# *Draft: 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*
*December 3, 2012*

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*Texas Water Development Board*
*December 3, 2012*

*This document is released for the purpose of draft review under the authority of Shirley C. Wade, P.G. 525, on December 3, 2012.*

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# *Draft: 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*
*December 3, 2012*

## *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 Groundwater 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 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, 2007a) with an expected increase in groundwater development in the future. The Presidio County Groundwater 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.

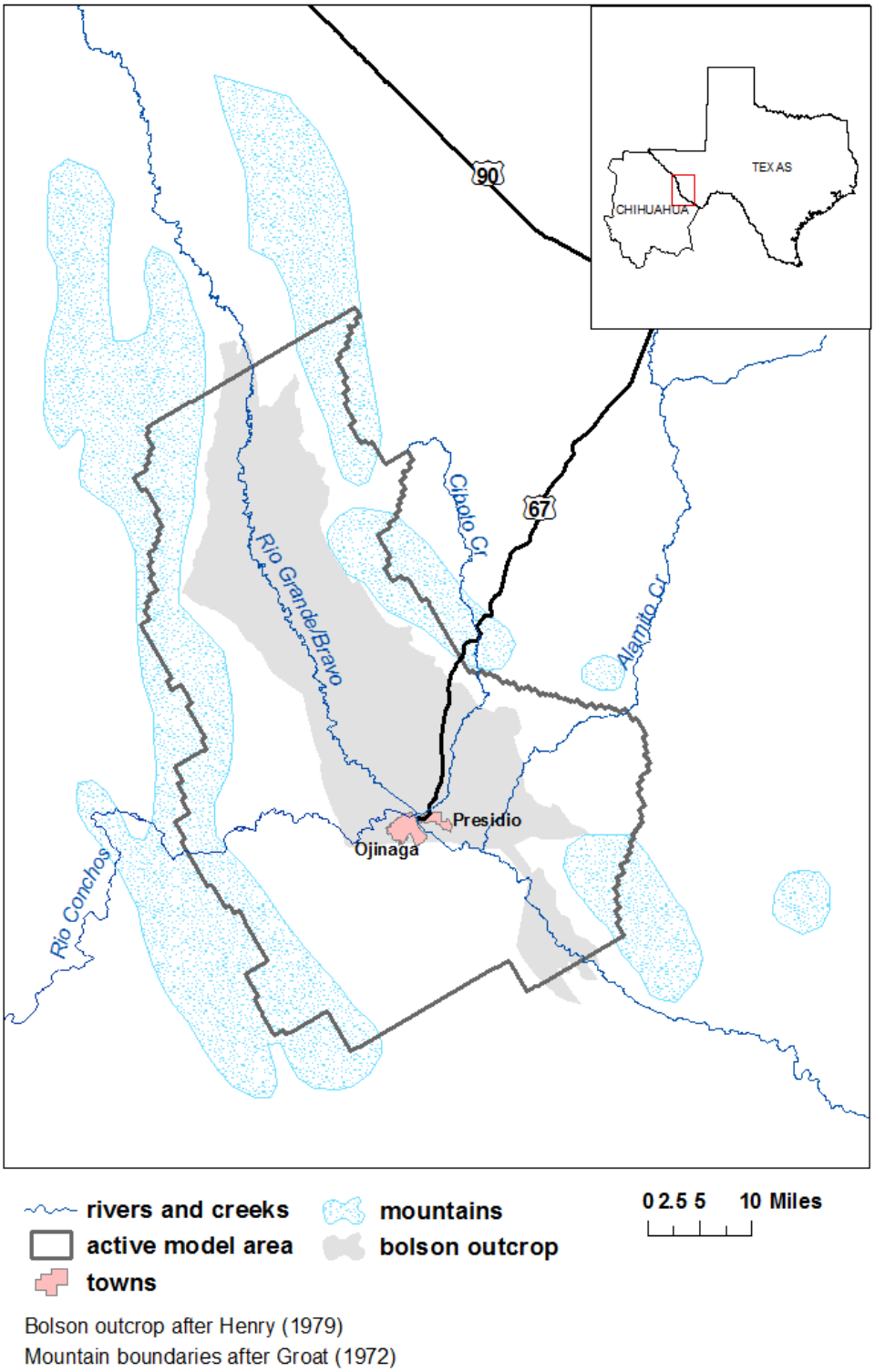
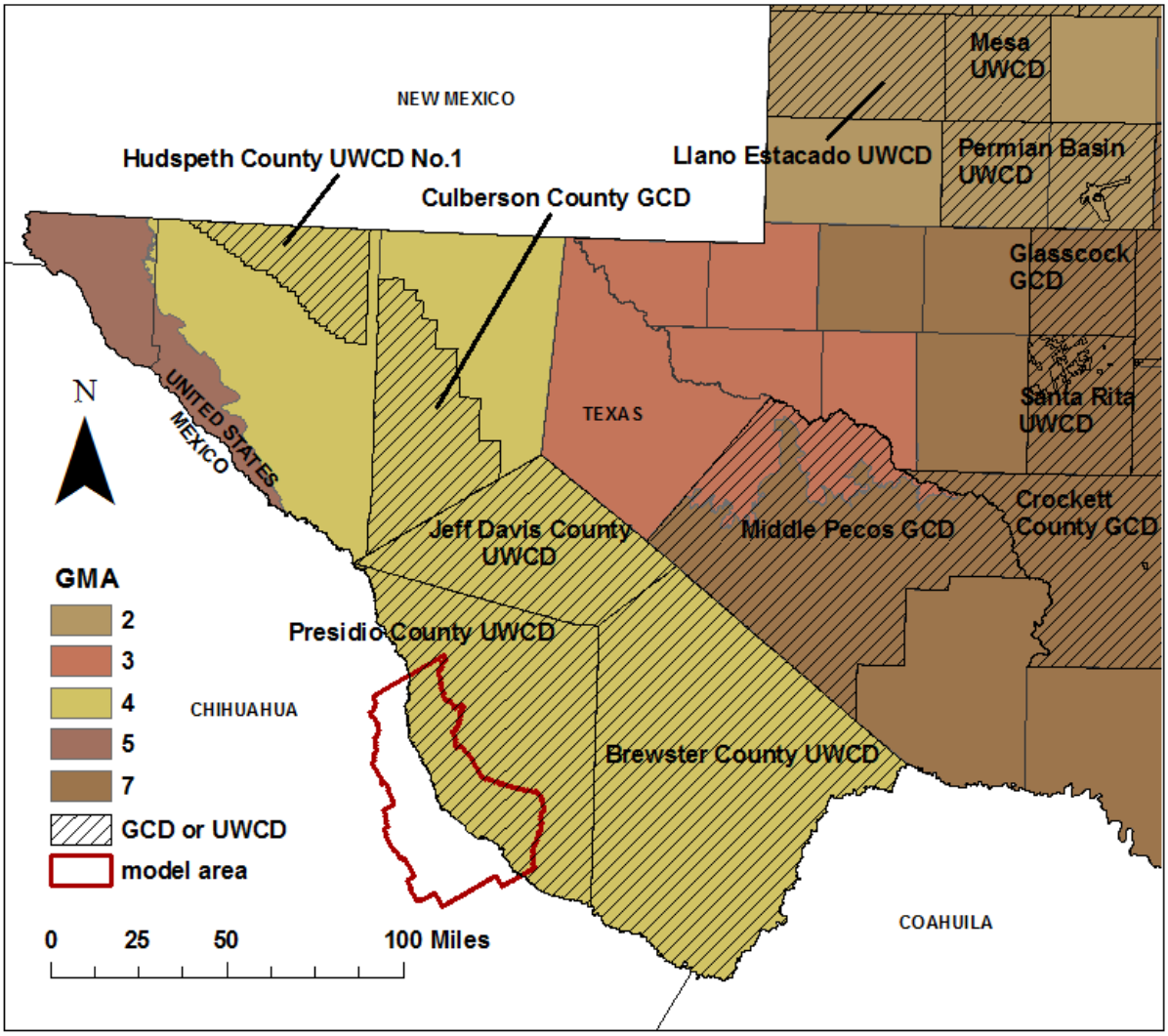



