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# THE ROLE OF ELECTRICITY IN PACIFIC NORTHWEST IRRIGATED AGRICULTURE

## 1979 - 1987

## VOLUME 1

**A Study of irrigation price elasticity of demand, the importance of irrigated agriculture to rural communities, and an evaluation of alternative targeted rate discount options for irrigation consumers.**

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**Submitted To**

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**February, 1989**

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## STUDY HIGHLIGHTS

### THE ROLE OF IRRIGATED AGRICULTURE IN THE PACIFIC NORTHWEST

- Annual cash receipts from crop production in the Pacific Northwest averaged $5.2 billion between 1984 and 1986. Cash receipts from irrigated crop production averaged $3.8 billion between 1984 and 1986, accounting for 73 percent of the value of crop production. Sprinkler irrigated crop receipts are estimated at $2.4 billion or 47 percent of Pacific Northwest crop production receipts.

- Harvested cropland and pasture account for over 16 million acres of total land area in the Pacific Northwest. Over 8 million acres of this total farmland is irrigated and 4.6 million are sprinkler irrigated.

- Approximately 56 percent of the irrigated lands use sprinkler irrigation systems. Sprinkler systems are more common on farms that use groundwater as an irrigation source.

- The relative importance of sprinkler versus flood irrigation methods varies across the region. Nearly 75 percent of the irrigated lands in Washington use sprinkler methods while only 48 percent of irrigated acreage in Idaho is under sprinkler systems.

- Export markets are an important outlet for Pacific Northwest agricultural commodities, particularly wheat, meat, and processed potatoes, fruits and vegetables.

- In the BPA region, the agriculture sector is estimated to have provided nearly 160,000 on-farm jobs in 1986. Another 73,000 jobs were provided by the food processing industry. These 233,000 jobs are about 7 percent of Pacific Northwest employment.

- Electricity use for irrigation has increased approximately 12 percent since the mid-1970's but has been generally flat since the early 1980's. Approximately 46 percent of electricity used for irrigation is supplied by public utilities; the remaining 54 percent is provided by private utilities.

- On average, electricity costs account for less than 10 percent of total irrigated crop production costs; relative shares are significantly less for high-valued commodities such as tree fruits and vegetables. However, in high-lift areas electricity costs exceed 25 percent of total costs for irrigated wheat production.

## SPRINKLER IRRIGATED AGRICULTURE AND RURAL COMMUNITIES

- Irrigated acreage ranges from a low of 6 percent of total crop acreage in Production Area 14 (Eastern Washington) to a high of 89 percent in Production Area 23 (Central Oregon). The Columbia Basin in Central Washington (PA 13) and the Snake River region in Southern Idaho (PA 32) are the largest areas of irrigated agriculture in the Pacific Northwest. Sprinkler irrigated acreage as a percent of total irrigated acreage averages 56 percent for the region, varying from 31 percent in Western Oregon to 97 percent in Eastern Washington.

- Crop production accounts for less than 1 percent up to 12 percent of the value of all regional output across the nine agricultural production areas of the Pacific Northwest. Irrigated agriculture varies from 0.5 percent to more than 10 percent of regional output. Sprinkler output varies from 0.5 percent to nearly 7 percent of regional product by production area.

- Sprinkler irrigated crop production ranges from $34 million in Central Oregon to nearly $600 million in Western Oregon and Western Washington.

- For every dollar of output in Pacific Northwest crop production an additional 70 cents is generated throughout the regional economy. Each dollar of income to the farm sector generates an additional 74 cents in regional income. For every 10 jobs in agriculture-related sectors, an additional 5 jobs are generated throughout the local economy. Similar values are associated with all irrigated and sprinkler irrigated crop production.

- Higher relative yields and a higher valued crop mix cause the average value of per acre crop production to be significantly higher on irrigated croplands relative to the overall average. Therefore, the per acre direct and indirect impacts associated with changes in agricultural output and income will also be greater for irrigated lands. Average per acre direct and indirect impacts associated with sprinkler irrigation are significantly higher than those for all irrigation because of the higher-valued crop mix associated with sprinkler lands.

- Value added in the Pacific Northwest food processing industry is over $2 billion; a significant share of this is measured as income to employees and plant owners.

## ESTIMATING IRRIGATION ELECTRICITY PRICE ELASTICITY

### Econometric Model

- A three equation simultaneous demand system was developed for individual utilities and for groups of utilities within agricultural production areas.

- Explanatory variables included average electricity price, sprinkler irrigated acreage as a percent of total irrigated acreage, weighted pumping efficiencies, precipitation, output value per acre, average wages paid for labor used in crop production, net farm returns, farm interest rate, federal acreage programs, and utility location. Endogenous variables included kWh use per acre, sprinkler irrigated acreage as a percent of total irrigated acreage, and total irrigation acreage.

- Electricity price elasticities were estimated for three time periods: the irrigation season (April-November), the spring period (April-May), and the summer period (June-November).

- Short-run elasticities estimated for the irrigation season were found to be price inelastic, with a regional average of -0.49. Values ranged across production areas from -0.42 to -0.72. Long-run price elasticities varied from -0.66 to -1.32, with a weighted regional average of -0.81.

- Summer period elasticities were somewhat lower than elasticities estimated for the entire irrigation season, while spring period elasticities were higher, approaching 0.90 to 1.00 in absolute value for the short-run.

- The variation in spring and summer elasticities is consistent with the seasonal water use constraints faced by producers.

- Price elasticity estimates derived in this study fall within the general range of figures calculated for the Pacific Northwest in other econometric studies. For example, Horner and Wesseils calculated a long-run price elasticity of -0.76 for the region while Maddigan, et al estimated a long-run elasticity of -1.29.

**Mathematical Programming Model**

- The mathematical programming model estimates short-run (1-3 years) price elasticities of demand for electricity by Pacific Northwest irrigators. Producer responses to increasing electricity rates include changes in cropping mix, adjustment of water application levels, improved irrigation efficiency, and the removal of land from production.

- The estimated elasticities are low, indicating that short-run demand for electricity by irrigators is inelastic.

- The elasticities for small price increases (0-33%) are lower in absolute value than those for large price increases (34-100%).

- The Pacific Northwest regional elasticity at the lowest price increase is -0.14, with state-level elasticities ranging from -0.08 for Washington to -0.33 for Montana.

- As electricity prices increase, farmers substitute irrigation labor and management for energy and water. Irrigated acreage and crop mix remains relatively constant. Therefore, price elasticity estimates calculated from the mathematical programming model will be lower than those calculated from the econometric models.

## IRRIGATED AGRICULTURE SITUATION AND OUTLOOK

- Like most U.S. agriculture, Pacific Northwest irrigated agriculture has the capability to push production beyond the growth in demand. Irrigated crop producers are likely to face stable prices for their output over the next several years.

- With the potential for excess agriculture capacity, there may be continued pressure for government programs to idle cropland in order to balance supply and demand for agricultural commodities. Dryland agriculture is more likely to be idled than irrigated cropland.

- Irrigated agriculture will begin to face more restrictions on fertilizer, pesticides, and tillage practices in view of concerns over water quality and restriction on surface water diversion and groundwater pumping. These developments will be minor compared to the influence of trade, technology, and agricultural programs.

- Within the immediate two to three year outlook, there does not appear to be any pressing demand for large scale increases in agricultural production requiring significant expansion of Pacific Northwest irrigated cropland.

- Prospects are more optimistic for specialized high margin or high quality crops with competitive production costs and market share growth potentials, especially in foreign markets. These commodities include orchard crops, onions, potatoes, low cost forages, and specialty crops.

- The ability of producers to increase yields and manage weather risks through irrigation will continue to favor irrigated acreage in many crops.

- The Pacific Northwest irrigated agriculture is as competitive, if not more competitive, than other irrigated producing areas of the United States.

## IRRIGATION RATE STRUCTURES IN THE PACIFIC NORTHWEST

- Wholesale rates as a share of retail rates averaged 46 percent in 1980. By 1987 wholesale rates as a share of retail irrigation rates had increased to 67 percent with average wholesale rates ranging from 19.6 mills to 22.2 mills across production regions.

- Average retail irrigation rates rose from 16.1 mills in 1980 to 30.6 mills in 1987, varying from 25.1 mills in Eastern Washington to 60.0 mills in Western Oregon. Between 1980 and 1987 average wholesale rates paid by irrigation utilities increased over 180 percent while average retail irrigation rates charged by these utilities increased 90 percent.

- Between 1980 and 1987 the BPA general summer energy rate to preference customers increased over 280 percent while at the same time the summer demand charge increased 190 percent. With the irrigation discount, the wholesale summer energy rate increase was 160 percent. At the retail level energy rates increased 130 percent while estimated demand rates increased 49 percent reflecting the trend at the wholesale level.

- Approximately 49 percent of irrigation revenues in 1980 were derived from energy charges; by 1987 the share had increased to 60 percent.

- Although each irrigation utility has unique rate schedule characteristics, several general comments can be made: i) most have a flat per kWh charge for energy, ii) most include a horsepower charge rather than a per kW charge, and iii) time-of-day metering is not widespread.

## TARGETING WHOLESALE RATES TO IRRIGATION CUSTOMERS

- BPA has never implemented a targeted irrigation discount, but has a history of region wide irrigation discounts, starting in 1942. The most recent irrigation discounts were for the 1985 and 1987 rate periods, with discounts of 3.7 and 4.6 mills per kWh.

- Possible criteria for evaluating targeted rate discounts include economic efficiency, equity, administrative ease, need, costs, and legality.

- Targeting rate discounts to subgroups, rather than region wide, is costly and difficult to administer.

- Data to identify and quantify specific irrigator and utility groups that might be considered for targeted irrigation discounts are limited, making implementation and monitoring a targeted irrigation discount difficult.

- Alternatives to a targeted rate discount include: more rate stability, more encouragement for irrigation utility participation in the Partnership Program, increased technology transfer, and continuation of the current irrigation discount.

## ESTIMATED IMPACTS OF THE 1985 AND 1987 IRRIGATION RATE DISCOUNTS

- The irrigation rate discounts are estimated to have helped maintain producer incomes at a level above that which could have been achieved without the discount. It is estimated that the irrigation rate discount has led to an increase in farm incomes of $6.5, $7.0, and $8.5 million in 1986, 1987, and 1988, respectively.

- Using the short-run elasticities estimated for the irrigation sector, the 1985 and 1987 irrigation rate discounts resulted in a negative impact on revenue requirements for BPA. The net cost of the discount was estimated to be $9.7 million in 1986, $10.4 million in 1987, and $12.9 million in 1988.

- The wholesale rate increase needed to offset the cost of the discount was estimated to be 0.08 mills per kWh in 1986, 0.09 mills per kWh in 1987, and 0.11 mills per kWh in 1988.

- For 1988, a 0.11 mill increase in the Priority Firm rate is estimated to result in a $4.2 million direct income loss to non-irrigation consumers served by public utilities; total income loss (direct, indirect, and induced) is estimated at $8.2 million. Irrigation consumers served by public utilities are estimated to have gained $5.0 million and $8.0 million in direct and total income, respectively, as a result of the discount program. Similar changes in income have been estimated for 1986 and 1987.

## IRRIGATOR SURVEY

- Growers today are using less water and energy per acre than they did in the 1970s.
- Growers, in response to the farm recession and rising electricity prices, have shifted to "higher valued" crops.
- Expectations for the next few years are that the agricultural economy should remain somewhat static or improve slightly.
- Irrigation discounts have affected water and energy use and added to the perception of rate stability. Relatively few changes have been made to irrigated acreage, irrigation systems, and hired labor requirements.
- Irrigation rates in the last ten years were very important in determining irrigation system changes and per-acre water and energy use. Electricity rates were not as important in determining irrigated acreage, cropping patterns, and hired labor.
- In the future, electricity rates will play an important role in per-acre water and energy use and a lesser role in cropping patterns, irrigation systems, and hired labor decisions. Depending on the farm economy, the role of electricity rates on irrigated acreage varies (higher farm prices–less important role, lower farm prices–more important role).
- Irrigators do not expect to make any significant change in per-acre, monthly, or total electricity use in the next three years.
- Responses to future rate increases are inconclusive.
- Irrigators do not favor targeting irrigation rates within or between utilities based on farm characteristics.

- Irrigators want simple, stable, long-term electricity rates.

## CONCLUSIONS

- Irrigated agriculture is an important and significant economic base for rural communities and utilities within the BPA service area.

- The big growth period of Pacific Northwest irrigated agriculture appears to be over. Most irrigation utilities are faced with the task of protecting or maintaining their existing irrigation load.

- The BPA wholesale power rates in the 1980s have assumed a greater role in irrigation utility costs and irrigator profit and loss. From 1980 to 1987 BPA wholesale rates increased 180 percent, while average irrigation retail rates increased 90 percent. During the same period, the wholesale share as a percent of the retail rate increased from 46 percent to 67 percent.

- The irrigation electricity price elasticity of demand is estimated to be inelastic, with a weighted regional average of -0.49 in the short-run and -0.81 in the long-run.

- Farmers cannot pass on electricity rate increases to consumers. Farmers sell their crops in markets where prices are set by national and world supply and demand. Because irrigators cannot influence their crop prices, and the demand for electricity is inelastic, most electricity rate increases come out of farmers profits or contribute to greater losses.

- Given limited data and issues studied, the current irrigation discount may be more equitable to irrigators and more administratively efficient than a targeted discount.

- There is a general customer satisfaction among irrigators and irrigation utilities with the current irrigation discount.

- Irrigation discounts will not pay for themselves in the short-run and probably will not generate sufficient additional revenues in the long run to cover yearly discount costs.

- An important issue faced by BPA is whether or not the benefits of the irrigation discount to irrigators, irrigation utilities, and regional economies offset the costs of the discount program and the concerns of nonirrigation utilities and customers.

- The income to irrigators, from the irrigation discount, and those indirectly associated with irrigated agriculture would be about equal to the income loss to nonirrigators, if this group has to pay for the irrigation discount through increased rates.

## INTRODUCTION

Irrigation electricity sales in the Pacific Northwest averaged 4.5 million MWh annually between 1984 and 1987, with nearly one-half of that served by utility customers of BPA. Because of the depressed market conditions facing regional agriculture in recent years, BPA has offered a wholesale rate discount to irrigation customers since 1985. The discount has been justified on the basis of economic need in an effort to preserve an important load share that might otherwise be reduced.

Increased regional pressure for and against the wholesale rate discount has prompted BPA to evaluate the quantitative, qualitative, economic, and policy issues associated with an irrigation rate discount. BPA determined that more information was required in the following areas:

- Irrigation price elasticities at the subregional level (utility, group of utilities and/or production areas),
- Importance of irrigated agriculture to local and regional economies,
- Issues related to targeting an irrigation rate discount, and
- The role of BPA wholesale rates and rate discounts on Pacific Northwest sprinkler irrigation and the supporting economies.

In response to this request for additional information, the analysis in the present study is conducted in four parts:

- Document the importance of irrigated agriculture, particularly sprinkler irrigated agriculture, to the Pacific Northwest economy and quantify the impact of the rate discount on regional agriculture and local communities;
- Estimate irrigation price elasticities for BPA customers at a subregional level, so that load impacts associated with the rate discount can be evaluated at a more localized level;

- Identify the economic, policy, and practical application issues associated with targeting a rate discount to groups of utilities or irrigators; and

- Review the short-term economic and policy outlook for irrigated agriculture in the Pacific Northwest and draw implications regarding the impact on producer response to electricity rates.

## STUDY DESIGN AND REVIEW

This study was designed to allow for all interested parties to participate in the quantitative design and estimation of information, and to review data input and specific task reports. The study was conducted jointly by Northwest Economic Associates (prime contractor) and Washington State University (in particular, Drs. Norman Whittlesey and Larry James), and included a team of respected agricultural economists and engineers from major Land-Grant Universities:

Oregon State University
Dr. Marshal English
Dr. A. Gene Nelson
Dr. James Cornelius

Texas A&M University
Dr. Bruce McCarl

University of California, Davis
Dr. Richard Howitt

Private Consultant
Dr. Hans Radtke

The study also benefited greatly by the review of the Northwest Irrigation Utilities and their economic consultant, Dr. David Glyer, University of Colorado. Dr. Glyer helped in specifying the irrigation elasticity models and testing for statistical properties.

The study was designed to allow for a continuous input of information from reviewers. In addition to a series of preliminary report presentations, an irrigator survey was conducted at meetings in Pasco, Washington, and Burly, Idaho. The Northwest Irrigation Utilities and BPA Area Offices coordinated the irrigator meetings and helped design survey questions.

The Task 1, 2, and 3 reports were reviewed and presented at meetings to representatives from:

Bonneville Power Administration, District and Area Offices
Northwest Irrigation Utilities
Pacific Power and Light
Public Power Council
Northwest Power Planning Council
Washington Public Agencies Group
Representatives from Public and Private Utilities

A technical workshop was also conducted to review the economic models and to redesign equations to estimate irrigation electricity price elasticities. A consensus was reached at this workshop as to the variables, equations, and data needed to estimate price elasticities for Pacific Northwest irrigation utilities. These equations and elasticities are presented in this report.

## STUDY APPROACH AND METHODOLOGY

There is significant debate in the economic literature whether to use econometric or programming models to estimate irrigation electricity price elasticities in the short and long run. This study uses both econometric and programming models for estimating price elasticities for utilities and groups of utilities. The results of the programming models tend to give short-run elasticities, while the econometric model provides both short-run and long-run elasticities. In addition, irrigation electricity price elasticities are documented from other studies and research.

The community and regional impacts of sprinkler irrigation are estimated using IMPLAN, a subarea input/output model developed by the U.S. Forest Service.

The data used in this study are the best available data for sprinkler irrigated agriculture and utility irrigation electricity load in the Pacific Northwest. The data have been reviewed by Bonneville Power Administration, Northwest Irrigation Utilities, specific private and public utilities, the Land-Grant Universities, and selected agricultural experts. These data are consistent with BPA Agricultural Model, Northwest Agricultural Development Project, IMPLAN Input/Output Model, State and Federal Statistical Reporting Services, and available utility load information.

## STUDY AREAS

Throughout the report, results and information are presented by production areas, utilities, or group of utilities. The Agricultural Production Areas (APA) are groups of counties in the Pacific Northwest (PNW) with similar agricultural production characteristics. These areas were originally developed in the Northwest Agricultural Development Project and have been used for the last ten years by BPA and the Land-Grant Universities in describing agriculture in the Pacific Northwest. Figure 1 and Table 1 show the Agricultural Production Areas and the study utilities by production area.

This study is concerned primarily with public utilities that rely on BPA power and have a significant irrigation load. Private utilities are not included in the study with the exception of Pacific Power and Light, which made data available to the study and participated in the review process.

