A Pricing Model to Assess the Effect of Groundwater Availability on Land Valuation

2006-07 USGS Research Grant Final Report
for
Texas Water Resources Institute (TWRI)
Texas A&M University, College Station, Texas

April 30, 2007

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Abstract:

The Ogallala Aquifer provides 90% of the water used for irrigated agriculture in the Texas Panhandle. Due to this reliance on groundwater, pumping for irrigation purposes has had a significant impact on the amount of water available for agriculture over the years. While the adoption of new technology has resulted in an efficient use of groundwater, the region still is faced with declining groundwater availability. This is due primarily to the slow or non-existent recharge rate of the aquifer in the High Plains and the increased levels of irrigation by producers. Land valuation by both taxing entities and purchasers or sellers of property should reflect the amount of water available under the land being valued, but often times the valuation does not fully or accurately reflect the availability of groundwater. Adding to the problem more recently is the purchasing of "water rights" in the region, which has raised further issues concerning how the value of the available water should be considered, both for tax purposes (regionally in the form of property tax and nationally in the form of capital gains and losses taxes).

This study sought to determine the price being paid for irrigated, dryland, grassland, and CRP acreage in order to determine the value purchasers are placing on each factor. It also looked at the importance that purchasers of agricultural land place on such variables as saturated thickness, well capacity, and pump lift. This yielded a hedonic pricing model that incorporates land usage as well as water availability that can be used to estimate the sales price for agricultural land in the region. The study results can be used to help landowners, tax authorities, credit institutions, and potential purchasers to better understand the effect that water availability currently has on land values. The results can also provide a basis for determining the value for water buyout programs for management, conservation, and planning purposes.

Introduction:

The availability of water in the Texas Panhandle is a major concern, as is the conservation of the limited supply of water in the region. The Texas High Plains area has a semi-arid climate and average low rainfalls which results in little surface water being available year-round for agriculture. Thus, more than 90% of the water used in agriculture in the High Plains area comes from the Ogallala Aquifer (Stewart, 2003 and Jenson, 2004). The aquifer covers about 36,080 square miles and it currently has a supply of water of approximately 6.1 million acre feet of water, which is expected to decline to 4.8 million acre feet by 2060 (Jenson, 2004). From 1994 to 2004, the aquifer declined at an average of 1.28 feet per year (Jenson, 2004). Adding to the problem is the low recharge rate of the aquifer in the High Plains area (Postel, 1998). In the southern region, the recharge rate has been reported to be as low as 0.024 inches per year from precipitation (Ryder, 1996).

The use of low-energy-application (LEPA) and low-energy-spray-application (LESA) have allowed for more efficient use of water in the region (Howell, 2001). However, producers have had the benefit of increased technology in drilling and installing these systems, which has led to increased irrigation use. In the southern High Plains, which uses intense irrigation, the decline in the water table has been estimated to be between 50 and 100 feet (Ryder, 1996). A contributing factor to the increased use of groundwater comes from the state laws covering the right of capture of ground water beneath the land, by which the land owner may capture the water beneath the land regardless of the effect on nearby or distant users of the water supply (Stewart, 2003). A survey conducted in 2003 showed that of 63,602 operating wells, only 4,530 wells had a meter installed (NASS, 2004). Finally, recent trends in purchasing "water rights" and the potential uses of the water associated with these rights threaten to result in further depletion.

The importance of irrigation in the area can also be seen by the difference in the price being paid for dryland acreage versus that paid for irrigated acreage. Land prices in the region have remained stable despite higher energy costs over the last seven years (Texas ASFMRA, 2005). This stability has partially been caused by the amount of good irrigated land available for sale gradually declining and the continued demand for irrigated acreage in the area. Other contributing factors in stabilizing irrigated acreage prices in spite of the rising cost to irrigate include an increased number of cotton crops in the region and the marketing of water rights (Gilliland and Klassen, 2006).

