Appendix C
Technical Evaluation Procedures for Edwards Aquifer Recharge Enhancement

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C.1 Introduction

One recommended water management strategies in the 2011 South Central Texas Regional Water Plan involve the enhancement of recharge to the Edwards Aquifer: Edwards Recharge – Type 2 Project (Section 4C.4). Such recharge enhancement is intended not only to increase springflows protecting endangered species and downstream water uses, but also to enhance the reliability of the Edwards Aquifer as a regional water supply. With regard to enhanced water supply, the Edwards Aquifer Authority (EAA) has adopted rules regarding recharge recovery permits, which define the amount of additional authorized pumpage to which the developer of a recharge enhancement project might be entitled.

For the purposes of regional water supply planning under rules set forth by the Texas Water Development Board (TWDB), recharge enhancement strategies are evaluated herein based on the reliable supply available during the drought of record. In this way, recharge enhancement strategies may be considered by the South Central Texas Regional Water Planning Group (SCTRWPG) on the same basis as surface water supply strategies, such as reservoirs and run-of-river diversions. While numerous studies quantifying recharge enhancement on both long-term and drought average bases have been completed in recent years, the quantification of additional reliable supply based on maintenance of springflows during the drought of record has not always been a part of these studies. Hence, the TWDB's model of the Edwards Aquifer is used in this regional water supply planning effort to simulate aquifer performance subject to recharge enhancement, quantify the associated increase in reliable supply, and allow for more direct comparisons between recharge enhancement and other water management strategies. The following paragraphs provide a brief summary of the technical procedures used for evaluation of Edwards Aquifer recharge enhancement strategies.

C.2 Edwards Aquifer Model

In order to simulate aquifer response to recharge enhancement, the TWDB GWSIM4 Edwards Aquifer groundwater flow model (Figure C-1) is used to make the necessary calculations. It is designed to simulate aquifer response in terms of water levels and springflows for specified recharge and pumping rates. The model was developed by the TWDB in the 1970s[1] as a tool for use in developing a water resources management program for the Nueces and Guadalupe - San Antonio River Basins. Originally, the model operated on an annual timestep and was calibrated to data collected from 1947 to 1971. Major assumptions in the model include: (1) no lateral movement of water from the Glen Rose formation in the Hill Country (Trinity Aquifer-Edwards Plateau); (2) no water movement across the so-called 'bad-water line'; and (3) no leakage from underlying or overlying formations except in an area southeast of Uvalde near Leona Springs.

The TWDB recalibrated the model in the early 1990s[2] with information compiled between 1971 and 1989 and refined the timestep to monthly intervals. The recalibration was based on comparisons of water levels and springflows for 1947 to 1959 and "verified" with 1978 to 1989 data. During the process of adjusting the aquifer parameters for recalibration, the model developers gave special emphasis to minimum flow periods at Comal and San Marcos Springs

