Irrigation In Montana

A Program Overview and Economic Analysis

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ECONorthwest specializes in the economic and financial analysis of public policy. ECONorthwest has analyzed the economics of resource-management, land-use development, and growth-management issues for municipalities, state and federal agencies, and private clients for more than 30 years.

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Executive Summary

This report describes the relationship between irrigated agriculture and Montana's economy, and examines how this relationship might be affected through potential state investments in existing and new irrigation projects. It was prepared for the Montana Department of Natural Resources and Conservation (DNRC) by ECONorthwest, an economic consulting firm, with the assistance of staff from another firm, PBS&J. To complete the report, we reviewed relevant data and past studies, interviewed persons knowledgeable about irrigation from throughout the state, and prepared ten technical memoranda for interim review by staff from DNRC and the state Department of Agriculture.

Irrigation is the dominant commercial use of the state's water resources, accounting for 96 percent of all surface and ground water withdrawn for any purpose, about 11 million acre feet (an acre-foot of water is the amount that would cover an acre one foot deep). Irrigated agriculture also is an important component of the state's economy. It directly produces economic benefits by increasing the supply and/or value of some crops, and it generates jobs and income for many Montanans. Data are not available to isolate irrigated agriculture, *per se*, but the overall agricultural sector in 2006 produced crops worth $1.1 billion, livestock and related products worth $1.3 billion, and net farm income of $250 million. It also employed about 31,000 people (full- and part-time). About 18 percent of all harvested cropland in the state is irrigated, but irrigated crops represent a higher percentage of the overall agricultural sector, as irrigation increases the crop yield per acre and allows some lands to produce higher-value crops. About 72 percent of all irrigation water is used to produce hay and pastureland, which are inputs to the production of livestock and related products.

Irrigation also has important indirect economic effects. These materialize as irrigation increases the ecosystem's ability to produce some non-crop goods and services, and decreases its ability to produce others. These effects, which economists call externalities, impact jobs and income throughout Montana. For example, some irrigation systems increase the supply of recreational opportunities on reservoirs and generate jobs in related economic sectors. At the same time, they eliminate recreational opportunities and affiliated jobs by dewatering streams and reducing instream water quality.

The externalities of irrigation are economically important throughout the state, although their importance varies from place to place. In many locations, they are more important than the direct increase in crop values resulting from irrigation. Evidence for this conclusion comes from several sources. In many places, the value of irrigated land is determined more by the land's ability to provide attractive scenery and other amenities than by its ability to increase net farm earnings. Several analyses have determined that society's willingness to pay to leave water in some streams and rivers exceeds farmers' willingness to pay to use the water for irrigation. All else equal, counties in the Upper Great Plains with greater water-related recreational opportunities, often at irrigation-related reservoirs, typically have higher household incomes than those with lesser opportunities. Throughout Montana and other western states, counties with stronger natural-resource amenities, such as water-related recreational opportunities, have higher rates of growth in jobs, higher levels of household income, and higher concentrations of entrepreneurs.

There is a widespread belief—the data currently available, however, are too limited to fill-in the details—that many of the state's irrigation systems are in disrepair. Moreover, it appears that, in certain locations, serious, if not insurmountable, hurdles are likely to keep the irrigators who historically have borne responsibility for maintaining irrigation systems from mustering sufficient funds to keep the systems from deteriorating further and, perhaps, falling out of service. Many systems lack the institutional foundation needed to plan refurbishment, raise sufficient funds, and complete the job. In some locations, residential farms and ranches—called hobby farms or ranchettes—have replaced commercial agriculture, reducing the number of commercial operations that historically have had financial responsibility for irrigation infrastructure and, more fundamentally, raising questions about who bears what responsibility for the system. In surveys, irrigators commonly assert that they lack sufficient financial resources to undertake significant investments on their own. It is not clear that investment of state funds, alone, would be adequate to overcome these and other factors contributing to the decline of some irrigation systems. Circumstances vary widely from system to system, indicating that further investigation of this question likely should occur on a case-by-case basis.

To ascertain the overall economic consequences of potential state investment in irrigation infrastructure, future analyses should consider more than just the direct effects on the production of irrigated crops. The externalities of irrigation, both positive (e.g., contribution to an agrarian quality of life) and negative (e.g., water quality problems and diminished in-stream recreational opportunities), are sufficiently important that one cannot fully understand the potential economic consequences of investing in an irrigation system unless the impacts on them are accounted for. In addition, future analysis should consider factors that are likely to exert considerable influence over the irrigation-economy relationship in the future. Foremost among these are the future evolution of agricultural markets, the effects of anticipated changes in climate, amenity-driven growth and its impacts on the price of irrigated lands, and the resolution (or not) of intrastate and interstate disputes over water.

We examined three aspects of the economic consequences of investments in irrigation: (1) the *net economic benefits*, i.e., the net value of the goods and services available to consumers; (2) the economic *net impacts*, i.e., the net changes in jobs, incomes, and related variables; and (3) the changes in economically important *uncertainties and risks* regarding values and impacts. Based on our findings, we offer the following recommendations for those seeking to enhance the net economic benefits and net economic impacts derived from irrigation.

A. Before investing public funds in irrigation, Montanans should consider the full suite of positive and negative consequences, as well as the major trends likely to affect the future relationship between irrigation and the economy.

To determine the overall net benefits and the net impacts of an irrigation investment, one must consider how it would affect the supply of goods and services associated with all the competing demands for water-related goods and services. These include the demand for irrigation water, of course, but also competing commercial demands from other irrigators and/or other sectors of the economy. They also include consumers' demands, which we separate into two categories. One is consumers' demands for amenities that affect the quality of life for residents and visitors to the state. The other is their demands for environmental values associated with the ecosystem's ability to lower the cost of living and to sustain valuable species, resources, and landscapes.

Public funds should not be used to modernize or expand irrigation if private parties would undertake such actions without public funding. Spending public funds in such instances would not increase net economic benefits or impacts above what otherwise would occur. Public funds should be invested in irrigation only when doing so would generate net economic benefits from projects that otherwise would not occur. Stated differently: a public investment should be undertaken only in circumstances where (a) private parties have determined that the investment would yield net costs (would not yield net benefits) for private investors; and (b) the externalities from the investment are expected to yield net benefits sufficiently large to outweigh these net costs. This decision-making approach will guard against making investments in irrigation projects that irrigators, themselves, are willing to make, and ensure that public funds generate the highest net benefit for Montanans as a whole.

Similar reasoning applies to the extent that Montanans care about the impact of an investment in irrigation on jobs and related variables rather than on its net benefits. Public funds should be invested in irrigation to generate jobs only when doing so would have a greater net impact than allocating the funds to alternative uses.

B. Montanans should consider the distribution of positive and negative economic consequences among different groups.

Any investment in irrigation will yield both positive and negative economic consequences, and their distribution among different groups must be determined on a case-by-case basis. As a general rule, however, the direct distributional outcome will be that taxpayers will incur the monetary cost of the investment and the irrigators—as well as the consumers of irrigated crops and the land owners, workers, businesses, and communities linked to the resulting increase in irrigation water—will realize the economic benefits and/or increases in jobs, income, and property value. The externalities of the investment—positive and negative—are harder to predict. Changes in recreational opportunities and other amenities likely will affect both local residents and businesses as well as those farther away, in correspondence with the households' willingness to travel to take advantage of them. Changes in the ecosystem's ability to produce goods and services, such as flood control, also may have both local and distant consequences.

C. Montanans should consider investments in improving irrigation efficiency as a reasonable complement or alternative to refurbishing existing irrigation infrastructure or constructing new infrastructure.

Although some are far better than others, Montana's irrigation systems, as a whole, are among the least efficient in the West, withdrawing much more water from streams and aquifers than irrigated crops require. Improving the efficiency of inefficient systems may leave current irrigators with adequate water for their crops and increase the supply of water for additional irrigation or for the production of non-crop goods and services. There are three general efficiency-enhancement strategies: (1) convert less-efficient, surface-irrigation methods to more-efficient methods; (2) use irrigation-scheduling techniques that measure crops' irrigation requirements precisely; and (3) reduce losses of water by lining ditches and canals that deliver irrigation water. Such actions probably would have multiple economic consequences, some positive and some negative, which must be determined on a case-by-case basis.

Public investment in water-use efficiency may be warranted insofar as irrigators expressing a desire to invest in water-use efficiency often say they lack the financial means to make the investments. Public investment also may be influenced by current water law, which can discourage private investments in water-use efficiency, because the current water user may realize few of the benefits when such investments make water available for other uses and users.

D. Montanans should investigate and pursue opportunities to develop markets that offer opportunities to increase farm income derived from irrigation water.

Two types of markets offer opportunities for additional farm income. One creates or expands opportunities for irrigators to receive Payments for Ecosystem Services (PES) they produce. The other facilitates the transfer of water from a lower-value use to a higher-value use.

Some PES markets, such as the Conservation Reserve Program, are familiar and long-standing. Over the past couple of decades, however, programs with greater diversity have emerged, enabling some farmers to receive payments for restoring wetlands (the Montana Enhancement Program) and expanding hunting opportunities (Montana Block Management Program). Public investment to broaden the scope of such programs may be warranted to overcome hurdles that impede even further diversification. Efforts might be targeted at reducing administrative costs, creating pilot projects, reducing farmers' risk and liability, and increasing the funds available to state agencies for making appropriate payments for ecosystem services.

Water markets can offer robust opportunities for increasing the value of the crops (and other goods and services) derived from a given supply of water. Market-based, voluntary transfers of water should increase the economic well-being of both the sellers and the buyers because a transaction would occur only if both parties expected it to be beneficial. Public investment in water markets, at least until more experience with them is accomplished, may be beneficial to overcome administrative, legal, and other barriers that are insurmountable by individual irrigators. Intervention might lower the costs to consider and resolve the concerns of third parties that might be affected by a water transfer, help potential buyers and sellers find one another, and verify that water is moved and used in accordance with the terms of a transaction.

E. Montanans should sponsor research targeted at developing a better understanding of the economic consequences of potential, water-related investments.

We urge giving priority to Montana-specific research aimed at developing a better understanding of the following:

- The non-crop ecosystem goods and services affected by irrigation, their value, and their impacts on jobs and income.
- Opportunities and risks associated with anticipated changes in climate and its potential effects on the demand for crops, the ability of Montana's farmers to grow specific crops, the frequency and severity of drought, the demand for and supply of non-crop ecosystem goods and services, and the economic consequences of decreases or increases in irrigated agriculture.
- Factors other than climate change that might undermine the economic stability of irrigated agriculture in Montana as a whole or in regions of the state. Special concern should address potential conflicts between irrigation and society's demands for non-crop goods and services adversely affected by irrigation.
- The status of existing irrigation systems, the likelihood of a major system disruption or failure, the economic consequences of such an event, and the economic consequences of state intervention to prevent it.
- Opportunities to increase the water-use efficiency of existing irrigation systems, the economic consequences of current inefficiencies, and the potential economic requirements and consequences of efforts to make systems more efficient.
- Opportunities to grow higher-value crops on irrigated cropland, and expand production of value-added agricultural products.
- Potential markets that would expand opportunities for irrigators to increase earnings derived from irrigation water, through payments for ecosystem services and voluntary transactions that transfer water from lower-value to higher-value uses.

We finish our discussion with these final observations. Nothing in this report should be construed as an economic evaluation of any specific, potential investment in irrigation infrastructure. The level of analysis in this report is not sufficiently detailed to provide support for or against any specific public investment in irrigation. Moreover, nothing in this report should be construed as disregarding water rights and the system of laws that support them. Instead, this report describes the relationship between irrigation and the economy and recognizes that, although some elements of this relationship are intertwined with the system of existing water rights, others are not.

I. Introduction

In December, 2007, the Montana Department of Natural Resources and Conservation (DNRC) contracted with ECONorthwest and its subcontractor, PBS&J, to describe the relationship between irrigation and the economy in Montana, and to provide decision-makers with information about the potential economic consequences of investing in new and existing irrigation projects. This is our report of our findings. It describes the statewide relationship and how the relationship varies as one moves across Montana, providing information about how irrigation is used, the prospects for future use, the net benefits of irrigation, and the impacts on income, employment, land values, and other economic variables.

To prepare the report, we completed these tasks:

- Applied our knowledge of irrigation and economic issues in Montana, derived from professional and personal experience that stretches over the past three decades.
- Prepared ten technical memoranda that present most of the contents of this preliminary draft report in greater detail. The memoranda supplement the data and discussion presented in this report.
    - Technical Memorandum 1.1 – Financial and Technical Assistance Programs for Irrigated Agriculture in Montana
    - Technical Memorandum 1.3 – Irrigation Management Systems in Montana
    - Technical Memorandum 1.2-1.4 – Availability of Land and Water Resources & Crop Type by Basin
    - Technical Memorandum 1.5 – Overview of Financial and Technical Assistance Programs in Surrounding States and Provinces
    - Technical Memorandum 2.1 – Irrigation and Montana's Economy: A Conceptual Framework
    - Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana
    - Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana
    - Technical Memorandum 2.4 – Emerging Opportunities for Sustaining or Expanding Irrigated Agriculture in Montana
    - Technical Memorandum 2.5 – Case Studies of Irrigation in Different Regions of Montana
    - Technical Memorandum 2.6 – Data Limitations and Recommendations for Future Research
- Reviewed the reports from past studies of the relationship between irrigation and the economy, as well as past and current data regarding this relationship, in Montana and in surrounding states and provinces.

- Acquired insights regarding the irrigation-economy relationship by interviewing almost 50 individuals: irrigation-system managers, irrigators, farmland and ranchland appraisers, staff of agencies that administer irrigation programs, and economists.
- Responded to comments on the Technical Memoranda from staff of DNRC and the Montana Department of Agriculture.

In the next section of this report, **Section II, Program Overview**, we summarize our findings regarding irrigation systems and irrigated agriculture in Montana, the availability of water and land resources for expanding irrigation in the future, and the existing programs providing financial and technical assistance to irrigation in the state. We also provide an overview of irrigation, water-resource development, and assistance programs in surrounding states and the Canadian Provinces of Alberta and Saskatchewan.

In **Section III, Economic Analysis**, we describe the methods and assumptions we used to describe the relationship between irrigation and the economy in Montana, and to assess the potential economic consequences of investing in new and existing irrigation projects. We then present our analytical findings and discuss their limitations.

In **Section IV, Policy Implications of the Economic Analysis**, we discuss the implications of our findings for current and potential future investments in irrigation, and how they might be applied in future assessments of irrigation projects and irrigation investment proposals.

In **Section V, Conclusions and Recommendations**, we summarize our overall findings.

We conclude the report with **References** and **Appendices**.

We emphasize, here and throughout the report, that no element of this report should be construed as an assessment of the economic feasibility of any particular irrigation-development project. Instead, this report aims to provide background information that irrigation-system managers, farmers and ranchers, program mangers, legislators, and others can use as they consider whether or not to initiate a feasibility assessment for an individual project. We also anticipate that the contents of this report will provide a useful context for evaluating the findings of such an assessment.

II. Program Overview

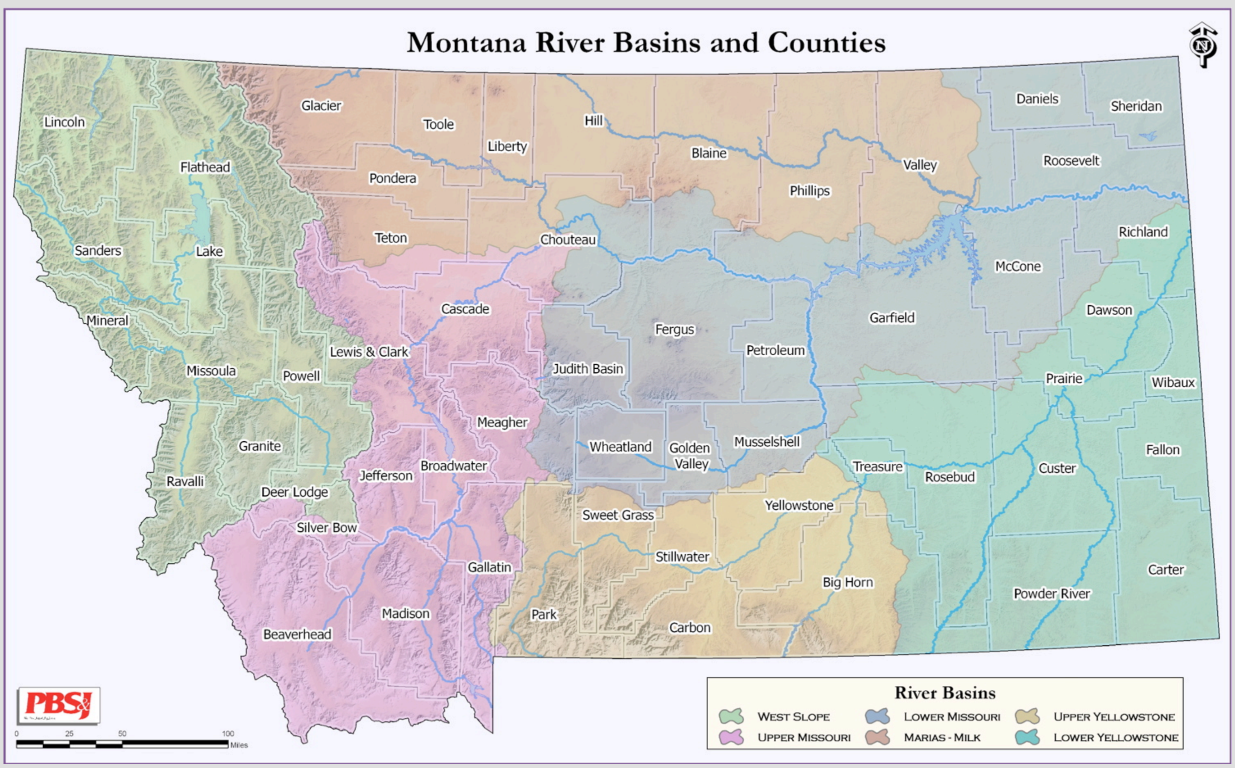
In this section we summarize our findings regarding:

A. Irrigation systems in Montana
B. The availability of land and water resources for additional irrigation
C. Major crop types, by basin
D. Financial and technical assistance programs for irrigation in Montana
E. Assistance programs in neighboring states and provinces
F. Case studies

ECONorthwest and PBS&J collaborated on the case studies; otherwise, the research was completed by PBS&J. See *Technical Memoranda 1.1, 1.2-1.4, 1.3, 1.5, and 2.5* for further detail.

Throughout this report, when possible, we present and analyze data organized around six drainage basins in Montana, shown in Figure 1. We combine the Milk and Marias basins into one unit, although we recognize that they are not technically part of the same hydrologic unit, because the geography and agricultural use of the Marias basin more closely patterns that of the Milk River basin than the Upper Missouri basin. A full-page version of the map shown in Figure 1 is available as Map B-1 in Appendix B.

Figure 1. The Six River Basins Used in this Study



Source: PBS&J

A. Irrigation Systems in Montana

Montana contains approximately 2 million acres of irrigated land (USDA National Agricultural Statistics Service 2004). The number of irrigated acres has fluctuated slightly, but remained largely unchanged over the last fifty years. On a county level, however, irrigated acres have changed considerably in certain parts of the state since the mid-1980s.

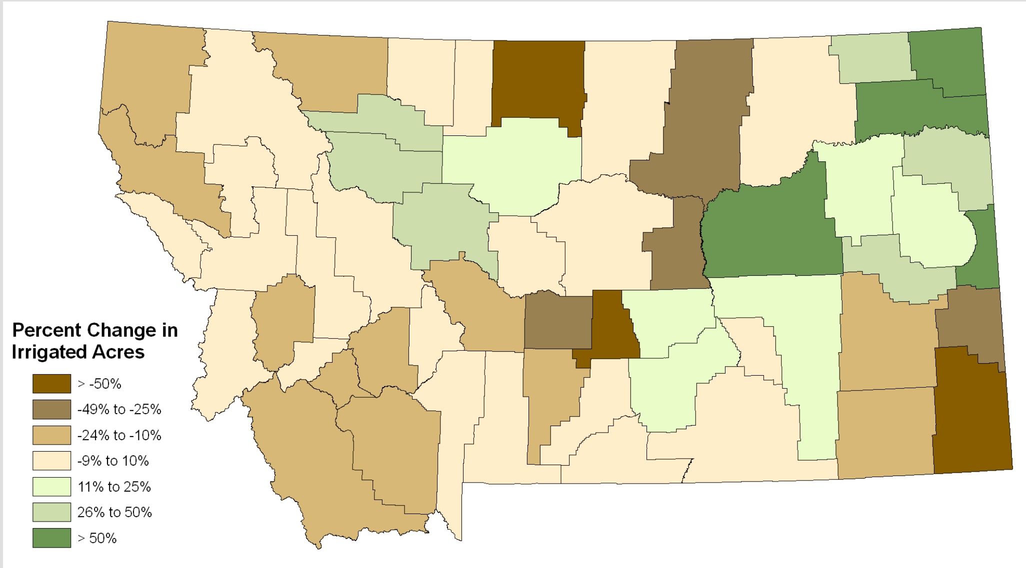
Figure 2 shows the percent change and change in number of irrigated acres by county between 1987 and 2002. For most counties (those in light beige on the maps in Figure 2), the overall change in irrigated acres is not great. Counties with more substantial declines are concentrated in the southwestern and southeastern regions of the state, and it is likely that drought has contributed to these losses. The loss of irrigated acres in counties throughout the western region of Montana is likely also due to the transition from agricultural to recreation-based economies that these counties have experienced in recent years (for more discussion of these trends, see the Bitterroot Case Study in *Technical Memorandum 2.5 – Case Studies*). Irrigated acres in some counties, particularly in the central and northeastern regions of the state have increased. The increases in counties where the lower Missouri and lower Yellowstone Rivers flow, including Richland, Roosevelt, Rosebud, Prairie, and Wibaux counties is potentially related to the state's water reservations for irrigated agriculture in these rivers (for more discussion of these trends, see the Lower Yellowstone and Lower Missouri River Case Study in *Technical Memorandum 2.5 – Case Studies*). The increase in Teton, Cascade, and Pondera counties, in the central part of the state, is likely driven by several well-run irrigation systems, operated by irrigation districts and companies, which have been able to increase efficiencies and bring more acres under irrigation (for more discussion of these trends, see the Greenfields Irrigation District Case Study in *Technical Memorandum 2.5 – Case Studies)*.

Ownership and control of Montana's irrigation systems fall into nine categories:

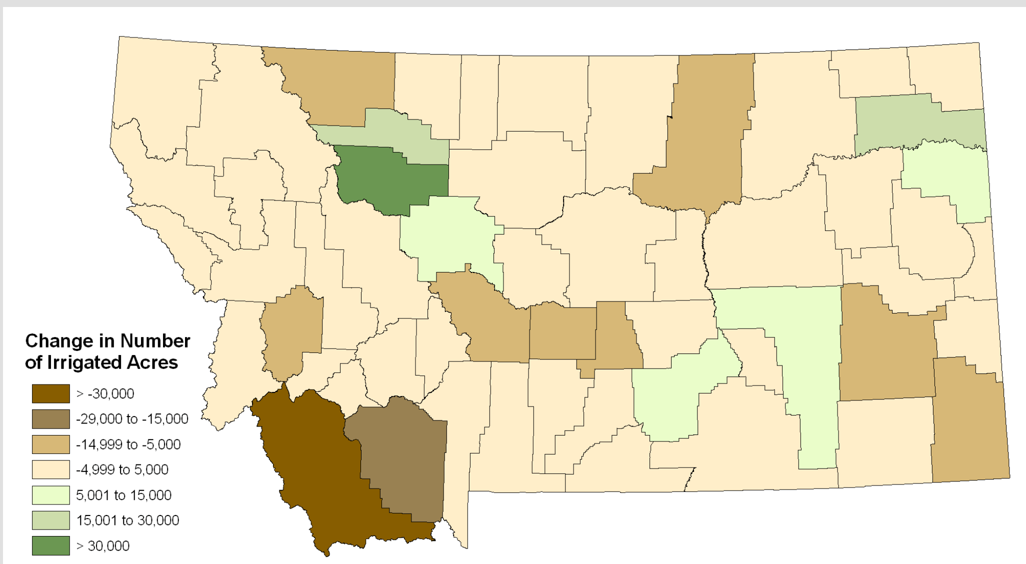
- Federal
- State
- Tribal
- Federal/ BOR Irrigation Districts
- Non-BOR Irrigation Districts
- Conservation Districts
- Municipalities
- Irrigation Companies and Associations
- Private

These categories represent both public and private irrigation systems. The first eight categories are public systems, managed or maintained by governmental agencies and collections of users. The last category, private, includes systems that are maintained by individual users who are solely responsible for the ownership of infrastructure and water rights. The difference between Federal Irrigation Districts and Non-Federal Irrigation Districts deserves further definition. Irrigation districts are quasi-governmental entities formed under Montana law. Some irrigation districts were formed because of the development of a federal water project by the Bureau of Reclamation (BOR), and these fall into the category of "Federal/BOR Irrigation Districts." Others, categorized as "Non-BOR Irrigation Districts" formed in the absence of any federal infrastructure project, and are not supported or beholden to a federal agency. A more detailed

Figure 2. Change in Percent and Number of Irrigated Acres by County, 1987 to 2002



Source: ECONorthwest, with data from U.S. Department of Agriculture, National Agriculture Statistics Service (2004a). See *Technical Memorandum 2.3 – Net Impacts of Irrigation in Montana* for more detail.



Source: ECONorthwest, with data from U.S. Department of Agriculture, National Agriculture Statistics Service (2004a). See *Technical Memorandum 2.3 – Net Impacts of Irrigation in Montana* for more detail.

discussion of each of these categories is provided in *Technical Memorandum 1.3 – Irrigation Management Systems in Montana.*

Maps B-2 through B-7 in Appendix B show the distribution of private and public irrigation systems in each of the state's six river basins.

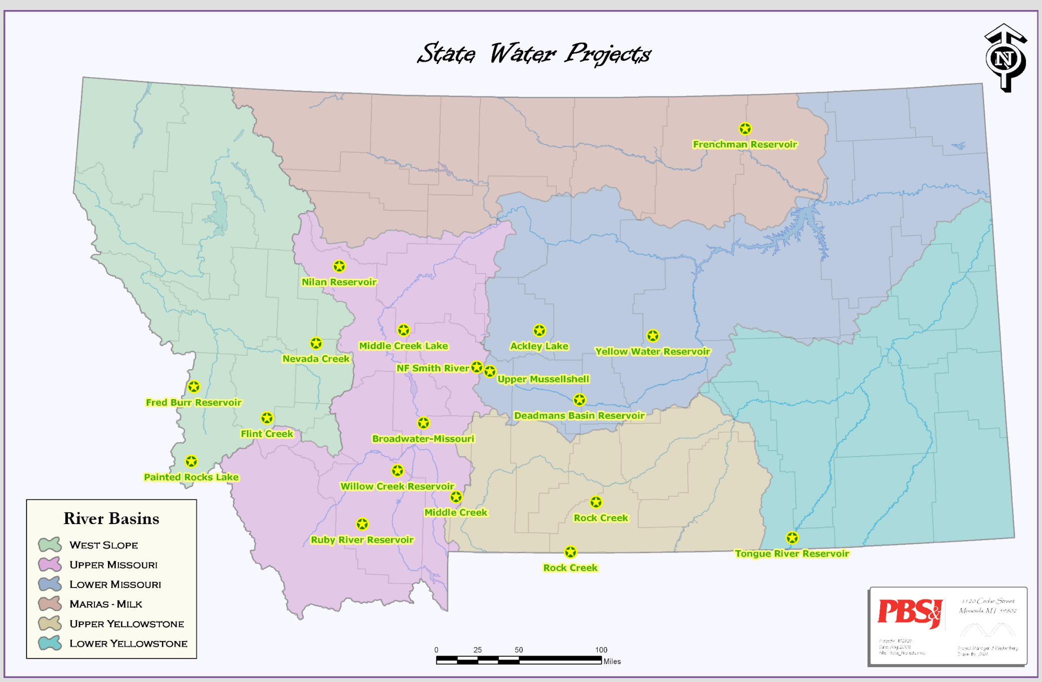
The State of Montana owns several water-storage projects, which are managed by the Montana Department of Natural Resources and Conservation (DNRC) Water Resources Division, State Water Projects Bureau (SWPB). Table 1 shows the amount of water marketed by each active SWPB project, which are depicted on a map in Figure 3. SWPB manages the projects based on acre-feet (ac-ft) of water marketed, not on the number of acres served, allowing water to be moved

Table 1. Currently Active State Water projects

Project	Water Marketed (acre-feet)	Project	Water Marketed (acre-feet)
Ackley Lake	4,766	North Fork Smith River	11,000
Broadwater-Missouri	29,217	Painted Rocks	10,000
Deadman’s Basin	40,500	Rock Creek	21,770
Flint Creek	27,180	Ruby River	38,845
Fred Burr	515	Tongue River	40,000
Frenchman	7,000	Upper Musselshell	21,718
Middle Creek	10,184	Willow Creek	11,900
Nevada Creek	8,440	Yellow Water	2,000
Nilan	8,500		

Source: PBS&J. See *Technical Memorandum 1.3 – Irrigation Management Systems in Montana* for more detail.

Figure 3. Map of Active State Water Projects



Source: PBS&J.

from one parcel to the next. Identifying the number of acres served by these projects is difficult because the water is typically used as supplemental water on ground that is irrigated with privately owned water rights.

B. Availability of Land and Water Resources, by Basin

The availability of water for irrigation use is governed by Montana's water law, which reflects the Prior Appropriation Doctrine, and allocates water with the rule: first in time, first in right. That is, rights to water are ordered in a queue, with rights established earlier having priority over those established later. A water right specifies the point at which water is to be diverted, where the water must be used, the period of use, and the purpose for which it must be used. In most parts of the state, the rights at the front of the queue were established over a century ago, and lock water use to the priorities and technologies, as well as the economic and ecological conditions of the 19th and early 20th centuries.

Over time, claims on water have grown to exceed the amount of water available for many streams and rivers in Montana. One result of this has been to prohibit or restrict new appropriations of water in certain areas. These restrictions are known as basin closures. Montana's basin closures, as of 2007, are listed in Table 2, organized by the mechanism by which they have been closed to new

Table 2. Montana Basin Closures as of 2007

Closure Type	Closure Name
Closure by Montana Supreme Court Order	Flathead Indian Reservation
Closure by Legislative Statute	Bitterroot, Jefferson & Madison, Teton, Upper Clark Fork, and Upper Missouri Basins
Department-Ordered Closure	Milk River Basin Mainstem and Southern Tributaries
Closure by Tribal or Federal Compact	Benton Lake NWR, Big Hole Battlefield, Bighorn Canyon, Black Coulee NWR, Crow Reservation, Fort Belknap Reservation, Glacier NP, Little Bighorn Battlefield National Monument, Northern Cheyenne, Red Rock Lakes NWR, Rocky Boy's Reservation & Yellowstone NP
Closure by Administrative Rule	Walker Creek, Truman Creek, Musselshell River, Sixmile Creek, Houle Creek, Towhead Gulch, Sharrott Creek, Willow Creek & Rock Creek
Closure due to Controlled Groundwater Area	Bitterroot Valley Sanitary Landfill, BNSF Somers Site, Bozeman Solvent Site, Hayes Creek, Horse Creek, Larson Creek, Old Butte Landfill/Clark Tailings Site, Paradise Railyard, Powder River Basin, Rocker, South Pine, Sypes Canyon, Warm Springs Ponds & Yellowstone

Source: PBS&J. See *Technical Memorandum 1.2-1.4 – Availability of Land and Water Resources and Crop Type by Basin* for more detail.

appropriations of water. Map B-8 in Appendix B shows the locations of these restrictions. Five basins, the Bitterroot, the Jefferson and Madison, the Teton, the Upper Clark Fork and the Upper Missouri are closed to new appropriations by statute. Several other areas, mostly more localized, have been closed through a petition and rule-making process. Most notable among these administrative-rule closures are the mainstem of the Musselshell River and the Rock Creek drainage in Carbon County. Also, an administrative decision by the DNRC in a contested case hearing has resulted in a situation where mitigation is required for new developments that will withdraw large quantities of water from any source in the Clark Fork basin above Noxon Reservoir, including the Flathead River and the Swan River drainages. The implications of this decision have not been fully realized. Additionally, groundwater concerns have prompted limitations on groundwater developments in the area surrounding Yellowstone National Park and in the Powder River basin.

