6.0 USGS MODEL

6.1 Background

A groundwater flow model is a simplification of a real groundwater flow system. Real groundwater flow systems are complex, and they are often simplified with a model for the purposes of resource planning and making management decisions. Groundwater flow models use mathematical equations and data related to the location and amount of inflows and outflows to simulate the movement and changing storage of groundwater over a defined area.

The US Geological Survey developed the most recent groundwater flow model of the Hueco Bolson (Heywood and Yager, 2003). EPWU (2002) circulated a report that describes the input and output files of the model. The objectives of the model were:

- Develop a tool to assist in the understanding of groundwater flow
- Develop a tool to evaluate potential groundwater management strategies

The model area covers the Hueco and extends slightly into the Tularosa Basin in New Mexico, covers the Hueco in Texas (except for the southeastern tip in Hudspeth County, and most of the Hueco in Mexico. The coverage is presented in Figure 6-1.

The model code (the computer program that contains the set of mathematical equations) was a modified version of MODFLOW-96, an industry-standard FORTRAN finite-difference code developed by the USGS. As described in Heywood and Yager (2003), the STR (stream) and MAW (multi-aquifer well) packages were modified in order to deal with the large magnitude of historic drawdown that has been observed in the area, and the consequential issue of dried model cells.

The model grid consists of 165 rows and 100 columns in a variable grid of 500 meters by 500 meters to 1000 meters by 1000 meters, with the finer grid in the area of interest in the El Paso and Juarez area. The model was calibrated with data from 1903 to 1996. More recently, EPWU has updated the model to include input data from 1997 to 2002.

The key concept from the results of the model is that the groundwater flow system is dynamic (inflow to the system is not fixed and is influenced by pumping). The key limitation of the model is that it is a regional model, which cannot address local questions such as predicting well yield at a particular location, predict movement of groundwater on a small scale, or evaluate changes in pumping on a wellfield scale. Moreover, the model only simulates groundwater flow, and cannot directly address groundwater quality changes. However, this flow model can be used as the foundation for a solute transport (water quality) model.

6.2 Overview of Results

The results of the model are described in Heywood and Yager (2003). The purpose here is to simply summarize the results in the context of future groundwater management for the El Paso area. These results consist of examples of calibration results and groundwater budget results for the El Paso area.

Heywood and Yager (2003, pp. 23-26) calibrated the model by adjusting parameter values representing aquifer properties and specified boundary conditions using nonlinear regression techniques to minimize the difference between measured data and model-estimated data. Calibration relied on comparisons between actual and estimated groundwater elevation data and selected surface water flows.

This report presents data and analysis that are not duplicative of the results presented in Heywood and Yager (2003), but are intended to supplement their analysis and focus attention on information needed for groundwater management.

6.3 Selected Hydrograph Comparison

Figures 6-2 to 6-5 present hydrographs of groundwater elevations of selected wells in the El Paso area that cover the calibration period as well as the update (1997 to 2002). The locations of these wells are presented in Figure 6-6.

These comparison hydrographs show the actual data points measured in the field as points and the model estimates of groundwater elevation as lines. Note the reasonable agreement between the actual data and model estimates, even in the update period (1997 to 2002).

The conclusion from this comparison is that the model is able to reasonably reproduce the changes in groundwater elevation caused by groundwater pumping and the associated changes in the flow system (i.e. induced inflow and changing flow directions).

6.4 Groundwater Flow Direction and Drawdown

Figure 6-7 presents the groundwater flow direction in “pre-development” times. Pre-development is taken to be prior to 1903. Note that the groundwater is flowing essentially north to south in New Mexico and Texas until it reaches the Rio Grande, when it turns to the southeast.

Figure 6-8 presents the groundwater flow direction in 2002. Note the development of a significant cone of depression in the airport area caused by high pumping. Groundwater flow changes in response to the pumping by turning towards the high pumping area. As described earlier, this condition has caused brackish groundwater east of the airport to intrude into areas that once had fresh groundwater.

Figures 6-9 to 6-13 depict drawdown estimates for selected time periods. Drawdown is defined in this case as the difference in groundwater levels in 1903 and the year of interest. It is representative of the change in storage in the groundwater system relative to pre-development conditions.

Note that the drawdown in the El Paso area increases dramatically between 1960 and 1990. This represents the period with the largest increase in EPWU pumping. The 2002 drawdown, while larger than the 1990 pumping, appears to have stabilized somewhat due to the decreased pumping during that period. The drawdown maps provide an illustration of where the storage decline has been greatest.

6.5 Groundwater Budget of the El Paso Area

In order to develop an understanding of the changes to the flow system in the El Paso area, a subregional groundwater budget was developed from the output from the model. This approach allows for the quantification of inflows, outflows and storage change within a defined area. Figure 6-14 presents the location of the "El Paso Area".

Figures 6-15 and 6-16 present the conceptual framework of the groundwater budget. Note that the inflows consist of inflow from New Mexico, natural recharge from the Franklin Mountains, flow from the eastern boundary of the area, and surface water recharge. Outflow consists of flow to Juarez and groundwater pumping within the El Paso area.

