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Break-Even Investment in a Wind Energy Conversion System for an Irrigated Farm on the Texas High Plans

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ABSTRACT

The purpose of this study was to quantify the benefits of using a wind energy system for irrigation. The value of wind energy was estimated on both a static basis (where the annual value of wind power was assumed to be constant over the life of the machine) and on a temporal basis (where the annual value of wind power was estimated recursively).

The model for static analysis contained two components which were applied consecutively. The first was a linear programming (LP) model for the High Plains region. Production activities were included which allowed both optimal and non-optimal timing of post-plant irrigations, giving the producer added flexibility in the employment of limiting water resources. The optimal irrigation schedule determined by the LP solution was used as input to the second component. A simulation model matched stochastically generated estimates of wind power availability with irrigation fuel requirements (derived from the profit maximizing irrigation schedule) by three-hour time periods throughout a year.

For the temporal analysis, a Fortran subroutine was added to the LP model to operate the model recursively over the life of the wind system and to account for the annual decline of the aquifer. Both fixed and variable costs were included. The basic LP model was applied to develop the benchmark case (i.e., without wind power). The farm operation with wind power was analyzed by applying the LP model with the monthly expectations of wind-generated electricity added.

Two wind machines were analyzed, with rate outputs of 40 to 60 kilowatts (KW). Each was applied to the Northern and Southern Texas

High Plains over a range of land and water resource situations. Break-even investment was estimated at discount rates of three, five and ten percent.

Cropping patterns on the Southern High Plains were dominated by irrigated cotton and were insensitive to changes in crop or electricity prices. On the Northern High Plains, irrigated corn and grain sorghum were the major crops, with acreage reverting to dryland wheat at the higher electricity prices. The cropping patterns in this area were impacted heavily by labor restrictions. Consideration of wind power had little effect in determining optimal cropping patterns.

When wind power was applied to an irrigated farm on a static basis, the set of crop prices applied had little effect on the annual value of a wind system. Value of wind power was increased, but by smaller proportions than associated increases in the price of electricity. Each machine size had a greater value when operated on the larger of the two applicable land units (100 acres for the 40 KW machine and 144 acres for the 60 KW system). The 60 KW system was also tested on the 100 acre unit but returned less per KW than the 40 KW system.

Available wind power in the temporal analysis was less than in the static analysis, thus temporal estimates of wind system value should be regarded as conservative. On the Southern High Plains, break-even investment was decreased slightly from the static analysis. However, in some situations on the Northern High Plains, break-even investment increased. This indicates that the value of wind power could increase as the aquifer declines in some situations. Break-even investment increased by up to 80 percent when the price of electricity was increased by $.005 per KWH per year. The most significant effect of wind power was that it allowed the maintenance of irrigation levels which, without wind power, had been made uneconomical.

These results indicate that, at least in the future when wind system costs decrease and stabilize, wind-assisted irrigation could be an economically viable alternative for Texas High Plains producers. The results are limited by the need for future research regarding the effect of irrigation timing on crop yield as well as some of the long-term characteristics of wind system operation, such as durability and the requirements and costs for system repairs and maintenance.

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CHAPTER I

INTRODUCTION

The Texas High Plains is a fairly level, semi-arid region located on the Southern Great Plains, encompassing about 35,000 square miles. The region's climate and land resource capability support dryland production of cotton, grain sorghum and wheat. With irrigation, yields of these crops can be increased substantially and other crops such as corn and soybeans can be produced. In addition, irrigation can greatly reduce the risk of drought (Black).

Irrigation water on the High Plains is pumped from the underlying Ogallala aquifer. This aquifer receives a negligible amount of recharge (one-half to one inch per year) compared to the amount of water withdrawn annually. Average annual rates of decline in the static water level have been projected to be from .35 to 4.08 feet, depending on the original saturated thickness (Wyatt, et al.). For the farmer, this results in (1) declining well yields, where less water can be pumped in a given period of time, (2) increased energy requirements as pumping lift increases and (3) eventual economic exhaustion of the water supply for irrigation.

Energy is one of the most important input factors in irrigated crop production. In 1973, it was estimated that 39 percent of the

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total agricultural energy demand in Texas was for pumping groundwater (Coble and LePori). This figure is likely understated for the High Plains, due to the relatively higher intensity of irrigation in the area. An estimate for this region in 1975 showed that 53.4 percent of the total variable costs of producing irrigated corn was energy related (Skold).

The dramatic increases in energy prices since 1973, in conjunction with higher variability of crop prices, have accelerated research directed to reducing costs of production. For example, emphasis has been placed on modified crop production systems which seek to improve the energy efficiency of irrigated production by reducing the usage of energy inputs (Condra, et al.; Sprott, et al.). Other studies have focused on the benefits of reducing energy requirements through reducing the amount of water pumped, improving irrigation and pumping plant efficiencies, and lowering the distribution system pressure requirements (Hardin, et al.; Hardin and Lacewell, 1979).

The sensitivity of irrigated agriculture to increased fuel costs has placed considerable emphasis on the development of new and competitive alternative energy supplies. Much of the research emphasis in agriculture has been placed on biomass; i.e., the conversion of crop residue into usable energy (LePori and Lacewell). In addition, the utilization of grain for the production of alcohol has gained substantial interest (Hiler). Solar energy has been proposed as an alternative to the use of natural gas in grain drying applications (Knutson, et al.) and for irrigation (Katzman and Matlin).

The use of wind energy is being developed in a number of agricultural applications, including water heating (Gunkel, et al.) and for cooling and refrigeration (O'Brien, et al.). The application which is of most interest to High Plains crop producers is that of wind-assisted irrigation pumping. Large scale wind systems have been developed which are capable of providing supplemental energy to an existing electrical pumping plant. The electric motor is sized to operate the pump on a stand-alone basis. However, when the wind velocity is sufficient, the wind system operates and reduces the load on the electric motor (Clark and Schneider).

The wind-assist concept appears to be a particularly attractive alternative on the High Plains. A study by Elliot shows that the mean annual wind power available is as high as in any other area in the nation, with monthly average wind speeds ranging from 15.6 miles per hour (mph) in March to 12.1 mph in August. In addition, about 50 percent of the energy used on irrigated farms in the area is accounted for by irrigation pumping (Clark and Schneider), thus providing a large potential for energy substitution.

Previous studies (Clark and Schneider; Buzenberg, et al.) considering wind power application to irrigation have shown potential savings but have assumed no load management; i.e., rescheduling energy use to periods of expected high winds. This leaves open the possibility of further savings. For example, on the High Plains, traditional cropping patterns (involving corn, grain sorghum and cotton) make the summer months (when post-plant irrigations are applied) the peak water use period. However, peak winds occur in the spring months when wheat, which in the past has not been one of the area's major irrigated crops, uses the bulk of its irrigation water. Further load management strategies might include the consideration of non-optimal irrigation timing, that is, shifting one or more post-plant irrigations to different time periods. The negative effect on yield might be compensated for not only in energy savings from wind, but also through the possible extension of a seasonally limited water supply. High Plains producers, faced with declining well yields and increasing energy requirements due to the continuing depletion of the Ogallala aquifer, are in a position to benefit considerably from the use of wind energy. However, these benefits must be quantified.

Objectives

The general objective of this study is to determine the economic value of a wind energy conversion system (WECS) for an irrigated farm on the Texas High Plains. Specific objectives of the study are:

1. Develop a model to plan the optimal farm organization and simulate the energy generated by a wind system.
2. Estimate the value of wind energy under alternative situations of groundwater availability and size of wind system.
3. Test the sensitivity of the results to changes in energy costs and crop prices.
4. Estimate the value of wind energy considering load management strategies.
5. Estimate the temporal value of wind energy considering a declining groundwater supply.

The Study Area

The High Plains of Texas includes 42 counties and is roughly rectangular, averaging about 300 miles north to south and 120 miles east to west. The Canadian River flows from west to east, dividing the region. The main soils in the region include Pullman, Mansker and Richfield in the "Hardlands", Amarillo and Portales in the "Mixed Lands", and Brownfield and Tivoli in the "Sandy Lands". Average annual rainfall averages from 14 to 21 inches, with the growing season ranging from 180 to 220 days (Godfrey, et al.).

The High Plains region has 34 percent of the total cropland, and approximately 70 percent of the irrigated cropland in Texas. Over the period from 1970 to 1977, crop production from the region (as a percentage of total state production) was 61 percent of cotton, 50 percent of grain sorghum and 61 percent of wheat. The area also produces 78 percent of the fed cattle in Texas, enough to feed 13.2 million people (Texas Department of Water Resources).

Pumpage from the Ogallala for irrigation purposes began to rise to a significant level in the late 1930's and accelerated in the 1950's, spurred by the availability of low-cost natural gas. This rapid development has resulted in the mining of Ogallala water. In 1974, there were nearly 5.9 million irrigated acres on the High Plains. However, based on projected pumpage rates, the aquifer will be able to supply enough water to irrigate only 53 percent of these acres by the year 2000 and only 35 percent in 2030 (Texas Water Development Board).

The study area lies within a 21-county sub-region of the High

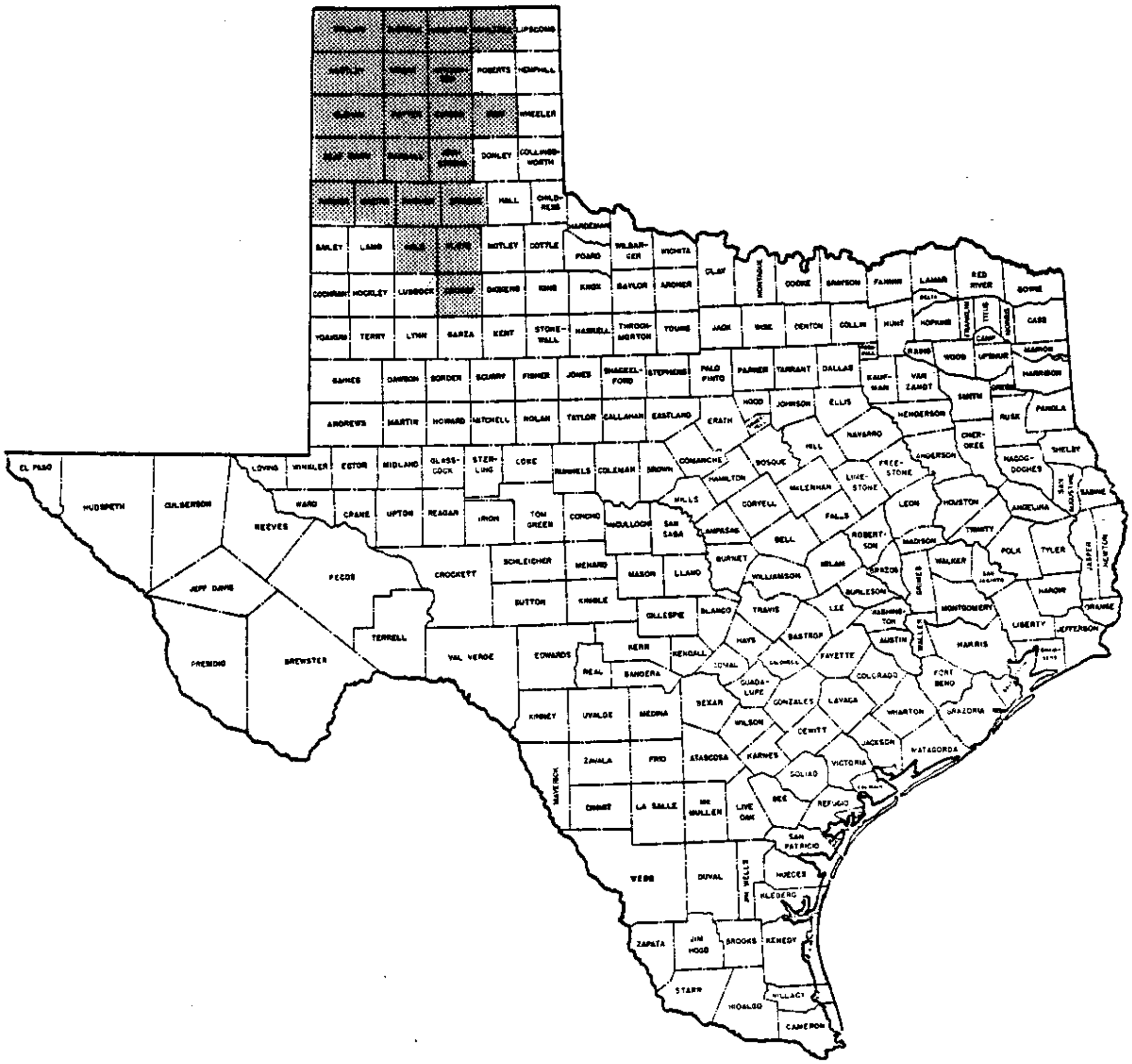

Figure 1. Map of the Study Area.

Plains, Figure 1. In 1974, 4.16 million acres in the region were irrigated, which was 66 percent of the total crop acreage (New, 1977). In 1979, irrigated acreage had decreased to 3.27 million acres (57 percent of total cropland), while total crop acreage had declined by over 572 thousand acres (Texas Crop and Livestock Reporting Service, 1979). Much of this decrease comes from the area south of the Canadian River, where irrigation development began earlier than in the northern region.

Even though irrigated acreage is decreasing, irrigated agriculture continues to be of vital importance to the state and regional economies. The region produced 77 percent of the grain sorghum and 87 percent of the wheat harvested from irrigated acreage in the state in 1979. Due to the length of the growing season, cotton can be produced only south of the Canadian River. Still, this portion of the study area produced 24 percent of the state's irrigated cotton output (Texas Crop and Livestock Reporting Service, 1979).

There were 37,010 irrigation wells in the area in 1977, 9,029 of which were powered by electricity. Natural gas was the predominant fuel used, powering 27,323 wells. Ninety-eight percent of the wells lift water from a depth greater than 125 feet, while 73 percent produce less than 700 gallons per minute (New, 1977). Most of the lower yielding wells were situated in the southern part of the region. Surface irrigation methods were used on 90 percent of the irrigated acres, while sprinkler systems were in use on the remaining 10 percent.

Review of Literature

The following review of literature was developed to address two major areas. The first section, in general, deals with irrigation on the High Plains. This includes studies which address the impacts of, and adjustments to, the problems of increasing energy costs and declining groundwater levels. The second section examines wind energy applications.

High Plains Irrigation

The High Plains has been the focus of several studies on the expected effect of increasing irrigation fuel prices. A common thread among these studies has been the significance of crop price levels on the ability of producers to adjust to increasing energy costs.

Break-even relationships between product and irrigation fuel prices for High Plains irrigators were estimated for natural gas (Hardin and Lacewell, 1977) and for electricity (Shipley and Goss). Both studies showed that all crops except cotton were threatened for continued irrigation at prevailing prices, particularly for farm operators who did not own their land. However, relatively small crop price increases could have changed several cases. A regional study for the High Plains (Lacewell, Condra and Fish) showed similar effects. When average 1971-1974 crop prices were assumed, significant cropping pattern adjustments would be made when natural gas price reached $2.47 per thousand cubic feet (mcf). When higher crop prices were used, indicative of 1975-1976, irrigated acreage held constant up to a price of $5.46 per mcf for natural gas.

A more recent analysis (Petty, et al.) examined both static (one year) and temporal effects of increasing energy prices. In response to an increase from $1.50 per mcf to $2.50 per mcf, annual net returns were decreased by from 9 to 15 percent for sprinkler irrigation, and from 5 to 13 percent for furrow irrigation, depending on well yield and pumping level. A temporal analysis with natural gas price increasing $.10 mcf per year showed reductions in the present value of the water supply of up to 59 percent, while an increase of $.25 per mcf per year decreased returns to water by as much as 79 percent. In both cases, the economic life of the water supply was reduced significantly.

The continuing decline of the Ogallala aquifer not only affects the profitability of individual producers but, due to reductions in irrigated acreage, will exert significant downward pressure on the economy of the region. Several attempts have been made to quantify this conclusion.

In 1967, the value of crop output in the High Plains was estimated by Osborn and Harris to be $778.1 million, of which nearly 82 percent was attributed to irrigated crops. By the year 2015, it was forecast that irrigated production would decrease by 61.6 percent. Even with an increase in dryland production value, the total value of crop production would be only 60.9 percent of the 1967 value. For approximately the same time period (1966 to 2015), Hughes and Harman predicted massive reductions in production of cotton and grain sorghum, with a smaller increase in the production of wheat. Total value of agricultural production was estimated to decline by more than 70 percent.

In another study, Harman, Hughes and Martin evaluated increases in farm size necessary to adjust from irrigated to dryland farming without sacrificing living standards or net worth. It was shown that only those producers in areas having more than 225 feet of initial saturated thickness (approximately 30 percent of the area) would be able to make this transition.

Rising costs of all inputs, not only energy, have given rise to the development of new production systems. Of particular interest are those which improve the efficiency of water use; thus, also attempting to reduce the requirements for groundwater pumpage. The use of conservation bench terraces (Jones) and, more recently, furrow diking (Clark) have been tested. Both practices have the effect of holding more runoff water on the field so that it may be utilized by the crop. Over 21 years, average grain sorghum yields on conservation benches were 60 percent higher than shown from land where runoff was lost. Furrow dams have been shown to increase yields of dryland cotton from 11 to 25 percent and dryland grain sorghum from 25 to 40 percent (Runkles). Further efficiency gains are expected from a developing system which combines furrow diking with a low energy-precision system of applying irrigation water (Lyle). The system is designed to use all water more efficiently as well as reduce energy requirements for pumping.

Wind Energy

As is to be expected in a developing field, the major proportion of the studies in wind energy deal solely with the engineering aspects of wind systems. Of the limited number of studies making any mention of economics, most have simply amortized the expected cost of a wind machine and divided by expected output to find cost per kilowatt-hour produced (e.g., Eldridge). However, these estimates have little relevance when examining the use of wind for irrigation purposes, where the actual timing of wind power received and electricity used is of critical importance. The articles cited below represent the available literature which actually considers such factors.

A wind energy project for irrigation pumping was started at the U.S. Department of Agriculture Southwestern Great Plains Research Center in Bushland, Texas in late 1976 (Clark and Schneider). A vertical-axis wind turbine was installed which was designed to produce 40 kilowatts (KW) in a 32 mph wind and furnish power only when the wind speed is above 13 mph. A test of the system was reported for the period between 9:00 a.m. and 4:00 p.m. on September 18, 1978. The pump produced 458 gallons per minute with a total dynamic head of 344 feet. In the seven hour period reported, the wind turbine produced an average of 35.9 KW. Overall, 65 percent of the energy required to pump water was produced by the wind, despite the fact that the long-term average wind speed for September is one of the lower in the year (U.S. Department of Commerce).

A 1980 study also shows the High Plains to have considerable potential for using wind power for irrigation (Lansford, et al.). Average monthly wind power was estimated from historical data and, along with load characteristics, were used to estimate break-even investment values for three energy price scenarios and two discount rates. Wind-assist electric systems with sale of surplus electricity were shown to be economically viable in the high energy price scenario. At lower energy prices, break-even values were less than the cost of prototype units. However, irrigators in a position to take advantage of tax savings could afford to make the investment, even at lower energy prices.

A study using a simulation model to determine the optimum size wind system for each of 1.775 million potential farm applications in 23 states included both farm operation and residential uses (Buzenberg, et al.). Wind velocity was described by Beta distributions for each of 15 wind reporting stations. Other input into the model included load characteristics for each application, wind turbine capital costs (high and low estimates) and alternative electricity costs of \$.04, \$.06 and \$.08 per kilowatt hour (KWH). Wind systems were found to be economically feasible only with low capital costs and electricity priced at \$.06 and \$.08 per KWH. In the state of Texas, there were estimated to be 3200 potentially viable wind systems with annual net savings of \$1.92 million when electricity was priced at \$.06 per KWH. With electricity at \$.08 per KWH, there were 187,700 viable systems with annual savings of \$9.04 million.

The initial cost of a wind system is also subject to some uncertainty as different producers are in different stages of technological development. Recent estimates of installed costs for small systems (less than 100 KW rated output) have been as low as \$500 to \$700 per installed KW (Gipe) and ranging up to \$2000 per KW (Alternative Energy Institute). Again, this is due to the relatively new nature of the field. As more companies move past the prototype stage into production, prices should decrease and stabilize. A typical prediction of mature costs is in the \$300 to \$500 per KW range (Katzenberg). Another cost factor is the possibility of tax savings. Federal solar tax credits, which effectively reduce the initial cost, are available with individuals receiving 40 percent of the first $100,000 invested, while businesses can claim 25 percent with no upper limit (Alternative Energy Institute). However, these are credits, meaning that the investor must have taxes due to be reduced.

An Overview of the Study

The following chapter presents some of the major theoretical concepts which provide a background for the study. Chapter III chronicles the development of the study's data base and analytical models. Some results relating to wind power are included in Chapter IV, while Chapter V presents the results of wind-assisted irrigation. A summary and some of the limitations inherent to the study make up the final section.

CHAPTER II

THEORETICAL CONSIDERATIONS

The theoretical background in this study encompasses two areas. Elements of probability theory provide the basis for the estimation of power generated by a wind machine. Economic theory presents the conditions necessary for optimal allocation of resources by the profit maximizing firm. These theoretical principles will be discussed in this chapter, as well as the quantitative techniques selected to estimate the value of wind power.

Probability Theory

Stochastic generation of wind power requires knowledge of the magnitude, and the relative frequency thereof, of wind velocities. These characteristics can be described by a probability density function (p.d.f.), a mutually exclusive list of all values of a random variable which may result from a random process, and the probability associated with each (Richmond). For a discrete random variable, the probability of each event can be shown. For example, there are only two possible outcomes associated with the toss of a fair coin. The probability of each is 1/2.[1]

A continuous random variable, such as wind speed, has no

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[1] This illustrates another characteristics of a p.d.f.. that the sum of all probabilities of all events equals one.

probability associated with the occurrence of a given point, since there are an infinite number of points. Statements of probability associated with a continuous p.d.f. can, however, be expressed in terms of intervals. Using the example of wind, the probability of a velocity of 15 mph is zero, while it would be possible to determine the probability of wind speeds greater than 14.99 mph and less than 15.01 mph.

This evaluation requires a further concept, cumulative probabilities, which state the probability that the random variable assumes a value less than or equal to a given number. A distribution that gives the cumulative probabilities for every value of the random variable is known as the cumulative distribution function (c.d.f.) (Kmenta). If the p.d.f. is represented by f(v), the c.d.f. at any point X is given by

$$F(X) = \int_{-\infty}^{X} f(v)dv \tag{1}$$

and is subject to the following properties (Hogg and Craig):
(a) $0 \leq F(X) \leq 1$; (b) F(X) is a non-decreasing function of X; and
(c) $F(\infty) = 1$ and $F(-\infty) = 0$. Given the cumulative distribution, the probability of wind speeds between 14.99 and 15.01 mph could be determined by evaluating F(15.01) minus F(14.99).

Simulation

Once the c.d.f. is identified, it can be used to stochastically generate random wind speeds. The c.d.f. is transformed such that v, the value of the random variable, is expressed as a function of its cumulative probability. Since, as is shown above, the cumulative probability is always between 0 and 1, a random number drawn from a uniform distribution (0-1) can be substituted. By solving the transformation of the c.d.f., a unique value of v is generated which is associated with the cumulative probability represented by the value of the random number. Use of this procedure will allow the generation of a series of independent, stochastic wind speeds which will be used in the simulation model to calculate electricity produced by a wind machine.

Mathematical Expectation

The planning and temporal models will require estimates of average wind power over a given time period rather than individual, stochastically generated values. Let f(v) represent a p.d.f. of wind speed and g(v) a function which represents the amount of electrical power generated as a function of wind speed. Thus, g(v) may be thought of as the "payoff" of each value of v. The mathematical expectation or expected value of wind power generated, E[g(v)], can be expressed as

$$E[g(v)] = \int_{-\infty}^{\infty} f(v)g(v)dv. \qquad (2)$$

Selection of a Density Function

Previous studies (Doran, et al.; Cliff; Hennessey) have proposed two general analytical forms as appropriate for the description of wind velocity density functions. The Weibull distribution is a function of two parameters measuring, indirectly, the mean and standard deviation of wind speed, while the Rayleigh distribution has a single parameter, the long-term mean wind speed. At low average wind speeds (less than 10 mph) the Weibull distribution is significantly better. However, at higher average wind speeds, there is little difference between the two (Doran, et al.). Since, as noted earlier, average High Plains wind speeds are considerably above 10 mph, the Rayleigh distribution was selected for this study due to is simpler form.

The Rayleigh distribution of wind speed can be expressed as

$$f(v) = \frac{\Pi v}{2\bar{v}^2} \exp\left[-\frac{\Pi}{4}\left(\frac{v}{\bar{v}}\right)^2\right] \qquad (3)$$

where $\bar{v}$ represents the mean wind speed. This yields the cumulative distribution

$$F(x) = 1 - \exp\left[-\frac{\Pi}{4}\left(\frac{v}{\bar{v}}\right)^2\right]. \qquad (4)$$

The transformation of this distribution for use in simulation would be

$$V = {\frac{-\ell n(1-F(x))f\bar{v}^2}{\Pi}}^{\frac{1}{2}} . \qquad (5)$$

Selection of a Power Function

The choice of a function to relate electrical power generation to wind speed was dictated by the need for the function to apply to different sizes of wind machines. A typical power function of the quadratic form applies to a National Aeronautics and Space Administration prototype unit (Puthoff and Sirocky). The general form of this function has been applied to different machines in other studies

(Doran, et al.; Justus, et al.).

The power function is described by

$$g(v) = 0 \quad , \qquad v \leq v_o \tag{6}$$

$$g(v) = a + bv + cv^2, \qquad v_o < v \leq v_1 \tag{7}$$

$$g(v) = P \quad , \qquad v_1 < v \leq v_2 \tag{8}$$

$$g(v) = 0 \quad , \qquad v > v_2 \tag{9}$$

where:

$g(v)$ = wind generator output, in KW

P = rated (maximum) power output

v_o = cut-in speed, below which the machine does not operate

v_1 = rated speed, at which the machine begins to produce its rated output

v_2 = cut-out speed, above which the machine does not operate.

Power output is assumed to be constant at rated power when wind velocity is between rated speed and cut-out speed, and varies parabolically from zero at cut-in speed to rated power at rated speed. The parameters a, b and c are estimated as functions of these variables and are determined by solving the following set of simultaneous equations (Justus, et al.).

$$a + bv_o + cv_o^2 = 0 \tag{10}$$

$$a + bv_1 + cv_1^2 = P \tag{11}$$

$$a + bv_c + cv_c^2 = P\ (V_c/V_1)^3 \tag{12}$$

where

$$v_c = (v_0 + v_1)/2. \tag{13}$$

Economic Theory

The typical farm operator on the Texas High Plains is assumed to use production economic theory to allocate resources among competing enterprises such that net returns to the farm firm are maximized. The primary focus of this study is on resources; irrigation water pumped from an exhaustible aquifer and the fuel necessary to pump it. Some of the theoretical principles which underlie optimal resource allocation will be discussed here. More detailed expositions of economic theory may be found in other references, such as Leftwich or Henderson and Quandt.

Allocation of Variable Resources

The profit maximizing firm determines its optimal resource allocation from the interrelationships of the production function and the input and output prices. The production function measures the relationship between a firm's inputs of resources and its level of output. Marginal physical product (MPP), defined as the first derivative of the production function, measures the change in output per unit change in the quantity employed of a given input, holding all other input levels constant. This study focuses on crop output with the major variable input being irrigation water. Typically, crop production functions are characterized by diminishing marginal productivity of water, meaning that each successive unit of water contributes less to output than the preceding unit.

Input levels are determined by the point at which the last unit of input used makes the same contribution to profit as its price. The contribution of an input to profits is measured by its marginal value product (MVP), which, for a firm facing perfect competition in the product market, is equal to MPP times the product price. The profit maximizing firm will employ that quantity of the resource for which MVP equals input price. Over all outputs and all inputs, the ratio of MVP to input price must equal one for each input in the production of each output.

The relationships specified above will hold true if all resources are unlimited in quantity. However, the typical Texas High Plains farmer is faced with limitations in the amounts of many resources, the most important being land, labor and irrigation water. At the maximum level of input usage, the MVP will be equal to the factor price plus some unknown value, which is known as the shadow price. The shadow price measures the additional amount the firm could afford to pay to obtain one more unit of the resource. Thus, the last unit of a limited resource would be allocated to the use showing the highest shadow price. In addition, a limited quantity of one resource may affect the level of employment of another if the level of the first input is a factor in the MVP of the second input.

Effect of Irrigaton Timing on Crop Yield

Previous studies involving irrigation on the High Plains have assumed that, for any given number of post-plant irrigations, each irrigation was timed such that the maximum yield was achieved for the given amount of irrigation water. However, actual practices suggest that this is not always the case. Due to physical limitations on the amount of water that can be pumped in any time period, the producer may not be able to apply a timely irrigation to all land. For the remaining acres, he is faced with the choice of (a) applying the irrigation in an untimely manner, resulting in some moisture stress and reduced yield or (b) eliminating that post-plant watering altogether and facing further yield reduction.

Even though the first choice would not make the most technically efficient use of the water, its marginal value could still be greater than its marginal cost, hence making it economically viable. In addition, the use of wind energy could result in a relatively greater reduction in marginal cost for the untimely irrigation, making it a more attractive alternative than the timely irrigation even if there is no physical limitation on irrigation water.

Effect of Wind Energy on Resource Allocation

The amount of electricity used by the firm in any given time period will, in effect, be limited. This is because electricity requirements are directly affected by the amount of irrigation water pumped, which is physically limited.

Operation of a wind machine will provide part or all of the electricity required in any given time period at zero variable cost. In effect, this will reduce the marginal factor cost (MFC) of electricity by the ratio of wind generated electricity to total electricity requirements. Since the actual wind power available will be unknown in advance, some estimate of its magnitude must be developed for planning purposes. By using long-term average wind speed for the time period in question and the chosen density and power functions, average wind power availability can be estimated using the principles of mathematical expectation as shown above.

Since the MVP of electricity in the production of crops is assumed to be a decreasing function over the relevant range, a decrease in the effective cost of electricity would indicate that optimal usage of electricity would increase in all time periods. However, this would not be possible in all cases due to limitations on irrigation water and land. It would, in fact, be possible for usage to be decreased in a given time period. With wind energy, the effective MFC would be lower in time periods with historically higher wind speeds. If the relative difference were great enough, it could cause a shift in the employment of water and complementary resources away from previous usage to time periods having higher winds.

Allocation of Exhaustible Resources

Recharge to the Ogallala aquifer is negligible in comparison with the rate of extraction. Groundwater stocks will eventually become depleted. Depletion can occur in the physical sense, meaning simply that the well runs dry, or more likely in the economic sense, where the cost of extracting the groundwater is greater than the revenues to be derived from its use.

A major issue for individual farmers is temporal allocation of their underground water supply to maximize returns to the water. This involves not only annual allocation of water among competing crops but also allocation of water over time (Lacewell and Grubb). Optimal temporal allocation involves equating the present value of a unit of water used in the future with the incremental value of using an additional unit in the present time. This allocation is difficult to estimate quantitatively and even more difficult to achieve in actual practice. Thus, this study will assume, as have others (such as Petty, et al.; Bredehoeft and Young), that producers will allocate the water supply through maximization of annual net returns.

Application of the Theory

The decision-making process of the profit maximizing firm operator is based on the theoretical principles discussed above. Linear programming (LP) is one of the most widely used analytical techniques by which economic theory is applied. The following section is designed to give a brief overview of the linear programming method, including the underlying assumptions, mathematical formulation and some comparisons with marginal analysis. Other references (e.g., Heady and Chandler; Beneke and Winterboer) provide more detailed presentations.

There are many similarities between models which determine the profit maximizing position of a firm in a linear programming framework and those which use the neoclassical marginal analysis approach. Some of the more basic comparisons will be made here. A more detailed discussion of these similarities is given by Naylor.

The production function gives rise to the principal differences between the two approaches. The neoclassical model is assumed to have a production function which, in the relevant range, exhibits diminishing marginal productivity. A linear programming model is comprised of activities which are linear, thereby having constant marginal productivity. The activity is a more specifically defined concept than a production function. A production function may be thought of as a family of activities which use the same resources and turn out the same products. Comparing any two points of the production surface, if the ratios of the inputs and outputs are the same, they represent the same activity; otherwise there are two different activities. Thus, the production function is a tool for exhibiting and comparing different but related activities. The production function may be presented as a family of linear activities which have constant marginal returns, but each successive activity having a lesser slope, thereby depicting diminishing marginal returns for the production function as a whole.

Linear Programming Model

The four basic assumptions underlying a linear programming model are:

(1) Additivity or linearity -- The net returns and resources required by two or more activities are the sum of the amount required by each. In addition, each activity is assumed to exhibit constant returns to scale.

(2) Divisibility -- All of the firm's factors and products are perfectly divisible. This assumption may be relaxed. In some cases, it is possible to formulate an integer model.

(3) Finiteness -- The number of resource restrictions and the number of alternative activities is finite.

(4) Single-valued expectations -- The amount of each resource available, the input-output coefficients, and prices are

fixed and known with certainty.

Mathematically, the linear programming model with n activities and k resource constraints maximizes a given objective function:

$$Z = C_1X_1 + C_2X_2 + \dots + C_nX_n \tag{14}$$

subject to the resource constraints:

$$A_{11}X_1 + A_{12}X_2 + \dots + A_{1n}X_n \leq b_1 \tag{15}$$

$$A_{21}X_1 + A_{22}X_2 + \dots + A_{2n}X_n \leq b_2 \tag{16}$$

$$A_{k1}X_1 + A_{k2}X_2 + \dots + A_{kn}X_n \leq b_k \tag{17}$$

also subject to the condition that a negative amount of an activity can not be produced:

$$X_k \geq 0 \text{ for all j.} \tag{18}$$

In these equations:

X_j represents the output of the j-th activity,

C_j represents the net returns per unit of the j-th activity,

A_{ij} represents the amount of the i-th resource required to produce one unit of the j-th activity,

b_i represents the amount of the i-th resource available.

