Death Valley Regional Ground-Water Flow System, Nevada and California—Hydrogeologic Framework and Transient Ground-Water Flow Model

Edited by Wayne R. Belcher

Abstract

A numerical three-dimensional (3D) transient ground-water flow model of the Death Valley region was developed by the U.S. Geological Survey for the U.S. Department of Energy programs at the Nevada Test Site and at Yucca Mountain, Nevada. Decades of study of aspects of the ground-water flow system and previous less extensive ground-water flow models were incorporated and reevaluated together with new data to provide greater detail for the complex, digital model.

A 3D digital hydrogeologic framework model (HFM) was developed from digital elevation models, geologic maps, borehole information, geologic and hydrogeologic cross sections, and other 3D models to represent the geometry of the hydrogeologic units (HGUs). Structural features, such as faults and fractures, that affect ground-water flow also were added. The HFM represents Precambrian and Paleozoic crystalline and sedimentary rocks, Mesozoic sedimentary rocks, Mesozoic to Cenozoic intrusive rocks, Cenozoic volcanic tuffs and lavas, and late Cenozoic sedimentary deposits of the Death Valley regional ground-water flow system (DVRFS) region in 27 HGUs.

Information from a series of investigations was compiled to conceptualize and quantify hydrologic components of the ground-water flow system within the DVRFS model domain and to provide hydraulic-property and head-observation data used in the calibration of the transient-flow model. These studies reevaluated natural ground-water discharge occurring through evapotranspiration (ET) and spring flow; the history of ground-water pumping from 1913 through 1998; ground-water recharge simulated as net infiltration; model boundary inflows and outflows based on regional hydraulic gradients and water budgets of surrounding areas; hydraulic conductivity and its relation to depth; and water levels appropriate for regional simulation of prepumped and pumped conditions within the DVRFS model domain. Simulation results appropriate for the regional extent and scale of the model were provided by acquiring additional data, by reevaluating existing data using current technology and concepts, and by refining earlier interpretations to reflect the current understanding of the regional ground-water flow system.

Ground-water flow in the Death Valley region is composed of several interconnected, complex ground-water flow systems. Ground-water flow occurs in three subregions in relatively shallow and localized flow paths that are superimposed on deeper, regional flow paths. Regional ground-water flow is predominantly through a thick Paleozoic carbonate rock sequence affected by complex geologic structures from regional faulting and fracturing that can enhance or impede flow. Spring flow and ET are the dominant natural ground-water discharge processes. Ground water also is withdrawn for agricultural, commercial, and domestic uses.

Ground-water flow in the DVRFS was simulated using MODFLOW-2000, a 3D finite-difference modular ground-water flow modeling code that incorporates a nonlinear least-squares regression technique to estimate aquifer parameters. The DVRFS model has 16 layers of defined thickness, a finite-difference grid consisting of 194 rows and 160 columns, and uniform cells 1,500 meters (m) on each side.

Prepumping conditions (before 1913) were used as the initial conditions for the transient-state calibration. The model uses annual stress periods with discrete recharge and discharge components. Recharge occurs mostly from infiltration of precipitation and runoff on high mountain ranges and from a small amount of underflow from adjacent basins. Discharge occurs primarily through ET and spring discharge (both simulated as drains) and water withdrawal by pumping and, to a lesser amount, by underflow to adjacent basins, also simulated by drains. All parameter values estimated by the regression are reasonable and within the range of expected values. The simulated hydraulic heads of the final calibrated transient model generally fit observed heads reasonably well (residuals with absolute values less than 10 m) with two exceptions: in most areas of nearly flat hydraulic gradient the fit is considered moderate (residuals with absolute values of 10 to 20 m), and in areas of steep hydraulic gradient, such as Indian Springs, western Yucca Flat, and the southern part of the Bullfrog Hills, the fit is poor (residuals with absolute values greater than 20 m). Ground-water discharge residuals are fairly random, with as many areas where simulated flows are less than observed flows as areas where simulated flows are greater. The highest unweighted ground-water discharge residuals occur at Death

Valley and Ash Meadows. High weighted discharge residuals were computed in the Pahrump Valley, possibly indicating a poor definition of hydraulic properties or discharge estimates in that area.

The model represents the large and complex ground-water flow system of the Death Valley region at a greater degree of refinement and accuracy than has been possible previously. The representation of detail provided by the 3D digital hydrogeologic framework model and the numerical ground-water flow model enabled greater spatial accuracy in every model parameter. The lithostratigraphy and structural effects of the hydrogeologic framework; recharge estimates from simulated net infiltration; discharge estimates from ET, spring flow, and pumping; and boundary inflow and outflow estimates all were reevaluated, some additional data were collected, and accuracy was improved. Uncertainty in the results of the flow model simulations can be reduced by improving on the quality, interpretation, and representation of the water-level observations used to calibrate the model and improving on the representation of the HGU geometries, the spatial variability of HGU material properties, the flow model physical framework, and the hydrologic conditions.

View from Mount Stirling (2,506 m) in the Spring Mountains to the northeast toward the Pintwater, Desert, and Sheep Ranges. The Las Vegas Valley shear zone runs across the middle of the photograph between the Spring Mountains and the mountain ranges to the north. Playas are visible in Indian Springs Valley (toward the west or left side of the photograph) and in Three Lakes Valley (to the east or the right side of the photograph). Indian Springs Air Force Base is visible in the center foreground, at the base of the Pintwater Range. Photograph by Nancy A. Damar, U.S. Geological Survey.