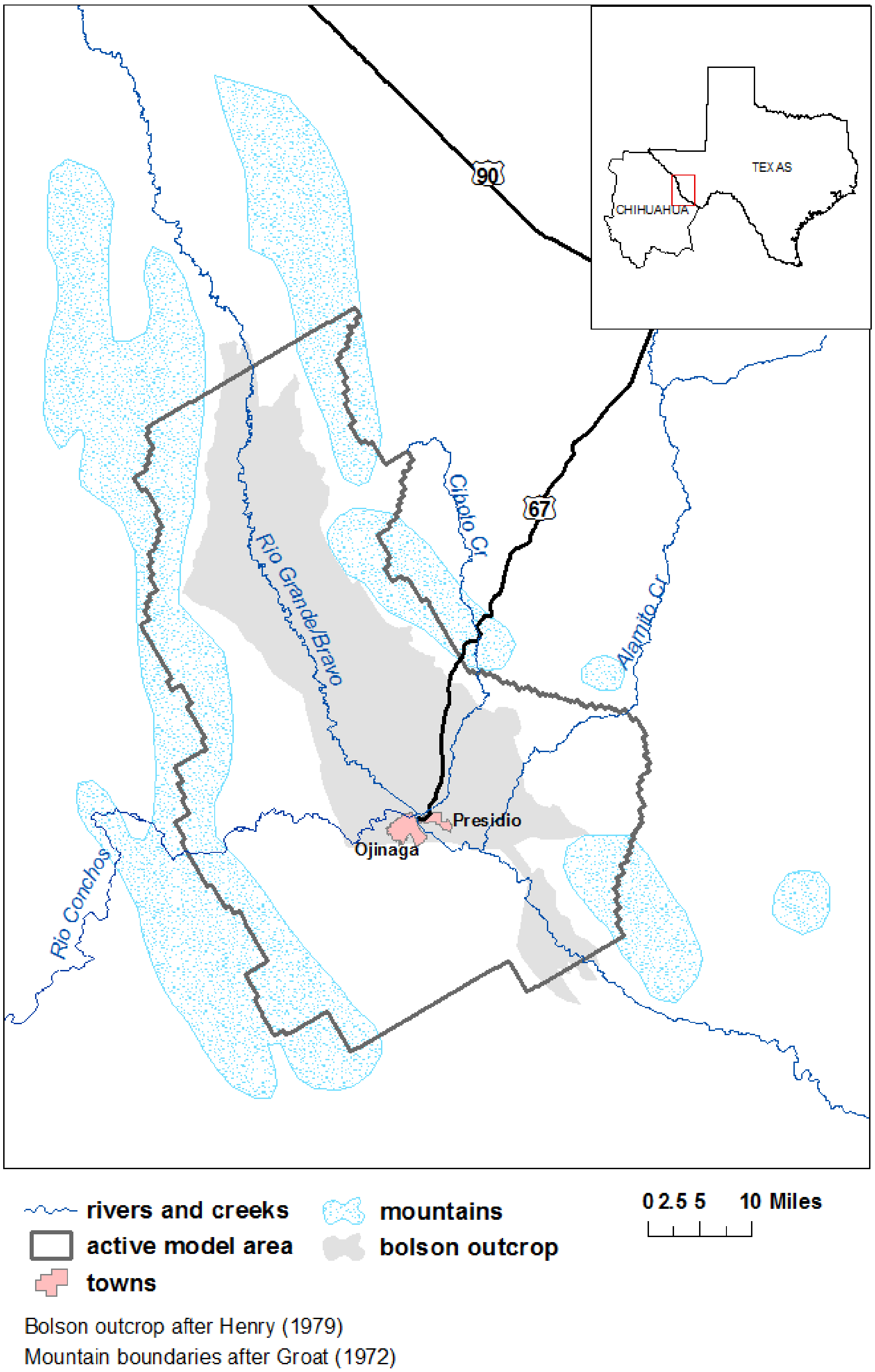

FIGURE 1 STUDY AREA

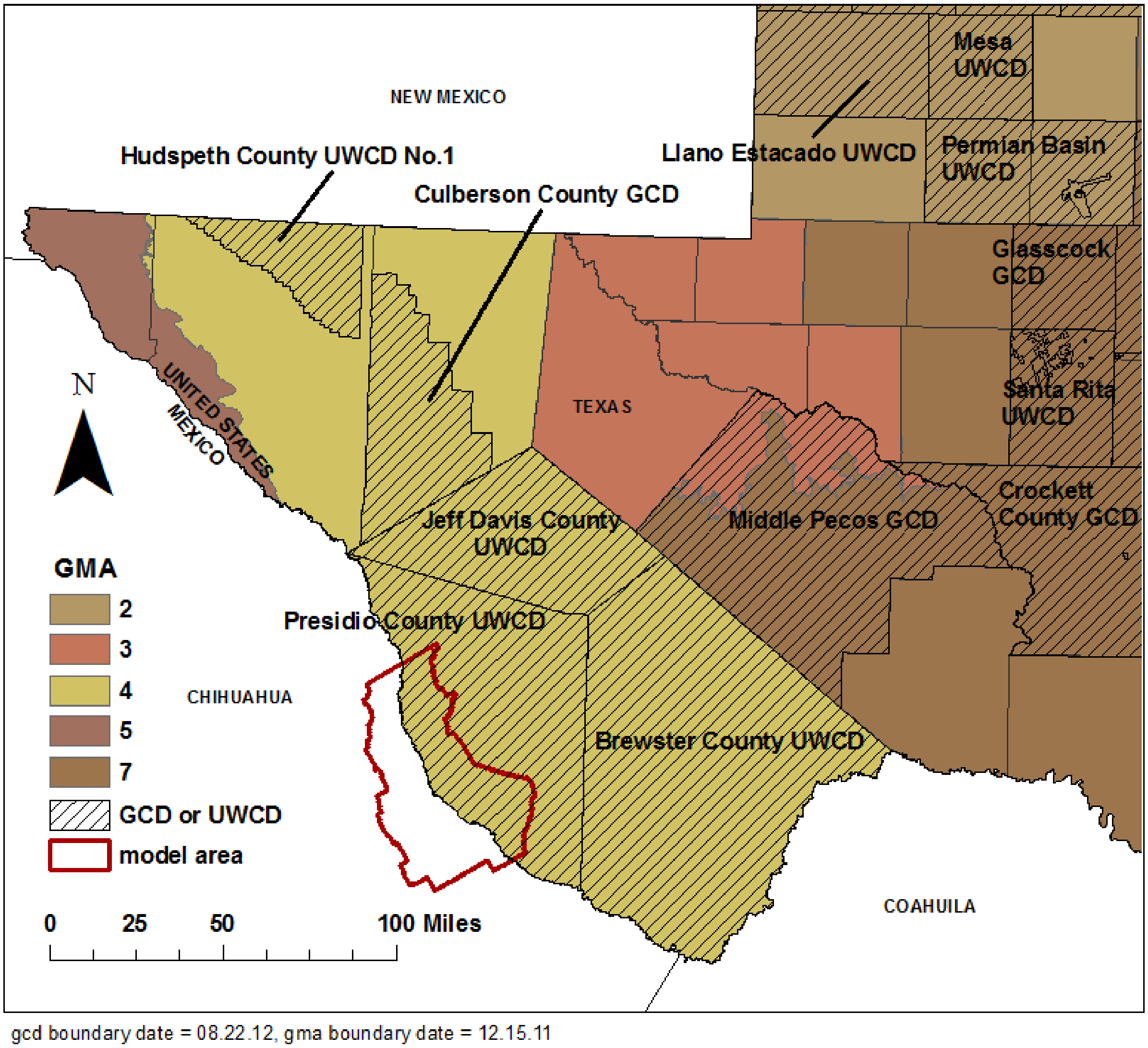

FIGURE 2 GROUNDWATER MANAGEMENT AREAS (GMA), GROUNDWATER CONSERVATION DISTRICTS (GCD), AND UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD) IN STUDY AREA.

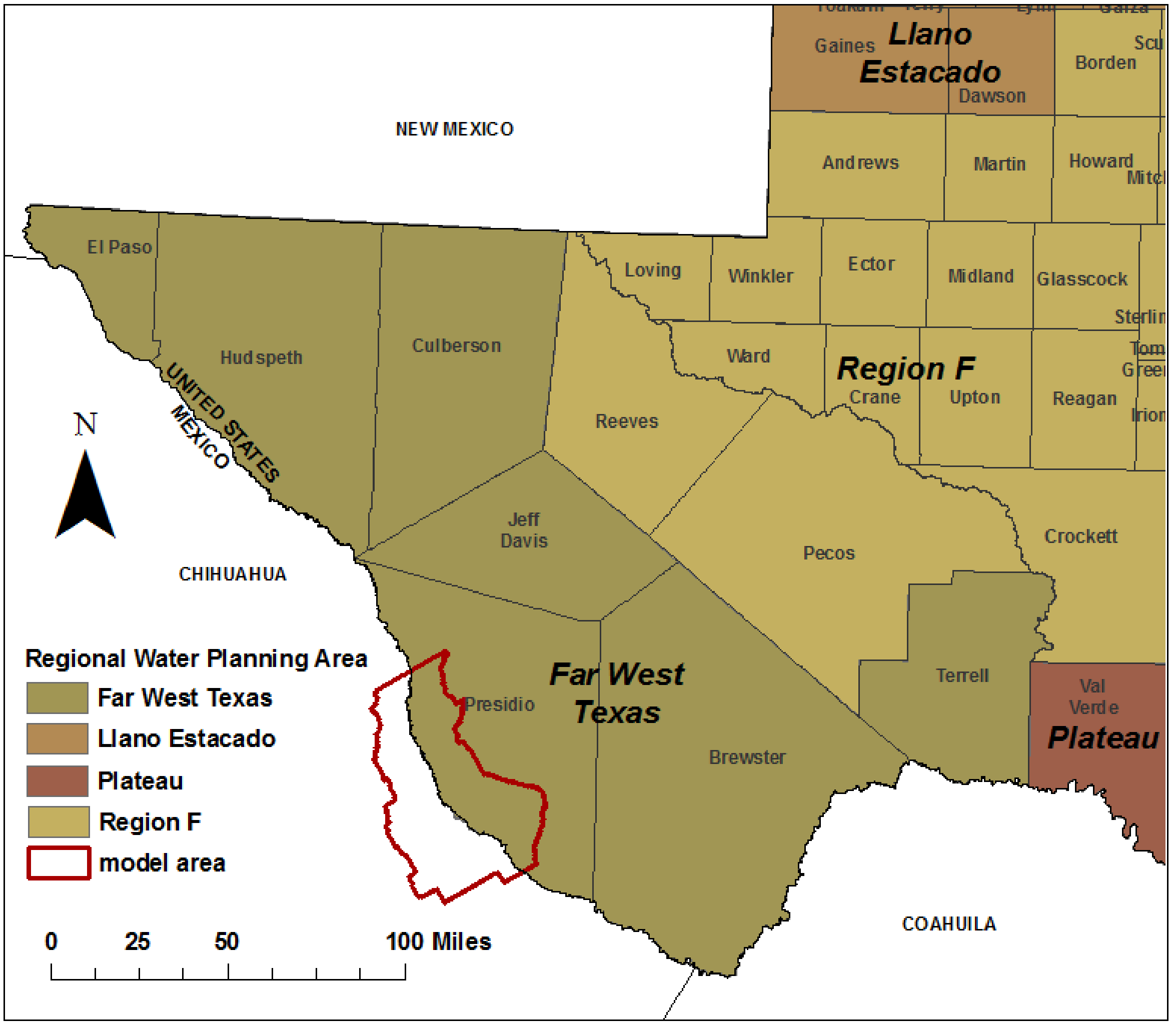

FIGURE 3 REGIONAL WATER PLANNING AREAS IN STUDY AREA.

2.0 MODEL OVERVIEW AND PACKAGES

In the model area, groundwater occurs in Quaternary-age Rio Grande alluvium and side-stream alluvium deposits, Quaternary-Tertiary age Presidio and Redford Bolsons, and in underlying and surrounding Tertiary igneous, and Cretaceous age rocks (Figure 4; Wade and others, 2011). The igneous and Cretaceous and Permian-age rocks are included in the model to serve as a lower boundary condition and also because we believe they indirectly provide recharge derived from precipitation via the higher elevations of the drainage basin through underflow to the bolsons. The Igneous Aquifer is an important aquifer in large parts of Presidio County and that aquifer is modeled explicitly in the West Texas Bolsons and Igneous Groundwater Availability Model (Beach and others, 2004).

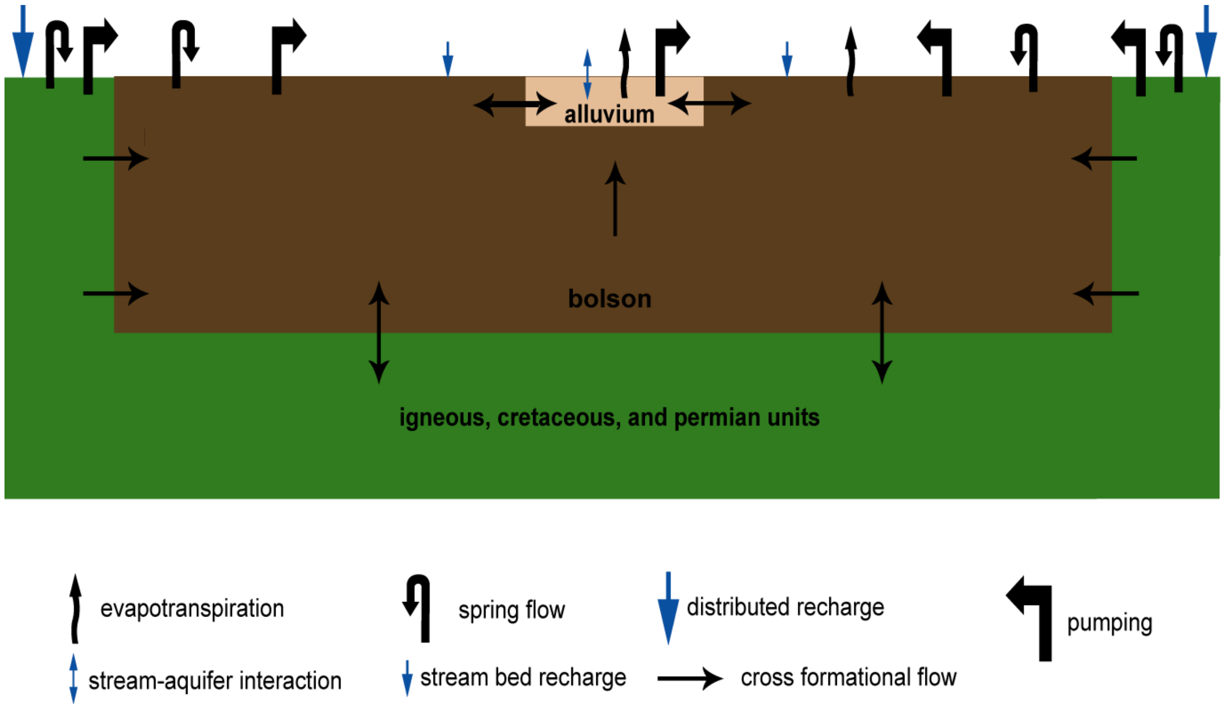

FIGURE 4 CONCEPTUAL MODEL DIAGRAM (WADE AND OTHERS, 2011).

We developed the model using MODFLOW-2000 (Harbaugh and others, 2000) with three layers of quarter mile grid cells (Figures 5, 6, and 7). The top model layer represents the Rio Grande alluvium. The second layer consists of the Presidio and Redford Bolsons, and the bottom layer represents the Tertiary igneous and Cretaceous and Permian-age rocks beneath and surrounding the bolsons. The grid has 340 rows and 200 columns and is rotated 30 degrees counter clockwise so that the model rows generally correspond to the principal groundwater flow direction. The model coordinate system is based on an Albers Equal Area projection with parameters shown in Table 1. The x and y coordinates of the centroid of the upper leftmost grid cell in Row 1, Column 1 is 3,278,645.25 feet and 19,280,530.00 feet respectively.

Most of the model boundaries (Figure 8) were selected to coincide with topographic and inferred groundwater flow divides and are assigned as no-flow boundaries in the model. The northwest and southeast model boundaries, perpendicular to the axis of the Rio Grande Valley, are regional groundwater flow boundaries and are modeled using the General Head Package (McDonald and Harbaugh, 1988) in all layers (Figure 8). The portion of the eastern boundary that crosses the Alamito Creek watershed is also a regional flow boundary in the model and is also modeled with the General Head Package.

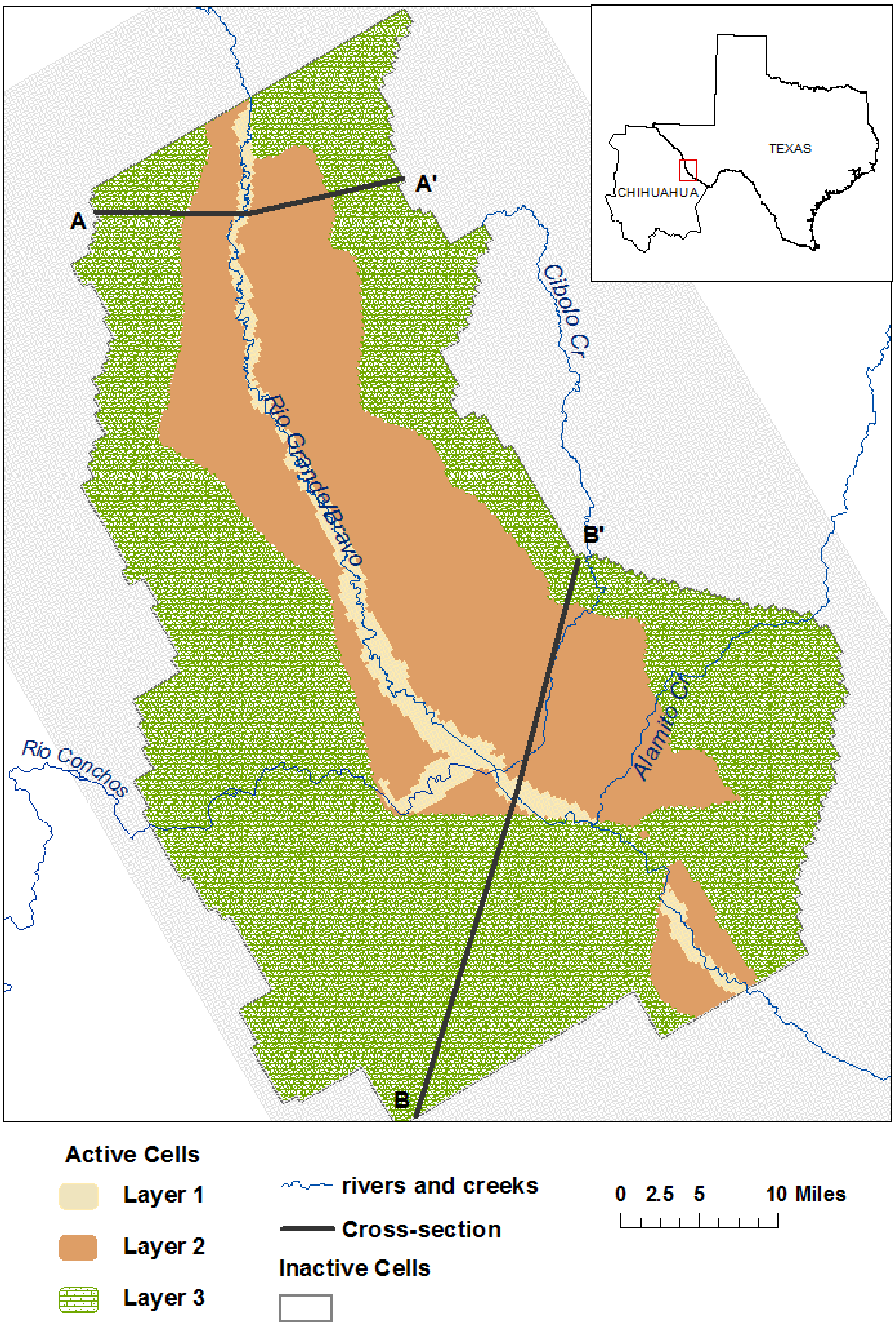

FIGURE 5 MODEL GRID, HYDROGEOLOGIC UNITS, INACTIVE AREAS, AND LOCATIONS OF CROSS-SECTIONS.

TABLE 1 MODEL COORDINATE SYSTEM AND PARAMETERS.

Projection	Albers equal area conic
Datum	North American datum 1983
Spheroid	Geodetic reference system 1980
Longitude of origin	-100.00 degrees west
Latitude of origin	31.25 degrees north
Lower standard parallel	27.50 degrees north
Upper standard parallel	35.00 degrees north
False easting	4,921,250.00000 feet
False northing	19,685,000.00000 feet
Unit of linear measure	U.S. survey feet

Our conceptual model is that precipitation enters the bolson via diffuse recharge in the mountain areas surrounding the bolsons and through the permeable ephemeral stream deposits during high flow events (Wade and other, 2011). We are representing both inflows using the MODFLOW Recharge Package. We are using the MODFLOW River Package to model net groundwater-surface water interaction with the Rio Grande and Rio Conchos and riparian evapotranspiration. We are modeling spring discharge using the MODFLOW Drain Package.

The Presidio and Redford Bolsons groundwater availability model input (Table 2) and output packages (Table 3) are included in a name file (prbl.nam). The MODFLOW-2000 code initiates a model run by calling this name file.

TABLE 2 SUMMARY OF MODEL INPUT PACKAGES.

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

TABLE 3 SUMMARY OF MODEL OUTPUT FILES.

