8-1-1987

The Impacts of Alternative Electric Rate Structures for Irrigation: Cam-Wal REC

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THE IMPACTS
of
ALTERNATIVE ELECTRIC RATE STRUCTURES
FOR IRRIGATION

CAM-WAL REC

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Research Report 87-4

August 1987

ACKNOWLEDGEMENT

The author acknowledges with appreciation (1) the cordial and open discussions concerning electric rate structure pricing policies that he had in the process of undertaking the research with Roger Spiry, Manager, Cam-Wal Rural Electric Cooperative; (2) the invaluable services of Todd A. Lone in developing the linear programming model for the research project; (3) the care and competence shown by Lonna V. Walters, Sandra J. Oswald, and Rodney D. Kappes in running the programming model and performing subsequent calculations; (4) the constructive comments on an earlier draft of the manuscript by Ardelle A. Lundeen and Donald L. Peterson; and (5) the patience and competence shown by Verna Clark in typing the research report manuscript.

The responsibility for any errors of fact or interpretation in the report, of course, rests with the author.

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THE IMPACTS OF ALTERNATIVE ELECTRIC RATE STRUCTURES FOR IRRIGATION
CAM-WAL REC

SUMMARY AND CONCLUSIONS

In this research report, the impacts of alternative electric rates and rate structures for irrigation for the Cam-Wal Rural Electric Cooperative (REC) are evaluated. Consideration is given to both different levels and different forms of electric rate charges.

The alternative electric rate structures are evaluated in terms of the behavior of managers of hypothetical farms designed to represent two types of "typical" irrigator clients served by the REC: "low-lands" irrigators with 150 feet of water lift and "bluffs" irrigators with 300 feet of water lift. A linear programming model was developed to portray as fully as possible the technical, institutional, and economic features associated with the representative farms.

The managers of the representative farms are assumed to be able to make short-term farm enterprise and irrigation adjustments--as well as long-term changes in the numbers of and energy sources for their irrigation systems--in response to pre-season declared changes in electric rate structures for irrigation by the Cam-Wal REC electric power supplier. The specific types of irrigation adjustments considered are the use or non-use of two existing electric power center pivots, the conversion of the existing center pivots to diesel power, and the purchase of new electric or diesel powered irrigation systems for use on dryland.

The reference point in the linear programming analysis of the representative farms is the 1985 Cam-Wal REC electric rate structure for irrigation. The rate structure involves (1) a **monthly minimum** charge of $2.20 per nameplate horsepower during any of five monthly billing periods during the irrigation season when an irrigation system (pump) is not operated; (2) a **monthly demand** charge of $8.70 per kilowatt (kW) used per month, during each monthly billing period when an irrigation system (pump) is operated; and (3) a **three-step energy** charge involving 4.2 cents per kilowatt hour (kWh) for the first 100 kWh per kW per month, 3.7 cents per kWh for the next 200 kWh per kW per month, and 2.2 cents per kWh for all additional kWhs used.

The study's "baseline solutions" involve the modeling of each representative farm with the Cam-Wal REC actual electric rate structure for 1985 under two different types of situations. The first, involving irrigators with debt- versus equity-financed new irrigation equipment, is undertaken to determine the impacts of financial leveraging on irrigator behavior. The second, involving 1985 government grain commodity program, 1985 free market, or 1980 free market crop prices, is undertaken to determine the impacts of government program participation and different commodity price levels on irrigator behavior. Attention is given to expected electric power revenues received by the REC and levels of farm income earned by irrigators with normal precipitation, as well as the estimated range in year-to-year revenue/income associated with unusually heavy and light precipitation.

A series of electric rates and rate structures differing from those in 1985 is examined through linear programming analysis as follows: (1) electric energy (kWh) charges both lesser and greater than those assessed in 1985, which enables the estimation of derived demand functions for electric power to pump irrigation water, (2) greater and lesser "fixed" up-front monthly minimum and monthly demand and variable energy (kWh) charges, and (3) differently configured energy (kWh) block rates, namely, single-step, modified three-step declining, and three-step increasing block rates.

Major findings

1. In 10 of the 12 **baseline solutions** for the low-lands and bluffs representative farms, irrigated crop production is profitable. The irrigation systems, numbering up to six per farm and each involving corn production, are all electrically powered (i.e., diesel systems are not part of the baseline solutions). The enterprises common to all 12 baseline solutions are beef production (ranging from 42 to 125 beef brood cows and associated wintering calves), corn grain (130 - 780 acres), alfalfa (54 - 162 acres), oats (10 - 31 acres), and corn silage (4 - 12 acres). The last three crops are grown exclusively as livestock feed. In addition, either spring wheat (80 - 525 acres) or barley (462 - 767 acres) is grown as a cash crop in each solution.

2. The impacts of **150 feet of additional pumping lift on the bluffs farm** on the profitability of using already-present center pivot units and/or in investing in new irrigation systems are very considerable. For example, from one to six (including four newly purchased) center pivot systems can be profitably operated in the different low-lands farm baseline solutions. For the bluffs farm, on the other hand, one existing center pivot system is left idle in all six optimal (most profitable) baseline farm plans, and the other existing center pivot system is operated in only four of the six baseline solutions. Even so, in five of the six comparable baseline farming situations, the total annual payments for irrigation pumping energy are more on the bluffs farm than on the low-lands farm. The differences range from $4,400 to $25,900 per irrigator. This outcome reflects the 3.5 times greater energy requirement per acre-foot of water pumped associated with the 150 feet greater water lift on the bluffs farm.

The returns to operator labor and management on the bluffs farm are from $37,000 to over $50,000 less than for comparable baseline situations for the low-lands farm. These profit differentials arise primarily from (1) the $24,000 greater annual cost associated with the two existing center pivots on the bluffs farm and (2) a combination of the higher operating costs for the one center pivot that is used in some of the bluffs farm solutions and the need for the bluffs irrigators to pay monthly minimum charges on one or two idled center pivots, while being unable to reap the benefits of irrigated (versus dryland) production that their low-lands counterparts do.

Diesel systems are not profitable in any of the bluffs farm models examined. With higher electricity prices for the derived demand functions estimated for the low-lands farm, however, diesel systems replace part of the otherwise more profitable electric systems.

3. The solutions for irrigators who **finance newly purchased irrigation equipment with debt-capital rather than lower annualized cost equity-capital** sometimes differ--especially for the low-lands farm. Except for some tendency for more extensive irrigation by equity-financing irrigators, however, common patterns do not characterize the differences.

4. The impacts of **farmers participating in the 1985 government grain commodity program** on the economics of irrigation and the overall profitability of farming are considerable. The baseline study results show that in 1985 government program participants, in contrast with non-participants, (a) on the bluffs could afford to operate one rather than neither existing center pivot system, (b) on the low-lands with debt-financing could afford to operate both rather than only one of their existing center pivot systems, and (c) on the low-lands with equity-financing could afford to purchase four rather than no new irrigation systems. By participating in the government program, losses from farming are reduced between $8,400 and $25,300.

5. The short-term impacts of **unusual precipitation** on the Cam-Wal REC are expectedly the opposite of those on irrigators. With the baseline solutions, for example, unusually heavy precipitation results in a $830 to $2,500 reduction (8% to 10%) in REC electric power revenue per irrigator but a $12,600 to $37,200 increase in irrigator profits. With unusually light precipitation, on the other hand, REC electric power revenues per irrigator are $680 to $2,000 more, and irrigator profits are $13,500 to $47,500 less. These outcomes arise primarily because of a much greater impact of unusual precipitation on irrigators' dryland crop yields and income than on their irrigation electric power payments.

6. Results of the analysis on **derived demand functions** for electric power to energize irrigation pumps show that:

- Low-lands debt-financing irrigators would begin to cut back on electric energy use if electricity prices were to rise between 10 and 13 cents per kWh from the 1985 rate, and that they would totally shift away from electric power to pump irrigation water at 18 cents per kWh electricity;

- Low-lands equity-financing irrigators would totally stop using electric power for pumping at 8 cents per kWh; and

- Bluffs irrigators not participating in the government grain commodity program would find it profitable to operate one of their two existing center pivots if the average energy charge were to drop to 3 cents per kWh, but even with a price as low as 1 cent per kWh they would not find it profitable to operate their second existing center pivot unit.

7. The **"fixed" cost electric power components** (the monthly minimum and monthly demand charges) comprise between 68% and 75% of the total electricity costs for pumping irrigation water in the baseline solutions. Because of the need for an REC's capital assets to eventually be replaced, the relative importance of "fixed" costs does not generally diminish over time.

8. A one-at-a-time **doubling of the individual monthly minimum, monthly demand, and energy electric rate charges** results in either no change or a decrease in irrigation pumping and electric power usage. REC irrigation power revenues thereby increase in some instances, but decrease in just as many cases. The annual decreases in irrigator profits, from the doubled electric rate charges, relative to the respective baseline values, range from $1,000 to $10,000 for the low-lands farm and from $5,500 to $6,500 for the bluffs farm.

9. A one-at-a-time **75% reduction in the individual electric rate charges** results in either no change or an increase in irrigation pumping and electric power usage. REC irrigation power revenues either remain the same, or more often decrease (by as much as 57%). Irrigator profits increase with the reduced electric rate charges roughly to the same extent that they are reduced with the respective increased charges.

10. **The single-step, more steeply graduated three-step declining, and three-step increasing energy (kWh) block rates** examined have no effect on irrigation electric power and water usage in a majority of the circumstances examined. This includes all instances in which the 1985 "fixed" up-front electric rate components are retained in the rate structure. When the "fixed" up-front electric rate components are set at zero on the bluffs farm, however, the modified energy (kWh) block rates do induce changes in energy and water use. But the directions of impact are sometimes contrary to that expected.

Implications of findings to electric rate pricing policies

These findings have at least three direct implications to electric rate pricing policies.

1. The technical (e.g., feet of water lift), institutional (e.g., whether government grain commodity participants), and economic (e.g., whether debt- or equity-capital is used to finance the purchase of new irrigation equipment) circumstances facing different irrigators in the Cam-Wal REC service area strongly influence irrigator demand for electric power to energize irrigation pumps. For some farmers, the 1985 average energy cost of 3.8 to 3.9 cents per kWh was high enough to make the use of even existing irrigation systems unprofitable. For others, the electric energy cost could increase up to 8 cents per kWh before they would totally shift away from electric power to energize their irrigation pumps. For still others, the increase could be up to as much as 18 cents per kWh.

These findings show that any changes made by the Cam-Wal REC in electric energy (kWh) rates are likely to impact the quantity of electric power that will be purchased collectively by irrigators in the Cam-Wal REC service area. The findings also suggest that, with diesel fuel at $0.97 per gallon and even at considerably higher electrical energy (kWh) prices, some irrigators would likely remain as REC customers.

2. The short-run implications of unusual precipitation on REC revenues are expectedly the opposite of those on irrigator profits. If the negative impacts on irrigators from drought are great enough to force the irrigators out of business, however, both the irrigators and their "parent" RECs stand

to lose. Thus, a rate structure that provides for the sharing of risks between RECs and irrigators of unusual precipitation can be expected to be in the best long-term economic interests of both irrigators and RECs.

Two features of the current Cam-Wal REC electric rate structure for irrigation provide for the sharing of risks between irrigators and RECs during seasons of unusual pumping. The spreading of the "fixed" up-front costs over fewer kWhs results in higher average costs per kWh in years of unusually limited irrigation pumping. The three-stepped declining energy (kWh) block rate also results in higher average variable energy (kWh) costs with limited pumping. Conversely, when pumping during an irrigation season is unusually great, both features contribute to a below normal overall average cost per kWh for the electric power used by an irrigator.

3. The findings from this case study provide only limited support for the possibility of structural changes in electric pricing policies being used to effect desired changes in electric power use by irrigators.

For 27% of the hypothesized relationships, modified rate structures provide inducement for irrigators to make expected changes in electric power use to energize irrigation pumps. In 5% of the cases, changes contrary to expectations are induced. In the vast majority of cases (68%), irrigators show no response to the structural changes in electricity prices examined.

Thus, the study results show one positive and one negative finding on the use of structural changes in electric pricing policies for electricity use in irrigation. On the one hand, electric rate structure pricing policies can be used to impact effectively the sharing of revenue/income risks associated with unusually great or little irrigation pumping between irrigators and their parent RECs. On the other hand, the prospects of being able to effectively use policies for **structural changes** in electric rate structures to provide incentives for greater or lesser electric energy use by irrigators appear to be very limited. Changes in the **level** of electric energy charges, however, can definitely be expected to impact electric power use by irrigators.

INTRODUCTION

This is the fifth in a first-round series of five Economics Department reports on a research project, "The Economic Impact of Alternative Electric Rate Structures on Energy and Water Use", sponsored by the South Dakota Agricultural Experiment Station. Supplemental funding for the research was provided by the Western Area Power Administration (WAPA), Golden, Colorado.

The purpose of this report is to present the empirical results from the study of different electric rates and rate structures for irrigation for the Cam-Wal Rural Electric Cooperative (REC) in north central South Dakota. As a prelude to the presentation of results, abbreviated descriptions of the overall irrigation electric rate structure research project and the Cam-Wal REC representative farm models used in the research are provided.

The initially presented results--termed the "baseline solutions"--involve the modeling of the representative farms with the actual electric rate structure for irrigation used in 1985 by the Cam-Wal REC. The next group of results shows the impacts of variable energy [kilowatt hour = kWh] charges that are both lower and higher than those assessed in 1985 on the prospective demands for electric power and water for irrigation. The results for two types of alternative rate structure analysis are then presented. These involve greater and lesser "fixed" up-front and variable energy charges and differently configured energy (kWh) block rates. The impacts of unusually heavy and light precipitation on REC power sales and revenues and irrigator profits are also covered.

The other reports in this research report series are as follows:

- No. 1, Enterprise Budgets and Other Data-Sets; Electric Rate Structure-Irrigation Study; Clay-Union, Union, Cherry-Todd, and Cam-Wal RECs;

- No. 2, Mixed Integer Linear Programming Model; Electric Rate Structure-Irrigation Study; Clay-Union, Union, Cherry-Todd, and Cam-Wal RECs;

- No. 3, The Impacts of Alternative Electric Rate Structures for Irrigation, Clay-Union and Union RECs; and

- No. 4, The Impacts of Alternative Electric Rate Structures for Irrigation, Cherry-Todd REC.

