The Edwards Aquifer's Water Resource Conflict: USDA Farm Program Increase Irrigation Water-Use?

By

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Abstract

This paper summarizes an economic and hydrological analysis of the impact of 1990 and 1996 USDA farm programs on irrigation water withdrawals from the Edwards Aquifer in South-Central Texas, and on spring flows which support endangered species. Economic modeling and, a regional survey institutional analysis are used to examine likely irrigation water use impacts. Hydrological modeling is used to examine spring flow effects. Study results show that 1990 USDA commodity program components cause producers to require less water, in turn increasing rather than decreasing aquifer spring flows. Farm tenure arrangements and Edwards Aquifer Authority water management activities, indicate that 1996 Farm Act provisions will not cause an increase in irrigation withdrawals. Broader actions such as long-term water supply enhancement/conservation programs, dry-year water use reduction incentives and water markets all provide tools for Edwards water use conflict resolution. USDA farm programs do not apparently play a material part in the total debate.

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In recent years, irrigated agriculture has come under increased scrutiny for its alleged impact on resources and habitats essential for the survival of threatened and endangered species Schaible et al., 1995. Moore, et al. (1996) demonstrates the level of interest being attached to this concern for Western surface-waters, identifying 50 Federally-listed endangered or threatened fish species where irrigated agriculture has been identified as a "factor in decline". They assert that reallocating western surface-water supplies to fish-species habitat restoration would impact irrigation in at least 235 counties. Endangered species protection has also recently become a factor in Bureau of Reclamation (BoR) water management -- an agency responsible for annual delivery of 25 million acre-feet to Western farms (Moore 1991).

It also has been alleged that USDA farm programs adversely impact environmental quality and species habitat through their influences on agricultural activity (Antle and Just, 1991). USDA farm programs influence farm production through price and income supports as well as resource-based conservation-incentive programs (Pollack and Lynch, 1991; Nelson and Schertz, 1996). However, measures of links between farm program features, production resource use, and species habitat availability are generally inadequate to identify cause-and-effect relationships. Farm production and resource-use decisions are not made within a financial-based, economic-efficiency vacuum. Producer decisions reflect opportunity values of resources influenced by production opportunities and by producer, farm, and institutional characteristics and constraints (Beattie and Taylor; Schaible, 1997). Examining farm program and agricultural resource use linkages to endangered species concerns involves consideration of the influence of market economic factors, producer behavior and farm structural characteristics, as well as resource, institutional and hydrologic relationships with and without program incentives. We will examine these issues in the context of a water-use /endangered species conflict involving the Edward's Aquifer (EA) of South-Central Texas.

USDA administers agricultural commodity, conservation, and rural development programs within the EA area. Because agriculture uses aquifer water supplies, USDA entered into informal consultations with the U.S. Fish & Wildlife Service (FWS) in 1995 to determine whether USDA farm programs adversely affect aquifer-dependent threatened and endangered aquatic species. USDA completed two Endangered Species Act (ESA) Biological Evaluations (BE's) of farm programs implemented within the EA, assessing their impact on aquifer withdrawals, and flows from aquifer springs. (A BE is an ESA requirement which may encompass assessments of Federal program impacts, particularly when such activity is alleged to affect species critical habitat.) Particular attention was devoted to assessing USDA farm program impacts on aquifer withdrawals for irrigated agriculture. The USDA studies included: 1) a BE (USDA,1996) of farm programs under the amended1990 Food, Agriculture, Conservation and Trade Act ; and 2) a BE (USDA,1997) for programs under the 1996 Federal Agriculture Improvement and Reform Act. This paper describes the EA water-use environment/conflict, summarizes the research approach taken to evaluate program effects for the BE studies, presents principal research findings, and provides a brief discussion of conflict-resolution options. Special emphasis is given to the economics aspects of commodity programs impact.

The EA Water-Use Environment/Conflict

The San Antonio Segment of the EA of South-Central Texas is an annually recharged aquifer, depending on rainfall. The EA is the primary water-supply source for both agriculture, human and endangered aquatic species water-resource demands (See the San Antonio Water System web page for links to many physical descriptions). Pumping of aquifer water has become controversial because, in some years, pumping has exceeded aquifer recharge, with reduced aquifer levels and resultant spring flows. The springs support endangered species.

The EA drainage, recharge and artesian (withdrawal) area covers portions of 15 counties (Figure 1). The artesian portion of the EA flows from west to east within Kinney, Uvalde, and Medina counties, then shifts northeast within Bexar, Comal, and Hays counties. The aquifer is the sole source water-supply source for about 1.3 million people (including the city of San Antonio), many rural and municipal water-supply systems, military bases, about 80,000 acres of irrigated agricultural land, livestock production, and springfed water-based recreation along the Comal and San Marcos Rivers.

The aquifer supports the existence of five Federally-listed threatened and endangered aquatic species and three proposed-listed, endangered aquatic species at Comal and San Marcos Springs or within associated river ecosystems. The Federally-listed aquatic species include two fish -- San Marcos gambusia and fountain darter; one plant -- Texas wild-rice; and two salamanders --Texas blind salamander and San Marcos salamander. All of these species are listed as endangered, except the San Marcos salamander which is listed as threatened. Other species are also being considered for listing.

Species habitat is dependent on spring flow, particularly during drought years when reduced natural aquifer recharge occurs (FWS, 1996). Spring flow level is dependent on the aquifer water table. Annual pumping influences aquifer water table. Estimated annual aquifer discharge averaged 730.6 thousand acre-feet from 1955-1994; 49.2 percent through groundwater pumping, and 50.8

percent through spring flows (Edwards Underground Water District (EUWD), 1995). Estimated annual recharge averaged 676.6 thousand acre-feet during 1934-1994, but ranged from 43.7 thousand acre-feet in 1956 (the most severe drought of record) to 2.486 million in 1992 (EUWD, 1995).