Hedonic pricing models are most commonly used in valuing real estate in housing markets, incorporating such factors as number of bathrooms, bedrooms, square footage, garage capacity, and living areas. However, several researchers have been incorporating the hedonic approach to valuing agricultural land in recent years to analyze such factors as easement payments (Lynch and Lovell, 2002), the level of accessibility and remoteness (Sengupta and Osgood, 2002), and the importance of irrigation in light of global warming (Schlenker, Hanemann, and Fisher, 2004).

Objectives:

This project was aimed at evaluating the effect that the availability of groundwater in the Texas High Plains area has on the value of the property overlying the aquifer. This is critical for a number of reasons, including possible reductions in tax bases for property tax evaluation, the value of land in purchase and sale transactions, the taxes associated with capital gains and losses for federal tax purposes, and to provide a possible further incentive to encourage greater conservation of ground water.

The specific objectives of this study were as under:

- To develop a pricing model to determine the price per acre paid for irrigated, dryland, grassland, and CRP acreage in the Texas Panhandle.
- To determine the value placed on the availability of ground water in terms of saturated thickness, depth to the aquifer (pump lift), well capacity (in gallons per minute), and acreage type (irrigated, dryland, CRP, and grassland) by purchasers of agricultural land in the region.
- To integrate the results of the first two objectives into a hedonic pricing model that accurately estimated the sales price (net of any improvements) with respect to the availability of water for irrigated acres and the value of dryland, grassland, and CRP acres.

These results provide the basis for determining the value that is added by the amount of available water, which then can be compared to the rates being paid per acre for "water rights" as well as a means for estimating the changes in land value due to future declines in the level of the Ogallala Aquifer.

Data and Methods:

Actual sales data was collected from the Panhandle Groundwater District, which includes Carson, Donley, Wheeler, Gray, Roberts, and Armstrong Counties, and the North Plains Water District, which covers Dallam, Hartley, Hansford, Hutchinson, Lipscomb, Moore, Ochiltree, and Sherman Counties. The data obtained from these two districts included the total price paid for each parcel sold, the value of any improvements to the land such as buildings, irrigation wells and equipment conveyed with the real estate sale, the legal description of the property sold, and the total acres included in the sale during a two year period covering the last half of 2004, all of 2005, and the first half of 2006. Purchaser and seller surveys conducted by the water development boards also provided information relating to the number of irrigated acres, dryland acres, grassland acres, CRP acres, the acres of unusable land (roads, easements, etc.), estimated well capacities, and price paid for each irrigated acre. Water development board records also provided information on the estimated saturated thickness, depth to the aquifer, and additional well capacity estimates for each parcel sold.

A total of 71 observations, 28 of which included irrigated acreage, and the supporting data associated with each sale was obtained for the 14 counties represented by the North Plains and Panhandle Water Districts were collected. The first phase of building the model involved regressing the net sales price, which was derived by subtracting the value of improvements from the total sales price, against the total irrigated acres, total dryland acres, total grassland acres, and total CRP acres for each sale using SAS software. This gave the contribution of each acreage type to the total price. The second phase in building the model involved regressing the actual price paid per irrigated acre against the estimated saturated thickness in feet, estimated depth to the aquifer in feet, and the estimated well capacity in gallons per minute, both individually and with the others, for each parcel sold that included irrigated acreage using SAS software. This provided the significance and the value contributed by each variable.