A casual reader can expect to find this report to stand on its own. Readers with a more serious interest in the empirical findings in this report, however, will find it helpful to consult Reports 1 and 2 for detailed information on the data-sets and modeling used in the study. Where linkages between this and the other reports are particularly strong, references are made parenthetically to pertinent sections from the prior reports.

OVERVIEW OF THE RESEARCH

About 80% of South Dakota's irrigation pumps are energized by electricity. The high cost and under-utilization of recently developed, coal-based electric power generation facilities have resulted in increased wholesale costs of electric power and, in turn, in higher electric rates for irrigators and other electric power consumers. Operating within an already financially-stressed agriculture, RECs that supply electricity to irrigators are exploring possible revisions to rate structures for the mutual benefit of the RECs and their members.

The research results reported in this publication show the impacts of alternative electric rates and rate structures on (1) the demands for power to energize irrigation pumps and for irrigation water and (2) expected levels of irrigator farm income and REC electric power revenue. Special analytic attention is given to different levels of commodity prices, debt- versus equity-financed irrigation equipment, and both average income/revenue levels and the estimated range in year-to-year income/revenue associated with unusually heavy and light precipitation.

What represents a "most appropriate" irrigation electric rate structure for one REC may not be most appropriate for another. A host of rather location-specific factors determines what is most appropriate. These factors include (1) average amounts of and year-to-year variations in precipitation and solar radiation (as these impact amounts of irrigation water that must be pumped), (2) the lift and source of pumped water, (3) the nature of soils and topography, (4) the spectrum of potentially profitable farm enterprises, (5) the internal financial structure of an REC, (6) the importance of irrigation relative to other sectors in an REC's power sales, and (7) the philosophic positions of an REC's manager and governing board. Taking into account the first four factors, study sites in four different South Dakota RECs were selected for separate study and analysis. In selecting the RECs and study sites within their respective service areas, efforts were made to cover as wide a range as possible of conditions for each of the four factors.

The study sites for the four selected RECs and a brief description of their attributes, relative to the four selection criteria, are as follows (for more details, see pp 3-6 and Figures 1 and 2 in Report 1):

- Cam-Wal REC, irrigated area south of Mobridge and just east of the Missouri River in Walworth County,

*Precipitation--lowest of the study sites,

*Pump lift from the Missouri River--about 150 ft for the "low-lands" research site and 300 ft for the "bluffs" research site,

*Soils--generally heavy, with an undulating topography, which precludes "low pressure" water distribution, and

*Farm enterprises--cow-calf operations and the widest range of crops for any study site, including corn, alfalfa, small grains, and annual forages (corn silage, sorghum sudan pasture);

- Clay-Union REC, irrigated area east of Vermillion and south of Route 50 in Clay County,

*Precipitation--relatively high and stable from year to year, *Pump lift--shallow ground water (about 25 ft of lift is common),

*Soils--light and low-lying, and

*Farm enterprises--mainly corn and soybeans, but some hog farrowing-finishing, small grains, and alfalfa as well;

- Union REC, irrigated area primarily east of Elk Point and just west of the Big Sioux River, but also extending along the north side of Route 29 north of Elk Point to Route 50,

*Precipitation and pump lift--similar to the Clay-Union REC,

*Soils--heavy, with some areas having sufficiently flat topography to permit gated pipe irrigation, and

Farm enterprises--similar to the Clay-Union REC, except for fewer hog enterprises and more limited alfalfa production; and

- Cherry-Todd REC, irrigated area south of a line roughly between St. Francis and Olsonville to the southern border in Todd County,

*Precipitation--limited,

*Pump lift--deep ground water (about 130 ft of lift is common),

*Soils--light, sandy, well-drained to excessively drained, and

*Farm enterprises--somewhat narrow range, with cow-calf enterprises, corn, alfalfa, and oats being most common.

In this report, the results from the study for the Cam-Wal REC are presented. In Reports 3 and 4, the results for the Clay-Union, Union, and Cherry-Todd RECs are presented. Subsequent publications will cover more generalized findings based on the results for all four RECs. In those publications, the overall implications of the study's findings for the four RECs to the formulation of electric rate pricing policies for irrigation will be stressed.

REPRESENTATIVE FARM MODEL ANALYSIS

To accomplish the purpose of the research, two hypothetical farms were identified to represent "typical" irrigator clients served by the REC: a "low-lands" farm with 150 feet of water lift from the Missouri River and a "bluffs" farm with 300 feet of water lift. The added pumping energy requirement associated with the greater water lift on the bluffs farm implies well over twice the investment in irrigation equipment and over 3.5 times the energy for pumping water (see p 17 and Tables 17 and 18 in Report 2). Otherwise, the nature of the two representative farms is identical. A linear programming model was developed to portray as fully as possible the technical, institutional, and economic features associated with the representative farms (for a detailed description of the model, see Report 2).

Nature and role of representative farms in the research

The representative farm models are intended to reflect conditions on typical irrigated farms with above-average management in the Cam-Wal REC service area in 1985. Irrigator farm managers are assumed to be able to make short-term farm enterprise and irrigation adjustments in response to preseason declared changes in electric rates and rate structures for irrigation by their REC electric power supplier. They are also assumed to be able to make changes in irrigation technology (namely, shifting from electric to diesel power sources and/or purchasing new irrigation systems) which have long-term implications to farm resource use. Thus, while the models involve only a single production period, a longer term (7 to 15 years) decision-making planning horizon is envisioned for the managers of the representative farms.

The representative farms are assumed to already be in operation. They have 260, 490, and 750 acres of irrigated cropland, non-irrigated cropland, and rangeland, respectively, and generally adequate machinery and equipment, farm buildings, and a breeding herd to make economic use of the land. The available machinery and equipment includes two electric power, high pressure center pivot systems (for more details on the assumed availability of resources and the constraints on resource use for the representative farms, see pp 19-20 and Tables 26 and 26 in Report 1 and pp 7-8 in Report 2).

Electric rate structures examined

In 1985, the electric rate structure for irrigation for the Cam-Wal REC contained provisions for monthly minimum, monthly demand, and three-step declining block rate charges. The specific provisions of the rate structure are as follows:

- Monthly minimum charge: $2.20 per nameplate horsepower (HP) payable for each of the five monthly billing periods when an irrigation system (irrigation pump) is not used;

- Monthly demand charge: $8.70 per kW used per month, during each monthly billing period when an irrigation system (pump) is operated;

- Energy charges:

  * First-step, 4.2 cents per kWh for the first 100 kWh per kW per month;

  * Second-step, 3.7 cents per kWh for the next 200 kWh per kW per month; and

* Third-step, 2.2 cents per kWh for all additional kWh.[1]

This is the "baseline" electric rate structure used in the study. A series of electric rates and rate structures differing from that in 1985 was also examined, as follows:

- Estimated demand for electric power to pump irrigtion water, with per kWh charges both higher and lower than those assessed in 1985;

- Higher and lower "fixed" up-front (monthly minimum and monthly demand) and variable energy electric rate charges; and

- Differently configured block rates, namely, single step, modified three-step declining, and three-step increasing energy (kWh) block rates.

Using the linear programming model, optimal (most profitable) solutions for the representative farms with the 1985 electric rate structures were first determined. The results of this analysis show the most profitable farm enterprises, irrigation technologies, and amounts of electric power use and electric power revenue for irrigation pumping, and the return to operator labor and management for each representative farm situation. Most profitable farm plans were then determined for each of these electric rate and rate structure alternatives. The conclusions of the study are based on a comparison of the farm organization, energy use, electric power revenue, and irrigated farm profit features of these various plans.

Irrigation alternatives considered

Several options are open to irrigators in responding to different electric rates and rate structures. In the study of electric rate structures for irrigation for the Cam-Wal REC, three irrigation alternatives were considered. The alternatives and the underlying rationale for including each in the study are as follows (for added detail covering these alternatives, see pp 14-16 and Tables 17 and 19 of Report 1 and pp 8-11 of Report 2).

The use or non-use of two existing, electric power, high pressure [a pivot pressure of about 75 pounds per square inch] center pivots. An important practical question is whether energy prices are so high (relative to commodity price levels) that farmers should no longer use irrigation systems already present on their farms. Thus, one objective of the analysis is to determine how high electric power rates can rise before it becomes uneconomic to use existing electrically powered pumps to lift and distribute irrigation

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[1] The two suppliers of electric power to the Rushmore Electric Power Cooperative--which in turn supplies electric power to the Cam-Wal REC--are the Western Area Power Authority (WAPA) and the Basin Electric Power Cooperative. During 1985 and 1986; Basin Electric granted a 2 cents per kWh credit on all electric power used for irrigation. This credit was passed "down the line" to irrigators. The impact of the Basin credit on irrigators served by the Rushmore Electric Power Cooperative is 1.3 cents per kWh; the energy charges shown in the text take into account this Basin credit. The irrigator credit is less than 2 cents per kWh because some of the electric power supplied to Rushmore is from WAPA.

irrigation water.[2]

Conversion of existing center pivots to diesel power

In response to rising electric power rates, irrigators may find it economic to convert their existing electrically powered irrigation systems to diesel power. The economic question is whether prospective energy cost savings from diesel power will more than offset the annualized costs of converting existing equipment from electric to diesel energy sources. The representative farm analysis is structured so as to enable a determination of how high electric rates can rise before it becomes economic for irrigators to substitute diesel fuel for electricity to energize irrigation pumps.

The purchase of new irrigation systems. A further practical question is whether irrigators can economically convert more land to irrigation. Provision is made in the model for the purchase of either electric or diesel powered new center pivot systems for use on dryland. Provision is also made for renting up to 300 acres of additional dryland at $20 per acre.

Financing the purchase of new irrigation equipment with debt- versus equity-capital

Irrigation systems represent multi-period inputs. In economic analysis, the investments required for purchasing them need to be spread out (i.e., amortized) over a number of years. Two types of amortization can be undertaken.

A "financial" type of amortization pertains to debt-financed purchases. The most commonly reported method for debt-financed irrigation system purchases in South Dakota is via a lease-purchase program involving an initial downpayment of 15.5%, six annual payments of 15.7% each, and a terminal "buy-out" payment of 10% of the purchase price. The debt repayment for converting electric power systems to diesel power is commonly amortized over four years, while the smaller investments for converting from high to low pressure water distribution are commonly amortized over two years.

An "economic" type of amortization reflects a longer-term, equity-capital (i.e., farmer-owned capital or savings), economic-profit perspective in which no attention is paid to debt repayment terms. The number of years and interest rate used in this type of amortization reflect a long-term opportunity cost investment perspective of the decision-maker. In this study, the "economic" amortization of investment costs was assumed to extend over 15 years.

The annualized "financial" costs of investing in new irrigation systems in the Cam-Wal REC service area are 1.3 times higher than the corresponding annualized "economic" costs (for more detail, see pp 15-16 and Table 17 in

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[2]Unless the existing electrically powered center pivot systems are converted to diesel power (see the next para), the model requires the payment of the monthly minimum charges no matter whether the systems are used or not.

Report 1).[3] This outcome arises primarily because of a shorter amortization period (7 versus 15 years), and also because of the somewhat higher interest rate implicit in the lease-purchase terms. These cost differences imply that the most rational behavior of irrigators who purchase new irrigation equipment with equity-capital may be different from that for irrigators who have to meet the schedule of debt-repayments associated with recently or newly purchased irrigation equipment financed by debt-capital.

Commodity price assumptions

The farm enterprise budgets used in analysis were developed using 1985 input prices, insurance rates, custom rates, wage rates, and capital costs. In most of the alternative electric rate and rate structure scenarios, it was assumed that the representative farm managers participated in the 1985 government price support program and therefore received full price support payments. The government grain commodity program prices used in the representative farm analysis reflect the 1985 seasonal average "free market" prices--as reported by the South Dakota Agricultural Statistical Service and the U.S. Department of Agriculture--plus the government deficiency payments (Table 1).[4]

To obtain some idea of the impact of different levels of commodity prices, in part of the analysis 1985 government program non-participant free market and 1980 free market crop prices were also used. The 1985 free market prices are 17% less (corn grain) to 24% less (spring wheat) than the government program crop prices. The 1980 free market prices, in "real" (inflation-adjusted) 1985 terms, range from 12% less (spring wheat) to 22% more (barley) than the government program crop prices.

Gross profit maximization

Solving the linear program representative farm models involved selecting the combination of crop and livestock production enterprises and irrigation technologies that would maximize the farm's "gross profit", where "gross profit" is defined as the difference between gross revenue and the variable costs of farm production. The variable costs of farm production are those which could be avoided if production were to be stopped. These include out-of-pocket production costs (e.g., for fertilizer, tractor fuel, land rent) and the annualized costs of newly purchased irrigation equipment.

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[3]The annualized "financial" ownership costs represent the present value of the series of payments to meet the terms of the lease-purchase agreement--expressed on an annual basis. The annualized "economic" ownership costs represent the present value of a series of payments amortized over 15 years at 11% interest to offset the purchase price of irrigation systems. The payment factors for the annualized "economic" and "financial" ownership costs are 0.14 and 0.21, respectively.

[4]To avail of the government deficiency payments in 1985, farmers were required to set-aside 30% of their base wheat acreage and 10% of their base corn, oats, and barley acreages. Adjustments to the total owned and rented acreages, consistent with these set-aside requirements, were made in the process of determining the optimal solution for each model run. A cost of $15 per acre was assumed for controlling weed growth on the set-aside area.

Table 1. Farm gate 1985 government program, 1985 free market, and 1980 free market crop prices; Cam-Wal REC service area.

