

Statistical Testing for Precision Graded Verification

Does precision leveling save water?

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1. Executive Summary

The purpose of this report is to evaluate the effectiveness of on-farm water conservation practices and, in particular, whether precision leveling of farmland saves water using a statistically rigorous approach. In 1999 the Texas Legislature passed a bill that authorized the Lower Colorado River Authority (LCRA) to transfer up to 25,000 acre feet of water to Williamson County, if the transfer results in “no net loss” to the Colorado River Basin. LCRA has collected data to statistically evaluate the net water savings associated with precision leveling. To isolate precision leveling water savings, one needs to separate the effects of other factors that can reasonably be expected to influence water usage.

From 2009 to 2012, this study developed, tested and validated qualitative and statistical methods for evaluating how on-farm water usage varies in the Lakeside Irrigation Division between fields and between farmers. This study estimates the water savings from precision land leveling, compared to other factors that influence water use. The study had three primary goals, to: (a) determine the extent to which precision leveling explains reductions in on-farm water use; (b) identify other factors that affect water consumption (c) examine how farming practices among groups of fields managed by the same farmer affect on-farm water use.

This study uses Hierarchical Linear Models (HLM) to separate the effects of precision leveling fields from weather variability, other conservation measures, and farmer’s management skills. Results indicate that the following factors have a significant effect on the water use of fields: rain, evapotranspiration, precision leveling, levee density, multiple inlets, whether a farmer cash-rents a field, seed and hybrid rice along with its growing period, and the year 2011.

The data show that the consequence of water conservation investment in precision leveling has both direct and indirect effects on the water use of fields. Precision leveling, in and of itself, accounts for a 0.30 ac-ft/ac reduction in on-farm water use for the first crop at a 95 percent confidence interval. Accounting for precision leveling in combination with a levee reduction of 20 levees in a 100-acre field could potentially save 0.70 ac-ft of water used over an acre farmed, if the levee density was verified. Given that when a field is precision leveled, the number of levees decreases, the indirect savings from this levee reduction could be attributable to precision leveling.

The model was run for ratoon crop alone, but the small sample size resulted in a large associated confidence interval, meaning that there is significant uncertainty associated with the precision leveling water savings estimate for the ratoon crop. If more data could be collected, LCRA could compute a robust and accurate estimate for the ratoon crop.

Other factors were found to have a significant effect on water use during the first crop. For each additional multiple inlet the water usage of a field decreases by 0.03 ac-ft/ac. Farmers who cash-rent their land use 0.12 ac-ft/ac of water less than farmers who share-rent or farm land they own. A field in production in 2011 used on average 0.64 ac-ft/ac more irrigation water in 2011 compared to other years (2006-2010). Rice variety in relation to the growing period has a slight effect on water use.

2. Introduction

The Agricultural Water Conservation Program (HB1437 program) is a central component of the Lower Colorado River Authority's (LCRA) water conservation programs for agricultural uses. The HB1437 program is tied to a mandate from the Texas Legislature to develop water for transfer to the Brazos River Basin, which in effect requires that the LCRA reduce the volume of water used by agricultural customers to comply with its water transfer responsibility. To account accurately for the conserved water developed through this program, the LCRA depends upon its ability to explain the difference in water use between many potential sources of water savings and the HB1437 conservation programs LCRA implements, such as precision leveling of farmland. The LCRA monitors and evaluates to ensure that sufficient water savings targets are achieved so water can be transferred to the Brazos River Basin with no adverse impact on the Colorado River Basin, as required in the HB1437 legislation. The objective of this Statistical Testing for Precision Graded Verification is to develop and implement a reliable and rigorous water conservation savings verification program for precision leveling. This study focuses on the Precision Graded Verification Study in Lakeside Irrigation Division.

3. Data Sources

This study uses three data sources: LCRA data collected for billing purposes from WAMS (Water Application Management System), information collected through a survey of farmers and weather data. These data sources are described below. A more extensive description of the data sources (including a survey instrument) can be found in the interim report 2010 "Statistical Testing for Precision Graded Verification." This study uses a sample set of approximately 174 fields each year over a six-year period, or a total of 966 observations. This is the third year (2006-2009, 2010 and 2011) that the survey and "Precision Graded Verification" methodology have been implemented in Lakeside Irrigation Division.

Water Application Management System (WAMS) Database

LCRA staff collects information about field characteristics through its annual water contracting process. For example, the LCRA's water customer billing system collects the following information for first crop and ratoon crop: contract name, field name, year the field was in production, whether the field was in production during the ratoon crop, field acreage (ac), field water use (ac-ft) and number of delivery structures.