Aquifer drawdown is also argued to have a potential link to diminished water quality in the aquifer, springs, and partially spring fed Guadalupe River ecosystem. Low water tables might cause saline or brackish water to move into the EA (FWS, 1996). A "bad water" line is a major topic of controversy relative to potential intrusion into the EA.

The level of aquifer withdrawals for irrigated agriculture is part of the aquifer drawdown and is alleged to contribute to declining spring flows and endangered species habitat loss, particularly during low rainfall years (U.S. FWS, 1996). Average annual withdrawals from the EA for irrigated agriculture have increased from 73.8 to 119.9 thousand acre-feet (62.5 percent) between 1960-1969 and 1985-1994, but declined slightly as a share of total withdrawals for human use, from 27.6 to 26.7 percent (EUWD, 1995). Annual withdrawals for irrigation have ranged from 59 to 204 thousand acre-feet, depending on rainfall (Moore and Votteler, 1994). Withdrawals for irrigated agriculture occur primarily in the western aquifer region (Uvalde, Medina, and Bexar counties), which accounts for 99 percent of total irrigation water pumpage from the aquifer (USDA, 1996). The principal irrigated crops in the three-county region are cotton, corn, sorghum, peanuts, hay, and vegetables.

USDA's EA BE Research Approach

The BE studies were conducted by the **USDA EA Evaluation Team**, comprised of staff from the USDA Natural Resources Conservation Service, Farm Service Agency, Rural Development, and Office of General Council divisions. Staff participated from both national and Texas offices.

Information on the economic implication's of commodity programs on irrigated crop production was assembled through a producer survey and a regional economic modeling study. The producer behavioral survey was designed to both provide data used in the analysis and yield additional information on producer behavior and concerns. Subsequently, EA hydrological simulation models(Thorkildsen and McElhaney, 19XX and Wanakule and Anaya 19XX) were used to evaluate the spring flow impact of alternative irrigation scenarios.

Regional Economic Modeling.

A stochastic, mathematical-programming economic model of irrigated agriculture adapted from the work of Dillon, (1991), Williams, (1996), and McCarl et. al(1993), was developed for this area to evaluate the impact of USDA commodity programs on irrigated crop production and water use (Lacewell and McCarl, 1996). The model is a stochastic program with recourse (Dantzig, 1955; Cocks, 1968), similar in structure to the framework presented in Ziari et al. (1995)

Agricultural decision making is modeled as a two stage process. The first stage involves a decision at pre irrigation season which involves an annual decision and are made independent of actual annual irrigation water needs and water supply. These include decisions on: a) irrigation equipment installation, including choice between sprinkler and furrow irrigation; b) farm program participation; and c) irrigated and dryland crop mix. These decisions are made in the face of probability distributions for the outcomes of the second stage decisions (i.e., they are locked in before rainfall and recharge are known and are not subject to "recourse").

The second stage of the economic model deals with choice of water management strategy. Therein, weather is known and crop specific irrigation water application strategies are chosen in accordance with weather (and thus are subject to “recourse”). Thus, irrigation intensity adjusts to weather events, but the crop acreage and furrow/sprinkler/dryland mix do not. The water management strategies within the model strategies included fully-irrigated, less-than fully-irrigated and midyear irrigation abandonment crop water management options for both participating and nonparticipating crops. Data on the performance of these irrigation strategies were specified based on runs of the EPIC crop simulation model (Williams, 1996) as described in (Lacewell and McCarl,1996) or as summarized in (Keplinger et al.,1998) or (McCarl et al., 1998). The second stage decisions permit abandonment of irrigation because of ample rainfall or insufficient profitability.

Weather years were incorporated within the model to reflect the stochastic character of weather which affects irrigated production in the area. Weather-year scenarios were defined for dry, wet, and normal conditions for the study area based on Palmer’s Drought Severity Index values for the period 1895 to 1994. These data indicated that 22 percent of the years were dry, 21 percent were wet, and 57 percent were normal. Three weather events were specified that reflected the historic temperature, rainfall and recharge conditions in region which influence irrigation water needs, yields, and pumping lifts.

Pumping lifts are not endogenous in the model, but rather are specified exogenously from related studies. Here we model the agricultural component of water use, leaving out the municipal and industrial component which is substantially larger. The pumping lifts utilized were derived from the EDSIM model from the work of McCarl et al. (1998) and were derived from a more extensive set of states of nature. The pumping lift data reflected higher pumping lifts under drier conditions.

A key constraint is imposed to cause realistic crop mixes. Namely, dry and irrigated crop mixes must be convex combinations of prespecified crop mixes following McCarl (1982), and Onal and McCarl, (1991). These mixes are those historically observed on dry and irrigated acres by county from 1975 to 1994, plus mixes reflecting farmer opinions about actions if the farm program were decoupled (which has subsequently happened). The latter mixes arose from the BE farm survey.

The model accounted for commodity-program linkages by incorporating Acreage Reduction Program (acreage set-aside) requirements within the model's constraint set, and Price Support Program benefits (commodity-specific deficiency payments) within the model objective function. The model included data on historical maximum participation rates for commodity programs.

Farm Survey and Associated -Economic Analysis.

The farm survey and associated analysis was used to both gather data for the modeling exercise use and validation as well as to assess the: 1) farmer characteristics; 2) the crop mixes changes farmers projected if farm program participation was not an option; 3) the degree of importance of non-price factors on irrigation and farm program participation decisions; and 4) farmer opinions about the effect of farm program participation on irrigation reliance and intensity.