Crop	Unit	1985 government program prices ($)	1985 free market prices: Dollars	1985 free market prices: As a ratio to the 1985 government program prices	1980 free market prices: In 1985 dollars	1980 free market prices: As a ratio to the 1985 government program prices
Spring wheat	bu	4.58	3.50	0.76	4.05	0.88
Corn grain	bu	2.84	2.36	0.83	2.93	1.03
Oats	bu	1.56	1.27	0.81	1.68	1.08
Barley	bu	2.34	1.82	0.78	2.85	1.22
Alfalfa	ton	n/a	45.00	n/a	48.00	n/a

The gross profits determined in the computer-based optimal solutions were adjusted to cover the annual costs of (1) the existing resources on the farm and (2) the weed control on set-aside areas. The annualized costs associated with the existing land, farm machinery and equipment, and livestock-related resources for the Cam-Wal REC low-lands and bluffs representative farms are $79,000 and $103,000, respectively. These costs differ by the $24,000 difference in the annualized costs for owning two center pivot systems on the bluffs farm compared to the low-lands farm (see p 20 and Table 26 of Report 1 and pp 6 and 7 of Report 2 for added detail). As indicated in the prior footnote, a charge of $15 per acre was assumed for controlling weed growth on the set-aside area. The resulting "net profit" thereby calculated for each model run represents the return to the irrigator's labor and management.

Unusual precipitation

In years of unusually heavy precipitation, farmers pump less irrigation water. Other things the same, this impacts REC irrigation revenues negatively, and irrigator profits positively. In years of unusually light precipitation, the implications are the converse. Examining the impacts on REC revenues and irrigator profits of unusually heavy and light precipitation is, therefore, one analytic focal point in the study.

The mean May-September precipitation level over the past 31 years at the Mobridge weather station--which serves as the precipitation reference point for the Cam-Wal REC service area--is 11.2 inches. To determine pertinent levels of unusually heavy and unusually light precipitation to use in analysis, the yearly May-September precipitation amounts were arrayed from smallest to largest. "Unusually heavy precipitation" was defined to represent an amount exceeded in no more than one to three years out of the 30-34 years for which data were available for each of the four REC service areas.[5] An analogous procedure was followed to determine the "unusually light precipitation" level. Resulting from the application of this general procedure was the identification of 17.4 and 6.7 inches to represent May-September unusually heavy and light precipitation, respectively, for the Cam-Wal REC service area.

It was assumed in analysis that representative farm managers had already made their farm organizational plans and planted their crops based on normally expected precipitation. Selected most profitable solutions for the representative farms which were based on normally expected precipitation, thus, became the reference point for examining the impacts of unusually heavy and light precipitation. The examination was via partial budgeting, with joint attention to:

- The reduced (increased) irrigation system (a) pumping and (b) repair and maintenance costs resulting from reduced (increased) irrigation water application rates;

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[5]The years of available precipitation data for the different reference point weather stations in the study range from 30 to 34. The unusually heavy and light precipitation levels were determined in relation to natural break-points among the one to three years of both heaviest and lightest annual precipitation.

- The increased (reduced) dryland crop yields; and

- The increased (reduced) costs of drying and storing the increased (reduced) dryland crop production output associated with unusually heavy (light) precipitation (see pp 13-14 and Tables 11 and 12 in Report 1 for added detail).

BASELINE SOLUTIONS

The baseline solutions involve the modeling of the representative farms with the actual electric rate structure for irrigation used by the Cam-Wal REC in 1985. Both the low-lands and bluffs farms were examined under the following conditions: either debt- or equity-financed new irrigation equipment and either participants or non-participants in the 1985 farm program or with 1980 free market farm crop prices. An overview of the results for the 12 baseline solutions is first presented. Attention is then given to contrasting results, in turn, for the low-lands versus bluffs representative farms, irrigators with debt- versus equity-financed new irrigation equipment, and irrigators faced with different farm crop price situations.

Overview of results

In 10 of the 12 baseline solutions for the two representative farms (Tables 2 and 3), irrigated crop production is profitable. The irrigation systems, numbering up to six per farm, are all electrically powered (i.e., diesel systems are not part of the baseline solutions). The irrigator payments for irrigation pumping energy (which, in turn, become irrigation revenues to the REC) range from about $4,400 to $25,900 per irrigator per season.

The maximum of 300 acres of dryland is rented in all 12 baseline solutions. The crops common to all 12 solutions are corn grain (ranging from 130 acres to 780 acres per farm), alfalfa (54 - 162 acres), oats (10 - 31 acres), and corn silage (4 - 12 acres). The last three crops are grown exclusively as livestock feed. Either spring wheat (80 - 525 acres) or barley (642 - 767 acres) is grown as a cash crop in each solution. In those solutions involving 125 beef brood cows and associated wintering calves, 62 acres of sorghum-sudan pasture are also grown. In 8 of the 12 most profitable solutions, however, herds of only 42 or 94 beef brood cows can be economically maintained on the farms. Herd size differences arise because of differences, in various solutions, in the competitiveness of wheat and barley relative to livestock forages.

The returns to operator labor and management from farming in 9 of the 12 solutions are strongly negative (ranging from about - $13,200 to -$63,400). The only baseline solutions not involving losses are for the low-lands farm with 1980 free market crop prices in which the return for the operator's labor and management is roughly $20,000.

Low-lands versus bluffs farms

The optimal solutions for the low-lands farm differ greatly from those for the bluffs farm. From one to six center pivot systems can be profitably

Table 2. Baseline solutions; irrigators with debt- versus equity-financed new irrigation equipment; 1985 government program, 1985 free market, and 1980 free market crop prices; Cam-Wal low-lands representative farm.

	1985 government program prices[a]		1985 free market prices		1980 free market prices (in 1985 dollars)	
	Debt-financing	Equity-financing	Debt-financing	Equity-financing	Debt-financing	Equity-financing
<u>Resource acquisition</u>						
New center pivot systems purchased	0	4	0	0	0	2
Dryland rented (acres)	300	300	300	300	300	300
<u>Irrigated production (acres)</u>						
Corn grain	260	780	130	130	260	520
<u>Dryland production (acres)</u>						
Spring wheat	484	80	328	328	0	0
Corn grain	0	0	325	325	0	0
Oats	10	10	31	31	10	10
Barley	0	0	0	0	722	462
Alfalfa	54	54	162	162	54	54
Corn silage	4	4	12	12	4	4
Sorghum-sudan pasture	0	0	62	62	0	0
Total	552	148	920	920	790	530
<u>Cow-calf beef production and associated calf wintering (brood cows)</u>	42	42	125	125	42	42
<u>Electric power used for irrigation</u>						
Total cost ($)	8,623	25,869	5,466	5,466	8,623	17,246
Total kWh	71,687	215,062	35,844	35,844	71,687	143,375
Average cost per kWh (cents)	12.0	12.0	15.3	15.3	12.0	12.0
<u>Irrigation water used (acre-feet)</u>	158	474	79	79	158	316
<u>Return to operator labor and management ($)</u>	-13,165	-1,185	-26,500	-26,500	19,835	21,000

[a]The government grain commodity program acreage set-asides associated with the corn, wheat, and oats in the baseline solutions for the debt- and equity-financing situations are 238 and 122, respectively.

Table 3. Baseline solutions, 1985 government program, 1985 free market, and 1980 free market crop prices; Cam-Wal bluffs representative farm[a].

	1985 government program prices[b]	1985 free market prices	1980 free market prices (in 1985 dollars)
Resource acquisition			
New center pivot systems purchased	0	0	0
Dryland rented (acres)	300	300	300
Irrigated production (acres)			
Corn grain	130	0	130
Dryland production (acres)			
Spring wheat	525	303	0
Corn grain	0	480	0
Oats	23	31	23
Barley	0	0	767
Alfalfa	121	162	121
Corn silage	9	12	9
Sorghum-sudan pasture	0	62	0
Total	678	1,050	920
Cow-calf beef production and associated calf wintering (brood cows)	94	125	94
Electric power used for irrigation			
Total cost ($)	18,568	7,739	18,568
Total kWh	130,108	0	130,108
Average cost per kWh (cents)	14.3	n/a	14.3
Irrigation water used (acre-feet)	79	0	79
Return to operator labor and management ($)	-54,980	-63,420	-22,465

[a]For each crop price situation, the debt-financing baseline solution is identical to the equity-financing baseline solution.

[b]The government grain commodity program acreage set-aside associated with the corn, wheat, and oats in the baseline solution is 242.

operated in the six different situations examined for the low-lands farm. For the bluffs farm, on the other hand, one existing center pivot system is left idle in all six most profitable farm plans, and the other existing center pivot system is operated in only four of the six situations examined. Even so, in five of the six comparable farming situations, the total payment for irrigation pumping energy is more on the bluffs farm than on the low-lands farm. This outcome reflects the 3.5 times greater energy requirement per acre-foot of water pumped that is associated with the greater water lift (300 ft versus 150 ft) for the bluffs farm compared to the low-lands farm.

With the 1985 government program and 1980 free market prices, the beef cow-calf and associated calf wintering activities are larger on the bluffs than on the low-lands farm (94 versus 42 brood cows). Even so, the returns to operator labor and management for comparable situations on the bluffs farm are between $37,000 and $50,000 less than for the low-lands farm. These profit differentials arise from (1) the $24,000 larger annual cost associated with the two existing center pivots on the bluffs farm and (2) the need for the bluffs irrigators to pay monthly minimum charges on their two existing center pivots, while being unable to reap the benefits of irrigated (versus dryland) production that their low-lands counterparts do.

Debt- versus equity-capital for purchasing new irrigation equipment

For all three crop price situations for the bluffs farm and for the 1985 free market price situation for the low-lands farm, the debt-financing baseline solutions are identical to the respective equity-financing baseline solutions. With the 1985 government program and 1980 free market crop prices, on the other hand, the solutions for the low-lands farm with the equity-financed new irrigation equipment are substantially different from those with debt-financed irrigation equipment.

The point of greatest difference concerns the purchase of new center pivot systems. The annualized costs of debt-financed center pivots are high enough to make unprofitable the investment in new irrigation systems. With the relatively lower annualized costs of equity-financed center pivots, however, the equity-financing irrigator finds it profitable to invest in either two or four new center pivot systems. As a result, the equity-financing irrigator uses 2.0 to 3.0 times as much electric power to energize his irrigation pumps as his debt-financing counterpart. Finally, the return to labor and management for the debt-financing irrigator is between $1,200 and $12,000 less than for the equity-financing irrigator.

Different farm crop price situations

As indicated above, the 1985 free market crop prices are 17% less (corn grain) to 24% less (spring wheat) than the 1985 government program prices. These price differences have major influences on the extensiveness of irrigation, the enterprise mix, and the return to irrigator labor and management in the optimal solutions.

For example, with the lower 1985 free market crop prices, (1) the bluffs irrigators can no longer afford to operate either existing center pivot system, (2) the debt-financing low-lands irrigator idles one of his two existing center pivots, and (3) the equity-financing low-lands irrigator cuts back from six to two center pivots. Coupled with this reduction in irrigation is a reduction in the wheat acreage for three of the four comparable pairs of solutions. The enterprises which expand, on the other hand, are dryland corn, beef, and the oats and forages (alfalfa, sorghum-sudan pasture, and corn silage) associated with the beef enterprise. Finally, with the lower 1985 free market prices, the reductions in irrigator profits range from about $8,400 to $25,300.

The inflation-adjusted 1980 crop prices, except for spring wheat, are higher than the 1985 government program prices. The difference is the greatest for barley (22% higher in 1980). By far the dominant change with 1980 crop prices in farm enterprises is the substitution of barley for wheat. Also, in one of the four comparable solutions, two fewer center pivots with corn are economic with the 1980 crop prices. Associated with the higher 1980 crop prices are increases in the return to labor and management ranging from $22,200 to $32,500 per irrigator.

UNUSUALLY HEAVY OR LIGHT VERSUS NORMAL PRECIPITATION

In the part of the analysis described now, the impacts on the baseline solutions of unexpected precipitation during the irrigation season are examined. The irrigators are assumed to have (1) based their farm plans on normal precipitation, (2) planted their crops in the spring, and (3) followed fertilization, plant protection, and other cultural practices in accordance with expected yields based on normal precipitation. As the crop season unfolds, however, precipitation is assumed to depart from the normal and to be either unusually heavy (reaching a level experienced during only 3 to 10 years out of 100 years) or unusually light (again, a 3 to 10 out of a 100 year occurrence).[6] This is presumed to result in reduced (increased) irrigation requirements for irrigated crops and higher (lower) yields for dryland crops.

For each representative farm with 1985 commodity prices and for both the debt- and equity-financed new irrigation equipment situations, the impacts of unusual precipitation on the amount of irrigation water pumped, the amount of electricity used for pumping irrigation water, the irrigation power revenues received by RECs, and the return to operator labor and management were determined (Figures 1 and 2). The middle histogram-bars in the panels comprising the two figures reflect outcomes with normal precipitation; these are termed 100%-level outcomes. The left histogram-bars reflect outcomes with unusually heavy precipitation, and the right bars outcomes with unusually light precipitation. The percentages shown at the top of the bars indicate unusually heavy and light precipitation outcome values relative to the respective normal precipitation values.

With unusually heavy precipitation, the acre-feet of irrigation water pumped and the kWh of electricity for pumping irrigation water in each farming situation both decrease by 30%. Because of the "fixed" up-front electric rate charges, payments for electrical pumping energy decrease by only 8% to

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[6] This reflects the one to three year cut-off points for unusually heavy and light precipitation that were identified relative to the 30-34 years of available precipitation data for the reference point weather stations in the study.

