PRAM

PLATTE RIVER AGRICULTURAL MODEL

MODEL DOCUMENTATION

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INTRODUCTION

The Platte River Agricultural Model (PRAM) is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers (farmers) in the Platte River Basin of Colorado, Wyoming, and Nebraska. The PRAM model is a mathematical programming model written in a programming language called GAMS (Generalized Algebraic Modeling System). The benefits of using a programming language such as GAMS include the ability to compactly represent large, complex models. Changes to the specified model can be addressed quickly and easily through the use of algebraic relationships. Additionally, the model can be thoroughly documented within the model code, which lends itself to keeping the model documentation current and increasing the portability of the model to other users. The end result of the internal documentation is a more understandable, verifiable, and hence, more credible model.

This technical appendix describes the version of PRAM developed to analyze impacts identified in the Platte River Environmental Impact Statement.

PRAM MODEL

The PRAM model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers buy and sell in competitive markets, and no one farmer can affect or control the price of any commodity. To obtain a market solution, the model's objective function maximizes the sum of producers' surplus (net income) subject to the following relationships and restrictions:

Linear, increasing marginal cost functions estimated using the technique of positive mathematical programming. These functions incorporate acreage response elasticities that relate changes in crop acreage to changes in expected returns and other information; and

A variety of constraints involving land and water availability.

The model selects those crops that maximize profit subject to these constraints. Profit is calculated as revenue minus costs. From 1 above, cost per acre increases as production increases. Revenue is calculated as harvested acres times crop yield per acre times crop price. Component 2 is used to analyze the impacts of operational or management provisions that change water availability.

PRAM IMPACT REGIONS

In order to identify the economic effects of potential activities carried out under the Platte River Cooperative Agreement, eight separate economic impact regions were defined. The purpose of breaking the entire Platte River Basin into smaller regions was to identify and locate, as accurately as possible, where various economic impacts would occur. A number of factors were used to determine each economic impact region, including agricultural production areas and practices, location of recreation sites and activities, origin and final use of water supplies, location and size of cities or industrial markets, highways or other transportation routes, and availability of appropriate economic data, to name a few.

The smallest geographic area for which agricultural economic and land use data was consistently available was the county level. The Platte River Basin covers all or some portion of approximately 60 different counties located in Colorado, Nebraska, and Wyoming. Of the total, 48 counties were determined to essentially contain all of the possible economic impacts that might result from any potential Program action occurring within the entire Platte River Basin. Agricultural economics and land use data were collected for 18 counties in Colorado, 22 counties in Nebraska, and 8 counties in Wyoming. Figure 1 indicates the geographic location of the impact regions and Table 1 identifies the counties included in each region.

Figure 1. Map of PRAM Regions.

Economic Region	Counties Included
Central Platte Habitat Area	Adams, Buffalo, Dawson, Gosper, Hall, Hamilton, Kearney, Merrick, and Phelps in Nebraska.
Lake McConaughy Area	Arthur, Cheyenne, Custer, Deuel, Garden, Keith, Lincoln, and Mcpherson in Nebraska. Logan and Sedgwick in Colorado.
Scott’s Bluff Area	Banner, Kimball, Morrill, Scotts Bluff, and Sioux in Nebraska. Goshen in Wyoming.
Eastern Wyoming	Albany, Laramie, and Platte in Wyoming.
North Platte Headwaters	Carbon, Converse, Fremont, and Natrona in Wyoming. Jackson in Colorado.
East Central Colorado	Larimer, Morgan, Washington, and Weld in Colorado.
South Platte Headwaters	Clear Creek, Gilpin, Park, and Teller in Colorado.
Denver Metro	Adams, Arapahoe, Boulder, Denver, Douglas, Elbert, and Jefferson in Colorado.

SOURCES OF INFORMATION

Agricultural economics and land-use data from 1972 to 1996 were collected to develop an historical perspective and to describe recent trends and conditions in agricultural production and land use. The primary data sources for the discussions are:

- National Agricultural Statistics Service (NASS). Surveys and reports covering virtually every facet of U.S. agriculture -- production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm aspects of the industry. More specifically, NASS's State Statistical Offices (SSO's) in Colorado, Nebraska, and Wyoming provided additional data as indicated below.

- State Agricultural Statistical Reports -- Colorado, Nebraska, and Wyoming. Detailed data on harvested acreage, yield, and value of production for the principal crops produced in each county were obtained from these annual reports for the period from 1977 to 1997. Original data published in these reports were collected from county records and visual surveys. The reports record all harvested acreage (irrigated and dry land) by county and state.

- U.S. Department of Commerce Census of Agriculture. These agricultural census reports provide information by county. The data include the number and size of farms, extent of farmlands, cropland acreage, irrigated acreage, types of farm ownership, market value of production, production expenses, and acreage of principal crops. The Census of Agriculture is a legally required report that is sent to each farmer in an area.

- Cooperative Extension Service (CES) Crop Budgets. The CES of Colorado State University, University of Nebraska, and University of Wyoming has developed budgets for representative crops in many counties and regions in Colorado, Nebraska, and Wyoming, respectively. These budgets can be used by farmers as guides for making production decisions and determining potential returns. The budgets are based on typical production practices for the area and are detailed and documented.

CROP DATA

Data for eleven different irrigated crops were collected and incorporated into the model. The specific crops analyzed by the model were alfalfa, other hay, barley, corn for grain, corn silage, dry beans, potatoes, sorghum, soybeans, sugar beets, and wheat. Specific data collected for each crop included acres harvested, yield, price, and production costs.

Cropping Patterns and Yields

The cropping pattern is the share of acres within a region planted to individual crops. Table 2 summarizes the 10-year average acreage of irrigated crops harvested between 1988 and 1997 by crop categories for the eight economic regions.

There is considerable variation in cropping pattern and associated gross production value among the regions. On the basis of crop acreage, corn is the major crop in four of the regions. Alfalfa and other hay are important in all of the impact regions in the Platte River Basin. Potatoes are important in the East Central Colorado region, while soybeans are a major crop in the Central Platte Habitat area. Dry beans are important in the Scotts Bluff, McConaughy, and East Central Colorado regions. Sugar beets are found in all but two regions, with the majority of the acreage found in the Scotts Bluff and East Central Colorado regions.

Table 2. Harvested Acreage of Irrigated Crops, by Impact Region, 10-year Average (1988-1997)

Impact Region	Alfalfa	All Other Hay	Barley	Corn for Grain	Corn Silage	Dry Beans	Potatoes	Sorghum	Soybeans	Sugarbeets	Wheat	Region Totals
Central Platte Habitat	50,580			1,481,020	22,630			13,190	138,990			1,706,410
Lake McConaughy	102,560	5,760		480,470	23,820	39,770			17,110	7,860	23,680	701,030
Scotts Bluff	92,790	11,300		172,490	17,900	91,920				56,280	11,810	454,490
Eastern Wyoming	51,420	86,250	3,370	8,870	8,430	6,940				4,540	6,760	176,580
North Platte Headwaters	117,770	186,780	11,190	1,890	6,590	2,700						326,920
East Central Colorado	121,450	22,100	18,350	254,730	60,640	51,150	5,120			35,550	17,940	587,030
South Platte Headwaters		8,460										8,460
Denver Metro	34,900	13,010	2,810	16,790	3,980	2,660				1,930	4,170	80,250
Crop Totals	571,470	333,660	35,720	2,416,260	143,990	194,140	5,120	13,190	156100	106,160	64,360	

Source: Colorado, Nebraska, and Wyoming Agricultural Statistics.