**FIGURE 1 STUDY AREA**




gcd boundary date = 08.22.12, gma boundary date = 12.15.11

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

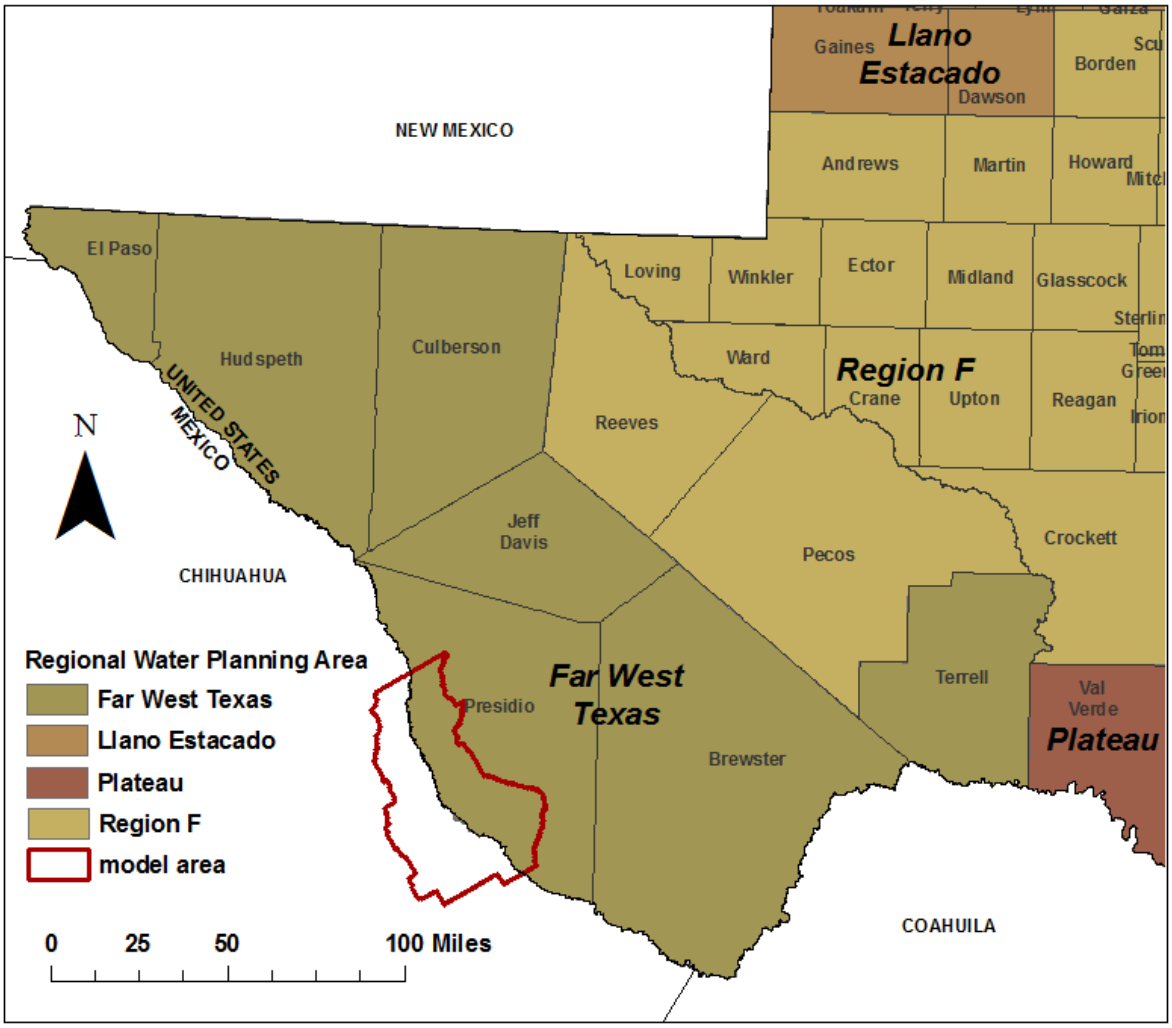



**FIGURE 3 REGIONAL WATER PLANNING AREAS IN STUDY AREA.**

# *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).

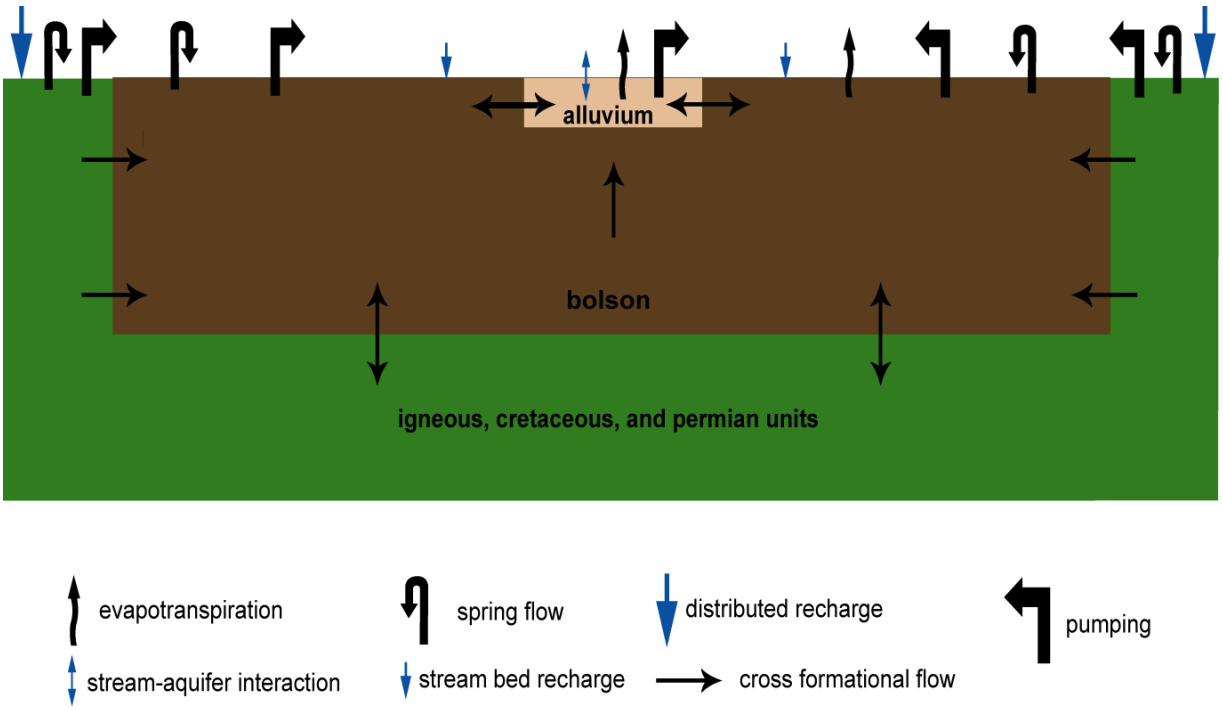



**FIGURE 4 CONCEPTUAL MODEL DIAGRAM (WADE AND OTHERS, 2011).**

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.

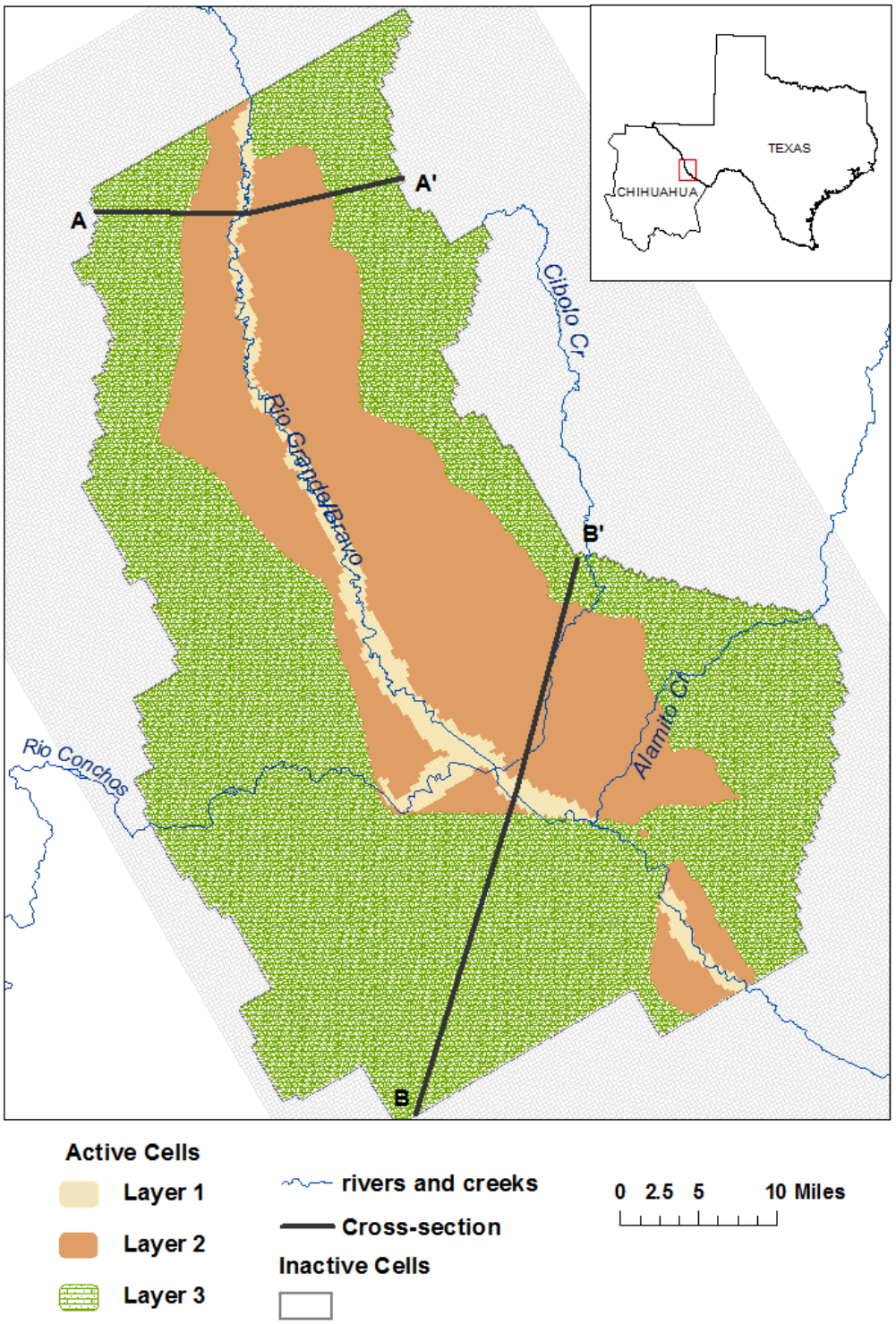



**FIGURE 5 MODEL GRID, HYDROGEOLOGIC UNITS, INACTIVE AREAS, AND LOCATIONS OF CROSS-SECTIONS.**

**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.

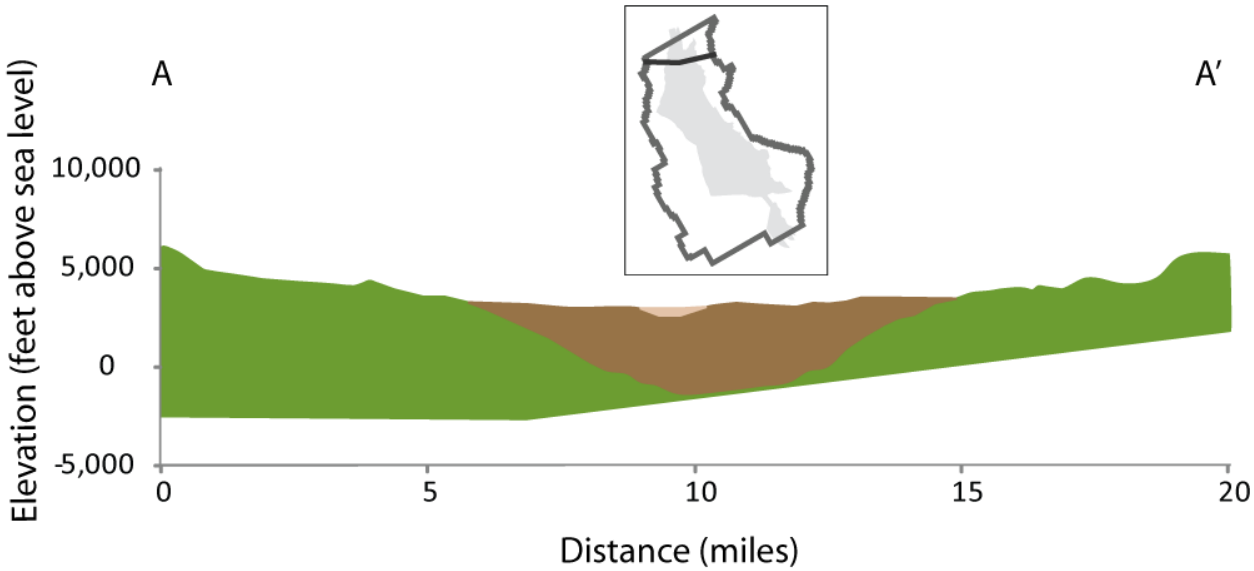



**FIGURE 6 MODEL CROSS-SECTION A-A' THROUGH NORTHERN PART OF MODEL (SEE FIGURE 5 FOR LOCATION).**

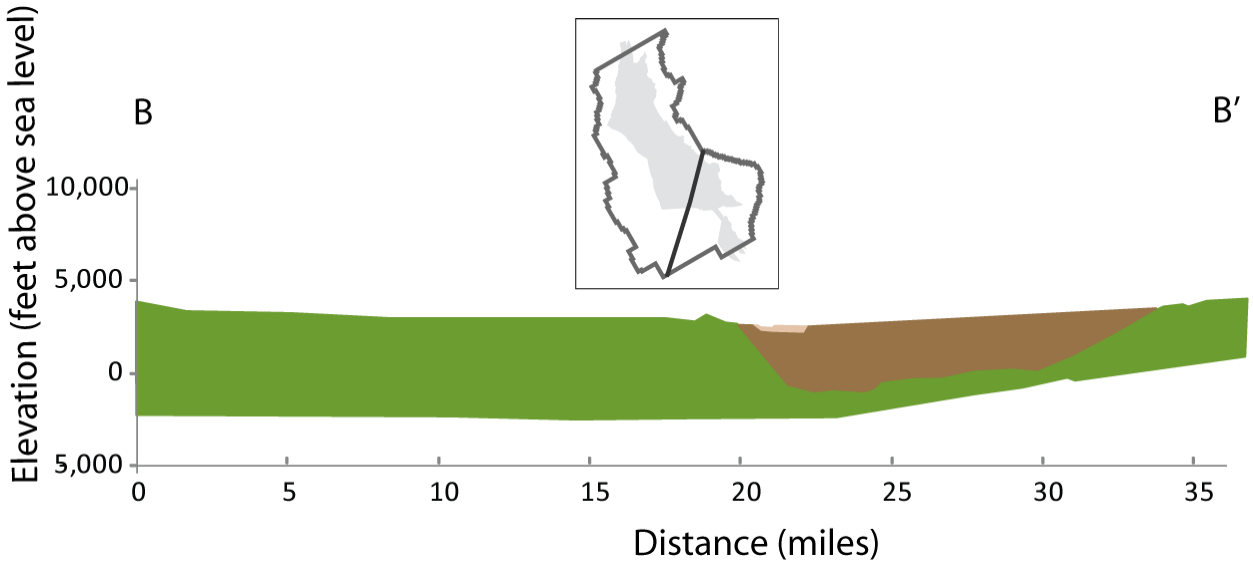



**FIGURE 7 MODEL CROSS-SECTION B-B' THROUGH SOUTHERN PART OF MODEL (SEE FIGURE 5 FOR LOCATION).**

## 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 | 3652.50 | 10 |
| 3 | 1947* | 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 |

[1] *Stress periods 1, 2, and 3 are meant to establish starting conditions for the transient calibration period and do not necessarily represent a particular period of time.

| Stress Period | Time Period | Length (days) | Time Steps |
|---|---|---|---|
| 18 | 1962 | 365.250 | 1 |
| 19 | 1963 | 365.250 | 1 |
| 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 |

| Stress Period | Time Period | Length (days) | Time Steps |
|---|---|---|---|
| 40 | 1984 | 365.250 | 1 |
| 41 | 1985 | 365.250 | 1 |
| 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 |

| Stress Period | Time Period | Length (days) | Time Steps |
|---|---|---|---|
| 62 | 2006 | 365.250 | 1 |
| 63 | 2007 | 365.250 | 1 |
| 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 | $6.4 \times 10^{-2}$ 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 | $1.333 \times 10^{6}$ |
| | 2 | 6,596 |
| | 3 | 6.667 |
| | 4 | 6.667 |
| | 5 | 6.667 |
| Storage Coefficient | 1 | 0.1 |
| | 2 | $5. \times 10^{-3}$ |
| | 3 | $1.0 \times 10^{-4}$ |
| | 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), 2008).