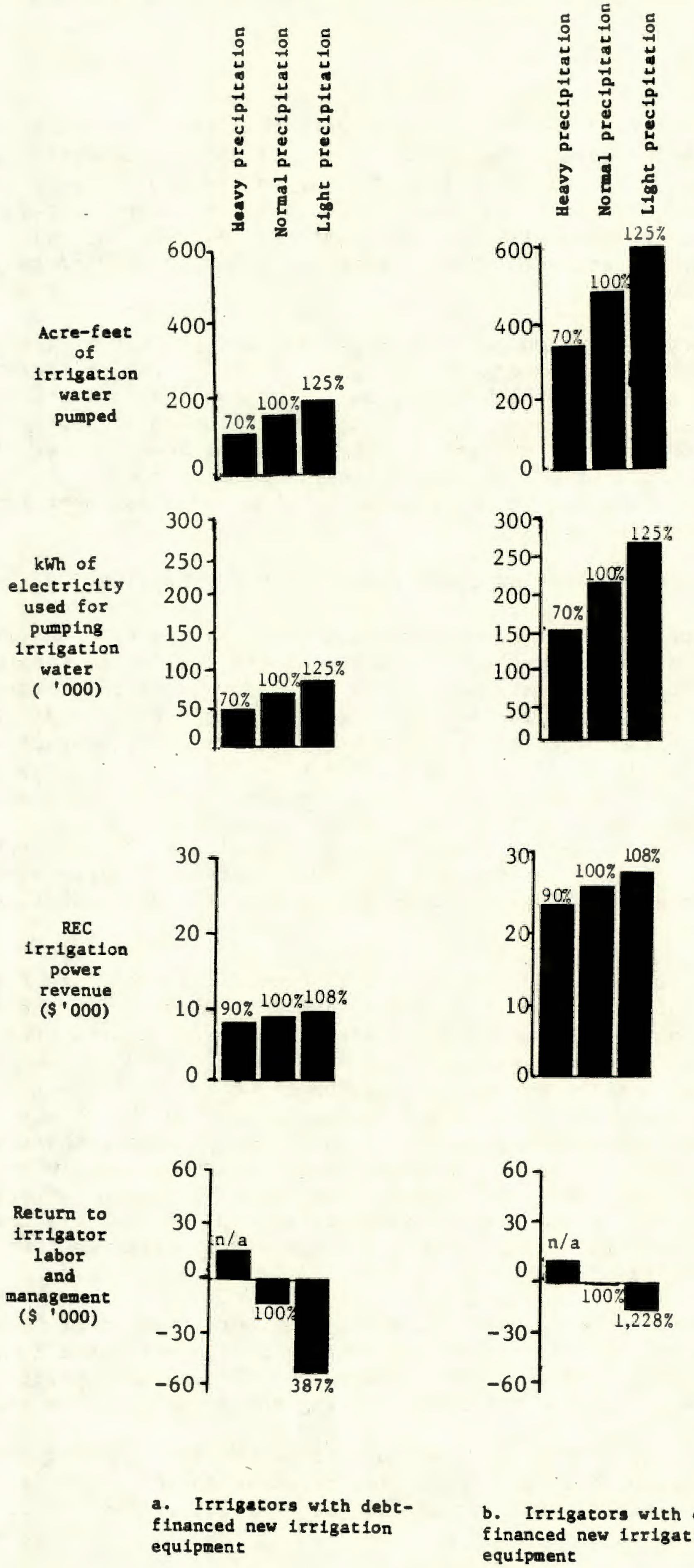

Figure 1. Impacts of unusual precipitation, baseline solutions with 1985 government program crop prices, irrigators with debt- versus equity-financed new irrigation equipment, Cam-Wal REC low-lands representative farm.

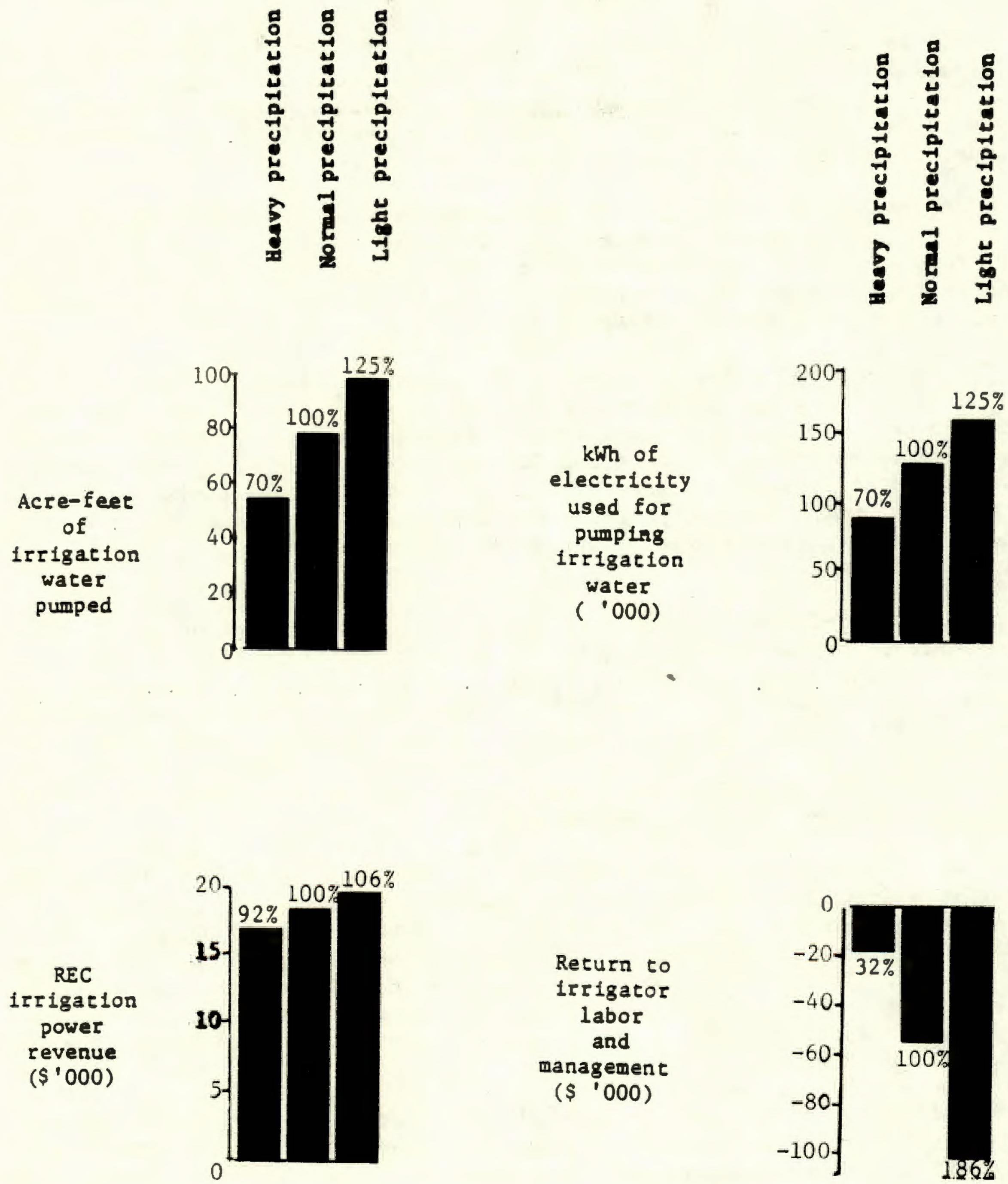

Figure 2. Impacts of unusual precipitation, baseline solutions with 1985 government program crop prices, irrigators with debt- and equity-financed new irrigation equipment, Cam-Wal REC bluffs representative farm.

10% ($830 to $2,500 per irrigator). Irrigator profits with unusually heavy precipitation are much greater than with normal precipitation, with the increase ranging from $12,600 to $37,200 per irrigator. These differences in profits arise primarily from differences in the dryland acreages in the baseline solutions.

With unusually light precipitation, opposite and somewhat smaller impacts on irrigation water and electric power usage and REC revenues are realized. This outcome arises because the unusually light seasonal precipitation is only 4.5 inches less than normal, whereas the unusually heavy seasonal precipitation is 6.2 inches more than normal.

The impacts on irrigator profits of unusually light precipitation are $720 to $10,200 greater, however, than are the impacts of unusually heavy precipitation. This outcome is directly associated with the assumed nature of the underlying production function for irrigated corn. The yield response per acre-inch of irrigation water with unusually light pecipitation is enough greater than with unusually heavy precipitation[7] --to more than counterbalance the smaller precipitation differential with unusually light precipitation.

The impacts of unusual precipitation on irrigator profits originate from four sources, as shown in Tables 4 and 5. The main finding from this analysis is that the change in electric power payments for irrigation associated with unusual precipitation is relatively small. The dominant influence on irrigator profits is that which arises from the impact of unusual precipitation on changes in dryland crop yields.[8] To illustrate, the changes in dryland crop production values are 4 to 57 times greater than the changes in the electric power payments for irrigation.

These findings confirm the expectation that the short-term impacts of unusual precipitation on RECs are the opposite of those on irrigators. If the negative impacts on irrigators from drought are great enough to force them out of business, however, both the irrigators and their servicing RECs stand to lose. Thus, a rate structure that provides for the sharing of risks between RECs and irrigators under circumstances of unusual precipitation can be expected to be in the best long-term economic interests of both irrigators and RECs.

Two features of the current Cam-Wal REC electric rate structure for irrigation provide for the sharing of risks between irrigators and RECs during seasons of unusual precipitation. The spreading of the "fixed" up-front

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[7] In terms of a "textbook" soil moisture-yield production function, the yield response involves movement from the "normal" soil moisture-yield point along the production function (1) with heavy precipitation toward the function's maximum versus (2) with light precipitation toward the function's inflection point. The slope of the production function toward its maximum is, of course, shallower than toward its inflection point.

[8] Since crop irrigation requirments were adjusted in accordance with the amounts of unusually heavy and light precipitation, irrigated crop yields were assumed to be constant across the three precipitation levels considered in the study.

Table 4. Sources of impact of unusual precipitation on irrigator profits, baseline solutions with 1985 government program crop prices, debt- versus equity-financed new irrigation equipment, Cam-Wal REC low-lands representative farm.

Source of change in profits	Change in return to irrigator labor and management associated with unusually heavy precipitation: Dollars	Change in return to irrigator labor and management associated with unusually heavy precipitation: Ratio to electric power payment change[a]	Change in return to irrigator labor and management associated with unusually light precipitation: Dollars	Change in return to irrigator labor and management associated with unusually light precipitation: Ratio to electric power payment change[a]
Irrigators with debt-financed new irrigation equipment				
Dryland crop production value	+28,238	33.9	-38,691	56.7
Irrigation system repair and maintenance	+ 357	0.4	- 292	0.4
Electric power payment for irrigation	+ 834	1.0	- 683	1.0
Grain storage and drying	- 1,550	n/a	+ 1,826	n/a
Total	+27,879	33.4	-37,840	55.4
Irrigators with equity-financed new irrigation equipment				
Dryland crop production value	+ 9,735	3.9	-10,936	5.3
Irrigation system repair and maintenance	+ 1,072	0.4	- 877	0.4
Electric power payment for irrigation	+ 2,502	1.0	- 2,048	1.0
Grain storage and drying	- 661	n/a	- 493	n/a
Total	+12,648	5.1	-13,368	6.5

[a]These are the ratios of the changes in profits for the respective sources of profit change to the change in the electric power payment for irrigation, e.g., 28,238 ÷ 834 = 33.9 (see the encircled data in the table).

Table 5. Sources of impact of unusual precipitation on irrigator profits, baseline solutions with 1985 government program crop prices, irrigators with debt- and equity-financed new irrigation equipment, Cam-Wal REC bluffs representative farm.

	Change in return to irrigator labor and management associated with unusually heavy precipitation		Change in return to irrigator labor and management associated with unusually light precipitation	
Source of change in profits	Dollars	Ratio to electric power payment change[a]	Dollars	Ratio to electric power payment change[a]
Dryland crop production value	+37,671	25.6	-48,242	40.0
Irrigation system repair and maintenance	+ 293	0.2	- 239	0.2
Electric power	+ 1,473	1.0	- 1,205	1.0
Grain storage and drying	- 2,243	n/a	+ 2,248	n/a
Total	+37,194	25.3	-47,438	39.4

[a]These are the ratios of the changes in profits for the respective profit-sources to the change in the electric power payment for irrigation, e.g., 37,671 ÷ 1,473 = 25.6 (see the encircled data in the table).

costs over fewer kWhs results in higher average costs per kWh in years of unusually heavy precipitation (and hence limited irrigation pumping). The three-stepped declining energy (kWh) block rate also results in higher average variable energy (kWh) costs with heavy precipitation. Conversely, when precipitation during an irrigation season is unusually light, both features contribute to a below normal overall average cost per kWh for the electric power used by an irrigator.

THE ESTIMATED DEMANDS FOR ELECTRIC POWER AND WATER FOR IRRIGATION

In this section, the impacts of different prices per kWh of electricity on the quantities of electricity used to pump irrigation water and the quantities of irrigation water pumped are presented. For each representative farm situation examined, a series of optimal solutions was determined. The basic reference point for pricing electricity in the models is the 1985 electric rate structure for the REC. To simplify the interpretation of the results of analysis, however, a single- rather than three-step kWh energy charge is used.

In each of the six situations examined for each representative farm, starting with a price of 1 cent per kWh, the price of electricity was raised successively by 1 cent per kWh increments--with all other prices and technological coefficients held constant--until the use of electric power to pump irrigation water just became uneconomic. Changes in both the quantities of electric power used for pumping irrigation water and quantities of irrigation water pumped were determined. Figures 3 and 4 show the price-quantity relationships for electric power and Figures 5 and 6 the price-quantity relationships for pumped irrigation water.[9] In economic terms, the first series of functional relationships is termed the estimated "direct price demand functions for electricity" and the second is termed the estimated "cross price demand functions for irrigation water".

These demand functions are stepped, as is characteristic of any derived demand function estimated with a linear programming model. The dotted portions in the functions represent non-empirically estimated segments between the respective pairs of one cent energy charges for which the empirical estimations were made.

Because the kWh prices are specified in the model runs in integer values and the irrigation crop production activities are specified in 130 acre units, many of the steps and vertical segments in the estimated demand functions for the individual irrigated farms are rather long. The steps between the respective pairs of kWh energy costs reflect changes in the numbers of irrigation systems in the most profitable representative farm solutions.

The real-world aggregate demand functions for all irrigators served by any one REC are much smoother (i.e., more continuous) than the functions reported in Figures 3-6. They are smoother because the economic behavior of every irrigator is not identical and because some irrigators have non-130 acre center pivot fields. Nevertheless, a common practice in applied

[9]The figures are presented on pp. 27, 28, 30, and 31, immediately after the points in the text at which the empirical findings portrayed in them are first discussed.

economic analysis is to assume that the general shape of demand functions estimated from the analysis of "typical" individual farms is a reasonable proxy for the general shape of the aggregate demand functions for the real-world situation being examined.