These equations are used to solve for the output of each activity which will maximize net income to the firm. The procedure used most often to solve linear programming problems is the Simplex method. This is an iterative procedure which, on each iteration, adds to the solution the activity which will increase net returns by the greatest amount. Iterations are continued until the objective function is maximized. A more detailed outline of the Simplex method can be found in the linear programming texts mentioned above.

Estimation of the Value of Wind Power

To appropriately estimate the ability to pay for a wind machine, it is necessary to establish net returns for the farm under two situations: with wind power and without wind power, all other things being identical. The predicted operation of the farm without wind power serves as a benchmark. This makes it possible to determine the benefits directly attributable to wind power as the difference in net returns between the two situations.

The investment in a wind machine involves a cost in the present which will generate a stream of future returns. Thus, the farmer's maximum economically feasible investment would be determined by the present value of the future income stream. The discounting procedure is

$$NPV = \sum_{i=1}^{n} \frac{NR_i}{(1+d)^i} \tag{19}$$

where:

NPV = the net present value of wind power

NR_i = net returns to wind power in year i

d = the discount rate

n = number of years.

The discount rate selected in evaluating a capital decision represents the fact that a dollar at some point in the future is not worth as much as a dollar at present. The time value of money, allowance for risk and alternative earning potential of capital are all reflected in the discount rate. Obviously, this will not be the same for all individuals. For this reason, this study will use alternative discount rates to provide a range of results.

CHAPTER III

PROCEDURES

This chapter presents the data base underlying the analysis and the development of the analytical models used to estimate the value of wind energy. The study is based on a typical farm operation on the Texas High Plains, having 640 acres of land irrigated by a furrow or gravity flow distribution system (Petty, et al.). This analysis will, in all scenarios, include the land unit which can be irrigated by one well, applicable to a single wind machine. The size of the land unit will be based on the "rule of thumb" that 0.18 acres can be irrigated per gallon per minute (GPM) of well yield (Lacewell, Hardin, McGrann and Griffin). Well yield is a function of saturated thickness, which will depend on the scenario to be analyzed. These scenarios will be specified subsequently.

Crop Yield and Irrigation Timing

Expected yield reductions resulting from non-optimal irrigation timing were estimated for the study area. Experimental data from the Texas A&M Research Centers in Amarillo and Lubbock and from the U.S. Department of Agriculture Southwestern Great Plains Research Center in Bushland, Texas were obtained for corn, cotton, grain sorghum and wheat. Original intentions were to also include soybeans in the analysis. However, insufficient data were available to provide reliable yield estimates. Since soybeans comprise a minor portion of irrigated acreage in the region (less than five percent), they were excluded from the remainder of the study.

Cotton data were obtained from an experiment which was replicated over five years (1950-54). Even though the study is an old one, it was felt that the reported yield levels were representative of those in more recent years. Average yield over the five year period for each reported combination of irrigation timings was used for this study, shown in Table 1. Current tillage and herbicide practices were included in the crop enterprise budgets.

Data were obtained from mixed sources for each of the remaining crops. This often resulted in differences in nomenclature regarding the stages of growth at which water was applied. Thus, the first step was to group post-plant irrigation applications into common time periods. (Adequate pre-plant watering was provided in all experiments.) Actual dates of application, length of time from planting and relation to commonly named growth stages were among the criteria used in making the groupings. It was assumed that the "critical periods" for irrigation applications were ten days long. For purposes of generality, it was further assumed that each month had 30 days, thus establishing three critical water periods per month.

The greatest number of post-plant irrigations common to all experiments for a particular crop was used to establish a base for that crop. A base yield for the given amount of seasonal irrigation water was established from statistical production functions estimated for the area (Shipley 1977a, Shipley 1977b). Then, within each experiment, yields for all reported combinations of irrigation timings were

Table 1. Timing of Irrigation and Related Yield for Irrigated Cotton: Texas High Plains

Irrigation Level	Time of Post-Plant Irrigation June (3)[a]	July (2)	Aug. (1)	Yield Per Acre (lbs. of lint)
Pre-Plant Only				420 *[c]
Pre-Plant + 1 Post-Plant:				
	X[b]			451 *
		X		470 *
			X	517 *
Pre-Plant + 2 Post-Plants:				
	X	X		468
	X		X	588 *
		X	X	590 *
Pre-Plant + 3 Post-Plants:				
	X	X	X	518

[a] Numbers in parentheses refer to the first, second or third 10-day critical water period in a month.

[b] "X" indicates a post-plant irrigation at the specified time.

[c] "*" indicates the activity was included in the LP model.

Source: Jones, et al.

expressed as a percentage of the highest yield reported for the base number of post-plants. This was done to remove annual variations in yield levels and attempted to isolate the yield reduction effect of differences in timing of irrigation water.

Across all experiments for each crop, these percentages were averaged for each combination of irrigation timings. The average percentages were then applied to the base yield, the results of which were used in this study and are presented in Tables 2, 3 and 4. Due to a limited number of data points, it was recognized that little statistical significance could be attached to these estimates of reduced yield. However, it was felt that they would still be effective as a broad representation of the alternatives available to an irrigated producer and represent the relative yields for alternative timings of irrigaton water application.

Each of the combinations of irrigation timing could be included in a linear programming model as a separate activity. Clearly, in many cases, yield levels are low enough to be effectively dominated. It was decided to use only those activities for which yield is greater than the highest yield achieved by applying one less irrigation. For example, an activity with three post-plant irrigations would be included only if its yield were greater than the yield from the optimal timing of two post-plants.

Cotton and wheat are characterized by the production of joint products. Cotton income is derived from the sale of lint and seed, while wheat produces both grain and grazing. In both cases, yield of the joint product (seed or grazing) is a function of the main product

Table 2. Timing of Irrigation and Related Yield for Irrigated Corn: Texas High Plains

Irrigation Level	Time of Post-Plant Irrigation						Yield Per Acre (bu. of grain)
	July (1)[a]	July (2)	July (3)	Aug. (1)	Aug. (3)	Sept. (1)	
Pre-Plant + 2 Post-Plants:							
	X[b]	X					58.5
	X		X				83.1 *[c]
	X			X			61.1
	X				X		62.9
	X					X	42.8
		X	X				76.8 *
		X		X			73.0 *
		X			X		76.8 *
		X				X	52.9
			X	X			60.4
			X		X		61.1
			X			X	54.1
				X	X		73.0 *
				X		X	22.7
					X	X	20.1
Pre-Plant + 3 Post-Plants:							
	X	X	X				62.9
	X	X		X			91.2 *
	X	X			X		88.8 *
	X	X				X	62.9
		X	X	X			115.8 *
		X	X		X		107.0 *
		X	X			X	89.4 *
			X	X	X		90.6 *
			X	X		X	59.2
				X	X	X	35.3
	X		X	X			83.1
	X		X		X		64.8
	X		X			X	68.0
	X			X	X		98.8 *
	X			X		X	56.7
	X				X	X	55.4
		X		X	X		101.7 *
		X		X		X	60.4
		X			X	X	64.2
			X		X	X	51.6

Table 2. (Continued)

Irrigation Level	Time of Post-Plant Irrigation						Yield Per Acre (bu. of grain)
	July (1)[a]	July (2)	July (3)	Aug. (1)	Aug. (3)	Sept. (1)	
Pre-Plant + 4 Post-Plants:							
	X	X	X	X			119.6 *
	X	X	X		X		108.3
	X	X	X			X	96.9
	X		X	X	X		98.2
	X		X	X		X	95.7
	X			X	X	X	42.8
		X	X	X	X		122.1 *
		X	X	X		X	125.9 *
		X		X	X	X	83.1
			X	X	X	X	91.9
	X	X		X	X		113.9
	X	X		X		X	105.1
	X	X			X	X	88.1
		X	X		X	X	93.2
	X		X		X	X	80.6
Pre-Plant + 5 Post-Plants:							
	X	X	X	X	X		146.4 *
	X	X	X	X		X	136.0 *
	X	X	X		X	X	112.1
	X	X		X	X	X	137.2 *
	X		X	X	X	X	103.2
		X	X	X	X	X	131.8 *
Pre-Plant + 6 Post-Plants:							
	X	X	X	X	X	X	147.7 *

[a] Numbers in parentheses refer to the first, second or third 10-day critical water period in a month.

[b] "X" indicates a post-plant irrigation at the specified time.

[c] "*" indicates the activity was included in the LP model.

Sources: Shipley and Regier (1976); Musick and Dusek (1978); Musick; Undersander.

Table 3. Timing of Irrigation and Related Yield for Irrigated Grain Sorghum: Texas High Plains

Irrigation Level	Time of Post-Plant Irrigation				Yield Per Acre (cwt. of grain)
	July (1)[a]	July (3)	Aug. (2)	Aug. (3)	
Pre-Plant Only:					29.6 *[c]
Pre-Plant + 1 Post-Plant:					
	X[b]				18.6
		X			38.4 *
			X		45.1 *
				X	36.7 *
Pre-Plant + 2 Post-Plants:					
	X	X			38.4
	X		X		50.4 *
	X			X	28.4
		X	X		53.7 *
		X		X	51.9 *
			X	X	48.9 *
Pre-Plant + 3 Post-Plants:					
	X	X	X		63.0 *
	X	X		X	47.6
	X		X	X	52.9
		X	X	X	60.5 *
Pre-Plant + 4 Post-Plants:					
	X	X	X	X	69.0 *

[a] Numbers in parentheses refer to the first, second or third 10-day critical water period in a month.

[b] "X" indicates a post-plant irrigation at the specified time.

[c] "*" indicates the activity was included in the LP model.

Sources: Shipley and Regier (1975); Musick and Dusek (1971).

Table 4. Timing of Irrigation and Related Yield for Irrigated Wheat: Texas High Plains

Irrigation Level	Time of Post-Plant Irrigation				Yield Per Acre (bu. of grain)
	Mar. (2)[a]	Apr. (2)	May (1)	May (3)	
Pre-Plant Only:					22.8 *[c]
Pre-Plant + 1 Post-Plant:					
	X				24.9 *
		X			32.2 *
			X		33.2 *
				X	25.9 *
Pre-Plant + 2 Post-Plants:					
	X	X			35.1 *
	X		X		41.5 *
	X			X	30.7
		X	X		42.0 *
		X		X	35.1 *
			X	X	38.1 *
Pre-Plant + 3 Post-Plants:					
	X	X	X		40.0
	X	X		X	35.6
	X		X	X	45.9 *
		X	X	X	48.3 *
Pre-Plant + 4 Post-Plants:					
	X	X	X	X	48.8 *

[a] Numbers in parentheses refer to the first, second or third 10-day critical water period in a month.

[b] "X" indicates a post-plant irrigation at the specified time.

[c] "*" indicates the activity was included in the LP model.

Sources: Schneider, Musick and Dusek; Harman.

yield. Cotton yields 1.67 pounds of seed per pound of lint (Parnell). Income from wheat grazing is assumed to be $11.25 for dryland wheat (15 bu. per acre grain yield) and increases by $0.45 for each additional bushel of grain. The dryland wheat yield, as well as the other dryland yields used in this study, are based on the 1975-1979 average for the area (Lacewell, Hardin, McGrann and Griffin).

Input Requirements and Costs

For each of the selected yield levels, resource requirements and costs were compiled from a variety of sources. Crop enterprise budgets developed by Extension Economists-Management of the Texas Agricultural Extension Service for the 1980 crop year were the basis for developing many of the coefficients. Modifications were required where input levels vary with yield or with number of irrigations, since budgets were published for only one irrigation level.

The most common cost components related to yield are the costs of harvesting and hauling done on a custom basis, with the rates reflecting common practices in the area (Extension Economists-Management). In most cases, these costs are on a direct, per unit of yield basis. There are two exceptions. For cotton, the cost of stripping (harvesting), hauling and ginning is based on the total amount of material (seed contton) brought to the gin, and is computed as 4.75 pounds of seed cotton per pound of lint yield (Parnell). Seed cotton includes seed, lint, burrs, leaves, trash and dirt. The harvest cost of wheat is based on a flat rate of $10 per acre plus $.10 per bushel of grain over 20.

Application rates for nitrogen and phosphorous were varied with expected yield for irrigated crops based on published recommendations for the area (Valentine, et al.). Existing soil test levels were assumed to be low for both nutrients in order to estimate fertilizer requirements. Recommendations are published for alternative yield levels. To estimate the amount to be applied for each of the many different yield levels, linear interpolations were made. The resulting equations for fertilizer application levels are given in Table 5. Fertilizer requirements for crops grown dryland are also presented, but are not dependent on yield.

Irrigation water is the most obvious input varying with irrigation level. To reflect "average" practices for furrow distribution systems in the area, pre-plant irrigations were specified as seven acre-inches per acre and post-plants as four acre-inches per acre (Shipley 1977b). These levels also approximate those used in the yield experiments discussed earlier. Irrigation labor is required at the rate of 0.1 hours per acre-inch applied (Extension Economists-Management).

Irrigation fuel is specified on a per acre-foot basis and varies with pumping lift (Kletke, et al.). The relationship is

$$ELEC = 48.725 + 2.109L \tag{20}$$

where

ELEC = Kilowatt-hours of electricity required to pump one acre-foot of water,

L = pumping lift in feet.

Table 5. Fertilizer Recommendation Equations for N and P_2O_5

Crop	Irrigated or Dryland	Yield Level	N (lbs.)	P_2O_5 (lbs.)
Corn	Irrigated	Y<100	1Y	.6Y
		100<Y<150	100 + .8(Y-100)	60.
Cotton	Irrigated	Y<750	.0533Y	.0533Y
	Dryland		20.	20.
Grain Sorghum	Irrigated	Y<40	1.5Y	1Y
		40<Y<60	60 + 2(Y-40)	40.
		60<Y<80	100 + 2(Y-60)	40 + 1(Y-60)
	Dryland		20.	20.
Wheat	Irrigated	Y<40	1.5Y	0.5Y
		40<Y<60	60 + 2(Y-40)	20 + 1(Y-40)
	Dryland		20.	0.

Source: Valentine, et al.

Imbedded in this equation are the assumptions for water pressure required at the wellhead (10 lbs. per square inch for furrow irrigation) and pump efficiency (50 percent, noted by Ulich as an average for the area). Non-fuel variable costs of irrigation are comprised of engine repairs (New 1980), engine lubrication and attendance labor (LePori, et al.) and distribution system repairs (Kletke, et al.).

Analytical Model for Static Analysis

The mathematical model for estimating the value of wind energy consists of two components. The first is a linear programming model which, based on a profit maximization objective, determines the optimal farm plan. The irrigation pattern developed here is used as input to the second phase, a simulation model, which will stochastically simulate wind speeds and thus electrical power generated by a wind machine.

Linear Programming Model

The basic linear programming model provides a means of determining optimal irrigation schedules for input into the simulation model, as well as the benchmark net returns for the farm operation without wind power. A simplified structure of the model is shown in Table 6. For the study of load management strategies, expectations of available wind power are added to the model. A complete version of the model, including the wind expectation structure (to be discussed subsequently), is presented in Appendix A.

Activities

The model includes dryland production activities for cotton, grain

Table 6. A Simplified Structure of the Basic Linear Programming Model

Item	Crop Production	Input Purchases	Crop Sales	Borrowing		Savings		Cash Transfer	RHS
				Period 1	Period 2...Period 6	Period 1	Period 2...Period 6		
Objective Function								+1.	
Constraints:									
Owned Resources	+a								$\leq$ b
Purchased Resources	+a	-1.							$\leq$ 0
Yield Transfer	-a		+1.						$\leq$ 0
Cash Flow:									
Period 1	$+d_1$	$+c_1$	$-c_1$	-1.		+1.			$\leq$ 0
Period 2	$+d_2$	$+c_2$	$-c_2$	+(1+r)	-1.	-1.	+1.		$\leq$ 0
Period 3	$+d_3$	$+c_3$	$-c_3$		+(1+r)		-1.		$\leq$ 0
.									
.									
.									
Period 6	$+d_6$	$+c_6$	$-c_6$		-1.		+1.		$\leq$ 0
Net Cash							-1.	+1.	= 0

Where

a = input-output coefficients

b = level of resources available

c_i = input-output prices (non-zero only for cash-flow period in which transaction takes place)

d_i = variable cost of production not accounted for by purchase activities.

r = rate of interest for borrowing capital.

sorghum and wheat. Irrigated production activities (including the above crops plus corn) were selected for inclusion according to the criterion discussed earlier, with a total of 51 irrigated activities over the four crops. In addition to the basic production activities, the model includes (1) purchase activities for selected inputs, (2) sell activities for crops produced, (3) activities which allow a choice in the timing of pre-plant irrigations and (4) borrowing and repaying activities for cash flow by two-month time periods.

The inclusion of purchasing and selling activities facilitates the evaluation of the effects of price changes. The model contains purchase activities for seed, insecticide, herbicide, fertilizer, diesel, gasoline and custom harvest and hauling for all crops. Price changes for these commodities were not considered in this study, but the activities were included in the interests of future research. Separate activities for a single item are required for each cash flow period in which purchases can be made. Buy activities are also included for electricity by critical water period. Electricity and crop prices were varied according to the scenario to be analyzed. Base prices for other input items are shown in Table 7.

Critical water periods 10 days in length were established for the effective timing of post-plant irrigations. However, the timing of the pre-plant watering was not considered to be as crucial. For each crop, activities are included which allow the pre-plant irrigation to be applied effectively in any of five contiguous 10-day periods.

The possibility of price changes makes prior determination of operating capital requirements impossible. For this reason, a separate

Table 7. Base 1980 Input Prices: Texas High Plains

Item	Unit	Price
Corn seed	lb.	$ 0.90
Cotton seed	lb.	.45
Grain sorghum seed	lb.	.50
Wheat seed	bu.	7.50
Nitrogen	lb.	.24
P_2O_5	lb.	.23
Custom application of fertilizer	acre	2.00
Gasoline	gal.	1.05
Diesel	gal.	1.00
Custom combining:		
Corn	bu.	.25
Grain sorghum, dryland	acre	8.00
Grain sorghum, irrigated	cwt.	.35
Wheat, dryland	acre	10.00
Wheat, irrigated	acre, bu.	[a]
Cotton stripping and hauling	cwt.s.c.[b]	1.50
Cotton ginning	cwt.s.c.[b]	2.00
Custom hauling:		
Corn	bu.	.15
Grain sorghum	cwt.	.25
Wheat	bu.	.12
Corn drying	bu.	.12
Labor, full-time	hr.	5.00
Labor, part-time	hr.	4.50

[a] Harvest cost for irrigated wheat is $10 per acre plus $.10 per bushel of yield greater than 20.

[b] 100 pounds of seed cotton, includes lint, seed, burr and other trash delivered to the gin.

Source: Extension Economists-Management

cash flow section is included. Capital requirements are specified in six two-month periods. Cash deficits at the end of each period are repaid, either by borrowing from the following credit period or by income from product sales. To reflect the producer's short-term capital costs, an interest rate of 2.33 percent is charged for borrowed capital in each two-month period. Excess funds do not earn interest, but are available for operating expenses in the next period. For buying and selling activities, the coefficients in the cash flow rows represent the input or output price. For production activities, these coefficients reflect costs which are not represented by purchase activities (labor and non-fuel machinery and equipment variable costs). The net cash position at the end of the year is equivalent to the traditional objective function value.

An accounting row is included for each cash flow period which measures the net cash position exclusive of carryover from previous periods. All transactions are included with the exception of electricity and capital costs. The values of these rows are input into the simulation model, where the electricity and capital costs are recomputed based on "actual" wind power availability.

Constraints

Constraints included in the model are (1) acres of land, (2) seasonal irrigation water by critical periods and (3) labor, divided into two-month periods to correspond with the cash flow section. The actual constraint levels depended on the scenario. Land and water were determined by well yield, while labor availability was based on the size of the land unit.

As was discussed earlier, the land unit included .18 acres per GPM. Well yield is a function of saturated thickness.[2] Maximum well yield of 800 GPM is assumed to remain constant for all levels of saturated thickness above 210 feet. This is representative of an average well in the region, where the maximum yield is much less than the potential that the aquifer can deliver (Reddell). The well yield relationship for lower levels of saturated thickness is represented by equation (21) (Hughes and Harman).

$$GPM = 800 * \left(\frac{ST}{210}\right)^2 \tag{21}$$

where

GPM = well yield in gallons per minute

ST = saturated thickness in feet.

Limitations on seasonal water availability were established by the physical maximum which could be pumped in a critical water period, based on well yield.

$$M = .0044 * GPM * T \tag{22}$$

where

M = maximum acre-feet of water that can be pumped in a critical water period,

---

[2] Saturated thickness refers to feet of water-bearing sand. The coefficient of storage of the Ogallala is about 15 percent, meaning that 100 feet of saturated thickness yields 15 feet of water (Cronin).

T = number of days in each period not used for well repairs and maintenance (assumed to be 8.5 for this study),

.0044 = constant value which translates gallons per minute into acre-feet per day.

Labor restrictions were based on the principle that two men, the operator and one full-time employee, will provide all labor (except part-time hoeing labor) for a 640 acre farm. Labor usage is separated into two-month periods in the model and is charged on an hourly basis. The number of hours available in each two-month period depends on weather patterns and length of days, and will thus be higher in the summer months. The amounts based on 640 acres (Petty, et al.) were placed on a per acre basis, then multiplied by the size of the land unit determined above for use as constraints in this study. The labor constraints also provide, indirectly, for machinery limitations.

Wind Energy

The consideration of wind in the LP model requires estimates of wind power availability in each critical water period. The expected value of wind energy was developed using monthly mean wind velocities, over the period 1941-1970, recorded at the Amarillo airport (Table 8). The use of monthly averages means that each ten-day critical irrigation period of any given month will have one-third of the expected monthly wind power.

Wind velocity increases with height above the surface. Accurate estimates of wind power require that the wind speed be adjusted from the height at which it was measured (in this case, 23 feet) to the height of the center of the wind machine, known as "hub height", which

Table 8. 1941-1970 Average Wind Speeds by Month: Amarillo, Texas

Month	Average Wind Speed (mph)
January	13.1
February	14.2
March	15.6
April	15.5
May	14.8
June	14.4
July	12.5
August	12.1
September	13.0
October	13.0
November	13.2
December	13.0

Source: U.S. Department of Commerce.

for this study is assumed to be 65.6 feet (Clark and Schneider). The most widely used method of performing this extrapolation is described by Reed.

$$V_t = V_m * (\frac{H_t}{H_m})^{1/7} \tag{23}$$

where

V_t = wind velocity at hub height

V_m = wind velocity at measured height

H_t = hub height

H_m = measured height.

The power functions used to develop the expectations depend on the size and specifications of the machine. Two different sizes, with rated output of 40 and 60 kilowatts (KW), were analyzed. The assumed specifications are the same for both machines and are based on the characteristics of the system in operation at the U.S. Department of Agriculture station in Bushland, Texas (Clark and Schneider). The cut-in speed is 13 mph, rated speed is 32 mph and cut-out speed is 45 mph. The resultant power functions are, for the 40 KW machine,

$$P = 0.72795 - 0.92401V + 0.06754V^2 \tag{24}$$

and for the 60 KW machine,

$$P = 1.09196 - 1.40101V + 0.10131V^2 \tag{25}$$

where

P = power output in KW

V = wind velocity in mph.

The coefficients in these power functions were estimated according to the procedure described by Justus, et al.

Using the transformed wind speed means, expectations of wind-generated electricity for 8.5 days (matching the maximum pumping time) were developed for each water period. The model allows this "free" electricity to be used for irrigation only in the same proportion as actual to maximum pumping time. For example, if irrigation takes place over only half of the 8.5 days, only half of the wind-generated electricity could be used for irrigation pumping. This requirement prevents electricity which was generated over the entire time period from being used in a shorter time. Ninety percent of any excess electricity can be sold to the electric utility. The 10 percent loss is due to alternator efficiency (Lansford, et al.). The selling price was assumed to be 60 percent of the purchase price (Lansford, et al.). Separate selling and buying activities for electricity are included for each water period along with extra selling activities, by cash flow period, to account for the wind power generated in the 1.5 days in each water period when no pumping takes place.

Simulation Model

The simulation model was designed to match the farm's optimal irrigation pattern (determined by the LP model) with stochastically generated wind power. This determines the amount of irrigation electricity purchased and the apportionment of wind-generated electricity (amounts used for irrigation and sold to the utility).

Simulation of the farm operation with a wind energy system involves four steps. This process includes (1) generation of random wind speeds by three-hour time periods, (2) power output in each period is determined, (3) power output in each period is matched with irrigation requirements to calculate electricity purchases and sales, and (4) capital costs and net returns to the farm are calculated. Input to the simulation model includes parameters defining the scenario being analyzed (saturated thickness, lift, purchase and selling price of electricity), and results from the LP solution relating to the optimal farm organization (acre-feet of water pumped by critical water period and the net cash position for each cash flow period).

Random wind speeds are drawn from probability distributions set up by month and time of day using the Rayleigh distribution. In each month, eight distributions were defined corresponding to the three-hour time intervals at which climatological data are reported in Local Climatological Data, U.S. Department of Commerce. The distributions were filled based on the mean speeds for Amarillo over the period 1965-1978 for each month and each reporting time, i.e., 12 midnight, 3:00 a.m., 6:00 a.m., etc. These are shown in Table 9. After height extrapolation, these means are used in the generation of stochastic, or "actual" wind speeds. These speeds are assumed to be constant over the three-hour time period. The power function uses the wind speed to calculate total kilowatt-hours of electricity generated by the system for each three-hour period in the year.

To match with the estimated wind power availabilities, irrigation fuel requirements are calculated for each three-hour time period. The

Table 9. 1965-1978 Average Wind Speeds by Month and Hour of Day: Amarillo, Texas

Month	Time of Day							
	Midnight	3 AM	6 AM	9 AM	Noon	3 PM	6 PM	9 PM
	(mph)							
January	12.5	12.5	12.0	12.2	15.6	15.7	12.2	12.3
February	12.9	12.9	12.6	13.7	16.6	16.2	13.8	12.5
March	14.5	13.8	13.3	16.3	18.3	18.6	17.3	14.4
April	14.9	14.2	13.1	17.5	18.1	18.5	17.8	14.3
May	13.9	13.2	11.9	16.1	16.1	16.6	16.8	14.3
June	14.5	13.0	11.7	15.8	14.9	15.7	16.6	14.4
July	12.1	11.0	10.0	14.2	13.6	14.1	15.2	12.2
August	11.9	11.2	10.2	13.8	13.7	14.2	15.2	12.0
September	12.2	11.5	10.9	14.0	14.1	14.4	14.4	12.2
October	12.7	12.2	11.5	14.8	15.7	15.8	13.1	12.6
November	12.8	12.2	11.9	13.2	15.9	15.8	11.7	12.3
December	12.8	12.4	12.7	12.8	16.2	16.1	12.0	12.5

Source: U.S. Department of Commerce.

program operates an outer loop for each 10-day period throughout the year. The amount of water pumped in the period is used to determine electricity requirements for irrigation. If irrigation occurs, it is assumed to begin at midnight on the first day and continue until completed. The number of acre-feet pumped is converted to gallons then divided by gallons per hour (GPM times 60) to determine hours required for pumping. This is divided by three to determine the number of three-hour wind periods required, which will be equal to a whole number K plus a fraction X/3.

The program then operates an inner loop over the 80 three-hour periods in a ten-day critical irrigation period. Using the results from above, an array is constructed which measures, for each wind period, the percentage of the three hours in which pumping occurs. This percentage will be equal to one for the first K periods, X/3 in the next period and zero in the remaining periods. The amount of electricity required to pump for three hours is calculated based on well yield and pumping lift.

These percentages are used in comparing wind-generated electricity with irrigation pumping requirements. If the percentage is zero, 90 percent of the generated electricity is sold for 60 percent of the purchase price, as stated earlier. If the proportion is one, all generated electricity can be used for irrigation. Any excess requirement is purchased from the electric utility. However, if there is a surplus of wind-generated electricity, it is assumed to be lost and cannot be sold. If the percentage is X/3 (from the example above), both wind power and the three-hour electricity pumping requirement are multiplied by X/3. These values are then matched in the same manner as when the proportion is one. Ninety percent of the remaining proportion of wind power (1 - X/3) is sold. This procedure prevents wind power generated over the entire period from being used for irrigation over a fraction of the period.

Simulated purchases and sales of electricity are summed by two-month periods, corresponding with the cash flow figures. Beginning with the January-February period, purchases are subtracted and sales added to the net cash for the period. Any deficit is borrowed at the same capital cost used in the LP model and is carried forward to the next period, while a cash surplus is carried forward but does not earn interest. The surplus at the end of the November-December period is net returns to the farm.

The simulation process is repeated twenty times in order to generate a range of solutions. The program then calculates the maximum, minimum, mean and standard deviation for net profit, electricity purchased, electricity sold and electricity generated. Sample output from the simulation program is presented in Appendix B.

Analytical Model for Temporal Analysis

As the Ogallala aquifer declines, requirements for irrigation fuel increase and seasonal water availability decreases. Consideration of these factors requires a model which operates recursively over the assumed 20 year useful life of the wind system (Lansford, et al.). The static linear programming model is modified to serve as the core of the temporal model. The temporal model is completed with the development of (1) fixed costs appropriate for a long-run analysis and (2) a Fortran subroutine which applies the LP model on a year-to-year basis.

Fixed Costs

Annual fixed costs were calculated for (1) machinery and equipment, (2) furrow distribution system, (3) irrigation wells and (4) pumping plants. The fixed costs are based on the expected life of the equipment, and include charges for deprecreation, taxes, insurance and opportunity cost of the investment. Depreciation was calculated using the straight-line method. Charges for taxes and insurance were one-half percent and one percent, respectively, of the initial investment. Interest charges were based on a rate of 14 percent on one-half of the initial investment.

Machinery and equipment fixed costs were calculated on a per acre basis to apply to different sizes of farms and estimated from the 1980 crop budgets (Extension Economists-Management). A single estimate of fixed cost was derived for irrigated production. The per acre values for each crop were weighted according to the number of acres of each crop in the study area. The machinery and equipment fixed cost thus derived was $32.79 per acre for irrigated production.

Also established on a per acre basis was the annual fixed cost of a furrow distribution system. Initial investment for a furrow distribution system was calculated to be $69,203 for 640 acres (Laughlin, et al.). Main line pipe and valves were depreciated over 20 years, while lateral pipe was depreciated over 15 years. Annual, per acre fixed cost was thus estimated to be $14.89 per acre. Machinery and equipment and distribution system fixed costs are charged according to the size of the land unit regardless of whether or not all acres are irrigated.

Fixed costs of wells and pumping plants were calculated on an annual basis and are charged in the Fortran subroutine regardless of the number of irrigated acres. Annual fixed costs were calculated for (1) developed wells of various depths and (2) pumping plants (engines, pumps and gearheads) for various combinations of well yield and pumping lift. These are shown in Tables 10 and 11.

Fortran Subroutine

An extension of linear programming is utilized which consolidates a Fortran program with an LP model. The Fortran program functions as a subroutine which modifies the LP model after each year's solution to reflect the farm situation for the following year. The procedure performs as follows:

1. Calculates the decrease in saturated thickness of the aquifer and associated increase in pumping lift based on the amount of water withdrawn in the previous year. The relationship is

$$D = W/(CA * .15) \tag{26}$$

where

D = decline in water level of the aquifer (in feet)
W = acre-feet of water pumped in the previous year
CA = acres contributing to the aquifer (including non-cultivated acres and dryland)[3]

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[3] Acres contributing irrigation water are expected to exceed acres irrigated since all acres cannot be cropped, i.e., there is water available beneath land used for turn rows, roads and homesteads.

Table 10. Annual Fixed Costs of Developed Irrigation Wells

Well Depth (feet)	Annual Fixed Cost (dollars)
150	863.35
200	1074.38
250	1285.38
300	1496.39
400	1918.42
500	2340.44

Source: Petty, et al.

Table 11. Annual Fixed Costs of Pumping Plants

Well Yield (gpm)	Pumping Lift (feet)				
	< 100	101-150	151-200	201-300	> 300
	(dollars)				
< 350	751.64	798.31	838.31	936.96	1252.57
351-600	789.64	883.63	1032.21	1239.24	1265.90
601-800	848.29	978.88	1172.57	1272.57	1285.90

Sources: Petty, et al.
Emerson Industrial Service

.15 = coefficient of storage for the Ogallala aquifer.

2. Calculates well yield based on the new saturated thickness, according to equation (21).
3. Calculates the amount of electricity required to pump an acre-foot of water based on the adjusted pumping lift, according to equation (20).
4. Calculates the maximum acre-feet of water which can be pumped in each critical water period based on the adjusted well yield, according to equation (22).
5. Calculates the present value of net returns using three different discount rates.
6. Modifies the LP tableau with new irrigation water upper limits and electricity requirements.

Input data specifying the scenario being analyzed are read into the subroutine, which creates a file to initialize the basic LP matrix. The program is called after each year's solution to perform the updating procedure. A summary table is printed for each year showing the activities in the solution and their level, irrigation pumping and shadow prices by water period, irrigation fuel requirements separated into the amounts purchased and wind-generated by month in addition to cropland acres and their shadow price. At the end of 20 years the temporal analysis is summarized in tabular form. An example of the output from the temporal model is shown in Appendix C.

Specification of Alternative Scenarios

Scenarios analyzed in this study are comprised of changes in four basic areas, (1) region of the study area, (2) the farm situation, (3) crop prices and (4) electricity prices. The region was separated into the areas north and south of the Canadian River. The basic difference between the two is that cotton is not included as a crop option in the northern area due to the shortness of the growing season. Another difference is that low lift wells are not common in the northern region, thus only a 60 KW machine was analyzed for this area.