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 °C (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 °C (Henry, 1979). We calculated the fraction of thermal springflow using the ratio of the difference between the spring temperature and 30 °C (thermal cutoff temperature) to the difference between the thermal reservoir temperature and 30 °C.

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 flow 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 | Simulated conductance (feet$^2$ per day) | Drain elevation (feet above mean sea level) | Number of flow targets |
|---|---|---|---|
| 1 | 500 | 2,555 – 2,822 | 37 |
| 2 | 5,000 | 2,767 – 3,553 | 1,256 |
| 3 | 500 | 2,557 – 5,413 | 933 |

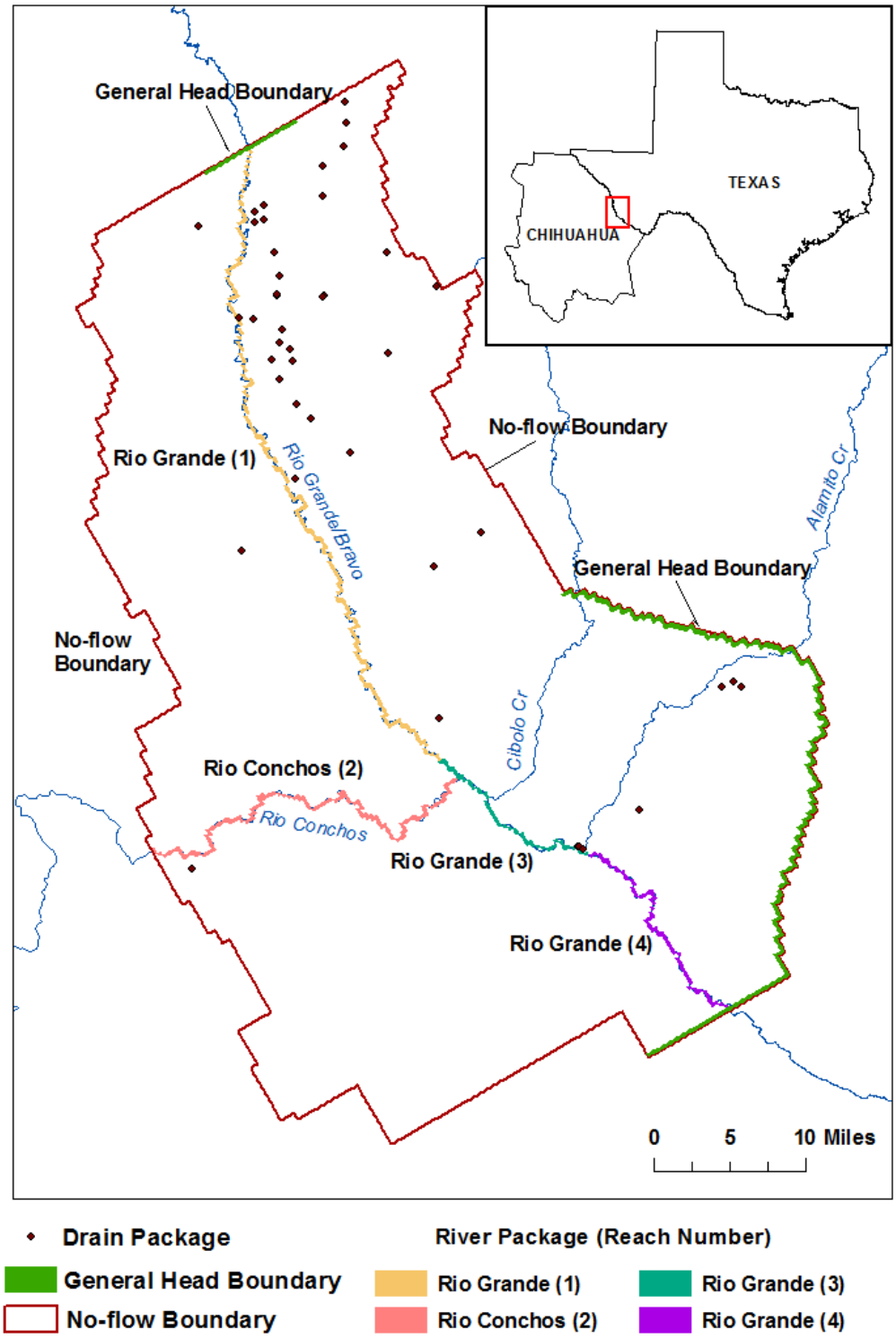



**FIGURE 8 LOCATION OF RIVER, GENERAL HEAD BOUNDARIES, AND DRAIN CELLS.**

## 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 | Simulated 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 | Simulated 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 of the aquifer. 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 was 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 flows 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.

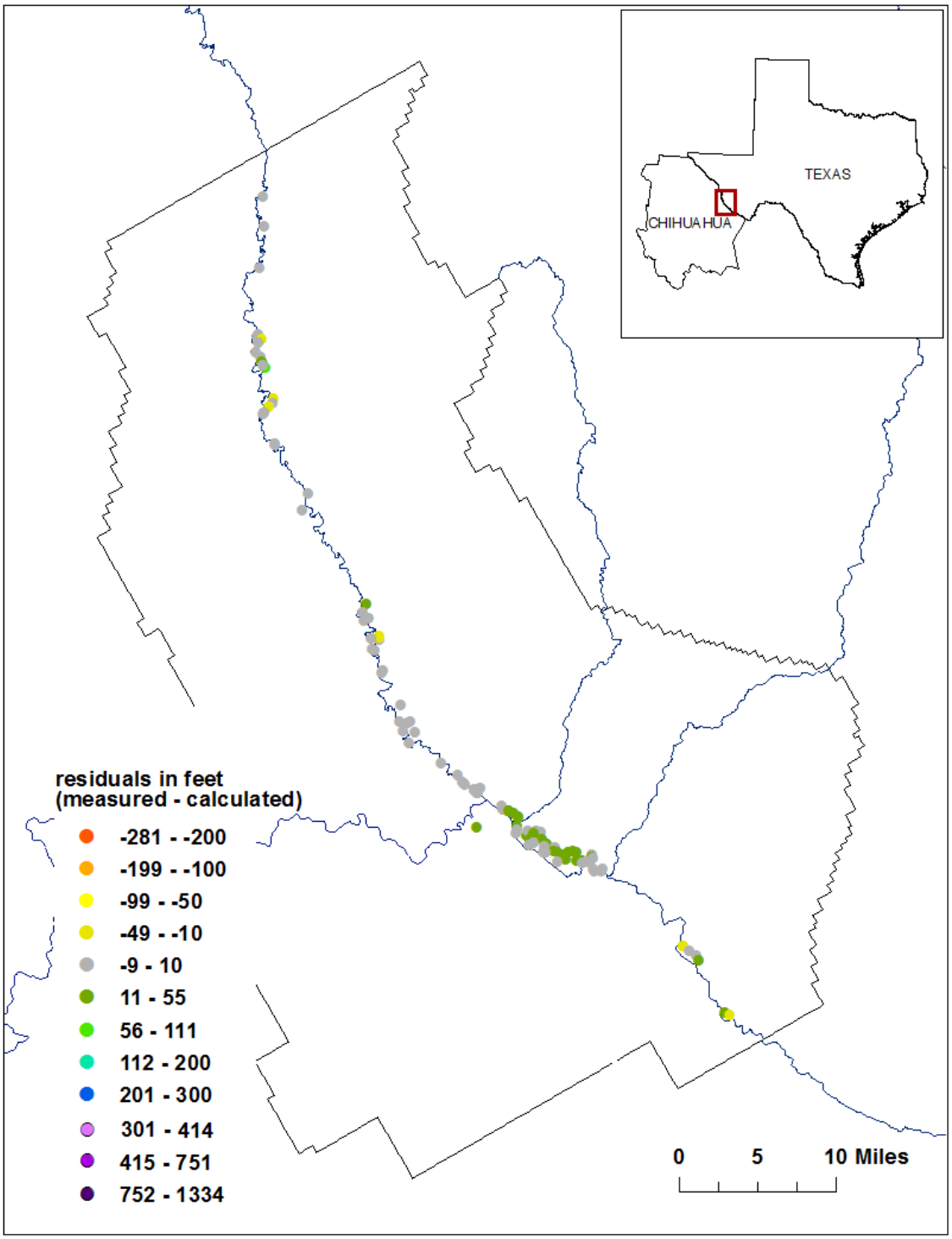



**FIGURE 9 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 1. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.**

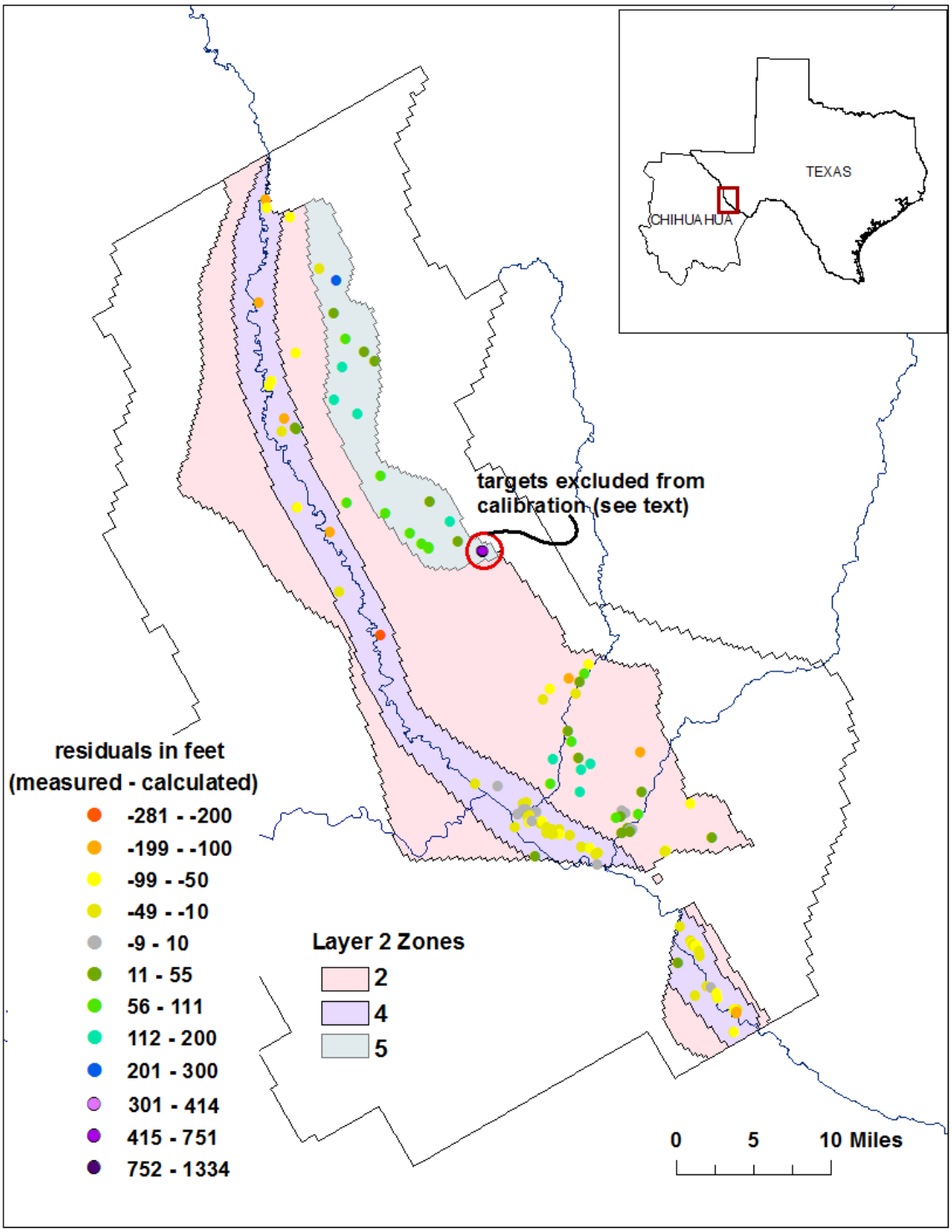



**FIGURE 10 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 2. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.**