Compacts with some of the tribes in Montana and with the federal government have resulted in other closures. For example, the Fort Belknap compact restricts new appropriations in the Milk River drainage, and the Crow Reservation compact affects several drainages, including the Big Horn and Little Big Horn Rivers. The Montana Supreme Court issued a decision that prohibits the state from issuing new water rights or authorizing changes to existing water rights on the Flathead Indian Reservation, though this does not actually preclude all water development activities.

The specific requirements and restrictions vary among the different locations but, in general, the closures severely limit or completely preclude the DNRC from issuing new water rights. In Western Montana, only the Kootenai River and the Yaak River drainages remain open to new appropriations of water with no mitigation requirements.

It is possible to change an existing water right, however the DNRC strictly evaluates applications before approving such changes. For example, if a farmer increases his efficiency by switching from flood to sprinkler irrigation, he cannot necessarily use the conserved water to irrigate additional land. This is so because, under flood irrigation, water applied to a field but not consumed by the crop or through evaporation would return to the stream and be available for a downstream water-right holder. Thus, the farmer installing a sprinkler system could not use conserved water to irrigate additional land if doing so would limit the return flow available downstream.

The availability of water for additional irrigation in basins not legally closed to new appropriations may be limited by hydrologic, topographical, and economic considerations. In much of the state, flows in smaller streams are limited to spring runoff, and there is little or no water during summer months. On larger streams and rivers, potential croplands lie high above deeply incised channels, often making pumping costs prohibitively high.

In some parts of eastern Montana, water is available for new irrigation under the Water Reservation Program. Created under the 1973 Montana Water Use Act, it allows state and federal agencies, as well as political subdivisions of the state, to reserve water for future uses. In 1978, the Board of Natural Resources and Conservation granted water reservations for irrigation use to 14 conservation districts (CDs) in the Yellowstone River Basin, and also granted water reservations for municipal uses and instream flows. In 1992, the Board granted irrigation reservations in the Upper Missouri River Basin to 15 CDs , as well as reservations for instream flow and municipal use. The junior priority date and the instream flow reservations make it unlikely that the reservations in some areas will be developed for irrigation purposes. The last reservations to be granted were in the Lower Missouri and Little Missouri River drainages, where 11 CDs received reservations for irrigation. Sheridan County CD also has received a reservation for the use of groundwater.

As of the end of the 2007 irrigation season, CDs in the Yellowstone River Basin have allocated water to 183 projects, using 75,854.3 acre-feet of water, or 15 percent of the CDs' total allocated water. CDs in the Missouri River Basin have issued 66 authorizations for water use as of the end of the 2007 irrigation season, using 27,652.1 acre-feet of water, or 9 percent of the CDs' total allocated water. Table 3 lists the CDs granted water reservations for irrigation and shows their utilization of these reservations to date.

Table 3. Water Reservations Granted and Allocated for Irrigation Use as of 2007

Basin	Conservation District	Number Approved Projects	Volume: Total Reserved (ac-ft)	Total Allocated (ac-ft)	Total Remaining (A/F)	Total Allocated (%)
Lower Missouri & Little Missouri	Blaine	0	18,934	0	18,934	0%
	Carter	0	4,684	0	4,684	0%
	Daniels	0	3,047	0	3,047	0%
	Liberty	0	122	0	122	0%
	Little Beaver	0	1,548	0	1,548	0%
	McCone	3	14,299	1,874	12,425	13%
	Richland	21	25,349	8,530	16,819	34%
	Roosevelt	19	73,115	8,801	64,314	12%
	Sheridan	15	15,479	4,095	11,384	26%
	Valley	0	7,668	0	7,668	0%
	Wibaux	0	1,509	0	1,509	0%
Upper Missouri	Broadwater	0	606	0	606	0%
	Cascade	0	9,314	0	9,314	0%
	Chouteau	2	33,123	2,481	30,642	7%
	Fergus	1	3,914	237	3,677	6%
	Gallatin	0	2,006	0	2,006	0%
	Glacier	0	1,271	0	1,271	0%
	Jefferson Valley	0	14,515	0	14,515	0%
	Judith Basin	0	731	0	731	0%
	Lewis & Clark	0	654	0	654	0%
	Liberty	0	2,002	0	2,002	0%
	Lower Musselshell	0	600	0	600	0%
	Pondera	2	1,975	494	1,481	25%
	Teton	3	3,253	1,140	2,113	35%
	Toole	0	641	0	641	0%
	Valley	0	92,000	0	92,000	0%
Yellowstone	Big Horn	21	20,185	6,507	13,678	32%
	Carbon	4	22,676	700	21,976	3%
	Custer	16	28,478	5,238	23,240	18%
	Dawson	14	45,855	5,525	40,330	12%
	Little Beaver	39	12,773	1,284	11,489	10%
	Park	5	64,125	1,586	62,539	2%
	Powder River	27	13,680	8,123	5,558	59%
	Prairie	10	68,467	5,009	63,458	7%
	Richland	10	45,620	30,335	15,285	66%
	Rosebud	13	87,003	2,555	84,448	3%
	Stillwater	8	16,755	362	16,394	2%
	Sweet Grass	5	46,245	4,275	41,970	9%
	Treasure	4	18,361	1,579	16,782	9%
	Yellowstone	7	57,963	2,777	55,186	5%

Source: PBS&J. See *Technical Memorandum 1.2/1.4 – Availability of Land and Water Resources and Crop Type by Basin* for more detail.

C. Crop Type, by Basin

Table 4 shows the distribution of crops within the state's six river basins (shown in Figure 1 and Figure B-1 in Appendix B). The data distinguish between major irrigated and non-irrigated crops, including pasture.

Table 4. Distribution of Irrigated and Non-Irrigated Crops by Basin, 2005

Commodity	Practice	Acres	Percent of Total Acres	Percent of Irrigated Acres
Lower Missouri River Basin				
Total Irrigated	**Irrigated**	**156,656**	**5%**	
Total Non Irrigated	**Non Irrigated**	**2,991,210**	**95%**	
Total Acreage		**3,147,866**		
Top 5 Irrigated Crops				
Alfalfa	Irrigated	76,010	2%	49%
Other Hay	Irrigated	40,660	1%	26%
All Wheat	Irrigated	14,103	Less than 1%	9%
Pastureland	Irrigated	11,319	Less than 1%	7%
Barley	Irrigated	5,167	Less than 1%	3%
Lower Yellowstone River Basin				
Total Irrigated	**Irrigated**	**239,290**	**17%**	
Total Non Irrigated	**Non Irrigated**	**1,145,684**	**83%**	
Total Acreage		**1,384,974**		
Top 5 Irrigated Crops				
Alfalfa	Irrigated	75,550	5%	29%
Other Hay	Irrigated	29,130	2%	11%
Sugarbeets	Irrigated	28,189	2%	11%
Corn For Grain	Irrigated	27,291	2%	11%
Barley All	Irrigated	22,343	2%	9%
Milk and Marias River Basins				
Total Irrigated	**Irrigated**	**230,381**	**9%**	
Total Non Irrigated	**Non Irrigated**	**2,375,091**	**91%**	
Total Acreage		**2,605,472**		
Top 5 Irrigated Crops				
Alfalfa	Irrigated	98,775	4%	43%
Barley All	Irrigated	47,288	2%	21%
Other Hay	Irrigated	32,960	1%	14%
Pastureland	Irrigated	25,010	1%	11%
All Wheat	Irrigated	24,053	1%	10%
Upper Missouri River Basin				
Total Irrigated	**Irrigated**	**924,384**	**56%**	
Total Non Irrigated	**Non Irrigated**	**713,784**	**44%**	
Total Acreage		**1,638,168**		
Top 5 Irrigated Crops				
Other Hay	Irrigated	327,215	20%	35%
Alfalfa	Irrigated	279,470	17%	30%
Pastureland	Irrigated	183,225	11%	20%
Barley All	Irrigated	75,646	5%	8%
All Wheat	Irrigated	48,808	3%	5%

Table 4 (cont.). Distribution of Irrigated and Non-Irrigated Crops by Basin, 2005

Commodity	Practice	Acres	Percent of Total Acres	Percent of Irrigated Acres
Upper Yellowstone River Basin				
Total Irrigated	**Irrigated**	**383,413**	**46%**	
Total Non Irrigated	**Non Irrigated**	**458,438**	**54%**	
Total Acreage		**841,851**		
Top 5 Irrigated Crops				
Alfalfa	Irrigated	131,780	16%	34%
Pastureland Irrigated	Irrigated	72,298	9%	19%
Other Hay	Irrigated	53,270	6%	14%
Barley All	Irrigated	36,048	4%	9%
Corn For Grain	Irrigated	22,476	3%	6%
West Slope Basin				
Total Irrigated	**Irrigated**	**370,517**	**81%**	
Total Non Irrigated	**Non Irrigated**	**84,535**	**19%**	
Total Acreage		**455,052**		
Top 5 Irrigated Crops				
Other Hay	Irrigated	147,810	32%	40%
Pastureland Irrigated	Irrigated	108,219	24%	29%
Alfalfa	Irrigated	78,650	17%	21%
All Wheat	Irrigated	18,274	4%	5%
Barley All	Irrigated	10,244	2%	3%

Source: PBS&J, with data from USDA, National Agricultural Statistics Service (2008). See *Technical Memorandum 1.2/1.4 – Availability of Land and Water* for more detail.

D. Financial and Technical Assistance Programs

We found 13 programs that provide financial or technical assistance available to irrigated agriculture in Montana. Two federal agencies provide assistance: the Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA). State assistance comes from the Montana Departments of Natural Resources and Conservation (DNRC), Agriculture, and Fish Wildlife and Parks (Montana FWP). Local conservation districts also provide assistance.

Four federal programs are significant. The **Environmental Quality Incentives Program** (EQIP) provides grants and cost-share programs to farmers and ranchers who face threats to soil, water, air and related natural resources. Under the **Conservation Technical Assistance Program**, the NRCS provides conservation planning and technical assistance, at no cost, to individuals, groups, and units of government facing natural resource challenges. Any landowner or group interested in developing a conservation plan is eligible to receive this assistance, but NRCS employees typically work with people who are developing a plan with the ultimate goal of obtaining funding through EQIP or any of the other Farm Bill programs. The FSA loans money directly to farmers and helps farmers obtain loans from others by providing lenders with a loan guarantee up to 95 percent of any loss of principal and interest on a loan. **FSA Loans** can be used for soil and water conservation projects, and **Direct Emergency Loans** can provide assistance to farmers and ranchers affected by drought and other natural disasters.

DNRC administers seven programs that have the potential to assist irrigation:

- The **Irrigation Development Grant Program** provides grants that typically do not exceed $15,000 to eligible public and private entities. Suitable projects are those that lead toward the development of new irrigation projects and activities that increase the value of agriculture for existing irrigated lands. Grant money cannot be used for final engineering work or equipment purchases. Total available funding in 2007 was $149,720.
- The **Renewable Resource Grant and Loan Program** grants and loans up to $100,000 for the repair of irrigation infrastructure and other projects that conserve, manage, develop, or preserve renewable resources, often in the context of drought. State agencies and universities, counties, incorporated cities and towns, conservation districts, irrigation districts, water/sewer/solid waste districts, and tribes are eligible. Loans distributed in 2007 amounted to $17,213,208.
- The **Private Water Development Loan Program** provides financial assistance in the form of loans for irrigation system improvements that benefit natural resources. Individuals, partnerships, associations and corporations, both for-profit and non-profit, are eligible for these funds. Loans to individual private entities may not exceed the lesser of $400,000 or 80 percent of the fair market value of the security given for the project. Private loans to individuals must be secured with real property. Loans up to $3 million are available for such organizations as water user associations and ditch companies. These loans are secured by the revenue produced by the system. Suitable projects would include irrigation system improvements, such as conversion from flood irrigation to sprinkler irrigation. To finance loans, the law provides authority to issue general obligation renewable resource bonds up to a total outstanding balance of $20 million.
- The **Renewable Resources Project Planning Grant Program** provides grants to public or government entities for the planning and development of projects that conserve, develop, manage, or protect Montana's renewable resources. Eligible projects include rehabilitation of a dam; installation and repair of irrigation infrastructure; development of recreation opportunities; and the conservation and management of water and other resources. There is $400,000 available for the biennium beginning July 1, 2007, of which $60,000 is available for irrigation-related projects. Individual grants may not exceed $15,000.
- The **Reclamation and Development Grant Program** funds projects that reclaim lands damaged by resource extraction and/or support activities that address crucial state needs. In 2007, to address crucial state needs, funds were supplied to conservation districts for a water storage project

on the Musselshell, for improvements to an irrigation canal in the Big Hole, and for the Milk-St. Mary rehabilitation project.

- The **HB 233 Grant Program** makes grants that typically do not exceed $15,000 per project to local conservation districts for planning, education, feasibility studies, or construction projects. The projects must show a public benefit as well as a conservation benefit, and landowners or other beneficiaries must provide a 50:50 cash match. In 2006, the most recent year for which data were available, $17,014 was distributed through this program.
- The **Conservation District Technical Assistance Grant Program** provides grants to conservation districts for limited engineering planning review and other technical assistance to get projects started. This program has $50,000 to $100,000 available annually.

The Montana Department of Agriculture administers the **Growth Through Agriculture Program**, providing grants and loans to public, private, educational, and local government entities to encourage economic growth though innovation and to strengthen Montana's agriculture industry. Total project investment for one company or one project may not exceed $150,000. The investment amounts are limited to three rounds of $50,000 financing, with a 9-month waiting period between separate investments. Common irrigation projects generally are not eligible for these funds but, in 2005, the program provided funds for project coordination and preliminary engineering design for a large irrigation project in north-central Montana, near Chester. This program may be suitable for projects focusing on the renewable fuels industry with significant local economic development to agriculture.

Montana FWP, in conjunction with the U.S. Fish and Wildlife Service, administers the **Fisheries Restoration and Irrigation Mitigation Program**, providing grants to counties, cities, towns, regional governments, and service districts for the design, construction, and installation of fish screens, fish ladders, and other fish passage devices associated with water diversions. While the intent of this program is not to benefit irrigators, the money available can make compliance with current regulations more affordable when there is a need to rehabilitate or replace existing irrigation diversion structures.

E. Assistance Programs in Neighboring Jurisdictions

Here, we briefly describe financial assistance programs available to private and public entities for irrigation-related projects and activities in Idaho, North Dakota, South Dakota, Wyoming, Alberta, and Saskatchewan. We focus on programs unique to each state or province, as well as on a Canadian national program that provides the bulk of the assistance available to irrigated agriculture in Alberta and Saskatchewan. See Technical Memorandum 1.5 – Overview of Financial and Technical Assistance Programs in Surrounding States and Provinces for more detail.

1. Idaho

The state of Idaho has three financial assistance programs available to private irrigators, irrigation districts and canal companies. The Idaho Water Resources Board Loan Program offers loans to canal companies and irrigation districts for development of centralized water delivery systems. All interest income is returned to help support the program. The Irrigation Efficiency Rewards Program, sponsored by Idaho Power, provides funding on a cost-share basis for the installation of new, more energy-efficient irrigation system or for the improvement of an existing system. The Resource Conservation and Rangeland Development Loan Program offers loans for all aspects of infrastructure development, or for conversion from flood irrigation to sprinkler.

The Resource Conservation and Rangeland Development Loan Program (RCRDP) is offered by the Idaho Soil Conservation Commission (ISCC) for private irrigators. The ISCC offers loans at varying interest rates based on the loan terms, including 1 to 5 years at 3 percent interest; 6 to 10 years at 4 percent interest; and 11 to 15 years at 5 percent interest. To date, the ISCC has issued over $14 million in loans to private irrigators in Idaho. Private irrigators can apply for multiple loans for new or separate projects.

The ISCC works in conjunction with the federal office of the local NRCS. The NRCS reviews all projects and offers the final certification for projects completed under the RCRDP. The NRCS standards for conservation are used as the measure for determining certification of a project. In many cases, the NRCS will also offer addition financial assistance through the EQIP program at the federal level as a secondary funding source for irrigation projects.

2. North Dakota

The State of North Dakota has one assistance program, Agriculture Partnership in Assisting Community Expansion, or Ag PACE. Administered through the Bank of North Dakota, in conjunction with the North Dakota Water Commission, it offers an interest rate buy-down for loans for the development of irrigation infrastructure or the purchase of irrigation equipment on new irrigated acreage.

3. South Dakota

We found no state-specific programs to assist irrigated agriculture in South Dakota. Most agricultural activity is in the eastern portion of the state, which generally receives enough precipitation during the growing season to preclude most demand for irrigation.

4. Wyoming

The State of Wyoming supports irrigation through three programs. The Wyoming Water Development Commission oversees the provision of grants and loans for river-basin planning, water-supply reconnaissance and feasibility studies, project planning, and construction projects. Through its Small Water

Project Program, it offers grants for the construction or rehabilitation of small reservoirs and stock watering ponds, wells, pipelines and conveyance facilities, springs, windmills, and wetland developments.

The Wyoming Office of State Lands and Investments administers the Small Water Development Project Loan Program, which provides loans for projects that convert dry land into irrigated land as well as for projects that will lead to more efficient use of water and/or increased crop or forage production.

The Wyoming Game and Fish Department offers grants to improve or maintain riparian and wetland resources through fencing, herding, stock-water development, streambank stabilization, small dams, beaver transplants, and similar efforts. It also provides grants to maintain or improve water for fish and wildlife through the development of springs and windmills, and the payment of irrigators' pumping costs.

5. Alberta

The Province of Alberta provides irrigators assistance through three programs. The Irrigation Rehabilitation Program provides cost-sharing grants to the province's 13 irrigation districts for maintaining irrigation infrastructure. The Canada Alberta Farm Water Program provides individual producers with financial and technical assistance for projects, such as dugouts, wells and pasture pipelines, that contribute to the development of long-term, on-farm water supplies. The Canada-Alberta Water Supply Expansion Program, which is part of the National Water Supply Expansion Program, provides technical and financial assistance for planning and the development of projects that will improve long-term, sustainable agricultural water supplies. Eligible applicants include incorporated groups of producers, agricultural and conservation groups, rural communities and municipalities, agri-businesses and rural enterprises, educational institutions, provincial government agencies, and Crown corporations. The program focuses on strategic partnerships and enhancing the understanding of the operational and developmental limitations to the water resources in rural communities and regions, such as regional groundwater studies, groundwater exploration or testing, regional water management planning and feasibility studies, and information extension activities. It also supports larger scale infrastructure projects, such as tank loaders, regional pipelines and reservoirs, which provide a long-term water source for multiple agricultural water users and promote economic growth in an area or region.

6. Saskatchewan

The Province of Saskatchewan provides assistance to irrigators through the Canada-Saskatchewan Water Supply Expansion Program, a component of the National Water Supply Expansion Program. Eligible applicants include incorporated groups of producers, agricultural and conservation groups, rural communities and municipalities, agri-businesses and rural enterprises, educational institutions, provincial government agencies, and Crown corporations. The program provides financial and technical assistance for on-farm water projects, such as dugouts, off-stream storage, wells and pasture pipelines, and for larger infrastructure projects, such as tank loaders, regional pipelines and reservoirs, that provide a long-term water source for multiple agricultural water users and promote economic growth in an area or region. It also supports strategic initiatives, such as regional groundwater studies, groundwater exploration and testing, regional water management and water supply planning, feasibility studies, demonstration projects and information extension activities.

F. Case Studies

We conducted four case studies to examine in greater detail the wide diversity of conditions associated with irrigated agriculture in Montana: the Greenfields Irrigation District northwest of Great Falls; the Bitterroot Valley; the Milk River Valley; and the Lower Yellowstone and Lower Missouri Valleys. The case studies reveal that there are many similarities as well as dissimilarities as one moves across the state. In each of the areas, there are irrigators or potential irrigators seeking to expand the extent of irrigation and stimulate development of industrial activities linked to irrigated crops. Each of these efforts, however, is encountering economic and financial hurdles difficult to overcome, and perhaps impossible to overcome in the foreseeable future without outside assistance from state or federal programs. Irrigators also face challenges maintaining existing irrigation systems, especially where the systems already have experienced serious depreciation, or where the organizational and financial responsibility for maintaining a system does not closely align with the benefits irrigators and others derive from the system.

The case studies also reveal that irrigation systems throughout the state produce many economically important externalities, both positive and negative. The nature and importance of these externalities is related to several factors, among them the proximity of urban development, the extent to which irrigation affects stream flows, and concerns about species at risk of extinction. The case studies indicate that, in most of the state outside the Lower Yellowstone and Lower Missouri Valleys, there is little, if any, water not already appropriated that can be used to expand irrigation. This indicates that, for much of the state, future investments in irrigation are likely to focus more on maintaining and improving the efficiency of existing systems than on creating new ones.

1. Greenfields Irrigation District

The Greenfields Irrigation District provides an example of a successful, large irrigation project. Located in Teton and Cascade Counties and largely centered on the town of Fairfield, about 35 miles northwest of Great Falls, it serves lands on the north slope of the Sun River valley, and on a series of benches along the tributary of Muddy Creek. The project includes three major storage facilities, Gibson Reservoir, Willow Creek Reservoir, and Pishkun Reservoir, with a collective capacity of 175,047 acre-feet, 99 miles of main supply canals, 385 miles of lateral distribution lines, and 239 miles of open drains and water-distribution canals. The district delivers 250,000 acre-feet of irrigation water per year, on average, to approximately 84,000 acres of irrigated land. The district, plus smaller, companion water developments in the area have essentially tripled irrigated acreage relative to pre-development levels. Average crop-water demand is about 159,000 acre-feet. Much of the area has been converted from flood to sprinkler irrigation, and on-farm irrigation efficiency is about 55 to 65 percent.

Most agricultural production in the area occurs on dry land, producing mostly wheat. The primary irrigated crops are barley, hay, and alfalfa, which account for nearly all irrigated land. The production of irrigated barley, in particular, is supported by Anheuser Busch's investments in grain facilities in Fairfield and a malting barley facility in Great Falls. Data are unavailable to determine the increase in net farm income provided by irrigation. Overall, net farm income represents 20 percent of total income in Teton County and two percent in Cascade County. Net farm income in Teton County was $8.7 million in 2006. Compared to many regions of Montana, farm incomes here are more robust: net farm income in Teton County dropped into negative territory in just four of the last 35 years.

Irrigation increases the value of land, but the extent of the increase is difficult to ascertain because factors other than the impact of irrigation on agricultural earnings are heavily influencing land values. Properties surrounding Fairfield are close enough to Great Falls that people are purchasing them as hobby farms, rather than as income-earning properties, and commuting to work in Great Falls. Property values to the west of Fairfield are being influenced by the recreational and amenity factors that are driving the markets for land in western Montana. Few properties in this area are being sold purely for production agriculture. However, appraisers point out that irrigated land values within the Greenfields Irrigation District are higher than those of nearby irrigated land served by other irrigation systems, and this difference can directly be tied to Greenfields' reputation for exceptionally reliable water delivery.

Positive externalities from irrigation include recreational opportunities at the reservoirs, fishing opportunities in Muddy Creek from enhanced year-round flows, enhanced bird-watching and hunting opportunities at Freezout Lake, which receives drainage water from irrigated lands, and flood control. Negative externalities arise primarily from problems with water quantity and quality in the Sun River and its tributaries. The mainstem of the Sun River is chronically dewatered, and water quality in Muddy Creek has been listed as impaired by Montana DEQ. These effects reduce recreational opportunities for anglers and boaters, and increase the costs of meeting environmental goals.

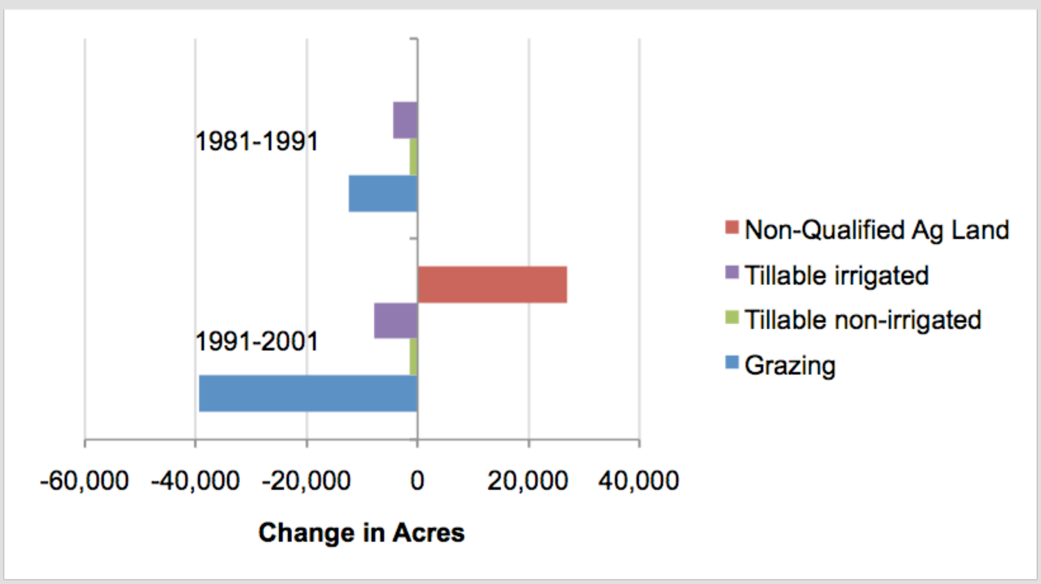
Little, if any, water is available to be appropriated for additional irrigation in this area. Hence, expansion of irrigated agriculture is possible only by improving the efficiency with which water is used in irrigation, or by purchasing water from other water-right holders.

2. Bitterroot Valley

The Bitterroot Valley, located south of Missoula, in Ravalli County, contains historically-irrigated valley bottoms and bench lands that form a band the length of the valley varying from 2 to 10 miles in width. Most of the valley's irrigated land lies in Ravalli County, which we use as our case study boundary. The area is closely tied economically to Missoula. It is one of the state's fastest growing regions, with population increasing 62 percent between 1990 and 2007. Farm employment has held steady over the past few decades, but has been dropping as a percent of total employment, and now provides fewer than 1,500 of the more than 20,000 jobs in the county.

The Bitterroot Valley was one of the state's first regions to be settled and irrigated. The narrow valley topography, relative abundance of water and mild climate lent to the development of smaller farm and ranch units than are found elsewhere in the state, a pattern reinforced from 1910 to 1920, when a substantial portion of the valley was subdivided into orchard tracts. Although most orchards were ultimately unsuccessful, one of their legacies was the existence of hundreds of small parcels already primed to become ranchettes. As of 1960, however, more than 110,000 acres were identified by the State Engineer's office as being irrigated, mostly producing forage for cattle, with additional lands in sugar beets and a few irrigated orchards. Since then, many acres in agricultural use have been converted to other uses. Between 1981 and 2001, the acres of tillable irrigated, tillable non-irrigated, and grazing land in Ravalli County decreased, while acres of non-qualified agricultural land increased, as Figure 4 shows. Non-qualified agricultural land includes parcels of 20 to 160 acres that

Figure 4. Change in Use of Agricultural Land in Ravalli County, Early 1980s to Early 2000s



Source: ECONorthwest, with data from Swanson (2006). See *Technical Memorandum 2.5 – Case Studies* for more detail.

have annual agricultural sales of less than $1,500—essentially this category describes land that has been taken out of commercial agricultural production. This trend away from commercial agricultural production seems likely to continue into the foreseeable future.

Irrigation continues to be a valuable activity in the valley, however. The major irrigation infrastructure in the valley remains intact and in use. The Lake Como reservoir stores 38,500 acre feet and the Painted Rocks Reservoir stores 24,300 acre feet. Several large ditches continue to serve thousands of acres. The large, professionally-managed irrigation projects generally operate as their counterparts do elsewhere in the state. On many streams and ditches, however, a number of individual water users compete for water without a manager or a management plan, resulting in water disputes, unnecessary water-use inefficiencies, withdrawals of water not consistent with the priorities associated with Prior Appropriation Doctrine, and some historically irrigated lands being deprived of their water entirely. Development of historically-irrigated lands often undermines past water-management arrangements by reconfiguring historic farm and ranch units into parcels that do not match up well with the historic ditch infrastructure. Some of the most problematic situations arise within the boundaries of a now-subdivided farm or ranch unit, where water-use decisions once vested in a single owner or manager are now made, typically without mutual consultation, by dozens of owners of the newly-formed ranchettes. Historically, irrigation water may have been moved around the farm or ranch. Now, many ranchette owners want water at the same time and for extended durations.

Sometimes, the operation of irrigated agriculture clashes with the values and activities of new suburban or exurban development. New landowners can impede irrigators from maintaining or diverting water from ditches. The juxtaposition of suburban development and irrigated fields raises liability issues, which can materialize if children fall into a ditch, for example.

The disconnect between development and water management has implications for water and land resources. Groundwater quantity and quality in the Bitterroot valley bottom area are beginning to show signs of degradation as a result of human population increase. The rate of new well development has been increasing for decades, with well depths generally increasing. In many instances, rural subdivision has left the majority of once-irrigated lands undeveloped. Much of this land, being too small to farm and too big to mow, is now dry, overgrazed, and weed-infested.

The most prominent externalities associated with irrigation are those associated with amenities. In general, the area's residents like having irrigated fields, the occasional horse, and water flowing through streams or ditches. They recently voted to spend $10 million to protect farmland and open space. The reservoirs provide recreational opportunities, and the ditches provide habitat for birds and small animals. However, negative externalities also accompany irrigation. Montana FWP has identified 77.5 miles of chronically dewatered streams in the valley, resulting primarily, if not exclusively, from irrigation withdrawals. The withdrawals reduce habitat for fish and other species, and some fish become trapped and die in ditches and canals (Gale and Zale 2005). Especially important are the impacts on bull trout, a federally listed threatened species, and westslope cutthroat trout, a species of special concern in Montana. A rough indication of the value of the fish harmed by irrigation activities comes from a survey of studies that have measured the economic importance of protecting species at heightened risk of extinction, such as the cutthroat trout in the Bitterroot Valley. The survey found that, on average, households would be willing to pay a one-time amount of $19 to ensure the continued survival of cutthroat trout.

3. Milk River

In its natural state, the Milk River was a prairie stream, fed by a watershed that includes no mountainous, high-precipitation areas. Prior to the development of the Bureau of Reclamation's Milk River Project early in the 20th century, the limited irrigation that occurred in the watershed frequently resulted in a complete de-watering of the stream. With the project and its associated imports of water, however, the Milk is likely the only major river system in Montana whose total flows actually exceed natural levels as a result of irrigation development. No other irrigated area in Montana is more dependent on water imported from another river basin.

The project diverts water from the St. Mary River, as it flows north into Canada from Glacier National Park, into a 29-mile canal/pipeline that carries water into the upper Milk River drainage. The diversion, canal, and pipeline are located on the Blackfeet Indian Reservation. The Milk then flows into Canada, but returns to Montana at a location northwest of Havre, over 200 miles later. The project also includes three storage reservoirs: Lake Sherburne, Fresno Reservoir, and Nelson Reservoir. It provides water to 98,777 acres in eight irrigation districts, plus 11,529 acres under contract, east of Havre, in the region's three eastern-most counties: Blaine, Phillips, and Valley. The number of irrigated acres has remained steady since 1944 due, in part, to limited, even somewhat reduced, water supplies. Irrigation has been almost exclusively oriented to the growth of hay and forage for use in cattle operations.

The area generally has experienced a loss of population for nearly 100 years. Consequently, urban encroachment has not displaced irrigated land here as it has elsewhere in the state. Conversely, the number of irrigated acres has not appreciably increased.

The linchpin of the Milk River Project is the St. Mary diversion and canal. This system was designed to convey up to 850 cubic feet per second (cfs) from the St. Mary River into the Milk River drainage. Deterioration of the St. Mary diversion and canal has reduced diversions to approximately 600 cfs. Further deterioration or major failures along the system could cause further reductions in flow, and even a complete system shut down. Other concerns regarding future water availability stem from the federal reserved water rights of the Fort Belknap, Rocky Boy, and Blackfeet Reservations, and the potential for significant increases in water use in the Canadian portion of the watershed.

Thus, the challenge on the Milk is not how to expand irrigated acres, but how to better manage and refurbish the existing infrastructure, and provide better water service to existing irrigated lands. The task is made especially challenging by the administrative nature of the project. The Bureau of Reclamation divides the project into three divisions, and water users are aggregated into eight irrigation districts (plus individual purchasers of water) strung out over 160 miles of the Milk River. Upstream users have little, if any direct incentive to manage water efficiently, because the benefits of such efforts accrue to downstream users. Water use typically is measured at diversion points on the river, not at individual user's headgates, and most diversions do not include measuring devices. In sum, there are limited individual incentives to use water efficiently, many incentives for a water user to act unilaterally, and a lack of infrastructure in place to administer water more effectively.

