

## **An Evaluation of the 1997 Edwards Aquifer Irrigation Suspension**

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### **ABSTRACT**

In early 1997, the Texas Edwards Aquifer Authority implemented a pilot Irrigation Suspension Program (ISP) with the objectives of increasing springflow and providing relief to municipalities during drought. Irrigators were paid \$2,350,000 to suspend water use. The price paid per suspended acre was substantially higher than regional lease rates and land prices would imply. The region experienced a wet Spring, but estimates show if conditions had been dry, that suspending irrigation would have substantially reduced pumping and augmented critical springflow. Effects on the local economy appeared to be small. We evaluate the ISP and two alternatives: (1) subsidizing more efficient irrigation technology and (2) buying land. The irrigation suspension is a more cost-effective source of critical water than subsidizing more efficient irrigation because it can be put in place only when water is most needed. But land purchases would reduce program cost if the bid levels remained at the level observed in the 1997 program.

(KEY TERMS: drought management, economics, water demand, water management, water policy/regulation/decision making, water resources planning, Edwards aquifer, dry year option.)

## **An Evaluation of the 1997 Edwards Aquifer Irrigation Suspension**

Early in 1997, the Edwards Aquifer Authority (EAA) implemented a pilot Irrigation Suspension Program (ISP) for the Edwards Aquifer (EA) region in Texas that paid farmers to not irrigate for the 1997 cropping season. The program was designed to raise EA levels, increase springflow, and provide municipalities with relief in case of drought. Similar programs have been tried elsewhere in the West (Michelson and Young, 1993; Colby, 1991). Important characteristics of this ISP are that (1) it applied to groundwater, whereas most similar programs have applied to surface water, and (2) it was administered in the absence of fully defined water rights, and (3) water for springflow to support endangered species was an important motivating factor. This paper

- 1) provides historical context leading up to ISP implementation;
- 2) describes the program;
- 3) reports results from a quantitative analysis of the potential impacts in terms of water use, crop mix, EA elevation, springflow, return flow; and impacts on the local economy;
- 4) provides a qualitative analysis of program design; and
- 5) analyzes the cost of the ISP in comparison to alternative approaches designed to achieve water use reductions.

### **BACKGROUND**

The EA supports a diversity of uses. At present, it supplies virtually all the municipal and industrial water for the greater San Antonio region (the 10th largest city in the United States). West of San Antonio, the EA supports an irrigated agricultural economy, while to the northeast, EA waters support springflow through two large springs (Comal and San Marcos). These springs are a significant source of flow in the Guadalupe and Blanco rivers, where the water is utilized for agricultural, municipal, and industrial uses. The springs and rivers are also

tourist attractions and support a significant recreation industry. The EA also supports a unique biological community largely in the region of the springs. Five EA species are currently listed as threatened or endangered by the United States Fish and Wildlife Service (USFWS).

Springflow is highly correlated with EA elevation, especially for Comal Springs, the larger of the two springs. EA elevation is determined by initial water stock, recharge, and pumping. Results in Keplinger et al. (1998b) indicates that a one foot increase in beginning year EA elevation at a San Antonio reference well increases Comal springflow by about 2,650 acre-feet over the course of a year. The same study suggests that one acre-foot of recharge (which occurs mainly in the west) increases Comal springflow by .08 acre-feet during the year of recharge, while one acre-foot of pumping in the eastern portion of the EA reduces Comal springflow by about .40 acre-feet during the year water was pumped. Although the relationships over time and space are complex, examination of annual EA recharge, pumping, and springflow, as depicted in Figure 1, reveals the positive correlation between recharge and springflow, and the inverse relationship between pumping and springflow. Increasing withdrawals from the EA over several decades by agricultural, municipal, and industrial interests have led to declining springflow, particularly during dry years.

Until recently, withdrawals from the EA were largely unregulated, and EA water use suffered from misallocation due to common property ownership (McCarl et al.,1999). Reduced springflow caused by withdrawals produced negative externalities to springflow and downstream interests. Under the prevailing 'right of capture' doctrine there were few options whereby these interests could secure additional water or protect existing levels of springflow. As a result, a number of challenges to EA management were made. One suit, *Sierra Club v. Babbitt*, filed in 1991 and upheld in federal court in 1993, alleged that the USFWS was not performing its duty under the Endangered Species Act (ESA). That action was as a major factor promoting the introduction, passage, and ultimate implementation of Senate Bill 1477 (SB1477). SB1477 was designed to improve EA management by creating the EAA, which was given powers to set overall pumping limits; adjudicate, define, and monitor individual pumping rights; collect fees,

and promote water marketing. Initially passed in 1993, legal challenges upheld full implementation until June 28, 1996. The EAA is now in the process of setting up a water rights permit system in accordance in SB1477.