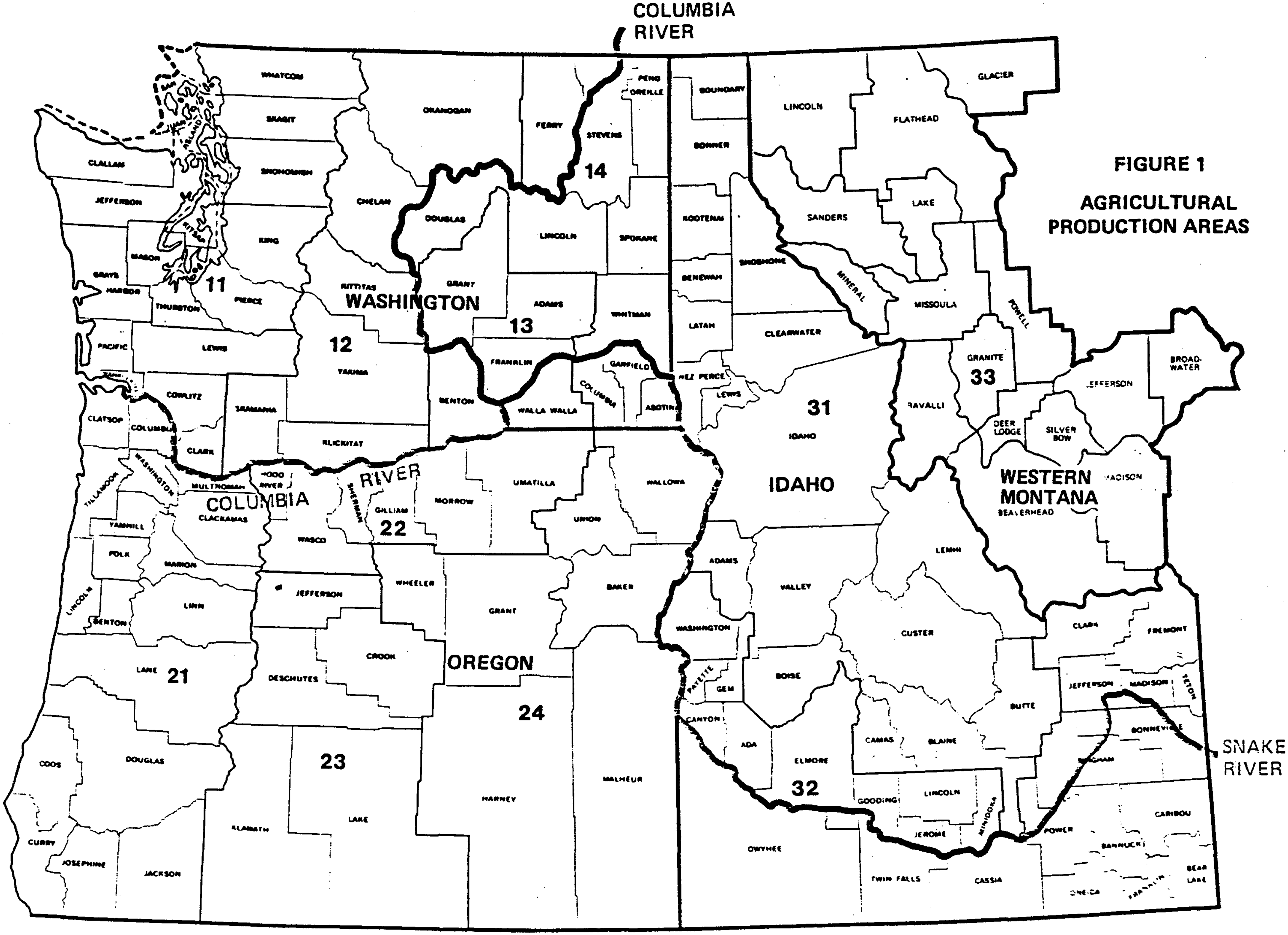


**FIGURE 1**

**AGRICULTURAL PRODUCTION AREAS**

## Table 1

## LIST OF STUDY UTILITIES BY AGRICULTURAL PRODUCTION AREA

| Irrigation Utility | Production Area | Percent of Service Area Within Production Area |
|---|---|---|
| Benton Co. PUD | 13 | 100 |
| Benton REA | 12 | 50 |
| | 13 | 50 |
| Big Bend Electric Coop. | 13 | 100 |
| Central Electric Coop | 23 | 100 |
| Columbia Basin Coop | 22 | 100 |
| Columbia REA | 13 | 92 |
| | 14 | 5 |
| | 22 | 3 |
| Consumers Power Inc. | 21 | 100 |
| Emerald Co. PUD | 21 | 100 |
| Fall River Electric Coop | 32 | 100 |
| Flathead Electric Coop | 33 | 100 |
| Franklin Co. PUD | 13 | 100 |
| Grant Co. PUD | 13 | 100 |
| Harney Electric Coop | 23 | 7 |
| | 24 | 93 |
| Inland Power and Light Co. | 14 | 100 |
| Klickitat Co. PUD | 12 | 100 |
| Kootenai Electric Coop | 33 | 100 |
| Lincoln WA Electric Coop | 13 | 6 |
| | 14 | 94 |
| Lost River Electric Coop | 31 | 100 |
| Midstate Electric Coop | 23 | 100 |
| Nespelem Valley Electric | 12 | 80 |
| | 14 | 20 |
| Raft River Electric Coop | 32 | 100 |
| Ravalli Electric Coop | 33 | 100 |
| Rural Electric Coop | 32 | 100 |

## Table 1 cont'd

## LIST OF STUDY UTILITIES BY AGRICULTURAL PRODUCTION AREA

| Irrigation Utility | Production Area | Approximate Percent in Production Area |
|---|---|---|
| Surprise Valley Electric Coop | 23 | 100 |
| Tillamook PUD | 21 | 100 |
| Umatilla Electric Coop | 22 | 94 |
| | 24 | 6 |
| Unity Light and Power | 32 | 100 |
| Vigilante Electric Coop | 33 | 100 |
| Wasco Electric Coop | 22 | 85 |
| | 23 | 10 |
| | 24 | 5 |
| Wells Rural Electric Coop | Nevada | |
| Pacific Power and Light | 22 | 30 |

# PACIFIC NORTHWEST IRRIGATED AGRICULTURE

Cropland production in the Pacific Northwest generates about 5.2 billion dollars annually. Over 3.8 billion dollars of these sales are from irrigated crops and 64 percent of the irrigated production is grown on electrically powered sprinkler-irrigated lands.

The importance of contributions from the agriculture sector to the overall economic health of the Pacific Northwest and the relationship of agriculture to local economies is reviewed and documented in the following sections. Input/output techniques are used to quantify the direct and indirect economic impacts between agriculture, irrigated agriculture, sprinkler irrigated agriculture, the food processing industry, and the local economy. The contribution of agriculture is measured with respect to output, employment and regional income.

## IRRIGATED AGRICULTURE IN THE PACIFIC NORTHWEST

### Irrigated Acreage

Approximately 14.8 million acres of agricultural cropland are harvested annually in Washington, Oregon, Idaho, and Western Montana. In addition, over 2.5 million acres of land are used exclusively for pasture, while an estimated 4.3 million acres of land are left fallow each year. Of this total 21.6 million acres of farmland in the Pacific Northwest, over 8 million acres are irrigated. Sprinkler systems are used on 4.6 million of the irrigated farmland; the remaining is flood irrigated. The majority of irrigation is for harvested cropland; the remainder is used on land for pasture. Irrigated alfalfa and other hay account for 2.7 million acres, or 33 percent of the total irrigated acreage. Irrigated grains (wheat, barley, oats, and grain corn) account for 2.4 million acres, or 29 percent of the total. Potatoes account for 6 percent, apples for 3 percent, and field crops (hops, mint, sugar beets, silage corn, beans, peas, lentils, and seed crops), vegetables and berries comprise the remaining 12 percent of irrigated acreage.[1]

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1/ Data obtained from *The 1978 and 1982 Census of Agriculture* and more recent state agricultural statistics.

The southern region of Idaho along the Snake River drainage is the largest irrigated agriculture area in the Pacific Northwest, encompassing 40 percent of the region's irrigated acreage.[1] Nearly half of this irrigated acreage is under sprinkler systems. The Columbia Basin region of Washington is also an important center of irrigated agriculture with over one million acres, or 13 percent, of irrigated cropland in the Northwest. Much of Pacific Northwest irrigated cropland is within federal irrigation project districts sponsored by the U.S. Bureau of Reclamation (USBR) where water is delievered to the farm. Farmers with lands in the irrigation districts pay relatively less to irrigate than do irrigators outside Bureau of Reclamation projects.[2]

A summary, by state, of irrigated and non-irrigated cropland acreage in the Pacific Northwest is illustrated in Table 2. Irrigated acreage as a share of total cropland varies significantly across the four states. Approximately 30 percent of cropland in Washington is irrigated while over 70 percent is irrigated in Western Montana. Oregon and Idaho have 50 percent and 68 percent irrigated cropland, respectively.

**Table 2**

**CROPLAND ACREAGE IN THE PACIFIC NORTHWEST**
**(1984-1986 Average)**

| State | Harvested Cropland | Irrigated Cropland | Irrigated Pasture | Sprinkler Irrigated Cropland | USBR Cropland |
|---|---|---|---|---|---|
| | Thousand Acres | | | | |
| Washington | 5,477 | 1,585 | 139 | 1,301 | 869 |
| Oregon | 3,331 | 1,447 | 431 | 960 | 448 |
| Idaho | 5,013 | 3,251 | 413 | 1,776 | 1,459 |
| Montana | 1,024 | 649 | 299 | 531 | 72 |
| **Pacific Northwest[a]** | **14,845** | **6,933** | **1,282** | **4,568** | **2,849** |

a/ State numbers may not add to total due to rounding error.

Source: Irrigated cropland harvested is an average of 1984-1986 data from the state Agricultural Statistics reports for each year. Irrigated pasture data are from the 1982 Census of Agriculture. Non-irrigated cropland is an estimated average of data from state Agricultural Statistics documents. USBR project acres were obtained from 1986 Summary Statistics published by the U.S. Bureau of Reclamation.

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1/ This area is served primarily by the Idaho Power Company.

2/ Although exact figures are not available, a large portion of USBR irrigated acreage is served by Grant Co. PUD in the Columbia Basin and Idaho Power Company in Southern Idaho.

Sprinkler irrigation methods are used on approximately 56 percent of all irrigated cropland in the Pacific Northwest. In areas supplied by surface water, sprinkler irrigation is used on 44 percent of the irrigated acreage. Farms that use groundwater as an irrigation source have a much higher proportion (93 percent) of their acreage under sprinkler systems. Approximately 76 percent of all irrigation in the region is from surface water (streams), while 24 percent is from groundwater (wells). The relationship between surface and groundwater use and sprinkler and flood irrigation is summarized in Table 3.

**Table 3**

**IRRIGATED ACREAGE BY WATER SOURCE IN THE PACIFIC NORTHWEST**
**(1984-1986 Average)**

| State | Surface Water | | Groundwater | |
|---|---|---|---|---|
| | Total | Sprinkler | Total | Sprinkler |
| | Thousand Acres | | | |
| Washington | 1,333 | 910 | 391 | 391 |
| Oregon | 1,616 | 698 | 262 | 262 |
| Idaho | 2,384 | 625 | 1,280 | 1,152 |
| Montana | 911 | 493 | 38 | 38 |
| **Pacific Northwest[a]** | **6,244** | **2,725** | **1,971** | **1,843** |

a/ State numbers may not add to total due to rounding error.

Source: Northwest Economic Associates. *Cropland Acreage in the Pacific Northwest*, April 1988.

Although much of the conversion from flood to sprinkler irrigation occurred prior to the late 1970's, new farmland established with sprinkler systems and the continued conversion from flood to sprinkler increased the importance of sprinkler irrigation in some parts of the region throughout the 1980's.

**Value of Agricultural Crop and Livestock Production**

Annual cash receipts from crop and livestock production in the Pacific Northwest averaged over $7.8 billion between 1984 and 1986; annual crop sales averaged $5.2 billion. Livestock and livestock products account for $2.6 billion of total sales. The demand for livestock feed provides a significant market for the many forage and feed crops produced in the region.

Total sales from irrigated cropland averaged $3.8 billion between 1984 and 1986. The value of irrigated crop sales, by major crop group is shown in Table 4.

**Table 4**
**VALUE OF IRRIGATED CROP PRODUCTION IN THE PACIFIC NORTHWEST**
**(1984-1986 Average)**

| State | Field Crops ($1,000,000) | Fruit, Nuts & Berries ($1,000,000) | Vegetables ($1,000,000) | Seed & Nursery Crops ($1,000,000) | Total Crops ($1,000,000) |
|---|---|---|---|---|---|
| Washington | 697 | 564 | 151 | 133 | 1,546 |
| Oregon | 437 | 155 | 154 | 188 | 934 |
| Idaho | 1,157 | 29 | 34 | 41 | 1,261 |
| Montana | 91 | 0 | 0 | 0 | 91 |
| **Pacific Northwest[a]** | **2,382** | **749** | **339** | **362** | **3,832** |
| **Value of Irrigated Production as a Percent of Total Value of Crop Production** | | | | | |
| Washington | 54 | 99 | 100 | 56 | 68 |
| Oregon | 67 | 100 | 100 | 44 | 67 |
| Idaho | 85 | 100 | 100 | 68 | 87 |
| Montana | 71 | | | | 70 |
| **Pacific Northwest** | **69** | **99** | **100** | **52** | **73** |

a/ State numbers may not add to total due to rounding error.

Source: Value of crop and livestock products are an average of 1984-1986 data from state Agricultural Statistics reports. Idaho data are 1983-1985 average.

Nearly 87 percent of total crop value in Idaho is derived from irrigated acreage, compared to 73 percent for the entire region. Irrigated crop sales account for just under 70 percent of the total crop sales for Oregon and Washington. Nearly 100 percent of fruit and vegetable production in the Pacific Northwest is irrigated, compared to under 70 percent for field crops (e.g., wheat, grains, alfalfa). The value of crop sales from lands under sprinkler irrigation is estimated to be $2.4 billion; sales across the four states are assumed to be distributed in the same proportion as sprinkler acreage.

## Agricultural Exports

Processed commodities, together with a substantial quantity of grain and other fresh products, are exported from the region to national and world markets. Production levels for many of the agricultural commodities produced for fresh and processed markets and the estimated quantities exported from Pacific Northwest ports to points overseas in 1985 are presented in Table 2 of Appendix A. Because exports from Pacific Northwest ports include products grown outside the region, as well as regional agricultural exports, it is difficult to isolate the quantities of Northwest grown products represented in the trade data. The figures presented in Appendix A are an attempt to show production and export commodities from the Pacific Northwest only. To develop this table, only exports that were likely to be from Pacific Northwest farms were included. For example, field corn was excluded because much of the field corn moves from midwestern farms to Pacific Northwest ports.

Estimated commodity production on irrigated lands is shown in the Table 5. Data on commodity exports from irrigated lands is unavailable, so the ratio of irrigated exports to irrigated production is assumed to be the same as the ratio of total exports to total production.[1] Sprinkler production is estimated to be 64 percent of irrigated production.

**Table 5**

**ESTIMATED PRODUCTION & EXPORT OF IRRIGATED COMMODITIES**

| Commodity[a] | COMMODITY PRODUCTION Washington (tons) | Oregon (tons) | Idaho/Montana (tons) | PNW Total (tons) | Exports From PNW Ports Exports (tons) | Percent of Production |
|---|---|---|---|---|---|---|
| Grains | 2,991,600 | 1,675,670 | 3,922,667 | 8,589,937 | 4,973,358 | 57.9 |
| Potatoes | 2,304,720 | 821,420 | 4,022,602 | 7,148,742 | 207,716 | 2.9 |
| Field Crops | 1,958,090 | 3,393,396 | 13,040,953 | 18,392,439 | 580,755 | 3.2 |
| Fruits & Vegetables | 1,830,300 | 310,500 | 72,300 | 2,213,100 | 183,796 | 8.3 |

a/ Data are based on average production between 1984 and 1986.

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1/ Estimated production and export of Pacific Northwest agricultural commodities is presented in Volume 2, Section A, Table 2.

## Agricultural Employment

Total agricultural employment was estimated using data provided by the state employment offices in Washington, Oregon, Idaho, and Montana.[1] Employment in the food processing industry, Standard Industrial Classification (SIC) 20, is reported by each state. Because farm workers are not usually covered under state unemployment insurance, the farm labor numbers represent only a fraction of total laborers. Family members that derive employment from the farm are not included in the state employment statistics. To more accurately reflect total employment associated with the agricultural sector, family employment is added to the state employment data. It was assumed that a farm would employ one family member. No other upward adjustments were made to the state data. Regional employment associated with agricultural production and food processing for 1986 is presented in Table 6.

### Table 6

**FARM AND FOOD PROCESSING EMPLOYMENT IN THE PACIFIC NORTHWEST**

| State | Crop Production[a] Employment | Livestock[a] Employment | Family Employment | Total Farm Employment | Food Processing[a] Employment |
|---|---|---|---|---|---|
| Washington | 27,879 | 2,934 | 38,000 | 68,813 | 31,005 |
| Oregon | 14,320 | 1,727 | 37,000 | 53,047 | 23,538 |
| Idaho | 6,935 [b] | | 24,000 | 30,935 | 15,435 |
| Montana | 158 | 319 | 6,203 | 6,680 | 2,785 [c] |
| **Pacific Northwest** | **49,292** | **4,980** | **105,203** | **159,475** | **72,763** |

Source: State Covered Employment Data for Washington, Oregon, Idaho, and Montana, 1986.

a/ Data are for covered employment only. Most on-farm workers are not covered by workers compensation or unemployment insurance.

b/ Data includes crop and livestock employment.

c/ Montana data for food processing is for entire state. Covered employment data for crop production employment and livestock employment for Western Montana was estimated using the proportion of farms in Western Montana in the 1982 Census. Family employment was also estimated using the 1982 proportion of farms in Western Montana applied to the 1986 total number of farm crop production employment and livestock employment.

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1/ State-level data on agriculture employment is likely to underestimate the total number of farm workers as state figures take into account only those workers covered by unemployment insurance.

Total farm employment in the Pacific Northwest, based on adjusted state reported data, is estimated to be nearly 158,000 persons. The majority of the employment is found in Oregon and Washington. Approximately 73,000 workers are employed in the regional food processing industry.

## SPRINKLER IRRIGATED AGRICULTURE AND RURAL COMMUNITIES

The relative importance of agriculture to local economies varies across the production acres of the Pacific Northwest. Cropland acreage for the nine regions is presented in Table 7.

**Table 7**

**CROPLAND ACREAGE PACIFIC NORTHWEST PRODUCTION AREAS**
**(1984-1986 Average)**

| Production Area | Total Cropland (1,000 acres) | Irrigated Cropland (1,000 acres) | Sprinkler Irrigated (1,000 acres) | Percent of Irrigated Acreage Under Sprinkler Systems |
|---|---|---|---|---|
| 11/21 - W. Washington/Oregon | 1,439 | 383 | 344 | 90 |
| 12 - Central Washington | 599 | 401 | 252 | 63 |
| 13 - Columbia Basin (WA) | 2,100 | 932 | 699 | 75 |
| 14 - Eastern Washington | 2,418 | 145 | 140 | 97 |
| 22 - North Central Oregon | 1,130 | 274 | 238 | 87 |
| 23 - Central Oregon | 428 | 383 | 130 | 34 |
| 24 - Eastern Washington | 695 | 516 | 160 | 31 |
| 31/33 - N. Idaho/W. Montana | 2,221 | 946 | 530 | 56 |
| 32 - Southern Idaho | 3,816 | 2,954 | 1,389 | 47 |
| **Pacific Northwest** | **14,845** | **6,933** | **3,883** | **56** |

Source: Northwest Economic Associates, Cropland Acreage in the Pacific Northwest, 1988. Acreage figures do not include pasture.

Irrigated acreage as a share of total acreage ranges from a low of 6 percent in Eastern Oregon to a high of 89 percent in Central Oregon. The Columbia Basin region in Central Washington and the Snake River region in Southern Idaho are the largest areas of irrigated agriculture in the Pacific Northwest. A substantial portion of the irrigated acreage in these two regions is associated with the large-scale federal irrigation project development that occurred during the last several decades. Sprinkler irrigated acreage as a percent of total irrigated acreage ranges from a low of 31 percent in Eastern Oregon to a high of 97 percent in Eastern Washington. Overall, sprinkler accounts for 56 percent of irrigated acreage in the region.

Irrigated crop mix also varies across the nine production areas. Potatoes, wheat, and grain corn are important crops in the Columbia Basin (Washington) and Southern Idaho while tree fruit and berry production occurs primarily in Central Washington and Western and North Central Oregon. Irrigated hay and alfalfa account for the largest portion of irrigated cropland in Central and Eastern Oregon, Northern Idaho, and Western Montana.

## VALUE OF OUTPUT AND EMPLOYMENT

In many rural communities of the Pacific Northwest agricultural production and food processing contribute significantly to the local economy. Farm producers purchase many of their production inputs from local suppliers and sell much of their harvested output to local processors and storage facilities. The interrelationships between agriculture and other sectors of the regional economy can be evaluated using an input/output modeling framework. A basic premise of the input/output framework is that each industry sells its output to other industries and final consumers who, in turn, purchase goods, services, and primary factors of production from other industries in the region. Therefore, the economic contribution of an industry to the local economy can be determined by changes in industry output and the relationships among industry purchasing patterns.

The economic models used to evaluate the relationship between sprinkler irrigated agriculture and local communities in this report are derived from the IMPLAN model developed by the U.S. Forest Service. IMPLAN can be used to construct county or multi-county input/output (I/O) models for any region of the United States. The regional I/O models are derived from the technical coefficients of a national model and localized estimates of total gross output for various industries and consumer sectors. The computer program IMPLAN adjusts the national data to fit the economic composition and estimated trade balance of a chosen region. For purposes of this task, regional input/output models for nine production areas of the Pacific Northwest were derived from the current IMPLAN model.[1] The regional input/output models include information on interindustry sales and purchasing patterns, value of gross output, income, employment, value

1/ Production Areas 11 and 21 are included in one region as are Production Areas 31 and 33.

added, and measures of the direct and indirect relationships among local industries.[1]

Value of production, net income, and employment associated with regional sprinkler irrigated agriculture are calculated for each production area. The value of production from sprinkler production is estimated from data reported by state agricultural statistical sources. The value of irrigated crop production, by region, is multiplied by the share of sprinkler acreage to provide an estimate of the value of sprinkler irrigated production. Regional income and employment are derived using relationships from the production area input/output models. The ratio of income per million dollars of output and jobs per million dollars of output are taken from the I/O models and multiplied by the estimates of gross output developed from the state data to give estimates of income and employment. Income and employment coefficients were modified using crop production budgets to derive appropriate relationships for sprinkler irrigation, resulting in slightly lower ratios relative to all irrigated production.[2]

Values for total production and per acre production are given in Table 8. In all regions, per acre value of output for sprinkler irrigated crop production is greater than that for all crops (irrigated plus non-irrigated). The significantly higher yields associated with irrigated production for many crop types lead to higher estimates of value per acre. Income and employment per acre for irrigated production are also higher than the overall average for crop production because of the higher value, more labor intensive crop types that tend to be grown on irrigated lands (e.g., vegetables and tree fruits). It is estimated that sprinkler

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1/ Output from the nine regional models has been placed on file with the Bonneville Power Administration, Economic Forecasting Section. The following information is included as part of each regional model: 1) Leontief inverse matrix, 2) output, personal income, total income, value added, and employment multipliers, 3) regional report on income, output, and government expenditures, and 4) regional consumption, investment, and trade demand.

2/ Sprinkler irrigation is more capital intensive and has a lower net income per acre (with similar yields) than other irrigation methods. For an example see *1988 Cost of Producing Crops Under Center Pivot Irrigation, Columbia Basin, Washington,* Extension Bulletin 1291, and *1988 Cost of Producing Crops Under Rill Irrigation, Columbia Basin, Washington,* Extension Bulletin 1292, Cooperative Extension, College of Agriculture and Home Economics, Washington State University, Pullman, Washington, 1988.

