Preliminary Working Draft

Montana Water Supply Initiative

Lower Missouri River Basin Water Plan

Photo by Michael Downey, DNRC

Lower Missouri River Basin Advisory Council

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Montana Department of Natural Resources & Conservation

Water Resources Division

Prepared for Montana Water Policy Interim Committee
May 12, 2014

Montana Water Supply Initiative – State Water Plan 2015
75% Draft Report for the Lower Missouri Basin

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The Montana Legislature recognizes that in order to achieve the public policy objectives specified in § 85-1-101 MCA "and to protect the waters of Montana from diversion to other areas of the nation, it is essential that a comprehensive, coordinated multiple-use water resource plan be progressively formulated to be known as the 'state water plan'" (§ 85-1-101(10) MCA).

Responsibility and statutory authority for developing the state water plan is given to DNRC in § 85-1-203 MCA with instructions to "gather from any source reliable information relating to Montana's water resources and prepare from the information a continuing comprehensive inventory of the water resources of the state." As directed by the Legislature in § 85-1-203(2) MCA, "the state water plan must set out a progressive program for the conservation, development, utilization, and sustainability of the state's water resources, and propose the most effective means by which these water resources may be applied for the benefit of the people, with due consideration of alternative uses and combination of uses".

Sections of the state water plan must be completed for the Missouri, Yellowstone, and Clark Fork River basins, submitted to the 2015 legislature, and updated at least every 20 years. Montana citizens are given a formal role in the planning process through water user councils established in accordance with the instructions given by the legislature in § 85-1-203(4) MCA. The role of the water user councils is to make recommendations to DNRC on the basinwide plans.

In developing and revising the state water plan, DNRC is instructed to consult with, and solicit advice from, the environmental quality council. The Legislature, by joint resolution, may revise the state water plan.

Question - Should § 85-1-101 and 85-1-203 be included as appendices?

D. History of Water Planning in MT

1. State-wide Planning History

Water is arguably Montana's most valuable natural resource. The rivers, streams, lakes, and groundwater have shaped the stories of our rich history of settlement, agriculture, mining, industry and recreation, and quality of life. As the physical and economic needs of the state evolve, planning for the conservation and development of our water resources also evolves.

Initial efforts at water resources planning in Montana centered on the development of irrigated agriculture to promote settlement of the west. Water development projects were seen not just as desirable, but as essential to the economic viability of the state. In 1895 the Montana Legislature created the Arid Land Grant Commission to manage the reclamation of lands granted to the State under the federal Carey Land Act of 1894. In 1903, the Commission was abolished and replaced by the Carey Land Act Board. 1903 also saw the U.S. Congress authorize construction of the Milk River Project as one of the first five reclamation projects built by the newly created Reclamation Service (now Bureau of Reclamation) under the Reclamation Act of 1902.

In the 1920's, the Montana Irrigation Commission produced county-by-county plans for irrigation development. In addition, the Commission assisted in organizing and management of irrigation districts around the state. It also had jurisdiction over the sale of water, water rights, and the contracting of water for irrigation. The Commission was abolished in 1929.

The precarious position of agriculture and the livestock industry in Montana during the early 1930's promoted extensive individual and group effort towards seeking ways to put Montana's water resources to beneficial use. Late in 1933, a special session of the state legislature passed House Bill No. 39 creating the State Water Conservation Board. The Act creating the Board declared that the public interest, welfare, convenience and necessity required the construction of a system of works for the conservation, development, storage, distribution and utilization of water. Broad powers were given to the Board allowing it to cooperate and enter into agreements with all federal and state agencies, investigate, survey, construct, operate and maintain, and to finance the construction of projects.

Between 1934 and 1960, the Board built 181 water conservation projects. These included; 141 dams and reservoirs, 815 miles of canals, 23 miles of domestic water supply pipelines, and 24 miles of transmission lines to bring power to pumping stations. All told, the Boards actions created 438,017 acre-feet of storage and developed 405,582 acres of irrigated land (R. Kingery, personal communication 12 July 2013.). This period also saw Congressional approval of all the major federal water projects in Montana. These include Fort Peck, Canyon Ferry, Hungry Horse, Tiber, Yellowtail, and Libby dams.

When Montana began to negotiate the Yellowstone Compact with Wyoming and North Dakota in 1939, the need for cataloging the state's water resources and its use became apparent. As a result, the 1939 Legislature authorized the collection of data pertaining to water use. Between 1942 and 1971, Montana undertook a comprehensive county-by-county assessment of water use. The resulting reports, known collectively as the Montana Water Resources Survey, contain an examination of water rights, water uses and irrigation development in almost every county in Montana. This information was collected and published from 1943 thru 1965 by the State Engineers Office and from 1966 thru 1971 by the Water Conservation Board. The historical information contained in the survey's are an invaluable tool in today's efforts to adjudicate Montana's water rights.

In 1967, the Montana Legislature recognized the need for a comprehensive state water plan with passage of the Montana Water Resources Act of 1967 (89-101.2 R.C.M. 1947). The Act abolished the Water Conservation Board and transferred its powers and duties to the Water Resources Board. The 1967 Act stated that the "public policy of the state is to promote the conservation, development, and beneficial use of the state's water resources to secure maximum economic and social prosperity for its citizens." The Act also designated the Water Resources Board as the state agency with responsibility to "coordinate the development and use of the water resources of the state as to effect full utilization, conservation, and protection of its water resources." The Board was empowered to prepare a "continuing comprehensive inventory of the water resources of the state", and prepare a "comprehensive, coordinate multiple-use water resources plan known as the 'state water plan'."

The responsibilities given to the Board reflect a change in direction and purpose of water resource planning – from "conservation" of water through irrigation to a total concern for full utilization of our water resources through comprehensive multiple-use planning. In 1971, the Water Resources Board became the Water Resource Division of the Montana Department of Natural Resources and Conservation (DNRC).

Between 1972 and 1981, DNRC conducted a number of reconnaissance-level planning studies in each of Montana's major river basins in conformance with federal principals and guidelines and with federal grant assistance. While these plans produced volumes of valuable technical information, inadequate consideration was given to the institutional and political feasibility of implementing the plan recommendations. Consequently, the plans had little effect on water management decision making. These large-scale plans were also ineffective vehicles for addressing the state's most critical water management problems such as interstate water allocation, quantification of federally reserved water rights, water use efficiency, instream flow protection and ground water management. Federal funding to support state water planning efforts ended in 1981.

In 1987, DNRC embarked on a new approach to developing the state water plan. After reviewing the water planning processes of other western states, DNRC adopted an approach similar to that used in Kansas. Under this approach, the state water plan provided a forum for all affected parties, including those affected by, but without jurisdictional responsibility, to collaboratively work together on resolving water management issues. This new approach included the formation of a

State Water Plan Advisory Council and issued-focused Steering Committees. The resulting state water plan focused on the following nine water resource issues:

Agricultural Water Use Efficiency (1989)

Instream Flow Protection (1989)

Federal Hydropower and State Water Rights (1989)

Water Information System (1989)

Water Storage (1990)

Drought Management (1990)

Integrated Water Quality and Quantity Management (1992)

Upper Clark Fork Basin Water Management (1994)

Ground Water (1999)

Between 1999 and 2009, DNRC' water planning resources were focused on assisting irrigation districts, conservation districts and locally lead watershed groups with water supply studies and drought management plans.

In 2009, the Montana Legislature amended the state water planning statute to direct DNRC to update the state water and report to the 2015 Legislature. The 2009 amendments also specify a number of items that the state water plan must address including:

Inventory of consumptive and non-consumptive uses associated with exiting water rights.

An estimate of the amount of GS and SW needed to satisfy new future demands;

An analysis of the effects of frequent drought and new or increased depletions on the availability of future water supplies.

Proposals for the best means to satisfy existing water rights and new demands.

Possible sources of water to meet the needs of the state; and

Legislation necessary to address water resource concerns in the Yellowstone, Missouri and Clark Fork basins.

2. Basin-specific Planning History

The Reclamation Act of 1902 provided funding for the development of irrigation projects in the 20 arid states that make-up the American West. This law marked the earliest effort to plan and implement an approach for managing water and developing the infrastructure critical to the success of the homesteaders that followed in the wake of the Homestead and Desert Land Acts. The Milk River Irrigation Project, authorized in 1903, was one of the first irrigation projects initiated in the United States under authority of the Reclamation Act. The project's objective was to provide a stable source of water for irrigation in the lower Milk River Valley. A bold plan to divert water from the St. Mary's river to augment flows in the Milk River emerged to become the largest and most ambitious trans-basin diversion project of the time.

At 2,320.7 miles the Missouri is America's longest river. it is not surprising, therefore, that the planning effort that continues to shape the river and the basin today started as a result of events far below the headwaters in southwestern Montana. A series of extreme droughts during the 1930's and severe flooding in 1943 that inundated many areas along the Missouri River prompted a surge of interest in water planning for the Missouri River Basin. Planners felt that increased management of the river and its tributaries would not only reduce future flooding, but also benefit the region through increased irrigation, hydropower production, and enhanced navigation.

The Bureau of Reclamation and the U.S. Army Corp of Engineers were both called upon by Congress to develop plans to harness the unruly river. Burec's plan sponsored by William Sloan focused upon increasing irrigation for agricultural stability and increasing hydropower for regional economic growth. The Corps of Engineer's plan, sponsored by Colonel Lewis Pick concentrated on reducing flooding and increasing navigation in the lower basin. The two plans were eventually merged into the Missouri River Basin Development Project commonly known as the Pick-Sloan Plan. The combined plan was submitted to Congress and enacted as part of the Flood Control Act of 1944. In appreciation of Colonel Pick and William Sloan's efforts in the development of the plan, the project was officially dedicated as the Pick Sloan Missouri Basin Program in 1970. The highlight of the plan was to be the construction of 5 large multi-purpose dams along the upper main stem of the Missouri.

Though previously constructed as part of the New Deal and the Public Works Administrations effort to help restore and develop regional economies left in tatters following the Great Depression, the operation and management of Fort Peck Dam was folded into the larger effort of the Pick Sloan Plan. The Fort Peck Dam is operated by the U. S. Army Corp of Engineers as a multi-purpose project, however, flood control and navigation in downstream states play primary roles in dam operation.

Montana's role as a headwaters state and its direct relationship to other states and their people that depend on these waters has driven much of the planning effort in Montana. In 1965, Congress passed the Water Resources Planning Act which provided funding to individual states for water planning activities. The act created river basin commissions to oversee planning for the development and protection of the country's major river basins. Basin planning emphasized close

coordination among interested local, state, and federal agencies. Though comprehensive, these plans were expensive. Preparation of Yellowstone River Basin Plan in the late 70's cost $2.4 million. Funding for this basin planning program ended in 1981 prior to completion of a plan for the Missouri River in Montana.

Water Resource Surveys

As mentioned above, early water planning activities in Montana and the nation were focused on developing irrigation projects to distribute water across the landscape to support and promote agricultural production. During the 1930-1940s, the state and federal government spent much of their time and money on designing and implementing water conservation projects. Following the construction and development of these projects was an effort to produce and publish comprehensive surveys of all of the irrigation projects in Montana. Between 1953 and 1972, the Montana Water Conservation Board and the State Engineers office developed comprehensive Water Resource Surveys for most of the counties in the State. These surveys were developed from court house records, individual contacts, state and federal agency data, field surveys and aerial photographs. They contain an historic summary of the settlement, water use and survey maps of current water use at the time of publication. These important documents are still used for historical reference and provide the basis for understanding water use, development, water planning and adjudication in each county. Also, keep in mind that the surveys were conducted for the counties, which are political subdivisions rather than watersheds, so it is more difficult to tease out the specific information that is related only to the areas within the counties that drain to the Lower Missouri Basin. However, these water resource surveys remain a valuable tool for characterizing and understanding the communities and water distribution systems in the basin.

E. Methodology

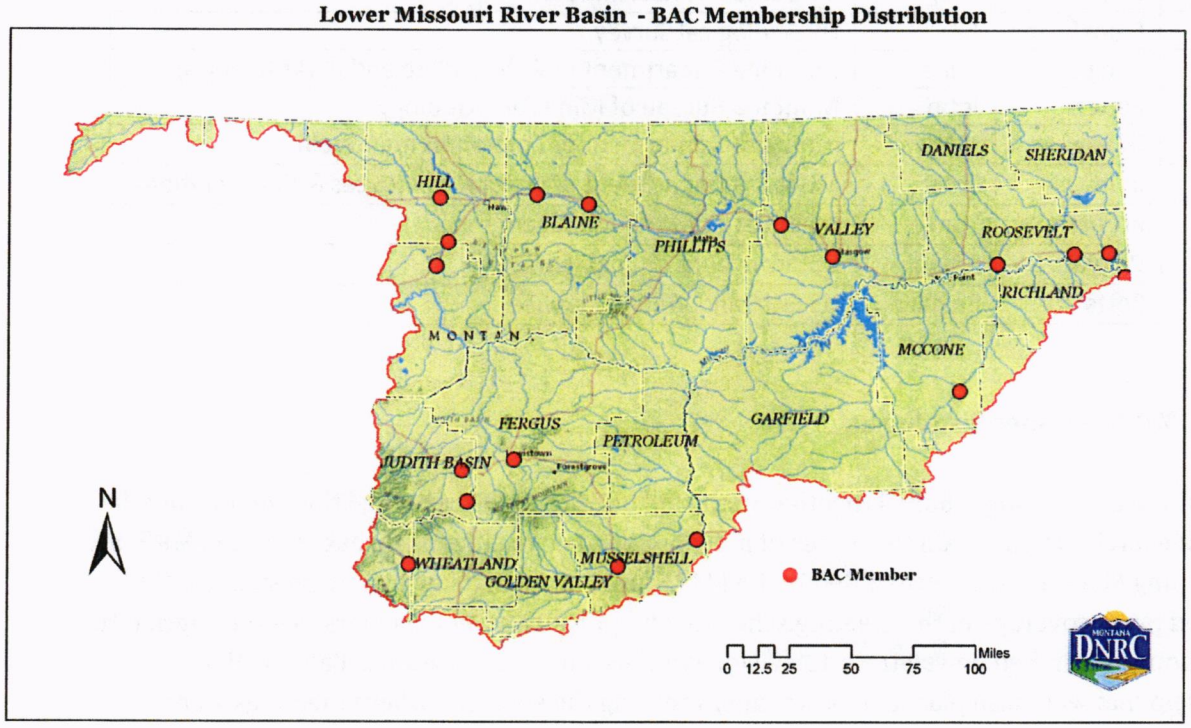
1. Convening the Lower Missouri Basin Advisory Council

To begin the legislatively mandated update of the state water plan, the Department of Natural Resources and Conservation (DNRC) launched the Montana Water Supply Initiative (MWSI). DNRC determined that public involvement was crucial to acceptance of any plan that might be drafted for later approval by the Montana Legislature. DNRC appointed a 20-member Basin Advisory Councils (BAC) in each of the major river basins in the state for the purpose of conducting public scoping sessions and developing recommendations for the state water plan. Due to its large size and geographic and climactic variability, the Missouri River watershed was split for planning purposes into Upper and Lower basins. The Upper Missouri Basin planning area was split from the Lower at the confluence of the Marias River. This point was chosen due to the fact that the Missouri River Basin above the Marias River is closed to new appropriations. In the Lower Missouri River Basin (LMRB), a facilitation contractor was engaged in early July to begin the process of soliciting and selecting BAC members.

Through several weeks of phone calls, emails, and personal contacts, a list of over one hundred potential candidates, or organizations that might wish to put forth candidate's names, was

developed, and letters and/or emails were sent out requesting applications. At the same time, several press releases were disseminated from both DNRC headquarters for state-wide distribution, and by the LMRB facilitation team for local distribution. Cooperation from news media was good, and enough applications were received to constitute broad representation on the LMR BAC. Representatives from agriculture, conservation, energy, municipal supply, and tribal interests were all well represented on the Lower Missouri BAC. A kick-off meeting of the BAC was held in Malta on October 2, 2013.

Lower Missouri River Basin - BAC Membership Distribution



Attention was also given to the need for technical advice throughout the planning process. At the request of the DNRC, ten individuals were named as ex-officio members of the Lower Missouri BAC (Table _). These individuals attend the meetings and provide input, however, per the BAC guidelines (Appendix A) they are not voting members.

Table __ : Lower Missouri Basin Advisory Council Ex-officio Members Spring 2013

	Last Name	First	Agency
1	Brummond	Andy	Montana Department of Fish Wildlife and Parks (Lewistown)
2	Kuzich	Greg	US Bureau of Reclamation
3	Frankfurter	Jill	US Geological Survey
4	Ruggles	Mike	Montana Department of Fish Wildlife and Parks (Billings)
5	Reiten	John	Montana Bureau of Mines and Geology
6	Ockey	Mark	Montana Department of Environmental Quality
7	Irvin	Scott	Montana Department of Natural Resources & Conservation
8	Probert	Tom	US Bureau of Land Management
9	Daggett	John	US Army Corp of Engineers
10	Potts	Richard	US Fish, and Wildlife Service

Phase 1 MWSI – Issues Scoping

After pulling the advisory council together in the fall of 2013. DNRC engaged the BAC in a public outreach exercise to ascertain the issues of most importance to citizens throughout the LMRB. Six BAC Scoping Meetings were scheduled in the LMRB, and an advertising campaign successfully produced press coverage of the meeting schedule and purpose by newspapers, regional agriculture publications, watershed newsletters, television stations, and radio stations. Paid display advertisements were also placed in newspapers serving the six areas where meetings were scheduled.