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

2.1 Basic (BAS6) Package

The Basic Package specifies the status of each cell (active or inactive), the assigned head for inactive cells (-9,999 feet), and specifications of starting heads. Inactive cells were used for areas where a specific hydrogeologic unit was absent in the related numerical model layer (Figures 5, 6, and 7). For instance, we set model cells of model layer 1 (Figure 5) in most of the model area as inactive because the Rio

Grande alluvium is only approximately two miles wide over the length of the model. Layer 2 (Figure 5) which represents the bolson deposits, covers about one-half of the model area and where the bolson deposits are not present, layer 2 cells are inactive.

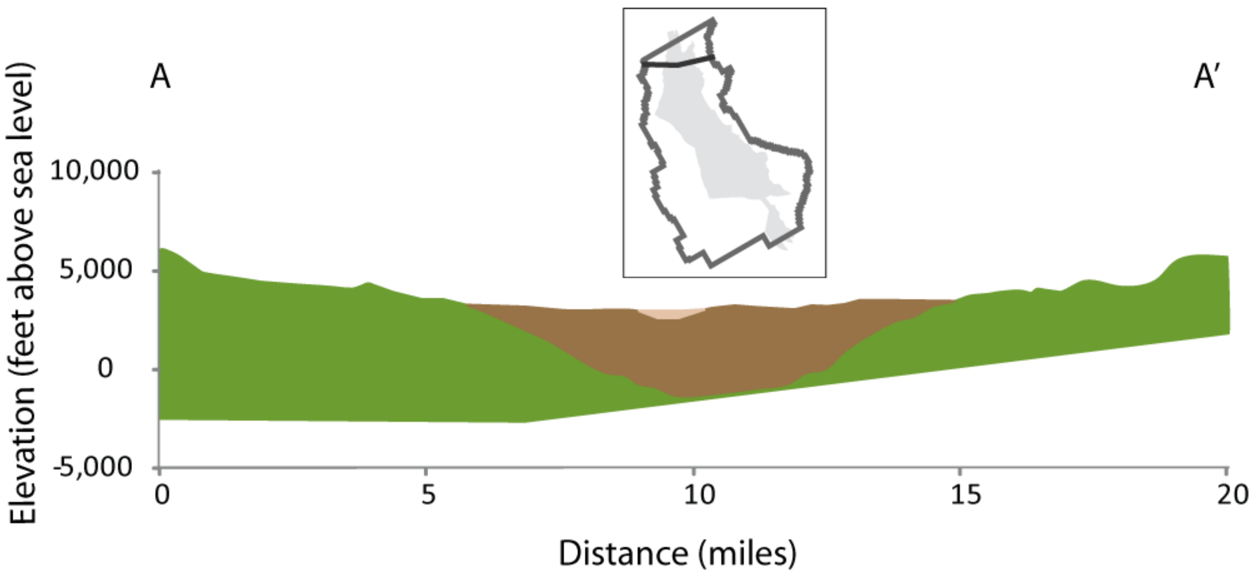

FIGURE 6 MODEL CROSS-SECTION A-A' THROUGH NORTHERN PART OF MODEL (SEE FIGURE 5 FOR LOCATION).

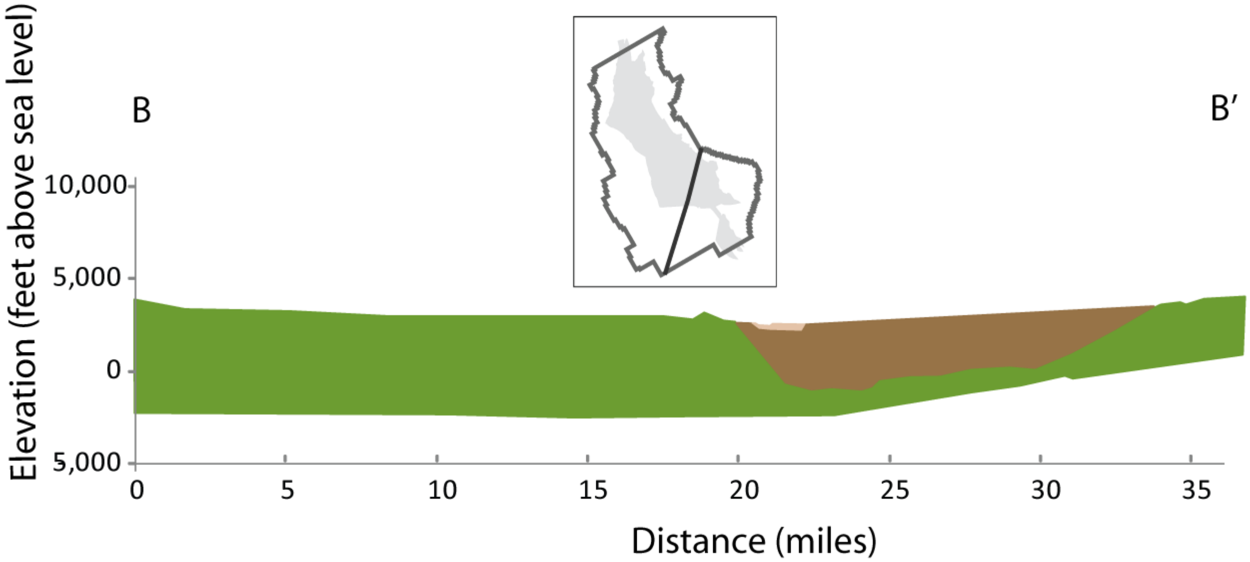

FIGURE 7 MODEL CROSS-SECTION B-B' THROUGH SOUTHERN PART OF MODEL (SEE FIGURE 5 FOR LOCATION).

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 elevation of model layer 1, bottom elevations of all model layers, and length and type of each stress period.

The MODFLOW-2000 model for the Presidio and Redford Bolsons contains three layers with 340 rows and 200 columns per layer. The row and column spacing is 1,320 feet (one quarter mile). The active model domain covers an area of 1,920 square miles with the bolsons located at the center (Figure 5). The three model layers represent, from top to bottom, the Rio Grande alluvium, the Presidio and Redford Bolsons (Figures 6 and 7), and the underlying older igneous and sedimentary rocks (Figures 6 and 7). We defined the layer surfaces based on (1) land surface elevation from a digital elevation model (DEM), (2) extent of the Presidio and Redford Bolsons mapped by Henry (1979), and (3) a bolson thickness map (Wade and others, 2011) created for this study from well logs and geophysical surveys supplemented with a geologic structure map (Henry, 1979).

The thickness of the Rio Grande alluvium layer was set at 100 feet except where the bolson deposits thin towards the edge of the basin. The base of layer 2 was assigned as land surface elevation (DEM) minus the estimated bolson thickness. Most active layer 1 and 2 model cells in those areas were assigned a minimum thickness of 50 feet (Wade and others, 2011). One exception is a layer 1 model cell with a thickness of 34 feet on the northern edge of the model.

The elevation of the base of the model was set at 2,500 below sea level from the western edge to approximately the center of the basin (Figures 6 and 7). The model area for the groundwater availability model for the Igneous Aquifer and parts of the West Texas Bolsons (Beach and others, 2004) is directly east of the study area for this model and the two models share a small overlap area. To be as consistent as possible between the two models we adjusted the base of layer 3 of the Presidio and Redford Bolsons model from the center of the basin to the eastern edge to allow a smooth transition from 2,500 feet below sea level to the elevation of the base of the groundwater availability model for the Igneous Aquifer and parts of the West Texas Bolsons. We set the minimum thickness for layer 3 model cells at 100 feet.

The temporal discretization (Table 4) includes one steady-state stress period (stress period 1) and sixty-three transient stress periods (stress periods 2 through 64). Stress periods one, two, and three don’t represent a particular time period, they are mainly for establishing reasonable starting conditions for the transient calibration. Stress periods 4 through 64 are annual and represent 1948 through 2008.

TABLE 4 STRESS PERIOD LENGTH AND TIME PERIOD

Stress Period	Time Period	Length (days)	Time Steps
1	Steady-state[1]	3652.50	1
2	1937 – 1946[1]	3652.50	10
3	1947[1]	365.250	10
4	1948	365.250	1
5	1949	365.250	1
6	1950	365.250	1
7	1951	365.250	1
8	1952	365.250	1
9	1953	365.250	1
10	1954	365.250	1
11	1955	365.250	1
12	1956	365.250	1
13	1957	365.250	1
14	1958	365.250	1
15	1959	365.250	1
16	1960	365.250	1
17	1961	365.250	1
18	1962	365.250	1
19	1963	365.250	1

[1] Stress periods 1, 2, and 3 are meant to establish starting conditions for the transient

Stress Period	Time Period	Length (days)	Time Steps
20	1964	365.250	1
21	1965	365.250	1
22	1966	365.250	1
23	1967	365.250	1
24	1968	365.250	1
25	1969	365.250	1
26	1970	365.250	1
27	1971	365.250	1
28	1972	365.250	1
29	1973	365.250	1
30	1974	365.250	1
31	1975	365.250	1
32	1976	365.250	1
33	1977	365.250	1
34	1978	365.250	1
35	1979	365.250	1
36	1980	365.250	1
37	1981	365.250	1
38	1982	365.250	1
39	1983	365.250	1
40	1984	365.250	1
41	1985	365.250	1

Stress Period	Time Period	Length (days)	Time Steps
42	1986	365.250	1
43	1987	365.250	1
44	1988	365.250	1
45	1989	365.250	1
46	1990	365.250	1
47	1991	365.250	1
48	1992	365.250	1
49	1993	365.250	1
50	1994	365.250	1
51	1995	365.250	1
52	1996	365.250	1
53	1997	365.250	1
54	1998	365.250	1
55	1999	365.250	1
56	2000	365.250	1
57	2001	365.250	1
58	2002	365.250	1
59	2003	365.250	1
60	2004	365.250	1
61	2005	365.250	1
62	2006	365.250	1
63	2007	365.250	1

Stress Period	Time Period	Length (days)	Time Steps
64	2008	365.250	1

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, horizontal and vertical anisotropy, and specific storage. In this model, the layer type was set to zero for all layers, which assumes a constant transmissivity throughout the simulation. This assumption is acceptable as long as water level drawdowns are a small fraction of the total saturated thickness. 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. We calibrated the effective storage coefficient S and back-calculated specific storage for the MODFLOW Layer-Property Flow Package based on the layer thickness.

The anisotropy for horizontal hydraulic conductivity in the Layer-Property Flow Package is the ratio of hydraulic conductivity along columns (y-direction) to hydraulic conductivity along rows (x-direction) and is based only on the hydraulic conductivity along rows. However, for the model we calibrated the vertical anisotropy (Table 5) based on an average of the row and column hydraulic conductivity.

We assigned hydraulic conductivity values based on zones (Table 5). At the beginning of model calibration we assigned one zone for each layer. During calibration two additional zones were defined in model layer 2 and one of those zones was extended to model layer 3 in a small area. The additional zones (4 and 5) were based on the distribution of water level residuals and location within the basin. Specific details about the calibration are provided in the Model Calibration and Results Section below. We also assigned and calibrated storage coefficient and vertical anisotropy according to the same zones as the horizontal hydraulic conductivity (Table 5).

TABLE 5 CALIBRATED HYDRAULIC PROPERTY VALUES FOR ZONES 1 THROUGH 5.

Property	Zone	Value
Horizontal Hydraulic Conductivity	1	100 feet/day
	2	6.4×10^{-2} feet/day
	3	0.1509 feet/day
	4	4.131 feet/day
	5	0.1435 feet/day
Horizontal Anisotropy	1	0.5
	2	0.5
	3	2
	4	2
	5	2
Vertical Anisotropy	1	1.333×10^{6}
	2	6,596
	3	6.667
	4	6.667
	5	6.667
Storage Coefficient	1	0.1
	2	$5. \times 10^{-3}$
	3	1.0×10^{-4}
	4	$5. \times 10^{-3}$
	5	$5. \times 10^{-3}$

2.4 Well (WEL) Package

The MODFLOW Well Package contains groundwater withdrawal information for municipal, domestic, irrigation, and livestock use. We compiled groundwater use estimates in the United States from the TWDB Water Use Survey, as well as several historic references (Davis and Leggatt, 1965; Broadhurst and others, 1948; and Groat, 1972). We estimated groundwater use in Mexico based on an online permit database from the Mexico National Water Commission (Comisión Nacional del Agua (CONAGUA), 2007).

The United States municipal and estimated Mexico uses were assigned to the model based on specific point locations and the United States domestic, irrigation, and livestock pumping was distributed in zones according to population density and land use information. Greater detail on the assumptions and development of the pumping file are given in the conceptual model report for this study (Wade and others, 2011).

Because of inherent uncertainty in pumping estimates, pumping was adjusted by category within plus or minus 50 percent during calibration. The three pumping categories include (1) distributed pumping in the United States, (2) point municipal pumping in the United States, and (3) point pumping in Mexico based on permit location. The calibrated multipliers for each category are 1.5, 0.8, and 1.5 for the distributed United States wells, point United States wells, and point Mexico wells respectively. Total modeled pumping ranges from approximately 12,400 acre-feet per year in 1964 to approximately 18,300 acre-feet per year in 2005 (Table 6).

TABLE 6 SUMMARY OF SIMULATED PUMPING RATES IN ACRE-FEET PER YEAR.

Year	Total estimated pumping rate in Mexico	Total estimated pumping rate in Presidio County	Total estimated pumping rate for whole model
Steady State	14,827	2,722	17,549
1948	14,827	2,722	17,549
1949	14,172	2,704	16,876
1950	13,516	2,687	16,203
1951	13,170	2,676	15,845
1952	12,822	2,665	15,486
1953	12,474	2,654	15,127
1954	12,127	2,642	14,769
1955	11,779	2,631	14,410
1956	11,431	2,620	14,051
1957	11,084	2,609	13,693
1958	10,736	2,598	13,334
1959	10,389	2,606	12,995
1960	10,041	2,638	12,678
1961	9,929	2,684	12,613
1962	9,815	2,731	12,546
1963	9,702	2,778	12,480
1964	9,588	2,825	12,413
1965	9,477	2,970	12,447
1966	9,364	3,115	12,480
1967	9,252	3,261	12,512

Year	Total estimated pumping rate in Mexico	Total estimated pumping rate in Presidio County	Total estimated pumping rate for whole model
1968	9,139	3,406	12,545
1969	9,028	3,551	12,579
1970	8,916	3,833	12,750
1971	8,982	4,119	13,101
1972	9,049	4,404	13,453
1973	9,113	4,690	13,803
1974	9,179	4,906	14,085
1975	9,243	4,911	14,154
1976	9,307	4,915	14,223
1977	9,371	4,996	14,367
1978	9,435	5,076	14,511
1979	9,499	5,156	14,656
1980	9,558	4,597	14,155
1981	9,818	4,049	13,867
1982	10,080	3,547	13,627
1983	10,341	3,032	13,372
1984	10,601	2,466	13,067
1985	10,869	2,605	13,473
1986	11,135	2,640	13,775
1987	11,401	2,701	14,103
1988	11,669	2,871	14,540

Year	Total estimated pumping rate in Mexico	Total estimated pumping rate in Presidio County	Total estimated pumping rate for whole model
1989	11,935	3,144	15,080
1990	12,200	2,849	15,048
1991	12,319	2,576	14,895
1992	12,438	2,292	14,730
1993	12,559	2,058	14,616
1994	12,678	1,908	14,586
1995	12,802	2,035	14,837
1996	12,924	1,987	14,911
1997	13,047	2,028	15,075
1998	13,171	2,244	15,415
1999	13,293	2,396	15,690
2000	13,417	2,530	15,947
2001	13,454	2,825	16,278
2002	13,490	3,072	16,563
2003	13,527	3,286	16,813
2004	13,562	3,305	16,866
2005	13,609	4,680	18,289
2006	13,641	4,525	18,167
2007	13,663	3,165	16,828
2008	13,695	3,042	16,737

2.5 Drain (DRN) Package

The MODFLOW-2000 Drain Package was used to simulate groundwater discharge at forty-three springs (Figure 8). Both hot and cold springs occur in the study area. In the study area springs qualify as thermal springs if the water is greater than 30 ºC (Wade and others, 2011). The thermal springs are likely to be part of a deeper flow system; however, some of the thermal springs may mix with shallow groundwater so they are included in the model. For the thermal springs the flow calibration target was reduced by an estimated thermal fraction. We estimated the thermal fraction based on an estimated maximum thermal reservoir temperature of 180 ºC (Henry, 1979). We calculated the fraction of thermal springflow using the ratio of the difference between the spring temperature and 30 ºC (thermal cutoff temperature) to the difference between the thermal reservoir temperature and 30 ºC.

The drain elevation for the drain cells were selected as land surface elevation. The conductance values of the drain cells were adjusted by layer during the model calibration to match the simulated to the estimated total discharge rates for the layer. The same values of elevation and conductance were used for each stress period (Table 7).

TABLE 7 SUMMARY OF DRAIN PROPERTIES AND FLOW TARGETS.

Layer	Conductance (feet^2 per day)	Drain elevation (feet above mean sea level)	Estimated total average discharge (acre-feet per year)
1	500	2,555 – 2,822	37
2	5,000	2,767 – 3,553	1,256
3	500	2,557 – 5,413	933

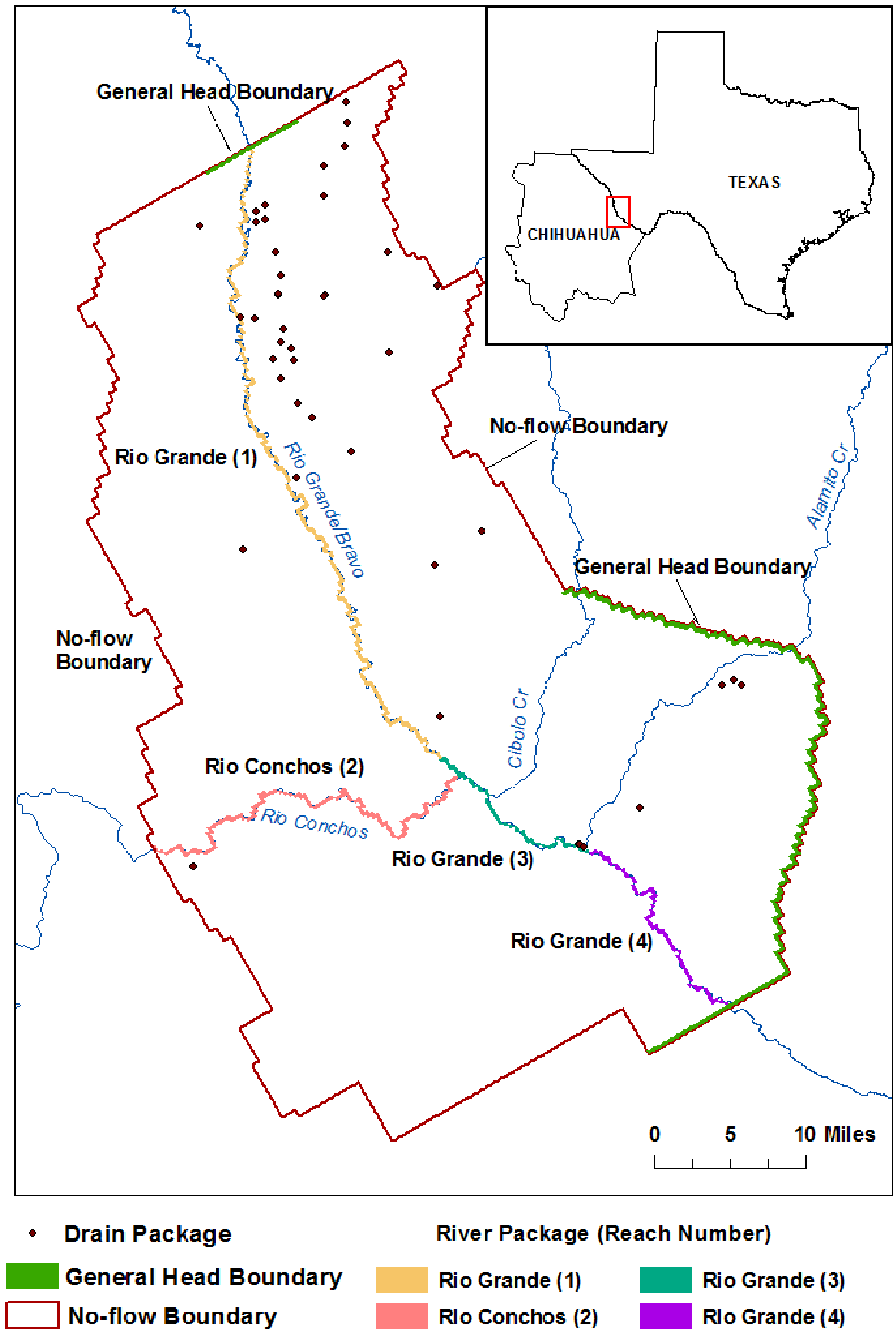

FIGURE 8 LOCATION OF RIVER, GENERAL HEAD BOUNDARIES, AND DRAIN CELLS.

2.6 River (RIV) Package

The River Package was used to simulate the interaction of groundwater with the Rio Grande and Rio Conchos (Figure 8). The River Package was also used to simulate the riparian groundwater evapotranspiration discharge. The river bottom at a cell was set as 15 feet below the cell top (digital elevation model (DEM) value) for the cell. Initially, the river stage was assumed ten feet above the river bottoms. During model calibration, river stage and conductance (by reach) were adjusted (Table 8). The calibrated stage is seven feet above the bottom of the river for each river cell. The flux target for reach 1 (Table 8) is the estimated net river gain/loss and evapotranspiration discharge (Wade and others, 2011). Flux targets were not estimated for reaches 2, 3, and 4 because stream gauge data were not available. The calibration results and river flow budget through time are presented in the Model Calibration and Results Section below (Section 3).

TABLE 8 SUMMARY OF SIMULATED RIVER CONDUCTANCE VALUES.

