The Effect of Bifurcated Permits on Spring Flow in the San Antonio Segment of the Edwards Aquifer

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Table of Contents

Table of Figures

Table of Tables

The Effect of Bifurcated Permits on Spring Flow in the San Antonio Segment of the Edwards Aquifer

Summary

Following the specifications in its Act, the Edwards Aquifer Authority has issued permits for the use of water from the San Antonio segment of the Edwards aquifer of about 550,000 acre-feet per year. The Act also requires that the amount of permitted withdrawal from the Edwards aquifer may not exceed 450,000 acre-feet per calendar year through December 31, 2007, and 400,000 acre-feet per calendar year after January 1, 2008. In order to comply with its Act, the Edwards Aquifer Authority has proposed a bifurcated permit system. Under this system, a permit to use groundwater is divided into two elements: (1) a senior right that is not interruptible until water levels in the aquifer fall below specified levels in specified wells and (2) a junior right that is available when water levels in the aquifer are above certain levels in certain wells. As a whole, when water levels in the aquifer are high, permit holders could withdraw at the 550,000 acre-feet per year rate. Once water levels fall below a certain threshold, all permit holders would be restricted to withdrawals totaling 450,000 acre-feet. Downstream surface-water interests have expressed concerns that a bifurcated permit system will affect downstream water rights. To assist in their analysis of these concerns, the Texas Commission on Environmental Quality requested that the Texas Water Development Board run the groundwater availability model of the San Antonio segment of the Edwards aquifer to assess the possible affects of bifurcated permits on spring flows.

We ran a recalibrated version of the GWSIM-IV model of the San Antonio segment of the Edwards aquifer to investigate the effect that bifurcated permits might have on spring flows. The model suggests that bifurcated permits affect water levels in the aquifer and flows in the springs and that the greatest effects occur during flood and above normal water-level and recharge conditions when junior groundwater permits are active. According to the model, flow at Comal Springs could be reduced as much as seven percent of peak flows and flow at San Marcos Springs could be reduced as much as one percent when spring flows are at their highest levels when bifurcated permits are used. During a drought similar to the one of the 1950s, flow in Comal Springs may be as much as one cubic feet per second lower when bifurcated permits are used. This reduction in spring flow during time of drought is due to the residual effect of pumping more when spring flows are high.

1.0 Introduction

In 1993, the Texas Legislature created the Edwards Aquifer Authority (the Authority) to, among other purposes, protect spring flows that support a number of threatened and endangered species. The Edwards Aquifer Authority Act (EAA, 2003) specifies maximum withdrawal rates from the aquifer and how the Authority assigns permits to withdraw water from the aquifer. The Act requires that the amount of permitted withdrawal may not exceed 450,000 acre-feet per calendar year through December 31, 2007, and that the amount of permitted withdrawal may not exceed 400,000 acre-feet per year beginning January 1, 2008. The Act also specifies how permits are to be granted and, in the case of agriculture, how many acre-feet per acre shall be assigned. Following the specifications of the Act in granting permits, the Authority granted initial permits allowing the withdrawal of about 550,000 acre-feet per year, well above the maximum amounts allowed in the Act.

Because the current permits (550,000 acre-feet per year) will be greater than allowed by the Act (450,000 and 400,000 acre-feet per year), the Authority has been faced with the dilemma of how to come into compliance with the Act. One possibility the Authority is considering is a bifurcated permit system. Under this system, a permit to use groundwater is divided into two elements: (1) a senior right that is not interruptible until water levels in the aquifer fall below specified levels in specified wells and (2) a junior right that is available when water levels in the aquifer rise above specified levels in specified wells. As a whole, when water levels in the aquifer are high, permit holders could withdraw within the 550,000 acre-feet per year limit. Once water levels fall to a certain threshold, everyone would be restricted to withdrawals within the 450,000 acre-feet per year limit.

The South Central Texas Water Advisory Committee, a group of downstream water interests created by the Edwards Aquifer Authority Act, has expressed concerns about bifurcated permits. The Committee sent the Texas Commission on Environmental Quality (the Commission) a letter dated June 3, 2004, requesting a review of the effects of bifurcated permits on downstream surface-water rights. Commission staff responded with a memo dated November 1, 2004, concluding that "...increased pumping, even when limited to 400,000 acre-feet per year, decreased the stream flow below the Comal Springs, making less water available to surface water right holders." The memo also noted that a more quantified assessment of the effects of bifurcated permits on spring flow could be done by the Texas Water Development Board (the Board).

After the Authority commented on the Commission's report, the Commission agreed to study the problem further and requested the Board to run the groundwater availability model of the San Antonio segment of the Edwards aquifer to assess how bifurcated permits may affect spring flows in the aquifer. The purpose of this report is to respond to the Commission's request and discuss the approach and results of our study of the possible effects of bifurcated permits on spring flows in the San Antonio segment of the Edwards aquifer.

2.0 Our approach

We used the groundwater availability model of the San Antonio segment of the Edwards aquifer and the latest permit information from the Authority to investigate the effects of bifurcated permits on spring flow.

2.1 Choice of model

At the time of the request, the groundwater availability model of the San Antonio segment of the Edwards aquifer was the GWSIM-IV model (Klemt and others, 1979; Thorkildsen and McElhaney, 1992). The GWSIM-IV model is a finite-difference model based on the Illinois State Water Survey code developed by Pricket and Lonnquist (1971). The U.S. Geological Survey, in cooperation with the Bureau of Economic Geology and Southwest Research Institute and under contract with the Authority, developed a new model of the Edwards aquifer (Lindgren and others, 2004) using MODFLOW-2000 (Harbaugh and others, 2000), also a finite-difference model. At the time the Board received the Commission's request for a model run and began work on the run, the Authority had not yet officially released the model or submitted it to the Board for consideration as the new groundwater availability model for the San Antonio segment of the Edwards aquifer. By the time we released this report, the Authority had submitted the model to the Board for consideration, but the model was still in staff review.

In 1999, in response to a request from the Texas Natural Resource Conservation Commission (since renamed the Texas Commission on Environmental Quality) and the South Central Texas Regional Water Planning Group, the Board modified GWSIM-IV to implement the Authority's critical period management rules (Texas Register, 1998; Kabir and others, 1999). Board staff distributed pumpage according to proposed permits and modified the code to adjust pumpage in response to water levels at three observation wells (Bexar County Index Well [J-17], Uvalde County Index Well [J-27], and Hondo Index Well). In addition, recharge was modified to account for long-term recharge enhancement from existing projects (Kabir and others, 1999). The other parameters in the model remained the same as in the calibrated model (Thorkildsen and McElhaney, 1992).

The rules implemented in the 1999 critical period management model were repealed in 2000 and were replaced with new rules. For this study we updated the 1999 GWSIM-IV critical period management code to reflect the Authority's current critical period management rules (as shown in EAA, 2005; Appendix A). When water levels at the Bexar County Index Well and the Uvalde County Index Well fall below trigger levels, the model code reduces the pumping discharge by a factor specified in the Authority's rules depending on the stage of the critical period. Trigger levels are also specified for San Marcos and Comal springs. The Authority's rules specify that interruptions shall be applied to quarterly scheduled withdrawal amounts and that the reductions shall be prorated based on the number of days of each critical period phase that occurred in the quarter. Because the model has monthly time steps with monthly pumping assignments, the rules are approximated by checking the index wells monthly and adjusting the pumping monthly.

We also updated GWSIM-IV to account for bifurcated permits as described in the Authority's rules (EAA, 2005; Chapter 711, Subchapter G §711.176). When the water-level elevation in the Bexar County Index Well falls below 665 feet, the total permitted pumping in the San Antonio pool is reduced to its portion of the senior permit total (450,000 acre-feet per year through December 31, 2007). When the water-level elevation in the Uvalde County Index Well falls below 865 feet, the total permitted pumping in the Uvalde pool is reduced to its portion of the senior permit total. For permitting, the San Antonio pool consists of Atascosa, Bexar, Comal, Hays, and Medina counties, and the Uvalde pool consists of Uvalde County.

It should be noted that in the 1999 critical period management model by Kabir and others (1999), the model subtracts 20 feet from the simulated water level at the Uvalde County Index Well before comparing the water-level value to the threshold values. This was done because the model overestimates water levels in the Uvalde County Index Well (Paul McElhaney, Texas Water Development Board, personal communication, 2005). We kept that adjustment for the current model. To account for the adjustment, we subtracted 20 feet from simulated water levels when we display results for the Uvalde County Index Well.

2.2 Pumping scenarios

We evaluated the effects of the bifurcated permits by simulating water levels and spring flow under the following two scenarios as requested by the Commission:

1. pumping capped at 450,000 acre-feet per year; and
2. permits in excess of 450,000 acre-feet per year as described in Section 2.1.

The above scenarios also adhered to the current critical period management rules as described in Section 2.1. For the scenarios, we ran the model using historical recharge over the period of 1934 to 1990. This period of time includes the drought of record: the drought of the 1950s. The historical recharge distribution is based on U.S. Geological Survey estimates (Thorkildsen and McElhaney, 1992). These scenarios allowed us to assess how bifurcated permits may affect water levels and spring flows. We compared water levels at the Bexar County Index Wells (CY-26 and J-17) and the Uvalde County Index Well (J-27) and we compared flows at Comal, San Marcos, Hueco, San Antonio, and San Pedro springs between using bifurcated permits (Scenario 2) and not using bifurcated permits (Scenario 1).

We discuss a third scenario, simulation of water levels and discharge assuming estimated historical pumpage from 1934 to 1989, in Appendix B. The Commission requested this scenario to complete their analysis of the impacts of the bifurcated permits on downstream surface-water rights.

2.3 Permit Data

In order to update the pumpage in the model, we requested and received the current database of permits from the Authority (Anne Kelley, Edwards Aquifer Authority, personal communication, March 2005). Because of transfers through the sale and lease of permits, the database did not contain sufficient information to update the spatial distribution of pumping in the model; however, the database did contain sufficient information to adjust total pumping volumes based on pool and use category. Therefore, we used the existing spatial pumping distribution from the 1999 critical period management model (Kabir and others, 1999), and we adjusted the total permitted pumpage according to the current database of permits obtained from the Authority. The junior and senior permits for nonexempt pumping in the Uvalde and San Antonio pools in the database sum to 545,397 acre-feet per year (Table 1).

We based rural domestic pumping and Kinney County pumping on the Edwards Aquifer Authority Hydrologic Data Report for 2003 (EAA, 2004). We increased rural domestic use in the model to the 2003 estimate of 13,700 acre-feet per year and left the Kinney County pumpage estimate at 1,600 acre-feet per year (EAA, 2004).

2.4 Performance of the GWSIM-IV model

We first verified that our version of the GWSIM-IV code was the same as the calibrated model documented in Texas Water Development Board Report 340 (Thorkildsen and McElhaney, 1992). We ran the model for the calibration and verification periods (1947 through 1959 and 1978 through 1989, respectively) and compared results with the documented results from the report and with published water-level and spring-flow information. We then ran the modified version of the model developed for this study (described in Section 2.1) using the historical recharge and pumpage from the calibrated 1992 model with the critical period and bifurcated permit rules turned off. We compared simulated water levels for the two models and verified that they matched (Figures 1 and 2).