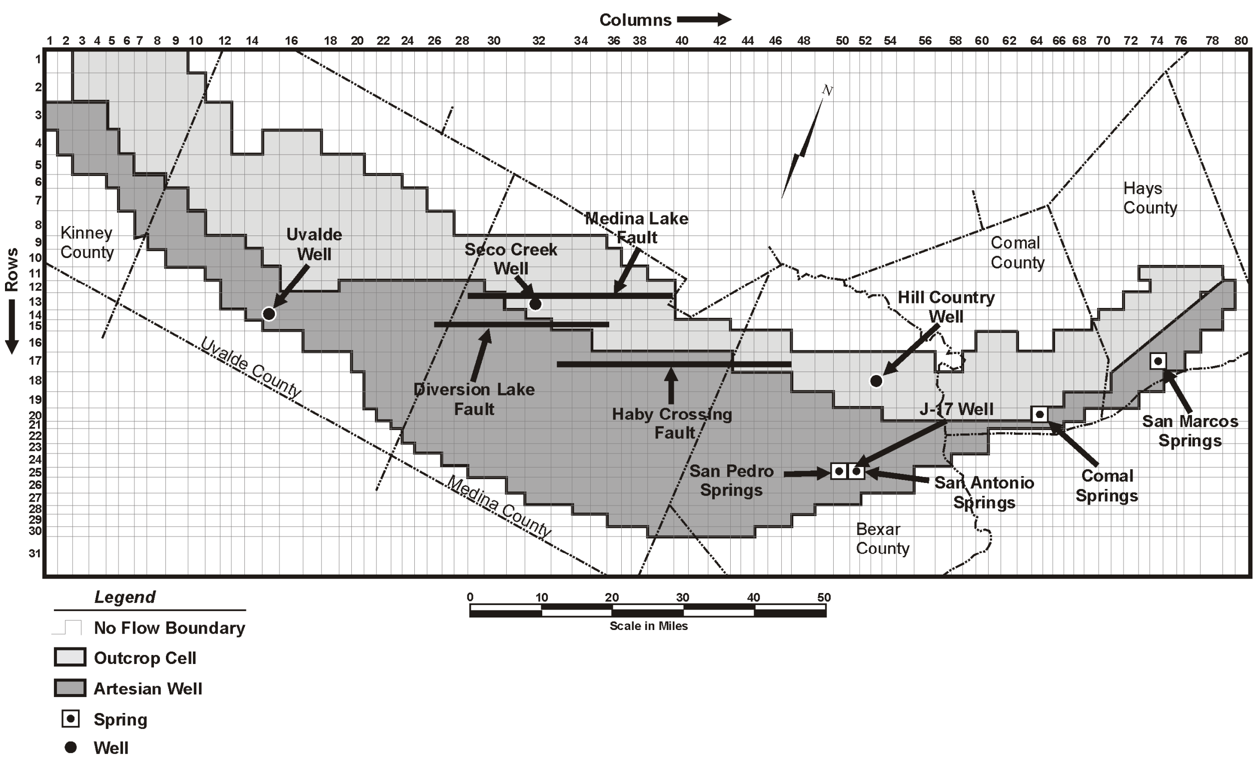

Figure C-1. GWSIM 4 Model for Edwards Aquifer

[1] Klemt, W.B., Knowles, T.R., Elder, G.R., and Sieh, T.W., "Ground-water Resources and Model Applications for the Edwards (Balcones Faulty Zone) Aquifer in the San Antonio Region, Texas," Texas Water Development Board Report 239, 88p., 1979.

and water levels at observation well J-17 in San Antonio. The recalibration did not revise any of the major assumptions used in the original model.

All model simulations for this study are for the 1934 through 1989 historical period and have monthly timesteps. The simulation period includes a severe drought in the 1950s (1947 to 1956) and wetter than normal conditions in much of the 1970s and 1980s, except for short, intense droughts in 1984 and 1989. Historical recharge to the Edwards Aquifer is based upon monthly estimates developed by HDR.[3,4] For the most recent version of GWSIM4, the TWDB used estimates of baseline recharge, developed by HDR, that reflect full utilization of current water rights and recharge enhancement associated with all existing projects as if they existed throughout the 1934 to 1989 historical period. The distributions to specific cells in GWSIM4 were made by the TWDB. Annual estimates of baseline recharge are shown in Figure C-2.

