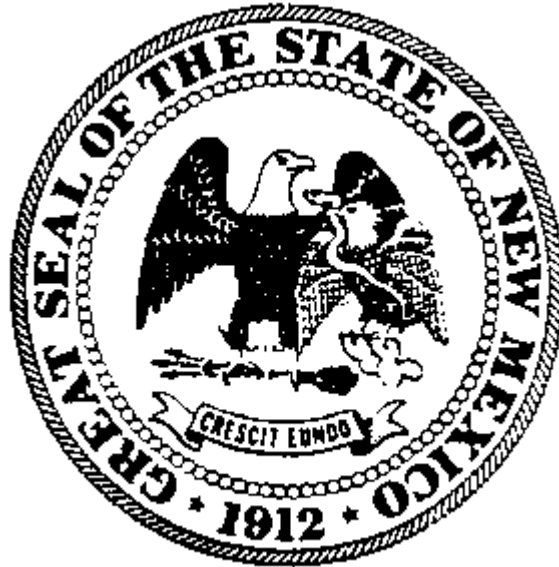


**COMPARISON OF TWO GROUND-WATER FLOW MODELS FOR  
ADMINISTRATION OF WATER RIGHTS IN THE  
SOUTHERN JORNADA DEL MUERTO BASIN  
LOWER RIO GRANDE UNDERGROUND WATER BASIN  
DOÑA ANA COUNTY, NEW MEXICO**



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## INTRODUCTION

At the request of the Water Rights Division of the Office of the State Engineer (OSE), the Hydrology Bureau is providing technical assistance in the administration of water rights in the Southern Jornada del Muerto Basin (SJMB) portion of the Lower Rio Grande Underground Water Basin. This assistance includes selection and development of appropriate technical tools for estimating the hydrologic effects of proposed appropriations in the SJMB. Two numerical ground-water flow models of the SJMB have previously been developed for this purpose: one by OSE (the OSE model); and one by John Shomaker and Associates, Inc. (JSAI), for the City of Las Cruces (the JSAI model). This report documents the Hydrology Bureau's comparison of these two models.

The OSE model is a two-dimensional (2-D), finite-difference superposition model of the SJMB (Rao, 1988a; 1988b), developed for water rights administration. Rao and Richardson (1996b) tested the OSE model using estimated historic pumping stresses and determined that it was satisfactory for predicting future hydrologic impacts.

In 1990 JSAI developed a 2-D, altitude-based finite-difference model to support the City of Las Cruces' application for supplemental well LRG-430-S-26 (Shomaker, 1990). Geoscience Consultants Ltd. (GCL) performed a transient calibration for the period 1962 to 1992 on this model, adjusting transmissivity and aquifer thickness and introducing deep geothermal influx. This 2-D regional model was then used to telescope to a three-dimensional (3-D) model of site-specific ground-water flow and contaminant transport at the NASA-White Sands Test Facilities site (GCL, 1995).

The 1995 GCL regional 2-D model was used by JSAI as the basis for a three-layer, 3-D model used to support the City's applications for supplemental wells LRG-430-S-29 and LRG-430-S-30 (Shomaker and Finch, 1996). In addition to introducing the multilayer, 3-D structure, JSAI extended the transient calibration period to 1994.

Catanach (1990) and Rao and Richardson (1996a) used the OSE model to evaluate hydrologic effects of those City of Las Cruces supplemental well applications that the JSAI model was developed to support. A slightly modified version of the 1996 JSAI model is now being used to support the City's applications LRG-3283 through 3296 for new appropriations of 14,000 acre-feet per year (ac-ft/yr) in the SJMB (Shomaker and others, 2000). This latest version of the JSAI model is evaluated in this report.

## CONCLUSIONS AND RECOMMENDATIONS

1. Both the JSAI and OSE numerical models are reasonable representations of the hydrogeology of the SJMB, and can be used to evaluate hydrologic effects of existing and proposed uses, including the new appropriations proposed by Moongate Water Company, the City of Las Cruces, and others.
2. The JSAI model incorporates the work of two ground-water consulting groups working on different problems: water rights/water resources, and contaminant characterization and remediation. Its three-layer structure and grid design are based on a sound conceptual model that incorporates the most comprehensive set of hydrogeologic data available. The JSAI model appears to more robustly simulate the hydrogeologic characteristics of the SJMB basin-fill aquifer, given the current state of knowledge.
3. Hydraulic properties assigned in the JSAI model are reasonable and typical of basin-fill aquifer models. In the JSAI model a uniform specific yield of 0.15 is assigned to layer 1, which is similar to the values used in the OSE model. Storage coefficients for layers 2 and 3 in the JSAI model are calculated as specific storage ( $10^{-6}$  feet<sup>-1</sup>) multiplied by layer thickness, a common practice for regional models with sparse storage coefficient information. Layer 2 is convertible from confined to unconfined conditions; if head falls below the top of the layer, the storage coefficient converts to a specific yield of 0.15. This is a more realistic representation of the response to pumping and consequent dewatering of the upper part of the aquifer. Hydraulic conductivity values for layers 1 and 2 in the JSAI model range from 0.1 to 45 feet per day, and reasonably match available published estimates based on pumping test data. Transmissivity values for layer 3 determined through model calibration (1 to 3,100 feet squared per day) are not unrealistic, although no data are available against which to compare these values.
4. Because transmissivity of the single, MODFLOW-type 0 layer does not change regardless of head changes, the OSE model may not be appropriate for evaluating large stresses capable of creating significant drawdowns (greater than 10 percent of saturated thickness), such as the 14,000 ac-ft/yr appropriations proposed by the City of Las Cruces. Keeping flow zone transmissivities constant despite saturated thickness changes may also overstate surface water depletions from large stresses. Modifying the current OSE model to a single unconfined layer or multilayer design would require significant effort, including developing arrays for hydraulic conductivity and elevations, essentially duplicating the JSAI modeling effort.
5. The average mountain-front recharge rate of 76 ac-ft/yr per mile used in the JSAI model appears reasonable and is near the low end of the range of other similar estimates for the region. The resulting flux from the SJMB to the Mesilla Basin in the JSAI model compares reasonably well with that estimated for the widely accepted model of the Mesilla Basin. The amount and location of recharge to layer 3 simulated in the JSAI model due to geothermal upwelling, although uncertain, are not crucial to model operation.