All other hay is the only crop grown in the South Platte Headwaters region. It should be recognized that in all regions, pasture, hay and alfalfa are often marketed through livestock production. The complementary relationship between forage production and livestock enhances the actual return. However, livestock production was not included in the PRAM model.

Crop yields were obtained from the annual State Agricultural Statistical Reports published by Colorado, Nebraska, and Wyoming. Weighted-average yields by crop and region are shown in Table 3.

Table 3. Weighted Average Crop Yields, by Impact Region (1988-1997).

Impact Region	Alfalfa	All Other Hay	Barley	Corn for Grain	Corn Silage	Dry Beans	Potatoes	Sorghum	Soybeans	Sugarbeets	Wheat
Yield Unit	ton	ton	bu.	bu.	ton	cwt.	cwt.	bu.	bu.	ton	bu.
Central Platte Habitat	4.61			148.68	18.55			92.48	47.09		
Lake McConaughy	4.50	2.16		141.69	18.55	17.37			42.44	19.41	51.33
Scotts Bluff	4.30	1.65		123.24	18.76	19.20				19.12	52.81
Eastern Wyoming	3.40	1.35	67.34	103.40	15.99	18.85				17.59	58.47
North Platte Headwaters	2.88	1.40	79.77	98.16	17.31	19.43					
East Central Colorado	4.97	2.25	83.30	149.17	23.11	20.50	302.33			22.08	59.14
South Platte Headwaters		1.32									
Denver Metro	4.16	2.18	72.18	136.62	19.90	18.76				21.10	56.19

Crop Prices Received

Prices received for crops were obtained from the Departments of Agriculture in Colorado, Nebraska, and Wyoming. Reported prices are averages of the marketing year average prices over 19~~88~~92-97. The different state-level prices are weighted by the number of acres included in a PRAM region that come from the respective states. Table 4 shows the prices received used in the PRAM model.

Crop Production Costs

Production costs are based primarily on budgets prepared by the Extension Service (various years). Variable crop production cost data appear in Table 5.

Table 4. State-Level, Marketing Year Crop Prices, Average for 1992-97.

		State Average Price Received		
Crop	Yield Units	Clorado	Nebraska	Wyoming
Alfalfa	Ton	85.23	62.24	75.97
Other Hay	Ton	81.75	62.24	70.37
Barley	Bushel	2.97	1.97	3.18
Corn – grain	Bushel	2.56	2.47	2.66
Corn – silage	Ton	21.61		
Dry Beans	CWT	21.40	20.93	20.83
Potatoes	CWT	4.90		
Soybeans	Bushel	0.00	6.08	
Sugar Beets	Ton	39.51	38.96	41.42
Wheat	Bushel	3.49	3.46	3.46

Source: Colorado, Nebraska, and Wyoming Agricultural Statistics

Crop production cost information was obtained from the Cooperative Extension Service county crop budgets. This information was then compiled on a crop by crop basis. The costs reflect typical growing conditions and typically sized farms for each crop but do not necessarily represent average conditions in a statistical sense. This cost information was then compiled with price, yield, water use, and irrigation cost data to reflect net returns to water.

Four different sets of crop enterprise budgets were used to estimate typical crop production costs for the various economic impact regions. Both Colorado and Nebraska prepare enterprise budgets for every agricultural production region in the entire state on a periodic basis. Colorado cost data used in the model was prepared in 1995, while Nebraska data was prepared in 1996. Wyoming publishes enterprise budgets for different production regions at differing times. There are two different agriculture production regions in Wyoming which lie within the Platte River Basin, the Wheatland area and the Riverton area. The most recent year for which cost information is available for the Wheatland area is 1992, while the most recent year for which Riverton data has been published is 1994. Unfortunately, this means that available cost data is not consistent throughout the area of analysis.

Table 5. Variable Crop Production Cost Estimates for Surface Irrigation, by Crop, Dollars per Acre.

Crop	Central Platte Habitat	Lake McConaughy	Scotts Bluff	Eastern Wyoming	North Platte Headwaters	East Central Colorado	South Platte Headwaters	Denver Metro
Alfalfa	176.85	130.85	142.85	63.83	73.25	150.6		119.18
OthHay		68.36	52.26	42.74	44.18	71.01	41.68	68.75
Barley					125.9	92.47		80.12
Corngrn	187.33	170.33	161.66	211.96	121.23	195.75		180.11
Cornslg	217.46	187.98	195.75	192.98	189.75	194.33		167.37
Beans		116.85	165.01	229.92	157.55	183.49		170.39
Potato						544.19		
Sorghum	100.80							
Soybean	97.00	87.19						
SgrBeet		611.88	417.43	434.97		812.38		776.65
Wheat		67.66	79.75	88.3		55		52.25

One way to bring production costs to a consistent level is to index them to a common year. However, methodological and philosophical differences between the states in their approach to preparing and publishing enterprise budgets are more likely to cause significant differences in cost estimates than would occur as a result of using costs from a number of different time periods. Therefore, based on past experience with enterprise budget data, the differences in cost level was addressed by averaging the prices received for each crop over a period of time which encompassed the different years for which costs were estimated (1992-1997).

INTERACTIONS WITH OTHER MODELS

Hydrology Links

Irrigation Water Deliveries

Deliveries of irrigation water to each of the economic impact regions are based on the 48-year hydrologic period from 1947 to 1994. Three different hydrology models were used to estimate irrigation deliveries within the Platte River Basin. Assumptions and methodologies pertinent to each model are described in the Hydrology Appendix. The three hydrology models are the North Platte River EIS model, the Central Platte Opstudy model, and the South Platte River EIS model.

Data from the North Platte River EIS model was used to estimate irrigation deliveries in the Scotts Bluff, Eastern Wyoming, North Platte Headwaters, and Lake McConaughy economic regions. Specifically, any project or any water leasing above Glendo Reservoir is included in the North Platte Headwaters economic region. This includes the Kendrick Project, the La Prele Irrigation district, and water leasing above Pathfinder Reservoir. The Eastern Wyoming economic region is basically the Laramie River basin and includes water leasing in the Laramie River Basin. The Scotts Bluff economic region includes all other deliveries, except the Lisco and Midland-Overland canals, modeled by the North Platte River EIS model. This includes the North Platte Project, the Glendo Unit, and non-project diversions in Nebraska. The Lisco and Midland-Overland canals are included in the Lake McConaughy economic region.