Results and Discussion:

The first objective was to determine the price that was paid for each acre of irrigated cropland, dryland cropland, grassland, and each acre in CRP. The net price paid for a parcel can be defined as being a function of the number of acres each type of acreage multiplied by the price per acre for each type. The SAS results presented in Table 1 show the SAS regression of the Net Sales Price (the total price paid minus the value of any improvements to the land), and the associated coefficients for the value of irrigated, dryland, grassland, and CRP acreage. The estimated equation for the total purchase price for a parcel can be shown by the equation:

Total Sales Price=\$17,118.83 + \$526.45(Number of Irrigated Acres) + \$335.64(Number of Dryland Acres) + \$359.57(Number of CRP Acres) + \$207.19(Number of Grassland Acres)

The SAS results for the 71 observations of land sales showed an R^2 of 0.9247, reflecting that the variables adequately explain the variation in the total price paid for each sale. The F-value for the model was 202.55 with a p-value of <0.001, reflecting that the independent variables are significant to the model. The results also show that each variable included in the model had a p-value of less than 0.001, showing that all of the variables are significant. Finally, the Variance Inflation Factor for each independent variable was less than 10, meaning that multicolinearity does not exist in the model.

The second objective was to analyze the effect that water availability had on the price paid for each acre of irrigated cropland. It is often assumed that the saturated thickness of the Ogallala Aquifer below the surface of irrigated cropland is the best measure of water availability and as such would be a dominant deciding factor (along with the depth to the aquifer in terms of pump lift) in a purchaser’s decision on how much to pay for irrigated cropland. However, it appears that purchasers do not consider saturated thickness at all when deciding to buy a parcel. Figure 1 shows a scatter plot of the actual price paid for irrigated cropland versus the saturated thickness in feet for each of the 28 observations for irrigated cropland sales in the study region. The trend line showed an R^2 of 0.0011, which signifies that purchasers do not consider the saturated thickness in their decision on how much to pay for irrigated acreage.

The next logical variable to consider is the well capacity of existing wells on the parcel. As Figure 2 shows, well capacity in gallons per minute is a better explanatory variable for the price of irrigated acreage than saturated thickness. The trend line shows an R^2 of 0.3153, representing that well capacity represents 31.53% of the variability in price. The independent variable also was significant, with a t-value of 3.46 and an associated p-value of less than 0.002. However, the scatter plot also shows the possible presence of heteroscedasticity, which is evidenced by the data points diverging from the trend line as well capacity increases. One of the key assumptions in regression is that the variance of the errors is constant across all observations. When the variance of the errors is not constant, standard estimation methods can yield inaccurate results. As a result, a test for heteroscedasticity was also performed.

The model procedure in SAS provides the ability to test for heteroscedasticity using Whit's test, which is a general test that does not make any assumptions about the form of heteroscedasticity, and the Modified Breusch-Pagan test, which is less sensitive to the assumption of normality than the original test. The null hypothesis for both tests is that the error variances are constant (no heteroscedasticity). Table 2 gives the SAS model test statistics for both White's and the Breusch-Pagan tests Calculated in SAS for well capacity.

The test statistic for White's was 2.57 with a p-value of 0.2761 and the Modified Breusch-Pagan statistic was a 1.12 with a p-value of 0.2892. This means that the null hypothesis can not be rejected and thus heteroscedasticity does not exist. This was also confirmed by conducting a standard Breusch-Pagan test by regressing the squared residuals against the independent variable which gave a F-test statistic of 0.857 and a p-value of 0.363, meaning that the independent variables are not jointly significant and thus the null hypothesis of no heteroscedasticity can not be rejected, or the model is homoscedastic.

Another factor to be considered in building the model is the effect that pump lift may have on price. As the pump lift increases, the cost to irrigate also increases. This means that a purchaser of irrigated cropland should consider what it will cost to irrigate the acreage. Figure 3 shows a plot of the price per irrigated acre versus pump lift in feet for the 28 observations of irrigated acreage sales. As the plot shows, the pump lift has a negative impact on irrigated acreage prices. The R^2 associated with the trend line in the scatter plot was a 0.4054, which signifies that pump lift does describe some of the variability in irrigated land prices. Here again, however, it appears that heteroscedasticity may be present, necessitating the need to conduct a White's and a Modified Breusch-Pagan test.