During 1996, the region experienced a drought. Comal Springs dropped to its lowest level since 1990 at 79 cubic feet per second (cfs), well under the USFWS determined jeopardy level of 150 cfs. A number of drought management plans were implemented, but these plans were insufficient in achieving springflow objectives. Another idea that emerged to augment declining springflow was to pay farmers not to irrigate.

Approximately 80,000 acres of cropland are irrigated using EA waters. Between 1982 and 1996, irrigation from the EA is estimated to have averaged 127,000 acre-feet annually (USGS, 1996). Agricultural water use is highly sensitive to weather conditions as Figure 2 suggests. For six of these fifteen years, agricultural water use topped 170,000 acre-feet. Irrigation use is estimated to have been 180,800 acre-feet in 1996. These figures suggest that considerable amounts of irrigation water pumped from the EA could potentially be diverted to other uses, especially during water-short years.

In 1996, the Edwards Underground Water District (forerunner of the EAA) and the Texas Water Development Board organized investigations into the issues and opportunities of initiating a Dry Year Option (DYO) program for 1996 (Rothe, 1996; McCarl et al., 1997). A report was prepared by an engineering consulting firm that outlined elements of a pilot DYO in sufficient detail for legal counsel to draft an option contract (Rothe, 1996).

In Fall of 1996, spurred on by a Court Order (Bunton, 1996), the San Antonio Water System (SAWS) and the EAA expressed renewed interest in developing a DYO for the 1997 season. The concept that emerged involved contracts between irrigators and a purchasing entity. Because water rights were not established nor were most pumps metered, payment was to be based on the number of acres withdrawn from irrigation. A program, officially designated the ISP, was developed by the EAA. ISP funding was sought from regional water utilities who in turn were provided relief under the EAA Interim Critical Period Management Rules (1996). In

December 1996, an agreement between the EAA and funding agencies was reached. A schedule of public hearing, notices in newspapers, requests for submission of offers, and evaluation and selection of offers was promptly executed in order to implement the program for the upcoming 1997 crop season. Contracts between the EAA and irrigators were executed on January 15, 1997. Additional background material is provided in Keplinger et al. (1998a, 1998b). A detailed description of the EA and region is provided in Grubb (1997); legal issues are discussed in Shenkkan (1997).

### **ISP DESIGN AND ENROLLMENT**

The 1997 Pilot ISP was designed “to cause suspension of irrigation with Edwards Aquifer water of at least 10,000 acres in 1997” and in doing this “(1) to increase the water levels in the aquifer; (2) to help prevent or delay cessation of springflow in the Comal Springs and the San Marcos Springs; and (3) to obtain useful data relating to the effect [of] partial suspension of irrigation withdrawals on the Aquifer” (EAA, 1996). The three key entities involved in the 1997 ISP were: (1) participating irrigators, (2) funding agencies, and (3) the EAA; which correspond to sellers, buyers, and administrators of the program, respectively. Here we review a number of features of that program.

#### **Selection Criteria**

Eligible irrigators were invited to submit sealed bids to the EAA for entire farm units. Bid selection was based on four criteria: (1) location of well and strength of the hydrologic connection to Comal Springs, (2) irrigation water requirements based on crops produced in 1995 and 1996, (3) irrigation equipment used, and (4) commitment to plant a dryland crop on the proposed acres. The first three of the four criteria were aimed at tilting selection in favor of those irrigators whose suspension of pumping would have the greatest per acre impact in producing springflow at Comal Springs. The final criterion was included to help protect agriculture-dependent industries and community interests. A score from 0 to 10 (or sometimes 11) was assigned for each criteria, higher scores being more favorable. Scores of the four criteria

were summed to produce a total score. Per acre bids were then divided by total score to arrive at final scores and ordered, with lower scores being more favorable.