Six derived demand functions, rather than one, were estimated for each representative farm. This approach enables the reflection of a variety of different circumstances that either apply in fact or could conceivably apply to different irrigators served by the REC at one or more points in time. These different circumstances are now briefly noted, along with the pairs of analogous panels in the figures that are compared in drawing conclusions concerning the respective sets of circumstances:

i. Irrigators with **debt- versus equity-financed new irrigation equipment:** Panels **a** versus **b** and Panels c versus **d**;

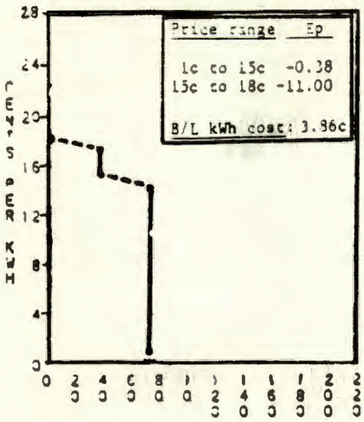
ii. **1985 government program versus 1985 free market prices,** to reflect the impact of farmer non-participation in the 1985 government grain commodity program on the demands for electric power and irrigation water: Panels **a** versus c and Panels **b** versus **d,** and

iii. **With versus without monthly minimum and monthly demand charges,** to reflect the impact of a possible structural change in the electric rate structure in which the "fixed" up-front charges would be eliminated and electricity payments would be exclusively via an energy (kWh) charge: Panels **a** versus **e** and Panels c versus **f.**

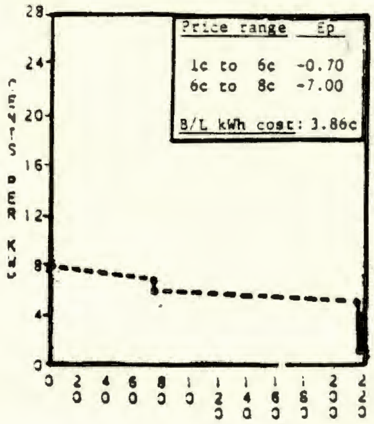
Estimated direct price demand functions for electricity to pump irrigation water

In describing the demand functions in Figures 3 and 4, emphasis is given to (1) the "endpoints" of the functions, i.e., the amounts of electric power used (a) when electricity is priced at 1 cent per kWh and (b) when the price of electricity is just high enough that pumping irrigation water with electric power becomes uneconomic, and (2) the direct price elasticities of demand for electricity to pump irrigation water. The direct price elasticities of demand reflect percentage changes in the quantity of electricity used as ratios to corresponding percentage changes in the price of electricity. Because of the discrete nature of the functions, "arc elasticities" were calculated over specified segments of the demand functions. The pertinent price ranges and estimated elasticities for each demand function are shown in the inset for each panel in the two figures.

Also noted in the insets are the average "variable" energy charges per kWh (termed "B/L kWh costs") in the respective baseline solutions that are analogous to the kWh costs reflected in the respective estimated demand functions. In the panels (**e** and **f**) which involve "without" monthly minimum (MM) and monthly demand (MD) charges, the MM and MD charges in the baseline solutions are allocated across kWhs--in addition to the nominal energy (kWh) charges. By noting the "location" of these average "B/L kWh costs" on the respective demand functions, one can envision the expected type of response by irrigators to possible changes from the 1985 levels for the kWh energy charge.

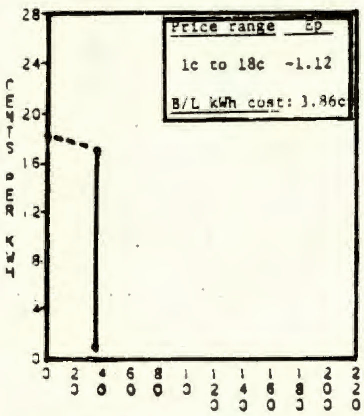


a. Debt-financing, 1985 gov't program prices, with MM and MD charges

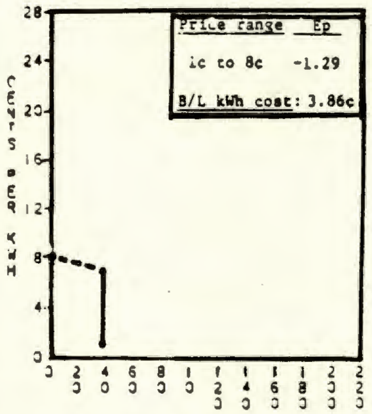


b. Equity-financing, 1985 gov't program prices, with MM and MD charges

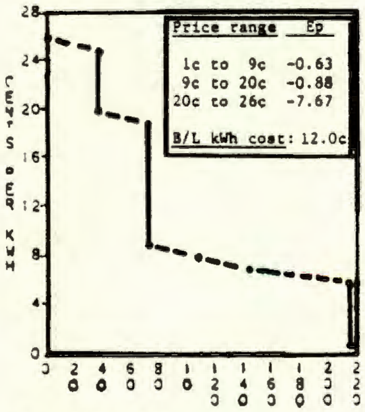
Note: On the horizontal axis are kWh ('000).



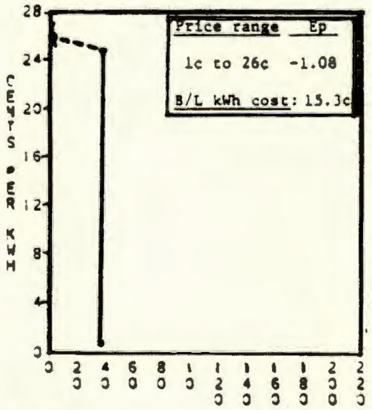
c. Debt-financing, 1985 free market prices, with MM and MD charges



d. Equity-financing, 1985 free market prices, with MM and MD charges



e. Debt-financing, 1985 gov't program prices, without MM and MD charges

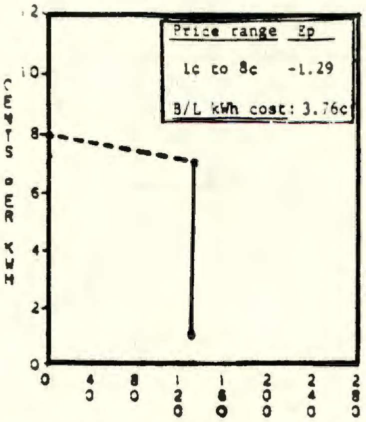


f. Debt-financing, 1985 free market prices, without MM and MD charges

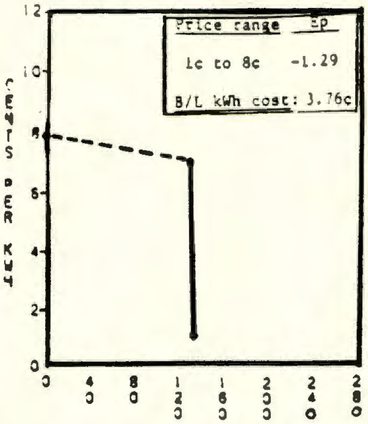
Notes: 1. In the above panel titles, (a) MM = monthly minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

2. The "price range" and "Ep" insets show the "direct price elasticities of demand for electricity to pump irrigation water" (Ep) for various kWh energy charges (c per kWh). The "B/L kWh cost" is the average variable energy cost per kWh in the respective baseline solutions that is analagous to the kWh cost reflected in the respective estimated demand functions.

Figure 3. Estimated direct price demand functions for electricity to pump irrigation water, Cam-Wal REC low-lands representative farm.

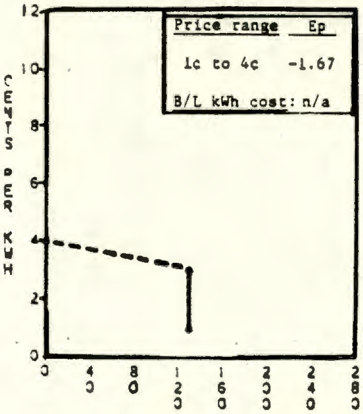


a. Debt-financing, 1985 gov't program prices, with MM and MD charges

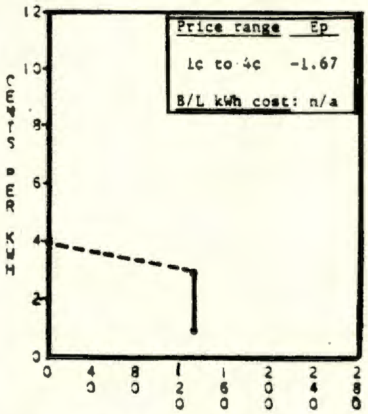


b. Equity-financing, 1985 gov't program prices, with MM and MD charges

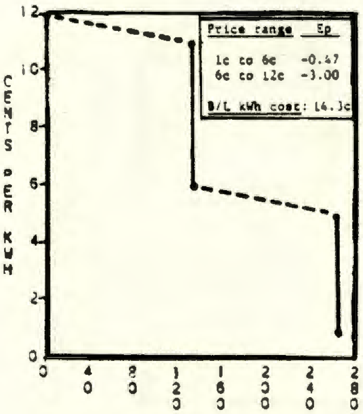
Note: On the horizontal axis are kWh ('000).



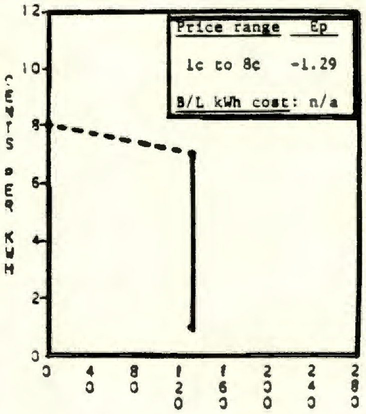
c. Debt-financing, 1985 free market prices, with MM and MD charges



d. Equity-financing, 1985 free market prices, with MM and MD charges



e. Debt-financing, 1985 gov't program prices, without MM and MD charges



f. Debt-financing, 1985 free market prices, without MM and MD charges

Notes: 1. In the above panel titles, (a) MM = monthly minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

2. The "price range" and "Ep" insets show the "direct price elasticities of demand for electricity to pump irrigation water" (Ep) for various kWh energy charges (¢ per kWh). The "B/L kWh cost" is the average variable energy cost per kWh in the respective baseline solutions that is analagous to the kWh cost reflected in the respective estimated demand functions.

Figure 4. Estimated direct price demand functions for electricity to pump irrigation water, Cam-Wal REC bluffs representative farm.

Eight of the estimated demand functions have only one step. Three pertain to the low-lands farm, and five to the bluffs farm. In each such instance, only one electrically powered center pivot system is operated over lower ranges of kWh prices (with the upper price in these ranges varying from 3 to 26 cents). The other four demand functions have from two to five steps, with between two and six center pivots being operated at the lower kWh prices.

The direct price elasticities of demand for electricity to pump irrigation water for the single-step functions are from -1.08 to -1.67. The elasticities for the multi-step functions range from being quite inelastic (as small as -0.38) at "low" electricity prices to being very elastic (between -3.00 and -11.00) at "high" electricity prices. These elasticity differences have important implications in the consideration of rate policies by RECs. If rates are increased over price ranges involving inelastic demand, total electric power revenues can be expected to increase. Conversely, if rates are increased over price ranges involving elastic demand, total electric power revenues can be expected to decline.

The four estimated demand functions intended to portray most directly the various conditions of different irrigators served in 1985 by the Cam-Wal REC are presented in Panels a through d in Figures 3 and 4. A review of the baseline average variable energy costs per kWh in relation to these demand functions shows that:

- Energy prices for the low-lands debt-financing irrigator could rise between 10 and 13 cents per kWh from the 1985 level before the amount of electric energy to energize irrigation pumps would begin to decrease, and at 18 cents per kWh irrigators would shift entirely from electric to diesel power;

- Energy prices for the low-lands equity-financing irrigator under both 1985 government program and 1985 free market crop prices and for the bluffs irrigator with 1985 government program crop prices would have to rise only to 8 cents per kWh before farmers would totally stop using electric power for irrigation; and

- Energy prices for bluffs irrigators with 1985 free market prices would have to drop to 3 cents per kWh before they would find it profitable to operate one of their existing center pivot systems, and that with a price even as low as 1 cent per kWh they would not find it to be profitable to operate the second existing center pivot unit.

The contrasts between the baseline solutions for the low-lands and the bluffs representative farms are generally reflected in the demand analysis as well. In only one situation (namely, debt-financing, 1985 government program prices, without MM and MD charges), for example, does the bluffs irrigator operate both of his existing center pivot units at "low" electricity prices. On the other hand, in two situations the low-lands irrigator operates six center pivots, and in a third situation be operates two center pivots. In five of the six comparable situations, the kWh price at which electric power irrigation systems are no longer economic is considerably higher for the low-lands than the bluffs farm. This price differential is as great as 18 cents per kWh.

No one pattern characterizes the impacts of leveraged newly purchased irrigation systems on the demand for electrical pumping energy. For the bluffs farm, no impact is shown in either pair of comparable situations. For the low-lands farm, on the other hand, the leveraged irrigator continues to pump with electrical energy at much higher kWh prices (10 cents) than his equity-financing counterpart. In the lower range of kWh prices, however, the use of equity capital facilitates a much greater investment in center pivot systems with 1985 government program prices, and no difference in investment with 1985 free market prices.

Consistent with simple micro-economic production theory, the derived demand function for electrical pumping energy is shifted farther from the origin with the relatively higher government program than free market prices in all four comparable situations. On the low-lands farm, however, the outward shift is limited to the lower kWh price range. For the bluffs farm, on the other hand, the outward shift is limited to the higher kWh price range.

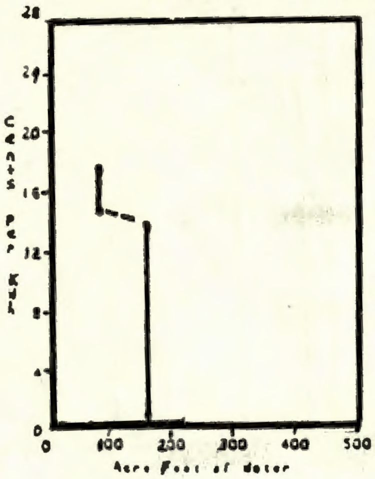
Finally, the derived demand functions that involve the elimination of the 1985 monthly minimum and monthly demand charges are also shifted farther from the origin than their 1985 baseline counterparts. The outward shift takes place over the entire span of the demand functions for the debt-financing irrigator with 1985 government program prices, but only over the upper kWh price range with 1985 free market prices. In no case does the degree of vertical displacement of the demand function conform at all closely to the per kWh cost equivalent of the monthly minimum and monthly demand charges. Thus, the structural change in the electric rate charges does induce structural changes in the demand for electrical pumping energy, but the induced charges show no common pattern.