With the exception of the water leased in the Laramie River Basin, the data provided by the North Platte EIS model is the delivery to the diversion structure that removes water from the North Platte River. Therefore, conveyance losses and on-farm efficiencies are needed to determine the changes in crop consumptive use. The water leased in the Laramie River Basin reported by the North Platte EIS model is the change in consumptive use.

Data from the South Platte River EIS model was used to estimate irrigation deliveries in the Eastern Colorado and Lake McConaughy economic regions. Water leased from Boyd, Fossil, Riverside, Empire, Jackson, & 10% of Prewitt reservoirs are included in the Eastern Colorado economic region. Water leased from Julesburg, North Sterling, & 90% of Prewitt reservoirs is included in the Lake McConaughy economic region. Conveyance losses and on-farm efficiencies are included in the South Platte River EIS model and all delivery data provided by the model is the change in consumptive use.

Data from the Central Platte Opstudy model was used to estimate irrigation deliveries in the Lake McConaughy and Central Platte Habitat economic regions. Deliveries from the North Platte River below Lake McConaughy and from the South Platte River in Nebraska are included in the Lake McConaughy economic region. This includes the Western, Keith-Lincoln, Paxton-Hershey, Cody-Dillon, North Platte, and Suburban canals. The remaining diversions in the Central Platte Opstudy model are included in the Central Platte Habitat economic region. This includes the Gothenburg, Cozad, Dawson County, Six Mile, Thirty Mile, Orchard-Alfalfa, Kearney, and Tri-County canals. All delivery data provided by the Central Platte Opstudy model is the change in consumptive use.

Annual deliveries of irrigation water from facilities in the Platte River Basin were averaged over the 48-year period of record (1947-1994) and used as the present condition baseline for deliveries of irrigation water.

The estimated amount of irrigation water delivered to crops modeled in each of the impact regions is presented in Table 6. The derivation of the values shown in Table 6 is explained below.

Table 6. Annual Irrigation Consumptive Use Modeled by Impact Region, 48-Year Average, 1947-1994.

Impact Region	**Irrigation Consumptive Use (ac-ft)**
Central Platte Habitat Area	391,500
Lake McConaughy Area	140,800
Scotts Bluff Area	438,500
Eastern Wyoming	143,400
North Platte Headwaters	225,200
East Central Colorado	1,065,700
South Platte Headwaters	8,100
Denver Metro	151,900

The North Platte River EIS hydrology model estimates water deliveries at the point of diversion from the North Platte River into the main irrigation delivery canal. However, the South Platte River EIS hydrology model and the Central Platte Opstudy hydrology model both estimate the amount of water actually used by the crop, or consumptive use. Since the agricultural impact model requires farm level, or consumptive use data, the North Platte River EIS hydrology model requires additional adjustments in the water delivery output. These adjustments include an average, county-level conveyance loss obtained from the USGS[1] and an average on-farm application efficiency. The imposition of the conveyance loss factor, in effect, derives the amount of water arriving at the farm head gate. The on-farm application efficiency factor is necessary to derive the residual amount of irrigation water actually used by the plant.

The output of the three hydrology models is displayed in Table 7 below. Since the North Platte model is based on diversions from the river to the main delivery canal, the data adjustments required for the Scotts Bluff, Eastern Wyoming, and North Platte Headwaters economic regions are explained below.

Table 7. Average Acre-Foot Irrigation Water Diversions to Canal Headgate by Economic Impact Region and EIS Alternative for Years 1947-98. (1,000 acre-feet)

	Central Platte Habitat	Lake McConaughy	Scotts Bluff	Eastern Wyoming	North Platte Headwaters	East Central Colorado	South Platte Headwaters	Denver Metro
Present Condition	391.50	140.78	1,414.59	276.39	517.17	1,065.75	8.09	151.93
Water Emphasis	364.50	119.53	1,382.46	276.39	502.37	1,055.95	8.09	151.93
Water Leasing	337.60	110.76	1,284.87	276.39	499.77	1,051.95	8.09	151.93
Wet Meadow	391.50	140.92	1,409.18	276.39	511.97	1,065.75	8.09	151.93
Governance Committee	375.60	140.92	1,414.18	273.49	500.47	1,065.75	8.09	151.93

Adjustments to Hydrology Model Output

Weighted average conveyance loss factors are applied to the canal headgate diversions to calculate the amount of water delivered to the farm headgate. The weighted average conveyance losses for each economic impact region are: Central Platte Habitat (25 percent), Lake McConaughy (23 percent), Scotts Bluff (52 percent), Eastern Wyoming (20 percent), North Platte Headwaters (34 percent), East Central Colorado (27 percent), South Platte Headwaters (38 percent) and Denver Metro (27 percent). Even though a conveyance loss factor is calculated for each region, only three regions (Scotts Bluff, Eastern Wyoming, and North Platte Headwaters) require an adjustment to be made. Where an adjustment is required, the average diversions to the canal headgate are multiplied by these percentages to derive the associated conveyance losses for each economic impact region. Diversions minus conveyance losses equal deliveries to the farm headgate, shown in Table 8 below.

Table 8. Average Acre-Fot Irrigation Water Deliveries to the Farm Headgate, by Economic Impact Region (1,000 acre-feet)

	Central Platte Habitat	Lake McConaughy	Scotts Bluff	Eastern Wyoming	North Platte Headwaters	East Central Colorado	South Platte Headwaters	Denver Metro
Present Condition	391.50	140.78	674.64	220.62	346.52	1,065.75	8.09	151.93
Water Emphasis	364.51	119.53	659.32	220.62	336.61	1,055.95	8.09	151.93
Water Leasing	337.63	110.76	612.78	220.62	334.87	1,051.95	8.09	151.93
Wet Meadow	391.50	140.92	672.06	220.62	343.04	1,065.75	8.09	151.93
Governance Committee	375.57	140.92	674.44	218.31	335.33	1,065.75	8.09	151.93

After deriving the farm headgate deliveries, the irrigation water supply is further modified to reflect how much water is available to the growing plant for consumptive use. This modification is made by simply multiplying the farm headgate delivery by the on-farm application efficiency factor. An average application efficiency of 65 percent was selected and applied to the farm headgate deliveries in the three identified regions. Table 9 shows the derived irrigation water available for consumptive use by the plant, which is on a comparable basis with published evapotranspiration rates.

Table 9. Average Acre-Foot Irrigation Water Supply Available for Consumptive Use by Irrigated Crops (1,000 acre-feet).