Reach number	Conductance (feet^{2}per day)	Reach Description	Estimated Flux Target (acre/feet per year)
1	3,335	Rio Grande (northwest boundary to north of Presidio)	34,796
2	1,000	Rio Conchos	NA
3	100,000	Rio Grande (North of Presidio to Alamito Creek)	NA
4	100,000	Rio Grande (Alamito Creek to southeast boundary)	NA

2.7 General Head Boundary (GHB) Package

We are using the General Head Boundary (GHB) Package to represent regional groundwater flow into and out of the model area. The General Head Boundary Package allows 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 the Presidio and Redford Bolsons model, the general head boundary was used at active cells in all model layers on the northwest and southeast model boundaries, perpendicular to the axis of the Rio Grande Valley, and along the portion of the eastern boundary that crosses the Alamito Creek watershed (Figure 8).

The head values along the northwest and southeast cross-river boundaries are based on the estimated water level surface. The general head boundary across Alamito Creek was selected to coincide with the location of the 3,500 feet estimated equipotential line. That head value was adjusted slightly during model calibration. The conductance values for the boundary cells were also adjusted during model calibration (Table 9).

TABLE 9 SUMMARY OF GENERAL HEAD CONDUCTANCE VALUES .

Reach Number	Layer	Conductance (feet^{2}per day)	Reach Description
1	2	500	Northwest regional flow boundary
2	3	1,000	Northwest regional flow boundary
3	1 and 2	500	Southeast regional flow boundary
4	3	10,000	Southeast regional flow boundary
5	3	1,000	Alamito Creek watershed regional flow boundary

2.8 Recharge (RCH) Package

The Recharge Package was used to simulate inflow to groundwater due to precipitation on the outcrop areas. The Recharge Package contains recharge rates (feet per day) on a cell-by-cell basis which are applied to the uppermost active cells during simulations.

The Recharge Package was constructed based on a modified version of the algorithm developed by Maxey and Eakin (1949). A pre-processor written in Perl, a scripting language, was used to implement this algorithm. The pre-processor reads in cell-by-cell distributed rainfall data for each stress period, a dampening factor, a recharge multiplication factor, and a threshold minimum rainfall amount. The rainfall data is from the Parameter-Elevation Regressions Independent Slopes Model (PRISM; 2004 and 2010) data supplemented with coarser resolution data from Mexico (Universidad Nacional Autonoma de Mexico, 2010) where the Parameter-Elevation Regressions Independent Slopes Model data were absent. The pre-processor then (1) calculates dampened rainfall (Equation 2.1), (2) calculates recharge (Equation 2.2), and (3) writes a MODFLOW Recharge Package file.

$$\text{Rainfall} = \begin{cases} (\text{AAP} \times \text{damp}) + (1 - \text{damp})\text{x PYR}, & \text{PYR} > \text{Minrain} \\ 0, & \text{PYR} < \text{Minrain} \end{cases} \qquad (2.1)$$

where:

Rainfall = annual precipitation for specific stress period
AAP = average annual precipitation (from PRISM)
PYR = PRISM yearly rainfall
damp = overall dampening factor
Minrain = threshold rainfall below which recharge is zero

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

where:

Recharge = recharge for each model cell in feet per day
Rainfall = annual precipitation for specific stress period (eqn. 2.1)
rfac = fraction of rainfall becoming recharge

The dampening factor accounts for lag time associated with travel time in the unsaturated zone. A dampening factor of one applies average rainfall every stress period and a dampening factor of zero results in no adjustment to annual rainfall amounts. The threshold minimum rainfall (Minrain), the dampening factor (damp) and the fraction of rainfall becoming recharge (rfac) were adjusted during calibration (Table 10).

TABLE 10 SUMMARY OF RECHARGE PARAMETERS.

Parameter	Value
Threshold minimum rainfall	12 inches per year
Recharge factor	0.10
Dampening factor layer 1	1
Dampening factor layer 2	0.4065
Dampening factor layer 3	1

2.9 Output Control (OC) Package

The MODFLOW-2000 Output Control Package specifies when to save head, drawdown, and water 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 write head, drawdown, and budget information at the end of each stress period. Because the first three stress periods do not necessarily represent a particular period of time, the output control file specifies that drawdown be referenced to stress period 4 (1948).

2.10 Geometric Multigrid (GMG) Solver Package

We are using the Geometric Multigrid (GMG) solver developed by Wilson and Naff (2004) to solve the finite difference equations that simulate groundwater flow in the model. We have specified the solver to use 0.001 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

The calibration of a groundwater model involves adjusting hydraulic properties and boundary conditions in the model, within a reasonable range, to match the simulated water levels and flows to measured water levels and flows. A calibrated groundwater flow model is a tool that can be used to test or predict future pumping and recharge conditions. A model which is calibrated over a range of historical conditions can improve reliability of the prediction.

We calibrated the Presidio and Redford Bolsons groundwater availability model to measured water levels at wells, estimates of average total spring flow, average net evapotranspiration, and estimated groundwater-surface water interaction. We adjusted hydraulic conductivity, recharge, and boundary conditions (both head and conductance) using parameter estimation (PEST), an industry-standard inverse modeling software package (Watermark Numerical Computing, 2004), and by trial-and-error. We also adjusted pumping discharge within plus or minus 50 percent because of some uncertainty in the data. Because of the limited amount of transient water level data we did not calibrate storativity. Instead we assumed reasonable values for storativity for each layer and used layer thickness to calculate specific storage values.

3.1 Calibration Procedure

Because of the large topographic relief in the model area the difference in elevation within one model grid cell could easily exceed the model layer thickness. For this reason we used the layer 1 cell top elevation (average elevation from the digital elevation model (DEM)) as the reference point for the water level targets rather than the reported elevation of the well head.

We began calibration with 592 water level targets at 281 wells. During the initial calibration runs water levels in five wells at high elevations near the edges of the basin dominated the calibration. In other words, in order to match those 5 higher elevation heads, water levels at most of the other targets were too high and hydraulic conductivity values were very low. We investigated the 5 target wells and hypothesized that they may be part of a different groundwater flow system or in a perched system. Therefore we excluded the 5 wells from the calibration procedure. The final calibration included 587 water level targets at 276 wells (Figures 9, 10, and 11).

Spring discharge targets included average total spring discharge for each layer (Table 7). We initially assigned weights to the drain targets based on the ratio of the flux values in acre-feet per year to head values so that the head and flux targets would receive approximately equal consideration in the calibration. However, we noticed that the PEST runs would match the flux targets very well at the expense of the water level targets and since we have much more confidence in the water level data we lowered the flux target weights for the remainder of the calibration runs.

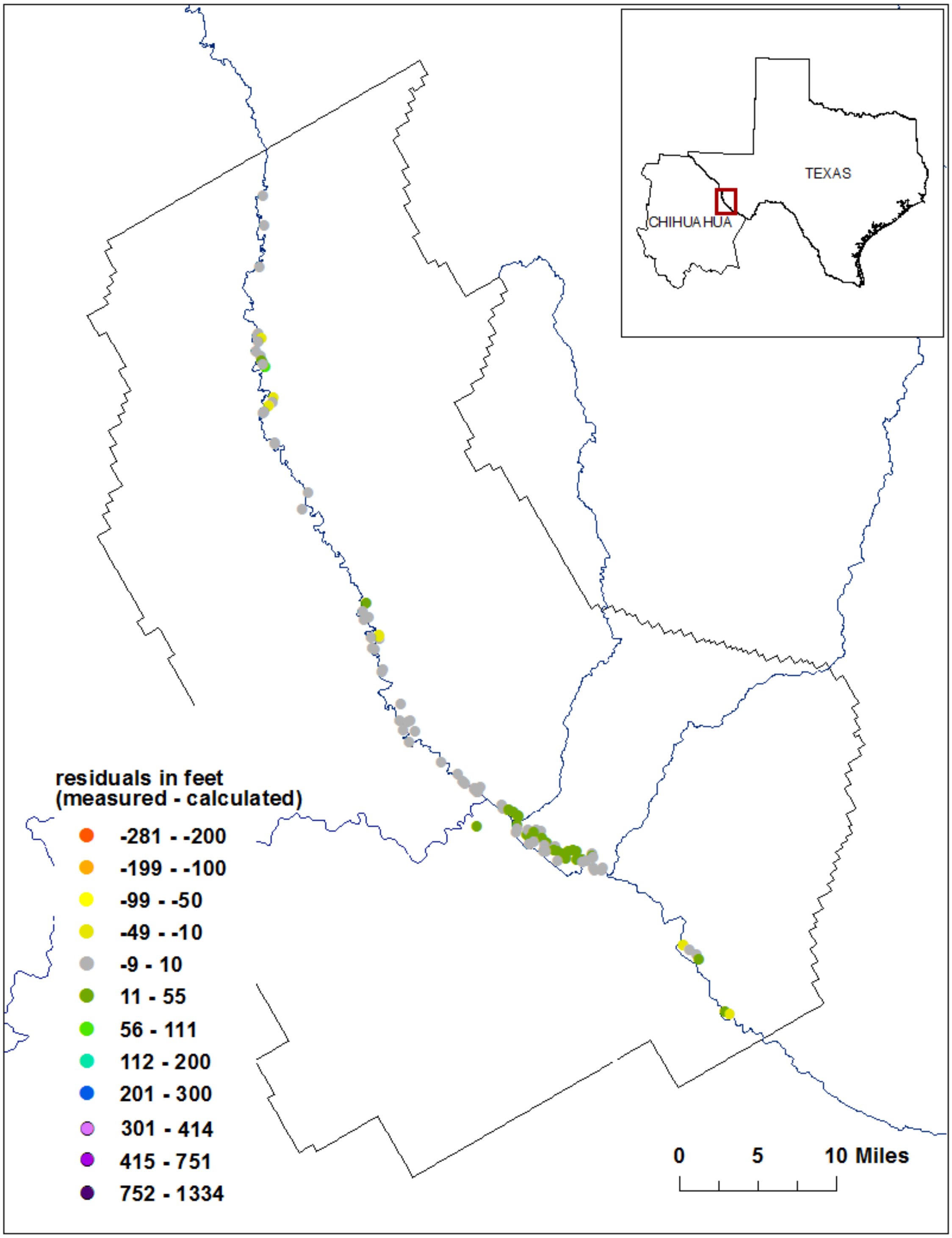

FIGURE 9 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 1. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.

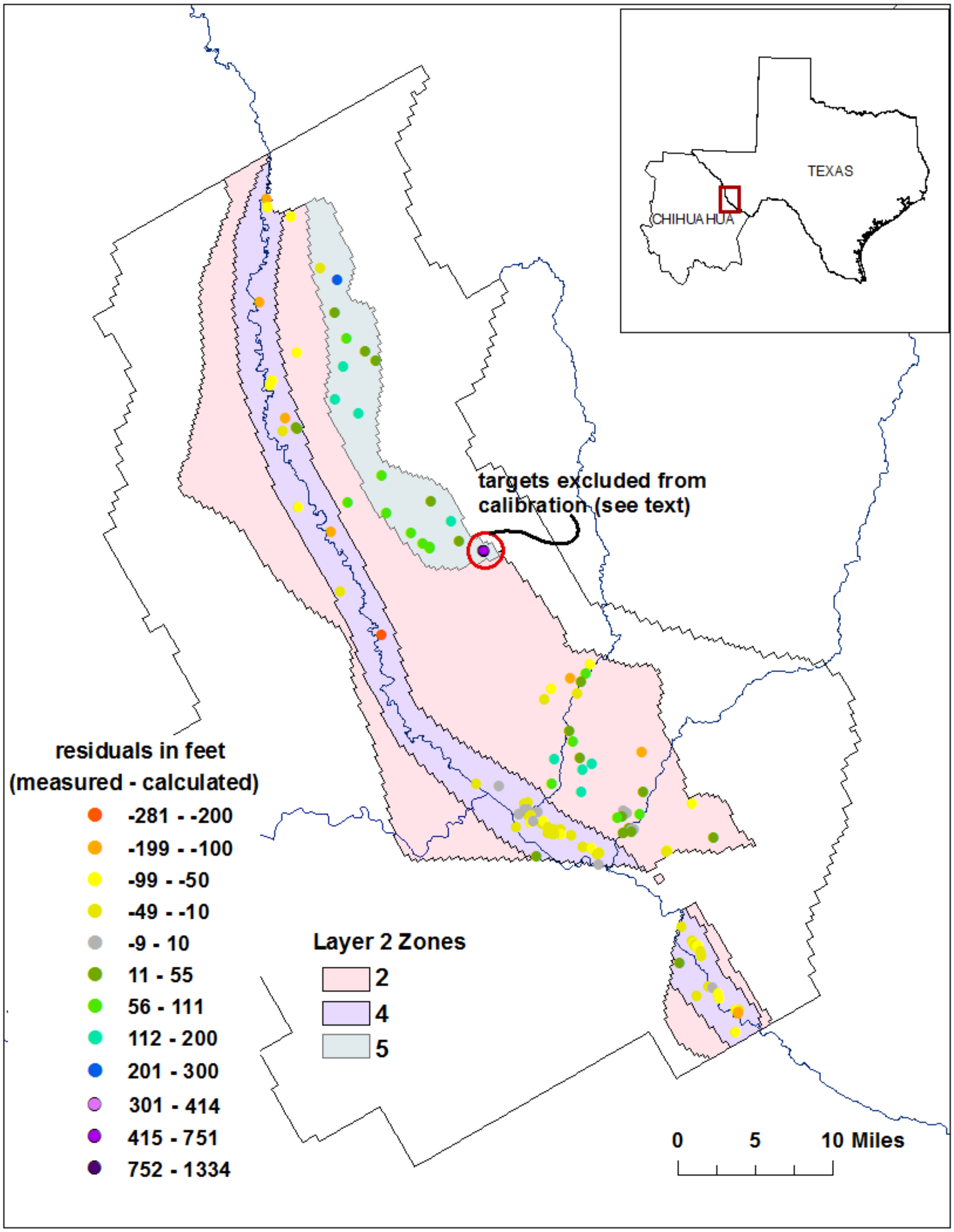

FIGURE 10 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 2. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.

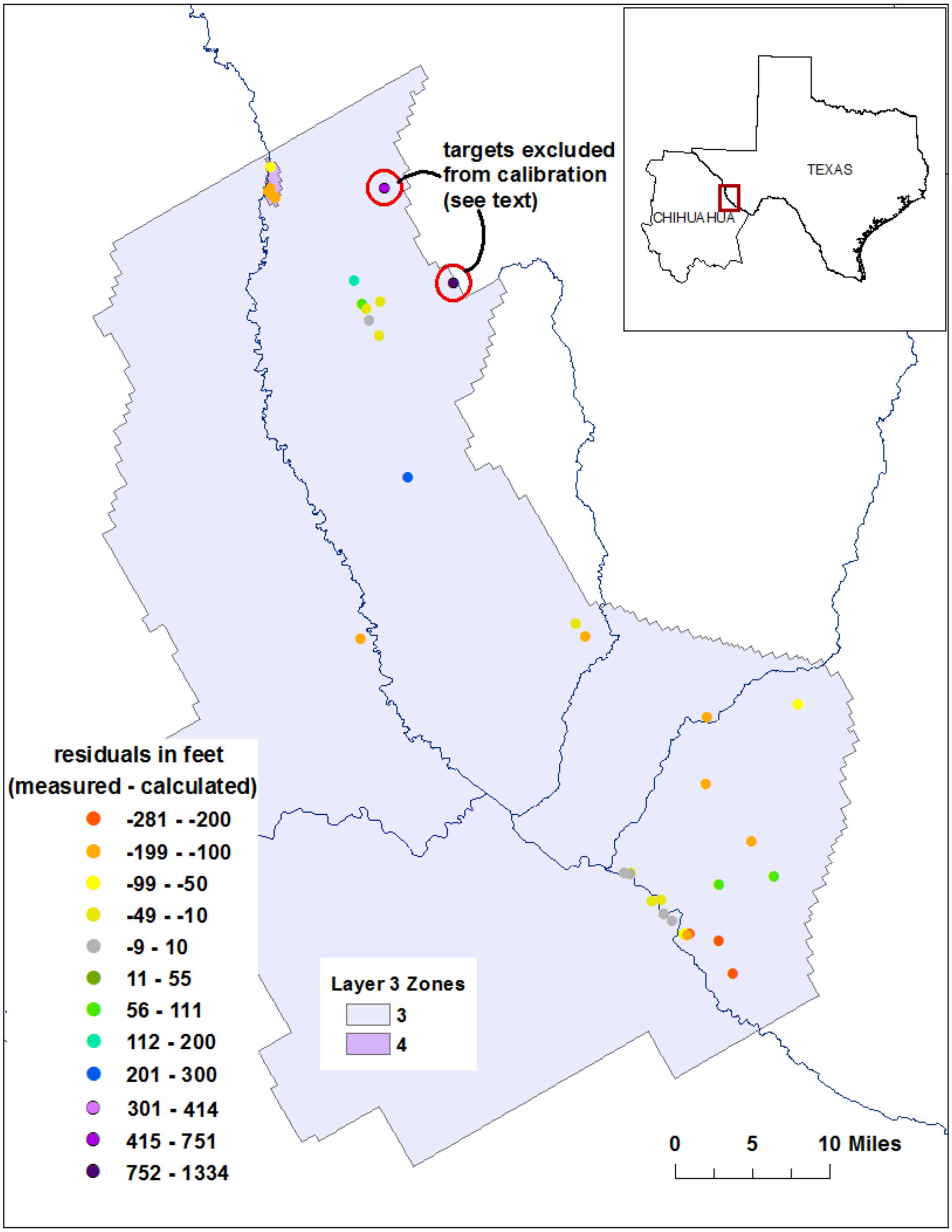

FIGURE 11 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 3. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.

The net surface water interaction and evapotranspiration target represents average net groundwater discharge along reach 1 (Figure 8; Table 8). As with the drain or spring discharge we initially assigned a weight proportional to the ratio between the target flux in acre-feet per year and the head target values. However, PEST matched the flux better than the head so we reduced the river discharge weight to give more preference to the head targets.

For model calibration we used pre- and post-processor programs to create model input files and convert model output files to compare with target water levels and discharge estimates. During the automated model calibration, PEST adjusted the following parameters: hydraulic conductivity by zone, horizontal and vertical anisotropy by zone, drain conductance by layer, river conductance by reach, average river stage, general head boundary head conductance by reach, general head boundary head across the Alamito Creek watershed, recharge parameters (Table 10), and well multipliers. PEST selects the parameter combination which produces the best fit to the target values. The fit is determined by the value of the objective function φ. The objective function, φ, is the sum of squared deviations between model-generated observations and measured (or estimated) field observations. The lower the value of φ, the better the model fits the data (Watermark Numerical Computing, 2004).

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 Calibration Results

Water Level Targets

The standard head error for all layers for the final model calibration is 63 feet, which is 5.2 percent of the range in heads (Table 11; Figure 12). The mean head residual for all targets is -13.7 feet. The standard head error over range for layers 1, 2, and 3 are 3.0, 6.6, and 9.5 percent respectively. Each model layer meets the goal of a standard head error of no greater than 10 percent of the range in heads for each layer (Table 12). However, the modeled heads are biased somewhat high in layer 3 and slightly high overall. Generally the model overestimates the lowest groundwater elevations and underestimates the highest (Figure 13). The water level residual distribution is somewhat skewed (Figure 14). Most of the positive residuals (measured values greater than modeled values) are less than 50 feet, while the negative residuals (modeled values exceed measured values) range evenly from zero to -200 feet.

The measured water levels, model estimates, and residuals for each target are listed in Appendix A (Table A.1)

TABLE 11 FINAL CALIBRATION STATISTICS OVERALL

Parameter	Value
Total φ	5.0×10^6
Head φ	2.35×10^6
Flux φ	2.65×10^6
Standard Head Error	63 feet
Mean head residual	-13.7 feet
Standard Head Error/ Range in heads	5.2 percent

TABLE 12 FINAL CALIBRATION STATISTICS BY LAYER

Layer	Mean Residual (feet)	Standard Head Error	Range (feet)	Standard Head Error/Range (percent)
1	6.3	12	401	3.0
2	-10.4	74	1,125	6.6
3	-82.6	115	1,215	9.5
Overall	-13.7	63	1,215	5.2

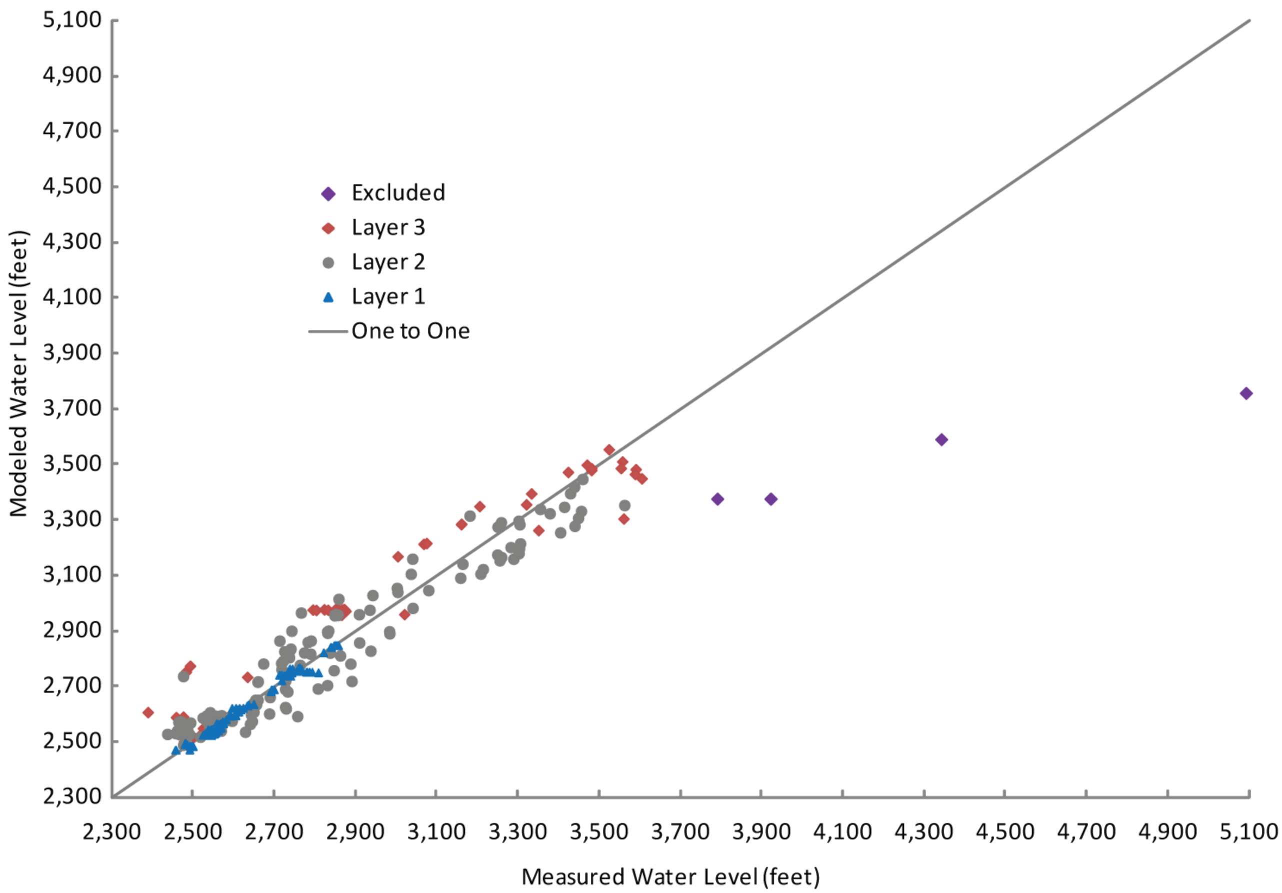

FIGURE 12 MEASURED VERSUS MODEL CALCULATED WATER LEVELS. FIVE TARGETS WERE EXCLUDED FROM THE CALIBRATION BECAUSE THEY MAY BE PART OF A DIFFERENT FLOW SYSTEM (SEE TEXT).