Location	BAC Members	Staff Members	Technical Advisers	Public	Total Attendance
Lewistown, 10-8-13	7	5	4	14	30
Glasgow, 10-23-13	5	7	4	1	17
Culbertson, 10-24-13	7	4	1	13	25
Roundup, 10-30-13	4	7	1	15	27
Harlowton, 10-31-13	5	6	4	22	37
Havre, 11-7-13	6	7	2	16	31

Table 2: LMRB Scoping Meeting Attendance

Total attendance for the six scoping meetings was 167, including 81 members of the public. Public participation at Glasgow was the biggest disappointment, with only one person representing the public present, but the BAC, Staff, Technical Advisers, and other agency representatives nevertheless carried on a valuable discussion of issues. The best public participation occurred in Harlowton, largely the result of involvement of a local community leader to assist in setting up the meeting and encouraging attendance. The success of this method will guide the LMRB preparations for public meetings during the basin Recommendations hearings phase of the MWSI process.

Each of the scoping meetings began with introductions around the tables, which were arranged so that participants faced each other. DNRC staff members made brief presentations for the purpose of education on the MWSI process and to present current data on water resources in the basin. Because of the small size of the gatherings and the wishes of the public participants, the whole group participated in an active discussion format to develop a listing of important water resource issues at each meeting. The Facilitator made sure that every person attending had an opportunity to express their personal concerns, and participants rated the meetings successful. Some written testimony was presented by participants, or was submitted later, and that testimony is a part of the record for the scoping meetings. A complete list of issues developed at the six scoping meetings appears in Appendix A of the Final Issues Scoping Report (link).

Lower Missouri River Basin Advisory Council Selected Core Issues

A two-day meeting was scheduled in Lewistown on December 2-3 to allow the LMR BAC time to consider all the issues raised at the scoping sessions, and choose which ones would be selected to be considered in the next phases of the MWSI process. A draft of this report was made available to them prior to the meeting, although no selection of issues of highest concern was made.

Discussion and debate of all issues of concern to the public participants continued during the remainder of the two-day meeting. Two additional meetings conducted via conference calls allowed BAC members to make final decisions on issues to be considered in Phases 2 and 3 of the MWSI. The issues ultimately selected by the LMR BAC are listed below.

1. <u>Surface Water Availability and Quality</u>

There is widespread concern among participants in the LMRB scoping process that, given the current status of the state's water rights adjudication process, water compacts, and water resource research, it is not possible to determine how much water is legally and physically available for existing and future uses. A complete inventory of current consumptive and non-consumptive uses has not yet been compiled by the state. Participants also generally agree that it might be possible to store more water from spring runoff by increasing the capacity of existing reservoirs or by building new small-scale reservoirs. Negotiation for additional lease water from federal storage projects for use within the state may be an option. Water supply might be increased by adoption of voluntary conservation programs, or in the case of industrial water use, development of recycling technology. Permits allowing the mixing of fresh water with water recycled from other uses might be a way to

reduce quantity otherwise lost to consumptive uses. Water is lost for use by its original appropriator as it is delivered to a field by aging infrastructure that could more efficiently serve its purpose if repaired or replaced. Residents who rely on surface water for domestic and agricultural uses are concerned about the poor quality of water flowing in many streams in the LMRB and the need for better coordination among the state agencies charged with managing water quantity and quality.

2. Groundwater Availability and Quality

Researchers, working with limited funding, have mapped and characterized some aquifers in the state that might provide opportunities for future uses. Participants in the MWSI process agree that more study is needed on recharge rates, quality, and usage of groundwater, and that interactions between groundwater and surface water should be more thoroughly explored. The Madison Group aquifer, the largest known high quality aquifer underlying the central part of the state, is a possible source of additional water, but limited data exist on its age and the effects large drawdowns might have on its discharge to springs (i.e., Big Springs and Warm Springs.) There is a perception that new monitoring wells should be added to the MBMG's database to gather long-term information on groundwater level response to climate and nearby water use, and on changes in water quality.

3. Water Management

Fair enforcement of water rights decrees is important to Montana's water users, and they don't like having to file suit against their neighbors to protect their rights. They also want assurances that their senior rights will be protected whenever new water right permits are granted by the state. Streamflow gages are an important tool used by water commissioners to ensure accurate deliveries, as well as to provide data about how much water might be available for storage or distribution, predict floods, and in some cases provide a method for monitoring surface water quality. Long-term funding for operation and maintenance of existing gages is at risk, and if additional gages were installed in critical areas, water management could improve. Management of water levels in reservoirs in the LMRB is critical to recreational uses and to the businesses that depend upon those uses. Residents are nervous about energy development and the possibility of accidental contamination of aquifers or streams. There is a perception that the permit process for acquiring a new water right or changing the use of an existing one takes too long resulting in slower economic development in some areas.

4. Future Needs

Demand for water at a point twenty years into the future is difficult if not impossible to forecast. Global and national economics drive the energy industry through its boom and bust periods, towns grow and shrink in response, and the technology used for exploration and production changes rapidly. Water re-cycling processes are being developed so that industrial water can be re-used. Everyone agrees, however, that the state will need more water rather than less in the future, and various factors including climate change, may affect water supply. Changes such as the timing of

spring run-off may interfere with available water supply for beneficial uses, necessitating revisions of water management practices. Water management concerns are no longer limited to irrigation, floods, or hydroelectric power, but now encompass sufficient water supplies for municipalities, recreation, industry, wildlife, and instream flows. There is a recognition that water quantity and quality are directly related, and that poor water quality impacts some types of beneficial use. A healthy river ecology is also an important consideration.

5. Implementation Strategies

BAC members and public participants alike expressed reservations about how a state-wide water use plan could be implemented. Such a plan based on recommendations made through the MWSI process will of necessity be complex, and there is concern that our state senators and representatives will be pressed to find time to study and understand it. Implementation will require broad-based support from stakeholders to help legislators understand the critical importance of water to our citizens and our economy. There are watershed organizations in the LMRB that can serve as examples of the positive results of communication and collaboration on local water management issues. The adopted state-wide water use plan will need to be adaptable and responsive to changing water resource supply and demand.

6. Issues Specific to LMR Sub-basins

In the **Musselshell River** basin, the accuracy of the adjudication process is in question because of the method used by the Water Court to determine claimed historical place and amount of use. This basin also suffers more from a burgeoning noxious weed crop than some other basins, the result of weed seed dispersal by the catastrophic 2011 flood.

The **Milk River** basin is dependent on the St. Mary's diversion canal for much of its water supply for agricultural and municipal use. There are questions of infrastructure condition, project funding, and tribal water rights that need to be addressed before a rehabilitation project can begin. Water quality and shrinking capacity of water storage reservoirs are also critical concerns.

Judith River basin residents are protective of the high quality water flowing from Big Spring, and are concerned that possible high volume production wells proposed for tapping the Madison aquifer might jeopardize the quantity or quality of the spring water. More research needs to be conducted on recharge rates and interactions between surface water and the aquifer. The number and location of oil and gas leases in the Judith River basin is a concern because of potential contamination of the Madison Group Aquifer and its recharge areas due to energy development. Irrigators are concerned that Ackley Lake will not provide enough water to meet their needs in the future.

Residents in the **Missouri River** basin downstream of Ft. Peck dam are heavily impacted by water releases made by the Army Corps of Engineers. Water flows can cause river channels to migrate,

erosion eats away at productive fields, and the cold water affects the downstream fishery. Because of the almost annual necessity to perform bank stabilization, there may be a need for an expedited permit process for approval of these projects. Energy development in Montana and North Dakota is raising concerns about water quantity and quality in the future.

Phases 2 - Information Transfer

Members of the LMR BAC conducted several conference calls to begin the process of developing goals, objectives, and recommendations. The group met again in Lewistown on February 18, 2014, and at Fort Peck Dam on March 5, to engage in the process of developing recommendations and alternatives that will be forwarded to DNRC for consideration in development of a state-wide water resource plan. Due to weather, long distances, and difficult travel routes, the LMRBAC also utilized a series of conference calls to work through the process of developing policy alternatives to address prioritized issues. The group also relied upon the technical advisors and other experts to provide background information and data on a host of issues. The table below identifies the experts that presented information to the BAC and the topics they covered.

Date	Speaker	Topic
12/2/2013	Jim Peterson – State Senator	Water In The American West
2/18/2014	Jill Frankforter – U.S. Geological Survey	Water Quality & Energy Development- Historic and Current Issues in Eastern MT
2/18/2014	John Reiten – MT Bureau Of Mines & Geology	Status of Groundwater Investigations in Eastern MT
2/18/2014	Tom Richmond- MT Board of Oil & Gas	Historic and Current Energy Production Trends in Montana
3/5/2014	Clayton Jordon – USBR	Reservoir Operations at USBR Projects in MT
3/5/2014	John Daggett – US Army Corp of Engineers	Reservoir Operations at Fort Peck Dam as a Component of Missouri River Management

Phase 3 - Recommendation Development

In an effort to get the LMRBAC to begin thinking about recommendations, Bill Milton, facilitator requested that each of BAC members choose one of the issues that emerged from the scoping process and craft a policy recommendation that would address the issue in a state wide context. This exercise generated a series of weekly conference calls among the BAC members, DNRC staff, facilitation staff and technical advisors for the development of policy recommendations.

Finish out this section with information detailed in the Recommendations Report.

III. Basin Profile of Lower Missouri Basin

A. Demographic, Economic, and Social Setting

1. Land Use and Ownership (HUC scale?)

Insert land ownership map for the Lower Missouri

The following demographic data is excerpted from a longer report. The full text of the complete report is included at the end of this document.

POPULATION

Recent Estimates

Between the 2010 census and July 1, 2013, the population of the Lower Missouri Basin increased 2.4 percent to 76,209. During the same period Montana's population increased 2.6 percent to 1,015,165. The Lower Missouri Basin is the only of Montana's four major basins with neither a "Metropolitan" nor a "Micropolitan" Statistical Area. According to the White House Office of Management and Budget (OMB 2013), a "Metropolitan Statistical Area" is considered to have "at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties." "Micropolitan Statistical Areas" are defined similarly with the exception that the area's core consists of "at least one urban cluster" with a population between 10,000 and 50,000.

Populations of counties in the Lower Missouri Basin for 2013 are listed in Figure 1. Nearly one-fifth of the Basin's residents lived in Hill County. More than half of the Basin's population resides in the three largest counties, Hill, Fergus, and Roosevelt. The populations of six of the Basin's 15 counties declined between 2010 and 2013. Between 2010 and 2013, Roosevelt County ranked 90th among the fastest growing U.S. counties with populations of at least 10,000 after growing by 6.7 percent to 11,125 during the period. The fastest growing county in the nation was Roosevelt County's neighbor across the North Dakota border, Williams County, which grew by 32.1 percent between 2010 and 2013.

Lower Missouri Basin Counties
Populations - 2013

Blaine	6,604
Daniels	1,791
Fergus	11,501
Garfield	1,290
Golden Valley	859
Hill	16,568
Judith Basin	2,016
McCone	1,709
Musselshell	4,629
Petroleum	506
Phillips	4,179
Roosevelt	11,125
Sheridan	3,668
Valley	7,630
Wheatland	2134

Figure 1

Reservations	Population 2010	% Change 2000-10
Fort Belknap	2,851	-3.7
Fort Peck	10,008	-3.0
Total	12,859	-3.2

Figure 2 Source: U.S. Census Bureau, Population Division

The populations of Montana's seven Indian reservations totaled 66,598 in 2010 with one-fifth residing in the Lower Missouri Basin. Figure 2 displays the populations of Indian reservations in the Basin and the percentage change in population between 2000 and 2010. The Fort Belknap and Fort Peck Reservations saw population declines during the period.

Projections

Population trends can be somewhat mysterious. States have experienced various trends reflecting each state's particular natural endowments and historical circumstances. Those circumstances arise from unique, complex national, regional, and local dynamics that determine the geography of socioeconomic development and patterns of population change over time. For example: Iowa has seen consistent, low levels of population growth broken only by negative growth in the 1980s; California experienced very high levels of growth throughout the twentieth century, tapering off in recent decades at lower, but still high, levels; North Dakota's pattern of low levels of alternating population increases and declines is now being broken by rapid growth since 2010.

Predicting population changes is an undertaking that grows increasingly speculative as the time horizon expands and the region under consideration diminishes in size. For the purposes of this planning effort, population projections are provided to inform deliberations of water management issues in which population levels are one factor among many comprising the demand for water. The intent of these projections is neither to predict nor forecast precise population levels at particular points in time and locations in Montana; the purpose, rather, is to offer reasonable estimates of magnitudes of population growth that would presumably relate to the supply and demand for water in various ways over the course of the planning period.

Two sets of population projections are offered here. One set extrapolates trends seen in the period between the 1990 and the 2010 censuses. These projections are provided at the state, county, basin, and sub-basin levels. The other set relies on projections at the state and county levels developed by the Montana Department of Commerce (MT Commerce) using eREMI, a population projection product of Regional Economic Models, Inc. (REMI). Population levels were projected through the twenty-year planning period to 2035.

Figure 12 displays projections of the Lower Missouri Basin's population based on each method. Extrapolating Basin-wide population growth at the average annual rate of population change for the period between 1990 and 2010 would result in 8,159 fewer Basin residents in 2035.

Rather than extrapolate recent trends, the MT Commerce projections forecast moderate rates of population increase through 2035, reflecting assumptions about changes in the Basin's age structure, natality and survival rates, and migration patterns over the period. This projection forecasts a substantially higher average annual rate of growth and an increase in the Basin's population of 7,508 by 2035.

Population Projections – Lower Missouri Basin

	Average Annual Rate	2035	Change 2010-35
1990-2010 Extrapolation	-0.43%	70,871	-8,159
MT Commerce	0.38%	82,070	7,508

Figure 12

Figure 13 displays estimated populations for the Basin's counties in 2035 as projected by each method. The MT Commerce forecasts predict reductions in population decline in the Basin and higher populations than those that would result from the continuation of trends of recent decades. The sum of the county projections does not equal the basin population projected due to compounding effects related to the basin and county projection calculations.

Population Projections – 2035
Lower Missouri Basin Counties

	1990-2010 Extrapolation	MT Commerce
Blaine	6,640	7,236
Daniels	1,343	1,981
Fergus	10,897	11,338
Garfield	920	1,513
Golden Valley	811	846
Hill	14,697	18,674
Judith Basin	1,817	2,312
McCone	1,257	1,968
Musselshell	5,234	5,618
Petroleum	483	834
Phillips	3,312	4,156
Roosevelt	10,309	11,033
Sheridan	2,458	3,719
Valley	6,652	8,093
Wheatland	2,020	2,749
	69,446	82,070

Figure 13

HOUSING

The number of households in the Lower Missouri Basin in 2010 was 29,129 with an average size of 2.4 people (U.S. Census Bureau; 2007-2011 American Community Survey Profile Report). The total number of housing units was 37,629 with 29,129 occupied and 2,555 for seasonal, recreational, or occasional use.

INCOME and EMPLOYMENT

Total personal income (TPI) is comprised of: net earnings in the forms of wages and salaries, supplemental earnings, and proprietors' income; transfer payments; and income from dividends, interest, and rent. In 2012, TPI in the Lower Missouri Basin was $3.1 billion, 8 percent of TPI for

Montana of $39.3 billion.[1] Between 1990 and 2012, TPI in the Lower Missouri Basin increased by 49 percent, compared to an increase for Montana of 80 percent.

Per capita personal income (PCPI) in the Lower Missouri Basin in 2012 was reported to be $40,528, compared to $39,126 for Montana. Personal income in 2012 (adjusted to 2013 $s) for the major basins in Montana is displayed in Figure 18. With $13.0 billion, the Clark Fork Basin was the basin with the highest amount of total personal income, but the lowest per capita personal income by a substantial margin. The sparsely populated Lower Missouri had the lowest TPI by a considerable amount, but the Basin nearly matched the Upper Missouri's $40,676 for the highest PCPI among the state's four major basins.

Personal Income – Major Basins 2012

	Total	Per Capita
Clark Fork	13.0 billion	35,896
Lower Missouri	3.1 billion	40,528
Upper Missouri	12.8 billion	40,676
Yellowstone	10.4 billion	41,448
Montana	39.3 billion	39,126

Adjusted to 2013 $s.

Figure 18

Figure 19 presents similar upward trends in PCPI for each of the major basins over the period. PCPI in the Lower Missouri and the Yellowstone Basins increased at rates greater than the statewide increase with increases of 61 percent and 58 percent, respectively. Between 2007 and 2012, PCPI in the Lower Missouri increased by 19 percent while PCPI in the Clark Fork declined by 1 percent. The impacts of the recent recession are evident from the graph as are the contributions of strong prices for agricultural commodities and activity in the energy sector.