Farm situations were specified according to the beginning water resource (saturated thickness and lift), size of the land unit and rated output of the wind system. Four combinations (Situations 1-4) were considered (Table 12). Three different water resource situations are utilized to represent the area. Two sizes of wind machines (40 and 60 KW) were chosen to analyze the effects of the size of wind machine for a given water resource situation as well as to analyze a single machine size on two different water resource situations.

Two sets of crop prices were specified. The first was intended to reflect recent levels, based on 1974-1978 average prices received (Texas Crop and Livestock Reporting Service). To estimate future situations, a set of 1985 prices (in 1980 dollars), estimated by an econometric simulation model (Collins) was used. Cotton prices are adjusted to reflect quality differences. Both price sets are shown in Table 13.

For static analysis, three levels of electricity prices, \$.05, \$.075 and \$.10 per KWH, were analyzed. The first approximates current prices in the area, with the others included to evaluate the effects of price increases. Two scenarios were specified for the temporal

Table 12. Characteristics of the Farm Situation Scenarios

Farm Situation	Saturated Thickness (feet)	Well Yield (GPM)	Lift (feet)	Cropland (acres)	Power Required for Pumping (KW)	Rated Output of Wind System (KW)
1	100	181	125	32.65	10.4	40
2	175	555	175	100	42.7	40
3[a]	175	555	175	100	42.7	60
4[a]	225	800	200	144	69.3	60

[a] Only Farm Situations 3 and 4 were analyzed for the Northern High Plains.

Table 13. Crop Price Scenarios

Commodity	Unit	1974-1978 Average[a] (dollars)	1985 Simulated[b] (dollars)
Corn	bu.	2.48	3.06
Cotton Lint[c]	lb.	.533	.823
Cotton Seed[c]	ton	96.20	137.94
Grain Sorghum	cwt.	4.02	5.52
Wheat	bu.	3.08	3.14

[a] Source: Texas Crop and Livestock Reporting Service.

[b] Source: Collins.

[c] Cotton was not included as a crop option for the Northern High Plains.

analysis, one in which price remains constant at \$.05 per KWH while the second increases the price by one-half cent per year.

Method of Analysis

Static Applications

To estimate benchmark net returns and optimal cropping patterns, the basic LP model was applied over all scenarios. The irrigation schedule derived was used as input to the simulation model. The annual value of wind power was calculated as the average simulated net returns minus benchmark net returns.

For the analysis of load management strategies, the LP model including wind expectations was solved. If the optimal irrigation schedule was changed in response to wind power, the simulation model was applied to the new schedule using the same set of random wind speeds as for the simulation of the benchmark case. Again, benchmark returns were netted out of average simulated returns to determine value of including wind expectations in the planning process.

The annual value of wind power was assumed to be constant over 20 years. Break-even investment value was estimated by discounting this constant stream of returns. Since the discount rate is a subjective judgement on the part of the investor, break-even investment was calculated at discount rates of three, five and ten percent to indicate the range of values. A complicating factor was the requirement of an allowance for yearly operation and maintenance costs for the wind system. Available estimates of these costs were all based on a percentage of initial investment. For this study, an annual charge of one percent was assumed (Traudt). The discounting equation thus becomes

$$I = \sum_{t=1}^{20} \frac{V-.01T}{(1+d)^t} \qquad (27)$$

where

I = break-even investment value in a wind system

V = annual value of wind power

d = discount rate

t = years.

Over the 20 year period, inflation was not explicitly considered but was assumed to apply equally to all costs and returns. Thus, d is in real, rather than nominal terms (Watts and Helmers). The discount rate is of the form

$$d = [(1+r)/(1+i)] - 1 \qquad (28)$$

where

r = nominal discount rate

i = rate of inflation.

Temporal Applications

Over all scenarios, benchmark net returns on a temporal basis were estimated by applying the temporal model without wind. The value of wind power was estimated by adding wind expectations to the temporal model, maximizing over the 20 years, and netting out benchmark net returns. The discounting procedure is the same as above, with the exception that the annual value of wind power is not constant.

CHAPTER IV

WIND AND POWER RESULTS

This chapter is designed to give a brief overview of some of the study results relating solely to wind power. Break-even investment values are presented based on the assumption that all electricity produced is sold to the utility, hence these results will provide a lower bound on the value of wind energy as compared to its value in irrigation use. Results relating to the use of wind energy in irrigation will be shown in Chapter V.

Results are presented for the 40 KW and 60 KW wind systems. In each case, benchmark simulations from the Southern High Plains analyses were aggregated over all crop and electricity price scenarios to obtain the wind and power results. Thus, the wind and power results are based on 240 annual simulations.

Power Output and Operating Characteristics

Physical characteristics of the simulated wind system operation are presented in Table 14. Maximum, minimum, mean and standard deviation are shown for power output, percent down time (during which the machine does not operate) and percent of time producing rated output. Predicted performance parameters from the 40 KW machine in operation at Bushland, Texas (Clark and Schneider) will be used for purposes of comparison. It should be noted that these predictions are based on

Table 14. Simulation Results of Annual Power Output and Operating Characteristics[a]

Item	Unit	Rated Output Of Wind Machine (KW) 40	Rated Output Of Wind Machine (KW) 60
Electric Power Generated:			
Maximum	KWH	74085.4	108131.3
Minimum	KWH	62316.8	95372.3
Mean	KWH	67679.4	101618.6
Standard deviation	KWH	2024.4	2558.4
Down Time:[b]			
Maximum	percent	44.06	44.65
Minimum	percent	39.06	39.10
Mean	percent	41.58	41.42
Standard deviation	percent	0.95	0.89
Time Producing Rated Output:[c]			
Maximum	percent	5.97	6.15
Minimum	percent	3.65	4.06
Mean	percent	4.91	4.93
Standard deviation	percent	0.41	0.39

[a] These results are based on 240 annual simulations.

[b] Down time measures the times during which wind velocity is less than cut-in speed or greater than cut-out speed.

[c] Time producing rated output measures the time during which wind velocity is between rated speed and cut-out speed.

monthly averages while the simulation results are based on eight average wind speeds (corresponding to time of day) within each month. The use of less frequent sampling periods tends to underestimate the power available from higher wind speeds, since power is proportional to the cube of wind speed (Doran, et al.). Thus, the power results from the simulation model are expected to be higher than the predicted performance of the 40 KW machine at Bushland.

Annual power output from the 40 KW machine ranged from 62,316.8 to 74,085.4 KWH, with a mean of 67,679.4. Predicted output from the Bushland system was 65,190 KWH. The 60 KW machine produced an average of 101,618.6 KWH, with individual observations ranging from 108,131.3 to 95,732.3 KWH. No figures are available for direct comparison; however, the ratio of power output of the 60 KW machine to the 40 KW would be expected to be the same as the ratio of their rated outputs, i.e., 1.5. The actual ratio of the means is 1.501, indicating a slight bias in favor of the 60 KW unit.

Since both machines have the same operating specifications, expected down time and time running at rated output would not be expected to differ between sizes of machine, as they are dependent only on wind speeds. Thus, any differences would be resultant only from the simulation process.

Predicted down time of the Bushland unit was 43.7 percent, compared with 41.58 and 41.42 for the 40 and 60 KW machines, respectively. For the same reasons as noted earlier, the machine is expected to operate longer, thus having less down time, under the simulated results. The simulated operation of wind machines produced rated output between 3.65

and 6.15 percent of the time, with an average for both machine sizes of approximately 4.9 percent. No estimate of time running at rated output was made for the Bushland system.

Monthly average wind speeds over the period 1941-1970 were used in determining the expectations of wind power applied in the LP model. Expected output was 65,075.9 KWH for 40 KW (compared with 65,190 at Bushland) and 97,613.8 for the 60 KW unit. However, predicted down time of 41.5 percent corresponded more closely with that from the simulation model. In both cases, all months were assumed to have the same number of days, in contrast to the predictions from the Bushland unit.

Value of Wind Energy

The power output results were used to calculate the expected (mean) annual value of wind power if sold to the power grid only and the related maximum and minimum values. These are presented in Table 15 along with break-even investment values, based on mean returns to wind as a constant over 20 years, at each of three discount rates. Break-even investment represents the maximum economically feasible price that could be paid for a wind system.

Three selling prices of electricity ($.03, $.045, and $.06 per KWH) were used. These correspond to the electricity price scenarios specified for static analysis, with each adjusted to 60 percent of the purchase price, which is the assumed fuel replacement value that utilities would pay (Lansford, et al.). Power output that can be sold is 90 percent of the total generated, with the 10 percent loss due to to alternator efficiency (Lansford, et al.). In this analysis, the

Table 15. Annual Revenue and Break-Even Investment Where all Power Output is Sold to the Utility

Item	Selling Price of Electricity (cents per KWH) 3	4.5	6
	---------(dollars)-----------		
40 KW Machine			
Annual Revenue:			
Maximum	2000.31	3000.46	4000.61
Minimum	1682.55	2523.83	3365.11
Mean	1827.35	2741.02	3654.69
Break-Even Investment:[a]			
3% Discount rate	23665.52	35498.21	47330.90
5% Discount rate	20249.29	30373.88	40498.48
10% Discount rate	14336.69	21505.00	28673.30
60 KW Machine			
Annual Revenue:			
Maximum	2919.55	4379.32	5839.09
Minimum	2575.05	3862.58	5150.11
Mean	2743.70	4115.55	5487.40
Break-Even Investment:[a]			
3% Discount rate	35532.92	53299.37	71065.83
5% Discount rate	30403.58	45605.37	60807.16
10% Discount rate	21526.02	32289.04	43052.05

[a] Break-even investment is calculated based on mean annual revenue.

same electricity amounts were applied to each price, thus changes in returns are proportional to the changes in electricity price.

In the situations where annual returns are assumed constant over the life of the wind system, changes in the discount rate will have the same proportional effect on break-even investment values in each scenario analyzed. For example, break-even investment calculated at the three percent discount rate will be 16.9 percent higher than for the five percent discount rate and 65.1 percent higher than for the ten percent discount rate. The different disciount rates reflect differences in the return on investment required to satisfy an individual investor's subjective judgement of risk and time preference for money. An example of the implications is the person who requires a greater return for risk, who would be willing to make a smaller initial investment, other factors being equal.

Based on the maximum and minimum electricity production, the annual value of wind power can vary by as much as $317.76 for the 40 KW machine and $344.50 for the 60 KW, while selling electricity at three cents per KWH. Average value was $1,827.35 and $2,743.70, respectively. These values increase by 50 and 100 percent for electricity selling at $.045 and $.06 per KWH. Break-even investment values for a 40 KW machine range from $14,336.69 ($358.42 per KW) with three cent electricity and ten percent discounting to $47,330.90 ($1,183.27 per KW) with six cent electricity and the three percent discount rate. At the same combinations of electricity price and discount rate, values for the 60 KW machine vary from $21,526.02 ($358.77 per KW) to $71,065.83 ($1,184.43 per KW).

As was noted earlier, these values reflect lower limits to the value of wind power. When used for irrigation, part of the power will take on a higher value as it replaces electricity which would otherwise need to be purchased. The following chapter will detail the results of the use of wind energy in conjunction with an irrigated farm.

CHAPTER V

IMPLICATIONS FOR IRRIGATION WITH WIND ENERGY

This chapter extends the analysis of wind energy from exclusive sales of electricity to the electric utility to use on an irrigated farm. Benchmark situations will be analyzed with respect to cropping patterns and water use. Simulation results for the benchmark solutions, including break-even investment for wind power, are presented along with some comparisons among the applicable farm situations. The results from the static analysis are concluded with the analysis of the effect of wind expectations on cropping patterns and value of wind power. Finally, selected results from a temporal analysis are shown.

Static Analysis

In the static analysis, the annual value of wind power was estimated and assumed to be constant over the life of the wind system. For each farm situation, three electricity prices ($.04, $.075 and $.10 per KWH) were analyzed with each of two sets of crop prices (1974-78 average prices and 1985 simulated prices).

Effect of Non-Optimal Irrigation Timing

To give a broader presentation of an irrigated producer's alternatives, irrigated activities with both optimal and non-optimal irrigation timings were included in all analyses. To indicate the effects of the inclusion of non-optimal timings, one situation was analyzed with only optimal timings. These results are compared with those of the full model in Table 16. The results are from the Northern High Plains under farm situation 3, with 1974-78 average crop prices and electricity purchased at five cents per KWH.

With only optimal timings allowed, 8.52 acres of the total of 100 acres are left idle, as labor availability is restrictive in three of the six two-month periods. The optimal cropping pattern includes 39.52 acres of grain sorghum with three post-plant irrigations, 23.15 acres of both grain sorghum with one post-plant and corn with five post-plants and 5.66 acres of wheat with three post-plants. Returns over variable costs are $5,797.63.

With non-optimal timings added to the model, irrigated acreage increases by 5.13 acres (although 3.39 acres still remain idle) while net returns show an increase of $50.50. There are 3.5 additional acre-feet of water pumped, but the average application rate is reduced from 1.58 to 1.54 acre-feet per acre. Cropping pattern changes feature, besides the total increase in irrigated acreage, shifts which allow an increase in the production of grain sorghum. Corn acreage decreases and shifts to a non-optimal timing, as an irrigation is shifted from late July to early September. Yield is reduced by nine bushels per acre but releases amounts of two limiting inputs; late July water and July-August labor. Acreage of grain sorghum with one post-plant irrigation is also decreased as sorghum with three post-plants increases and sorghum with two post-plants and non-optimal timing enters the solution. In this case, 1.8 cwt. of grain per acre are forfeited as compared to optimal timing. An irrigation is applied in late

Table 16. Effect of the Inclusion of Non-Optimal Irrigation Timings on Estimated Farm Organization, Northern High Plains, Farm Situation 3[a]

Item			Unit	Optimal Timing Only	Non-optimal Timing Allowed
Crop Acreage:					
Crop	Post-Plants[b]	Rank[c]			
Corn	5	1	acres	23.15	
Corn	5	2	acres		13.98
Grain Sorghum	1	1	acres	23.15	13.98
Grain Sorghum	2	2	acres		13.98
Grain Sorghum	3	1	acres	39.52	48.69
Wheat	3	1	acres	5.66	5.98
Total Planted Acres			acres	91.48	96.61
Irrigation Water:					
Water Pumped			acre-feet	144.8	148.3
Number of Limiting Seasonal Water Periods			number	3	3
Range of Shadow Prices			dollars	11.51-30.77	7.79-26.45
Net Returns[d]			dollars	5797.63	5848.13

[a] This analysis is based on 1974-78 average crop prices and electricity at $.05 per KWH. Wind expectations are not included. Farm situation 3 has a saturated thickness of 175 feet, lift of 175 feet and 100 acres of cropland.

[b] Refers to the number of post-plant irrigations applied.

[c] Refers to the relative yield ranking among all activities of a given crop with a given number of post-plant irrigations.

[d] Returns are net of variable costs only.

August rather than mid-August, when water is limiting. In both cases, three water periods are limiting but, with non-optimal timings allowed, shadow prices decrease by approximately $4 per acre-foot.

As was discussed earlier, the inclusion of non-optimal irrigation timings was originally hypothesized primarily to take advantage of wind energy and secondarily as a method of easing seasonal water limitations. These results point out a further advantage, the increased flexibility of labor utilization. This, in addition to the extension of the limited pumping capacity in critical water periods, allows the irrigated producer in this situation to increase both irrigated acreage and net returns. In more practical terms, the extended model more closely represents the situation faced by irrigation farms on the Texas High Plains.

Cropping Pattern Results

Selected results from the benchmark LP solutions for the Southern and Northern High Plains are presented in this section. Acreage planted in the various crop activities and some of the characteristics of the limiting resources are discussed.

Southern High Plains

Benchmark solutions for the Southern High Plains area are presented in Tables 17, 18 and 19. Each table represents one of the three land units analyzed, with all combinations of crop and electricity prices included.

Optimal cropping patterns for the area are devoted to irrigated cotton. The solution is not sensitive to electricity price, commodity

Table 17. Cropping Pattern Results, Southern High Plains, Farm Situation 1[a]

Item			Unit	Purchase Price of Electricity (cents per KWH)		
				5	7.5	10
1974-78 Average Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	1	2	acres	12.19	12.19	12.19
Cotton	2	1	acres	8.28	8.28	8.28
Cotton	2	2	acres	12.19	12.19	12.19
Cropland Shadow Price			dollars	107.19	99.40	91.62
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	3.26-125.44	3.45-117.26	3.64-109.08
1985 Simulated Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	1	2	acres	12.19	12.19	12.19
Cotton	2	1	acres	8.28	8.28	8.28
Cotton	2	2	acres	12.19	12.19	12.19
Cropland Shadow Price			dollars	259.19	251.40	243.62
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	5.25-242.60	5.44-234.42	5.63-226.24

[a] Farm situation 1 has a saturated thickness of 100 feet, lift of 125 feet and 32.65 acres of cropland.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Refers to the number of post-plant irrigations applied.

[d] Refers to the relative yield ranking among all activities of the given crop with a given number of post-plant irrigations.

Table 18. Cropping Pattern Results, Southern High Plains, Farm Situations 2 and 3[a]

Item			Unit	Purchase Price of Electricity (cents per KWH)		
				5	7.5	10
1974-78 Average Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	1	2	acres	37.33	37.33	37.33
Cotton	2	1	acres	25.34	25.34	25.34
Cotton	2	2	acres	37.33	37.33	37.33
Cropland Shadow Price			dollars	102.33	91.91	81.48
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	3.38-120.35	3.64-109.40	3.90-98.44
1985 Simulated Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	1	2	acres	37.33	37.33	37.33
Cotton	2	1	acres	25.34	25.34	25.34
Cotton	2	2	acres	37.33	37.33	37.33
Cropland Shadow Price			dollars	254.33	243.91	233.48
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	5.38-237.51	5.63-226.56	5.89-215.61

[a] Farm situations 2 and 3 differ only in the size of wind machine; thus, their basic cropping patterns will be identical. Both have a saturated thickness of 175 feet, lift of 175 feet and 100 acres of cropland.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Refers to the number of post-plant irrigations applied.

[d] Refers to the relative yield ranking among all activities of the given crop with a given number of post-plant irrigations.

Table 19. Cropping Pattern Results, Southern High Plains, Farm Situation 4[a]

Item			Unit	Purchase Price of Electricity (cents per KWH)		
				5	7.5	10
1974-78 Average Crop Prices[b]						
Crop Acreages:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	0	1	acres			53.76
Cotton	1	2	acres	53.76	53.76	
Cotton	2	1	acres	36.49	36.49	90.24
Cotton	2	2	acres	53.76	53.76	
Cropland Shadow Price			dollars	99.83	88.14	76.68
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	3.45-117.73	3.73-105.44	3.31-93.15
1985 Simulated Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Cotton	1	2	acres	53.76	53.76	53.76
Cotton	2	1	acres	36.49	36.49	36.49
Cotton	2	2	acres	53.76	53.76	53.76
Cropland Shadow Prices			dollars	251.83	240.14	228.44
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	2	2	2
Range of Shadow Prices			dollars	5.44-251.83	5.73-222.60	6.01-210.31

[a] Farm situation 4 has a saturated thickness of 225 feet, lift of 200 feet and 144 acres of cropland.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Refers to the number of post-plant irrigations applied.

[d] Refers to the relative yield ranking among all activities of the given crop with a given number of post-plant irrigations.

price, lift or saturated thickness changes, as acreage in each crop activity remains the same (as a proportion of the total land unit) in all cases but one. In the predominant cropping pattern (all cotton), 37.33 percent of the acreage is planted with both one and two post-plant irrigations applied non-optimally. The remaining 25.34 percent receives two post-plants timed optimally. The yield differential for the non-optimal two post-plant irrigations is only two pounds of lint per acre. Both receive an irrigation in early August, the same time at which one post-plant, optimally timed, would be applied. Thus, the acreage receiving one post-plant is shifted to a mid-July irrigation, even at the loss of 47 pounds of lint per acre as compared to optimal timing of irrigation.

The optimal cropping pattern is changed only for farm situation 4 with 1974-78 average crop prices and electricity purchased for $.10 per KWH. Here, 37.33 percent of the total acreage shifts from one post-plant application to a pre-plant only. The remaining 62.67 percent receives two post-plants applied optimally, as the elimination of the single post-plant releases water in mid-July.

In all cases, two seasonal water periods are limiting. The low shadow price is between three and four dollars for the average crop prices and between five and six dollars per acre-foot for the simulated prices. The higher shadow price ranges for the 1974-78 average crop prices are from $93.15 to $125.44 and for the 1985 simulated crop prices are from $210.31 to $251.83. Additional cropland also has a relatively large value, up to $107.19 per acre with 1974-78 average crop prices and $259.19 for simulated crop prices.

Northern High Plains

In contrast to the results for the area south of the Canadian River, cropping patterns for the northern region vary considerably over the alternative scenarios. These results are shown in Tables 20 and 21 for farm situations 3 and 4, respectively. Again, all crop and electricity price scenarios are reflected in each table.

Under 1974-78 average crop prices, the optimal cropping patterns change in response to changes in the price of electricity. With electricity at $.05 per KWH corn, grain sorghum and wheat are produced under irrigation, although land is left idle in both farm situations. With an increase in electricity price from $.05 to $.075 per KWH, all land is utilized as dryland wheat enters the solution. Irrigated corn production increases (and shifts to an optimal timing) while irrigated grain sorghum and wheat acreage decrease. Finally, with $.10 per KWH electricity, irrigated wheat leaves the solution and dryland wheat acreage increases. All irrigated acreage shifts to grain sorghum in farm situation 4 while approximately 17 acres of irrigated corn remain in farm situation 3.

Cropping patterns stabilize in response to the 1985 simulated crop prices. The solutions do not change in response to electricity prices and are the same (proportionate to total acreage) for both farm situations. All acres are irrigated, as 1.37 percent of the available acreage is planted to corn, with the remaining 98.63 percent in grain sorghum. Five different sorghum activities are included, receiving one, two, three and four post-plant irrigations.

The solutions are very sensitive, as is emphasized by the results

Table 20. Cropping Pattern Results, Northern High Plains, Farm Situation 3[a]

Item			Unit	Purchase Price of Electricity (cents per KWH)		
				5	7.5	10
1974-78 Average Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Corn	5	1	acres		22.05	16.98
Corn	5	2	acres	13.98		
Grain Sorghum	1	1	acres	13.98	22.05	16.98
Grain Sorghum	2	2	acres	13.98		
Grain Sorghum	3	1	acres	48.69	40.62	45.68
Wheat	3	1	acres	5.98	2.43	
Wheat	Dryland		acres		12.84	20.35
Cropland Shadow Price			dollars	0	6.65	13.31
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	3	3	3
Range of Shadow Prices			dollars	7.79-26.45	10.63-35.50	1.84-47.63
1985 Simulated Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Corn	5	2	acres	1.37	1.37	1.37
Grain Sorghum	1	1	acres	8.31	8.31	8.31
Grain Sorghum	2	2	acres	35.96	35.96	35.96
Grain Sorghum	2	3	acres	27.66	27.66	27.66
Grain Sorghum	3	1	acres	1.37	1.37	1.37
Grain Sorghum	4	1	acres	25.34	25.34	25.34
Cropland Shadow Price			dollars	0.64	9.56	18.47
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	3	3	3
Range of Shadow Prices			dollars	4.28-93.28	4.28-93.28	4.28-93.28

[a] Farm situation 3 has a saturated thickness of 175 feet, lift of 175 feet and 100 acres of cropland.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Refers to the number of post-plant irrigations applied.

[d] Refers to the relative yield ranking among all activities of the given crop with a given number of post-plant irrigations.

Table 21. Cropping Pattern Results, Northern High Plains, Farm Situation 4[a]

Item			Unit	Purchase Price of Electricity (cents per KWH)		
				5	7.5	10
1974-78 Average Crop Prices[b]						
Crop Average:						
Crop	Post-Plants[c]	Rank[d]				
Corn	5	1	acres		31.76	
Corn	5	2	acres	20.13		
Grain Sorghum	1	1	acres	20.13	31.76	
Grain Sorghum	2	2	acres	20.13		
Grain Sorghum	3	1	acres	70.12	58.49	90.24
Wheat	3	1	acres	8.61	3.51	
Wheat	Dryland		acres		18.50	53.76
Cropland Shadow Price			dollars	0	9.81	13.44
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	3	3	2
Range of Shadow Prices			dollars	6.88-27.79	10.09-42.51	17.08-30.64
1985 Simulated Crop Prices[b]						
Crop Acreage:						
Crop	Post-Plants[c]	Rank[d]				
Corn	5	2	acres	1.97	1.97	1.97
Grain Sorghum	1	1	acres	11.96	11.96	11.96
Grain Sorghum	2	2	acres	51.79	51.79	51.79
Grain Sorghum	2	3	acres	39.38	39.38	39.38
Grain Sorghum	3	1	acres	1.97	1.97	1.97
Grain Sorghum	4	1	acres	36.49	36.49	36.49
Cropland Shadow Price			dollars	2.78	12.78	22.79
Irrigation Water:						
Number of Limiting Seasonal Water Periods			number	3	3	3
Range of Shadow Prices			dollars	4.28-93.28	4.28-93.28	4.28-93.28

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[a] Farm situation 4 has a saturated thickness of 225 feet, lift of 200 feet and 144 acres of cropland.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Refers to the number of post-plant irrigations applied.

[d] Refers to the relative yield ranking among all activities of the given crop with a given number of post-plant irrigations.

with average 1974-78 crop prices. At low electricity prices, land is left idle due to labor restraints. As the electricity price increases, irrigated acreage is forced out; however, this frees enough labor in critical periods for dryland crops to utilize all available acreage. The phenomena of cropland shadow prices rising with electricity price is caused by the tight labor situation. To fully utilize the marginal unit of land, some additional acreage must be shifted to dryland (along with the marginal unit) to stay within the labor restrictions. Thus, the value of the marginal unit of land would be the added returns from dryland production minus the returns foregone from the acreage withdrawn from irrigation. As electricity price increases, the foregone irrigated returns decrease, thus increasing the value of the marginal unit.

Shadow prices for irrigation water, with 1985 simulated crop prices, remain constant as electricity price increases. Again, this is due to restrictions on labor availability. Each of the three limiting seasonal water periods fall within the most restrictive labor period, July-August. Thus, to obtain sufficient labor to apply the marginal unit of water, a like amount of water from a different water period but the same labor period must be deleted. This results in an even trade-off in costs regardless of the electricity price, with the marginal value of water remaining constant.

Break-Even Analysis

The cropping patterns and associated irrigation schedules discussed above were used as input to the simulation model to estimate the annual value of wind power. Results relating to these simulations are shown in Tables 22 through 25 for the Southern High Plains and in Tables 26 and 27 for the Northern High Plains. Each table consists of all combinations of crop and electricity prices for a given farm situation.

The benchmark net returns (calculated as returns above variable cost for the static analysis) from the LP solution are shown for each scenario. These returns are netted out of the "actual" returns as estimated by the simulation model to determine returns to wind power. Maximum, minimum, mean and standard deviation of returns to wind over 20 annual simulations are shown to indicate the dispersion of values. Mean returns are used in the calculation of break-even investment at three discount rates. As was noted in the previous chapter, the value estimated using the three percent discount rate will be 16.9 percent higher than at five percent and 65.1 percent higher than for the ten percent discount rate.

Crop Price Effects

All crop prices were higher in the 1985 simulated prices than in the 1974-78 average prices. These differences are reflected in the benchmark returns. Wtih 1985 prices, benchmark returns range from $9,459.15 for farm situation 1 with $.10 per KWH electricity to $39,246.10 for farm situation 4 with $.05 per KWH electricity in the Southern High Plains. With average 1974-78 prices, the same returns are $3,684.43 (61 percent lower) and $13,790.32 (65 percent lower). In the northern region, benchmark returns are much lower than in the south, less than half in all situations, as cotton is not included as a crop option. The different sets of crop prices have a wider

Table 22. Break-Even Investment in a Wind Energy System, Southern High Plains, Farm Situation 1[a]

Item	Price of Purchased Electricity (cents per KWH)		
	5	7.5	10
1974-78 Average Crop Prices[b]			
Benchmark Returns	4301.65	3993.04	3684.43
Returns to Wind:			
Maximum	2006.12	2997.48	3897.91
Minimum	1854.05	2738.85	3506.73
Mean	1935.63	2883.36	3702.11
Standard Deviation	47.97	78.91	110.74
Break-Even Investment[c]:			
3% Discount Rate	25067.82	37341.61	47945.02
5% Discount Rate	21449.17	31951.19	41023.95
10% Discount Rate	15186.21	22621.74	29045.34
1985 Simulated Crop Prices[b]			
Benchmark Returns	10076.37	9767.76	9459.15
Returns to Wind:			
Maximum	2055.58	3023.60	4077.76
Minimum	1824.01	2739.98	3698.81
Mean	1920.43	2909.50	3865.83
Standard Deviation	57.41	70.39	112.86
Break-Even Investment[c]:			
3% Discount Rate	24870.97	37680.15	50065.32
5% Discount Rate	21280.73	32240.85	42838.17
10% Discount Rate	15066.96	22826.83	30329.83

[a] Farm situation 1 has a saturated thickness of 100 feet, lift of 125 feet, 32.65 acres of cropland and a 40 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

Table 23. Break-Even Investment in a Wind Energy System, Southern High Plains, Farm Situation 2[a]

Item	Price of Purchased Electricity (cents per KWH)		
	5	7.5	10
	(dollars)		
1974-78 Average Crop Prices[b]			
Benchmark Returns	12725.17	11459.64	10194.11
Returns to Wind:			
Maximum	2331.16	3383.83	4782.47
Minimum	2108.09	3136.98	4179.77
Mean	2201.47	3276.04	4387.45
Standard Deviation	61.25	69.70	147.00
Break-Even Investment[c]:			
3% Discount Rate	28510.64	42427.11	56820.68
5% Discount Rate	24395.00	36302.57	48618.36
10% Discount Rate	17271.89	25702.56	34422.26
1985 Simulated Crop Prices[b]			
Benchmark Returns	30411.67	29146.14	27880.60
Returns to Wind:			
Maximum	2342.21	3493.96	4682.08
Minimum	2052.43	3179.70	4158.58
Mean	2181.53	3291.59	4418.71
Standard Deviation	81.22	86.78	138.12
Break-Even Investment[c]:			
3% Discount Rate	28252.40	42628.49	57225.52
5% Discount Rate	24174.04	36474.88	48964.76
10% Discount Rate	17155.45	25824.56	34667.51

[a] Farm situation 2 has a saturated thickness of 175 feet, lift of 175 feet, 100 acres of cropland and a 40 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

Table 24. Break-Even Investment in a Wind Energy System, Southern High Plains, Farm Situation 3[a]

Item	Price of Purchased Electricity (cents per KWH)		
	5	7.5	10
	(dollars)		
1974-78 Average Crop Prices[b]			
Benchmark Returns	12725.17	11459.64	10194.11
Returns to Wind:			
Maximum	3315.28	5082.86	6622.14
Minimum	3096.49	4573.62	6120.27
Mean	3198.66	4809.38	6339.44
Standard Deviation	69.89	130.21	154.83
Break-Even Investment[c]:			
3% Discount Rate	41424.98	62284.98	82100.37
5% Discount Rate	35445.10	53293.87	70248.82
10% Discount Rate	25095.47	37732.56	49736.83
1985 Simulated Crop Prices[b]			
Benchmark Returns	30411.67	29146.14	27880.60
Returns to Wind:			
Maximum	3338.79	5078.47	6673.12
Minimum	3069.88	4607.80	6157.61
Mean	3212.75	4804.09	6415.65
Standard Deviation	81.53	132.71	143.26
Break-Even Investment[c]:			
3% Discount Rate	41607.45	62216.47	83087.34
5% Discount Rate	35601.23	53235.25	71093.32
10% Discount Rate	25206.01	37691.06	50334.74

[a] Farm situation 3 has a saturated thickness of 175 feet, lift of 175 feet, 100 acres of cropland and a 60 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

Table 25. Break-Even Investment in a Wind Energy System, Southern High Plains, Farm Situation 4[a]

Item	Price of Purchased Electricity (cents per KWH)		
	5	7.5	10
	(dollars)		
1974-78 Average Crop Prices[b]			
Benchmark Returns	17867.17	15822.35	13790.32
Returns to Wind:			
Maximum	3408.06	5070.22	6868.51
Minimum	3058.82	4680.56	6155.72
Mean	3255.36	4893.37	6469.62
Standard Deviation	103.22	114.93	197.82
Break-Even Investment[c]:			
3% Discount Rate	42159.29	63372.71	83786.30
5% Discount Rate	36073.41	54224.58	71691.37
10% Discount Rate	25540.31	38391.51	50758.17
1985 Simulated Crop Prices[b]			
Benchmark Returns	43335.73	41290.91	39246.10
Returns to Wind:			
Maximum	3444.59	5118.83	6990.00
Minimum	3107.94	4691.82	6306.04
Mean	3274.71	4852.47	6568.25
Standard Deviation	91.64	115.48	189.81
Break-Even Investment[c]:			
3% Discount Rate	42409.88	62843.02	85063.63
5% Discount Rate	36287.83	53771.36	72784.32
10% Discount Rate	25692.13	38070.63	51531.98

[a] Farm situation 4 has a saturated thickness of 225 feet, lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

Table 26. Break-Even Investment in a Wind Energy System, Northern High Plains, Farm Situation 3[a]

Item	Price of Purchased Electricity (cents per KWH)		
	5	7.5	10
	(dollars)		
1974-78 Average Crop Prices[b]			
Benchmark Returns	5848.13	4275.61	2788.58
Returns to Wind:			
Maximum	3287.77	4769.88	6584.74
Minimum	3043.68	4366.18	5889.24
Mean	3182.57	4553.45	6255.45
Standard Deviation	61.75	115.92	175.55
Break-Even Investment[c]:			
3% Discount Rate	41216.60	58970.50	81012.64
5% Discount Rate	35266.80	50457.84	69318.11
10% Discount Rate	24969.23	35724.63	49077.87
1985 Simulated Crop Prices[b]			
Benchmark Returns	13836.62	12296.59	10756.56
Returns to Wind:			
Maximum	3341.92	5100.99	6598.11
Minimum	2989.96	4576.96	6063.60
Mean	3156.93	4784.64	6315.91
Standard Deviation	84.27	162.38	163.79
Break-Even Investment[c]:			
3% Discount Rate	40884.54	61964.58	81795.64
5% Discount Rate	34982.68	53019.72	69988.08
10% Discount Rate	24768.07	37538.46	49552.22

[a] Farm situation 3 has a saturated thickness of 175 feet, lift of 175 feet, 100 acres of cropland and a 60 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

Table 27. Break-Even Investment in a Wind Energy System, Northern High Plains, Farm Situation 4[a]

Item	Price of Purchased Electricity (cents per KWH) 5	7.5	10
	--------------(dollars)---------		
<u>1974-78 Average Crop Prices</u>[b]			
Benchmark Returns	7843.70	5353.52	3218.64
Returns to Wind:			
Maximum	3438.41	5074.93	6329.64
Minimum	3144.07	4629.34	5796.76
Mean	3255.60	4812.68	5997.10
Standard Deviation	77.94	121.12	143.62
Break-Even Investment[c]:			
3% Discount Rate	42162.39	62327.71	77666.82
5% Discount Rate	36076.07	53330.43	66455.27
10% Discount Rate	25542.20	37758.45	47050.96
<u>1985 Simulated Crop Prices</u>[b]			
Benchmark Returns	19373.22	16884.89	14396.55
Returns to Wind:			
Maximum	3444.01	5084.94	6829.57
Minimum	3022.35	4632.90	6073.30
Mean	3220.47	4860.32	6463.27
Standard Deviation	107.12	120.79	211.21
Break-Even Investment[c]:			
3% Discount Rate	41707.43	62944.69	83704.06
5% Discount Rate	35686.78	53858.34	71621.01
10% Discount Rate	25266.58	38132.22	50708.35

[a] Farm situation 4 has a saturated thickness of 225 feet, lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[b] See Table 13 for a listing of the crop price scenarios.