6. Due to its multilayer design, the JSAI model has better capability to simulate vertical variations in head and the location of pumping stresses. The potential for more detailed evaluation of effects on water levels, fluxes and water quality in the future is enhanced by this multilayer design.
7. The JSAI model has been calibrated to both steady-state and transient heads, although data available for calibration in the SJMB are very limited. Steady-state heads computed by the JSAI model showed reasonable agreement with pre-development water levels reported for wells in the SJMB and Mesilla Basin. The OSE model has been tested but not calibrated.
8. Although in some ways the OSE model is more convenient for use in water rights administration, the JSAI model is also readily usable for this purpose. Either model could be used to estimate potential effects on water quality including reductions in freshwater zone thickness in the SJMB and drawdowns at the NASA-White Sands Test Facility ground-water contamination site, and either model could be coupled with solute transport codes for prediction of water quality changes.
9. Administrative criteria and guidelines for the SJMB are needed. Until such time as formal criteria are officially adopted, informal criteria based on principles used in other mined basins, adapted to the hydrology of the SJMB, should be used for evaluating impacts. These would include managing the SJMB as both a stream-connected and mined ground-water basin, with limits on rates of water-level decline and dewatering of the freshwater zone, and requirements to offset surface water depletions. Both the OSE and the JSAI models can be used to evaluate and quantify the hydrologic effects of a proposed use in relation to such criteria, although the JSAI model appears to be preferable.
10. It is recommended that the JSAI model be used to evaluate the hydrologic effects of water rights applications in the Southern Jornada Basin, and that the model be periodically re-evaluated and modified as necessary. Recommended future work includes readying the model for administrative use, and conducting further research into the layer 3 geothermal recharge. Modifying the location and/or amount of this recharge or removing this flux altogether may be warranted, which could necessitate other modifications. It is also recommended that modification of the JSAI model to a superposition configuration be investigated.

## PREVIOUS STUDIES

King and others (1971) and Wilson and others (1981) included the Southern Jornada del Muerto in comprehensive studies of the geohydrology and water resources of the region. Seager and others (1987) describe the regional geologic setting of the area, and Hawley's (1984) cross sections of the Mesilla Basin and SJMB provide the basic hydrogeologic framework. Cochran (1984) and Gross and others (1985) investigated uranium isotope geochemistry to define the influence of the East Mesa Geothermal Field on the SJMB. Studies of the hydrologic relationship between the SJMB and the Mesilla Basin include Rao and Hirsch (1985), and Woodward and Myers (1997). Rao and Richardson (1996b) and Wilson (1996) estimated the amount of mountain-front recharge and fresh ground water in storage, and proposed administrative criteria for the SJMB.

## HYDROGEOLOGIC SETTING

The following discussion is drawn from numerous published and unpublished reports. The SJMB is part of the larger Jornada geologic basin, which is separated from the Mesilla Basin by the Jornada fault zone and the Tonuco and Doña Ana-Tortugas-Franklin uplifts. These uplifts are exposed in the Rincon Hills, San Diego Mountain, Doña Ana Mountains, Goat Mountain, Tortugas Mountain and Bishops Cap (figure 1), and a buried segment between Goat Mountain and Tortugas Mountain is known as the Jornada Horst (Woodward and Myers, 1997).

The principle aquifer in the SJMB is comprised of basin-fill sediments of the Santa Fe Group up to 5,000 feet thick consisting of stratified sand, gravel, silt and clay. Ground water occurs at depths ranging from less than 100 to over 500 feet below land surface. A layer of fresh water possibly up to 2,000 feet thick occurs above more saline water at depth. Transmissivity of the upper 1,000 feet of saturated material ranges from less than 5,000 to about 15,000 feet squared per day ( $\text{ft}^2/\text{d}$ ), and well yields range from less than 10 to over 1,000 gallons per minute (gpm). Recharge occurs along the Organ and San Andres Mountain fronts, and possibly at depth from geothermal upflow along the Jornada fault zone. Ground water flows west, northwest and southwest from recharge areas to discharge mainly into the Rincon Valley near Rincon, and into the Mesilla Basin over the Jornada Horst, although flow over the Horst is thought to be relatively minor.

## MODEL COMPARISON

### Conceptual basis

Rao (1988a; 1988b) relied primarily on Wilson and others (1981) to develop the conceptual basis for the OSE numerical model of the SJMB. For most of the modeled area, transmissivity values were taken from plate 12 of that report. Initially a storage coefficient of 0.1 was used for the entire basin-fill aquifer, on the grounds that this value best represented the storage properties of the aquifer in response to long-term stresses (Rao, 1988a). Subsequently the Mesilla Valley portion of the model was assigned a storage coefficient of 0.21 (Rao, 1988b).

Hawley (1984) defined the hydrogeologic units that provide the basis for the JSAI multilayer model of the SJMB. Shomaker and Finch (1996) based their layers 1 and 2 on the “younger basin-fill”, and layer 3 on the “older basin-fill” units of Hawley (1984). Thickness and hydraulic characteristics of layers 2 and 3 are poorly constrained because few wells penetrate into the older basin-fill units. Gravity data (Seager and others, 1987) were interpreted to estimate layer thicknesses and the base of the basin fill, primarily north of the Doña Ana Mountains. Hawley’s cross sections were used to estimate layer thicknesses south of the Doña Ana Mountains (Shomaker and Finch, 1996).

Both models simulate the SJMB as having restricted hydraulic connection to the Mesilla Basin and the Rio Grande surface water system (defined as the Rio Grande and associated irrigation works in the Mesilla Valley), due to the presence of the Doña Ana-Tortugas-Franklin uplift, including a buried portion called the Jornada Horst (Woodward and Myers, 1997). Rao and Hirsch (1985) determined the average saturated thickness of the basin-fill aquifer at three zones identified by Hawley (1984) where ground-water flow across the Jornada Horst appeared to be occurring. Rao (1988a) calculated transmissivity values for these three flow zones using average saturated thickness and estimated hydraulic conductivity values. The OSE model simulates flow over the Jornada Horst from the SJMB into the Mesilla Basin using these zones of constant transmissivity.

For the JSAI model Shomaker and Finch (1996) also used Hawley’s (1984) cross-sections to estimate properties for simulating flow across the Horst. Their “flow zones” are represented by cells in layers 1 and 2 of relatively low (0.1 to 5 feet per day; ft/d) hydraulic conductivity and moderate thickness, which varies with water-level changes.

## Model code and discretization

Both the OSE and JSAI models use the U. S. Geological Survey (USGS) modular finite-difference ground-water flow code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996). The active portions of both model grids cover roughly the same area of the SJMB, and both have cells ranging down to one square mile in size (figures 2 and 3). However, the basic model structures differ in other ways (table 1).