Table 3 gives the SAS model results for the irrigated price per acre against pump lift in feet and the associated heteroscedasticity tests. The statisitic for the White's test was 8.59 with an associated p-value of 0.0136, and the statisitic for the Modified Breusch-Pagan test was 8.55 with an associated p-value of 0.0035. Both tests show that the hypothesis of no heteroscedasticity can be rejected, meaning that heteroscedasticity is present with pump lift. A standard Breusch-Pagan test confirmed these findings, yielding an F-value of 14.54 and an associated p-value less than 0.001, meaning that the independent variables are jointly significant and thus the null hypothesis is rejected, resulting in the conclusion that heteroscedasticity does exist. This means that any model using pump lift will require transforming the pump lift variable. Figure 4 shows the plot of dividing negative 1 by the pump lift and plotting against the price per irrigated acre. It is clearly apparent by the plot that this corrects for the heteroscedasticity, and increases the R^2 to 0.47.

Due to the fact that both well capacity and pump lift were found to be significant to purchasers' decisions, both are included in the final model on water availability. Table 4 presents the SAS regression output for the combined model with the two independent variables. The heteroscedastic situation with pump lift was corrected in the model by dividing negative one by the pump lift in feet, then running the regression is SAS along with well capacity and irrigated acre price. The overall model returned an R^2 of 0.6304, which was significantly better than either of the two models with individual independent variables. The F-value for the overall model was 21.32 with a p-value less than 0.001, signifying that the independent variables are significant to the model. The overall model can thus be expressed as:

Price per Irrigated Acre = $166.17 + $0.49(Well Capacity in GPM) +

-1/(– 26541.90(Pump Lift in Feet))

The coefficient associated with well capacity had a t-value of 3.29 and an associated p-value of 0.002, and the coefficient associated with pump lift had a t-value of -4.62 and a p-value of less than 0.001. This shows that that both independent variables are significant to the overall model and thus should be included. One possible concern with using both well capacity and pump lift is the possibility of multicolinearity, as there is it is possible for pump capacity to be affected by pump lift. However, the Variance Inflation Factor for both variables was less than 10, showing that multicolinearity does not exist in the model.

The final hedonic price model can now be derived by combining the two models developed previously:

Total Price = $17,118.83 + ($166.17 + $0.49(Well Capacity in GPM) + -1/(– 26541.90(Pump Lift in Feet)) +

$335.64(Number of Dryland Acres) + $359.57(Number of CRP Acres) +

$207.19(Number of Grassland Acres)

The total sales price is a function of the individual prices for irrigated cropland, dryland cropland, grass land, and acreage in CRP, and the price for irrigated cropland is a function of well capacity and pump lift.

Conclusion:

The model for total sales price as a function of each type of acreage was shown to be a significant model. However, in order to incorporate the full effect that water availability has on land valuation, a separate model had to be developed to account for the variables that contribute to the amount of water available for irrigation. This was accomplished by developing a second model for that sole purpose. The result is a hedonic pricing model for valuing agricultural land that is more accurate in terms of the effect of water availability, while retaining non-irrigation variables. This model allows for assessors, appraisers, purchasers, and policy makers to better understand what buyers of agricultural land are actually paying for irrigated farm land as well as for non-irrigated acreage.

Future research endeavors will seek to acquire more observations, as well as more accurate data from other groundwater districts not included in this study. Additional observations are available as data exists for land sales prior to 2004, though this study did not utilize them in order to avoid complications due to inflationary issues. One possible method for correcting for price changes over time would be the development of an index based in part on the Consumer Price Index. Additional research will also focus on adding variables for soil type and climatic changes, though preliminary results showed that climate may have a minimal effect as there is not a lot of variability from one county in the region to another.

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Exhibits:

Table 1: SAS Regression Results, Net Parcel Price against Acres by Type.