The 1992 calibration of GWSIM-IV focused on matching water levels and spring flows during drought periods (Paul McElhaney and David Thorkildsen, Texas Water Development Board, personal communication, 2005). Therefore, the existing model is less well suited for simulating water levels under higher recharge conditions. However, those are the conditions under which the senior permits would be enacted. To check model performance, we ran a test case with the model using pumpage capped at 450,000 acre-feet per year (Figure 3). This test case showed that, according to the model, simulated water levels in the Bexar County and Uvalde County index wells are below the bifurcated permit threshold most of the time; therefore, junior permits would rarely be active. Because the model underestimates water levels in the Bexar County Index Well, we do not believe that this result is realistic Therefore, the GWSIM-IV model as calibrated by Thorkildsen and McElhaney (1992) is not appropriate for evaluating the effects of bifurcated permits on spring flows.

2.5 Recalibration of the GWSIM-IV model

In order for GWSIM-IV to be able to consider the effect of bifurcated permits on spring flows, we needed to recalibrate the model with a focus on matching average aquifer conditions. Our calibration focused on matching water levels as closely as possible in the Bexar County Index Well, the Uvalde County Index Well, and San Marcos and Comal springs. The original Bexar County Index well, CY-26, was replaced with J-17 in 1962. Therefore, we compared water levels with CY-26 for the calibration period and J-17 for the verification and predictive periods. CY-27 and J-17 are both located in the same GWSIM-IV model grid cell.

To recalibrate GWSIM-IV, we decreased the conductance of Comal Springs from 3.74×10^6 ft^2/day to 1.7×10^6 ft^2/day to better match water levels in the Bexar County Index Well (CY-26, Figure 4) and spring flows in Comal and San Marcos springs (Figures 5 and 6) for all climatic conditions. We investigated adjusting other parameters to recalibrate the model but found that adjusting the conductance at Comal Springs resulted in the best recalibration. The model fit at the Uvalde County Index Well remained the same. All other parameters in the model remain at the values set in the 1992 calibration.

We again modeled the test case with pumpage capped at 450,000 acre-feet per year (Figure 7). With the model calibrated to average aquifer conditions, water levels in the Bexar County Index Well were above 665 feet more frequently during the simulation period. Therefore, we decided that the model would be useful for investigating the effects of bifurcated permits, and we continued the analysis using the recalibrated model.

2.6 Modeling approach

We investigated the effects of bifurcated permits on spring flows by running the two modeling scenarios described in Section 2.2 using the recalibrated model. We ran the model with bifurcated permits where junior permits are allowed at water levels above 665 feet at the Bexar County Index Well and water levels are above 865 feet at the Uvalde County Index Well. We compared the results with pumping capped at 450,000 acre-feet per year.

3.0 Results and discussion

The recalibrated GWSIM-IV model suggests that bifurcated permits affect water levels in the aquifer and flows in the springs (Figures 8 to 19). This is not surprising because any change in pumping would be expected to cause a change in water level and spring flow. The greatest differences in simulated water levels between implementing and not implementing bifurcated permits occur when water levels are above 665 feet in the Bexar County Index Well (Figure 8) and when water levels are above 865 feet in the Uvalde County Index Well (Figure 9). This makes sense because junior permits allow more pumping when the water levels are above these threshold values. Similar to water levels in the index wells, springs flows are most affected during flood and above normal conditions when junior rights are active (Figures 10 to 14).

According to the model, flow at Comal Springs could be reduced as much as 30 cubic feet per second if bifurcated permits are used, about a seven percent reduction (when compared to the peak spring flow value for 1987 recharge conditions, Figures 10 and 15). Spring flow in Comal Springs is also slightly lower between periods when junior permits are active. During drought conditions similar to 1950s, spring flow could be as much as one cubic foot per second lower because of bifurcated permits. This reduction in spring flow during time of drought is due to the residual effect of pumping more when spring flows are high. It should be noted that there are a few occasions at Comal, San Marcos, and Hueco springs where spring discharge for the bifurcated permit scenario is actually higher than for the capped pumping scenario resulting in a negative difference in spring discharge in Figures 15 through 17. These occasions occur when the water level in the Bexar County Index Well approaches a threshold value for critical period management. When the bifurcated permit scenario reaches that threshold at an earlier time step, pumping is reduced. Pumping is also reduced for the capped pumping scenario, but at a later time step. This time lag results in slightly higher simulated water levels for the bifurcated permit scenario for a few time steps. Spring discharge under the bifurcated permit scenario on those occasions is greater for a brief time.

The model shows a similar pattern for spring flow in San Marcos Springs (Figure 16). Flow at San Marcos Springs could be reduced as much as 3.5 cubic feet per second if bifurcated permits are used, about a one percent reduction (when compared to the peak value for 1988 recharge conditions, Figures 11 and 16). The behavior of Hueco, San Pedro, and San Antonio springs is similar to Comal and San Marcos springs (Figures 17 through 19).

Flow budgets for each of the scenarios are shown in Table 2. The term "reduction in recharge" refers to recharge rejected by GWSIM-IV because water levels were above land surface. The term "reduction in pumping" refers to pumping that was reduced by the model because water levels drop below the base of the aquifer. Negative recharge refers to recharge that was subtracted from the two model cells representing Hueco Springs. That spring is modeled by GWSIM-IV using an empirical relationship with water levels at the model cell that includes the Bexar County Index Well. The calculated discharge is then subtracted from the model cells to account for spring discharge. The simulated flow budget—which is a yearly average of the simulation period from 1934 to 1990—suggests that when senior permits total 450,000 acre-feet per year, about 5,930 acre-feet per year (8.2 cubic feet per second) more spring flow occurs for the capped pumpage versus bifurcated permit scenario. It should be noted that for all of the scenarios, the critical period management rules reduce pumpage during drought periods; therefore, the total pumpage in the model run is on average less than the total senior permits.

4.0 Limitations

Klemt and others (1979) and Thorkildsen and McElhaney (1992) describe assumptions and approximations for the development of the original GWSIM-IV models. Because GWSIM-IV uses monthly stress periods, we needed to approximate the implementation of the critical management period. Although the GWSIM-IV model better reproduces water levels in the Bexar County Index Well for all climatic conditions, it appears the new MODFLOW model does an even better job (Lindgren and others. 2004). Therefore, the effects of bifurcated permits on spring flow should also be investigated using the MODFLOW model.

5.0 Conclusions

Simulations using a recalibrated version of GWSIM-IV suggest that bifurcated permits affect water levels in the aquifer and flows in the springs with the greatest effects when junior groundwater permits are active. According to the model, flow at Comal Springs could be reduced as much as 30 cubic feet per second and flow at San Marcos Springs could be reduced as much as 3.5 cubic feet per second during high flow periods if bifurcated permits are used. During the drought of the 1950s, flow in Comal Springs might have been as much as one cubic foot per second lower because of bifurcated permits. The average annual decline of total spring flow due to bifurcated permits for climatic conditions that occurred from 1934 to 1990 is about eight cubic feet per second.

6.0 References

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Texas Register, 1998, Volume 23, Number 1, Chapter 709, Critical Period Management Rules.

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Table 1. Junior and senior permits by category and county or user.

County or user	Irrigation (AFY)	Municipal (AFY)	Industrial (AFY)
Uvalde	110,208	587	5,647
Bexar and Atascosa	30,701	16,351	74,376
Comal	*	*	14,091
Hays	*	*	11,275
Medina	73,042	760	8,130
SAWS	*	24,897	175,332
Total	213,951	42,595	288,851

AFY = acre-feet per year
SAWS = San Antonio Water System
* = category not included

Table 2. Average annual flow budget for 1934 to 1990 for pumping capped at 450,000 acre-feet per year and for bifurcated permits.

	Pumpage (acre-feet)	Recharge (acre-feet)	Change in water table storage (acre-feet)	Change in artesian storage (acre-feet)	Reduction in pumpage (acre-feet)	Reduction in recharge (acre-feet)	Spring flow (acre-feet)	Leakage (acre-feet)	Total (acre-feet)
Pumping capped at 450,000 acre-feet per year									
In	0	636,617	297,229	8,904	120	0	0	0	942,871
Out	-402,082	-2,865	-309,854	-8,888	0	-2,499	-199,609	-16,861	-942,658
Net	-402,082	633,752	-12,625	16	120	-2,499	-199,609	-16,861	213
Bifurcated permits with senior permits capped at 450,000 acre-feet per year									
In	0	636,617	298,574	9,014	121	0	0	0	944,326
Out	-410,885	-2,440	-309,053	-8,983	0	-2,482	-193,678	-16,578	-944,098
Net	-410,885	634,177	-10,480	31	121	-2,482	-193,678	-16,578	227

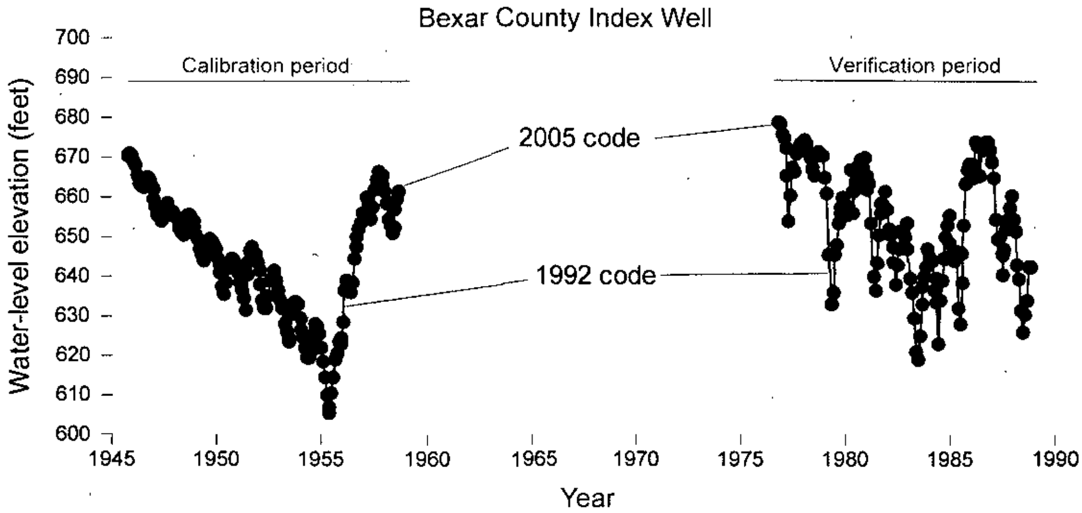

Figure 1. Comparison of the 1992 version of the GWSIM model (1992 code) and the version developed for this study (2005 code) for water levels corresponding to the cell that includes the Bexar County Index Well during calibration and verification periods.