[c] Break-even investment is calculated based on mean returns to wind.

percentage effect in the north. Returns under average crop prices are as much as 77 percent lower than with simulated prices in farm situation 4 with $.10 per KWH electricity ($14,396.55 vs. $3,218.87). The smallest decrease in returns is 57 percent, $13,836.62 to $5,848.13, in farm situation 3 with electricity at $.05 per KWH.

In contrast, the set of prices utilized has little effect on returns to wind. On the Northern High Plains, returns to wind are greater under average crop prices with electricity at $.05 per KWH. This is reversed at higher electricity prices, where the 1985 simulated crop prices yield higher returns to wind. No tests for statistical significance were made; however, in only two cases was the difference in annual returns greater than $100. Southern High Plains results show no pattern of higher returns with either set of prices. The difference in annual returns with respect to crop prices is greater than $100 in only one situation.

Electricity Price Effects

Increases in electricity price have a constant effect on benchmark returns with farm situations where cropping patterns remain constant. This is most easily seen in the Southern High Plains results. In farm situation 1, returns decrease by $308.61 for each 2½ cent increase in electricity prices. Other rates of change are $1,265.53 in situations 2 and 3 and $2,044.82 in situation 4. The only exception is in farm situation 4 with average crop prices, where the increase in electricity price from $.075 to $.10 per KWH results in a decrease in benchmark returns of $2,032.03. This is the only scenario in the southern region where cropping patterns change.

On the Northern High Plains, cropping patterns are constant with simulated crop prices. As electricity price increases by 2½ cents per KWH, benchmark returns decrease by $1,540.03 in farm situation 3 and by $2,488.33 in situation 4. With average crop prices, the decrease in returns is slightly greater than above when moving from $.05 to $.075 per KWH but less than above for the next electricity price increment.

The decline in returns in response to increasing electricity prices is mitigated by the addition of a wind energy system to the farm operation. In farm situations 1 and 3, total returns (equivalent to benchmark returns plus returns to wind) actually increase with an increase in electricity prices, as increased income from the sale of surplus electricity offsets the added cost of electricity purchases. In each case, the applicable wind system operates on the smaller of the two land units applied to a given size of machine. When the 40 KW and 60 KW machines are placed on the larger land unit for each (farm situations 2 and 4, respectively), higher electricity prices cause a decrease in returns, but the decrease is of a much smaller magnitude than in the benchmark case. For example, in farm situation 2 with average crop prices (Southern High Plains), benchmark returns decrease by $2,531.06 in response to a five cent increase in electricity price. However, when a wind system is utilized, simulated returns decrease by only $345.08 in the same situation.

Overall, annual returns to wind energy do not increase in strict proportion to electricity price increases. On the Southern High Plains, simulated returns to wind increase by an average of 49.8 percent in response to a 50 percent increase in electricity prices and by 99.2 percent when electricity price increases by 100 percent. In the northern region, where irrigated acreage is more likely to decrease in response to higher fuel prices, the respective increases in returns to wind average 48.4 percent and 95.4 percent.

Feasibility of Investment

Break-even investment values for the Southern High Plains range from $15,186.21 to $56,820.68 for a 40 KW system and from $25,095.47 to $83,786.30 for a 60 KW machine. For the Northern High Plains, where only the 60 KW machine was analyzed, break-even values range from $24,969.23 to $81,012.64. These values are somewhat lower than for the southern region, indicating that cotton can make more profitable use of wind energy than the northern crop mix, dominated by grain sorghum.

The wide divergence in both present and projected future costs of wind systems makes a "yes or no" recommendation on the investment decision beyond the scope of this study. One general conclusion can be made. Cost projections for the mature industry often mention $500 per installed KW (Alternative Energy Institute, Katzenberg). These results show break-even investment values over $500 per KW in all cases except where electricity is priced at $.05 per KWH and returns discounted at 10 percent.

Comparisons Among Farm Situations

The farm situations were specified to permit the analysis of a given size of wind system on two different land units as well as examine the two machine sizes on a common land unit. The 100 acre farm unit was analyzed with both 40 KW and 60 KW wind systems for the Southern High Plains only. These results are shown in Table 28.

Break-even investment values, calculated at a five percent discount rate, are adjusted to a per installed kilowatt of generating capacity basis. In all cases, the ability to pay per KW of capacity is higher for the smaller, 40 KW machine. In farm situation 3, revenue from the sale of electricity offsets purchases for irrigation as electricity price increases, thus suggesting that the 60 KW machine in this situation may be over-sized for irrigation purposes.

In all cases, break-even investment rates are higher for farm situation 2 than for 1 as well as for situation 4 over 3. This means that each size of wind system is more effective on the larger of the two land units applied. Table 29 presents further confirmation of this conclusion. Simulation results within each farm situation were aggregated over all crop and electricity price scenarios. Averages were calculated for wind generated electricity, both sold and used for irrigation, as well as the percentage of total irrigation requirements fulfilled by wind power.

As was noted earlier, cotton production (only in the Soutern High Plains) makes more efficient use of wind energy. In the situations applicable to both regions (farm situations 3 and 4), the amount of wind energy used for irrigation is higher on the Northern High Plains by slightly less than one thousand KWH. However, the percentage of irrigation requirements fulfilled by wind energy is higher in the southern region, 27.56 percent as compared to 23.98 percent in the north for farm situation 3 and 18.79 vs. 16.4 percent for farm

Table 28. Comparison of the Value of 40 Kilowatt and 60 Kilowatt Wind Energy Systems on a 100 Acre Farm Unit, Southern High Plains

Item	Purchase Price of Electricity (cents per KWH)		
	5	7.5	10
	(dollars)		
1974-78 Average Crop Prices[a]			
Break-Even Investment[b]:			
40 KW Wind System (Farm Situation 2)	609.88	907.56	1215.46
60 KW Wind System (Farm Situation 3)	590.75	888.23	1170.81
1985 Simulated Crop Prices[a]			
Break-Even Investment[b]:			
40 KW Wind System (Farm Situation 2)	604.35	911.87	1224.12
60 KW Wind System) (Farm Situation 3)	593.35	887.25	1184.89

[a] See Table 13 for a listing of the crop price scenarios.

[b] Break-even investment, discounted at 5 percent, is expressed on a per kilowatt of capacity basis.

Table 29. Simulation Results of Electricity Sold and Used for Irrigation

Item	Wind Generated Electricity			
	Sold (KWH)	Used for Irrigation (KWH)	% of Total Requirements[a] (percent)	% of Total Generated[b] (percent)
Northern High Plains				
Farm Situation 3[c]	76994.7	13937.4	23.98	13.80
Farm Situation 4[c]	77339.7	14970.6	16.40	14.84
Southern High Plains				
Farm Situation 1[c]	52095.5	4823.5	42.05	7.16
Farm Situation 2[c]	52518.1	9601.0	20.43	14.13
Farm Situation 3[c]	78444.7	12952.0	27.56	12.73
Farm Situation 4[c]	78677.3	14057.0	18.79	13.86

[a] Represents the average percentage of total irrigation requirements fulfilled by wind power.

[b] Represents the average percentage of total wind generated electricity used for irrigation.

[c] Refer to Table 12 for a description of the farm situations.

situation 4. In farm situations 1 and 2 (analyzed only for the southern region) the percentages of irrigation requirements satisfied by wind power are 42.05 and 20.43 percent, respectively.

Even though the proportion of irrigation requirements fulfilled by wind power decreases when a machine is operated on the larger land unit, the percentage of total electricity generated applied to irrigation increases. The increase is slightly more than one percent when moving from farm situation 3 to 4 in both regions, and 6.97 percent when moving from farm situation 1 to 2 in the Southern High Plains. In all cases, the magnitude of wind generated electricity sold and applied to irrigation is higher on the larger land unit for each machine (farm situations 2 and 4). This is due to the assumption that wind power cannot be used for both purposes at the same time. If the wind system is producing more power than required for pumping, the excess power was assumed to be wasted. This was more likely to occur on the smaller land unit.

Effect of Load Management Strategies

The previous results were based on an irrigation schedule that was planned without taking into account the availability of wind power. It was hypothesized that, if wind energy was included in the planning process, irrigation scheduling might be changed to take advantage of periods havinghigher wind power. Thus, expectations of available wind power were included in the LP model to test their effect on cropping patterns. However, wind power expectations result in changes in only four situations.

In the southern region, benchmark cropping patterns were identical in proportion in all situations but one (farm situation 4, 1974-78 average crop prices and $.10 per KWH electricity). The addition of wind expectations to this situation resulted in a cropping pattern shift to the same solution as in the other benchmark situations. This was 53.76 acres of cotton receiving one post-plant irrigation (in mid-July) rather than zero, while the remaining 90.24 acres of cotton continue to receive two post-plant irrigations. Average annual returns to wind increase by $96.06. This was the only scenario in the Southern High Plains where the cropping pattern was affected.

In contrast, the Northern High Plains benchmark results varied considerably under average crop prices. Wind power expectations changed the optimal cropping pattern for farm situation 3, with electricity priced at $.075 and $.10 per KWH. These changes are detailed in Table 30.

With electricity at $.075 per KWH, irrigated corn and dryland wheat acreage decrease in favor of irrigated grain sorghum, with a small increase in irrigated wheat acreage. Irrigation pumping decreases slightly in the two months (July and August) having the lowest average wind speeds, while pumping increases in the spring months. Total pumping increases by 7.41 acre-feet. However, these changes have little effect on the annual value of wind energy, which increases by less than eight dollars for the farm.

When electricity is priced at $.10 per KWH, wind expectations allow the cropping pattern to return to the benchmark solution that was optimal with electricity at $.075 per KWH. Again, dryland wheat acreage decreases and 2.43 acres of irrigated wheat enter the solution.

Table 30. Effects of Wind Energy Expectations on the Optimal Farm Organization: Northern High Plains, Farm Situation 3[a], 1974-78 Average Crop Prices[b]

Item	Unit	Purchase Price of Electricity (cents per KWH)			
		7.5		10	
		Benchmark	With Wind	Benchmark	With Wind
Crop and Irrigation Level:					
Corn (PP+5)[c]	acres	22.05	13.70	16.98	22.05
Grain Sorghum (PP+1)	acres	22.05	13.70	16.98	22.05
Grain Sorghum (PP+2)	acres		13.70		
Grain Sorghum (PP+3)	acres	40.62	48.96	45.68	40.62
Wheat (PP+3)	acres	2.43	4.65		2.43
Wheat (Dryland)	acres	12.84	5.27	20.35	12.84
Water Pumped by Month:					
February	acre-feet	8.92	10.12		8.92
March	acre-feet	40.49	42.42	46.46	40.49
April	acre-feet	0.81	1.55		0.81
May	acre-feet	1.62	3.10		1.62
July	acre-feet	49.08	46.30	47.40	49.08
August	acre-feet	35.55	34.56	32.18	35.55
September	acre-feet	1.42	7.27		1.42
Total	acre-feet	137.99	145.40	126.04	137.99
Simulated Returns to Wind	dollars	4553.45	4561.37	6255.45	6284.55

[a] Farm situation 3 has 175 feet of saturated thickness, 175 feet of lift, 100 acres of cropland and a 60 KW wind machine.

[b] 1974-78 average crop prices are listed in Table 13.

[c] Indicates a pre-plant plus the given number of post-plant irrigations.

Grain sorghum with three post-plants shows a decrease and acreage of grain sorghum with one post-plant and corn with five post-plant irrigations increase. Total irrigation water application increases by 11.95 acre-feet, with increases in each month except March, where average wind speed is highest. The increase in returns to wind is $29.10.

The final cropping pattern change was also in farm situation 3, but with 1985 simulated crop prices and $.05 per KWH electricity (Table 31). Acreage in grain sorghum with two post-plants decreases dramatically and acreage of all other crops in the solution (corn with five post-plants and sorghum with one, three and four post-plants) increases. However, as in the previous case, irrigation actually shifts away from periods with higher wind speeds, as returns to wind increase by less than five dollars per year.

The consideration of wind expectations in the planning process had little effect, with cropping pattern changes occurring in only four of the thirty-six situations analyzed. In two situations, unique cropping patterns were developed, involving relative changes of irrigation scheduling to higher wind speed months, but the increase in returns to wind was negligible (less than eight dollars per year). More substantial increases occurred where wind power simply eased the effect of higher electricity prices by allowing the farm plan to return to a cropping pattern which had been optimal at lower electricity prices.

Table 31. Effects of Wind Energy Expectations on the Optimal Farm Organization: Northern High Plains, Farm Situation 3[a], 1985 Simulated Crop Prices[b]

Item	Unit	Benchmark[c]	With Wind[c]
Crop and Irrigation Level:			
Corn (PP+5)[d]	acres	1.37	10.07
Grain Sorghum (PP+1)	acres	8.31	22.57
Grain Sorghum (PP+2)	acres	63.62	22.57
Grain Sorghum (PP+3)	acres	1.37	10.07
Grain Sorghum (PP+4)	acres	25.34	30.02
Water Pumped by Month:			
February	acre-feet	11.28	10.72
March	acre-feet	47.05	44.87
July	acre-feet	39.88	40.93
August	acre-feet	42.19	45.09
September	acre-feet	0.46	3.35
Total	acre-feet	140.96	145.08
Simulated Returns to Wind	dollars	3156.93	3161.52

[a] Farm situation 3 has 175 feet of saturated thickness, 175 feet of lift, 100 acres of cropland and a 60 KW wind machine.

[b] 1985 simulated crop prices are listed in Table 13.

[c] The purchase price of electricity is $.05 per KWH.

[d] Indicates a pre-plant plus the given number of post-plant irrigations.

Temporal Analysis

The results above assumed the value of wind power to be constant over a 20 year period, the expected life of a wind system. However, the irrigated farmer on the High Plains does not face a constant situation. As the water level of the Ogallala aquifer declines, the producer faces declining well yield, which reduces the amount of water that can be pumped in any seasonal water period, and increasing pumping costs due to increasing pumping lift. These factors will cause net returns to decrease. Whether or not there will be a differential effect on returns to wind power is unknown. The linear programming model was revised and applied on a recursive basis to estimate the effects of the declining water level. The simulation model is not applied in temporal analysis; rather, the mathematical expectation of available wind power, calculated based on monthly average wind speeds, is assumed to be received in each year. As was noted in Chapter IV, this will result in slight underestimates of wind energy availability as compared to that estimated by the simulation model.

Only farm situations 2 and 4 were selected for temporal analysis, as the static results above showed each to be the more efficient application of the given machine size. Both situations were analyzed for the Southern High Plains while only farm situation 4 was included in the northern region. The 1985 simulated crop prices were used. Two scenarios were established for electricity prices; one where the price is held constant at \$.05 per KWH and another where the price is increased from \$.05 per KWH by one-half cent per KWH per year.

Constant Electricity Price

With electricity prices constant, cropping patterns do not change between the benchmark (without wind power) solution and the solution with wind power.

Southern High Plains

Selected physical results of the constant electricity price case are shown in Appendix D, Tables 1 and 2 for the Southern High Plains farm situations 2 and 4, respectively. Comparisons between the first and last year of each analysis are presented.

In the southern region, where all land is initially in irrigated cotton, acreage gradually shifts away from two post-plant irrigations with optimal timing. Eventually, the optimal timing of two post-plants is replaced by a pre-plant irrigation only. This occurs in year 8 in farm situation 2 and in year 15 in farm situation 4. From this point, the above situation reverses, as pre-plant only acreage increases with equal declines in the other activities. By year 19 on the smaller land unit, well yield declines to the point where the five pre-plant irrigation periods are not sufficient to cover all 100 acres. At this point, a small amount of irrigated grain sorghum enters the solution.

By year 20, total irrigation fuel requirements increase by 10 and 11 percent, respectively, in farm situations 2 and 4. The proportion of the requirement fulfilled by wind power is 19.4 and 18.1 percent in year 1, increasing to 30.6 and 22.4 percent, respectively, by year 20. The amount of purchased electricity actually decreases in farm situation 2, as the more rapid decline in well yield and subsequent extension of irrigation over more seasonal water periods allows the use of wind power to increase.

As was done earlier, present value of returns is calculated at three different discount rates to reflect a range of estimates. However, since annual returns are not constant, changes between discount rates are not proportional. Returns without wind power (the benchmark) are netted out, with the difference adjusted for the assumed operation and maintenance cost to determine break-even investment, shown in Table 32. When expressed on a per KW basis, break-even investment is slightly higher at all discount rates for the 40 KW machine. These values range from $421.51 to $700.96 at ten and three percent discount rates, respectively, as opposed to $415.08 to $688.18 for the 60 KW machine.

Northern High Plains

Only farm situation 4 was examined for the northern region. As in the south, wind power does not affect cropping patterns when electricity price remains constant (Appendix D, Table 3). The optimal farm plan consists almost entirely of irrigated grain sorghum in year 1, with only 1.97 acres of irrigated corn. This remains constant until year 7, as corn acreage begins to increase. The following year, irrigated wheat enters the solution. Both wheat and corn acreage increase annually through the remainder of the analysis.

Regardless of whether wind power is included, labor constraints make the optimal land use pattern sensitive to the declining water level. As was the case in the static analysis with increasing electricity prices, the shadow price of cropland does not behave as would

Table 32. Temporal Analysis[a] of Break-Even Investment in a Wind Energy System: Constant Electricity Price[b]

Item	Present Value of Returns[c]		Break-Even
	With Wind Power	Without Wind Power	Investment
	----------(dollars)----------		
Southern High Plains			
Farm Situation 2[d]:			
3% Discount Rate	344184.81	311975.13	28038.29
5% Discount Rate	289852.75	262933.88	23935.93
10% Discount Rate	200385.06	182089.38	16860.27
Farm Situation 4[d]:			
3% Discount Rate	518283.16	470849.41	41290.73
5% Discount Rate	435580.89	395902.89	35281.19
10% Discount Rate	299706.64	272681.58	24904.78
Northern High Plains			
Farm Situation 4[d]:			
3% Discount Rate	151193.91	103206.79	41772.44
5% Discount Rate	128843.83	88796.64	35609.47
10% Discount Rate	91307.52	64168.39	25009.90

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Constant electricity price of $.05 per KWH.

[c] Returns are net of variable and fixed costs.

[d] Refer to Table 12 for a description of the farm situations.

be expected. The shadow price increases over the first six years, then goes to zero as land is left idle beginning year 7. Full irrigated acreage returns in year 15. From that point, the shadow price makes one large increase, then decreases for the remainder of the analysis.

More water is pumped in the northern region, as ending saturated thickness is 18 feet lower than in the south (156 feet vs. 174 feet). The annual amount of electricity required for irrigation increases substantially by year 20, 45 percent higher than in year 1. The proportion of irrigation fuel fulfilled by wind power increases from 15.9 percent to 22.3 percent over the time of the analysis. The beginning figure is lower than in the south, but in year 20 the percentages are nearly identical. Break-even investment ranges from $41,772.44 ($696.20 per KW) at a three percent discount rate to $25,009.90 ($416.83 per KW) with returns discounted at 10 percent.

Increasing Electricity Price

Southern High Plains

In farm situation 4, cropping patterns are the same as with constant electricity prices, both with and without wind power (Appendix D, Table 4). The primary difference in the two analyses is in break-even investment (Table 33), which increases substantially compared to constant prices (80, 75 and 64 percent, respectively, at three, five and 10 percent discount rates).

In farm situation 2, increasing electricity prices result in minor cropping pattern changes (less than one acre) when comparing with and without wind power (Appendix D, Table 5). Both solutions are

Table 33. Temporal Analysis[a] of Break-Even Investment in a Wind Energy System: Increasing Electricity Price[b]

Item	Present Value of Returns[c]		Break-Even Investment
	With Wind Power	Without Wind Power	
	(dollars)		
Southern High Plains			
Farm Situation 2[d]:			
3% Discount Rate	336740.81	278641.25	50575.24
5% Discount Rate	284051.94	237045.88	41797.21
10% Discount Rate	197093.56	167530.75	27243.43
Farm Situation 4[d]:			
3% Discount Rate	499116.91	413561.16	74475.66
5% Discount Rate	420740.14	351483.83	61581.86
10% Discount Rate	291435.27	247815.39	40197.63
Northern High Plains			
Farm Situation 4[d]:			
3% Discount Rate	124383.85	40638.60	72899.63
5% Discount Rate	107739.45	39849.64	60367.14
10% Discount Rate	79076.71	36180.96	39530.31

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Initial electricity price of $.05 per KWH and increasing by $.005 annually.

[c] Returns are net of variable and fixed costs.

[d] Refer to Table 12 for a description of the farm situations.

practically identical to those with constant electricity prices. The major difference in the analyses is an increase in ending well yield of one gallon per minute. Again, break-even investment increases substantially (80, 75 and 62 percent at three, five and ten percent discount rates).

Northern High Plains

Wind power has its greatest effect on cropping patterns in this situation, as shown in Appendix D, Table 6. With and without wind power, cropland shifts to dryland grain sorghum by year 20. However, there are 29 acres of dryland sorghum when wind energy is used compared to 45 acres in the benchmark solution. Irrigation is more intensive, with 16.63 acres of grain sorghum receiving three post-plants, in the benchmark solution. With wind power, only one and two post-plant sorghum activities are in the solution.

Irrigation fuel requirements decrease by year 20 in response to the increasing fuel price by 26,806 KWH without windpower and by 21,506 KWH with wind power. Even though the total fuel requirement decreases substantially, wind-generated electricity used for irrigation increases, as pumping is spread over a longer time period in response to declining well yield. Again, break-even investment values are increased over the constant electricity price case, but by smaller rates than in the south (75, 70 and 58 percent).

Comparison of Static and Temporal Results

Some general conclusions may be made by examining a cross-section of the results. Table 34 shows break-even investment values for the

Table 34. Comparison of Break-Even Investment Values[a] Derived from Static and Temporal Analysis

Item	Sell-Only Analysis[b]	Static Analysis[c]	Temporal Analysis[d]
	--------(dollars per KWH)--------		
Southern High Plains			
40 KW Machine (Farm Situation 2)	591.64	706.31	700.96
60 KW Machine (Farm Situation 4)	592.22[e]	706.83	688.18
Northern High Plains			
60 KW Machine (Farm Situation 4)	592.22[e]	695.12	696.21

[a] All values were discounted at three percent and expressed in dollars per KWH.

[b] Electricity sold at $.03 per KWH.

[c] Electricity purchased at $.05 per KWH and 1985 simulated crop prices.

[d] Electricity purchase price constant at $.05 per KWH and 1985 simulated crop prices.

[e] No distinction was made between regions for the sell-only option.

sell-only option (discussed in the previous chapter) and from the static and temporal analysis. In all cases, the price of purchased electricity is constant at $.05 per KWH. This is the assumed equivalent of selling electricity at $.03 per KWH. The three percent discount rate is used, with 1985 simulated crop prices assumed.

The sell-only option provides a lower limit to the value of a wind system compared to the other analyses, where part of the wind generated electricity is substituted for higher valued purchased electricity. Break-even investment values are approximately $100 per KW lower when all electricity is sold to the utility.

Due to the difference in the way wind speed distributions were specified, available wind power is lower in the temporal analysis than in the static. In the Southern High Plains, this is reflected by estimated break-even investment being less than for the static analysis. However, north of the Canadian River, estimated break-even investment is higher under the temporal analysis. It is also higher than for the Southern High Plains temporal analysis for the same machine size, a reversal of the static analysis results.

The benchmark returns (without wind power) in the Northern High Plains are much more sensitive to the declining water level than in the south. This is the major reason behind the increase in value of wind energy, even with lower wind power estimates. The increase in break-even investment for a wind power system as compared to static analysis in the north indicates that temporal analysis could yield higher estimated break-even investment in the south if wind power estimates were equal. Due to the lower wind power estimates, the value of wind power estimated on a temporal basis should be regarded as conservative in nature.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The High Plains region of Texas is one of the major agricultural areas of the state. The agricultural, as well as the entire regional economy, is heavily dependent on irrigation. Irrigation increases the productivity of crops previously produced under dryland conditions and allows the production of other higher valued crops which cannot be grown without irrigation.

The viability of irrigated agriculture is threatened by continually increasing costs of pumping groundwater. This is due not only to increasing energy prices but also to the declining water level of the Ogallala aquifer, which increases the amount of energy required to lift the groundwater. Since dramatic energy price increases began in 1973, much research has been directed toward increasing the energy efficiency of irrigated agriculture. Other major research efforts have examined the development of energy from renewable sources.

One readily abundant renewable source of energy on the Texas High Plains is wind power. The High Plains has as much available wind power as any region in the country. Due to the importance of irrigation in the region, the concept of wind-assisted irrigation pumping could be an important alternative. Wind systems have been developed which are capable of providing supplemental energy to an existing electrical pumping plant. The electric motor is sized to operate the pump on a stand-alone basis. However, when the wind velocity is sufficient, the wind system operates and reduces the load on the electric motor. When pumping is not taking place, electricity can be generated and sold to the electric utility. The purpose of this study was to quantify, on both a static and temporal basis, the benefits of a wind energy system in an irrigation application on the Texas High Plains.

Methodology

The procedure for the static analysis involved determination of an optimal cropping pattern by a linear programming model developed for the Texas High Plains region. The optimal irrigation schedule was used as input to a simulation model. The simulation model matched stochastically generated wind power estimates to the irrigation schedule to estimate the annual value of wind energy.

The production activities in the LP model included dryland and irrigated options for cotton, grain sorghum and wheat along with irrigated corn. To give a broader representation of the choices available to an irrigated producer, activities were included assuming both optimal and non-optimal timing of irrigation applications. The yield reduction effects of non-optimal timing were estimated from experimental data for the region. In addition to the production activities, there were separate purchasing activities for selected inputs, selling activities for crops produced and a cash flow section divided into two-month periods.

Constraining resources included land, labor and irrigation water.

Labor restrictions were divided into two-month periods. Irrigation water applications were divided into ten-day periods, with restrictions based on the physical maximum that could be pumped.

The simulation model generates random ("actual") wind speeds by three-hour time periods throughout a year. Random wind speeds are drawn from Rayleigh distributions, the single parameter of which is mean wind velocity. Frequency distributions were set up by month and time of day (each three-hour interval for which wind speed is recorded), making eight distributions per month. Each three-hour estimate of wind power availability is matched with the amount of irrigation fuel required in that period, as determined by the LP model. Irrigation requirements in excess of wind power are purchased. Surplus generated electricity while pumping is assumed to have no value. If irrigation does not take place, 90 percent of excess wind power is sold to the electric utility for 60 percent of the purchase price. The annual value of wind power is calculated based on irrigation fuel saved and excess power sold. The simulation process is repeated 20 times for each situation analyzed to generate a range of solutions.

Mathematical expectations of available wind power based on single monthly average wind speeds were added to the LP model to test if cropping patterns would change when the availability of wind power was considered in the planning process. If this resulted in a change in cropping patterns, the simulation model was applied to the new irrigation schedule using the same set of random wind speeds.

For the temporal analysis, a Fortran subroutine was added to the LP model to operate the model recursively over the assumed twenty year life of a wind system. Annual farm plans are developed by the LP model. Based on the quantity of irrigation water applied in year t for the LP farm plan, the Fortran subroutine calculates the deline in saturated thickness of the aquifer and associated new well yield, pumping lift and irrigation fuel requirements for year t+1. The LP matrix is then updated with the new coefficients. This procedure continues over the twenty years of analysis.

The benchmark case involved application of the basic LP model. To estimate the value of wind power in the temporal framework, the monthly expectations of wind-generated electricity were added to the model. In both cases, fixed costs appropriate for a long-run analysis are deleted from returns.

Alternative Scenarios

The scenarios analyzed consisted of changes in four basic areas. The region was separated into the areas north and south of the Canadian River, with cotton included as a crop option only south of the river, due to the length of the growing season. Four farm situations were specified: (1) a saturated thickness of 100 feet, lift of 125 feet, 32.65 acres of cropland and a 40 KW wind machine; (2) a saturated thickness of 175 feet, lift of 175 feet, 100 acres of cropland and a 40 KW machine; (3) the same as situation 2 with the exception of a 60 KW machine; and (4) a saturated thickness of 225 feet, lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

Two sets of crop prices were used, one reflecting 1974-78 averages and the other based on simulated 1985 prices. For the static analysis, electricity purchase prices of $.05, $.075 and $.10 per KWH were analyzed. In the temporal analysis, a constant purchase price of $.05 per KWH was specified, plus a situation where the price increased by one-half cent per KWH per year.

Results

Operating Characteristics

The randomly generated wind speeds and power output from the Southern High Plains benchmark simulations were aggregated to examine some predicted performance parameters. Average annual output was 67,679.4 KWH for a 40 KW system and 101,618.6 KWH for the 60 KW machine. Over both machines, the average proportion of time producing rated (maximum) output was 4.92 percent, while the average time not operating due to low or high wind speed was 41.5 percent. Value of wind power was estimated assuming all power was sold to the utility. Break-even investment (on a per KW basis) ranged from $358.42 at a ten percent discount rate and $.03 per KWH electricity to $1,184.43 with three percent discounting and $.06 per KWH electricity. These selling prices are 60 percent of the assumed purchase price of electricity at $.05 and $.10 per KWH, respectively.

Static Analysis

Non-Optimal Irrigation Timing

The effect of the inclusion of non-optimal irrigation timings was examined for a specified situation on the Northern High Plains. The model was applied with only optimal irrigation timings included and with non-optimal irrigation timings included. Labor constraints were binding, as land was left idle in both cases, but 5.13 more acres were irrigated where non-optimal timing was allowed. Irrigations were applied non-optimally on 28.9 percent of the irrigated acres. The inclusion of non-optimal timings allowed added flexibility in the usage of labor as well as irrigation water, and increased returns over variable costs to the 100 acre farm by $50.50. This was felt to more accurately reflect the situation faced by High Plains producers, thus, non-optimal timing of irrigation was permitted in further analyses.

Cropping Patterns

In the analysis of alternative scenarios for the benchmark solutions, cropping patterns were found to be insensitive to changes in crop prices or electricity prices in the southern region. All acres were planted to irrigated cotton over all farm situations. The specific cropping pattern was identical (in proportion to total acreage) in all cases except in farm situation 4 with electricity at $.10 per KWH and 1974-78 average crop prices, where 37.33 percent of the acreage shifted from one post-plant irrigation to a pre-plant only.

On the Northern High Plains, cropping patterns were insensitive to electricity price changes under 1985 simulated crop prices. Irrigated grain sorghum dominated these solutions, with a small amount of irrigated corn. With 1974-78 average crop prices, land was left idle with electricity at $.05 per KWH. At higher electricity prices, irrigated acreage declined, but sufficient labor was released to allow dryland wheat to use all remaining acreage. Again, irrigated grain sorghum and corn dominated the solution, with a small amount of irrigated wheat in the farm plan except where electricity costs $.10 per KWH. Labor restrictions impacted heavily in this region, actually causing the shadow price of cropland to increase with higher electricity prices.

Returns to Wind Energy

The set of crop prices applied had very little effect on returns to wind. In the northern region, the annual value of a wind system was higher for the average 1974-78 crop prices with electricity at $.05 per KWH. At higher electricity prices, value of wind was higher for 1985 simulated crop prices. No such pattern existed in the south. Any differences in annual returns to wind with respect to crop prices were negligible, less than $100 in most cases.