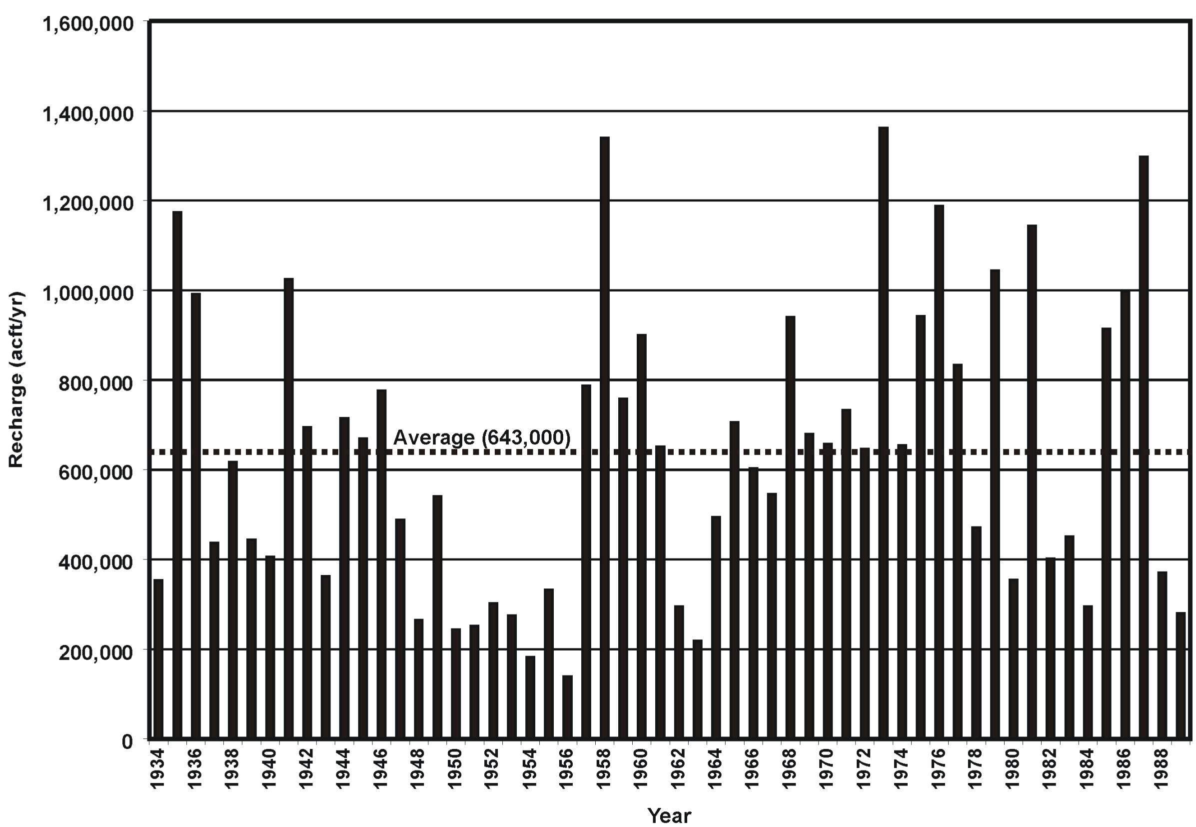

Figure C-2. Edwards Aquifer Recharge

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[2] Thorkildsen, D. and McElhaney, P.D.., "Model Refinement and Applications for the Edwards (Balcones Fault Zone) Aquifer in the San Antonio Region, Texas," Texas Water Development Board Report 340, 33p., 1992.
[3] HDR, "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September 1993.
[4] HDR, "Nueces River Basin Regional Water Supply Planning Study," Nueces River Authority, et al., May 1991.

Natural water losses from the Edwards Aquifer model are springflow at Leona, San Pedro, San Antonio, Comal, and San Marcos Springs. Springflow is calculated from aquifer heads at the springs and an aquifer head-springflow rating curve for each spring. Another natural loss is cross-formational leakage in an area southeast of Uvalde. This loss is calculated similarly to springflow. The current version of GWSIM4 includes an estimate of discharge to the Guadalupe River (largely associated with Hueco Springs) and is considered a negative (rejected) recharge by the model. The discharge is estimated from a regression equation of streamflow gains and water levels in observation well J-17.

Pumpage is assigned by category to specific cells in the model by the TWDB, based on the locations of permitted wells. For the baseline permitted pumpage, the total pumpage for irrigation, industrial, and municipal purposes in Kinney, Uvalde, Medina, Bexar, Atascosa, Comal, and Hays Counties, is 572,000 acft/yr. Domestic, livestock, and Federal pumpage does not require permits and totals 20,449 acft/yr. Thus, the total annual pumpage used in the model is 592,449 acft/yr. Annual pumpage is distributed to monthly pumpage values by multiplying the annual pumpage for each category by a monthly distribution factor in accordance with type of use.

C.3 Technical Evaluation Procedure

The technical evaluation procedure used in determining the increase in water supply attributable to a recharge enhancement strategy is based on the definitions, assumptions, and steps summarized in the following paragraphs.

Definitions:

- *Baseline Pumpage:* The sum of the regular permitted industrial, municipal, and irrigation pumpage categories adjusted to 572,000 acft/yr plus the unpermitted domestic, livestock, and Federal pumpage. The total is 592,449 acft/yr.
- *Baseline Sustained Yield:* The portion of baseline pumpage that will maintain a minimum monthly flow at Comal Springs of 60 (cfs) in one and only one month of the simulation period. This simulation is performed merely to obtain a baseline estimate of aquifer yield for the "no enhanced recharge" case.
- *Sustained Yield with Recharge Enhancement Project(s)*: The sum of the pumpages for the baseline sustained yield scenario plus an across the board increase in pumpage such that the minimum monthly flow at Comal Springs is 60 cubic feet per second (cfs) in one and only one month of the simulation period.
- *Additional Dependable Supply:* The increase in sustained yield attributable to the recharge enhancement project(s).

Assumptions:

- The GWSIM4 Model provides a reasonable simulation of Edwards Aquifer response (in terms of springflow and water levels) to enhanced recharge and various pumpage rates. Note that the EAA, in cooperation with regional, state, and federal interests, has nearly completed the development of a new model of the Edwards Aquifer.
- Minimum Comal Springs discharge of 60 cfs (in one and only one month of the 56-year simulation period) provides a reasonable point of reference for assessment of potential changes in sustained yield of the Edwards Aquifer associated with recharge enhancement. Note that the selection of 60 cfs as a minimum discharge simply provides a point of reference for consistent computations and does not necessarily imply acceptability under the law.
- The increase in sustained yield of the Edwards Aquifer during the drought of record provides a reasonable basis for consideration of recharge enhancement strategies in a manner consistent with other water management strategies in the regional water planning process.