# Table 8

## VALUE OF PRODUCTION, INCOME, AND EMPLOYMENT FOR PACIFIC NORTHWEST SPRINKLER IRRIGATED AGRICULTURE

**VALUE OF PRODUCTION, INCOME, AND EMPLOYMENT**

| Production Area (PA) | Value of Production ($1,000,000) | Value Per Acre ($) | Net Farm Income ($1,000,000) | Income Per Acre ($) | Employment (no. of jobs) | Employment Per 1,000 Acres |
|---|---|---|---|---|---|---|
| 11/21 - W. Washington/Oregon | 598 | 1,736 | 307 | 892 | 20,561 | 59.7 |
| 12 - Central Washington | 403 | 1,597 | 198 | 786 | 14,594 | 57.8 |
| 13 - Columbia Basin (WA) | 475 | 679 | 208 | 297 | 9,513 | 13.6 |
| 14 - Eastern Washington | 62 | 442 | 28 | 196 | 1,807 | 12.9 |
| 22 - North Central Oregon | 163 | 679 | 74 | 310 | 4,205 | 17.7 |
| 23 - Central Oregon | 34 | 258 | 15 | 113 | 597 | 4.6 |
| 24 - Eastern Oregon | 60 | 376 | 24 | 151 | 1,024 | 6.4 |
| 31/33 - N. Idaho/W. Montana | 95 | 180 | 33 | 63 | 1,587 | 3.0 |
| 32 - Southern Idaho | 556 | 400 | 235 | 169 | 10,787 | 7.8 |
| **Total for Sprinkler Irrigated Crops** | **2,445** | **630** | **1,122** | **289** | **64,677** | **16.7** |
| **Total for All Crops[a]** | **5,231** | **352** | **2,338** | **157** | **131,225** | **8.8** |
| **Total for Irrigated Crops[a]** | **3,833** | **553** | **1,791** | **258** | **97,718** | **14.1** |

**MULTIPLIERS FOR VALUE OF PRODUCTION, INCOME, AND EMPLOYMENT**

| Production Area | Value of Production | Net Farm Income | Employment |
|---|---|---|---|
| 11/21 - W. Washington/Oregon | 2.06 | 1.93 | 1.53 |
| 12 - Central Washington | 1.77 | 1.75 | 1.43 |
| 13 - Columbia Basin (WA) | 1.51 | 1.54 | 1.47 |
| 14 - Eastern Washington | 1.76 | 1.86 | 1.50 |
| 22 - North Central Oregon | 1.43 | 1.45 | 1.37 |
| 23 - Central Oregon | 1.42 | 1.46 | 1.42 |
| 24 - Eastern Oregon | 1.39 | 1.43 | 1.50 |
| 31/33 - N. Idaho/W. Montana | 1.66 | 1.87 | 1.63 |
| 32 - Southern Idaho | 1.67 | 1.70 | 1.59 |
| **Pacific Northwest** | **1.73** | **1.72** | **1.50** |

**DIRECT AND INDIRECT ECONOMIC ACTIVITY ASSOCIATED WITH SPRINKLER IRRIGATED AGRICULTURE**

| Production Area (PA) | Value of Production ($1,000,000) | Output Per Acre ($) | Total Income ($1,000,000) | Income Per Acre ($) | Employment (no. of jobs) | Employment Per 1,000 Acres |
|---|---|---|---|---|---|---|
| 11/21 - W. Washington/Oregon | 1,231 | 3,576 | 593 | 1,722 | 31,459 | 91.4 |
| 12 - Central Washington | 714 | 2,827 | 347 | 1,375 | 21,870 | 82.7 |
| 13 - Columbia Basin (WA) | 717 | 1,026 | 320 | 458 | 13,985 | 20.0 |
| 14 - Eastern Washington | 109 | 778 | 51 | 365 | 2,711 | 19.3 |
| 22 - North Central Oregon | 233 | 977 | 107 | 450 | 5,761 | 24.2 |
| 23 - Central Oregon | 48 | 367 | 21 | 165 | 848 | 6.5 |
| 24 - Eastern Oregon | 84 | 523 | 35 | 216 | 1,537 | 9.6 |
| 31/33 - N. Idaho/W. Montana | 158 | 298 | 62 | 117 | 2,586 | 4.9 |
| 32 - Southern Idaho | 928 | 668 | 400 | 288 | 17,151 | 12.4 |
| **Pacific Northwest** | **4,221** | **1,087** | **1,937** | **499** | **96,908** | **25.0** |

a/ See Tables 3, 5, and 6 of Volume 2, Section A for more detail.

irrigation accounts for 64 percent of the value of irrigated production in the Pacific Northwest (or 47 percent of the value of total crop production).[1]

Although per acre value of production on sprinkler lands is assumed to be the same as for all irrigation, income and employment values are lower due to the higher cost, more capital intensive nature of sprinkler production. Per acre value of sprinkler production is greatest in Western Oregon and Western and Central Washington, regions with high concentrations of high-valued fruit and vegetable production. Net farm income and employment per acre are also greater in these areas. Regions characterized primarily by hay and alfalfa production have the lowest per acre values for output, income, and employment.

## MEASURING THE LINKAGE BETWEEN SPRINKLER IRRIGATED AGRICULTURE AND THE LOCAL ECONOMY

The nine regional input/output models are used to link the indirect and direct impacts of sprinkler irrigated agriculture to other sectors of the local economy. This linkage is done with multipliers. An output multiplier measures the local output activity associated with money generated from out-of-region sales. In input/output models the exporting sectors of local economies are called "basic" sectors. It is the dollars brought into the local economy from the basic or exporting sectors that begin the multiplied process. When out-of-region sales are made by a local business, the firm spends some part of its new dollars on local goods or services; the remainder is spent on nonlocal purchases, referred to as "leakages." Additional activity is generated when the owner of the purchased goods or services spends some part of the dollar again, and so on until the value becomes too small to measure. The value of the multiplier is determined by adding the initial dollar to the sum of local spending.

While output (sales) multipliers are useful in describing the interrelationships between business sectors, they do not adequately describe the amount of income or employment generated locally by specific business activities. A more useful measure of the contribution of an industry to local economic

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1/ Value of production, net income, and employment are presented in Volume 2, Section A, Table 3 for all Pacific Northwest agriculture, crop production only, all irrigated crop production, and sprinkler irrigated crop production.

activity is the amount of local income that is directly and indirectly generated from an increase in sales. The local income coefficient measures the income generated as a result of a change in sales. In agriculture, for each new dollar of farm sales made out-of-region, part of the dollar is retained in the local area as income to the farm producer (direct income generated). That portion of the new dollar spent on supplies and services for farm production also generates additional income (indirect income generated). As the new income is spent on general goods and services, even more income is generated (induced income). The income multiplier is the total direct, indirect, and induced income generated for each new dollar of direct income. The size of the income multiplier is largely determined by the amount of income generated in the first round. Labor intensive industries tend to have larger income multipliers than capital intensive industries, whereas the opposite is often true for output multipliers.

When an industry increases output as a result of new out-of-region sales, additional production inputs are required, including more labor (direct employment generated). As additional output is generated from the indirect and induced purchase of new goods and services, additional employment is also generated. Employment multipliers are measured as the direct, indirect and induced employment associated each new job generated by out-of-region sales.

Production area multipliers for sprinkler irrigation value of output, net farm income, and employment are presented in the middel section of Table 8.[1] The multipliers in Table 8 are calculated as a weighted average of individual commodity group multipliers from the regional input/output models; shares of output, income, and employment by commodity group are used as weights.[2]

The total direct, indirect, and induced regional economic activity related to sprinkler irrigated crop production is presented in the lower portion of Table 8.[3]

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1/ Production area multipliers are presented in Volume 2, Section A, Table 5 for all agriculture, crop production only, all irrigated crop production and all sprinkler irrigated crop production.

2/ The regional input/output multipliers are a weighted average of multipliers for nine crop groups: food grains, feed grains, hay and pasture, seed crops, vegetables, fruits, tree nuts, sugar crops, and miscellaneous crops.

3/ Gross economic activity, by production area, for all agriculture crop production only, all irrigated crop production only, and all sprinkler irrigated crop production is presented in Volume 2, Section A, Table 6.

Values are calculated using the regional output, income, and employment totals by the related multiplier. Total activity is measured in terms of absolute and per acre values. In addition to the $2.4 billion in direct value of sprinkler irrigated crop production, $1.8 billion of indirect and induced output is generated throughout the local economy, resulting in $4.2 billion in direct, indirect, and induced value of output. It is estimated that $1.9 billion of direct, indirect, and induced regional income is generated by farm production on sprinkler irrigated lands; approximately $0.8 billion of this is attributable to indirect and induced income. Approximately 97,000 jobs are also estimated to be associated with sprinkler agricultural production in the Pacific Northwest; 64,677 of these are direct jobs while an additional 32,231 indirect and induced jobs are generated throughout the economy.

The importance of sprinkler irrigated agriculture to the local economic base is demonstrated when total direct and indirect value of output, net income, and employment is measured on a per acre basis. The average direct and indirect value of crop production is $605 per acre whereas total output generated per acre of sprinkler irrigated crop production is $1,087. Total income generated by crop production averages $276 per acre compared to $499 per acre for sprinkler production. Employment generated by sprinkler irrigated farming is estimated to be 25 jobs per 1,000 acres compared to 13 jobs for all agriculture.

**Sprinkler Irrigated Agriculture As A Share of All Regional Output**

In many regions of the Pacific Northwest, particularly in the more rural areas, agriculture is a significant part of the regional economic base. Estimates of sprinkler agricultural output, income, and employment as a share of regional activity are presented in Table 9.[1] Relative to other regions of the Pacific Northwest, sprinkler irrigated agriculture is most important in Production Areas 12, 13, 22, 24, and 32. Value of output ranges from 0.4 percent of regional output in Western Washington and Western Oregon to over 8 percent of regional output in the Columbia Basin. Agricultural employment also varies across the region, ranging from 1.5 percent in Area 11/21 to 20 percent in Production Area 12.

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1/ Estimates of output, income, and employment as a share of regional activity are presented in Volume 2, Section A, Table 4 for all agriculture, all crop production, all irrigated crop production, and all sprinkler irrigated crop production.

Sprinkler irrigated employment accounts for approximately 2.0 percent of regional employment, varying from 0.8 percent of production in Area 11/21 and Area 31/33 employment to nearly 12 percent of employment in Central Washington.

**Table 9**
**SPRINKLER IRRIGATED AGRICULTURE AS A SHARE OF REGIONAL ECONOMIC ACTIVITY**

| Production Area (PA) | Value of Production | | Net Farm Income | | Employment | |
|---|---|---|---|---|---|---|
| | All Crop Production[a] | Sprinkler Production | All Crop Production[a] | Sprinkler Production | All Crop Production[a] | Sprinkler Production |
| | (Percent) | | | | | |
| 11/21 - W. Washington/Oregon | 0.7 | 0.4 | 0.8 | 0.4 | 1.5 | 0.8 |
| 12 - Central Washington | 12.0 | 6.7 | 13.1 | 7.5 | 20.0 | 11.9 |
| 13 - Columbia Basin (WA) | 13.0 | 8.3 | 13.1 | 8.3 | 14.8 | 9.7 |
| 14 - Eastern Washington | 5.2 | 0.9 | 3.8 | 0.9 | 6.0 | 1.4 |
| 22 - North Central Oregon | 11.2 | 6.7 | 11.3 | 7.2 | 16.4 | 11.0 |
| 23 - Central Oregon | 3.3 | 1.0 | 3.2 | 0.9 | 3.9 | 1.2 |
| 24 - Eastern Oregon | 10.6 | 3.1 | 10.5 | 2.9 | 9.9 | 2.8 |
| 31/33 - N. Idaho/W. Montana | 4.3 | 1.3 | 3.1 | 1.0 | 3.6 | 1.1 |
| 32 - Southern Idaho | 10.4 | 4.6 | 10.6 | 4.4 | 10.4 | 4.5 |
| Pacific Northwest | 3.1 | 1.5 | 2.9 | 1.4 | 4.3 | 2.2 |

a/ All crop production refers to all irrigated and non-irrigated production.

## FOOD PROCESSING

A substantial portion of crops grown in the Pacific Northwest (especially fruits and vegetables) are processed within the region. Food processing is a major industry, arising from the production of nearly 15 million tons of potatoes, apples, and other fruit and vegetables that are frozen, canned, dehydrated, or concentrated for consumption throughout the region, the country, and the world. It is estimated that the food processing industry accounts for nearly two percent of gross state product in the region. The industry accounts for over ten percent of gross product in the manufacturing sector.[1]

The processing of agricultural commodities contributes additional off-farm economic benefits to the rural communities of the Pacific Northwest. Regional

1/ Based on 1986 data for Oregon, Washington, and Idaho. Data from "Gross State Product Indicators," *Pacific Northwest Executive*, October, 1988. Figures developed from the gross state product data series maintained by the U.S. Bureau of Economic Analysis.

economic activity associated with the food crop processing industry is presented in Table 10. Employment in the industry is estimated to be over 60,000 workers, approximately 12,000 fewer workers than estimated using state data. The employment figures from the input output model reflect only crop-related food processing activities.

To avoid double counting with the farm sector, the appropriate measure of output used for the food processing sector is "value added". Value added is the difference between gross output of food processing and the cost of inputs including labor and raw materials. Value added by the food processing industry varies widely across the region. Western Washington and Oregon have the greatest value added of any region but, because other high value added industries exist in this area, the food processing industry contributes only 1.7 percent to total value added in the region. By contrast, the Columbia Basin and Southern Idaho have fewer value added dollars but the food processing industry is relatively more important to the local economy. A similar pattern is found in the total income and employment figures. The additional gross economic activity attributable to food processing can be calculated by multiplying value added,[1] total income, and employment by the respective multipliers. Food processing generates the most sigponificant additional impacts in Western Washington/Oregon and Southern Idaho.

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1/ The indirect impacts currently estimated for the food processing sector include some overlap with indirect inputs previously estimated crop production. It is expected that impacts are relatively more overstated in regions where a larger share of agricultural output is related to processed commodities (Western Washington/Oregon, Central Washington, and Southern Idaho).

# Table 10
# VALUE ADDED, INCOME, AND EMPLOYMENT IN THE PACIFIC NORTHWEST FOOD PROCESSING INDUSTRY [a]

VALUE ADDED, INCOME, AND EMPLOYMENT

| Production Area (PA) | Value Added ($1,000,000) | % of PA Value Added | Net Income ($1,000,000) | % of PA Net Income | Employment (no. of jobs) | % of PA Employment |
|---|---|---|---|---|---|---|
| 11/21 - Western Washington/Oregon | 1,154 | 2.6 | 1,067 | 2.6 | 28,160 | 1.3 |
| 12 - Central Washington | 117 | 3.9 | 110 | 4.0 | 2,683 | 2.1 |
| 13 - Columbia Basin (WA) | 181 | 5.5 | 178 | 5.7 | 6,220 | 5.0 |
| 14 - Eastern Washington | 55 | 1.2 | 53 | 1.3 | 1,547 | 0.9 |
| 22 - North Central Oregon | 65 | 4.2 | 57 | 4.0 | 2,349 | 4.4 |
| 23 - Central Oregon | 14 | 0.7 | 14 | 0.7 | 481 | 0.8 |
| 24 - Eastern Oregon | 28 | 3.1 | 27 | 3.3 | 1,203 | 3.4 |
| 31/33 - N. Idaho/W. Montana | 35 | 0.7 | 34 | 0.8 | 904 | 0.5 |
| 32 - Southern Idaho | 434 | 6.4 | 424 | 6.7 | 16,579 | 5.8 |
| **Pacific Norhtwest** | **2,083** | **2.2** | **1,966** | **2.9** | **60,128** | **1.9** |

VALUE ADDED, INCOME, AND EMPLOYMENT MULTIPLIERS

| Production Area | Value Added | Total Income | Employment |
|---|---|---|---|
| 11/21 - Western Washington/Oregon | 2.20 | 2.20 | 2.72 |
| 12 - Central Washington | 2.13 | 2.10 | 3.15 |
| 13 - Columbia Basin (WA) | 2.36 | 2.29 | 2.72 |
| 14 - Eastern Washington | 2.10 | 2.03 | 2.51 |
| 22 - North Central Oregon | 2.11 | 2.17 | 2.51 |
| 23 - Central Oregon | 1.92 | 1.86 | 2.06 |
| 24 - Eastern Oregon | 2.16 | 2.10 | 2.16 |
| 31/33 - N. Idaho/W. Montana | 2.51 | 2.40 | 3.21 |
| 32 - Southern Idaho | 2.90 | 2.77 | 2.99 |
| **Pacific Northwest** | **2.35** | **2.32** | **2.79** |

ADDITIONAL GROSS REGIONAL ACTIVITY ATTRIBUTABLE TO FOOD PROCESSING

| Production Area (PA) | Value Added ($1,000,000) | Total Income ($1,000,000) | Employment ($1,000,000) |
|---|---|---|---|
| 11/21 - Western Washington/Oregon | 2,539 | 2,347 | 76,595 |
| 12 - Central Washington | 249 | 231 | 8,451 |
| 13 - Columbia Basin (WA) | 427 | 408 | 16,918 |
| 14 - Eastern Washington | 116 | 108 | 3,883 |
| 22 - North Central Oregon | 137 | 124 | 5,896 |
| 23 - Central Oregon | 27 | 26 | 991 |
| 24 - Eastern Oregon | 60 | 57 | 2,598 |
| 31/33 - N. Idaho/W. Montana | 88 | 82 | 2,902 |
| 32 - Southern Idaho | 1,259 | 1,174 | 49,571 |
| **Pacific Northwest** | **4,902** | **4,566** | **167,806** |

a/ Figures are derived from the nine production area input/output models developed for this study. Values are in 1986 dollars.

## THE ROLE OF ELECTRICITY IN PACIFIC NORTHWEST

### IRRIGATED AGRICULTURE

Approximately 4.5 million megawatt hours of electricity are consumed annually in pumping water for irrigation application in the Pacific Northwest. Of the total, 46 percent is supplied by public utilities while 54 percent is supplied by private utilities. Irrigation electricity sales and average price per kWh are presented by state and utility-type in Table 11. Idaho and Washington have significantly higher levels of irrigation electricity use than Oregon or Western Montana. Both states have regions of large-scale irrigation project development. The average retail electricity rate is significantly lower in Washington, nearly 20 percent below the regional average.

**Table 11**

**ELECTRICITY SALES FOR IRRIGATION PUBLIC & PRIVATE UTILITIES**
**(1984-1986 Average)**

| | Public Utilities | | Private Utilities | | Total | |
|---|---|---|---|---|---|---|
| State | MWh | mills/kWh | MWh | mills/kWh | MWh | mills/kWh |
| Washington | 1,329,527 | 23.0 | 234,299 | 39.3 | 1,563,757 | 25.5 |
| Oregon | 499,399 | 35.4 | 382,293 | 33.0 | 881,691 | 34.3 |
| Idaho | 211,867 | 38.0 | 1,791,681 | 34.7 | 2,003,548 | 35.0 |
| Montana | 64,935 | 39.6 | 21,624 | 49.1 | 86,559 | 42.0 |
| **Total** | **2,105,728** | **28.0** | **2,429,827** | **35.0** | **4,535,555** | **31.7** |

Source: Bonneville Power Administration 1988. Aggregated to state level by Northwest Economic Associates.

As the use of sprinkler irrigation has increased, so has the amount of electricity sold to agriculture. Electricity use varies from year to year depending on weather conditions, crop mix, and availability of water supplies. The overall level of electricity use for irrigation has increased approximately 12 percent since the mid-1970's; however, in recent years, electricity use has shown some decline, with total sales varying between 4.0 and 4.8 million megawatt hours. The recent leveling off and downward trend in irrigation energy use appears to be due more to reduce per acre use than to acreage reduction. The most recent BPA long-term forecast for irrigation load is a slight decrease over the next 20 years.

The irrigation season in the Pacific Northwest generally starts in March or April and ends in October. Peak electricity use occurs in June, July, and August, with August being the highest month of sales. Monthly use of irrigation electricity varies throughout the region due to climatic conditions and cropping patterns. The western part of the region, which experiences late spring rains, generally does not start irrigating until June, peaks in August, and then drops off rapidly. Irrigation in the drier, lower elevation areas of the eastern part of the region starts in April, increases rapidly in May, stays fairly constant in June, July, and August and then drops off in September to about May levels. Farmers in the higher elevation production areas with shorter growing seasons generally start irrigating in June and peak in July or August. The irrigation season generally ends in October, although there may be some pre-irrigation in November to increase soil moisture for spring planting of grain and other crops.

## ON FARM ELECTRICITY USE

Relative to other inputs, irrigation electricity generally accounts for a small part of agricultural production costs, although the actual share varies with production area, system type, electricity price, conservation practice, and crop type. Electricity costs also vary significantly with pumping lifts. Generally, the kilowatt-hours per acre required to provide water to lands under high lift are two to three times greater than that required for lower lift lands. A comparison of average kWh per acre required for irrigation on high lift and average lift lands is presented in Table 12 for selected production areas. High lift requirements are given for both center pivot and side roll systems. A comparison of electricity costs per acre for representative high lift and average lift lands is also presented. Assuming three acre-feet of applied water and the average electricity rate indicated in the table, electricity costs per acre in the high lift areas, using a pressurized irrigation system, exceed the production area average irrigation electricity costs by two to four times. It should be noted that there are some growers, particularly in Eastern Washington (PA 14), with pumping lifts in excess of 500 feet. These growers are irrigating wheat, but have cut back applied water use to 10 to 16 inches per acre compared to 19 to 25 inches elsewhere.