As expected, returns to wind were higher at higher electricity prices, but by slightly smaller proportions than the increases in electricity price. The addition of a wind system significantly abates the adverse effects of increasing electricity prices. In farm situations where a given wind system is operated on the smaller of the two applicable land units, total returns (returns to wind plus benchmark returns) actually increased with increases in electricity price. On the larger land units, returns did decrease as electricity price was increased, but by a much smaller percentage, where wind power was available, than the decrease in benchmark returns.

Estimated break-even investment was higher for the Southern High Plains, where cotton was available as a crop option. With electricity at $.05 per KWH, 1985 simulated crop prices and returns discounted at three percent, break-even investment for the 60 KW machine ranged up to $42,409.88 ($706.83 per KW) in the south compared with $41,707.43 ($695.12 per KW) in the north. The 40 KW machine was analyzed only in the southern region. At the same prices and discount rate cited above, maximum break-even investment for the 40 KW system was $28,252.40 ($706.31 per KW).

On the 100 acre land unit, where both machines were analyzed in the south, the 40 KW machine (farm situation 2) was found to be the better investment on a per KW basis. Each machine had higher value on the larger of the two land units tested, farm situation 2 for the 40 KW machine and situation 4 for the 60 KW system.

Effect of Load Management

The inclusion of wind power expectations in the planning process had little effect on irrigation scheduling, with cropping pattern changes occurring in only four of the 36 situations analyzed. In two of these cases, irrigations were shifted to higher wind speed periods, but this resulted in only a small increase in returns to wind. More significant increases occurred where wind power eased the impact of increasing electricity price, allowing the farm to maintain the irrigation levels estimated without wind power, but which had been decreased due to the price increase.

Temporal Analysis

Only farm situations 2 and 4 were analyzed temporally, as the static analysis results showed each to be the more efficient application of the given size of machine. To reflect the future situation, 1985 simulated crop prices were used.

Cropping Patterns

Wind power had no effect on the optimal farm plan when the price of electricity was held constant through time. Cotton again dominated southern solutions, with a small amount of irrigated grain sorghum planted on the 100 acre unit in the last two years of the analysis. Initial acreage on the Northern High Plains was planted almost entirely to irrigated grain sorghum, with acreage of irrigated wheat and corn increasing through time.

On the Southern High Plains, with electricity price increasing through time, the optimal farm plan remained the same as with constant price for farm situation 4, and changed only minutely in situation 2. In the north, wind power had a significant effect on cropping patterns through time. Acreage reverted to dryland with and without wind power; however, more irrigated acreage was maintained when wind power was available.

Returns to Wind Energy

In contrast to the static results, the estimated break-even investment was higher on the Northern High Plains where electricity price was held constant, with values on the 60 KW power system as high as $41,772.44 with the three percent discount rate (compared to $41,290.73 in the south). This is due largely to the more adverse effect of the declining water level in the north. For the 40 KW machine (analyzed only on the Southern High Plains), break-even investment on a per KW basis was higher than for the 60 KW machine in either region.

When electricity price increased annually, break-even investment showed significant increases, as was expected. The increases were as much as 80 percent on the Southern High Plains and up to 75 percent in the north. For the 60 KW system, the results were again reversed, with higher investment values in the south. Even with wind power, the increasing electricity price forced land out of irrigation in the north, thus reducing the potential for electricity substitution.

Conclusions

With the wind energy industry still in largely a developmental stage, estimates of the initial cost of a wind system can vary considerably. This makes it difficult to draw firm conclusions on the profitability of investment, at least in the short term. As more firms begin mass production of wind systems, prices should decrease and stabilize. Available estimates of the industry's mature cost range around $500 per KW. Estimated break-even investment rates for wind-assisted irrigation were greater than $500 per KW in all cases except where electricity was purchased for $.05 per KWH and returns discounted at ten percent. The possibility of tax credits for the purchase of a wind system was not explicitly considered. However, for the farm business in a position to take full advantage of the credits, the effective break-even investment rate could be increased by as much as one-third.

Limitations

This study uses the typical farm approach, thus, the results will likely not apply directly to any specific farm due to the "average" nature of the data. This should be noted particularly in view of the Northern High Plains results, where the assumed labor restrictions had a large effect on the optimal farm plan chosen. A producer able to hire additional summer labor could have a significantly different result. In addition, the producer was assumed to be a strict profit maximizer. Personal preferences or consideration of risk could cause changes in an individual's cropping pattern.

The consideration of non-optimal irrigation timing gives the model additional flexibility that more accurately represents the decision making process of the irrigated producer. However, the yield reductions estimated for this study were based on limited data. Further research is needed regarding the effects of irrigation timing.

The monthly wind power expectations used in the LP model were, in total, slightly less than the averages of output from the simulation model. Thus, the temporal results should be regarded as conservative. These same expectations, as a factor in the planning process, were estimated to have little effect on cropping patterns, contrary to what was expected. The use of wind speed distributions based on averages for each ten-day period could improve the model; however, these data would be difficult to obtain.

The price at which the utility will buy back surplus electricity was assumed to be a constant percentage of the purchase price. In actual practice, this price may vary greatly. Peak load pricing structures, where the price of electricity varies according to the time of use, were not considered. This type of pricing might apply not only to electricity purchases but also to sales, where the utility might pay a premium price for electricity generated at times of peak demand.

The study assumed that normal wind system down time (when the machine does not operate due to insufficient wind speed) could be used for all necessary repairs and maintenance. Major breakdowns could render the system inoperative for long periods of time; however, data regarding the frequency or duration of such breakdowns were unavailable. The cost of normal repairs and maintenance has not been established on a long-term basis. Available estimates varied considerably and were all based on a percentage of the initial investment rather than on operating time or other performance parameters. This type of data should become more readily available as the industry matures.

Break-even investment was estimated over a period of 20 years assuming constant levels of technology, crop prices and input costs (except where specified differently). The future values are, of course, unknown. Significant changes in any of these factors could have a great impact on the value of wind energy.

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APPENDIX A

THE LINEAR PROGRAMMING MATRIX FOR A 100 ACRE SOUTHERN HIGH PLAINS FARM WITH A 40 KILOWATT WIND SYSTEM

Definitions of Linear Programming Activities and Restraints

Columns (Activities or Enterprises)

Dryland crop production:

Cols. 1-4	DRYL
Cols 5-8	COTN = cotton GRSO = grain sorghum WHET = wheat

Irrigated crop production:

Cols. 1-4	CORN = corn COTN = cotton GRSO = grain sorghum WHET = wheat
Col. 5	number of post-plant irrigations
Col. 6	A or B = two activities have the same yield, 0 otherwise
Col. 7	relative rank in yield among all activities of the given crop and the given number of post-plant irrigations
Col. 8	F

Pre-plant irrigations:

Cols. 1-2	PP
Cols. 3-6	crop code (see above)
Col. 7	month
Col. 8	first, second or third 10-day critical water period in a month

Wind power, electricity and water:

Cols. 1-6 SLKWAT = slack water
FRELEC = wind-generated electricity
BYELEC = electricity purchase
SLELEC = electricity sale
IRELEC = irrigation fuel

Col. 7 month

Col. 8 critical water period

The model printout shows this complete structure for one critical water period.

Other electricity sales:

Cols. 1-7 SLELECO = sale of electricity during time for well repairs and maintenance

Col. 8 cash flow period

Seed purchases:

Cols. 1-4 crop code

Cols. 5-8 SEED

Other input purchases:

Cols. 1-8 INSECT_ = insecticide in cash flow period (Col. 7)
HERB_ = herbicide in cash flow period (Col. 5)
FERTAPP_ = custom application of fertilizer in cash flow period (Col. 8)

NITROGEN_ = nitrogen in cash flow period (Col. 8)

PHOS_ = phosphorous in cash flow period (Col. 5)

DIESELP_ = diesel in cash flow period (Col. 8)

GASOLNP_ = gasoline in cash flow period (Col. 8)

Custom harvest, hauling and drying:

Cols. 1-8 CORNCOMB = combining corn

GRSOCOMD = combining dryland grain sorghum

GRSOCOMI = combining irrigated grain sorghum

WHTCOMBD = combining dryland wheat

WHTCOMBI = combining irrigated wheat

COTNSAHL = stripping and hauling cotton

COTNGING = ginning cotton

CORNHAUL = hauling corn

GRSOHAUL = hauling grain sorghum

WHETHAUL = hauling wheat

CORNDRYG = drying corn

Cash flow:

Cols. 1-7 BORROWP = borrowing

INVSTRP = accumulating surplus cash

Col. 8 cash flow period

Crop sales:

Cols. 1-4 SELL

Cols. 5-8 CORN = corn

COTN = cotton lint

CTSD = cotton seed

GRSO = grain sorghum

WHET = wheat

GRAZ = wheat grazing

Other activities:

Cols. 1-8 OBJCOL = cash transfer column

IRRGVC1 = per acre-foot cost of engine lubrication, attendance labor and distribution system repairs

IRRGVC2 = per horsepower cost of engine repairs

Right hand side:

Cols. 1-3 RS1

Rows (Restraints)

Objective function:

Cols. 1-4 OBJ1

Accounting rows:

Cols. 1-8 TOTWATER = total water pumped

ELIRRG__ = irrigation fuel required in month (Cols. 7-8)

ELBUYS__ = electricity purchased in month (Cols. 7-8)

ELSOLD = total electricity sales

WATER__ = water pumped in month (Col. 6) and critical water period (Col. 7)

Land and labor restraints:

Cols. 1-8 LAND = cropland restraint

RMAXLAB = labor restraint in cash flow period (Col. 8)

Pre-plant irrigation transfers:

Cols. 1-4 PREP

Cols. 5-8 crop code (see above)

Wind power, electricity and water:

Cols. 1-6 FWATER = water restraint

IRFUEL = irrigation fuel transfer

UELECT = wind-generated electricity transfer

SELECT = requires sale of electricity in proportion to unused pumping capacity

Col. 7 month

Col. 8 critical water period

Seed requirements:

Col. 1 R

Cols. 2-5 crop code

Cols. 6-8 SED

Other input requirements:

Cols. 1-8 RINSECT__ = insecticide in cash flow period (Col. 8)

RHERB__ = herbicide in cash flow period (Col. 6)

RFERTAP__ = fertilizer application in cash flow period (Col. 8)

RNITROG__ = nitrogen in cash flow period (Col. 8)

RPHOS__ = phosphorous in cash flow period (Col. 6)

RDIESEL__ = diesel in cash flow period (Col. 8)

RGASOLN__ = gasoline in cash flow period (Col. 8)

Harvesting, hauling and drying requirements:

Cols. 1-8 RCCCORNN = combining corn

RCCGRSOD = combining dryland grain sorghum

RCCGRSOI = combining irrigated grain sorghum

RCCWHETD = combining dryland wheat

RCCWHETI = combining irrigated wheat

RCSHCOTN = stripping and hauling cotton

RGINCOTN = ginning cotton

RHAULCRN = hauling corn

RHAULGRS = hauling grain sorghum

RHAULWHT = hauling wheat

RDRYCORN = drying corn

Cash flow:

Cols. 1-7 RCASHFL = total cash flow

ACCTGCF = cash flow exclusive of carryovers, electricity and capital costs.

Col. 8 cash flow period

Yield transfers:

Cols. 1-5 RSELL

Cols. 6-8 CRN = corn

COT = cotton lint

CTS = cotton seed

GRS = grain sorghum

WHT = wheat

GRZ = wheat grazing

Other transfers:

Cols. 1-8 IRRIGVC1 = per acre-foot irrigation variable cost (non-fuel)

IRRIGVC2 = per engine horsepower irrigation variable cost (non-fuel)

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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                              PAGE    13  -  81/145

              DRYLCOTN      DRYLGRSO      DRYLWHET      CORN201F      CORN2A2F      CORN2B2F      CORN2A4F      CCRN2B4F       1....1
BOUND         LOWER         LOWER         1.OWER        LOWER         LOWER         LOWER         LOWER         LOWER          BOUND

TOTWATER        .             .             .           1.25000       1.25000       1.25000       1.25000       1.25000      TOTWATER
WATER71         .             .             .            .33300        .             .             .             .           WATER71
WATER72         .             .             .            .             .33300        .33300        .33300        .           WATER72
WATER73         .             .             .            .33300        .33300        .             .             .           WATER73
WATER81         .             .             .            .             .             .             .33300        .33300      WATER81
WATER83         .             .             .            .             .             .33300        .             .33300      WATER83
LAND          1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000      LAND
PREPCORN        .             .             .           1.00000       1.00000       1.00000       1.00000       1.00000      PREPCORN
FWATER71        .             .             .            .33300        .             .             .             .           FWATER71
IRFUEL71        .             .             .            .33300        .             .             .             .           IRFUEL71
FWATER72        .             .             .            .             .33300        .33300        .33300        .           FWATER72
IRFUEL72        .             .             .            .             .33300        .33300        .33300        .           IRFUEL72
FWATER73        .             .             .            .33300        .33300        .             .             .           FWATER73
IRFUEL73        .             .             .            .33300        .33300        .             .             .           IRFUEL73
FWATER81        .             .             .            .             .             .             .33300        .33300      FWATER81
IRFUEL81        .             .             .            .             .             .             .33300        .33300      IRFUEL81
FWATER83        .             .             .            .             .             .33300        .             .33300      FWATER83
IRFUEL83        .             .             .            .             .             .33300        .             .33300      IRFUEL83
RMAXLAB1       .43000        .56000        .25000       1.03000       1.03000       1.03000       1.03000       1.03000      RMAXLAB1
RMAXLAB2       .45000        .65000        .25000       1.47000       1.47000       1.47000       1.47000       1.47000      RMAXLAB2
RMAXLAB3       .90000        .86000        .13000        .44000        .44000        .44000        .44000        .44000      RMAXLAB3
RMAXLAB4       .12000        .12000        .51000       1.04000       1.04000       1.04000       1.04000       1.04000      RMAXLAB4
RMAXLAB5       .12000        .12000        .75000        .24000        .24000        .24000        .24000        .24000      RMAXLAB5
RMAXLAB6       .90000         .            .25000        .82000        .82000        .82000        .82000        .82000      RMAXLAB6
RCORNSED        .             .             .          11.50000      11.50000      11.50000      11.50000      11.50000      RCORNSED
RCOTNSED     15.00000         .             .            .             .             .             .             .           RCOTNSED
RGRSOSED        .           3.75000         .            .             .             .             .             .           RGRSOSED
RWHETSED        .             .            .80000        .             .             .             .             .           RWHETSED
RINSECT2        .             .             .          15.00000      15.00000      15.00000      15.00000      15.00000      RINSECT2
RHERB2        6.00000         .             .           9.00000       9.00000       9.00000       9.00000       9.00000      RHERB2
RFERTAP2      1.00000       1.00000         .           1.00000       1.00000       1.00000       1.00000       1.00000      RFERTAP2
RFERTAP4        .             .           1.00000        .             .             .             .             .           RFERTAP4
RNITROG2     2C.C00CC      20.00000         .          83.00000      77.00000      77.00000      73.00000      73.00000      RNITROG2
RNITROG4        .             .          20.00000        .             .             .             .             .           RNITROG4
RPHOS2       20.00000      20.00000         .          50.00000      46.00000      46.00000      44.00000      44.00000      RPHOS2
RDIESEL1      1.14000       2.79000         .           4.46000       4.46000       4.46000       4.46000       4.46000      RDIESEL1
RDIESEL2      1.04000       2.45000         .           5.03000       5.03000       5.03000       5.03000       5.03000      RDIESEL2
RDIESEL3      2.07000       1.83000         .            .97000        .97000        .97000        .97000        .97000      RDIESEL3
RDIESEL4        .             .           1.32000        .             .             .             .             .           RDIESEL4
RDIESEL5        .             .           2.48000        .             .             .             .             .           RDIESEL5
RDIESEL6      2.53000         .             .           3.47000       3.47000       3.47000       3.47000       3.47000      RDIESEL6
RGASOLN1       .50000         .            .50000        .50000        .50000        .50000        .50000        .50000      RGASOLN1
RGASOLN2       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000      RGASOLN2
RGASOLN3       .84000        .84000        .25000        .50000        .50000        .50000        .50000        .50000      RGASOLN3
RGASOLN4       .25000        .25000        .50000        .50000        .50000        .50000        .50000        .50000      RGASOLN4
RGASOLN5       .25000        .25000        .50000        .50000        .50000        .50000        .50000        .50000      RGASOLN5
RGASCLN6       .25000         .            .50000        .25000        .25000        .25000        .25000        .25000      RGASOLN6
RCCCORNN        .             .             .          83.10000      76.80000      76.80000      73.00000      73.00000      RCCCORNN
RCCGRSOD        .           1.00000         .            .             .             .             .             .           RCCGRSOD
RCCWHETD        .             .           1.00000        .             .             .             .             .           RCCWHETD
RCSHCOTN      9.50000         .             .            .             .             .             .             .           RCSHCOTN
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..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                          PAGE    13  -  81/145

              DRYLCOIN      DRYLGRSO      DRYLWHET      CORN201F      CORN2A2F      CORN2B2F      CORN2A4F      CCRN2B4F        1....1
BOUND         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

TOTWATER          .             .             .            1.25000       1.25000       1.25000       1.25000       1.25000    TOTWATER
WATER71           .             .             .             .33300        .             .             .             .         WATER71
WATER72           .             .             .             .             .33300        .33300        .33300        .         WATER72
WATER73           .             .             .             .33300        .33300        .             .             .         WATER73
WATER81           .             .             .             .             .             .             .33300        .33300    WATER81
WATER83           .             .             .             .             .             .33300        .             .33300    WATER83
LAND             1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000    LAND
PREPCORN          .             .             .            1.00000       1.00000       1.00000       1.00000       1.00000    PREPCORN
FWATER71          .             .             .             .33300        .             .             .             .         FWATER71
IRFUEL71          .             .             .             .33300        .             .             .             .         IRFUEL71
FWATER72          .             .             .             .             .33300        .33300        .33300        .         FWATER72
IRFUEL72          .             .             .             .             .33300        .33300        .33300        .         IRFUEL72
FWATER73          .             .             .             .33300        .33300        .             .             .         FWATER73
IRFUEL73          .             .             .             .33300        .33300        .             .             .         IRFUEL73
FWATER81          .             .             .             .             .             .             .33300        .33300    FWATER81
IRFUEL81          .             .             .             .             .             .             .33300        .33300    IRFUEL81
FWATER83          .             .             .             .             .             .33300        .             .33300    FWATER83
IRFUEL83          .             .             .             .             .             .33300        .             .33300    IRFUEL83
RMAXLAB1          .43000        .56000        .25000       1.03000       1.03000       1.03000       1.03000       1.03000    RMAXLAB1
RMAXLAB2          .45000        .65000        .25000       1.47000       1.47000       1.47000       1.47000       1.47000    RMAXLAB2
RMAXLAB3          .90000        .86000        .13000        .44000        .44000        .44000        .44000        .44000    RMAXLAB3
RMAXLAB4          .12000        .12000        .51000       1.04000       1.04000       1.04000       1.04000       1.04000    RMAXLAB4
RMAXLAB5          .12000        .12000        .75000        .24000        .24000        .24000        .24000        .24000    RMAXLAB5
RMAXLAB6          .90000        .             .25000        .82000        .82000        .82000        .82000        .82000    RMAXLAB6
RCORNSED          .             .             .           11.50000      11.50000      11.50000      11.50000      11.50000    RCORNSED
RCOTNSED        15.00000        .             .             .             .             .             .             .         RCOTNSED
RGRSOSED          .            3.75000        .             .             .             .             .             .         RGRSOSED
RWHETSED          .             .             .80000        .             .             .             .             .         RWHETSED
RINSECT2          .             .             .           15.00000      15.00000      15.00000      15.00000      15.00000    RINSECT2
RHERB2           6.00000        .             .            9.00000       9.00000       9.00000       9.00000       9.00000    RHERB2
RFERTAP2         1.00000       1.00000        .            1.00000       1.00000       1.00000       1.00000       1.00000    RFERTAP2
RFERTAP4          .             .            1.00000        .             .             .             .             .         RFERTAP4
RNITROG2        2C.C00CC      20.00000        .           83.00000      77.00000      77.00000      73.00000      73.00000    RNITROG2
RNITROG4          .             .           20.00000        .             .             .             .             .         RNITROG4
RPHOS2          20.00000      20.00000        .           80.00000      46.00000      46.00000      44.00000      44.00000    RPHOS2
RDIESEL1         1.14000       2.79000        .            4.46000       4.46000       4.46000       4.46000       4.46000    RDIESEL1
RDIESEL2         1.04000       2.45000        .            5.03000       5.03000       5.03000       5.03000       5.03000    RDIESEL2
RDIESEL3         2.07000       1.83000        .             .97000        .97000        .97000        .97000        .97000    RDIESEL3
RDIESEL4          .             .            1.32000        .             .             .             .             .         RDIESEL4
RDIESEL5          .             .            2.48000        .             .             .             .             .         RDIESEL5
RDIESEL6         2.53000        .             .            3.47000       3.47000       3.47000       3.47000       3.47000    RDIESEL6
RGASOLN1          .50000        .             .50000        .50000        .50000        .50000        .50000        .50000    RGASOLN1
RGASOLN2          .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000    RGASOLN2
RGASOLN3          .84000        .84000        .25000        .50000        .50000        .50000        .50000        .50000    RGASOLN3
RGASOLN4          .25000        .25000        .50000        .50000        .50000        .50000        .50000        .50000    RGASOLN4
RGASOLN5          .25000        .25000        .50000        .50000        .50000        .50000        .50000        .50000    RGASOLN5
RGASCLN6          .25000        .             .50000        .25000        .25000        .25000        .25000        .25000    RGASOLN6
RCCCORNN          .             .             .           83.10000      76.80000      76.80000      73.00000      73.00000    RCCCORNN
RCCGRSOD          .            1.00000        .             .             .             .             .             .         RCCGRSOD
RCCWHETD          .             .            1.00000        .             .             .             .             .         RCCWHETD
RCSHCOTN         9.50000        .             .             .             .             .             .             .         RCSHCOTN
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                  PAGE    14  -  81/145

            DRYLCOTN     DRYLGRSO     DRYLWHET     CORN201F     CORN2A2F     CORN2B2F     CORN2A4F     CORN2B4F     1....2
BOUND       LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        BOUND

RGINCOTN      9.50000        .            .            .            .            .            .            .        RGINCOTN
RHAULCRN       .             .            .        83.10000     76.80000     76.80000     73.00000     73.00000     RHAULCRN
RHAULGRS       .         15.00000         .            .            .            .            .            .        RHAULGRS
RHAULWHT       .             .        15.00000         .            .            .            .            .        RHAULWHT
RDRYCORN       .             .            .        83.10000     76.80000     76.80000     73.00000     73.00000     RDRYCORN
RCASHFL1      3.10000      3.92000      1.53000    12.00000     12.00000     12.00000     12.00000     12.00000     RCASHFL1
RCASHFL2      3.10000      5.02000      1.52000     9.82000      9.82000      9.82000      9.82000      9.82000     RCASHFL2
RCASHFL3      6.22000      5.94000       .79000     3.03000      3.03000      3.03000      3.03000      3.03000     RCASHFL3
RCASHFL4      7.73000       .73000      3.51000     5.48000      5.48000      5.48000      5.48000      5.48000     RCASHFL4
RCASHFL5       .74000       .74000      5.33000     1.47000      1.47000      1.47000      1.47000      1.47000     RCASHFL5
RCASHFL6      6.12000        .          1.52000     5.99000      5.99000      5.99000      5.99000      5.99000     RCASHFL6
ACCTGCF1      3.10000      3.92000      1.53000    12.00000     12.00000     12.00000     12.00000     12.00000     ACCTGCF1
ACCTGCF2      3.10000      5.02000      1.52000     9.82000      9.82000      9.82000      9.82000      9.82000     ACCTGCF2
ACCTGCF3      6.22000      5.94000       .79000     3.03000      3.03000      3.03000      3.03000      3.03000     ACCTGCF3
ACCTGCF4      7.73000       .73000      3.51000     5.48000      5.48000      5.48000      5.48000      5.48000     ACCTGCF4
ACCTGCF5       .74000       .74000      5.33000     1.47000      1.47000      1.47000      1.47000      1.47000     ACCTGCF5
ACCTGCF6      6.12000        .          1.52000     5.99000      5.99000      5.99000      5.99000      5.99000     ACCTGCF6
RSELLCRN       .             .            .        83.10000-    76.80000-    76.80000-    73.00000-    73.00000-    RSELLCRN
RSELLCOT    200.00000-       .            .            .            .            .            .            .        RSELLCOT
RSELLCTS       .16700-       .            .            .            .            .            .            .        RSELLCTS
RSELLGRS       .         15.00000-        .            .            .            .            .            .        RSELLGRS
RSELLWHT       .             .        15.00000-        .            .            .            .            .        RSELLWHT
RSELLGRZ       .             .        11.25000-        .            .            .            .            .        RSELLGRZ
IRRIGVC1       .             .            .         1.25000      1.25000      1.25000      1.25000      1.25000     IRRIGVC1
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..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                          PAGE    15  -  81/145

            CORN301F      CORN302F      CORN303F      CORN304F      CORN305F      CORN306F      CORN307F      CORN308F        2....1
BOUND       LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

TOTWATER      1.58300       1.58300       1.58300       1.58300       1.58300       1.58300       1.58300       1.58300     TOTWATER
WATER71        .             .             .             .33300        .33300       .             .             .33300     WATER71
WATER72        .33300        .33300        .33300       .             .33300       .             .33300        .33300     WATER72
WATER73        .33300        .33300       .             .             .             .33300        .33300       .           WATER73
WATER81        .33300       .             .33300        .33300        .33300        .33300       .             .           WATER81
WATER83        .             .33300        .33300        .33300       .             .33300       .             .33300     WATER83
WATER91        .             .             .             .             .             .             .33300       .           WATER91
LAND          1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     LAND
PREPCORN      1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     PREPCORN
FWATER71       .             .             .             .33300        .33300       .             .             .33300     FWATER71
IRFUEL71       .             .             .             .33300        .33300       .             .             .33300     IRFUEL71
FWATER72       .33300        .33300        .33300       .             .33300       .             .33300        .33300     FWATER72
IRFUEL72       .33300        .33300        .33300       .             .33300       .             .33300        .33300     IRFUEL72
FWATER73       .33300        .33300       .             .             .             .33300        .33300       .           FWATER73
IRFUEL73       .33300        .33300       .             .             .             .33300        .33300       .           IRFUEL73
FWATER81       .33300       .             .32300        .33300        .33300        .33300       .             .           FWATER81
IRFUEL81       .33300       .             .33300        .33300        .33300        .33300       .             .           IRFUEL81
FWATER83       .             .33300        .33300        .33300       .             .33300       .             .33300     FWATER83
IRFUEL83       .             .33300        .33300        .33300       .             .33300       .             .33300     IRFUEL83
FWATER91       .             .             .             .             .             .             .33300       .           FWATER91
IRFUEL91       .             .             .             .             .             .             .33300       .           IRFUEL91
RMAXLAB1      1.03000       1.03000       1.03000       1.03000       1.03000       1.03000       1.03000       1.03000     RMAXLAB1
RMAXLAB2      1.47000       1.47000       1.47000       1.47000       1.47000       1.47000       1.47000       1.47000     RMAXLAB2
RMAXLAB3       .44000        .44000        .44000        .44000        .44000        .44000        .44000        .44000     RMAXLAB3
RMAXLAB4      1.44000       1.44000       1.44000       1.44000       1.44000       1.44000       1.04000       1.44000     RMAXLAB4
RMAXLAB5       .24000        .24000        .24000        .24000        .24000        .24000        .64000        .24000     RMAXLAB5
RMAXLAB6       .82000        .82000        .82000        .82000        .82000        .82000        .82000        .82000     RMAXLAB6
RCORNSED     12.40000      12.40000      12.40000      12.40000      12.40000      12.40000      12.40000      12.40000     RCORNSED
RINSECT2     15.00000      15.00000      15.00000      15.00000      15.00000      15.00000      15.00000      15.00000     RINSECT2
RHERB2        9.00000       9.00000       9.00000       9.00000       9.00000       9.00000       9.00000       5.00000     RHERB2
RFERTAP2      1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     RFERTAP2
RNITROG2    113.00000     106.00000     102.00000      99.00000      91.00000      91.00000      89.00000      89.00000     RNITROG2
RPHOS2       60.00000      60.00000      60.00000      59.00000      55.00000      55.00000      53.00000      53.00000     RPHOS2
RDIESEL1      4.46000       4.46000       4.46000       4.46000       4.46000       4.46000       4.46000       4.46000     RDIESEL1
RDIESEL2      5.03000       5.03000       5.03000       5.03000       5.03000       5.03000       5.03000       5.03000     RDIESEL2
RDIESEL3       .97000        .97000        .97000        .97000        .97000        .97000        .97000        .97000     RDIESEL3
RDIESEL6      3.47000       3.47000       3.47000       3.47000       3.47000       3.47000       3.47000       3.47000     RDIESEL6
RGASOLN1       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN1
RGASOLN2       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN2
RGASOLN3       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN3
RGASOLN4       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN4
RGASOLN5       .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN5
RGASOLN6       .25000        .25000        .25000        .25000        .25000        .25000        .25000        .25000     RGASOLN6
RCCCCRNN    115.80000     107.00000     101.70000      98.80000      91.20000      90.60000      89.40000      88.80000     RCCCORNN
RHAULCRN    115.80000     107.00000     101.70000      98.80000      91.20000      90.60000      89.40000      88.80000     RHAULCRN
RDRYCORN    115.80000     107.00000     101.70000      98.80000      91.20000      90.60000      89.40000      88.80000     RDRYCORN
RCASHFL1     12.00000      12.00000      12.00000      12.00000      12.00000      12.00000      12.00000      12.00000     RCASHFL1
RCASHFL2      9.82000       9.82000       9.82000       9.82000       9.82000       9.82000       9.82000       9.82000     RCASHFL2
RCASHFL3      3.03000       3.03000       3.03000       3.03000       3.03000       3.03000       3.03000       3.03000     RCASHFL3
RCASHFL4      7.48000       7.48000       7.48000       7.48000       7.48000       7.48000       5.48000       7.48000     RCASHFL4
RCASHFL5      1.47000       1.47000       1.47000       1.47000       1.47000       1.47000       3.47000       1.47000     RCASHFL5
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                              PAGE    16  -  81/145

          CORN301F    CORN302F    CORN303F    CORN304F    CORN305F    CORN306F    CORN307F    CORN308F       2....2
BOUND     LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LCWER        BOUND

RCASHFL6     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000   RCASHFL6
ACCTGCF1    12.00000    12.00000    12.00000    12.00000    12.00000    12.00000    12.00000    12.00000   ACCTGCF1
ACCTGCF2     9.82000     9.82000     9.82000     9.82000     9.82000     9.82000     9.82000     9.82000   ACCTGCF2
ACCTGCF3     3.03000     3.03000     3.03000     3.03000     3.03000     3.03000     3.03000     3.03000   ACCTGCF3
ACCTGCF4     7.48000     7.48000     7.48000     7.48000     7.48000     7.48000     5.48000     7.48000   ACCTGCF4
ACCTGCF5     1.47000     1.47000     1.47000     1.47000     1.47000     1.47000     3.47000     1.47000   ACCTGCF5
ACCTGCF6     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000     5.99000   ACCTGCF6
RSELLCRN   115.80000-  107.00000-  101.70000-   98.80000-   91.20000-   90.60000-   89.40000-   88.80000-  RSELLCRN
IRRIGVC1     1.58300     1.58300     1.58300     1.58300     1.58300     1.58300     1.58300     1.58300   IRRIGVC1
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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                          PAGE    17  -  81/145

               CORN401F     CORN402F     COFN403F     CORN501F     CORN502F     CORN503F     CORN504F     CORN601F        3....1
BOUND          LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LCWER         BOUND