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                             Dependent Variable: price

                      Number of Observations Read          71
                      Number of Observations Used          71


                                Analysis of Variance

                                       Sum of           Mean
   Source                   DF        Squares         Square    F Value    Pr > F

   Model                     4    1.125005E12    2.812512E11     202.55    <.0001
   Error                    66    91642405151     1388521290
   Corrected Total          70    1.216647E12


                Root MSE                37263    R-Square     0.9247
                Dependent Mean         176003    Adj R-Sq     0.9201
                Coeff Var            21.17173


                                Parameter Estimates

                     Parameter       Standard                              Variance
Variable     DF       Estimate          Error    t Value    Pr > |t|      Inflation

Intercept     1          17119     7742.16271       2.21      0.0305              0
irrigated     1      526.44747       23.13958      22.75      <.0001        1.19938
dryland       1      335.63837       23.80685      14.10      <.0001        1.06788
crp           1      359.57293       45.13412       7.97      <.0001        1.14745
grass         1      207.19266       53.96070       3.84      0.0003        1.17659
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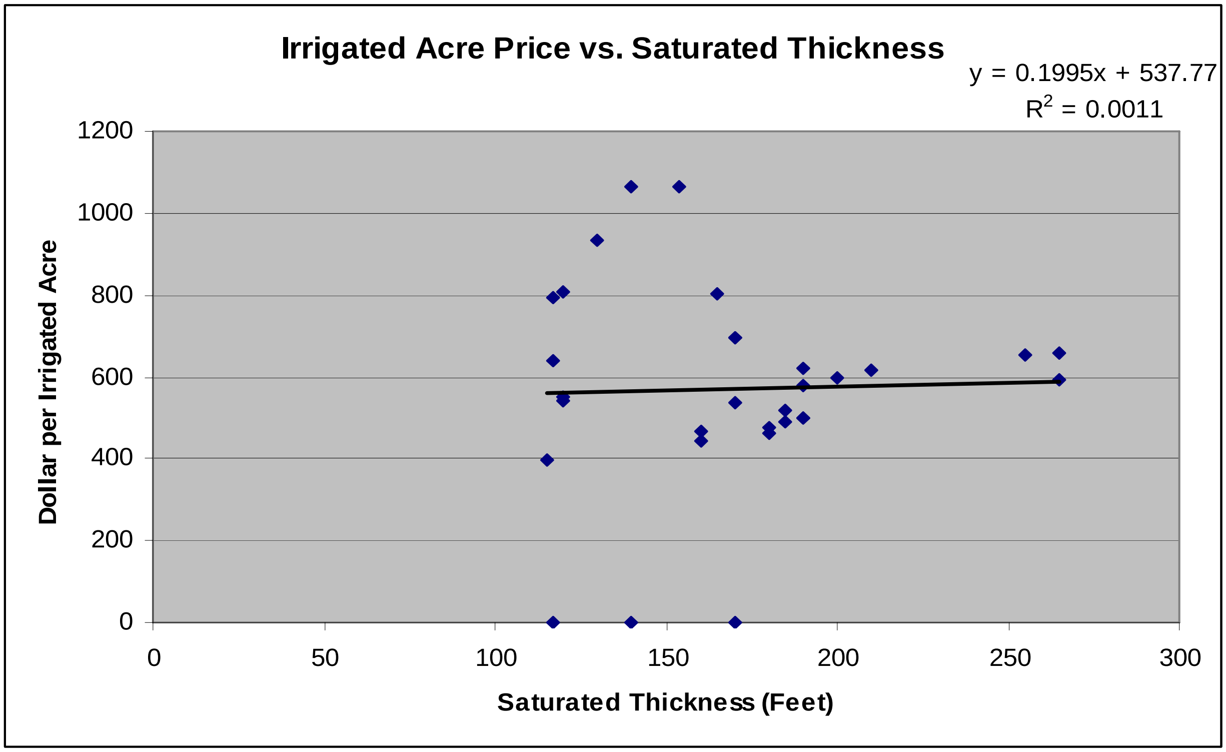

Figure 1: Plot of Actual Price Paid for Irrigated Acreage versus Saturated Thickness in Feet.