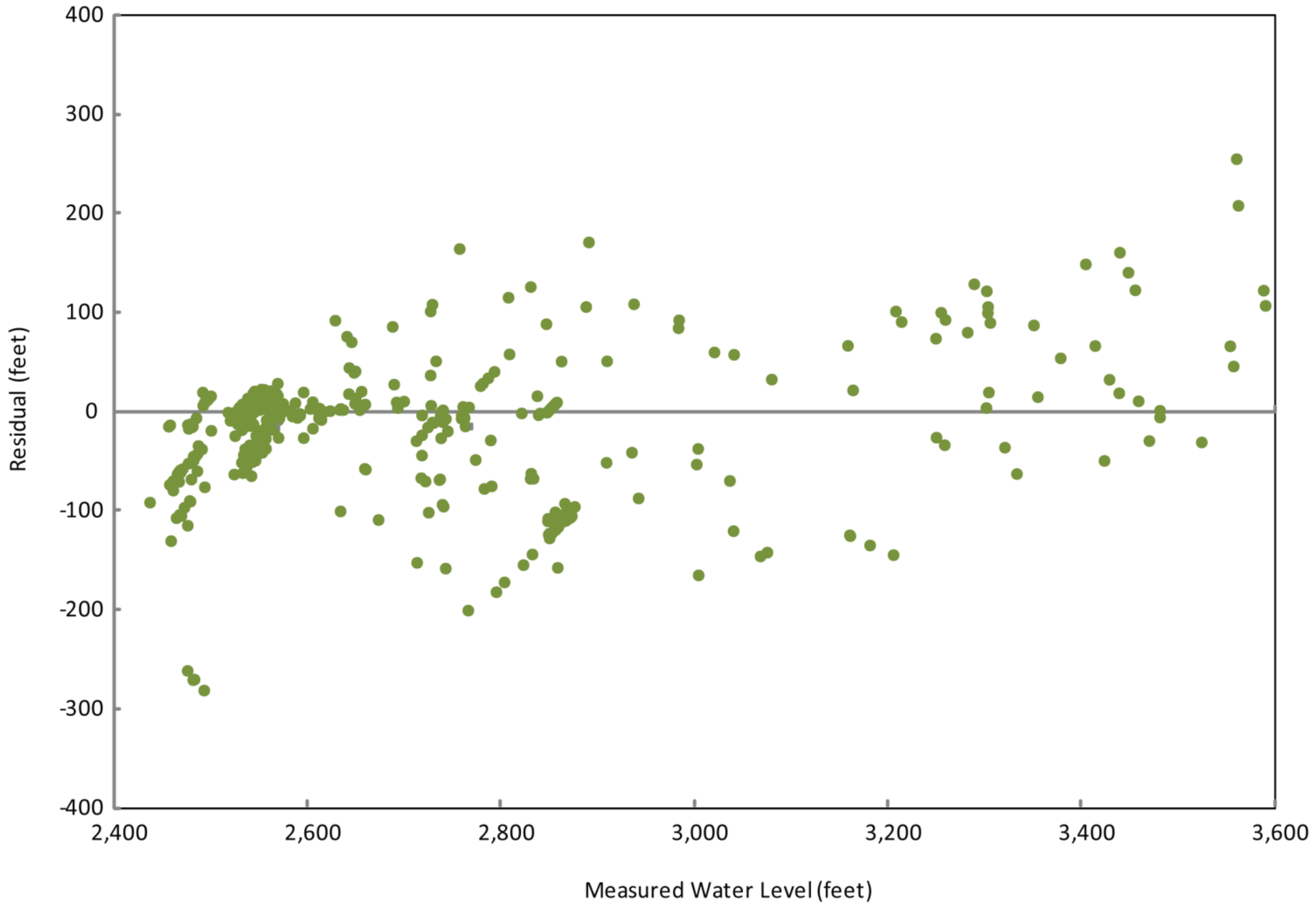

FIGURE 13 MEASURED WATER LEVLES VERSUS MODEL RESIDUALS

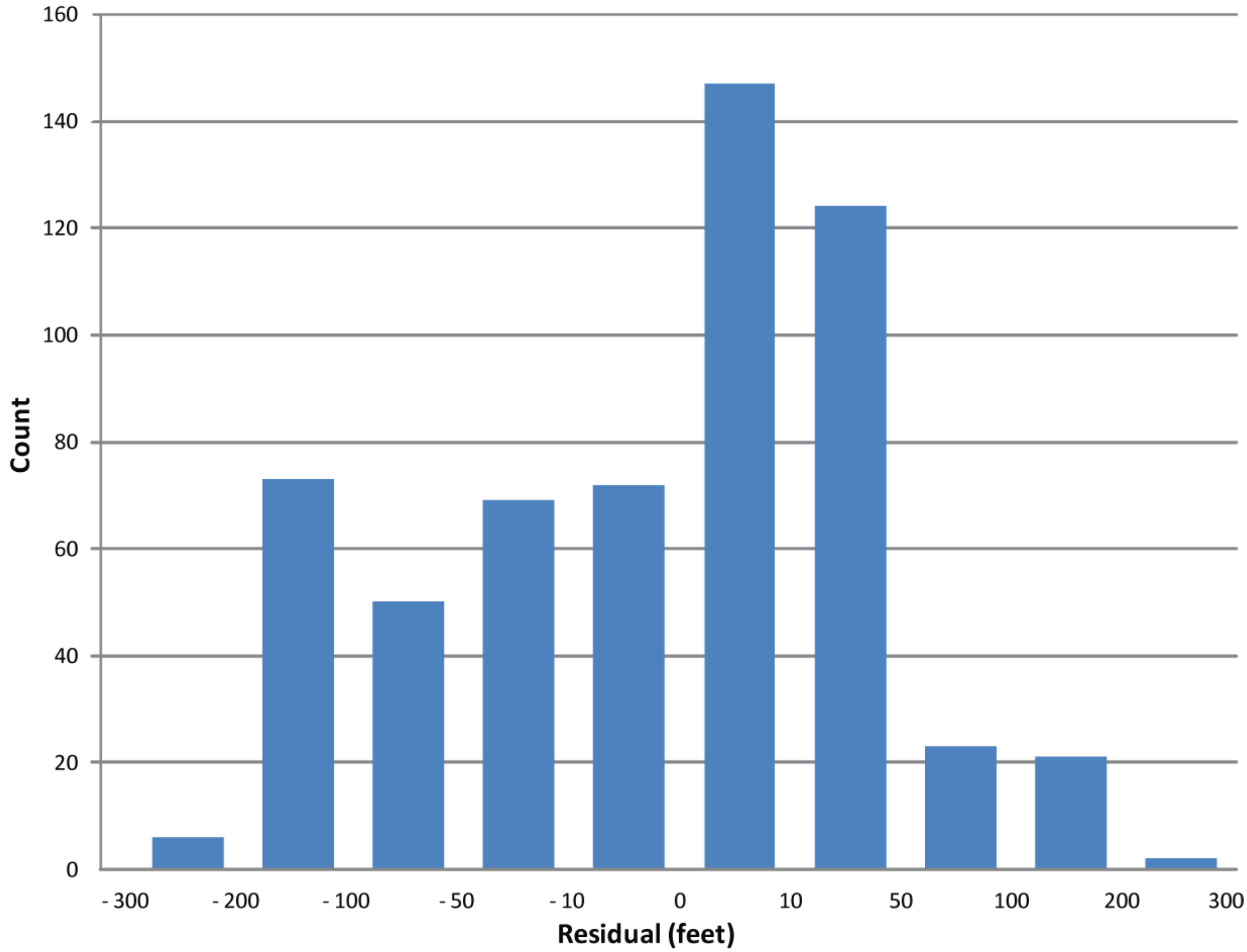

FIGURE 14 HISTOGRAM OF MODEL RESIDUALS.

Hydrographs

Six wells in the study area include multiple water level measurements through time. We extracted and compared modeled water levels at those six wells to evaluate how well the model responds to changing recharge and pumping through time (Figures 15, 16, and 17). In most cases the water level measurement and modeled water levels do not change much through time. This suggests that the estimated storage coefficient in the model is reasonable. The water levels vary at most 10 feet with no net change in water levels over 60 years. One exception is state well number 7430407 located in layer 2. The model shows water levels varying 60 feet with a net rise in water levels (Figure 16). For the hydrographs located in layer 1 there is very little offset between the measured and modeled water levels. For the layer 2 hydrographs (Figures 15 and 16) the model overestimates water levels, although overall the layer 2 modeled water levels are only slightly biased high (Figure 12, Table 12).

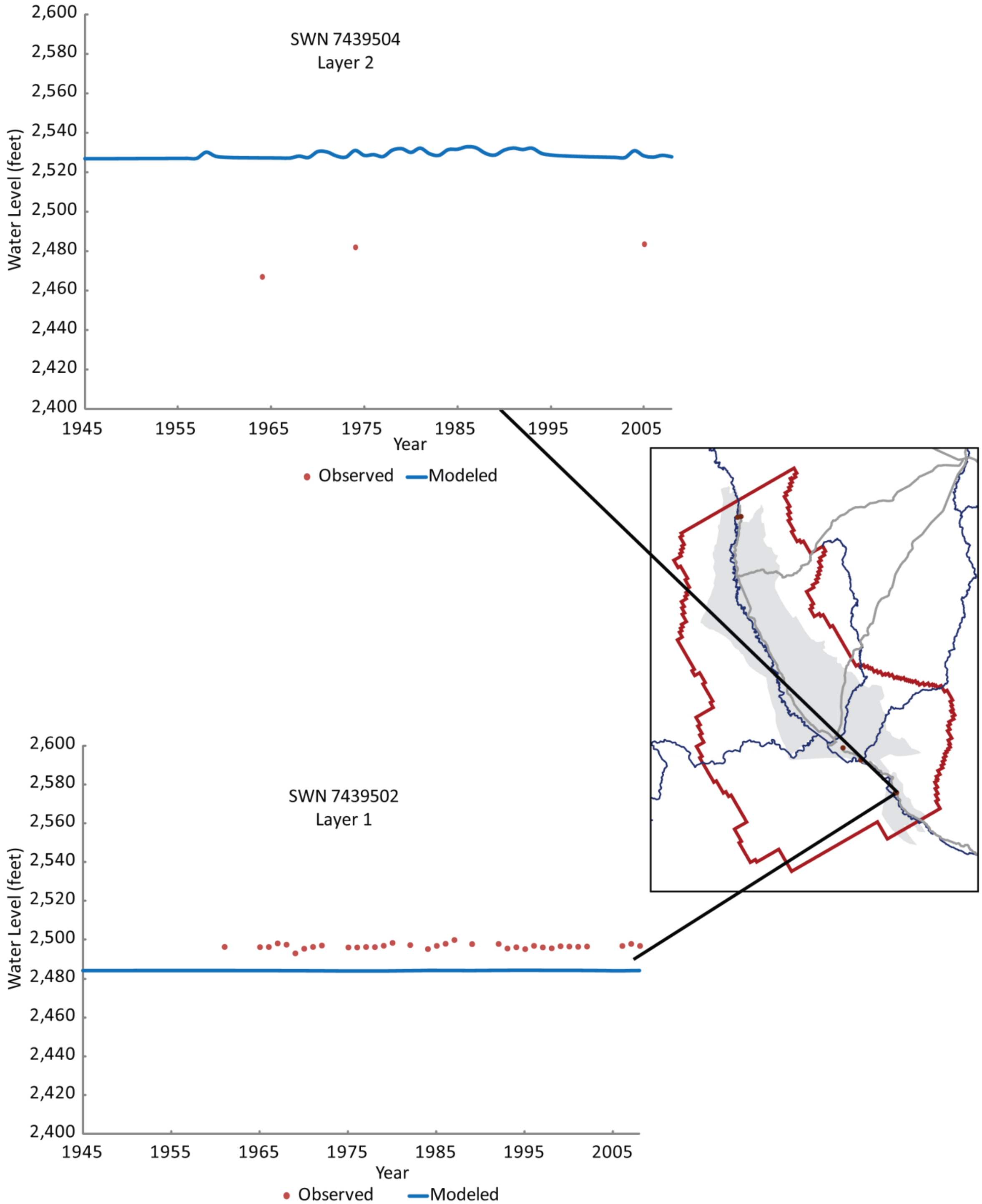

FIGURE 15 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE SOUTH END OF THE MODEL.

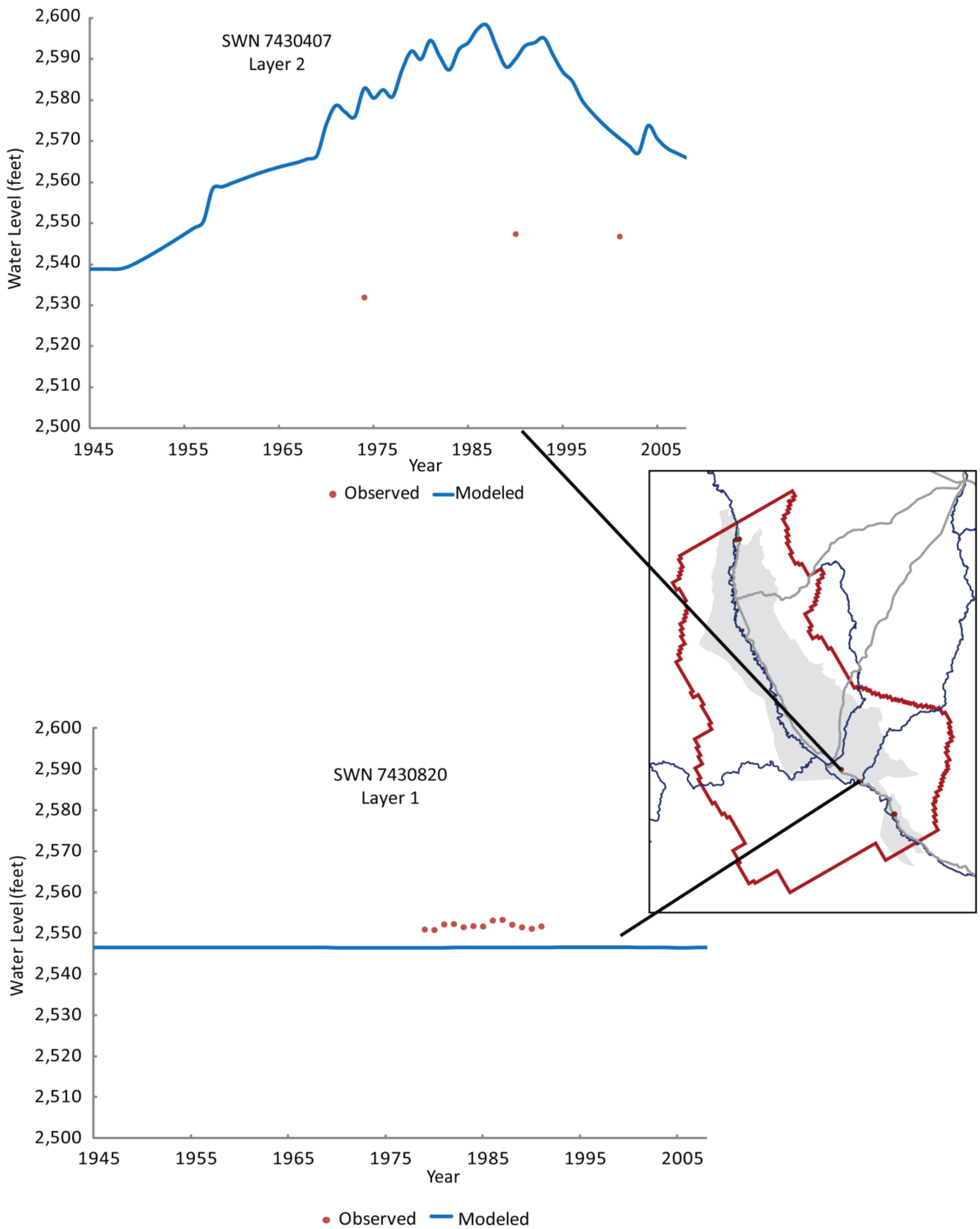

FIGURE 16 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE CENTRAL PART OF THE MODEL.

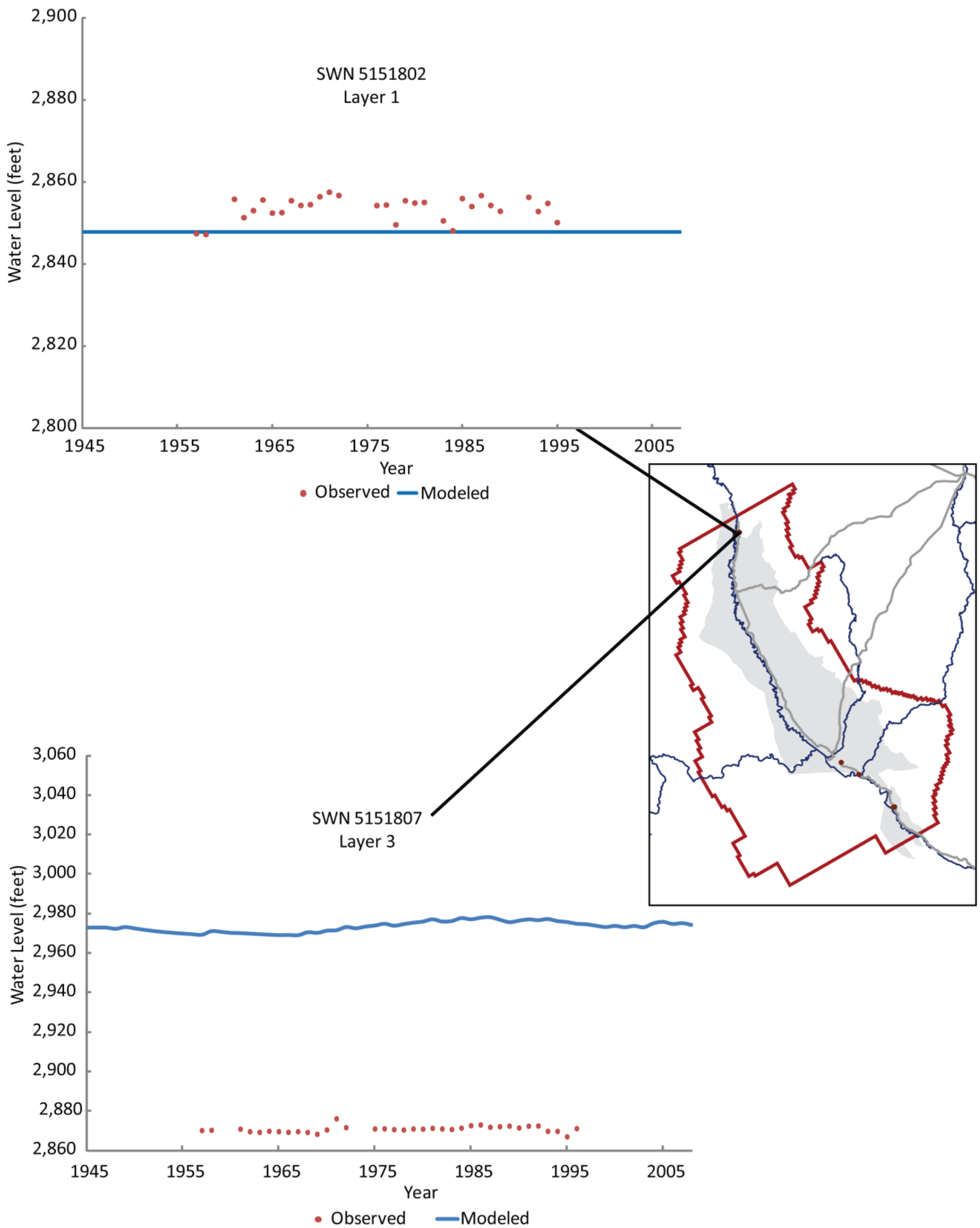

FIGURE 17 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE NORTH END OF THE MODEL.

Some of the variation in the layer 1 hydrographs near the river is not captured because the calibrated river stage is seven feet above the bottom of the river for each river cell and does not vary through time in the model. Instead the river stage represents a time average over the entire calibration period.