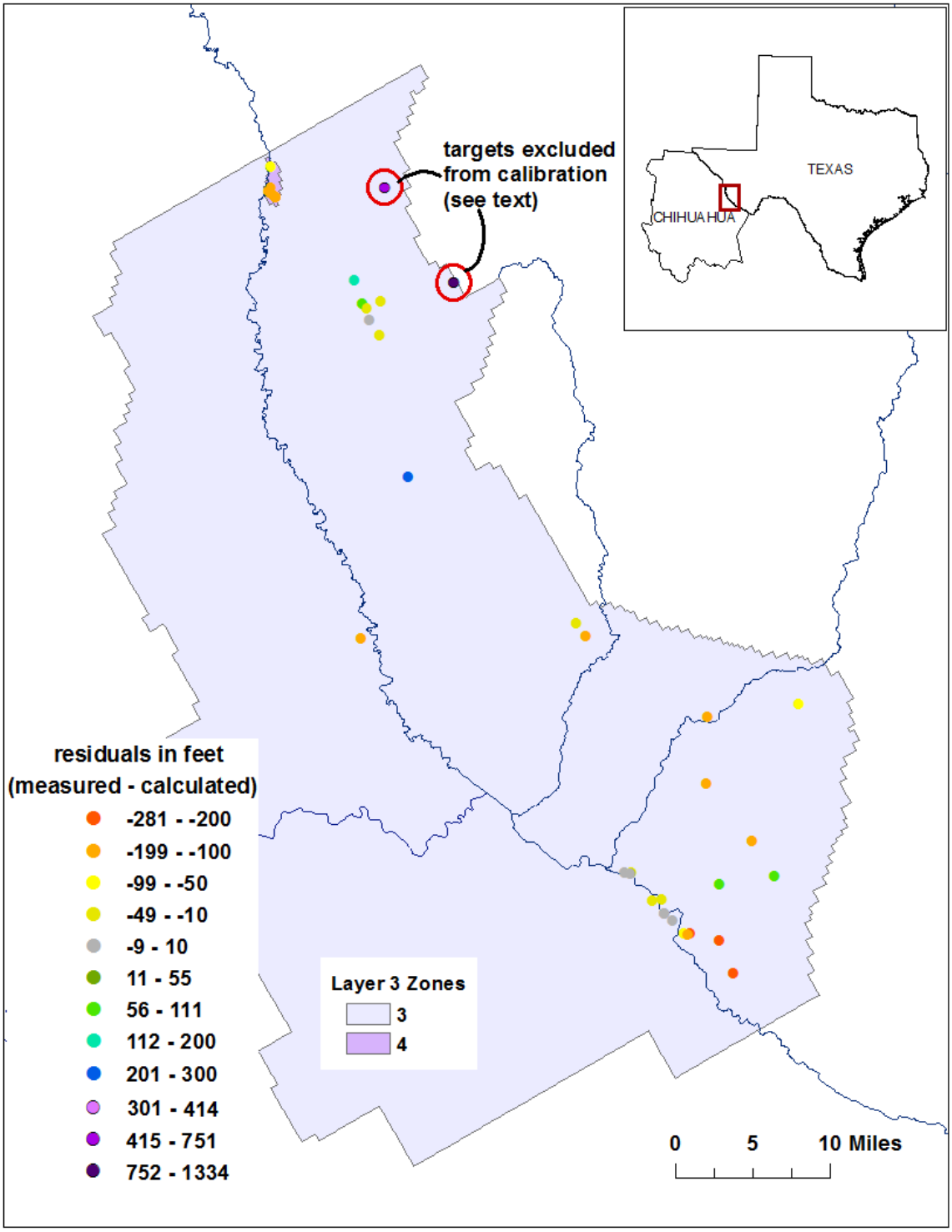



**FIGURE 11 HEAD RESIDUALS BETWEEN MEASURED AND SIMULATED WATER LEVELS FOR THE ENTIRE CALIBRATION PERIOD IN LAYER 3. WELLS WITH MORE THAN ONE MEASUREMENT ARE AVERAGES.**

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. We also used post-processing programs developed to display hydrographs from the model-generated results and we used the USGS code, ZONEBUDGET (Version 3.01) to post-process the model flow budget.

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, and well multipliers (Table 10). 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 | $5.0 \times 10^6$ |
| Head φ | $2.35 \times 10^6$ |
| Flux φ | $2.65 \times 10^6$ |
| 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 |

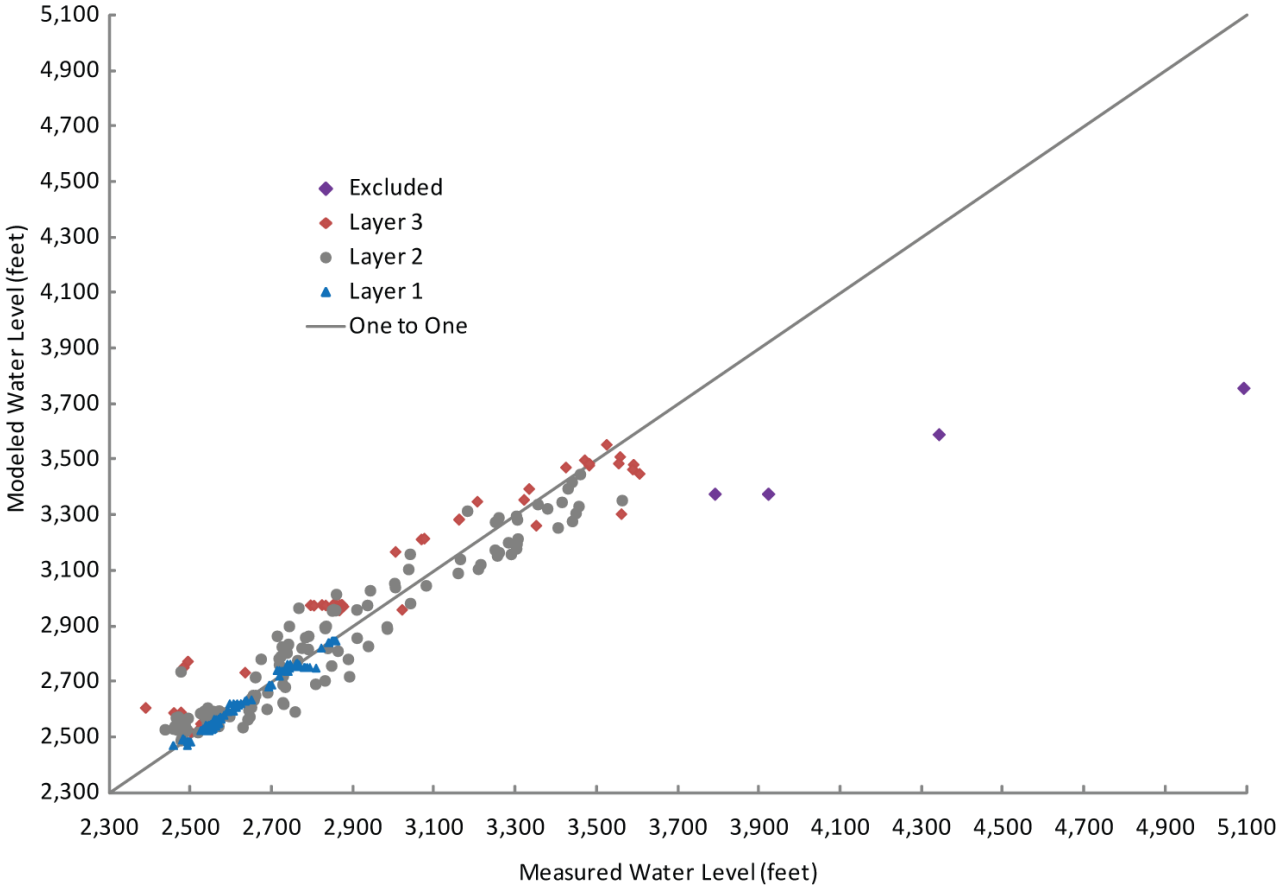



**FIGURE 12 MEASURED VERSUS MODEL CALCULATED WATER LEVELS. FIVE TARGETS WERE EXCLUDED FROM THE CALIBRATION BECAUSE THEY MAY BE PART OF A DIFFERENT FLOW SYSTEM (SEE TEXT).**