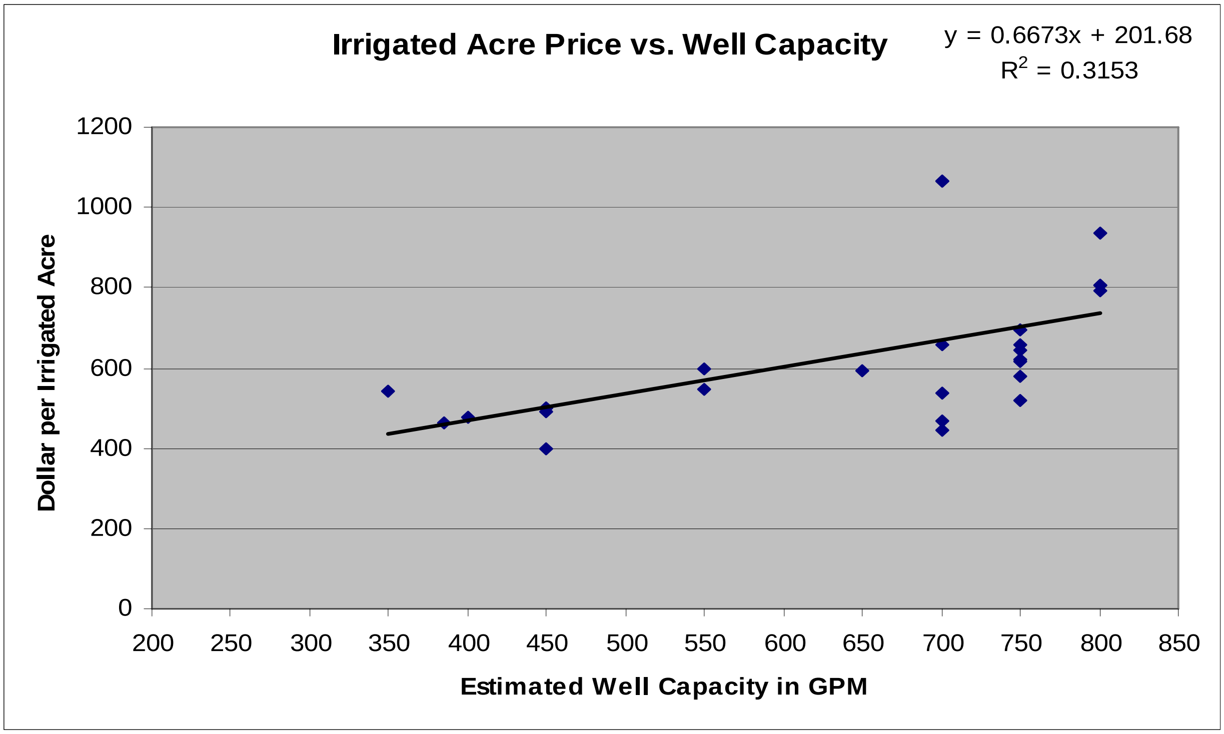

Figure 2: Plot of Actual Price Paid for Irrigated Acreage versus Well Capacity in Gallons per minute.

Table 2: SAS Model Results with White's and Breusch-Pagan Tests for Heteroscedasticity, Net Parcel Price against Well Capacity in Gallons per Minute.

Model R^2	0.3153			
Observations	28			
DF Model	2			
DF Error	26			
Parameter	Estimate	Standard Error	t-Value	p-Value
Intercept	201.68	127.7000	1.58	0.126
GPM	0.667	0.193	3.46	< 0.002
Test	Statistic	DF	Pr > ChiSq	Variables
White's	2.57	2	0.2761	All
Breusch-Pagan	1.12	1	0.2892	GPM