### **Participation and Enrollment**

The EAA received 125 offers, 120 of which were found to meet requirements of the program. Per acre bids ranged from \$116 to \$750 per acre, with the median bid at about \$300. There was relatively little variation in total point scores assigned by the selection criteria, thus, final scores were determined mainly by the bidders' per acre bids. Bids were accepted until the amount of program acreage reached the 10,000 acre goal. This resulted in the EAA accepting offers on 39 farm units with 10,067 irrigable acres. Subsequent verification of enrolled acreage reduced the number of enrolled acres to 9,669. Participating farm size ranged from 45.3 to 1,269 acres. Per acre bids of accepted offers ranged from \$116 to \$300, and total amount of bid (per acre bid times participating acres) ranged from \$12,495 to \$304,560. Median values for bids, and total payments for successful bidders were \$240, and \$45,617 respectively. Payments to all farmers totaled \$2,295,132.

The EAA was successful in soliciting pledges from approximately 32 water utilities and other large pumpers of approximately \$2,350,000. Pledges were proportional to share of 1995 pumping. Funding was dominated by the San Antonio Water System, which accounted for 77% of 1995 water use. Another large water utility, Bexar Metropolitan Water District, accounted for about 10% of use, while all other utilities pumped 1% or less of the total.

### **ESTIMATES OF HYDROLOGIC AND ECONOMIC EFFECTS**

We constructed ex poste estimates of the impacts of the ISP in terms of: (1) changes in crop mix, (2) decreased pumping by irrigators, (3) increased EA elevation, (4) increased springflow, (5) changes in return flow, and (6) effects on the local economy.

Spring 1997 was wet in the EA region, however, anticipated effects are also estimated for typical dry, average, and wet conditions. To assist in ISP evaluation, a questionnaire was administered to participating ISP irrigators that included questions on how the ISP might have changed irrigators' crop mixes and purchases, and opinions regarding administration of the

program and adjudication of pumping rights. Fourteen of the 39 program irrigators participated in the survey. Tabulation of questionnaire results is included in Keplinger et al. (1998a).

### **Changes In Crop Mix**

Interview comments by irrigators indicated that changes in the 1997 crop mix were made as a result or in anticipation of an ISP. Comments reflect a shift away from corn and peanuts in favor of sorghum and wheat. Actual changes in crop mix were determined from EAA data on irrigators' information sheets and verifications of 1997 cropping activities for all participants (not just those in the survey). Figure 3 displays ISP participants crop mixes for the years 1995 to 1997 and reveals substantial increases in sorghum and wheat acreage, a substantial decline in corn acreage, and the elimination of peanuts, vegetables, and cotton.

### **Reduction in Irrigation Water Use**

Two questions can be asked regarding reduced irrigation resulting from ISP implementation: (a) what reduction might be expected based on the probability of experiencing wet, normal, or dry years and (b) what was the actual reduction of irrigation as a result of the 1997 pilot ISP implementation?

Application of water for irrigation is highly dependent on weather conditions. Table 1 reports estimated water use reductions based on an analysis of the past fifteen years of irrigation activity in the EA region using USGS and TWDB statistics. The third column of Table 1, 'Pumping Reduction', is developed by multiplying average per acre usage by the number of acres suspended (9,669) to produce an estimate for the amount of reduction for the three weather scenarios. Since each weather scenario occurs one third of the time, expected or average water savings is estimated at 15,470 acre-feet.

Addressing the second question, the EA region experienced very favorable weather condition for dryland cropping in Spring 1997. Rains were of near ideal spacing and intensity and some farmers reported their best yields ever. Irrigators in the region not enrolled in the ISP were estimated to have used .4 acre-feet of water per acre, on average, for the 1997 cropping season. This estimate is corroborated by historical records, indicating that irrigation applications



for the two wettest of the past 15 years averaged only .4 acre-feet (USGS, 1996). Given these favorable conditions, water use by irrigators is estimated to have reduced EA pumping by only 3,868 acre-feet.

### **Springflow Effects**

Regression coefficients reported in Keplinger et al. (1998b) were used to estimate increased annual and critical period (August) springflow at Comal Springs as a result of the ISP. The amount of additional springflow for the program year (Table 1), is estimated to be about 40% of the amount of reduced irrigation. The remaining 60% augments flows in other springs (particularly San Marcos), may leak into other aquifers, and contributes to EA elevation which increase springflow in subsequent years.