	Central Platte Habitat	Lake McConaughy	Scotts Bluff	Eastern Wyoming	North Platte Headwaters	East Central Colorado	South Platte Headwaters	Denver Metro
Present Condition	391.50	140.78	438.52	143.40	225.24	1,065.75	8.09	151.93
Water Emphasis	364.51	119.53	428.56	143.40	218.80	1,055.95	8.09	151.93
Water Leasing	337.63	110.76	498.30	143.40	217.66	1,051.95	8.09	151.93
Wet Meadow	391.50	140.92	436.84	143.40	222.98	1,065.75	8.09	151.93
Governance Committee	375.57	140.92	438.39	141.90	217.97	1,065.75	8.09	151.93

The average change in consumptive use of irrigation water within each impact region is calculated by subtracting the average water delivery for a selected alternative from the Present Condition. For example, if the change in water deliveries for the Program Water Alternative is compared to the Present Condition for the Habitat Region, there are 27,000 fewer acre-feet of water (391,500 af - 364,500 af = 27,000 af) available to be consumed by irrigated crops. This equates to a 6.9 percent reduction in irrigation water diversions.

Balancing Irrigation Water Demands and Supplies

The following assumptions were made and imposed on the PRAM Model. Since data was not available to delineate irrigation water supplies by source for all of the included regions, PRAM calculated total irrigation water demands based on crop irrigation requirements and total crop acreage in each region. Next, the calculated water demand is assumed to be equal to the total irrigation water supply, irrespective of water source. The underlying logic of this assumption is that in order for the crops to be grown and harvested, the total amount of water demanded is available for irrigation, either from surface water or groundwater sources.

After determining the irrigation demand for all crops in all regions and adding them together to derive the total irrigation demand (ergo, the total required water supply) for each region, the calculated changes to average water deliveries from the hydrology model were imposed. For example, the total irrigation water requirement for the Habitat Region was 2,299,700 acre feet. Of this amount, the hydrology model identified irrigation deliveries of 391,500 acre feet under present conditions. The balance of the water supply equals 1,908,200 acre-feet (2,299,700af - 391,500af) and is assumed to come from other existing sources such as groundwater pumping or natural flow rights.

When going from the present condition to say, the Water Emphasis Alternative, a comparison of the available water supply is necessary. Under Present Conditions, irrigation deliveries identified by the hydrology model came to 391,500 acre-feet. Under the Water Emphasis Alternative, irrigation deliveries decrease to 364,510 acre-feet, a reduction of 26,990 acre-feet. This 26,990 acre-foot reduction in water deliveries in turn reduces total water supplies from 2,299,700 acre-feet to 2,272,710 acre-feet. Then, PRAM solves for the optimal distribution of the 2,272,710 acre-feet of irrigation water amongst the crops grown in the region. This process is followed for all PRAM regions and all alternatives. In each case, the optimal distribution of remaining water for each region is calculated simultaneously and reported as the agricultural impact due to a change in water supply. PRAM reports details about changes in acres produced, cropping patterns, and subsequent changes in total net farm income.

Regional Economic Model Links

PRAM estimates changes to the irrigated agriculture sector when changes to water deliveries are imposed. Additionally, PRAM provides information about crop acres, cropping patterns, and gross revenues to IMPLAN. IMPLAN is a regional economic impact model that follows the economic impacts originating at the farm level as they ripple through the rest of the local economy. Defining a link between the agriculture impact model, PRAM, and the regional impact model, IMPLAN, yields a beneficial relationship for a more complete analysis of agricultural sector impacts.

PRAM estimates impacts to crop production; this is considered the direct impact and is an on-farm affect brought about by changes to available water deliveries. After the direct impacts are estimated for irrigated production agriculture, IMPLAN is used to calculate indirect and induced effects. Indirect effects are defined as the changes in inter-industry purchases by industries directly affected by changes in irrigated regional agricultural crop production. For example, this includes fertilizer dealers, implement dealers, agricultural chemical distributors, and custom operators. Induced effects are the result of changes in spending by employees of industries directly and indirectly affected by changes in regional agricultural crop production.

Crop Aggregation

The PRAM model reports output for each commodity or individual crop such as barley, wheat, corn, etc. Each commodity output, as measured by PRAM, is aggregated into separate industries or sectors used by IMPLAN. Table 10 shows the aggregation scheme linking the commodities in PRAM with their respective industries in IMPLAN.

Table 10. Commodity to Industry Links Used for Exporting PRAM Data to IMPLAN.

IMPLAN INDUSTRY	COMMODITY NAME
Forage	Alfalfa hay, All Other Hay, Corn Silage
Feed Grains	Barley, Corn grain, Sorghum
Food Grains	Wheat
Vegetables	Dry Beans, Potatoes
Oil Crops	Soybeans
Sugar Crops	Sugar Beets

The output from PRAM that is used by IMPLAN includes total acreage and gross value of production by IMPLAN industry. Total acres by IMPLAN sector is simply the sum of all acres for each crop included in an IMPLAN industry for a selected region. Gross value of production is the sum of each commodities' price times yield times acres harvested. For an IMPLAN industry such as Food Grains, the gross value is the price of wheat times the yield for wheat times the number of acres of wheat produced. For the Food Grains industry, the gross values for barley, corn grain, and sorghum are added together, as are the number of acres of each crop produced.

TECHNICAL DESCRIPTION OF PRAM

Traditional optimization models such as linear programming rely on data based on observed average conditions (e.g., average production costs, yields, and prices), which are expressed as fixed coefficients. As a result, these models tend to select crops with the highest average returns until resources (land, water, capital) are exhausted. The predicted crop mix is therefore less diverse than we observe in reality. The most widespread reason for diversity of crop mix is the underlying diversity in growing conditions and market conditions. Simply put, any crop-producing region includes a broad range of production conditions. All farms and plots of land do not produce under the same, average set of conditions; therefore, the marginal cost and revenue curves do not coincide with average cost and revenue curves.

Economic theory suggests that economic decisions are based on marginal (incremental) conditions, and that these differ from the average conditions. Positive Mathematical Programming (PMP) is a technique developed to incorporate both marginal and average conditions into an optimization model (Howitt 1995). In the conventional case of diminishing economic returns, productivity declines as output increases. Therefore, the marginal cost of producing another unit of crop increases as production increases and the marginal cost exceeds the average cost. The PMP technique uses this idea to reproduce the variety of crops observed in the data.

The PMP approach used in PRAM uses empirical information on acreage responses and shadow prices—implicit prices of resources—based on standard linear programming techniques and a calibration period data set. The acreage response coefficients and shadow prices are used to calculate parameters of a quadratic cost function that is consistent with economic theory. The calibrated model will then predict exactly the original calibration data set, and can be used to predict impacts of specified policy changes such as changes in water supplies.

Calibration consists of calculating the coefficients for the quadratic cost function using PMP. The derivation of these parameters guarantees that the model will duplicate the calibration period crop acreage if no other data are changed. In addition, the calibration parameters for crop acres are calculated so net revenue in the calibration period equals the observed net revenue for that period. In other words, the acreage calibration parameters change the marginal costs but not the average or total costs in the calibration period. The other piece of information used to calculate the calibration parameters is the acreage response elasticity, described below.