The OSE model simulates the basin-fill aquifer using one layer, specified as MODFLOW layer type 0, therefore transmissivity and storage properties of the aquifer do not change regardless of changes in head or depth. Shomaker and Finch (1996) divided the basin-fill aquifer into three layers: layer 1 is simulated as unconfined (layer type 1); layer 2 as confined with a provision to convert to unconfined conditions if heads drop below the top of the layer (type 3); and layer 3 as confined (type 0).

## Hydraulic properties

Horizontal hydraulic conductivity ( $K_h$ ) values for layers 1 and 2 in the JSAI model range from 0.1 to 45 ft/d (table 1). Distribution of  $K_h$  values in layers 1 and 2 is similar, and was determined during model calibration. Values of  $K_h$  assigned to specific model cells compare reasonably well with 21 values calculated from pumping test data (Shomaker and Finch, 1996; table 1, fig. 15). The ratio of  $K_h$  to vertical hydraulic conductivity ( $K_v$ ) of 200 used in the JSAI model is within the range of reasonable values for basin-fill aquifers (Kernodle, 1992); this same value was used in the USGS Mesilla Basin model (Frenzel and Kaehler, 1992). Transmissivity (T) values for layer 3 ranging from 1 to 3,100 ft<sup>2</sup>/d determined during model calibration are not unrealistic. In the OSE model the T values used were derived from pumping test estimates extrapolated through the upper 1,000 feet of aquifer, resulting in values as high as 30,000 ft<sup>2</sup>/d (table 1).

The OSE model uses a storage coefficient of 0.21 for the Mesilla Valley and 0.1 for the remainder of the model area. In the JSAI model a uniform specific yield of 0.15 is assigned to layer 1, and layer 2 when under unconfined conditions. Storage coefficients for layer 2 (under confined conditions) and for layer 3 are calculated as specific storage of  $10^{-6}$  ft<sup>-1</sup> multiplied by layer thickness (table 1). The JSAI values of specific yield and specific storage are typical of those used for basin-fill aquifer models (Kernodle, 1992).

## **Boundary conditions**

Table 2 summarizes how the OSE and JSAI models simulate boundary conditions for the SJMB. Consolidated rocks bounding the basin laterally and beneath the basin-fill sediments were considered impermeable and simulated in both models using no-flow boundaries. Other boundary conditions are discussed in separate sections below.

### Rio Grande surface water system

The Rio Grande and associated irrigation works in the Mesilla Valley constitute the Rio Grande surface water system. Both the OSE and JSAI models simulate this system as a constant-head boundary (table 2). However, treatment of this boundary condition differs slightly between the two models. The OSE model includes active areas in the Mesilla Basin west of the Rio Grande. In the JSAI model the Rio Grande is treated as a true hydrologic boundary; all model cells west of the constant-head cells are inactive.

Because heads in the SJMB are higher than those in the Mesilla Basin and at the river, the Mesilla Basin and Rio Grande act together as a hydrologic sink to the SJMB in the JSAI model. A “western limit of model validity” (Shomaker and Finch, 1996) is designated in the JSAI model by a line along the divide between the SJMB and the Mesilla Basin, west of which the model is not used for prediction. Stresses west of this limit are not simulated, and calculated heads and drawdowns are not considered reliable.

### Recharge

An important difference between the two models is that the OSE model does not simulate recharge to the basin-fill aquifer, while the JSAI model uses the MODFLOW wells module to simulate a total of approximately 5,190 ac-ft/yr of recharge and lateral inflow. This total is applied as mountain-front recharge to layer 1 (3,800 ac-ft/yr), upwelling of geothermal water from deeper units into layer 3 (60 ac-ft/yr), and lateral inflow across the northern model boundary (1,330 ac-ft/yr; table 2).

These values were estimated and assigned during model calibration. Lateral inflow to the northern end of the model estimated through calibration was simulated using the MODFLOW well package. As a result of steady-state (pre-development) calibration, mountain-front recharge was estimated to average 76 ac-ft/yr (0.10 cubic feet

per second) per mile, over approximately 50 miles of mountain front along the San Andres and Organ Mountains. Rao and Richardson (1996b) derived an independent estimate of mountain-front recharge of 10 ac-ft/yr per mile for the western front of the Organ Mountains, but concluded that this was probably too low. They recommended that a conservative estimate of 50 ac-ft/yr per mile (4 percent of average precipitation) be used for recharge to the SJMB. Other modeling studies in the region (Peterson and others, 1984; S. S. Papadopoulos & Associates, 1987; Frenzel and Kaehler, 1992; GCL, 1995) have estimated mountain-front recharge ranging from 75 to 354 ac-ft/yr per mile.

Recharge to layer 3 in the form of upwelling water from the East Mesa Geothermal Field was estimated based on upward flow estimates by Gross and others (1985). Uncertainty regarding this recharge led to testing the effect of its removal from the model. Steady-state heads from model runs with and without this recharge were compared. Heads on the northeast edge of the model area in layers 1 and 2 were most affected, with maximum residuals of about  $\pm 60$  feet. However, over most of the model area the absolute mean residual for heads in all three layers was only about one foot. Similarly, the 2-D model was found to be insensitive to changes in this recharge (GCL, 1995). Therefore the inclusion of this recharge is considered acceptable, given the mostly minor head changes observed when it is removed.

### Discharge

Given the depth to the water table over most of the SJMB, neither model simulates natural discharge through evapotranspiration. In both models the Rio Grande is the ultimate regional discharge. Ground-water withdrawal by pumping wells is simulated in both models using the MODFLOW well package.

Steady-state flux from the SJMB to the Mesilla Basin can be used as a check on model validity. Frenzel and Kaehler (1992) applied a flux of about 3,800 ac-ft/yr as recharge to the Mesilla Basin along the common boundary between the basins. The comparable flux between basins in the JSAI model is about 2,860 ac-ft/yr. About 330 ac-ft/yr of the difference is accounted for by recharge along the west side of the Doña Ana Mountains, which is not included in the JSAI model. The OSE superposition model does not calculate a comparable flux between the basins.

## Calibration

The OSE model is a transient superposition model for evaluation of water rights applications. Neither steady-state nor transient calibrations of the original model were attempted, but Rao and Richardson (1996b) tested the model using estimated historic pumping stresses and determined that it was satisfactory for predicting future hydrologic impacts resulting from changes in simulated stresses. No model parameters were changed as a result of this testing.