August Comal Springflow increases as a result of ISP are estimated at 17.7 cfs in dry years, 11.8 cfs in average years, and 5.9 cfs in wet years (Table 1). This represents a considerable portion of total springflow at Comal Springs when EA levels are low. For the entire months of July and August 1996, Comal springflow was less than 100 cfs. The 1997 ISP would have raised flows closer to the USFWS determined jeopardy level of 150 cfs for the fountain darter. Larger programs would have proportionately greater effects. Although flow increases for wet years are small, it should be noted that increased springflow is not critical during wet years, but is critical during dry years, when increased springflow produced by ISP implementation is greater.

### **Effect on Aquifer Elevation**

Table 1 presents estimated increases for year-end EA levels as a result of the 1997 ISP. Results indicate elevation is increased 3.8 feet in dry years, 2.5 feet in average years and 1.3 feet in wet years. For the very wet 1997 scenario, EA elevation is estimated to have increased by 0.6 feet by year-end as a result of the ISP.

### **Effects on Return Flow and Recharge to Other Aquifers**

Due to inefficiencies in irrigation technology, the portion of irrigation water not taken up by crops is either evaporated, percolates past plant roots and becomes groundwater, or enters river systems. Average application rates by type of irrigation system were estimated, based on irrigation efficiencies. Based on estimated loss rates, by system, and data on participant system use, we estimate a loss of .82 acre-feet for an average application of 2.4 acre-feet for dry years. Thus, we estimate that approximately 7,948 acre-feet of water, or about a third of the water applied, would run off or evaporate. Since most irrigable land is not over the EA recharge zone, elimination of return flow represents a loss to other area aquifers or rivers.

### **Effects on the Regional Economy**

Theoretic and empirical evidence suggests that converting to dryland during an ISP reduces purchases by irrigators from input suppliers. Survey results on 9 of the 14 irrigators indicated that they purchased less inputs from suppliers. Dryland planting resulted in lessened seed usage and reduced fertilization. In addition, diesel or electricity was not needed to operate pumps. One participant indicated hiring one less person to apply fertilizer. While regional agricultural suppliers would experience a modest reduction in sales as a result of a widespread ISP, the intermittent nature of ISP implementation mitigates against a noticeable restructuring of the agricultural input supply economy.

Upwardly linked crop dependent industries do not constitute a large component of the local economy, therefore, little economic impact would occur from these sources. A Frito Lay plant in the San Antonio area, for instance, does not contract with EA producers. During the regional 1996 drought, it was reported that landscaping and swimming pool businesses in the San Antonio metropolitan area were suffering reduced sales and loss of employment as the result of drought management restrictions. To the extent an ISP would ease municipal pumping restrictions, its implementation would benefit these impacted industries.

There are also economic benefits derived from springflow. If an ISP resulted in significantly higher springflow, commercial benefits to recreation - based businesses in New Braunfels would likely accrue. Downstream agricultural, municipal, and industrial interests

would also benefit. Non-market valuations associated with springflow and endangered species also accrue to a broader environmental community that includes area residents.

## **IMPLEMENTATION**

In this case and probably in future cases, low elevation triggered ISP implementation. Although a prediction of a coming dry year would add to the attractiveness of implementing an ISP, long range weather forecasts are not totally reliable. Thus, ISP implementation is insurance against a dry year following a low beginning elevation. Thus, funding agencies cannot expect to ‘cash in’ on their ‘insurance policy’ all the time. In this regard, the 1997 ISP can be deemed successful in that if it had been a dry year it would have made a significant contribution to EA elevation and springflow.

### **Proof of Program Concept**

While limited in scope, the pilot 1997 ISP demonstrated that willing buyers and sellers can be found to implement such a program, and that verification, monitoring, and enforcement posed no overwhelming obstacles. Judging by survey responses, participants were quite pleased with the EAA’s administration of the 1997 ISP. Thirteen of 14 respondents indicated they would participate in another ISP if one is offered within the next three to five years.

### **Timing**

The ISP was rapidly implemented in December 1996 and finalized by January 1997. Earlier ISP start dates may have lessened program costs since some irrigators may have made commitments making it more expensive for them to participate. When participants were asked when they would like to know about future ISPs, the majority answered October or November.