The producer survey was conducted by USDA's National Agricultural Statistical Service, through the Texas Agricultural Statistics Service (TASS). A four-page questionnaire, was pre-mailed to a complete list of farm operations in the study area. Data was subsequently collected via telephone interviews. Out of 1,864 farm contacts, 996 (53.4%) indicated positive cropland and 369 (19.8%) zero cropland. The remaining 499 either refused to participate or were inaccessible or out-of-business. Of the 996 respondents with cropland, 224 employed irrigation.

Aquifer Hydrologic Analysis.

Projected aquifer spring-flow impacts of altered program participation were assessed using hydrologic simulation. Namely hydrologic simulators were run with scenarios that imposed altering irrigation withdrawals (USDA, 1996, Appendix IV). Because of the short timeframes allowed for the study, the simulation for done before model based projections on the exact irrigation withdrawal effects of farm program elimination were available. Consequently a range of pumping levels were simulated. The scenarios involved increased pumpage use by five or 10 percent as well as, decreased irrigation pumping by five, ten, fifteen, or twenty percent from the average.

Hydrologic simulation analyses were conducted using the **Edwards Balcones Fault Zone Aquifer Flow Model- GWBSIM IV** (Thorkildsen and McElhaney, 1992) and the Southwest Texas State Edwards Underground aquifer data center **Lumped Parameter Model for the EA** (Wanakule and Anaya, 1993). GWBSIM IV is a distributed-parameter, finite difference model (depicting many aquifer cells -- based on a grid system). The second model uses an aggregate approach, modeling the aquifer's interconnected hydrology based on a single mass-balance equation (derived from a system of ordinary differential equations using control theory) for each of eight subbasins.

Two models were used for several reasons. First, these models were available and are the two recognized and accepted models for the EA. Second, the first model was calibrated for data years 1978-1989 and the second model for data years 1975-1990. Third, using both models allowed a balanced assessment across two different hydrologic modeling approaches. (For model details, see Thorkildsen and McElhaney, 1992, and Wanakule and Anaya, 1993.)

Additional Approaches for the 1996 Farm Act Appraisal

Evaluation of 1996 for program impacts emphasized the effect on economic, farm structural, institutional, and investment uncertainty factors and groundwater withdrawals as well as aquifer-dependent spring flows. Specifically, evaluation of the 1996 Farm Act emphasized the impact of the Act's production flexibility contract (PFC) payment program, and whether the PFC payment program provides incentives that would encourage increased irrigation water use. The analysis also assessed: 1) the impact of farm land tenure characteristics and a newly established aquifer- management institution, the EA Authority (EAA), on irrigation investment and aquifer withdrawals; and 2) the impact of producer water-supply uncertainty on irrigation well-investment decisions.

Economic/Hydrologic Study Results of USDA's EA BE Analyses

The portion of the USDA BE evaluation results reported here focuses on three different questions.

1) Do the 1990 farm program provisions cause farmers to increase irrigation water usage relative to a no program scenario?

2) Do the 1996 farm program provisions cause farmers to increase irrigation water usage relative to a no program scenario?

3) Do the irrigation water use results found under the farm program provisions related evaluations done under questions one and two imply decreased spring flow and thereby less suitable aquatic habitat for endangered species?

These questions are addressed based on the model results and the survey.

<u>Does the 1990 Farm Program Increase Farm Irrigation Water Usage?</u>

This question is best addressed by looking at a combination of the survey and regional economic modeling results. From a modeling standpoint, this question was addressed by running the regional economic model with and without the farm program under the three different pricing alternatives drawn from the cropping years 1992 through 1994. Since the model uses a stochastic program with recourse formulation which incorporates three uncertain weather states, we get results for each weather state under each scenario. The results on total irrigation water use appear in Table 1 and the results for crop choice are presented in Table 2. In all of these cases, the model results showed irrigation water increases when the farm program provisions were eliminated. The reason for this increase can be explained by considering three factors: crop mix, the way that farm program incentives treat yield increases, and sit aside cropland provisions.

Regarding irrigation choice and crop mix, when commodity programs are eliminated, total irrigated acres increase. The elimination of acreage set-aside provisions causes acres farmed to expand. In addition crop mix changes with cotton, sorghum and wheat acreage reduced, while corn, hay, and vegetable acreage increases. The net result of this crop mix change and farm acreage increase is increased irrigation water use. All three of the crops whose acreage is being increased have larger peracre water uses than the crops and set-aside acres they are replacing. The crop mix substitution occurs because without farm program support payments, cotton, sorghum, and wheat (which are farm program supported) become less attractive economic alternatives than corn, hay and vegetables even though they have higher water requirements. Thus, the economic modeling results imply that the presence of USDA’s 1990 commodity programs in the EA area resulted in producers reducing irrigation withdrawals from the EA.

In terms of water use intensity, the irrigation scheduling regimes chosen by the model generally had yields above the farm program yield. The farm program payment was based on historical crop program yield and historical base acres as dictated by program provisions. Thus, our finding that the farm program did not increase irrigation water use was not surprising. In fact, in the more detailed results presented in Lacewell and McCarl, the per acre water use figures by crop did not markedly change when farm program provisions were added.

These results were backed up by findings in the producers survey. The crop mix that the survey nonparticipant producers indicated they use differed from the farm program mix (as shown in Table 3) in the dimensions indicated by the regional economic model. The participant producer prediction responses were also in the same basic direction as the economic model. Furthermore, the continued reliance on irrigation and types of crop mix adjustments projected by the model mirrored the hypothetical adjustment responses of the participating farmers when responding about what they would do if the farm program was eliminated. The similarity of the economic model results and the producer survey provides a higher level of assurance than either alone.