TOTWATER        1.91700      1.91700      1.91700      2.25000      2.25000      2.25000      2.25000      2.58300     TOTWATER
WATER71         .            .             .33300       .33300       .33300       .33300      .             .33300     WATER71
WATER72          .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     WATER72
WATER73          .33300       .33300       .33300       .33300      .             .33300       .33300       .33300     WATER73
WATER81          .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     WATER81
WATER83         .             .33300      .             .33300       .33300      .             .33300       .33300     WATER83
WATER91          .33300      .            .            .             .33300       .33300       .33300       .33300     WATER91
LAND            1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     LAND
PREPCORN        1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     PREPCORN
FWATER71        .            .             .33300       .33300       .33300       .33300      .             .33300     FWATER71
IRFUEL71        .            .             .33300       .33300       .33300       .33300      .             .33300     IRFUEL71
FWATER72         .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     FWATER72
IRFUEL72         .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     IRFUEL72
FWATER73         .33300       .33300       .33300       .33300      .             .33300       .33300       .33300     FWATER73
IRFUEL73         .33300       .33300       .33300       .33300      .             .33300       .33300       .33300     IRFUEL73
FWATER81         .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     FWATER81
IRFUEL81         .33300       .33300       .33300       .33300       .33300       .33300       .33300       .33300     IRFUEL81
FWATER83        .             .33300      .             .33300       .33300      .             .33300       .33300     FWATER83
IRFUEL83        .             .33300      .             .33300       .33300      .             .33300       .33300     IRFUEL83
FWATER91         .33300      .            .            .             .33300       .33300       .33300       .33300     FWATER91
IRFUEL91         .33300      .            .            .             .33300       .33300       .33300       .33300     IRFUEL91
RMAXLAB1        1.03000      1.03000      1.03000      1.03000      1.03000      1.03000      1.03000      1.03000     RMAXLAB1
RMAXLAB2        1.47000      1.47000      1.47000      1.47000      1.47000      1.47000      1.47000      1.47000     RMAXLAB2
RMAXLAB3         .44000       .44000       .44000       .44000       .44000       .44000       .44000       .44000     RMAXLAB3
RMAXLAB4        1.44000      1.84000      1.84000      2.24000      1.84000      1.84000      1.84000      2.24000     RMAXLAB4
RMAXLAB5         .64000       .24000       .24000       .24000       .64000       .64000       .64000       .64000     RMAXLAB5
RMAXLAB6         .82000       .82000       .82000       .82000       .82000       .82000       .82000       .82000     RMAXLAB6
RCORNSED       13.30000     13.30000     13.30000     15.70000     15.70000     15.70000     15.70000     17.20000     RCORNSED
RINSECT2       15.00000     15.00000     15.00000     15.00000     15.00000     15.00000     15.00000     15.00000     RINSECT2
RHERB2          9.00000      9.00000      9.00000      9.00000      9.00000      9.00000      9.00000      9.00000     RHERB2
RFERTAP2        1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     RFERTAP2
RNITROG2      121.00000    118.00000    116.00000    137.00000    130.00000    129.00000    126.00000    138.00000     RNITROG2
RPHOS2         60.00000     60.00000     60.00000     60.00000     60.00000     60.00000     60.00000     60.00000     RPHOS2
RDIESEL1        4.46000      4.46000      4.46000      4.46000      4.46000      4.46000      4.46000      4.46000     RDIESEL1
RDIESEL2        5.03000      5.03000      5.03000      5.03000      5.03000      5.03000      5.03000      5.03000     RDIESEL2
RDIESEL3         .97000       .97000       .97000       .97000       .97000       .97000       .97000       .97000     RDIESEL3
RDIESEL6        3.47000      3.47000      3.47000      3.47000      3.47000      3.47000      3.47000      3.47000     RDIESEL6
RGASOLN1         .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000     RGASOLN1
RGASOLN2         .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000     RGASOLN2
RGASOLN3         .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000     RGASOLN3
RGASOLN4         .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000     RGASOLN4
RGASOLN5         .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000     RGASOLN5
RGASOLN6         .25000       .25000       .25000       .25000       .25000       .25000       .25000       .25000     RGASOLN6
RCCCORNN      125.90000    122.10000    119.60000    146.40000    137.20000    136.00000    131.80000    147.70000     RCCCORNN
RHAULCRN      125.90000    122.10000    119.60000    146.40000    137.20000    136.00000    131.80000    147.70000     RHAULCRN
RDRYCORN      125.90000    122.10000    119.60000    146.40000    137.20000    136.00000    131.80000    147.70000     RDRYCORN
RCASHFL1       12.00000     12.00000     12.00000     12.00000     12.00000     12.00000     12.00000     12.00000     RCASHFL1
RCASHFL2        9.82000      9.82000      9.82000      9.82000      9.82000      9.82000      9.82000      9.82000     RCASHFL2
RCASHFL3        3.03000      3.03000      3.03000      3.03000      3.03000      3.03000      3.03000      3.03000     RCASHFL3
RCASHFL4        7.48000      9.48000      9.48000     11.48000      9.48000      9.48000      9.48000     11.48000     RCASHFL4
RCASHFL5        3.47000      1.47000      1.47000      1.47000      3.47000      3.47000      3.47000      3.47000     RCASHFL5
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                        PAGE    18  -  81/145

           CORN401F      CORN402F      CORN403F      CORN501F      CORN502F      CORN503F      CORN504F      CCRN601F      3....2
BOUND      LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

RCASHFL6     5.99000       5.99000       5.99000       5.99000       5.99000       5.99000       5.99000       5.99000    RCASHFL6
ACCTGCF1    12.00000      12.00000      12.00000      12.00000      12.00000      12.00000      12.00000      12.00000    ACCTGCF1
ACCTGCF2     9.82000       9.82000       9.82000       9.82000       9.82000       9.82000       9.82000       9.82000    ACCTGCF2
ACCTGCF3     3.03000       3.03000       3.03000       3.03000       3.03000       3.03000       3.03000       3.03000    ACCTGCF3
ACCTGCF4     7.48000       9.48000       9.48000      11.48000       9.48000       9.48000       9.48000      11.48000    ACCTGCF4
ACCTGCF5     3.47000       1.47000       1.47000       1.47000       3.47000       3.47000       3.47000       3.47000    ACCTGCF5
ACCTGCF6     5.99000       5.99000       5.99000       5.99000       5.99000       5.99000       5.99000       5.99000    ACCTGCF6
RSELLCRN   125.90000-    122.10000-    119.60000-    146.40000-    137.20000-    136.00000-    131.80000-    147.70000-   RSELLCRN
IRRIGVC1     1.91700       1.91700       1.91700       2.25000       2.26000       2.25000       2.25000       2.58300    IRRIGVC1
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MCD LEVEL 7                                      PAGE    19  -  81/145

              COTN001F    COTN101F    COTN102F    COTN103F    COTN201F    COTN202F    GRS0001F    GRS0101F     4....1
BOUND          LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       BOUND

TOTWATER        .58330      .91700      .91700      .91700     1.25000     1.25000      .58330      .91700  TOTWATER
WATER63         .           .           .           .33300      .           .33300      .           .       WATER63
WATER72         .           .           .33300      .           .33300      .           .           .       WATER72
WATER81         .           .33300      .           .           .33300      .33300      .           .       WATER81
WATER82         .           .           .           .           .           .           .           .33300  WATER82
LAND           1.00000     1.00000     1.00000     1.00000     1.00000     1.00000     1.00000     1.00000  LAND
PREPCOTN       1.00000     1.00000     1.00000     1.00000     1.00000     1.00000      .           .       PREPCOTN
PREPGRSO        .           .           .           .           .           .          1.00000     1.00000  PREPGRSO
FWATER63        .           .           .           .33300      .           .33300      .           .       FWATER63
IRFUEL63        .           .           .           .33300      .           .33300      .           .       IRFUEL63
FWATER72        .           .           .33300      .           .33300      .           .           .       FWATER72
IRFUEL72        .           .           .33300      .           .33300      .           .           .       IRFUEL72
FWATER81        .           .33300      .           .           .33300      .33300      .           .       FWATER81
IRFUEL81        .           .33300      .           .           .33300      .33300      .           .       IRFUEL81
FWATER82        .           .           .           .           .           .           .           .33300  FWATER82
IRFUEL82        .           .           .           .           .           .           .           .33300  IRFUEL82
RMAXLAB1        .65000      .65000      .65000      .65000      .65000      .65000      .62000      .62000  RMAXLAB1
RMAXLAB2       1.21000     1.21000     1.21000     1.21000     1.21000     1.21000      .76000      .76000  RMAXLAB2
RMAXLAB3       1.07000     1.07000     1.07000     1.47000     1.07000     1.47000      .73000      .73000  RMAXLAB3
RMAXLAB4        .12000      .52000      .52000      .12000      .92000      .52000      .51000      .91000  RMAXLAB4
RMAXLAB5        .12000      .12000      .12000      .12000      .12000      .12000      .12000      .12000  RMAXLAB5
RMAXLAB6        .67000      .67000      .67000      .67000      .67000      .67000      .55000      .55000  RMAXLAB6
RCOTNSED      20.00000    20.00000    20.00000    20.00000    20.00000    20.00000      .           .       RCOTNSED
RGRSOSED        .           .           .           .           .           .          5.60000     7.20000  RGRSOSED
RINSECT3        .           .           .           .           .           .          5.00000     5.00000  RINSECT3
RHERB2         6.00000     6.00000     6.00000     6.00000     6.00000     6.00000      .           .       RHERB2
RHERB3          .           .           .           .           .           .          6.95000     6.95000  RHERB3
RFERTAP2       1.00000     1.00000     1.00000     1.00000     1.00000     1.00000     1.00000     1.00000  RFERTAP2
RNITROG2      22.00000    28.00000    25.00000    24.00000    31.00000    31.00000    45.00000    70.00000  RNITROG2
RPHOS2        22.00000    28.00000    25.00000    24.00000    31.00000    31.00000    30.00000    40.00000  RPHOS2
RDIESEL1       2.40000     2.40000     2.40000     2.40000     2.40000     2.40000     2.27000     2.27000  RDIESEL1
RDIESEL2       1.55000     1.55000     1.55000     1.55000     1.55000     1.55000     2.53000     2.53000  RDIESEL2
RDIESEL3       2.72000     2.72000     2.72000     2.72000     2.72000     2.72000     2.97000     2.97000  RDIESEL3
RDIESEL4        .           .           .           .           .           .          1.40000     1.40000  RDIESEL4
RDIESEL6       2.26000     2.26000     2.26000     2.26000     2.26000     2.26000     2.26000     2.26000  RDIESEL6
RGASOLN1        .50000      .50000      .50000      .50000      .50000      .50000      .50000      .50000  RGASOLN1
RGASOLN2        .50000      .50000      .50000      .50000      .50000      .50000      .50000      .50000  RGASOLN2
RGASOLN3        .84000      .84000      .84000      .84000      .84000      .84000      .59000      .59000  RGASOLN3
RGASOLN4        .25000      .25000      .25000      .25000      .25000      .25000      .25000      .25000  RGASOLN4
RGASOLN5        .25000      .25000      .25000      .25000      .25000      .25000      .25000      .25000  RGASOLN5
RGASOLN6        .50000      .50000      .50000      .50000      .50000      .50000      .25000      .25000  RGASOLN6
RCCGRSO1        .           .           .           .           .           .         29.60000    45.10000  RCCGRSO1
RCSHCOTN      19.95000    24.56000    22.33000    21.42000    28.03000    27.93000      .           .       RCSHCOTN
RGINCOTN      19.95000    24.56000    22.33000    21.42000    28.03000    27.93000      .           .       RGINCOTN
RHAULGRS        .           .           .           .           .           .         29.60000    45.10000  RHAULGRS
RCASHFL1       4.99000     4.99000     4.99000     4.99000     4.99000     4.99000     8.23000     8.23000  RCASHFL1
RCASHFL2       7.16000     7.16000     7.16000     7.16000     7.16000     7.16000     5.29000     5.29000  RCASHFL2
RCASHFL3       7.79000     7.79000     7.79000     9.79000     7.79000     9.79000     5.63000     5.63000  RCASHFL3
RCASHFL4      10.36000    13.23000    13.23000    11.23000    16.10000    14.10000     3.58000     5.58000  RCASHFL4
RCASHFL5        .74000      .74000      .74000      .74000      .74000      .74000      .74000      .74000  RCASHFL5
RCASHFL6       4.77000     4.77000     4.77000     4.77000     4.77000     4.77000     4.03000     4.03000  RCASHFL6
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..MPSX-VINT7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                              PAGE     20  -  81/145

            COTN001F      COTN101F      COTN102F      COTN103F      COTN201F      COTN202F      GRS0001F      GRS0101F        4....2
BOUND       LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

ACCTGCF1      4.99000       4.99000       4.55000       4.99000       4.99000       4.99000       8.23000       8.23000     ACCTGCF1
ACCTGCF2      7.16000       7.16000       7.16000       7.16000       7.16000       7.16000       5.29000       5.29000     ACCTGCF2
ACCTGCF3      7.79000       7.79000       7.79000       9.79000       7.79000       9.79000       5.63000       5.63000     ACCTGCF3
ACCTGCF4     10.36000      13.23000      13.23000      11.23000      16.10000      14.10000       3.58000       5.58000     ACCTGCF4
ACCTGCF5       .74000        .74000        .74000        .74000        .74000        .74000        .74000        .74000     ACCTGCF5
ACCTGCF6      4.77000       4.77000       4.77000       4.77000       4.77000       4.77000       4.03000       4.03000     ACCTGCF6
RSELLCOT    420.00000-    517.00000-    470.CC000-    451.00000-    590.00000-    588.00000-        .             .         RSELLCOT
RSELLCTS       .35100-       .43200-       .39200-       .37700-       .49300-       .49100-        .             .         RSELLCTS
RSELLGRS       .             .             .             .             .             .           29.60000-     4E.10000-    RSELLGRS
IRRIGVC1       .58330        .91700        .91700        .91700       1.25000       1.25000        .58330        .91700     IRRIGVC1
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                            PAGE    21  -  81/145

                GRS0102F      GRS0103F      GRS0201F      GRS0202F      GRS0203F      GRS0204F      GRS0301F      GRS0302F        5....1
BOUND           LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

TOTWATER           .91700        .91700       1.25000       1.25000       1.25000       1.25000       1.58300       1.58300     TOTWATER
WATER71           .             .             .             .              .33300      .              .33300      .            WATER71
WATER73            .33300      .              .33300        .33300      .             .              .33300        .33300     WATER73
WATER82           .             .              .33300      .              .33300        .33300        .33300        .33300     WATER82
WATER83           .              .33300      .              .33300      .              .33300      .              .33300     WATER83
LAND              1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     LAND
PREPGRSO          1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     PREPGRSO
FWATER71          .             .             .             .              .33300      .              .33300      .            FWATER71
IRFUEL71          .             .             .             .              .33300      .              .33300      .            IRFUEL71
FWATER73           .33300      .              .33300        .33300      .             .              .33300        .33300     FWATER73
IRFUEL73           .33300      .              .33300        .33300      .             .              .33300        .33300     IRFUEL73
FWATER82          .             .              .33300      .              .33300        .33300        .33300        .33300     FWATER82
IRFUEL82          .             .              .33300      .              .33300        .33300        .33300        .33300     IRFUEL82
FWATER83          .              .33300      .              .33300      .              .33300      .              .33300     FWATER83
IRFUEL83          .              .33300      .              .33300      .              .33300      .              .33300     IRFUEL83
RMAXLAB1           .62000        .62000        .62000        .62000        .62000        .62000        .62000        .62000     RMAXLAB1
RMAXLAB2           .76000        .76000        .76000        .76000        .76000        .76000        .76000        .76000     RMAXLAB2
RMAXLAB3           .73000        .73000        .73000        .73000        .73000        .73000        .73000        .73000     RMAXLAB3
RMAXLAB4           .91000        .91000       1.31000       1.31000       1.31000       1.31000       1.71000       1.71000     RMAXLAB4
RMAXLAB5           .12000        .12000        .12000        .12000        .12000        .12000        .12000        .12000     RMAXLAB5
RMAXLAB6           .55000        .55000        .55000        .55000        .55000        .55000        .55000        .55000     RMAXLAB6
RGRSOSED          7.20000       7.20000       8.75000       8.75000       8.75000       8.75000      10.30000      10.30000     RGRSOSED
RINSECT3          5.00000       5.00000       5.00000       5.00000       5.00000       5.00000       5.00000       5.00000     RINSECT3
RHERB3            6.95000       6.95000       6.95000       6.95000       6.95000       6.95000       6.95000       6.95000     RHERB3
RFERTAP2          1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000     RFERTAP2
RNITROG2         57.00000      54.00000      88.00000      84.00000      80.00000      78.00000     106.00000     100.00000     RNITROG2
RPHOS2           38.00000      36.00000      40.00000      40.00000      40.00000      40.00000      43.00000      40.00000     RPHOS2
RDIESEL1          2.27000       2.27000       2.27000       2.27000       2.27000       2.27000       2.27000       2.27000     RDIESEL1
RDIESEL2          2.53000       2.53000       2.53000       2.53000       2.53000       2.53000       2.53000       2.53000     RDIESEL2
RDIESEL3          2.97000       2.97000       2.97000       2.97000       2.97000       2.97000       2.97000       2.97000     RDIESEL3
RDIESEL4          1.40000       1.40000       1.40000       1.40000       1.40000       1.40000       1.40000       1.40000     RDIESEL4
RDIESEL6          2.26000       2.26000       2.26000       2.26000       2.26000       2.26000       2.26000       2.26000     RDIESEL6
RGASOLN1           .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN1
RGASOLN2           .50000        .50000        .50000        .50000        .50000        .50000        .50000        .50000     RGASOLN2
RGASOLN3           .59000        .59000        .59000        .59000        .59000        .59000        .59000        .59000     RGASOLN3
RGASOLN4           .25000        .25000        .25000        .25000        .25000        .25000        .25000        .25000     RGASOLN4
RGASOLN5           .25000        .25000        .25000        .25000        .25000        .25000        .25000        .25000     RGASOLN5
RGASOLN6           .25000        .25000        .25000        .25000        .25000        .25000        .25000        .25000     RGASOLN6
RCCGRS01         38.40000      36.70000      53.70000      51.90000      50.40000      48.90000      63.00000      60.50000     RCCGRS01
RHAULGRS         38.40000      36.70000      53.70000      51.90000      50.40000      48.90000      63.00000      60.50000     RHAULGRS
RCASHFL1          8.23000       8.23000       8.23000       8.23000       8.23000       8.23000       8.23000       8.23000     RCASHFL1
RCASHFL2          5.29000       5.29000       5.29000       5.29000       5.29000       5.29000       5.29000       5.29000     RCASHFL2
RCASHFL3          5.63000       5.63000       5.63000       5.63000       5.63000       5.63000       5.63000       5.63000     RCASHFL3
RCASHFL4          5.58000       5.58000       7.58000       7.58000       7.58000       7.58000       9.58000       9.58000     RCASHFL4
RCASHFL5           .74000        .74000        .74000        .74000        .74000        .74000        .74000        .74000     RCASHFL5
RCASHFL6          4.03000       4.03000       4.03000       4.03000       4.03000       4.03000       4.03000       4.03000     RCASHFL6
ACCTGCF1          8.23000       8.23000       8.23000       8.23000       8.23000       8.23000       8.23000       8.23000     ACCTGCF1
ACCTGCF2          5.29000       5.29000       5.29000       5.29000       5.29000       5.29000       5.29000       5.29000     ACCTGCF2
ACCTGCF3          5.63000       5.63000       5.63000       5.63000       5.63000       5.63000       5.63000       5.63000     ACCTGCF3
ACCTGCF4          5.58000       5.58000       7.58000       7.58000       7.58000       7.58000       9.58000       9.58000     ACCTGCF4
ACCTGCF5           .74000        .74000        .74000        .74000        .74000        .74000        .74000        .74000     ACCTGCF5
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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                  PAGE    22  -  81/145

              GRSO102F     GRSO103F     GRSO201F     GRSO202F     GRSO203F     GRSO204F     GRSO301F     GRSO302F       5....2
BOUND         LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        BOUND

ACCTGCF6       4.03000      4.03000      4.03000      4.03000      4.03000      4.03000      4.03000      4.03000    ACCTGCF6
RSELLGRS      38.40000-    36.70000-    53.70000-    51.90000-    50.40000-    48.90000-    63.00000-    60.50000-    RSELLGRS
IRRIGVC1        .91700       .91700      1.25000      1.25000      1.25000      1.25000      1.58300      1.58300    IRRIGVC1
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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                              PAGE    23  -  81/145

              GRSO401F     WHET001F     WHET101F     WHET102F     WHET103F     WHET104F     WHET201F     WHET202F       6....1
BOUND         LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        BOUND

TOTWATER       1.91700       .58330       .91700       .91700       .91700       .91700      1.25000      1.25000    TOTWATER
WATER32         .            .            .            .            .            .33300      .            .33300     WATER32
WATER42         .            .            .            .33300       .            .            .33300      .          WATER42
WATER51         .            .            .33300       .            .            .            .33300      .33300     WATER51
WATER53         .            .            .            .            .33300       .            .            .          WATER53
WATER71         .33300       .            .            .            .            .            .            .          WATER71
WATER73         .33300       .            .            .            .            .            .            .          WATER73
WATER82         .33300       .            .            .            .            .            .            .          WATER82
WATER83         .33300       .            .            .            .            .            .            .          WATER83
LAND           1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     LAND
PREPGRSO       1.00000       .            .            .            .            .            .            .          PREPGRSO
PREPWHET        .           1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     PREPWHET
FWATER32        .            .            .            .            .            .33300      .            .33300     FWATER32
IRFUEL32        .            .            .            .            .            .33300      .            .33300     IRFUEL32
FWATER42        .            .            .            .33300       .            .            .33300      .          FWATER42
IRFUEL42        .            .            .            .33300       .            .            .33300      .          IRFUEL42
FWATER51        .            .            .33300       .            .            .            .33300      .33300     FWATER51
IRFUEL51        .            .            .33300       .            .            .            .33300      .33300     IRFUEL51
FWATER53        .            .            .            .            .33300       .            .            .          FWATER53
IRFUEL53        .            .            .            .            .33300       .            .            .          IRFUEL53
FWATER71        .33300       .            .            .            .            .            .            .          FWATER71
IRFUEL71        .33300       .            .            .            .            .            .            .          IRFUEL71
FWATER73        .33300       .            .            .            .            .            .            .          FWATER73
IRFUEL73        .33300       .            .            .            .            .            .            .          IRFUEL73
FWATER82        .33300       .            .            .            .            .            .            .          FWATER82
IRFUEL82        .33300       .            .            .            .            .            .            .          IRFUEL82
FWATER83        .33300       .            .            .            .            .            .            .          FWATER83
IRFUEL83        .33300       .            .            .            .            .            .            .          IRFUEL83
RMAXLAB1        .62000       .25000       .25000       .25000       .25000       .25000       .25000       .25000     RMAXLAB1
RMAXLAB2        .76000       .25000       .25000       .65000       .25000       .65000       .65000       .65000     RMAXLAB2
RMAXLAB3        .73000       .13000       .53000       .13000       .53000       .13000       .53000       .53000     RMAXLAB3
RMAXLAB4       2.11000      1.54000      1.54000      1.54000      1.54000      1.54000      1.54000      1.54000     RMAXLAB4
RMAXLAB5        .12000       .25000       .25000       .25000       .25000       .25000       .25000       .25000     RMAXLAB5
RMAXLAB6        .55000       .25000       .25000       .25000       .25000       .25000       .25000       .25000     RMAXLAB6
RGRSOSED      11.90000       .            .            .            .            .            .            .          RGRSOSED
RWHETSED        .           1.25000      1.25000      1.25000      1.25000      1.25000      1.50000      1.50000     RWHETSED
RINSECT3       5.00000       .            .            .            .            .            .            .          RINSECT3
RINSECT5        .           4.92000      4.92000      4.92000      4.92000      4.92000      4.92000      4.92000     RINSECT5
RHERB3         6.95000       .            .            .            .            .            .            .          RHERB3
RHERB4          .           3.50000      3.50000      3.50000      3.50000      3.50000      3.50000      3.50000     RHERB4
RFERTAP2       1.00000       .            .            .            .            .            .            .          RFERTAP2
RFERTAP4        .           1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000     RFERTAP4
RNITROG2     118.00000       .            .            .            .            .            .            .          RNITROG2
RNITROG4        .          33.00000     51.00000     48.00000     39.00000     36.00000     64.00000     64.00000     RNITROG4
RPHOS2        49.00000       .            .            .            .            .            .            .          RPHOS2
RPHOS4          .          11.00000     17.00000     16.00000     13.00000     12.00000     22.00000     22.00000     RPHOS4
RDIESEL1       2.27000       .            .            .            .            .            .            .          RDIESEL1
RDIESEL2       2.53000       .            .            .            .            .            .            .          RDIESEL2
RDIESEL3       2.97000       .            .            .            .            .            .            .          RDIESEL3
RDIESEL4       1.40000      6.44000      6.44000      6.44000      6.44000      6.44000      6.44000      6.44000     RDIESEL4
RDIESEL6       2.26000       .            .            .            .            .            .            .          RDIESEL6
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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                    PAGE    24  -  81/145

            GRS0401F     WHET001F     WHET101F     WHET102F     WHET103F     WHET104R     WHET201F     WHET202F      6....2
BOUND       LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER         BOUND

RGASOLN1      .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000    RGASOLN1
RGASOLN2      .50000       .50000       .50000       .50000       .50000       .50000       .50000       .50000    RGASOLN2
RGASOLN3      .59000       .25000       .25000       .25000       .25000       .25000       .25000       .25000    RGASOLN3
RGASOLN4      .25000       .50000       .50000       .50000       .50000       .50000       .50000       .50000    RGASOLN4
RGASOLN5      .25000       .50000       .50000       .50000       .50000       .50000       .50000       .50000    RGASOLN5
RGASOLN6      .25000       .50000       .50000       .50000       .50000       .50000       .50000       .50000    RGASOLN6
RCCGRSO1    69.00000         .            .            .            .            .            .            .       RCCGRSO1
RCCWHETD       .          1.00000      1.00000      1.00000      1.00000      1.00000      1.00000      1.00000    RCCWHETD
RCCWHETI       .          2.80000     13.20000     12.20000      5.90000      4.90000     22.00000     21.50000    RCCWHETI
RHAULGRS    69.00000         .            .            .            .            .            .            .       RHAULGRS
RHAULWHT       .         22.80000     33.20000     32.20000     25.90000     24.90000     42.00000     41.50000    RHAULWHT
RCASHFL1     8.23000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000    RCASHFL1
RCASHFL2     5.29000      1.52000      1.52000      3.52000      1.52000      3.52000      3.52000      3.52000    RCASHFL2
RCASHFL3     5.63000       .79000      2.79000       .79000      2.79000       .79000      2.79000      2.79000    RCASHFL3
RCASHFL4    11.58000     15.22000     15.22000     15.22000     15.22000     15.22000     15.22000     15.22000    RCASHFL4
RCASHFL5      .74000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000    RCASHFL5
RCASHFL6     4.03000      1.52000      1.52000      1.52000      1.52000      1.52000      1.52000      1.52000    RCASHFL6
ACCTGCF1     8.23000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000    ACCTGCF1
ACCTGCF2     5.29000      1.52000      1.52000      3.52000      1.52000      3.52000      3.52000      3.52000    ACCTGCF2
ACCTGCF3     5.63000       .79000      2.79000       .79000      2.79000       .79000      2.79000      2.79000    ACCTGCF3
ACCTGCF4    11.58000     15.22000     15.22000     15.22000     15.22000     15.22000     15.22000     15.22000    ACCTGCF4
ACCTGCF5      .74000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000      1.53000    ACCTGCF5
ACCTGCF6     4.03000      1.52000      1.52000      1.52000      1.52000      1.52000      1.52000      1.52000    ACCTGCF6
RSELLGRS    69.00000-        .            .            .            .            .            .            .       RSELLGRS
RSELLWHT       .         22.80000-    33.20000-    32.20000-    25.90000-    24.90000-    42.00000-    41.50000-   RSELLWHT
RSELLGRZ       .         14.76000-    15.44000-    18.99000-    16.16000-    15.71000-    23.40000-    23.18000-   RSELLGRZ
IRRIGVC1     1.91700       .58330       .91700       .91700       .91700       .91700      1.25000      1.25000    IRRIGVC1
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..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                         PAGE    25  -  81/145

              WHET203F      WHET2A4F      WHET2B4F      WHET301F      WHET302F      WHET401F      PPCORN22      PPCORN23         7....1
BOUND         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

TOTWATER         1.25000       1.25000       1.25000       1.58300       1.58300       1.91700        .             .        TOTWATER
WATER22           .             .             .             .             .             .          .58330        .        WATER22
WATER23           .             .             .             .             .             .             .          .58330     WATER23
WATER32           .          .33300           .             .          .33300        .33300        .             .        WATER32
WATER42           .          .33300        .33300        .33300           .          .33300        .             .        WATER42
WATER51        .33300           .             .          .33300        .33300        .33300        .             .        WATER51
WATER53        .33300           .          .33300        .33300        .33300        .33300        .             .        WATER53
LAND           1.00000       1.00000       1.00000       1.00000       1.00000       1.00000        .             .        LAND
PREPCORN          .             .             .             .             .             .         1.00000-      1.00000-   PREPCORN
PREPWHET       1.00000       1.00000       1.00000       1.00000       1.00000       1.00000        .             .        PREPWHET
FWATER22          .             .             .             .             .             .          .58330        .        FWATER22
IRFUEL22          .             .             .             .             .             .          .58330        .        IRFUEL22
FWATER23          .             .             .             .             .             .             .          .58330     FWATER23
IRFUEL23          .             .             .             .             .             .             .          .58330     IRFUEL23
FWATER32          .          .33300           .             .          .33300        .33300        .             .        FWATER32
IRFUEL32          .          .33300           .             .          .33300        .33300        .             .        IRFUEL32
FWATER42          .          .33300        .33300        .33300           .          .33300        .             .        FWATER42
IRFUEL42          .          .33300        .33300        .33300           .          .33300        .             .        IRFUEL42
FWATER51       .33300           .             .          .33300        .33300        .33300        .             .        FWATER51
IRFUEL51       .33300           .             .          .33300        .33300        .33300        .             .        IRFUEL51
FWATER53       .33300           .          .33300        .33300        .33300        .33300        .             .        FWATER53
IRFUEL53       .33300           .          .33300        .33300        .33300        .33300        .             .        IRFUEL53
RMAXLAB1       .25000        .25000        .25000        .25000        .25000        .25000        .70000        .70000     RMAXLAB1
RMAXLAB2       .25000       1.05000        .65000        .65000        .65000       1.05000        .             .        RMAXLAB2
RMAXLAB3       .93000        .13000        .53000        .93000        .93000        .93000        .             .        RMAXLAB3
RMAXLAB4      1.54000       1.54000       1.54000       1.54000       1.54000       1.54000        .             .        RMAXLAB4
RMAXLAB5       .25000        .25000        .25000        .25000        .25000        .25000        .             .        RMAXLAB5
RMAXLAB6       .25000        .25000        .25000        .25000        .25000        .25000        .             .        RMAXLAB6
RWHETSED      1.50000       1.50000       1.50000       1.50000       1.50000       1.50000        .             .        RWHETSED
RINSECTS      4.92000       4.92000       4.92000       4.92000       4.92000       4.92000        .             .        RINSECTS
RHERB4        3.50000       3.50000       3.50000       3.50000       3.50000       3.50000        .             .        RHFRB4
RFERTAP4      1.00060       1.00000       1.00000       1.00000       1.00000       1.00000        .             .        RFERTAP4
RNITROG4     57.00000      54.00000      54.00000      76.00000      72.00000      78.00000        .             .        RNITROG4
RPHOS4       19.00000      18.00000      18.00000      28.00000      26.00000      29.00000        .             .        RPHOS4
RDIESEL4      6.44000       6.44000       6.44000       6.44000       6.44000       6.44000        .             .        RDIESEL4
RGASOLN1       .50000        .50000        .50000        .50000        .50000        .50000        .             .        RGASOLN1
RGASOLN2       .50000        .50000        .50000        .50000        .50000        .50000        .             .        RGASOLN2
RGASOLN3       .25000        .25000        .25000        .25000        .25000        .25000        .             .        RGASOLN3
RGASOLN4       .50000        .50000        .50000        .50000        .50000        .50000        .             .        RGASOLN4
RGASOLN5       .50000        .50000        .50000        .50000        .50000        .50000        .             .        RGASOLN5
RGASOLN6       .50000        .50000        .50000        .50000        .50000        .50000        .             .        RGASOLN6
RCCWHETD      1.00080       1.00000       1.00000       1.00000       1.00000       1.00000        .             .        RCCWHETD
RCCWHETI     18.10000      15.10000      15.10000      28.30000      25.90000      28.80000        .             .        RCCWHETI
RHAULWHT     38.10000      35.10000      35.10000      48.30000      45.90000      48.80000        .             .        RHAULWHT
RCASHFL1      1.53000       1.53000       1.53000       1.53000       1.53000       1.53000        .             .        RCASHFL1
RCASHFL2      1.52000       5.52000       3.52000       3.52000       3.52000       5.52000        .             .        RCASHFL2
RCASHFL3      4.79000        .79000       2.79000       4.79000       4.79000       4.79000        .             .        RCASHFL3
RCASHFL4     15.22000      15.22000      15.22000      15.22000      15.22000      15.72000        .             .        RCASHFL4
RCASHFL5      1.53000       1.53000       1.53000       1.53000       1.53000       1.53000        .             .        RCASHFL5
RCASHFL6      1.52000       1.52000       1.52000       1.52000       1.52000       1.52000        .             .        RCASHFL6
ACCTGCF1      1.53000       1.53000       1.53000       1.53000       1.53000       1.53000        .             .        ACCTGCF1
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..MPSX-VINT7..  EXECUTOR.  MPSX  RELEASE 1  MCO LEVEL 7                                             PAGE   26  -  81/145

              WHET203F      WHET2A4F      WHET2B4F      WHET301F      WHET302F      WHET401F      PPCORN22      PPCORN23       7....2
BOUND         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

ACCTGCF2       1.52000       5.52000       3.52000       3.52000       3.52000       5.52000         .             .          ACCTGCF2
ACCTGCF3       4.79000        .79000       2.79000       4.79000       4.79000       4.79000         .             .          ACCTGCF3
ACCTGCF4      15.22000      15.22000      15.22000      15.22000      15.22000      15.22000         .             .          ACCTGCF4
ACCTGCF5       1.53000       1.53000       1.53000       1.53000       1.53000       1.53000         .             .          ACCTGCF5
ACCTGCF6       1.52000       1.52000       1.52000       1.52000       1.52000       1.52000         .             .          ACCTGCF6
RSELLWHT      38.10000-     35.10000-     35.10000-     48.30000-     45.90000-     48.80000-        .             .          RSELLWHT
RSELLGRZ      21.65000-     20.30000-     20.30000-     26.24000-     25.16000-     26.46000-        .             .          RSELLGRZ
IRRIGVC1       1.25000       1.25000       1.25000       1.58300       1.58300       1.91700         .             .          IRRIGVC1
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..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                        PAGE    27  -  81/145

           PPCORN31   PPCORN32   PPCCRN33   PPCOTN31   PPCOTN32   PPCOTN33   PPCOTN41   PPCOTN42    8....1
BOUND      LOWER      LOWER      LOWER      LOWER      LOWER      LOWER      LOWER      LCWER       BOUND