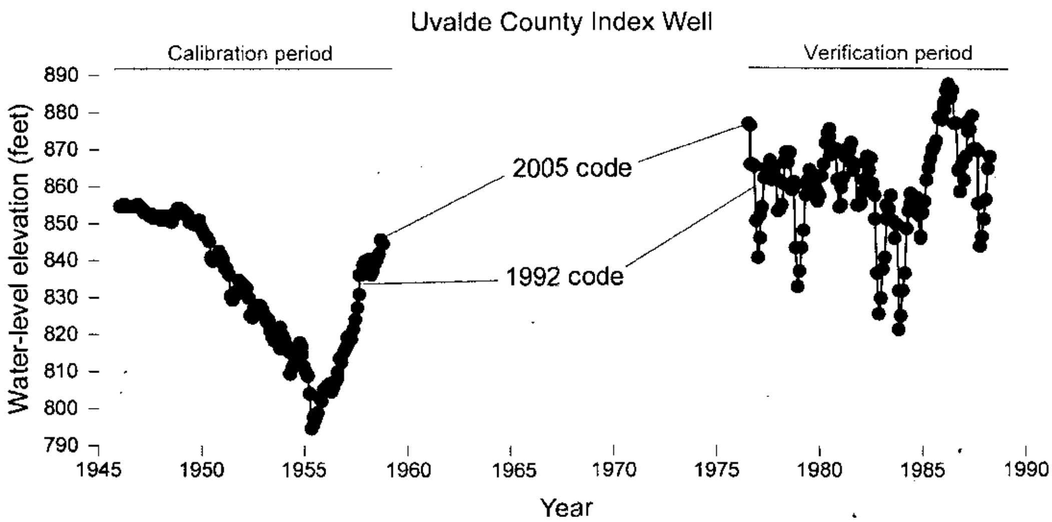

Figure 2. Comparison between the 1992 version of the GWSIM model (1992 code) and the version used for this study (2005 code) for water levels corresponding to the cell that includes the Uvalde County Index Well during calibration and verification periods.

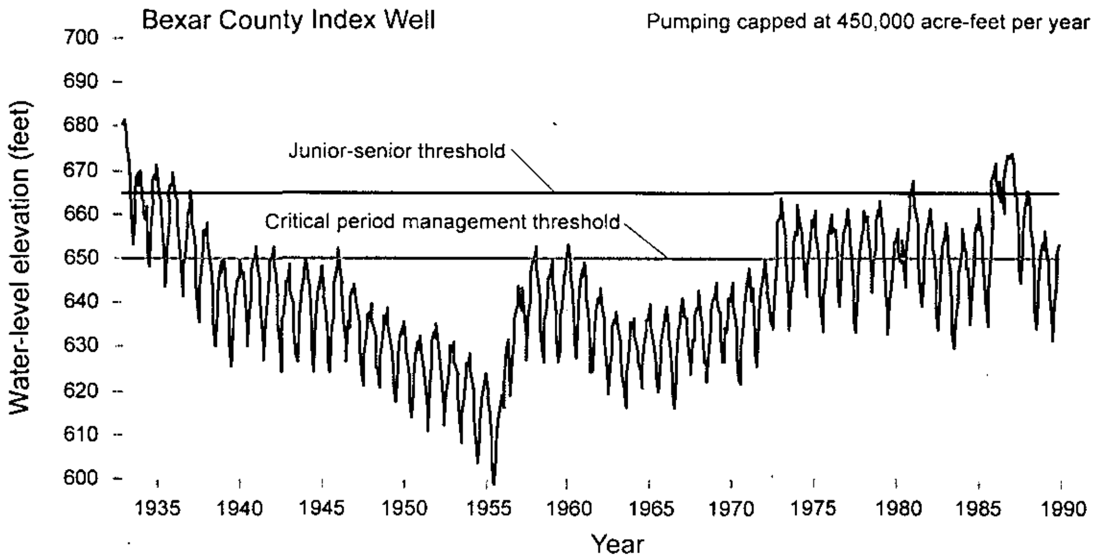

Figure 3. Simulated water levels at the Bexar County Index Well using the original GWSIM-IV calibration with permitted pumping capped at 450,000 acre-feet per year (junior-senior threshold is the level above which junior rights become active and critical period management threshold is the level below which critical period management becomes active).

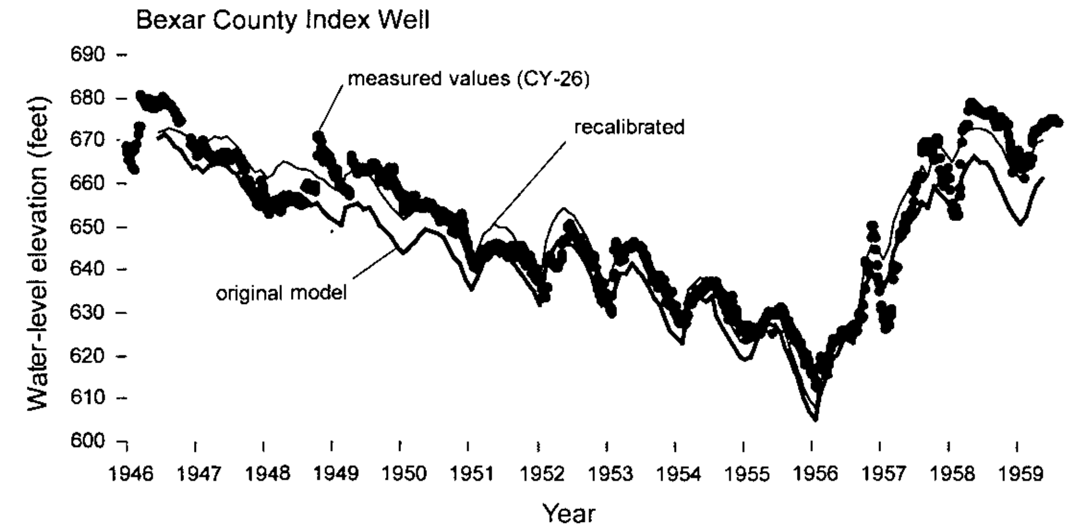

Figure 4. Simulated water levels at the Bexar County Index Well (CY-26) using the original model and the recalibrated model. Measured water levels are also shown for reference.

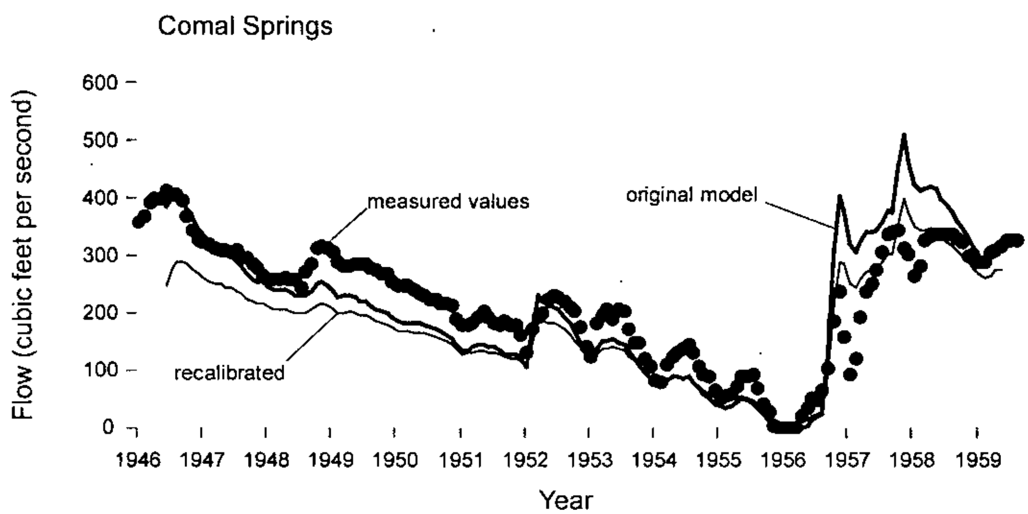

Figure 5. Simulated discharge at Comal Springs using the original model and the recalibrated model. Measured spring flows are shown for reference.

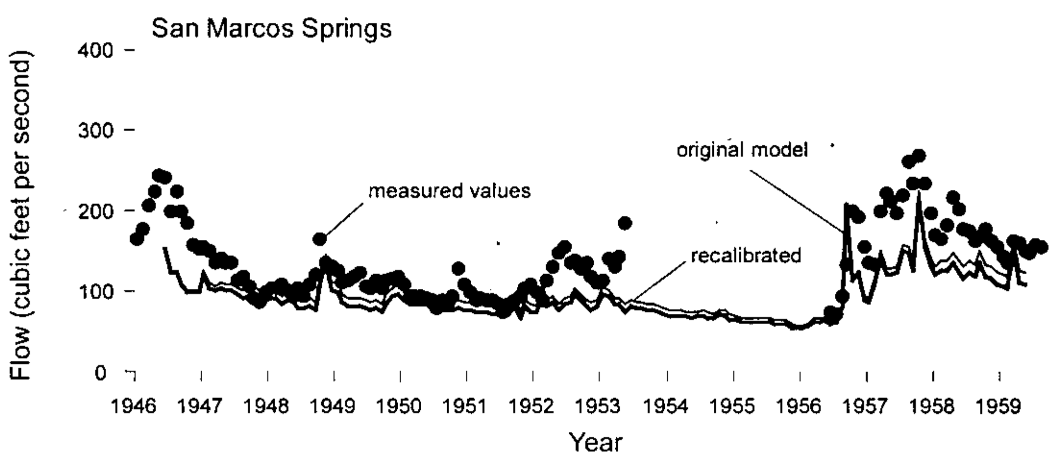

Figure 6. Simulated discharge at San Marcos Springs using original calibration and recalibrated model. Measured spring flows are shown for reference.

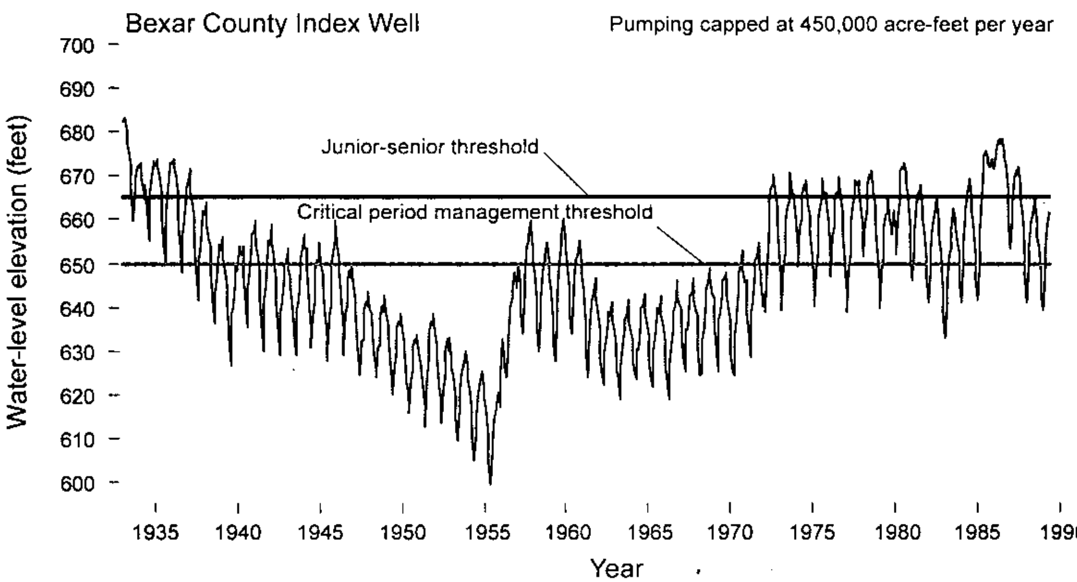

Figure 7. Simulated water levels at the Bexar County Index Well using the recalibrated version of GWSIM-IV with permitted pumping capped at 450,000 acre-feet per year (junior-senior threshold is the level above which junior rights become active and critical period management threshold is the level below which critical period management becomes active).