Also, the large degree of nonparticipation (67%) and similarity of participating and nonparticipating crop mix indicate the economic efficiency of irrigation within the EA region -- even without USDA program benefits. In fact, 75% of nonparticipants indicated that they have not ever considered participating in USDA commodity program. The survey results suggest: 1) producers perceived commodity program benefits as income supplements, not production incentives, 2) historical participating irrigators respond that they apply “about the same” water per acre when participating or not participating in a commodity program, that is, commodity-program participation does not cause water-use changes by crop at the intensive margin, 3) producers indicated their irrigated acreage was unlikely to decline in the absence of USDA commodity programs, 4) program benefits were not found to be the dominant criteria influencing Edwards-area irrigation mix and acreage expansion decisions.

Collectively the analysis reveals: 1) the economic-efficiency of crop irrigation in the Edwards region without commodity program benefits; 2) that Edwards producers will continue to plant and irrigate program and non-program crops without program benefits; and 3) that market-economic factors dominate Edwards-area irrigation decisions (Schaible, 1996).

Does the 1996 Farm Program increase Farm Irrigation Water Usage

The economic and producer behavior impact of the PFC payment program on irrigation water use for the study area included using both the economic model and producer survey results from USDA's initial BE analysis. PFC payments under the 1996 Farm Act are decoupled from (not tied to) actual crop acreage or level of production. The PFC program then, characterizes a "no commodity program" or "without program" scenario. The economic behavior exhibited under the "no commodity program" scenarios for the initial BE analysis then, provide an appropriate indicator of market-based behavior under the PFC payment program.

The question of what happens to irrigation water use with the 1996 farm program revisions depends on one's frame of reference. In particular, one can look at the question from the standpoint of a no farm program or one can look at the question from the standpoint of the 1996 program replacing the 1990 program.

If one looks at the 1996 farm program results with respect to a no farm program scenario, then inference from the modeling and survey based economic analysis indicates that the decoupling of farm program payments from production lead to no change in farm water use. In particular, this would involve a comparison of what happens in the model: a) without the farm program; versus b) what happens without the farm program when a set of fixed income payments are paid that are independent of production. Provisions of the 1990 Farm Act did require that a commodity crop be grown and typically that there be set-aside or idle acreage for a producer to collect the deficiency payment. This requirement however, would not materially affect the farm's crop mix since it has basically the same amount of program crop acres grown after the 1996 program as before. From the standpoint of the above economic analysis, one can only conclude that the results would be virtually the same. However, there is one factor which might have an influence. Namely, the PFC payments might be used to fund irrigation system investment and perhaps increased irrigated acres might result. Thus, the BE needed to investigate the decision as to whether not the revised farm program(1996) provides incentives to increase irrigation investment. This will be discussed below.

A totally different new way of looking at the question: What did the 1996 farm program revision do to relative to the water use under the 1990 farm program. Under this viewpoint, provided that farmers could increase their water use, then it would appear that the revision from the 1990 to the 1996 farm program would increase water use. This implied a need to investigate whether farmers actually could increase their water use. This question again will be addressed below.

Suppose we consider whether farmers could increase water use. Bringing set aside acres into production and possibility shifting to higher water use crops could result in more water pumped for irrigation. However, institutional factors make this questionable. The EA Authority (EAA), formally established on June 28, 1996, requires that all existing users file for a water-use pumping permit based on their proven historical annual withdrawal. The historical period actually starts and ends over a time period before the 1996 farm program revision. Under the EAA authorizing legislation (Texas Senate Bill 1477) no new wells can be drilled without a permit, and new well permits will be issued on an “interruptible” basis with pumping permitted only if sufficient water is available. The EAA is now in the process of issuing permits for water rights and has applications in excess of the legislative mandates for future Edwards water use. In particular, Texas Senate bill 1477 requires the EAA to limit total annual pumpage, initially to 450,000 acre feet or less, but after January 1, 2010 to 400,000 acre feet or less; and to reduce aquifer withdrawals even further if drought conditions threaten the springs and endangered aquatic species. No permits to drill new agricultural wells have been issued. Given that pumpage by existing users already surpasses aquifer withdrawal limits, the EAA then, creates sufficient economic uncertainty such that investment in new wells is very unlikely. Also, water would be available for pumping only in “wet” years when it is least needed.

Let us now turn to the question of whether or not irrigation investment would be encouraged by PFC payment. First, in order that PFC payments be invested in new wells the farmer would either have to have a EAA issued permit or would have to purchase water through the water rights market which Senate bill 1477 facilitates. Studies in other arenas indicate that agricultural water rights purchases will be highly unlikely as the price of is likely to be substantially higher than the agricultural water values (McCarl et al.[1998]). Land tenure results from the survey also cast doubt on the likelihood that PFC payments will become a source of investment capital for very many new irrigation wells (Lacewell and Schaible, 1997). Nearly 50% of the PFC payments will go to cash-leased operators, with an average annual payment of $3,500 (Table 4). Under a cash/case arrangement, the landlord, who is responsible for irrigation well investments, receives no PFC payment. Thus, there is no program incentive encouraging the cash rental landlord to invest in costly new irrigation wells (which can approach $100,000). For share-rental farms, the average annual PFC payment is $1,800 (Table 7), with 87% of these farms receiving less than $3,000 and only 12 farms receiving more than $10,000 (Lacewell and Schaible, 1997). Landlords for these farms would receive only about 25 to 33% of the annual PFC payment which would again make in investment unlikely.

