GAM Run 10-002

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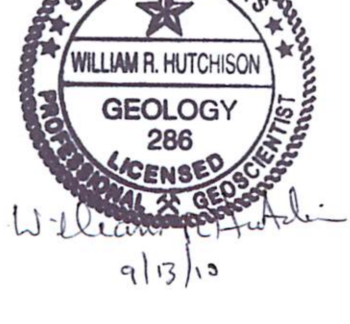

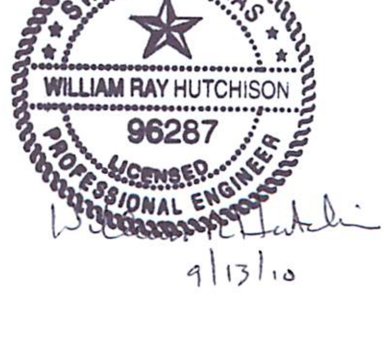

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EXECUTIVE SUMMARY:

The groundwater availability model for the Lipan Aquifer was used to simulate current operational practices. The objective of these simulations was to develop estimates of groundwater pumping under a wide variety of recharge conditions. These simulations were completed in order to quantitatively assess pumping and impacts of pumping based on the Lipan-Kickapoo Water Conservation District's stated plans to continue with the current groundwater management for the aquifer.

REQUESTOR:

Mr. Allan Lange of the Lipan-Kickapoo Water Conservation District (on behalf of Groundwater Management Area 7).

DESCRIPTION OF REQUEST:

Mr. Lange requested we use the groundwater availability model for the Lipan Aquifer to conduct a series of pumping scenarios for a 60-year predictive simulation. The initial request was to investigate the following two scenarios for the Lipan Aquifer:

(1) Continue to use 75 percent of all groundwater annually for the next 50 years.
(2) Continue to use 100 percent of all groundwater annually for the next 50 years.

During follow-up conversation with Mr. Lange, Texas Water Development Board staff expressed concern that the results associated with 60-year simulations using average recharge conditions and varied pumping were not useful in the context of the Lipan-Kickapoo Water Conservation District's historic practices, and did not provide an opportunity to quantitatively assess pumping and impacts of pumping.

As a result of this conversation, the simulations were redesigned to better address the objectives of the Lipan-Kickapoo Water Conservation District. Groundwater pumping in the Lipan Aquifer is variable, and the variation is based largely on the groundwater levels in the aquifer at the beginning of the irrigation season. When groundwater levels are high at the beginning of the irrigation season, groundwater pumping is relatively high. When groundwater levels are low, groundwater pumping is relatively low. Groundwater pumping generally reduces storage each year to the point that pumping is no longer economically feasible. Once the irrigation season ends, winter precipitation recharges the aquifer and causes groundwater levels to recover. Thus, the amount of pumping in a particular irrigation season is largely controlled by the amount of recharge during the preceding winter. Over the long term, there is no drawdown in the aquifer due to the relatively small storage and high pumping.

METHODS:

The groundwater availability model of the Lipan Aquifer was calibrated with data from 1980 to 1999. As part of the development of the model, 21 annual estimates of recharge were developed. This provided the opportunity to develop 12 separate 10-year periods based on these 21 annual estimates of recharge. Period 1 used recharge data from 1980 to 1989. Period 2 used recharge data from 1981 to 1990. This sequence was repeated, and Period 12 used recharge data from 1990 to 1999. The use of ten-year periods was chosen for the simulations because they were short enough for the average recharge to vary among the simulations, but long enough to evaluate the cumulative impact of pumping and recharge over several years.

Pumping was estimated based on the previous years recharge. In discussions with Mr. Lange, he estimated average total pumping from the Lipan Aquifer in the Lipan-Kickapoo Water Conservation District was about 50,000 acre-feet per year with a range between 36,000 and 60,000 acre-feet per year. Based on these initial estimates, a pumping curve was developed as shown in Figure 1.

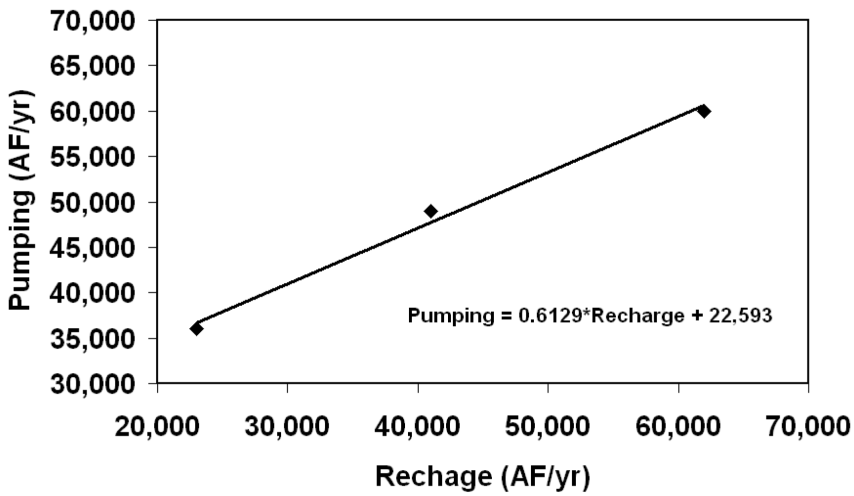

Figure 1. Initial estimate of relationship between preceding year recharge and current year pumping