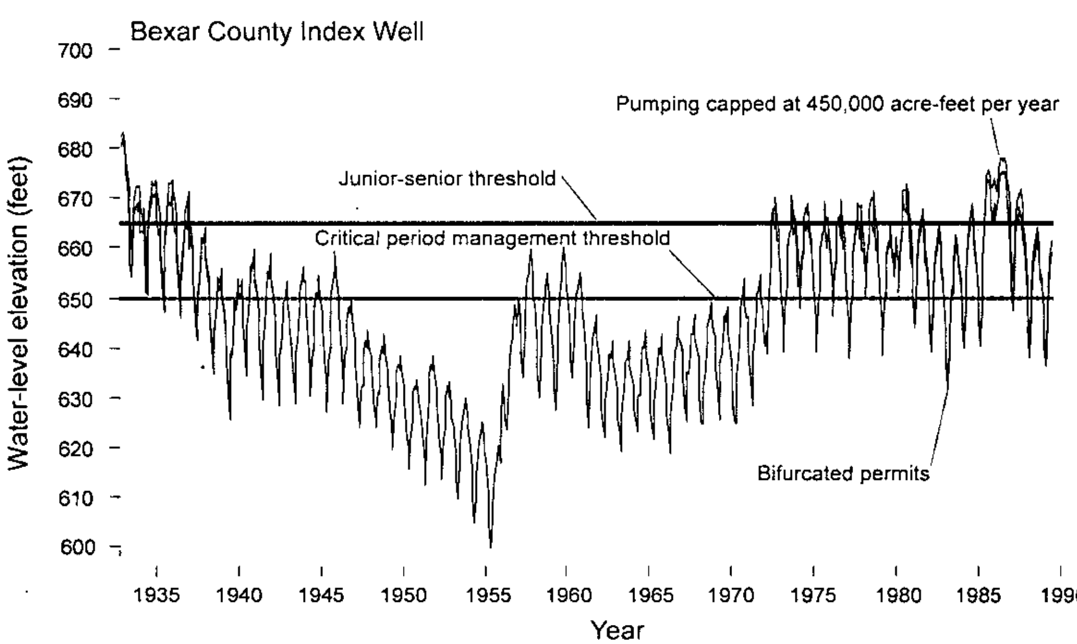

Figure 8. Simulated water levels at the Bexar County Index Well for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year (junior-senior threshold is the level above which junior rights become active and critical period management threshold is the level below which critical period management becomes active).

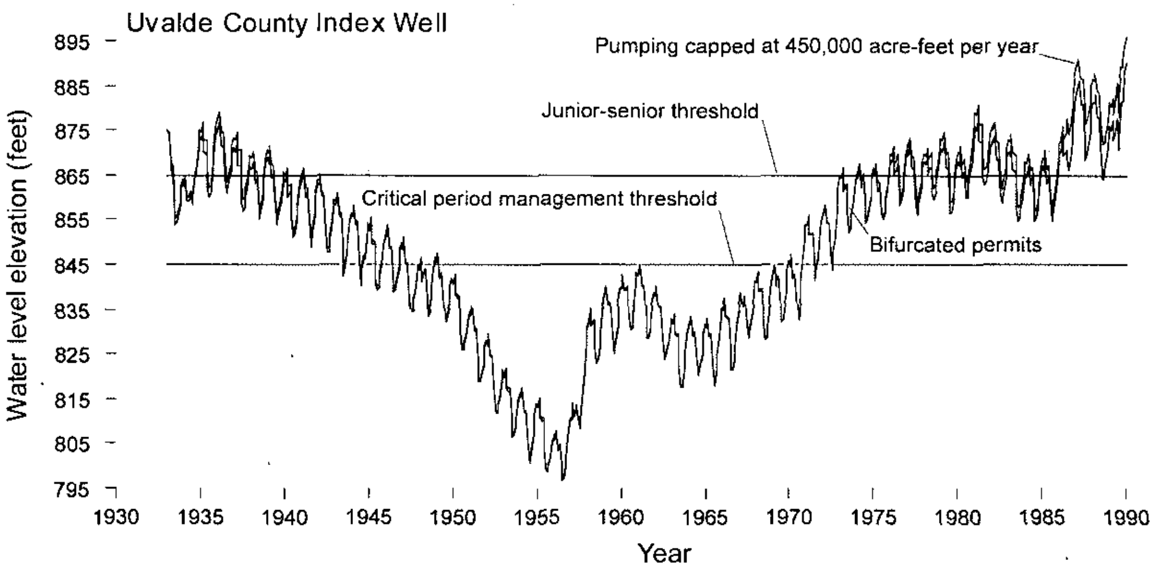

Figure 9. Simulated water levels at the Uvalde County Index Well for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year (junior-senior threshold is the level above which junior rights become active and critical period management threshold is the level below which critical period management becomes active).

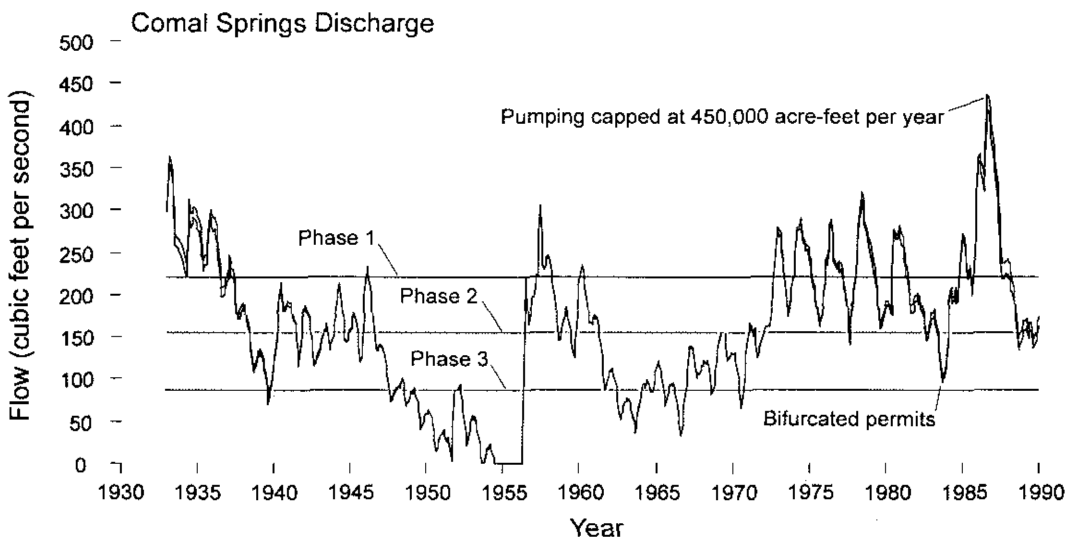

Figure 10. Simulated discharge at Comal Springs for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year (Phase I is 220 cubic feet per second, Phase II is 154, and Phase III is 86).

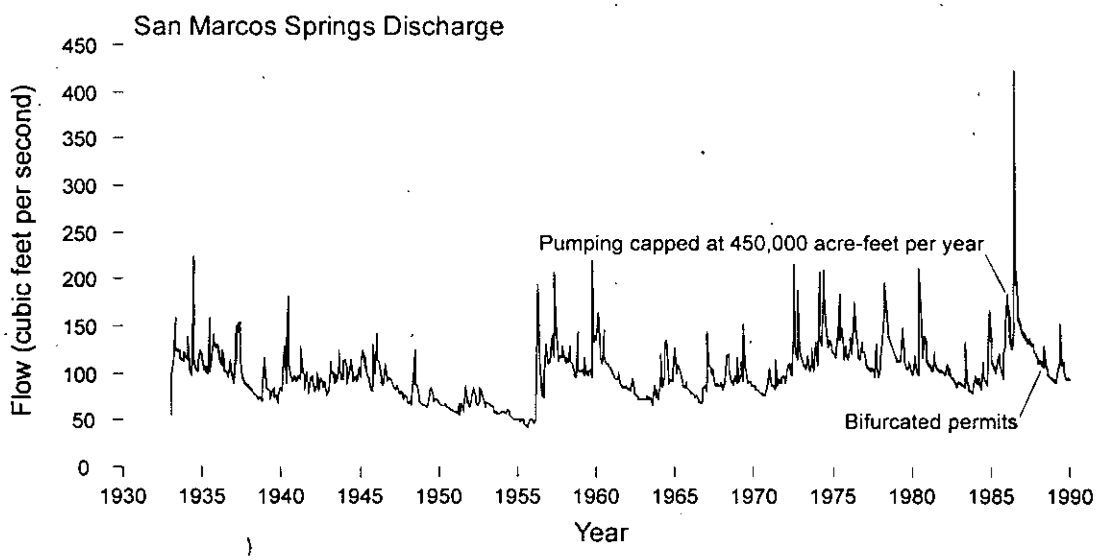

Figure 11. Simulated discharge at San Marcos Springs for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year.

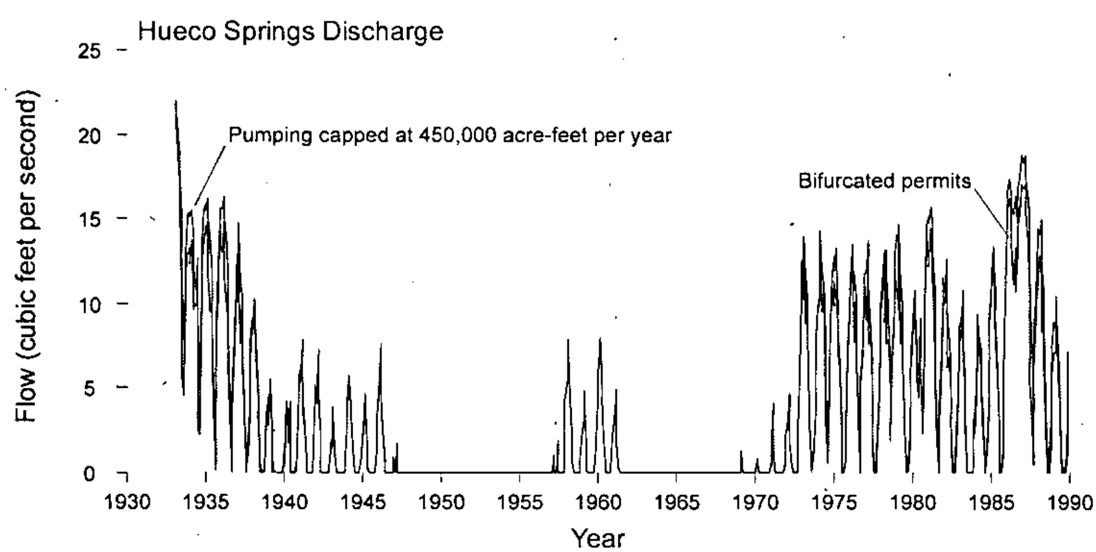

Figure 12. Simulated discharge at Hueco Springs for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year.