There are several proposals to correct these deficiencies. Some entail major investments to refurbish the diversion and delivery system. Others aim to improve water-use monitoring and management, perhaps through investments in water-conveyance and measurement systems, in water-conservation efforts, and in the development of a water market that would facilitate transfer of water from the production of crops yielding low net earnings to crops having a better financial return. One of the concepts being explored would entail creating a legal entity having authority to manage water on a basin-wide basis.

Economic studies indicate that farming in the Milk River Basin does not, on average, yield positive net earnings for either dry land farms or irrigated farms. A 2003 analysis by the Bureau of Reclamation found, for example, that farmers lost $226 per acre on dry land and $186 on irrigated land. Reclamation also estimated that the value of irrigated land was $280 per acre higher than non-irrigated land: $610 vs. $330 per acre. Thus, irrigation produces an economic benefit, insofar as it reduces farmers' losses, but irrigated farming does not, in the absolute, yield crops worth more than it costs to produce them. Farming can continue, even at a net economic loss, if farm families are willing to accept a loss so they can enjoy the related lifestyle.

Positive economic externalities from the Milk River Project take several forms. The project provides municipal water supplies for at least five towns and water districts, plus some domestic water users. At least 18,000 people in the three-county region served by these systems likely would incur higher costs to secure alternative sources of water. The project also directly or indirectly provides water for wetlands, improves the quality of water in the Milk River, and generates recreational opportunities associated with the reservoirs, such as in-stream angling, wildlife watching, and other activities. From a national perspective, perhaps the externality with the greatest value arises insofar as the Milk River contains five species of concern—the pallid sturgeon, paddlefish, blue sucker, pearl dace, and sauger—and research suggests that irrigation flows in Milk River contribute to continued survival of these species in this region.

Negative externalities materialize largely because the project removes water from the St. Mary River, which flows north into Canada. The effects of the diversion in the St. Mary River basin have not been evaluated.

4. Lower Missouri and Lower Yellowstone Valleys

This case study embraces the lower Missouri River Valley downstream of Fort Peck Reservoir, and the lower Yellowstone River Valley downstream of its confluence with the Powder River, and focuses on Dawson, McCone, Prairie, Richland, Roosevelt, and Valley Counties. This area comprises the epicenter of agriculture in the eastern third of Montana. Although rural in nature, in economic terms it is connected to two urban centers: Billings to the west, and Williston, North Dakota, to the east.

Irrigated agriculture here generally is more robust economically than in other parts of the state. It is expanding, with more expansions being planned, in part because water supplies are available for appropriation and suitable land is relatively cheap and available. In 2007, 63 pivots systems were installed on the Yellowstone and Missouri corridors by just one of the region's leading suppliers of irrigation equipment. Eighty percent of those are believed to have been installed on newly irrigated lands. Assuming the typical pivot coverage of 130 acres, this equals an expansion of irrigated land by 6,500 acres in 2007 alone. Several processing facilities in the area are supported by the production or irrigated crops, including a sugar beet plant and Anheuser Busch barley storage facilities in Sidney, and, to a lesser degree, an oilseed processing plant in Culbertson. Byproducts from the processing of irrigated crops, including sugar beets and some oilseed crops, also have supported the development of a few large dairies in the region.

Unlike the Milk River and Greenfields areas, no single project or infrastructure development dominates this area, nor is there a profusion of systems and small irrigation projects, such as those found in the Bitterroot area. The area reflects a blend of Bureau of Indian Affairs projects, Bureau of Reclamation projects, private ditch companies, and an increasing number of individual pump systems. Recent expansion in irrigated agriculture in the study area appears to be continuing, notwithstanding some challenges. For example, the cost of infrastructure, such as pumps, pipelines and pivots have increased in recent years, and pumping costs continue to rise. In the future, however, water availability may be diminished, due to increased demands from upstream users, particularly on the Yellowstone River. For example, coal development in the Wyoming portion of the Yellowstone basin may negatively impact both water quality and quantity of water flowing into Montana, and tribal claims to water by the Northern Cheyenne and Crow Tribes may reduce the total quantity of water available to other users in the basin.

Irrigation can yield economic benefits by increasing the yield of a crop that was previously cultivated without irrigation, or by enabling a farmer to grow a higher-valued crop. Both effects occur in the lower Missouri and lower Yellowstone Valleys. Much of the irrigated land in the valleys is dedicated to alfalfa and hay production, and irrigation increases the yields of these crops compared to growing them without irrigation. Some farmers in the area also grow sugar beets, malt barley, and other crops that require irrigation. In recent years, farmers have developed new irrigation almost exclusively to produce higher-valued crops, such as sugar beets, malt barley, and potatoes.

The production of more and higher-valued crops results in higher land values for irrigated land. According to appraisers familiar with the area, an acre of irrigated land in the lower Yellowstone Valley is around seven times more valuable than an acre of rangeland, and about five times more valuable than an acre of dry cropland. In the lower Missouri, the differences are about the same, perhaps slightly less, due to differences in the quality of the soil and reliability of water delivery in some projects. Overall, prices are highest in the lower Yellowstone Valley, where an acre of non-irrigated land may be valued between $350 and $475, while an acre of good-quality irrigated land may be valued as high as $4,000. Land values are beginning to be affected by the demand for the area's wide-open spaces, large undeveloped river bottoms, and world-class hunting opportunities, especially land adjacent to the Yellowstone River. For the most part, though, it is an area where the goal of passing a farm and ranch on to the next generation remains reasonable and viable, without outside demand pushing land values out of reach.

Irrigation in the lower Yellowstone and lower Missouri River Valleys is accomplished largely without the aid of large storage reservoirs (with the exception of Fort Peck Dam, which stabilizes the flow of the lower Missouri River), but several diversion structures and canals draw water from the rivers. These create both positive and negative externalities. For example, the Intake Dam on the lower Yellowstone River, which diverts water in the Intake Canal for the Lower Yellowstone Irrigation Project, creates a popular spot for anglers to catch the ancient Paddlefish, which migrates up the river each spring. This migration draws 3,000 anglers each year to Intake Dam. Over 500,000 fish, however, become stranded and die in the Intake Canal each year, which Montana FWP biologists estimate decreases recreational fishing opportunities downstream in the Yellowstone River for up to 10,000 anglers each year. The dam and canal also prevent upstream migration of several species of fish, having a negative impact on important populations, including the endangered Pallid Sturgeon. Proposed changes to the Intake Dam to allow fish passage is likely to change the way positive and negative externalities materialize in the future. For example, more fish will be able to migrate upstream and fewer will die as a result of irrigation infrastructure, increasing fish populations and fishing opportunities upstream of the dam, but the prime fishing locations downstream of the dam may diminish in importance.

III. ECONOMIC ANALYSIS

In this section, we examine the relationship between irrigation and Montana's economy from three perspectives. One, we look at the economic benefits and costs of irrigation, indicated by the extent to which using water to irrigate crops increases the supply of some valuable goods and services (a benefit) and decreases the supply of others (a cost). Two, we consider the extent to which irrigation has positive and negative impacts on jobs, income, and related variables. Three, we appraise emerging opportunities and constraints that are likely to affect the irrigation-economy relationship in the future. First, however, we briefly present a conceptual framework for understanding the relationship.

A. Conceptual Framework for the Economic Analysis

Decades ago, the relationship between irrigated agriculture and Montana's economy was straightforward. Agriculture dominated economic activities in most communities and, for many, a reliable supply of cheap water for irrigating crops was required to increase farm incomes or, in some cases, to make farming feasible. Accordingly, investments in irrigation infrastructure were seen as a straightforward way to promote economic development and improve the well being of the state's families and communities.

Today, the relationship is more complex. The agricultural sector has strengthened in some communities but weakened in others. The economy has evolved so that the economic strength of many communities derives less from the strength of their farms and ranches and more from their ability to attract productive people and cultivate business activity in non-farm sectors. A wide range of public policies—farm subsidies, international trade, environmental protection, and much more—can both encourage and discourage irrigation. Extreme prices for energy and fertilizer, growing demand for food from China and other developing countries, and changes in climate create both challenges and opportunities not imaginable just a few years ago. Within this setting, one reasonably can conclude that investments to maintain or increase the supply of irrigation water will have multiple economic consequences, some positive and some negative.

To help understand and sort through these consequences, we employ an analytical framework that begins by recognizing they arise insofar as irrigation alters the ability of a water-related ecosystem to provide not just water for crops but also a diverse set of other goods and services. Whenever there is insufficient water to provide all the goods and services society desires, an investment in irrigation affects all of the competing demands for water resources, and accounting for all these effects is required to understand the overall economic consequences. We distinguish among three types of economic consequences arising from an investment in irrigation: (1) changes in the *value* of the goods and services themselves; (2) *impacts* on the jobs and incomes (and related variables) that derive from the goods and services; and (3) changes in economically important *uncertainties and risks* regarding future values and impacts. We also consider potentially important issues associated with the distribution of positive and negative consequences among different groups. In the following few pages we elaborate on the different elements of the analytical framework; for more detail please see *Technical Memorandum 2.1 – Irrigation and Montana's Economy: A Conceptual Framework*.

1. Ecosystem Goods and Services

Over the past several decades, ecologists and economists have greatly expanded their understanding of the economically important goods and services provided by water-related ecosystems. Table 5 illustrates their diversity. Some are economically important when they are extracted, as when water is diverted from a stream to irrigate crops; others when they remain *in situ*, as when boaters and anglers use instream flows for recreation. For the remainder of this report we simplify things by using the terms "goods and services" to refer to those that make a positive contribution to the economy, but we recognize that there are others, such as damaging floods, that are economically important in a negative sense.

2. Competition for Water Resources

In most times and places there is insufficient water to satisfy all the demands for all of the goods and services in Table 5. Hence, there is competition for the water and, when water is used to produce one set of goods and services, the demands

Table 5. Summary of Goods and Services Produced by Montana's Water-Related Ecosystems

Examples of Goods and Services Produced					
1	Production and regulation of water	7	Production of food for humans	12	Production of ornamental resources
2	Formation & retention of soil	8	Production of raw materials for industry	13	Production of aesthetic resources
3	Regulation of atmosphere & climate	9	Pollination of wild plants and agricultural crops	14	Production of recreational resources
4	Regulation of floods and other disturbances	10	Biological control of pests & diseases	15	Production of spiritual, historic, & cultural resources
5	Regulation of nutrients and pollution	11	Production of genetic & medicinal resources	16	Production of scientific & educational resources
6	Provision of fish and wildlife habitat				

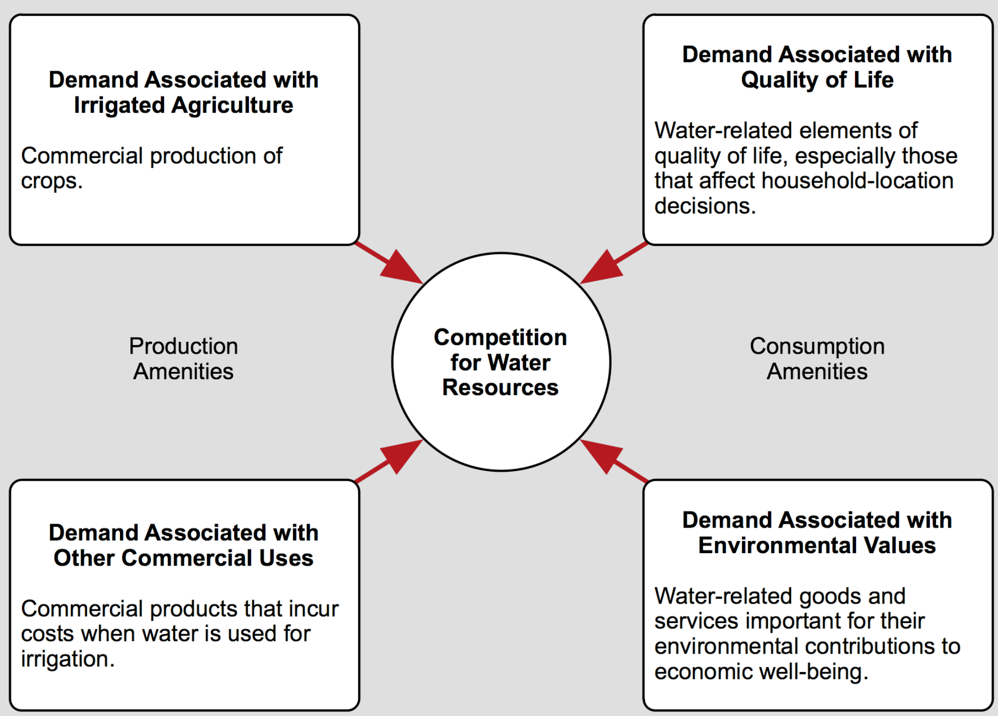
Source: Adapted by ECONorthwest from De Groot, Wilson, and Boumans (2002); Kusler (2003); and Postel and Carpenter (1997). See *Technical Memorandum 2.1 – Irrigation and Montana's Economy: A Conceptual Framework* for more detail.

for others go unmet. This competition is distinct from the system of water rights that allocates water to satisfy some demands and leaves others wanting. Because they both reflect and shape the economic importance of different water-related goods and services, the characteristics of this competition provide useful insights into the economic consequences of future investments in irrigation infrastructure.

One could categorize the competition in any of a number of ways, but we employ a taxonomy that distinguishes among four types of demand, as illustrated in Figure 5. Two of these are called demands for production amenities, i.e., those goods and services that are, or could be, inputs to processes that produce other goods and services. The other two are called demands for consumption amenities, i.e., those goods and services that directly enhance the well being of consumers. To facilitate the discussion, we assume that one of them—the demand for irrigation, shown in the upper left of Figure 5—prevails and then look at the consequences for the others.

Competition for Production Amenities. Demands for Montana's water-related production amenities, represented on the left side of Figure 5, come from private and public enterprises, defined broadly to include private corporations, incorporated cities, and public agencies, as well as households that conduct commercial activities, such as ranching operations. We separate the demands for production amenities into two groups—irrigated agriculture and other

Figure 5. The Competing Demands for Montana's Water Resources



Source: ECONorthwest. See *Technical Memorandum 2.1 – Irrigation and Montana's Economy: A Conceptual Framework* for more detail.

commercial demands—to show that, sometimes, the positive consequences arising from irrigation can be offset, more or less, by negative effects on other commercial sectors, which are represented in the bottom left of Figure 5. When an irrigator depletes stream flows and reduces fish habitat, for example, he may reduce the production by irrigators downstream who now have less water for their fields, or impose costs on fishing guides who now have fewer prime fishing spots for their customers.

Competition Directly from Consumers. On the left side of Figure 5, water-related goods and services are economically important because they are inputs in the production of other things (e.g. crops, hydroelectricity, etc.) that consumers want to have. On the right side, the connection to consumers is more direct. Here, consumers consider Montana's water resources economically important for how they directly contribute to their well-being. In economic parlance, these are known as consumption amenities.

Some water-related goods and services, such as recreational opportunities and scenic vistas, contribute directly to the well-being of people who have access to them. Their contribution to consumers' well-being makes them economically important in their own right, but they have additional economic importance when they also influence the location decisions of households and firms. We show the demands for consumption amenities that influence location decisions of households sensitive to spatial variation in the quality of life, in the upper right portion of Figure 5. In general, the nearer people live to amenities, the lower their cost of using them. Thus, consumers can increase their economic well-being by living in a place that offers recreational opportunities, pleasant scenery, wildlife viewing, and other amenities they consider important. Quality-of-life values can be powerful. Differences in quality of life explain about half the interstate variation in job growth (Partridge and Rickman 2003), and the quality of life available in Montana is a major factor influencing why many households come to and stay in the state. Some Montanans undoubtedly could enjoy higher earnings living elsewhere, but choose not to do so because their overall economic welfare—the sum of their earnings plus quality of life—is higher here. Some aspects of this quality of life—the strength of communities, schools, and churches, for example—are not directly related to water, but others are: open space, way of life, and opportunities for fishing and hunting, to mention a few. All else equal, if the state's water-related consumption amenities improve, some people already here will tend to stay and additional people will tend to move in. Degradation of the amenities will have the reverse impacts.

The lower right portion of Figure 5 represents demands associated with economic values that do not necessarily entail a conscious, explicit use of water-related goods and services. We call these environmental values. There are two general categories: nonuse values and values of goods and services that generally go unrecognized. Nonuse values arise whenever people place a value on maintaining some aspect of the environment, even though they do not use it and have no intention to do so. Research has documented nonuse values for maintaining the existence of species threatened with extinction, for example, and for special natural areas, such as national parks. They also can materialize when people want to maintain a particular cultural or ecological characteristic of a resource, as when people want to maintain the existence of landscapes associated with traditional agriculture or native wilderness, for enjoyment by future generations.

Environmental values also can be important when a water-related ecosystem provides valuable services that people generally consume without being aware of them. Some of these are part of the so-called web of life. Others, such as the ability of wetlands to purify water and mitigate flood damage, have a more direct link to the well-being of Montanans. Some scientists and economists believe many services have great economic value, even though people generally are unaware of their importance (Daily 1997). Environmental values typically increase as people learn more about the environment, the services it provides, and environmental degradation (Blomquist and Whitehead 1998). Many people today, for example, consciously consider the economic values associated with the services produced by the global climate in ways that were unknown, even to scientists, just a few years ago.

The demands associated with the consumer amenities represented on the right side of Figure 5 are typically harder to measure, or even to observe, than the commercial demands shown on the left side of the diagram. This difficulty does not diminish their value or impact on jobs and incomes, however. Instead, it merely reflects the lack of tools for measuring them.

3. Measuring the Benefits and Costs of Irrigation

Irrigation generates an economic benefit when it increases the economic value of a good or service. It can do this either by increasing the supply of the good or service available for society's use at a given price or by reducing the cost of producing the good or service. Conversely, it generates an economic cost when it diminishes the supply at a given price or increases production costs.

Economists typically measure the economic value of a good or service in terms of what a person, group, or firm, which does not have it, is willing to give up to acquire it. It is not necessary to measure value in monetary terms, but doing so generally simplifies the measurement. If money is used as the units of measurement, then the value of a good or service is the amount the person, group, or firm is willing to pay for it. Sometimes, value is measured when a person, group, or firm already possesses a good or service, so that the value of the good or service equals the amount the person, group, or firm is willing to accept as compensation for relinquishing it.

When a good or service is traded in a fully-functioning, competitive market, the price at which it is traded provides a good representation of both what the seller requires as compensation to relinquish it and what the buyer is willing to pay to acquire it. Thus, the market price a farmer receives for an irrigated crop traded in a competitive market probably provides a reasonable representation of the crop's value both to the farmer and to the overall economy. Most water-related goods and services are not traded in competitive markets, however, and there are no prices one can use to measure their economic value. The absence of a market price does not mean these goods and services have no value, only that they are not traded. When goods and services are not traded in markets, economists must use non-market techniques for measuring their value. Some of these techniques look at consumers' behavior to see what it reveals about the value they place on goods and services. To estimate the values recreationists place on distinct recreation sites, for example, economists have looked at how much visitors pay in travel costs to reach them, and concluded that households are willing to pay more to reach higher-quality sites. Other techniques ask people what they are willing to pay to retain, acquire, or protect a good or service. This technique is used, for example to determine the value people place on protecting habitat for endangered species.

Some of the studies and data we employ directly describe the value of goods and services in Montana. Others describe economic research that has focused elsewhere, but we include it in the discussion because there are reasons to believe that similar findings would be obtained if the studies were repeated in Montana. We also describe some studies with findings that are not specifically applicable to Montana, because they offer useful insights into the general nature and magnitude of the value of various irrigation-related goods and services.

Irrigation yields a net economic benefit when the value of the goods and services it produces exceeds the value of those that were used in the production process. When the converse is true, then it yields a net cost. A net benefit or cost can accrue to different parties. An irrigator realizes a net benefit, called a producer's surplus, when she sells a unit of a crop for a price higher than the cost she incurred to produce it. A consumer can realize a net benefit, called a consumer's surplus, when she buys a unit of a crop for less than she is willing to pay for it. A third party—an individual, household, business, or society as a whole—realizes a net cost or benefit, called a negative or positive externality, respectively, when the transaction between an irrigator and a consumer reduces or increases the value of goods and services available for its use.

In general, irrigators' costs to produce an additional unit of a crop increase as quantity increases, and, conversely, the amount consumers are willing to pay for an additional unit of a crop decreases as quantity increases. When large quantities of an irrigated crop are produced and sold under competitive market conditions, producers increase production and consumers increase their purchases until the point where the amount consumers are willing to pay for an additional unit of the crop equals the producers' cost. This balance point determines the market price. When the market clears at this price, most units of the crop being sold cost irrigators less than this amount to produce and they realize a producer's surplus. At the same time, most consumers would have been willing to pay more than the market price for the units of the crop they purchased and, hence, they realize a consumer's surplus. As we explain below, irrigation typically results in externalities, some positive and some negative, for others.

4. Measuring the Economic Impacts of Irrigation

Following standard practice, we use the term, *economic impacts*, to refer to the changes in jobs, income, and related variables, such as property values, that result from irrigation. Economic impacts are not the same thing as benefits and costs. It is possible for irrigation to produce a large benefit, i.e., a big increase in the supply of a valuable good or service, yet have little impact on jobs and income, and *vice versa*. Economic impacts generally reflect expenditures; if more money should flow through the economy, all else equal, the economy should experience an increase in the number of jobs and/or in the level of incomes. Many of the goods and services affected by irrigation, however, are valued in ways that do not involve monetary expenditures.

Irrigation usually has both positive and negative economic impacts, arising from the competing demands for water illustrated in Figure 5. Increasing the supply of water for irrigation might increase jobs and income in agriculture and farm-related sectors, but if it reduces instream flows, it might also decrease jobs and income associated with commercial enterprises that sell services to anglers and boaters. It might increase the value of residential properties with an attractive view of irrigated fields, but decrease the value of those that now look onto a dewatered stream. Irrigation might increase farmers' incomes so they are willing to pay additional taxes to support public services, but the availability of some services might be diminished if local and state agencies must dedicate resources to cope with the negative impacts of water withdrawals on fish and other aquatic species.

Initial expenditures, jobs, and incomes resulting from irrigation can have a ripple, or multiplier effect in the economy, so that the overall impact is larger. When a farmer earns $1 from irrigated crops, he will spend some of this amount to purchase goods and services from outside the local area, but will spend the remainder in local businesses, creating income for the business owners and their workers. They, in turn, will spend some outside and some locally, and this process will repeat itself until, after several iterations, none of the farmer's initial income remains in the local economy. The overall income will be greater than the farmer's initial income resulting from the production of irrigated crops, and the ratio of the overall income to the farmer's initial income is a measure of the multiplier effect. Research shows that the multiplier effect is limited in most settings, so that the ratio is often smaller than 1.5, and rarely more than 2.0.

Two major factors limit the multiplier. One is the broad regional, national, and even international integration of today's economy, which increases the percentage of income that households and firms use to purchase goods and services from outside the local economy. The other is the competition for water, illustrated in Figure 5, which means that an increase in jobs and income associated with the production of irrigated crops often is offset by a decrease in other sectors of the economy. This latter factor is reinforced when the economy is operating at its full capacity, so that irrigated agriculture can attract capital investment, workers, and supplies only by drawing them away from other enterprises.

The importance of offsetting impacts is diminished when irrigation attracts expenditures from outside sources that otherwise would not take place. Such an occurrence materializes perhaps most visibly when federal funds, which come primarily from taxpayers outside Montana, are available to support irrigated agriculture and failure to spend the funds in Montana would result in their being spent elsewhere.

B. Economic Benefits and Costs of Irrigation

In this section, we describe the economic benefits of irrigation, describe the costs, discuss the overall net benefits (or costs), and address several factors likely to affect benefits and costs in the future. We distinguish among three measures of economic value. The most fundamental is the public's total willingness to pay for a good or service (or for a set of goods and services). This measure can have two components. One is the amount people actually pay for the good or service, i.e., their expenditures. The other exists if the amount they pay is less than what they would be willing to pay. In such an instance, the difference between the two is a net economic benefit consumers enjoy from acquiring the good or service. This net economic benefit is called *consumer's surplus*.

We encourage readers to use the information in this section cautiously. The numbers we report represent not precise measurements, but general indicators of the economic costs and benefits related to irrigation in Montana. Many numbers come from studies conducted several years ago or in another state, and, as a general rule, the greater the temporal, ecological, or economic distance between a study and Montana, the greater the ambiguity when applying its results to Montana. Moreover, observable values of water-related goods and services are distorted by what economists call externalities. These arise whenever a decision affecting a water resource yields costs or benefits that accrue to individuals, households, firms, or governments that are not a party to the decision. In sum, the information below provides a general representation of the benefits and costs associated with irrigation in Montana; it would be inappropriate, however, to assume, without further investigation, that the estimates herein represent the benefits and costs of irrigation in a specific location within the state. All values reported in this section are in 2006 dollars, unless otherwise noted.

1. Net Benefits to Irrigators

The net benefits irrigators derive from irrigation water are indicated by two variables: the amount farmers are willing to pay per acre-foot of water; and the amount they are willing to pay for irrigated farm land.

Irrigation and Net Farm Earnings. The most recent and authoritative review of past studies concludes that, although values can differ over time and space, under the "most plausible assumptions," U.S. farmers are willing to pay about $46 to have an additional acre-foot available on the farm for irrigation, and about $31 per additional acre-foot for water at its source (Young 2005). These values indicate that, on average, when farmers have an additional acre-foot of water

Table 6. Increase in Annual Net Farm Earnings Resulting from Irrigation, as Indicated by Recent Studies in or near Montana

	Increase in Annual Net Farm Earnings from Irrigation	
Study Location	**Per Acre-Foot**	**Per Irrigated Acre**
Missouri River Basin	$23	$32
Milk River Basin[a,b]	$30	$42
Beaverhead Valley[a]	$32	$45
Black Hills SD-WY[a]	$22	$51
Statewide Class III Land Growing Alfalfa[c]	$5	$7

Source: ECONorthwest, with data from sources described in *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana*.

[a] Estimated difference in net earnings for a typical farm, with vs. without irrigation.

[b] Both dryland and irrigated farming yield negative net farm income, but losses are less with irrigation.

[c] Statewide difference between the average value of class III irrigated land and the average value of class III non-irrigated land; not an estimate of the difference in the value of the same property, with-versus-without irrigation. Value in 2008 dollars.

available on the farm (at the source) they experience an increase in crop sales, minus their increased operating costs equal to $46 ($31).

The value of irrigation water in Montana appears to generally be less than the national average, which is not surprising insofar as most of the water used in the state irrigates low-value forage crops on lands without cheap access to large markets. The results of recent research in or near Montana, shown in the middle column of Table 6, confirm this conclusion. The top four rows of the table show the results of site-specific studies that estimated how the net earnings on a typical farm would differ, with vs. without irrigation. The results vary, from $23 per acre-foot in the Missouri River basin, to $32 per acre-foot in the Beaverhead Valley. The lowest values materialize where the water is used to produce forage on lands with poor growing conditions (high elevations, poor soils, etc.) or poor market conditions (isolation from markets, etc.). Research results from the Milk River Basin indicate, for example, that net farm earnings are negative for both dry land and irrigated land, but the losses are less with irrigation. A preliminary feasibility assessment completed for the proposed Chester Irrigation Project, located in the Marias River Basin, indicated that irrigation may not always produce higher net earnings for farmers than non-irrigated crop production, as additional revenues for the sale of irrigated crops would not offset the additional costs associated with irrigation (Montana DNRC 2005).

The right column of Table 6 shows the value of irrigation water in terms of the increase in annual net earnings farmers realize per irrigated acre. The top four rows show the increase, derived from studies that compared, for a typical farm in each study area, the annual net earnings with vs. without irrigation.

The last row of Table 6 also indicates the value of irrigation, but with an important difference. It reflects calculations, by the Montana Department of Revenue, of the average, statewide difference in the value of irrigated and non-irrigated class III land used to grow alfalfa. The calculations are important because much of the water used for irrigation in Montana irrigates alfalfa. The calculations indicate that the irrigated land has higher annual, net farm earnings of about $5 per acre-foot, or $7 per acre. These figures are not strictly comparable to those on the first four lines of Table 6, however, because, unlike in the other studies, the department's calculations do not isolate the effects of irrigation from those of other factors that might affect the difference in the value of irrigated and non-irrigated class III land growing alfalfa.

Table 7 provides a broader context for considering the value of irrigation water. The figures in the table show the estimated increase in net farm earnings from irrigation water reported in recent, significant studies conducted in Oregon, California, and Alberta, Canada. The figures indicate that the highest values occur in the Central Valley of California, with lower values on lower-quality land in Malheur County, Oregon (near Boise, Idaho), in the Klamath Basin (east of the Cascade Mountains, on the Oregon-California border), and in Douglas County, Oregon (west of the Cascades). The values in Tables 6 and 7, from studies in and near Montana, generally indicate that the value of irrigation water in Montana is less than the values in highly productive agricultural areas, such as the Central Valley and the best areas in eastern Oregon, but are comparable to or greater than the values in the less productive areas of Oregon. All of these value should be used with some caution, as they come from imperfect data sets and analytical techniques, such as hedonic price analysis, that have limited ability to isolate irrigation from other factors that affect crop production and cropland values (Griffin 2006, Young 2005). Insofar as they reflect past conditions, the values in Tables 6 and 7 may offer a poor indication of the value of irrigation in the future if market conditions, climate, and other factors should be markedly different (Deschenes and Greenstone 2007).

Table 7. Increase in Annual Net Farm Earnings Resulting from Irrigation, as Indicated by Recent Studies Elsewhere

Description	Value per acre-foot
Central Valley, CA	$27 – $58
Malheur County, OR	$11 – $54
Klamath Basin, OR	$5 – $58
Douglas County, OR	$16
Alberta, Canada	$8[a]

Source: ECONorthwest, with data from sources described in *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana*.

[a] Value in 1997 Canadian dollars.

Absent a major structural change in agricultural markets, it seems likely that the value of an incremental change in the supply of irrigation water is and will continue to be less than the current, average values represented in Table 6. (Later in this section we discuss the factors that might bring about a major structural change.) In general, farmers irrigate the land and crops that yield the highest net earnings before they irrigate those with lower net earnings (Griffin 2006). As a consequence, the irrigation-related net earnings from an incremental increase in the supply of irrigation water is likely to be less than the net earnings from on-going irrigation. Where water is being used to irrigate low-value crops far from major markets, the net benefits to farmers of an incremental increase in the supply of irrigation water would fall to zero (Hansen and Hallam 1990). Indeed, the Milk River study, shown in Table 6, indicates that using new water supplies to irrigate land currently not in crop production would yield negative net farm earnings (Otstot 2003).

None of this is to say that the on-farm value of water used for irrigation in Montana can never exceed $46 per acre-foot, or that the at-the-source value can never exceed $31 per acre foot. The irrigation value of water depends on many factors, including the amount and timing of the water available, and the evolution of agricultural market conditions. These and other factors must be evaluated to ascertain the value of irrigation water in a specific time and place.

Irrigation and the Value of Farm Land. For the most part, Montana's farmers do not buy and sell water, *per se*, and, hence, it is not possible to observe the value of irrigation water directly from water-market transactions. Farmers do, however, buy and sell farm land, and the value of irrigation water manifests itself in the higher price of irrigated land relative to comparable dry land. The higher price of irrigated land reflects the extent to which farmers expect to realize higher net farm earnings from this land relative to dry land.

Table 8 shows estimates of the effect of irrigation on the value of farm land, derived from the recent studies in or near Montana incorporated in Table 6. The figures in the first three rows, derived from studies in different locations, indicate that adding water to land that otherwise would be farmed as dry land increases the land's value by about $650 to $800 per acre. This is not inconsistent with the effect of irrigation on land value observed by appraisers in Montana. Appraisers in western Montana are generally reluctant to generalize the difference in value between irrigated and non-irrigated land, because the price of most parcels reflects not their agricultural production value, but the potential for development or their scenic and recreational amenities; prices for these parcels far exceed any realistic rate of return from agriculture. Appraisers in eastern Montana, where these factors have less (but not zero) influence on the price of agricultural land, report that, in general, dry crop land runs several hundred dollars per acre, and irrigated land is anywhere from 4 to 7 times more valuable, depending on a variety of factors, including location, soil quality, and reliability of water delivery. Irrigated land in the most productive areas of eastern Montana can sell for as high as $4,000 per acre (see *Technical Memorandum 2.5 – Case Studies* for more detail).

Table 8. Increase in the Value of Farm Land Due to Irrigation, as Indicated by Recent Studies in or near Montana

Study Location	Increase in Value Per Irrigated Acre
Milk River[a]	$656[c]
Beaverhead Valley[a]	$703[c]
Black Hills SD-WY[a]	$797[c]
Statewide Class III Land Growing Alfalfa[b]	$108[c]

Source: ECONorthwest, with data from sources described in *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana*.