See Appendix ___ for a more detailed analysis of demographic trends in the Lower Missouri River Basin.

2. Key Economic and Water Use Sectors

Agricultural

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

[1] Figures are from the U.S. Department of Commerce, Bureau of Economic Analysis, Table CA30, adjusted for inflation to 2013 dollars. Estimates are based on administrative records and survey and census data collected by various agencies.

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 impacts 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, called externalities, have an impact on 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.
Consider inserting county specific ag production data for the Lower Missouri

Industrial

Energy and Mineral Resources

Municipal and Domestic

Recreation and Tourism

3. **Water User Profile**

Narrative description of water user or group in the basin

4. **Environmental Concerns**

Endangered Species

Water Resources in the LMRB

Physical Setting

Physiography

The LMRB in Montana starts at the confluence of the Missouri and Marias Rivers at Loma at an elevation of 2,575 feet. Heading downstream the river cuts a path through the historic territory of the Lewis and Clark Expedition. The river is bounded by prairie benchlands and badlands and flanked by distant small mountain ranges with elevations exceeding 8,000 feet. The river passes the coal bank areas near Virgelle then winds through sandstone canyons and hoodoos on its way through the Upper Missouri Breaks National Monument.

Streamside topography increases as the river flows downstream, and eventually the valley opens up to extensive cottonwood galleries, multiple river channels and large islands. After passing Fred Robinson Bridge, the river joins the impounded waters of Fort Peck Reservoir. The Musselshell River contributes from the south near here, after running through a few hundred miles of central Montana prairie and cottonwood bottoms.

Below Fort Peck Dam, the Milk River joins from the north and the combined flow heads east. The Milk River itself originates high on the east slopes of Glacier National Park, passing through

200 miles of Canada prairie before reentering Montana north of Havre. Downstream of the Milk River confluence, the Poplar River and Big Muddy Creek contribute small flows as the Missouri

River continues on its way to meet with the Yellowstone River just over the state line in North Dakota.

In Montana, the LMRB drainage area encompasses 49,800 square miles; about one third of the total land area of the state. There are only a few major tributaries to the mainstem, and although they may originate in mountainous settings, they generally they drain large, semi-arid, relatively low elevation prairie landscapes. Arrow Creek and the Judith River drain a significant portion of central Montana, including the north slope of the Big Snowy Mountains. On the other side of the range, the Musselshell River drains the south slope; a huge basin containing a relatively small river.

The LMRB includes a variety of landscapes ranging from alpine zones above 9,000 feet in the upper Milk and Musselshell subbasins, to the low elevation dinosaur badlands of the Redwater River and Big Dry Creek. The Missouri River exits the state at an elevation of 1,870 feet near Culbertson.

[NEED LINE MAP like Dolan's, with Indian Reservation boundaries]

Geology

Eastern Montana (MT) has gently rolling plains made up of large quantities of sediment accumulated in broad valleys and reworked by glacial episodes. At least three times during the Pleistocene Epoch, the northern part of the Missouri plateau has been the terminal area of continental ice sheets (Clayton et al., 1980; Zelt et al., 1999).

The Tertiary and Quaternary valley fill deposits consist of unconsolidated gravel, sand, silt, till and clay and occur adjacent to the larger streams and rivers in the Lower Missouri River Basin (LMRB) (Whitehead, 1996). The origin of the valley fill material includes eolian, fluvial, glacial, alluvial fan, and landslide depositional environments that are deposited above older bedrock. Their high permeability makes them great sources for aquifers, but in some areas their water quality may make them not fit for human or livestock consumption. Areas where the surrounding geologic formations have high concentrations of saline minerals and the interaction of water with the soil from these geologic formations makes many of the shallow aquifers north of the Missouri River not potable.

Gravel-covered benches obscure bedrock in some areas, but elsewhere, deep incision by the river drainage such as the Milk River, Judith River, Musselshell River, and Missouri River has provided excellent exposures of the bedrock in the stratigraphic section. The bedrock includes sandstone, siltstone, shale and carbonate rock types of the Cenozoic Era, Mesozoic Era, and Paleozoic Era. The youngest bedrock exposed in the LMRB is the Tongue River Member of the Tertiary Fort Union Formation. The oldest rocks exposed are in the Big Snowy and Little Belt Mountains and are the Mississippian/Paleozoic Madison Group. Bedrock aquifers in the Kootenai Formation, Swift Formation, and Madison Group outcrop in the surrounding mountains, dipping gently beneath the relatively low permeability Colorado Group across the LMRB.

The LMRB contains numerous faults, crustal folds, arches, and troughs that buckled the rocks underneath the plains. These hydrostructures may exist sub-regionally and locally and consist of geologic folds and fault/fracture zones that play a role in defining the limits of groundwater

boundaries in the LMRB. These features can be either barriers to, or pathways for, groundwater flow. Faults that are barriers have the type of displacement that grinds up rock and creates very low permeability fault gouge along the fault plane, isolating the aquifers on each side. Additionally, faults with significant vertical displacements may offset the interflow zones that host the aquifers on each side of the fault. Significant water level differences have been identified in wells near such hydrostructures in the LMRB. Folds and their associated faults can create linear zones of low permeability that affect the lateral continuity of groundwater flow in aquifers.

Dense metamorphic, igneous, or Paleozoic sedimentary rocks form the cores of the island mountain ranges such as the Sweet Grass Hills, Little Rocky, Bears Paw, Big Snowy, Little Belt, and Judith Mountains. While folded and faulted Mesozoic and Paleozoic sandstone, shale and limestone outcrop along the margins of these mountain ranges.

Hydrography

The Missouri River enters the Lower Missouri River Basin near Loma, at an elevation of 2,575 feet, running to the northeast. Downstream 20 miles at Virgelle, the river switches direction and trends southeast through the Upper Missouri Breaks National Monument. After reaching the Judith River, the Missouri generally runs east for the remainder of its course in Montana. The two largest tributaries, the Milk and Musselshell rivers, also generally run from west to east. From Loma to the North Dakota state line, the Lower Missouri River is 457 miles long and drops 785 feet, exiting the state at an elevation of 1,800 feet.

Arrow Creek and the Judith River are two of the larger tributaries and are located relatively high up in the basin. Both streams run northerly from their headwaters in the Little Belt and Big Snowy mountains, respectively.

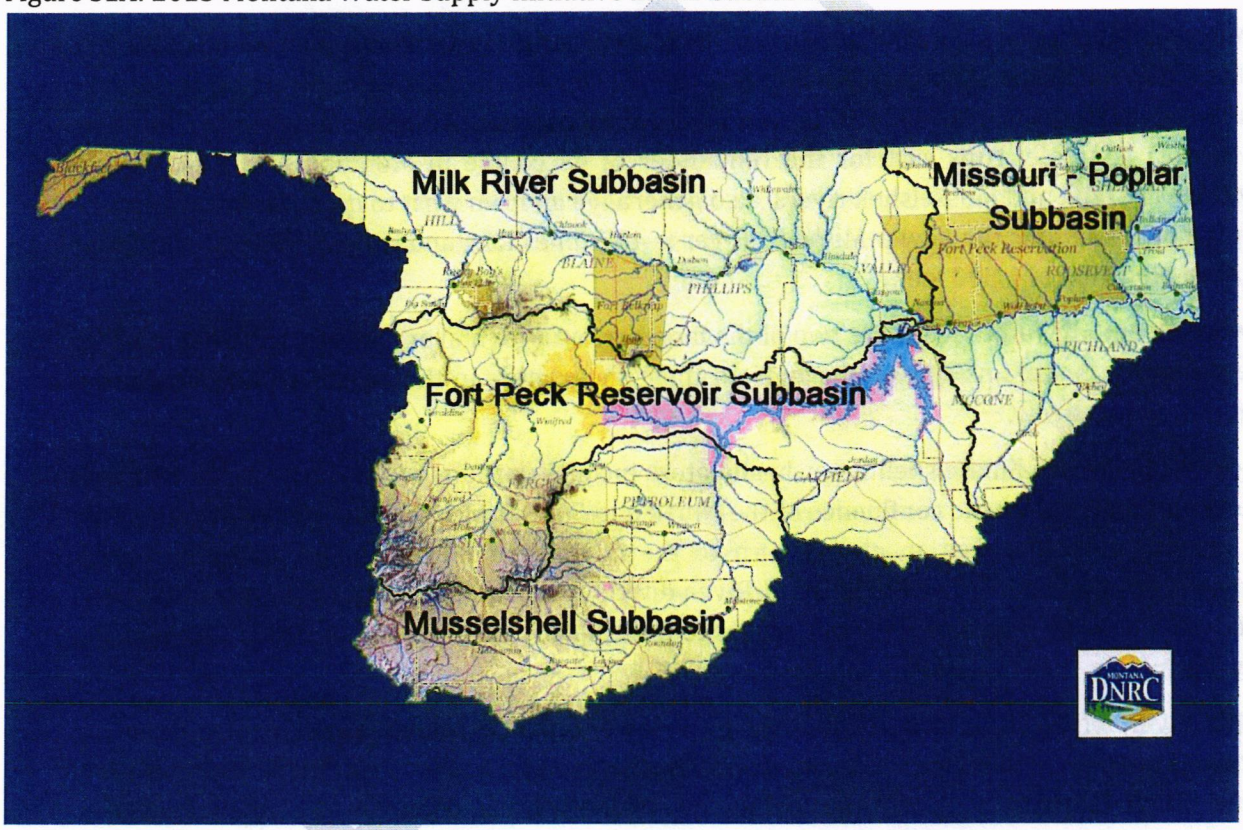
A larger tributary, the Musselshell River headwaters include portions of the Crazy, Little Belt, and Castle Mountains. Below the confluence of the North and South forks, the Musselshell runs east for over 200 miles, then makes an abrupt turn to the north near Melstone and meets Fort Peck Reservoir from the south. The Musselshell River drains a substantial portion of central Montana wedged between the Yellowstone River drainage and the south slopes of the Little Belt and Big Snowy Mountains.

The Milk River, which is the largest tributary in the lower basin, eventually runs in a southeasterly direction to contribute from the north, immediately downstream of Fort Peck Dam. There are few Missouri River tributaries of any size below the Milk River confluence. The Redwater River contributes a small flow from the south, and the Poplar River contributes from the north at almost the same location, near Poplar. Further downstream near Culbertson, Big Muddy Creek is the last major tributary in Montana, contributing from the north.

Subbasins

The LMRB is divided into four large, distinct subbasins, each having unique water resource features and issues; Milk River, Musselshell River, Fort Peck Reservoir, and Missouri-Poplar (Figure S1A). The subbasin divisions are hydrologically and geographically distinctive, and correspond to existing Hydrologic Unit Code (HUC) boundaries. Table S8 lists subbasin land areas and approximate median outflows. Total outflow from the Fort Peck Reservoir subbasin includes inputs from the entire UMRB and the Musselshell River, which contributes at the subbasin mid-point. Outflow from the Missouri – Poplar subbasin represents outflow volume for the entire Missouri River basin in Montana, since it is the furthest downstream mainstem gage in the state. At this point, the Missouri River drains approximately 92,000 square miles, including the UMRB and portions of southern Canada.

Figure S1A: 2015 Montana Water Supply Initiative LMRB subbasins



Each subbasin hosts several small or intermittent tributaries to their respective mainstem river. The tributaries are important mainly on a local basis, providing some water to irrigated prairie uplands, but failing to add much additional flow to the river mainstems. Some of these tributaries, such as the Judith River or Frenchman River, are relatively significant and will be detailed within the context of their host subbasin. However they are not regionally significant and will not be delineated as individual subbasins.

Table S8. Subbasins of the LMRB.

Subbasin	Drainage Area (square miles)	Approximate Median Annual Subbasin Outflow (acre-feet)
Milk River	22,322	474,300
Fort Peck Reservoir	14,080	6,732,000
Musselshell River	7,846	198,500
Missouri – Poplar	10,800	7,326,000

Surface Water Resources of the LMRB

Climate

There are no "mild" climatic zones within the LMRB. The climate ranges from very cold and moist at the higher elevations of the western LMRB to arid, cold desert status in parts of the lower elevations to the east (Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006). Climate of the lower basin, which is mainly a steppe landform, is generally classified as Continental as it is located entirely east of the Continental Divide. However, zones in and around the higher elevations represent more of a Highlands climate regime, which is partially characterized by heavy seasonal snowpack. Temperature and precipitation vary greatly by season and elevation throughout the LMRB.

Climate in the study area is influenced by the interplay of air masses originating in the northern Pacific Ocean, the Gulf of Mexico and Arctic regions (Missouri Basin Inter-Agency Committee, 1969). Winter climate is largely dominated by frigid Arctic air masses, although the winter is also known for periodic westerly, relatively warm "Chinook" winds originating from the northern Pacific coast. The greatest 24 hour temperature change attributed to Chinook winds occurred at Loma at the upper extent of the LMRB. The warm winds raised the temperature from -54 degrees F to 48 degrees (Horvitz, et al., 2002).

Spring and summer seasons are influenced by the interaction of air masses from these three regions, which bring the most moisture during these seasons (WRCC, Climate of Montana).

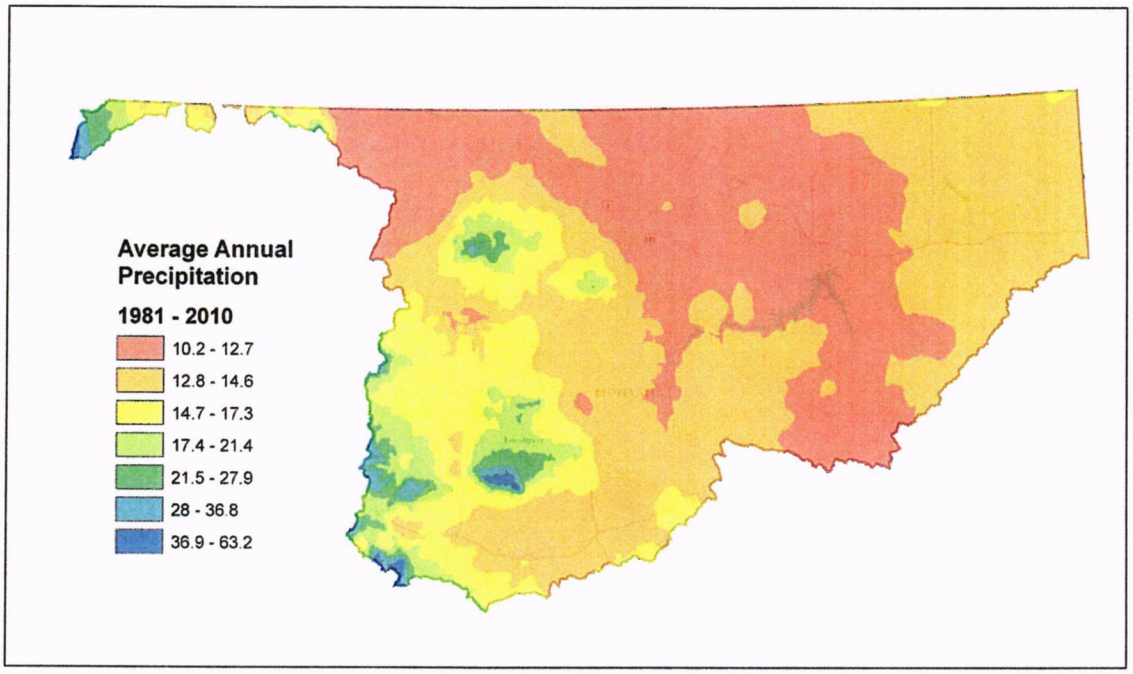
Precipitation

The majority of the LMRB is arid or semi-arid, receiving only 11 to 13 inches of precipitation annually (Figure P1). At an elevation of 2,570 feet above mean sea level, Loma receives 12.6 inches of precipitation, and downstream 350 miles, Wolf Point receives the same amount. Further downstream near the Montana – North Dakota state line, Culbertson receives slightly more, 13.4 inches, at an elevation of 1,920 feet.

With few exceptions, average annual precipitation at valley bottom sites in the LMRB is remarkably similar. In the Milk River subbasin, the cities of Havre and Glasgow are separated by 150 miles and about 400 vertical feet difference in elevation. Havre receives 12.7 inches and Glasgow receives 12.2 inches of precipitation annually. Malta, located midway between these two cities receives 12.6 inches. Similarly, in the Musselshell River subbasin, Mosby receives 12.2 inches, Roundup receives 12.4 inches, and Harlowton, which is located 140 miles upstream from Mosby and is 1,800 feet higher, receives 13.1 inches.

Some portions of the Milk River and Fort Peck Reservoir subbasins are especially arid. Areas around Jordan, Glasgow, Malta, and to the northwest of Havre receive less than 11 inches annually (WRCC, 2013).

Figure P1. LMRB Average Annual Precipitation, inches.