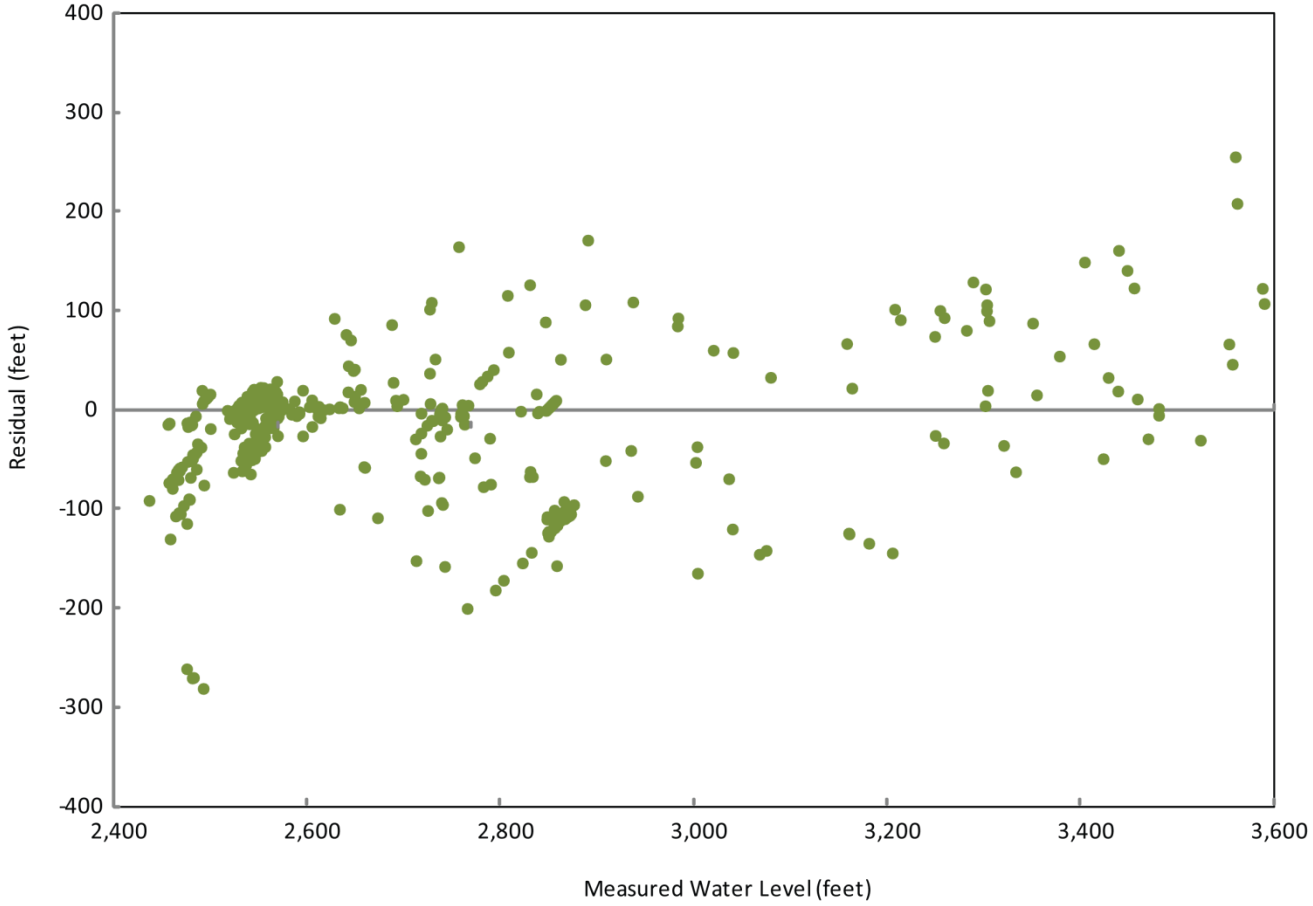



**FIGURE 13 MEASURED WATER LEVELS VERSUS MODEL RESIDUALS.**

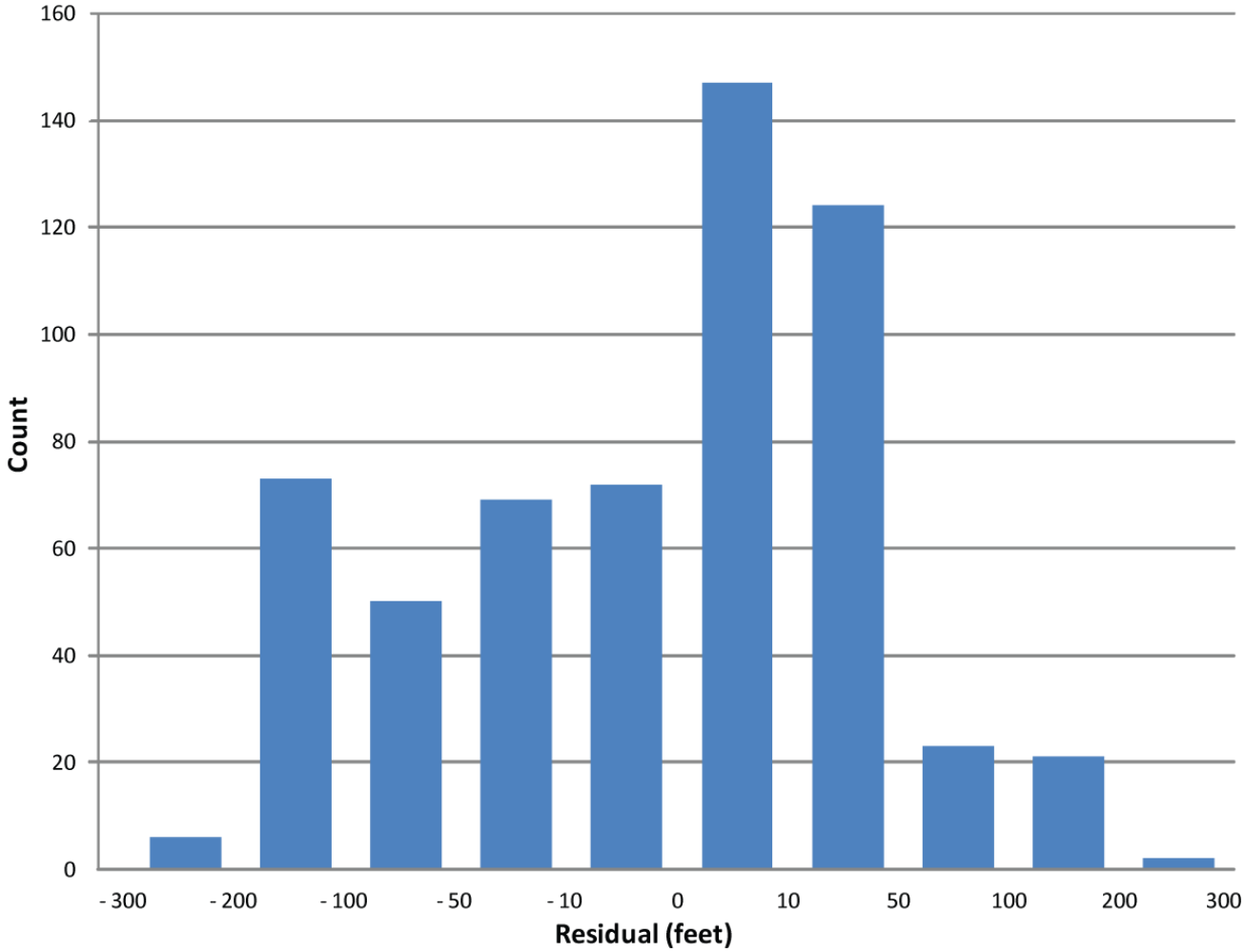



**FIGURE 14 HISTOGRAM OF MODEL RESIDUALS.**

## *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).

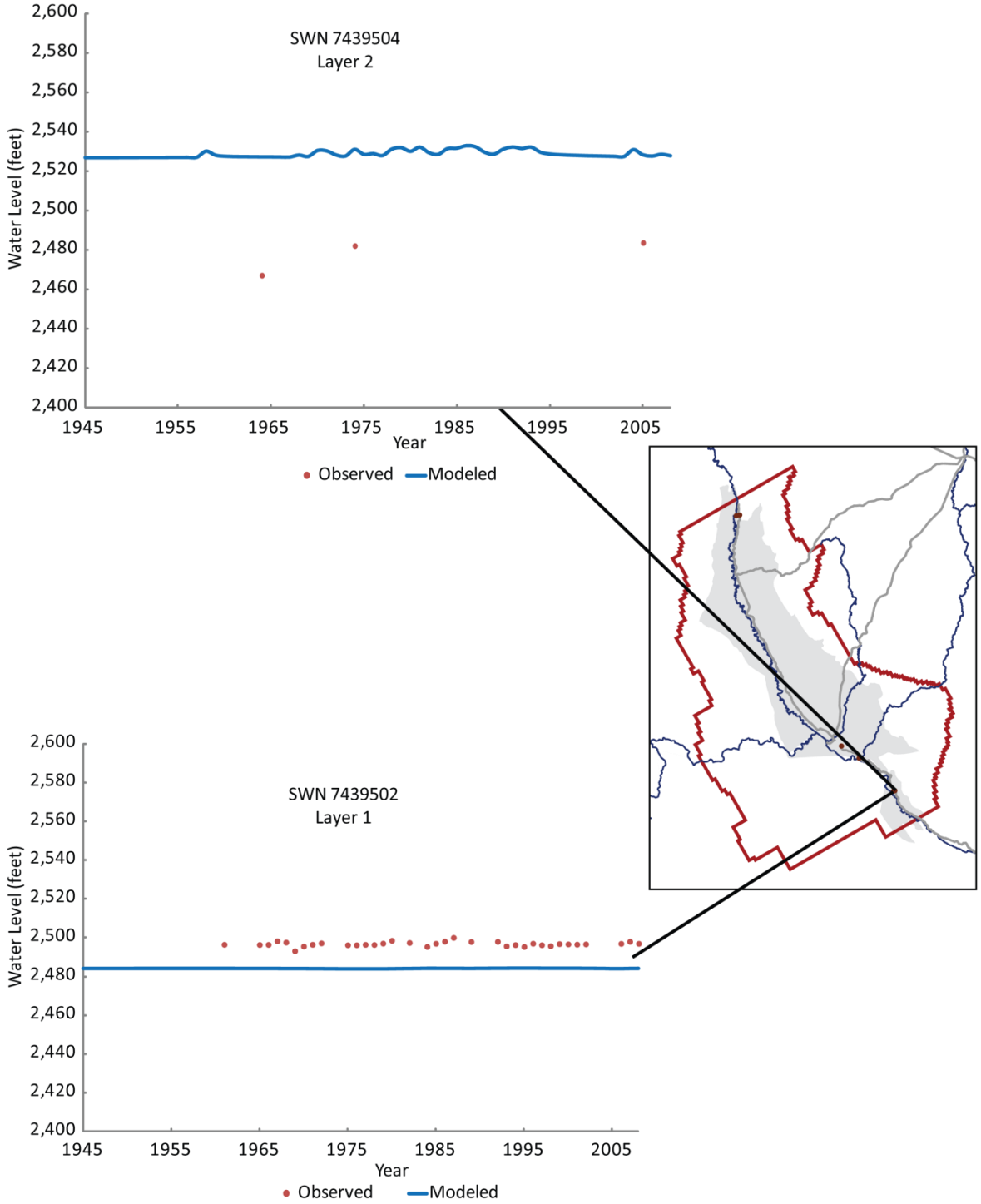



**FIGURE 15 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE SOUTH END OF THE MODEL.**

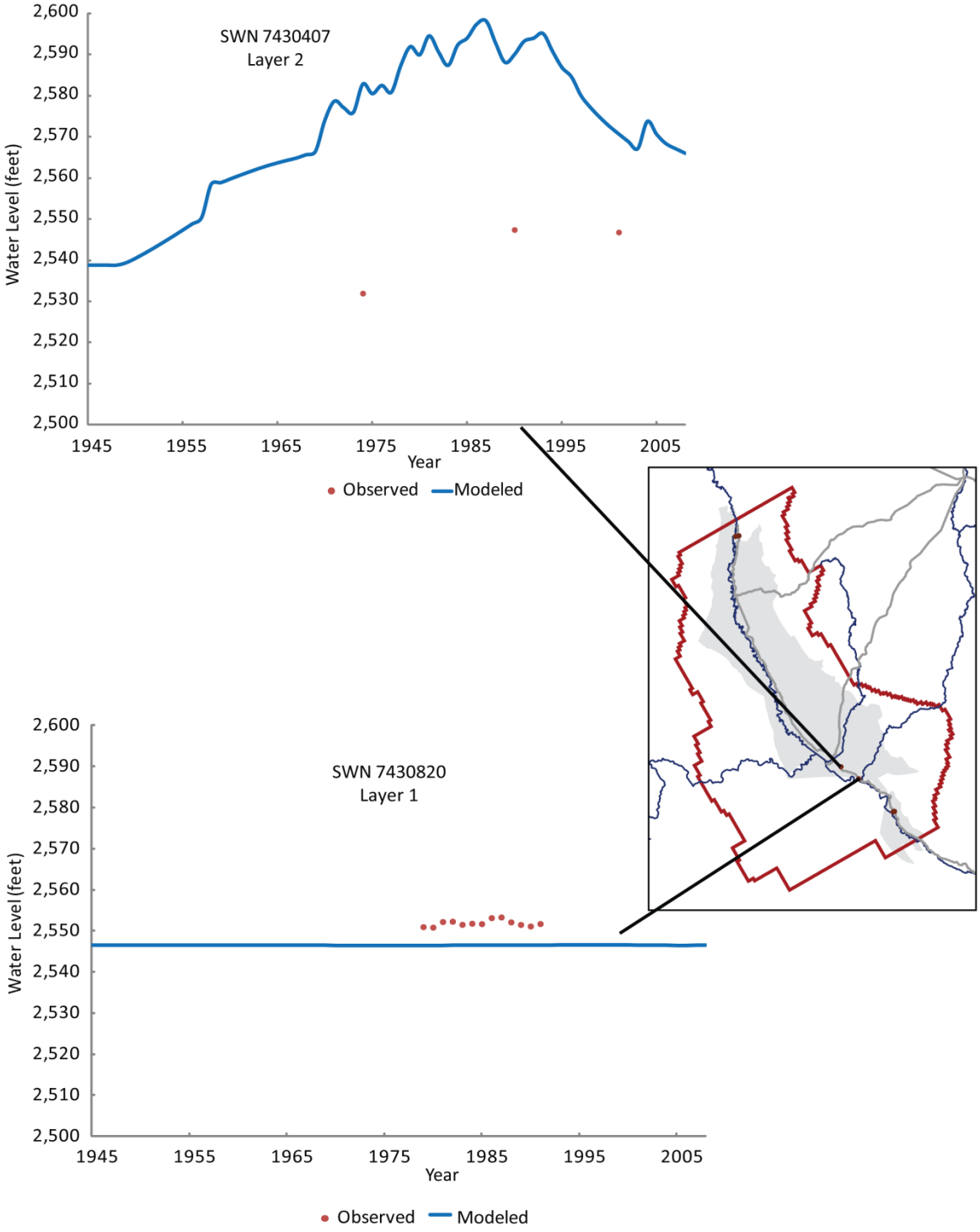