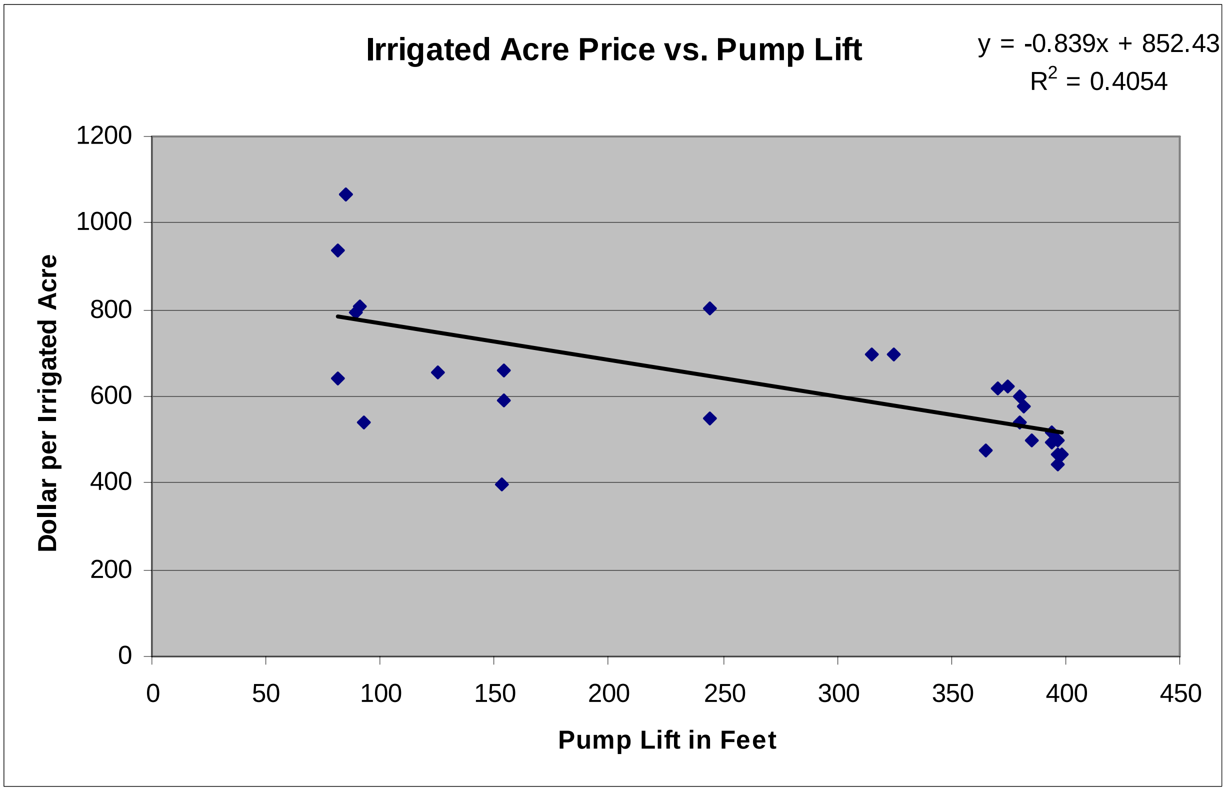

Figure 3: Plot of Actual Price Paid for Irrigated Acreage versus Pump Lift in Feet.

Table3: SAS Model Results with White's and Breusch-Pagan Tests for Heteroscedasticity, Net Parcel Price against Pump Lift in Feet.

Model R^2	0.4054			
Observations	28			
DF Model	2			
DF Error	26			
Parameter	Estimate	Standard Error	t-Value	p-Value
Intercept	852.43	58.315	14.62	< 0.001
GPM	-0.84	0.193	3.46	< 0.001
Test	Statistic	DF	Pr > ChiSq	Variables
White's	8.59	2	0.0136	All
Breusch-Pagan	8.55	1	0.0035	Lift