Positive Mathematical Programming and Model Calibration

PMP is a technique developed to incorporate both marginal and average conditions into a regional optimization model (Howitt, 1995). Traditional regional models have relied on data based on observed average conditions (e.g., average production costs, yields, and prices). According to economic theory, the short- or long-run equilibrium level of activities is determined by marginal conditions. PMP is a technique whereby information on the marginal value of resources (derived from shadow prices) is used to augment the average cost/revenue information and calibrate a regional model to a baseline condition. This allows the model to predict a more diverse set of activities than would be possible with a simple linear framework.

A number of economic or market conditions can influence the marginal tradeoffs among crops and therefore the observed crop mix; a) Risk considerations—crop diversification is a known strategy for reducing downside risk; b) Crop rotations can improve yields or reduce costs; c) Marketing/processing constraints; d) Government farm programs may encourage some crops and limit production of others; e) Other resource constraints—restrictions on water, labor, or capital can force a crop mix that does not appear to be the most profitable.

Regional models can accommodate all of these constraints in various ways. Perhaps the most widespread reason for crop diversity is the underlying diversity in growing conditions and market conditions. All farms and plots of land do not produce the same, average set of conditions, and therefore the marginal cost and revenue curves do not coincide with the average cost and revenue curves. A linear programming model based on average costs and returns does not capture this. PMP uses information about the average and the marginal conditions to generate appropriate marginal cost and/or revenue functions that can predict the observed diversity of activities.

To illustrate, consider a two-crop (wheat and potato) regional production model. Let the average observed net return to wheat be $50 per acre (as estimated from county-wide yields and prices and estimated production cost budgets), and let the average net return to potatoes be $135 per acre. With 100 acres of land available, a simple linear programming model would obviously allocate all 100 acres to potatoes and none to wheat, based on the average costs and returns. In fact, however, we observe that 40 acres are growing wheat and 60 are growing potatoes. In the absence of externalities or other market-distorting considerations, economic theory requires that the equilibrium condition allow the same net return, at the margin, to either crop. Otherwise total net return could be increased by shifting an acre to the crop yielding the greater net return. In order to create a condition of marginal equality, PMP augments the linear total cost (or revenue) function with quadratic terms that guarantee the marginal equality conditions will hold at the observed crop mix. For the example above, a difference of $85 per acre between marginal and average net return to potatoes would explain the apparent suboptimal solution observed. A simple PMP model could add a linear marginal cost of production to potatoes such that, at the observed acreage, the average net return to potatoes is $135 but the marginal net return is only $85.

Because the marginal cost is rising, additional potato acreage beyond its observed level would be less profitable than wheat acreage, while potato acreage below the observed level would be more profitable than wheat acreage. Under this structure, predicted potato and wheat acreage would exactly match the observed values. This simple example can be generalized mathematically. The objective of the standard programming approach is to maximize net revenue, defined as:

$$NR = \left(p_y Y - AC\right) X \qquad (1)$$

where p is a vector of prices per unit, y is a vector of yield in units per acre, AC is a vector of average production costs per acre, and X is a vector of acres. This expresses net revenue (NR) in terms of average revenues and costs. PMP augments this linear specification with a nonlinear function of acreage by crop, f(X):

$$NR = \left(p_y Y - AC\right) X + f\left(x\right) \qquad (2)$$

The nonlinear function is quadratic in the case of PRAM. Calculated properly, the augmented, nonlinear objective function can produce the same level of NR as the linear function at the baseline acreage, but can create marginal conditions that also satisfy the profit-maximizing first order conditions at the baseline acreage.

The PMP procedure is mathematically equivalent to adding a nonlinear adjustment cost function onto the linear NR specification, although the rationale and interpretation are quite different. The variability in marginal NR embodied in the PMP function can represent variation in production cost, variation in yield, variation in crop quality (which affects the crop price), or a combination of all three. In PRAM, these possibilities can be classified into production cost effects. For example, let a, b, and c be parameters of a quadratic cost function. Assuming farmers use the land best suited to a given crop first and expand to less suitable land as total production increases, then marginal revenue declines and/or marginal cost increases as X increases, so:

$$c >= 0$$

Total cost becomes:

$$TC = (AC)X + \left(\alpha + \beta X + .5\gamma X^2\right) \tag{3}$$

Then

$$NR = p_y Y - (AC)X + \left(\alpha + \beta X + .5\gamma X^2\right) \tag{4}$$

For this example, it is assumed that all variables are scalars. Marginal net revenue can be broken into average net revenue (which is constant with respect to acreage) and the components of the marginal cost functions (which exhibit declining marginal net revenue).

$$MNR = p_y Y - AC - \left[\beta + \gamma X\right] \tag{5}$$

PRAM assumes that the marginal function represents increasing marginal production cost. This assumption affects how the PMP parameters are estimated. The next section derives the approach used for estimating the PMP parameters.

Acreage Response Elasticities and PMP Coefficients

Acreage response elasticities show how farmers change their planted acreage in response to changes in expected price, revenue, or profit. Acreage response elasticity is defined here as the percent change in acreage of a crop due to a percent change in expected revenue per acre. PRAM incorporates acreage response elasticities directly within the linear marginal cost functions as part of the PMP calculations. The shadow prices calculated as part of the PMP procedure indicate the deviation between marginal and average cost, but they do not provide information on the slope of the marginal cost function, which is the role of the acreage response elasticity.

The following describes how the acreage response elasticities and the crop shadow values are used to create the marginal cost functions in PRAM. The example in the section above showed how a point estimate of the difference between marginal and average conditions can be used to calibrate a model to observed crop mix. Essentially the calibration condition provides one point on the marginal cost function. Additional assumptions or information are needed to determine the slope of the marginal cost function. PRAM addresses this need by incorporating acreage response elasticities directly in the linear marginal cost functions. Acreage elasticity is defined as the percent change in acreage of a crop due to a percent change in expected revenue. Basically, this is an acreage supply elasticity with per-acre revenue acting as the unit price received for an acre of production. Because PRAM will be used primarily to assess long-tern, permanent changes in water supply and prices, long-run supply elasticities are employed, However, the following derivation can be used with either long-run or short-run elasticities. The total cost of production in the PRAM objective function includes both an observed average cost per acre derived from cost-of-production analyses (denoted AC), and a quadratic component in acreage. The total cost for all k crops is:

$$TC = \sum_k \left[AC_k X_k + \left(\alpha + \beta_k X_k + .5\gamma_k X_k^2 \right) \right] \qquad (6)$$

where AC is observable production costs per acre, X is crop acres, and α, βand γ are parameters of the imputed cost function. Then marginal cost for each crop is:

$$MC_k = AC_k + \beta_k + \gamma_k X_k \qquad (7)$$

Set MC_k = marginal revenue, $p_k Y_k$ where Y_k is crop yield and solve for acres

$$X_k = \frac{\left(p_k Y_k - AC_k - \beta_k\right)}{\gamma_k} \quad (8)$$

Then

$$\frac{\partial X_k}{\partial p_k Y_k} = \frac{1}{\gamma_k} \quad (9)$$

thus the acreage elasticity for the kth crop is

$$\varepsilon_k = \left(\frac{1}{\gamma_k}\right)\left(\frac{p_k Y_k}{X_k}\right) \quad (10)$$

when evaluated at observed X_k, p_k, and Y_k

This shows the relationship between elasticity and γ, which combines with the other conditions needed for calibration to define the quadratic PMP function. The conditions described below must hold at the observed acreage for each crop:

1. The exogenously determined acreage supply elasticity determines the slope of the MC function, as derived above: $\gamma_k = (1 / e_k) (p_k Y_k / X_k)$.