**FIGURE 16 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE CENTRAL PART OF THE MODEL.**

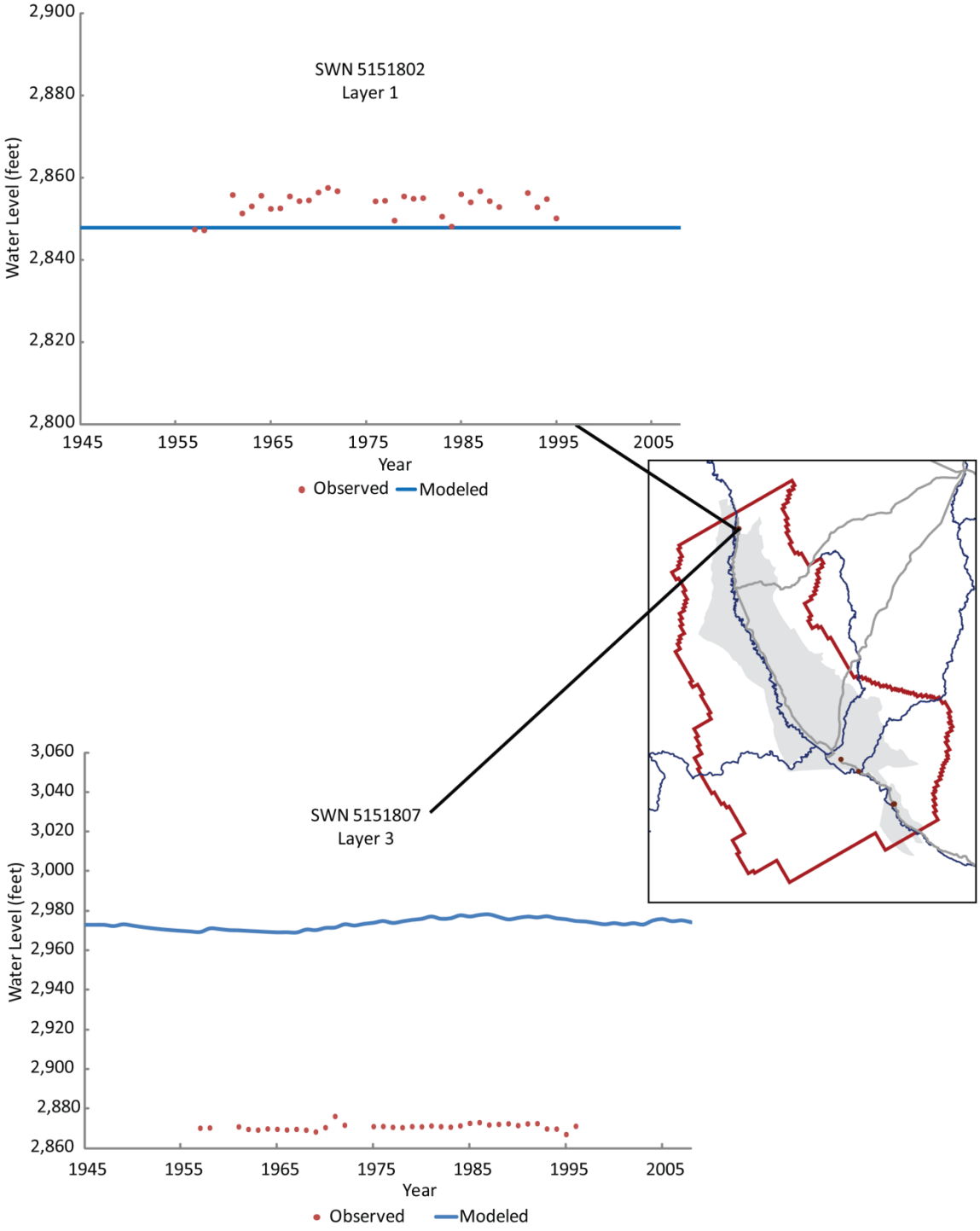



**FIGURE 17 COMPARISON OF MODELED TO MEASURED HYDROGRAPHS IN THE NORTH END OF THE MODEL.**

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 flow 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).

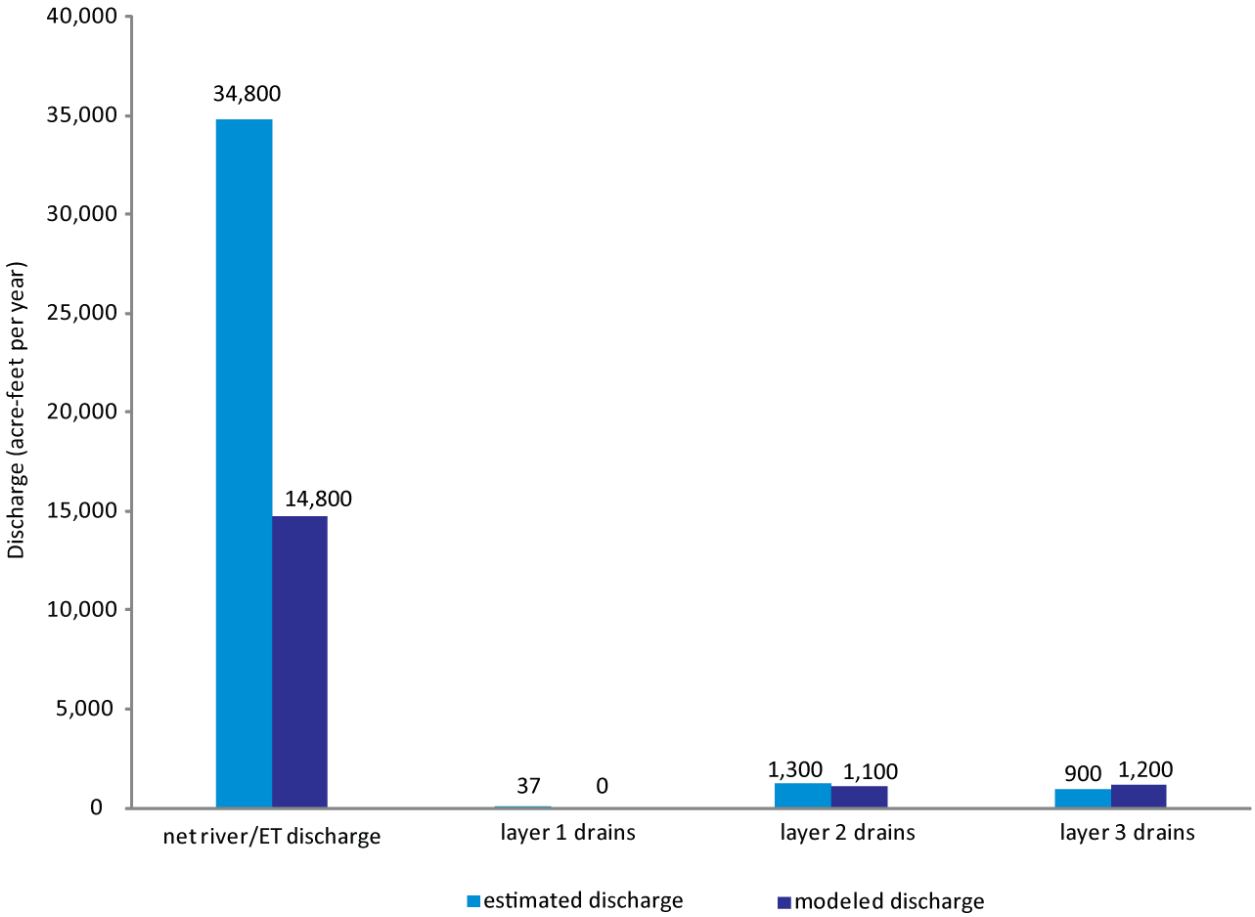



**FIGURE 18 COMPARISON BETWEEN ESTIMATED AVERAGE DISCHARGE AND MODELED AVERAGE DISCHARGE FOR DRAINS AND NET RIVER/ EVAPOTRANSPIRATION.**