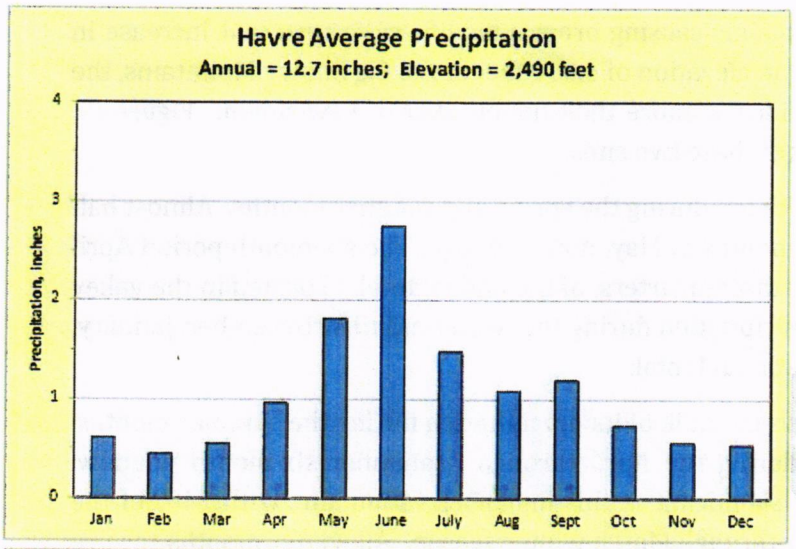


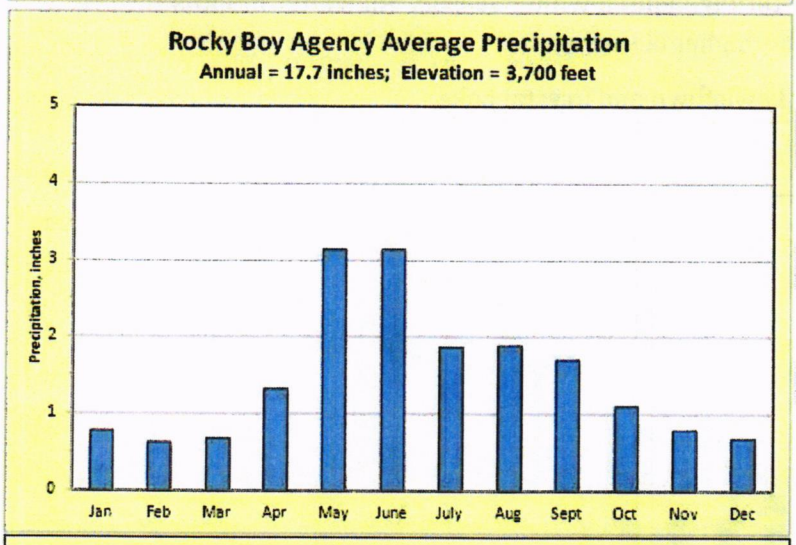
Mountains comprise a relatively small portion of the LMRB total land area, but they are important because of the water their winter snowpack contributes during the springtime snow melt period. High elevation snow water accumulates over a seven month period in Montana, and the National Resource Conservation Service (NRCS) Snowpack Telemetry (SNOTEL) sites measure precipitation and snow water accumulation in mountain ranges throughout the state.

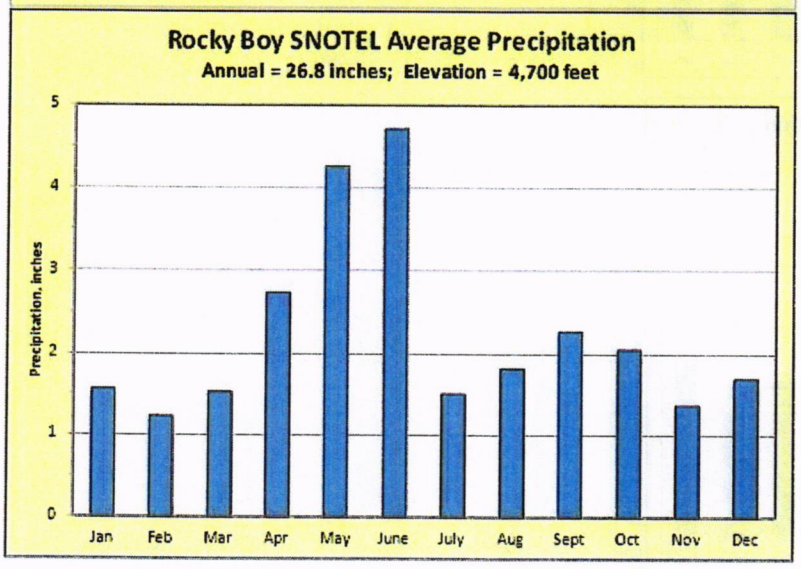
The Bears Paw, Big and Little Snowy, Little Belt, and northern Crazy Mountains, and the Sweet Grass Hills, all contribute valuable snowmelt water to their respective subbasins and to the overall water budget of the LMRB. Runoff from the mountains is especially important to local water sources and stream management, since many of the smaller tributaries drop to extremely low flow levels or temporarily dry completely during the summer season.

Areas in and around the mountain ranges receive greater precipitation than the surrounding lower elevation prairie benches and valley bottoms. At 2,490 feet, Havre receives 12.7 inches of precipitation. In the same vicinity, Rocky Boy Agency at 3,700 feet on the edge of the Bears Paw Mountains receives 17.7 inches. The Rocky Boy SNOTEL site, located another 1,000 feet higher, receives almost 27 inches (Figure P1B). Not only does elevation increase the total amount of precipitation and snow, but it alters the timing of greatest water supply, which occurs when the snow melts in the spring months.

Figure P1B: Precipitation Comparison in the Upper Milk River subbasin.







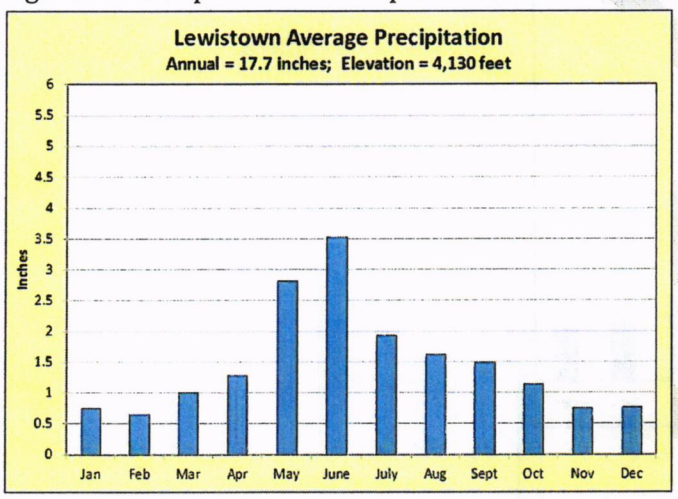
At an elevation of 4,130 feet, Lewistown averages 17.7 inches of precipitation annually, which is a relatively large amount for a valley bottom in the LMRB. But Lewistown is located at the end of a

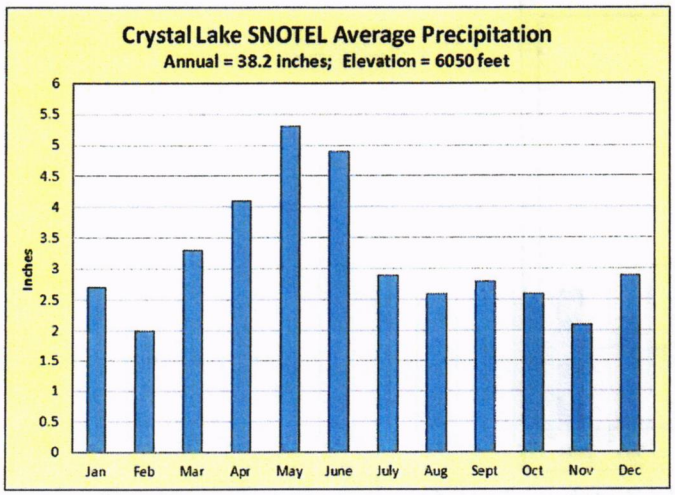
large valley bounded to the east by mountains causing orographic lift and a resultant increase in precipitation. Just south of Lewistown at an elevation of 6,050 feet in the Big Snowy Mountains, the Crystal Lake SNOTEL site receives 38.2 inches; more than double that of Lewistown. Figure P2 compares monthly precipitation amounts at these two sites.

Lewistown receives the bulk of its precipitation during the spring and summer months. Almost half of the annual total falls during the three months of May, June and July. The six-month period April through September receives 72%, almost three-quarters, of the annual total. Located in the valley bottom, Lewistown receives much less precipitation during the winter months. December, January, and February account for only 12% of the annual total.

The Crystal Lake SNOTEL site also receives the bulk of its precipitation during the summer months. Sixty percent of the annual total falls during the April through September six-month window. However, winter accumulations are also significant at this higher elevation site, with 34% of the annual total coming during the November through March winter season. All winter months receive more than two inches of precipitation at this higher elevation.

Figure P2. Comparison of Precipitation at Lewistown and Crystal Lake.





In general, the upstream portions of the Musselshell and Fort Peck Reservoir subbasins receive substantially more precipitation than the Milk River and Missouri – Poplar subbasins, because they contain several mountainous areas. The towns of Stanford and Judith Gap are located in the upper Judith River watershed within the Fort Peck Reservoir subbasin. Both towns are near the Little Belt and Big Snowy mountains at 4,500 feet elevation and both towns receive 15.1 inches. Lennep, at 5,880 feet on the edge of the Castle mountains in the Musselshell subbasin, receives 16.6 inches of precipitation annually.

Temperature

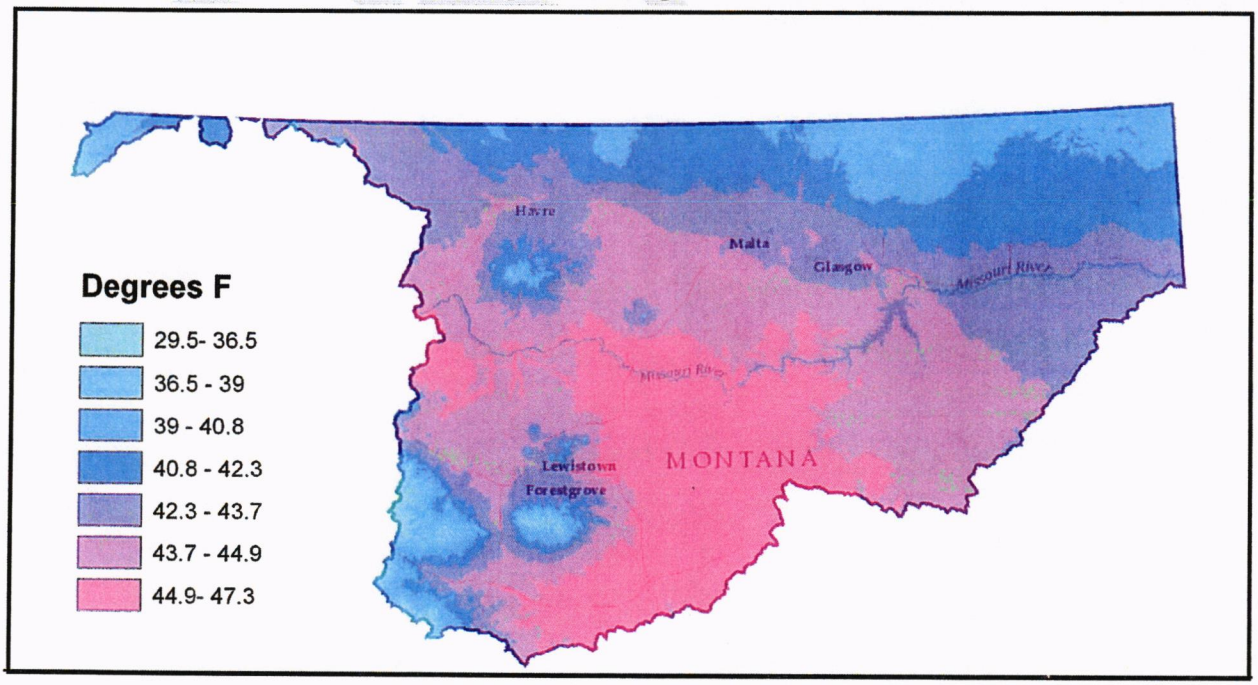
Air temperatures of the LMRB are highly variable, but are generally frigid in the winter and hot in the summer. January is typically the coldest month and July is the warmest. The historic record high temperature in Montana is 117 F at Medicine Lake, in the extreme northeast corner of the state. Winter low temperatures within the LMRB have been recorded as low as -54 F at Poplar, -51 F at Glasgow and Opheim, and -46 F at Lewistown (WRCC).

The lowest temperature recorded at the Crystal Lake SNOTEL station (6050 feet) is -38 F. The record low at the Rocky Boy SNOTEL site (4700 feet) is -31 degrees F, and the record low at the Spur Park SNOTEL site in the Little Belt Mountains (8,100 feet), is -41 degrees F.

Figure P3 illustrates Mean Annual Air Temperatures within the LMRB. The higher elevations within the western mountains have the lowest annual mean temperatures, less than 37 degrees F. However, the lowest instantaneous temperatures may be found at the lower elevation plains or valley bottom town sites, where cold winter air sometimes stagnates.

The average annual temperature of the LMRB is 43 degrees F, which is slightly warmer than that of the UMRB, and resulting partially from the overall lower elevations of the LMRB.

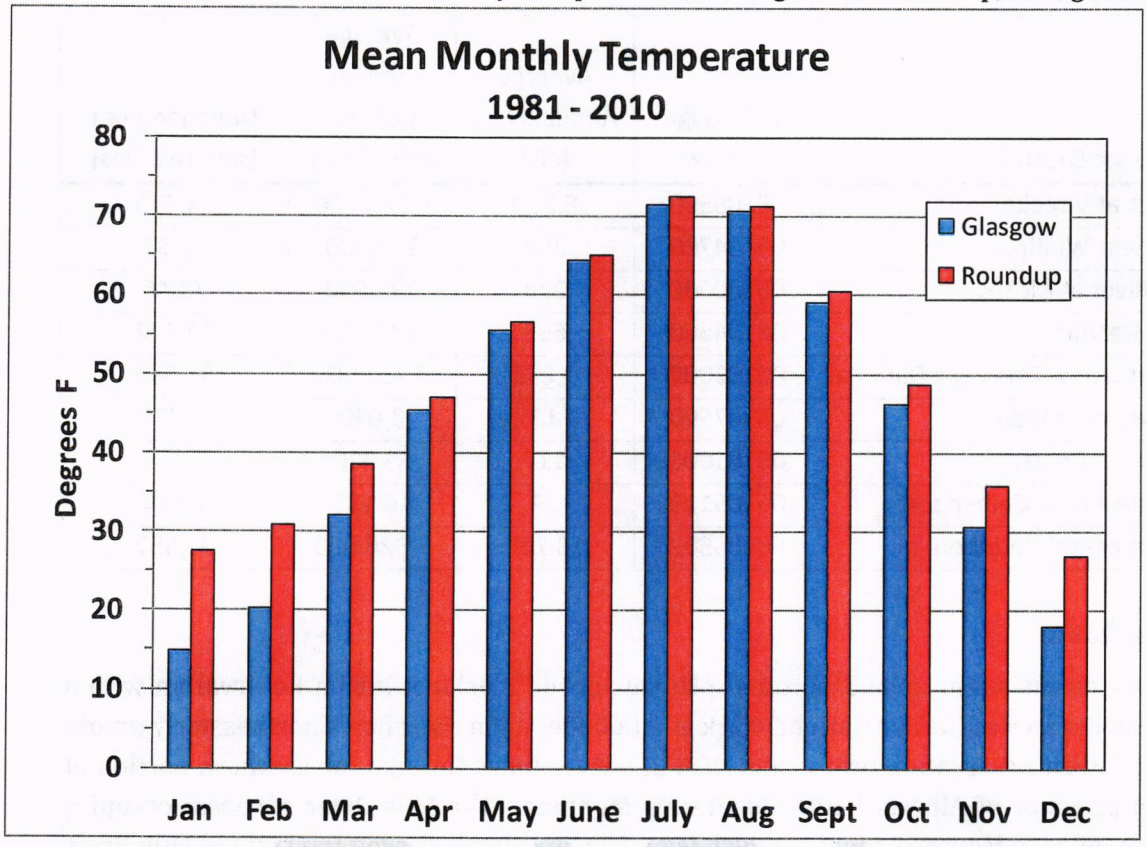
Figure P3: LMRB Mean Annual Air Temperature, degrees Fahrenheit.



Basinwide, the 1981 – 2010 normal annual minimum air temperature is about 29 degrees F, and the annual maximum temperature is 57 degrees F. In general, the most northern parts of the basin have colder temperatures than the southern parts of the basin, in areas of similar elevation.

Lewistown, Havre, Glasgow and Culbertson all have similar mean annual temperatures, which range from 43 to 44 degrees F, although mean monthly temperatures vary from town to town. In the Musselshell subbasin, Roundup is much warmer in the winter months and slightly warmer in the summer months. Consequently, Roundup has a mean annual temperature of 48.5 degrees, almost 5 degrees warmer than the high-line towns (WRCC). Figure T18 shows a comparison of monthly mean temperatures for Glasgow, located in the Milk River subbasin, and Roundup, located in the Musselshell subbasin.