Discharge

We assigned lower weights to the estimates of average spring discharge (Table 7) and average net river interaction/evapotranspiration (Table 8) during model calibration because the discharge estimates were much less certain and involved several assumptions. Consequently, the model estimated net river flux is off by over 50 percent (Figure 18).

The modeled drain discharge values for layers 2 and 3 match the estimated values fairly well (Figure 18).

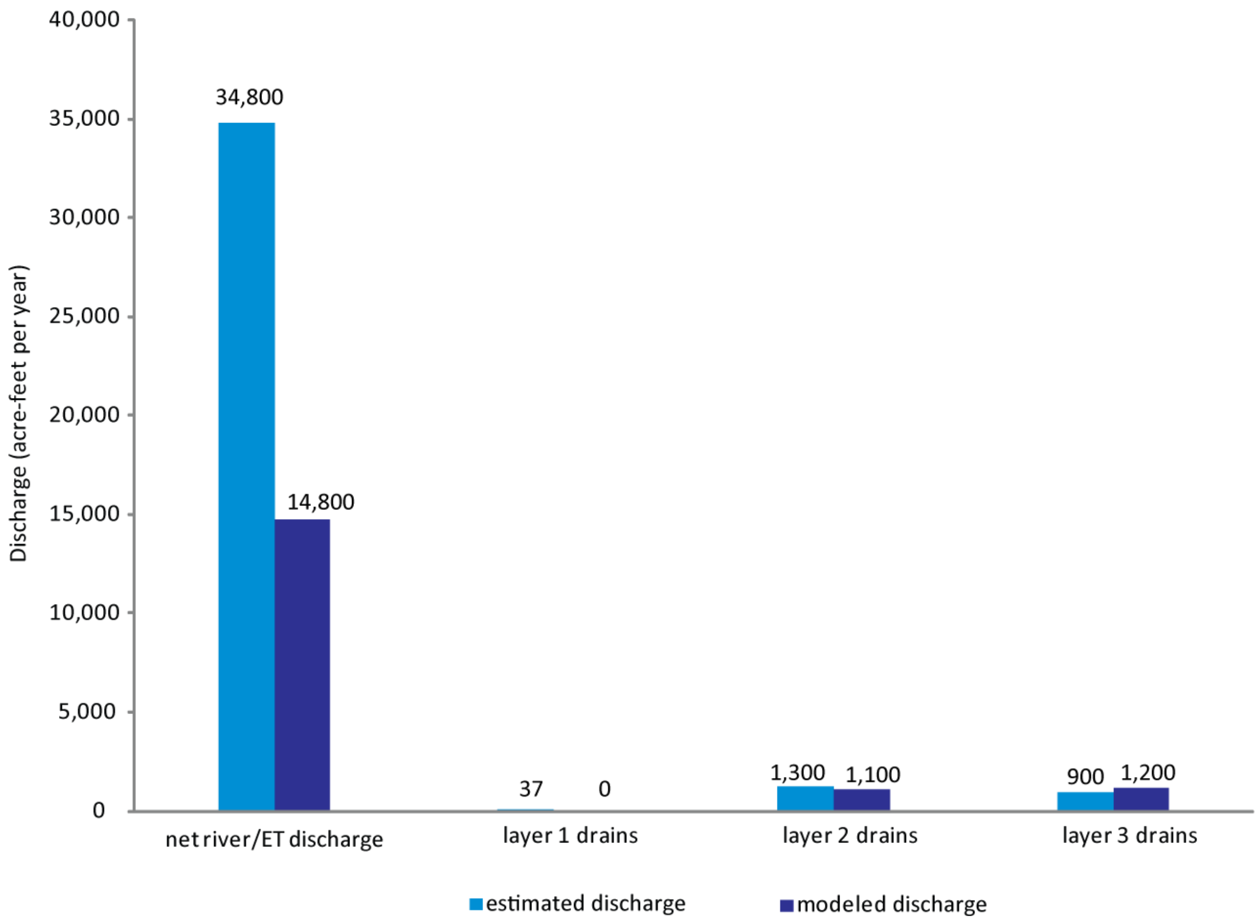

FIGURE 18 COMPARISON BETWEEN ESTIMATED AVERAGE DISCHARGE AND MODELED AVERAGE DISCHARGE FOR DRAINS AND NET RIVER/ EVAPOTRANSPIRATION.

Recharge

The calibrated distribution of recharge (Figure 19) is based on 10 percent for rainfall over 12 inches and zero percent when rainfall is below 12 inches per year. The estimated recharge is somewhat greater than other estimates for the area (Wade and others, 2011).

Groundwater Flow Direction

To compare the modeled groundwater flow directions to our conceptual understanding of the flow system (Wade and others, 2011) we plotted maps of groundwater flow direction at the end of the last year of the calibration (2008). The flow direction maps are derived from the cell-by-cell flow output from MODFLOW using GWVistas Version 6 (Rumbaugh and Rumbaugh, 2011).

In layer 1 the groundwater flow is principally southeastward following the axis of the Rio Grande (Figure 20). In layer 2 (Figure 21) the groundwater flows from the edges of the bolsons towards the river and southeast ward along the river axis. At the center of the bolson the groundwater flow is net upward toward the Rio Grande alluvium in layer 1 (Figure 21). A few diversions from the general trend are caused by local gradients due to pumping. In layer 3 (Figure 22) on the eastern side of the river the flow is towards the center of the basin and on the northwestern portion of the model (north of Rio Conchos and west of Rio Grande) the flow is southeast toward the Rio Conchos. South of the Rio Conchos the flow is toward the Rio Grande. In the center of the basin the flow is generally upward into the overlying bolson in layer 2 (Figure 22).

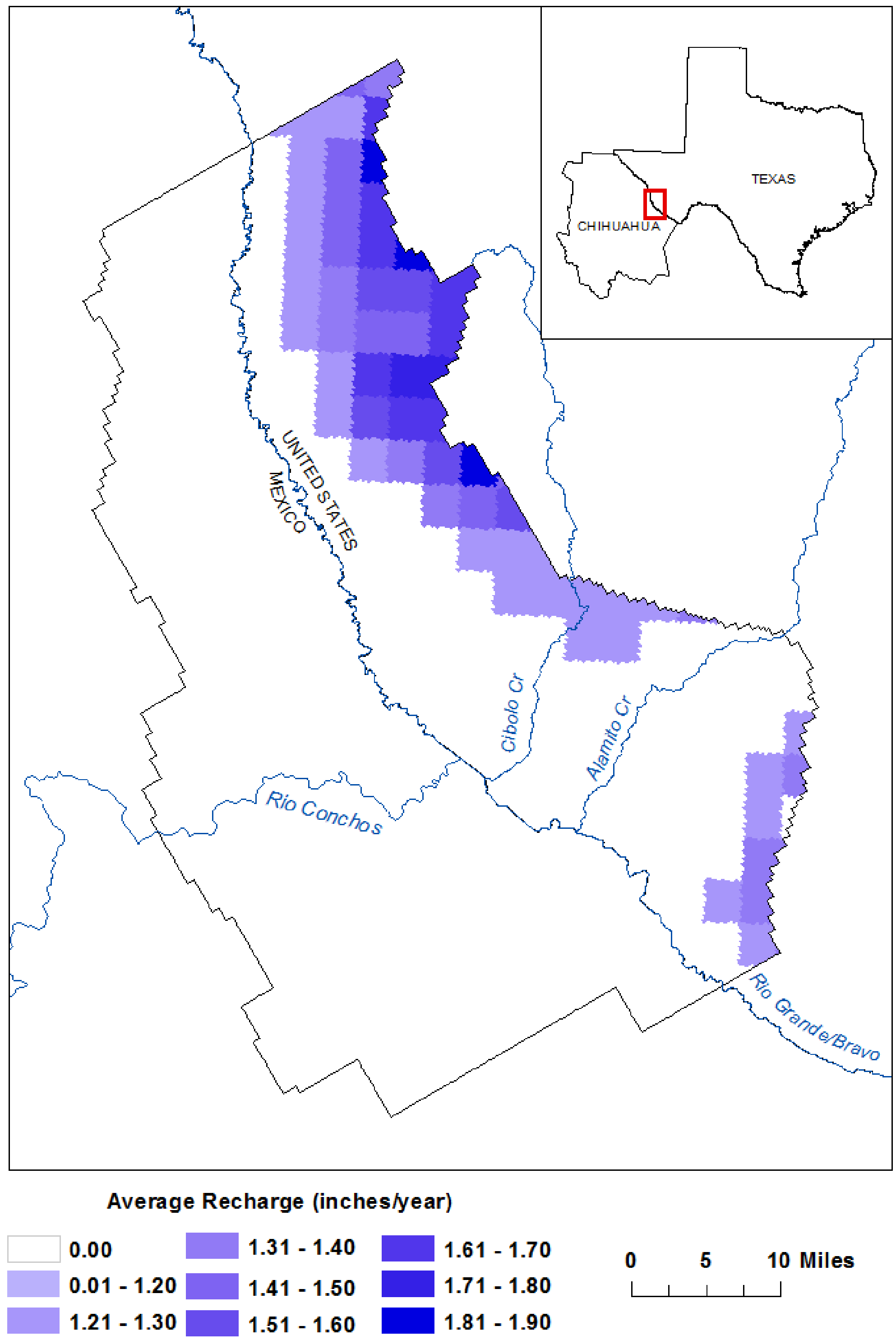

FIGURE 19 DISTRIBUTION OF RECHARGE BASED ON AVERAGE RAINFALL.

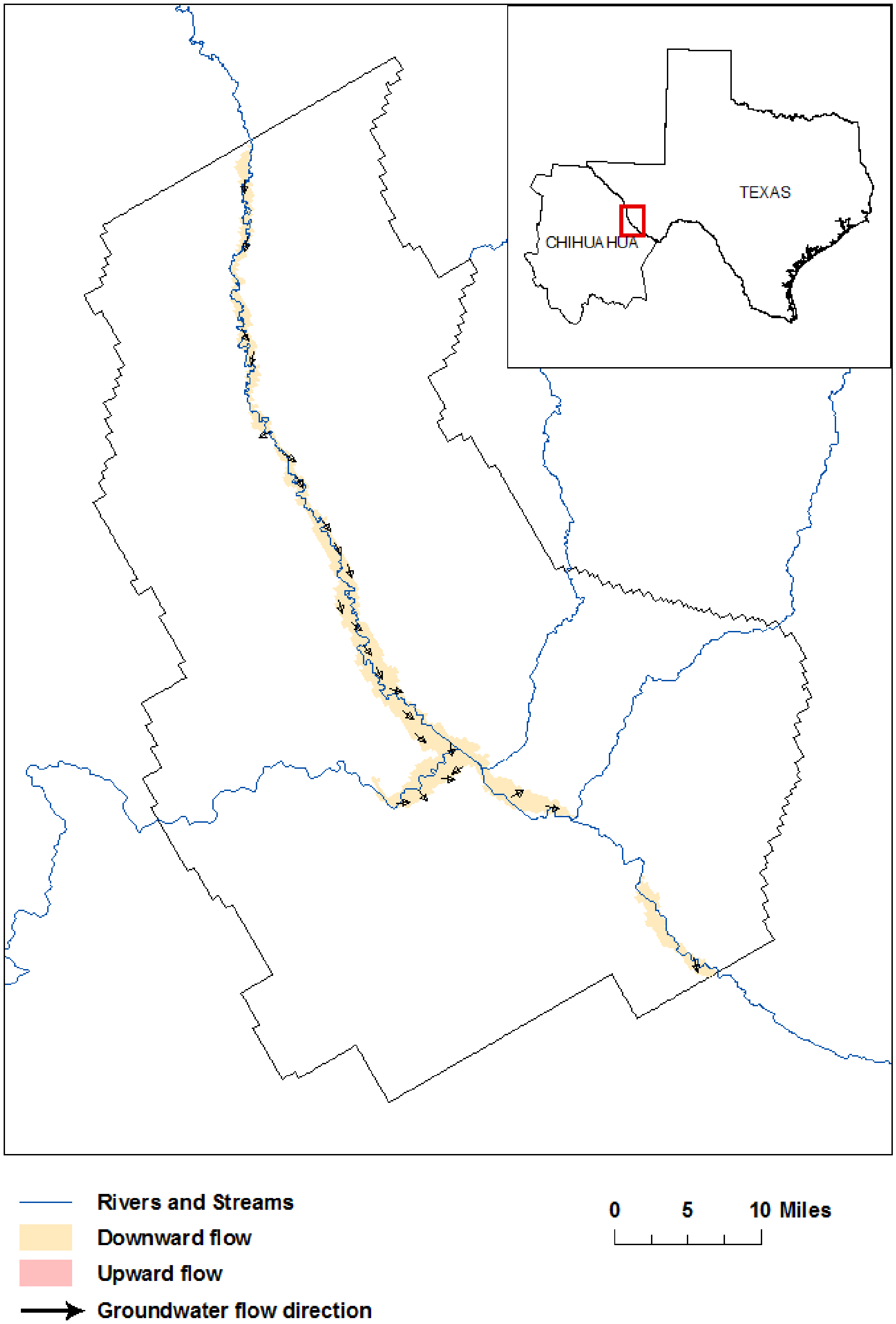

FIGURE 20 GROUNDWATER FLOW DIRECTIONS IN LAYER 1.

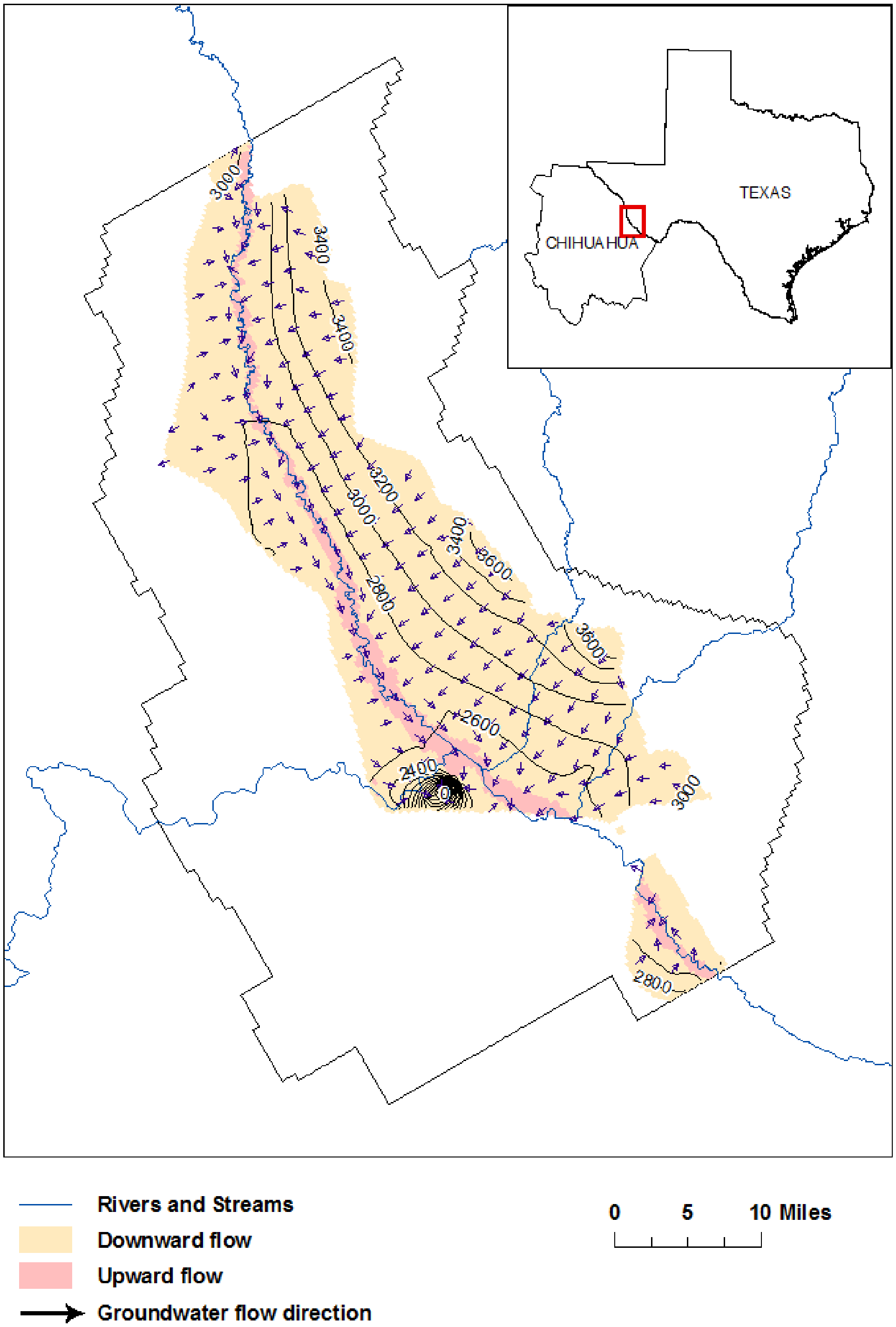

FIGURE 21 GROUNDWATER FLOW DIRECTIONS AND POTENTIOMETRIC ELEVATIONS IN LAYER 2.

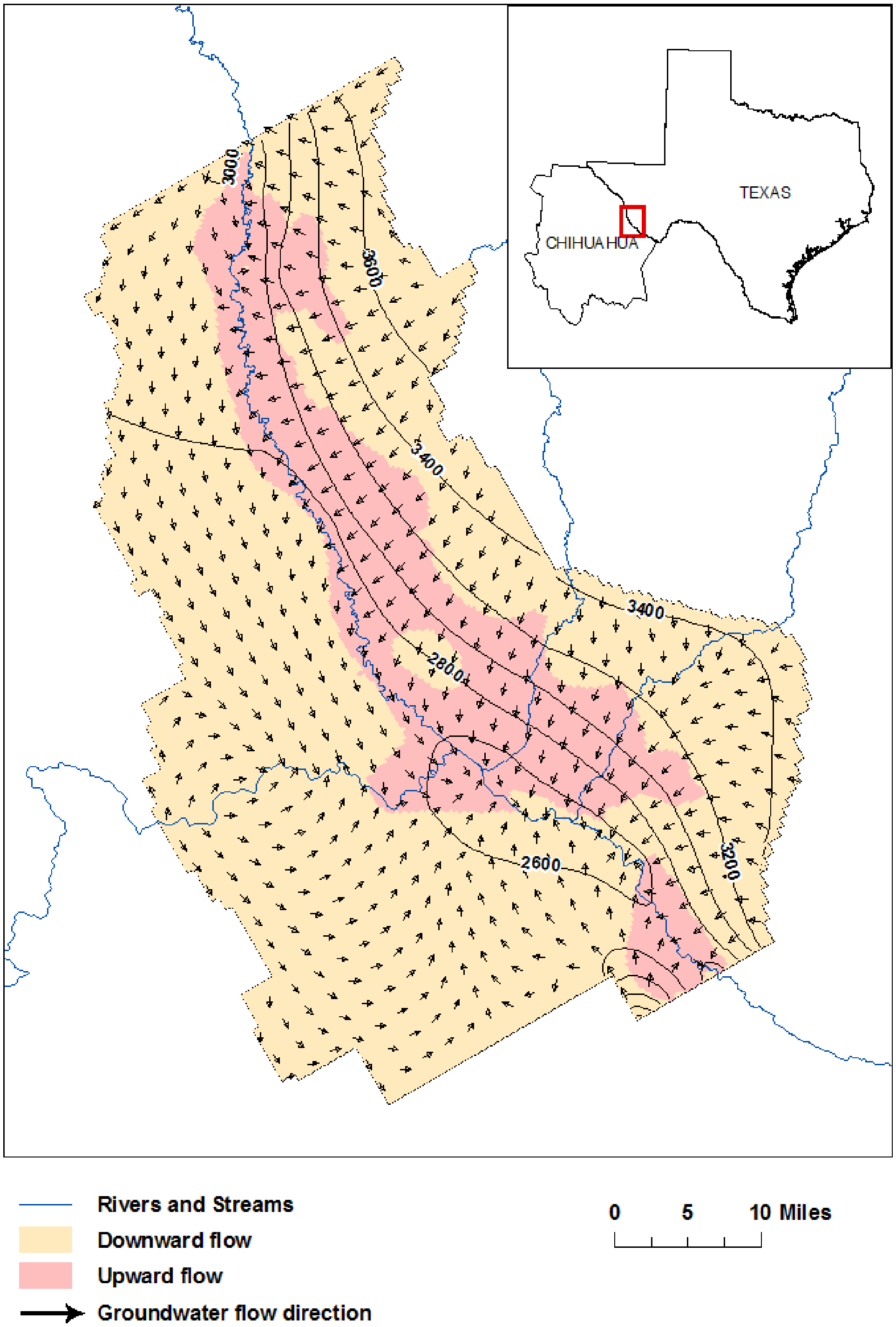

FIGURE 22 GROUNDWATER FLOW DIRECTIONS AND POTENTIOMETRIC ELEVATIONS IN LAYER 3.

3.3 Model Simulated Water Budgets

Evaluation of the simulated water budget helps to verify that the model is consistent with our conceptual understanding of the regional hydrogeology, surface water hydrology, and regional weather conditions. For a groundwater system near equilibrium prior to development (prior to groundwater pumping for irrigation or other human use) groundwater inflow equals groundwater outflow and little change in storage occurs over time.

Introduction of pumping wells can result in 1) storage decline (lowered groundwater levels), 2) induced flow (generally manifested by increased surface water recharge), and/or 3) captured natural outflow (decreased springflow, river baseflow, or evapotranspiration). 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 can be used to help understand capture. Output from the model includes estimates of the various components of the water budget. For the study area historically there has not been significant groundwater development as indicated by the water level hydrographs; however, the numerical model can be used to investigate the effects of increased future development on the regional water budget. It is important to note though that predictions outside the range of historical stresses are more uncertain and that models should also be updated to reflect new data as it becomes available.