Survey data

To increase the accuracy of the conservation verification analysis during this survey effort, project staff collected new data in 2011 and 2012 to complement information collected in a 2006-2009 survey. The data collected in the survey represents farmers' self-reported information; field verification of this information was outside of the scope of the study.

Weather data

Weather data were collected from Eagle Lake 7 NE station, Colorado River at Altair and Wharton station from the Lower Colorado River Authority's (LCRA) Hydromet System.¹ Daily weather data were averaged during the average growing season for each station. Growing season refers to the average time between the first and last water delivery of the set of fields within each polygon.

Farmer Management Data

This analysis separates the 'precision leveling effect' from 'management skills' related to on-farm water usage. Although it is plausible that a single farmer may manage one field, information from Lakeside from 2006-2011 shows that this one-to-one relationship is unlikely. Table 1 shows the presence of groupings of fields by farmer: on average one farmer managed five fields. Grouping of fields by farmers supports the idea that different fields managed by the same farmer may display some similarities in water use.

Table 1: Number of Fields per Farmer

Year	Average	Maximum
2006	5	11
2007	5	16
2008	5	18
2009	5	18
2010	5	11
2011	5	17

Source: Survey and WAMS database 2012

4. Analytical Approach

A first step is to evaluate whether different types of fields have different patterns of water use. To tease-out precision leveling water savings, one needs to separate the effects of factors that can reasonably be expected to influence water usage of fields. Different fields managed by the same farmer may display some similarities in water use. Farmers may differ from one another on the judgments and choices they make about how, when and what amount of water to apply to their fields among other farming decisions they make. Hierarchical Linear Models (HLM) are useful for evaluating water use on fields that share management style (fields operated by the same farmer) as well as when the same data points (fields in this case) do not re-occur at a regular intervals (yearly). This project used expanded and validated data to quantify separate effects from a range of factors that influence farmers' use of irrigation water. A more extensive description can be found in the 2010 interim report "Statistical Testing for Precision Graded Verification."

¹ LCRA's website <http://hydromet.lcra.org/>

5. Analytical Results

Data from both WAMS and the Survey were used in modeling water usage and savings. Water demand is measured in acre-feet of water used per each acre farmed. An acre-foot is the amount of water required to cover an area of one acre to a depth of one foot. Table 2 lists factors included in the HLM analysis. Table 3 describes the relationship among factors and water usage. Table 4 lists the lessons learned from this study.

Table 2: Factors Included in the HLM Analysis

WHAT ARE THE FACTORS?	
FACTORS	DESCRIPTION
PRECISION LEVELING	Whether a field has been precision leveled or not
WATER INLETS	Number of unmetered and metered water inlets in a field
RAIN	Average daily precipitation during the average growing season
EVAPOTRANSPIRATION	Average daily evapotranspiration during the average growing season
CASH	When the person who farms the land pays cash to rent the field from the landowner
GROWING	Number of additional days water was delivered to a field beyond the average growing period
LEVEE DENSITY	Number of internal levees in a field plus one divided by the field size
YEAR 2011	Whether a field was in production in 2011

Factors that influence water use

The 2012 results suggest that precision land leveling reduces water use in fields. Farmers who precision leveled a field use on average 0.30 acre-feet per acre less irrigation water than a farmer who does not precision level a field (see Table 3). The probability is greater than 999 times out of 1000 that a farmer who precision levels saves irrigation water. The best estimate of mean water savings year in and year out is 0.30 ac-ft/ac during the first crop due to precision leveling based on six years of data collection. The 95 percent confidence interval indicates that precision leveling, per se, reduces the water usage of a field by no less than 0.12 acre-feet per acre and no more than 0.47 acre feet per acre. Water savings due to precision leveling, during the first crop, occurs every year and across the 2011, 2010 and 2006-2009 studies (0.30 ac-ft/ac, 0.33 ac-ft/ac and 0.31 ac-ft/ac respectively). The 2012 confidence intervals are slightly tighter due to a larger sample size. The results indicate that the water savings estimate for precision leveling is robust, as the values are essentially the same even with two additional years of data and the removal of the ratoon crop (see Figure 1). Separating first and ratoon crop is an important step, because in the ratoon crop the rice plant is well-established resulting in different water usage patterns. These crops were combined in the first analysis (2006-2009) due to data constraints.