Figure T18. Comparison of Mean Monthly Temperature at Glasgow and Roundup, in degrees F.



Streamflow

Most of the LMRB mainstem flow comes as melted snow water from the mountainous UMRB. Near the upstream extent of the lower basin at Virgelle, average annual mainstem flow is 8,510 cubic feet per second (cfs). Downstream near the Montana - North Dakota state line at Culbertson, the average annual flow is 10,110 cfs. Therefore, the LMRB contributes only 16% of the total Missouri River flow. The additional water comes from the few major tributaries, such as the Judith, Musselshell, and Milk rivers, with some water imported from the Saint Mary River via transbasin diversion. Table S9 lists important gages and flow volumes within the LMRB.

Table S9. Selected USGS gaging stations in the LMRB.

Stream and Gage Location	USGS Gage Number	Average Annual Flow (cfs)	Average Annual Volume (acre-feet)	Drainage Area (square miles)
Missouri River at Virgelle	06109500	8,510	6,160,000	34,379
Judith River near Winifred	06114700	292	211,600	2,731
Musselshell River at Mosby	06130500	274	198,500	7,846
Milk River at Nashua	06174500	655	474,300	22,322
Missouri River below Fort Peck Dam	06132000	9,293	6,732,000	57,556
Redwater River near Vida	06177500	11	8,030	547
Poplar River near Poplar	06181000	117	85,110	3,174
Big Muddy Creek near Culbertson	06185110	22	16,130	2,684
Missouri River near Culbertson	06185500	10,110	7,326,000	91,557

Milk River Subbasin

The Milk River originates in upland hills and plateaus of the Blackfeet Indian Reservation with a small headwaters piece in Glacier National Park at 9,000 feet. The river flows northeasterly across the Blackfoot Indian Reservation prairie and than 216 river miles through the southern portion of the Canadian province of Alberta before reentering Montana. The Milk River subbasin occupies 15,500 square miles in Montana, most of which is prairie grassland. Fresno Dam stores Milk River water near Havre and the river continues easterly to eventually join the Missouri River below Fort Peck Dam.

The St. Mary River also begins high in Glacier National Park. The Saint Mary Siphon, a trans-basin project constructed between 1907 and 1925, sends additional water into the Milk River Basin for use in Montana. This project is administered by the Boundary Waters Treaty of 1909, which allocates water between Canada and the United States (International Joint Commission).

[MAP OF MILK SUB BASIN]

Surface Water

North of Browning, Montana, the Milk River mainstem is formed at the confluence of the south and middle forks of the Milk River. The US Geological Survey (USGS) operates 15 stream gaging stations in the Milk River subbasin, although several of these are operated only during the irrigation season (Table S1).

Table S1: Selected Continuous USGS Gage Sites in the Milk River subbasin.

Site Name	USGS Site Number	Mean Annual Streamflow (AF)	Mean Annual Streamflow (cfs)	Period of Record	Drainage Area (sq. miles)
Milk River at Eastern Crossing	06135000	245,600	339	1917 - 2013	2,525
Big Sandy Creek near Havre	06139500	18,320	25.3	1946 - 2013	1,805
Milk River at Havre	06140500	279,300	386	1898 - 2013	5,785
Milk River near Saco	06164510	278,500	384	1977 - 2013	17,670
Milk River at Nashua	06174500	474,300	655	1940 - 2013	22,332

The Milk River subbasin generally lacks high elevation, mountainous, snow-accumulating areas. Due to this predominant prairie topography and a lack of high elevation snowpack to bolster spring and summer stream flows, the Milk River water supply is naturally very inconsistent from year to year. The Milk River and most of its tributaries are generally more dependent on rain than snow. Milk River water is stored in a succession of reservoirs, which helps to build a more dependable supply. Water imported from the St. Mary River (about 178,500 acre-feet (AF) annually) also enhances supply (BOR study cite).

Tributaries

The few major tributaries to the Milk River are not large, but they are very important to the subbasin uplands and to the river mainstem. Like the Milk River itself, these are prairie streams, exhibiting a high degree of variability in flow characteristics. They typically originate at low elevations, lacking the snowpack-dominated character of mountain streams and therefore provide an inconsistent annual water supply.

Big Sandy Creek originates in the Bears Paw Mountains and runs north to contribute an average of 25 cfs during the irrigation season (April through October). Battle Creek and the Frenchman River begin in the Cypress Hills region of the Canadian province of Saskatchewan. Battle Creek joins the Milk River near Chinook, Montana, contributing an average of 63 cfs. The Frenchman River is larger, averaging 100 cfs at the Canada border, ultimately reaching the Milk River near Saco, MT. South of Saco, Beaver Creek originates in the Little Rocky Mountains, flows north and adds an average of 158 cfs. Rock Creek adds 22 cfs near Hinsdale, Montana.

Streamflow Variability

The Milk River subbasin water supply is largely dependent on rain instead of snow. As a result, the supply is highly variable, both monthly and annually.

Figure S1B shows daily discharge of the Milk River at the 10-, 50-, and 90-percentile levels, at Nashua. These flow levels correspond to the highest year in 10, the middle or median year, and the lowest year in 10, respectively. This gage is located near the mouth of Milk River and measures the flow remaining after all upstream uses of Milk River water have been satisfied.

Figure S1B: Normal Range of Flow for the Milk River at Nashua, MT.

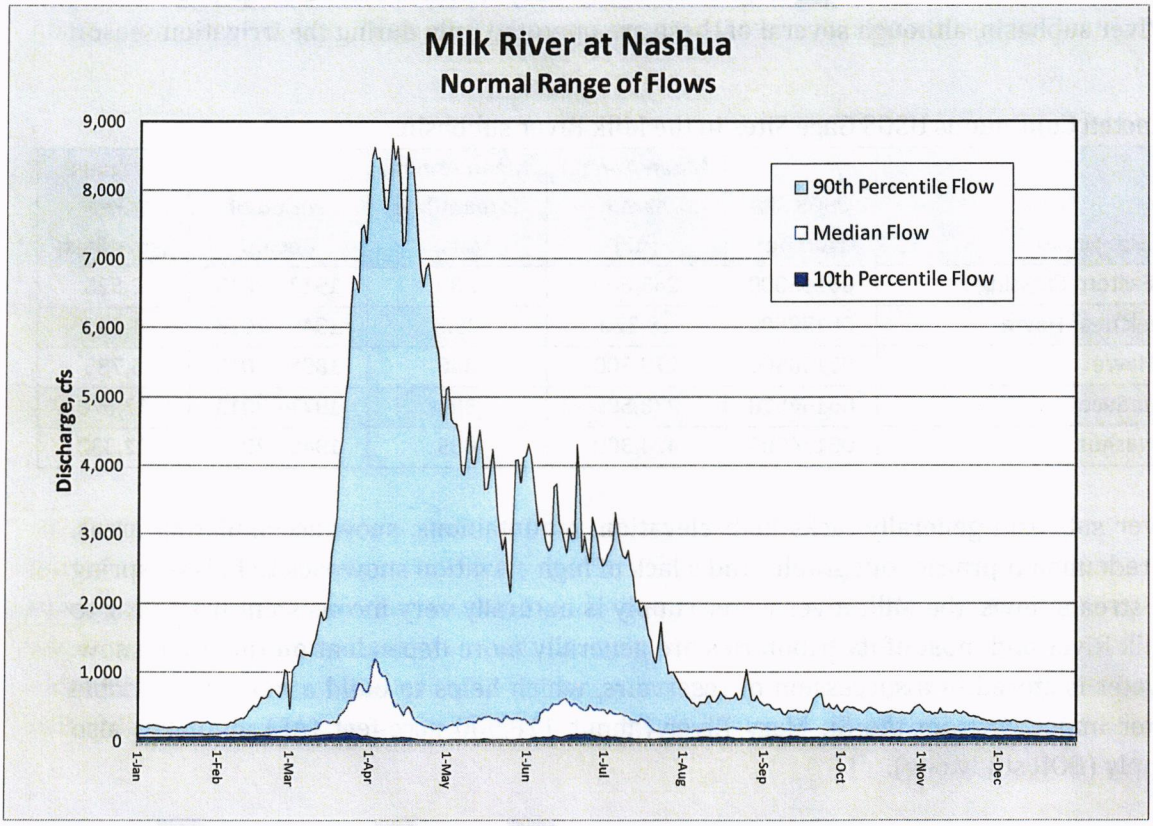


Figure S1B illustrates the vast range of Milk River flows. The highest year in 10 (90th percentile flow) approaches 9,000 cfs, while the lowest year in 10 (10th percentile flow) is barely visible at the bottom of the graph, peaking in late March at 118 cfs. The high flows are related to extreme precipitation events, such as the spring rains during 2011.

The Milk River also exhibits large variability in annual yield. Figure S2 shows the annual yield of the river at Nashua. In 1984, the annual yield was only 37,000 AF, but in 2011 the annual yield was 2.5 million AF. Flow volume during 2011 was 68 times greater than it was in 1984. The middle years experienced annual yields of 300,000 AF to 400,000 AF.

Figure S2: Milk River at Nashua, Ranked Annual Runoff by Year.

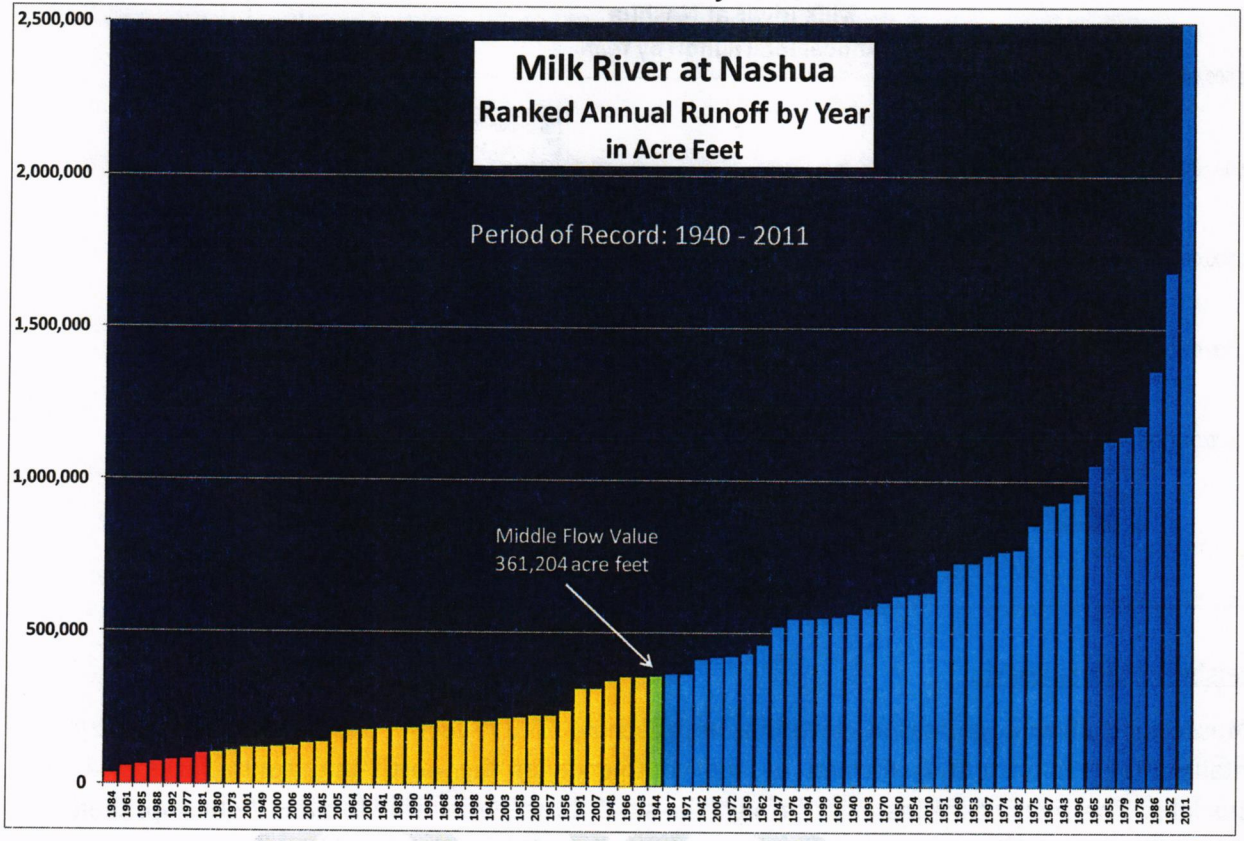
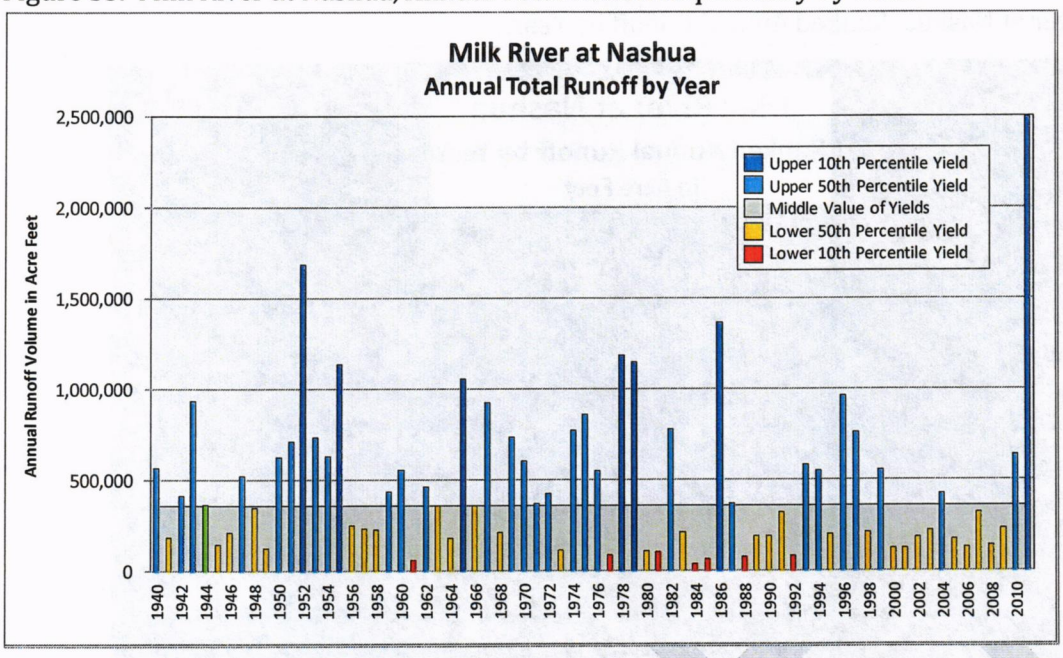


Figure S3 shows total annual runoff volume for the Milk River at Nashua sequentially by year. The period 2000 through 2009 appears to be the longest nearly continuous period of low water conditions for the Milk River. Through this period of gaged record, there are several years of below-median flow volume, as indicated by the orange and red columns. However, the drought periods shown here are not as continuous as in other locations, owing to the highly variable nature of a prairie water supply environment, and partially attributable to the greater importance of rain as opposed to snow.

Figure S3. Milk River at Nashua, Annual Total Runoff Sequentially by Year.



Musselshell River Subbasin

The Musselshell River originates at elevations approaching 10,000 feet in the Little Belt and Crazy mountains. The mainstem is formed by the confluence of the north and south forks near Martinsdale. The river first runs east through the small towns of Harlowton and Roundup, then swings north near Mosby, eventually emptying into Fort Peck Reservoir after 340 miles.

[MUSSELSHELL SUB BASIN MAP]

Much of this 9,600 square mile subbasin is prairie grassland, although the upper subbasin is defined by mountain ranges and upland hills. There are two somewhat distinct areas of the Musselshell subbasin: the mountainous, snow-dominated upper subbasin, and the prairie, rain-dominated, lower subbasin. Stream gradient is vastly different in these two parts of the Musselshell subbasin, with the upper reaches being much steeper, typical of their mountainous setting. The lower reaches exhibit extensive meandering typical of prairie streams with a lower gradient. The upper subbasin also receives much more precipitation than the lower subbasin, mainly due to the higher elevations which accumulate a significant winter snowpack.

The entire river benefits greatly from the seasonal snowpack of the Castle, Crazy, Little Belt, and Snowy Mountains, and hydrographs at various stations throughout the length of the river reflect both a classic snowmelt-influenced supply peak, and a rapid decrease and low supply of a prairie stream. Streamflows are typically very high in May and June, peaking during the annual snowmelt, then taper off rapidly through the summer months. Musselshell River water is stored in a succession of reservoirs having a total storage capacity of about 165,000 AF.

Surface Water

The USGS currently operates seven stream gaging stations in the Musselshell River subbasin, although three of these are operated only during the irrigation season. Table S1 summarizes the mean annual streamflow, period of record, and drainage area for the year-round gages. In this subbasin, as in the entire LMRB, water yield per square mile greatly decreases as drainage area increases downstream away from the higher elevation mountain regions.