Estimated cross price demand functions for irrigation water

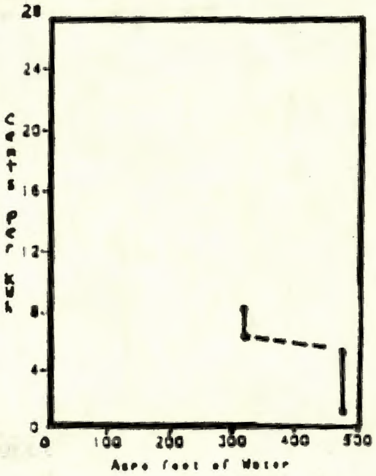
For the bluffs farm, the shapes of the estimated cross price demand functions for irrigation water are identical to those for the direct price demand functions (Figure 6). This outcome reflects the fact that diesel systems never become economic on the bluffs farm.

For all six low-lands farm situations, however, diesel systems do become economic (Figure 5). This circumstance arises in five of the six situations when high electric prices cause the last electric powered center pivot system to become uneconomic. At that point, the electrically powered center pivot is converted to diesel power.

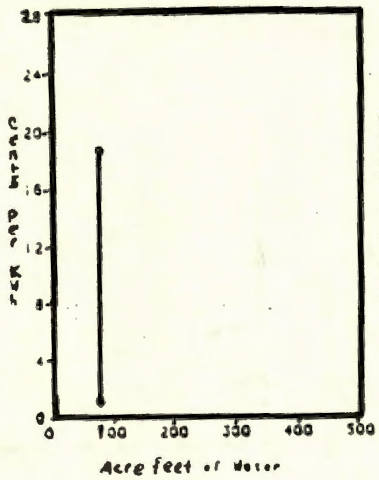
In the sixth situation, with 1985 government program crop prices and electricity at 7 cents per kWh, two new diesel systems are purchased. At 8 cents per kWh, two new diesel systems are purchased, and the two originally-present electric systems are converted to diesel power.



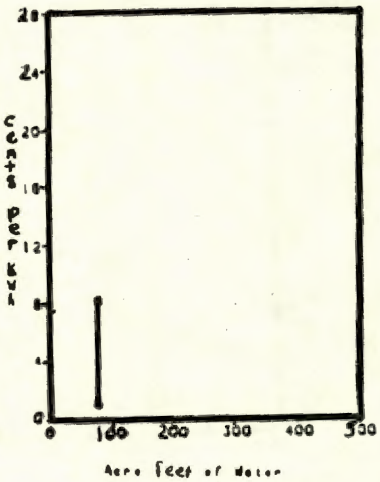
a. Debt-financing, 1985 gov't program prices, with MM and MD charges



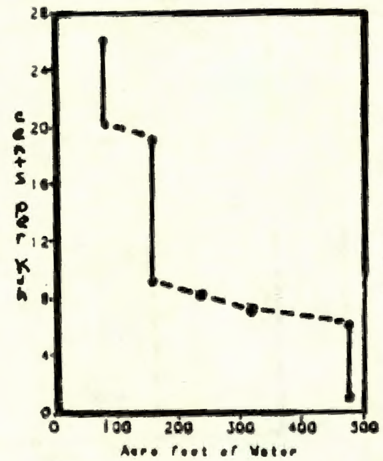
b. Equity-financing, 1985 gov't program prices, with MM and MD charges



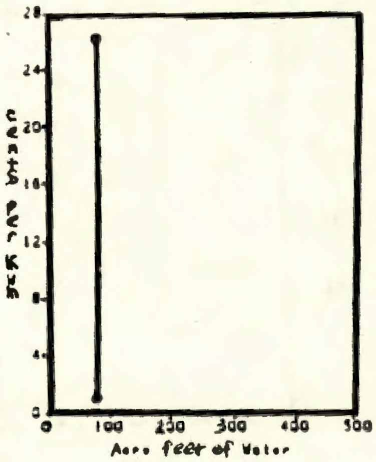
c. Debt-financing, 1985 free market prices, with MM and MD charges



d. Equity-financing, 1985 free market prices, with MM and MD charges



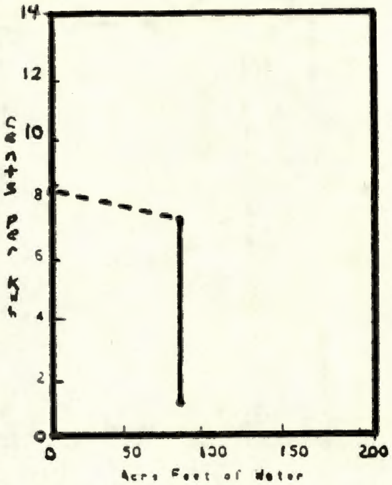
e. Debt-financing, 1985 gov't program prices, without MM and MD charges



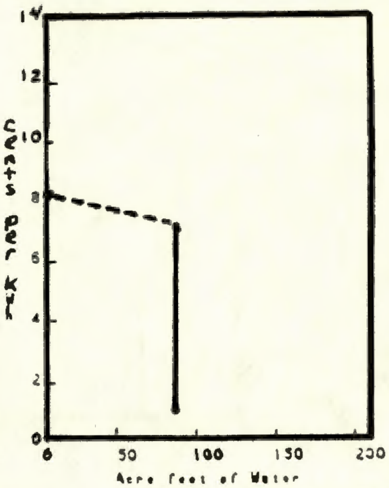
f. Debt-financing, 1985 free market prices, without MM and MD charges

Note: In the above panel titles, (a) MM = monthly minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

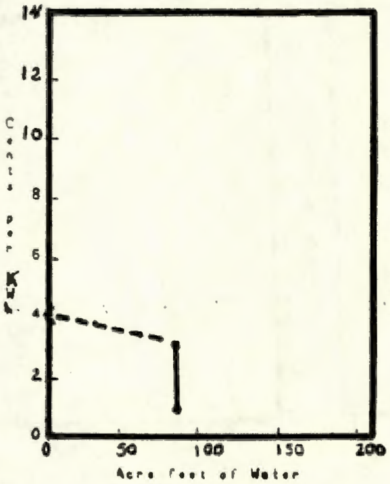
Figure 5. Estimated cross price demand functions for irrigation water, Cam-Wal REC low-lands representative farm.



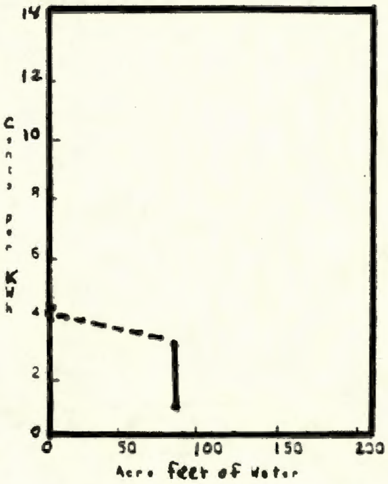
a. Debt-financing, 1985 gov't program prices, with MM and MD charges



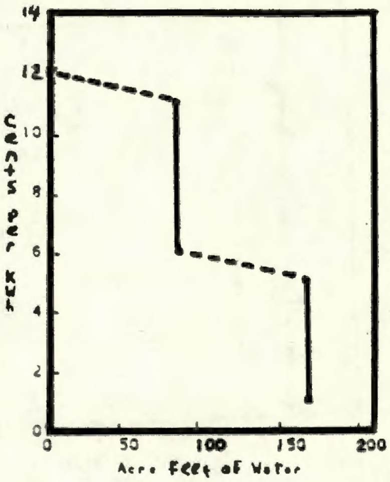
b. Equity-financing, 1985 gov't program prices, with MM and MD charges



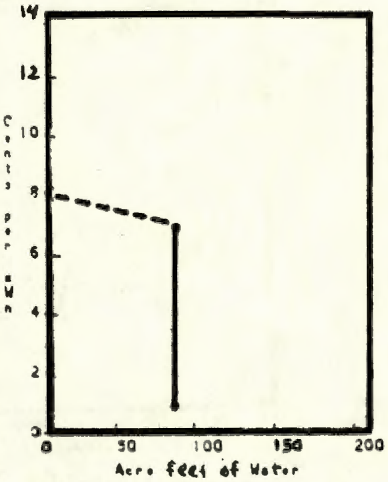
c. Debt-financing, 1985 free market prices, with MM and MD charges



d. Equity-financing, 1985 free market prices, with MM and MD charges



e. Debt-financing, 1985 gov't program prices, without MM and MD charges



f. Debt-financing, 1985 free market prices, without MM and MD charges

Note: In the above panel titles, (a) MM = monthly minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

Figure 6. Estimated cross price demand functions for irrigation water, Cam-Wal REC bluffs representative farm.

RATE STRUCTURE ANALYSIS

In the prior demand analysis, greater attention is given to changes in the rate level than to the rate structure for electricity. In this section, relatively more explicit attention is given to rate structures. The impacts on irrigators and the REC of different levels of up-front (monthly minimum and monthly demand) and energy charges and differently configured energy (kWh) block rates are each examined.

Different levels of "fixed" up-front and variable energy electric rate charges

Rural electric cooperatives are faced with high fixed costs. These costs derive from (1) substantial investments by RECs in electric power transmission and physical plant facilities and (2) wholesale power demand charges paid by RECs to offset the high fixed cost of coal-based electric generation facilities. In this study's baseline solutions, for example, the "fixed" up-front monthly minimum and monthly demand charges account for 68% to 75% of the irrigators' total electric power payments for irrigation (Table 6).

In years of unusually great precipitation and/or widespread participation of irrigators in acreage set-aside government commodity programs, irrigation pumping may decline greatly. To guard against electric power revenue shortfalls in such circumstances, most RECs adopt electric pricing policies that result in the passing on of their "fixed" costs to their customers in the form of "fixed" up-front electric rate charges.

Some irrigators object to having to make large up-front payments for their electrically powered irrigation systems. They would prefer that a larger proportion of their irrigation electric power payments be in the form of energy (kWh) charges. They place particular value on being able to exercise direct control over their irrigation power bills by determining when and for how long they run their systems. Further, some irrigators believe that many of the REC fixed cost facilities are already paid off and, therefore, that they should not have to continue to bear large up-front electricity payments.[10]

In practice, many of an REC's capital assets are depreciated over as many as 10 to 30 years. Even after these depreciation periods are exhausted, the capital assets usually have to be replaced, which sets in motion new series of even higher dollar rates of depreciation (because of inflation) for the RECs.

Although large proportions of REC operating costs are "fixed" and the fixed costs do not generally diminish over time, the impacts of pricing electricity through varying proportions of up-front and variable energy (kWh) charges are examined. The rationale for undertaking this analysis is partly scientific curiosity and partly to generate information that could be used in responding to the concerns of irrigators who would strongly prefer to pay for

[10]The periods specified in contracts between irrigators and RECs are generally much shorter than the average length of time over which an REC's various capital assets are depreciated.

Table 6. "Fixed" up-front versus variable energy charges; baseline solutions; 1985 government program, 1985 free market, and 1980 free market crop prices; irrigators with debt- versus equity-financed new irrigation equipment; Cam Wal REC low-lands and bluffs representative farms.

	Low-lands farm				Bluffs farm: debt- and equity-financing	
	Debt-financing		Equity-financing			
	Dollars	Percent	Dollars	Percent	Dollars	Percent
Solutions with 1985 government commodity program prices						
Monthly minimum charges	924	10.7	2,772	10.7	5,417	29.2
Monthly demand charges	4,933	57.2	14,799	57.2	8,263	44.5
Sub-total of up-front charges	(5,857)	(67.9)	(17,571)	(67.9)	(13,680)	(73.7)
Energy charges	2,766	32.1	8,298	32.1	4,888	26.3
Total electric power charges	8,623	100.0	25,869	100.0	18,568	100.0
Solutions with 1985 free market prices						
Monthly minimum charges	1,617	29.6	1,617	29.6	7,739	100.0
Monthly demand charges	2,466	45.1	2,466	45.1	0	0
Sub-total of up-front charges	(4,083)	(74.7)	(4,083)	(74.7)	(7,739)	(100.0)
Energy charges	1,383	25.3	1,383	25.3	0	0
Total electric power charges	5,466	100.0	5,466	100.0	7,739	100.0
Solutions with 1980 free market prices						
Monthly minimum charges	924	10.7	1,848	10.7	5,417	29.2
Monthly demand charges	4,933	57.2	9,866	57.2	8,263	44.5
Sub-total of up-front charges	(5,857)	(67.9)	(11,714)	(67.9)	(13,680)	(73.7)
Energy charges	2,766	32.1	5,532	32.1	4,888	26.3
Total electric power charges	8,623	100.0	17,246	100.0	18,568	100.0

electric power via rate structures with a higher proportion of total costs included in the kWh charges.

In exploring this issue, the impacts of both increasing and decreasing one-at-a-time each of the monthly minimum, monthly demand, and energy charges are determined. All other prices (including only 1985 government program crop prices) and the technological coefficients are held constant in analysis. The "increased" electric rates are arbitrarily set at double their respective 1985 baseline levels. The "decreased" electric rates are set at 25% of their baseline levels (i.e., at 75% less than their respective 1985 baseline levels). Normal precipitation is assumed. Optimal solutions for each of the representative farms are determined with each of these alternate electric rate structures.

The results of this analysis for the low-lands and bluffs representative farms are presented in Figures 7 and 8. The histogram-bars that reflect results from the baseline solutions with 1985 electric power rates are described as showing 100%-level outcomes. The three histogram-bars to the left of the center baseline bars reflect outcomes for the respective one-at-a-time doubling in price for the three electric rate components, and the bars to the right of center reflect outcomes for the 75% reduced electric rate charges.