WATER31     .58330     .          .          .58330     .          .          .          .         WATER31
WATER32     .          .58330     .          .          .58330     .          .          .         WATER32
WATER33     .          .          .58330     .          .          .58330     .          .         WATER33
WATER41     .          .          .          .          .          .          .58330     .         WATER41
WATER42     .          .          .          .          .          .          .          .58330    WATER42
PREPCORN   1.00000-   1.00000-   1.00000-    .          .          .          .          .         PREPCORN
PREPCOTN    .          .          .         1.00000-   1.00000-   1.00000-   1.00000-   1.00000-   PREPCOTN
FWATER31    .58330     .          .          .58330     .          .          .          .         FWATER31
IRFUEL31    .58330     .          .          .58330     .          .          .          .         IRFUEL31
FWATER32    .          .58330     .          .          .58330     .          .          .         FWATER32
IRFUEL32    .          .58330     .          .          .58330     .          .          .         IRFUEL32
FWATER33    .          .          .58330     .          .          .58330     .          .         FWATER33
IRFUEL33    .          .          .58330     .          .          .58330     .          .         IRFUEL33
FWATER41    .          .          .          .          .          .          .58330     .         FWATER41
IRFUEL41    .          .          .          .          .          .          .58330     .         IRFUEL41
FWATER42    .          .          .          .          .          .          .          .58330    FWATER42
IRFUEL42    .          .          .          .          .          .          .          .58330    IRFUEL42
RMAXLAB2    .70000     .70000     .70000     .          .          .          .          .         RMAXLAB2
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..MPSX-VIN7..   EXECUTOR.   MPSX   RELEASE 1   MOD LEVEL 7                                                     PAGE    28  -  81/145

              PPGRSO22        PPGRSO23        PPGRSO31        PPGRSO32        PPGRSO33        PPWHET82        PPWHET83        PPWHET91        9....1
BOUND         LOWER           LOWER           LOWER           LOWER           LOWER           LOWER           LOWER           LOWER           BOUND

WATER22       .58330          .               .               .               .               .               .               .               WATER22
WATER23       .               .58330          .               .               .               .               .               .               WATER23
WATER31       .               .               .58330          .               .               .               .               .               WATER31
WATER32       .               .               .               .58330          .               .               .               .               WATER32
WATER33       .               .               .               .               .58330          .               .               .               WATER33
WATER82       .               .               .               .               .               .58330          .               .               WATER82
WATER83       .               .               .               .               .               .               .58330          .               WATER83
WATER91       .               .               .               .               .               .               .               .58330          WATER91
PREPGRSO      1.00000-        1.00000-        1.00000-        1.00000-        1.00000-        .               .               .               PREPGRSO
PREPWHET      .               .               .               .               .               1.00000-        1.00000-        1.00000-        PREPWHET
FWATER22      .58330          .               .               .               .               .               .               .               FWATER22
IRFUEL22      .58330          .               .               .               .               .               .               .               IRFUEL22
FWATER23      .               .58330          .               .               .               .               .               .               FWATER23
IRFUEL23      .               .58330          .               .               .               .               .               .               IRFUEL23
FWATER31      .               .               .58330          .               .               .               .               .               FWATER31
IRFUEL31      .               .               .58330          .               .               .               .               .               IRFUEL31
FWATER32      .               .               .               .58330          .               .               .               .               FWATER32
IRFUEL32      .               .               .               .58330          .               .               .               .               IRFUEL32
FWATER33      .               .               .               .               .58330          .               .               .               FWATER33
IRFUEL33      .               .               .               .               .58330          .               .               .               IRFUEL33
FWATER82      .               .               .               .               .               .58330          .               .               FWATER82
IRFUEL82      .               .               .               .               .               .58330          .               .               IRFUEL82
FWATER83      .               .               .               .               .               .               .58330          .               FWATER83
IRFUEL83      .               .               .               .               .               .               .58330          .               IRFUEL83
FWATER91      .               .               .               .               .               .               .               .58330          FWATER91
IRFUEL91      .               .               .               .               .               .               .               .58330          IRFUEL91
RMAXLAB1      .70000          .70000          .               .               .               .               .               .               RMAXLAB1
RMAXLAB2      .               .               .70000          .70000          .70000          .               .               .               RMAXLAB2
RMAXLAB4      .               .               .               .               .               .70000          .70000          .               RMAXLAB4
RMAXLAB5      .               .               .               .               .               .               .               .70000          RMAXLAB5
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..MPSX-VIM7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                         PAGE    29  -  81/145

            PPWHET92    PPWHET93    FRELEC11    SLELEC11    FRELEC12    SLELEC12    FRELEC13    SLELEC13     10.....1
BOUND       LOWER       LOWER                   LOWER                   LOWER                   LOWER        BOUND

ELSCLD         .           .           .          .90000       .          .90000       .          .90000     ELSOLD
WATER92       .58330       .           .           .           .           .           .           .         WATER92
WATER93        .          .58330       .           .           .           .           .           .         WATER93
PREPWHET     1.00000-    1.00000-      .           .           .           .           .           .         PREPWHET
UELECT11       .           .         1.00000-    1.00000       .           .           .           .         UELECT11
UELECT12       .           .           .           .         1.00000-    1.00000       .           .         UELECT12
UELECT13       .           .           .           .           .           .         1.00000-    1.00000     UELECT13
FWATER92      .58330       .           .           .           .           .           .           .         FWATER92
IRFUEL92      .58330       .           .           .           .           .           .           .         IRFUEL92
FWATER93       .          .58330       .           .           .           .           .           .         FWATER93
IRFUEL93       .          .58330       .           .           .           .           .           .         IRFUEL93
RMAXLABS      .70000      .70000       .           .           .           .           .           .         RMAXLABS
RCASHFL1       .           .           .          .02700-      .          .02700-      .          .02700-    RCASHFL1
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..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                              PAGE    30  -  81/145

            FRELEC21     SLELEC21     SLKWAT22     FRELEC22     BYELEC22     SLELEC22     IRELEC22     SLKWAT23     (I....I
BOUND                    LOWER        LOWER                     LOWER        LOWER        LOWER        LOWER        BOUND

ELIRRG02     .            .            .            .            .            .           1.00000       .           ELIRRG02
ELBUYS02     .            .            .            .           1.00000       .            .            .           ELBUYS02
ELSOLD       .            .90000       .            .            .            .90000       .            .           ELSOLD
UELECT21    1.00000-     1.00000       .            .            .            .            .            .           UELECT21
FWATER22     .            .           1.00000       .            .            .            .            .           FWATER22
IRFUEL22     .            .            .            .            .            .            .00239-      .           IRFUEL22
UELECT22     .            .            .           1.00000-     1.00000-     1.00000      1.00000       .           UELECT22
SELECT22     .            .           1.00000       .            .            .01235-      .            .           SELECT22
FWATER23     .            .            .            .            .            .            .           1.00000      FWATER23
SELECT23     .            .            .            .            .            .            .           1.00000      SELECT23
RCASHFL1     .            .02700-      .            .            .05000       .02700-      .            .           RCASHFL1
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..MPSX-VINT..  EXECUTOR.  MPSX  RELEASE 1  MCD LEVEL 7                                                  PAGE    46  -  81/145

             SLELEC03     SLELEC04     SLELEC05     SLELEC06     CORNSEED     COTNSEED     GRSOSEED     WHETSEED     27....1
BOUND                                                            LOWER        LOWER        LOWER        LOWER        BOUND

ELSOLD        .90000       .90000       .90000       .90000       .            .            .            .           ELSOLD
RCORNSED      .            .            .            .           1.00000-      .            .            .           RCORNSED
RCOTNSED      .            .            .            .            .           1.00000-      .            .           RCOTNSED
RGRSOSED      .            .            .            .            .            .           1.00000-      .           RGRSOSED
RWHETSED      .            .            .            .            .            .            .           1.00000-     RWHETSED
RCASHFL2      .            .            .            .            .90000       .            .            .           RCASHFL2
RCASHFL3      .02700-      .            .            .            .            .45000       .50000       .           RCASHFL3
RCASHFL4      .            .02700-      .            .            .            .            .            .           RCASHFL4
RCASHFL5      .            .            .02700-      .            .            .            .           7.50000      RCASHFL5
RCASHFL6      .            .            .            .02700-      .            .            .            .           RCASHFL6
ACCTGCF2      .            .            .            .            .90000       .            .            .           ACCTGCF2
ACCTGCF3      .            .            .            .            .            .45000       .50000       .           ACCTGCF3
ACCTGCF5      .            .            .            .            .            .            .           7.50000      ACCTGCF5
```

```
..MPSX-VIN7..  EXECLTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                 PAGE    47  -  81/145

              INSECT2     INSECT3     INSECT5     HERB2       HERB3       HERB4       FERTAPP2    FERTAPP4     28....1
BOUND         LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER        BOUND

RINSECT2      1.00000-     .           .           .           .           .           .           .           RINSECT2
RINSECT3       .          1.00000-     .           .           .           .           .           .           RINSECT3
RINSECT5       .           .          1.00000-     .           .           .           .           .           RINSECT5
RHERB2         .           .           .          1.00000-     .           .           .           .           RHERB2
RHERB3         .           .           .           .          1.00000-     .           .           .           RHERB3
RHERB4         .           .           .           .           .          1.0000C-     .           .           RHERB4
RFERTAP2       .           .           .           .           .           .          1.00000-     .           RFERTAP2
RFERTAP4       .           .           .           .           .           .           .          1.00000-     RFERTAP4
RCASHFL2      1.00000      .           .          1.00000      .           .          2.00000      .           RCASHFL2
RCASHFL3       .          1.00000      .           .          1.00000      .           .           .           RCASHFL3
RCASHFL4       .           .           .           .           .          1.00000      .          2.00000      RCASHFL4
RCASHFL5       .           .          1.00000      .           .           .           .           .           RCASHFL5
ACCTGCF2      1.00000      .           .          1.00000      .           .          2.00000      .           ACCTGCF2
ACCTGCF3       .          1.00000      .           .          1.00000      .           .           .           ACCTGCF3
ACCTGCF4       .           .           .           .           .          1.C000C      .          2.00000      ACCTGCF4
ACCTGCF5       .           .          1.00000      .           .           .           .           .           ACCTGCF5
```

```
..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                                 PAGE    48  -  81/145

              NITROGN2      NITROGN4      PHOS2         PHOS4         DIESELP1      DIESELP2      DIESELP3      DIESELP4      29....1
BOUND         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         LOWER         BOUND

RNITROG2       1.00000-      .             .             .             .             .             .             .            RNITROG2
RNITROG4       .            1.00000-       .             .             .             .             .             .            RNITROG4
RPHOS2         .             .            1.00000-       .             .             .             .             .            RPHOS2
RPHOS4         .             .             .            1.00000-       .             .             .             .            RPHOS4
RDIESEL1       .             .             .             .            1.00000-       .             .             .            RDIESEL1
RDIESEL2       .             .             .             .             .            1.00000-       .             .            RDIESEL2
RDIESEL3       .             .             .             .             .             .            1.00000-       .            RDIESEL3
RDIESEL4       .             .             .             .             .             .             .            1.00000-      RDIESEL4
RCASHFL1       .             .             .             .            1.00000        .             .             .            RCASHFL1
RCASHFL2      .24000         .            .23000         .             .            1.00000        .             .            RCASHFL2
RCASHFL3       .             .             .             .             .             .            1.00000        .            RCASHFL3
RCASHFL4       .            .24000         .            .23000         .             .             .            1.00000       RCASHFL4
ACCTGCF1       .             .             .             .            1.00000        .             .             .            ACCTGCF1
ACCTGCF2      .24000         .            .23000         .             .            1.00000        .             .            ACCTGCF2
ACCTGCF3       .             .             .             .             .             .            1.00000        .            ACCTGCF3
ACCTGCF4       .            .24000         .            .23000         .             .             .            1.00000       ACCTGCF4
```

```
..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                      PAGE    49  -  81/145

             DIESELP5    DIESELP6    GASOLNP1    GASOLNP2    GASOLNP3    GASOLNP4    GASOLNP5    GASOLNP6     30....1
BOUND        LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER        BOUND

RDIESEL5      1.00000-     .           .           .           .           .           .           .          RDIESEL5
RDIESEL6       .          1.00000-     .           .           .           .           .           .          RDIESEL6
RGASOLN1       .           .          1.00000-     .           .           .           .           .          RGASOLN1
RGASOLN2       .           .           .          1.00000-     .           .           .           .          RGASOLN2
RGASOLN3       .           .           .           .          1.00000-     .           .           .          RGASOLN3
RGASOLN4       .           .           .           .           .          1.00000-     .           .          RGASOLN4
RGASOLN5       .           .           .           .           .           .          1.00000-     .          RGASOLN5
RGASOLN6       .           .           .           .           .           .           .          1.00000-    RGASOLN6
RCASHFL1       .           .          1.05000      .           .           .           .           .          RCASHFL1
RCASHFL2       .           .           .          1.05000      .           .           .           .          RCASHFL2
RCASHFL3       .           .           .           .          1.05000      .           .           .          RCASHFL3
RCASHFL4       .           .           .           .           .          1.05000      .           .          RCASHFL4
RCASHFL5      1.00000      .           .           .           .           .          1.05000      .          RCASHFL5
RCASHFL6       .          1.00000      .           .           .           .           .          1.05000     RCASHFL6
ACCTGCF1       .           .          1.05000      .           .           .           .           .          ACCTGCF1
ACCTGCF2       .           .           .          1.05000      .           .           .           .          ACCTGCF2
ACCTGCF3       .           .           .           .          1.05000      .           .           .          ACCTGCF3
ACCTGCF4       .           .           .           .           .          1.05000      .           .          ACCTGCF4
ACCTGCF5      1.00000      .           .           .           .           .          1.05000      .          ACCTGCF5
ACCTGCF6       .          1.00000      .           .           .           .           .          1.05000     ACCTGCF6
```

```
..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                           PAGE    50  -  81/145

             CORNCONB     GRSOCOND     GRSOCONI     WHTCONBD     WHTCONBI     COTNSAHL     COTNGING     CORNHAUL     31....1
BOUND        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        BOUND

RCCCORNN      1.00000-      .            .            .            .            .            .            .          RCCCORNN
RCCGRSOD      .            1.00000-      .            .            .            .            .            .          RCCGRSOD
RCCGRSOI      .            .            1.00000-      .            .            .            .            .          RCCGRSOI
RCCWHETD      .            .            .            1.00000-      .            .            .            .          RCCWHETD
RCCWHETI      .            .            .            .            1.00000-      .            .            .          RCCWHETI
RCSHCOTN      .            .            .            .            .            1.00000-      .            .          RCSHCOTN
RGINCOTN      .            .            .            .            .            .            1.00000-      .          RGINCOTN
RHAULCRN      .            .            .            .            .            .            .            1.00000-   RHAULCRN
RCASHFL3      .            .            .           10.00000      .10000       .            .            .          RCASHFL3
RCASHFL5      .25000       8.00000      .35000       .            .            .            .            .15000     RCASHFL5
RCASHFL6      .            .            .            .            .           1.50000      2.00000       .          RCASHFL6
ACCTGCF3      .            .            .           10.00000      .10000       .            .            .          ACCTGCF3
ACCTGCF5      .25000       8.00000      .35000       .            .            .            .            .15000     ACCTGCF5
ACCTGCF6      .            .            .            .            .           1.60000      2.00000       .          ACCTGCF6
```

```
..MPSX-VINT..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                  PAGE    51  -  81/145

            GRSOHAUL    WHETHAUL    CORNDRYG    BORROWP1    BORROWP2    BORROWP3    BORROWP4    BORROWP5    32....1
BOUND       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       BOUND

RHAULGRS    1.00000-      .           .           .           .           .           .           .         RHAULGRS
RHAULWHT      .         1.00000-      .           .           .           .           .           .         RHAULWHT
RDRYCORN      .           .         1.00000-      .           .           .           .           .         RDRYCORN
RCASHFL1      .           .           .         1.00000-      .           .           .           .         RCASHFL1
RCASHFL2      .           .           .         1.02330     1.00000-      .           .           .         RCASHFL2
RCASHFL3      .          .12000       .           .         1.02330     1.C000C-      .           .         RCASHFL3
RCASHFL4      .           .           .           .           .         1.02330     1.00000-      .         RCASHFL4
RCASHFL5     .25000       .          .12000       .           .           .         1.02330     1.00000-    RCASHFL5
RCASHFL6      .           .           .           .           .           .           .         1.02330     RCASHFL6
ACCTGCF3      .          .12000       .           .           .           .           .           .         ACCTGCF3
ACCTGCF5     .25000       .          .12000       .           .           .           .           .         ACCTGCF5
```

```
..MPSX-VIN7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                          PAGE    52  -  81/145

                BORROWP6     INVSTRP1     INVSTRP2     INVSTRP3     INVSTRP4     INVSTRP5     INVSTRP6     SELLCORN     33....1
BOUND           LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        LOWER        BOUND

RCASHFL1          .          1.00000        .            .            .            .            .            .         RCASHFL1
RCASHFL2          .          1.00000-     1.00000        .            .            .            .            .         RCASHFL2
RCASHFL3          .            .          1.00000-     1.00000        .            .            .            .         RCASHFL3
RCASHFL4          .            .            .          1.00000-     1.00000        .            .            .         RCASHFL4
RCASHFL5          .            .            .            .          1.00000-     1.00000        .          2.48000-    RCASHFL5
RCASHFL6       1.00000-        .            .            .            .          1.00000-     1.00000        .         RCASHFL6
RCASHFL7       1.02330         .            .            .            .            .          1.00000-       .         RCASHFL7
ACCTGCF5          .            .            .            .            .            .            .          2.48000-    ACCTGCF5
RSELLCRN          .            .            .            .            .            .            .          1.00000     RSELLCRN
```

```
..MPSX-V1M7..  EXECUTOR.  MPSX  RELEASE 1  MOD LEVEL 7                                          PAGE    53  -  81/145

              SELLCOTN    SELLCTSD    SELLGRSD    SELLWHET    SELLGRAZ    OBJCOL      IRRGVC1     IRRGVC2      34....1
BOUND         LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER       LOWER        BOUND

OBJ1             .           .           .           .           .       1.00000         .           .         OBJ1
RCASHFL3         .           .           .       3.08000-    1.00000-        .           .           .         RCASHFL3
RCASHFL5         .           .       4.02000-        .           .           .           .           .         RCASHFL5
RCASHFL6      .53300-    96.20000-       .           .           .           .        .77308     1.50000       RCASHFL6
RCASHFL7         .           .           .           .           .       1.00000         .           .         RCASHFL7
ACCTGCF3         .           .           .       3.08000-    1.00000-        .           .           .         ACCTGCF3
ACCTGCF5         .           .       4.C2000-        .           .           .           .           .         ACCTGCF5
ACCTGCF6      .53300-    96.20000-       .           .           .           .        .77308     1.50000       ACCTGCF6
RSELLCOT     1.000CC         .           .           .           .           .           .           .         RSELLCOT
RSELLCTS         .       1.00000         .           .           .           .           .           .         RSELLCTS
RSELLGRS         .           .       1.00000         .           .           .           .           .         RSELLGRS
RSELLWHT         .           .           .       1.00000         .           .           .           .         RSELLWHT
RSELLGRZ         .           .           .           .       1.00000         .           .           .         RSELLGRZ
IRRIGVC1         .           .           .           .           .           .       1.00000-        .         IRRIGVC1
IRRIGVC2         .           .           .           .           .           .           .       1.00000       IRRIGVC2
```

```
..MPSX-V1M7..   EXECUTOR.   MPSX   RELEASE 1   MCD LEVEL 7

                   RS1
BOUND                              BOUND

LAND            100.00000          LAND
FWATER22         20.86861          FWATER22
FWATER23         20.86861          FWATER23
FWATER31         20.86861          FWATER31
FWATER32         20.86861          FWATER32
FWATER33         20.86861          FWATER33
FWATER41         20.86861          FWATER41
FWATER42         20.86861          FWATER42
FWATER51         20.86861          FWATER51
FWATER53         20.86861          FWATER53
FWATER62         20.86861          FWATER62
FWATER63         20.86861          FWATER63
FWATER71         20.86861          FWATER71
FWATER72         20.86861          FWATER72
FWATER73         20.86861          FWATER73
FWATER81         20.86861          FWATER81
FWATER82         20.86861          FWATER82
FWATER83         20.86861          FWATER83
FWATER91         20.86861          FWATER91
FWATER92         20.86861          FWATER92
FWATER93         20.86861          FWATER93
RMAXLAB1         76.09375          RMAXLAB1
RMAXLAB2        133.43750          RMAXLAB2
RMAXLAB3        145.31250          RMAXLAB3
RMAXLAB4        149.21875          RMAXLAB4
RMAXLAB5        119.37500          RMAXLAB5
RMAXLAB6         91.25000          RMAXLAB6
IRRIGVC2         60.00000          IRRIGVC2
```

APPENDIX B

AN EXAMPLE OF THE SIMULATION MODEL COMPUTER OUTPUT

The simulation model generates 20 stochastic estimates of the annual value of wind power. Sample output from the simulation model is shown on the following two pages. The first, as an example, shows the results from one of the 20 simulations. The second is a table summarizing the results of all 20 simulations.

```
        ELECTRICITY ELECTRICITY ELECTRICITY ELECTRICITY
MONTH       USED     PURCHASED      SOLD     GENERATED
  1          0.00         0.00     4955.98     5506.65
  2          0.00         0.00     4426.38     4918.20
  3      15651.70     11431.26     3800.93     8443.63
  4       8720.00      6628.71     4703.02     7316.83
  5          0.00         0.00     5804.54     6449.49
  6       5193.56      4475.42     4913.87     6177.97
  7       8720.00      7602.56     2633.37     4043.36
  8       8720.00      7775.94     2816.23     4073.16
  9          0.00         0.00     4817.98     5353.31
 10          0.00         0.00     4246.25     4718.07
 11          0.00         0.00     4171.38     4634.88
 12          0.00         0.00     3548.97     3943.31
  TOTAL  47005.25     37913.89    50838.90    65578.81

NET PROFIT =    14842.29
```

	PROFIT	ELECTRICITY PURCHASED	ELECTRICITY SOLD	ELECTRICITY GENERATED
MAXIMUM	15040.05	39268.67	54719.17	70953.50
MINIMUM	14795.27	36174.59	50084.71	65220.67
MEAN	14908.98	37566.66	52442.95	67708.25
STD. DEV.	60.93	718.22	1321.00	1708.03

APPENDIX C

AN EXAMPLE OF THE TEMPORAL MODEL COMPUTER OUTPUT

```
ITEM                                      UNIT      VALUE
CORN PRICE                               $/BU.      3.060
COTTON LINT PRICE                        $/LB.      0.0
COTTON SEED PRICE                        $/TON      0.0
GRAIN SORGHUM PRICE                     $/CWT.      5.520
WHEAT PRICE                              $/BU.      3.140
ELECTRICITY PURCHASE PRICE               $/KWH      0.050
ELECTRICITY SELLING PRICE                $/KWH      0.030
DIESEL FUEL PRICE                       $/GAL.      1.000
GASOLINE PRICE                          $/GAL.      1.050
NITROGEN PRICE                           $/LB.      0.240
PHOSPHOROUS PRICE                        $/LB.      0.230
CROPLAND ACRES                           ACRES    144.000
LAND CONTRIBUTING TO IRRIGATION          ACRES    393.000
YEAR 1 SATURATED THICKNESS                FEET    225.000
YEAR 1 LIFT                               FEET    200.000
BEGINNING SATURATED THICKNESS             FEET    250.000
BEGINNING WELL YIELD                       GPM    800.000
WECS RATED OUTPUT                           KW     60.000
WECS CUT-IN SPEED                          MPH     13.000
WECS RATED SPEED                           MPH     32.000
WECS CUT-OUT SPEED                         MPH     45.000
WECS HUB HEIGHT                           FEET     65.600
PLANNED YEARS OF ANALYSIS                YEARS     20.000
```

```
SUMMARY FOR YEAR  1

ACTIVITY LEVELS
 CORN502F       1.97   GRS0101F      11.96   GRS0202F      51.79
 GRS0203F      39.83   GRS0301F       1.97   GRS0401F      36.49
 PPCORN33       1.97   PPGRS022      27.84   PPGRS023       0.00
 PPGRS031      51.52   PPGRS032      13.12   PPGRS033      49.55
 PPGRS031      51.52   PPGRS032      13.12   PPGRS033      49.55

IRRIGATION WATER       ACRE-FEET           SHADOW
                        PUMPED             PRICE
          WATER22        16.24              0.0
          WATER23         0.00              0.0
          WATER31        30.05             -2.59
          WATER32         7.65              0.0
          WATER33        30.05             -2.59
          WATER41         0.0               0.0
          WATER42         0.0               0.0
          WATER51         0.0               0.0
          WATER53         0.0               0.0
          WATER62         0.0               0.0
          WATER63         0.0               0.0
          WATER71        26.72              0.0
          WATER72         0.66              0.0
          WATER73        30.05             91.90
          WATER81         0.66              0.0
          WATER82        30.05             77.10
          WATER83        30.05              2.89
          WATER91         0.66              0.0
          WATER92         0.0               0.0
          WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED         GENERATED
          MONTH  2      6254.63           1369.27
          MONTH  3     24698.06           7112.40
          MONTH  4         0.0               0.0
          MONTH  5         0.0               0.0
          MONTH  6         0.0               0.0
          MONTH  7     23590.37           3372.03
          MONTH  8     25308.92           3215.59
          MONTH  9       264.21             43.57

CROPLAND                 ACRES             SHADOW
                        CROPPED            PRICE
                         144.00             2.21
```

```
SUMMARY FOR YEAR  2

ACTIVITY LEVELS
 CORN502F       1.97   GRSO101F      11.96   GRSO202F       51.79
 GRSO203F      39.83   GRSO301F       1.97   GRSO401F       36.49
 PPCORN33       1.97   PPGRSO22      27.84   PPGRSO23        0.00
 PPGRSO31      51.52   PPGRSO32      13.12   PPGRSO33       49.55
 PPGRSO31      51.52   PPGRSO32      13.12   PPGRSO33       49.55

IRRIGATION WATER       ACRE-FEET           SHADOW
                        PUMPED             PRICE
          WATER22        16.24              0.0
          WATER23         0.00              0.0
          WATER31        30.05             -2.59
          WATER32         7.65              0.0
          WATER33        30.05             -2.59
          WATER41         0.0               0.0
          WATER42         0.0               0.0
          WATER51         0.0               0.0
          WATER53         0.0               0.0
          WATER62         0.0               0.0
          WATER63         0.0               0.0
          WATER71        26.72              0.0
          WATER72         0.66              0.0
          WATER73        30.05             91.90
          WATER81         0.66              0.0
          WATER82        30.05             77.10
          WATER83        30.05              2.89
          WATER91         0.66              0.0
          WATER92         0.0               0.0
          WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED         GENERATED
          MONTH  2      6400.55           1369.27
          MONTH  3     25306.87           7112.40
          MONTH  4         0.0               0.0
          MONTH  5         0.0               0.0
          MONTH  6         0.0               0.0
          MONTH  7     24106.40           3372.03
          MONTH  8     25854.84           3215.58
          MONTH  9       270.10             43.57

CROPLAND                  ACRES            SHADOW
                         CROPPED           PRICE
                          144.00             2.60
```

```
SUMMARY FOR YEAR  3

ACTIVITY LEVELS
 CORN502F       1.97    GRS0101F       11.96    GRS0202F       51.79
 GRS0203F      39.83    GRS0301F        1.97    GRS0401F       36.49
 PPCORN33       1.97    PPGRS022       27.64    PPGRS023        0.00
 PPGRS031      51.52    PPGRS032       13.12    PPGRS033       49.55
 PPGRS031      51.52    PPGRS032       13.12    PPGRS033       49.55

IRRIGATION WATER        ACRE-FEET           SHADOW
                          PUMPED             PRICE
             WATER22        16.24              0.0
             WATER23         0.00              0.0
             WATER31        30.05            -2.59
             WATER32         7.65              0.0
             WATER33        30.05            -2.59
             WATER41         0.0               0.0
             WATER42         0.0               0.0
             WATER51         0.0               0.0
             WATER53         0.0               0.0
             WATER62         0.0               0.0
             WATER63         0.0               0.0
             WATER71        26.72              0.0
             WATER72         0.66              0.0
             WATER73        30.05             91.90
             WATER81         0.66              0.0
             WATER82        30.05             77.10
             WATER83        30.05              2.89
             WATER91         0.66              0.0
             WATER92         0.0               0.0
             WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION         FURCHASED         GENERATED
             MONTH  2     6513.70           1369.27
             MONTH  3    25779.00           7112.40
             MONTH  4        0.0               0.0
             MONTH  5        0.0               0.0
             MONTH  6        0.0               0.0
             MONTH  7    24506.57           3372.03
             MONTH  8    26278.20           3215.58
             MONTH  9      274.67             43.57

CROPLAND                    ACRES            SHADOW
                           CROPPED            PRICE
                            144.00             2.90
```

```
SUMMARY FOR YEAR  4

ACTIVITY LEVELS
 CORN502F      1.97   GRSO101F     11.96   GRSO202F      51.79
 GRSO203F     39.83   GRSO301F      1.97   GRSO401F      36.49
 PPCORN33      1.97   PPGRSO22     27.84   PPGRSO23       0.00
 PPGRSO31     51.52   PPGRSO32     13.12   PPGRSO33      49.55
 PPGRSO31     51.52   PPGRSO32     13.12   PPGRSO33      49.55

IRRIGATION WATER       ACRE-FEET          SHADOW
                        PUMPED            PRICE
           WATER22       16.24              0.0
           WATER23        0.00              0.0
           WATER31       30.05            -2.59
           WATER32        7.65              0.0
           WATER33       30.05            -2.59
           WATER41        0.0               0.0
           WATER42        0.0               0.0
           WATER51        0.0               0.0
           WATER53        0.0               0.0
           WATER62        0.0               0.0
           WATER63        0.0               0.0
           WATER71       26.72              0.0
           WATER72        0.66              0.0
           WATER73       30.05             91.90
           WATER81        0.66              0.0
           WATER82       30.05             77.10
           WATER83       30.05              2.89
           WATER91        0.66              0.0
           WATER92        0.0               0.0
           WATER93        0.0               0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED        GENERATED
           MONTH  2      6630.20          1369.27
           MONTH  3     26265.08          7112.39
           MONTH  4         0.0              0.0
           MONTH  5         0.0              0.0
           MONTH  6         0.0              0.0
           MONTH  7     24918.57          3372.03
           MONTH  8     26714.07          3215.59
           MONTH  9       279.37            43.57

CROPLAND                  ACRES           SHADOW
                         CROPPED          PRICE
                          144.00            3.20
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SUMMARY FOR YEAR  5

ACTIVITY LEVELS
 CORN502F      1.97   GRSO101F     11.96   GRSO202F      51.79
 GRSO203F     39.83   GRSO301F      1.97   GRSO401F      36.49
 PPCORN33      1.97   PPGRSO22     27.84   PPGRSO23       0.00
 PPGRSO31     51.52   PPGRSO32     13.12   PPGRSO33      49.55
 PPGRSO31     51.52   PPGRSO32     13.12   PPGRSO33      49.55

IRRIGATION WATER       ACRE-FEET          SHADOW
                        PUMPED            PRICE
          WATER22        16.24              0.0
          WATER23         0.00              0.0
          WATER31        30.05            -2.59
          WATER32         7.65              0.0
          WATER33        30.05            -2.59
          WATER41         0.0               0.0
          WATER42         0.0               0.0
          WATER51         0.0               0.0
          WATER53         0.0               0.0
          WATER62         0.0               0.0
          WATER63         0.0               0.0
          WATER71        26.72              0.0
          WATER72         0.66              0.0
          WATER73        30.05             91.90
          WATER81         0.66              0.0
          WATER82        30.05             77.10
          WATER83        30.05              2.89
          WATER91         0.66              0.0
          WATER92         0.0               0.0
          WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED        GENERATED
          MONTH  2      6750.19          1369.27
          MONTH  3     26765.74          7112.40
          MONTH  4         0.0              0.0
          MONTH  5         0.0              0.0
          MONTH  6         0.0              0.0
          MONTH  7     25342.93          3372.03
          MONTH  8     27163.01          3215.59
          MONTH  9       284.22            43.57

CROPLAND                   ACRES          SHADOW
                          CROPPED         PRICE
                          144.00            3.52
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SUMMARY FOR YEAR  6

ACTIVITY LEVELS
 CORN502F      1.97   GRSO101F      4.38   GRSO202F      53.68
 GRSO203F     49.30   GRSO301F      1.97   GRSO401F      32.70
 PPCORN33      1.97   PPGRSO22     27.84   PPGRSO31      50.44
 PPGRSO32     15.29   PPGRSO33     48.47                  0.0

IRRIGATION WATER       ACRE-FEET          SHADOW
                        PUMPED            PRICE
          WATER22        16.24              0.0
          WATER23         0.0               0.0
          WATER31        29.42             -2.64
          WATER32         8.92              0.0
          WATER33        29.42             -2.64
          WATER41         0.0               0.0
          WATER42         0.0               0.0
          WATER51         0.0               0.0
          WATER53         0.0               0.0
          WATER62         0.0               0.0
          WATER63         0.0               0.0
          WATER71        28.62              0.0
          WATER72         0.66              0.0
          WATER73        29.42             91.87
          WATER81         0.66              0.0
          WATER82        29.42             77.07
          WATER83        29.42              2.86
          WATER91         0.66              0.0
          WATER92         0.0               0.0
          WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED        GENERATED
          MONTH  2      6844.79          1398.31
          MONTH  3     27129.17          7264.88
          MONTH  4         0.0              0.0
          MONTH  5         0.30            -0.30
          MONTH  6         0.0              0.0
          MONTH  7     26272.98          3519.77
          MONTH  8     26984.65          3216.06
          MONTH  9       288.88            43.90

CROPLAND                 ACRES            SHADOW
                        CROPPED           PRICE
                         144.00             3.85
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SUMMARY FOR YEAR  7