2. In order to calibrate to observed acreage by crop, the marginal cost of an acre of production must equal the observed portion (AC) plus the unobserved portion, indicated by the shadow price from the calibration model (λ). The shadow price represents the deviation between average and marginal cost. Therefore, using the derivation of MC above: In order to calibrate to observed production cost and net revenue, the unobserved portion of total cost must equal zero at the observed acreage. Therefore using the total cost notation above:

$$MC_k = AC_k + \lambda_k \text{ implies } \beta_k = \lambda_k - \frac{p_k Y_k}{\varepsilon_k} \quad (11)$$

3. In order to calibrate to observed production cost and net revenue, the unobserved portion of total cost must equal zero at the observed acreage. Therefore using the total cost notation above:

$$TC_k = AC_k X_k \text{ implies } \alpha_k + \beta_k X_k + .5\gamma_k X_k^2 = 0, \quad (12)$$

which indicates that

$$\alpha_k = -\left(\lambda_k - \frac{p_k Y_k}{\varepsilon_k}\right) X_k - .5\left(\frac{1}{\varepsilon_k} p_k Y_k\right) X_k^2$$

$$\therefore \alpha_k = \left(\frac{.5 p_k Y_k}{\varepsilon_k - \lambda_k}\right) X_k \qquad (13)$$

These conditions must hold at the level of observed acreage for PRAM to calibrate. Cost function parameters calculated in this way are largely governed by exogenously determined acreage response elasticities, with the shadow price information used to shift the intercept of the marginal and total cost functions so that the model calibrates to a particular set of base conditions.

Calibrating PRAM

The calibration procedure followed by PRAM is fairly easy to implement and consists of first defining and solving a linear programming model based on the 10-year average data previously described.

To illustrate how PRAM was calibrated, let's first return to the two-crop (wheat and potato) production model referred to on page 14 Remember that the average observed net return to wheat and potatoes were $50 and $135, respectively and 100 acres of land were available. Acreage constraints in the model allocated the 100 total acres to 60 acres of potatoes and 40 acres of wheat.

After defining the linear model, a perturbation term is introduced. The purpose of the perturbation term is to force the linear programming model into disequilibrium so that marginal values for the crops are calculated. In practice, this simply means that the limit of the number of acres for each crop are multiplied by a number slightly greater than one (1). This number is arbitrarily chosen by the analyst and is 1.0001 for this example. Meanwhile, the other constraints (total available acreage) remain the same. The linear programming model evaluates the profitability of each crop and increases the number of acres of the higher profitability crops at the expense of the lower-profitability crop.

Using the two-crop example, this means that the total acreage (100 acres) remains constant. However, the limits set for potatoes (60 acres) and wheat (40 acres) are multiplied by 1.0001. The model is in a situation where only 100 acres of land are available for the two crops, but the sum of the limits set for each crop now add to more than 100 acres. We see this by multiplying 60 times 1.0001 = 60.006 and multiplying 40 by 1.0001 = 40.004 and then adding them together, a sum of 100.01.

The model must choose how to satisfy the constraint of only having 100 acres available while maximizing net profits. Potato acreage will increase to 60.006 acres because this is the highest profit-yielding crop. There are only 39.994 acres left for the production of wheat. Now, the linear model yields information that is used in the PMP calculations.

The first bit of information pertains to the marginal value of land, which in this example is $50. If an additional unit of land were available, more crops could be produced. No more potatoes can be grown because they already occupy all the land that the model allows; 60.006 acres. Therefore, if more land becomes available, it will go into wheat production. The marginal value of adding another unit of land is the net profitability of wheat, $50 per acre. This means that if another unit of land is acquired, the overall profitability of this farm can expand by $50.

Another important piece of information indicates the marginal value associated with the cropping pattern constraints (the limits on how many acres of each crop are produced). No more potatoes can be produced because they have reached the upper end of their production limit. This limit on potato production is considered a binding constraint and is calculated as the difference between the net profitability of potatoes and wheat. Potatoes bring in $135 per acre after paying all production costs while wheat brings in $50 per acre. The difference is $85 and this is the marginal value for the potato acreage constraint.

The limit on wheat production is a non-binding constraint because the upper limit has not been reached. The upper limit was set at 40.004 acres but only 39.994 acres were planted. The marginal value of wheat is $0. Wheat, in this example, can be described as the marginal crop in the existing crop mix.

By following this procedure, the linear programming model has identified marginal values for land ($50) and for each of the crop acreage constraints ($85 for potatoes and $0 for wheat). This information is equivalent to the λ referred to in the equations on pages 16-18 of this document and is used to solve for the unknowns in the non-linear equations introduced after the calibration model is complete.

Generalizing this procedure is as easy as adding new crops and/or production regions to the initial linear programming model. The process remains the same. The linear programming model has now completed its tasks necessary to solve the non-linear, PMP model. The linear programming model used linear specifications for the objective function and for each of the constraints. For example, the objective function of the linear programming model simply multiplied price times yield to derive gross revenues per acre and then subtracted variable costs to arrive at an estimate of net income per acre. Net income per acre was multiplied by the number of acres to get total net income for the crops included in each region. This specification for the objective function follows the form shown in equation 1 on page 15

Now, an additional, non-linear term is added to the total cost function that increases the costs of production at the margin. This is depicted in equations 2, 3, and 4. When no limits are placed on the model in terms of a reduced water supply, the non-linear portion of equation 2 and equation 3 equals zero (0) and PRAM returns exactly the 10-year average for crop acreage shown in Table 2. As the available water supply is reduced, the marginal costs begin to increase causing a reduction in crop acreage. This crop acreage reduction, along with its associated change in net income is the reported economic impact to the farm sector.

DRYLAND CROP SUBSTITUTIONS

The default agricultural model estimates impacts to agricultural crop production under the assumption that irrigated lands going out of production become fallow because of the reduction in water supplies. This assumption may result in over-estimating impacts to crop production. To more fully understand the net effects of irrigated land going out of production, the agricultural model was modified to estimate agricultural sector impacts if a portion of previously irrigated lands were to switch to dryland production rather than being fallowed.

To estimate the impacts of previously-irrigated lands switching to dryland production, the model first identifies the number of acres going out of irrigated production. This information comes out of the model's optimization routine. For example, Table 11 shows the base number of acres in irrigated production for the Habitat Region under the Present Condition Alternative. Under the Water Emphasis Alternative, irrigation water supplies were reduced by 26,990 acre-feet, resulting in a loss of 1,872 acres of alfalfa, 16,690 acres of corn, 172 acres of corn silage, 103 acres of sorghum, and a net gain of 72 acres of soybeans.