Figure 1: Precision Leveling Water Saving Estimates

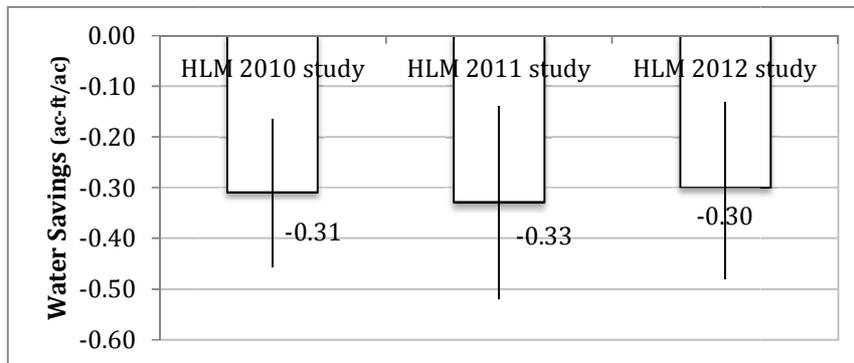


Table 3: Influence of Factors on Water Usage of Fields

STATISTICALLY SIGNIFICANT VARIABLES		
FACTORS	(AC-FT/AC)	DESCRIPTION
PRECISION LEVELING	-0.30	Precision land leveling, on average, reduces farmers' water usage by 0.30 acre-feet per acre during the 1st crop.
WATER INLETS	-0.03	For each additional multiple inlet the water usage of a field decreases by 0.03 acre- feet per acre during the first crop.
LEVEE DENSITY	0.51	For a non-precision leveled field with an average levee density of 0.3114 levees/ac, water use increases by 0.51 ac-ft/ac with each levee/ac.
LEVEE DENSITY*LL	1.907	For a precision leveled field, an increase of the levee density by 1 levee/ac will increase the water use by 1.907 ac-ft/ac.
RAIN	-0.542	A one-tenth inch average per day increase in rain, on average decreases the water usage of a field by 0.542 acre-feet per acre.
EVAPOTRANSPIRATION	4.25	A one-inch per month increase in evapotranspiration, on average increases the water usage of a field by 4.25 acre-feet per acre.
CASH	-0.12	Farmers who cash-rent their land, from planting to harvest during the first crop, use 0.12 acre-feet of water less than farmers who share-rent or farm land they own.
RICE*DIFF_GROW	0.008	Farmers that plant seed or hybrid rice use 0.008 acre-feet per acre more irrigation water for each additional day water is delivered to a field.
YEAR 2011	0.637	During 2011, the water use of fields increased on average by 0.637 ac-ft/ac as compared to other years in the study (2006-2010).

Table 4: What this Study Documents

FACTORS	DESCRIPTION
PRECISION LEVELING	Precision land leveling reduces water use in fields
MULTIPLE INLETS	Water inlets in a field reduce irrigation water
LEVEE DENSITY	A field with fewer levees uses less irrigation water
LEVEE DENSITY*LL	If a field is precision leveled, the land is flatter; fewer levees are necessary; water use is reduced.

RAIN	In a wet year, a farmer uses less irrigation water
EVAPOTRANSPIRATION	In a dry, hot year a farmer uses more irrigation water
CASH	A farmer who cash-rent uses less irrigation water than other farmers
RICE*DIFF_GROW	A farmer who plants seed or hybrid rice use more irrigation water
YEAR 2011	During a drought year, a farmer will use more irrigation water

This study's analysis suggest that if a field is precision leveled, the type of levee (straight or contour) does not affect a field's water usage (see Table 3). The correlation is high (0.81) between whether a field is precision leveled and the type of levee of levee system. A possible explanation for this result is that of the 101 precision-leveled fields with a contour levee-system in Lakeside Irrigation Division, almost half (43 percent) are managed by two farmers with superb management practices.

Water inlets in a field reduce irrigation water. The first survey in 2009 gathered multiple inlet data in intervals. To improve accuracy of results, the 2010 study collected the exact number of multiple inlets in each LCRA field. Results in the 2011 study show that if a field has one additional water inlet, the use of irrigation water will be reduced by 0.035 acre-feet per acre per additional inlet (see Table 3). Results in 2012 show that the presence of an additional water inlet (measured or unmeasured) in a field decreases water usage by 0.033 ac-ft/ac per additional inlet.

In a wet year, a farmer uses less irrigation water. A one-tenth inch per day increase in rain on average decreases the irrigation water usage of a field by 0.542 acre-feet per acre (see Table 3). This result indicates that farmers reduce the use of irrigation in years with high rainfall, which contributes to the supply of water.