Most irrigation in the EA region occurs in April, May, and June, however a January 1 ISP is implemented before weather for the heavy recharge and water use months is revealed. An ISP starting in April or May is also a possibility after more information has been received. However, when asked how an ISP starting in March or April would have impacted their bid, four of 14 respondents answered that it would be “too late”, and two indicated it would be more difficult.

Evidence in Keplinger et al. (1998b) indicates that the per acre-foot cost of reducing irrigation is approximately 2 ½ times greater if a June 1 DY0 is implemented, and that the cost of springflow is more than 3 times greater. However, if the EAA could wait until May, fewer ISPs would be implemented. This almost certainly would have been the case with the 1997 ISP. If 2 out of 3 January ISPs could be avoided by waiting until May, a May ISP would produce cheaper, but less, water.

### **Selection Criteria**

#### **Bids for 1997 ISP participants were ranked according the formula**

$$(1) \quad \text{Ranking} = \text{Per Acre Bid} / \text{Score},$$

where

$$(2) \quad \text{Score} = \text{Loc} + \text{Crop} + \text{Equip} + \text{Dryland},$$

and Loc = location score, Crop = crop score, Equip = equipment score, and Dryland = dryland score, where scores ranged from 0 to 11 as previously described.

A conceptual formulation that would minimize the cost of additional springflow would rank bids in terms of cost for an additional unit of springflow, specifically

$$(3) \quad \text{Ranking} = \text{Bid} (\$) / \text{Springflow Effect} (\text{af}),$$

where Bid is an irrigator's bid and Springflow Effect is the amount of additional water produced (acre-feet) at Comal Springs over the course of the program year as the result of suspending irrigation on the farm unit.

Additional springflow is a function of both reduced pumping and location of the irrigation well. Amount that pumping is reduced is, in turn, a function of crop needs and irrigation technology. These variables relate to springflow as follows:

$$(4) \quad \text{Per Acre Springflow Effect} (\text{af}) = (\text{Irrigation Demand For a Given Crop Mix}) / (\text{Irrigation Efficiency}) * (\text{Per Acre-foot Springflow Effect from pumping reduction}).$$

Three elements in Equation (2) (Crop, Equip, and Loc) were designed to capture the three elements in Equation (4). In Equation (4), however, total springflow effect due to suspension of pumping is a multiplicative function of the three elements, whereas it is an additive function in

(2). Moreover, the Loc score in Equation (4) ranged from 6 to 11, whereas the relative impact on springflow from pumping in various regions of the EA varies considerably more. Keplinger et al. (1998b) show it varies by a factor of 7 when comparing pumping from the western and eastern regions. Thus, while the score in (2) takes into account many factors, it likely does not give enough weight to the to impact of water reductions on springflow. An approach, based on Equations (3) and (4), would reduce the cost of current year springflow.

### **Bidding Process and Price Determination**

A sealed bidding process was used to solicit offers from farmers. Thirty-nine of 120 offers were selected ranging from \$116 to \$300 per acre, with an average of \$243 per acre. An economic model based analysis by Keplinger et al. (1998b) suggests that, on average, it would have been profitable for many irrigators to submit bids of \$50 per acre. The discrepancy between model results and actual ISP experience merits exploration

The Keplinger et al. (1998b) model simulated producer response to per acre offers of various amounts to suspend irrigation. The model is a nonlinear programming model which essentially compares the returns to irrigated cropping with irrigation suspension payments plus expected profits from dryland cropping, when the ISP offer is accepted. When irrigation suspension payments exceed the difference between average irrigated and dryland cropping profits minus pumping costs, the model chooses the ISP payment and dryland farming. Model results, therefore, were sensitive to per acre economic rent to irrigation, hereafter referred to as an irrigation premium.

Differences between irrigated and dryland rental rates and land values can be used to check the reasonableness of the irrigation premiums produced by Keplinger et al. According to statistics gathered by the Medina County office of USDA NRCS, dry land rental rates ranged between \$16 and \$25 per acre while irrigated land rents for between \$90 and \$100 per acre. The difference between the midpoints of the ranges is \$75 per acre, which can be considered an average per acre premium to irrigated land. This indicates that farmers in the region estimate the

pure land returns as they differ between irrigated and dryland cropping at \$75 per acre which is closer to the Keplinger et al. estimate than the observed bid.

