Simulation of Spring Valley ground water development, as proposed by the Southern Nevada Water Authority

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Introduction

A MODFLOW model covering a significant portion of the Great Basin was produced by Donald H. Schaefer and James R. Harrill (1995), which was developed based on the model designed by Prudic et al (1995). This model was constructed for the purpose of estimating effects of the Southern Nevada Water Authority (SNWA) proposed pumping in 17 Hydrographic Areas (HA's) on aquifers of the region. The model, being regional in scale, is somewhat generalized. The grid spacing is uniform 5 by 7½ miles for the entire model domain. With 61 rows and 60 columns, this translates to a regional scale model covering 137,250 square miles. All model parameters are averaged over very large areas.

I utilized the Schaefer and Harrill (1995) model to simulate currently proposed groundwater pumping in the Spring Valley HA only, and to make an estimation of the effects of that pumping on the potentiometric surface. The only changes I made to the original simulation were elimination of most of the pumping wells, rearrangement of some of the Spring Valley wells and their pumping schedules, and to the transient time sequence.

The model

The model domain is shown in Figure 1. The model covers about half of Nevada and a third of Utah; therefore parameters are very generalized. Spring Valley, shown in red, accounts for approximately 2% of the active cells. The model is described in detail in Prudic, et al (1995) and in Schaefer and Harrill (1995). I received my copy of the model files directly from David Prudic at the US Geological Survey in Carson City by email. I utilized the Groundwater Vistas (Version 4.21, Build 3, available from Environmental Simulations, Inc.) pre- and post-processing software to import, modify, and run the simulation.

Before I modified the model to simulate pumping in Spring Valley only, I ran it with all settings used by Schaefer and Harrill (1995). Figure 2 shows a contour map from Schaefer and Harrill (1995) with contours of head from my first model run as an overlay (red contours). The contour lines are nearly identical, small differences being the result of different contouring software.

In brief, the model is a two layer simulation of the carbonate aquifer zone which covers about two thirds of the Great Basin. The grid is aligned with the general north-south trend of Great Basin mountain ranges, which facilitates simulating the flow directions dictated by their presence. Drain nodes in layer 2 (the regional carbonate aquifer) simulate major regional springs, such as those at Ash Meadows and Muddy River Springs. Layer 1, which simulates the basin fill and mountain block aquifers is differentiated mainly by storage parameters and to a lesser degree by hydraulic conductivities.

The mountain blocks, as simulated in this model, are not absolute barriers to flow. North-south trending faults, common in the Great Basin, and mountain geology may often be significant interbasin barriers to ground water flow, model results must be viewed accordingly. Drawdown cones may in reality not cover as much geographic area; however, a cone of depression may be deeper locally.

Bear in mind that, this being a general simulation covering a vast area, that recharge and pumping rates never vary, regardless of the position of the potentiometric surface.

In Schaefer and Harrill (1995) the authors indicate that layer one is unconfined. Layer one has the MODFLOW setting of Layer Control (LAYCON) = 0, which is generally used to model confined aquifers, and is also used to model the lower layer. According to McDonald and Harbaugh (1983) this setting may be utilized for unconfined aquifers as long as the amount of head change is a small fraction of the total saturated thickness.

The original model utilized 85 pumping wells, 46 of which were in layer 1. These wells were distributed amongst the 17 basins documented in Schaefer and Harrill (1995). I deleted all pumping wells from the original model and replaced them with pumping wells in Spring Valley only. Figure 3 shows the exact location of these wells. Because a cell in MODFLOW may only contain a single pumping well, model cells with more than one well were simply given the additive total of pumping rates therein. SNWA proposes pumping 6 cfs from each alluvial well and 10 cfs from each carbonate well. Consequently, the total pumping rate in this model is 126 cfs (91,220 afy); 96 cfs (69,500 afy) in layer 1 and 30 cfs (21,720 afy) in layer 2 (Figure 3). This compares with 58 cfs (41,668 afy) total for Spring Valley in the original model; 46 cfs (33,334 afy) in layer 1 and 11.5 cfs (8,334 afy) in layer 2. Well positions, based on the current SNWA proposal, were shifted only slightly from the original model. Because of the changed positions, layer one has 8 pumping wells in layer one compared with 12 in the original model. Layer 2 has three pumping wells in each model. Figure 4 shows the old and new model well locations for Spring Valley.