[a] Estimated difference in net earnings for a typical farm, with vs. without irrigation.

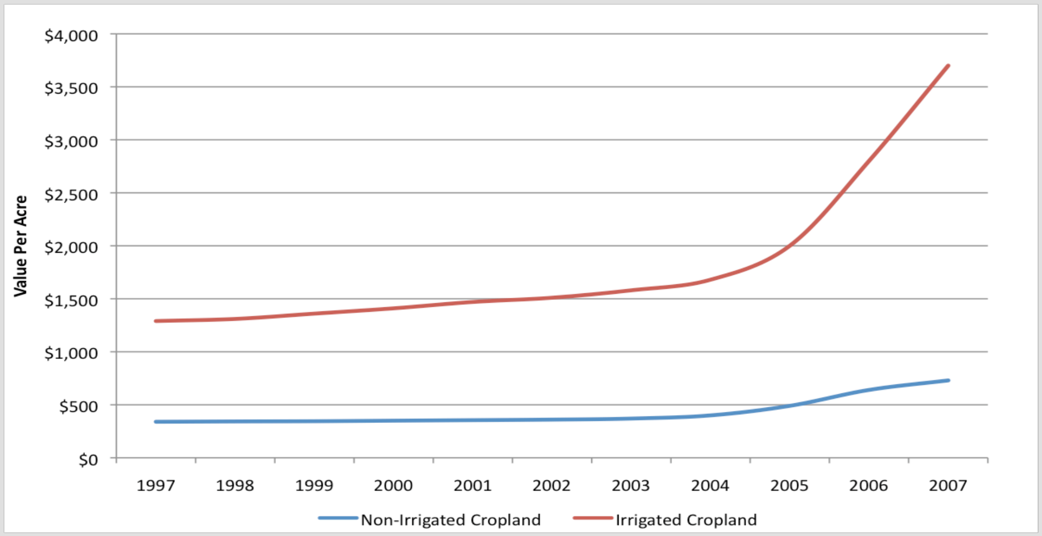
[b] Statewide difference between the average value of class III irrigated land and the average value of class III non-irrigated land; not an estimate of the difference in the value of the same property, with-versus-without irrigation. Value in 2008 dollars.

[c] Values from Table 6, capitalized at a rate of 6.4 percent.

The bottom row of Table 8 shows the 2008 calculations by the Montana Department of Revenue of the average difference in the value of irrigated vs. non-irrigated class III land used to grow alfalfa. For the state as a whole, the value of the irrigated class III land used to grow alfalfa is about $108 greater per acre than comparable non-irrigated land.

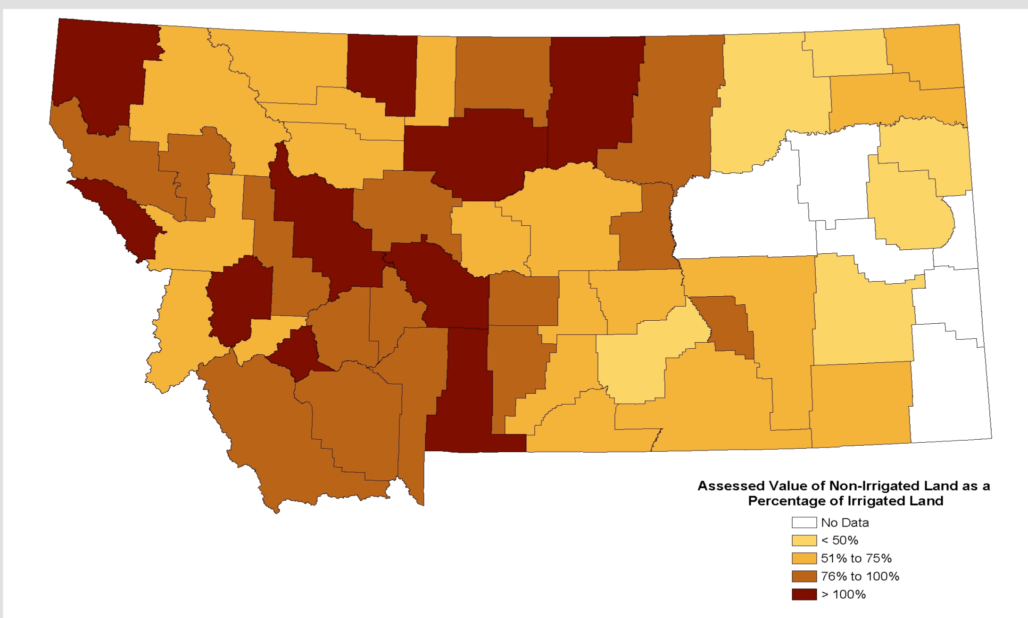
The graph in Figure 6 and the map in Figure 7 provide broader perspectives on the impacts of irrigation of the value of farm land. The graph shows the average value of irrigated and non-irrigated lands in the state over the past decade, as measured by U.S. Department of Agriculture. For the first few years, the difference was less than $1,000 per acre, but this has grown rapidly, to about $3,000 per acre in 2007. The data underlying this graph are not strictly comparable to the figures shown in Table 8, insofar as they do not separate the impact on irrigation of land value from the impact of other factors. Anecdotal information from appraisers an landowners, as well as other indirect evidence suggests that much of the recent increase in the value of irrigated land stems from the growing demand to use this land more for residential and investment purposes than for agricultural production. It is too early to tell what impact, if any, the collapse of the real estate "bubble" nationwide will have on this component of demand for irrigated land. The increase also might reflect rising prices for some irrigated crops, such as corn, relative to prices for crops grown on dry land. It is too early to tell what impact, if any, the recent fluctuations in the price of wheat, which is grown mostly on dry land and the price of corn, which is grown on irrigated land, will have on the separation between the price of irrigated and non-irrigated land.

Figure 6 Average value of Irrigated and Non-Irrigated Cropland in Montana



Source: ECONorthwest, with data from the U.S. Department of Agricultural, National Agricultural Statistics Service, Montana Field Office (2007). See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for details.

Figure 7. Average Assessed Value of Class III Non-Irrigated Land as a Percentage of the Average Assessed Value of Class III Irrigated Land, by County for 2008



Source: ECONorthwest, with data from the Montana Department of Revenue, Property Assessment Division (2008). See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for more detail.

The map in Figure 7 shows the relationship, by county, between the value of irrigated and non-irrigated land. The underlying data come from the Montana

Department of Revenue's calculation of farm land values. The darkest areas of the map identify counties where dry land is, on average, more valuable per acre than irrigated land; the lighter areas show the reverse. The department strives to make its data reflect only land values associated with agricultural production.

2. Net Benefits to Montanans as a Whole

The increases in net farm earnings and land values resulting from irrigation tell only part of the story about the overall net benefits of irrigation. Also important are the economic consequences that accrue to others, which economists call externalities. Externalities can be positive or negative. They can come in two forms: as cash transfers (subsidies) and as changes in the surrounding ecosystem's ability to produce goods and services. We are aware of no study that provides a full accounting of the externalities of an irrigation project in Montana or its neighbors, although several explore externalities with some vigor:

- The most thorough, recent analysis examined a proposal to rehabilitate and expand the irrigation infrastructure that delivers water from the St. Mary River to the Milk River (Bioeconomics 2006). It considered several kinds of externalities: an increase in the supply of water for municipal-industrial use, changes in recreational opportunities, changes in water quality, creation of wetlands, and the creation of opportunities for job creation in an area experiencing chronic, high unemployment and poverty. It concluded that, overall, the benefits of the proposal outweigh the costs.

- The Bureau of Reclamation developed a feasibility study to evaluate the present and potential water supplies, water uses, water management, water-related issues, and potential solutions in north-central Montana, including the St. Mary River, Milk River, and Marias River (U.S. Department of the Interior, Bureau of Reclamation 2004). The study analyzed a variety of potential benefits that would result from more water being available in the region, including benefits for irrigation, municipal, residential, and industrial water supplies, threatened and endangered species, water quality, fish and wildlife habitat, recreation, and hydropower. The Bureau concluded that one potential alternative, St. Mary Canal System Enhancement, would produce positive economic benefits.

In the remainder of this section, we summarize information regarding the general value of different types of externalities that might accompany a future investment to maintain, rehabilitate, or expand the state's irrigation infrastructure. We emphasize that this information does not necessarily represent the externalities that would accompany any specific investment. Instead, it identifies the types of externalities that might be important and illustrates their potential importance.

Subsidies to and from Irrigation. Direct subsidies to irrigation occur when households and businesses that do not derive a benefit from irrigation pay some

Table 9. Status of Repayment of Costs Allocated to Irrigation for Bureau of Reclamation Projects in Montana[a], as of September 1994[b]

Project	Repayment to Date	Future Repayment	Charge-offs and Discounted Loans
Bitter Root	$2,426,120	$10,102,720	$2,620
Buffalo Rapids	$1,260,220	$573,780	$5,063,150
Frenchtown	$389,070	$0	$1,310
Huntley	$2,181,150	$310,470	$537,100
Intake	$61,570	$0	$61,570
Lower Yellowstone	$5,205,940	$0	$856,740
Milk River	$8,862,150	$3,584,160	$4,421,250
Missoula Valley	$49,780	$0	$314,400
Sun River	$17,014,280	$0	$8,115,450

Source: ECONorthwest, with data from United States General Accounting Office. 1996. *Bureau of Reclamation Information on Allocation and Repayment of Costs of Constructing Water Projects.* Report to the Ranking Minority Member, Committee on Resources, House of Representatives. GAO Report No. GAO/RCED-96-109. July. Retrieved February 19, 2008, from http://www.gao.gov/archive/1996/rc96109.pdf

[a] Not included below are seven projects in Montana that are individual units of the larger Pick-Sloan Missouri Basin Program. They include the Canyon Ferry, Cow Creek Pump, East Bench, Helena Valley, Lower Marias, Savage, and Yellowtail Units. Of the 6 million acres of irrigation envisioned through the development of the Pick Sloan Program nation-wide, only 500,000 acres across the country were actually developed. Determining irrigators' repayment obligations and federal subsidies of irrigation development for these projects is complicated by hydropower subsidies and other provisions unique to the Flood Control Act of 1944 and the Pick Sloan Missouri Basin Program.

[b] Values are converted to 2007 dollars.

or all of the cost of providing water to irrigators. Public subsidies to irrigation in Montana and other western states have existed for more than a century (Reisner 2003). We are aware of no data describing all of the direct subsidies to irrigation in Montana or the non-federal subsidies. Table 9, however, summarizes some of the federal subsidies, showing the extent to which Congress has absolved irrigators from their obligation to repay the costs of federal dams and related facilities. The right column of the table shows, for example, that as of 1994, irrigators receiving water from the Bitter Root Project had been relieved of $2,620 (2007 dollars) of their obligation. Irrigators receive additional subsidies for federal projects insofar as Congress does not require them to pay interest on their obligation or to pay that share of their obligation that project administrators determine they are unable to pay.

Irrigated agriculture also receives a subsidy when federal farm programs pay farmers amounts they otherwise would not receive. The data in Table 10 report the amounts of the top six farm subsidy programs paid to Montana farmers for the period, 2003 to 2005. We are unaware of any data that isolate the subsidy amounts attributable solely to irrigated agriculture. The top two subsidy programs in Montana, for the Conservation Reserve Program (CRP) and for

Table 10. Top Federal Subsidy Programs in Montana, 2003 to 2005[a]

Program	Subsidy Total
Conservation Reserve Program	$366,652,080
Wheat Subsidies	$308,008,564
Disaster Payments	$244,405,362
Barley Subsidies	$97,779,931
Livestock Subsidies	$48,964,651
Environmental Quality Incentive Program	$16,409,856

Source: Environmental Working Group (2006). See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for more detail.

[a] Values in 2007 dollars.

wheat, probably are not contributing much to support irrigated agriculture, insofar as wheat is primarily a dry land crop in Montana, and CRP provides support for farmers to convert sensitive agricultural land to native vegetative cover that would require little to no irrigation. In fact, environment-based subsidies, such as those provided under the CRP, have lowered the demand for irrigation in some areas by providing farmers with income as they preserve, or even restore the landscape. Some consider CRP and similar payments subsidies because they reward farmers for practices they should undertake without the payments; others consider them payments for ecosystem services (PES) farmers otherwise would not provide society. We discuss CRP in the context of PES in a later section. The other top subsidy programs in Montana—barley, livestock, disaster payments, and EQIP—probably do benefit irrigators:

- In 2002, 23 percent of Montana's barley crop was irrigated; in comparison, just over 2 percent of the wheat crop was irrigated. Assuming irrigators received barley subsidies at the same rate as dryland farmers, and assuming the proportion of the barley crop that was irrigated remained constant between 2002 and 2005, subsidies for irrigated barley totaled around $22.4 million.
- The EQIP program helps farmers conserve ground and surface water resources. EQIP funds, for example, allow farmers to convert flood irrigation systems to more efficient irrigation technologies. Between 2004 and 2008, irrigators received $18.6 million in EQIP funds.
- Livestock producers rely heavily on irrigation to produce alfalfa and feed grains, which they feed to their animals throughout the winter months.
- Irrigators may apply for disaster payments when their crops fail, due to drought, flooding, or other natural disasters. It is likely that irrigators face damage from natural disasters just as dryland farmers do, and may disproportionately experience the effects of drought if they plant crops that require more water and sufficient irrigation water does not materialize. On the other hand, irrigation can act as an insurance policy against drought, allowing farmers to produce some crops during

droughts when dryland farmers experience near-total crop failure, lowering their need to apply for disaster payments. Data on the extent to which irrigators receive disaster payments are unavailable.

It is important to note that, from the perspective of the State of Montana as a whole, farmers' receipt of subsidies from the federal government constitutes an economic benefit, for little cost. All but a small fraction of federal tax receipts comes from taxpayers outside the state and, hence, federal subsidies paid to Montana's farmers are, for the most part, a transfer of money from those taxpayers to Montana residents. From this perspective, if state investments in irrigation infrastructure stimulate agricultural activities that attract federal subsidies, then these subsidies should be viewed as an economic benefit, or return, on the investment.

Environmental Externalities of Irrigation. Through its impacts on the environment, irrigated agriculture can yield many economic benefits and costs that accrue to households and firms other than irrigators. Table 11 illustrates some of these externalities, identifying some of the ways in which irrigation affects the three types of competing demands associated with other commercial demands, quality-of-life demands, and environmental-value demands (see the discussion, above, in conjunction with Figure 5). The list demonstrates that irrigation can have both positive and negative externalities, which often are similar to one another. For example, some irrigation systems make water available for nearby municipal-industrial water users, provide agricultural open space and scenic vistas enjoyed by neighbors, create reservoir-related recreational opportunities, and, through leakage from canals, create wetlands. At the same time, irrigation systems deplete the amount of water available for other commercial uses, reduce the amount of water to support stream-related open space and scenic vistas, and diminish stream-related wetlands.

Most of the externalities are familiar, at least in concept, but some warrant further explanation. Two positive externalities stand out. One that many Montanans consider quite valuable materializes when irrigated fields provide open space and improve the quality of life for nearby residents. In addition, some Montanans realize a benefit when irrigation maintains traditional agricultural lifestyles and landscapes they consider to have value, even though they do not live this lifestyle or manage lands to sustain this landscape.

More of the potential negative externalities require clarification. When an irrigator uses water, it imposes costs on other potential commercial users—other farmers and enterprises in other sectors—able to generate higher net earnings from the water. Other enterprises also incur costs, similar to a tax, when an irrigated field delivers sediment, nutrients, and other pollutants to water bodies. The sediment can clog ditches and stream beds, diminishing their ability to handle high water flows and increasing the risk of flooding. Nutrients and other pollutants—primarily herbicides, but also petroleum and other products spilled during the operation of irrigations systems—can require costly removal before the water is appropriate for municipal-industrial uses. Although many people recognize the flood-control benefits of dams built to collect water in the spring for irrigation use in the summer, such a dam may also reduce the viability of downstream soils and vegetation to mitigate flooding, thereby creating a risk for downstream property owners. Irrigation can have negative impacts on habitat for some species while it has positive impacts for others. The negative impacts become especially important , however, when the population of an affected species declines to the point where it faces significant threat of extinction. Montanans and other Americans repeatedly express a desire to prevent extinctions, almost without regard for the economic consequences and, hence, when an irrigation system has a negative impact on such a species, the economic value of the externality can be huge.

Table 11. Illustration of Potential Externalities of Irrigated Agriculture

Potential Positive Externalities	Potential Negative Externalities
Commercial Demands • Increased municipal-industrial water supplies • Irrigation-related business opportunities • Groundwater recharge from infiltration of irrigation water	**Commercial Demands** • Depletion of water available for other commercial uses • Off-farm costs to cope with irrigation-related erosion and sediment • Off-farm costs to remove irrigation-related nutrients and pollutants from water supplies
Quality-of-Life Demands • Contributions to recreation: o Reservoirs and canals o Hunting birds and wildlife supported by reservoirs and irrigated fields • Contributions to communities: o Agricultural contributions to rural economies o Traditional agricultural life style • Maintenance of agricultural open space and scenic vistas	**Quality-of-Life Demands** • Decreased recreational opportunities: o Instream boating and fishing o Watching wildlife dependent on natural streamflows • Detriments for communities: o Reductions in water quality o Loss of stream-related contributions to rural and urban economies • Loss of stream-related open space and scenic vistas
Environmental-Value Demands • Wetlands resulting from leakage of irrigation water • Dam-related flood control • Improved habitat for species associated with reservoirs, canals, and irrigated fields • Maintenance of agricultural lifestyles and landscapes that are valuable to those Montanans who are not irrigators	**Environmental-Value Demands** • Loss of wetlands associated with dewatered streams • Reduction in ability of natural floodplains to control floods • Loss of habitat for species associated with instream flows and related riparian, areas and wetlands • Degradation of water quality from irrigation-related soil erosion and runoff • Threats of extinction for some species dependent on water and land diverted to irrigated agriculture • Ecosystem fragmentation and loss of biodiversity • Loss of natural streams and landscapes that are valuable to Montanans, whether they interact with them or not

Source: ECONorthwest. See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for more detail.

In the remainder of this section we provide information regarding some of the potential externalities of irrigation in Montana. This information is not intended to quantify the externalities, positive or negative, associated with any particular irrigation system. Instead, it provides background for understanding the nature and potential importance of the different externalities. For more detail, see *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana*.

Municipal-Industrial Water. Several communities receive water from systems developed primarily to provide farmers irrigation water. Table 12 identifies the communities served by projects established by the Bureau of Reclamation and shows the retail and wholesale rates they pay for the water.

Recreational Opportunities Enhanced by Irrigation Projects. State parks, the Bureau of Reclamation's recreation sites, the Bureau of Land Management's recreation sites, and National Wildlife Refuges offer public access to boating, fishing, wildlife-watching, camping, swimming, and picnicking opportunities in and around reservoirs in Montana that provide water for irrigation. Eleven major recreation sites surround reservoirs that are part of Bureau of Reclamation water projects. Many of these sites provide a full suite of recreational facilities, others sites are less developed, and offer opportunities for hunting, fishing and wildlife watching. For example, Canyon Ferry Reservoir is a haven for bird watchers; tailwater below the Bureau's Yellowtail Dam produces blue-ribbon fisheries on

Table 12. Municipal & Industrial Water Rates in Areas Served by Bureau of Reclamation Water Projects in Montana

Project	City/Town	Retail Water Rate ($ per acre-foot)	Wholesale Water Rate ($ per acre-foot)
Milk River	Chinook	$700.58	$244.01
Milk River	Harlem	$700.58	$198.81
Milk River	Kremlin	$700.58	$263.49
Milk River	Gilford	$700.58	$263.49
Milk River	Hingham	$700.58	$68.94
Milk River	Rudyard	$700.58	$263.49
Milk River	Inverness	$700.58	$263.49
Milk River	Joplin	$700.58	$263.49
Milk River	Havre	$700.58	$242.54
Lower Marias	Chester	$700.58	$195.61
Huntley	Ballantine	$474.80	$178.57
Huntley	Worden	$474.80	$134.61
Helena Valley	Helena	$322.50	$125.90

Source: U.S Department of the Interior, Bureau of Reclamation, Contract Services Office, Office of Program and Policy Services (2006). See *Technical Memorandum 2.2 – Net Economic Value of Irrigation in Montana* for more detail.

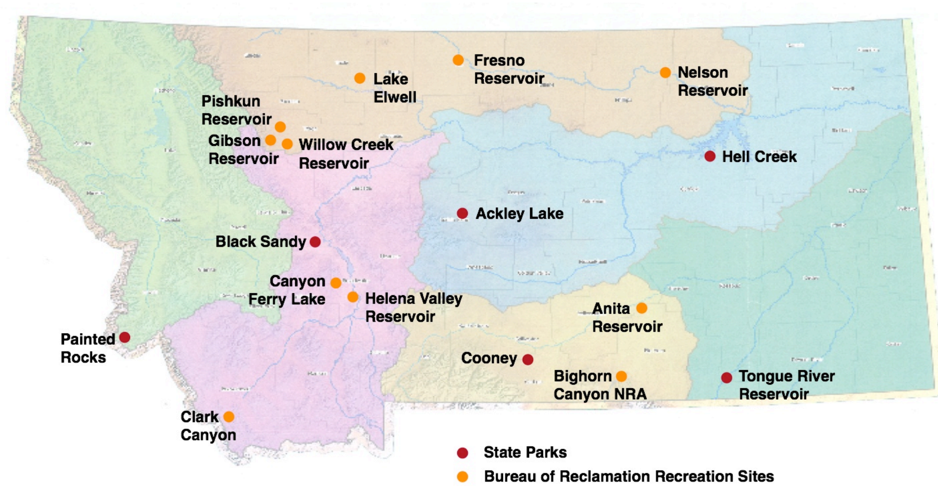
the Big Horn River; and anglers flock to similar world-class blue-ribbon tailwater fisheries on the Missouri River, below a series of dams, including the state-owned Toston Dam, and the Bureau's Canyon Ferry Dam.

State parks also provide public access to reservoirs, and Cooney Reservoir State Park is one of the most-visited state parks in Montana. Figure 8 shows the locations of these state parks, as well as the relevant Bureau of Reclamation recreation sites related to irrigated agriculture. Other state lands throughout Montana are managed to provide recreational opportunities in conjunction with irrigation. For example, Montana Fish Wildlife and Park's (FWP) Freezout Lake Wildlife Management Area, located in Teton County, is augmented by canal drainage from the Greenfields Irrigation District.

Recreational Opportunities Diminished by Irrigation. Diverting water from streams for irrigation means less instream flow to support fishing, boating, wildlife watching, and other stream-related recreation in some areas. In the extreme, streams are left without water. Montana FWP estimates that there are over 2,000 miles of chronically dewatered streams in the state. Of these, Montana FWP has created a list of dewatered streams that support important fisheries by providing spawning and rearing habitat. This list includes 278 streams, which are significantly dewatered, and 103 streams, which are periodically dewatered. Figure 9 shows the Montana FWP's list of dewatered streams on a state map. According to Montana FWP, most stream dewatering is a result of irrigation withdrawals, although dam regulation for power production also contributes to the problem. Most human-caused dewatering occurs during the irrigation season (July through September).

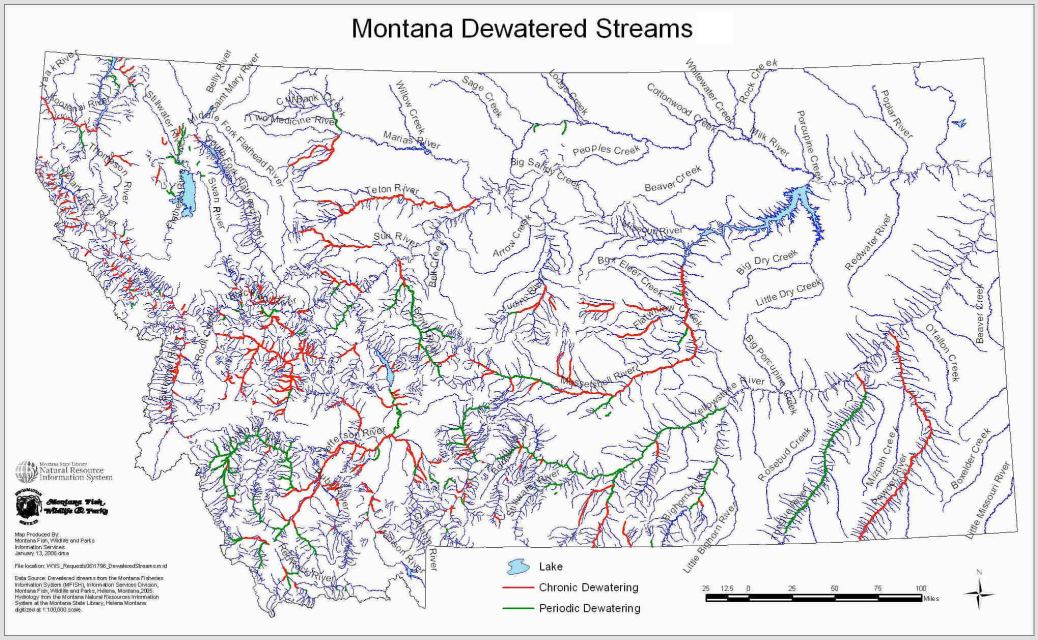
Evidence from several sources indicates the value of stream-based fishing in

Figure 8. State Parks and Bureau of Reclamation Recreation Sites Related to Irrigation Infrastructure in Montana, by Basin



Source: ECONorthwest. Base map by PBS&J. See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for more detail.

Figure 9. Dewatered Streams in Montana



Source: Montana Fish, Wildlife & Parks. See *Technical Memorandum 2.2 – Net Economic Benefits of Irrigation in Montana* for more detail.

Montana and other activities affected when water is diverted from streams. Table 13, for example, shows several indicators, derived from a 2005 survey of anglers completed by Montana Fish, Wildlife, and Parks. The top row shows there were about 1.9 million activity-days of angling on Montana's streams that year (an activity-day is one person angling for some portion of one day). On average, anglers spent $76 per activity-day and would have been willing to spend an additional $54. This latter amount, called the consumer's surplus by economists, reflects the net benefit an angler derives from a day of fishing and roughly corresponds conceptually to the net earnings irrigators derive from using one

Table 13. Components of the Value of Stream-Based Recreational Fishing in Montana, 2005[a]

	Components of Value		
	Expenditure	Consumer's Surplus	Total
$ Per Activity Day:			
	$76	$54	$130
Total (million $ for 1.9 million Activity-Days):			
	$144	$103	$247

Source: ECONorthwest, with data from Montana Fish, Wildlife, and Parks (2005).

[a] Values in 2007 dollars.

acre-foot of water for irrigation. The total value per activity-day of fishing was $130. The numbers indicate that, for the 1.9 million activity-days of fishing, the total expenditures were about $144 million, the total consumer's surplus was about $103 million, and the total value (expenditures plus consumer's surplus) was about $247 million (all values in 2007 dollars).

A recent analysis in the Salt River Valley of Western Wyoming illustrates the general nature and magnitude of the tradeoffs that can occur between irrigation and recreational fishing. The authors found that, if 3,200 acre-feet of water were left in the stream over 90 days, both stream flows and the population of adult brown trout would triple (Covington and Hubert 2003). We explain above that, if the water were used efficiently, irrigators likely would place a point-of-diversion value of about $31 per acre-foot, or about $99,000 total, on this water. On average, however, irrigation systems divert about three times the amount of water that crops consume, so the actual cost, in forgone crop production, would be one-third of $99,000, or about $33,000. If the water were, instead, left in the stream and attracted additional recreational fishing with a net value of $54 per activity-day (the average consumer's surplus for all streams in Montana), then the loss to irrigators would be offset if there were about 600 additional activity-days of fishing (all values in 2007 dollars).

Although this brief assessment focuses on the economic tradeoffs that can arise when irrigation reduces stream flows, it also is possible, in appropriate circumstances, for an irrigation system to increase recreational fishing opportunities. This outcome materializes most commonly when a system involves a reservoir that produces angling opportunities that otherwise would not exist. Our discussion of the Milk River case study, above, also provides an example of an irrigation system boosting instream-flows above levels that otherwise would exist.

Considerable evidence indicates that the value of recreational fishing is even higher on many streams in Montana and that the value is likely to grow rapidly in the future. A recent study found that consumer's surplus associated with fishing on high-quality streams in Wyoming and Idaho is $100 per activity-day (Loomis et al. 2005). The authors of another study concluded that the economic values associated with outdoor recreation in the U.S., as a whole, are growing faster than inflation, with the value of an outdoor recreational activity-day growing by about $1.00 per year (Rosenberger and Loomis 2001).

Alteration of Natural Flow Regimes. Biologists have observed that the alteration of stream flows occasioned by the diversion of water for irrigation can have profound effects on the ability of a water-related ecosystem to provide goods and services. One survey of the literature concluded with this statement: "The alteration of flow regimes is the most serious contemporary threat to the ecological sustainability of rivers and their associated floodplains" (Naiman, et al. 1997). Although in a few cases, flow alterations may produce positive consequences for certain kinds of fisheries, as in the tailwater fisheries below the dams on the Upper Missouri River, in many other cases, such as in the cool streams that support cutthroat trout throughout western Montana, withdrawals from the stream for irrigation can have considerable negative consequences for the ecosystem that support aquatic life (USDA Natural Resources Conservation Service 2005).

Existing information and current analytical tools are insufficient to yield a reliable estimate of the overall value of the changes in the production of ecosystem goods and services that accompany alteration of natural flow regimes. Several studies, however, do provide some insight. One examined the overall recreational and nonuse values of instream water in the Missouri River Basin, above Ft. Peck Dam, in July and August of 1989 (Duffield et al. 1990). It found that, in the upper portion of this basin, the average value of instream flows ranged from about $54 to $77 per acre-foot. In the lower portion of this basin, the average value of instream flows ranged from about $9 to $14 per acre-foot. Another study examined the recreational (trout fishing) values in 1988 associated with instream flows on the Big Hole and Bitterroot Rivers (Duffield, Neher and Brown 1992). It found that, at low flows of about 100 cubic feet per second (cfs), the incremental value of increasing flows was $16 per acre-foot on the Bitterroot and $40 per acre-foot on the Big Hole. At higher flows (2,000 cfs), the incremental values were $0 per acre foot and $1.75 per acre-foot, respectively. As we note above, there are strong reasons to believe that these figures underestimate current and future values of instream flows and natural flow regimes.

C. Net Economic Impacts of Irrigation

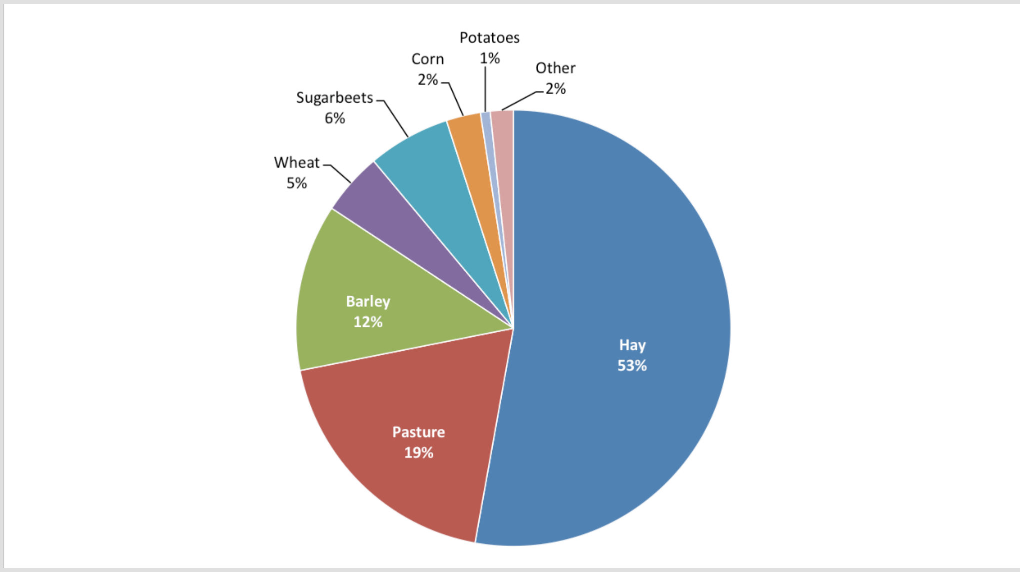
Water-related goods and services have economic importance not just for their *economic value,* but also for their *economic impacts*, i.e., their ability to generate jobs and income. Economic values and impacts are not the same thing. Something with a high value may generate few jobs and little income, and *vice versa*. In general, goods and services generate impacts when people spend money on them, and the expenditures course through the commercial sectors of the economy; this is what happens when water is used to irrigate crops. They also can have impacts by influencing household-location decisions that, in turn, influence business-investment decisions. Others have high environmental values, which can have indirect impacts by affecting the cost of living and doing business in a location and by stimulating voluntary or regulatory changes in behavior.