Table S2. Summary of Continuous USGS Stream Gages in the Musselshell subbasin.

Site Name	USGS Site Number	Mean Annual Streamflow (AF)	Mean Annual Streamflow (cfs)	Period of Record	Drainage Area (sq. miles)
Musselshell River at Harlowton	06120500	112,989	156	1907 - 2013	1,125
Musselshell River near Roundup	06126500	145,582	201	1946 - 2013	4,023
Musselshell River at Musselshell	06127500	155,800	215	1928 - 2013	4,568
Musselshell River at Mosby	06130500	198,500	274	1929 - 2013	7,846

Tributaries

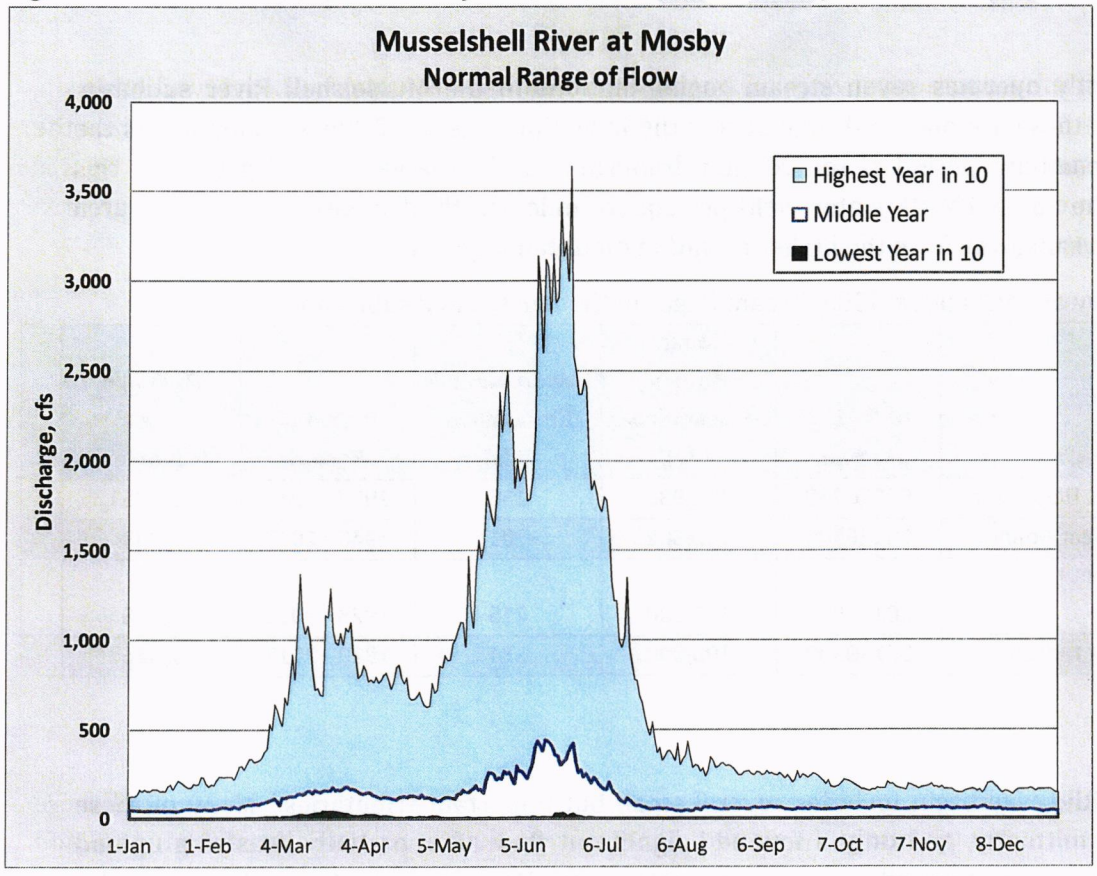
The Musselshell River subbasin includes several small but important tributaries. Many of these streams run intermittently, and only a few add significant flow after partially satisfying upland water uses. The upper watershed receives some input from Haymaker, Hopley, and Lebo creeks. Near Harlowton, American Fork adds an average of 44 cfs to the Musselshell River main stem during the May through October irrigation season.

The river transitions to more of a prairie stream character in the area between Ryegate and Roundup, losing gradient and increasing in sinuosity. There are very limited tributary inflows through this mid-section of the watershed. Streams such as Big Coulee and Willow Creek run intermittently and typically dry up completely during the summer.

Relatively far downstream in the subbasin near Mosby, Box Elder Creek adds an average 30 cfs to Flatwillow Creek during the irrigation season. Flatwillow Creek, perhaps the most important tributary to the main stem and especially the lower part of the Musselshell subbasin, then contributes 130 cfs to the Musselshell River.

Musselshell River streamflows exhibit large seasonal fluctuations. Spring snowmelt peak flows can be greater than 50 times the mean annual streamflow. Figure S3 shows Musselshell River daily discharge at Mosby. The lowest year in 10 is barely visible at the bottom of the graph, as flows are actually non-existent during much of the year. The highest year in 10 shows a high range of flows that result from generous snow melt or rain events. There is an extreme difference in flows between the middle or median year and the highest year in 10. The high flows were easily exceeded during the record flood events in 2011, which mainly resulted from heavy spring rains.

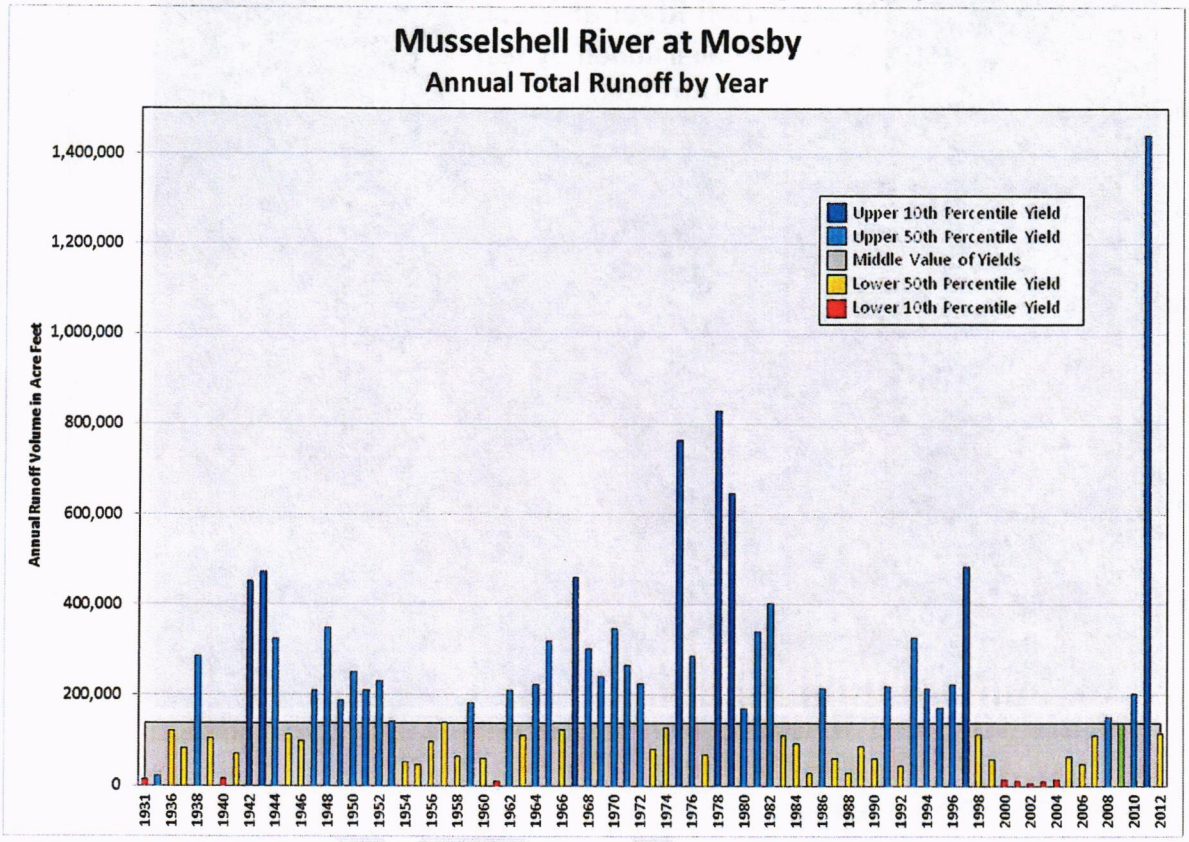
Figure S3. Musselshell River at Mosby: 10-, 50-, 90-Percentile Daily Streamflows



Musselshell River flows can be erratic during any given year and between years. For the gaged period of record, 1934 through 2012, the annual average flow is 156 cfs. In 2011, the annual average flow exceeded the period of record average by 1,715 cfs. But the following year, 2012, the

river was short of the long term average by 116 cfs. Figure S4 illustrates this range of variability of total annual runoff for the Musselshell River at Mosby, sequentially by year.

Figure S4: Musselshell River at Mosby, Annual Total Runoff Sequentially by Year.



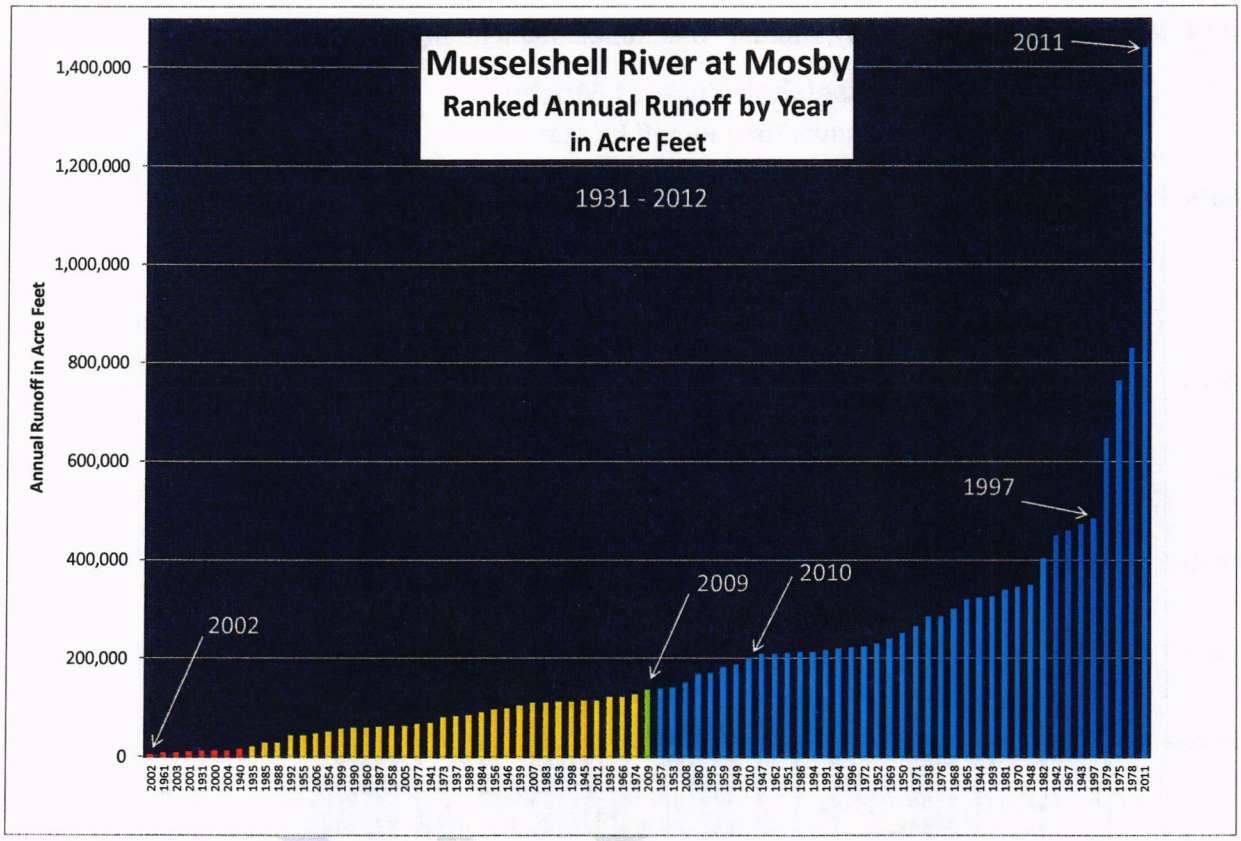
2011 was an extremely wet year in the subbasin, and many records were set on the Musselshell River in terms of peak flow, annual yield, and high flow duration. The 2011 flood peak at Roundup was estimated at over 25,000 cfs, flooding much of the town and far exceeding the 100-year return period event.

Figure S5 illustrates the wide range of ranked annual runoff for the Musselshell River at Mosby, which is located downstream in the subbasin after most water use has occurred. Annual runoff in 2002 was a meager 6,000 acre feet. Eight years later, in 2010, yield was slightly above the median at 202,000 acre feet, and in 2011 the total yield was over 1.4 million acre feet.

The 1997 snowpack is generally regarded as the highest on record in western Montana. While the 1997 runoff in the Musselshell River was in the upper 10% of annual yields measured, the mostly rain-induced 2011 runoff was three times as large.

In general, the late 1970's were the highest-yielding years of record for the Musselshell River at Mosby (blue columns), and the early 2000's were the lowest (red columns). 2009 is the median runoff year (green column), with 138,000 acre feet passing the gage location.

Figure S5. Annual Runoff of the Musselshell River at Mosby, MT ranked by year.



Peck Reservoir Subbasin

The Fort Peck Reservoir subbasin includes the Missouri River downstream of the Marias River confluence, and a few major tributaries such as the Judith River, Arrow Creek and Bullwhacker Creek. Several island mountain ranges delineate the upper reaches of this 14,100 square mile area, including the Bears Paw, Little Rocky, Judith, and Moccasin mountains. Fort Peck Dam impounds a reservoir that is the dominate feature of the subbasin. This U.S. Army Corps of Engineers (USACE) project stores nearly 19 million AF of Missouri River water in the 134-mile long, 245,000 surface acre reservoir.

[FORT PECK SUB BASIN MAP]

Surface Water

The Missouri River enters this subbasin near Virgelle and is soon joined by Arrow Creek and the Judith River. These are the two largest tributaries to the river mainstem in this subbasin. The Judith River is especially important as it adds 292 cfs of water and is much larger than Arrow Creek. Further downstream, the Musselshell River flows into the impounded water of Fort Peck Reservoir,

adding another 190 cfs to the system. Table S3 provides details of the four continuous USGS stream gages in the Fort Peck Reservoir subbasin.

Table S3 USGS gages of the Fort Peck subbasin.

Site Name	USGS Site Number	Mean Annual Streamflow (AF)	Mean Annual Streamflow (cfs)	Period of Record	Drainage Area (sq. miles)
Judith River near Winifred	06114700	211,600	292	2000 - 2013	2,731
Missouri River near Landusky	06115200	6,505,000	8,979	1934 - 2013	40,987
Big Dry Creek near Van Norman	06131000	34,710	47.9	1939 - 2013	2,554
Nelson Creek near Van Norman	06131200	1,170	1.61	1975 - 2013	100

Missouri River main stem flows entering the Fort Peck Reservoir subbasin are somewhat less variable than those of its tributaries, the extremes being moderated by substantial storage facilities upstream, including Canyon Ferry, Hauser, and Holter reservoirs. Figure S6 shows annual yield of the river near Landusky. For the 1935 – 2011 period of record, the lowest yield was about 3,000,000 AF in 1937 (red columns), and the greatest yield was almost 12,000,000 AF, in 1975 (blue columns). 1963 is the median runoff year (green column), with 6,000,000 AF passing the gage location. It is notable that the highest annual yield at this location was not produced by the widespread 2011 rain-influenced floods.