I modified the transient time schedule somewhat. Each Stress Period in this model exercise consists of ten steps, with a Time Step Multiplier of 1.2. The length of each Stress Period was 5 years, 5 years, 40 years, 60 years, 100 years, and 100 years, respectively for simulating future times of 5, 10, 50, 100, 200, and 300 years from the start of pumping. No change in model results were obtained from the addition of time steps and changing the Time Step Multiplier, but the changes made for more uniform time distribution and greater ease of extracting final output. Also, a time step multiplier between one and two is a more conventional approach for pumping scenarios because drawdown tends to taper off after time. For the first 5 Stress Periods I simulated the constant pumping rate of 126 cfs (91,220 afy). In the final Stress Period, no pumping occurred in order to evaluate 100 years of recovery.

Model Results

Figures 5A through 10B show the resultant cones of depression from the model run. As indicated above, effects translate beyond the boundaries of the Spring Valley Hydrographic Area. However, the 100 foot contour generally stays near, or inside the Spring Valley boundaries. Despite the generalized nature of the model, it is clear that significant drawdown will occur as a result of pumping of the proposed magnitude. The potentiometric surface should show, as indicated in Figures 5A through 10B, a greater decline and extent of influence in the regional carbonate aquifer because of the smaller value of Storage Coefficient (0.0006 versus 0.1 to 0.05 for the unconfined aquifers). This number represents the fraction of water released from an aquifer for a unit decline in head caused by pumping. For example, a Storage Coefficient of 0.0006 means that an induced decline in head of 10 meters would release 6 millimeters of water over the area of decline. The explanation for choice of storage parameters is found in Schaefer and Harrill (1995, page 8).

Figure 11 shows the locations for the cross sectional views of the potentiometric surface shown in Figure 12. The cross sections show head decline in Spring Valley following 200 years of groundwater withdrawal in both model layers. The more pronounced effect of pumping a confined aquifer (layer 2) is clearly shown in these diagrams.

I modeled the effects of pumping only in layer 2. Figure 13 shows the cones of depression in layer 1 resulting from pumping layer 2. The pumping rate for layer 2 was kept at the same level: 30 cfs. The ability of the model to show the effects in layer 1 from pumping in layer 2 depends on the leakance values input into the data files. This is essentially a numerical expression for the ability of the model to transmit water between layers (McDonald and Harbaugh, 1988, page 5-11). The higher the value, the more readily water is able to flow between layers. Leakance (or vertical conductance) values were originally assumed to be 1×10^{-11} per second, and then adjusted during model calibration to better match observed heads (Prudic, et al, 1995, pp. D28-D31). Figure 13 shows drawdown in layer 1 after pumping for 200 years in layer 2.

Figure 14 shows the effect of pumping only the alluvial aquifer (layer 1) at the total rate of 96 cfs after 200 years. The resulting cone of depression is similar to, but somewhat smaller and shallower than the total pumping proposal shown in Figure 9A.

Summary

It is my expert opinion that, although the Schaefer and Harrill model (1995) was designed to show regional scale effects of pumping in multiple basins by SNWA, the model clearly shows a cone of depression for the carbonate and the alluvial aquifers that could reasonably be expected to develop due to proposed pumping in Spring Valley. Water table levels in the alluvial aquifer could decline by 200 feet or more following 200 years of pumping at the proposed rates. If pumping of this magnitude takes place for long enough, springs, creeks, ponds, and wetlands in Spring Valley have the potential to be dried up or experience reduced flow if and when the potentiometric surface falls below spring orifices or the surface elevation of wetlands, streams and ponds. The possibility also exists, provided there is a hydraulic connection such as that suggested by Rush and Kazmi (1965) between Spring Valley and Hamlin valley, that water resources in those Hydrographic Areas which are near the Spring Valley boundary, may also be affected. Elliott, et al (2006, page 44) postulate that water resources in southern Snake Valley would likely be affected by large scale water withdrawal from Spring Valley. Springs that are relatively high on the sides of the surrounding mountains would probably not be affected because they are likely to be sustained by perched aquifers in the mountains. Otherwise the large gradients between such springs and hydraulic heads at the valley margins and floor would imply that transmissivity was much too low for there to be a significant connection.

The confined carbonate aquifer would be affected by greater decline in the potentiometric surface than the alluvial aquifer, due to typically smaller storage values in confined aquifers. If the vertical conductance terms of the model are appropriate, pumping the carbonate aquifer alone could also result in effects to surface water resources, as indicated by the carbonate-pumping only scenario.

The model runs indicate, whether pumping is from both aquifers, or either alone, that Shoshone Pond is likely to be affected.

The model also shows that there would be a residual cone of depression remaining for at least 100 years following cessation of 200 years of pumping at the proposed rate. Potential effects to local water resources could persist through much of the recovery period.

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