For three of the six modified electric rate pricing situations, irrigation pumping and electric power usage are unaffected: a doubling of the monthly minimum and a 75% reduction of either the monthly minimum or energy charge. In three of the four cases involving a doubling of the monthly demand or energy charge, on the other hand, irrigation pumping and electric power usage are negatively impacted. For the bluffs farm, the negative impact involves the total elimination of electrically energized irrigation pumps. Finally, with a 75% reduction in the monthly demand charge for both equipment financing situations on both the low-lands and bluffs farms, pumping and electric power use double (reflecting the operation of one additional center pivot).

A one-at-a-time doubling of the individual electric rate charges results in as many instances of decreased as increased REC irrigation power revenue. The increases range from 11% to 57% of the respective baseline values. Five of the six decreases are to 41% to 44% of the respective baseline values. One-at-a-time reductions in the electric rate charges, on the other hand, lead to an almost consistent pattern (only one exception) of reduced REC irrigation power revenues. The reductions are as much as 57% of the respective baseline levels.

The returns to irrigator labor and management are without exception negatively impacted by a doubling of the individual electric rate charges. The decreases in returns relative to the respective baseline values, range from about $1,000 to $10,000 for the low-lands farm and from about $5,500 to $6,500 for the bluffs farm. With one-at-a-time reductions in the electric rate charges, an opposite type of outcome prevails. The extent of increase in irrigator profits with a 75% reduction in each electric rate charge ranges on the low-lands farm from $600 to $11,000 and on the bluffs farm from $4,000 to $8,500.

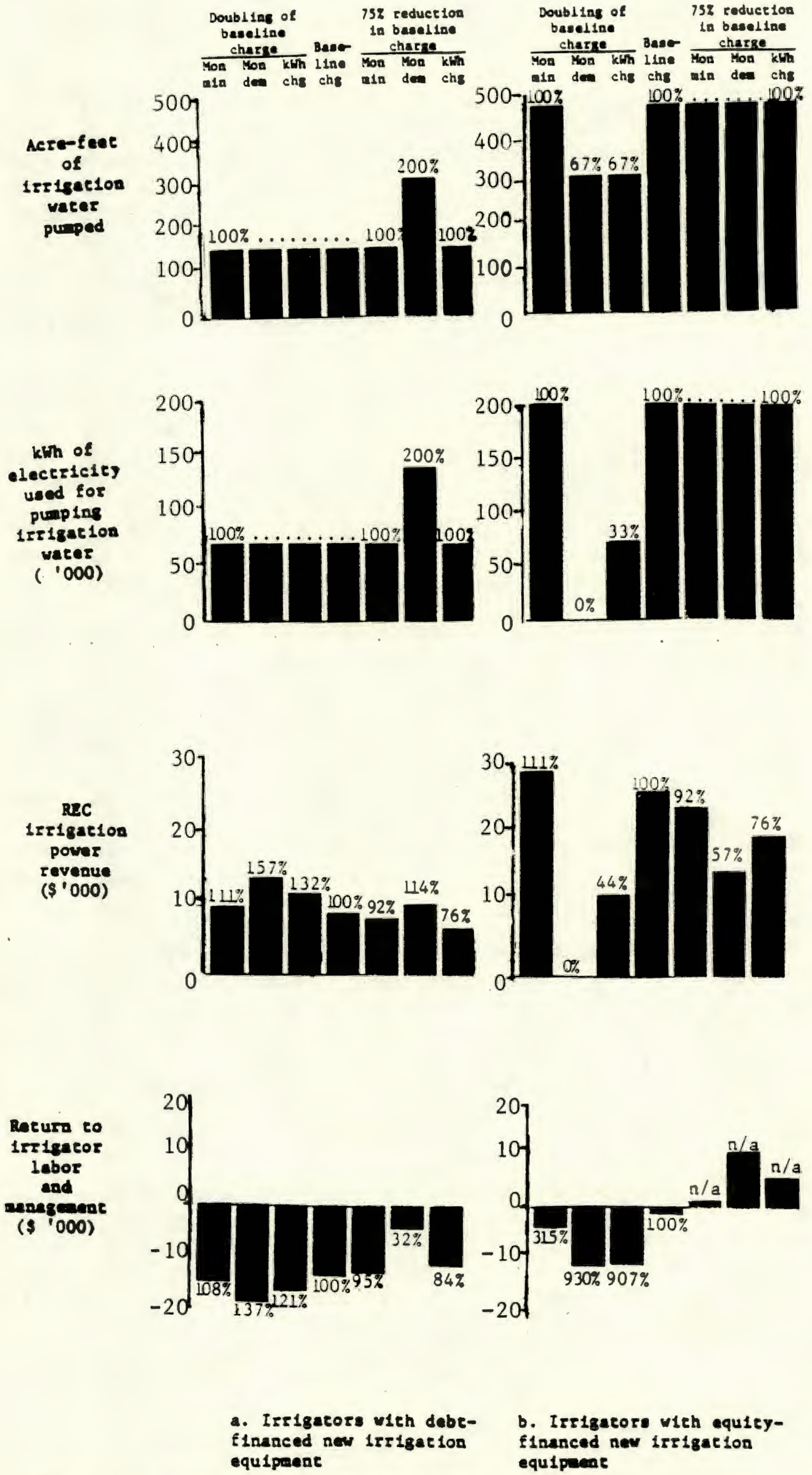


Figure 7. Impacts of one-at-a-time increased and decreased monthly minimum, monthly demand, and energy electric rate charges, irrigators with debt- versus equity-financed new irrigation equipment, 1985 government program prices, Cam-Wal REC low-lands representative farm.

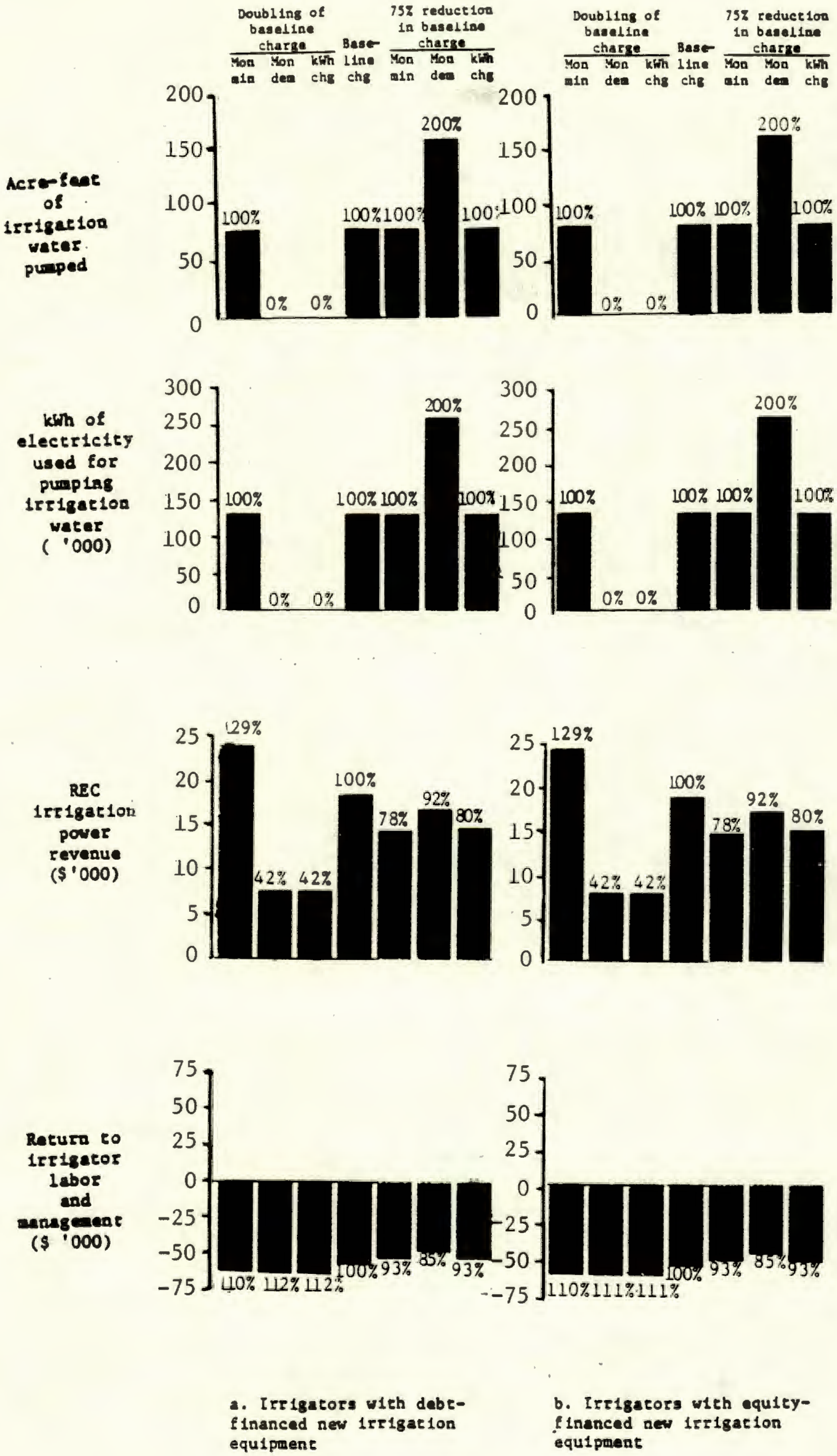


Figure 8. Impacts of one-at-a-time increased and decreased monthly minimum, monthly demand, and energy electric rate charges, irrigators with debt- versus equity-financed new irrigation equipment, 1985 government program prices, Cam-Wal REC bluffs representative farm.

The final focus of analysis in this section is on a very practical consideration to REC management. What if the Cam-Wal REC were to decrease its monthly minimum or monthly demand charges and then unusually heavy precipitation were to be experienced? To what extent would REC revenues become vulnerable from such a policy decision on rates and such a natural circumstance?

To investigate this question, differences in REC revenues (and irrigator profits) in circumstances with normal versus unusually heavy precipitation--under assumed one-at-a-time 75% reductions in monthly minimum and monthly demand charges--are examined. The normal precipitation circumstances are those just described. The budgeting of the impacts of unusually heavy precipitation is based on the assumptions and procedures used for examining this phenomenon in the section entitled "unusually heavy or light versus normal precipitation."

The findings from this analysis for the two representative farms are presented in Table 7. If RECs were to reduce either of their up-front electric rate charges by 75% and their irrigator clients were then to experience unusually heavy precipitation, the irrigation generated revenues would be reduced by $835 to $2,945 per irrigator. These reductions amount to 10% to 17% of the respective REC revenues with normal precipitation. Simultaneously, irrigators would realize added profits ranging from $12,650 to $37,150.

Because RECs are not permitted by federal law to carry forward positive margins from one year to another, even a 10% to 17% unexpected reduction in REC revenue in a particular year would somehow have to be covered in that same year. If the REC revenue shortfall occurred as a result of unusually heavy precipitation, irrigators with dryland would derive substantial economic benefits from the added precipitation. In principle, an after-season rate adjustment mechanism could be created to transfer enough of that precipitation benefit to the REC to meet its fixed cost obligations--in exchange for a concession by the REC to irrigators for part of the burden of the electric payment for irrigation to be shifted from up-front to variable energy charges. From three standpoints, however, such a pricing policy would probably be ill-advised.

1. The more complex a rate pricing policy, the greater the difficulties in administering the policy. Administrative encumberances could be expected to arise in (a) ensuring that all irrigators would know about and clearly understand the after-season rate adjustment provision, (b) arriving at a common agreement between individual irrigators and the REC on whether (and, if so, how much) precipitation during the irrigation season is "unusually great", and (c) collecting the additional electric payments after the irrigation pumping season ends. In addition, special pricing features for one electric rate class (electric power consuming sector) not shared by other rate classes can be expected to lead to possible customer discontent and misunderstanding.

2. Such a rate adjustment policy would do nothing to compensate for REC revenue shortfalls that could arise from non-precipitation based reductions in irrigation pumping, e.g., from acreage set-aside government commodity

Table 7. Selected impacts of unusually heavy precipitation when monthly minimum and monthly demand charges are reduced one-at-a-time to 25% of their respective levels in 1985, irrigators with debt-financed versus equity-financed new irrigation equipment, Cam-Wal REC low-lands and bluffs representative farms.

	Low-land farm		Bluffs farm	
	Monthly minimum charge	Monthly demand charge	Monthly minimum charge	Monthly demand charge
<u>Irrigators with debt-financed new irrigation equipment</u>				
Impacts on REC revenues				
Dollar decrease per irrigator	835	1,670	1,475	2,945
Dollar decrease as a percent of the revenue with normal precipitation	10.5	16.9	10.2	17.3
Impacts on irrigator profits				
Dollar increase per irrigator	27,835	20,350	37,150	30,220
Dollar profits with normal precipitation per irrigator	-12,550	- 4,150	-50,995	-46,545
<u>Irrigators with equity-financed new irrigation equipment</u>				
Impacts on REC revenues				
Dollar decrease per irrigator	2,500	2,500	1,475	2,945
Dollar decrease as a percent of the revenue with normal precipitation	10.5	16.9	10.2	17.3
Impacts on irrigator profits				
Dollar increase per irrigator	12,650	12,650	37,150	30,220
Dollar profits with normal precipitation per irrigator	1,115	10,135	-50,995	-46,545

programs.

3. Perhaps most significant and as indicated above, two features of the current electric rate structure already provide for the sharing of risks between irrigators and RECs during seasons of unusual irrigation pumping. The spreading of the "fixed" up-front costs over fewer kWhs results in higher average costs per kWh in years of unusually little pumping. The three-stepped declining energy (kWh) block rate also results in higher average variable kWh costs with limited irrigation pumping. Conversely, when irrigation pumping during an irrigation season is unusually great, both features contribute to a below-normal overall average cost per kWh for the electric power used by an irrigator.

Differently configured energy (kWh) charge block rates

The 1985 Cam-Wal REC electric rate structure for irrigation provides for a three-step variable energy (kWh) charge--in addition to up-front monthly minimum and monthly demand charges. In the analysis of differently configured energy (kWh) block rates, attention is given to a single-step energy charge, a modified three-step declining energy block rate, and a three-step increasing energy block rate. The up-front electric charges are specified in some models at 1985 levels and in others at zero levels. The primary purpose of this analysis is to determine if differently configured energy block rates, and a different policy regarding the assessment of up-front electric rate charges, would provide incentive for either greater or lesser electric power and water usage in irrigation.