The 1990 2-D JSAI model was calibrated only to steady-state heads. Work performed by GCL on the 1990 JSAI model included conducting a transient calibration for the period 1962 to 1992 (GCL, 1995). Shomaker and Finch (1996) incorporated the calibration made by GCL (1995) in development of the multilayer JSAI model. Steady-state heads computed by the 1996 JSAI model showed reasonable agreement with pre-1970 water levels reported at wells in the SJMB and Mesilla Basin. Transient calibrations for two historical periods were conducted by JSAI, with acceptable results: 1) 1962 to 1994 (Shomaker and Finch, 1996); and 2) 1962 to 1999 (Shomaker and others, 2000).

The amount of measured water-level and pumping data in the SJMB for use in model simulations and calibration is relatively meager. The period of record for water-level measurements at most of the wells is short. Measurements are available from at most 20 wells for any decade during the period 1941 to 2000. Also, pumping data for the transient calibration period (1962 to 1999) are not available for most of the wells in the SJMB, especially prior to 1989. Model calibration under such conditions is problematic, as noted by Rao and Richardson (1996a; 1996b), who found that modification of OSE model parameters was not justified due to the limited amount of historical data.

## Water quality considerations

Rao and Richardson (1996b; appendix C) used total dissolved solids (TDS) concentrations and well completion information to estimate an average thickness of 323 feet for the zone of freshwater (defined as ground water with a TDS content of less than 1,000 milligrams per liter; mg/l) in the SJMB basin-fill aquifer. Most wells used by Rao and Richardson (1996b) only partially penetrate the entire thickness of the freshwater zone, so their estimates represent minimum values (Wilson, 1996).

Wilson and others (1981; plate 15) mapped thickness of the freshwater zone in part of the SJMB. Their contours indicate that the zone is thickest (2,000 feet) north of U.S. Highway 70 (figure 4), and thins within a few miles to the south, east and west to about 400 feet or less. However, deep well data indicates that the freshwater zone may only be 800 feet thick near Section 6, T22S, R03E, illustrating the uncertainty involved in published freshwater thickness estimates and the importance of site-specific data.

Rao and Richardson (1996b) estimated that the basin-fill aquifer underlying a three-township area in the SJMB (T21S, R03E; T22S, R02E; T22S, R03E) contains 1.5 million acre-feet (MAF) of practically recoverable fresh ground water in storage. Wilson (1996) estimated 12 MAF of freshwater to be recoverable from the entire SJMB, based primarily on Wilson and others (1981; plate 15). Whatever the volume, studies in the Hueco Bolson (SSP&A, 1987) indicate that only up to half the freshwater thickness in any area may be recoverable without causing degradation of the fresh water zone.

The NASA-White Sands Test Facility is remediating a plume of contaminated ground water located in sections 32 through 35, T20S, R3E and sections 2 through 5, T21S, R3E. The contaminant plume is in the fractured bedrock flow system underlying the SJMB basin-fill aquifer. In the GCL regional 2-D and site 3-D models this flow system was simulated as an equivalent porous medium continuous with the basin-fill aquifer flow system (GCL, 1995).

Neither the OSE model nor the JSAI model explicitly simulates chemical concentrations, reactions or transport in the SJMB basin-fill aquifer. However, either model could be used to evaluate effects on the thickness of the freshwater zone in the SJMB, and either model could be coupled with solute transport codes for prediction of TDS changes. Either model could also be used to estimate drawdowns at the NASA site.

### **Other considerations**

The OSE model is a superposition model, simplifying its use for water rights administration. Also, the OSE model grid is oriented with columns running north-south and rows running east-west (table 1, figure 2). Model cells are thus aligned with and in some cases correspond with sections in the public land survey system (figure 2). This facilitates locating existing wells and proposed well locations on the grid.

Whenever possible the axes of finite-difference grids should be aligned with the principal directions of the hydraulic conductivity tensor (Anderson and Woessner, 1992). Water-table contour maps (Wilson and others, 1981; plate 9), and basin stratigraphy and structure (Hawley, 1984; Seager and others, 1987), indicate that the JSAI model grid is aligned more closely to the presumed principle directions of hydraulic conductivity.

## COMPARISON OF TEST CASE RESULTS

Applications LRG-451, LRG-452, LRG-453, LRG-479, LRG-480, LRG-532 and 533 for new appropriations of ground water in the Lower Rio Grande Underground Water Basin were filed by Moongate Water Co., Inc. (Moongate) and Louis Gariano. Applications LRG-451, 452, 453, 479 and 480 propose the diversion of 370 ac-ft/yr each, and applications LRG-532 and 533 propose the diversion of 350 ac-ft/yr each, for a total diversion of 2,550 ac-ft/yr. The seven proposed wells would be drilled to depths of 1,000 to 1,500 feet, in the SJMB about 2 to 4 miles west of Organ (figure 5).

The OSE and JSAI models were used to evaluate effects of the proposed diversions on existing water rights, including drawdown at wells of other ownership, depletions to the Rio Grande surface water system, and impacts to the freshwater zone. Results are hypothetical and for use only to compare the models; they were not intended and should not be used for any other purpose. These applications were chosen as a test case because of their priority, and their typical location and appropriation amounts.

Table 3 provides a summary comparing results from the two models. Calculated drawdowns of ground-water levels differ significantly between the two models. Maximum drawdowns at 40 years were calculated as 98 feet (OSE), or 405 feet (JSAI), for maximum average rates of decline of 2.45 ft/yr (OSE), versus over 10 ft/yr (JSAI).

After 40 years the maximum predicted reductions in recoverable freshwater thickness (RFWT) due to existing rights and the proposed pumping are 98 feet (24 percent of RFWT; OSE), versus 405 feet, or over 100 percent of RFWT (JSAI).

The JSAI model predicted that a total of 26 wells would lose 70 percent or more of their water column after 40 years of pumping under existing rights plus the proposed pumping, compared to 18 wells predicted by the OSE model. Of these, 23 (JSAI) or 13 (OSE) wells would be dewatered after 40 years by pumping under existing rights alone.

Calculated surface water depletions also differ significantly between the models. After 100 years the OSE model calculates depletions from the proposed pumping of 361 ac-ft/yr, or 14 percent of pumping. In contrast, the JSAI model calculates that only 101 ac-ft/yr, just four percent of pumping, will be derived from depletion of surface water sources at 100 years (table 3).

The results in table 3 indicate that for this test case the JSAI model calculated significantly greater water-level declines than the OSE model, which calculated greater surface-water depletions. Given the differences in model construction discussed in previous sections of this report, this relationship could be expected to hold true for predictions in other cases.