When irrigated land was allowed to continue producing in a dryland production mode, the model showed no net loss of productive acres, but that 18,765 acres switched to a dryland production with corresponding changes in yields and costs of production.

Table 11. Number of Acres in Production Under Present Conditions and the Number of Acres Lost by Alternative and Crop.

REGION	CROP	Present Condition	Water Emphasis	Water Leasing	Wet Meadow	Governance Committee
Central Platte	Alfalfa	50,580	(1,872)	(3,132)		(1,354)
Habitat Area	Corn Grain	1,481,020	(16,690)	(33,306)		(9,859)
	Corn Silage	22,630	(172)	(399)		(78)
	Sorghum	13,190	(103)	(298)		(22)
	Soybean	138,990	72	(1,127)		565
	TOTAL	1,706,410	(18,765)	(38,262)		(10,749)
Lake McConaughy	Alfalfa	102,560	(5,142)	(6,541)		
Area	Other Hay	5,760	(1,607)	(2,137)		
	Corn Grain	480,470	(4,830)	(7,606)		
	Corn Silage	23,820	(104)	(224)		
	Dry Beans	39,770	120	60		
	Soybean	17,110	216	137		
	Sugar Beets	7,859	(45)	(59)		
	Wheat	23,680	430	287		
	TOTAL	701,029	(10,963)	(16,083)		
Scotts Bluff Area	Alfalfa	92,790	(2,614)	(7,883)	(1,171)	(125)
	Other Hay	11,300	(1,544)	(6,609)	(157)	(7)
	Corn Grain	172,490	(1,057)	(5,974)	289	45
	Corn Silage	17,900	(22)	(402)	83	11
	Dry Beans	91,920	256	(279)	402	48
	Sugar Beets	56,281	(185)	(604)	(70)	(7)
	Wheat	11,810	231	(35)	304	36
	TOTAL	454,491	(4,934)	(21,787)	(320)	
Eastern Wyoming	Alfalfa	51,420				(74)
	Other Hay	86,250				(915)
	Barley	3,370				(2)
	Corn Grain	8,870				(6)
	Corn Silage	8,430				(6)
	Dry Beans	6,940				(1)
	Sugar Beets	4,542				(1)
	Wheat	6,760				(4)
	TOTAL	176,582				(1,008)

(Table 11 Continued)

REGION	CROP	Present Condition	Water Emphasis	Water Leasing	Wet Meadow	Governance Committee
North Platte	Alfalfa	117,772	(450)	(529)	(158)	(507)
Headwaters	Other Hay	186,781	(3,867)	(4,546)	(1,359)	(4,363)
	Barley	11,192	(12)	(14)	(4)	(13)
	Corn Grain	1,889	(4)	(5)	(1)	(4)
	Corn Silage	6,587	(9)	(11)	(3)	(10)
	Dry Beans	2,700	(1)	(1)		(1)
	TOTAL	326,921	(4,342)	(5,105)	(1,526)	(4,900)
East Central	Alfalfa	121,450	(4,244)	(4,735)		
Colorado	Other Hay	22,100	(1,477)	(2,077)		
	Barley	18,350	1,432	1,400		
	Corn Grain	254,730	(128)	(857)		
	Corn Silage	60,640	617	500		
	Dry Beans	51,150	685	652		
	Potato	5,122	(3)	(5)		
	Sugar Beets	35,553	(129)	(149)		
	Wheat	17,940	1,152	1,108		
	TOTAL	587,035	(2,095)	(4,163)		
South Platte	Other Hay	8,460				
Headwaters	TOTAL	8460				
Denver Metro	Alfalfa	34900				
	Other Hay	13010				
	Barley	2810				
	Corn Grain	16790				
	Corn Silage	3980				
	Dry Beans	2660				
	Sugar Beets	1933				
	Wheat	4170.02				
	TOTAL	80253.02				

In a post-optimization calculation, these lost-production acres were allocated to a dryland cropping pattern based on 5-year county averages for the number of acres and crop yields for dryland crops. Then, the 5-year crop acreage averages were transformed into a percentage cropping pattern. These percentages were added into the agricultural model's code so that the acres going out of irrigated production were multiplied by the dryland cropping pattern percentages. Table 12 shows the acres of dryland crop production, the percentage-split cropping pattern, weighted dryland yields and weighted dryland costs of production.

Table 12. Acres of Dryland Crops, Percentage Split Cropping Pattern, Weighted Average Yield, and Weighted Variable Costs of Production.

Habitat Region	Acres	% Split	Wtd Yield	Wtd Var Cst
Dry Alfalfa	97,600	29.0%	3.48	$112.49
Dry Corn	91,320	27.1%	84.49	$117.44
Dry Corn Silage	7,771	2.3%	10.08	$136.59
Dry Soybeans	39,940	11.9%	32.30	$83.66
Dry Wheat	100,037	29.7%	34.72	$52.77
Total	336,668			
McConaughy Region				
Dry Alfalfa	48,260	6.1%	2.90	$93.73
Dry Corn	67,210	8.6%	71.07	$123.29
Dry Corn Silage	4,210	0.5%	9.30	$126.02
Dry Soybeans	9,900	1.3%	28.40	$73.56
Dry Wheat	655,150	83.5%	32.57	$51.96
Total	784,730			
Scotts Bluff Region				
Dry Wheat	218,590	100%	27.25	$50.68
East Central CO				
Dry Corn	10,940	2.1%	49.05	$141.26
Dry Wheat	509,180	97.9%	31.63	$51.99
Total				
Denver Metro				
Dry Alfalfa	540	0.2%	1.65	$40.96
Dry Corn	1,125	0.4%	40.13	$115.56
Dry Corn Silage	-	0.0%	-	$0.00
Dry Soybeans	-	0.0%	-	$0.00
Dry Wheat	292,140	99.4%	28.83	$55.80
Total	293,805			

After finding the percentage split of dryland crops for each area, the acres previously irrigated can be allocated to a dryland cropping pattern by multiplying the number of acres removed from irrigation by the dryland cropping pattern percentages. For example, 18,765 acres came out of irrigated production in the Habitat Region under the Water Emphasis Alternative. These acres are allocated to 29.0 percent dryland alfalfa (5,442 acres), 27.1 percent dryland corn (5,085acres), 2.3 percent dryland corn silage (432acres), 11.9 percent dryland soybeans (2,233 acres), and 29.7 percent dryland wheat (5,573 acres).

Table 13 shows the loss in total irrigated acres for each affected area and how those lost irrigated acres were allocated into a dryland cropping pattern where a dryland rotation could be identified. Data for dryland cropping patterns are not available for the Eastern Wyoming, North Platte Headwaters, South Platte Headwaters, or the Denver Metro areas.

Table 13. Loss in Irrigated Acres and the Allocation of Lost Irrigated Acres into a Dryland Cropping Pattern, by Region.