Steps:

1. Make a baseline GWSIM4 simulation with baseline pumpage and baseline recharge. Count the number of months when flow at Comal Springs (Figure C-3) is less than specified value of interest (60 cfs).
2. Make a series of trial and error GWSIM4 simulations with reductions in baseline pumpage until the flow at Comal Springs is 60 cfs in one and only one month of the simulation period. The final run provides the baseline sustained yield of the Edwards Aquifer (Figure C-3).
3. Calculate the enhanced recharge provided by the water management strategy using a surface water model.
4. Add the baseline recharge and the enhanced recharge.
5. Make a series of trial and error GWSIM4 simulations (including enhanced recharge) with the baseline sustained yield pumpage plus across the board increases in pumpage until the flow at Comal Springs is 60 cfs in one and only one month of the simulation period. The final run provides the sustained yield with the recharge enhancement strategy.

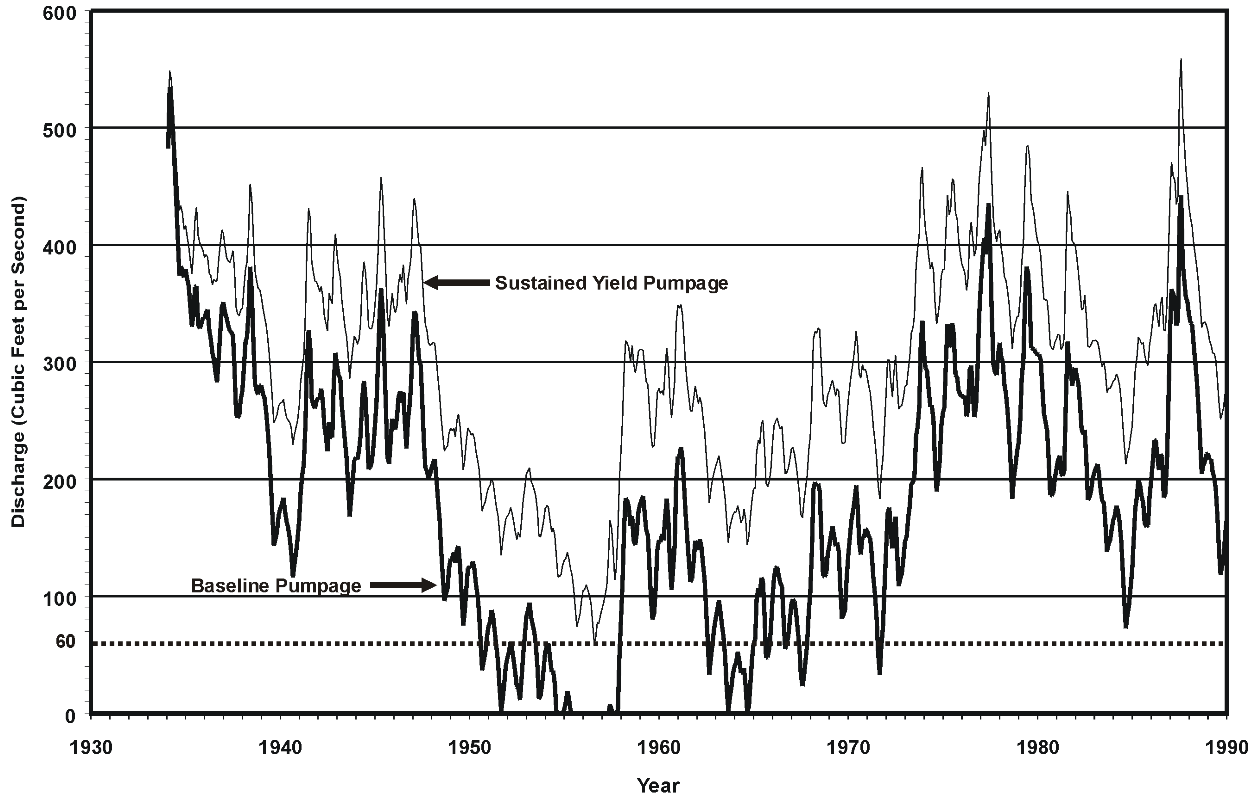

Figure C-3. Comal Springs Discharge Subject to Pumpage Scenarios

6. Calculate the amount of additional dependable supply available during a repeat of the drought of record by subtracting the baseline sustained yield from the sustained yield with recharge enhancement.