Figure S6 Missouri River near Landusky, MT Annual Runoff

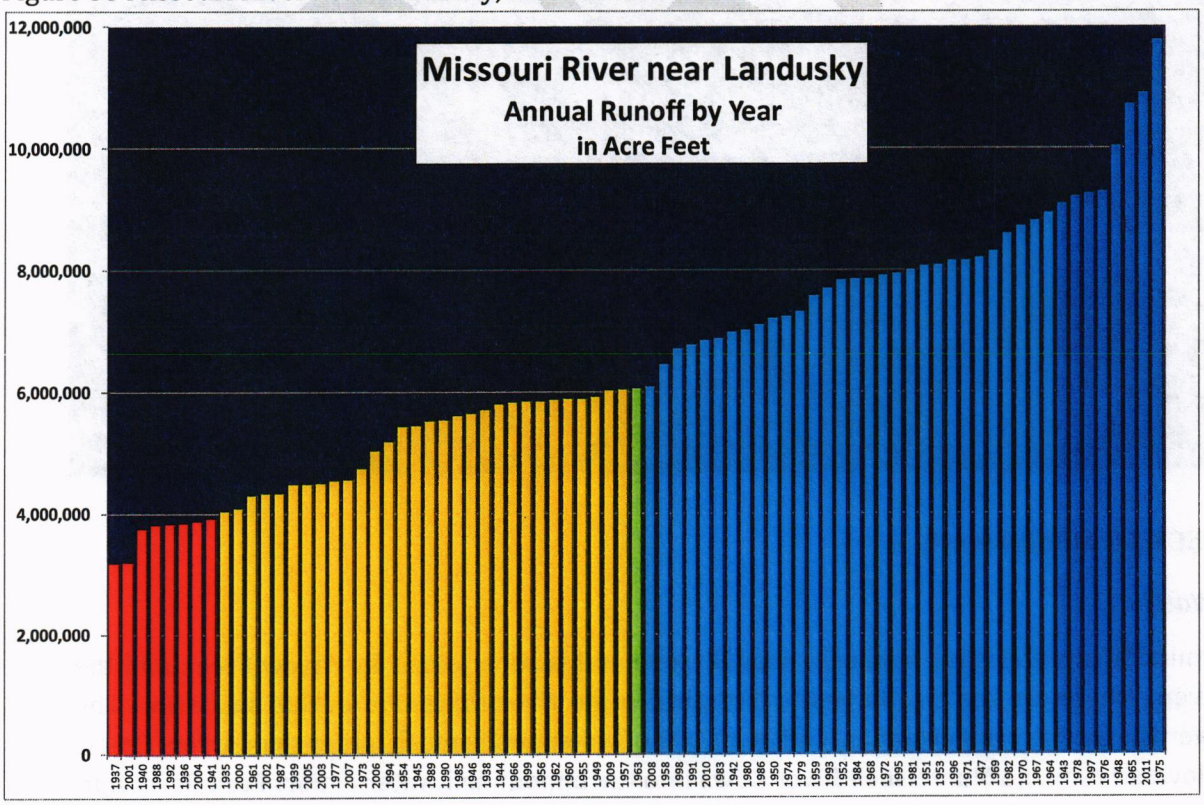
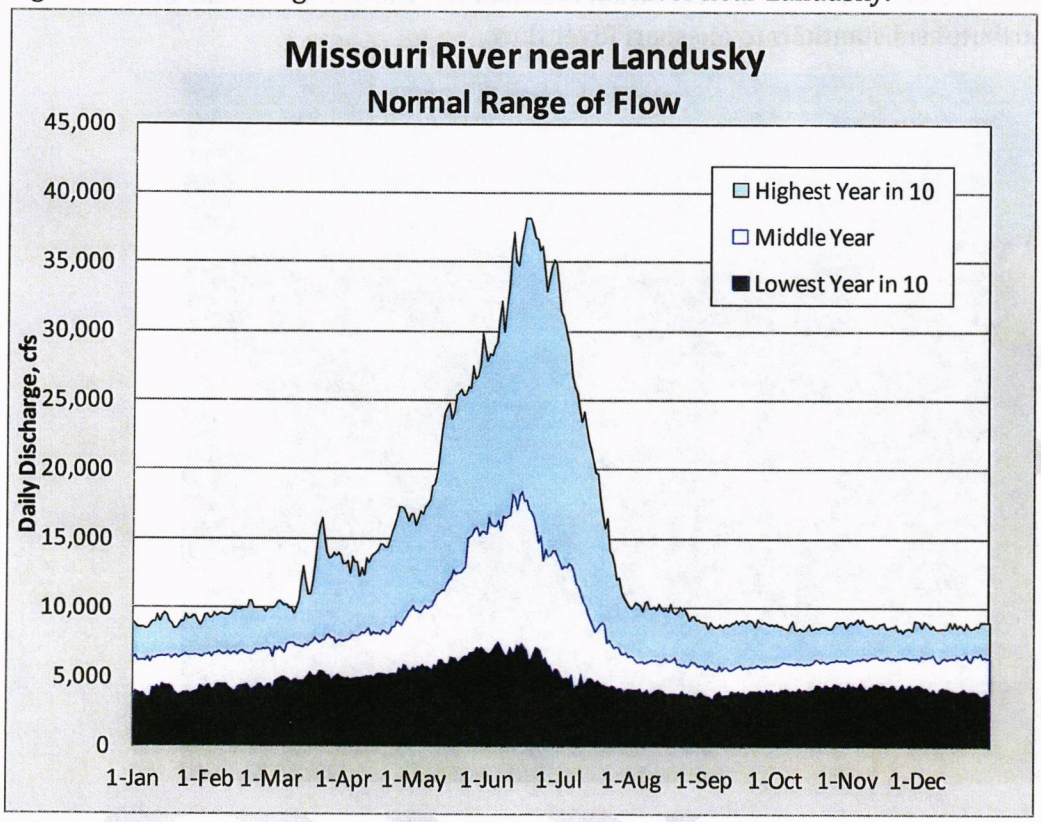


Figure S7 shows the normal range of flow for the Missouri near Landusky which is located just above the impounded water of Fort Peck Reservoir and near the middle of the Fort Peck Reservoir subbasin. Median daily flows at this site are just about double the 10th Percentile flows. In turn, the 90th Percentile flows are about double the Median flows.

Figure S7. Normal Range of Flow for the Missouri River near Landusky.



Missouri-Poplar Subbasin

The 10,800 square mile area below Fort Peck Dam is known as the Missouri-Poplar subbasin. The Milk River immediately joins the Missouri River from the north and the river heads east. This is a prairie landscape, with the farthest northeast portions of the subbasin dotted with numerous pothole lakes and wetlands. There are only a few relatively major prairie tributaries, such as the Poplar River and Big Muddy Creek. Just downstream from the Montana-North Dakota state line, the Yellowstone River contributes substantially to Missouri River flow.

Medicine Lake National Wildlife Refuge is located in the northeast portion of the subbasin. The refuge includes a large lake of the same name, which holds 67,000 AF of water. Aside from the refuge and several small natural lakes, there are only small reservoirs in this vast subbasin.

The Fort Peck Indian Reservation is located almost entirely within the Missouri-Poplar subbasin. The Reservation has a population of 10,000 people over a land area of 3,290 square miles, comprising about one third of the area of the Missouri-Poplar subbasin.

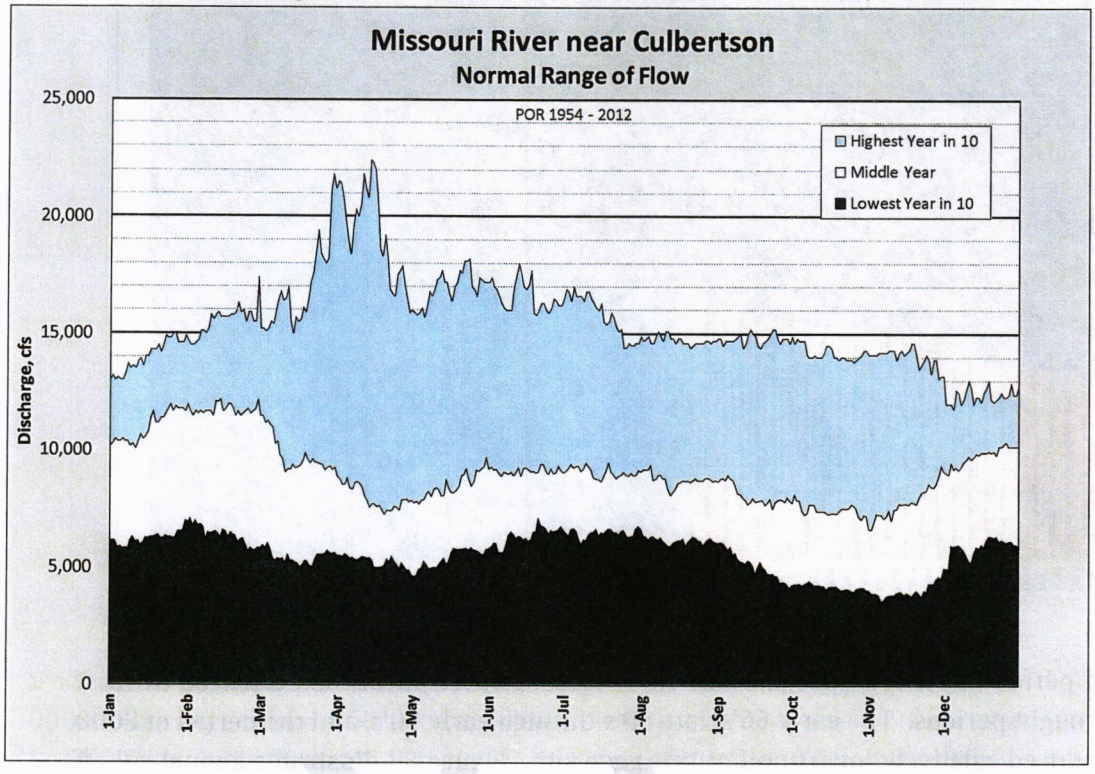
[Map of MISSOURI – POPLAR SUB BASIN]

Surface Water

Although prairie tributary flows into the Missouri River are highly variable, flows of the Missouri River itself are relatively stable, because the river is regulated upstream by Fort Peck Dam. Annual water supply in the main stem is heavily influenced by snowpack conditions in the UMRB, spring rainfall events in the LMRB and by the operations of the several large reservoirs in both the UMRB and

LMRB. Figure S6 shows the normal range of flows for the Missouri River at Culbertson, downstream of Fort Peck Dam, and near the Montana - North Dakota state line.

Figure S6. Normal Range of Flow for the Missouri River at Culbertson, MT.

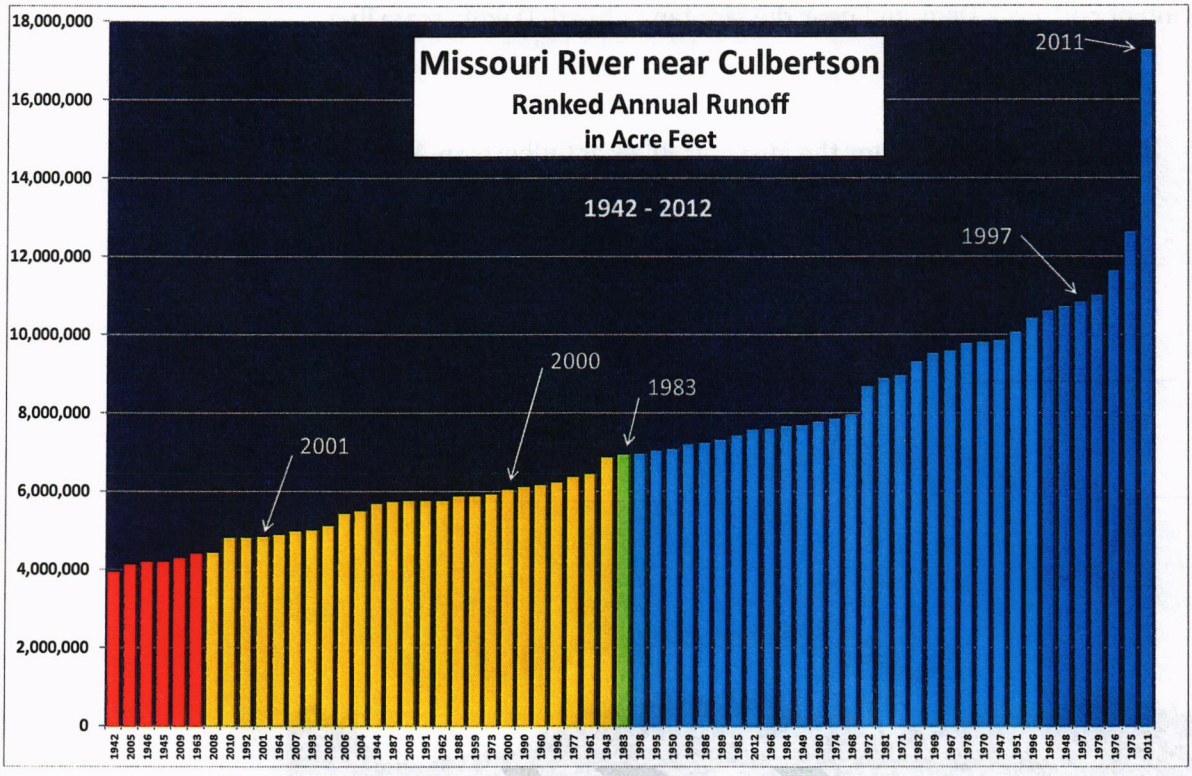


The March and April peaks in Figure S6 are the result of reservoir operations in response to extreme precipitation or snowmelt events which sometimes impact the LMRB. Figure S6 also illustrates the relative stability of flows through the entire year, which is typical of a heavily regulated river system.

Similarly, the total annual volume yield of the Missouri River near Culbertson is not as variable as it would be on an undammed, unregulated system. Figure S7 shows the total annual runoff by year from 1942 through 2012, ranked from low to high. Not considering 2011, the variability of total annual yield between was from about 4 million AF in 1942 (red columns), to about 12.6 million AF in 1975 (blue columns). The yield in 1975 is about three times the total yield during the lowest yield, which occurred in 1942. 1963 is the median runoff year (green column), with 6,500,000 AF passing the gage location.

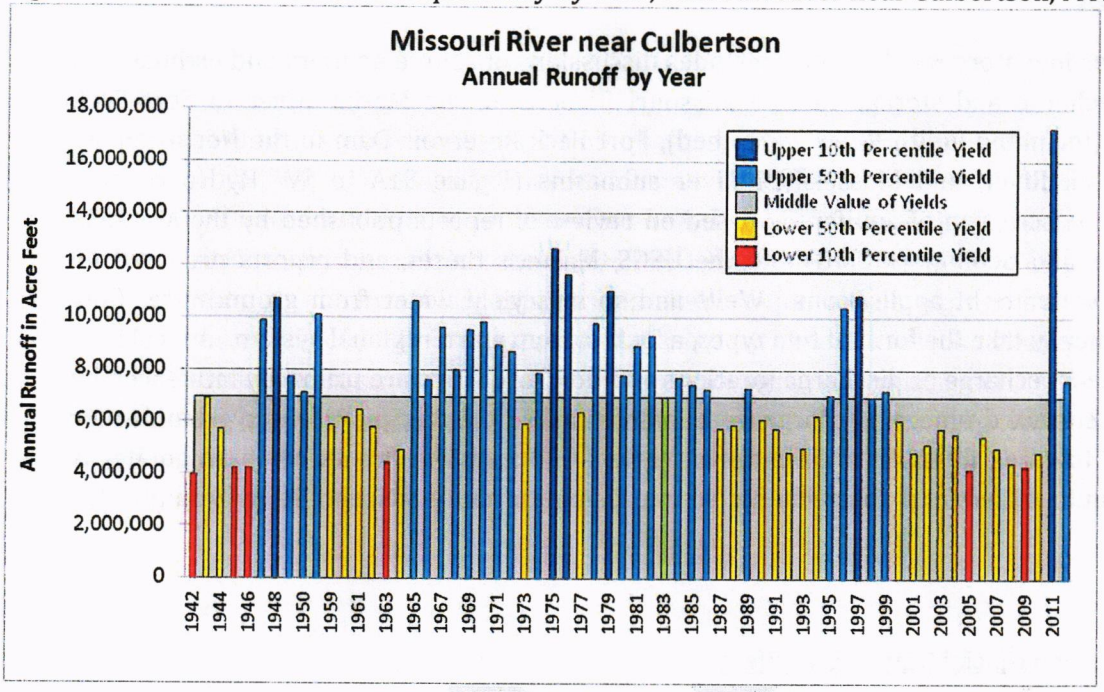
Heavy precipitation combined with snowmelt during 2011 produced record flows in the Missouri River in some locations. Peak flow for 2011 is estimated at 94,000 cfs for the USGS gage near Wolf Point, MT and 104,000 cfs for the USGS gage near Culbertson, MT. Both peaks far exceeded the 100-year event benchmark.

Figure S7. Ranked Annual Runoff for the Missouri River near Culbertson, MT.



During the gaged period of record, the Missouri River near Culbertson has experienced at least three extended drought periods. The early 60's, late 80's through early 90's, and the period of 2000 through 2010 produced relatively low runoff at this gage site. Figure S8 illustrates annual runoff sequentially by year, and reveals the extent of drought conditions during the 2000's. The median year water yield for this period of record is 1983, denoted by the green column or the dark gray background.

Figure S8. Annual Total Runoff Sequentially by Year, Missouri River near Culbertson, MT.



Data Gaps and Areas of Uncertainty

While the Milk, Musselshell and Missouri River mainstems appear to be adequately gaged through a partnership agreement between the USGS and DNRC, flows of most tributary streams are not measured. Local water management efforts would benefit from additional gaging on tributaries such as the Judith, Frenchman and Poplar rivers, in addition to a large number of smaller tributary streams in the LMRB.

The amount of water diverted from streams is also not well known. Therefore, not much is known about actual water consumption within the LMRB. Measurement of water diverted from surface and ground sources would greatly enhance understanding of the resources, assist in local water management, and help to document changes in water use and consumption trends through time. Measurement of water use can help protect existing water uses from future uses which might infringe on senior water uses.