Note that the estimates of pumping by Mr. Lange were plotted against the low, average and high recharge estimates from the Lipan Aquifer groundwater availability model. Further, a linear regression of the points yields an equation that allows an estimate of annual pumping given an annual amount of recharge from the previous year. During the simulations, the slope of this pumping curve (0.6129) was held constant, and the y-intercept (22,593) was varied to more precisely determine the relationship between pumping and recharge that achieves essentially no drawdown, on average, for different ten-year periods.

Results of the simulations include drawdown at the end of each of the 12 ten-year periods and pumping during each of the 12 ten-year periods. For both drawdown and pumping, the minimum, average and maximum values are reported.

PARAMETERS AND ASSUMPTIONS:

- Version 1.01 of the groundwater availability model for the Lipan Aquifer was used for all simulations (see Beach and others (2004) for assumptions and limitations of the groundwater availability model for the Lipan Aquifer).

- The model includes one layer representing the Quaternary Leona Formation, the underlying Permian Formations, and the Edwards-Trinity (Plateau) Aquifer to the west, south, and north. It should be noted that extent of the Lipan Aquifer in the model pre-dates the updated footprint noted in the 2007 State Water Plan and does not include all of the aquifer as it is currently delineated.

- The mean error (a measure of the difference between simulated and actual water levels during model calibration) in the groundwater availability model is 4.7 feet for the calibration period (1980-1989) and 1.8 feet for the verification period (1990-1999, Beach and others, 2004).

- Recharge rates were varied as described above.

- Evaporation rates and initial streamflow rates are the average long-term values used in the predictive model for the Lipan Aquifer (Beach and others, 2004).

- Pumping rates were varied as described above.

RESULTS:

Initially, five scenarios were run (each scenario consisted of 12 ten-year simulations as described above). These scenarios were based on variations of the y-intercept in the equation presented above. Table 1 summarizes the results for Tom Green County (where about 96% of the Lipan Aquifer pumping in the Lipan-Kickapoo Water Conservation district occurs). Pumping values are reported as minimum, average and maximum for any single year in the ten-year period.

Table 1. Summary of initial five scenarios of model runs (Tom Green County only)

		Scenario				
		1	**2**	**3**	**4**	**5**
Y-intercept		8,000	11,500	15,000	18,500	22,000
Drawdown after 10 years (ft)	**Minimum**	-1.8	-1.1	-0.4	0.3	1.0
	Average	1.6	2.3	2.9	3.6	4.3
	Maximum	5.5	6.2	6.9	7.6	8.3
Pumping (acre-feet per year)	**Minimum**	25,925	29,426	32,926	36,426	39,926
	Average	34,744	38,244	41,744	45,244	48,744
	Maximum	45,499	48,999	52,500	56,001	59,501

Note that for each scenario, drawdown after 10 years is expressed as a minimum, average and maximum. Also note that pumping is expressed as a minimum, average and maximum. The variation in pumping for each year is a result of the variation in recharge. Drawdown variation is attributable to variations in recharge and pumping. Drawdown in each time period can vary based on whether the 10-year period ends with a wet year/high pumping condition or a dry year/low pumping condition. Thus, any particular year is not a sufficient gage to see if a particular pumping scenario is consistent with the groundwater management objectives of the Lipan-Kickapoo Water Conservation District. Evaluating the consistency of a particular amount of pumping requires the evaluation of the full range of conditions, hence the results are reported as minima, averages and maxima.

Figures 2 and 3 summarize the results of the initial five scenarios for Tom Green County. Figure 2 is a summary of the average pumping versus the range of drawdown. Figure 3 is a summary of the average drawdown versus the range of pumping.