## **IMPLICATIONS FOR ADMINISTRATION**

There are currently no formal criteria or guidelines for administration of water rights within the SJMB. Hydrologic studies indicate that the SJMB is connected to a surface water source: the Rio Grande stream system. The SJMB can also be considered a mined basin in the sense that the surface water connection is restricted and distant enough that the most profound short-term ( $10^1$  to  $10^2$  years) hydrologic effects are related to depletion of ground-water storage (water-level drawdown and dewatering of the freshwater zone). Because the Rio Grande stream system is fully appropriated, and recoverable ground water in storage in the SJMB is finite, both surface-water and ground-water effects must be considered in basin administration. However, it should be noted that current and projected pumping, and resulting surface water depletions, are probably several orders of magnitude smaller in the SJMB than in the Mesilla Basin.

Both the OSE and JSAI models are capable of estimating surface-water depletions and effects on the ground-water resource such as water-level declines. However, the JSAI model is a more robust representation of the hydrologic system of the SJMB than the OSE model, and estimates of hydrologic effects made by the JSAI model may be more hydrologically reasonable than those calculated by the OSE model. Hydrology Bureau recommends that the JSAI model be used for evaluation of the hydrologic effects of water rights applications in the Southern Jornada del Muerto Basin, and that the model be periodically re-evaluated and modified as needed.

## RECOMMENDED MODIFICATIONS AND RESEARCH

Several minor modifications to the JSAI model would make it easier to use for water rights administration. These include modifying input files to create a version of the model that will perform future predictive runs without rerunning the historical calibration period each time. Such a version would use heads generated from the final time step of the calibration run (1999) as initial heads for predictive runs that begin in the year 2000.

Although the JSAI model runs using standard MODFLOW source code, given the relatively large water-level drawdowns calculated by the model problems may be encountered if cells with pumping stresses designated in the well file go dry. (In the test case several model cells in layer 1 went dry under the pumping scenarios simulated.) Using standard MODFLOW this results in the loss of that amount of pumping designated for that location. To avoid this the OSE has used a modified version of MODFLOW (after Balleau, 1998), which moves pumping from a dry cell to the layer below in order to maintain that stress. This simulates either an increase in pumpage from deeper layers penetrated by the well, or the effect of deepening or drilling deeper wells as necessary to maintain pumping. For water rights administration the JSAI model should be run using this modified “well-deepening” code, although appropriate care should be exercised to ensure that simulated withdrawals are not deepened beyond reasonable limits. Also, as permits are approved in the SJMB, permitted diversions should be added to the well file.

Further research regarding the postulated upwelling of geothermal water into the basin-fill aquifer, and its simulation in the model as recharge to layer 3, is warranted. Possible outcomes could include modifying the location and/or amount of this recharge, or removing it from the model altogether. Conversion of the JSAI model to a superposition version should also be investigated. This would simplify calculation of surface-water depletions, in that only one model run would be required rather than two. Finally, as additional data are obtained in the SJMB, the transient calibration should be extended and further refinement or modification of the model should be considered, in particular changes to layer properties.

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Figure 1. Location of the Southern Jornada del Muerto Basin, Lower Rio Grande Underground Water Basin