The question can also be approached through the land sale market. According to a regional real estate appraiser, irrigated cropland in Medina County sells for between \$1,500 and \$1,750 per acre, while nonirrigated cropland sells for between \$800 and \$1,000 per acre. The difference between the midpoints is \$725 per acre. At 7%, the annual interest expense on this amount ( $\$725 \times .07$ ) is \$50.75 per acre per year, which is another estimate of an irrigation premium, again consistent with results in Keplinger et al.

This consistency suggests the discrepancy between per acre payments produced by Keplinger et al. and those actually bid and received by irrigators may in part be due to the structure of the bidding process, the market, and some potential dimensions of farmer behavior. In particular we think the following factors may have influenced bids.

1. Modeling such as in Keplinger et al. assumes a perfectly competitive market with perfect information, a large number of buyers and sellers, and no transactions costs. But there was only one buyer and potential sellers numbered only 125. Information was sparse since this was the first implementation.
2. The motivation of bidders was to bid the highest price that would likely be accepted although this price was unknown. This suggests individual bids might have been conditioned upon what bidders thought other participants would bid rather than upon cost considerations.
3. Irrigators may have included their expected returns to labor as well as their returns to land in their bids. In the survey, some irrigators claimed to have made their bid according to this criterion.
4. Reportedly, some irrigators believed that the payment they received for the ISP might determine the price for which they might be able to sell water in the future after SB1477 adjudication and therefore inflated their bid.

5. Anecdotal evidence suggests explicit collusion among a group of bidders to all offer a set rate.
6. The late start of the ISP may have caused some irrigators to bid higher than they otherwise due to the short timeframe and some prior farming commitments.
7. Leasing arrangements of irrigators may have caused higher bids than otherwise would have occurred due to the transaction costs inherent in sharing arrangements of ISP payments between owners and leasees. Only ten percent of selected participants were leasees, whereas 44 percent of rejected, higher bids were made by irrigators who rented all or part of the farm unit.

Thus the question arises: Would a different bidding arrangement have resulted in lower overall cost to the EAA? The sealed bid arrangement used to solicit ISP offers was reminiscent of an early implementation of the Conservation Reserve Program (CRP). Beginning in 1986, USDA held periodic sign-ups during which farmers offered acres for enrollment for annual per acre rental rates they were willing to accept (US GAO, 1989). USDA set rental rates ceilings that, in many cases, were far higher than local cash rental rates, and for a time, accepted all bids falling under the rental rate ceilings. A GAO report (1989) estimates that this process resulted in CRP rates as much as 200 to 300 percent higher than local cash rental rates. The CRP method of price determination was later changed so that the CRP rental rate ceiling was set at prevailing local rental rates. It is not clear if the desired level of participating land could have been attained by setting a maximum bid at or near reported land rental rates since this is an empirical question. It is likely the EAA could have suspended a similar number of irrigated acres for a substantially reduced cost if it had offered the right ‘take it or leave it’ payment to irrigators. Discussion with EAA and other regional decision makers indicates that if more time were available, they would have considered rejecting bids and making counter offers.

## **COMPARISON WITH OTHER IRRIGATION WATER USE REDUCTION OPTIONS**

Water rights purchase, lease, or option agreements on water rights is a more direct route to reducing irrigation than an ISP but requires tradable water rights which were not in place. Two other alternatives could be pursued: (1) purchase irrigated agricultural land, and lease it for dryland use when water is needed elsewhere, while permitting irrigated use otherwise, and (2) subsidize adoption of improved irrigation technology to reduce water use. We compared these three alternatives based on (a) how much additional water would be produced, and (b) the cost of producing additional water. The specific alternative we examined were:

- 1) An ISP that costs \$234 per acre under which all participating acres would suspend irrigation.
- 2) A lower cost of \$75 per acre ISP.
- 3) An intermediate cost \$150 per acre ISP.
- 4) A land purchase program where an agency would purchase irrigated agricultural lands and rent them back to tenant farmers for irrigated use when water is plentiful, and for dryland use otherwise. The assumed price for irrigated land is \$1,625 per acre. Using 7%, the annual finance cost on this amount is \$113.75 per acre. We assume the land will be leased land back to farmers at \$95 an acre when irrigation is allowed and at \$20 an acre for dryland farming when the water is needed elsewhere.
- 5) Subsidized Low Energy Precision Application (LEPA) irrigation systems, which would replace less efficient existing systems. Conversion to LEPA involves additional equipment costs, which varies by system, but reduced farm labor and pumping costs. Considering the incidence of existing systems results in an average conversion cost of \$442 per acre or at 7%, \$30.94 per acre per year. Water savings depend on rainfall but in dry conditions yield a 30.5 % reduction in water use.