In a dry, hot year a farmer uses more irrigation water. With an average one-inch per month increase in evapotranspiration, water usage in a field would increase on average by 0.14 acre-feet per acre (see Table 3). Evapotranspiration accounts for changes in maximum and minimum temperature, humidity, wind speed, and sunshine hours.

During 2011, Texas experienced one of the most extreme drought periods in the past 50 years. A field in production used on average 0.637 ac-ft/ac more irrigation water in 2011 compared to other years (2006-2010). A possible explanation for the statistical significance of the variable "Year 2011" above and beyond the other weather factors is low soil moisture; as both weather factors represent average rain and evapotranspiration only during the growing season (six months out of the year). Weather conditions before farmers start taking water does influence soil moisture, which affects the water usage of fields. Also

the “average rain” does not capture the frequency of rain events nor is it based on a long historical times series.

A farmer who plants seed or hybrid rice uses more irrigation water because he takes water for a longer period. Farmers who plant seed and hybrid rice use 0.008 ac-ft/ac more irrigation water for each additional day water is delivered to a field; irrigation continues beyond the average growing period (see Table 3). Seed and hybrid rice in itself does not affect the water usage of a field, but seed and hybrid rice in relation to the growing period does affect water use. When farmers plant seed or hybrid rice, these cultivars’ longer growing periods lead to higher levels of water usage.

A farmer who cash-rents the land uses less irrigation water than other farmers. In both the 2011 and 2012 study, the data indicate that farmers who cash-rent use less irrigation water per acre farmed than do farmers who share-rent or farm their own land. For example, results from the 2012 verification study show that farmers who cash-rent on average use 0.12 acre-feet per acre less water. When the person who farms the land cash-rents a field, the effect of costs (such as labor and water costs) and profit are tangible and immediate. A farmer who cash-rents bears all the financial risk in the rice production of any given field. Due to the increased financial risk, farmers appear to pay more attention to the amount and management of the water they order.

A field with fewer levees uses less irrigation water. If a field is precision leveled, the land is flatter so fewer levees are necessary and water use is reduced. The factor “levee density” captures the marginal effect that the distribution of internal levees (sparsely or densely distributed) has on a field’s water usage. Results suggest that as the levee density of a field increases, so does the water use in fields. Likewise, as the levee density of a field decreases, the water use also decreases. Because precision leveling decreases the elevation between high and low spots in a field, one would expect a decrease in the number of internal levees required to buttress the terrain at different altitudes. Thus, precision leveling has a direct effect on water use and also an indirect effect through the variable “levee density” because precision-leveled fields are more likely to have lower levee density. For a non-precision leveled field, a decrease in 1 levee/ac of the levee density will decrease the water use by 0.509 ac-ft/ac. For a precision-leveled field, a decrease in 1 levee/ac of the levee density will decrease the water use by 1.907 ac-ft/ac. Precision leveling water savings change with different ranges of levee reduction, or in other words, different levee density.

6. Recommendations

There are a range of investments irrigation districts can make to save water: volumetric measurement and pricing, improvements to the canal and conveyance system, rehabilitation and maintenance of the canal network, precision leveling and multiple inlets among others. This study’s main objective is to quantify the on-farm water savings following from precision leveling.

This study has proven beyond a reasonable doubt that precision leveling saves 0.30 acre-feet per acre of irrigation water in fields during the first crop. This water savings coefficient has been verified in three different analyses, which span over six years.

Precision leveling does more than save water on farms. In addition to its direct effect, precision leveling is a catalyst for a wide range of field upgrades and management changes that save water on farm fields. As a result, precision leveling is a more valuable investment than is indicated simply by estimating the difference in water use attributable solely to precision leveling. Water conservation investment in precision leveling has at least three indirect effects on the water use of fields: (a) levee density, (b) precision leveling savings during the ratoon crop, and (c) cropping changes. Verifying these indirect water savings from precision leveling, although outside of the scope of this analysis, is an important next step. This study has attempted where it could to calculate an estimate of these sources with the data available. If at some point the LCRA would like to compute and verify these water savings, more data collection would be necessary.