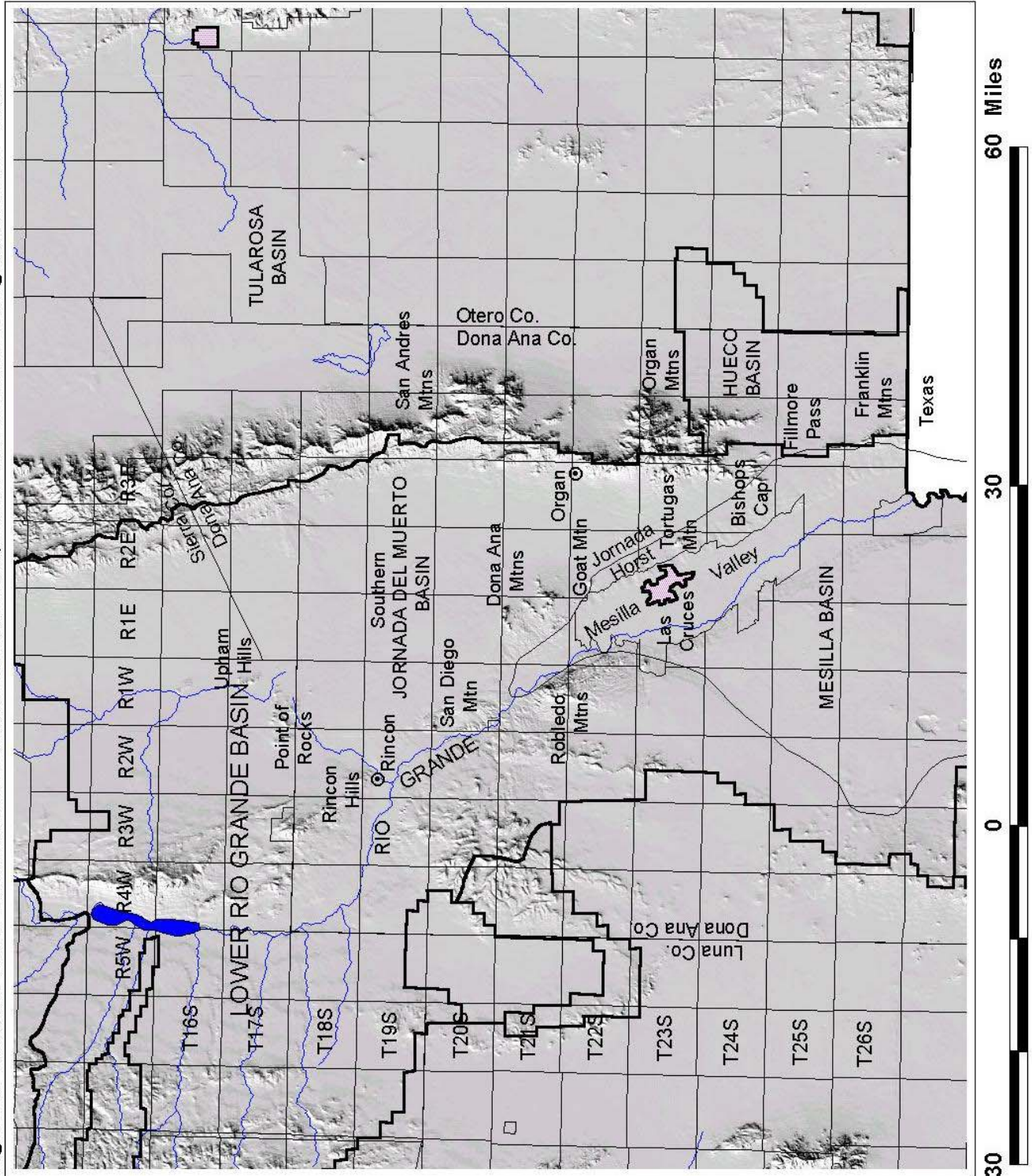


Figure 2. Finite-difference grid for the OSE model of the Southern Jornada Basin

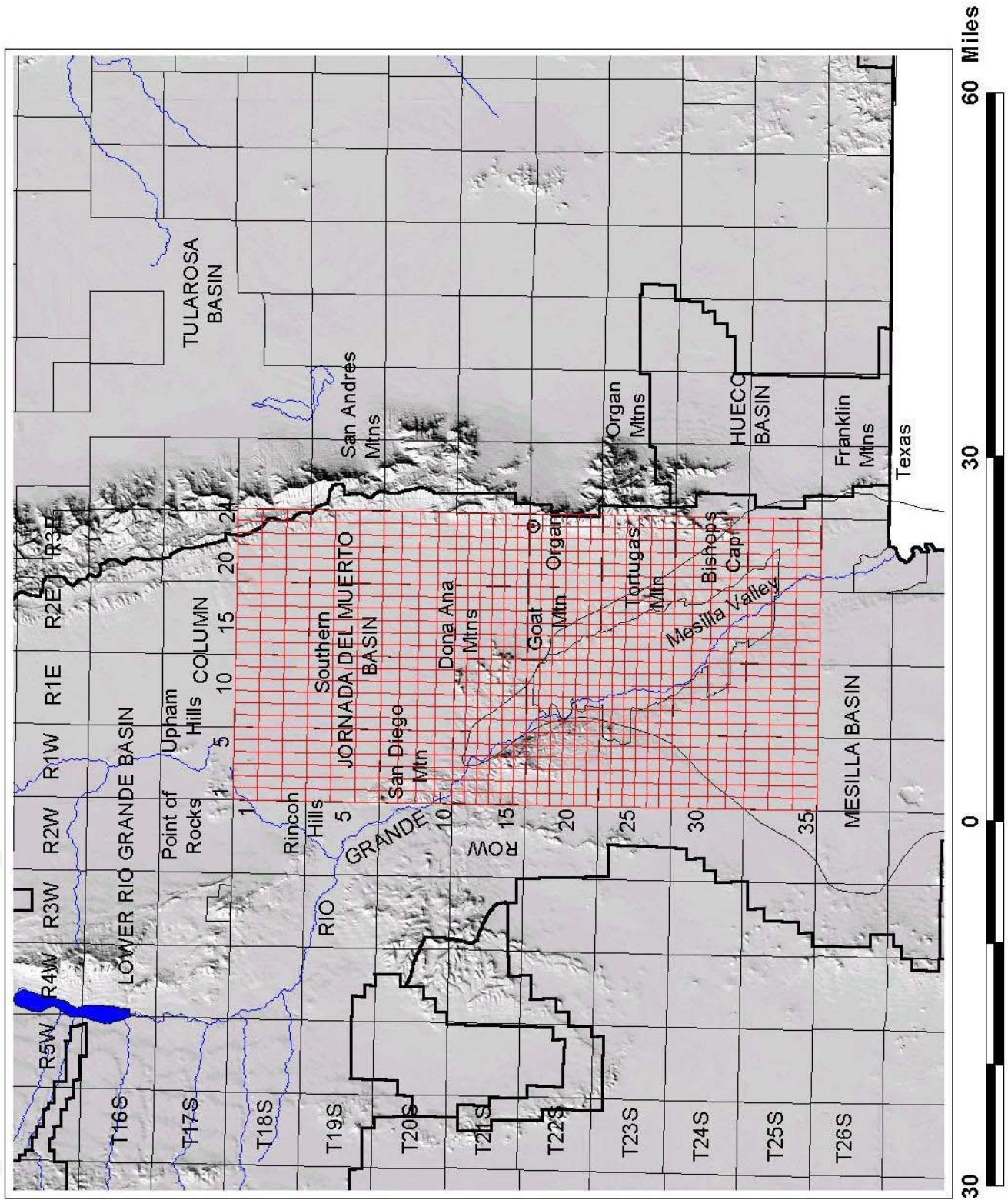




Figure 3. Finite difference grid for the JSAI model of the Southern Jornada Basin