		Water Emphasis	Water Leasing	Wet Meadows	Governance Committee
Central Platte Habitat Area					
Irrigated Acres Lost		(18,765)	(38,262)		(10.749)
Dryland Crop Acres	DryWht	5,573	11,364		3,192
	DryAlf	5,442	11,096		3,117
	DryCorn	5,085	10,369		2,913
	DrySlg	432	880		247
	DrySoyB	2,233	4,553		1,279
Lake McConaughy Area					
Irrigated Acres Lost		(10,963)	(16,082)		
Dryland Crop Acres	DryWht	9,154	13,429		
	DryAlf	669	981		
	DryCorn	943	1,383		
	DrySlg	55	80		
	DrySoyB	143	209		
Scotts Bluff Area					
Irrigated Acres Lost		(4,934)	(21,787)	(320)	
Dryland Crop Acres	DryWht	4,934	21,787	320	
East Central Colorado					
Irrigated Acres Lost		(2,095)	(4,163)		
Dryland Crop Acres	DryWht	2,051	4,076		
	DryCorn	44	87		

Once the previously irrigated crops have been apportioned into a dryland cropping pattern, applicable county yields, prices received, and costs of production for each of these crops are incorporated into the analysis. Finally, the returns from the dryland production are added to the returns from the irrigated production to get a net change in agricultural production under the selected alternative. In Table 13, the total number of cropped acres in each region remains the same. The effect on net returns, due to the substitution, to the agricultural sector is to lessen the overall economic impact. Table 14 shows the estimated change in net revenues when substitution from irrigated to dryland production is allowed.

Table 14. Estimated Change in Gross Revenues ($1,000) for Each Alternative, by Crop, when Dryland Substitution is allowed.

REGION	CROPS	Present Condition	Water Emphasis	Water Leasing	Wet Meadows	Governance Committee
Central Platte	Alfalfa	$841.94	($31.16)	($52.14)	$0.00	($22.54)
Habitat Area	Corn Grain	$66,273.28	($746.87)	($1,490.37)	$0.00	($441.17)
	Corn Silage	$826.58	($6.27)	($14.57)	($0.00)	($2.86)
	Sorghum	$219.56	($1.71)	($4.96)	$0.00	($0.37)
	Soybean	$5,050.85	$2.60	($40.97)	$0.00	$20.52
	Dry Wheat	$0.00	$406.38	$828.61	$0.00	$232.78
	Dry Alfalfa	$0.00	$539.83	$1,100.71	$0.00	$309.21
	Dry Corn	$0.00	$614.43	$1,252.80	$0.00	$351.94
	Dry Corn Silage	$0.00	$36.02	$73.44	$0.00	$20.63
	Dry Soybeans	$0.00	$258.21	$526.49	$0.00	$147.90
	TOTAL	$73,212.21	$1,071.46	$2,179.05	($0.00)	$616.05
Lake McConaughy	Alfalfa	$6,093.45	($305.52)	($388.60)	$0.00	($0.00)
Area	Other Hay	$191.01	($53.29)	($70.87)	$0.00	$0.00
	Corn Grain	$35,690.05	($358.79)	($564.97)	($0.00)	$0.00
	Corn Silage	$1,572.49	($6.90)	($14.80)	($0.00)	$0.00
	Dry Beans	$3,887.82	$11.76	$5.84	($0.00)	$0.00
	Soybean	$865.79	$10.93	$6.92	($0.00)	$0.00
	Sugar Beets	$260.61	($1.51)	($1.94)	$0.00	$0.00
	Wheat	$1,143.75	$20.79	$13.87	($0.00)	($0.00)
	Dry Wheat	$0.00	$603.63	$885.55	$0.00	$0.00
	Dry Alfalfa	$0.00	$55.29	$81.11	$0.00	$0.00
	Dry Corn	$0.00	$74.39	$109.13	$0.00	$0.00
	Dry Corn Silage	$0.00	$4.22	$6.19	$0.00	$0.00
	Dry Soybeans	$0.00	$14.49	$21.26	$0.00	$0.00
	TOTAL	$49,704.97	$69.49	$88.69	($0.00)	$0.00
Scotts Bluff	Alfalfa	$2,924.76	($82.39)	($248.48)	($36.92)	($3.96)
Area	Other Hay	$286.51	($39.14)	($167.57)	($3.98)	($0.18)
	Corn Grain	$7,988.47	($48.95)	($276.67)	$13.39	$2.08
	Corn Silage	$1,008.37	($1.22)	($22.66)	$4.65	$0.59
	Dry Beans	$5,095.69	$14.18	($15.46)	$22.30	$2.68
	Sugar Beets	$3,851.97	($12.66)	($41.35)	($4.80)	($0.50)
	Wheat	$427.27	$8.36	($1.27)	$11.00	$1.31
	Dry Wheat	$0.00	$236.48	$1,044.21	$15.36	$0.00
	TOTAL	$21,583.03	$74.67	$270.74	$21.00	$2.02

Table 14 Continued

REGION	CROPS	Present Condition	Water Emphasis	Water Leasing	Wet Meadows	Governance Committee
North Platte	Alfalfa	$8,350.27	($31.87)	($37.47)	($11.20)	($35.96)
Headwaters	Other Hay	$6,850.51	($141.82)	($166.74)	($49.83)	($160.03)
	Barley	$338.90	($0.36)	($0.42)	($0.13)	($0.40)
	Corngrn	$100.87	($0.21)	($0.25)	($0.07)	($0.24)
	Corn Silage	$362.45	($0.50)	($0.59)	($0.18)	($0.57)
	Dry Beans	$167.45	($0.06)	($0.08)	($0.02)	($0.07)
	TOTAL	$16,170.45	($174.83)	($205.54)	($61.43)	($197.28)
East Central	Alfalfa	$19,295.68	($674.22)	($752.31)	($0.00)	$0.00
Colorado	Other Hay	$1,933.56	($129.21)	($181.69)	$0.00	$0.00
	Barley	$1,543.93	$120.45	$117.80	($0.00)	$0.00
	Corn Grain	$28,306.28	($14.21)	($95.23)	($0.00)	($0.00)
	Corn Silage	$9,793.07	$99.65	$80.69	$0.00	$0.00
	Dry Beans	$5,528.82	$74.03	$70.44	$0.00	$0.00
	Potato	$1,958.10	($1.16)	($1.89)	$0.00	$0.00
	Sugar Beets	$3,139.34	($11.36)	($13.15)	($0.00)	$0.00
	Wheat	$1,715.78	$110.17	$105.98	($0.00)	$0.00
	Dry Wheat	$0.00	$131.43	$261.22	$0.00	$0.00
	Dry Corn	$0.00	($0.45)	($0.90)	$0.00	$0.00
	TOTAL	$73,214.56	($294.89)	($409.04)	$0.00	$0.00

As with Table 13, only the regions where a dryland cropping pattern could be identified are included since there will be no difference in economic impacts for the regions where dryland cropping is not a viable option.

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