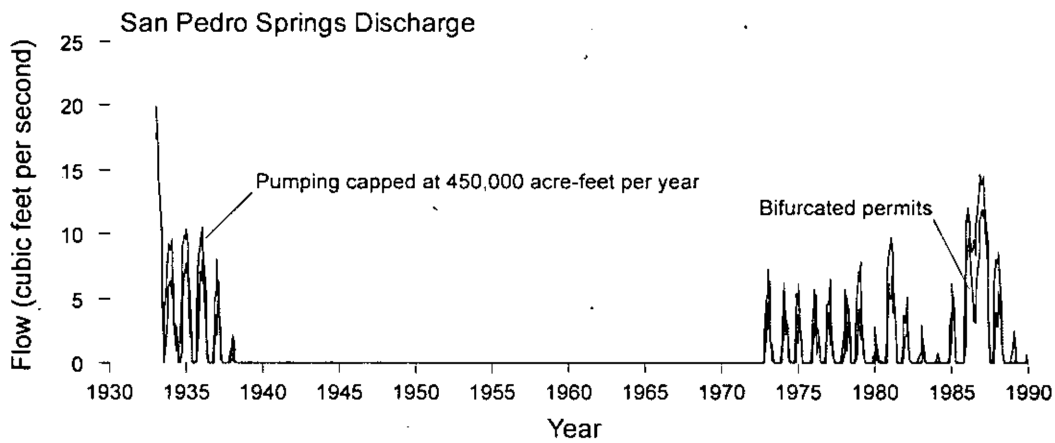

Figure 13. Simulated discharge at San Pedro Springs for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year.

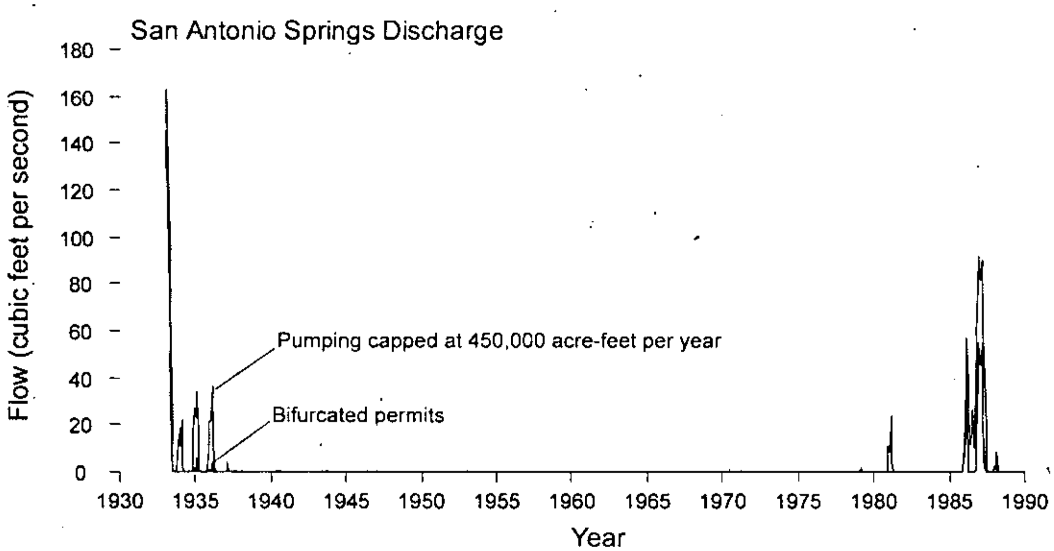

Figure 14. Simulated discharge at San Antonio Springs for pumping capped at 450,000 acre-feet per year and for bifurcated permits with senior permits capped at 450,000 acre-feet per year.

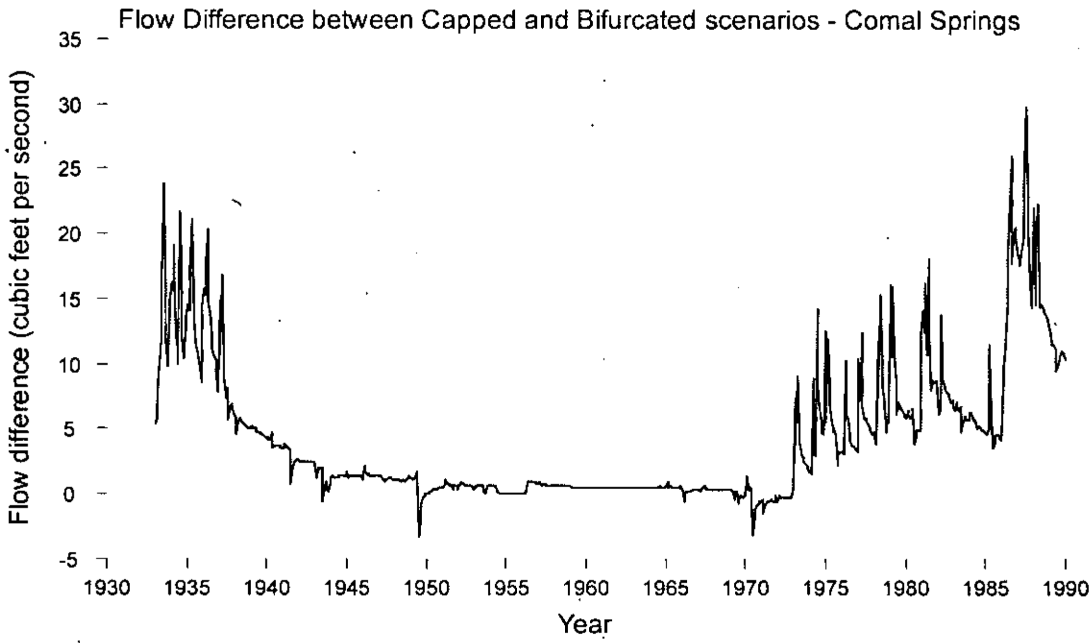

Figure 15. Difference in spring flow at Comal Springs attributable to bifurcated permits. A positive flow difference indicates how much lower spring flow is when bifurcated permits are used. Negative flow differences occur on a few occasions because of a slight time lag between pumping reduction associated with critical period management. Simulated water levels drop below the threshold value slightly earlier for the bifurcated permit scenario and pumping reduction occurs earlier. This time lag results in a brief period when water levels and spring discharge are actually greater for the bifurcated permit scenario.

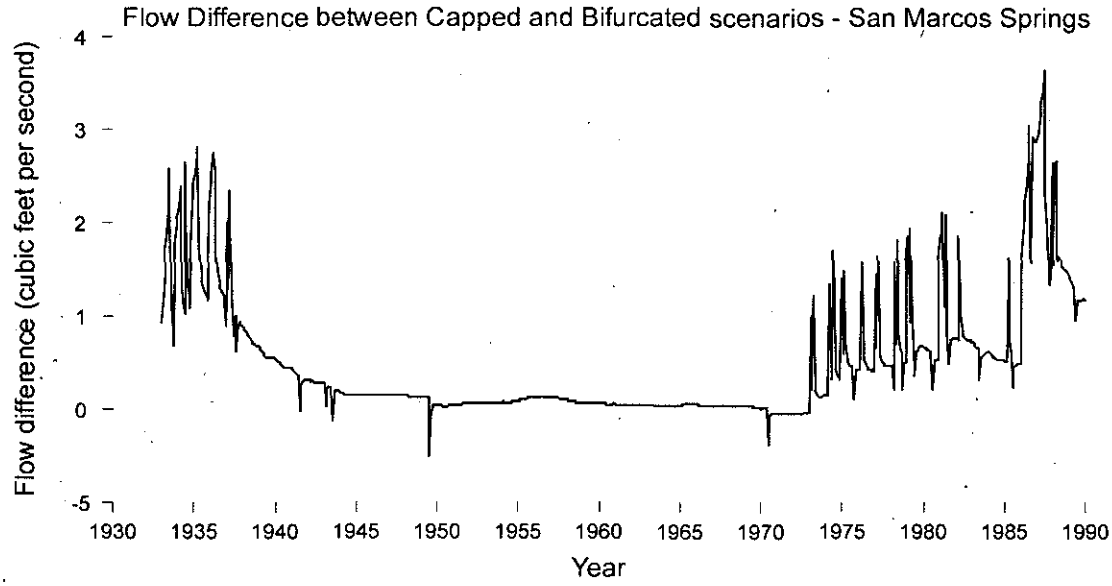

Figure 16. Difference in spring flow at San Marcos Springs attributable to bifurcated permits. A positive flow difference indicates how much lower spring flow is when bifurcated permits are used. Negative flow differences occur on a few occasions because of a slight time lag between pumping reduction associated with critical period management. Simulated water levels drop below the threshold value slightly earlier for the bifurcated permit scenario and pumping reduction occurs earlier. This time lag results in a brief period when water levels and spring discharge are actually greater for the bifurcated permit scenario.

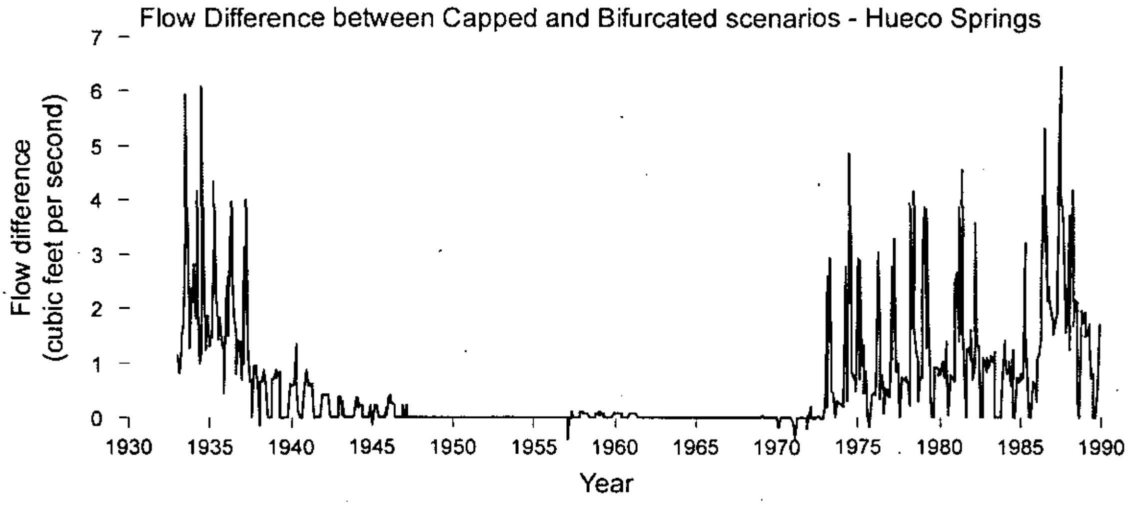

Figure 17. Difference in spring flow at Hueco Springs attributable to bifurcated permits. A positive flow difference indicates how much lower spring flow is when bifurcated permits are used. Negative flow differences occur on a few occasions because of a slight time lag between pumping reduction associated with critical period management. Simulated water levels drop below the threshold value slightly earlier for the bifurcated permit scenario and pumping reduction occurs earlier. This time lag results in a brief period when water levels and spring discharge are actually greater for the bifurcated permit scenario.