To describe the net economic impacts of irrigation we first examine jobs and incomes derived directly from irrigation and then we look at the potential impacts that derive from irrigation's externalities, i.e., its unintended consequences for other elements of the economy.

1. Irrigation-Related Jobs and Incomes in Montana

Data on the impacts of irrigated crops, *per se*, are often lacking. Hence, we augment the available information regarding irrigated agriculture with information for the agricultural sector as a whole.

Figure 10. Percent of Irrigation Water Applied by Crop[a] in Montana, 2003



Source: ECONorthwest, with data from USDA, National Agricultural Statistics Service (2004b). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

[a] Hay includes alfalfa and other hay varieties; Corn includes seed and silage varieties; Other includes soybeans, dry edible beans, other grains, vegetables, orchards, and other crops.

Irrigated Crops. Figure 10 shows that irrigation in Montana is used primarily to produce hay and pasture, but also barley, wheat, sugar beets, corn, potatoes, and other crops. Although some hay, pasture, barley, and wheat is irrigated, considerable production of these crops comes from non-irrigated lands. The percents shown in Figure 10 are rough approximations, derived from a survey of farmers and ranchers (USDA, National Agricultural Statistics Service 2004b). The survey results indicate that 72 percent of all irrigation water in Montana is applied to irrigate hay and pastureland. Only about 18 percent of all harvested cropland in the state is irrigated.

In 2006, the last year for which data are available, agricultural sales in Montana totaled $2.8 billion, farms received direct government payments of $275 million, and farm operators realized net farm income of $257 million after incurring expenses (USDA, Economic Research Service 2007). Table 14 shows the cash receipts farmers received from selling different crops in 2006. Wheat was by far the largest revenue generator. Sugar beets, potatoes, and corn, which require intensive irrigation, generated revenues of $52 million, $29 million, and $5 million respectively. Sales of livestock, which consumes irrigated pasture and hay, and related products generated revenues of $1.3 billion in 2006. Irrigated lands typically produce crops with higher value than non-irrigated lands: on average, the market value of crops produced on irrigated lands is 64 to 80 percent higher per acre than those produced on dryland (USDA, National Agricultural Statistics Service 2004a). The higher revenues can arise because irrigation increases the yield of a crop: the average yield of alfalfa hay on irrigated land is about 3 tons per acre, but only about 1 ton per acre on dry land.

Table 14. Cash Receipts from Marketing, by Commodity, 2006

Commodity	Receipts (thousand dollars)
Wheat	$688,415
Barley	$96,561
Sugar beets	$51,778
Hay	$93,642
Potatoes, fall	$28,880
Oil crops	$9,977
Oats	$2,037
Dry beans	$5,846
Corn	$5,198
Cherries, sweet	$1,071
All other crops	$86,572
Total Crops	**$1,069,977**

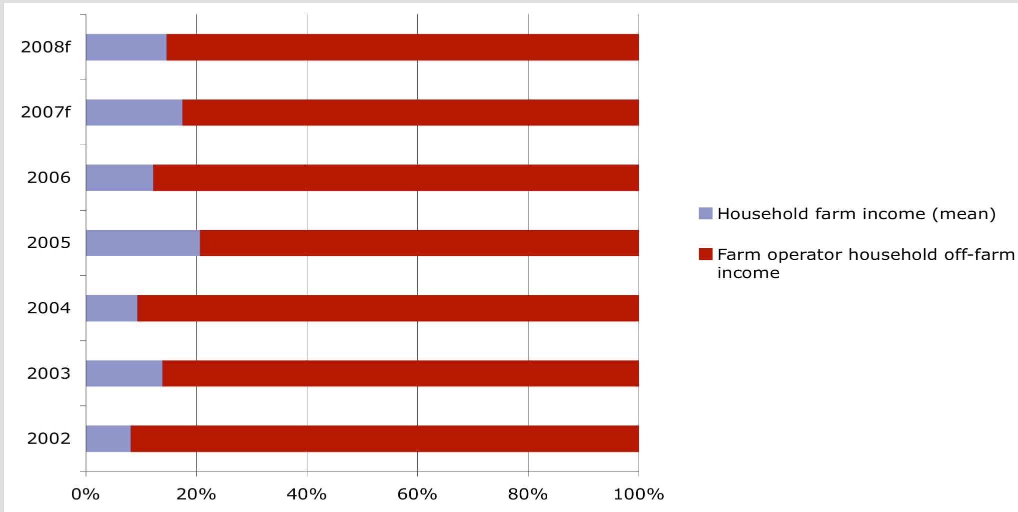
Source: ECONorthwest, with data from USDA, National Agricultural Statistics Service (2006). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

Irrigation also may enable a farmer to grow a high-value crop that cannot be grown on dry land. For example, irrigation in eastern Montana has allowed farmers to expand production of sugar beets, a higher-value crop, and farmers in the region are looking to expand into other emerging higher-value crops, such as oil crops, plant-based pharmaceuticals, herbs, and biofuel feedstocks (*see* "Case Study 4: Irrigation on the Lower Yellowstone and Lower Missouri River Valleys" in *Technical Memorandum 2.5 – Case Studies* for more detail).

Agricultural Jobs and Income. Montana's agricultural industry employed 31,535 people (both full-time and part-time) in 2005. Farm owners' net earnings plus payments to employees totaled almost $464 million that year, equal to about 20 percent of the total receipts from agricultural sales. For most farmers and ranchers, however, income derived from farm operations is a small proportion of total income. Figure 11 shows that, for the Mountain Region, which includes Montana, farm income was only 20 percent of total income for farm households in 2005. According to the Census of Agriculture, only 13 percent of farms in Montana count farm income as their primary source of income (USDA, National Agricultural Statistics Service 2004a).

Figure 12 illustrates how average farm income (the operator's net earnings from farm operations) varies across the state's counties. In 2002, ten counties—Beaverhead, Glacier, Liberty, Hill, Choteau, Broadwater, Meagher, Wheatland, Musselshell, and Treasure—saw average farm incomes greater than $15,000 per farm. Average farm income was less than $5,000 in seven counties—Lake, Silver Bow, Carbon, Sheridan, Richland, Wibaux, and Fallon. In every county, farm income represents less than 50 percent of average personal income per household, and in most counties, it represents less than 25 percent. It is

Figure 11. Farm Income (from Farm Operations) as a Percentage of Total Income of Farm Households, Mountain Region, 2002 to 2008[a]



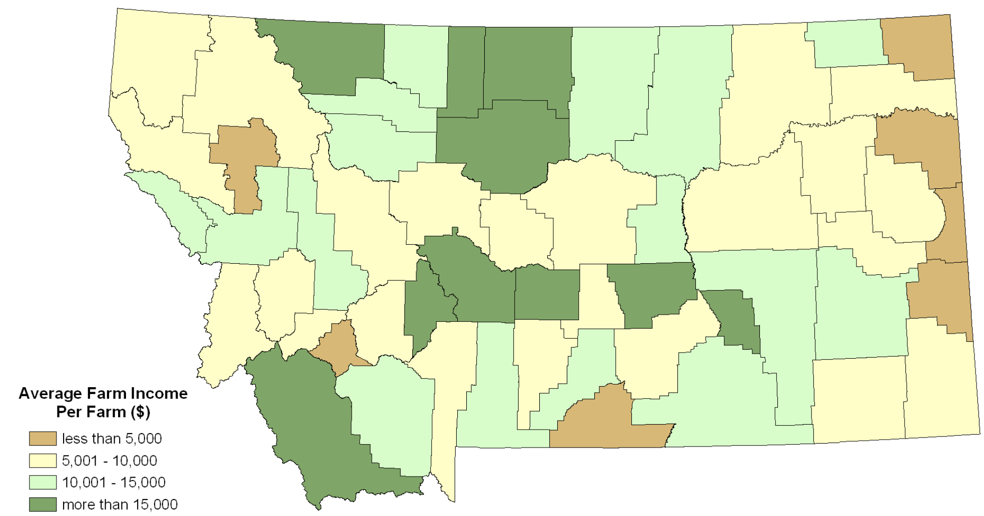
Source: ECONorthwest, with data from the U.S. Department of Agriculture, Economic Research Service (2008). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

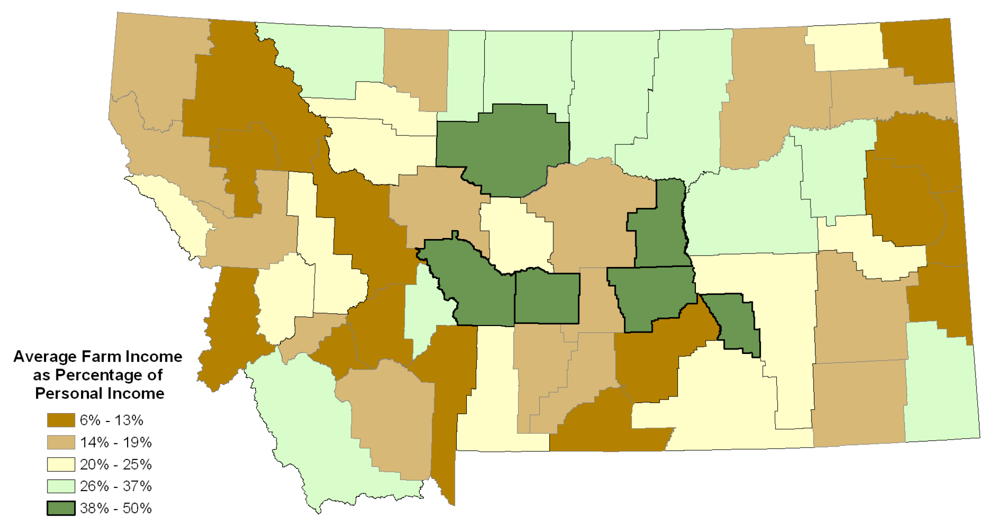
[a/f] Data from years 2007 and 2008 are forecasts.

important to recognize that the reported farm income in a particular county can change dramatically from year to year, depending on crop yields and prices, which are affected by weather patterns and market conditions. Figure 12 presents a snapshot of income in 2002, the last year for which these data were available from the Census of Agriculture. Comparing these data to farm income statistics reported by the Bureau of Economic Analysis indicate that incomes in 2002 were lower than the average farm income reported between 2000 and 2006.

Changes in farm employment and income show mixed patterns and trends over the past several decades. Most counties lost farm jobs and farm income between 1970 and 2000. Figure 13 shows more recent patterns and trends, from 2001 to 2005. Changes in farm employment were slight, but most counties lost some jobs. Farm employment includes the sole proprietors of farms, their business partners, and any hired farm labor. Seventeen counties experienced a reduction in farm income, which includes the net income of sole proprietors and wages, salaries, pay-in-kind, and supplements to wages and salaries of hired farm laborers. Farm incomes generally have risen since 2001.

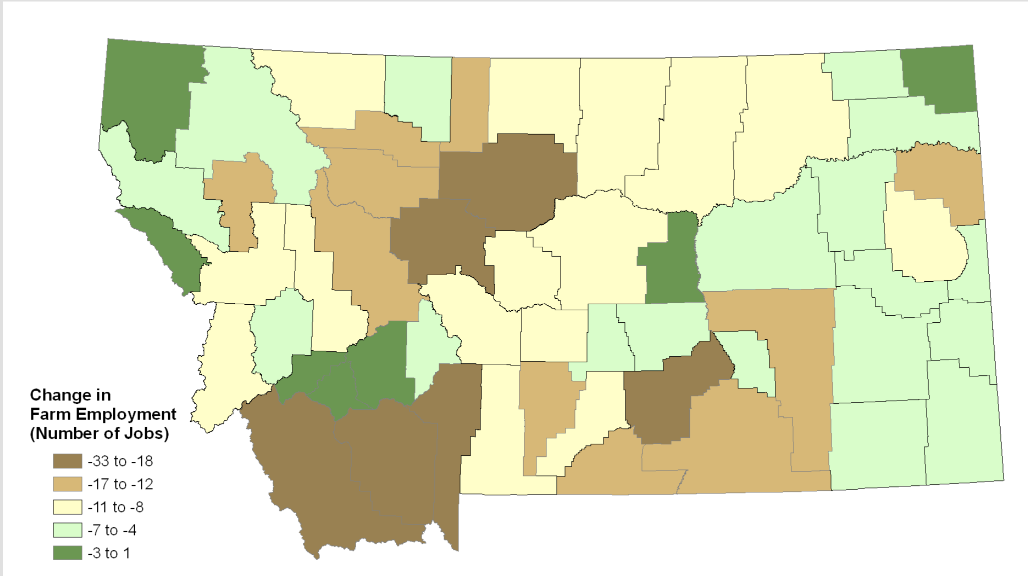
Figure 12. Average Farm Income per Farm and as a Percent of Personal Income per Household, by County, 2002

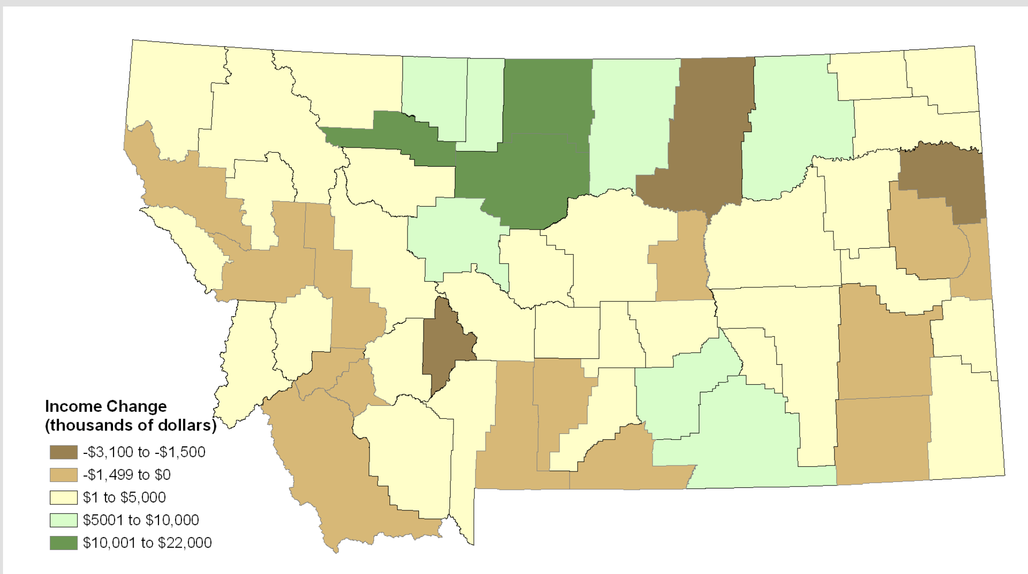




Source: ECONorthwest, with data from USDA, National Agricultural Statistics Service (2004a). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

Figure 13. Changes in Farm Employment and Income, by County, 2001 to 2005

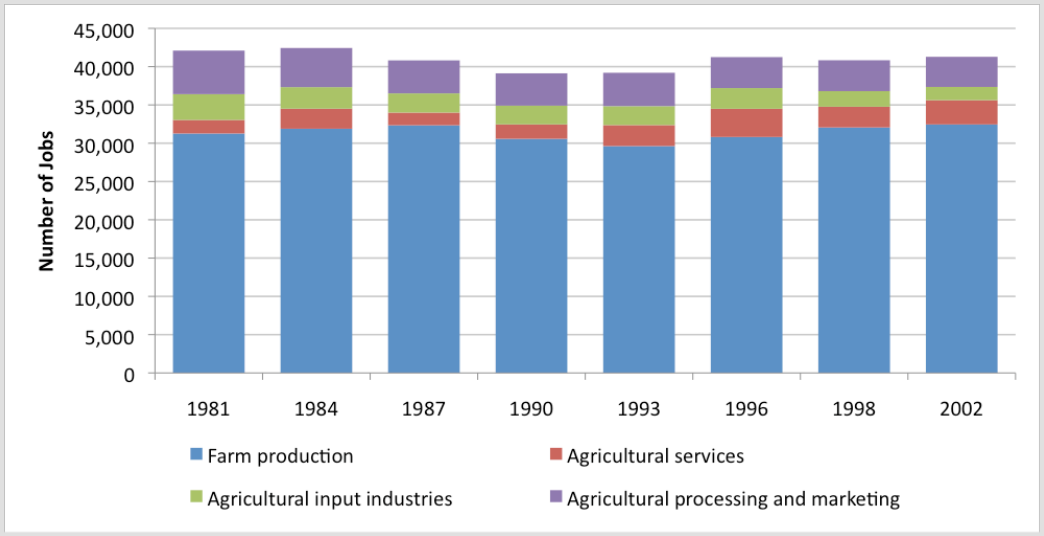




Source: ECONorthwest, with data from U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System (2007a,b). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

Farm-Related Jobs. As farm operations purchase inputs (i.e., farm equipment, seed, fertilizer, etc.), they generate jobs for the providers of such inputs. Figure 14 illustrates the magnitude of these jobs, relative to on-farm jobs in Montana. Jobs that provide inputs for agricultural operations fall into two categories: agricultural services (in red on Figure 14) and agricultural input industries (in green on Figure 14). The former includes services from legal and financial advisors, farm-maintenance and repair providers, and similar vendors. The latter

Figure 14. Farm and Farm-Related Employment in Montana, 1981 to 2002



Source: ECONorthwest, with data from USDA, Economic Research Service (2005). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

includes purchases, such as seed and farm equipment. Figure 14 also reflects jobs in industries that directly process and market agricultural products (in purple in Figure 14). On-farm jobs account for about 80 percent of the total, the two input categories combined for about 10 percent, and the processing/marketing industries for about 10 percent. During the period shown, on-farm jobs and jobs in agricultural services grew relative to the others. Jobs in processing and marketing declined. In 2004, less than 10 percent of Montana's agricultural exports were in a processed or value-added form (Kiwi TB Inc. 2006).

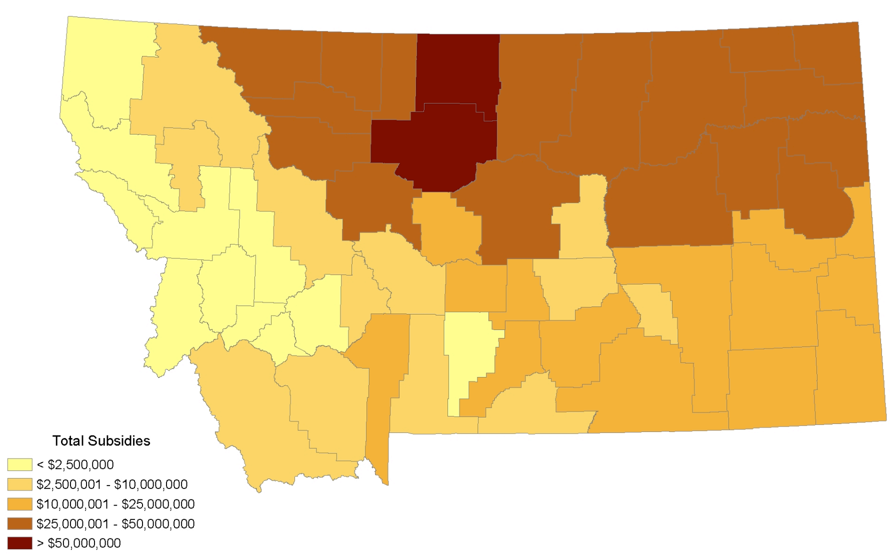
Some past studies of jobs have reasoned that the expenditures of the input industries would create additional jobs, as would the expenditures of farm families, farm workers, and the employees of the input industries. The firms and workers benefiting from these expenditures would, in turn spend their income, creating even more jobs, and the process would continue until eventually it would peter out. The tool for tracing the these so-called ripple effects on jobs (and income) is known as an input-output matrix. It also calculates the multiplier, i.e., the ratio of the total number of jobs linked directly or indirectly to farm operations to the number of on-farm jobs. A wide body of research conducted across the U.S. indicates that multipliers for economic regions centered on large metropolitan areas usually are no more than two (Siegfried, Sanderson, and McHenry 2008). This finding indicates that, for each job in irrigated agriculture in Montana, the ripple effects probably generate less than one additional job somewhere in the state. Multipliers applicable to sub-state regions, counties, or communities are smaller.

2. Impacts on Jobs and Income from the Externalities of Irrigation

Irrigation can have positive or negative impacts on jobs and income through the externalities it creates for commercial interests (other than those related to agriculture), quality of life, and environmental values. Because the data regarding these impacts are limited, they do not offer precise measurements of the external impacts but, instead, a general understanding of the mechanisms by which they occur.

Subsidies. Figure 15 shows the extent to which farmers and ranchers in the state received cash from federal farm-subsidy programs between 2003 and 2005. Some subsidies are for conservation activities, such as protecting riparian (streamside) areas; others sustain commercial operations by offsetting losses from drought, storms, and other disasters, and supporting production of farm commodities. Additionally, some of Montana's ranchers currently receive federal subsidies of about $14 per animal-unit-month (AUM) in the form of reduced costs for grazing permits on federal lands. These subsidies increase the incomes of recipients and, through the ripple effects described above, generate additional jobs and incomes for others. Their impact is considerable, insofar as, absent the federal direct subsidies, net farm income would have been negative three of the last five years, 2002-2006, for which data are available (USDA Economic Research Service 2007). Most of the money for federal subsidies comes from taxpayers in other states and, hence, the subsidies represent an infusion of cash that has a positive impact on jobs and income in the state.

Figure 15. Payments from Federal Farm-Subsidy Programs by County, 2003 to 2005[a]



Source: ECONorthwest, with data from the Environmental Working Group (2006). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

[a] All values adjusted to 2007 dollars.

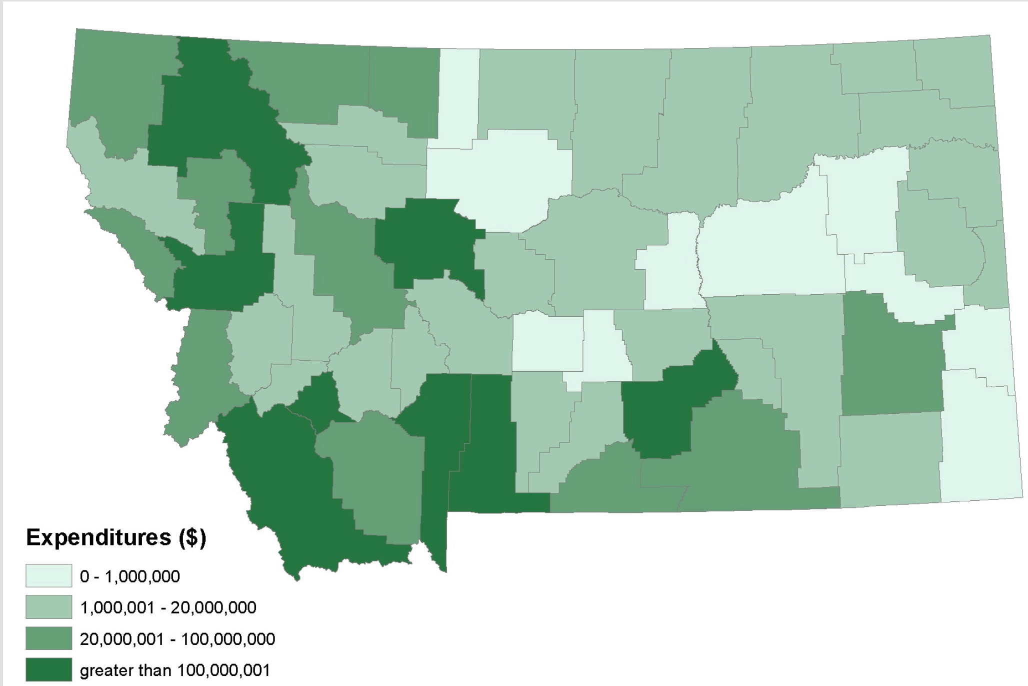
The same is not necessarily the case for subsidies paid by in-state taxpayers. With such subsidies, any jobs and income resulting from the receipt of the subsidy comes at the expense of jobs and income associated with the households and businesses that contributed the funds.

Municipal, Domestic, and Industrial Water Users. Irrigated agriculture generates impacts on jobs and income when it affects the supply and the cost of water available to meet the demands of municipal, domestic, and industrial water users. Sometimes the impact is positive, as is the case in the Milk River area, where irrigation infrastructure carries water for municipal and industrial water (the Milk River Case Study in *Technical Memorandum 2.5 – Case Studies* provides more detail). Sometimes it is negative, as when irrigation reduces the supply of water for these competing uses. Both types of impacts are likely to become more important in the future, as Montana's population grows and the water use per household increases.

In places where irrigated agriculture and urbanization are in competition, the latter often will ultimately prevail, because the value of goods and services urban households and businesses derive from water exceeds the value of the net earnings farmers receive from irrigated crops, and because the jobs and income urban businesses generate exceed the irrigation-related jobs and income. A 1997 study by Forest Service economists estimated that, between 1990 and 2040, urban development would occupy lands previously devoted to irrigated agriculture, reducing the water available for irrigation by 94.77 million gallons per day and irrigated acreage by 25,070 acres in the region that includes Lincoln, Flathead, Sanders, Lake, Mineral, Missoula, and Ravalli Counties (Haynes and Horne 1997). They also anticipated that urbanization would reduce the water available for irrigation by 18.05 million gallons per day and irrigated acreage by 4,620 acres in the region that includes Powell, Lewis and Clark, Granite, Deer Lodge, and Silver Bow Counties.

Recreation. Irrigation appears to have both positive and negative impacts on the ability of the state's water resources to generate recreation-related jobs and income. Reservoirs, canals, and irrigated fields associated with an irrigation system might create opportunities for fishing, hunting, and watching wildlife, for example, as it diminishes analogous opportunities by withdrawing water from a stream and reducing instream flows. The net impact varies from place to place around the state. For the state as a whole, the expenditures of recreationists and tourists translate into gross earnings of firms in the recreation and tourism industries that are roughly comparable to the gross earnings of the agricultural industry. Moreover, until recently they have been growing faster, from $1.76 billion in 1997 to $2.77 billion in 2005 (University of Montana Institute for Tourism and Recreation Research 2005). These expenditures create jobs: about 45,900 in 2005, or 7.9 of Montana's total non-farm employment (Grau, Bruns-Dubois, and Nickerson 2006). Figure 16, which maps the distribution of recreation expenditures by nonresidents, shows that expenditures are concentrated in the state's western and southwestern counties. The extent to which these expenditures are linked to water resources is not known. Evidence we discuss below suggests, however, that the impacts of water-related

Figure 16. Nonresident Travel Expenditures in Montana, 2005



Source: ECONorthwest, with data from University of Montana, Institute for Tourism and Recreation Research. (2006). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.

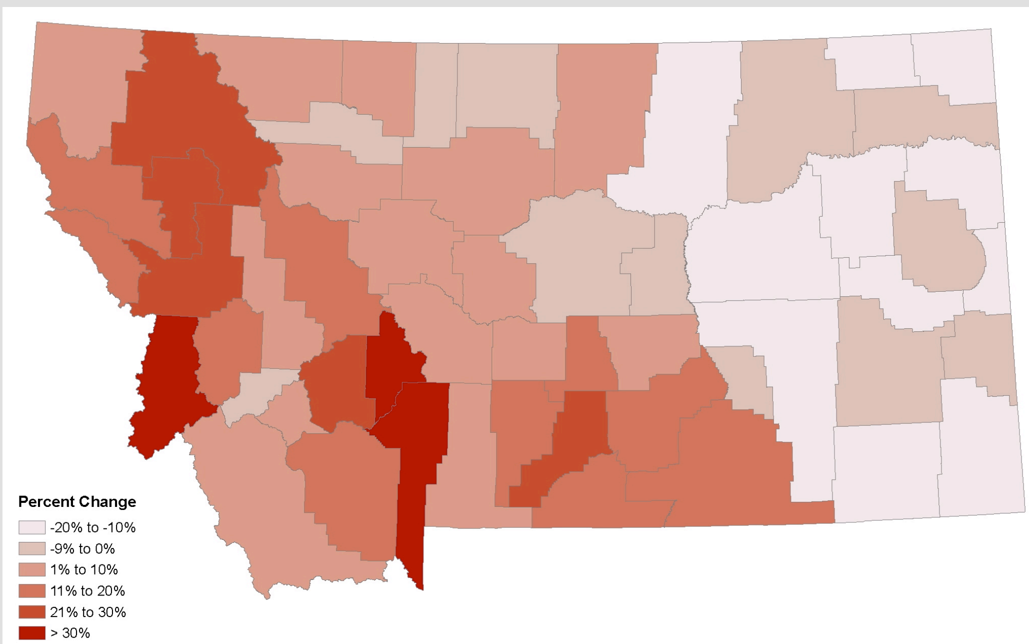
recreational opportunities on jobs and income are important in all parts of the state.

Amenities. Recreational opportunities have impacts on jobs and income not just through the expenditures of those who take advantage of them but also by influencing the location-decisions of households and businesses. Other water-resource-related amenities, such as the scenery of mountainous streams and lakes, also are important in this manner.

Numerous studies have examined and confirmed the importance of recreational opportunities, scenery, and other natural-resource amenities as a source of jobs and income, especially in rural communities of western states. One found that two factors have been especially important: proximity to public lands managed for the protection of their amenities rather than for the production of commodities; and proximity to an airport (Rasker et al. 2004). Another concluded that counties in the Rocky Mountains and the Midwest that have attractive scenery experienced job growth about twice as fast as counties without it (Henderson and McDaniel 1998). Other studies have found that counties with high levels of resource-related amenities experience faster growth in population and jobs, higher levels of education and income, and a greater concentration of entrepreneurs (Shumway and Otterson 2001; Gibbs 2005; and Low, Henderson, and Weiler 2005).

The state's resource-related amenities are not distributed equally across the state, with most people concluding they are greatest in the western and more mountainous areas. Figure 17 suggests that this distribution is exerting an influence on the pattern of growth in population and, by extension, in jobs and income. One should not conclude, however, that amenities, and the management of water resources to provide amenities are unimportant in eastern Montana. One recent study found that amenities associated with local water resources exert a stronger influence on county-level employment in the eastern part of the state than in the western part (Partridge et al. 2008). These findings are reinforced by research focused on the Upper Great Plains, with landscapes and economies similar to those of eastern Montana, strongly suggests that amenities play an important economic role in this region (Monchuk et al. 2005). The authors included two indicators of natural-resource amenities: swimming areas at facilities operated by the U.S. Army Corps of Engineers, and an index of outdoor recreation amenities that includes rails-to-trails miles, acres of recreational land in the National Resources Inventory, acres of recreational water in the National Resources Inventory, and comparable data on the amenities of state parks. The authors found that, for a representative county, with an increase in the value of the amenity index by one standard deviation (a standardized measure), per capita income would be $270 higher, and an increase in the number of swimming areas by a comparable amount would correlate with $187 higher per capita income. In contrast, an increase in a county's economic concentration in agriculture would correlate with a lower or slightly higher per capita income. A comparable increase in the share of total county income from farming would

Figure 17. Population Change in Montana, 1990-2000



Source: ECONorthwest, with data from U.S. Census Bureau (2007). See *Technical Memorandum 2.3 – Net Economic Impacts of Irrigation in Montana* for more detail.0

decrease per capita county income by $1,410, and a comparable increase in the growth in livestock receipts would increase per capita income by $47. Based on these and related findings, the authors concluded that, for this region:

> This evidence highlights the potential for natural-resource amenities, especially those in public ownership, to contribute to the economies of all parts of the state, even eastern counties. The studies strongly suggest that communities that manage their water and other resources to enhance the amenities available to the public have a greater likelihood of generating jobs and income than those that don't.