## Table 12

## ESTIMATED IRRIGATION ELECTRICITY REQUIREMENTS FOR CENTER PIVOT AND SIDE-ROLL SYSTEMS FOR SELECTED PRODUCTION AREAS

### ELECTRICITY REQUIRED FOR IRRIGATION

| Production Area | High Lift Electricity Use[a] Center Pivot (kWh/AF) | Side Roll (kWh/AF) | Production Area Average[b] Electricity Use (kWh/AF) |
|---|---|---|---|
| 12 - Central Washington | 862 | 723 | 224 |
| 13 - Columbia Basin (WA) | 1,033 | 872 | 323 |
| 14 - Eastern Washington | 848 | 710 | 406 |
| 22 - North Central Oregon | 701 | 562 | 456 |
| 32 - Southern Idaho | 913 | 740 | 191 |

### COST COMPARISON OF ELECTRICITY REQUIRED FOR PRODUCTION

| Production Area | High Lift Electricity Use[a] Center Pivot ($/acre) | Side Roll ($/acre) | Production Area Average[b] Electricity Use ($/acre) | Average Electricity Price (mills/kWh) |
|---|---|---|---|---|
| 12 - Central Washington | 84 | 70 | 22 | 32.3 |
| 13 - Columbia Basin (WA) | 73 | 61 | 23 | 23.5 |
| 14 - Eastern Washington | 68 | 57 | 33 | 26.9 |
| 22 - North Central Oregon | 65 | 52 | 42 | 30.8 |
| 32 - Southern Idaho | 95 | 77 | 20 | 34.8 |

a/ High lift areas have pumping lifts that exceed 250-300 feet and/or there is a long lift (1-2 miles) from surface water sources. For purposes of this example with center pivot and side roll, electricity use includes both lift and system pressurization based on a 70 percent pump efficiency.

b/ Total electricity use divided by total irrigation water use (both flood and sprinkler).

Electricity costs also vary significantly with crop type. Wheat, alfalfa, potatoes, fruit, vegetables, and a variety of field crops are the primary crops irrigated in the Pacific Northwest. Alfalfa and potatoes require relatively more water for production than other crops, and therefore have higher electricity use requirements. For example, electricity costs as a share of total production costs range from 1 to 2 percent for apples, 3 to 9 percent for potatoes, 5 to 8 percent for other vegetables, and 5 to 25 percent for wheat. Electricity costs as a percent of total production costs for wheat and potatoes are presented in Table 13 for selected production regions. Cost shares are identified for both high lift and average lift lands. Relative electricity costs are substantially higher for wheat, a lower valued commodity.

### Table 13

### ELECTRICITY COSTS AS A PERCENT OF TOTAL CROP PRODUCTION COST [a]

| Production Area | Wheat[b] High Lift Center Pivot | Wheat[b] High Lift Side Roll | Wheat[b] Average Lift | Potatoes[b] High Lift Center Pivot | Potatoes[b] Average Lift |
|---|---|---|---|---|---|
| | Percent | | | | |
| 12 - Central Washington | 21 | 19 | 6 | 6 | 2 |
| 13 - Columbia Basin (WA) | 18 | 17 | 6 | 5 | 2 |
| 14 - Eastern Washington | 17 | 15 | 8 | 5 | 2 |
| 22 - North Central Oregon | 16 | 14 | 11 | 5 | 3 |
| 32 - Southern Idaho | 23 | 21 | 5 | 7 | 2 |

a/ It is estimated that approximately 10-15 percent of irrigated acreage can be considered as high lift.

b/ Average production costs for wheat, excluding land costs are $407/acre for center pivot and $371/acre for side roll. Average production costs for potatoes, excluding land costs, are $1,391/acre for Areas 12, 13, 14, 22 and $1,106 for Area 32.

Source: Washington, Oregon, and Idaho Agricultural Extension Service and Northwest Economics Associates, Crop Budget Data File.

The importance of electricity costs to the farm production decision varies among farmers. The type of crop grown and the profitability of that crop will affect the way in which a farmer responds to increasing electricity rates. Profitability is affected not only by increasing electricity rates but also by market demand and price, both foreign and domestic, regional and national competition, the costs of land, labor, capital, water, and energy, processing costs, transportation costs, yields and technological change, and future conditions as they affect risk and uncertainty.

The agricultural economy is very complex and irrigation rates are only one component of the cost and returns to farmers. Pacific Northwest farmers compared to other irrigated areas of the U.S., have relatively inexpensive land, water and electricity costs while experiencing relatively high yields. However, the Pacific Northwest has become more isolated from eastern U.S. markets due to increased transportation costs. For the same reason, the Pacific Northwest is becoming more competitive in Pacific Rim markets relative to other U.S.

producers. It is the availability of markets or prices in markets that produce a profit, that impacts the economic viability of Pacific Northwest agriculture more than any production cost item.

## ELECTRICITY AS A DERIVED DEMAND

Demand for electricity in irrigated agriculture is a derived demand. That is, the demand for electricity is dependent on the level of demand for the crops that electricity is used to produce. Electricity demand by irrigated agriculture will, therefore, be dependent not only on weather and the price of electricity, but also on the price of the final product, the cost of alternative production inputs, and the technological characteristics of the production process. In the short run, an irrigator's response to an electricity price change will reflect the current crop mix, the type of irrigation system in place, and, to some extent, the ability to substitute electricity for other management and labor inputs. In the longer term, farm-level response to price changes can include updating or replacing irrigation systems and changing acreage and crop-mix patterns.

The quantity of on-farm electricity used by Pacific Northwest irrigators is as diverse as the many production areas within the region. The amount of energy required for irrigation pumping is affected by crop water requirements, soil conditions, weather patterns, irrigation system type, pump size, pumping efficiencies, and pumping lifts. In addition to these "technical" factors, electricity use is affected by crop prices, the relative cost of other inputs, the degree to which these other inputs can be substituted for applied water, the flexibility with which applied water levels can be controlled, and the degree to which risk-avoidance behavior affects applied water decisions. Finally, a very direct relationship exists between the cost of electricity and quantity demanded for on-farm use.

## DEFINING THE PRICE ELASTICITY OF DEMAND

Knowledge of how producers will respond to changes in electricity price is important when evaluating proposed changes in electricity rate designs and rate levels. The quantity demanded for a product is the amount of that product that will be purchased at a given price. By changing the price and holding all other technical factors and economic variables constant, the change in quantity demanded can be identified. The tracing of resulting price and quantity pairs results in a demand curve for the product, in this case electricity. The slope of the curve indicates the sensitivity of quantity demanded to price changes. The steeper the curve, the less quantity demanded is affected by price changes.

Price sensitivity is more formally expressed in a measure known as the "own-price elasticity of demand." The elasticity of demand is defined as the percentage change in quantity demanded resulting from percentage change in price. Since quantity typically decreases as price increases, the elasticity of demand is usually negative. Elasticity measures relative changes in quantity along a single demand curve. Although the combination of inputs used in the production process may alter as a result of a change electricity price, all other prices remain constant.

Demand is said to be price inelastic if the change in quantity is less than the change in price. Demand is price elastic if the percentage change in quantity is greater than the percentage change in price. If price increases occur along an inelastic region of the demand curve, the resulting change in revenues received (price times quantity) will be positive, since the increase in price more than compensates for the decline in quantity. However, a price increase implemented along an elastic portion of the demand curve will have negative impact on revenues received. A revenue or pricing policy that does not accurately consider the elasticity of the demand response may result in impacts considerably different from those which had been intended.

## ESTIMATING IRRIGATION PRICE ELASTICITY FOR THE PACIFIC NORTHWEST

In order to better understand the response of Pacific Northwest irrigators to changes in electricity price, linear programming and econometric models of regional irrigation electricity use were developed.[1] Representative farm models developed in a linear programming framework evaluate the impact of short-run changes in electricity price on farm-level energy use. The econometric models take into account factors that affect both short-run and long-run changes in electricity use by irrigators. Short-run changes are evaluated using a factor demand equation for electricity use, based on the existing irrigated acreage base and distribution of irrigation system types. Longer run changes in electricity use are measured using structural equations for irrigated acreage and the share of irrigated acreage using sprinkler-type systems. Results from the econometric and linear programming approaches are presented below. A more extensive review of the models and results can be found in Volume 2, Sections C (econometric models) and D (linear programming model) of this report.

### LINEAR PROGRAMMING MODEL

A linear programming approach is used to examine how the irrigated agriculture sector will respond in the short run (1-3 years) if faced with rising electricity costs. The analysis includes estimation of the price elasticity of demand for electricity by irrigators. It also describes the impacts of energy price changes to individual representative farms, to larger areas with similar production characteristics, to individual states, and to the Pacific Northwest region.

Mathematical programming is used to model irrigator response to rising energy costs for several alternative farm types considered representative of farming practices and conditions in various production areas throughout the region. Irrigator responses considered include changes in crop mix, adjustment of water application levels, improved irrigation efficiency, and the removal of land from production. The formulation of the programming model allows for

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1/ A review of previous studies of irrigation price elasticity estimations for the Pacific Northwest is presented in Volume 2, Section B.

simultaneous consideration of trade-offs among irrigation efficiency, labor input, water application level, and the use of electricity for irrigation.

Short-run managerial options for adjusting to increasing electricity rates by conserving irrigation water are varied and sometimes complex. The short-run setting implies that adjustment in the method of irrigation is not a choice. When water is plentiful or relatively inexpensive, the farmer correctly substitutes water for other inputs like labor and management. Water is also frequently used in excess of that necessary to obtain a given crop yield, in order to avoid the risks of weather uncertainty. When water cost becomes a constraint, there are many possible changes in production activity that can occur.

As farm energy costs are increased, the producer responds in several ways: Cropping patterns can be changed within limits, water application levels can be adjusted, irrigation efficiency can be increased with better irrigation management, and land can be idled. The range of adjustments that can occur will depend on the cropping pattern which is typical for the farm, the existing irrigation system, and the level of irrigation management and efficiency that prevails. A farm with an abundant supply of low-cost water under normal conditions may be using the water to substitute for labor, management, and capital cost of irrigation systems. Farms with these characteristics will have more potential adjustment opportunities than a high-lift, center-pivot irrigated farm already faced with relatively high energy costs. The linear programming analysis is used to investigate these expected responses of irrigators to changing energy costs.

A reduced form of the Bernardo/Whittlesey simulation model is used in this study to develop crop irrigation activities for the linear programming model.[1] The scaled-down version of the model facilitates analysis of numerous representative farm types and alternative energy price levels while retaining most of the power of the more detailed model design. By allowing for a simultaneous consideration

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1/ A more extensive discussion of the modified Bernardo/Whittlesey model used in the current study is included in Volume 2, Section D of this report.

of trade-offs among labor, energy, and water use, the model represents a significant improvement over previous applications using models of similar scale.[1]

## Model Results

Short-run price elasticities of demand are calculated for three ranges of percentage price increases: zero to 33 percent, 34 to 67 percent, and 68 to 100 percent. The estimated arc elasticities are quite small, with no elasticity having an absolute value greater than one. These elasticity estimates indicate that the short-run demand for energy by irrigators is inelastic. In general, the elasticities for small price increases (0-33%) are lower in absolute value than those for the next increment of price increase.[2] The regional elasticity at the lowest price increase is estimated to be -0.14, while comparable state values range from -0.08 for Washington to -0.33 to Montana. There is a greater range in elasticities among regional production areas and representative farms. Elasticity results, by production area, are presented in Table 15.

As farmers adjust individual operations to changing electricity prices, aggregate input use changes within production areas, states, and the region. A general pattern of response to higher electricity costs is farmer substitution of irrigation labor and management for energy and water. At the production area level, percentage reductions in farm income are relatively minor, particularly for small electricity price increases. However, the analysis does illustrate that income impacts are distributed unevenly over the region.

## ECONOMETRIC MODELS

With the econometric approach irrigation electricity use is modeled as a system of three equations describing the relationship between electricity use per acre, electricity price, irrigated acreage, and the share of irrigated acreage with

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1/ The only major limitation in using the reduced model rather than the much larger Bernardo-Whittlesey model is the need to assume that the irrigator will distribute the available water optimally over the irrigation season and achieve the maximum attainable yield for the specified production conditions.

2/ Derived elasticity estimates for each production area are presented in Volume 2, Section D, Table 16.

sprinkler-type systems. For purposes of this study, average irrigation electricity price is considered to be determined exogenously to the electricity demand model.

## Model Specification

The general specification of the econometric model used for estimating irrigation electricity demand is given by the following three equation simultaneous system:

| | | | |
|---|---|---|---|
| (1) | $kWh/Acre_{jt}$ | = | f (Average Electricity $Price_{jt}$, $Rainfall_{jt}$, Sprinkler $\%_{jt}$, Pumping $Efficiency_{jt}$, Output $Value/Acre_{jt}$). |
| (2) | Sprinkler $\%_{jt}$ | = | f (Net Farm $Returns_{jt}$, Labor $Wage_{jt}$, Interest $Rate_{jt}$, $Location_{jt}$). |
| (3) | $Acreage_{jt}$ | = | f (Acres $Lagged_{jt}$, Average Electricity $Price_{jt}$, Net $Returns_{jt}$, Farm $Programs_{jt}$). |

Where[1]

| | | |
|---|---|---|
| $kWh/Acre_{jt}$ | = | Average electricity use per irrigated acre for utility j during irrigation season t, |
| Average Electricity $Price_{jt}$ | = | Average irrigation electricity price (mills/kWh) for utility j during irrigation season t, |
| $Rainfall_{jt}$ | = | Difference between weighted crop water requirement and irrigation season precipitation for utility j during irrigation season t, |
| Sprinkler $\%_{jt}$ | = | Sprinkler irrigated acreage as a percent of total irrigated acreage for utility j during irrigation season t, |
| Pumping $Efficiency_{jt}$ | = | Weighted irrigation pumping efficiency for utility j during irrigation season t, |
| Output $Value/Acre_{jt}$ | = | Weighted value per acre for irrigated crop production for utility j during irrigation season t, |
| Net Farm $Returns_{jt}$ | = | A 3-year moving average of net farm returns for utility j during irrigation season t, |

1/ A more extensive description of the data used in the estimations is included in Volume 2, Section C.

| | | |
|---|---|---|
| Labor $Wage_{jt}$ | = | Average second and third quarter earnings for hired farm-labor for utility j during irrigation season t, |
| Interest $Rate_t$ | = | Average new loan rate for agricultural loans in year t, |
| Farm $Programs_t$ | = | Qualitative variables indicating years during which the PIK program (1983) and Acreage Reserve program were in effect (1986-1987), and |
| $Location_j$ | = | Qualitative variables indicating utility location by agricultural production area. |

The per acre electricity use equation is defined as a function of electricity price, physical characteristics known to affect per acre electricity requirements, weather factors, and output value per acre. Sprinkler percent, indicating the adoption of new irrigation technologies, is defined as a function of net farm returns, the cost of new capital, the substitution between labor and capital, and a location variable to capture the impacts of regional differences in overall levels of sprinkler percent. The final equation, irrigated acreage, is defined as a function of the existing acreage base, electricity price, net returns to irrigated production, and farm programs that may cause acreage to move in and out of production. The equations were estimated using three-stage least squares with pooled utility-level data for the period 1979 to 1987.

One of the primary objectives of the present study is to evaluate measures of the irrigation price elasticity for smaller areas within the Pacific Northwest, rather than for the entire region. Accordingly, elasticities are estimated for production areas and for individual utilities. The estimates are made using electricity sales and revenue data supplied by BPA for 28 public utilities and 1 private utility in the Pacific Northwest.[1] A list of the 29 utilities, by production area, is presented in Table 14.

Production area elasticity estimates were derived using a number of alternative econometric model specifications.[2] The models were run using the cross-sectional time-series data for all 29 utilities. Elasticities for individual production areas were derived using slope shifters on the electricity price variable.

1/ The original list included 30 public utilities; however, sufficient time-series data was unavailable for two of the utilities. Data for the private utility includes only a portion of the company's total irrigation load.

2/ Alternative model specifications are discussed on page 44.

## Table 14

## IRRIGATION UTILITIES INCLUDED IN THE ECONOMETRIC ANALYSIS [a]

**Production Area 12:**
**Central Washington**

(303) Benton Rural Electric Association
(250) Klickitat PUD
(367) Nespelem Valley Electric Cooperative

**Production Area 13:**
**Columbia Basin**

(203) Benton Co. PUD
(306) Big Bend Electric Cooperative
(324) Columbia Rural Electric Association
(233) Franklin Co. PUD
(238) Grant Co. PUD

**Production Area 14:**
**Eastern Washington**

(348) Inland Power & Light
(358) Lincoln Electric Cooperative

**Production Area 21:**
**Western Oregon**

(327) Consumers Power, Inc.
(229) Emerald PUD
(288) Tillamook PUD

**Production Area 22:**
**North Central Oregon**

(318) Columbia Basin Electric Cooperative
(388) Umatilla Electric Cooperative
(394) Wasco Electric Cooperative

**Production Area 23:**
**Central Oregon**

(312) Central Electric Cooperative
(361) Midstate Electric Cooperative
(386) Surprise Valley Electric Cooperative

**Production Area 24:**
**Eastern Oregon**

(341) Harney Electric Cooperative

**Production Area 31:**
**Northern Idaho**

(351) Kootenai Electric Cooperative
(359) Lost River Rural Electric Cooperative

**Production Area 32:**
**Southern Idaho**

(337) Fall River Rural Electric Cooperative
(379) Raft River Rural Cooperative
(382) Rural Electric Cooperative
(389) Unity Light & Power

**Production Area 33:**
**Western Montana**

(339) Flathead Electric Cooperative
(380) Ravalli Electric Cooperative
(390) Vigilante Electric Cooperative

**Pacific Power and Light**

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a/ Numbers in parentheses refer to utility reference codes used in Table 17. Emerald PUD and Unity L&P were excluded from the actual estimations due to lack of sufficient time-series data.

The regional slope shifters are calculated as electricity price multiplied by the qualitative variable for the production area, allowing the production area elasticities to be computed as the sum of the electricity price coefficient and the coefficient from the relevant slope shifter. Based on statistical properties, consistency of estimates, and reviewer comments, the log-log average electricity price specification of the simultaneous model was considered to be the preferred formulation of the various models that were estimated. Results from the log-log model provide consistent, stable estimates of both the short-run and long-run regional irrigation price elasticities. The long-run elasticities are derived using the lagged acreage specification from the third equation. Initial estimations resulted in a long-run adjustment period in excess of twenty years. In order to derive elasticities under a more realistic adjustment period, the three equation system was re-estimated using restricted least squares, with a restriction placed on the length of the adjustment period.

The lagged adjustment of irrigated acreage to electricity price implies that there is a continual longer run adjustment to past irrigation rates. Thus, growers five, ten or even forty years in the future will continue to make acreage adjustments to current electricity prices. The lagged adjustment has two components: 1) the total amount of adjustment (all acreage changes and resulting load changes); and 2) the time period over which the adjustment takes place. Based on our past studies, discussion with irrigators, and the relatively constant level of irrigated acreage during the 1980's when electricity prices increased 100 percent, it is expected that the acreage response to electricity price changes has been relatively minor. During this period of relatively constant input costs, the real price of electricity increased substantially while irrigated acreage increased slowly throughout the Pacific Northwest.

Acreage adjustments corresponding to electricity price changes are most likely to take place during the first five years after the price increase. If rates are high enough to drive growers out of irrigated agriculture, a farmer can usually survive two to four years until his asset base erodes to the point where he can no longer borrow from the bank. When this occurs, the bank or lender generally takes over the farm, attempts to sell the land at a discount, and, if needed, sells the irrigation equipment separate from the land. In most cases the land does not go out of production, but changes ownership at a lower value.

The "longer run" irrigated acreage adjustment to electricity prices is also not very dependent on the life of a sprinkler irrigation system. The decision to use a sprinkler system is more dependent on soils, slopes, and labor substitution than on electricity prices. Center pivot systems must be used on sandy soils and lands with steeper slopes. In many cases, farmers have substituted capital for the convenience of not changing sprinkler sets and worrying about farm labor. The adoption of new technologies, in particular low head sprinkler and improved pump efficiency, usually has a limited payback period. Most farmers (and lenders) desire a one to three year payback period. These adjustments to electricity price are generally reflected on the kWh per acre equation and occur fairly rapidly if technology is cost effective and can pay for itself in a short period of time.

The majority of load response to electricity rate changes is expected to occur in a one to five year period. In a practical sense, it is hard to accept a significant load response after the five to ten year period. Also, it is hard to accept an additional long-run response that is equal to or greater than the short-run load response where farmers have the greatest ability to adjust their kWh use per acre. However, some members of the project review team have indicated that they believe eight to ten years is a more appropriate time period for measuring acreage adjustments corresponding to changes in electricity price. The justification is based on using a nine year time frame for the useful life of irrigation equipment. Equations (1) - (3) are estimated using restricted least-squares, where the coefficient of adjustment on lagged acreage in equation (3) is restricted to a value such that 90 percent of the long-run adjustment is allowed to occur within five years and 99 percent by the tenth years.[1]

**Model Results**

Short-run and long-run elasticity estimates derived from the restricted model are presented in Table 15. Elasticity estimates from the linear programming model are also included for comparison. The linear programming model is considered to provide alternative estimates of the short-run producer response to changes in electricity price.

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1/ An expanded discussion of the calculated restriction is included in Volume 2, Section C.