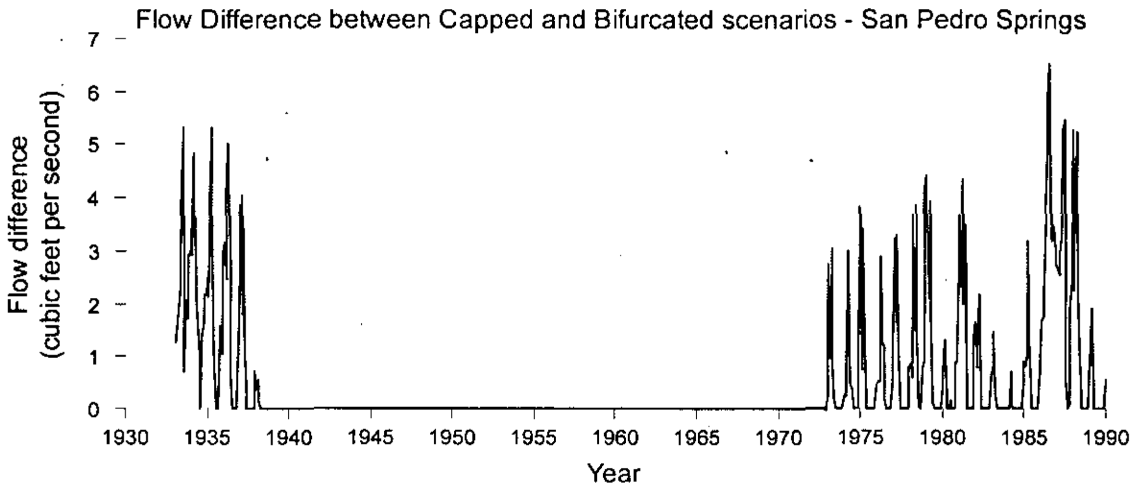

Figure 18. Difference in spring flow at San Pedro Springs attributable to bifurcated permits.

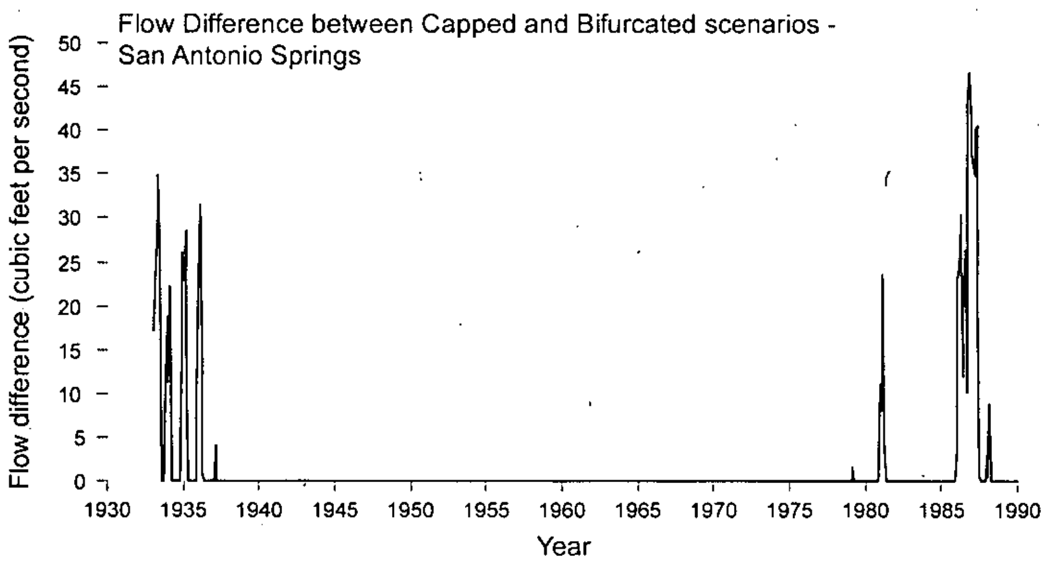

Figure 19. Difference in spring flow at San Antonio Springs attributable to bifurcated permits.

Appendix A: Edwards Aquifer Authority Rules

Chapter 715, Subchapter D, Demand Management and Critical Period Management Rules

Subchapter D. Demand Management and Critical Period Management Rules
Section

§ 715.200 Purpose

The purpose of this chapter is to implement §§ 1.14(h), 1.25, and 1.26 of the Act, which requires that the Authority prepare and implement a management plan for critical periods and implement and enforce certain water management practices. These rules are intended to authorize the maximum aggregate withdrawals from the aquifer from wells with groundwater withdrawal permits, interim authorization status, or exempt well status balanced against the Authority's aquifer management strategy to slow the rate of decline of springflows in Comal or San Marcos Springs. Slowing the rate of decline of springflows will allow more time for the return of normal precipitation events resulting in the maintenance or increase of aquifer levels which would concomitantly result in the maintenance or increase in springlevels.

§ 715.202 Applicability

This subchapter applies to the following persons or entities that withdraw or beneficially use groundwater from the Aquifer:
(1) permitted users;
(2) interim authorization users;
(3) where expressly referenced, owners of exempt wells;
(4) where expressly referenced, owners of non-exempt wells with interim authorization status or an initial regular permit authorized to withdraw no more than three acre-feet of groundwater annually;
(5) contractual users; and
(6) water utilities.

§ 715.204 Authorized Withdrawals; Demand Management and Critical Period Withdrawal Schedules

(a) During a quarter in which a demand management or critical period is in effect for any length of time, groundwater from the Aquifer may be withdrawn only if:
  (1) the withdrawal is made pursuant to a groundwater withdrawal permit, interim authorization status, or a transfer thereof;
  (2) the groundwater is scheduled for withdrawal during the applicable quarter in a demand management and critical period withdrawal schedule required to be filed with the Authority as provided in this section; and
  (3) the groundwater is withdrawn at no more than the applicable reduced rate mandated by § 715.218 (Interruption of Withdrawals During Demand Management and Critical Periods) of this chapter (the Adjusted Quarterly Withdrawal Amount).

(b) The volume of groundwater that may be withdrawn by a permitted user, interim authorization user, or contractual user who directly withdraws groundwater from the aquifer at an authorized point of withdrawal owned or operated by the contractual user based on a transfer of a groundwater withdrawal permit or interim authorization status, from the aquifer during a quarter in which a demand management or critical period is in effect, is the Quarterly Scheduled Withdrawal Amount as required to be established under this section adjusted by the interruption coefficient as determined by § 715.218 (Interruption of Withdrawals During Demand Management and Critical Periods) of this chapter.

(c) Each permitted user, interim authorization user, and contractual user who directly withdraws groundwater from the aquifer at an authorized point of withdrawal owned or operated by the contractual user based on a transfer of a groundwater withdrawal permit or interim authorization status, shall file with the Authority a demand management and critical period withdrawal schedule on a form to be provided by the Authority as follows:
  (1) for municipal and industrial users, not later than 4:30 p.m. of the last business day on or before December 1 of each year; and
  (2) for irrigation users, not later than 4:30 p.m. of the last business day on or before February 1 of each year.

(d) The schedule shall include the following information:
  (1) the Initial Regular Permit application number or permit number for each groundwater withdrawal permit applied for or owned by the person or entity filing the withdrawal schedule, and the total volume of groundwater authorized to be withdrawn thereunder;
  (2) the Initial Regular Permit Application number or groundwater withdrawal permit number for which the person or entity filing the withdrawal schedule is the transferee, including the effective date of the transfer, the pool from which the transfer was made, and the total volume of groundwater authorized to be withdrawn pursuant to the transfer;
  (3) the volume of groundwater proposed to be withdrawn for each quarter of the year (1st quarter - January 1 to March 31; 2nd quarter - April 1 - June 30; 3rd quarter - July 1 to September 30; and 4th quarter - October 1 to December 31) (this will establish the Quarterly Scheduled Withdrawal Amounts); and
  (4) the pool from which the withdrawal will occur.

(e) A withdrawal schedule may not be amended when a demand management or critical period is in effect unless the following conditions are met:

(1) during a quarter in which a demand management or critical period is in effect, the person seeking to amend his demand management and critical period withdrawal schedule is the recipient (transferee) of an intra-pool transfer of groundwater;
(2) at the time of the transfer, the groundwater withdrawal right transferred is authorized to be withdrawn by the transferor during the quarter in which the transfer occurs pursuant to the transferor's demand management and critical period withdrawal schedule; and
(3) the transferor's demand management and critical period withdrawal schedule is also amended to reduce his authorized withdrawal amount by the amount of the transfer.

§ 715.206 Transfers

A permitted user, interim authorization status user, or contractual user may, during a quarter in which a demand management or critical period is in effect, withdraw groundwater from the Aquifer pursuant to a transfer of a groundwater withdrawal permit or interim authorization status only in accordance with § 711.344 (Transfers during a Demand Management or Critical Period).

§ 715.208 Groundwater Carryforwards Generally Prohibited; Irrigation Carryforwards

(a) Except as provided in subsection (b), groundwater scheduled for withdrawal in a quarter but not actually withdrawn in that quarter may not be carried forward for withdrawal to a subsequent quarter of the year in which a Notice of Cessation, demand management or critical period is in effect for all or part of the quarter.
(b) An irrigator may carry forward to the third quarter in which a Notice of Cessation, demand management or critical period is in effect for all or part of the quarter groundwater scheduled for withdrawal in the second quarter but not actually withdrawn, and carry forward to the fourth quarter groundwater scheduled for withdrawal in the third quarter but not actually withdrawn, in order to finish an existing crop planted in the year for which the withdrawal schedule is effective, if the irrigator provides notification to the Authority of the intent to carry forward groundwater in the timely-filed monthly report form prescribed by the Authority for the last month of the quarter from which groundwater is to be carried forward.

§ 715.210 Monthly Groundwater Withdrawal Reports

(a) Each permitted user, interim authorization user, and contractual user who directly withdraws groundwater from the aquifer at an authorized point of withdrawal owned or operated by the contractual user based on a transfer of a groundwater withdrawal permit or interim authorization status, must file monthly groundwater withdrawal reports with the Authority containing withdrawal data in weekly increments when a demand management or critical period is in effect. These reports must be filed on the form prescribed by the Authority and contain the following information:
(1) the person's name, address, and telephone number;
(2) contact person and title;

(3) the reporting month;
(4) by well, the total volume of groundwater withdrawn during the reporting month in weekly increments; and
(5) any other information requested by the general manager.