Thus, because of water allocation institutions and the investment incentives under prevailing land tenure systems, it is unlikely that expanded irrigation well investment would occur because of the 1996 farm program provisions. The conclusion reached is that the farm program revision 1996 coupled with other institution leaves wateruse unchanged.

Hydrological Implications of Farm Program influences on Agricultural Pumping

______Hydrological analysis of the impact of changes in irrigation pumpage on spring flows provides additional insight on the effect of farm programs on the habitat for aquifer-dependent, threatened and endangered aquatic species. Results from the hydrological models demonstrate that changes in EA irrigation pumpage do not have a large effect on aquifer spring flows at Comal or San Marcos Springs (Table 5). The 1996 BE finds that a one percent increase in irrigation water pumping results in approximately a one cfs (cubic-feet per second) flow change at Comal Springs (against a base level spring flows well in excess of 200 cfs) and a 15 percent change in irrigation results in a one cfs flow change at San Marcos Springs (against a base spring flow in excess of a 100 cfs [USDA, 1996, p. 81]).

Results from both hydrologic models predict that reductions in irrigation pumpage reduce the time that spring flow levels would remain below "take levels" established for aquifer-dependent aquatic species by the FWS but that low flow levels would still be attained.[5] Hydrologic simulation indicates that a 20 percent reduction in irrigation pumpage reduces the time period that Comal Springs are at or below 200 cfs by two months, while there is no significant change in the time that flows at San Marcos Springs are at or below 100 cfs. In establishing the FWS take levels, it was recognized the "it may be possible for flow levels to fall below these levels for short periods of time, but not for extended periods without causing take, jeopardy, and/or adverse modifications" (U.S. FWS, 1996, p. 17). Reductions in irrigation pumpage alone do not solve the low flow problem. Such reductions may become more important when they are part of a comprehensive aquifer management plan.

The location of aquifer withdrawals also has an important influence on changes in spring flows (Thorkildsen and McElhaney, 1992), in part because of the Knippa Gap -- a "groundwater flow restriction resulting from fault set, lithologic and petrologic conditions within the aquifer" near the Uvalde-Medina county line (USDA, 1996, pp. 81-82). Reduced pumpage in the far western EA region (Uvalde county, which accounts for 52 percent of Edwards irrigated acres) increases spring flows by much less than pumpage reductions elsewhere (by only 34 percent of the pumpage reduction with the full effect taking up to nine years). However, similar reduced pumpage in Medina county (which accounts for 37 percent of Edwards irrigated acres) increases spring flows by approximately 67 percent of the reduced pumpage (Keplinger et al report similar results).

Summarizing, the economic analysis indicates that the USDA programs in 1990 did not increase irrigation water use and that the 1996 program coupled with EAA actions would not increase irrigation withdrawals from the aquifer compared to a no program scenario. In turn, the hydrologic simulation results, suggest that USDA programs have not negatively impacted spring flows at Comal and San Marcos Springs, and therefore have not adversely affected the habitat of aquifer-dependent threatened and endangered aquatic species.

Potential EA Conflict-Resolution Options

Even though BE study results show that USDA programs do not encourage agricultural use of Edwards water, groundwater withdrawals for irrigated agriculture remain an important component of the EA human/species water-resource conflict. As part of a comprehensive conservation/aquifer management program, reduced irrigation could become an important part of a larger shared burden across all users.

Recent research efforts demonstrate the potential for several EA conflict-resolution options. A recent cooperative research study involving USDA, Texas A&M University, and the Texas State Soil & Water Conservation Board proposed a plan of action for the region (USDA-NRCS, et al., 1996). The plan calls for several actions and provides water savings estimates for each. In particular the plan suggests: 1) a regional brush management/rangeland restoration program designed to increase rainfall runoff and percolation that is estimated to increase annual water recharge by 40,000 acre-feet after 10 years; 2) a regional program to improve irrigation technology and farm-level water management that is estimated to reduce pumping by 68,000 acre-feet annually; 3) an urban water conservation/wastewater reuse program that is estimated to conserve up to 17,000 acre-feet annually; and 4) a regional program encouraging installation of water/sediment control structures that would retard runoff that is estimated to enhance annual aquifer recharge by 16,000 acre-feet after 10 years.

Recent research conducted at Texas A&M University on the dry year irrigation suspension program highlights the merits of critical water year management as an EA conflict-resolution alternative.

Keplinger et al. (1998) and McCarl et al. (1996) evaluated the economic and aquifer water-supply benefits of paying farmers not to irrigate in dry years, thereby leaving more water for urban, industrial, and springflow water users. Results of this research suggest that significant water savings could augment spring flows in dry years, but that these water savings would vary depending upon option price, location of reduced aquifer withdrawals, and program implementation timing. The authors found that offering farmers in the eastern EA $10 per acre (plus perhaps some premium for incentive) not to irrigate would save about 37,000 acre-feet of water which would contribute about 15,000 acre-feet (or 28.3 cfs of flow) to flows at Comal and San Marcos Springs during a dry year. At $60 per acre, they estimate that 87,600 acre-feet would be saved contributing more than 35,000 acre-feet (or 66.86 cfs flow) to spring flows during the dry year. Western results yield substantially less spring flow due to the Knippi Gap flow constriction discussed above.

Finally, McCarl et al's (1998) results indicate large economic benefits to a flexible and effective water marketing program for the Edwards region, allowing for both annual and/or permanent water transfers. Such a market is envisioned under Senate bill 1477 and would provide an economically efficient basis for transferring water use among regional entities that would provide for both short- and long-term conflict resolution. There are third party effects that have not been resolved.