## Table 15

### IRRIGATION PRICE ELASTICITY ESTIMATES BY PRODUCTION AREA [a, b]

| Production Area | | Short-Run Estimates LP Model | Short-Run Estimates Econometric Model | Long-Run Estimates Econometric Model |
|---|---|---|---|---|
| 11/21 | W.Washington/Oregon | -0.44 | -0.72 | -1.32 |
| 12 | Central Washington | -0.07 | -0.66 | -1.18 |
| 13 | Columbia Basin (WA) | -0.08 | -0.42 | -0.66 |
| 14 | Eastern Washington | -0.16 | -0.59 | -1.19 |
| 22 | N. Central Oregon | -0.44 | -0.51 | -1.00 |
| 23/24 | Central/Eastern Oregon | -0.17 | -0.60 | -0.91 |
| 31/33 | N. Idaho/W. Montana | -0.33 | -0.70 | -1.11 |
| 32 | Southern Idaho | -0.16 | -0.48 | -0.86 |
| | Pacific Power | na | -0.54 | -0.88 |
| Pacific Northwest[b] | | -0.14 | -0.49 | -0.81 |

a/ Statistical output for the elasticity estimates derived from the econometric model can be found in Volume 2, Section C.

b/ Elasticity estimates based on a weighted average of production area elasticities. Total irrigation kWh (average 1986/1987) for sample utilities is used for weights.

Short-run estimates of the annual irrigation price elasticity vary only somewhat across agricultural production areas. For the period over which the elasticity is measured, irrigated acreage and cropping patterns are held relatively constant. This fixed resource base, combined with the competitive nature of the output market (where adjustments in final product price are relatively unaffected by producer actions), allows for only minor flexibility in response to changing electricity prices. Therefore, in the short-run irrigator response to increasing electricity rates is most likely to occur through adjustments in energy use per acre. Previous work by Northwest Economic Associates has indicated that irrigators are more likely to make short-run adjustments to applied water use per acre on crops with marginal net returns. These crops generally include hays and gains.[1] Producers tend to exhibit more risk avoidance behavior (only minor adjustments in water and energy use) on higher-valued crops such as vegetables and tree fruits.

1/ Northwest Economic Associates, Partial Irrigation Feasibility Study and Demonstration Project, prepared for Bonneville Power Administration, September, 1987.

The variation in the short-run elasticity estimates that does occur across production regions reflects the differences in energy-use response associated with the primary cropping patterns. Measured elasticities are lowest in the Columbia Basin (PA 12), North Central Oregon (PA 22), and Southern Idaho (PA 32) where crop production includes vegetables and potato rotations. These areas, generally characterized by higher relative yields, tend to be very competitive in output markets. The elasticities are relatively higher in Northern Idaho/Western Montana (PA 31/33) and Central/Eastern Oregon (PA 23/24) where production is characterized by hay/pasture and some grains. Study utilities located in Western Oregon (PA 21) and Central Washington (PA 12) reflect hay/pasture cropping patterns although some tree fruit/tree nut production is included.

In the long-run, producer response to increasing electricity rates can include adjustments in both acreage and cropping patterns. Variations in the long-run elasticities across producing areas take into account not only adjustments to kWh use per acre but also changes in these additional factors. Cropping patterns in the Pacific Northwest have been relatively constant over time. As irrigated acreage has moved in and out of production, the relative distribution across crop types has been the same. This can be explained by several factors including crop rotation requirements, establishment costs associated with perennial acreage, processing plant locations, an established output market infrastructure, and producer risk avoidance behavior. Although increases in irrigated acreage occur across all crop types, downward adjustments are less likely to occur on acreage included in long-term high valued rotations or planted in perennial crops. Acreage planted with marginal crops tends to move out of production during periods of rising input costs or adverse output market conditions.

The variation in long-run elasticities across producing areas is similar to the distribution found with the short-run measures. Regions with lower relative short-run estimates have lower relative long-run estimates. The exception is Eastern Washington (PA 14) with a mid-range short-run elasticity but a higher long-run measure. Study utilities included in Area 14 are characterized by relatively high pumping lifts on irrigated wheat acreage with marginal returns. This area has the highest probability of shifting land out production.

Elasticities measured for the only private utility included in the study, Pacific Power & Light, were not found to be significantly different from elasticities estimated for the remaining study utilities. Under several alternative specifications of the slope shifter for PP&L the measured elasticity was found to be within the range of estimates for all utilities.

## Explanatory Variables[1]

All variable signs in the annual model were consistent with a-priori expectations, with the exception of federal programs in the acreage equation. In the kWh/acre equation the following results occurred:

| | |
|---|---|
| Electricity Price: | Negative, higher electricity prices are associated with lower levels of energy use per acre. Significant at $\alpha = 0.01$. |
| Required Rainfall: | Positive, indicating that larger rainfall deficits were associated with higher levels of irrigation electricity use. Significant at $\alpha = 0.01$. |
| Sprinkler Percent: | Positive, reflecting the expectation that higher levels of energy use per acre would be associated with regions characterized by larger relative shares of sprinkler-type irrigation systems. Not significant. |
| Pumping Efficiency: | Negative, consistent with the lower relative energy use requirements of more efficient pumping systems. Significant at $\alpha = 0.15$. |
| Value per Acre: | Positive, reflecting the theoretically consistent relationship between factor demand and value of the final output. Not significant. |

1/ Discussion refers to explanatory variables other than electricity price. Statistical results are presented in Volume 2, Section C.

The following variables were included in the sprinkler percent equation:

| | |
|---|---|
| Net Returns per Acre: | Positive, indicating that higher levels of capital investment are associated with increased levels of farm profitability. Significant at $\alpha = 0.15$. |
| Average Farm Labor Wage: | Positive, indicating that capital and labor are substitutes in the production process. Not significant. |
| Interest Rate: | Negative, indicating that lower levels of capital investment are associated with higher costs of capital financing. Significant at $\alpha = 0.10$. |

Variables included in the acreage equation:

| | |
|---|---|
| Electricity Price: | Negative, indicating on inverse relation between electricity price and irrigated acreage. In the unrestricted estimations the coefficient was less than one-quarter the magnitude of the price coefficient in equation (1) with significance at $\alpha = 0.15$. In the restricted runs the coefficient was only slightly less then the coefficient in equation (1) and significant at $\alpha = 0.01$. |
| Net Returns: | Positive, reflecting the correlation between higher levels of irrigated acreage and increased levels of net farm profitability. Significant at $\alpha = 0.10$. |
| Lagged Acreage: | Positive and less than one, indicating that irrigated acreage in the current period is less than irrigated acreage in the previous period (other things held constant). Coefficient restricted. |
| Federal Programs: | Positive. It was expected that the program variables would be negative, reflecting the acreage set-asides associated with the programs. PIK significant at $\alpha = 0.10$; ARP not significant. |

**Seasonal Variations**

Specification of the annual model was modified to allow for evaluation of seasonal variations in irrigator response to electricity price. A seasonal energy use model was specified by replacing equation (1) with, two equations describing spring and summer kWh use per acre.[1] Energy use equations for the seasonal model are given by the following:

(4) Spring $kWh/Acre_{jt}$ = f (Spring Average Electricity $Price_{jt}$, $Rainfall_{jt}$, $Sprinkler\%_{jt}$, Pumping $Efficiency_{jt}$, Output $Value/Acre_{jt}$)

(5) Summer $kWh/Acre_{jt}$ = f (Summer Average Electricity $Price_{jt}$, $Rainfall_{jt}$, $Sprinkler\%_{jt}$, Pumping $Efficiency_{jt}$, Output $Value/Acre_{jt}$)

Where:

Spring $kWh/Acre_{jt}$ = Irrigation electricity use in April and May per irrigated acre for utility j in irrigation season t,

Summer $kWh/Acre_{jt}$ = Irrigation electricity use between June and November per irrigated acre for utility j in irrigation season t,

Spring $Rain_{jt}$ = Total precipitation in April and May for utility j in irrigation season t, and

All other variables have been previously defined.

In the seasonal model, production area elasticities calculated for the spring period were significantly greater than elasticities computed for the summer period, implying a greater price sensitivity in the early part of the irrigation season.[2] This is consistent with the production-related constraints associated with crop water requirements. During the spring the producer has some flexibility in the timing of the water application. Once plant growth has begun however, water must be applied to meet the consumptive requirements of the plant. Reliable data were generally unavailable to estimate a price elasticity for the fall period of the irrigation season. It is likely, however, that a fall elasticity would be relevant only for Eastern Washington (PA 14) where some pre-irrigation occurs to enhance soil moisture for the following spring.

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1/ Energy use in April and May is included in the spring equation while energy use from June to November is included in the summer equation. However, very little energy use occurred in October and November.

2/ The seasonal models were also estimated using restricted least squares. Statistical results are presented in Volume 2.

Seasonal elasticity estimates, by production area, are presented in Table 16. In all regions summer elasticities are lower than estimates from the annual model covering the entire irrigation period; the spring elasticities are somewhat higher than the annual estimates. Spring estimates were highest in Idaho and Western Montana where cropping patterns do not require significant spring irrigation. The spring elasticity in North Central Oregon is significantly lower than elasticities in other areas because of the much longer spring irrigation period in this region. Summer elasticities vary across production areas in a manner similar to the annual elasticities.

**Table 16**

**SPRING AND SUMMER ELASTICITY ESTIMATES BY PRODUCTION AREA [a, b]**

| Production Area | | Spring Short-Run | Spring Long-Run | Summer Short-Run | Summer Long-Run |
|---|---|---|---|---|---|
| 11/21 | W.Washington/Oregon | na | na | na | na |
| 12 | Central Washington | -0.81 | -0.86 | -0.48 | -0.93 |
| 13 | Columbia Basin (WA) | -0.92 | -0.98 | -0.46 | -0.94 |
| 14 | Eastern Washington | -0.79 | -0.85 | -0.38 | -0.86 |
| 22 | N. Central Oregon | -0.44 | -0.50 | -0.48 | -0.96 |
| 23/24 | Central/Eastern Oregon | -0.93 | -0.99 | -0.62 | -1.10 |
| 31/33 | N. Idaho/W. Montana | -0.93 | -0.99 | -0.62 | -1.10 |
| 32 | Southern Idaho | -0.98 | -1.03 | -0.39 | -0.87 |
| | Pacific Power | -0.84 | -0.90 | -0.50 | -0.98 |
| **Pacific Northwest** | | **-0.79** | **-0.85** | **-0.48** | **-0.96** |

a/ Statistical output for the elasticity estimates derived from the econometric model can be found in Volume 2, Section C.

b/ Elasticity estimates based on a weighted average of production area elasticities. Total irrigation kWh (average 1986/1987) for sample utilities is used for weights.

## Comments On Estimations[1]

Initial runs of the production area irrigation electricity demand models were characterized by serial correlation in the sample data set. A correction was made for positive autocorrelation using the correlation factor calculated for the first equation (kWh use per acre) in the simultaneous system. Because several of the variables appeared in more than one equation, we were unable to make individual

1/ All statistical estimations were computed using RATS 3.0 statistical software.

corrections to each equation. While the correction removed correlation in the first equation, the remaining components of the model continue to exhibit some correlation. It was the general consensus of the study team and reviewers, however, adjusting the first equation was the best available alternative for correcting correlation within the system.

Earlier specifications of the three equation irrigation demand model included an additional equation for pumping efficiency. It is expected that adjustments to pumping efficiency are motivated, in part, by changes in electricity price.[1] The decision to exclude pumping efficiency as an endogenous variable was based on the availability of only a subset of data over the time period of analysis. Because pumping efficiency is not include as an endogenous variable, it is likely that the estimated short-run elasticities are slightly underestimated. Based on earlier single equation and simultaneous equation estimates, pumping efficiency-related impacts were found to adjust the elasticities upward in the range of five to ten percent.[2]

**Alternative Model Specifications**

Several alternative specifications of the three equation simultaneous model were developed in order to derive elasticity estimates under alternative model assumptions. Variations on the general form included a single equation specification using equation (1) and a linear specification of the three equation model. The linear simultaneous model was also specified using the seasonal energy use equations. Each of the alternative specifications, including the base model, was further modified by replacing the average electricity price variable with two price variables. Marginal energy price and a residual price variable, calculated as the difference between average and marginal price, were incorporated into the models in order to evaluate the impact of changes in the marginal energy price relative to changes in the fixed component of the electricity rate schedules. The general specification of each alternative model is included in Volume 2, Section C. General results from the alternative specifications include the following:

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1/ Improvements in pumping efficiency have also occurred as a result of conservation assistance programs sponsored by BPA and area utilities.

2/ A short-run elasticity adjustment of -0.04 has been recommended by reviewers for Northwest Irrigation Utilities as an appropriate adjustment for pumping efficiency.

- Elasticity estimates from the single equation models were lower than those calculated from the simultaneous model, indicating the longer run nature of the impacts included in the simultaneous specification.

- The linear specification of the simultaneous model provided inconsistent elasticity estimates across production regions. In both the annual and seasonal models, and with average and marginal price specifications, the long-run specification failed to provide reliable estimates for the electricity price variable.

- In each of the alternative functional forms of the electricity demand model (single equation, simultaneous log-log, simultaneous linear) elasticities derived from the average price specifications were larger than those derived from the marginal price specification. The sum of the marginal and residual impacts was also found to be less then the average price response.

**Utility-Level Estimates**

A restricted least squares single equation model was used to derive utility-level estimates of the irrigation price elasticity. The restricted model was run using pooled data for utilities within a given production area. The weighted sum of the utility-level electricity estimates was restricted to be equal to the value of the production area estimate from the simultaneous model.[1] The restricted model, estimated separately for each production area, is given by the following specification:

(6) $\text{Electricity Use/Acre}_{jt} = f\,(\text{Electricity Price}_{jt}, \text{Rainfall}_{jt})$

A relatively simple model form was used for the restricted analysis because many of the economic and physical characteristic variables do not vary across utilities within the same production area.

Utility level elasticity estimates were calculated using the production area elasticities from both the annual and seasonal models. The derived estimates are presented in Table 17. Results from the restricted estimations, while providing

1/ Utility load as a percent of production area load was used as the weight.

## TABLE 17

## IRRIGATION PRICE ELASTICITY ESTIMATES BY UTILITY [a]

| | Annual Model | | Seasonal Model | | | |
|---|---|---|---|---|---|---|
| **Utility** | **Short-Run** | **Long-Run** | **Spring Short-Run** | **Spring Long-Run** | **Summer Short-Run** | **Summer Long-Run** |
| **Central Washington** | | | | | | |
| Benton REA | -0.63 | -1.13 | -0.83 | -0.89 | -0.48 | -0.96 |
| Klickitat PUD | -0.74 | -1.31 | -0.73 | -0.75 | -0.48 | -0.95 |
| Nespelem Valley Elec. Coop. | -0.71 | -1.25 | -0.86 | -0.90 | -0.50 | -0.98 |
| **Columbia Basin** | | | | | | |
| Benton Co. PUD | -0.38 | -0.60 | -0.69 | -0.74 | -0.42 | -0.89 |
| Big Bend Elec. Coop. | -0.35 | -0.57 | -0.42 | -0.49 | -0.43 | -0.85 |
| Columbia REA | -0.37 | -0.58 | -0.45 | -0.51 | -0.43 | -0.85 |
| Franklin PUD | -0.42 | -0.64 | -0.72 | -0.76 | -0.46 | -0.91 |
| Grant PUD | -0.51 | -0.80 | -1.63 | -1.70 | -0.52 | -1.07 |
| **Eastern Washington** | | | | | | |
| Inland P&L | -0.50 | -1.04 | -1.18 | -1.23 | -0.22 | -0.62 |
| Lincoln Elec. Coop. | -0.60 | -1.21 | -0.74 | -0.80 | -0.40 | -0.89 |
| **Western Oregon** | | | | | | |
| Consumers Power, Inc. | -0.76 | -1.40 | | | | |
| Tillamook PUD | -0.55 | -1.08 | | | | |
| **North Central Oregon** | | | | | | |
| Columbia Basin Elec. Coop. | -0.41 | -0.86 | -0.30 | -0.35 | -0.42 | -0.89 |
| Umatilla Elec. Coop. | -0.53 | -1.03 | -0.45 | -0.52 | -0.49 | -0.97 |
| Wasco Elec. Coop. | -0.37 | -0.79 | -0.51 | -0.56 | -0.47 | -0.89 |
| **Central Oregon** | | | | | | |
| Central Elec. Coop. | -0.59 | -0.89 | | | | |
| Midstate Elec. Coop. | -0.56 | -0.87 | -0.89 | -0.94 | -0.57 | -1.06 |
| Surprise Valley Elec. Coop | -0.47 | -0.77 | -0.93 | -0.99 | -0.51 | -0.99 |
| **Eastern Oregon** | | | | | | |
| Harney Elec. Coop. | -0.70 | -1.01 | -0.95 | -1.01 | -0.70 | -1.18 |
| **Northern Idaho** | | | | | | |
| Kootenai Elec. Coop. | -0.52 | -0.92 | | | | |
| Lost River REA | -0.58 | -0.99 | -0.93 | -0.99 | -0.62 | -1.10 |
| **Southern Idaho** | | | | | | |
| Fall River REA | -0.39 | -0.71 | | | | |
| Raft River REA | -0.50 | -0.89 | -0.99 | -1.04 | -0.39 | -0.87 |
| Rural Elec. Coop. | -0.50 | -0.87 | -0.85 | -0.90 | -0.40 | -0.89 |
| **Western Montana** | | | | | | |
| Flathead Elec. Coop. | -0.68 | -1.06 | | | | |
| Ravalli Elec. Coop. | -0.69 | -1.09 | | | | |
| Vigilante Elec. Coop. | -0.68 | -1.25 | | | | |

a/ Statistical output for elasticity estimates derived from the econometric model can be found in Volume 2, Section C.

statistically significant utility-level estimates, failed to converge to a final solution.[1] This would appear to indicate that a dynamic specification of the restricted model, allowing the estimates of the price coefficient to seek a solution within a band of a-priori expected outcomes, would be more appropriate. However, formulating the dynamic specification was considered to be beyond the scope and time-frame of the current study.

The estimated elasticities differ only slightly across utilities in the same production area. Variations in utility estimates are likely to occur as a result of differences in cropping patterns, weather conditions and soil types, average electricity price levels, and differences in irrigation rate designs. However, because of data limitations and constraints posed by the statistical model, explanations of differences in utility estimates are better evaluated for groups of utilities using the production area models. These differences were discussed at length in an earlier section.

**Impact of Emerging Policy and Economic Issues on Price Elasticity**

In general, the situation and outlook for Pacific Northwest irrigated agriculture over the next two to three years is for a slight improvement in the farm economy. There should not be any major economic changes that would change the estimated electricity price elasticities. If the farm economy softens, price elasticities may become more elastic. If the economy continued to improve, the electricity price elasticities may become more inelastic as electricity cost has a smaller share of total production cost and farmers profit. In either case, it is the author's best estimate that the range of elasticities would probably not differ by more than ± 0.10 or 0.20 from the reported results (e.g. -0.49 ± 0.20).

A detailed discussion of the situation and outlook for Pacific Northwest irrigated agriculture over the next two to three years is presented in Volume 2, Section F. Several important issues can be identified:

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1/ Statistical results from the utility estimates can be found in Volume 2, Section C.

- Like most U.S. agriculture, Pacific Northwest irrigated agriculture has the capability to push production beyond the growth in demand. Irrigated crop producers are likely to face stable prices for their output over the next several years.

- With the potential for excess agriculture capacity, there may be continued pressure for government programs to idle cropland in order to balance supply and demand for agricultural commodities. Dryland agriculture is more likely to be idled than irrigated cropland.

- Irrigated agriculture will begin to face more restrictions on fertilizer, pesticides and tillage practices in view of concerns over water quality and restriction on surface water diversion and groundwater pumping. These developments will be minor compared to the influence of trade, technology and agricultural programs.

- Within the immediate two to three year outlook, there does not appear to be any pressing demand for large scale increases in agricultural production that would require significant expansion of Pacific Northwest irrigated cropland.

- Prospects are more optimistic for specialized, high margin or high quality crops with competitive production costs and market share growth potentials, especially in foreign markets. These crops include orchard crops, onions, potatoes, low cost forages, and specialty crops.

- The ability of producers to increase yields and manage weather risks through irrigation will continue to favor irrigated acreage in many crops.

- The Pacific Northwest irrigated agriculture is as competitive, if not more competitive than other irrigated producing areas of the United States.

**Issues For Future Research**

Several alternative model specifications were used to derive estimates of an irrigation price elasticity for groups of utilities within the BPA service area. The models included a single equation formulation, a three-equation simultaneous system in log-log form, and a three-equation system in linear form with a first difference specification on the acreage equation. All models were estimated first with average electricity price and then with a two price, marginal and residual, specification. The simultaneous models were further modified to reflect seasonal rather than annual electricity use. For reasons described earlier, the log-log three-equation model with average electricity price was the model used to report the elasticity estimates described in this section.[1] Based on the range of model specifications that were estimated the following issues for future research are suggested:

- The log-log model results in constant elasticity measures over all price levels and for all values of the other exogenous variables included in the model. Although the linear models provided initial estimates of a non-constant elasticity, further evaluation may be of interest.

- Irrigators are typically faced with a two 'commodity' rate schedule. Different tariffs are applied to energy and capacity requirements. Response to relative changes in these two rates may not be the same. Although BPA provided only average electricity price data to be used in the elasticity estimations, additional data were developed on marginal energy rates. Preliminary estimates seemed to indicate a differing response to average and marginal rates. Further work to evaluate differing price response to energy and capacity rates may be of interest.

- Elasticities were estimated for the period 1979-1987, the years for which load and price data were made available by BPA. It may be of interest to evaluate the price elasticity over a period of falling real prices, 1970-1979, relative to a period of increasing real prices, 1980-1987.