We extracted the overall water budget for this groundwater flow model using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The budget includes the following components: recharge, general head boundaries, rivers, springs, pumping, and storage change. Inflow and outflow components contribute groundwater to or take groundwater away from the aquifers in the model domain, respectively. The groundwater inflow (Tables 13 and 14) is mainly from recharge due to precipitation and regional inflow from the general head boundaries. The outflow components include (in descending order of flow magnitude): net leakage to rivers and evapotranspiration, pumping, and discharge to springs.

The modeled recharge inflow fluctuates through time and is based on the annual variation of precipitation (Figures 23 and 24). The model responds to increasing recharge with inflow to storage (water levels rise) and increased discharge to the rivers and evapotranspiration and to a lesser extent increased spring discharge. Pumping to wells varies somewhat through time based on historical use information. Net inflow from the general head boundaries shows little variation through time (Figures 23 and 24).

Table 13 SUMMARY OF OVERALL ANNUAL GROUNDWATER BUDGET FOR THE MODEL IN ACRE-FEET PER YEAR. POSITIVE STORAGE CHANGE INDICATES WATER LEVEL RISE AND NEGATIVE STORAGE CHANGE INDICATES WATER LEVEL DECLINE.

Flow components	1948	1978	2008	Average 1948 - 2008
Recharge Inflow	22,862	56,243	25,882	33,110
Net Regional Inflow (ghb)	13,527	12,908	13,106	13,172
Total Inflow	36,389	69,151	38,988	46,281
Net Rivers and ET Outflow	20,848	28,534	26,165	26,849
Spring Outflow	1,508	2,680	2,360	2,263
Pumping Outflow	17,549	14,512	16,738	14,526
Total Outflow	39,905	45,726	45,263	43,639
Total Inflow - Total Outflow	-3,516	23,425	-6,275	2,642
Storage change	-3,519	23,423	-6,276	2,640

TABLE 14 SUMMARY OF OVERALL ANNUAL GROUNDWATER BUDGET FOR PRESIDIO COUNTY IN ACRE-FEET PER YEAR. POSITIVE STORAGE CHANGE INDICATES WATER LEVEL RISE AND NEGATIVE STORAGE CHANGE INDICATES WATER LEVEL DECLINE.

Flow components	**Average 1948 – 2008** **Presidio County**
Recharge Inflow	30,737
Net Regional Inflow (ghb)	4,780
Inflow from Mexico	38,441
Total Inflow	73,958
Net Rivers and ET Outflow	12,360
Spring Outflow	2,263
Pumping Outflow	3,168
Outflow to Mexico	54,258
Total Outflow	72,049
Total Inflow - Total Outflow	1,909
Storage change	1,909

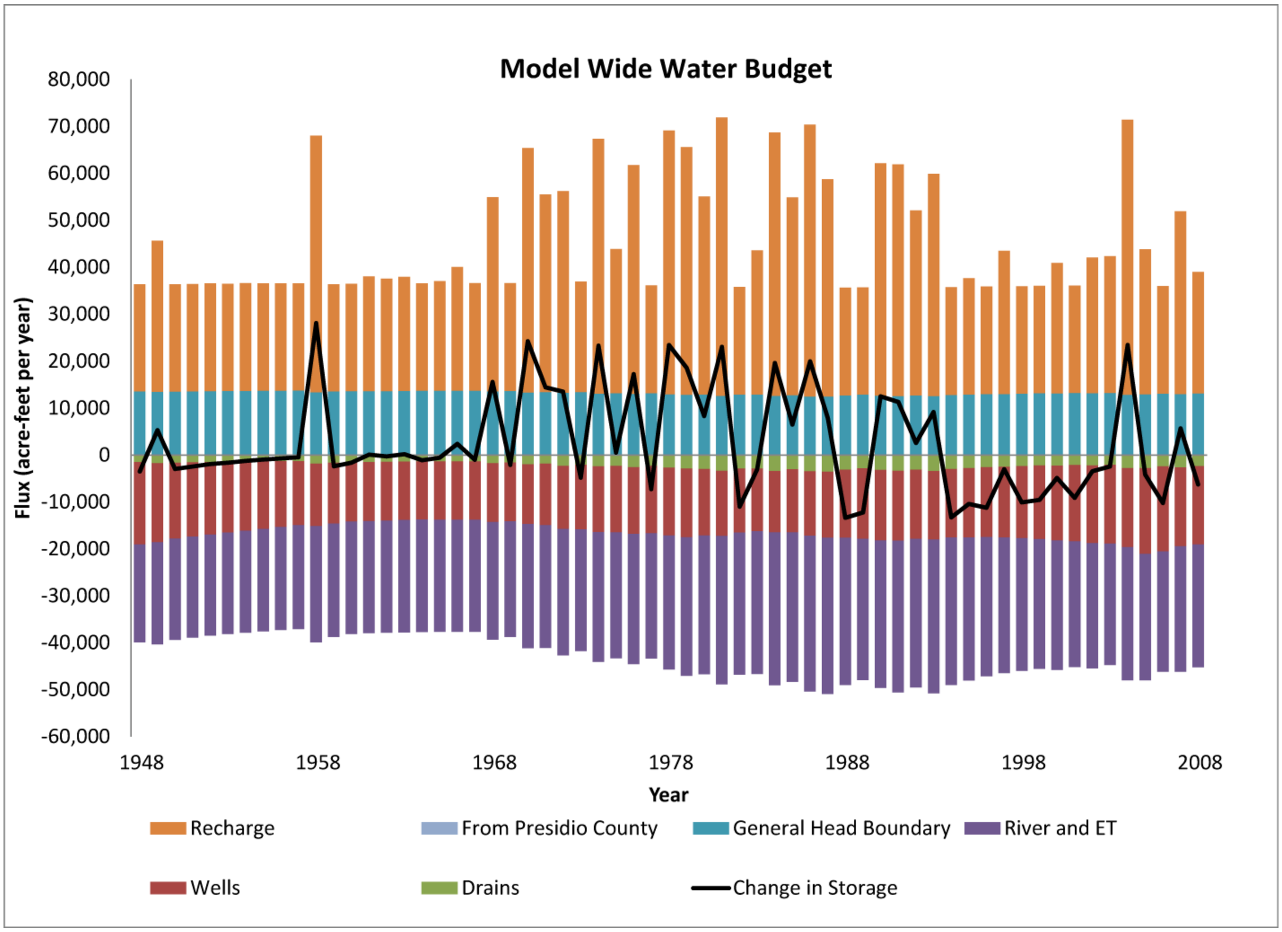

FIGURE 23 OVERALL GROUNDWATER BUDGET BY YEAR FOR THE MODEL IN ACRE-FEET PER YEAR.

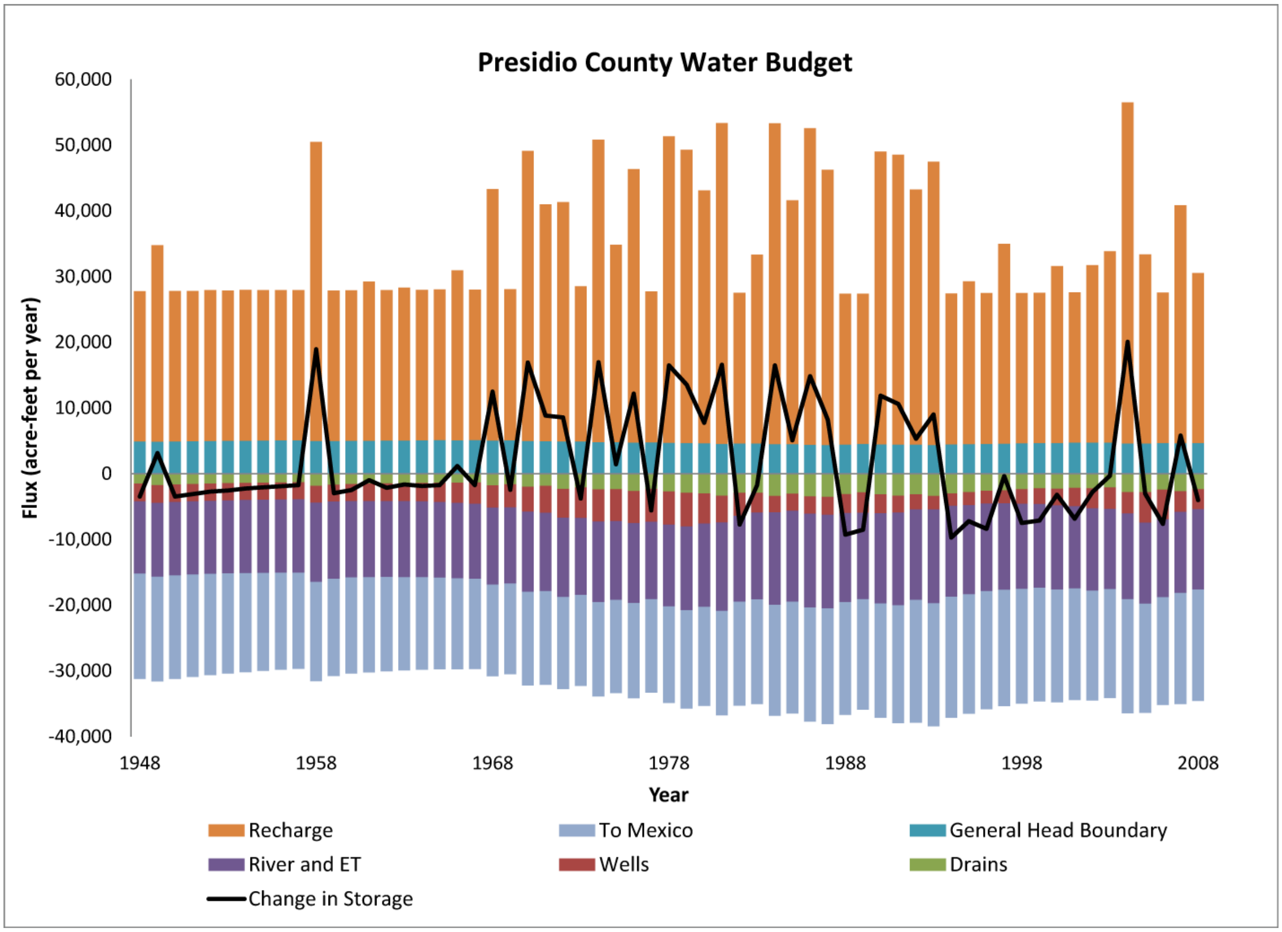

FIGURE 24 GROUNDWATER BUDGET BY YEAR FOR PRESIDIO COUNTY PORTION OF MODEL IN ACRE-FEET PER YEAR.

4.0 SENSITIVITY ANALYSIS

Sensitivity analyses are performed to illuminate the uncertainty in calibrated models caused by uncertainty in the model parameters (Anderson and Woessner, 1992). Typically the parameter values are varied one at a time within a specified range. The results of the sensitivity analysis can be reported as the effect of the parameter change on either all water levels in the model or on water levels at the calibration targets. It is important to note that in addition to uncertainty in model parameter values there is also uncertainty in model design (Freeze and others, 1990). Model geometry, and stratigraphy and sources of recharge and discharge all have associated uncertainty.

4.1 Sensitivity Analysis Procedure

For the sensitivity analysis we varied horizontal hydraulic conductivity, vertical anisotropy, river conductance, recharge, and pumping. We adjusted each parameter to 20, 50, 80, 120, 150, and 200 percent of its calibrated value and held all of the other model parameters at their calibrated value. We then ran the model and calculated the average change in head values for all targets (Table 15, Figure 25).

TABLE 15 AVERAGE CHANGE IN TARGET HEAD (IN FEET) AS A FUNCTION OF PARAMETER VARIATION.

Factor	Hydraulic conductivity	Specific Storage	Vertical Anisotropy	River Conductance	Recharge	Wells
0.2	57.6	13.0	-1.3	11.1	-49.8	11.8
0.5	22.6	5.8	5.8	5.0	-30.6	7.4
0.8	6.7	1.8	1.8	1.6	-11.9	3.0
1	0.0	0.0	0.0	0.0	0.0	0.0
1.2	-4.9	-1.4	-1.4	-1.2	11.4	-3.0
1.5	-10.1	-2.9	-2.9	-2.7	27.2	-7.4
2	-16.2	-4.6	-4.6	-4.6	51.9	-14.9

Note: - Change in head (feet) = Sensitivity Run Target Head – Calibrated Model Target Head

4.2 Results of Sensitivity Analysis

The sensitivity analysis results indicate that the model is most sensitive to recharge and horizontal hydraulic conductivity (Figure 25). The model is moderately sensitive to pumping wells, specific storage, and river conductance.

The sensitivity plot is asymmetric for increasing versus decreasing values of horizontal hydraulic conductivity (Figure 25). This is most likely because there is much more room for target heads to increase—from 3,600 feet to over 5,000 feet in layers 2 and 3 adjacent to the mountains (Figures 10 and 11). In contrast, heads near the river or general head boundaries are limited to not drop below those boundary heads.

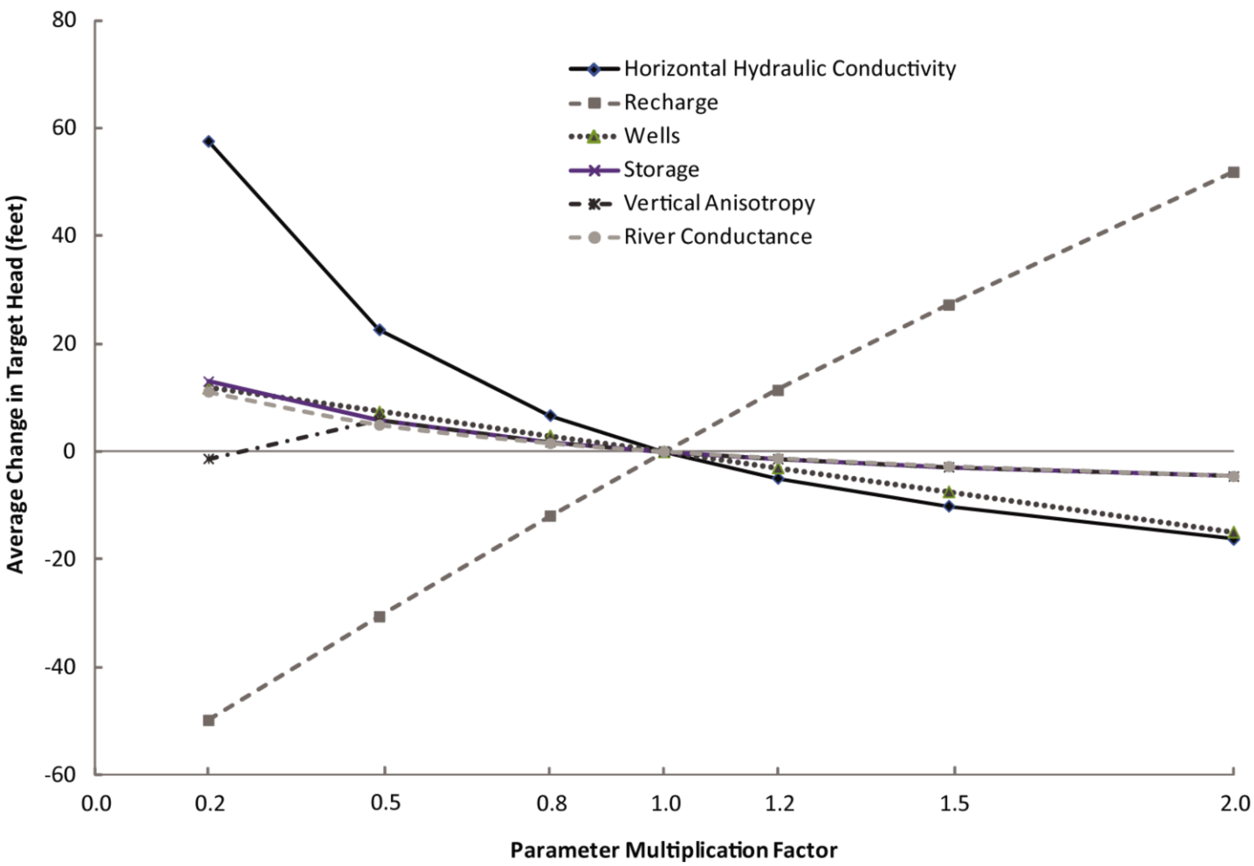

FIGURE 25 AVERAGE CHANGE IN TARGET HEAD (COMPARED WITH CALIBRATED MODEL) AS A FUNCTION OF VARIATION OF PARAMETER VALUES (SENSITIVITY ANALYSIS).

5.0 MODEL LIMITATIONS

Numerical groundwater flow models are approximate representations of aquifer systems (Anderson and Woessner, 1992), and as such have limitations. These limitations are usually associated with (1) the purpose for the groundwater flow model, (2) the extent of the understanding of the aquifer(s), (3) the quantity and quality of data used to constrain parameters in the groundwater flow model, and (4) assumptions made during model development. Models are best viewed as tools to help form decisions rather than as machines to generate truth or make decisions. The National Research Council (2007) concluded that scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or be able to prove that a given model is correct in all respects for a particular application.

The nature of regional groundwater flow models affects the scale of application of the model. This model is most accurate in assessing subregional-scale groundwater issues, such as predicting aquifer-wide water level changes and trends over the next 50 years that may result from different proposed water management strategies. Accuracy and applicability of the model decreases when using it to address more local-scale issues because of limitations of the information used in model construction and the model cell size that determines spatial resolution of the model. Consequently, this model is not likely to accurately predict water level declines associated with a single well or spring because (1) these water level declines depend on site-specific hydrologic properties not included in detail in regional-scale models, and (2) the cell size used in the model is too large to resolve changes in water levels that occur over relatively short distances. Addressing local-scale issues requires a more detailed model, with local estimates of hydrologic properties, or an analytical model. This model is more useful in determining the impacts of groups of wells distributed over many square miles. The model predicts changes in ambient water levels rather than actual water level changes at specific locations, such as an individual well.

A key aspect of using the groundwater model to evaluate historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. In addition, assumptions regarding precipitation, recharge, and streamflow are specific to a particular historic time period. It is important to continue to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the Presidio County Underground Water Conservation District work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

To a certain extent this model is interpretive rather than being a fully predictive model because of the limited historical stresses on the aquifer and limited amount of water level and hydraulic property data. In addition, because of the lack of historical stresses it was not possible to fully calibrate the storage coefficient.

In this model, the layer type was set to zero for all layers, which assumes a constant transmissivity throughout the simulation. This assumption is acceptable as long as water level drawdowns are a small fraction of the total saturated thickness. This is not a significant limitation during the calibration period of the model because of the small changes in historic water levels; however, the limitation should be considered for predictive scenarios involving significant drawdowns. It is also possible for water levels to drop below the base of the model cell, so modeled water levels should also be carefully evaluated.

Lastly it is important to note that the great majority of the water level data and all of the hydraulic property data are from the United States portion of the model area. The amount of data available for the Mexico portion of the model area was very limited. Because of this data limitation the model may not be the best tool to evaluate water resources on the Mexico portion. However, it should be sufficient to serve as a boundary condition for the United States portion of the model.

6.0 FUTURE IMPROVEMENTS

As discussed in Section 5, we used the constant transmissivity (fully saturated) option in MODFLOW-2000 for this model. We chose this option because of the difficulty during initial calibration of keeping model cells from going dry on the edge of the bolson. When a model cell goes dry it does not receive recharge or pumping. A version of MODFLOW, MODFLOW-NWT (Niswonger and others, 2011), has recently been released which improves the way MODFLOW handles cell rewetting for variably saturated cells. When the model for the Presidio and Redford Bolsons is updated in the future, we recommend investigating the use of MODFLOW-NWT or future developments of MODFLOW rather than MODFLOW-2000.

Also discussed above, in the model limitations section, was the scarcity of water level data and hydraulic property information for the Mexico portion of the model. As more data become available for Mexico it should be included in the model.

Another data limitation is the lack of transient water level data. Few wells in the study area include more than one water level measurement. All of the wells with multiple measurements are close to the river. Therefore, the calibration of the variation of recharge through time is based on very limited spatial data. It may be valuable to recalibrate an alternate steady-state model representing long-term average conditions. Similarly, the deepest well used in the calibration is about 600 feet below land surface yet the model extends to a depth of up to 7,500 feet. It may be useful to develop an alternate shallow model which includes only the shallower potions of the bolson and surrounding older rocks.