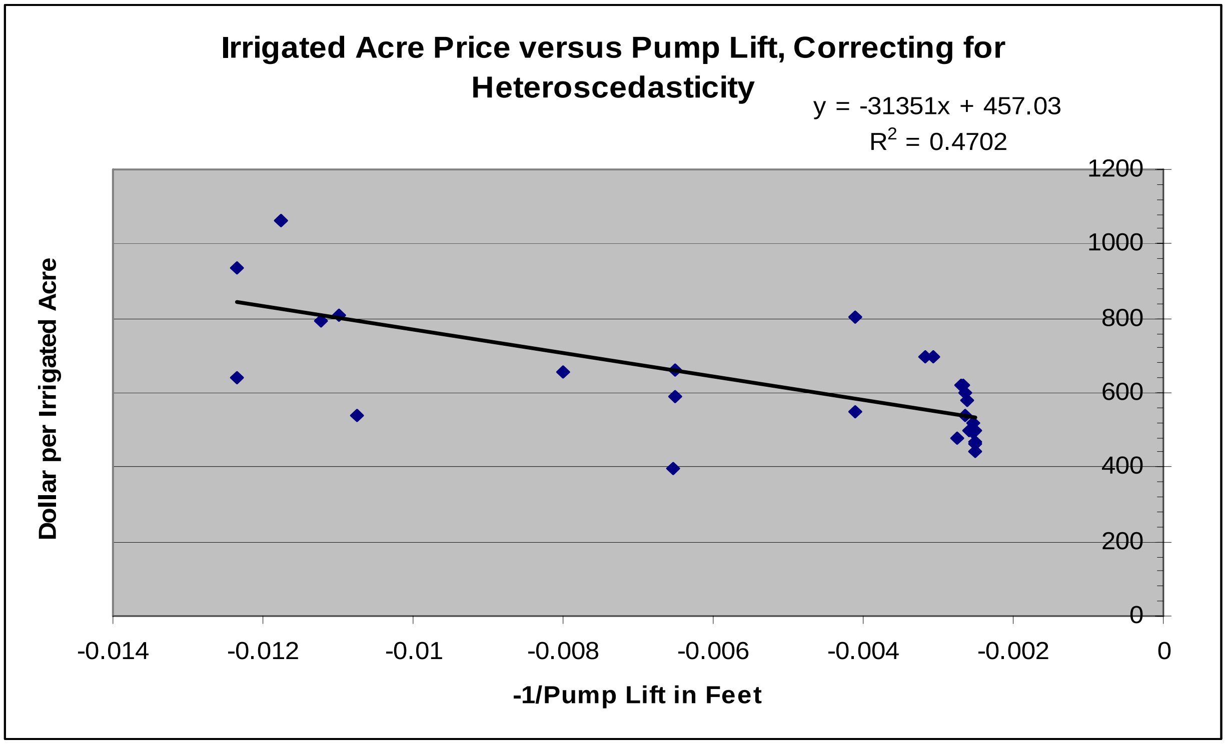

Figure 4: Plot of Actual Price Paid for Irrigated Acreage versus Negative 1 over the Pump Lift in Feet to correct for Heteroscedasticity.

Table 4: SAS Regression Results , Net Parcel Price against Well Capacity in Gallons per Minute and Negative One over Pump Lift in Feet.

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                       Analysis of Variance

                                      Sum of           Mean
      Source                DF       Squares         Square    F Value    Pr > F

      Model                  2        522855         261428      21.32    <.0001
      Error                 25        306603          12256
      Corrected Total       27        829458


                 Root MSE            110.74341    R-Square     0.6304
                 Dependent Mean      632.71429    Adj R-Sq     0.6008
                 Coeff Var            17.50291


                             Parameter Estimates

                           Parameter       Standard                                Variance
   Variable      DF         Estimate          Error    t Value    Pr > |t|        Inflation

   Intercept      1        166.21128       95.96520       1.73      0.0956                0
   gpm            1          0.49205        0.14942       3.29      0.0030          1.06906
   lift           1           -26533        5748.10      -4.62      0.0001          1.06906
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