Comparison of costs and water use requires an assumption of how often the ISP (or conversion to dryland under an LPP) will be implemented. We do not assume foreknowledge of



weather conditions but assume that our 3 state of nature characterization of wet, average, and dry years is relevant for all years. To simulate a range of conditions over a ten year period, we examine an ISP implementation occurring once, twice, 3 times, 4 times, and 5 times within a 10 year period.

The value of saved water depends on EA levels and weather. Water saved during a dry year following low EA elevations is more valuable than water saved in a wet year when EA elevations are high. Thus, three classes of water are defined: (1) 'most valuable water,' (2) 'valuable water,' and (3) 'all water.' 'Most valuable water' is defined as water saved during a dry year when an ISP is implemented. 'Valuable water' includes 'most valuable water' plus two other types of water: (1) water saved during an average weather year after implementation of an ISP and (2) water saved during a dry year when an ISP is not implemented. 'All water' is all water saved regardless of weather conditions and ISP implementation. Absent storage mechanisms, which currently have not been developed, much of this this water cannot be saved and later used when EA elevations are low.

Table 2 lists the amounts of water saved and increase in Comal Springflow, for the 3 programs described assuming implementation on 9,669 acres for the 3 classes of water. As previously mentioned, hydrologic effects of an ISP and an LPP are identical, and expected water savings for all classes of water is simply a function of how many times the program is implemented. LEPA on the other hand saves water whether or not an ISP is implemented, and the amount of 'all water' produced by LEPA is invariant with respect to how many times an ISP is implemented. The ISP or an LPP produces more 'most valuable water' because these programs cut out irrigation completely, whereas LEPA only reduces irrigation water use by increasing efficiency. LEPA, however, produces more 'valuable water' than an ISP or LPP implemented 2 or less times in 10 years. Finally, LEPA produces more water for the entire 10 year period ('all water') than other alternatives if an ISP is implemented 3 or less times in a 10 year period.

Program cost for an ISP is proportional to how many times the program is implemented. LEPA cost is fixed. LPP implementation has both fixed and variable components. Land purchase cost is fixed, but rental rate depends on frequency of dry or irrigated land rental which is assumed the same as the frequency of ISP implementation. Section A of Table 3 indicates that the \$75 ISP is always less expensive than the LPP. The LPP, however, becomes less expensive than the \$150 ISP if implemented 3 or more times in a ten year period and less expensive than the \$234 ISP if implemented 2 or more times in a ten year period. We cannot directly compare total cost of LEPA to an ISP or an LPP because different amounts of water are being saved.

Sections B-D of Table 3, depict per acre-foot costs of program alternatives for the 3 classes of water. Since the hydrologic effects of an ISP and LPP are identical, the same pattern emerges for cost per acre-foot of water saved for all classes of water as for total cost of the program, namely, the \$75 ISP is always cheaper, but LPP is less expensive than the \$150 ISP if implemented 3 or more times during a ten year period and less expensive than the \$234 ISP if implemented 2 or more times during a ten year period.

Focusing on LEPA, the cost of saving 'most valuable water' is more expensive than ISP or LPP programs, except for a \$234 ISP implemented 5 times during a ten year period. LEPA subsidization, however, produces substantial amounts of 'valuable water' in a cheaper fashion than the \$234 under all scenarios, and cheaper 'valuable water' than the \$150 ISP if implemented 2 or more times in a ten year period. Compared to the LPP, subsidized LEPA produces less expensive 'valuable water' if implemented 2 or fewer times in a 10 year period. For 'all water,' LEPA is always less expensive than the \$150 and \$234 ISPs and the LPP, but still more expensive than the \$75 ISP. Again we note that much 'all water' saved as a result of converting to LEPA would occur when the water is not especially valuable.