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1/ Results from all estimations can be found in Volume 2, Section C.

- The acreage equation was included in the simultaneous model to account for the impact of changes in electricity price on agricultural 'plant capacity'. Lack of sufficient data describing the range of factors affecting the movement of land in and out of production resulted in a relatively simple specification of the acreage equation. Further work to refine this equation and to identify what land moves in and out of production at the margin may be of interest.

- In addition to the factors included in the simultaneous model, changes in electricity price are also expected to affect changes in the efficiencies associated with new and existing irrigation systems. However, due to the lack of a sufficient set of specific data, the decision was made to exclude pumping efficiency as an endogenous variable in the model. Given the importance of pump efficiency adjustments in the Irrigation Conservation Program, further work to develop a pump efficiency equation may be of interest.

- Utility-level elasticities were estimated using a single-equation model with price and rainfall, where the weighted average of the utility elasticities was restricted to be equal to the elasticity for the respective production area. Limited production, price, and program-related data at the utility level led to the decision to use the restricted model. Further work to develop utility-level estimates would require significant data development on utility and irrigator characteristics.

- Finally, further work may be of interest to evaluate the ability of the model to track historical movements in load, acreage, and sprinkler adoption. This analysis may provide a basis from which the model can be used for forecasting future changes in irrigation electricity use.

## IRRIGATION RATE STRUCTURES IN THE PACIFIC NORTHWEST

When making decisions regarding electricity use irrigators in the Pacific Northwest react to prices charged by their local utility. The effectiveness of any BPA rate structure targeted for the irrigation sector depends in part on the corresponding rate structure at the retail level. The next two sections discuss wholesale/retail rate relationships in the BPA region, with particular emphasis on retail rate structures for irrigation customers.

## WHOLESALE/RETAIL ELECTRICITY RATE RELATIONSHIPS

To better understand the impact of wholesale electricity rate changes on irrigated agriculture, the relationship between BPA wholesale rates and retail irrigation rates is reviewed. Average retail irrigation electricity rates for individual production areas were developed for 1980 and 1987. Figures are based on weighted irrigation sales for study utilities. Average retail rates vary widely across production areas, as presented in Table 18. Differences are likely to be caused by any of several cost components, including retail utility transmission and distribution cost differences, operational and administrative costs, and the relative demand/energy mix of purchased electricity requirements

Average retail irrigation power rates in 1980 ranged from 12.9 mills/kWh in the Columbia Basin to 37.7 mills/kWh in Western Oregon. Average wholesale rates paid by the utilities varied from 7.1 to 7.6 mills/kWh during the same time period.[1] Wholesale rates as a share of retail rates averaged 46 percent in 1980.

By 1987, wholesale rates as a percentage of retail rates had risen to 67 percent, with average wholesale rates ranging from 19.6 mills to 22.2 mills. Average retail rates rose from 16.1 mills to 30.6 mills, varying from 25.1 mills in Eastern Washington to 60.0 mills in Western Oregon. Between 1980 and 1987, average wholesale rates increased nearly 180 percent while average retail rates increased only 90 percent.

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1/ Average wholesale rates vary across utilities because of differences in relative purchases of demand and energy.

## Table 18

## AVERAGE WHOLESALE AND RETAIL IRRIGATION RATES BY PRODUCTION AREA

| Production Area | Year | Average Retail Rate (mills/kWh) | Average Wholesale Rate (mills/kWh) | Wholesale Unit Cost as a Percent of Retail Unit Cost |
|---|---|---|---|---|
| 11/21 - W. Washington/Oregon | 1980 | 37.7 | 7.5 | 20 |
| | 1987 | 60.0 | 22.2 | 37 |
| 12 - Central Washington | 1980 | 17.3 | 7.4 | 43 |
| | 1987 | 31.6 | 21.4 | 68 |
| 13 - Columbia Basin (WA)[a] | 1980 | 12.9 | 7.4 | 57 |
| | 1987 | 26.3 | 21.1 | 80 |
| 14 - Eastern Washington | 1980 | 16.4 | 7.4 | 45 |
| | 1987 | 25.1 | 19.6 | 78 |
| 22 - North Central Oregon | 1980 | 14.7 | 7.1 | 48 |
| | 1987 | 29.4 | 20.2 | 69 |
| 23 - Central Oregon | 1980 | 22.0 | 7.5 | 34 |
| | 1987 | 43.4 | 21.3 | 49 |
| 24 - Eastern Oregon | 1980 | 21.3 | 7.1 | 33 |
| | 1987 | 36.8 | 19.5 | 53 |
| 31 - N. Idaho | 1980 | 20.7 | 7.5 | 36 |
| | 1987 | 43.0 | 19.9 | 46 |
| 32 - Southern Idaho | 1980 | 19.9 | 7.6 | 38 |
| | 1987 | 36.4 | 19.6 | 54 |
| 33 - W. Montana | 1980 | 21.2 | 7.6 | 36 |
| | 1987 | 40.9 | 21.2 | 52 |
| **Pacific Northwest[b]** | **1980** | **16.1** | **7.4** | **46** |
| | **1987** | **30.6** | **20.7** | **67** |
| **Percent Change 1980-1987** | | **90.1** | **179.7** | **45.7** |

a/ Figures do not include Grant Co. PUD.

b/ Based on a weighted average for study utilities.

The level and design of BPA wholesale power rates directly impacts retail irrigation rates. As the design of the wholesale rate becomes more or less energy intensive (relative to capacity), it is likely that a corresponding relationship will be carried through to the retail level. Between 1980 and 1987 the BPA summer energy rate increased over 280 percent while at the same time the summer demand charge increased 190 percent. Using irrigation rate schedules for individual utilities, the energy and capacity components of the average retail rates were estimated. The marginal energy rate obtained from the rate schedule was subtracted from the average rate to derive an estimate of the average capacity rate (in mills per kWh). The energy and capacity breakouts, by production area, are presented in Table 19 for 1980 and 1987.

**Table 19**

**ESTIMATED ENERGY AND DEMAND COMPONENTS OF AVERAGE RETAIL IRRIGATION RATES**

| Production Area | Year | Average Rate (mills/kWh) | Energy Rate (mills/kWh) | Demand Rate (mills/kWh) | Energy Share (%) | Demand Share (%) |
|---|---|---|---|---|---|---|
| 11/21 - W. Washington/Oregon | 1980 | 37.7 | 10.1 | 27.7 | 27 | 73 |
| | 1987 | 60.1 | 35.4 | 25.8 | 58 | 42 |
| 12 - Central Washington | 1980 | 17.3 | 6.8 | 10.5 | 39 | 61 |
| | 1987 | 31.6 | 17.7 | 13.9 | 56 | 44 |
| 13 - Columbia Basin (WA)[a] | 1980 | 12.9 | 5.6 | 7.3 | 44 | 56 |
| | 1987 | 26.3 | 15.8 | 10.4 | 60 | 40 |
| 14 - Eastern Washington | 1980 | 16.4 | 14.5 | 1.9 | 89 | 11 |
| | 1987 | 25.1 | 19.4 | 5.8 | 77 | 23 |
| 22 - North Central Oregon | 1980 | 14.7 | 6.8 | 7.9 | 46 | 54 |
| | 1987 | 29.4 | 15.3 | 14.2 | 52 | 48 |
| 23 - Central Oregon | 1980 | 22.0 | 10.7 | 11.3 | 49 | 51 |
| | 1987 | 43.4 | 25.9 | 17.4 | 60 | 40 |
| 24 - Eastern Oregon | 1980 | 21.3 | 20.0 | 1.3 | 94 | 6 |
| | 1987 | 36.8 | 36.0 | 0.8 | 98 | 2 |
| 31 - N. Idaho | 1980 | 20.7 | 13.3 | 7.3 | 64 | 36 |
| | 1987 | 43.0 | 28.5 | 14.4 | 66 | 34 |
| 32 - Southern Idaho | 1980 | 19.9 | 6.3 | 13.6 | 32 | 68 |
| | 1987 | 36.4 | 17.8 | 18.6 | 49 | 51 |
| 33 - W. Montana | 1980 | 21.2 | 10.8 | 10.3 | 51 | 49 |
| | 1987 | 40.9 | 25.3 | 15.6 | 62 | 40 |
| **Pacific Northwest[b]** | **1980** | **16.1** | **7.9** | **8.2** | **49** | **51** |
| | **1987** | **30.6** | **18.4** | **12.2** | **60** | **40** |
| **Percent Change 1980-1987** | | **90.1** | **132.9** | **48.8** | **22.4** | **-21.6** |

a/ Figures do not include Grant Co. PUD.

b/ Based on a weighted average for study utilities.

Approximately 49 percent of irrigation revenues in 1980 were derived from energy charges; by 1987 the share had increased to 60 percent. A similar trend is found in all production areas. Overall, retail energy rates increased 133 percent while estimated demand rates increased 49 percent, reflecting the trend at the wholesale level.[1]

## GENERAL DESCRIPTION OF RETAIL IRRIGATION RATE SCHEDULES

Irrigation utilities in the Pacific Northwest are not a homogeneous group. Differences in utility load, diversity of customers, management approach, and many other factors make each utility unique. This lack of homogeneity is reflected in the diversity of the retail irrigation rate schedules presented in Table 20.

While each utility has unique irrigation rate schedule characteristics, some general comments can be made regarding overall similarities. A majority of the utilities have a flat per kilowatt-hour charge for energy; only a few have block structure energy prices. Both increasing block rates (e.g., Umatilla Electric Cooperative) and declining block rates (e.g., Rural Electric Cooperative) are currently offered.

A majority of the region's irrigation utilities include a horsepower charge as a part of their irrigation rate schedule. In some cases, the horsepower charge declines with larger horsepower customers. Other utilities have a per-kilowatt demand charge, with some including an annual horsepower charge in combination with a monthly per kilowatt demand charge. Other fixed charges are commonly assessed, usually on an annual basis. Time-of-day metering, while still not widespread, has gained acceptance by some irrigation utilities. Often an extra fee is charged for the metering service. In some cases, time-of-day service is offered only to a utility's larger irrigation customers.

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1/ The estimated increase in demand rates is likely to be somewhat understated; as electricity price has increased over time, relative electricity use has declined causing the average rate measure to include both changes.

## Table 20

## GENERAL DESCRIPTION OF PACIFIC NORTHWEST RETAIL UTILITY IRRIGATION RATE DESIGNS

| Utility | —Demand Rate Design— Hp Charge | kW Charge | —Energy Rate Design— Flat Rate | Block Rate | —Seasonal Rates— Demand | Energy | Time-of-day Metering |
|---|---|---|---|---|---|---|---|
| Benton Co. PUD | X | X | X | | X | X | X |
| Benton REA | X | | X | | | | |
| Big Bend Elec. Coop. | X | | X | | X | X | |
| Central Electric Coop. | | X | X | | | | |
| Columbia Basin Coop. | X | | X | | | | X |
| Columbia REA | X [a] | X | X | | X | | X |
| Consumers Power, Inc. | X | X | | X | | | |
| Emerald PUD | X | | X | | | X | X |
| Fall River REC | | X | | X | X | X | |
| Flathead Elec. Coop. | X | | X | | | X | |
| Franklin Co. PUD | X | X [b] | X | | X | X | X |
| Grant Co. PUD | X | | | X | | X | |
| Harney Elec. Coop. | X | | X | | | | |
| Inland P&L, Co. | X | | | X | | X | |
| Klickitat Co. PUD | X [c] | | X | | X | | X |
| Kootenai Elec. Coop. | X | | X | | | X | |
| Lincoln Elec. Coop. | X | | | X | | | |
| Lost River REC | X | | X | | | | |
| Nespelem Valley Elec. Coop. | X | | X | | | | |
| Pacific Power & Light | X | X | | X | | X | |
| Raft River REC | X [d] | X | X | | X | X | X |
| Ravalli Elec. Coop. | X | | X | | | | |
| Rural Elec. Coop. | X | | | X | | | |
| Surprise Valley Elec. Coop. | X | | X | | | | |
| Tillamook PUD | X | | X | | | | |
| Umatilla Elec. Coop. | X | X | | X | X | X | X |
| Wasco Elec. Coop. | X | X | X | | | | |

a/ Horsepower charge on <250 kV accounts; demand charge on accounts >250 kV; fixed metering charge for time-of-day customers.

b/ Large users (>300 h.p.) have a seasonal T.O.D. demand charge; small users (<300 h.p.) have a horsepower charge.

c/ Time-of-day differential on horsepower charge.

d/ Fixed charges in addition to per kW demand charge.

Wholesale rates targeted to irrigation customers should be designed to be easily integrated into existing retail rate structures. Although rate designs at the retail level generally reflect the wholesale design, at least in terms of the emphasis on the energy component of the rate structure, the retail schedules are more likely to reflect the specific electricity use requirements of the irrigation sector. For example, most utilities include capacity rates as an annual horsepower charge rather than a per kW charge, reflecting more directly irrigation end-use characteristics. Seasonality in the retail schedules takes into account not only wholesale price differences but also the timing of irrigation water requirements. The irrigation season may not necessarily correspond to the wholesale summer period. Various alternatives for a targeted irrigation rate are discussed at length in the following sections.

## TARGETING A WHOLESALE RATE TO IRRIGATION CUSTOMERS

A rate discount targeted to specific groups within the irrigation sector was discussed in the 1987 Bonneville Power Administration Rate Hearings. However, the concept was not included as part of the 1987 rate schedule. Instead, the general rate discount for the irrigation sector included in 1985 rate schedule was continued at a higher rate.

A targeted irrigation discount is defined as a reduction in the Priority Firm (PF) rate which is passed on by retail utilities to some class of irrigators who are expected to be most responsive in increasing their energy purchases. One objective of such a targeted discount would be to increase BPA revenues. When a discount is given to irrigators who can not respond with increased energy purchases, BPA experiences a decline in revenues from the irrigation sector which must be balanced by a increase in the PF rate.

BPA could have several objectives in offering an irrigation rate discount, including revenue enhancement, load retention, and maintenance of good public relations. In the following sections economic, administrative, and institutional issues which could be considered by BPA if it evaluates a targeted program are outlined and potential targeting criteria and options based on either utility or irrigator characteristics are developed. The evaluation criteria are then applied to these hypothetical targeting options to provide insights into the advantages and disadvantages of each option.

### REVIEW OF PAST IRRIGATION INCENTIVE RATES

While BPA has never implemented a targeted irrigation rate discount, the agency has a history of region-wide rate discount programs for the irrigation sector. These discounts are briefly reviewed here with the intent of providing some background on the intended goal of each program, participation rates, impacts on revenues, and administrative problems identified with each program Although previous discounts were not targeted at specific types of irrigators, experiences from these programs may be useful in evaluating targeted irrigation discounts.

**Irrigation Wholesale Rate Discount (1942-1974)**

From 1942 to 1974 BPA offered a wholesale irrigation discount to qualifying public and private utilities. During this period the storage dams for the Northwest hydrosystem were constructed. The primary goal of the discount was to provide markets for spill power until adequate storage for hydroregulation was available. The irrigation discount was applied to all energy sold to a utility for irrigation use between the months of May and September.

The discount program met its original objective of providing a market for spill power but management objectives changed somewhat when the storage dams were completed. The irrigation discount was phased out between 1975 and 1979. At this time BPA instituted seasonally differentiated energy and demand rates to reflect differences in cost between the winter and summer seasons.

**1983 and 1984 Nonfirm Energy Sales to Irrigation Utilities**

In 1983 and 1984 BPA offered nonfirm energy to its irrigation utility customers. A review of these two programs provides some insight into potential problems for future incremental sales proposals within the irrigation sector.

Prior to 1983 sales during the spring portion of the irrigation season had been declining. The purpose of the 1983 nonfirm sale was to encourage irrigation electricity use during the early portion of the season in order to improve BPA and retail utility revenues. The offer of nonfirm power was made for incremental loads. Although 27 utilities participated in the program, sales were limited as a result of weather patterns, poor timing of the offer in some production areas, and a lack of agreement about appropriate utility markup [Bonneville Power Administration, 1984].

A major problem with this program was the method for determining firm (base load) sales. It was necessary to identify a base load from which the incremental load could be measured. For the 1983 nonfirm offer, the base level was calculated as a percentage of 1982 irrigation load for each utility. Incremental load for 1983 was then defined as the amount over the 1982 load. While this was a straightforward approach in terms of data requirements, it was not acceptable for all utilities, i.e. 1982 loads were not necessarily typical of longer run load patterns.

In an internal (BPA) review of the 1983 program it was suggested that utilities could provide better estimates of their base loads since they have more information about irrigation patterns within their service area.

Another problem with the 1983 program was the lack of incentive offered to irrigators located at higher elevations; all sales were made in March and April without regard for frost dates. The 1984 experimental nonfirm program was an attempt to correct for this equity issue between irrigators at different elevations. Offers of nonfirm power for incremental load under the 1984 program were made over a period of several months. The primary requirement was that utilities have less than ten percent of their load (based on 1983 levels) in the month of the offer. This criteria allowed nonfirm sales as late as June to higher elevation utilities.

Post-program evaluation of the 1984 nonfirm sale revealed that the nonfirm sales had reduced BPA revenues by nearly one half million dollars. While early spring sales levels did appear to be higher than historical levels, firm sales were displaced by nonfirm energy thereby reducing annual revenues. Twenty-seven utilities signed up under the program, but two utilities used over 50 percent of the nonfirm power sold to the irrigation sector. Annual electricity expenses for irrigators that were customers of participating utilities were reduced by only 1 to 3 percent. In addition to displacement of firm sales, reduced revenues to BPA, and fairly insignificant cost reductions to end users, the program proved to be more difficult to administer than was anticipated. As with the 1983 sale, the program lacked an appropriate means of determining a weather-corrected base load.

**The 1985 and 1987 Wholesale Irrigation Discounts**

In the 1985 rate case BPA reinstituted a region-wide irrigation discount. Economic need was the primary justification for the program. Although the discount of 3.7 mills per kWh went into effect July 1, 1985, the full impact of the lower rate was not evident until the 1986 irrigation season. Continued concern about economic need within the farm sector resulted in the continuation of the irrigation discount program in the 1987 rate case. In addition to economic need, the absence of a wholesale seasonal summer demand rate was also considered an additional justification for continuation of the discount. The 1987 rate hearing established a discount of 4.6 mills per kWh which will be in effect until the next rate case.[1] With both discount programs the lower rate was passed through directly to retail irrigation consumers.

## CRITERIA FOR EVALUATION OF A TARGETED RATE DISCOUNT

In order to evaluate the impacts of alternative electricity rate discount targeting options, an appropriate set of evaluating criteria should be determined. Any change in electricity rate structure or rate level raises revenue and other questions for BPA, as well as for individual utilities. Beyond direct revenue impacts, there are equity, administrative, and institutional questions that must be examined in evaluating rate targeting. Three types of targeting criteria are discussed here: economic, administrative, and institutional/legal.

### Economic Issues

#### Efficiency Considerations

The economic efficiency criteria suggests that resources should be allocated as if the market were "perfect." In a perfect market the price at which a good is sold will equal the marginal cost of producing that commodity. Use of the efficiency criterion will assure policy makers of an optimum balance between depletion and conservation of resources.[2] For electric generation the efficiency criteria would guarantee that the costs of generation and distribution are fully borne by the end-users.

A list of economic efficiency questions that deserve consideration in proposals for a targeted rate discount include the following:

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1/ The 1987 rate case increased the Priority Firm summer demand rate from $2.60/kW to $3.46/kW and the summer energy rate from 14.0 mills/kWh to 14.4 mills/kWh. The 4.6 mill discount was taken on the revised summer energy rate.

2/ As long as commodities are priced at their marginal cost of production.

- What are the expected impacts on BPA revenues?
- How does the discounted energy price compare with the cost of prov iding power during the irrigation season?
- What are the expected impacts on utility revenues?
- What are the expected impacts on irrigator production costs?
- Does the incentive rate maintain inefficient producers?
- What impact will the incentive program have on BPA conservation goals?
- Should eligibility for an incentive program be linked to required participation in other load management programs that have longer term positive revenue impacts on the region (e.g. time-of-day metering as a criteria for utility participation)?

Equity Considerations

For any type of rate discount program offered exclusively to one group of BPA customers or a particular group of end-users, consideration must also be given to the welfare of excluded groups. In some cases the long-run benefits associated with such programs may outweigh the short-term costs or inequities to other consumers. Equity addresses questions of "fairness": who benefits, who pays, how many benefit, and how many pay.

Equity considerations in targeted rate discounts may involve the following questions:

- Does the rate discriminate between consumers within a consumer class ?
- Does the incentive program shift revenue burdens to other consumer classes?

- Does the rate discriminate between consumers of investor owned utilities and consumers of public utilities and cooperatives?

- Does the rate discriminate between large and small utilities? Between large and small end-users?

- Would the program limit the discount to consumers with alternative fuel choices?

This list is not intended to be all-inclusive. Other unique issues will surface in discussions of a particular incentive program. It is important to identify all equity and efficiency concerns prior to approval of a discounted rate. However, in order to thoroughly analyze the benefits of a special incentive, the direct and indirect economic impacts generated by the particular target group should be estimated. It is also important to recognize that some equity/efficiency problems may be balanced by a potential gain to the overall regional economy and to the financial health of BPA.

**Administrative Issues**

BPA should further consider the administrative costs of implementing and monitoring a rate discount program, particularly programs that require implementation at the retail utility level. There may also be institutional or legal constraints to implementation of such discounts.