Study Conclusions

The impact of USDA commodity programs under the 1990 and 1996 Farm Act on the EA irrigation were investigated in light of market economics and the current institutional structure. The findings of an economic model collaborated by a farm survey were that the farm programs collectively lowered, rather than increased, total irrigation water use. This coupled with a hydrological analysis show that farm programs increased aquifer spring flows rather than decreasing them. Consequently, these programs most likely had a positive effect, and did not have a negative effect, on aquifer-dependent aquatic species and their habitats.

Results from both USDA's Biological Evaluation studies and Texas A&M University research demonstrate that the EA total human pumpage/spring flow/species water-resource conflict with agricultural/urban dimensions and there is not a USDA program/species conflict. Resolution of the EA conflict will need to involve both short- and long-term solution strategies. Conservation and aquifer recharge enhancements , critical year water management and water marketing can all help provide long-term conflict-resolution strategies. Ultimately, resolution of this conflict will depend upon the effectiveness of EA water management and the willingness of local parties to implement both short- and long-term solution strategies.

(Page for Figure 1, page 28)

Table 1. Effect of Weather Year, Price Scenario, and Availability of 1990 USDA Commodity Programs on Regional Irrigation Water Use from the EA

	Weather Year Scenario								
	-----------DRY-----------			---------NORMAL--------			-------------WET------------		
Price Year Scenario	With Program	Without Program	Difference	With Program	Without Program	Diffenence	With Program	Without Program	Difference
	(1000 acre feet)								
1992	174.82	181.47	+6.65	152.41	167.98	+15.57	129.24	146.87	+17.63
1993	173.95	181.47	+7.52	165.01	173.21	+8.20	135.54	149.48	+13.94
1994	178.14	181.47	+3.34	154.75	167.98	+13.23	130.96	146.87	+15.91

Source: Lacewell, R. D. and B. A. McCarl, 1996, Table 1.

Table 2. Irrigated Cropland Use under Alternative Crop Prices, With and Without 1990 USDA Commodity Programs (for Bexar, Medina, and Uvalde Counties)

Crop	----------With Commodity Programs---------- 1992 crop prices	1993 crop prices	1994 crop prices	Without Programs (under 1992, 1993, or 1994 crop prices)
	(in 1000 acres)			
Irrigated:				
Cotton	10.9	11.2	10.8	5.7
Corn	24.7	23.8	25.6	29.0
Sorghum	11.4	11.4	11.9	4.5
Oats	3.0	3.0	3.0	10.9
Hay	11.2	11.2	11.2	16.2
Wheat	7.9	8.2	8.2	2.1
Vegetables	10.8	10.8	10.8	13.8
Other*	3.0	3.0	3.0	3.3
Subtotal:	82.9	82.6	84.5	85.6
Set-Aside Acres	2.7	3.0	1.1	0.0
Total	85.6	85.6	85.6	85.6

* Other crops category include sesame, soybeans, and peanuts.
Source: Lacewell, R. D. and B. A. McCarl, 1996, Tables 2.1 - 2.3. (Statistics here were rounded to the nearest hundreth acre.)

Table 3. Irrigated Acres by Crop for Survey Respondents by Program Participants and Nonparticipants

1994 Irrigated Cropping Patterns											
	Respondant 1994 Irrigated Acres			Acres of EA 1994 Farm Program Participants			Acres of 1994 Nonparticipants		Anticipated Land Use by Participants under Farm Program Elimination[2]		
										Change from 1994 Reported	
Crop	All Acres Farmed	% of EA Regional Acres[2]	Crop Share in Crop Mix	All Acres Farmed	Crop Share in Crop Mix	Acres Enrolled in Program	All Acres Farmed	Crop Share in Crop Mix	Anticipated Total Acres to be Farmed	Acres	% Change (by crop)
Corn for grain	24,828	24.1%	42.4%	17,441	47.4%	14,696	7,387	33.9%	18,648	+1,207	6.9%
Cotton - pima	491	0.5%	0.8%	491	1.3%	391	0	0.0%	420	-71	-14.5%
Cotton -upland	6,460	6.3%	11.0%	5,000	13.6%	4,770	1,460	6.7%	5,141	+141	2.8%
Oats	4,430	4.3%	7.6%	1,653	4.5%	475	2,780	12.8%	1,838	+185	11.2%
Peanuts	990	1.0%	1.7%	990	2.7%	990	0	0.0%	915	-75	-7.6%
Sorghum	4,109	4.0%	7.0%	2,970	8.1%	2,388	1,139	5.2%	2,847	-123	-4.1%
Wheat	2,152	2.1%	3.7%	1,614	4.4%	1,162	538	2.5%	1,709	+95	5.9%
Hay	4,986	4.8%	8.5%	853	2.3%		4,133	19.0%	828	-25	-2.9%
Vegetables	5,209	5.1%	8.9%	2,149	5.8%		3,060	14.0%	2,165	+16	0.7%
Fruit	553	0.5%	0.9%	106	0.3%		447	2.1%	106	0	0%
All Other	4,394	4.3%	7.5%	3,550	9.6%		844	3.9%	1,094	-2,456	-69.2%
Total	58,605	57.0%	100.0%	36,817	100.0%	24,872	21,788	100.0%	35,711	-1,106	-3%

1 Across the whole EA region participating irrigators reported 63,749 acres of cropland and nonparticipating irrigators reported 39,072 acres of cropland, for a total of 102,821 cropland acres.

2 Results here identify what crops and acres 1994 participants indicated they would have irrigated had USDA commodity programs not existed in 1994. These irrigated acres, however, do not include those irrigable acres that were enrolled in a USDA commodity set-aside program.