## *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).

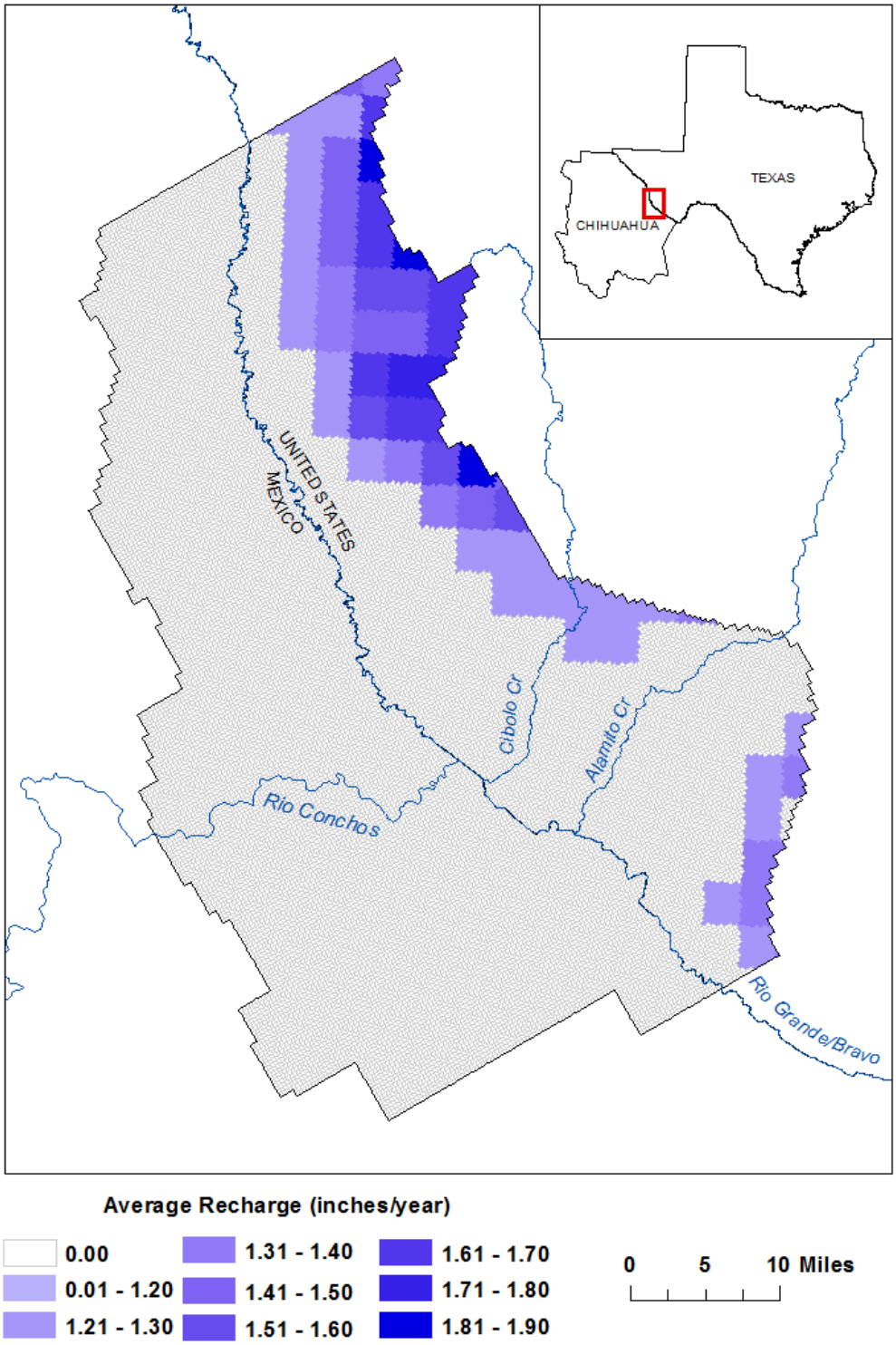



**FIGURE 19 DISTRIBUTION OF RECHARGE BASED ON AVERAGE RAINFALL.**

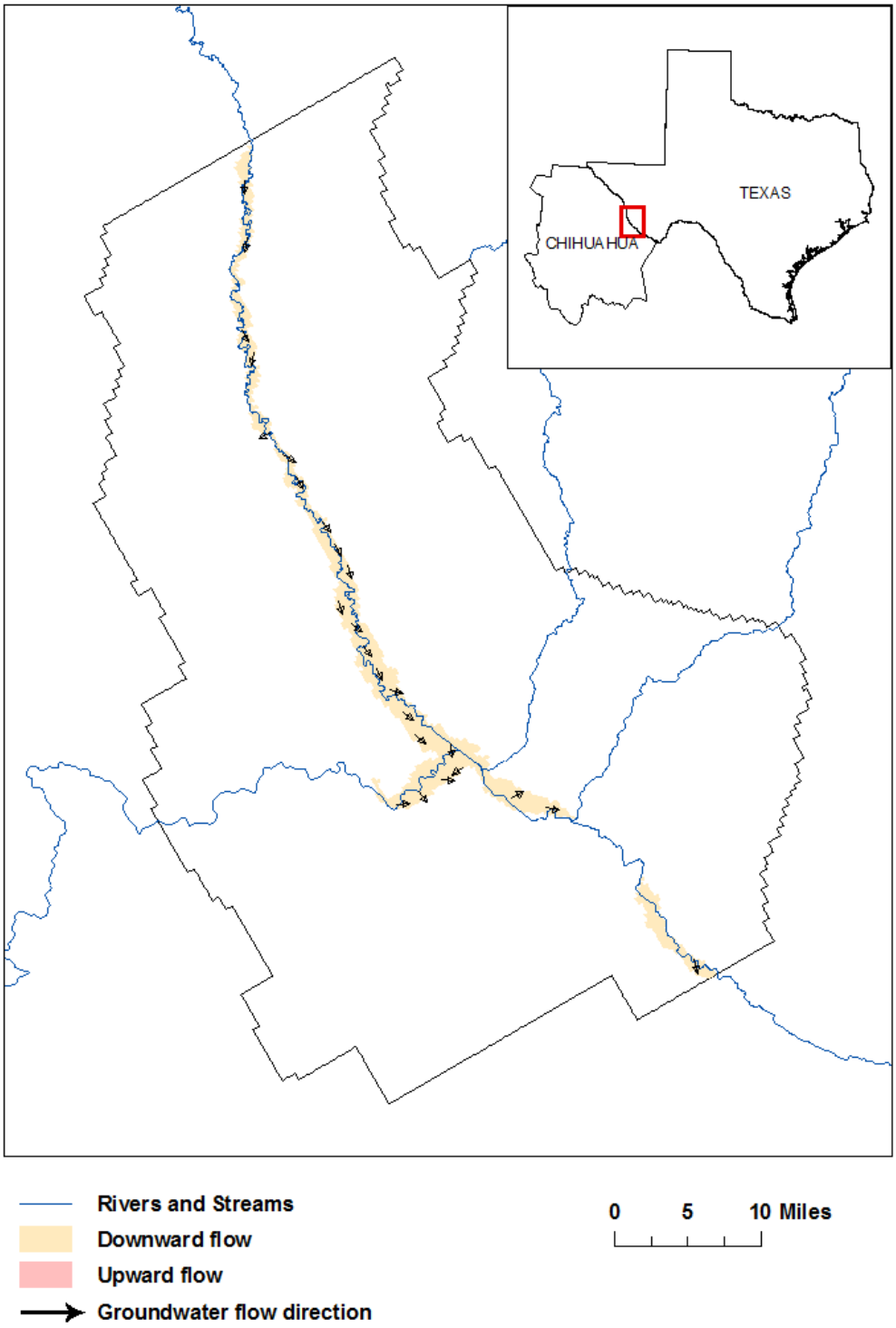



**FIGURE 20 GROUNDWATER FLOW DIRECTIONS IN LAYER 1.**

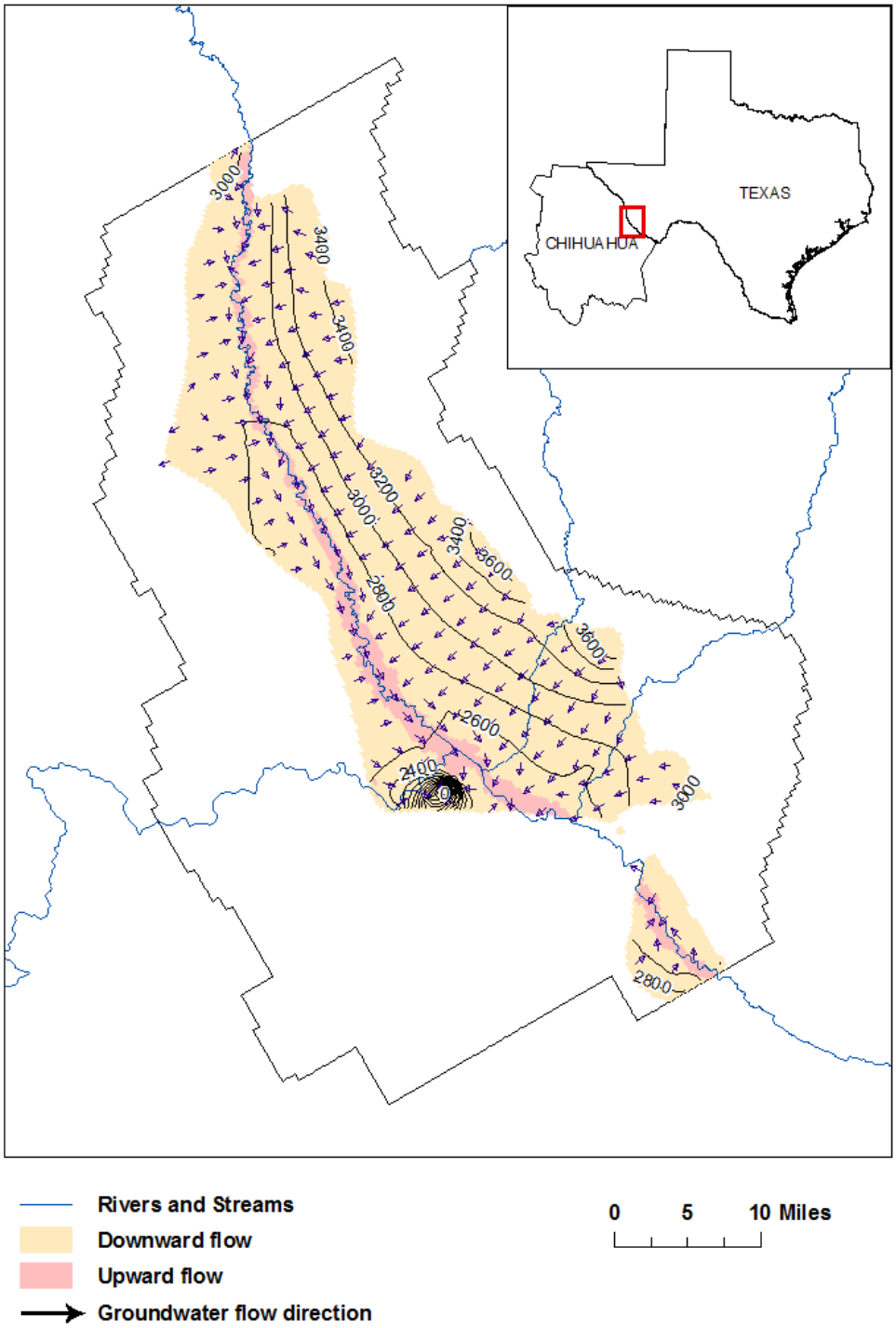



**FIGURE 21 GROUNDWATER FLOW DIRECTIONS AND POTENTIOMETRIC ELEVATIONS IN LAYER 2.**

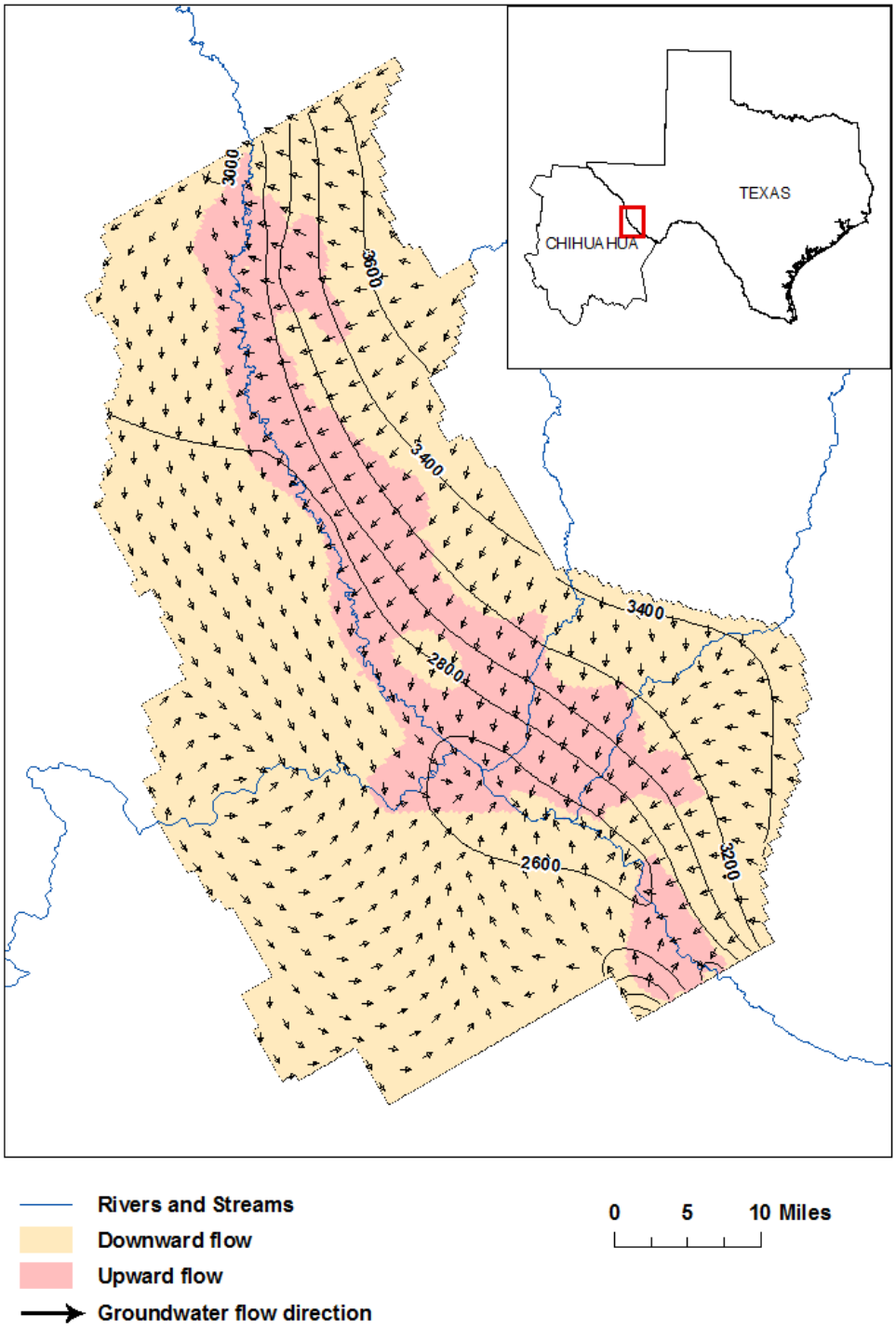



**FIGURE 22 GROUNDWATER FLOW DIRECTIONS AND POTENTIOMETRIC ELEVATIONS IN LAYER 3.**

## 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<br><br>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 |

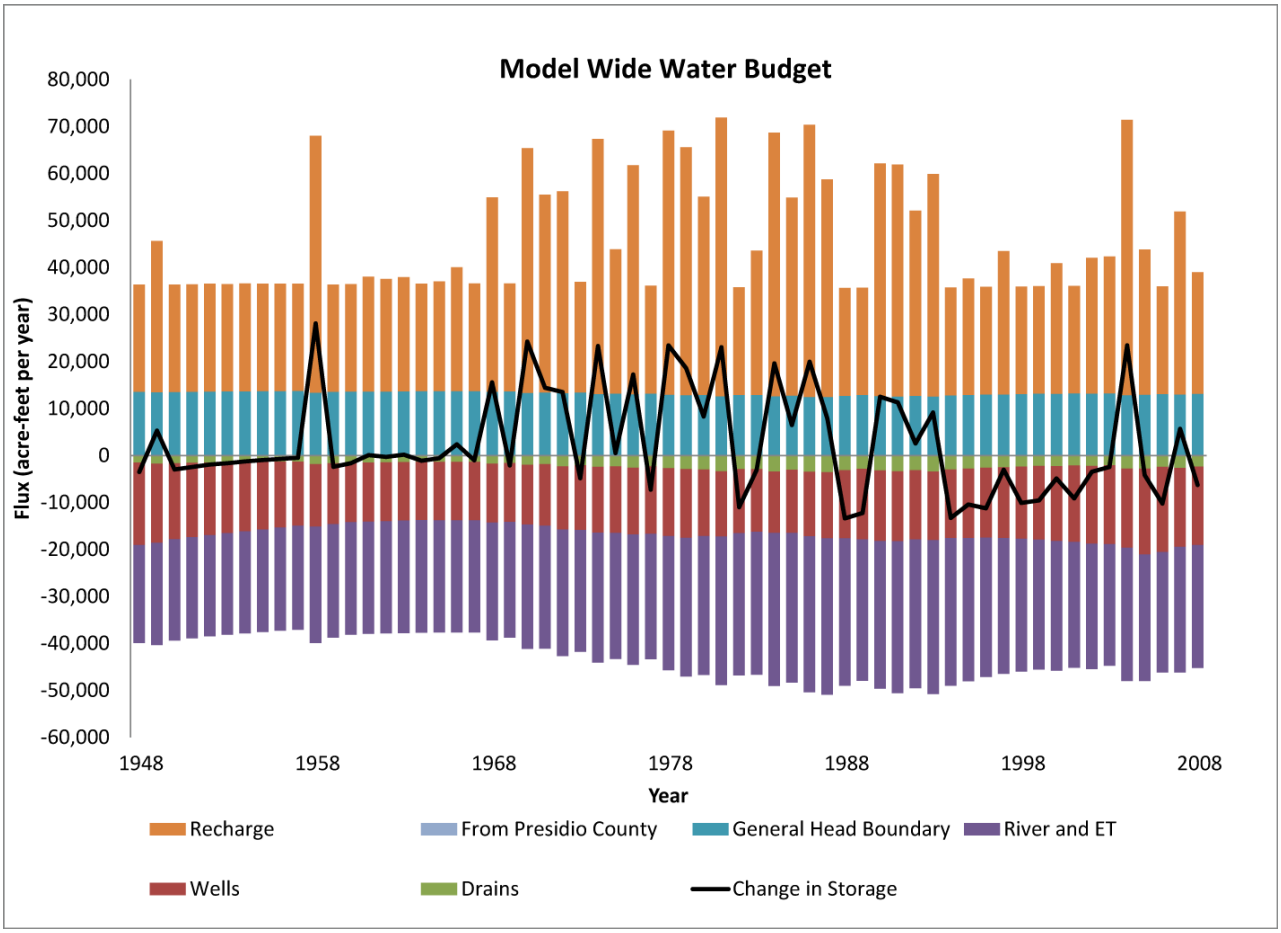



**FIGURE 23 OVERALL GROUNDWATER BUDGET BY YEAR FOR THE MODEL IN ACRE-FEET PER YEAR.**

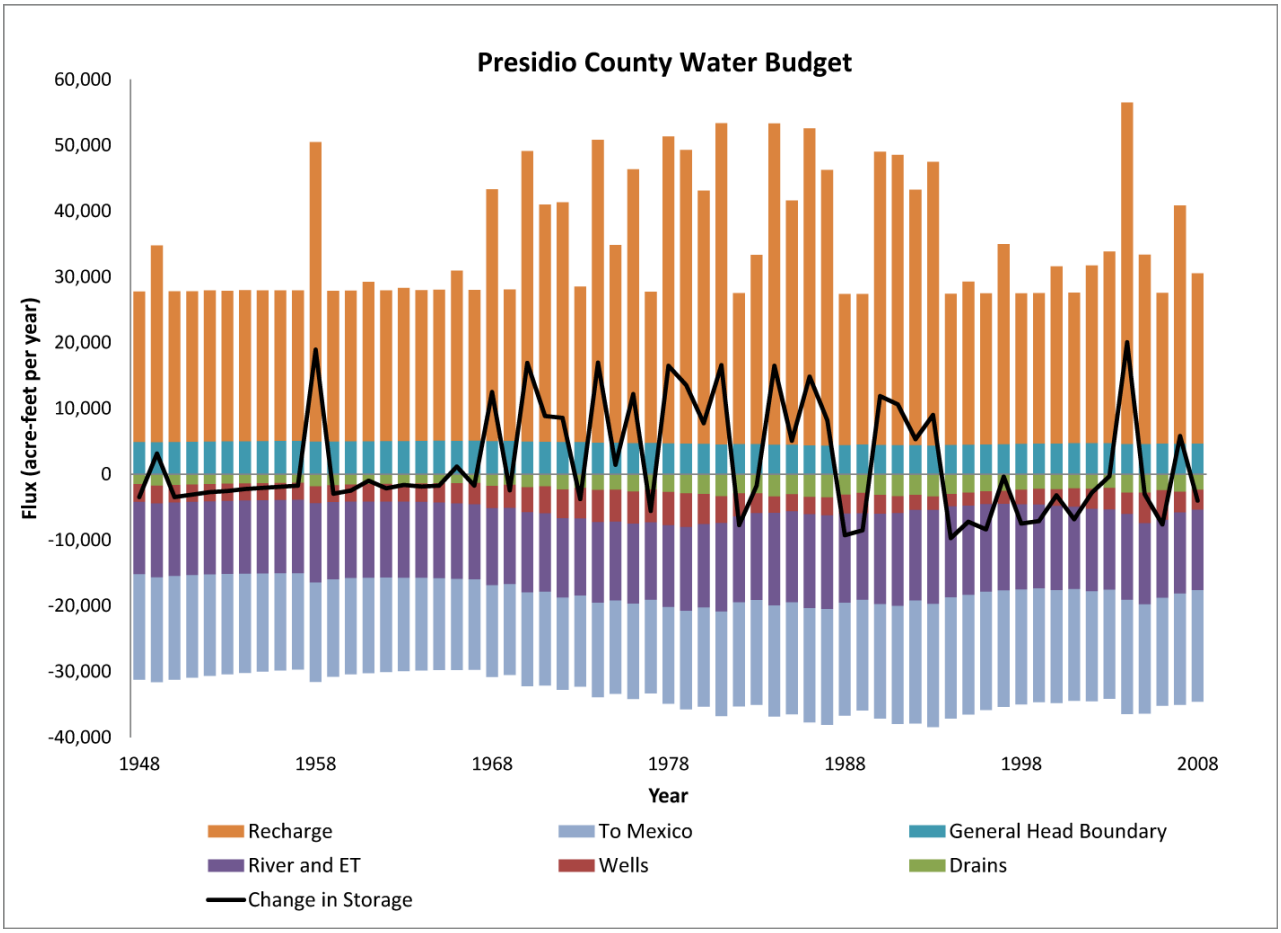