The administrative burden associated with a rate discount program should also be addressed prior to adoption of a program. Such programs can require substantial time in development, implementation, and monitoring. The expected administrative costs of a special rate should be estimated and netted out of any anticipated economic benefits from the program.

BPA has considerable experience in the potential problems involved with special incentive rates. The agency has gained this background through experience with the Nonfirm Energy Mining Pilot Program, the Industrial Incentive Rate Program, the Special Industrial Power Rate, past irrigation discounts, the Surplus Firm Block Sale in 1987, and other past rate actions. Planning and implementation of each of these programs involved input from many different divisions of BPA. For example, a review of the Nonfirm Energy Mining Pilot Program indicates that for this program input was required from Customer Services, Power Forecasting, Rates, Power Supply, the General Consul, BPA area office staff, and the general public [Bonneville Power Administration, 1985].

The major areas that involve administrative costs and the questions that need to be resolved are:

**Implementation**

- Is it clear which consumer qualifies for the program? How much work would be required to establish eligibility for participation in the incentive program? What is the burden to BPA staff? To area office staff? To utility managers?

- How much time will be required for approval of the retail rate structure of utilities that choose to participate in the program?

**Monitoring**

- What procedures will be implemented at BPA to handle record keeping?

- What record keeping and reporting will be required at the utility level beyond normal billing records? A potential problem is that monthly billing loads are often estimated, not actual loads.

- What will be the record keeping responsibility for the ultimate consumer?

- What potential problems are there with proprietary information?

**Review**

- Will formal review of the discount program be mandated? If so, how will this be accomplished, what are the data needs for such a review, and what parties will be responsible for the process?

**Institutional and Legal Issues**

Adoption of a targeted rate program will involve institutional and legal questions as well as equity, efficiency, and administration concerns. The entities involved in approval of a targeted discount will depend on the breadth of the program. For example, retail passthrough of a rate that is offered to private utilities would require approval by the four state public utility commissions. Specific policies regarding incentive rates in each state are reviewed in Volume 2, Section E.. In general, it appears unlikely that irrigation users would meet the criteria set by most of the utility regulatory bodies for design of incentive rates. Most irrigation users do not have a single-point of distribution large enough to be considered a hardship on the utility if that service is lost. Many irrigation rates are presently structured to provide as many incentives as possible to irrigators and the percentage of total utility load that irrigation makes up is often very small. Generally the public utility commissions require substantial documentation of need and cost recovery before approving rate discounts or incentive programs. It is also possible that a targeted wholesale irrigation rate would raise inter-state equity issues that would inhibit easy passage through to the retail level.

A partial list of potential institutional issues that may be considered by BPA in evaluating a targeted rate discount includes:

- How can the 7(i) process be most efficiently handled?
- Would a generic contract for utility participation suffice or would individualized contracts be necessary?
- Do equity issues present potential legal pitfalls?

Again, this list is not comprehensive as particular incentive proposals are likely to raise unique legal concerns.

## POSSIBLE OPTIONS FOR TARGETING AN IRRIGATION RATE DISCOUNT

If BPA should decide to evaluate a targeted irrigation discount what are the possible groups that could receive the discount? Formulation of an effective targeted rate for the irrigation sector would require an understanding of the characteristics of the irrigation utilities served by BPA as well as an understanding of the pattern of energy use by the end-users of these utilities. Information regarding retail rate design characteristics and on-farm water and energy use patterns is also necessary to develop a discount program designed to meet BPA objectives while at the same time reducing power costs to irrigators.

A detailed discussion of the Pacific Northwest agricultural production areas, comprised of counties having similar production characteristics (i.e., soils, climate, growing season, and cropping patterns) is presented in Volume 2, Section A. The discussion emphasizes the similarities and differences among the irrigation utilities as well as the diversity found among customers within individual utilities. This diversity may create opportunities for rate targeting. A description of monthly energy use patterns for selected irrigation utilities is also included in Volume 2, Section A.

**Targeting to Specific Utilities**

Targeting on a utility by utility basis could be based on a variety of criteria. These criteria and potential problems associated with them include:

<u>Rate Sensitivity</u>

If the goal of an incentive rate is to maintain or increase revenues, a targeted rate reduction could be applied to the most price responsive portion of the irrigation sector. If rates are to be increased, then the least responsive portion of the irrigation sector could be targeted for an increase. Elasticity estimates at the utility level could be used to define eligibility for the discount. Although measured utility response is an aggregation of individual irrigator responses, measurement beyond the utility level would likely not be practical. The elasticity results in Volume 2, Section C provide information regarding the feasibility of targeting by elasticity.

A discount based on price responsiveness would raise equity concerns among utilities. Irrigators may have limited ability to respond to price because of cropping patterns, climatic conditions, and soil types. A rate discount based on price elasticity would discriminate against these consumers. It may also encourage inefficient energy use and subsidize large, profitable irrigators. The legality of BPA practicing price discrimination based on price responsiveness is another issue that may need to be examined.

### Retail Irrigation Rate Levels

Another alternative for a targeted rate would be to limit the rate discount to utilities that have relatively high rates. While this may apply rate relief to those irrigators that most need it, there are obvious economic efficiency problems with this approach as it would provide a disincentive for utilities to reduce average costs. It may also run counter to BPA conservation goals.

### Utility Dependence On Irrigation Load

A rate discount for irrigators could be applied to those utilities most dependent on irrigation load. Utilities that are dependent on one customer class for a large proportion of load are more subject to load variability caused by macroeconomic influences. An argument could be made that the large irrigation utilities, through the direct and indirect regional economic linkages associated with agricultural production, create loads in other parts of the region (primarily rural areas) thereby making it important to keep the utility financially healthy. From an administrative viewpoint, a discount targeted by size of irrigation load would be fairly straightforward to implement and monitor.

## Targeting by Irrigator Characteristics

Rather than targeting selected utilities by utility characteristics, the criteria of a targeted rate could be based on irrigator characteristics. A utility could qualify for the rate based on the proportion of irrigators meeting the targeting criteria. The discount would only apply to the qualifying portion of the irrigation load. Some potential targeting options and associated problems include:

### Crop Price and/or Cropping Pattern

If the objective of an irrigation discount is to provide income stability to irrigators, a rate discount linked to crop prices would meet this objective. To apply this targeting scheme, appropriate output prices would need to be established at a regional or state level (versus using national output indices). This targeting option would, by design, require substantial record-keeping by the utility regarding the crop mix of individual customers. The wholesale rate discount could be based on some weighted crop price for the utility. The retail rate would be different for different irrigators based on their crop mix. Aside from the administrative difficulties, the most significant theoretical problem with this approach is that output price alone is not an adequate representation of farm profits. Other input costs vary with different crops. Targeting by output price would ignore these differences and therefore would raise obvious economic equity issues.

### Parity Index

A parity index, which is the ratio of "farm prices received" to "farm prices paid," could also be used as the basis for rate targeting at the customer level. While this approach gives recognition to variation in cost structures, implementation of such a targeting program would require substantial time and effort on the part of BPA and participating utilities to develop and maintain an index. Another problem with using parity index as a rate setting tool is that it does not recognize changes in productivity and technology.

### Farm Size

If the objective of the discount is to provide rate relief to distressed farmers, farm size could be used as a criteria to determine the overall level of assistance provided to the irrigator. In a manner similar to current USDA farm subsidy programs, the total value of the discount could be limited so that smaller farms received a proportionately larger reduction in energy costs.

### Lift Class

As above, the targeted group would depend on the BPA objective in offering the discount. If the objective is to target the group with the highest electricity costs regardless of price elasticity, the high lift farms may be an appropriate target even if there is no perceptible difference in elasticity response between high and low lift farms.

As with the other "within" utility targeting options, targeting by lift class would require additional monitoring by the retail utility and annual updating of the eligibility of participants.

## Issues For Selecting a Targeted Rate Option

Critical issues for the alternative targeting options are summarized in Table 21. For purposes of comparison, the current BPA irrigation discount is presented as a targeting option. No form of targeting is problem free. Prudent evaluation by BPA requires identification and resolution of these problems prior to adoption of any targeted irrigation rate.

## Form of The Rate Discount

Another area of consideration for any new irrigation discount, whether it be targeted to selected utilities, to particular types of irrigators, or available for all irrigation load, is the form of the discount. The current wholesale discount is a flat reduction in the energy charge. Alternatives to the current form include:

- An extended seasonal discount to encourage more pre- and post-season irrigation.
- A reduction in the demand charge or a pro-rated demand charge for partial irrigation months.
- A longer off-peak period to allow irrigators to complete their daily irrigation without triggering a demand charge.

## Table 21
## SUMMARY OF IRRIGATION RATE TARGETING ISSUES

| Targeting Option | Summary of Issues |
|---|---|
| **By Utility Characteristics** | |
| Rate Sensitivity | • Politically sensitive approach.<br>• BPA would incur cost to estimate elasticities.<br>• Estimates would require frequent revisions.<br>• May be best targeting option for load maintenance objective. |
| Retail Rate Level | • Fails to promote good utility cost management.<br>• Uses federal power as a utility subsidy. |
| Irrigation Load | • May be justified to assure stability of agriculture and rural communities.<br>• Other customer classes may have rates increased. |
| **By Irrigator Characteristics** | |
| Crop Price | • Distorts markets for crops.<br>• Difficult to implement and monitor; requires annual updating if cropping patterns change. |
| Parity Index | • Difficult to implement and monitor; requires constant updating.<br>• Difficult to find localized input price data.<br>• Not a true representation of the economic condition of irrigated agriculture. |
| Farm Size | • Puts BPA in a position of choosing between helping large or small farms.<br>• Distorts market efficiency.<br>• Targeted farm size would depend on discount objective. |
| Lift Class | • May promote inefficient farming.<br>• Difficult to determine an appropriate measure of lift class. |
| **Current BPA Irrigation Discount** | |
| | • Historical basis for such rate.<br>• Easy to administer relative to targeted programs.<br>• Discounts is goal oriented; goal is rate stability and load maintenance.<br>• Eliminates many of the equity considerations involved in targeted rates.<br>• Least confusing to understand.<br>• Easier to administer than targeting by specific characteristics.<br>• Gives discounts to all irrigators, including those whose loads are not responsive to price reductions. |

**Alternatives to a Targeted Rate Discount**

A targeted rate discount may not offer BPA increased revenues, maintain loads for the irrigation utilities, or lower irrigation electricity costs. Irrigator interviews and previous research in rate design by the study team has indicated that the following areas should also be explored by BPA.

**Longer Rate Period**

Interviews with irrigators and evidence in the literature indicates that rate stability is as important to irrigators as absolute rate levels. Irrigators in the Pacific Northwest have already experienced many changes in rate structure and rate levels. The 1942-1974 rate discount was discontinued after irrigators had built systems based on low electric rates. Then in the early 1980's rates accelerated sharply upward. During the 1980's two experimental nonfirm energy offers were made and then discontinued and replaced by a Priority Firm rate discount.

While BPA can not guarantee a long-term rate level, the agency could provide some stability in rate structure e.g., assure irrigators that diurnal rates will remain in place for some predetermined duration.

**Encourage Better Passthrough of The Wholesale Rate Structure**

Retail passthrough of the BPA wholesale rates designed to benefit irrigators has not been very successful. Although the BPA Priority Firm energy rate has no demand charge at night, few irrigation utilities have an equivalent rate design. Nor do all of the irrigation utilities mirror the seasonal energy rate.[1] BPA could explore alternative ways of encouraging better passthrough of the wholesale rate design such as technical assistance to the retail utilities, including subsidization of time-of-day meters.

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1/ A review of retail utility irrigation rate schedules is presented on pages 54 to 55. Seasonal irrigation electricity use patterns for selected utilities are presented in Volume 2, Section A.

## Encourage Irrigation Utility Participation in the Partnership Program

BPA could encourage the irrigation utilities to submit proposals under the Power Advantage Program of the Partnership Program. This program is already in place and is not exclusively targeted at any one customer class, so that many of the equity issues inherent in a targeted irrigation discount are avoided. BPA had little success with the 1983 and 1984 nonfirm offers which were also incremental load programs but these programs were labeled "experimental" and hence did not encourage management practices to build incremental load. The Power Advantage Program, although based on short-term contracts, is intended to market firm surplus power, reducing the risk of supply shortages inherent in the nonfirm offer.[1]

BPA's emphasis on participation in the program would shift responsibility for creative load management to the individual utilities and their respective irrigation customers. Incremental load programs could also increase revenues to BPA and to the utilities.

## Technology Transfer

To assist irrigators in reducing costs, BPA could increase support of conservation and energy efficiency programs. This support could be directed at the utility or it could be in the form of a direct subsidy to the farmer. An example of the latter would be a direct subsidy for irrigation scheduling [Merchant and Herman, 1984].

Technology transfer, while a program cost in the short-term, would meet longer term objectives of BPA by reducing future generation costs. It also maintains the irrigation load by reducing energy costs to the consumer.

## Standard (Current) Irrigation Discount

An alternative to the various targeting options presented above would be to simply continue with the current wholesale irrigation discount. The present form of the irrigation discount has many advantages. The diverse characteristics of

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1/ The Power Advantage Program is a three year incremental load program specifically designed not to promote long-term load building.

irrigated agriculture and irrigation utilities could make a targeted discount difficult to administer. The current irrigation discount applies equally to all utilities and irrigators. This discount is the simplest and least confusing to understand by the participants.

# ESTIMATED IMPACTS OF THE 1985 AND 1987 IRRIGATION RATE DISCOUNTS

Estimated impacts associated with the 1985 and 1987 irrigation rate discounts are calculated for both irrigation and non-irrigation ratepayers in the Pacific Northwest. Impacts are evaluated using "with discount" and "without discount" scenarios. The "with discount" scenario is considered to be reflected by actual production and electricity use characteristics during 1986 and 1987.[1] "With discount" impacts are also estimated for 1988. For each year analyzed, average retail irrigation rates are increased by the amount of the discount in the "without discount" scenario so that revised production and electricity use levels can be estimated.

## MEASURING THE DIRECT IMPACTS OF THE RATE DISCOUNT

Because an irrigation electricity rate discount is currently in place, removing the discount would result in an increase in the retail price paid by irrigators.[2]

Response by irrigators to an increase in average electricity price can include a variety of production-related changes. Cropping patterns can be adjusted to reflect a shift to crops with lower water requirements. Water application levels on existing crops can be adjusted downward. Applied water and energy use efficiencies can be improved with better management. Irrigated acreage can be cut back in order to reduce overall water requirements. Each of these adjustments however, is likely to impact crop yields and overall input requirements.

Both the mathematical programming approach and the econometric analysis indicate that electricity use declines as average irrigation rates are increased. The relative impact of the price change varies across production regions, as reflected in the derived elasticity measures. Estimated short-run elasticities are less than one in

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1/ Impacts of the 1985 irrigation discount are measured using 1986 and 1987 loads and average prices. Impacts of the 1987 discount, which became effective during the 1988 irrigation season, are estimated using 1987 loads and average prices since 1988 data was unavailable at the time of the study.

2/ For this analysis it is assumed that the retail utilities will discontinue the irrigation discount if BPA discontinues the wholesale discount.

absolute value, indicating that the relative change in irrigation electricity use is less than the relative change in price. Water use can be affected by an increase in electricity rates in several ways. Price changes can result in improvements to irrigation system efficiencies, crop mix adjustments, or lower applied water applications. Each of these adjustments will cause overall water use to decline. In response to increasing electricity prices, the producer may substitute irrigation labor for water and energy use. Alternatively, the producer may decrease irrigation labor use if a significant decline in overall water use occurs.

## IMPACT OF THE DISCOUNT ON BPA IRRIGATION REVENUES

The estimated irrigation price electricity measures and the irrigation load data allow for calculation of BPA revenues with and without the discount program. Net revenue impacts to BPA are calculated as a combination of two offsetting factors. The first factor is the gross cost of the discount, which is calculated as total irrigation receiving the discount multiplied by the wholesale rate discount. The second component, which is an offset to the gross cost, is the revenue received from a price induced increase in irrigation load. Combining these two factors provides an estimate of the net revenue impact of the irrigation discount program. Net revenue estimates are based on the percent of utility irrigation load qualifying for the discount. For the public utilities, this was equivalent to the proportion of total utility load supplied by BPA. For the private utilities this percentage was calculated from actual 1987 load that qualified for the discount and 1987 total irrigation load. Qualification of private load for the irrigation rate discount is linked to participation in the residential exchange program.

Impacts of the 1985 and 1987 irrigation rate discounts programs on BPA irrigation revenues are summarized in Table 22. The program is estimated to have decreased BPA revenues by $9.7 million in 1986, by $10.4 million in 1987, and by $12.9 million in 1988. These figures include the revenue offset caused by the price induced increased in irrigation load as a result of the discount program.

To place the relative cost of the irrigation discount program in perspective, total revenues for BPA were $1.5 billion in 1987. Revenues from firm sales to irrigation customers were estimated to be approximately $36 million. The cost of

# Table 22

## ESTIMATED IMPACT OF THE IRRIGATION RATE DISCOUNT ON BPA REVENUES [a]

| Impact | | 1986 | 1987 | 1988[b] |
|---|---|---|---|---|
| **Public Utilities** | | | | |
| Total Qualifying Load (with discount) | 1,000 MWh | 1,713 | 1,819 | 1,819 |
| Net Change in Load (without discount) | 1,000 MWh | 75 | 79 | 79 |
| Total Revenues (with discount) | $1,000 | 17,639 | 18,732 | 17,822 |
| Total Revenues Before Elasticity Calculation (without discount) | $1,000 | 23,976 | 25,461 | 26,188 |
| Total Revenues After Elasticity Calculation (without discount) | $1,000 | 22,932 | 24,353 | 24,772 |
| Net Change in BPA Revenues Before Elasticity Calculation | $1,000 | 6,336 | 6,729 | 8,366 |
| Net Change in BPA Revenues After Elasticity Calculation | $1,000 | 5,292 | 5,622 | 6,950 |
| **Private Utilities** | | | | |
| Total Qualifying Load (with discount) | 1,000 MWh | 1,509 | 1,628 | 1,628 |
| Net Change in Load (without discount) | 1,000 MWh | 77 | 80 | 80 |
| Total Revenues (with discount) | $1,000 | 16,594 | 17,896 | 17,092 |
| Total Revenues Before Elasticity Calculation (without discount) | $1,000 | 22,179 | 23,919 | 24,580 |
| Total Revenues After Elasticity Calculation (without discount) | $1,000 | 21,048 | 22,749 | 23,085 |
| Net Change in BPA Revenues Before Elasticity Calculation | $1,000 | 5,585 | 6,023 | 7,488 |
| Net Change in BPA Revenues After Elasticity Calculation | $1,000 | 4,454 | 4,853 | 5,993 |
| **Total For All Utilities** | | | | |
| Total Qualifying Load (with discount) | 1,000 MWh | 3,222 | 3,446 | 3,446 |
| Net Change in Load (without discount) | 1,000 MWh | 152 | 159 | 197 |
| Total Revenues (with discount) | $1,000 | 34,233 | 36,628 | 34,915 |
| Total Revenues Before Elasticity Calculation (without discount) | $1,000 | 46,155 | 49,380 | 50,768 |
| Total Revenues After Elasticity Calculation (without discount) | $1,000 | 43,979 | 47,102 | 47,857 |
| Net Change in BPA Revenues Before Elasticity Calculation [c] | $1,000 | 11,921 | 12,752 | 15,854 |
| Net Change in BPA Revenues After Elasticity Calculation [d] | $1,000 | | | |

a/ Figures in this table summarize the utility-level impact calculations presented in Volume 2, Section E, Tables 1-3.

b/ Impacts based on 1987 data for load and average revenues. Data for 1988 was unavailable at the time of analysis.

c/ Net revenue impacts to BPA before the elasticity calculation are approximately the same as the net change in irrigation electricity costs (Table 22). A slight difference results because the electricity cost calculation for public utilities is based on total irrigation load whereas the net BPA revenue impacts for public utilities is based on total qualifying load. The same private utility load is used for both calculations.

d/ Net revenue impacts associated with deeming utilities are estimated to be $2.3 million in 1986, $2.6 million in 1987, and $3.2 million in 1988. These figures are based on estimates for Idaho Power Co. and Puget Sound Power & Light. Washington Water Power and Montana Power did not participate in the discount program.

irrigation discount to BPA is estimated to be $12.9 million. Irrigation revenues contribute about two percent of all BPA revenues. The discount, while it represents over one third of the irrigation revenues, amounts to less than one percent of total BPA revenues.

## IMPACTS OF THE DISCOUNT ON IRRIGATION CONSUMERS

Short-run and price elasticity estimates from the unrestricted model discussed in the econometrics section are used to evaluate the impact of the rate discount on irrigator income. The elasticities are used to calculate irrigation electricity use at retail price levels that would occur in absence of the discount. The impact of the discount on irrigator income is calculated as the difference between total electricity costs estimated to be paid by irrigators without the discount and total electricity costs currently paid with the discount. In the short-run the change in irrigator income is assumed to be reflected by the change in total electricity costs paid by producers. For purposes of this short-run analysis gross receipts and production expenses incurred for all other inputs are assumed to be the same in the with discount and without.

Estimated impacts of the irrigation rate discount on irrigation consumers are presented in Tables 23. Impacts for 1986 and 1987 are estimated using the 1985 discount level of 3.7 mills/kWh. Impacts for 1988 are calculated using the 1987 discount level of 4.6 mills and 1987 loads and prices.[1] Impacts to consumers of public utilities are based on total irrigation load, where as impacts to consumers of private utilities are based on total load qualifying for the discount.[2] The discount program is estimated to have reduced net irrigation electricity costs by $6.5 million in 1986, by $7.0 million in 1987, and by $8.5 million in 1988. These estimates include two components: The first is the reduction in irrigation costs resulting from lower

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1/ Irrigation load and average revenue data for 1988 is currently unavailable for use in the analysis.