(b) Monthly groundwater withdrawal reports must be filed with the Authority no later than ten business days after the end of the month in which the week occurs.

§ 715.212 Commencement and Expiration of Demand Management Periods for the San Antonio Pool

(a) A stage I demand management period for the San Antonio Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager will issue the notice if any of the criteria in subsection (b) of this section is satisfied. The notice shall be:
(1) published in a newspaper of general circulation throughout the Authority's jurisdiction;
(2) published in at least four other newspapers within the San Antonio Pool jurisdiction of the Authority; and
(3) posted on the Authority's internet site.

(b) The general manager shall issue notice of commencement of stage I of the demand management period if at least one of the following conditions occurs:
(1) at 8:00 a.m., the level of the aquifer is less than 650 feet above mean sea level as measured at well J-17; or
(2) the 5-day running average discharge rate of San Marcos Springs is below 110 c.f.s. as measured by the Authority at the San Marcos gauging station; or
(3) the 5-day running average discharge rate of Comal Springs is below 220 c.f.s. as measured by the Authority at the Comal Springs gauging station.

(c) Unless otherwise provided by the general manager, a stage I demand management period expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager will issue a notice of expiration by posting on the Authority's internet site. The general manager will issue the notice of expiration if none of the criteria in subsection (b) are any longer satisfied.

(d) A stage II demand management period for the San Antonio Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager will issue the notice if any of the criteria in subsection (e) of this section is satisfied. The notice shall be given as set out in subsection (a) of this section.

(e) The general manager shall issue notice of commencement of stage II of the demand management period if one of the following conditions occur:
(1) at 8:00 a.m., the level of the aquifer is less than 640 feet above mean sea level as measured at well J-17; or
(2) the 5-day running average discharge rate of San Marcos Springs is below 96 c.f.s. as measured by the Authority at the San Marcos gauging station; or
(3) the 5-day running average discharge rate of Comal Springs is below 154 c.f.s. as measured by the Authority at the Comal Springs gauging station.

(f) Unless otherwise provided by the general manager, a stage II demand management period expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager will issue a notice of expiration by posting on the Authority's internet site. The general manager will issue the notice of expiration if none of the criteria in subsection (e) is any longer satisfied.

§ 715.216 Commencement and Expiration of Critical Period Management for the San Antonio and Uvalde Pools

(a) A stage III critical period for the San Antonio Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager will issue the notice if any of the criteria in subsection (b) of this section is satisfied. The notice shall be given as set out in §§ 715.212(a) of this chapter.

(b) The general manager shall issue notice of commencement of stage III critical period if at least one of the following conditions occurs:

(1) at 8:00 a.m., the level of the aquifer is less than 630 feet above mean sea level as measured at well J-17; or

(2) the 5-day running average discharge rate of San Marcos Springs is below 80 c.f.s. as measured by the Authority at the San Marcos Springs gauging station; or

(3) the 5-day running average discharge rate of Comal Springs is below 86 c.f.s. as measured by the Authority at Comal Springs gauging station.

(c) Unless otherwise provided by the general manager, a stage III critical period for the San Antonio Pool expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager will issue a notice of expiration by posting on the Authority's internet site. The general manager must issue the notice of expiration if none of the criteria in subsection (b) of this section are any longer satisfied.

(d) A stage IV critical period for the San Antonio Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager must issue the notice if any of the criteria in subsection (e) is satisfied. The notice shall be given as set out in §§ 715.212(a) of this chapter.

This subsection is not applicable when the amount of groundwater available for permitted withdrawals for initial and additional regular permits does not exceed 400,000 acre-feet for each calendar year, pursuant to § 711.164(b) (Groundwater Available for Permitted Withdrawals for Initial and Additional Regular Permits) of Chapter 711 (Groundwater Withdrawals) of the Authority's rules.

(e) The general manager shall issue notice of commencement of stage IV of the critical period in the San Antonio Pool if at least one of the following conditions occurs:

(1) at 8:00 a.m. on the 30th day after the general manager issued his notice of commencement of stage III critical period, the level of the aquifer remains at less than 630 feet above mean sea level as measured as well J-17; or

(2) at 8:00 a.m., the level of the aquifer is less than 627 feet above mean sea level as measured as well J-17.

This subsection is not applicable when the amount of groundwater available for permitted withdrawals for initial and additional regular permits does not exceed 400,000 acre-feet for each calendar year, pursuant to § 711.164(b) (Groundwater Available for Permitted

Withdrawals for Initial and Additional Regular Permits) of Chapter 711 (Groundwater Withdrawals) of the Authority's rules.

(f) Unless otherwise provided by the general manager, a stage IV critical period in the San Antonio Pool expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager must issue a notice of expiration by posting on the Authority's internet site. The general manager must issue the notice of expiration if none of the criteria in subsection (e) are any longer satisfied.

(g) A stage III critical period for the Uvalde Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager will issue the notice if the criteria in subsection (h) of this section is satisfied. The notice shall be:

(1) published in a newspaper of general circulation throughout the Authority's jurisdiction;

(2) published in at least one other newspaper within the Uvalde Pool jurisdiction of the Authority; and

(3) posted on the Authority's internet site.

(h) The general manager shall issue notice of commencement of stage III critical period in the Uvalde Pool if at, 8:00 a.m., the level of the aquifer is less than 845 feet above mean sea level as measured at well J-27.

(i) Unless otherwise provided by the general manager, a stage III critical period for the Uvalde Pool expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager will issue a notice of expiration by posting on the Authority's internet site. The general manager must issue the notice of expiration if the criteria in subsection (h) of this section is no longer satisfied.

(j) A stage IV critical period for the Uvalde Pool commences at 8:00 a.m. on the day specified in the notice of commencement issued by the general manager. The general manager must issue the notice if any of the criteria in subsection (k) is satisfied. The notice shall be:

(1) published in a newspaper of general circulation throughout the Authority's jurisdiction;

(2) published in at least one other newspaper within the Uvalde Pool jurisdiction of the Authority; and

(3) posted on the Authority's internet site.

This subsection is not applicable when the amount of groundwater available for permitted withdrawals for initial and additional regular permits does not exceed 400,000 acre-feet for each calendar year, pursuant to § 711.164(b) (Groundwater Available for Permitted Withdrawals for Initial and Additional Regular Permits) of Chapter 711 (Groundwater Withdrawals) of the Authority's rules.

(k) The general manager shall issue notice of commencement of stage IV of the critical period in the Uvalde Pool if at least one of the following conditions occurs:

(1) at 8:00 a.m. on the 30th day after the general manager issued his notice of commencement of stage III critical period, the level of the aquifer remains at less than 845 feet above mean sea level as measured as well J-27; or

(2) at 8:00 a.m., the level of the aquifer is less than 842 feet above mean sea level as measured as well J-27.

This subsection is not applicable when the amount of groundwater available for permitted withdrawals for initial and additional regular permits does not exceed 400,000 acre-feet for each calendar year, pursuant to § 711.164(b) (Groundwater Available for Permitted Withdrawals for Initial and Additional Regular Permits) of Chapter 711 (Groundwater Withdrawals) of the Authority's rules.

(l) Unless otherwise provided by the general manager, a stage IV critical period in the Uvalde Pool expires at 8:00 a.m. on the 30th day after issuance by the general manager of a notice of expiration. The general manager must issue a notice of expiration by posting on the Authority's internet site. The general manager must issue the notice of expiration if none of the criteria in subsection (k) are any longer satisfied.

§ 715.218 Interruption of Withdrawals During Demand Management and Critical Periods

(a) The interruption coefficients to be applied during a demand management or critical period to the Quarterly Scheduled Withdrawal Amounts required to be scheduled pursuant to § 715.204 (Authorized Withdrawals; Demand Management and Critical Period Withdrawal Schedules) are as follows:

PERIOD	USER	450,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT	400,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT
Stage I Demand Management	Permitted users, interim authorization users, and contractual users, other than groundwater use for crop irrigation	0.05	0.05
	Permitted users, interim authorization users, and contractual users, with groundwater use for crop irrigation	0.00	0.00
	Owners of non-exempt wells with interim	0.00	0.00

PERIOD	USER	450,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT	400,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT
	authorization status or an initial regular permit authorized to withdraw no more than three acre-feet of groundwater annually		
	Owners of exempt wells	0.00	0.00
Stage II Demand Management	Permitted users, interim authorization users, and contractual users, other than groundwater use for crop irrigation	0.10	0.10
	Permitted users, interim authorization users, and contractual users, with groundwater use for crop irrigation	0.00	0.00
	Owners of non-exempt wells with interim authorization status or an initial regular permit authorized to withdraw no more than three acre-feet of groundwater annually	0.00	0.00
	Owners of exempt wells	0.00	0.00
Stage III Critical Period	Permitted users, interim authorization	0.15	0.15

PERIOD	USER	450,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT	400,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT
	users, and contractual users, other than groundwater use for crop irrigation		
	Permitted users, interim authorization users, and contractual users, with groundwater use for crop irrigation	0.15	0.15
	Owners of non-exempt wells with interim authorization status or an initial regular permit authorized to withdraw no more than three acre-feet of groundwater annually	0.00	0.00
	Owners of exempt wells	0.00	0.00
Stage IV Critical Period	Permitted users, interim authorization users, and contractual users, other than groundwater use for crop irrigation	0.23	N/A
	Permitted users, interim authorization users, and contractual users, with groundwater use for crop irrigation	0.23	N/A

PERIOD	USER	450,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT	400,000 AF/ANNUM CAP INTERRUPTION COEFFICIENT
	Owners of non-exempt wells with interim authorization status or an initial regular permit authorized to withdraw no more than three acre-feet of groundwater annually	0.00	0.00
	Owners of exempt wells	0.00	N/A

(b) If one demand management or critical period is effective for an entire quarter, a user's Adjusted Quarterly Withdrawal Amount for that quarter shall be calculated as follows:
Adjusted Quarterly Withdrawal Amount = Quarterly Scheduled Withdrawal Amount x (1 - Interruption Coefficient)

(c) If a demand management or critical period is effective for less than an entire quarter and no demand management or critical period is effective for the remainder of the quarter, a user's Adjusted Quarterly Withdrawal Amount for that quarter shall be calculated as follows:
Adjusted Quarterly Withdrawal Amount = Quarterly Scheduled Withdrawal Amount x (1 - (Interruption Coefficient x (number of days in stage / number of days in quarter)))

(d) If two or more different demand management or critical periods are effective during a quarter, a user's Adjusted Quarterly Withdrawal Amount for that quarter shall be calculated as follows, using two or more interruption coefficients, as appropriate:
Adjusted Quarterly Withdrawal Amount = Quarterly Scheduled Withdrawal Amount x (1 – (Interruption Coefficient$_x$ x (number of days in stage x / number of days in quarter)) + (Interruption Coefficient$_y$ x (number of days in stage y / number of days in quarter)))

(e) In implementing the appropriate water management strategies to accomplish the interruptions required by the table in subsection (a) of this section, a permitted user, interim authorization user, or contractual user who directly withdraw groundwater from the aquifer at an authorized point of withdrawal owned or operated by the contractual user based on a transfer of a groundwater withdrawal permit or interim authorization status, shall reduce, restrict, or limit the use of groundwater from the aquifer for the following uses in the following order of preference with (1) being the first use that should be reduced, restricted, or limited and (5) being the last use to be reduced, restricted, or limited:

(1) discretionary uses as is appropriate to that permittee or interim authorization user;
(2) the non-discretionary portion of recreation and pleasure use;
(3) the non-discretionary portion of residential landscape irrigation;
(4) the non-discretionary portion of industrial and crop irrigation; and
(5) the non-discretionary portion of municipal use from non-exempt wells, and the non-discretionary portion of domestic and livestock use from exempt wells.