The initial study released by Texas A&M Agricultural Extension Station, evaluated with a sample of 4 experimental plots, estimated a water savings of 0.75 ac-ft/ac from precision leveling. This study finds the direct effects of precision leveling alone to be a minimum of 0.30 ac-ft/ac. The direct and indirect effects of precision leveling together would yield a water savings estimate close to or maybe even above LCRA's current 0.75 ac-ft/ac savings coefficient. For example, by accounting for levee density decreases of 0.21 levees/ac when a field is precision leveled, 0.69 ac-ft/ac can be attributed to precision leveling. The actual precision leveling savings on an individual field may increase or decrease based on the change in levee density as a result of precision leveling. The average non-precision leveled field has a levee density of 0.31 levees/ac, whereas the average precision-leveled field has a levee density of 0.10 levees/ac, suggesting a change in 0.21 levees/ac as a result of precision leveling.

However, it is a challenge to calculate the change in levee density from a non-precision leveled field to a precision-leveled field. Anecdotal information from farmers suggests that some of the fields in this study have been precision leveled twice in a 15-year period.² The inclusion of fields that have been precision leveled twice decreases the average levee density for a precision-leveled field. The current estimate (0.10 levees/ac) may be artificially lower, because it does not accurately reflect the change in levee density from non-precision leveled to fields that have been precision-leveled only once.

This verification study has the added benefit of estimating water savings for water inlets.

² 15 years is the standard life of the precision leveling practices as defined by NRCS. <http://efotg.sc.egov.usda.gov/references/public/NE/NE464.pdf>

Multiple inlets are a less costly conservation measure than precision leveling and may have comparable water savings. Multiple inlets is an on-farm water conservation measure LCRA can invest in to reduce the volume of water used by agricultural customers. Multiple inlets could eventually complement precision leveling if and when precision-leveled acreage reaches a saturation point and remains steady over time.

LCRA has succeeded in verifying the precision leveling savings in a thorough and rigorous statistical analysis using Lakeside Irrigation District billing data and farmer surveys. There is a high degree of confidence in the estimates presented for the direct water conservation estimates for precision leveling. It is also true that if LCRA could collect more information, the indirect effects of precision leveling could be verified as well as yield more accurate estimates for precision leveling. The recommendations are discussed below.

5.1 Precision Leveling Direct Water Savings

5.1.1 Precision Leveling on Aggregate Fields

The precision leveling 0.30 acre-feet per acre is a conservative lower limit on the average water savings estimate because of the way that the LCRA classifies farmer fields. This study catalogues as “leveled” any LCRA field with at least half of the land leveled. LCRA’s field boundaries sometimes aggregate a number of different “physical” fields. The water usage of combining precision-leveled and non-precision leveled “physical” fields in one LCRA field is likely to be higher than the water use of a unique laser level physical field that corresponds to one LCRA field. The inclusion of non-precision leveled fields increases the average water use that would otherwise be recorded if all fields were 100% precision-leveled.

5.2 Precision Leveling Indirect Water Savings

5.2.1 Levee Density

A field that has been precision-leveled with fewer levees uses less irrigation water. For a precision leveled field, a decrease in 1 levee/ac of the levee density will decrease the water use by 1.907 ac-ft/ac. Given that the precision leveling of a field generally decreases the levee density; these indirect savings from levee density can also be attributable to laser leveling. For example, the potential direct and indirect benefits from precision-leveled fields could exceed 0.696 acre-feet of water used over an acre farmed (see Table 5) if the decrease in the number of internal levees in a field was monitored before and after precision leveling. If at some point the LCRA would like to compute and verify water savings associated with the reduction of levees due to precision leveling, data collection on levees by physical field versus LCRA billing field would be necessary. If the number of levees is not by physical field, it is imprecise since it adds the number of levees found in both physical fields. This will make the levee density estimate equally inaccurate, which in turn leads to an inaccurate estimate of water savings associated with levee density. It was not within the scope of the

2012 project to gather levee information by physical field. However, some levee information by physical field exists but is not available for all fields in 2011.

LCRA could gather levee data through the annual HB1437 application process, although this would not capture levee data on fields leveled outside of the HB1437 program. If written into the HB1437 application form, data on the number and type of levees, by physical field, could be gathered reliably and practically on a yearly basis. This would allow for accurate data on levees before and after precision leveling. One additional recommendation the LCRA could decide to implement could be to establish a levee reduction threshold, in other words limit the number of levees allowed in a field after precision leveling for the field to be eligible for funding

Table 5: Water Savings per 100-acre Field by Levee Density

DESCRIPTION	ac-ft
SCENARIO 1: Precision leveled (levee density remains constant)	29.6
SCENARIO 2: Precision leveled + levee density drops 0.11 levees/ac (10 levees/100 ac)	50.6
SCENARIO 3: Precision leveled + levee density drops 0.21 levees/ac (20 levees/100 ac) =Average difference	69.6

Estimated using the Survey database 2012, the estimates do not apply to non-precision land leveled fields.