2/ Qualifying load for all public utilities, with the exception of Grant Co. PUD, was generally almost equal to the total irrigation load. It was assumed that the utilities made the discount available to all customers. Grant Co. PUD did not participate in the discount program.

## Table 23

### IMPACT OF THE IRRIGATION RATE DISCOUNT ON IRRIGATION CONSUMERS [a]

| Impact | | 1986 | 1987 | 1988[b] |
|---|---|---|---|---|
| **Public Utilities** | | | | |
| Total Irrigation Load (with discount) | 1,000 MWh | 2,137 | 2,243 | 2,243 |
| Total Qualifying Load (with discount) | 1,000 MWh | 1,713 | 1,819 | 1,819 |
| Net Change in Load (without discount) | 1,000 MWh | 75 | 79 | 98 |
| Total Electricity Costs (with discount) | $1,000 | 53,203 | 56,195 | 56,195 |
| Total Costs Before Elasticity Calculation (without discount) | $1,000 | 59,598 | 62,987 | 64,639 |
| Total Costs After Elasticity Calculation (without discount) | $1,000 | 57,084 | 60,327 | 61,243 |
| Net Change in Irrigator Costs Before Elasticity Calculation | $1,000 | 6,395 | 6,791 | 8,443 |
| Net Change in Irrigator Costs After Elasticity Calculation | $1,000 | 3,881 | 4,132 | 5,048 |
| **Private Utilities** | | | | |
| Total Irrigation Load (with discount) | 1,000 MWh | 2,308 | 2,494 | 2,494 |
| Total Qualifying Load (with discount) | 1,000 MWh | 1,509 | 1,628 | 1,628 |
| Net Change in Load (without discount) | 1,000 MWh | 77 | 80 | 99 |
| Total Electricity Costs (with discount) | $1,000 | 56,471 | 63,749 | 63,749 |
| Total Costs Before Elasticity Calculation (without discount) | $1,000 | 62,055 | 69,772 | 71,237 |
| Total Costs After Elasticity Calculation (without discount) | $1,000 | 59,083 | 66,578 | 67,177 |
| Net Change in Irrigator Costs Before Elasticity Calculation | $1,000 | 5,585 | 6,023 | 7,488 |
| Net Change in Irrigator Costs After Elasticity Calculation | $1,000 | 2,612 | 2,829 | 3,428 |
| **Total For All Utilities** | | | | |
| Total Irrigation Load (with discount) | 1,000 MWh | 4,446 | 4,737 | 4,737 |
| Total Qualifying Load (with discount) | 1,000 MWh | 3,222 | 3,446 | 3,446 |
| Net Change in Load (without discount) | 1,000 MWh | 152 | 159 | 197 |
| Total Electricity Costs (with discount) | $1,000 | 109,674 | 119,944 | 119,944 |
| Total Costs Before Elasticity Calculation (without discount) | $1,000 | 121,653 | 132,759 | 135,876 |
| Total Costs After Elasticity Calculation (without discount) | $1,000 | 116,167 | 126,905 | 128,420 |
| Net Change in Irrigator Costs Before Elasticity Calculation | $1,000 | 11,979 | 12,814 | 15,931 |
| Net Change in Irrigator Costs After Elasticity Calculation | $1,000 | 6,493 | 6,961 | 8,476 |

a/ Figures in this table summarize the utility-level impact calculations presented in Volume 2, Section E, Tables 1-3.

b/ Impacts based on 1987 data for load and average revenues. Data for 1988 was unavailable at the time of analysis.

electricity rates; the second is the price-induced increase in irrigation load (and therefore costs) that is estimated to have resulted with the discount program. The net impact on irrigation electricity costs is the summation of these two factors.

The estimated income impacts reflect the short-run response of irrigators to price changes. If BPA were to remove the discount and retail rates increased to reflect this change, irrigators in the region would experience income losses calculated in Table 23. In the longer run, however, some of the impacts of higher electricity costs would be mitigated by changes in acreage, cropping pattern, and substitution of other inputs. These changes would reduce electricity use and hence reduce the impact of the higher electricity price, but this may or may not mitigate the impact on irrigator income. The net impact on income would depend on the changes in gross receipts and other production costs which occur as a result of reduced energy use and changes in land and other inputs.

## IMPACTS ON CONSUMERS IN THE BPA PRIORITY FIRM RATE CLASS

When a rate discount to one consumer sector reduces BPA revenues, these losses can be compensated for by increasing wholesale rates to a more general class of rate payers. Any subsequent increase in retail rates will result in an income loss to final consumers.

To estimate the increase in wholesale rates necessary to offset the costs of the irrigation discount, the net program cost (including the elasticity calculation) shown in Table 22 was divided by the Priority Firm load for the respective year.[1] For 1986, a 0.08 mill increase was needed to offset the cost of the discount. For 1987 the analysis showed a 0.09 mill increased was needed and for 1988 a 0.11 mill increase was required.

If the wholesale rate to the Priority Firm rate class was increased to compensate BPA for the irrigation revenue loss, retail rates may also increase. The change in retail rates would result in changes in direct income for each of the

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1/ Priority firm load was derived from *1987 Annual Historical Sales Report For The Pacific Northwest Region.* Priority firm load was estimated to be equal to the firm load minus the DSI load and the USBR irrigation load.

priority-firm consumer groups. To establish an estimated change in retail level rate, a wholesale-retail passthrough of 50 percent was assumed, i.e. a 1 percent change in wholesale rates would result in a 0.5 percent change in retail rates. It was also assumed that the non-irrigators had a zero price elasticity.[1] Using these assumptions, changes in retail revenues for residential, commercial, and industrial users in each utility were calculated. The estimated changes in utility revenues are used as proxies for changes in direct income to each of the three consumer sectors. These changes in direct income would also generate changes in indirect and induced income.

Production area total income multipliers from IMPLAN for the residential, commercial, industrial, and irrigated agriculture sectors were used to convert the direct income impact to total income impact. For residential consumers the household sector income multipliers were used to compute total income impacts. For the industrial sector a weighted multiplier was developed for each of the nine production areas. Using the IMPLAN run for the appropriate subregion multipliers for the major income producing industrial sectors were averaged to give an overall industrial sector multiplier. A similar process was used to develop appropriate income multipliers for the commercial sector. Multipliers for irrigation customers are shown in Volume 2, Section A.

Estimates of the direct income change and the total income change resulting from an increase in the Priority Firm wholesale rate are calculated for consumers of the public utility customers of BPA.[2] Income impacts are presented in Table 24 for irrigation and non-irrigation consumers. For 1988, a 0.11 mill increase in the Priority Firm rate is estimated to result in a $4.2 million direct income loss to non-irrigation served by public utility consumers, total income impacts are estimated at $8.2 million. Comparable figures for irrigation consumers are $5.0 million and $8.0 million for direct and total income changes, respectively. The gain to irrigator income is approximately equal to the loss in income to non-irrigators. Similar impacts are estimated for 1986 and 1987.

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1/ Using a zero price elasticity allows for a measure of the greatest implied impact of the higher PF rate. Deriving regional elasticity estimates for non-irrigation on consumers was beyond the scope of the present study.

2/ Estimates of direct and total income impacts are based on within utility consumer sector load shares. This data was unavailable for private utility customers of BPA. Income impacts are therefore estimated only for public utility consumers.

## Table 24

## TOTAL ESTIMATED INCOME CHANGES RESULTING FROM THE IRRIGATION DISCOUNT PROGRAMS FOR CONSUMERS SERVED BY PUBLIC UTILITIES [a]

| Production Area | Irrigation Consumers: Direct Income Impact ($1,000) | Irrigation Consumers: Total Income Impact ($1,000) | Non-Irrigation Consumers: Direct Income Impact ($1,000) | Non-Irrigation Consumers: Total Income Impact ($1,000) |
|---|---|---|---|---|
| | | 1986 | | |
| 11/21 - W. Washington/Oregon | 107 | 206 | (2,179) | (4,441) |
| 12 - Central Washington | 706 | 1,235 | (233) | (396) |
| 13 - Columbia Basin (WA) | 717 | 1,105 | (241) | (428) |
| 14 - Eastern Washington | 143 | 266 | (101) | (191) |
| 22 - North Central Oregon | 570 | 827 | (87) | (135) |
| 23 - Central Oregon | 344 | 502 | (84) | (142) |
| 24 - Eastern Oregon | 739 | 1,057 | (125) | (188) |
| 31/33 - N.Idaho/W.Montana | 226 | 423 | (204) | (384) |
| 32 - Southern Idaho | 329 | 560 | (129) | (270) |
| **Pacific Northwest 1986** | **3,881** | **6,180** | **(3,367)** | **(6,523)** |
| | | 1987 | | |
| 11/21 - W. Washington/Oregon | 114 | 219 | (2,288) | (4,663) |
| 12 - Central Washington | 751 | 1,315 | (245) | (416) |
| 13 - Columbia Basin (WA) | 764 | 1,176 | (253) | (449) |
| 14 - Eastern Washington | 152 | 283 | (106) | (201) |
| 22 - North Central Oregon | 607 | 880 | (91) | (142) |
| 23 - Central Oregon | 366 | 534 | (89) | (149) |
| 24 - Eastern Oregon | 787 | 1,125 | (131) | (197) |
| 31/33 - N.Idaho/W.Montana | 241 | 451 | (198) | (381) |
| 32 - Southern Idaho | 351 | 596 | (135) | (252) |
| **Pacific Northwest 1987** | **4,132** | **6,579** | **(3,535)** | **(6,849)** |
| | | 1988 | | |
| 11/21 - W. Washington/Oregon | 139 | 268 | (2,723) | (5,551) |
| 12 - Central Washington | 918 | 1,606 | (291) | (495) |
| 13 - Columbia Basin (WA) | 933 | 1,437 | (301) | (535) |
| 14 - Eastern Washington | 186 | 346 | (127) | (239) |
| 22 - North Central Oregon | 742 | 1,075 | (108) | (169) |
| 23 - Central Oregon | 447 | 653 | (106) | (178) |
| 24 - Eastern Oregon | 961 | 1,375 | (156) | (235) |
| 31/33 - N.Idaho/W.Montana | 294 | 550 | (235) | (453) |
| 32 - Southern Idaho | 428 | 728 | (161) | (300) |
| **Pacific Northwest 1987** | **5,048** | **8,038** | **(4,209)** | **(8,154)** |

a/ Figures in parentheses indicate an income loss.

## SURVEY OF PACIFIC NORTHWEST IRRIGATORS

An irrigator survey was conducted to help validate the estimated electricity price elasticities and to identify relationships between irrigation electricity rates and irrigators' sprinkler irrigation decisions. In particular, the survey was to identify:

- Possible responses to electricity rates, including crop acreage adjustments, changes in cropping patterns, adjustments in water and energy use, modifications to or adoptions of irrigation systems, and seasonal flexibility in water and energy use.
- Production changes that have occurred in the last ten years, including lands taken out of or put into irrigation, and adoption of new irrigation systems and technologies.
- Management changes within an irrigation season, including adjustments in water and energy use, peak/off-peak flexibility, and percent utilization of a system.

The irrigator survey was a limited cross section of 30 irrigators in the Pacific Northwest and was not expected to produce statistically valid results; no statistical tests of significance were conducted.

Producers responding to the survey represented 17,568 acres, of which 13,560 are irrigated; 12,940 of the irrigated acres are sprinkler irrigated. Five states, Washington, Oregon, Idaho, Nevada, and Montana, are represented in the survey. Irrigators grew a wide range of crops (grains, alfalfa, other hay, tree fruits, grapes, potatoes, field crops, pasture) using different irrigation systems (low- and high-pressure center pivot, side roll, hand lines, drip, and flood). Approximately one-third of the farms received water from U.S. Bureau of Reclamation, one-third from other surface water, and one-third from other groundwater.

Because of the limited sample size, it is difficult to present quantitative results from the survey. It is possible to capture from the survey the "mood" of the irrigators and also to identify certain trends and relative relationships. Pacific Northwest irrigated agriculture in the 1980s has gone through a transition from rapidly expanding acreage during the 1970s to a leveling off of irrigation development. In addition, the 1980s have been characterized as a farm recession period. In order to survive, irrigators have made production changes and management adjustments. Results of the survey show that more irrigators increased irrigated acreage than decreased acreage during the 1980s. These irrigators have adopted many water and energy saving techniques. Only 7 percent of the irrigators reported increases in per-acre water use, while 22 percent decreased use by 15 to 30 percent and 27 percent decreased use by 1 to 15 percent. This reduction in water use per acre was caused by improved irrigation management, shifting to sprinkler irrigation from flood irrigation, and a slight shift to less water intensive crops. Also in response to the farm recession, over one third of the growers have shifted to "higher value" crops such as fruit, vegetables, and field crops.

Over two-thirds of the growers have changed their pump pressure with improved pump efficiencies and conversions to lower pressure systems.

Irrigators generally felt that the agricultural economy over the next three years should remain fairly static or improve slightly.

Irrigators are knowledgeable about the irrigation discounts, but somewhat confused between special spill rates and the 1985 and 1987 irrigation discounts. The majority of the irrigators feel that the irrigation discounts have affected electricity and water use and added to rate stability. The irrigation discounts have had lesser impact (less than one-third of irrigators) on irrigated acreage, irrigation systems, and hired labor.

In the last ten years, the surveyed irrigators felt that electricity rates were very important in irrigation system changes and per-acre water and energy use. Electricity rates were not as important in determining cropping patterns, irrigated acreage, and hired labor.

When presented with irrigation price elasticities, in the range of -0.20 to -0.80, irrigators were inconclusive whether or not they agreed or disagreed with these estimates. It was difficult for the irrigators to evaluate the concept of a regional or subarea price elasticity relative to their individual situations. Some irrigators felt that any future rate increases could cause significant changes in electricity use, while other irrigators said they are price takers and have to pay whatever the price. These growers need water and energy to remain in irrigated agricultural production. There seemed to be a general agreement that future water and energy savings will be harder to come by because irrigators are getting closer to the consumptive water requirement of crops. Also, if crop prices continue to improve, the impacts of electricity rates on electricity use will be less than if crop prices fall.

In the next three years, irrigators see electricity rates playing an important role in water and energy use, and irrigated acreage decisions. Electricity rates will play a lesser role in determining cropping patterns, irrigation systems, and hired labor. Again, the level of farm prices and the condition of the agricultural economy will impact the role that electricity prices play in future farm management decisions.

Even though irrigators see electricity playing an important role in water and energy use, less than ten percent of the irrigators anticipate any major change in electricity use per acre, or in monthly and annual electricity use in the next three years.

If electricity rates were to increase ten percent, irrigators are divided as to how they would respond. Approximately one-half of the irrigators feel they would not reduce electricity use, while the other one-half feel they would reduce electricity use by adopting more conservation measures, converting to other energy uses, or shifting to dryland farming. In general, the response to this question is inconclusive.

Irrigators are in general agreement on wanting rate stability, doing away with demand charges, and not targeting rates within or between utilities by farm characteristics. Irrigators want to see simple, long-term stable rates on which they can depend.

## STUDY CONCLUSIONS

Irrigated agriculture, in particular sprinkler irrigated agriculture, is an important economic base for the Pacific Northwest and the BPA rural service area. The 7.7 million acres of irrigated cropland generates $5.2 billion of crop sales and $2.6 of livestock sales while employing 159,000 people on the farm and 73,000 people in food processing. In addition, for every dollar and job directly generated by agriculture, another 70 cents and 0.5 jobs are indirectly generated. In many rural areas of the Pacific Northwest crop production and food processing account for more than 25 percent of regional employment and 20 percent of regional income. Approximately 3.9 million acres are sprinkler irrigated, producing $2.4 billion of crop sales and 63,000 jobs.

The agricultural base of the Pacific Northwest grew significantly during the 1970s (approximately 7 percent per year), but more recently in the 1980s growth has leveled out or increased only slightly. It appears that the big growth period of Pacific Northwest irrigated agriculture is over. No major federal water projects are planned in the near future and competing demands for irrigation water should constrain future growth. This decrease in growth has also impacted irrigation electricity sales which grew substantially in the 1970s, peaked around 1980 and then fell to the current level of about 4.5 million MWh. Most irrigation utilities are faced with the task of maintaining existing irrigation load.

Irrigated agriculture has shown a tremendous ability to survive through recessions and periods of surplus production. This survival has seen the loss of farms, and farmers living off of past equity and earnings from their family farms. In particular, those farms that expanded and borrowed heavily in the late 1970s were extremely vulnerable in the last recession. Pacific Northwest irrigated agriculture is now competitive with other production areas of the U.S. as a result of several factors: i) favorable climate conditions and yield, ii) relatively low land, water, and energy costs, and iii) access to Pacific Rim markets. Irrigation electricity rates in the Pacific Northwest contribute to the favorable competitive position of its growers. But electricity rates are only one of many factors, with market prices being the most important determinant of farm profitability.

Even though Pacific Northwest irrigated agriculture is now more competitive in U.S. and world markets than it was in the early 1980s, it is also vulnerable. Growers cannot influence market prices that are determined by world demand and supply conditions. Therefore, any cost increases, such as electricity rates, during times of constant or falling crop prices impact growers' income directly. In general, for every ten percent increase in electricity rates, growers' net income falls one percent.

The Bonneville Power Administration wholesale power rates in the 1980s have assumed a greater role in irrigators' profits and loss. From 1980 to 1987, BPA wholesale rates increased 180 percent, while average irrigation retail rates increased 90 percent. During that same period of time, the wholesale share as a percent of the retail rate increased from 46 percent to 67 percent. Retail utility irrigation rates are now more dependent on BPA wholesale rates. Also, irrigators' profits are more dependent on retail electricity rates, due to the significant rate increases during a period of relatively constant production costs and falling commodity prices. In the last two years however, farm prices have improved.

The results of this study show that the demand for electricity is inelastic, with a weighted average regional elasticity of -0.49 in the short-run and -0.81 in the long run. This inelastic demand implies that growers will not, or are unable to, reduce electricity load proportionately when electricity price goes up or to increase load in proportional response to an electricity price discount. The inelastic nature of demand, together with the fixed nature of commodity prices received by producers, means that future rate increases will likely reduce profits or increase losses of irrigators.

This inelastic characteristic also implies that future rate increases should increase revenues to BPA and irrigation utilities, but rate discounts probably will not generate sufficient increase in load response to generate enough revenue to cover the rate discount. A range of irrigation electricity price elasticities based on different quantitative methods, model specifications, time periods, and constraints has been estimated for this study. Both short-run and long-run elasticities have been developed. Based on the results, the authors conclude that the demand for electricity by irrigated agriculture in the Pacific Northwest is inelastic in both the short- and long-run. Therefore, irrigation rate discounts should not be expected to return sufficient increase revenues to cover the cost of the discount. This conclusion is true at both the wholesale and retail level. The 1986, 1987 and 1988 estimated net costs of the irrigation discount to BPA was $9.7 million, $10.4 million and $ 12.9 million. The income savings to growers was $6.5 million, $7.0 million, and $8.5 million, respectively.

The situation and outlook for Pacific Northwest irrigated agriculture over the next two to three years is for a slight improvement in the farm economy. There should not be any major economic changes that would modify the estimated electricity price elasticities. If the farm economy softens, price elasticities may become more elastic. If the economy continues to improve, the electricity price elasticities may become more inelastic as electricity cost has a smaller share of total production costs and farm profits. In either case, the range would probably not be more than ± 0.10 or 0.20 different from the reported results.

The quantification of irrigation load response to electricity rates in the BPA service area was complex. Sprinkler irrigated agriculture is not a homogeneous industry. It is composed of many diverse farming operations growing different crops with different irrigation systems under different climatic and growing conditions. In addition, the retail utilities serving these irrigators all have unique load, rate, and operations characteristics. When evaluating the issues and merits of targeting electricity rate discounts, it is important to recognize the diversity of irrigated agriculture and the complexity of the potential response of retail utilities and irrigators to wholesale irrigation rates. This diversity of irrigated agriculture and irrigation utilities makes targeting electricity rate discounts to specific irrigators and utilities difficult.

This study has identified a series of economic, administrative, and legal issues that may be considered in an evaluation of targeted wholesale irrigation rate discounts for selected groups of utilities and irrigators. Given limited data and issues studied, the current irrigation discount may be more equitable to irrigators and more administratively efficient than a targeted discount. There is a general customer satisfaction among irrigators and irrigation utilities with the current irrigation discounts.

As BPA considers and evaluates future irrigator rate designs and discounts, unique characteristics of irrigated agriculture should be considered:

- Irrigated agriculture is an important and significant economic base for rural communities and utilities.

- Farmers can not pass on electricity rate increases to consumers. Farmers sell their crops in markets where prices are set by national and world supply and demand.

- Because irrigators cannot influence their crop prices, and the demand for electricity is inelastic, most electricity rate increases come out of farmers' profits or contribute to greater losses.

Irrigation discounts will not pay for themselves in the short run and probably will not generate sufficient additional revenues in the long run to cover the yearly discount costs. One important issue faced by BPA is whether or not the benefit to irrigators and the regional economy of the irrigation discount offset the net revenue loss and the concerns of nonirrigation utilities and customers. This study shows that the income to irrigators from the irrigation discounts and those indirectly associated with irrigated agriculture would be about equal to the loss of income to nonirrigators, if this group has to pay for the irrigation discount through increased rates.

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