D. Emerging Opportunities and Constraints

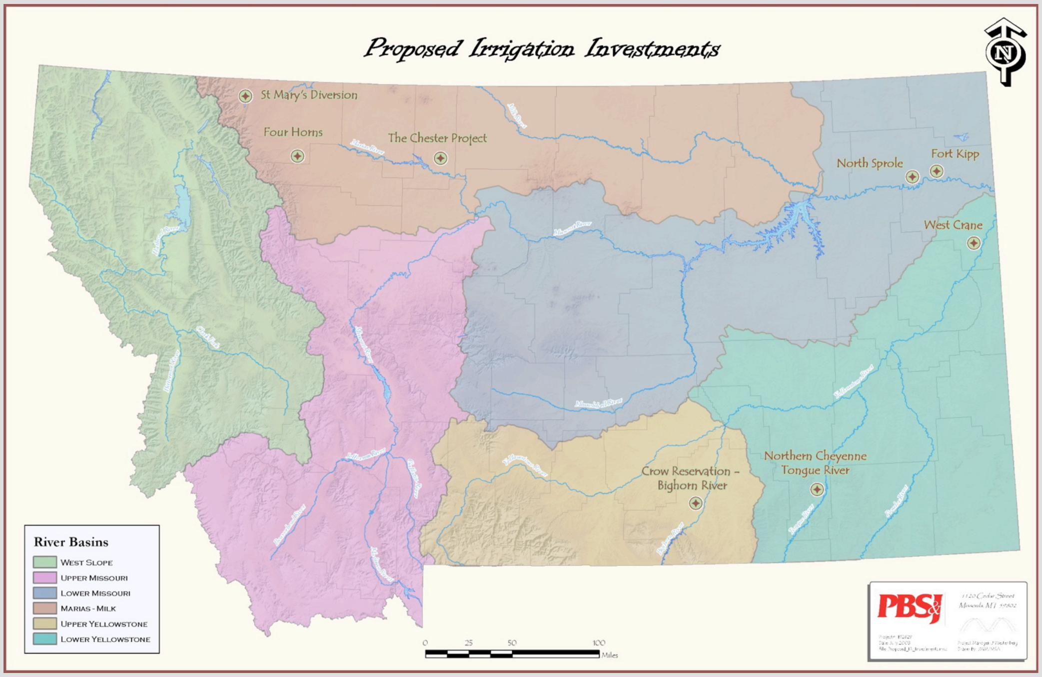
In this section we describe opportunities for sustaining or expanding irrigated agriculture in Montana. We first briefly summarize some of the significant proposals that have been developed over the past several years to reinforce or expand irrigated agriculture through investment in irrigation infrastructure. We then discuss the potential for irrigated agriculture to become more productive, looking at three general strategies: (1) improving the efficiency of irrigation systems; (2) developing water markets; and (3) creating new opportunities for irrigators to generate revenue by using water to provide products other than irrigated crops. We finish with a discussion of other factors and concerns that are likely to influence the emergence of opportunities and constraints for irrigation.

1. Proposed Irrigation Investments

Investments in irrigation infrastructure potentially could strengthen irrigated agriculture in Montana both by rehabilitating existing infrastructure and by developing new infrastructure. Here, we illustrate the types of investment proposals that have been under discussion over the past 10 years, organized by the state's six main water basins. Figure 18 presents these proposals on a map. See *Technical Memorandum 2.4 – Emerging Opportunities for Sustaining Or Expanding Irrigated Agriculture in Montana* for more detail.

Marias and Milk Basins. Three proposals typify efforts to rehabilitate or expand irrigation infrastructure in this basin. The first seeks to increase the amount and improve the reliability of water supplies in the Milk River. It would entail restoring facilities that divert water from the St. Mary Basin to the Milk Basin, installing pumping plants, improving canal capacity and efficiency, and adding storage facilities (U.S. Bureau of Reclamation, Montana Area Office 2003). The second seeks to increase the storage capacity of Four Horns Reservoir, an existing off-stream reservoir located on the Blackfeet Reservation. It would entail raising the level of the reservoir, rehabilitating canals, and improving other infrastructure to increase the supply of water to the tribe's Birch Creek irrigation project and the privately owned and operated Pondera County Canal and Reservoir Company. The third seeks to make water available to as many as 40,000 currently un-irrigated acres generally located south and west of Chester. It would entail developing capacity to pump water from the Bureau of Reclamation Project reservoir created by Tiber Dam on the Marias River (Lake Elwell) as well

Figure 18. Map of Proposed Investments in Irrigation



Source: PBS&J

as an appropriate supply of electricity—perhaps wind-powered generators—to drive the pumps. Prospective water users have initiated a process to form an irrigation district.

Lower Missouri Basin. The proposed North Sprole Project, located on the lower Missouri River between Poplar and Brockton on the Fort Peck Reservation, seeks to expand irrigated agriculture on 22,000 acres of tribal and allotted lands. The proposed Fort Kipp Project is nearby. It would provide water to expand irrigated agriculture by 2,000 acres and serve as a prototype for similar projects nearby. Both projects would require a source of energy to lift water, as much as 300 feet for the North Sprole Project. Although no formal proposals have been made, additional private irrigation development also is physically possible in the Lower Missouri Basin, to increase the supply of crops for facilities that process oil seed in Culbertson and malt barley and sugar in Sidney.

Lower Yellowstone Basin. With the proposed West Crane Project, water pumped from the Yellowstone River near Crane would irrigate perhaps 10,000 to 15,000 acres west of Sidney and north of Savage. The sponsoring irrigation district also is investigating the development of groundwater and other water sources. Another proposal would use the water-rights compact with the Northern Cheyenne Tribe to draw water from the tribe's allotment of water from Tongue River Reservoir to irrigate 5,000 to 6,000 acres. Although there are no known formal proposals, additional private irrigation development is possible in the Lower Yellowstone Basin as both water and land are available. As in the Lower Missouri Basin, these proposals originate out of expectations that there will be future demand for irrigation-intensive crops, such as seed potatoes, sugar beets, beans, corn, malt barley, and oil seeds.

Upper Yellowstone River Basin. One proposal would build on Montana's compact with the Crow Tribe, which allots 150,000 acre-feet of Bighorn River water to the tribe, and deliver water to about 60,000 acres of irrigable lands, both tribal and private, on the Crow Reservation. Most of these lands lie west of the Bighorn River, and at elevations that would require pumping.

Upper Missouri River Basin. There are no known new irrigation projects under discussion in the upper Missouri River Basin. This is likely the result of a number of factors, including the transition from an agriculture-based economy to an amenity-based economy, a lack of additional land suitable for new irrigation development, and the closure of most of the basin to new surface and groundwater rights.

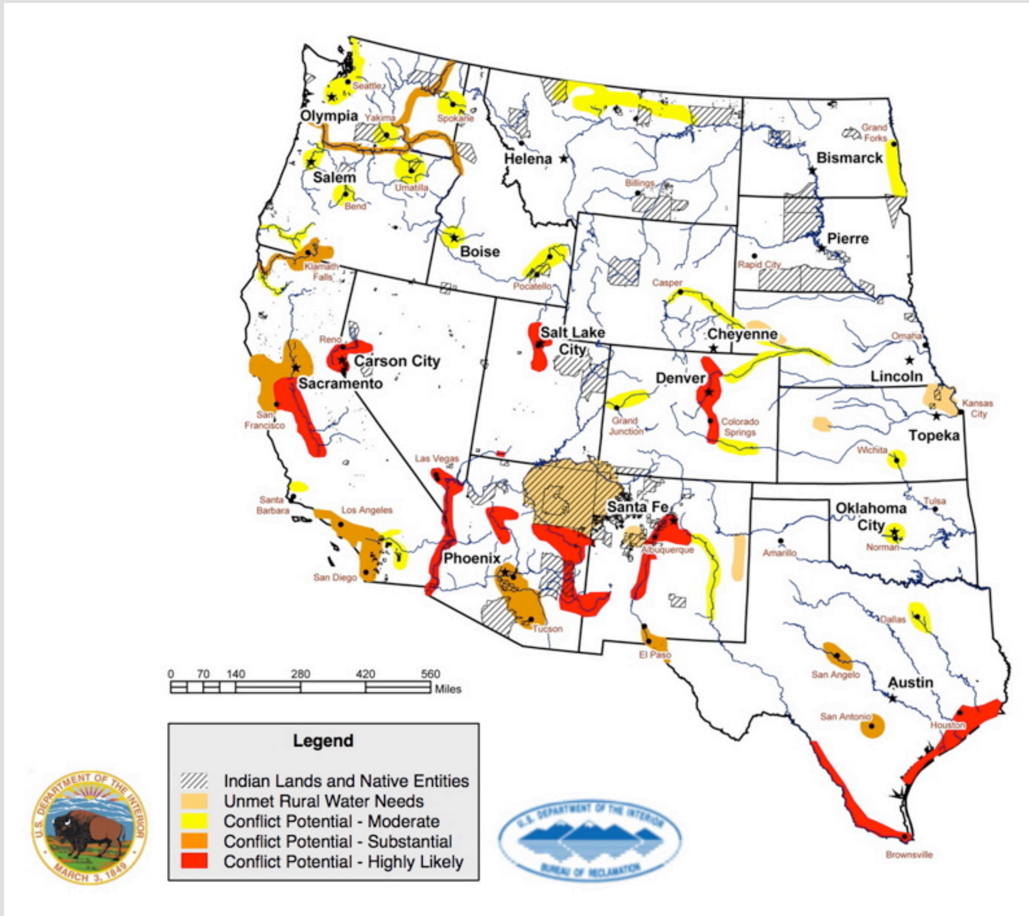
West Slope. We are aware of no new irrigation projects under discussion in the west slope basins, although the Flathead Irrigation Project on the Flathead Indian Reservation would likely benefit from rehabilitation of its infrastructure. The absence of activities in new projects likely is the result of several factors, including the transition from an economy based on agriculture, timber, and mining to an amenity-based economy, and a lack of additional land suitable for irrigation development. Also, in the Clark Fork Basin formal basin closures or the existence of senior downstream hydropower rights make it difficult to secure new groundwater or surface-water rights.

2. Making Irrigation More Productive

It is possible for irrigated agriculture to be strengthened not just by constructing new infrastructure to provide water for additional land but also by making irrigation more productive, so that irrigators can derive greater net revenue per unit of water. Improving irrigation efficiency is especially important in areas where irrigation and other demands have outstripped the supply of water, leaving streams dewatered (see Figure 9, above). Figure 19 provides another perspective of areas where improvements in efficiency probably will be important, highlighting areas where the Bureau of Reclamation expects water-supply crises to arise. The likelihood that these crises will materialize by 2025 ranges from *highly likely*, in areas where severe water supply problems already exist, due to demand from high population growth and reallocation of water resources for endangered species (indicated in red in Figure 19), to *moderate*, in areas where there is a risk that water supply will not meet the demand for water for threatened and endangered species, existing extractive uses, and potential population growth (indicated in yellow in Figure 19). The map identifies an area in northern Montana, along the Milk River, that may experience moderate conflicts by 2025. The likelihood that crises will materialize also will be affected by anticipated changes in climate (Karl et al. 2008).

Improved Irrigation Efficiency. We discuss irrigation-system efficiency in terms of the ratio of water consumed by crops (or other beneficial uses) to the total

Figure 19. Potential Water Supply Crises in the West



Source: Adapted from U.S. Department of the Interior, Bureau of Reclamation (2003). See *Technical Memorandum 2.4 – Opportunities for Sustaining or Expanding Irrigated Agriculture in Montana* for more detail.

amount of water withdrawn. When more water is applied than is actually needed for beneficial uses, the water-use-efficiency ratio declines. In concept, achieving a high efficiency-rate of water use allows farmers to produce more goods and services with the same amount of water. In practice, positive and negative consequences of gains in water-use efficiency are less straight-forward.

The available evidence indicates there are substantial opportunities for improving the efficiency of irrigation in Montana. The most recent (2000) data from the U.S. Geological Survey (USGS) show that Montana withdrew 5.3 acre-feet of water per acre of irrigated land, twice the national average, and the average efficiency for all irrigation systems, calculated as the ratio of total consumption to total withdrawals, was 21 percent (Cannon and Johnson 2004). In 1995, the last year for which data were available for all states, Montana had the lowest rate of water-use efficiency for irrigation (Solley, Pierce, and Perlman 1998).

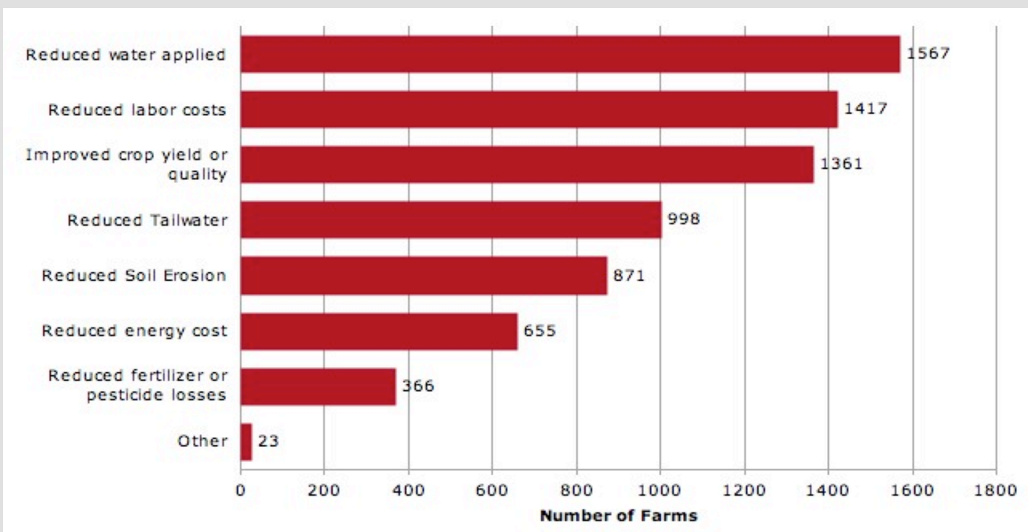
Three characteristics of Montana's irrigation systems are responsible for its water-use inefficiency. First, irrigators here employ surface irrigation methods (also known as flood-irrigation or gravity systems) to irrigate nearly two-thirds of all acres irrigated in the state (USDA, National Agricultural Statistics Service 2004b). These systems often divert large amounts of water relative to the amounts consumed by crops. Second, most irrigators determine when to apply water using methods—such as looking at the condition of the crop, feeling the soil, and following the lead of neighbors—that measure a crop's water requirements imprecisely and lead to applying more water than a crop needs (USDA, National Agricultural Statistics Service 2004b). Third, Montana's irrigation water-delivery systems tend to lose considerable amounts of water (Cannon and Johnson 2004).

These circumstances suggest three approaches that potentially could improve the efficiency of irrigation systems in Montana:

- Convert less-efficient surface-irrigation methods to more-efficient methods.
- Use irrigation-scheduling techniques that measure irrigation requirements precisely.
- Reduce losses by lining ditches and canals that deliver irrigation water.

Figure 20 shows that many irrigators in Montana already are taking action in one or more of these areas. These actions likely reduce the overall amount of water applied to Montana's crops, leaving more water available to produce additional crops and/or other goods and services.

Figure 20. Improvements in Water-Use Efficiency Reported by Montana Irrigators

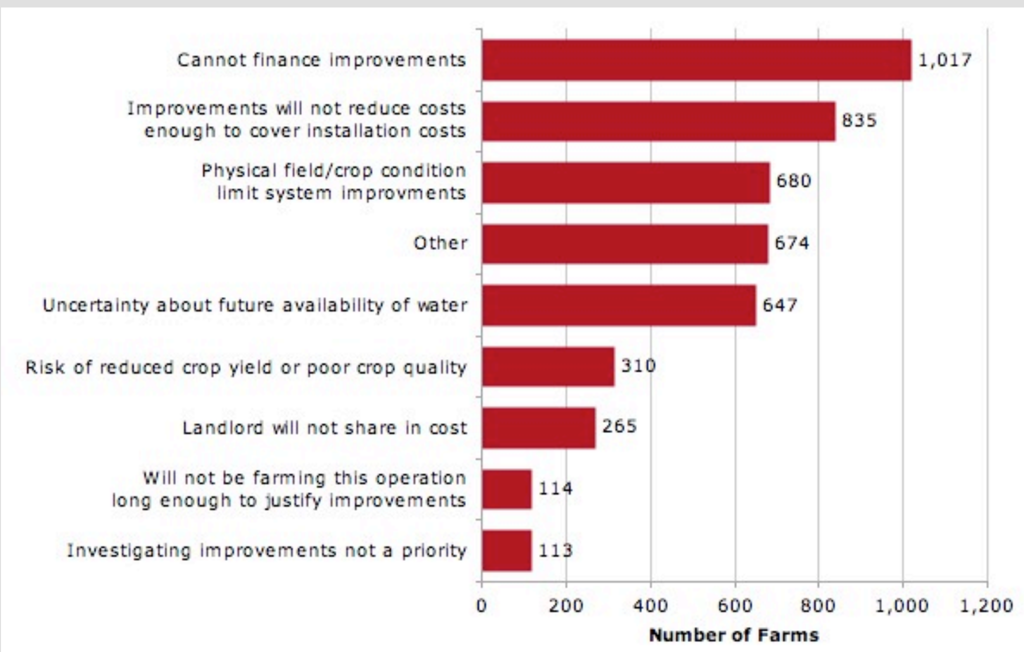


Source: ECONorthwest, with data from the U.S. Department of Agriculture, National Agricultural Statistics Service (2004b). Table 39. See *Technical Memorandum 2.4 – Opportunities for Sustaining or Expanding Irrigated Agriculture in Montana* for more detail.

Improvements in efficiency can have both positive and negative economic consequences. Many farmers experience improvements in crop yield after switching to more efficient irrigation methods. Moreover, with greater irrigation efficiency, irrigators often can reduce their use of fertilizer and pesticides (Montana Department of Agriculture, Agricultural Services Division, Technical Services Bureau 2005), lessen problems with salinity (Tyrell 2001), and reduce water pollution. The negative consequences arise as improvements in efficiency typically come only at some cost. In general, farmers tend not to take actions that would improve efficiency when crop prices are low; the investment, energy, and labor costs of the actions are high; the growing conditions are such that high-value crops can be grown with little or no irrigation; or the opportunities for expanding irrigation operations are limited.

Figure 21 illuminates the extent to which financial and other concerns are seen by irrigators as significant barriers to improving water-use efficiency. The most common barriers are farmers' lack of capital to make improvements, and the perception that investments in water-use efficiency will not yield an adequate financial return. Various governmental programs exist to share the costs of investments in efficiency and many of Montana's irrigators take advantage of them. The most popular is the Environmental Quality Incentives Program (EQIP) from USDA, with participation rates ranging from about 35 percent for the state's largest farms to about 10 percent for its smallest.

Figure 21. Barriers Montana Irrigators Face in Making Improvements to Reduce Energy Use or Conserve Water, 2003



Source: ECONorthwest, with data from the USDA, National Agricultural Statistics Service (2004b). Table 40. See *Technical Memorandum 2.4 – Opportunities for Sustaining or Expanding Irrigated Agriculture in Montana* for more detail.

Water Marketing. Water markets entail voluntary transactions that transfer the right to control water from one entity to another. A transaction can alter the use of water (from irrigation to municipal use, for example), or the timing and location of an on-going use (from irrigating one field and crop to another, for example). A water market, *per se*, comprises sellers and buyers who engage in transactions as well as the institutions and processes that facilitate, approve, and validate the transactions. In most cases, a market-based transaction results in immediate change in the goods and services derived from water, as the seller relinquishes control and the buyer assumes control. Sometimes, however, a transaction results in the control of a unit of water in a water bank, where it resides and remains idle, until it expires or is withdrawn.

A temporary transfer occurs when a water-right holder retains the water right but leases the related water for use by another. A permanent transfer occurs when the water-right holder sells the water right to another. Leases can have different lengths. Some exist for only part of a season, while others last an entire season, an entire year, or multiple years. A split-season lease, for example, might materialize when a farmer that typically produces two hay cuttings per year agrees to cut only once and then leases water for instream use to support fish populations during the late summer. A lease may last several years but come to life only when pre-specified conditions exist. A farmer growing an annual crop, for example, might enter into a multiple-year lease with a farmer growing perennial crops, but effect the transfer only during years when water supplies are forecasted to be low. During such a year, the seller would not plant the annual crop, transfer the water to the buyer to sustain the perennial crops, and use the compensation received from the buyer to offset the forgone revenues from the annual crops.

Water markets are most robust when they exhibit characteristics typical of other well-functioning markets. Potential sellers must have solid, verifiable property rights in the water to be leased or sold, which usually requires full adjudication of all rights in a basin. Buyers and sellers must be able to find one another easily, develop a reliable assessment of the value of the water available for lease or purchase, and execute transactions quickly. Third parties must have an opportunity to evaluate, in a timely manner, how each proposed transfer might affect them. The costs parties incur to execute a transaction must be reasonable. Once a transaction is completed, each party must have confidence that others will comply with all its terms.

Three entities have played a significant role in reserving water for in-stream uses through leasing or purchasing water rights in Montana: Montana Department of Fish, Wildlife, and Parks (FWP), Montana Water Trust, and Trout Unlimited. The law allows Montana FWP to change the use of water rights that they own from consumptive use to instream flows, without any time constraints, on up to 12 stream reaches, and Montana FWP is currently in the process of identifying the 12 streams that would provide the greatest returns. On the remaining streams, Montana FWP may lease water, but for no more than 10 years, though they may renew the 10-year lease an indefinite number of times. Montana Department of Natural Resources and Conservation (DNRC) must approve all leases. After June

30, 2019, Montana FWP may not renew any old leases or enter into new contracts (MCA 85-2-436, Kolman 2008). Since being granted authority to lease water rights for instream flow, Montana FWP has signed 17 leases. At the end of December 2006, 12 of these remained active, and FWP signed no new agreements in 2007. Since 1999, Montana FWP has spent more than $260,000 to restore almost 200,000 acre-feet of instream water flows.

Private entities, especially Montana Trout Unlimited (Montana TU) and Montana Water Trust (MWT), have acquired more than 57,000 acre-feet of water through leases and donations, spending about $1.3 million over five years (Scarborough and Lund 2007). Montana TU holds six leases, all in the Blackfoot River Valley. The agreements reveal ranchers' willingness to accept compensation to reduce irrigation is between 75 cents and more than $25 per acre-foot. MWT has signed 15 leases since 2001 for 2,600 acre-feet of water annually. In 2007, MWT paid out $63,000 to landowners for leased water flows.

Economists favor water markets because they offer robust opportunities for increasing the value of the goods and services derived from a given supply of water. Market-based, voluntary transfers of water should increase the economic well-being of both the sellers and the buyers because a transaction would occur only if both parties expected it to be beneficial. Much of the concern over water transfers arises from third parties who fear the transfers will cause them economic harm. A downstream farmer, for example, may fear that a transfer would increase the upstream consumptive use of water, leaving less water in the stream to meet downstream demands, or farm-supply businesses may fear that water transfers away from one type of agriculture to another will reduce the demands for their products. Nearby communities may fear that, once transfers are allowed from one farmer to another, they eventually will be allowed to shift water away from agricultural use altogether, with the water perhaps leaving the area entirely. An incremental transfer of water from one farmer to another growing similar crops might have little effect on the overall surrounding economy. The economy might experience a discernible shake-up, however, from a transfer that significantly increased the supply of high-value, scarce goods and services while having a minor impact on the supply of abundant goods and services.

Several factors impede growth in the number and extent of market-based water transfers. One major factor is lack of experience. Transfers have not occurred in enough volume or for a long enough time for there to be widespread awareness, among both potential sellers and potential buyers, of the mechanics and economic opportunities associated with transfers. This lack of awareness is made more acute because there exists no permanent set of institutions to facilitate transfers and, thereby, build familiarity and trust. Instead, *ad hoc* efforts to promote transfers have had intermittent and limited success. Additional barriers to water markets stem from the nature of water rights. Typically, the validity of one's water right is not confirmed until the state has fully adjudicated all water rights in a basin and even then, the DNRC asserts the authority to re-evaluate water rights when an application to change is filed. The adjudication process has proceeded slowly in Montana, as in other states, creating uncertainty about the validity of any market-based transaction transferring a water right. This uncertainty diminishes the willingness of potential buyers to pay for a right that might later prove to be invalid.

Montana FWP (2006) has identified these factors as the main challenges to its efforts to develop markets for leasing water in the state:

> *Adjudication of water rights.* The "slow pace of Montana's general water adjudication is resulting in the loss of potential leases. Inflated, unperfected and abandoned claims impede the process."
>
> *Limitations on lease renewals.* Some landowners refuse to enter into water-lease agreements because the term of the lease, 10 years maximum with review of the renewal every 10 years, is too restrictive and short. Extending leases past 20 years may increase the number of parties interested in instream-flow agreements.
>
> *Authorization of a permanent leasing program.* Statutory provisions guiding water leases in Montana must undergo a legislative review every 10 years, creating administrative and financial uncertainty.
>
> *Increased transaction costs for water leasing.* Costs of water leases have increased because water resources have been over-allocated and the number of parties looking to purchase new water rights has been constantly increasing.

New Revenue Opportunities. Irrigation systems and agricultural lands can provide a variety of goods and services besides crops. Some systems, for example, provide water for municipal-industrial users, habitat for fish and waterfowl, recreational opportunities, maintenance of dry-season instream flows, and more. Sometimes, the irrigation system or landowner receives payment for a good or service: from a municipality or industrial user for water, from a hunter for opportunities to hunt waterfowl, etc. In most instances, however, irrigation systems and landowners do not receive payment for providing goods and services that benefit others. This disconnect underlies the widely-held view, that there are significant and unavoidable tradeoffs between farmers' production goals and society's goals for environmental quality and protection (Claassen, Aillery, and Nickerson 2006). To offset this perception, many farmers and ranchers have begun investigating opportunities for earning revenues from their production of goods and services that benefit the environment. Economists often call this process "payments for ecosystem services" (Murtough, Aretino, and Matysek 2002).

Payments for ecosystem services (PES) can take many forms. One of the most common examples is USDA's Conservation Reserve Program (CRP), in which the federal government pays farmers to take land out of production and plant vegetation providing soil, water, and habitat benefits. Similar to the CRP, the Montana Enhancement Program, a joint venture of the Montana Farm Service Agency and the USDA, pays farmers to plant vegetation and restore wetlands to reduce sediment in on 26,000 acres across nine counties. Program participants receive $100 to $150 per acre for riparian buffer enrollment, cost sharing for plantings, and annual maintenance payments (USDA, Farm Service Agency

2002). The Block Management Program, in which the Montana FWP pays farmers and ranchers to allow hunters to access their land during the hunting season, is another example of a direct payment by a government agency for ecosystem services. The Montana FWP selects land for the program based on habitat type and quality, providing an incentive for farmers and ranchers to maintain good-quality habitat on their land. In exchange for allowing access, landowners receive up to $12,000 in direct compensation, limited liability protection, and a complementary sportsman's license (Montana FWP 2008a). During the 2007 hunting season, 1,250 landowners enrolled about 8 million acres of land in the Block Management Program (Montana FWP 2008b).

These and similar programs are most effective when they provide incentives that influence behavior, which usually means they must provide a farmer with sufficient revenue and/or reduce the farmer's risk sufficiently to offset the farmer's loss of expected agricultural earnings from the land as well as the costs of effecting the transaction. Although specific payments for ecosystem services often appear capable of producing net benefits for individuals and communities, these benefits do not always materialize. Some of the barriers to implementing payments for ecosystem services include the following:

High administrative costs. Valuing, verifying, monitoring and tracking activities that generate ecosystem services can require management systems and personnel. Some programs include fees on transactions to support these activities, but others require outside revenue support (Hall 2006).

No demonstration transactions or pilot projects. New types of transactions can have increased uncertainty regarding costs and benefits. Examples of transactions or service-generating activities might be necessary for others to feel confident with the investments needed.

Regulations that do not allow PES. Regulated entities under legislation, such as the Clean Water Act or the Endangered Species Act, might have obligations that could be more effectively met with PES. Permits or state-level rules might need to be modified to allow use of PES, however.

Funding constraints. Even though certain ecosystem services, such as instream habitat provision, might be valuable to communities, funding or mechanisms for coordinating funding might not exist.

Thin markets. While PES might offer benefits for buyers and sellers, they might not be aware of opportunities to buy or sell ecosystem services. They also might not have ways to find each other.

Increased uncertainty and risk. Buyers and sellers might perceive greater uncertainty and associated risk with PES than existing regulatory compliance or service opportunities.

Future liability. Farmers and ranchers might worry that, by providing ecosystem services on a voluntary basis, they may be required to provide them through government regulation.

If a particular payment for ecosystem services appears to be worthwhile, government assistance and program design can potentially overcome these barriers. Governmental or private organizations can take responsibility for establishing a PES framework and initiating pilot transactions. Funding and thin market constraints might be due to inadequate demand. Existing permits or regulatory obligations might need to be modified with participation of additional government agencies to allow compliance through PES to increase demand. Public funding in support of natural resources might need more flexibility to achieve potentially increased net environmental gains from PES as opposed to existing efforts. PES can also appear to have greater uncertainty and risk for all parties involved. Government agencies, with the help of private organizations, have overcome these obstacles by acting as brokers or insurers, taking on liability (potentially for a fee) to facilitate PES. Examples of these liability-bearing parties include wetland mitigation bankers and conservation districts for water-quality-trading programs. Concern for future liability might be legitimate for some farmers and ranchers. In addition, regulated parties that are buyers might see their obligations as unfair, particularly as transactions demonstrate lower provision costs for unregulated farmers and ranchers. These concerns might be insurmountable in some cases, but meetings and collaborations, as well as legally binding contracts and statues, have alleviated similar concerns in other situations.

3. Other Influences and Concerns

Irrigators, scientists, economists, and others have identified several factors that might markedly alter the benefits, costs, and impacts of irrigated agriculture in Montana. The following discussion briefly introduces some of those with the greatest potential influence.

Agricultural Trends and Market Conditions. Montana's agricultural producers compete in a global market for agricultural commodities; trends and developments worldwide affect Montana's farmers. Strong demand and higher prices for agricultural products, especially wheat, have made headlines, but those prices have fallen in the past few months. Perhaps of more consequence and longer lasting, increases in the costs of fertilizer, fuel, seeds, and other inputs to farm production have been rising, and may eventually offset the increases in revenues farmers have experienced from higher commodity prices (USDA Economic Research Service 2008b). Some analysts are optimistic that the demand for and prices of agricultural products will break the up-down pattern of the past as surge upward; others are less sanguine (Dohlman and Gehlhar 2007).

Most likely, in our view, agriculture, including irrigated agriculture, will continue to face considerable market-related uncertainty and risk, with periods of rising net earnings followed by periods of decline. This uncertainty and risk has implications for the feasibility of irrigation investments and merits careful investigation before committing funds to any particular investment.

Amenity-Driven Growth and Rising Property Values. In concept, the value of agricultural land should be determined solely by the expected net earnings that can be derived from using the land to produce agricultural products. In practice, agricultural land values in Montana are increasingly reflecting the demands for the land's recreational opportunities and amenities. Buyers interested in using the land for hobby ranches, conservation, recreation, retirement homes, and similar pursuits are willing to pay more than what the land would be worth if it were used to grow crops. This phenomenon has been observable in western Montana for decades, and it now is materializing in eastern sections of the state (Norman C. Wheeler & Associates 2006). Of the property transactions in Carbon County between 1990 and 2001, for example, about half of the buyers were investors and amenity buyers, and just 21 percent were traditional ranchers (Gosnell and Travis 2005). Amenity buyers have also been acquiring property adjacent to the lower Yellowstone and Milk Rivers, and in upland areas across eastern Montana that provide high-quality wildlife habitat and hunting opportunities.

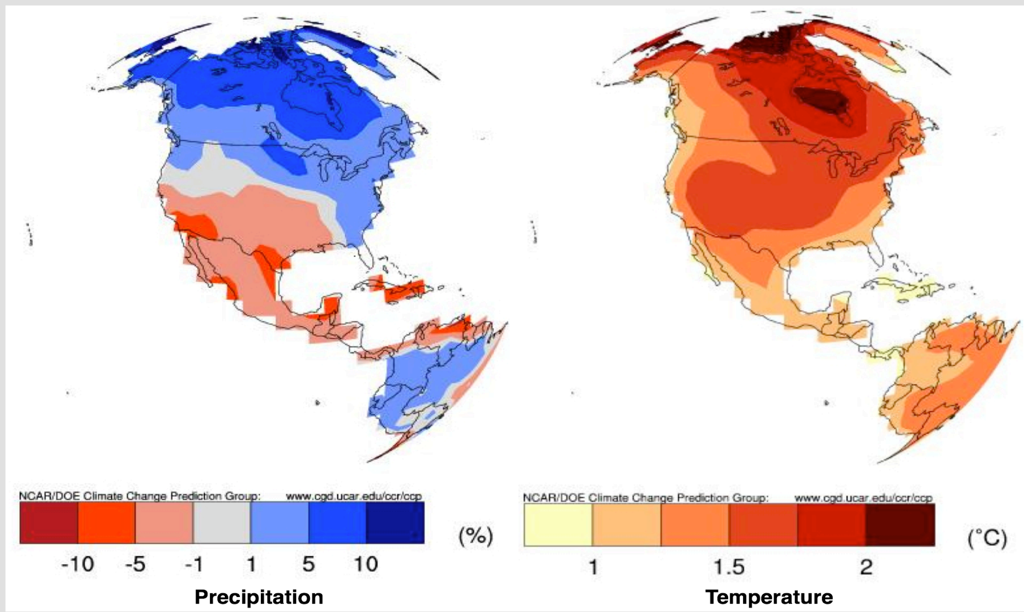
This phenomenon has important implications for irrigated agriculture. As more farms and ranches are purchased for purposes other than agriculture and property values increase to reflect these demands, new farmers entering the market will have a difficult time finding property at a price agricultural production can support. Moreover, as productive farms are converted to other uses, the remaining, fewer irrigators face higher costs to operate irrigation systems.