**FIGURE 24 GROUNDWATER BUDGET BY YEAR FOR PRESIDIO COUNTY PORTION OF MODEL IN ACRE-FEET PER YEAR.**

# *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 target (Table 15, Figure 25).

**TABLE 15 AVERAGE CHANGE IN TARGET HEAD 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.

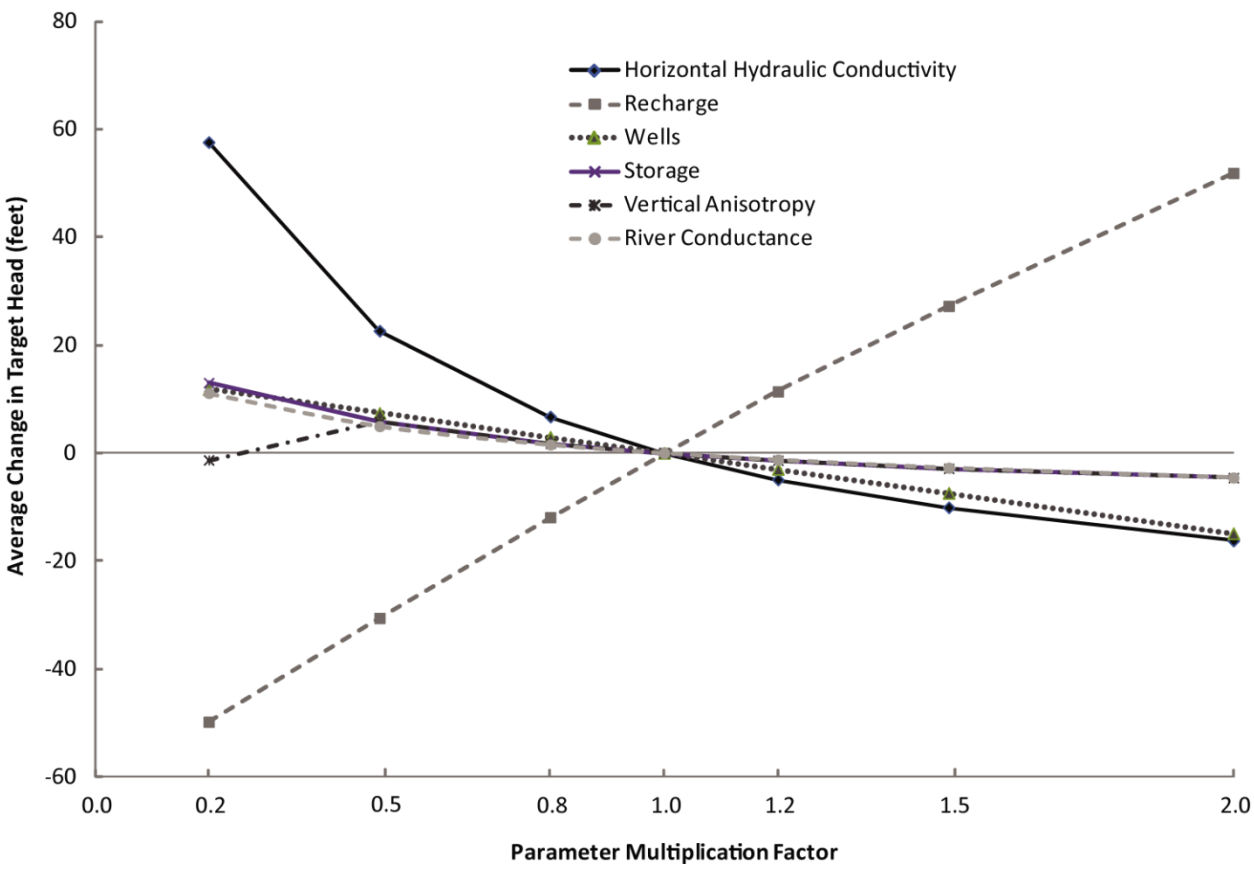



**FIGURE 25 AVERAGE CHANGE IN TARGET HEAD (COMPARED WITH CALIBRATED MODEL) AS A FUNCTION OF VARIATION OF PARAMETER VALUES (SENSITIVITY ANALYSIS).**

# *5.0 MODEL LIMITATIONS*

Numerical groundwater flow models are approximate representations of aquifer systems (Anderson and Woessner, 2002), 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.

# *7.0 ACKNOWLEDGEMENTS*

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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*

None received as of November 2012