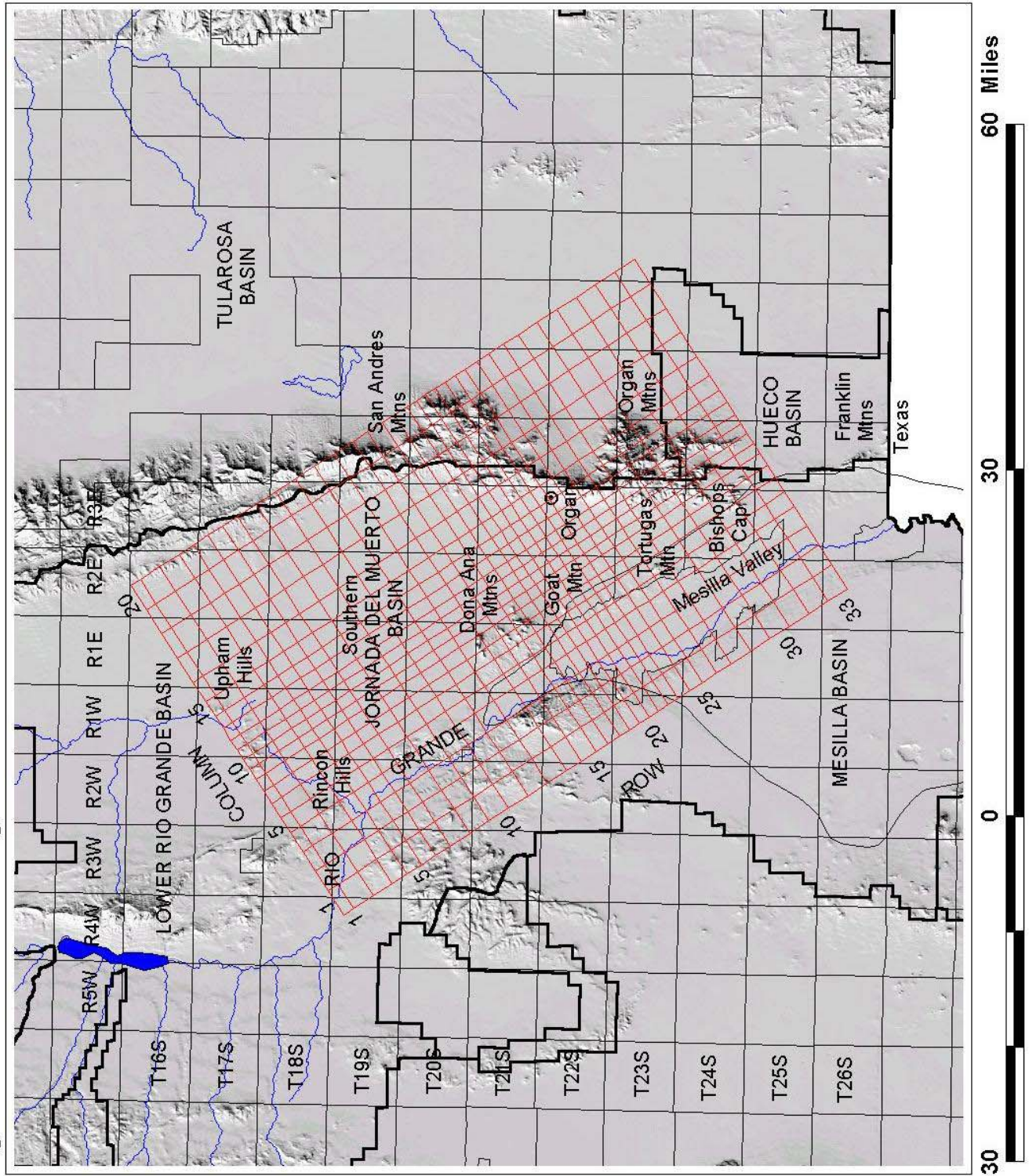
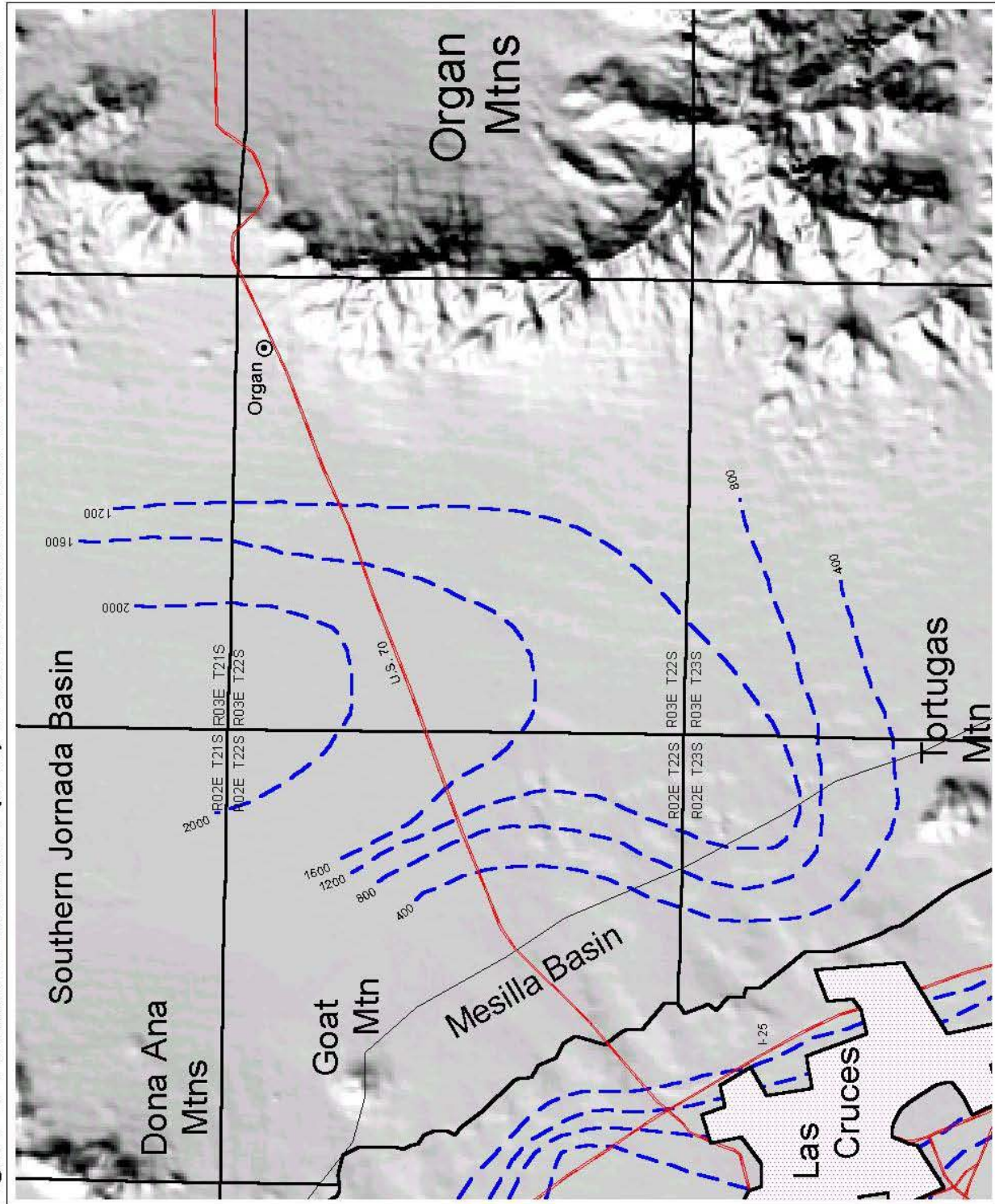