5.2.2 More Robust Precision Leveling Water Savings Estimates During the Ratoon Crop

This study was able to compute a water savings coefficient for precision leveling for the ratoon crop (-0.45 ac-ft/ac) using the methodology delineated in “Statistical Testing for Precision Graded Verification.” The negative sign of the precision leveling coefficient suggests that precision leveling saves water also in the ratoon crop. However, this result is from a small sample of precision-leveled fields (18-24 each year), during the ratoon crop. The first crop has 383 precision-leveled fields over a total of 966 fields in the sample, whereas ratoon crop only has 147 precision-leveled fields over a total of 476 fields in the sample. The small sample size results in a large associated confidence interval, meaning that there is significant uncertainty associated with the estimate for precision leveling water savings during the ratoon crop, per se. The LCRA could compute a robust and accurate water savings precision leveling during for the ratoon crop if more data could be collected. A more complete data set would improve the quality, accuracy and reliability of the ratoon crop precision leveling water savings estimates. An increase in the ratoon crop sample size is an important next step, as the accuracy of the ratoon crop estimate depends on the quantity and quality of the information collected.

5.2.3 Changes in Cropping Patterns

Another factor that decreases water usage is the decreased likelihood of watering and harvesting a ratoon crop on precision-leveled fields. Table 6 indicates that for non-precision leveled fields, farmers are likely to plant conventional rice varieties, while for precision-leveled fields farmers tend to plant seed or hybrid rice. When farmers plant seed and hybrid rice, this cultivar's longer growing periods constrain planting a ratoon crop. As a result of the increasing number of precision-leveled fields that use seed and hybrid rice, the number of fields during the ratoon crop has decreased. Some of the factors that increase water usage in the first crop include longer growing season due to rice variety change and crop rotation, but there may be higher total savings due to not watering a ratoon crop. If at some point the LCRA would like to compute and verify saving due to change in the cropping pattern, more data would have to be collected.

Table 6: Rice Variety in Precision Leveled Field

	CONVENTIONAL	SEED	HYBRID
PRECISION LEVELED	22%	65%	57%
NON-PRECISION LEVELED	78%	35%	43%

5.3 Other factors unrelated to Precision Leveling

5.3.1 Multiple Inlets

The quality of multiple inlet data could be improved if these data were collected by physical field and not by LCRA billing fields. LCRA's field boundaries sometimes aggregate a number of different "physical" fields for billing purposes. Water savings attributable to multiple inlets depend on the quality of these data. The LCRA should collect multiple inlet data for the physical field to achieve more precise water savings estimates.

5.3.2. Collect Rain Data from More Locations

This model has shown that precipitation affects water savings. Currently, sufficient rain data is only available at three stations in the study area. However, actual precipitation over a field is likely to vary geographically over the study area. If more rain gauging stations were available, then the model could more accurately account for the effect of precipitation on water usage.

7. Conclusion

LCRA has succeeded in its goal to evaluate its precision-leveling conservation program in Lakeside Irrigation Division. The verification study provides a conservative lower bound water savings of 0.30 ac-ft/ac for precision leveling during the first crop. The value is robust

as the values are essentially the same, or stable over the years of analysis, which include very wet years and very hot, dry years (2006-2011). The probability is greater than 999 times out of 1000 that a farmer who precision levels saves irrigation water. The best estimate of mean water savings year in and year out is 0.30 ac-ft/ac during the first crop due to precision leveling based on six years of data collection.

Progress in estimating the relationship between precision leveling and the water usage of fields should be directed to more accurate estimates of water savings during the ratoon crop. With better data, LCRA will have precision leveling water savings coefficients for both the first and ratoon crop to compare with the current 0.75 ac-ft/ac coefficient. Absence of adequate data on multiple inlets and levees by physical field also hampers LCRA's ability to capitalize on the added benefit of this verification study to estimate water savings attributable to other conservation measures besides precision leveling. With additional data on multiple inlets per physical field, LCRA will be in a stronger position to justify funding additional water conservation measures through the HB1437 grant program because the water saved by farmers is more certain. With verified water savings from precision leveling, LCRA can ensure that sufficient water savings targets are achieved so water can be transferred to the Brazos River Basin with no adverse impact on the Colorado River Basin, as required in the HB1437 legislation.

8. Acknowledgements

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