Source: G. D. Schaible, 1996, Table 6.

Table 4. Number of Farms, Acres Enrolled, and Payment Characteristics of Edwards-Area Farms Participating in USDA's 1996 Production Flexibility Contract (PFC) Payment Program, By Farm Tenure Arrangement

		Farm-Tenure Arrangement			
	County	Owner-Operator	Share Rental	Cash Lease	Total
Number of Farms Participating	Bexar	153	202	218	573
	Medina	157	232	217	606
	Uvalde	85	24	162	271
	Total	395	458	597	1,450
PFC Participating Acres	Bexar	12,608	15,213	14,137	41,958
	Medina	26,028	29,585	26,486	82,099
	Uvalde	29,045	5,665	40,025	74,735
	Total	67,681	50,463	80,648	198,792
Expected PFC Payments in $	Bexar	201,050	203,196	187,672	591,918
	Medina	484,567	513,975	513,777	1,512,319
	Uvalde	780,908	114,900	1,402,722	2,298,530
	Total	1,466,525	832,071	2,104,171	4,402,767

Sources: Guy,P., 1996; and R. D. Lacewell and G.D. Schaible, 1997, Tables 2-4

Table 5. Maximum Changes in Spring Flows at Comal and San Marcos Springs due to a Change in Irrigation Pumpage from the Edwards Aquifer

	Change in Springs Flows[1]		
	Irrigation Pumpage	Comal Springs	San Marcos Springs
Scenarios Using GWSIM IV Model[2]:			
	10% Increase	-12 cfs	0 cfs
	5% Increase	-6 cfs	0 cfs
	5% Reduction	+7 cfs	0 cfs
	10% Reduction	+12 cfs	0 cfs
	15% Reduction	+18 cfs	+1 cfs
	20% Reduction	+23 cfs	+1 cfs
Scenarios Using the SWT Model[3]:			
	5% Increase	-6 cfs	-2 cfs
	20% Reduction	+24 cfs	+9 cfs[4]

1 Change in spring flow estimates reflect the maximum change that occurred within the simulation period due to the specified change in irrigation pumpage. Average annual flow for Comal Springs (from 1928 to 1989) was 284 cfs (cubic feet per second), and for San Marcos Springs, average annual flow (from 1956 to 1994) was 170 cfs (U.S. FWS, 1996).

2 GWSIM IV to the analysis conducted using model by that name developed by the Texas Water Development Board (Thordildsen and McElhaney, 1992) over the simulation period 1978-89.

3 SWT refers to the analysis conducted sing the model developed at the Southwest Texas State Edwards Underground Aquifer Data Center (Wanakule and Anaya, 1993) over the simulation period 1975-90.

4 For San Marcos Springs, the +9 cfs maximum flow change occurred during the monthly simulation periods October 1985-February 1986 (when simulated spring flows averaged 112 cfs) and September 1990-February 1991 (when simulated spring flows averaged 85 cfs). These larger spring flow impacts, ranging from 8.0 to 10.6 percent, relative to the +1 cfs impact from the TWDB analysis, are likely (in part) due to differences in hydrologic modeling approaches. The TWDB analysis evaluates the aquifer's interconnected hydrology from a micro, "aquifer cell" perspective, while the TWRI analysis was conducted from an aggregate, "aquifer subbasin" perspective.

Source: USDA, 1996, Tables 9 and 10 (pages 80 and 83, respectively).

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Responses to the associate editor's comments

We agree this paper makes a nice contribution toward a policy issue. We have included a relative reallocation of material in the paper with increased space devoted to model description and analysis results with less direct reliance on the producer survey. However our revision is more along lines of your abstract comments. We focused more on the problems we were analyzing rather than the methods used. Thus, we reorganized the results section so it treated issues by problem rather than by analysis method. Messy individual components of the methodology are not the focus in the results section now, but rather the focus is the questions in we draw implications across all results. This makes for somewhat less reliance on the survey and places all of the methodologies used in a more holistic light devoted toward analysis of the questions posed in the paper.

We've expanded coverage of the economic model and its components. We have not entered a big mathematical description as we have a paper on water policy issues that recently received very favorable recommendation from water resources research and could easily be timed to be published in the same issue. That paper contains a full mathematical description of the whole EDSIM model including the hydrologic linkage and nonagricultural parts and its thus substantially broader than a model that would be included in this paper. We do not think that it's desirable to use scarce journal pages to present the same thing twice. Also, references are included that have detailed model descriptions.

Your point on the abstract is well taken. Basically we took that comment as a call for a more cautiously constructed abstract that only presented results pertinent to the paper titled and drew implications directly derived from paper content. We have the altered the abstract in such a fashion.

A point arising from your comments on the abstract we wish to respond to regards EAA existence and the need for this paper. At the time this analysis was undertaken USDA was actually under suit by the Sierra Club pertinent to the farm program effects on the farmers water use from the aquifer. This suit was proceeding regardless of the status of the EAA which was actually authorized at the time by state legislature but still in the political process of becoming approved. Thus, to say that EAA existence precludes any need for analysis is a bit strong. We feel that this study was justified. The other statement we should make is that this paper has spent almost a year and a half in review and things do change over time. In particular, at the time the paper first entered review, the EAA was still under a political cloud as to whether it would ever exist or not. Finally we think it is an important finding to know that the farm program has not increased water use results and thereby farmers access to water rights.

The section on findings of economic model analysis was also mentioned by you. This section has been re-oriented toward responding to the questions as set above with more treatment of the economic modeling results and several more economic modeling results introduced.