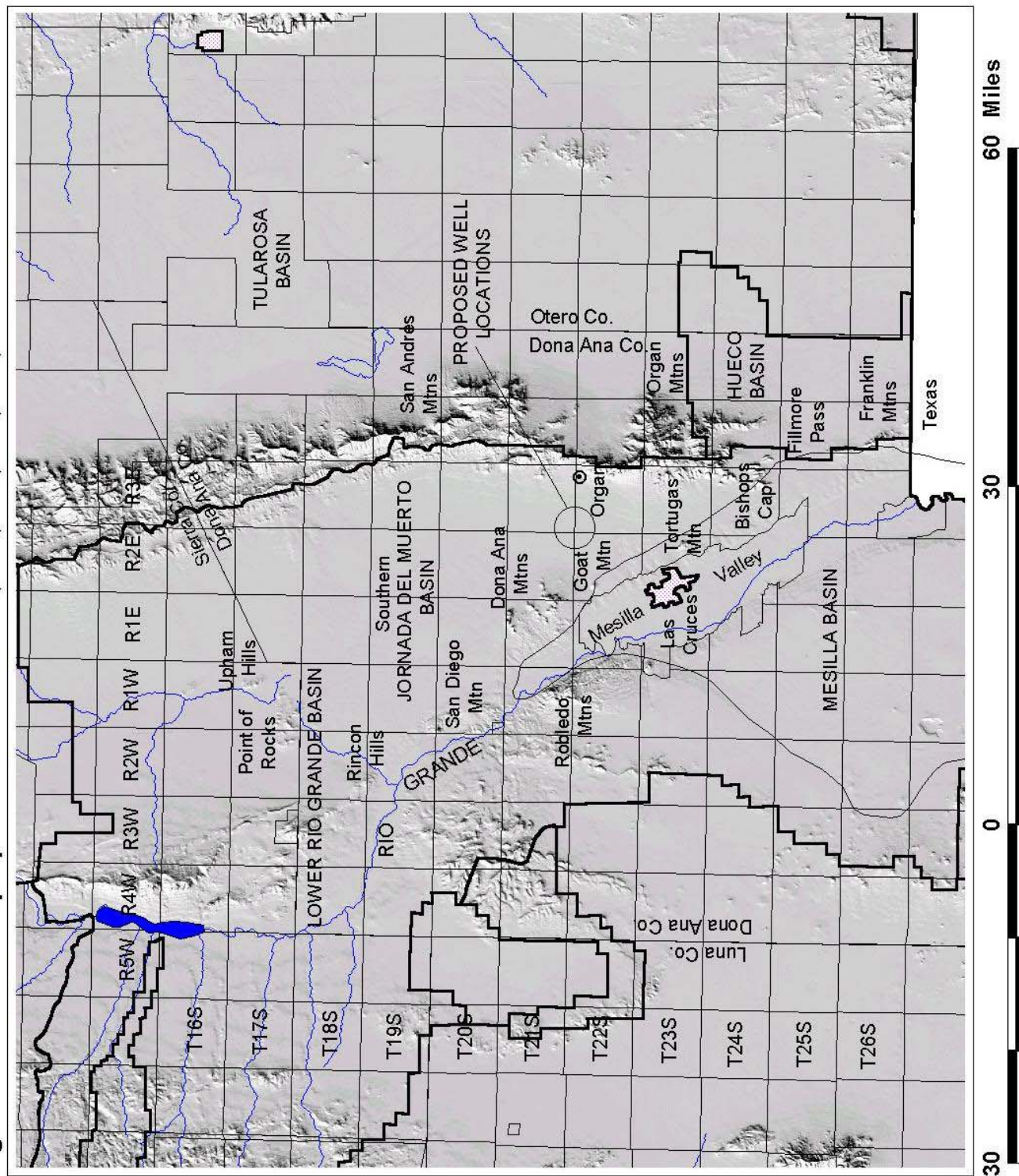
Figure 4. Estimated thickness (feet) of the freshwater zone in the Southern Jornada Basin



Contour interval = 400 feet  
 From: NMOSE Technical  
 Report 43, plate 15  
 (Wilson et al., 1981)



Figure 5. Location of proposed wells LRG-451, 452, 453, 479, 480, 532 and 533



**Comparison of Two Ground-Water Flow Models for Administration of the Southern Jornada Basin, New Mexico (Hydrology Report 01-6, Johnson 07/01)**

**Table 1.** Structure and properties of the OSE and JSAI models of the Southern Jornada del Muerto Basin.

Property <sup>a</sup>	OSE model	Comments	JSAI model	Comments
Model area (square miles)	1,150	T18-25S/R1W-3E	1,740	T16-25S/R3W-3E
Grid orientation and discretization	N-S E-W	24 columns 35 rows	NW-SE SW-NE	20 columns 33 rows
Layer number (MODFLOW layer type)	1 (0)	Constant T and S values	1 (1) 2 (3) 3 (0)	Unconfined Convertible Confined
Total thickness range (feet)	NA	Not applicable	65 – 4,250±	Hawley (1984)
Storage coefficients	0.21 0.10	Mesilla Valley Rest of model area	0.15	Sy for all layer 1 and converted layer 2
Specific storage	NA	Not applicable	1x10 <sup>-6</sup> ft <sup>-1</sup>	Layers 2,3
Range of K <sub>h</sub> (feet/day)	NA	Not applicable	0.1 – 45	Layers 1,2
K <sub>h</sub> :K <sub>v</sub> (vertical anisotropy)	NA	Not applicable	200:1	Model-wide value
Range of T (feet <sup>2</sup> /day)	100 – 30,000	Layer 1	1 – 3,100	Layer 3

<sup>a</sup>K<sub>h</sub> = horizontal hydraulic conductivity; K<sub>v</sub> = vertical hydraulic conductivity; T = transmissivity.

**Table 2.** Comparison of boundary conditions and fluxes for the Southern Jornada del Muerto Basin as simulated by the OSE and JSAI models.

Boundary	OSE model	JSAI model	Comments
Upper	Water table	Water table	Both no ET <sup>a</sup>
Lower	No-flow	No-flow	Base of fill
Lateral	No-flow	No-flow, specified flux and constant-head (Rio Grande)	JSAI west boundary is Rio Grande
Recharge <sup>b</sup> (acre-feet per year)	None simulated	Mountain front Inflow from north Geothermal upflow <b>Total</b>	Layer 1 (3,800) Layer 1 (1,330) Layer 3 (60) <b>(5,190)</b>
Surface water system	Constant-head	Constant-head	Rio Grande

a: ET = evapotranspiration; b: Sum of cell values from figure 10 in Shomaker and Finch (1996), in ac-ft/yr.

**Table 3.** Comparison of hypothetical hydrologic effects of applications LRG-451, 452, 453, 479, 480, 532 and 533, calculated using the OSE and JSAI models of the Southern Jornada del Muerto Basin.

Hydrologic effect	OSE model		JSAI model		Comments
	40 years	100 years	40 years	100 years	
Maximum drawdown (feet)	20	31	216	462	Proposed pumping
	98	166	405	666	Existing rights + proposed
Maximum average rate of water-level decline (feet/year)	2.45	1.66	10.12	6.66	Due to existing rights and proposed pumping combined
Max. reduction of recoverable freshwater thickness (RFTW) <sup>a</sup>	feet	98	166	405	Due to existing rights and proposed pumping combined
	%	24	42	101	
Number of wells with 70% water column dewatered	18	--	26	--	Existing rights + proposed
	13	--	23	--	Existing rights only
Surface water depletions due to proposed pumping	87.2	361	10.3	101	Acre-feet per year
	3.4	14.2	0.4	4.0	Percent of pumping

<sup>a</sup>Maximums in feet and as percentage of RFTW (%) may occur in different model cells; RFTW = 400 feet.