ACTIVITY LEVELS
 CORN502F      16.38   GRSO101F      16.38   GRSO202F      34.41
 GRSO203F      18.03   GRSO301F      16.38   GRSO401F      34.65
 PPCORN23       0.00   PPCORN33      16.38   PPGRSO22      26.27
 PPGRSO31      48.78   PPGRSO32      12.41   PPGRSO33      32.40
 PPGRSO31      48.78   PPGRSO32      12.41   PPGRSO33      32.40

IRRIGATION WATER     ACRE-FEET          SHADOW
                      PUMPED            PRICE
          WATER22       15.32              0.0
          WATER23        0.00              0.0
          WATER31       28.45            -2.73
          WATER32        7.24              0.0
          WATER33       28.45            -2.73
          WATER41        0.0               0.0
          WATER42        0.0               0.0
          WATER51        0.0               0.0
          WATER53        0.0               0.0
          WATER62        0.0               0.0
          WATER63        0.0               0.0
          WATER71       28.45             8.84
          WATER72        5.45              0.0
          WATER73       28.45           102.12
          WATER81        5.45              0.0
          WATER82       28.45            87.33
          WATER83       28.45            13.12
          WATER91        5.45              0.0
          WATER92        0.0               0.0
          WATER93        0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED       GENERATED
          MONTH   2      6493.72         1364.92
          MONTH   3     25783.97         7110.51
          MONTH   4         3.30           -3.30
          MONTH   5         0.0             0.0
          MONTH   6         0.53           -0.53
          MONTH   7     28112.16         3867.69
          MONTH   8     28494.50         3485.36
          MONTH   9      2418.03          379.31

CROPLAND                   ACRES          SHADOW
                          CROPPED          PRICE
                          136.24            0.0
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SUMMARY FOR YEAR  8

ACTIVITY LEVELS
 CORN502F      24.30    GRSC101F      24.30    GRS0202F      24.30
 GRS0301F      24.30    GRSC401F      33.90    WHET301F       2.05
 PPCORN33      24.30    PPGRS022      25.46    PPGRS031      47.09
 PPGRS032      11.44    PPGRS033      22.80    PPWHET92       2.05
 PPGRS032      11.44    PPGRS033      22.80    PPWHET92       2.05

IRRIGATION WATER        ACRE-FEET          SHADOW
                         PUMPED            PRICE
           WATER22        14.85              0.0
           WATER23         0.0               0.0
           WATER31        27.47             -2.83
           WATER32         6.67              0.0
           WATER33        27.47             -2.83
           WATER41         0.0               0.0
           WATER42         0.68              0.0
           WATER51         0.68              0.0
           WATER53         0.68              0.0
           WATER62         0.0               0.0
           WATER63         0.0               0.0
           WATER71        27.47             28.68
           WATER72         8.09              0.0
           WATER73        27.47            114.31
           WATER81         8.09              0.0
           WATER82        27.47             99.51
           WATER83        27.47             29.13
           WATER91         8.09              0.0
           WATER92         1.19              0.0
           WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED        GENERATED
           MONTH  2      6366.47          1369.49
           MONTH  3     25015.30          7074.52
           MONTH  4       277.27            77.46
           MONTH  5       567.86           141.60
           MONTH  6         0.0              0.0
           MONTH  7     28780.54          4048.85
           MONTH  8     29180.63          3648.76
           MONTH  9      4163.95           671.71

CROPLAND                    ACRES          SHADOW
                           CROPPED         PRICE
                           133.14            0.0
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SUMMARY FOR YEAR  9

ACTIVITY LEVELS
 CORNS02F      24.87   GRSO101F      24.87   GRSO202F      24.87
 GRSO301F      24.87   GRSO401F      29.80   WHET301F       5.52
 PPCORN33      24.87   PPGRSO22      25.49   PPGRSO31      45.41
 PPGRSO32      12.97   PPGRSO33      20.54   PPWHET92       5.52
 PPGRSO32      12.97   PPGRSO33      20.54   PPWHET92       5.52

IRRIGATION WATER       ACRE-FEET          SHADOW
                        PUMPED            PRICE
          WATER22        14.87              0.0
          WATER23         0.0               0.0
          WATER31        26.49             -2.93
          WATER32         7.57              0.0
          WATER33        26.49             -2.93
          WATER41         0.0               0.0
          WATER42         1.84              0.0
          WATER51         1.84              0.0
          WATER53         1.84              0.0
          WATER62         0.0               0.0
          WATER63         0.0               0.0
          WATER71        26.49             28.43
          WATER72         8.28              0.0
          WATER73        26.49            114.49
          WATER81         8.28              0.0
          WATER82        26.49             99.70
          WATER83        26.49             29.10
          WATER91         8.28              0.0
          WATER92         3.22              0.0
          WATER93         0.0               0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED       GENERATED
          MONTH  2      6446.06         1421.46
          MONTH  3     24821.15         7210.20
          MONTH  4       758.48          214.02
          MONTH  5      1558.21          386.78
          MONTH  6         0.87           -0.87
          MONTH  7     28328.95         4080.70
          MONTH  8     28732.09         3677.55
          MONTH  9      5224.25          861.24

CROPLAND                  ACRES           SHADOW
                        CROPPED           PRICE
                         134.80             0.0
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SUMMARY FOR YEAR 10

ACTIVITY LEVELS
 CORN502F       25.44    GRSC101F      25.44    GRSO202F       25.44
 GRSO301F       25.44    GRSC401F      25.75    WHET301F        8.95
 PPCORN23        0.00    PPCCRN33      25.44    PPGRSO22       25.52
 PPGRSO31       43.74    PPGRSO32      14.49    PPGRSO33       18.31
 PPWHET92        8.95    PPWHET93       0.00                    0.0

IRRIGATION WATER         ACRE-FEET          SHADOW
                          PUMPED            PRICE
          WATER22          14.89             0.0
          WATER23           0.00             0.0
          WATER31          25.51            -3.05
          WATER32           8.45             0.0
          WATER33          25.51            -3.05
          WATER41           0.0              0.0
          WATER42           2.98             0.0
          WATER51           2.98             0.0
          WATER53           2.98             0.0
          WATER62           0.0              0.0
          WATER63           0.0              0.0
          WATER71          25.51            28.18
          WATER72           8.47             0.0
          WATER73          25.51           114.69
          WATER81           8.47             0.0
          WATER82          25.51            99.89
          WATER83          25.51            29.07
          WATER91           8.47             0.0
          WATER92           5.22             0.0
          WATER93           0.00             0.0

ELECTRICITY
  FOR IRRIGATION         PURCHASED         GENERATED
          MONTH  2         6524.81           1478.39
          MONTH  3        24625.53           7353.17
          MONTH  4         1238.92            362.95
          MONTH  5         2547.75            656.00
          MONTH  6            0.87             -0.87
          MONTH  7        27874.38           4114.74
          MONTH  8        28280.87           3708.25
          MONTH  9         6291.91           1067.82

CROPLAND                    ACRES           SHADOW
                           CROPPED          PRICE
                            136.44           0.0
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SUMMARY FOR YEAR 11

ACTIVITY LEVELS
 CORN502F      25.99   GRSO101F      25.99   GRSO202F        25.99
 GRSO301F      25.99   GRSO401F      21.76   WHET301F        12.33
 PPCORN33      25.99   PPGRSO22      25.55   PPGRSO31        42.10
 PPGRSO32      15.98   PPGRSO33      16.11   PPWHET92        12.33
 PPGRSO32      15.98   PPGRSO33      16.11   PPWHET92        12.33

IRRIGATION WATER       ACRE-FEET           SHADOW
                        PUMPED             PRICE
          WATER22        14.90               0.0
          WATER23         0.0                0.0
          WATER31        24.56              -3.16
          WATER32         9.32               0.0
          WATER33        24.56              -3.16
          WATER41         0.0                0.0
          WATER42         4.11               0.0
          WATER51         4.11               0.0
          WATER53         4.11               0.0
          WATER62         0.0                0.0
          WATER63         0.0                0.0
          WATER71        24.56              27.97
          WATER72         8.66               0.0
          WATER73        24.56             114.79
          WATER81         8.66               0.0
          WATER82        24.56              99.99
          WATER83        24.56              29.01
          WATER91         8.66               0.0
          WATER92         7.19               0.0
          WATER93         0.0                0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED         GENERATED
          MONTH  2      6561.97           1536.98
          MONTH  3     24252.07           7506.75
          MONTH  4      1712.88            518.17
          MONTH  5      3522.66            939.43
          MONTH  6         0.0               0.0
          MONTH  7     27245.42           4151.14
          MONTH  8     27655.56           3740.99
          MONTH  9      7331.18           1280.91

CROPLAND                  ACRES            SHADOW
                         CROPPED           PRICE
                          138.06             0.0
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SUMMARY FOR YEAR 12

ACTIVITY LEVELS
 CORN502F      26.54    GRSO101F      26.54    GRSO202F      26.54
 GRSO301F      26.54    GRSO401F      17.83    WHET301F      15.66
 PPCORN23       0.00    PPCORN33      26.54    PPGRSO22      25.57
 PPGRSO31      40.48    PPGRSO32      17.45    PPGRSO33      13.94
 PPWHET92      15.66    PPWHET93       0.00                   0.0

IRRIGATION WATER        ACRE-FEET          SHADOW
                         PUMPED            PRICE
           WATER22        14.92             0.0
           WATER23         0.00             0.0
           WATER31        23.61            -3.29
           WATER32        10.18             0.0
           WATER33        23.61            -3.29
           WATER41         0.0              0.0
           WATER42         5.21             0.0
           WATER51         5.21             0.0
           WATER53         5.21             0.0
           WATER62         0.0              0.0
           WATER63         0.0              0.0
           WATER71        23.61            27.69
           WATER72         8.84             0.0
           WATER73        23.61           114.98
           WATER81         8.84             0.0
           WATER82        23.61           100.19
           WATER83        23.61            28.97
           WATER91         8.84             0.0
           WATER92         9.13             0.0
           WATER93         0.00             0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED        GENERATED
           MONTH  2      6640.89          1601.08
           MONTH  3     24047.57          7669.09
           MONTH  4      2193.62           687.30
           MONTH  5      4523.25          1238.59
           MONTH  6         0.0              0.0
           MONTH  7     26785.68          4189.24
           MONTH  8     27198.97          3775.95
           MONTH  9      8416.39          1512.99

CROPLAND                   ACRES           SHADOW
                          CROPPED          PRICE
                          139.65            0.0
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SUMMARY FOR YEAR 13

ACTIVITY LEVELS
 CORN502F      27.08    GRS0101F     27.08    GRS0202F      27.08
 GRS0301F      27.08    GRS0401F     13.95    WHET301F      18.94
 PPCORN33      27.08    PPGRS022     25.60    PPGRS031      38.89
 PPGRS032      18.90    PPGRS033     11.81    PPWHET92      18.94
 PPGRS032      18.90    PPGRS033     11.81    PPWHET92      18.94

IRRIGATION WATER        ACRE-FEET          SHADOW
                         PUMPED            PRICE
          WATER22         14.93              0.0
          WATER23          0.0               0.0
          WATER31         22.68            -3.43
          WATER32         11.03              0.0
          WATER33         22.68            -3.43
          WATER41          0.0               0.0
          WATER42          6.31              0.0
          WATER51          6.31              0.0
          WATER53          6.31              0.0
          WATER62          0.0               0.0
          WATER63          0.0               0.0
          WATER71         22.68             27.40
          WATER72          9.02              0.0
          WATER73         22.68            115.18
          WATER81          9.02              0.0
          WATER82         22.68            100.39
          WATER83         22.68             28.93
          WATER91          9.02              0.0
          WATER92         11.05              0.0
          WATER93          0.0               0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED         GENERATED
          MONTH  2       6722.39           1667.29
          MONTH  3      23840.53           7841.23
          MONTH  4       2678.60            864.76
          MONTH  5       5526.39           1560.32
          MONTH  6          1.69             -1.69
          MONTH  7      26322.54           4230.88
          MONTH  8      26740.82           3812.60
          MONTH  9       9515.50           1757.67

CROPLAND                   ACRES           SHADOW
                          CROPPED          PRICE
                          141.22             0.0
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SUMMARY FOR YEAR 14

ACTIVITY LEVELS
 CORN502F      27.61    GRSC101F      27.61    GRS0202F       27.61
 GRS0301F      27.61    GRSC401F      10.14    WHET301F       22.17
 PPCORN33      27.61    PPGRS022      25.63    PPGRS031       37.32
 PPGRS032      20.33    PPGRS033       9.70    PPWHET92       22.17
 PPGRS032      20.33    PPGRS033       9.70    PPWHET92       22.17

IRRIGATION WATER        ACRE-FEET         SHADOW
                         PUMPED           PRICE
          WATER22         14.95             0.0
          WATER23          0.0              0.0
          WATER31         21.77            -3.57
          WATER32         11.86             0.0
          WATER33         21.77            -3.57
          WATER41          0.0              0.0
          WATER42          7.38             0.0
          WATER51          7.38             0.0
          WATER53          7.38             0.0
          WATER62          0.0              0.0
          WATER63          0.0              0.0
          WATER71         21.77            27.16
          WATER72          9.20             0.0
          WATER73         21.77           115.28
          WATER81          9.20             0.0
          WATER82         21.77           100.48
          WATER83         21.77            28.85
          WATER91          9.20             0.0
          WATER92         12.93             0.0
          WATER93          0.0              0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED       GENERATED
          MONTH  2       6754.09         1739.68
          MONTH  3      23448.40         8026.42
          MONTH  4       3138.48         1056.33
          MONTH  5       6488.33         1901.29
          MONTH  6          2.56           -2.56
          MONTH  7      25686.57         4274.64
          MONTH  8      26108.71         3852.50
          MONTH  9      10552.53         2020.02

CROPLAND                  ACRES           SHADOW
                         CROPPED          PRICE
                          142.77            0.0
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SUMMARY FOR YEAR 15

ACTIVITY LEVELS
 CORN502F     28.21    GRSO101F     28.21    GRSO202F     28.21
 GRSO301F     28.21    GRSO401F      6.24    WHET301F     24.91
 PPCORN23      0.01    PPCORN33     28.21    PPGRSO22     25.63
 PPGRSO31     35.78    PPGRSO32     21.91    PPGRSO33      7.57
 PPWHET92     24.91    PPWHET93      0.00                  0.0

IRRIGATION WATER      ACRE-FEET          SHADOW
                       PUMPED            PRICE
          WATER22        14.95             0.0
          WATER23         0.00             0.0
          WATER31        20.87            -3.72
          WATER32        12.78             0.0
          WATER33        20.87            -3.72
          WATER41         0.0              0.0
          WATER42         8.29             0.0
          WATER51         8.29             0.0
          WATER53         8.29             0.0
          WATER62         0.0              0.0
          WATER63         0.0              0.0
          WATER71        20.87            43.09
          WATER72         9.39             0.0
          WATER73        20.87           113.39
          WATER81         9.39             0.0
          WATER82        20.87            98.60
          WATER83        20.87            35.88
          WATER91         9.39             0.0
          WATER92        14.53             0.0
          WATER93         0.00             0.0

ELECTRICITY
  FOR IRRIGATION      PURCHASED         GENERATED
          MONTH  2     6776.20           1817.33
          MONTH  3    23088.82           8240.39
          MONTH  4     3529.52           1237.62
          MONTH  5     7305.24           2229.04
          MONTH  6        0.63             -0.63
          MONTH  7    25061.42           4323.68
          MONTH  8    25488.67           3896.43
          MONTH  9    11470.23           2279.42

CROPLAND                  ACRES           SHADOW
                        CROPPED           PRICE
                         144.00            11.45
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SUMMARY FOR YEAR 16

ACTIVITY LEVELS
 CORN502F      29.11    GRSO101F      29.11    GRSO202F      29.11
 GRSO301F      29.11    GRSO401F       1.79    WHET301F      25.76
 PPCORN23       0.00    PPCORN33      29.11    PPGRSO22      25.56
 PPGRSO31      34.26    PPGRSO32      24.16    PPGRSO33       5.15
 PPWHET92      25.76                   0.0                     0.0

IRRIGATION WATER        ACRE-FEET           SHADOW
                         PUMPED             PRICE
          WATER22          14.91              0.0
          WATER23           0.00              0.0
          WATER31          19.98             -3.89
          WATER32          14.09              0.0
          WATER33          19.98             -3.89
          WATER41           0.0               0.0
          WATER42           8.58              0.0
          WATER51           8.58              0.0
          WATER53           8.58              0.0
          WATER62           0.0               0.0
          WATER63           0.0               0.0
          WATER71          19.98             41.65
          WATER72           9.69              0.0
          WATER73          19.98            113.73
          WATER81           9.69              0.0
          WATER82          19.98             98.93
          WATER83          19.98             35.32
          WATER91           9.69              0.0
          WATER92          15.03              0.0
          WATER93           0.0               0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED         GENERATED
          MONTH  2        6627.08           1891.44
          MONTH  3       23080.68           8532.75
          MONTH  4        3683.65           1333.35
          MONTH  5        7624.43           2409.57
          MONTH  6           3.06             -3.06
          MONTH  7       24657.50           4385.27
          MONTH  8       25090.52           3952.25
          MONTH  9       11999.71           2457.47

CROPLAND                    ACRES            SHADOW
                          CROPPED            PRICE
                           144.00             10.67
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SUMMARY FOR YEAR 17

ACTIVITY LEVELS
 CORN401F       1.54   CORN502F      29.49   GRSO101F      29.49
 GRSO202F      27.95   GRSO301F      27.95   WHET301F      27.58
 PPCORN23       0.00   PPCORN33      31.03   PPGRSO22      25.40
 PPGRSO31      32.79   PPGRSO32      25.44   PPGRSO33       1.76
 PPWHET92      27.58                  0.0                   0.0

IRRIGATION WATER        ACRE-FEET          SHADOW
                          PUMPED           PRICE
          WATER22          14.81             0.0
          WATER23           0.00             0.0
          WATER31          19.13           -4.07
          WATER32          14.84             0.0
          WATER33          19.13           -4.07
          WATER41           0.0              0.0
          WATER42           9.18             0.0
          WATER51           9.18             0.0
          WATER53           9.18             0.0
          WATER62           0.0              0.0
          WATER63           0.0              0.0
          WATER71          19.13            55.00
          WATER72          10.33             0.0
          WATER73          19.13            99.59
          WATER81          10.33             0.0
          WATER82          19.13           129.25
          WATER83          19.13            79.39
          WATER91          10.33             0.0
          WATER92          16.09             0.0
          WATER93           0.0              0.0

ELECTRICITY
  FOR IRRIGATION        PURCHASED        GENERATED
          MONTH   2       6803.08          1963.04
          MONTH   3      22660.69          8754.54
          MONTH   4       3940.12          1494.72
          MONTH   5       8176.51          2693.18
          MONTH   6          0.0              0.0
          MONTH   7      24267.55          4482.17
          MONTH   8      24709.90          4039.82
          MONTH   9      12889.12          2744.75

CROPLAND                   ACRES           SHADOW
                          CROPPED          PRICE
                          144.00            17.85
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SUMMARY FOR YEAR 18

ACTIVITY LEVELS
 CORN401F      4.11   CORN502F      29.52   GRSO101F      29.52
 GRSO202F     25.40   GRSO301F      25.40   WHET301F      30.05
 PPCORN23      0.00   PPCORN31       2.27   PPCORN33      31.35
 PPGRSO22     25.18   PPGRSO31      29.08   PPGRSO32      26.07
 PPWHET92     30.05                  0.0                   0.0

IRRIGATION WATER      ACRE-FEET        SHADOW
                        PUMPED         PRICE
           WATER22       14.69           0.0
           WATER23        0.00           0.0
           WATER31       18.29         -4.25
           WATER32       15.20           0.0
           WATER33       18.29         -4.25
           WATER41        0.0            0.0
           WATER42       10.01           0.0
           WATER51       10.01           0.0
           WATER53       10.01           0.0
           WATER62        0.0            0.0
           WATER63        0.0            0.0
           WATER71       18.29          54.25
           WATER72       11.20           0.0
           WATER73       18.29          99.53
           WATER81       11.20           0.0
           WATER82       18.29         129.89
           WATER83       18.29          79.68
           WATER91       11.20           0.0
           WATER92       17.53           0.0
           WATER93        0.0            0.0

ELECTRICITY
  FOR IRRIGATION      PURCHASED      GENERATED
           MONTH   2    6758.73        2036.05
           MONTH   3   22074.83        8930.80
           MONTH   4    4289.06        1703.06
           MONTH   5    8915.55        3068.70
           MONTH   6       0.0            0.0
           MONTH   7   23997.91        4609.21
           MONTH   8   24452.68        4154.44
           MONTH   9   14079.58        3122.22

CROPLAND                  ACRES         SHADOW
                        CROPPED         PRICE
                         144.00          17.49
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SUMMARY FOR YEAR 19

ACTIVITY LEVELS
 CORN401F     6.65   CORN502F    29.54   GRSO101F    29.54
 GRSO202F    22.89   GRSO301F    22.89   WHET301F    32.48
 PPCORN31     6.26   PPCORN33    29.93   PPGRSO22    24.96
 PPGRSO31    23.68   PPGRSO32    26.68   PPWHET92    29.93
 PPWHET93     2.55                0.0                 0.0

IRRIGATION WATER     ACRE-FEET         SHADOW
                      PUMPED           PRICE
          WATER22       14.56            0.0
          WATER23        0.0             0.0
          WATER31       17.46          -4.45
          WATER32       15.57            0.0
          WATER33       17.46          -4.45
          WATER41        0.0             0.0
          WATER42       10.82            0.0
          WATER51       10.82            0.0
          WATER53       10.82            0.0
          WATER62        0.0             0.0
          WATER63        0.0             0.0
          WATER71       17.46           53.49
          WATER72       12.05            0.0
          WATER73       17.46           99.47
          WATER81       12.05            0.0
          WATER82       17.46          130.52
          WATER83       17.46           79.96
          WATER91       12.05            0.0
          WATER92       17.46          -2.62
          WATER93        1.49            0.0

ELECTRICITY
  FOR IRRIGATION     PURCHASED      GENERATED
          MONTH  2     6712.59        2112.70
          MONTH  3    21477.59        9120.36
          MONTH  4     4629.49        1926.00
          MONTH  5     9635.07        3475.90
          MONTH  6        2.22          -2.22
          MONTH  7    23721.27        4747.12
          MONTH  8    24190.13        4278.26
          MONTH  9    15259.30        3527.62

CROPLAND                ACRES          SHADOW
                       CROPPED         PRICE
                        144.00          17.14
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SUMMARY FOR YEAR 20

ACTIVITY LEVELS
 CORN401F        9.14    CORN502F      29.57    GRSO101F       29.57
 GRSO202F       20.42    GRSO301F      20.42    WHET301F       34.88
 PPCORN23        0.00    PPCORN31      10.17    PPCORN33       28.54
 PPGRSO22       24.75    PPGRSO31      18.37    PPGRSO32       27.29
 PPWHET92       28.54    PPWHET93       6.34                    0.0

IRRIGATION WATER       ACRE-FEET             SHADOW
                        PUMPED               PRICE
           WATER22        14.44                0.0
           WATER23         0.00                0.0
           WATER31        16.65              -4.67
           WATER32        15.92                0.0
           WATER33        16.65              -4.67
           WATER41         0.0                 0.0
           WATER42        11.61                0.0
           WATER51        11.61                0.0
           WATER53        11.61                0.0
           WATER62         0.0                 0.0
           WATER63         0.0                 0.0
           WATER71        16.65              52.29
           WATER72        12.89                0.0
           WATER73        16.65              99.43
           WATER81        12.89                0.0
           WATER82        16.65             131.65
           WATER83        16.65              80.51
           WATER91        12.89                0.0
           WATER92        16.65              -2.75
           WATER93         3.70                0.0

ELECTRICITY
  FOR IRRIGATION       PURCHASED          GENERATED
           MONTH  2      6714.69            2197.76
           MONTH  3     21054.16            9325.03
           MONTH  4      4598.37            2170.43
           MONTH  5     10423.45            3914.15
           MONTH  6         2.21              -2.21
           MONTH  7     23613.70            4895.25
           MONTH  8     24096.74            4412.20
           MONTH  9     16547.61            3967.16

CROPLAND                   ACRES             SHADOW
                         CROPPED             PRICE
                          144.00              16.50
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YR.  IRR.  WATER  WELL   IRRIGATION FUEL     ELEC.   NET
    ACRES PUMPED YIELD *********************   SOLD RETURNS
                       PURCHASED WIND GEN.

  1  144.    203.  800.      80116.      15113. 74251. 12112.
  2  144.    203.  800.      81939.      15113. 74251. 11916.
  3  144.    203.  800.      83352.      15113. 74251. 11842.
  4  144.    203.  800.      84807.      15113. 74251. 11765.
  5  144.    203.  800.      86306.      15113. 74251. 11686.
  6  144.    203.  783.      87521.      15443. 73954. 11499.
  7  136.    210.  757.      91306.      16204. 73269. 11251.
  8  133.    214.  731.      94352.      17032. 72523. 10923.
  9  135.    215.  705.      95870.      17851. 71787. 10568.
 10  136.    216.  679.      97385.      18740. 70986. 10213.
 11  138.    217.  654.      98282.      19674. 70146.  9893.
 12  140.    218.  629.      99806.      20674. 69246.  9541.
 13  141.    219.  604.     101348.      21733. 68293.  9190.
 14  143.    220.  580.     102180.      22868. 67271.  8910.
 15  144.    221.  556.     102721.      24023. 66232.  8597.
 16  144.    219.  532.     102967.      24959. 65389.  8273.
 17  144.    219.  509.     103447.      26172. 64298.  7921.
 18  144.    221.  487.     104568.      27624. 62990.  7548.
 19  144.    223.  465.     105628.      29186. 61585.  7179.
 20  144.    224.  443.     107451.      30880. 60061.  6769.
PRESENT VALUE OF RETURNS AT  3% DISCOUNT RATE     151193.62
PRESENT VALUE OF RETURNS AT  5% DISCOUNT RATE     128842.50
PRESENT VALUE OF RETURNS AT 10% DISCOUNT RATE      91307.12
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APPENDIX D

PHYSICAL RESULTS FROM TEMPORAL ANALYSIS

Table D-1. Physical Results from Temporal Analysis[a] of a Wind Energy System: Southern High Plains, Farm Situation 2[b], Constant Electricity Price[c]

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Cotton	0	1	acres		28.80		28.80
Cotton	1	2	acres	37.33	32.86	37.33	32.86
Cotton	2	1	acres	25.34		25.34	
Cotton	2	2	acres	37.33	32.86	37.33	32.86
Grain Sorghum	4	1	acres		6.21		6.21
Cropland Shadow Price			dollars	256.50	179.41	254.33	173.81
Irrigation Characteristics:							
Well Yield			GPM	556	291	556	291
Number of Limiting Seasonal Water Periods			number	2	8	2	8
Range of Shadow Prices			dollars	3.31-237.51	67.75-231.58	5.38-237.51	30.41-268.91
Electricity:							
Required for Irrigation			KWH	47071	51783	47071	51783
Wind Generated			KWH	9154	15845		
Sold			KWH	50330	44307		

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 2 has initial saturated thickness of 175 feet, initial lift of 175 feet, 100 acres of cropland and a 40 KW wind machine.

[c] Constant electricity price of $.05 per KWH.

[d] Refers to the number of post-plant irrigations applied.

[e] Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.

Table D-2. Physical Results from Temporal Analysis[a] of a Wind Energy System: Southern High Plains, Farm Situation 4[b], Constant Electricity Price[c]

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Cotton	0	1	acres		20.01		20.01
Cotton	1	2	acres	53.76	61.99	53.76	61.99
Cotton	2	1	acres	36.49		36.49	
Cotton	2	2	acres	53.76	61.99	53.76	61.99
Cropland Shadow Price			dollars	254.09	226.72	251.83	224.51
Irrigation Characteristics:							
Well Yield			GPM	800	550	800	550
Number of Limiting Seasonal Water Periods			number	2	3	2	3
Range of Shadow Prices			dollars	3.29-234.89	65.03-228.93	5.44-234.89	27.69-266.27
Electricity:							
Required for Irrigation			KWH	76055	84352	76055	84352
Wind Generated			KWH	13735	18768		
Sold			KWH	75491	70961		

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 4 has initial saturated thickness of 225 feet, initial lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[c] Constant electricity price of $.05 per KWH.

[d] Refers to the number of post-plant irrigations applied.

[e] Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.

Table D-3. Physical Results from Temporal Analysis[a] of a Wind Energy System: Northern High Plains, Farm Situation 4[b], Constant Electricity Price[c]

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Corn	4	1	acres		9.14		9.14
Corn	5	2	acres	1.97	29.57	1.97	29.57
Grain Sorghum	1	1	acres	11.96	29.57	11.96	29.57
Grain Sorghum	2	2	acres	51.79	20.42	51.79	20.42
Grain Sorghum	2	3	acres	39.83		39.83	
Grain Sorghum	3	1	acres	1.97	20.42	1.97	20.42
Grain Sorghum	4	1	acres	36.49		36.49	
Wheat	3	1	acres		34.88		34.88
Cropland Shadow Price			dollars	2.21	16.50	2.78	10.90
Irrigation Characteristics:							
Well Yield			GPM	800	443	800	443
Number of Limiting Seasonal Water Periods			number	3	4	3	4
Range of Shadow Prices			dollars	2.81-91.90	52.29-131.65	4.28-93.28	48.88-141.86
Electricity:							
Required for Irrigation			KWH	95229	138331	95229	138331
Wind Generated			KWH	15113	30880		
Sold			KWH	74251	60061		

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 4 has initial saturated thickness of 225 feet, initial lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[c] Constant electricity price of $.05 per KWH.

[d] Refers to the number of post-plant irrigations applied.

[e] Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.

Table D-4. **Physical Results from Temporal Analysis[a] of a Wind Energy System: Southern High Plains, Farm Situation 4[b], Increasing Electricity Price[c]**

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Cotton	0	1	acres		20.01		20.01
Cotton	1	2	acres	53.76	61.99	53.76	61.99
Cotton	2	1	acres	36.49		36.49	
Cotton	2	2	acres	53.76	61.99	53.76	61.99
Cropland Shadow Price			dollars	254.09	195.47	251.83	189.39
Irrigation Characteristics:							
Well Yield			GPM	800	550	800	550
Number of Limiting Seasonal Water Periods			number	2	3	2	3
Range of Shadow Prices			dollars	3.29-234.89	6.19-171.42	5.44-234.89	13.10-177.62
Electricity:							
Required for Irrigation			KWH	76055	84352	76055	84351
Wind Generated			KWH	13735	18768		
Sold			KWH	75491	70961		

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[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 4 has initial saturated thickness of 225 feet, initial lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[c] Initial electricity price of $.05 per KWH and increasing by $.005 annually.

[d] Refers to the number of post-plant irrigations applied.

[e] Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.

Table D-5. Physical Results from a Temporal Analysis[a] of a Wind Energy System: Southern High Plains, Farm Situation 2[b], Increasing Electricity Price[c]

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Cotton	0	1	acres		28.09		28.13
Cotton	1	2	acres	37.33	32.87	37.33	32.92
Cotton	2	1	acres	25.34		25.34	
Cotton	2	2	acres	37.33	32.87	37.33	32.92
Cotton	Dryland		acres		5.31		6.02
Grain Sorghum	3	1	acres		0.86		
Cropland Shadow Price			dollars	256.50	89.48	254.33	89.48
Irrigation Characteristics:							
Well Yield			GPM	556	291	556	292
Number of Limiting Seasonal Water Periods			number	2	8	2	7
Range of Shadow Prices			dollars	3.31-237.51	14.73-180.04	5.38-237.51	21.85-195.33
Electricity:							
Required for Irrigation			KWH	47071	46318	47071	45445
Wind Generated			KWH	9154	14606		
Sold			KWH	50330	45423		

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 2 has initial saturated thickness of 175 feet, initial lift of 175 feet, 100 acres of cropland and a 40 KW wind machine.

[c] Initial electricity price of $.05 per KWH and increasing by $.005 per KWH annually.

[d] Refers to the number of post-plant irrigations applied.

[e] Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.

Table D-6. Physical Results from Temporal Analysis[a] of a Wind Energy System: Northern High Plains, Farm Situation 4[b], Increasing Electricity Price[c]

Item			Unit	With Wind Power		Without Wind Power	
				Year 1	Year 20	Year 1	Year 20
Crop Acreage:							
Crop	Post-Plants[d]	Rank[e]					
Corn	5	2	acres	1.97		1.97	
Grain Sorghum	1	1	acres	11.96	57.53	11.96	41.25
Grain Sorghum	2	2	acres	51.79	57.53	51.79	41.25
Grain Sorghum	2	3	acres	39.83		39.83	
Grain Sorghum	3	1	acres	1.97		1.97	16.63
Grain Sorghum	4	1	acres	36.49		36.49	
Grain Sorghum	Dryland		acres		28.94		44.88
Cropland Shadow Price			dollars	2.21	29.87	2.78	29.87
Irrigation Characteristics:							
Well Yield			GPM	800	510	800	513
Number of Limiting Seasonal Water Periods			number	3	3	3	2
Range of Shadow Prices			dollars	2.89-91.90	7.44-60.53	4.28-93.28	39.56-47.35
Electricity:							
Required for Irrigation			KWH	95229	73723	95229	68423
Wind Generated			KWH	15113	15684		
Sold			KWH	74251	73737		

[a] 1985 simulated crop prices (see Table 13) are used in all temporal analyses.

[b] Farm situation 4 has initial saturated thickness of 225 feet, initial lift of 200 feet, 144 acres of cropland and a 60 KW wind machine.

[c] Initial electricity price of $.05 per KWH and increasing by $.005 per KWH annually.

[d] Refers to the number of post-plant irrigations applied.

[e] **Refers to the relative yield ranking among all activities of the given crop and the given number of post-plant irrigations.**