6.5.1 Inflow from New Mexico

Figure 6-17 presents the model estimates of inflow from New Mexico. Note that over time, the inflow has increased due to decreasing groundwater levels in the El Paso and Juarez areas. Groundwater flows have increased across the state line due to increased gradients caused by cones of depression. Pre-development flow was about 6,000 AF/yr, and by 2002 flow was about 16,000 AF/yr. Pumping in El Paso and Juarez has "induced" an additional 10,000 AF/yr of inflow to the area.

6.5.2 Inflow from Area East of El Paso

Figure 6-18 presents the model estimates of inflow from east of the El Paso area. Note that prior to the mid 1960s, groundwater actually flowed from the El Paso area to the area to the east. In pre-development times this outflow was about 2,500 AF/yr. From the mid 1960s to 2002, groundwater flowed into the El Paso area as a result of cones of depression and increased gradients. From the early 1990s to 2002, the inflow was about 8,000 AF/yr. Therefore pumping has "induced" an additional 10,500 AF/yr of inflow into the area from east of El Paso.

6.5.3 Inflow from Surface Water System

Figure 6-19 presents the model estimates of net inflow from surface water in the El Paso area. Note that for purposes of this groundwater budget, surface water inflow represents a net value calculated as:

Net surface water inflow = Surface water inflow – drain flow – evapotranspiration (ET)

As noted in Heywood and Yager (2003, pg. 29), "Rio Grande water infiltrating into the shallow aquifer system is consumed primarily by ET and (or) flows to agricultural drains." Therefore, the net surface water inflow represents the actual inflow from the surface water system into the groundwater system.

Note that prior to about 1930, groundwater flowed into the surface water system. This is consistent with previous investigations that noted that the Rio Grande was a gaining stream. Based on inspection of the estimates, the gain to the surface water system was about 3,000 AF/yr. After 1930, however, the Rio Grande and the associated canals and drains act as a recharge source. By 2002, the net inflow from the surface water system was about 30,000 AF/yr. Therefore, pumping in Juarez and El Paso has resulted in an "induced" inflow of about 33,000 AF/yr from the surface water system.

6.5.4 Outflow to Juarez

Figure 6-20 presents the model estimates of net outflow from the El Paso area to Juarez. Note that prior to about 1960, groundwater flowed from Juarez to El Paso. Pre-development flows were about 1,200 AF/yr, and rose to about 5,000 AF/yr in the 1930s. Since 1960, increased pumping in Juarez has resulted in a reversal of this trend and groundwater now flows from El Paso to Juarez. In 2002, this flow rate was about 32,000 AF/yr.

6.5.5 Groundwater Storage Decline

Figure 6-21 presents the model estimates of storage decline in the El Paso area. Storage decline is estimated based on a comparison of all inflow and outflow components. When outflow is higher than inflow, storage is decreased. Note that prior to 1950, storage declines fluctuated, but were generally below 10,000 AF/yr. Storage declines increased rapidly from 1950 to the early 1990s, hitting a maximum decline of over 50,000 AF/yr. Since the reduction in pumping, storage decline rates have been decreasing. By 2002, the storage decline was about 11,000 AF/yr, a level that had not been observed since the 1950s.

Based on this analysis, it is clear that the action taken by EPWU to reduce pumping has resulted in a reduction in the annual storage decline. It is also interesting to note the following:

- Muller and Price (1979) estimated the total fresh water storage in the El Paso portion of the Hueco in 1974 to be 10.6 million AF.
- The analysis of current water quality in the El Paso portion presented in Section 4 of this report is about 9.4 million acre-feet.
- Because historic pumping in the El Paso area is limited to fresh groundwater, assume all estimated storage decline between 1974 and 2002 is attributed to fresh groundwater decline.
- The total storage decline between 1974 and 2002 estimated by the model is 1.2 million AF.
- Subtracting the total storage decline estimated by the model (1.2 million AF) from Muller and Price's (1974) estimate (10.6 million AF) yields an estimate of 9.4 million AF, which is in close agreement with the independent assessment based on discrete zone samples described in Section 4 of this report.

6.6 Conclusions from USGS Model

Based on an evaluation of the USGS model results, the following can be concluded:

- Groundwater pumping in the Hueco has resulted in storage declines and induced inflow to the area of both brackish and fresh groundwater
- Induced inflows include increased flow from New Mexico, the area east of El Paso, and the surface water system
- The increased pumping in Juarez has contributed to the increased inflow from New Mexico and the surface water system
- Outflow from El Paso to Juarez has increased as a result of increased Juarez pumping.
- Reduced EPWU pumping in the Hueco has resulted in storage declines that had not been observed since the 1950s.
- The cumulative storage change estimated by the model from 1974 to 2002 is about 1.2 million AF. In 1974, the total fresh groundwater storage was estimated to be 10.6 million AF. An independent analysis based on water quality data yields a current fresh groundwater estimate of about 9.4 million AF.