## SUMMARY AND CONCLUSIONS

The EAA implemented a pilot irrigation suspension program in 1997 with the objective of increasing springflow at Comal Springs, and providing relief to municipalities in meeting

drought management rules. The EA subsequently experienced a wet Spring, so that even irrigators not enrolled in the program applied little or no irrigation water. If conditions were dry, EA simulation results indicate that suspending irrigation would have substantially reduced pumping, augmented Comal springflow both during the program year and in the critical August time period, and increased the ending year elevation. Payments to irrigators totaled \$2,350,000 or \$234 per acre.

The ISP Program did cause farmer adjustments. Participants in the ISP program planted less corn, cotton, vegetables, and peanuts in favor of more sorghum and wheat. Irrigators purchased less fertilizer, seed, and labor, but secondary effects on the local economy appeared to be small.

The price paid per suspended acre was much higher than regional lease rates and land prices would imply. Factors which may have accounted for the high bids include: (1) lack of experience with an ISP, (2) its late start, (3) the belief that bids might affect future water prices or offers, (4) tendencies to bid high enough to cover costs under a worst case scenario of a total loss of dryland crops, (5) collusion, and (6) need to bid high enough to compensate both leasees and owners under current land lease arrangements. Bids in future ISP solicitations would likely be lower.

Alternatives to an ISP are limited. We evaluated the potential of (1) implementing more efficient irrigation technology and (2) buying land and leasing it back during wet or average years. The ISP is a more cost-effective source of critical water than is the use of subsidized irrigation efficiency largely because the ISP can put in place only when water is needed. The level of future ISP bids, however, is unknown. If ISP bids are high, a buy-leaseback arrangement could reduce the cost to the EAA of suspending irrigation. This, of course, would require an alternate set of administrative costs by the EAA.

The 1997 pilot ISP was a reasonable response to the low EA level and demonstrates that an ISP is practically feasible: farmers were willing to sell and regional water purveyors were

willing to fund the program. Fine-tuning the selection criteria, bidding procedures, and allowing greater lead time hold the potential for reducing program cost.

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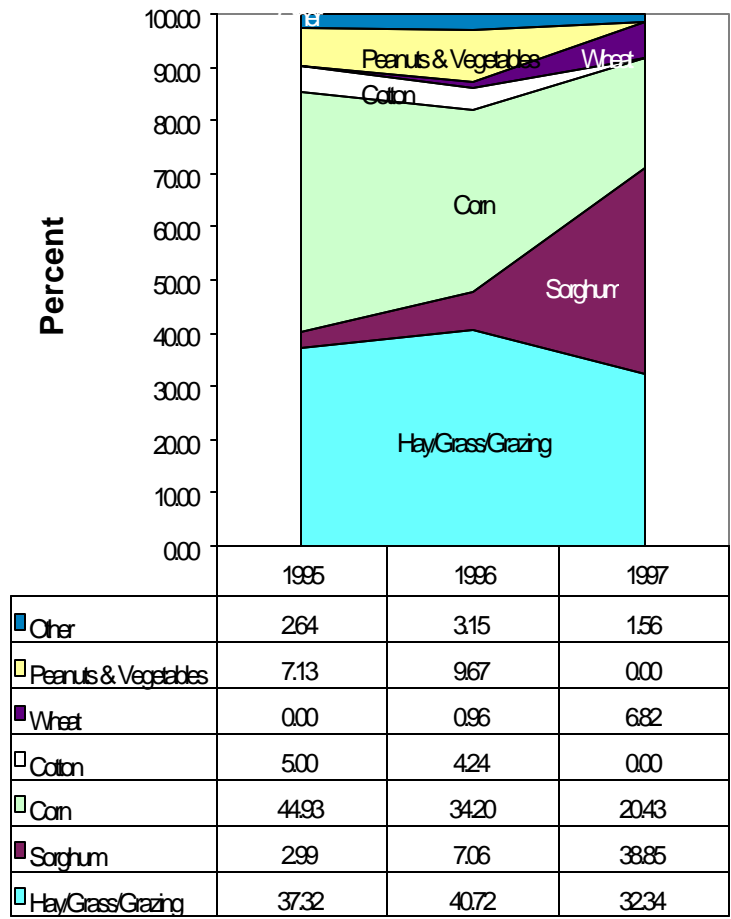
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**Figure 3. Crop Mix for ISP Participants, 1995- 1997**