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Appendix A:
Simulated Heads and Measured Heads at Wells

TABLE 16 WATER LEVEL TARGETS, SIMULATED VALUES AND RESIDUALS. AMSL=ABOVE MEAN SEA LEVEL

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5151801	3	43	121	1974	30	2,849.0	2,972.8	-123.8
5151802	1	43	120	1957	13	2,847.5	2,847.8	-0.3
5151802	1	43	120	1958	14	2,847.3	2,847.8	-0.5
5151802	1	43	120	1961	17	2,855.9	2,847.8	8.1
5151802	1	43	120	1962	18	2,851.4	2,847.8	3.6
5151802	1	43	120	1963	19	2,853.1	2,847.8	5.3
5151802	1	43	120	1964	20	2,855.7	2,847.8	7.9
5151802	1	43	120	1965	21	2,852.5	2,847.8	4.7
5151802	1	43	120	1966	22	2,852.6	2,847.8	4.8
5151802	1	43	120	1967	23	2,855.6	2,847.8	7.8
5151802	1	43	120	1968	24	2,854.4	2,847.8	6.6
5151802	1	43	120	1969	25	2,854.6	2,847.8	6.8
5151802	1	43	120	1970	26	2,856.5	2,847.8	8.7
5151802	1	43	120	1971	27	2,857.6	2,847.8	9.8
5151802	1	43	120	1972	28	2,856.8	2,847.8	9.0
5151802	1	43	120	1976	32	2,854.4	2,847.8	6.5
5151802	1	43	120	1977	33	2,854.5	2,847.8	6.7
5151802	1	43	120	1978	34	2,849.7	2,847.8	1.8
5151802	1	43	120	1979	35	2,855.6	2,847.8	7.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5151802	1	43	120	1980	36	2,855.0	2,847.8	7.1
5151802	1	43	120	1981	37	2,855.1	2,847.9	7.3
5151802	1	43	120	1983	39	2,850.6	2,847.9	2.8
5151802	1	43	120	1984	40	2,848.2	2,847.9	0.3
5151802	1	43	120	1985	41	2,856.1	2,847.9	8.2
5151802	1	43	120	1986	42	2,854.1	2,847.9	6.3
5151802	1	43	120	1987	43	2,856.8	2,847.9	9.0
5151802	1	43	120	1988	44	2,854.4	2,847.9	6.5
5151802	1	43	120	1989	45	2,853.0	2,847.8	5.1
5151802	1	43	120	1992	48	2,856.4	2,847.8	8.5
5151802	1	43	120	1993	49	2,852.9	2,847.8	5.1
5151802	1	43	120	1994	50	2,854.9	2,847.8	7.0
5151802	1	43	120	1995	51	2,850.2	2,847.8	2.4
5151803	2	43	120	1957	13	2,848.5	2,956.0	-107.5
5151803	2	43	120	1958	14	2,848.3	2,958.3	-110.0
5151803	2	43	120	1961	17	2,855.9	2,956.9	-101.0
5151803	2	43	120	1970	26	2,856.5	2,958.6	-102.1
5151803	2	43	120	1974	30	2,851.9	2,960.8	-108.9
5151804	2	46	119	1957	13	2,831.0	2,893.1	-62.1
5151804	2	46	119	1958	14	2,830.3	2,897.5	-67.2

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5151804	2	46	119	1974	30	2,833.4	2,900.6	-67.2
5151805	3	42	122	1957	13	2,866.3	2,968.3	-102.0
5151805	3	42	122	1958	14	2,867.1	2,969.9	-102.8
5151805	3	42	122	1974	30	2,871.5	2,972.1	-100.6
5151806	3	42	121	1974	30	2,849.9	2,972.4	-122.5
5151807	3	44	122	1957	13	2,870.1	2,969.4	-99.3
5151807	3	44	122	1958	14	2,870.3	2,971.2	-100.9
5151807	3	44	122	1961	17	2,870.8	2,970.2	-99.4
5151807	3	44	122	1962	18	2,869.5	2,969.9	-100.4
5151807	3	44	122	1963	19	2,869.2	2,969.7	-100.5
5151807	3	44	122	1964	20	2,869.8	2,969.4	-99.7
5151807	3	44	122	1965	21	2,869.6	2,969.2	-99.6
5151807	3	44	122	1966	22	2,869.2	2,969.3	-100.1
5151807	3	44	122	1967	23	2,869.5	2,969.1	-99.6
5151807	3	44	122	1968	24	2,869.1	2,970.6	-101.5
5151807	3	44	122	1969	25	2,868.2	2,970.3	-102.1
5151807	3	44	122	1970	26	2,870.4	2,971.4	-101.0
5151807	3	44	122	1971	27	2,876.1	2,971.6	-95.5
5151807	3	44	122	1972	28	2,871.6	2,973.2	-101.6
5151807	3	44	122	1975	31	2,870.9	2,973.9	-103.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5151807	3	44	122	1976	32	2,871.0	2,974.8	-103.8
5151807	3	44	122	1977	33	2,870.6	2,973.8	-103.3
5151807	3	44	122	1978	34	2,870.4	2,974.6	-104.2
5151807	3	44	122	1979	35	2,870.9	2,975.4	-104.5
5151807	3	44	122	1980	36	2,870.8	2,975.9	-105.0
5151807	3	44	122	1981	37	2,871.2	2,977.0	-105.8
5151807	3	44	122	1982	38	2,870.9	2,975.9	-105.0
5151807	3	44	122	1983	39	2,870.7	2,976.1	-105.5
5151807	3	44	122	1984	40	2,871.3	2,977.6	-106.3
5151807	3	44	122	1985	41	2,872.6	2,977.0	-104.4
5151807	3	44	122	1986	42	2,872.9	2,977.8	-104.8
5151807	3	44	122	1987	43	2,871.8	2,978.0	-106.3
5151807	3	44	122	1988	44	2,872.1	2,976.8	-104.7
5151807	3	44	122	1989	45	2,872.3	2,975.6	-103.3
5151807	3	44	122	1990	46	2,871.4	2,976.4	-104.9
5151807	3	44	122	1991	47	2,872.3	2,977.0	-104.7
5151807	3	44	122	1992	48	2,872.4	2,976.5	-104.1
5151807	3	44	122	1993	49	2,869.7	2,977.2	-107.4
5151807	3	44	122	1994	50	2,869.7	2,976.1	-106.4
5151807	3	44	122	1995	51	2,866.9	2,975.7	-108.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5151807	3	44	122	1996	52	2,871.1	2,974.8	-103.7
5151808	3	44	122	1957	13	2,869.8	2,969.4	-99.6
5151808	3	44	122	1990	46	2,866.7	2,976.4	-109.7
5151808	3	44	122	1999	55	2,861.0	2,973.2	-112.2
5151808	3	44	122	2000	56	2,858.2	2,973.8	-115.6
5151808	3	44	122	2001	57	2,863.2	2,973.1	-109.9
5151808	3	44	122	2002	58	2,862.4	2,973.7	-111.3
5151808	3	44	122	2004	60	2,858.9	2,975.1	-116.2
5151808	3	44	122	2006	62	2,852.3	2,974.7	-122.4
5151808	3	44	122	2007	63	2,856.3	2,975.1	-118.9
5151808	3	44	122	2008	64	2,854.6	2,974.2	-119.6
5151809	3	37	125	1974	30	2,865.8	2,958.1	-92.3
5151810	3	45	122	1992	48	2,823.0	2,977.3	-154.3
5151810	3	45	122	2004	60	2,832.2	2,975.8	-143.6
5151811	3	44	122	1992	48	2,795.0	2,976.5	-181.5
5151811	3	44	122	2004	60	2,803.4	2,975.1	-171.7
5151812	3	45	122	1992	48	2,850.0	2,977.3	-127.3
5159201	1	50	116	1957	13	2,840.2	2,841.5	-1.3
5159201	1	50	116	1974	30	2,838.6	2,841.6	-3.0
5159301	2	51	123	1974	30	2,942.0	3,029.0	-87.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5159501	1	59	110	1974	30	2,821.2	2,822.4	-1.2
5159602	2	66	123	1974	30	3,249.9	3,275.6	-25.7
5159602	2	66	123	2004	60	3,258.4	3,291.7	-33.3
5159801	1	73	101	1974	30	2,762.1	2,767.9	-5.8
5159803	2	66	105	1974	30	2,782.5	2,859.8	-77.3
5159803	2	66	105	1985	41	2,713.0	2,865.0	-152.0
5159803	2	66	105	2005	61	2,790.1	2,864.9	-74.8
5159804	1	74	101	1974	30	2,758.9	2,765.4	-6.5
5159805	1	75	100	1974	30	2,759.1	2,762.8	-3.6
5159806	1	75	101	2004	60	2,737.9	2,764.2	-26.3
5159806	1	75	101	2005	61	2,744.8	2,764.1	-19.3
5160401	3	73	129	1974	30	3,604.7	3,449.6	155.1
5160401	3	73	129	1990	46	3,590.0	3,482.7	107.3
5160401	3	73	129	2004	60	3,588.1	3,465.4	122.7
5160402	2	71	125	1974	30	3,561.9	3,353.6	208.3
5160501	3	82	132	1979	35	3,524.0	3,554.4	-30.4
5160703	2	85	120	1974	30	3,413.9	3,347.1	66.8
5160705	2	78	120	2004	60	3,354.7	3,339.4	15.2
5160801	3	81	128	1974	30	3,423.5	3,472.6	-49.1
5160803	3	89	127	1974	30	3,480.9	3,479.4	1.5

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
5160803	3	89	127	2004	60	3,469.8	3,498.8	-29.0
5160804	3	84	127	2004	60	3,480.9	3,486.1	-5.3
5160805	3	80	128	1985	41	3,557.0	3,510.8	46.2
5160805	3	80	128	2004	60	3,553.5	3,487.0	66.6
7403201	2	85	98	1974	30	2,740.5	2,835.8	-95.3
7403202	1	81	99	1974	30	2,808.5	2,750.2	58.3
7403203	1	81	98	1974	30	2,742.8	2,749.7	-6.9
7403203	1	81	98	2004	60	2,739.7	2,749.7	-10.1
7403204	1	79	99	1974	30	2,760.6	2,755.3	5.3
7403205	1	77	98	1974	30	2,766.8	2,762.0	4.8
7403206	2	86	97	1974	30	2,739.3	2,832.6	-93.3
7403207	1	80	99	1990	46	2,786.6	2,752.3	34.2
7403207	1	80	99	2001	57	2,781.1	2,752.3	28.8
7403207	1	80	99	2004	60	2,778.7	2,752.3	26.3
7403208	1	80	99	2004	60	2,793.1	2,752.3	40.7
7403305	2	82	107	2004	60	3,002.0	3,054.8	-52.8
7403501	1	91	92	1974	30	2,738.7	2,738.0	0.7
7403501	1	91	92	2004	60	2,738.3	2,738.2	0.2
7403502	1	91	92	1974	30	2,739.9	2,738.0	1.9
7403503	1	90	96	1974	30	2,737.3	2,740.9	-3.6

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7403503	1	90	96	2004	60	2,730.3	2,741.1	-10.8
7403504	1	89	96	1974	30	2,718.1	2,741.4	-23.3
7403504	1	89	96	2004	60	2,712.3	2,741.5	-29.2
7403505	1	91	94	1979	35	2,729.0	2,739.3	-10.3
7403505	1	91	94	2004	60	2,724.2	2,739.6	-15.4
7403602	2	99	97	2001	57	2,862.4	2,811.3	51.1
7403603	2	99	97	2004	60	2,837.3	2,821.2	16.1
7403604	2	95	96	2004	60	2,725.0	2,826.3	-101.3
7403605	2	98	94	2004	60	2,789.1	2,817.6	-28.5
7403901	1	100	91	1974	30	2,718.1	2,721.3	-3.2
7403902	1	100	91	1974	30	2,718.2	2,721.3	-3.1
7404101	2	91	115	1974	30	3,439.4	3,278.4	161.0
7404201	2	90	122	1974	30	3,428.7	3,395.9	32.8
7404201	2	90	122	2004	60	3,438.7	3,419.5	19.1
7404202	2	94	123	2004	60	3,458.8	3,447.7	11.1
7404401	2	97	109	1973	29	3,288.9	3,159.8	129.1
7404501	2	104	113	1973	29	3,404.2	3,255.0	149.2
7404801	2	121	110	1974	30	3,303.1	3,196.9	106.2
7404801	2	121	110	2004	60	3,305.5	3,215.4	90.1
7404901	3	124	116	1974	30	3,560.1	3,304.8	255.3

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7411301	1	115	92	1961	17	2,699.6	2,688.9	10.8
7411301	1	115	92	1974	30	2,693.1	2,688.9	4.2
7412101	2	122	99	1974	30	2,983.8	2,891.0	92.8
7412101	2	122	99	2004	60	2,983.2	2,898.5	84.7
7412201	2	129	106	1974	30	3,207.9	3,106.3	101.6
7412201	2	129	106	2004	60	3,213.8	3,122.8	91.0
7412401	2	127	91	1974	30	2,673.2	2,782.0	-108.8
7412601	2	137	109	1974	30	3,254.7	3,154.3	100.4
7412601	2	137	109	2004	60	3,249.3	3,175.1	74.2
7412602	2	141	110	1974	30	3,259.1	3,165.9	93.2
7412801	1	147	91	1974	30	2,649.6	2,635.8	13.8
7412802	1	148	89	1973	29	2,636.7	2,634.5	2.2
7412803	1	150	89	1961	17	2,634.1	2,630.8	3.3
7413101	2	132	117	1974	30	3,301.4	3,297.2	4.2
7413101	2	132	117	2004	60	3,378.3	3,323.9	54.4
7413102	2	140	119	1974	30	3,448.2	3,307.4	140.8
7413102	2	140	119	2004	60	3,455.4	3,332.4	123.0
7413401	2	142	111	1974	30	3,301.8	3,179.8	122.0
7413401	2	142	111	2004	60	3,302.9	3,202.9	100.0
7413402	2	145	118	1974	30	3,304.0	3,284.1	19.9

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7413403	2	143	111	2004	60	3,282.1	3,201.7	80.3
7420201	1	157	86	1961	17	2,611.6	2,617.6	-6.0
7420202	1	158	87	1974	30	2,617.2	2,616.9	0.3
7420203	1	155	87	1974	30	2,623.2	2,622.1	1.1
7420204	1	156	89	1974	30	2,614.1	2,621.9	-7.8
7420205	1	150	88	1974	30	2,633.1	2,630.9	2.2
7420206	2	156	89	2004	60	2,475.9	2,736.9	-261.0
7420207	1	156	89	2004	60	2,605.4	2,622.0	-16.6
7420208	1	156	89	2004	60	2,595.8	2,622.0	-26.2
7420601	1	164	86	1973	29	2,610.4	2,608.3	2.1
7420601	1	164	86	1990	46	2,610.3	2,608.7	1.6
7420602	1	164	85	1973	29	2,612.2	2,608.5	3.7
7420603	1	173	85	2005	61	2,602.7	2,599.4	3.3
7420901	1	183	82	1949	5	2,592.0	2,593.7	-1.7
7420902	1	181	85	1973	29	2,590.1	2,593.3	-3.2
7420903	1	180	83	1973	29	2,589.5	2,594.1	-4.6
7420904	1	177	83	1973	29	2,592.1	2,595.5	-3.4
7420905	1	178	85	1973	29	2,605.2	2,595.0	10.2
7420906	1	178	85	1973	29	2,589.3	2,595.0	-5.7
7422101	3	179	134	2004	60	3,320.6	3,356.3	-35.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7422201	2	190	132	1974	30	3,163.6	3,141.6	22.0
7422201	2	190	132	2004	60	3,181.2	3,315.6	-134.4
7422202	3	183	135	2004	60	3,205.5	3,349.6	-144.2
7422401	2	190	126	1974	30	2,858.4	3,015.4	-157.0
7422404	2	192	117	2005	61	3,003.5	3,040.5	-37.0
7422405	2	190	120	2005	61	3,036.3	3,105.6	-69.3
7422501	2	191	130	1974	30	3,158.3	3,091.3	67.0
7422502	2	194	125	1974	30	3,040.7	2,982.8	57.9
7422502	2	194	125	2004	60	3,040.1	3,160.2	-120.0
7422503	2	192	128	1974	30	3,079.6	3,046.6	33.0
7422701	2	202	119	1974	30	2,937.2	2,828.3	108.9
7422701	2	202	119	2004	60	2,935.1	2,975.9	-40.8
7422801	2	205	118	1974	30	2,887.8	2,781.7	106.2
7422902	2	216	132	1974	30	2,763.0	2,777.3	-14.3
7422902	2	216	132	2004	60	2,766.0	2,966.1	-200.1
7423801	3	217	152	1949	5	3,160.3	3,284.5	-124.2
7423801	3	217	152	1974	30	3,160.8	3,285.8	-125.0
7424402	3	226	174	2001	57	3,333.0	3,395.4	-62.4
7429101	1	191	87	1973	29	2,581.8	2,580.5	1.3
7429201	1	196	89	1973	29	2,573.3	2,573.5	-0.2

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7429201	1	196	89	2005	61	2,573.3	2,573.4	-0.1
7429202	1	198	89	1973	29	2,573.4	2,571.8	1.6
7429203	1	199	90	1973	29	2,573.1	2,570.9	2.2
7429204	1	199	89	1973	29	2,571.8	2,570.9	0.9
7429205	1	201	91	1973	29	2,574.7	2,566.4	8.3
7429206	2	202	91	1973	29	2,569.8	2,595.8	-26.0
7429207	1	202	91	1973	29	2,569.1	2,566.5	2.6
7429208	1	202	91	1973	29	2,571.8	2,566.5	5.3
7429209	1	202	91	1973	29	2,568.2	2,566.5	1.7
7429210	1	202	91	1973	29	2,568.4	2,566.5	1.9
7429211	1	203	91	1973	29	2,562.4	2,564.7	-2.3
7429212	1	202	92	2004	60	2,557.5	2,565.6	-8.1
7429301	2	205	96	1973	29	2,584.3	2,588.7	-4.3
7429601	1	216	95	1961	17	2,554.0	2,550.7	3.3
7429602	1	218	97	1961	17	2,558.3	2,547.8	10.5
7429602	1	218	97	1973	29	2,560.4	2,547.0	13.4
7429602	1	218	97	2005	61	2,561.6	2,547.6	14.0
7429603	1	213	97	1974	30	2,568.1	2,550.1	18.0
7429604	2	214	97	1973	29	2,570.7	2,576.9	-6.2
7429605	1	212	96	1973	29	2,563.9	2,550.7	13.2

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7429606	1	211	96	1973	29	2,566.4	2,551.6	14.8
7429607	1	210	96	1973	29	2,569.2	2,553.2	16.0
7429608	1	210	95	1973	29	2,562.5	2,554.2	8.3
7429609	1	213	97	1974	30	2,565.4	2,550.1	15.3
7429610	1	215	96	1973	29	2,564.1	2,549.1	15.0
7429611	2	212	99	1973	29	2,562.0	2,579.9	-17.9
7429611	2	212	99	2005	61	2,557.6	2,572.3	-14.7
7429612	2	216	94	1964	20	2,544.0	2,556.5	-12.4
7429612	2	216	94	1974	30	2,545.2	2,578.9	-33.7
7429613	1	208	95	1973	29	2,565.4	2,557.9	7.5
7429614	1	221	96	1974	30	2,552.1	2,544.0	8.2
7429616	2	216	99	1979	35	2,556.8	2,593.8	-36.9
7429616	2	216	99	2004	60	2,552.2	2,572.5	-20.3
7429617	2	216	99	1985	41	2,546.0	2,595.0	-49.0
7429618	2	213	100	1990	46	2,553.0	2,593.9	-40.9
7429618	2	213	100	2005	61	2,556.9	2,572.3	-15.4
7429619	2	217	98	1988	44	2,537.0	2,592.2	-55.2
7429620	1	217	95	2004	60	2,555.0	2,551.2	3.8
7429621	2	214	99	2005	61	2,567.6	2,570.6	-2.9
7429622	2	214	99	2005	61	2,568.5	2,570.6	-2.1

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7429623	2	214	99	2005	61	2,564.0	2,570.6	-6.6
7429624	1	218	97	2005	61	2,549.6	2,547.6	2.0
7430102	2	211	108	1973	29	2,728.9	2,620.4	108.5
7430103	2	206	112	1973	29	2,807.5	2,691.9	115.6
7430201	2	212	119	1974	30	2,890.6	2,719.3	171.3
7430202	2	217	114	1949	5	2,757.0	2,592.3	164.7
7430203	2	212	117	1974	30	2,830.5	2,704.2	126.3
7430204	2	209	118	2004	60	2,909.4	2,858.1	51.4
7430301	2	225	127	1949	5	2,727.0	2,625.3	101.7
7430301	2	225	127	1974	30	2,727.0	2,689.9	37.1
7430301	2	225	127	2005	61	2,721.7	2,791.7	-69.9
7430401	1	225	102	1949	5	2,541.0	2,537.2	3.8
7430402	1	219	99	1948	4	2,537.0	2,544.2	-7.2
7430402	1	219	99	1951	7	2,544.2	2,544.4	-0.2
7430402	1	219	99	1961	17	2,544.7	2,544.8	-0.1
7430402	1	219	99	1974	30	2,546.6	2,542.9	3.6
7430403	1	221	100	1973	29	2,561.1	2,541.5	19.7
7430404	1	221	97	1961	17	2,549.5	2,544.1	5.4
7430404	1	221	97	1974	30	2,552.5	2,543.1	9.4
7430407	2	222	103	1974	30	2,531.9	2,582.9	-51.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430407	2	222	103	1990	46	2,547.3	2,590.1	-42.7
7430407	2	222	103	2001	57	2,546.7	2,570.7	-24.0
7430408	2	223	104	1974	30	2,553.0	2,583.2	-30.2
7430409	2	222	102	1974	30	2,538.0	2,582.5	-44.5
7430410	2	221	102	1973	29	2,557.0	2,576.1	-19.1
7430411	2	219	101	1974	30	2,556.6	2,583.6	-27.0
7430412	1	220	100	1973	29	2,550.1	2,542.2	7.9
7430413	1	219	99	1949	5	2,544.5	2,544.3	0.2
7430413	1	219	99	1974	30	2,548.6	2,542.9	5.7
7430414	2	216	100	1973	29	2,569.6	2,577.6	-8.0
7430415	2	216	101	1973	29	2,587.3	2,578.1	9.1
7430416	1	219	98	1974	30	2,556.6	2,544.3	12.3
7430417	1	219	97	1973	29	2,558.9	2,545.7	13.2
7430418	1	223	100	1973	29	2,554.2	2,539.7	14.5
7430419	2	222	101	1973	29	2,549.3	2,575.2	-25.9
7430420	2	223	102	1974	30	2,543.3	2,581.9	-38.6
7430421	2	223	102	1974	30	2,542.6	2,581.9	-39.3
7430422	1	225	101	1974	30	2,554.4	2,536.8	17.6
7430424	2	218	99	1949	5	2,541.2	2,535.7	5.5
7430425	1	220	97	1973	29	2,559.4	2,544.3	15.1