The heights of the steps, i.e., the levels of the prices for the various steps, in the alternative block rate structures were determined as follows.[11] The alternative energy block rate prices were specified relative to the average energy costs per kWh in the respective baseline solutions (call them **AC**). These **AC** values became (1) the single-step block rate prices and (2) the middle-step prices in the modified three-step block rate models in which the up-front charges were set at the 1985 baseline levels (Table 8). In those model runs with zero monthly minimum and monthly demand charges, the **AC** values reflect the total electric payment for irrigation in the baseline solution divided by the total kWhs in the solution. To test the impact of more strongly graduated declining block rates, the first- and the third-step prices in the modified three-step declining block rate models were set at 90% more and 90% less than the respective **AC** values.[12] In the three-step increasing block rate models, the first and third-step declining block rate charges are interchanged.

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[11]The lengths of the steps, i.e., the numbers of kWhs covered by each bounded step, in the modified three-step block rate analysis are the same as those in the baseline models.

[12]With the baseline electric rate structure, the differences between the first- and second-step charges and between the second- and third-step charges are 0.52 cents and 1.58 cents per kWh, respectively. The first-to-second and second-to-third step electric rate charge differentials in the more strongly graduate three-step models with the 1985 up-front charges are between 3.4 and 3.5 cents per kWh. The corresponding differentials with zero up-front charges are between 10.8 and 12.8 cents per kWh.

Table 8. Differently configured variable energy (kWh) block rate charges assumed in analysis, Cam-Wal REC low-lands and bluffs representative farms.[a]

Block rate model	Level of charge (cents per kWh)					
	Low-lands farm			Bluffs farm		
	First step	Second step	Third step	First step	Second step	Third step
Baseline three-step declining block[b]	4.410	3.890	2.310	4.410	3.890	2.310
Single-step						
1985 up-front charges	3.858	n/a	n/a	3.757	n/a	n/a
Zero up-front charges	12.030	n/a	n/a	14.270	n/a	n/a
Modified three-step declining block						
1985 up-front charges	7.330	3.858	0.386	7.138	3.757	0.376
Zero up-front charges	22.856	12.030	1.203	27.110	14.270	1.427
Three-step increasing block						
1985 up-front charges	0.386	3.858	7.330	0.376	3.757	7.138
Zero-up-front charges	1.203	12.030	22.856	1.427	14.270	27.110

[a]The block rate charges in the debt-financing models are identical to those in the respective equity-financing models.

[b]The baseline block rate charges reflect the basic 4.2, 3.7, and 2.2 cent per kWh three-step energy charges, adjusted up by an assumed 5% interest time money cost.

The results of the alternative energy block rate analysis are presented in Figures 9 and 10. The first histogram-bar in each panel represents the baseline solution result. The other bars represent the results for the alternative block rate models as follows:

- Second and third bars: single-step models;
- Fourth and fifth bars: modified three-step declining block rate models; and
- Sixth and seventh bars: three-step increasing block rate models.

The up-front electric charges were set at the 1985 levels in the models underlying the first, second, fourth, and sixth bars and were eliminated in the models underlying the third, fifth, and seventh bars.

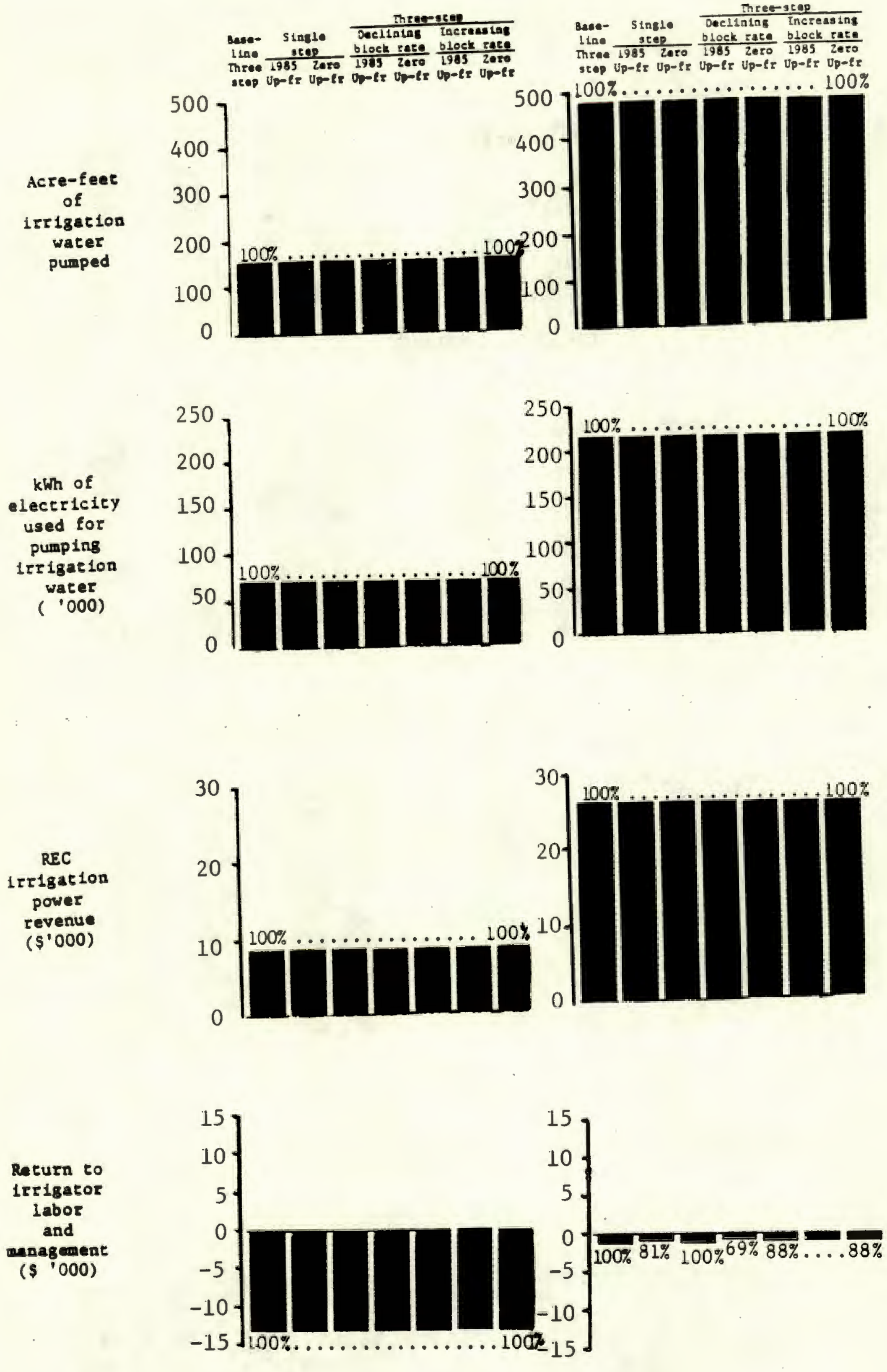
The various modified energy block rates have zero impact on irrigation electric power and water usage in all the low-land farm situations examined and in the bluffs farm models in which the 1985 up-front components are retained. Only for the bluffs farm with zero up-front charges, then, do the differently configured energy block rates impact irrigation electric power and energy use. In that case--no matter whether the modified block rate involves a single-step, modified declining three-step, or increasing three-step energy charge--it is more profitable to stop irrigating and dryland farm only.

The impacts of the differently configured energy block rate charges on REC irrigation power revenues correspond identically to the respective amounts of electricity used for pumping irrigation water in the various models. The impacts of the different energy block rates on the returns to irrigator labor and management are relatively minor, ranging from less than 0.5% (less than $50) to as much as a plus $1,500 for the bluffs irrigator in instances where the 1985 up-front electric rate charges are set at zero.

In summary, the results from the analysis of differently configured energy block rates do not conform to a particular type of pattern--especially as might be hypothesized on the basis of simple micro production theory (all other things the same). For example, in only two of eight situations is decreased energy and/or water usage associated with increasing block rate charges. Further, in two of eight situations, decreased energy and water usage are unexpectedly associated with more steeply declining three-step block rate charges. These findings suggest that the modified block rates set in motion other features of farm reorganization that more than counterbalance what otherwise would be expected to take place based on simple economic theory with all else the same.

LIMITATIONS OF THE STUDY

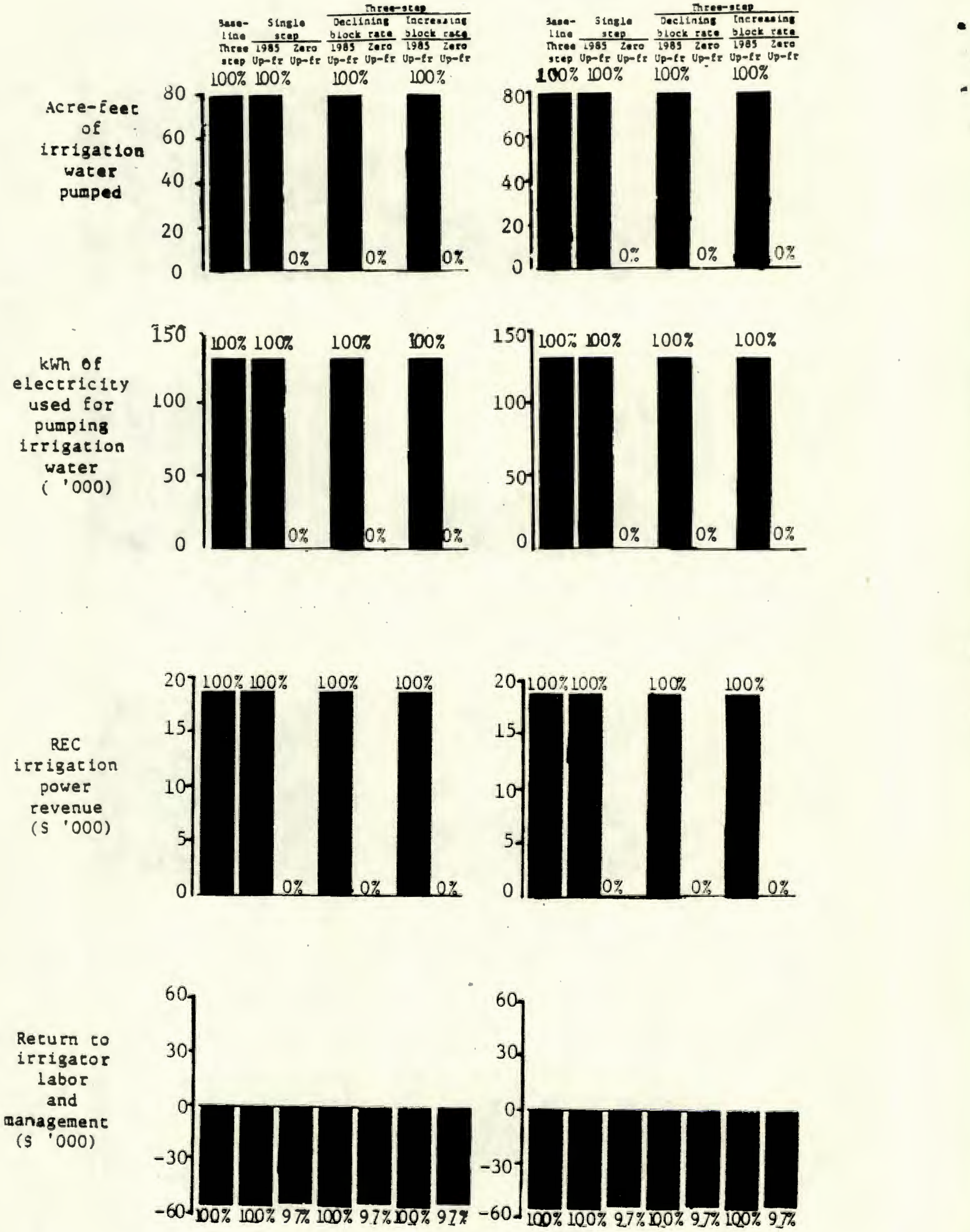
The analytic model employed in this study, as with any other study, fails to accommodate all pertinent features of the real-world environment being studied. Those features believed to be most limiting in this regard are the following.



a. Irrigators with debt-financed new irrigation equipment

b. Irrigators with equity-financed new irrigation equipment

Figure 9. Impacts of differently configured energy block rate charges, irrigators with debt- versus equity-financed new irrigation equipment, 1985 government program prices, Can-Wal REC low-lands representative farm.



a. Irrigators with debt-financed new irrigation equipment

b. Irrigators with equity-financed new irrigation equipment

Figure 10. Impacts of differently configured energy block rate charges, irrigators with debt- verus equity financed new irrigation equipment, 1985 government program prices, Cam-Wal REC bluffs representative farm.

The actual farmer decision-making process is only crudely incorporated into the linear programming model. The only farmer managerial objective explicitly considered in the model is the maximization of revenue over the variable costs of farm production. No attention is given to other potentially quantifiable objectives (regarding, for example, cash-flow management and risk management) and less quantifiable objectives (e.g., preferences regarding family involvement with the farm, farmer involvement in the home, leisure time). Neither is attention given to the investment credit (prevailing in 1985) and tax deduction dimensions of irrigation investments.

The model covers only a single production period; yet, many decisions are made by farmers within the context of several production periods. Crops are considered individually; yet, some farmers plan cropping patterns with rotational considerations in mind. Specific assumptions (e.g., center pivots that cover only 130 acres of land each, land and labor resource availabilities, insurance rates, commodity storage and marketing practices) may apply to some farms, but certainly not to all farms. The same is true for the assumed crop and livestock production coefficients and irrigation technologies. Because of these limitations, the findings from the study--while based on the soundest analytic procedures that we would find and further develop--should not be interpreted as absolutely definitive.

We also realize that the applicability of the findings from the study to individual RECs depends importantly on the cost structures and governing philosophies of each REC. It is hoped that this report and others prepared through this research project will provide some useful insights to RECs as they deal with the inherently multi-faceted and complex task of formulating electric rate pricing policies for irrigation.