(f) A higher preferred water use category shall not be reduced, restricted, or limited until the water use reductions from a lower preferred water use category have been accomplished to the maximum extent feasible as necessary. A permittee or applicant is not required to reduce, restrict, or limit its water use in an amount that exceeds the interruption coefficients as set out in subsection (a) above.

§ 715.220 Variance Applications

Any person seeking a variance from the operation of this subchapter based on the implementation of an alternative water management strategy, practice, procedure or method mayfile with the Authority an application for a variance pursuant to § 707.419 (Applications for Variance from Comprehensive Water Management Rules) of Chapter 707 (Procedure Before the Authority) of the Authority's rules.

Appendix B: Estimated Historical Pumping from 1934 through 1989

Because monthly historical pumping input was only developed for the calibration (1947 through 1959) and verification (1978 through 1989) years, we estimated pumping distributions for 1934 through 1946 and 1960 through 1977 in order to complete the time series of pumping information for the model. The Commission requested simulated spring flow based on historical conditions from 1934 through 1989 to complete their analysis of the impacts of the bifurcated permit rules. Thorkildsen and McElhaney (1992) had already developed monthly historical input for recharge for the period of 1934 through 1989 for the original model calibration.

The estimated pumpage input for 1934 through 1946 was based on annual estimated groundwater discharge data from EAA's 1999 Hydrologic Data Report (EAA, 2000; Table 6.1). The table lists total well discharge for the Edwards aquifer. We distributed the annual discharge to monthly GWSIM grid cell values by multiplying monthly unit cell factors by the annual pumping volume. The monthly unit cell factor is essentially the ratio of average monthly pumping per cell to average annual pumping. We used the existing historical pumpage (1947 through 1959 and 1978 through 1989) to determine the monthly unit cell factors by summing monthly cell pumpage values across all 25 years and dividing by the total model pumpage for all 25 years. For example, the January cell factor for cell 15,50 is equal to the sum of all 25 January pumpage values in cell 15,50 divided by the total model wide pumpage for all 25 years. We used this approach to average the variation in the spatial distribution of pumping over the 25 years.

The estimated pumpage input for 1960 through 1977 was based on monthly pumping extracted from the MODFLOW model of the Edwards aquifer (Lindgren and others, 2004). The monthly model-wide pumping from the MODFLOW model was distributed to the GWSIM grid cells by multiplying monthly unit cell factors by the total monthly pumping volume. In this case the factor is the ratio of cell pumping to total monthly model pumping. We determined monthly unit cell factors by summing monthly cell pumpage values across all 25 years and dividing by the sum of all 25 monthly pumping totals. For example, the January cell factor for cell 15,50 is equal to the sum of all 25 January pumpage values in cell 15,50 divided by the total model wide January pumpage for all 25 years. We used this approach to average the variation in the spatial distribution of pumping over the 25 years and to make use of the monthly variation in pumpage included in the MODFLOW Edwards aquifer model.

We then combined the estimated historic pumpage distributions for 1934 through 1946 and 1960 through 1977 with the calibration and verification pumpage distributions and. simulated water levels and spring discharge using GWSIM-IV. The results for the calibration period for the Bexar Index Well, Comal Springs, and San Marcos Springs are shown in Figures B-1, B-2, and B-3, respectively. Also shown are the simulated values for the calibration run. The full period simulation does not exactly reproduce the same spring discharge and water levels as the original calibration and verification runs. The difference is most likely due to differences in starting conditions. The full period run simulates higher water levels at the beginning of 1947, and the water levels stay higher over much of the period. Towards the end of the period the water levels are in closer agreement. However, it should be noted that in some cases the full period water levels actually match observed water levels better. In the case of Comal Springs, the full period historical run does a better job matching data over most of the calibration period, the exception being mid-1956, when Comal Springs was observed to go dry, and the historical run fails to simulate the springs going dry. During the verification period (1978 through 1989), the full period historical run simulates starting water levels that are lower than those for the verification run.

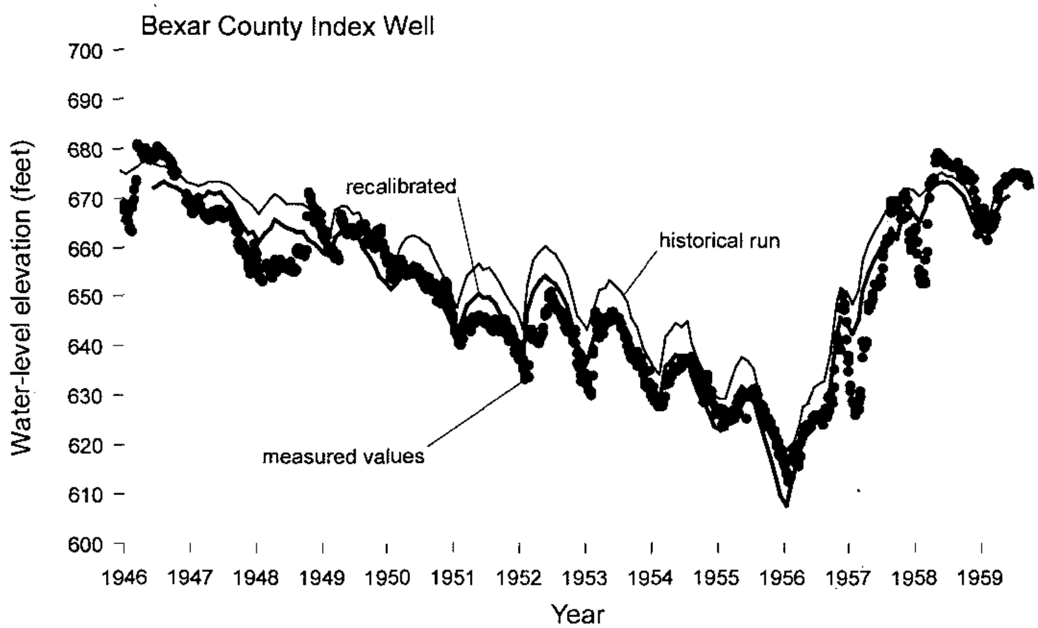

Figure 20. Simulated water levels at Bexar County Index well for historical run and calibrated model results. Measured water levels are also shown.

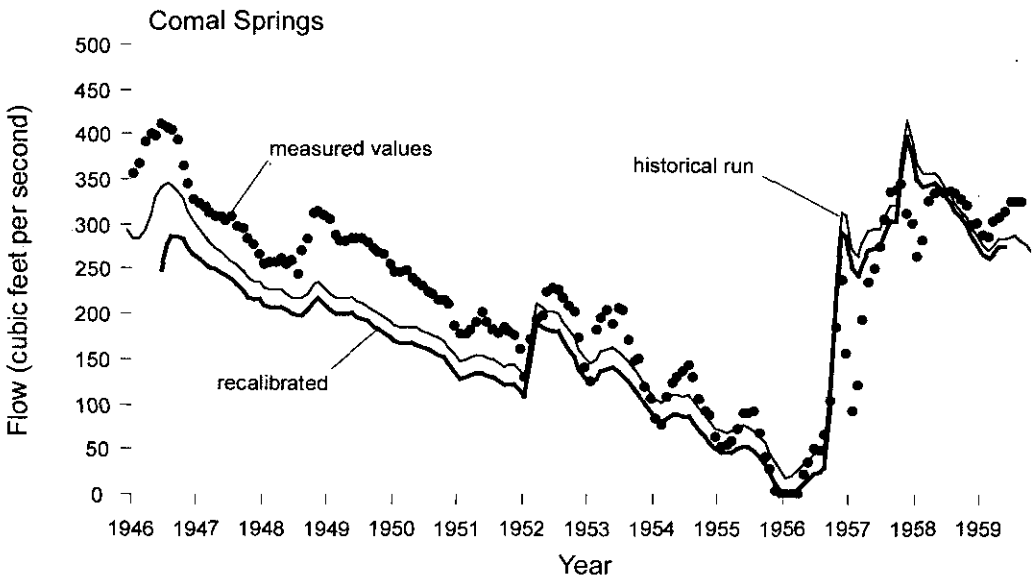

Figure 21. Simulated discharge at Comal Springs based on estimated historical pumpage and calibration run. Also shown are spring flow data.

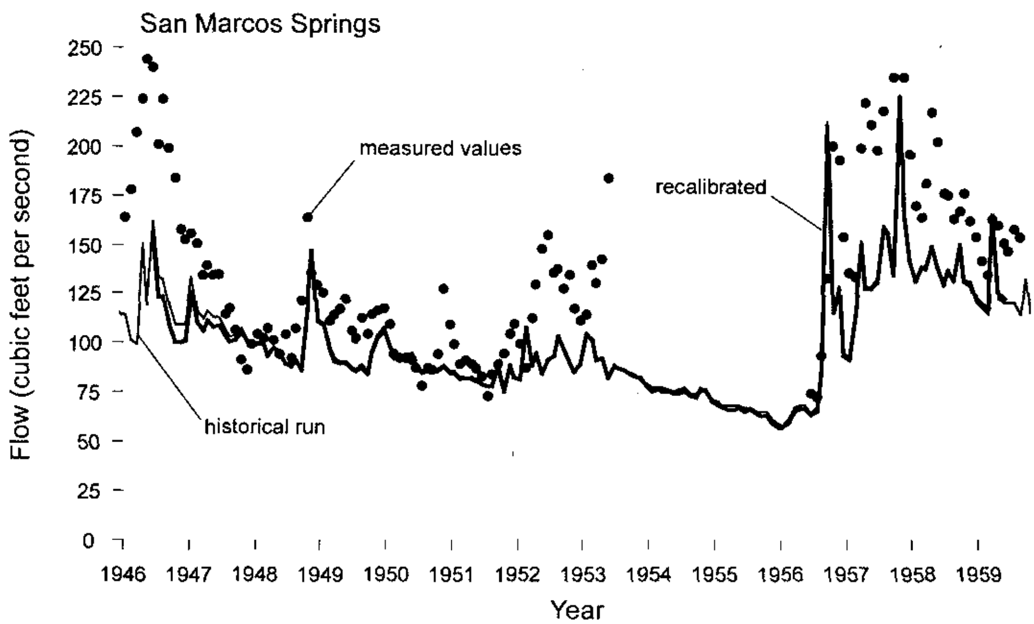

Figure 22. Simulated discharge at San Marcos Springs based on estimated historical pumpage and calibration run. Also shown are spring flow data.