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430426	1	226	101	1961	17	2,547.5	2,537.3	10.2
7430426	1	226	101	1974	30	2,550.2	2,535.8	14.4
7430426	1	226	101	2004	60	2,545.1	2,537.4	7.7
7430427	1	219	99	1990	46	2,559.9	2,545.6	14.3
7430428	2	219	101	1988	44	2,543.0	2,593.2	-50.2
7430429	1	223	99	2004	60	2,548.5	2,541.3	7.2
7430431	2	223	103	2004	60	2,540.1	2,573.5	-33.4
7430433	2	224	104	1981	37	2,533.0	2,594.4	-61.4
7430502	1	228	105	1974	30	2,551.5	2,529.3	22.2
7430502	1	228	105	2005	61	2,548.1	2,530.5	17.6
7430503	1	228	105	1969	25	2,530.0	2,530.7	-0.7
7430503	1	228	105	1974	30	2,552.2	2,529.3	22.9
7430503	1	228	105	2005	61	2,551.1	2,530.5	20.6
7430504	2	226	106	2005	61	2,535.3	2,572.6	-37.3
7430601	2	232	118	1974	30	2,649.3	2,608.2	41.2
7430602	2	232	118	1974	30	2,648.0	2,608.2	39.8
7430603	2	230	124	1949	5	2,687.8	2,601.7	86.1
7430603	2	230	124	1974	30	2,689.3	2,661.4	27.9
7430604	2	227	120	1991	47	2,660.0	2,717.9	-57.8
7430604	2	227	120	2004	60	2,640.6	2,564.4	76.2

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430605	2	228	121	1992	48	2,659.0	2,716.1	-57.1
7430605	2	228	121	2004	60	2,645.4	2,574.8	70.6
7430606	2	228	119	1999	55	2,642.9	2,598.3	44.6
7430607	2	228	118	2001	57	2,628.5	2,536.1	92.4
7430608	2	232	119	2005	61	2,655.7	2,634.9	20.8
7430610	2	231	120	2005	61	2,648.9	2,640.4	8.5
7430611	2	231	119	2005	61	2,642.5	2,624.3	18.3
7430612	2	232	120	2005	61	2,659.5	2,651.7	7.8
7430613	2	232	120	2005	61	2,653.9	2,651.7	2.1
7430701	1	228	100	1961	17	2,544.3	2,536.5	7.8
7430701	1	228	100	1974	30	2,549.4	2,535.3	14.2
7430701	1	228	100	2005	61	2,545.4	2,535.9	9.4
7430702	1	225	99	1973	29	2,537.8	2,539.5	-1.7
7430703	1	229	102	1974	30	2,552.3	2,530.9	21.4
7430704	1	228	103	1974	30	2,548.5	2,531.0	17.5
7430705	1	227	103	1974	30	2,555.0	2,532.4	22.6
7430706	1	224	98	1963	19	2,537.0	2,541.3	-4.3
7430706	1	224	98	1966	22	2,538.1	2,541.3	-3.2
7430706	1	224	98	1967	23	2,539.5	2,541.2	-1.7
7430706	1	224	98	1968	24	2,538.5	2,541.2	-2.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430706	1	224	98	1969	25	2,541.3	2,541.1	0.1
7430706	1	224	98	1970	26	2,538.6	2,541.1	-2.5
7430706	1	224	98	1971	27	2,538.7	2,541.0	-2.3
7430706	1	224	98	1972	28	2,540.1	2,540.9	-0.8
7430706	1	224	98	1973	29	2,539.1	2,540.8	-1.7
7430706	1	224	98	1975	31	2,541.0	2,540.7	0.3
7430706	1	224	98	1976	32	2,540.5	2,540.7	-0.2
7430706	1	224	98	1977	33	2,540.7	2,540.6	0.0
7430706	1	224	98	1980	36	2,539.9	2,540.8	-0.9
7430706	1	224	98	1982	38	2,540.6	2,541.1	-0.5
7430706	1	224	98	1983	39	2,541.6	2,541.3	0.3
7430706	1	224	98	1984	40	2,539.8	2,541.5	-1.6
7430706	1	224	98	1985	41	2,540.0	2,541.5	-1.5
7430706	1	224	98	1986	42	2,540.1	2,541.5	-1.4
7430706	1	224	98	1987	43	2,542.9	2,541.5	1.4
7430706	1	224	98	1988	44	2,541.0	2,541.5	-0.4
7430706	1	224	98	1989	45	2,540.9	2,541.4	-0.5
7430706	1	224	98	1991	47	2,540.9	2,541.5	-0.7
7430706	1	224	98	1992	48	2,539.4	2,541.6	-2.2
7430706	1	224	98	1993	49	2,541.7	2,541.7	0.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430706	1	224	98	1994	50	2,541.2	2,541.8	-0.6
7430706	1	224	98	1995	51	2,539.6	2,541.8	-2.2
7430706	1	224	98	1996	52	2,538.7	2,541.8	-3.1
7430706	1	224	98	1999	55	2,539.4	2,541.7	-2.3
7430706	1	224	98	2000	56	2,539.3	2,541.7	-2.4
7430706	1	224	98	2002	58	2,536.4	2,541.5	-5.2
7430706	1	224	98	2004	60	2,538.2	2,541.4	-3.2
7430706	1	224	98	2005	61	2,539.2	2,541.0	-1.9
7430706	1	224	98	2006	62	2,540.3	2,541.0	-0.7
7430706	1	224	98	2008	64	2,539.2	2,541.3	-2.1
7430708	1	224	99	2004	60	2,539.9	2,540.7	-0.8
7430709	1	227	102	2005	61	2,547.7	2,534.4	13.3
7430710	1	228	101	2005	61	2,547.9	2,534.5	13.5
7430801	1	232	108	1949	5	2,524.5	2,525.2	-0.7
7430801	1	232	108	1974	30	2,538.1	2,524.3	13.8
7430802	1	230	104	1961	17	2,541.4	2,529.3	12.1
7430802	1	230	104	1973	29	2,542.8	2,527.7	15.1
7430803	1	234	107	1961	17	2,531.8	2,527.7	4.1
7430803	1	234	107	1974	30	2,537.1	2,527.4	9.7
7430806	1	235	107	1974	30	2,536.5	2,532.8	3.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430807	1	231	108	1974	30	2,545.2	2,524.2	21.0
7430807	1	231	108	2004	60	2,543.6	2,525.4	18.2
7430810	2	233	110	1974	30	2,565.5	2,583.1	-17.6
7430811	2	233	109	1990	46	2,546.7	2,591.1	-44.4
7430812	2	231	108	1983	39	2,524.0	2,586.8	-62.8
7430812	2	231	108	2004	60	2,533.9	2,577.3	-43.4
7430813	1	231	108	2004	60	2,533.3	2,525.4	7.8
7430813	1	231	108	2005	61	2,532.8	2,524.8	8.0
7430813	1	231	108	2006	62	2,532.3	2,524.6	7.7
7430814	2	230	107	2004	60	2,553.1	2,576.6	-23.4
7430815	2	230	107	2004	60	2,553.3	2,576.6	-23.2
7430816	1	232	106	2004	60	2,529.5	2,524.8	4.7
7430817	1	232	105	1979	35	2,529.4	2,525.7	3.7
7430817	1	232	105	1980	36	2,529.1	2,525.7	3.4
7430817	1	232	105	1981	37	2,530.3	2,525.7	4.6
7430817	1	232	105	1982	38	2,529.0	2,525.8	3.2
7430817	1	232	105	1983	39	2,529.7	2,525.8	3.9
7430817	1	232	105	1984	40	2,529.3	2,525.9	3.4
7430817	1	232	105	1985	41	2,529.1	2,525.9	3.2
7430817	1	232	105	1986	42	2,529.9	2,525.9	4.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430817	1	232	105	1987	43	2,530.5	2,525.9	4.6
7430817	1	232	105	1988	44	2,528.7	2,525.9	2.8
7430817	1	232	105	1989	45	2,527.6	2,525.9	1.8
7430817	1	232	105	1990	46	2,528.2	2,525.9	2.3
7430817	1	232	105	1991	47	2,528.5	2,525.9	2.6
7430817	1	232	105	1993	49	2,529.9	2,525.9	4.0
7430818	1	231	106	1974	30	2,544.2	2,525.1	19.0
7430818	1	231	106	1979	35	2,543.6	2,524.9	18.7
7430818	1	231	106	1980	36	2,543.5	2,525.1	18.4
7430818	1	231	106	1981	37	2,544.5	2,525.4	19.1
7430818	1	231	106	1982	38	2,543.4	2,525.8	17.6
7430818	1	231	106	1983	39	2,544.4	2,526.2	18.2
7430818	1	231	106	1984	40	2,543.7	2,526.5	17.1
7430818	1	231	106	1985	41	2,543.9	2,526.7	17.2
7430818	1	231	106	1986	42	2,544.1	2,526.7	17.4
7430818	1	231	106	1987	43	2,545.0	2,526.6	18.3
7430818	1	231	106	1988	44	2,543.2	2,526.6	16.6
7430818	1	231	106	1989	45	2,542.3	2,526.5	15.9
7430818	1	231	106	1990	46	2,542.9	2,526.6	16.3
7430818	1	231	106	1991	47	2,543.4	2,526.7	16.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430818	1	231	106	1993	49	2,544.1	2,527.1	17.0
7430819	1	231	106	1979	35	2,543.9	2,524.9	19.0
7430819	1	231	106	1980	36	2,543.9	2,525.1	18.7
7430819	1	231	106	1981	37	2,545.0	2,525.4	19.5
7430819	1	231	106	1982	38	2,543.9	2,525.8	18.1
7430819	1	231	106	1983	39	2,544.9	2,526.2	18.7
7430819	1	231	106	1984	40	2,544.2	2,526.5	17.6
7430819	1	231	106	1985	41	2,543.9	2,526.7	17.3
7430819	1	231	106	1986	42	2,544.5	2,526.7	17.9
7430819	1	231	106	1987	43	2,544.9	2,526.6	18.2
7430819	1	231	106	1988	44	2,543.3	2,526.6	16.7
7430819	1	231	106	1989	45	2,542.3	2,526.5	15.8
7430819	1	231	106	1990	46	2,542.9	2,526.6	16.3
7430819	1	231	106	1991	47	2,543.4	2,526.7	16.7
7430819	1	231	106	1993	49	2,544.1	2,527.1	17.0
7430820	1	236	109	1979	35	2,551.0	2,546.5	4.5
7430820	1	236	109	1980	36	2,550.8	2,546.5	4.4
7430820	1	236	109	1981	37	2,552.2	2,546.5	5.7
7430820	1	236	109	1982	38	2,552.3	2,546.5	5.8
7430820	1	236	109	1983	39	2,551.5	2,546.5	5.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430820	1	236	109	1984	40	2,551.8	2,546.5	5.3
7430820	1	236	109	1985	41	2,551.7	2,546.5	5.2
7430820	1	236	109	1986	42	2,553.2	2,546.5	6.7
7430820	1	236	109	1987	43	2,553.3	2,546.5	6.8
7430820	1	236	109	1988	44	2,552.1	2,546.5	5.6
7430820	1	236	109	1989	45	2,551.5	2,546.5	5.0
7430820	1	236	109	1990	46	2,551.1	2,546.5	4.6
7430820	1	236	109	1991	47	2,551.7	2,546.5	5.2
7430821	1	236	109	1979	35	2,551.1	2,546.5	4.6
7430821	1	236	109	1980	36	2,550.6	2,546.5	4.1
7430821	1	236	109	1981	37	2,552.0	2,546.5	5.5
7430821	1	236	109	1982	38	2,551.6	2,546.5	5.1
7430821	1	236	109	1983	39	2,550.9	2,546.5	4.4
7430821	1	236	109	1984	40	2,551.1	2,546.5	4.6
7430821	1	236	109	1985	41	2,551.3	2,546.5	4.8
7430821	1	236	109	1986	42	2,552.9	2,546.5	6.4
7430821	1	236	109	1987	43	2,552.9	2,546.5	6.4
7430821	1	236	109	1988	44	2,551.6	2,546.5	5.1
7430821	1	236	109	1989	45	2,550.9	2,546.5	4.4
7430821	1	236	109	1990	46	2,550.7	2,546.5	4.2

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7430821	1	236	109	1991	47	2,551.2	2,546.5	4.7
7430822	2	236	108	1979	35	2,546.6	2,543.4	3.1
7430822	2	236	108	1980	36	2,545.7	2,543.4	2.3
7430822	2	236	108	1981	37	2,547.4	2,543.5	3.9
7430822	2	236	108	1982	38	2,548.5	2,543.4	5.1
7430822	2	236	108	1983	39	2,546.1	2,543.4	2.7
7430822	2	236	108	1984	40	2,546.4	2,543.5	2.9
7430822	2	236	108	1985	41	2,546.6	2,543.5	3.1
7430822	2	236	108	1986	42	2,548.4	2,543.5	4.9
7430822	2	236	108	1987	43	2,548.4	2,543.5	4.9
7430822	2	236	108	1988	44	2,547.0	2,543.5	3.5
7430822	2	236	108	1989	45	2,545.8	2,543.4	2.4
7430822	2	236	108	1990	46	2,546.0	2,543.5	2.5
7430822	2	236	108	1991	47	2,546.5	2,543.5	3.0
7430902	3	242	114	1949	5	2,525.0	2,549.1	-24.1
7430902	3	242	114	1974	30	2,532.0	2,550.2	-18.2
7430902	3	242	114	2005	61	2,536.0	2,550.1	-14.0
7430904	3	241	113	1974	30	2,535.1	2,540.5	-5.3
7430904	3	241	113	2005	61	2,540.2	2,540.4	-0.3
7430905	3	242	114	2005	61	2,541.4	2,550.1	-8.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7431201	2	234	137	1974	30	2,727.6	2,721.1	6.5
7431201	2	234	137	2004	60	2,742.6	2,900.3	-157.7
7431202	3	232	143	1949	5	3,004.0	3,168.6	-164.6
7431501	2	244	137	1974	30	2,846.7	2,757.9	88.8
7431501	2	244	137	2004	60	2,908.8	2,959.9	-51.0
7431602	3	250	146	1969	25	3,068.0	3,213.5	-145.5
7431602	3	250	146	2004	60	3,075.0	3,216.6	-141.6
7431704	2	241	125	1974	30	2,732.7	2,681.3	51.4
7431704	2	241	125	2005	61	2,736.1	2,804.5	-68.4
7431705	2	241	125	2005	61	2,736.8	2,804.5	-67.7
7431706	2	242	125	2005	61	2,773.5	2,821.8	-48.2
7431801	3	256	133	2005	61	3,020.4	2,960.0	60.3
7432701	3	261	146	2004	60	3,350.6	3,263.0	87.6
7439101	3	255	116	1961	17	2,520.2	2,528.9	-8.7
7439102	3	255	116	1974	30	2,522.3	2,528.9	-6.6
7439103	2	260	118	2005	61	2,476.1	2,489.1	-13.0
7439104	1	263	117	2005	61	2,480.5	2,495.6	-15.2
7439105	1	263	117	2005	61	2,481.2	2,495.6	-14.4
7439106	3	252	118	2005	61	2,527.8	2,540.0	-12.2
7439201	3	262	118	1949	5	2,478.0	2,567.6	-89.6

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7439201	3	262	118	1974	30	2,478.8	2,569.0	-90.2
7439202	3	263	120	1993	49	2,389.0	2,606.9	-217.9
7439203	3	263	119	1986	42	2,476.0	2,590.5	-114.5
7439203	3	263	119	2005	61	2,458.8	2,588.8	-130.1
7439501	2	269	119	1949	5	2,487.0	2,521.0	-34.0
7439502	1	268	119	1961	17	2,496.5	2,484.0	12.5
7439502	1	268	119	1965	21	2,496.4	2,484.0	12.4
7439502	1	268	119	1966	22	2,496.5	2,484.0	12.5
7439502	1	268	119	1967	23	2,498.3	2,484.0	14.3
7439502	1	268	119	1968	24	2,497.7	2,484.0	13.7
7439502	1	268	119	1969	25	2,493.2	2,483.9	9.3
7439502	1	268	119	1970	26	2,495.6	2,483.9	11.7
7439502	1	268	119	1971	27	2,496.5	2,483.9	12.6
7439502	1	268	119	1972	28	2,497.2	2,483.9	13.4
7439502	1	268	119	1975	31	2,496.3	2,483.8	12.4
7439502	1	268	119	1976	32	2,496.3	2,483.8	12.5
7439502	1	268	119	1977	33	2,496.5	2,483.8	12.7
7439502	1	268	119	1978	34	2,496.4	2,483.8	12.6
7439502	1	268	119	1979	35	2,497.1	2,483.8	13.3
7439502	1	268	119	1980	36	2,498.6	2,483.8	14.7

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7439502	1	268	119	1982	38	2,497.4	2,483.9	13.5
7439502	1	268	119	1984	40	2,495.4	2,484.0	11.4
7439502	1	268	119	1985	41	2,497.0	2,484.0	13.0
7439502	1	268	119	1986	42	2,498.1	2,484.0	14.1
7439502	1	268	119	1987	43	2,500.1	2,484.0	16.1
7439502	1	268	119	1989	45	2,498.0	2,484.0	14.0
7439502	1	268	119	1992	48	2,498.0	2,484.1	13.9
7439502	1	268	119	1993	49	2,495.7	2,484.1	11.6
7439502	1	268	119	1994	50	2,496.3	2,484.1	12.2
7439502	1	268	119	1995	51	2,495.4	2,484.1	11.3
7439502	1	268	119	1996	52	2,497.1	2,484.1	12.9
7439502	1	268	119	1997	53	2,496.3	2,484.1	12.2
7439502	1	268	119	1998	54	2,495.8	2,484.1	11.7
7439502	1	268	119	1999	55	2,496.9	2,484.1	12.8
7439502	1	268	119	2000	56	2,496.7	2,484.1	12.6
7439502	1	268	119	2001	57	2,496.6	2,484.1	12.5
7439502	1	268	119	2002	58	2,496.7	2,484.0	12.7
7439502	1	268	119	2006	62	2,497.0	2,483.9	13.1
7439502	1	268	119	2007	63	2,498.0	2,484.0	14.1
7439502	1	268	119	2008	64	2,497.0	2,484.0	13.0

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7439503	1	265	118	1961	17	2,479.2	2,491.3	-12.1
7439503	1	265	118	2005	61	2,485.0	2,491.1	-6.1
7439504	2	268	120	1964	20	2,467.0	2,527.2	-60.2
7439504	2	268	120	1974	30	2,482.0	2,530.9	-48.9
7439504	2	268	120	2005	61	2,483.6	2,528.2	-44.7
7439505	2	266	119	1974	30	2,457.4	2,530.7	-73.3
7439505	2	266	119	2005	61	2,470.7	2,528.2	-57.5
7439506	2	267	120	1949	5	2,437.0	2,528.2	-91.2
7439506	2	267	120	2005	61	2,468.5	2,529.7	-61.3
7439507	2	268	120	1949	5	2,482.0	2,526.8	-44.8
7439508	2	265	119	2005	61	2,484.5	2,528.5	-44.1
7439509	2	266	119	2005	61	2,490.7	2,528.2	-37.5
7439510	2	265	119	2005	61	2,476.6	2,528.5	-51.9
7439511	2	267	119	2005	61	2,468.5	2,527.0	-58.5
7439512	1	267	119	2005	61	2,491.9	2,485.3	6.6
7439513	2	266	119	2004	60	2,461.0	2,530.5	-69.5
7439513	2	266	119	2005	61	2,465.3	2,528.2	-62.9
7439514	2	266	119	2005	61	2,486.0	2,528.2	-42.2
7439516	2	267	120	2005	61	2,478.4	2,529.7	-51.3
7439517	3	269	125	1986	42	2,493.0	2,773.8	-280.8

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
7439601	3	278	124	1974	30	2,483.0	2,752.8	-269.8
7439601	3	278	124	2005	61	2,481.7	2,751.9	-270.3
7439801	2	277	117	1949	5	2,477.0	2,493.7	-16.7
7439802	2	278	118	1974	30	2,517.8	2,518.2	-0.4
7439803	2	280	118	1981	37	2,461.0	2,540.1	-79.1
7439803	2	280	118	2005	61	2,467.0	2,537.3	-70.3
7439901	2	287	120	1949	5	2,472.6	2,569.0	-96.4
7439901	2	287	120	1974	30	2,469.4	2,574.1	-104.7
7439902	1	283	118	1974	30	2,491.6	2,471.8	19.8
7439903	1	284	118	1974	30	2,456.4	2,471.0	-14.6
7439903	1	284	118	2005	61	2,457.8	2,471.0	-13.2
7439904	2	281	118	1974	30	2,479.7	2,547.7	-68.0
7439904	2	281	118	2005	61	2,485.9	2,545.5	-59.6
7439905	2	287	120	2005	61	2,467.7	2,571.2	-103.6
7439906	2	286	120	2005	61	2,493.7	2,569.3	-75.7
7439907	2	286	121	2005	61	2,549.8	2,568.8	-19.0
7439908	2	287	120	2005	61	2,464.3	2,571.2	-106.9
1000005	1	118	89	1978	31	2,691.9	2,682.0	9.9
1000006	2	117	87	1978	31	2,717.3	2,783.9	-66.6
1000008	2	291	117	1978	31	2,541.8	2,606.4	-64.5

State Well Number[1]	Layer	Row	Column	Year	Stress Period	Measured head (feet, amsl)	Simulated head(feet, amsl)	Residual (measured head - simulated head, feet)
1000009	3	155	84	1978	31	2,633.9	2,733.9	-100.1
1000010	2	141	86	1978	31	2,718.0	2,761.7	-43.7
1000011	2	226	95	1978	31	2,595.8	2,575.8	19.9
1000012	3	251	116	1978	31	2,500.3	2,519.0	-18.7
1000013	3	258	117	1978	31	2,542.0	2,531.6	10.3
1000014	2	278	113	1978	31	2,540.5	2,554.5	-14.0
1000015	2	268	113	1978	31	2,569.0	2,540.3	28.8
1000016	1	210	87	1978	31	2,561.9	2,540.5	21.3

1. Well numbers beginning with “1” are located in Mexico and data are from subsurface hydrology maps (INEGIa and INEGIb).

Appendix B: Responses to Stakeholder Comments

No comments have been received on the draft model report as of February 2013.