Comments on findings of the producer behavior economic analysis. This section has been re-oriented more around the questions posed in the paper with pertinent results drawn from the tables. Strong conclusions are not now being made solely based on survey results.

Other concerns

The model actually does have irrigation investment components as now explain in the model description part of the paper. However, in the analysis we limited potential irrigated acreage to current irrigated acreage. The model never irrigated less acreage than the current level. We also allowed investments to change the sprinkler furrow mix with the amount of sprinkler land allowed to increase but furrow land could not. The optimal solutions and irrigation system mix were static throughout the analysis. The current level is somewhat limited based on access to water, and suitable land for irrigation.

Regarding your question about set-aside land and base acreage restrictions, we have included coverage of these issues in the paper. We do not greatly deal with the base acreage restrictions as farmers were able to come into an out of the program to build base but we do deal with the set-aside acres in the model.

We have reduced the conflict resolution section substantially.

We are deeply appreciative to you and the reviewers for the time dedicated in helping us improve the paper. We must agree it has dramatically benefitted from your insight and patience. For all the authors I can say we are indebted.

Sincerely,

Glenn Schiable
Hopefully this is a more diplomatically responses worded response letter.

Responses to reviewer No. 1

Overall response

We have totally revised the results section to address questions not methods. You had a good point this leads us to far fewer statements solely based on one method or the other and provide what we think you will find less potentially questionable conclusions. We have also focused the results discussion more on the overall paper theme and spend less time addressing the motivation of the survey participants. We think this improved the quality the paper presentation. We hope that you agree.

Technical soundness

We have tried to expand the discussion of the methods and have greatly expanded the referencing to places where the economic methods are discussed in detail in a) peer reviewed journals (where possible), b) Ph.D. theses, c) station reports and d) USDA publications (a number of which were peer reviewed). We have not entered a tableau based presentation of the economic model as a related analysis by McCarl et al(see the 1998 reference) has recently received very favorable review at Water Resources Research (and could possibly be published in the same issue or probably in an earlier one). The paper has an algebraic model within it. Note the analysis in that paper is much broader, does not concentrate on the same issues as this one, and the model therein contains this one plus much more in a rather extensive summation notation based model discussion. We enclose a copy of this manuscript for the reviewers perusal.

B. Base case selection.

We've taken this point into major consideration in the revision. We focused on the 1996 farm bill both in terms of its decoupling effects and its effects relative to no farm bill in the revised paper. This does provide more clarity and insight.

D. producer behavioral ...

We maintain much of the discussion on the sampling method. However we have taken the sum total of your comments as a call for a restructuring of our results section relying much more upon the analysis of questions and drawing implications across the various methodologies used rather than presenting results by methodology. We believe this greatly strengthened the paper.

In this revision, we have taken your advice and somewhat diminished our reliance on the survey results and we've also introduced some more of the reasoning and results from our modeling, institutional and economic analyses.

We have constrained our treatment more to things that directly pertain to the overall question of what the farm program has done to water use. Thus, we are not drawing as many conclusions about principal motivating factors impacting decisions and the other points in your comment. This led to less time with Likert scale results and the other results that you draw attention to in the paragraph on likert scale interpretation.

Regarding the structure of participating vs nonparticipating farmers, we've removed this section from the manuscript and completely re-oriented the section in question. We no longer state goals like assessing differences between participating and nonparticipating irrigators. This and other similar comments helped us to focus our presentation more on the overall theme of the paper. We believe this helps overall paper communication, as you eluded to in your comments.

We have completely revised the table 3 headings.

E. interpretation of the results.

The review comment from the bottom of page 2 through page 3 stimulated us to make a substantial revision in the overall structure of the paper. Most of the sections commented on are completely restructured. Thus we will respond to just one or two of the major points in the comments in this section giving you a flavor of the types of changes.

Irrigation intensity -- We've now included some discussion about how the farm program would not increase per acre water use largely due to the lack of influence of the farm program on yields. This was done in the section on the 1990 farm bill analysis effects on farm water use

We've removed much of the discussion about what is relatively important in producers decisions and reduced some of the wording that the reviewer found problematic

We have now clarified the argument about the 1996 farm bill and water use. We say that because the 1990 farm program in effect reduced water use and the Edwards authority will not readily allow water use to increase, then the collective action of the USDA programs is a reduction in water use. We actually believe that the decoupling in the 1996 farm program could increase water use over the 1990 farm program and state this explicitly in the text. However we also state that the land tenure arrangements coupled with the EA authority make this water use expansion unlikely.

The conclusion about pumping not increasing was based largely on institutional rules and land tenure but we confirmed the study is still relevant. At the time this analysis was done USDA was actually under suit from the Sierra Club even though the EA authority had been authorized. Thus, we believe society had a need for the study and we thought that it was appropriate to do. We also feel that it is an important finding that farm program have reduced water over a no farm program scenario. Thus, we think the study is justified regardless of institutional structure.

Spring flow concerns. We have taken a less definitive stance that agricultural water use reductions would not affect spring flow. We do show their marginal effect on the time spent below the 200 cfs take level is reduced. We do not think we can necessarily conclude two months is a short time. However we are dealing with reductions in pumping because of USDA programs so that these results would lessen the time that it spends below 200 CFS.

Organization

We have rewritten the manuscript and tried to shorten and more cohesively integrate the conflict resolution section making it less prominent.

We’ve altered the noted ESA discussion.

Responses to review er No. 2

The producer behavioral economic analysis section has been re-oriented . In the reorientation we've taken your comment to heart.

We now have a paragraph summarizing what these findings mean for the impact of USDA programs on endangered species in the section were we address those issues.

Also we do have more analysis throughout the document of what results mean and less listings of survey and or economic model results.