Amenity-driven growth and rising property values have already eroded agricultural operations in western Montana, causing some irrigators to divest their irrigation infrastructure and sell their land to encroaching development or other uses more compatible with urban and suburban landscapes (See *Technical Memorandum 2.5 – Case Studies* for more detail). While it is unlikely that irrigated agriculture in eastern Montana will experience pressures from amenity-driven growth to the same degree, it is already experiencing upward pressure on property values in many locations, particularly nearby rivers and in upland areas with high-quality wildlife habitat. These trends are not unique to Montana, and represent changing preferences underlying competing demands for water across the United States. Demands for water for urban and environmental purposes continue to increase, directly affecting the shape of irrigated agriculture in many locations. A recent report on the nation's agricultural resources, from the USDA Economic Research Service, predicts that water withdrawals for agricultural production will likely continue to shift to satisfy these competing demands (Gollehon and Quinby 2006).

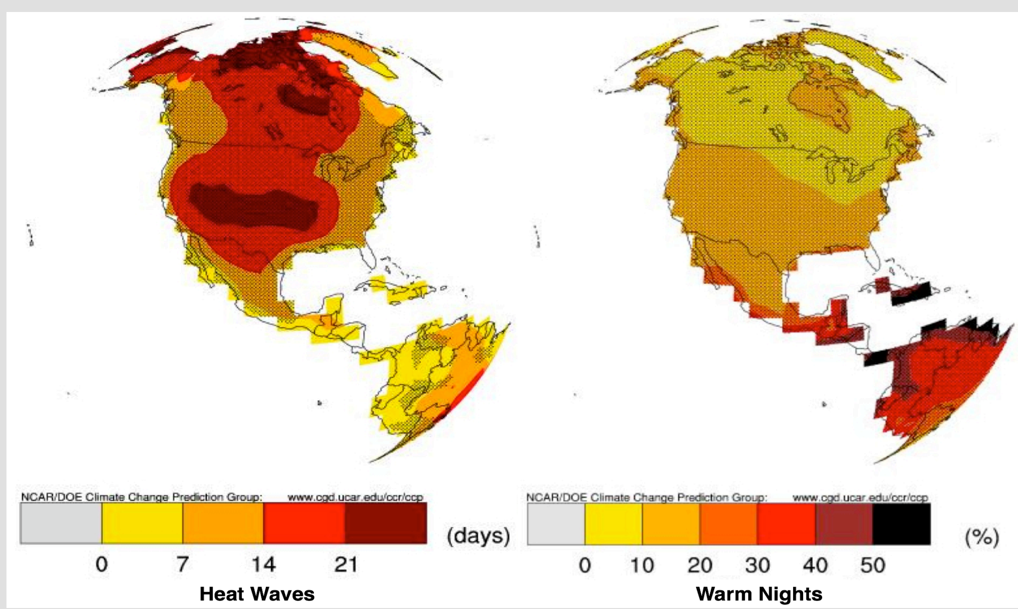
Many who want to continue irrigated farming will find they can do so only if they produce a variety of ecosystem goods and services in addition to crops and find ways to derive income from them, as we describe in our discussion above. Somewhat ironically, the amenity-driven growth that often has been a source of worry for farmers may prove a mainstay of agriculture in some locations, by strengthening non-agricultural sectors of the economy and creating opportunities for farm families to secure off-farm income, without which they would be unable to continue farming.

Climate Change. It is difficult to predict exactly how climate change will affect irrigated agriculture in Montana. Considerable information, however, indicates that higher temperatures and changing precipitation patterns likely will increase demand for water, while reducing available supplies during the dry summer months when irrigation demands are highest. Figure 22 illustrates expectations derived from recent modeling regarding changes in climate in Montana and other parts of North America between 1990 and 2030. Warmer average temperatures, more frequent heat waves, and warmer nights will increase demand for water in agriculture, requiring farmers to apply more water per acre

Figure 22. Expected Changes in Annual Precipitation, Temperature, …



… Heat Waves, and Warm Nights, 1990–2030

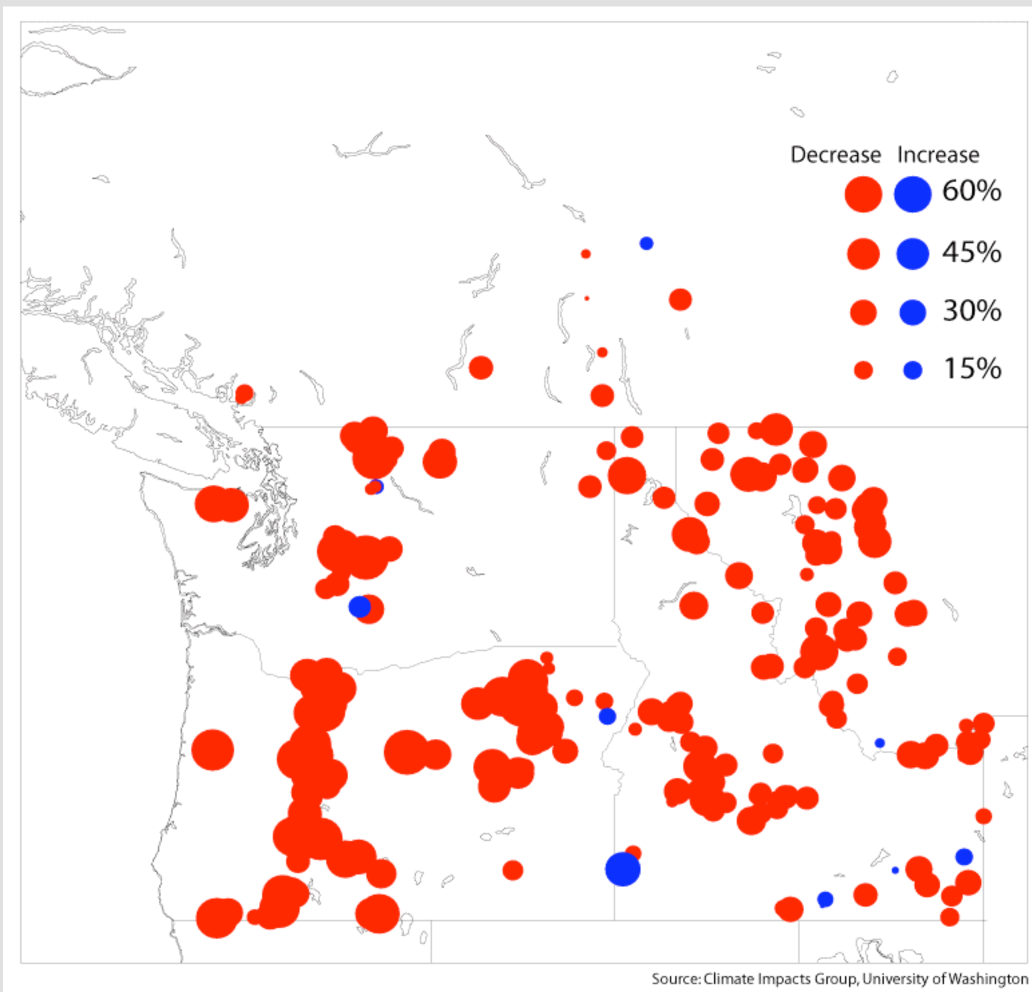


Source: Tebaldi et al. (2006).

of crop. Higher temperatures will also increase demand for water for municipal uses and instream flows, exacerbating competition between agricultural and other water users. At the same time, water availability during the summer months, when it is needed most for irrigation, is likely to decline because, although the map on the upper left in Figure 22 indicates annual precipitation likely will increase slightly to moderately in Montana, higher temperatures will reduce the amount of precipitation falling as snow. Summer irrigation in many regions of Montana is dependent on snowpack. Figure 23 shows one aspect of the impacts to runoff that have already occurred: the amount of water in Montana's snowpack on April 1st has declined up to 60 percent between 1950 and 2000. Further reductions are expected to accelerate with climate change (Karl et al. 2008).

It remains unclear how increases in temperature and atmospheric carbon dioxide concentrations will influence agricultural productivity in Montana. Some analyses indicate that, with increased concentrations of CO_2 in the atmosphere,

Figure 23. Change in Water Content of Snow on April 1st, 1950-2000



Source: Climate Impacts Group, University of Washington.

warmer temperatures, and longer growing seasons, crop yields will increase, and the kinds of crops that grown in Montana will diversify (Tubiello et al. 2000). Other analyses suggest that reduced water availability, extreme temperatures, increases in pests, and other changes associated with climate change will offset these gains in productivity, and may render some agricultural production infeasible (Antle et al. 2004). It remains to be see whether, in the long run, climate change will produce net positive, or net negative consequences for Montana's agricultural economy.

Montana's agriculture is also a contributor to climate change and, hence, it likely will be affected by regional, national, and global efforts to mitigate climate change. Agriculture is the second largest source of greenhouse gas emissions in Montana, producing 26 percent of its gross emissions (Montana Climate Change Advisory Committee 2007). The Governor's Action Plan identified several opportunities to decrease the greenhouse gases: production of renewable fuels, protection of agricultural land from conversion to developed use, and increase the organic carbon in soil by using no-till techniques.

Uncertainties about how climate change and efforts to mitigate it will affect agriculture on general carry over to assessments of the potential investments in irrigated agriculture. Under some circumstances, such investments may offset the adverse impacts of climate change and strengthen irrigators' ability to capitalize on opportunities to reduce emissions of greenhouse gases and fill the gaps that occur when climate change impedes agricultural production elsewhere. Under other circumstances, investments in irrigated agriculture may be rendered fruitless, if extreme temperatures and drought should dramatically reduce crop yields, for example.

Water conflicts. Long-standing conflicts over water continue to generate tension among water users, both inside Montana and between Montana and its neighbors. These conflicts provide ongoing sources of uncertainty for irrigators. Disputes with Wyoming involve disagreement over the requirements of the Yellowstone River Compact and the impacts of coal-bed methane extraction on water quality. Conflicts inside the state involve irrigators, tribes, the operators of hydroelectric dams, conservationists, and others. Conflicts ensuing from federal and Tribal claims to water, which can be the most senior rights in a basin, are settled by means of negotiating a Water Rights Compact between the State of Montana and the Tribe or federal agency holding the water right (Reserved Water Rights Compact Commission 2008). The resulting agreements typically mitigate impacts to other existing water users that would be affected by compact conditions, however, Tribal and federal reserved water rights compacts often close basins and constrain the availability of water for future use.

All else equal, the uncertainly stemming from these conflicts and disputes diminishes the expected net economic benefits of irrigated agriculture. Prudent decision-making warrants accounting for this uncertainty before making additional investments in irrigated agriculture. At the same time, the prospect that resolution of the conflicts and disputes would free-up land and water resources for further agricultural production provides justification for committing private and/or public resources to expedite their resolution.

E. Summary

Investments in irrigated agriculture yield both positive and negative economic consequences. The former accrue largely to irrigators and to the consumers, households, businesses, and communities who enjoy the benefits of irrigated crops and realize the jobs and income derived from the operations of irrigated farms and ranches. Additional positive consequences materialize as irrigation increases the supply of water-related goods and services other than crops, such as recreational opportunities associated with reservoirs and irrigated fields, and water for some municipal and industrial water users. The negative consequences occur as irrigated agriculture diminishes the supply of other goods and services, such as recreational opportunities and fish habitat in streams dewatered as water is diverted to irrigation systems. Much—and in many places most—of the overall economic importance of irrigated agriculture arises from these external effects on water-related goods and services other than crops. Moreover, these external effects likely will become even more important in the future. Hence, investment and operational decisions for irrigation systems that increase the positive externalities (i.e., quality of life, recreational opportunities) and decrease the negative ones (i.e., water quality problems, diminished in-stream recreation opportunities) are most likely to increase the overall, net economic benefits, jobs, income, and property values derived from the state's water resources.

Support for these conclusions comes from several sources. The state's agricultural sector and its irrigated component, have exhibited little ability to sustain rapid growth in jobs and income. Instead, these variables have grown slowly, remained steady, or declined over much of the past several decades and in most parts of the state. In contrast, the state's population has been growing and its economy has diversified rapidly, so that a declining percentage of the state's businesses and households derive their earnings from irrigated crops. Much of the state's economic activity is determined, and likely will be determined in the future, by its amenities that attract households, investment, and businesses. This relationship applies throughout the state, although it is stronger in some areas than in others. Many of the most important amenities—recreational opportunities, habitat for fish and wildlife, attractive scenery, open space, etc.—are subject to the external effects of irrigation.

Our assessment of economic issues associated with irrigated agriculture is limited by the lack of fine-resolution data regarding irrigation systems, agricultural market conditions, the status of the ecosystem's ability to produce water-related goods and services, and overall economic processes throughout the state. Additional uncertainty arises from various factors that are likely to have a strong influence on the future relationship between irrigation and the economy. Foremost among these factors are future agricultural market conditions affecting the demand for and the cost of producing irrigated crops; climate change; amenity-driven growth that is linked to the demand for water-related amenities affected by irrigation; increases in property values that alter the feasibility of irrigated farming; and intrastate and interstate conflicts over water. Thus, we cannot discern in detail the multiple economic consequences stemming from irrigated agriculture in different parts of the state or how further investment in irrigated agriculture would affect them.

These limitations do not, however, erode our confidence in the general applicability of our findings regarding the relationship between irrigated agriculture and Montana's economy. Both the ability of irrigation to produce crops and the external effects of irrigation on the ecosystem's ability to produce non-crop goods and services are important to the economy. The character of this importance varies from place to place. In general, amenity-related externalities (i.e. scenic views, pastoral landscapes) are more important near the mountains and metropolitan centers, and crop-production is more important on the plains and near rural communities, but these distinctions are a matter of degree, not absolutes. In short, the relationship between irrigation and the economy is complex, and all elements of the relationship are important everywhere—in eastern Montana as well as in western Montana, in isolated communities as well as near metropolitan centers—but with a different mix and to a different degree.

None of this is intended to diminish in any way the economic importance of irrigated agriculture in Montana's economy and communities, nor is it intended to disparage those who participate in or support irrigated agriculture. Rather, the core message of this section is this: powerful economic forces in Montana are increasing the value, jobs, and income associated with the external effects of irrigation (effects on the supply of goods and services other than crops) relative to those associated with the irrigated crops themselves, and the external effects, both positive and negative, are increasingly as important or more important than the effects on agriculture.

IV. Policy Implications of the Economic Analysis

Irrigation has widespread, intense effects on Montana's economy. It produces economic benefits by increasing the supply and/or value of some crops, and it generates jobs and income for many Montanans. At the same time, it produces other benefits by increasing the ecosystem's ability to produce some non-crop goods and services (such as recreational opportunities and wildlife habitat), and other costs by decreasing its ability to produce other goods and services (such as water quality and habitat for some threatened and endangered species). These external effects also impact jobs and income throughout Montana.

There is a widespread belief that state investment is required to prevent dissolution of existing irrigation systems and to spur expansion of new irrigation. Available information, however, is not sufficient to quantify the overall, net benefits (or net costs) or the net impacts of irrigated agriculture as a whole in the state, or of individual irrigation systems. It does, though, indicate that the externalities, such as diminished water quality and increased recreational opportunities, are important enough that one cannot overlook them and hope to have anything near an accurate assessment of irrigation's net economic consequences. Developing an accurate assessment will require further investigation of the externalities. Conditions are sufficiently variable across the state that no one size will fit all; instead, the assessment of net benefits and net impacts will require case-by-case analysis. Such analysis might find that state investment is warranted to increase the net benefits derived from the state's water resources or to increase jobs and income for Montanans. Or, it might not.

The same is true of the potential influence of several major sources of uncertainty and risk regarding the economic outlook for irrigated agriculture, its externalities, and its economic consequences. Foremost among these are the future of agricultural markets, the effects of climate change, the future role of water-related amenities as a source of economic growth, and the resolution (or not) of various intrastate and interstate disputes over water. These factors, individually or collectively, have the potential to alter markedly the economic importance of irrigation and its externalities, either upward or downward.

To obtain a full assessment of the potential economic consequences of investing in an irrigation system, one must also examine how it might interact with options for improving the productivity of irrigation. Available evidence suggests that, as a whole, irrigation systems in Montana are among the least efficient in the nation, withdrawing large amounts of water from streams and aquifers relative to the needs of irrigated crops. Evidence also indicates that, with appropriate market structures, many irrigators could increase the earnings they derive from irrigation water. Efforts to improve productivity might complement or supplant investments to refurbish existing irrigation infrastructure or to build new infrastructure.

The discussion in the preceding pages indentifies implications for specific programs and locations. They highlight the impacts, for example, of improving water-use efficiency, finding new ways to generate farm income, and sorting out obligations in the management and financial responsibility of some irrigation systems. To conserve space, we do not repeat the full set of implications here, but encourage readers to consult the earlier text.

V. Conclusions and Recommendations

The information we present above demonstrates that irrigated agriculture plays important and wide-ranging roles in the economies of Montana and its communities. Its importance materializes directly, insofar as irrigation enables farmers to increase their production of crops or produce higher- rather than lower-value crops. As a result, consumers enjoy an enhanced supply of food, irrigators realize higher net farm earnings, landowners see the value of irrigated land rise, and farm families, workers, businesses, and communities have expanded opportunities for jobs and higher income. The economic importance of irrigation also materializes indirectly, as it alters the ecosystem's ability to produce valuable, non-crop goods and services. Irrigation can have both positive and negative effects on the supply of non-crop goods and services. These external effects create economic benefits as well as costs, and have positive as well as negative impacts on jobs and income throughout Montana. In many, if not most, situations, these externalities accrue to households and businesses not directly linked to irrigation and, hence, they affect, both positively and negatively, the development of non-agricultural sectors of the state's economy.

Montana is subject to strong national and regional trends that are raising the economic importance of some of irrigation's externalities faster than that of irrigated crops. Especially important are irrigation's effects on amenities, such as scenic vistas and recreational opportunities. Households' growing demand for housing close to these amenities is, in most years and most parts of Montana, exerting greater influence on the price of irrigated lands than does the ability of irrigated lands to give farmers' higher net farm earnings. This is certainly the case in much of western Montana, but it also applies in much of the eastern part of the state, where land appraisers report a growing demand for irrigated farmland from individuals with little or no intent to manage the land primarily as a commercial farming enterprise. Recent research also shows that local water-related amenities have a stronger influence on county-level employment in eastern Montana than in western parts of the state. In some parts of Montana, such as the Milk River Basin, irrigation increases net farm earnings but, even so, they remain largely negative, which suggests that households in this area continue to farm, not to increase their net earnings, but to enjoy the quality of life associated with the farm-ranch lifestyle.

Too little is known about the externalities of irrigated agriculture to have anything near a full understanding of them, of how they affect the overall net economic consequences of irrigation, or of how these net consequences vary across Montana's landscape. Similarly, too little is currently known about factors likely to exert a strong influence on the financial feasibility of irrigation and the extent of its externalities. These factors include climate change and its potential impacts—not just on agriculture in Montana, but also on other agricultural areas around the world—the evolution of agricultural markets in Montana and elsewhere, the pattern of future amenity-driven growth in the state, and the outcome of intrastate and interstate water conflicts.

Our case study of the area documents evidence showing that the St. Mary–Milk River irrigation system exhibits substantial disrepair. There is a widespread belief—the data, however, are too limited to confirm it—that many of the state's other irrigation systems are in disrepair. Moreover, it appears that, in many instances, serious, if not insurmountable, hurdles must be overcome if the local irrigators are to muster sufficient funds to keep them from deteriorating further and, perhaps, falling out of service. Many systems lack the institutional foundation needed to plan refurbishment, raise sufficient funds, and complete the job. Our case study of the Bitterroot Valley exemplifies areas in the state where residential farms and ranches—called hobby farms or ranchettes—have replaced commercial agriculture, reducing the number of commercial operations that historically have had financial responsibility for irrigation infrastructure and, more fundamentally, raising questions about who bears what responsibility for the system. In surveys, irrigators throughout the state commonly assert that they lack sufficient financial resources to undertake significant net investments on their own.

Against this backdrop, some have called for the state to provide funding for refurbishment, both to sustain irrigated agriculture as a functioning sector of the economy and to accomplish various goals regarding the externalities of irrigation. Others seek state funding to expand irrigated agriculture, especially in eastern Montana where the state has reserved water for irrigation. The available information does not, however, provide an adequate basis for concluding that the investment of state funds necessarily would yield benefits that outweigh the costs or that it would have a positive, net impact on the state's jobs and income. To make such a determination, one must complete, on a case-by-case basis, an assessment of several factors, among them:

- The net farm earnings derived from irrigation, and the associated ability and willingness of irrigators to allocate the net earnings to support the cost of the investment.
- The nature and value of the externalities of irrigation.
- The extent to which the overall benefits resulting from irrigation exceed the costs, accounting for both the effects of irrigation on crops and non-crop goods and services.
- The extent to which the overall economic impacts of irrigation on jobs and income are positive.
- The nature of the economic risks and uncertainties associated with irrigation, relative to the non-irrigation baseline.
- The distribution of the positive and negative economic consequences of irrigation among different groups.

Actions that would increase the economic productivity of irrigation systems may constitute a reasonable complement or alternative to refurbishing existing irrigation infrastructure or building new infrastructure. Productivity increases can be accomplished by improving the water-use efficiency of irrigation systems, and by expanding markets that would allow irrigators to increase earnings by leasing or selling water rights or by receiving payments for ecosystem services they produce. Increasing productivity is especially important in areas where water resources are fully appropriated, so there is no water for additional irrigation, and where irrigation has caused severe environmental consequences, such as dewatering of streams and significantly degrading habitat for species facing significant risk of extinction.

Based on our findings, we offer the following recommendations for those seeking to enhance the net economic benefits and net economic impacts derived from irrigation.

A. Before investing public funds in irrigation, Montanans should consider the full suite of positive and negative consequences, as well as the major trends likely to affect the future relationship between irrigation and the economy.

There are hundreds of irrigation systems, varying in size and complexity, spread throughout Montana, mostly in locations where they draw water from one of the state's streams or rivers. Many systems that are several decades old require refurbishment, lack adequate capital-replacement funds to complete the job, and may look to the state for assistance. Others may look for assistance because urban development and the conversion of land from the commercial production of irrigated crops to other uses has altered the demands on the irrigation system and fractured the revenue base dedicated to its management. Proposals to expand irrigation infrastructure may come from existing systems or from farmers, landowners, and others seeking to develop new systems. The focus is generally on refurbishment in western basins, as most of these have been closed to further appropriation of water for consumptive use. In eastern Montana, there are potential opportunities to expand irrigation in the lower Missouri and lower Yellowstone Basins, where the state has formally reserved water for this purpose. Some systems in eastern Montana, such as the St. Mary-Milk River system, also require refurbishment.

The economic analysis shows that investments in irrigation infrastructure yield both economic benefits and economic costs. They also have positive as well as negative impacts on jobs, income, and property values. These varied consequences come about because the ecosystems from which irrigation water is obtained are able to produce many goods and services, and, when the water is used for irrigation it increases the supply of some and diminishes the supply of others. Historically, economic analyses of irrigation investments focused primarily on the benefits, costs, jobs, and income directly associated with the increased agricultural production resulting from irrigation. Today, to understand the full economic consequences of an irrigation investment, one must consider the external consequences, i.e., the changes in the goods and services other than crops.

These external consequences vary from place to place and over time, but they are important throughout the state. In some instances, their economic importance exceeds that of the increased production of crops resulting from irrigation. Their economic importance relative to that of increased crop production is likely to increase as Montana's population grows and its economy diversifies, so that an ever-increasing percentage of the state's households and businesses derive economic benefits, jobs, income, and higher property values from water-related goods and services other than irrigated crops. This does not mean that irrigation and irrigated agriculture are not economically important now or that they will not be economically important in the future. Instead, it merely recognizes powerful economic trends that have been underway for decades and show no signs of abating.

Economists urge public decision-makers to consider the net benefits and the net impacts of the expenditure of public funds. An irrigation investment would yield net benefits if the value of those goods and services whose supply would increase because of the investment, plus any savings in the operation and maintenance of the system, outweigh the monetary investment plus the value of those goods and services whose supply would decrease. It would yield net positive impacts if the jobs, income, and increase in property values resulting from the investment would be larger than the losses.

If Montanans want to use public funds to improve the value of the goods and services available for their consumption, then decision-makers should undertake an irrigation investment only if doing so would maximize the net benefits derived from the investment funds. If it would not, then it would be better to spend the money on alternative investments, or to tax less. Similar reasoning applies if the objective is to use public funds to generate jobs, income, and property value.

To determine the overall net benefits and the net impacts of an irrigation investment, one must consider how it would affect the supply of goods and services associated with all the competing demands for water-related goods and services. These include the demand for irrigation water, of course, but also competing commercial demands from other irrigators and/or other sectors of the economy. They also include consumers' demands, which we separate into two categories. One is consumers' demand for amenities that affect the quality of life for residents and visitors to the state. The other is their demand for environmental values associated with the ecosystem's ability to lower the cost of living and to sustain valuable species, resources, and landscapes.

A full assessment of a proposal to invest in irrigation also should weigh factors that influence the amount of uncertainty regarding the investment's potential economic outcomes. These factors include the markets whose evolution will determine the value of irrigated crops and the costs of producing them; the demands for water-related amenities, which will largely determine the nature of irrigation's externalities; the rising property values resulting from population growth and the demand for amenities, which will affect the land-related cost of farming; climate change, which influences water supplies and the potential resolution (or not) of significant water conflicts inside the state and between Montana and its neighbors.

Public funds also should not be used to modernize or expand irrigation if private parties would undertake such actions without public funding. Spending public funds in such instances would not increase net economic benefits or impacts above what otherwise would occur. Public funds should be invested in irrigation only when doing so would generate net economic benefits, from the overall public's perspective, from projects that otherwise would not occur. Stated differently: a public investment should be undertaken only in circumstances where (a) private parties have determined that the investment would yield net costs for private investors; and (b) the externalities from the investment are expected to yield net benefits sufficiently large to outweigh these net costs. This decision-making approach will guard against making investments in irrigation projects that irrigators, themselves, are willing to make, and ensure that public funds generate the highest net benefit for Montanans as a whole.

B. Montanans should consider the distribution of positive and negative economic consequences among different groups.

Any investment in irrigation will yield both positive and negative economic consequences, and their distribution among different groups must be determined on a case-by-case basis. As a general rule, however, the direct distributional outcome will be that taxpayers will incur the monetary cost of the investment and the irrigators—as well as the consumers of irrigated crops and the land owners, workers, businesses, and communities linked to the resulting increase in irrigation water—will realize the economic benefits and/or increases in jobs, income, and property value. The externalities of the investment—positive and negative—are harder to predict. Changes in recreational opportunities and other amenities likely will affect both local residents and businesses, as well as those farther away, in correspondence with the households' willingness to travel to take advantage of them. Changes in the ecosystem's ability to produce goods and services, such as flood control, also may have both local and distant consequences.

C. Montanans should consider investments in improving irrigation efficiency as a reasonable complement or alternative to refurbishing existing irrigation infrastructure or constructing new infrastructure.

Although some are far better than others, Montana's irrigation systems, as a whole, are among the least efficient in the West, withdrawing far more water from streams and aquifers than irrigated crops require. Improving the efficiency of inefficient systems may leave current irrigators with adequate water for their crops and increase the supply of water for additional irrigation or for the production of non-crop goods and services. There are three general, efficiency-enhancement strategies: (1) convert less-efficient, surface-irrigation methods to more-efficient methods; (2) use irrigation-scheduling techniques that measure crops' irrigation requirements precisely; and (3) reduce losses of water by lining ditches and canals that deliver irrigation water. Such actions probably will have multiple economic consequences, some positive and some negative, which must be determined on a case-by-case basis.

Public investment in water-use efficiency may be warranted insofar as irrigators expressing a desire to invest in water-use efficiency often say they lack the financial wherewithal to make the investments. Public investment also may be warranted by current water law, which can discourage private investments in water-use efficiency, because the current water user may realize few of the benefits when such investments make water available for other uses and users.

D. Montanans should investigate and pursue opportunities to develop markets that offer opportunities to increase farm income derived from irrigation water.

Two types of markets offer opportunities for additional farm income. One creates or expands opportunities for irrigators to receive Payments for Ecosystem Services (PES) they produce. The other facilitates the transfer of water from a lower-value use to a higher-value use.

Some PES markets, such as the Conservation Reserve Program, are familiar and long-standing. Over the past couple of decades, however, programs with greater diversity have emerged, enabling some farmers to receive payments for restoring wetlands (the Montana Enhancement Program) and expand hunting opportunities (Montana Block Management program). Public investment to broaden the scope of such programs may be warranted to overcome hurdles that impede even further diversification. Efforts might be targeted at reducing administrative costs, creating pilot projects, reducing farmers' risk and liability, and increasing the funds available to state agencies for making appropriate payments for ecosystems services.

Water markets can offer robust opportunities for increasing the value of the crops (and other goods and services) derived from a given supply of water. Market-based, voluntary transfers of water should increase the economic well-being of both the sellers and the buyers because a transaction would occur only if both parties expected it to be beneficial. Public investment in water markets, at least until more experience with them is accomplished, may be beneficial to overcome barriers that are insurmountable by individual irrigators. Intervention might lower administrative costs to consider and resolve the concerns of thirds parties that might be affected by a water transfer, help potential buyers and sellers find one another, and verify that water is moved and used in accordance with the terms of a transaction.

E. Montanans should sponsor research targeted at developing a better understanding of the economic consequences of potential, water-related investments.

We urge giving priority to Montana-specific research aimed at developing a better understanding of:

- The non-crop ecosystem goods and services affected by irrigation, their value, and their impacts on jobs and income.

- Opportunities and risks associated with anticipated changes in climate and its potential effects on the demand for crops, the ability of Montana's farmers to grow specific crops, the frequency and severity of drought, the demand for and supply of non-crop ecosystem goods and services, and the economic consequences of decreases or increases in irrigated agriculture.
- Factors other than climate change that might undermine the economic stability of irrigated agriculture in Montana as a whole or in regions of the state. Special concern should address potential conflicts between irrigation and society's demands for non-crop goods and services adversely affected by irrigation.
- The status of existing irrigation systems, the likelihood of a major system disruption or failure, the economic consequences of such an event, and the economic consequences of state intervention to prevent it.
- Opportunities to increase the water-use efficiency of existing irrigation systems, the economic consequences of current inefficiencies, and the potential economic requirements and consequences of efforts to make systems more efficient.
- Opportunities to grow higher-value crops on irrigated cropland, and expand production of value-added agricultural products.
- Potential markets that would expand opportunities for irrigators to increase earnings derived from irrigation water, through payments for ecosystem services and voluntary transactions that transfer water from lower-value to higher-value uses.

We finish our discussion with these final observations. Nothing in this report should be construed as an economic evaluation of any specific, potential investment in irrigation infrastructure. The level of analysis in this report is not sufficiently detailed to provide support for or against any specific public investment in irrigation. Moreover, nothing in this report should be construed as disregarding water rights and the system of laws that support them. Instead, this report describes the relationship between irrigation and the economy and recognizes that, although some elements of this relationship are intertwined with the system of existing water rights, others are not.

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APPENDIX A. PERSONAL COMMUNICATIONS

The following are the people with whom we have had personal conversations during the course of the project, listed in alphabetical order by last name.