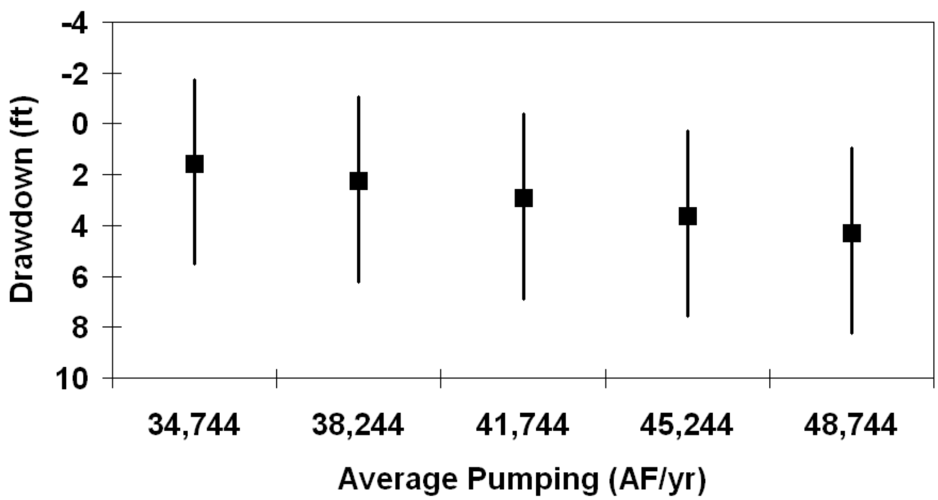

Figure 2. Average pumping versus drawdown in Tom Green County. The full range of drawdown is depicted by each vertical line, and the average drawdown is depicted by the box.

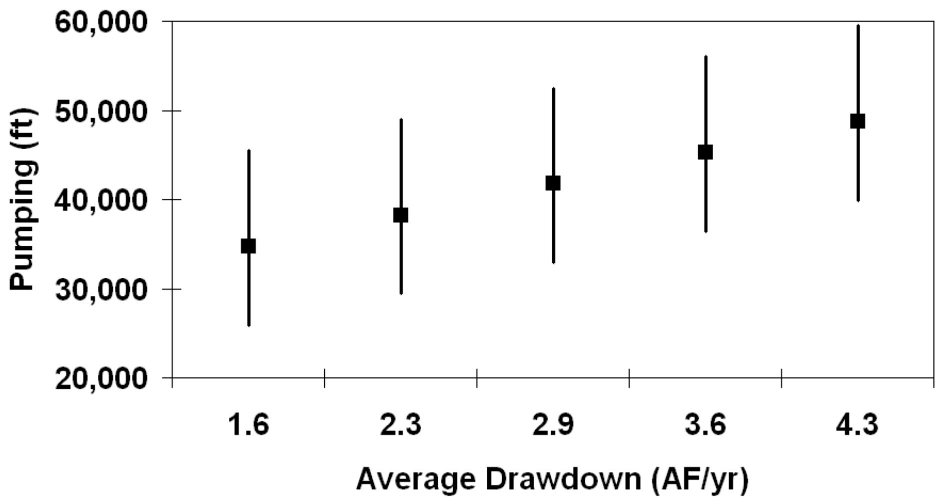

Figure 3. Average drawdown versus pumping in Tom Green County. The full range of pumping is depicted by each vertical line, and the average pumping is depicted by the box.

Because the objective of groundwater management of the Lipan Aquifer in the Lipan-Kickapoo Water Conservation District is to maintain the historic practice of pumping the maximum amount each irrigation season followed by recovery of storage during the winter, and allowing no long-term drawdown, Figures 2 and 3 can be used to see if average drawdown after 10 years is near zero.

The results presented in Figures 2 and 3 demonstrate that increases in average pumping result in increased drawdown. Also, all scenarios result in declines in groundwater levels in Tom Green County at the end of 10 years (on average). At first glance, this suggests that the management objectives cannot be achieved under any of the pumping amounts simulated. However, recall that the mean error of the model during the calibration period was 4.7 feet for the calibration period and 1.8 feet for the verification period. Since the calibration period and verification period cover approximately the same number of years, it is reasonable to state that the overall mean error of the model is about 3.3 feet (the average of the mean error of the calibration and verification periods). Thus, an average drawdown of less than 3.3 feet from the simulations could be reasonably expected to represent zero drawdown given the limitations of the model.

Scenario 3 suggests that an average pumping in Tom Green County of about 42,000 acre-feet per year results in an average drawdown in Tom Green County of 2.9 feet. Scenario 4 suggests that an average pumping in Tom Green County of about 45,000 acre-feet per year results in an average drawdown in Tom Green County of 3.6 feet. Thus, average pumping between 42,000 and 45,000 acre-feet per year would result in an average drawdown in Tom Green County near 3.3 ft, which, given the mean error of the model, could be taken to reflect a condition of no long term drawdown over the ten-year simulation period. Thus, a final simulation was completed using a y-intercept value of 16,750 (in-between scenarios 3 and 4) in the recharge/pumping equation previously presented. The pumping and drawdown results for this simulation for all three counties of the Lipan-Kickapoo Water Conservation District are summarized in Table 2.

Table 2. Summary of Final Simulation Results

County	**Pumping (acre-feet per year)**		
	Minimum	**Average**	**Maximum**
Tom Green	33,350	43,562	54,894
Concho	1,452	1,896	2,390
Runnels	35	46	58
Total	34,837	45,504	57,342

County	**Drawdown (ft)**		
	Minimum	**Average**	**Maximum**
Tom Green	-0.1	3.3	7.2
Concho	-3.3	0.2	4.2
Runnels	-0.8	-0.2	0.6

REFERENCES:

Beach, J.A., Burton, S. and Kolarik, B., 2004, Groundwater availability model for the Lipan Aquifer in Texas: contract report to the Texas Water Development Board.