Paul Azevedo, Planner, DNRC, Water Resources Division, Water Management Bureau

Mike Ames, AgriIndustries, Williston, North Dakota

Fred Bailey, USGS Montana Water Science Center

Larry Bloxsom, Financial Specialist, DNRC, Conservation and Resource Development Division, Resource Development Bureau

Jennifer Brandon, Manager, Milk River Joint Board of Control

Tim Bryggman, Natural Resource Economist, DNRC, Water Resources Division, Water Management Bureau

Dr. Gary Brester, Professor of Agricultural Economics, Montana State University

Duane Claypool, Program Manager, DNRC, Conservation and Resource Development Division, Resource Development Bureau

John Crowley, Manager, Bitter Root Irrigation District

Mike Dailey, Hydrologist/Planner, DNRC, Water Resources Division, Glasgow Regional Office

Lenny Duberstein, Planner, Bureau of Reclamation, Montana Area Office

Bob Fischer, Civil Engineer Specialist, DNRC, Conservation and Resource Development Division, Resource Development Bureau

Ralph Gourley, Appraiser, Gourley & Company

Rankin Holmes, Interim Executive Director, Montana Water Trust

Dan Huls, Right to Farm and Ranch Board

Dick Iversen, Coordinator, Eastern Plains Resource Conservation and Development

Rob Johnson, Extension Agent, Montana State University, Ravalli County Extension Office

Tom Konency, Appraiser, DNRC, Trust Land Management Division, Real Estate Management Bureau

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Harlan Lund, Appraiser, Farm Credit Services

George Luther, Appraiser, Luther Appraisal Services

Mike Mclane, Instream Flow Specialist, Montana Fish, Wildlife, and Parks

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Carrie Mosley, Assistant State Conservationist for Programs, USDA Natural Resources Conservation Service

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Randy Phelan, Acting Assistant State Conservationist (Operations), USDA Natural Resources Conservation Service

Damon Pellicori, Water Resource Manager, Montana Water Trust

Randy Reed, Farmer/Rancher, Chinook

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George St. George, Economist, Bureau of Reclamation, Montana Area Office

Rick Vinton, Manager, Bureau of Reclamation, Economics and Resource Planning Group, Technical Service Center

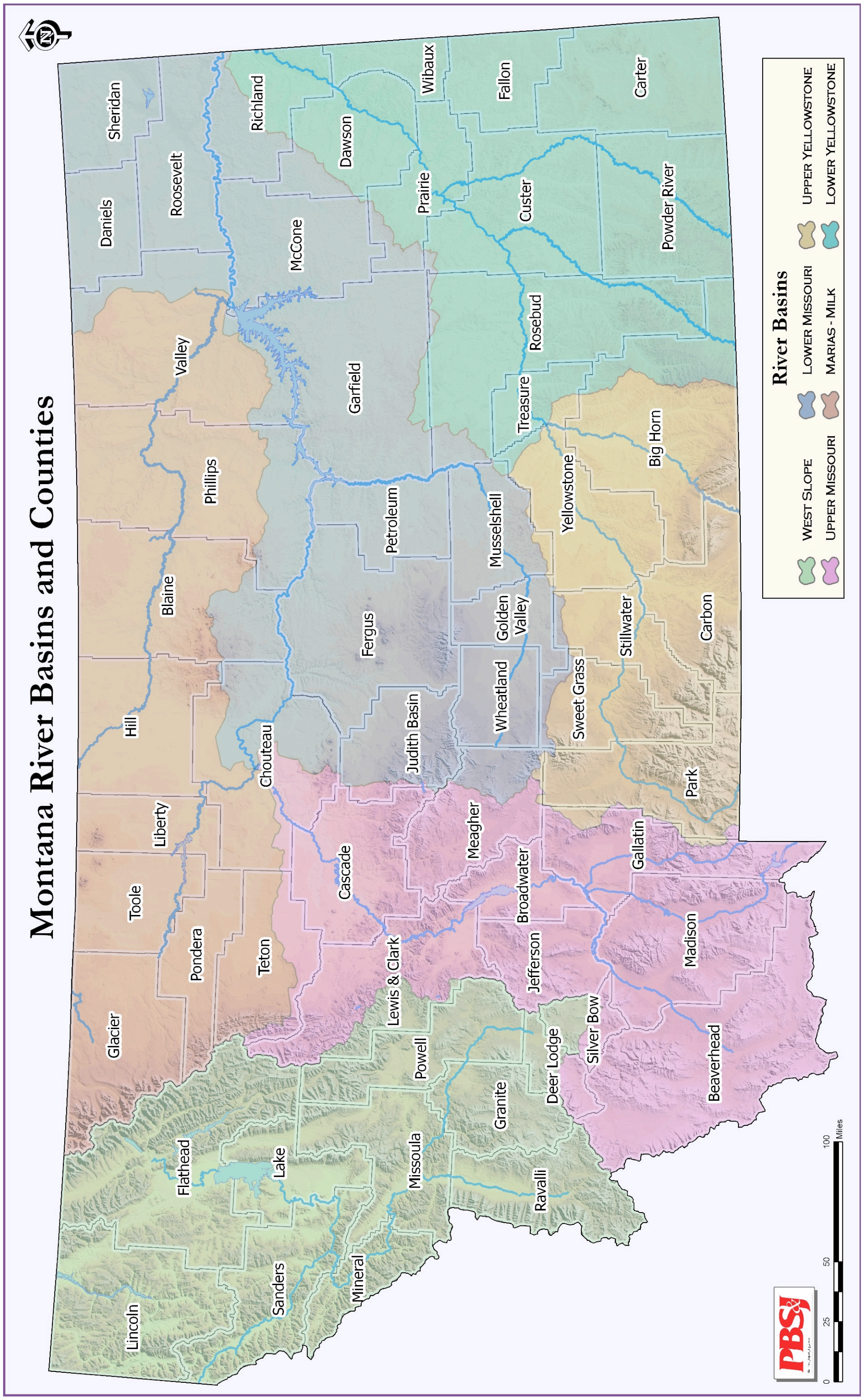
Collin Watters, Program Manager, Montana Department of Agriculture

Laurie Zeller, Resource Specialist, DNRC, Conservation and Resource Development Division, Conservation District Bureau

APPENDIX B. MAPS

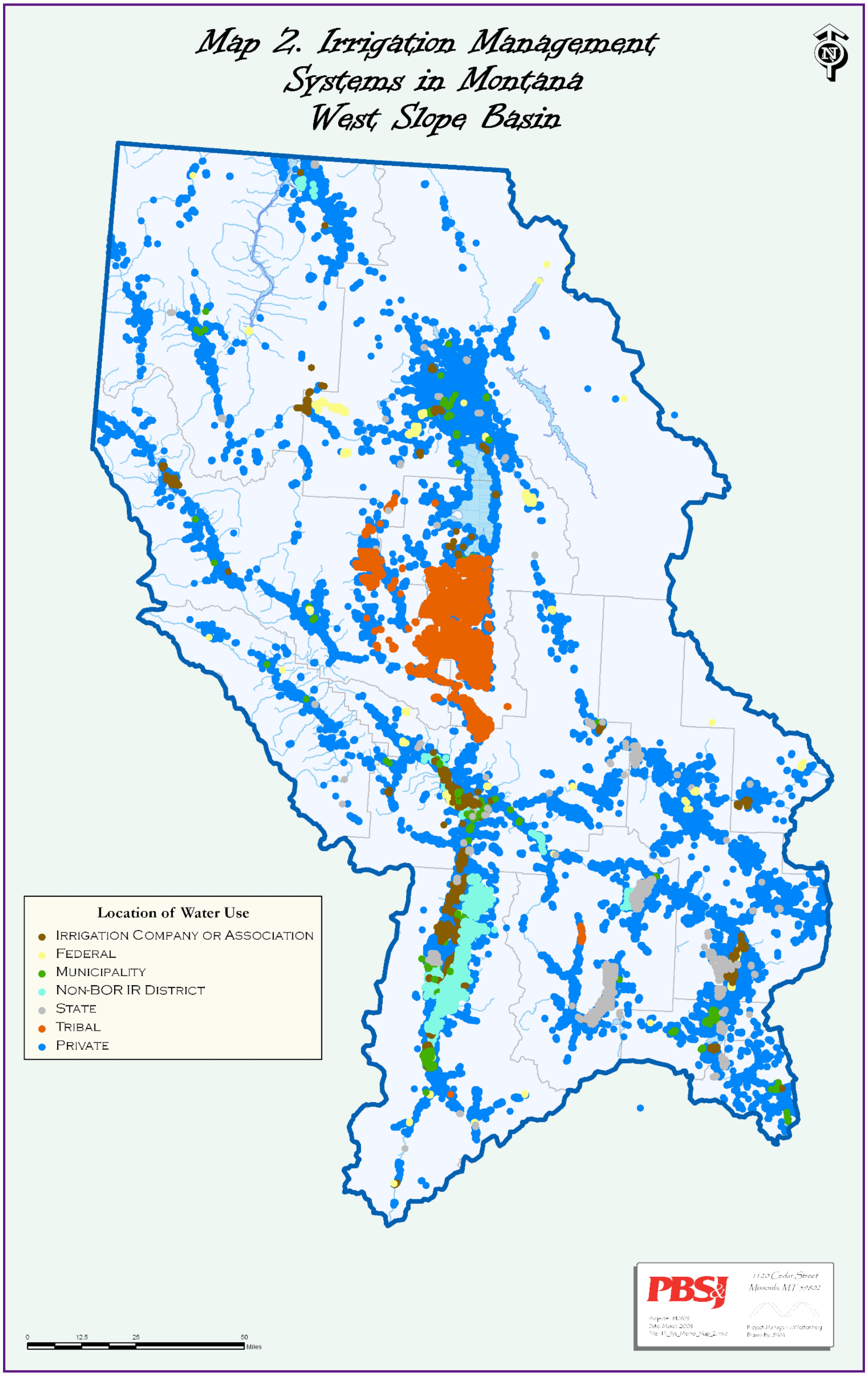
Below are the maps referenced in the report. Map B-1 (referenced on page 3) shows the six river basins used in this study. Maps B-2 through B-7 (referenced on page 5) show the distribution of private and public irrigation systems in each basin. For a more detailed description of each map, see *Technical Memorandum 1.3 – Irrigation Management Systems*. Map B-8 (referenced on page 8) shows the basins in Montana that are closed to further allocations of water.

Figure B-1. The Six Basins Used in this Study



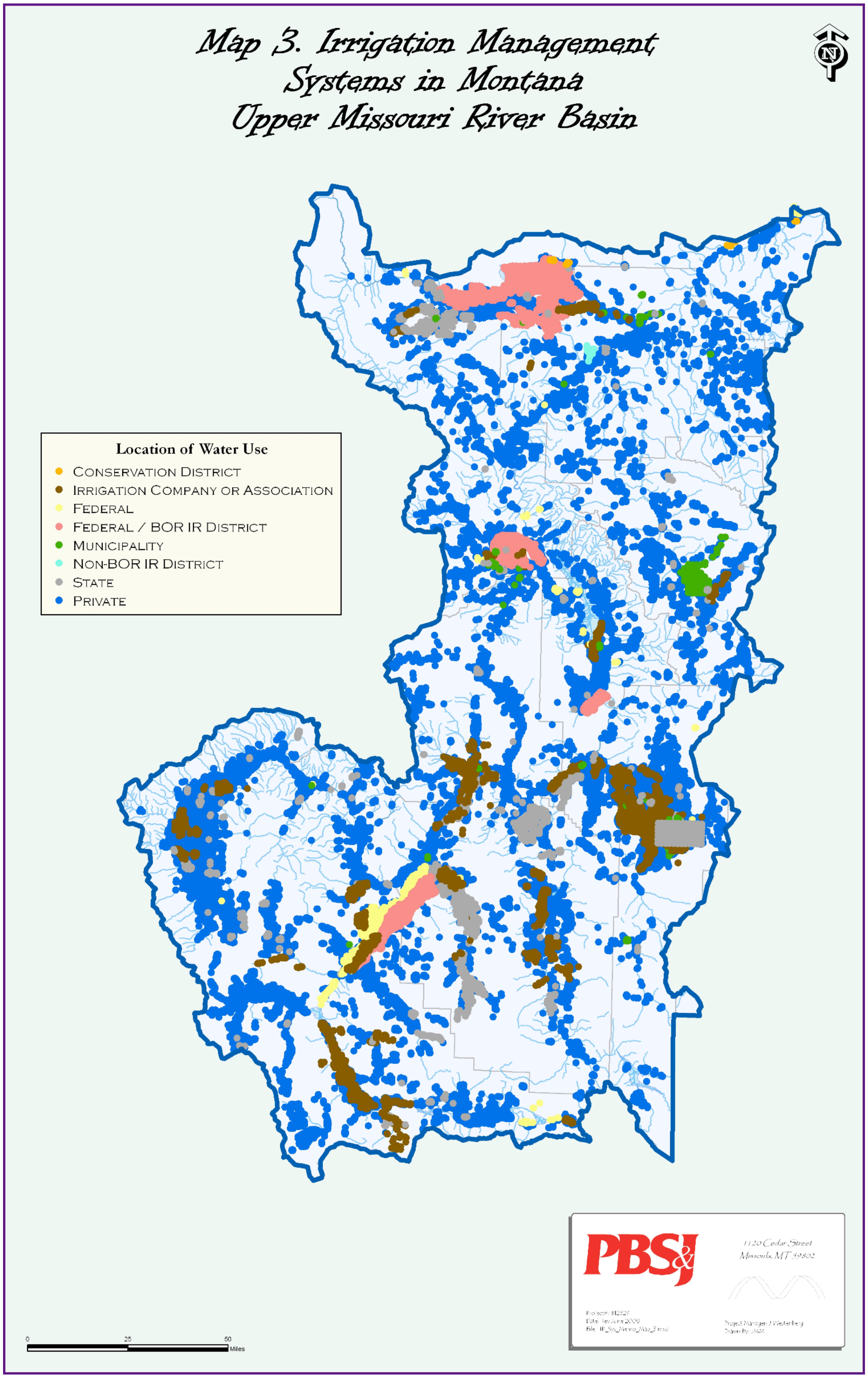
Source: PBS&J

Figure B-2. Irrigation Management Systems in the West Slope Basin



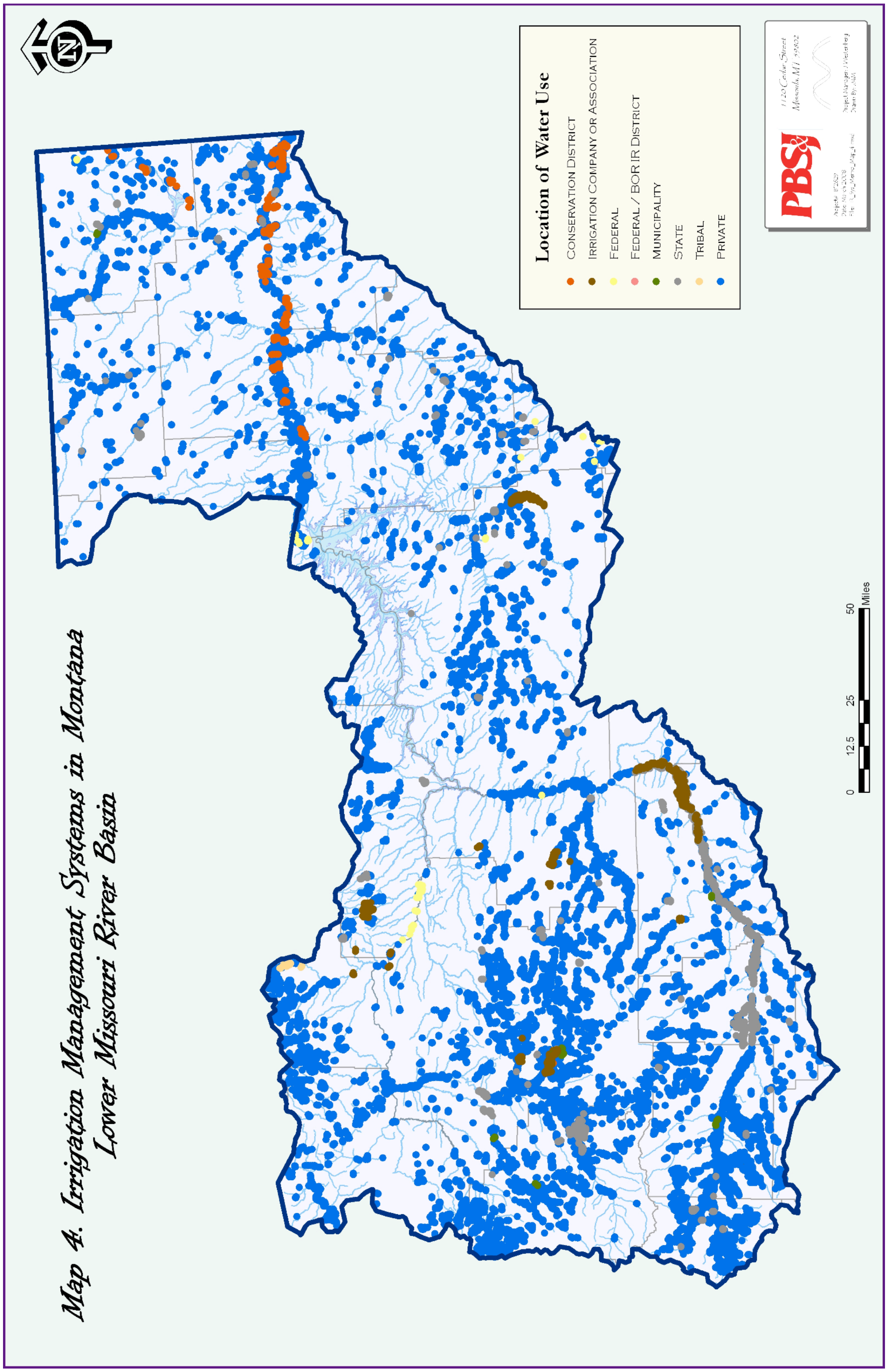
Source: PBS&J

Figure B-3. Irrigation Management Systems in the Upper Missouri River Basin



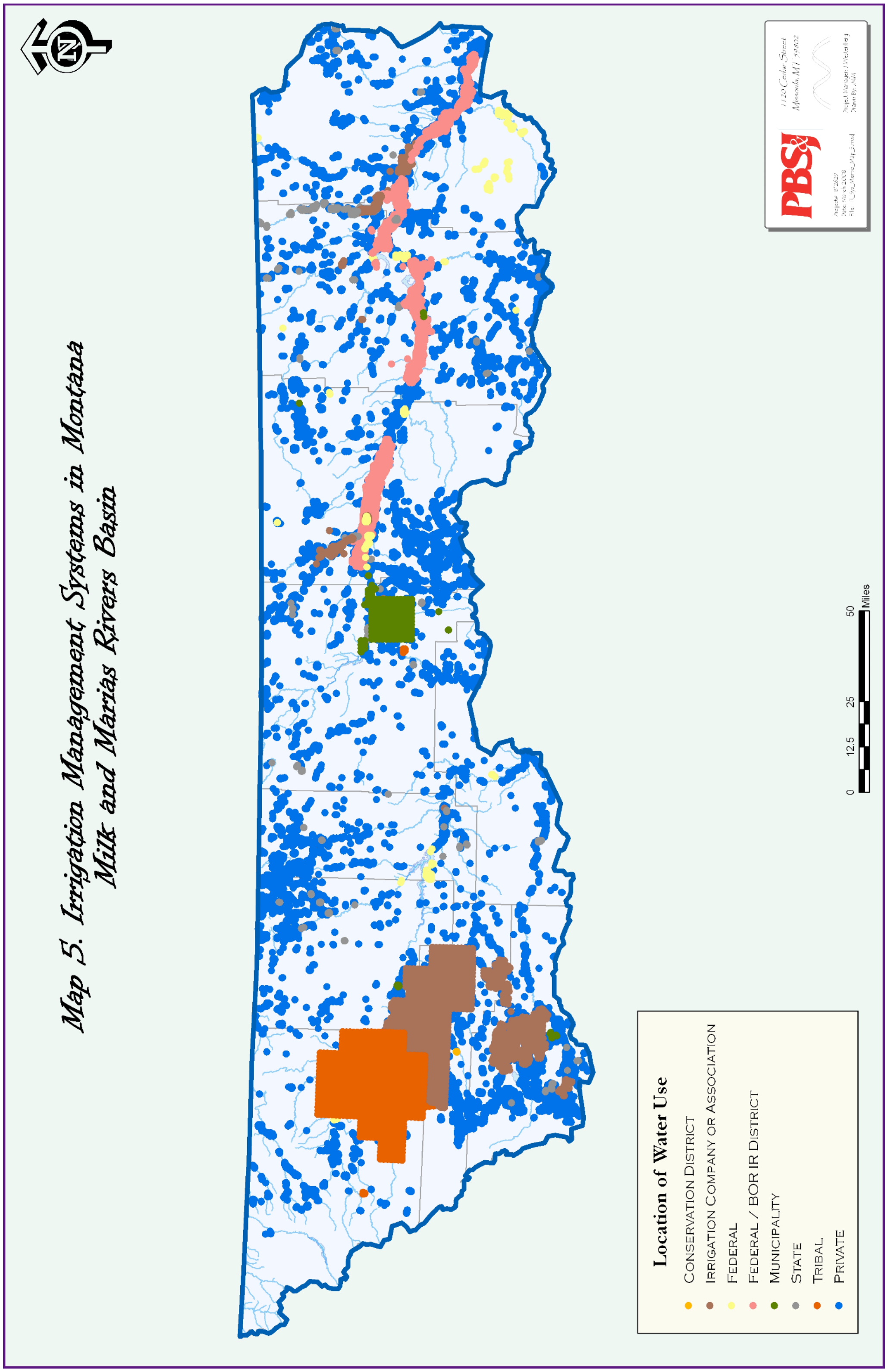
Source: PBS&J

Figure B-4. Irrigation Management Systems in the Lower Missouri River Basin



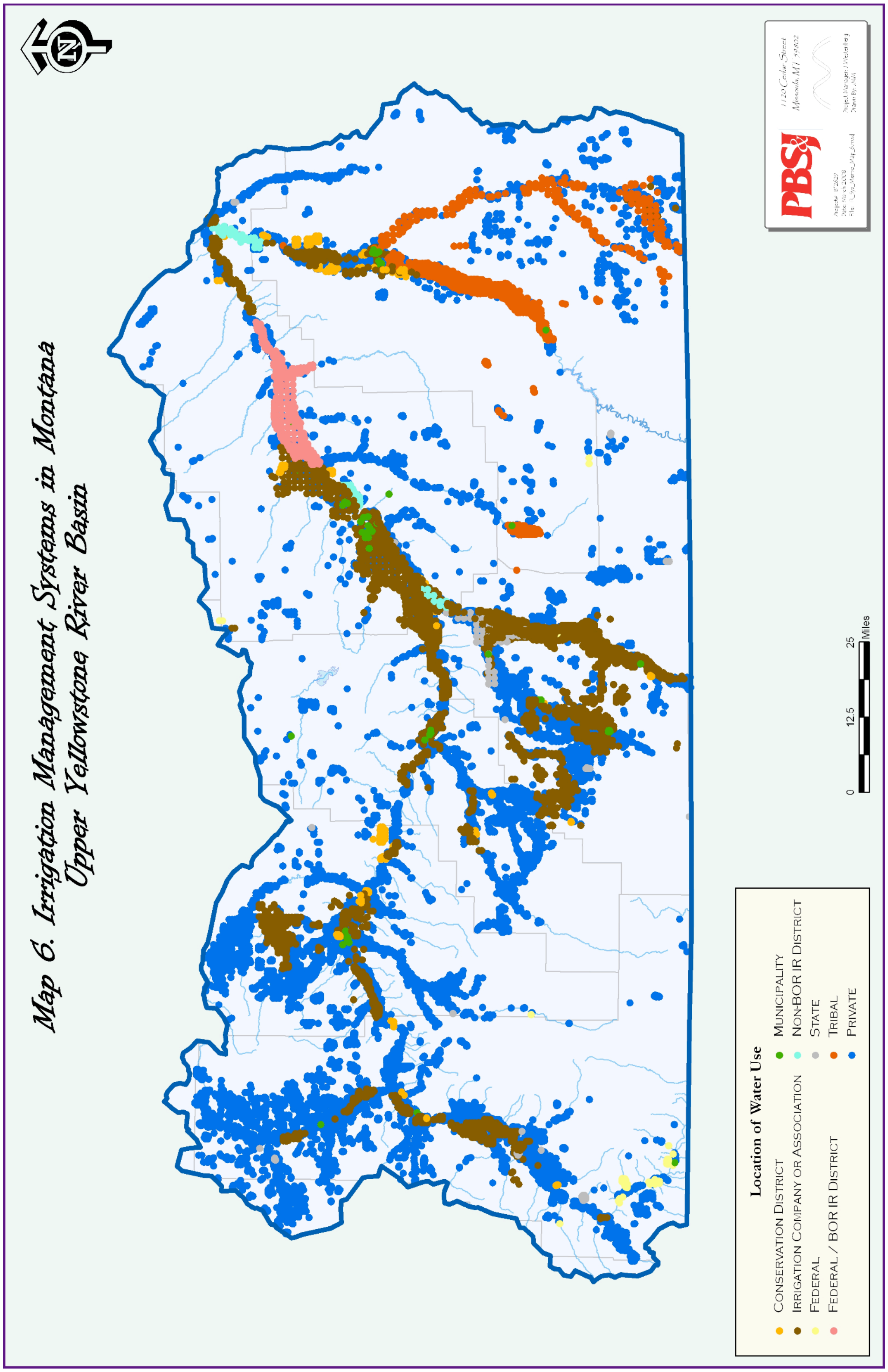
Source: PBS&J

Figure B-5. Irrigation Management Systems in the Milk and Marias Rivers Basin



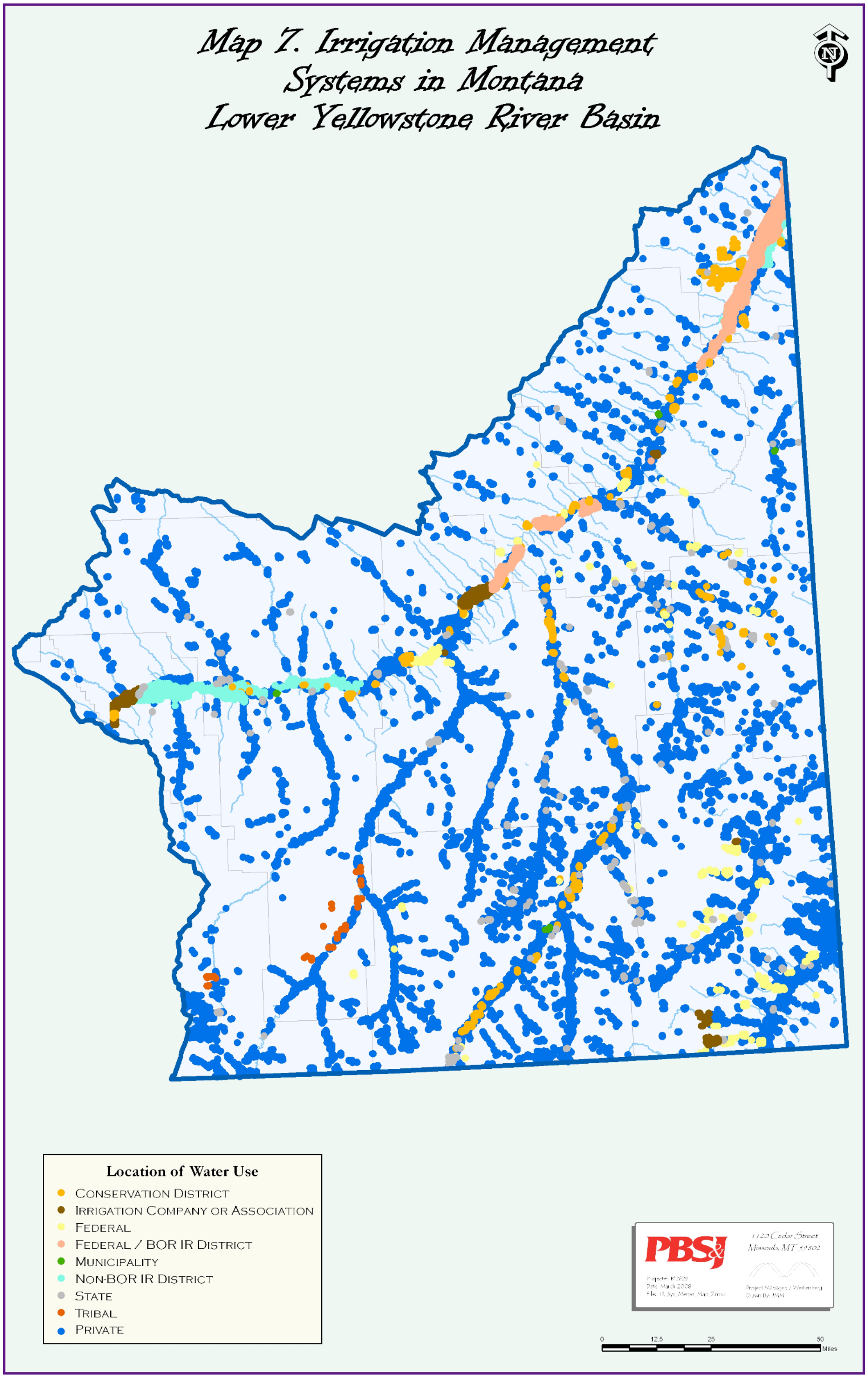
Source: PBS&J

Figure B-6. Irrigation Management Systems in the Upper Yellowstone River Basin



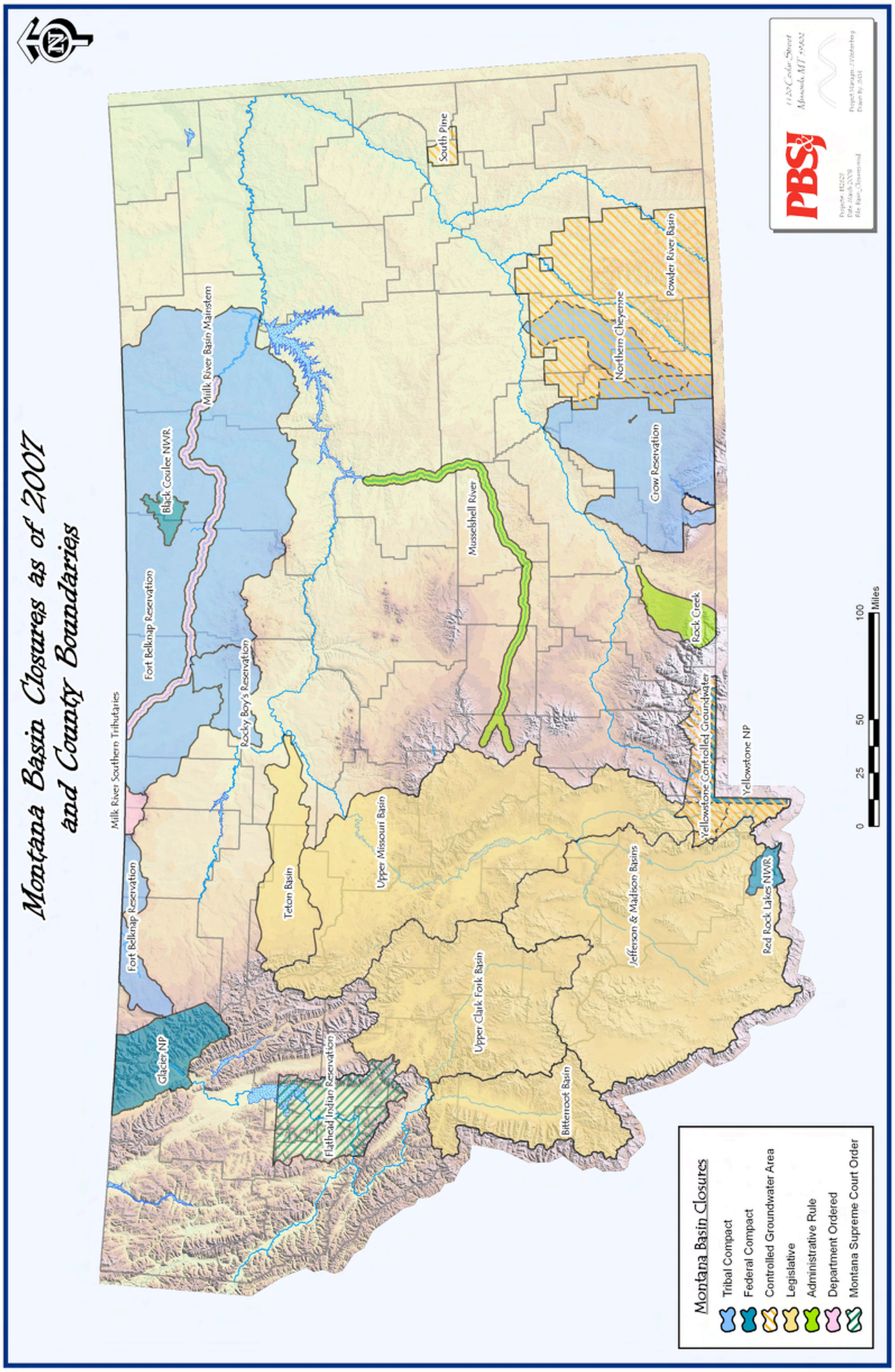
Source: PBS&J

Figure B-7. Irrigation Management Systems in the Lower Yellowstone River Basin



Source: PBS&J

Figure B-8. Montana Basin Closures as of 2007



Source: PBS&J