Groundwater Resources in the LMRB

Groundwater

The groundwater inventory for the LMRB includes discussions of source aquifers and estimates of groundwater recharge and storage for the Missouri River from the Marias River to Fort Peck Reservoir Dam (including Judith River watershed), Fort Peck Reservoir Dam to the North Dakota state border, Milk River, and Musselshell River subbasins (Figure S1A in SW Hydro report). Information and description of aquifers is based on review of reports published by the Montana Bureau of Mines and Geology (MBMG) and the USGS, Master's theses, and reports prepared by consultants for water right applications. Wells and springs yield water from groundwater flow systems that typically take the form of two types, a local system and a regional system. A local flow system occurs near recharge or discharge locations and flow directions are primarily influenced by topography and surface drainage. Recharge from infiltration of local precipitation and groundwater flow is directed towards the nearest drainage. A regional flow system occurs when an aquifer is deeply buried and further from the recharge source making it more susceptible to groundwater mining.

Aquifers

Shallow Alluvium and Glacial Outwash aquifers

Alluvial aquifers occur along the larger streams in Montana and are major sources of water for irrigation, municipal, industrial, household, and livestock purposes. These aquifers are comprised of Quaternary river alluvium, terrace deposits, dune sand, and glacial outwash deposits and occur along flood plains of all the major streams. River alluvium is the material constantly being eroded, transported, and deposited by a river. Shallow alluvial aquifers are generally less than 150 feet thick and therefore, are accessible by shallow wells at relatively low expense. Terrace deposits are older floodplain or alluvial deposits that have been left behind after a stream shifts position. These sediments are unconsolidated or poorly consolidated and consist of sand, gravel, silt, and clay. Hydrologically, alluvium and terrace deposits constitute a single water-bearing unit.

There are extensive alluvial deposits throughout the Judith River watershed on pediment surfaces and alluvial fans cap benches extending from the Little Belt, Big Snowy, Judith, and North and South Moccasin Mountains. Gravel deposits that represent a succession of several terrace surfaces exist in the Judith River and Arrow Creek drainages (Vine, 1956). The gravels form a permeable layer that is commonly water bearing. Most of the small towns and farms located on terrace gravels obtain water from wells completed in the base of the gravel deposit. Irrigation projects on the terrace gravels are generally more successful than those on bedrock, because the gravels provide a means of drainage for the water, thereby preventing the accumulation of saline minerals at the surface of the ground through evaporation.

The alluvial aquifers of the Musselshell River subbasin are composed of approximately 20 feet of unconsolidated gravel, sand and clay. The Musselshell River subbasin has alluvial deposits on pediment surfaces and alluvial fans cap benches extending from the Little Belt, Big Snowy, Castle, Bull, and Crazy Mountains. This alluvium is predominately underlain by Cretaceous sedimentary units that have been eroded and faulted. The terrace gravel aquifers consist of well-rounded pebbles that are firmly cemented into a conglomerate in some locations (Bowen, 1919). In the

lower Musselshell subbasin, deposits of rhythmically bedded silt and fine sand from glacial Lake Musselshell influence the groundwater system (Davis, 2006).

The alluvial and terrace aquifers of the Milk River subbasin are composed of generally less than 60 feet of unconsolidated, discontinuous lenses of fine-grained sand, silt, sandy clay, and clay. The older alluvium is composed of deposits of the ancestral Missouri River (Lawlor, 2000). The Milk River subbasin has alluvial deposits on pediment surfaces and alluvial fans cap benches extending from the Continental Divide, Bears Paw, Sweet Grass Hills, and Little Rocky Mountains. Glacial deposits range in thickness from 20 to 100 feet of mostly till but they can consist of unconsolidated gravel, sand, silt, and clay (Alverson, 1965). This is the case in places where glacial meltwater has sorted out and carried away most of the fine-grained material leaving behind well sorted and permeable glaciofluvial sand and gravel deposits.

The Flaxville gravels (Flaxville Formation) are late Tertiary in age and generally consist of unconsolidated, well rounded quartzite/argillite pebbles in a sand matrix. These gravels are 40 to 100 feet thick and have been one of the more productive aquifers in parts of northeastern Montana particularly in the Turner-Hogeland area. Well yields up to 1,200 gallons per minute (gpm) have been reported from the Flaxville gravels. Flaxville gravels has high permeability and generally contains shallow aquifer systems (<50 ft deep); therefore, aquifers in the Flaxville gravels are susceptible to impacts from the application of agricultural chemicals (Nimick and Thamke, 1998). These aquifers are usually perched on shale of the Tongue River Member of the Fort Union Formation (Cannon, 1987).

In the LMRB, there are numerous pre-glacial Missouri River channels that are overlain by glacial deposits with the Clear Lake aquifer being the most studied. The Clear Lake aquifer is a complex aquifer system composed of sand and gravel deposited by the ancestral Missouri River and by later glacial meltwater streams. The permeable units are separated by fine grained leaky confining sediments of variable thickness and leakage potential. There is little or no surface definition of the underlying buried channel aquifer. In addition, not all sites within the boundaries are capable of producing adequate volumes for irrigation and other large demands. Figure A shows the seasonal recharge and trends in precipitation and runoff that are typical of shallow aquifer systems. Another trend in shallow wells is increasing water levels during irrigation season from irrigation or canal leakage.

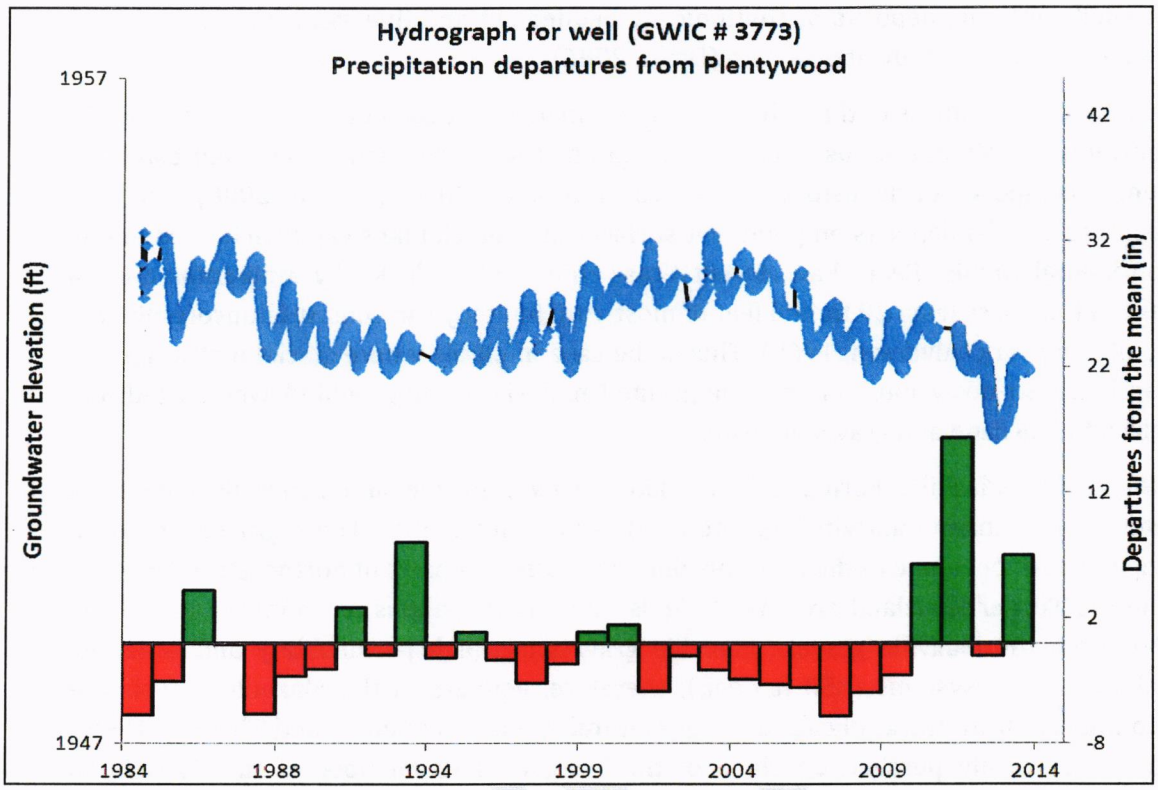


Figure A: Water level in a well (GWIC # 3773) completed in the Clear Lake aquifer near Dagmar, MT that responds to seasonal recharge from a nearby stream as well as multi-year trends in precipitation and runoff.

Recharge to the shallow aquifer systems is primarily derived from seepage from the streams/rivers, stored during periods of higher stream flow and discharged back to the stream/river during low flows. Other recharge sources include infiltration of precipitation, irrigation water lost by percolation through fields, and leakage from ditches. Places where water discharges includes springs and seeps along the valley bottom of the Missouri River and its tributaries.

Sandstone aquifers

The most commonly used sources of groundwater in the LMRB are found in sandstone aquifers. Sandstone of the Tongue River Member of the Tertiary Fort Union Formation is the shallowest and the most utilized sandstone source of groundwater (MBMG, 1978; Slagle, 1983). The Tullock Member of the Fort Union Formation is semi-productive in the LMRB. Figure B shows the groundwater level response to trends in precipitation, but depending on depth of the aquifer and other factors (i.e. distance from the recharge source) the shape of the hydrograph varies throughout the LMRB.

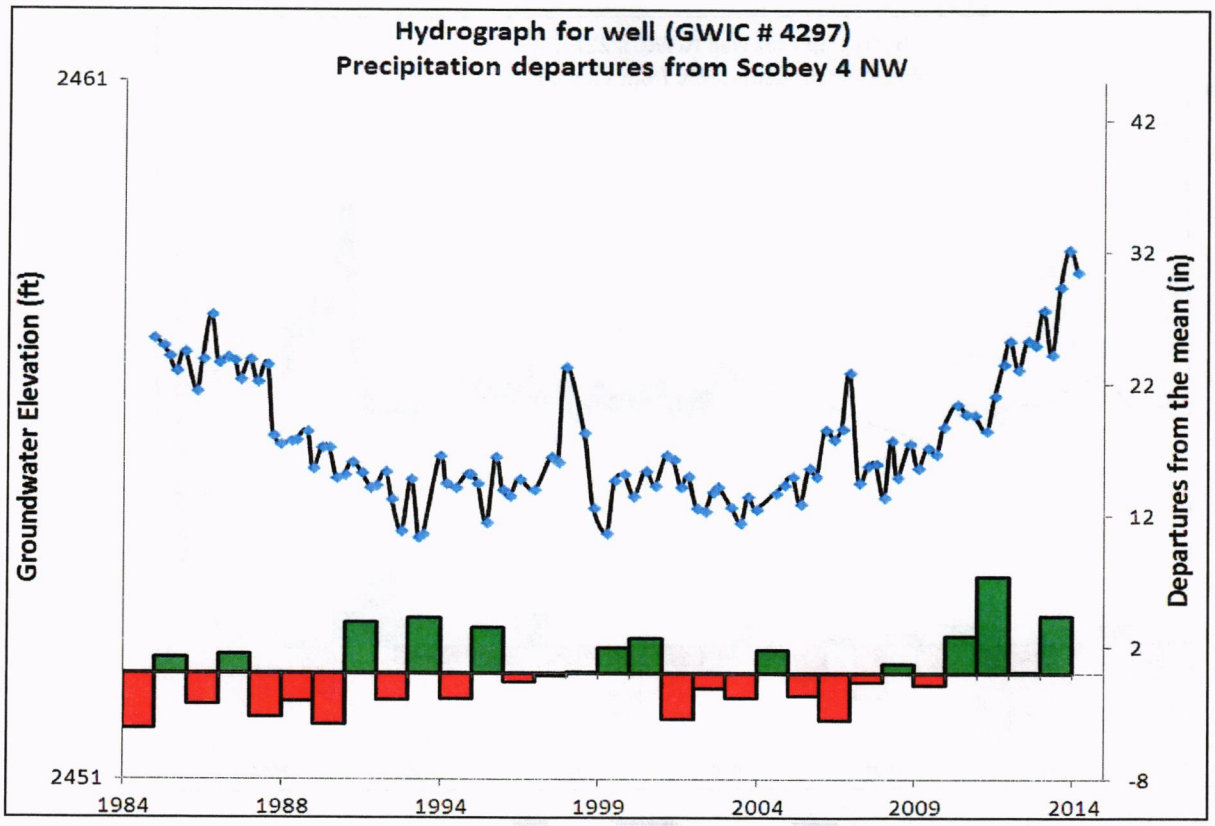


Figure B: Water level in a well (GWIC # 4297) completed in the Fort Union aquifer near Scobey, MT that responds to multi-year trends in precipitation and runoff.

Another sandstone aquifer is the lower portion of the Cretaceous Hell Creek Formation and the entire Cretaceous Fox Hills Formation. This is a regional aquifer and occurs at depths from 600 feet to 1,600 feet below land surface throughout most of the LMRB (Smith et. al., 2000). Flowing Fox Hills–lower Hell Creek aquifer wells are usually found in the valley bottoms of large streams and have potentiometric surfaces that are 50 to 100 feet above land surface. Figure C shows a stable trend during average precipitation years, but an increase in groundwater levels occurred during 2010 and 2011 due to above average precipitation. These stable trends exist in other monitoring wells in areas where the Fox Hills crops out at land surface and near Fort Peck Reservoir. However, the closer the monitoring well is to the Yellowstone River basin, a decline of 1 to 3 feet a year is observed in long-term monitoring wells.

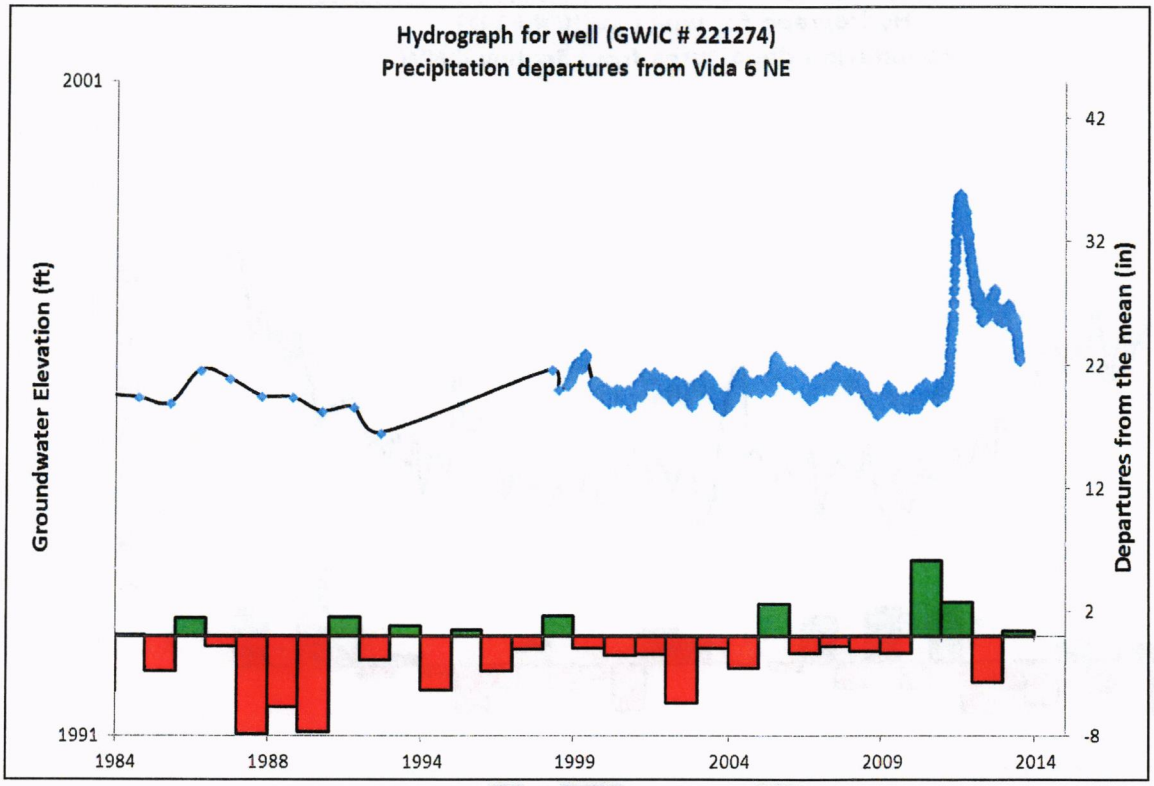


Figure C: Water level in a well (GWIC # 221274) completed in the Fox Hills–lower Hell Creek aquifer near Vida, MT that responds to above average years of precipitation, but otherwise has a stable water level throughout the period of record.

The Judith River Formation and Two Medicine Formation are characterized by relatively high porosity and permeability. The Judith River Formation is greater than 700 feet thick at the western margin of the Great Plains where it grades into the Two Medicine Formation, but thins to less than 50 feet near the eastern border of Montana and is over 500 feet below ground surface (EQC, 1983). Flowing Judith River aquifer wells are common along the Missouri River and Milk River valleys (Perry, 1931; Osterkamp, 1968). This aquifer has highly mineralized water where the Judith River Formation dips into the subsurface and is overlain by the Bearpaw Shale which is up to 800 feet thick.

The water saturated sandstone of the Eagle Formation and Telegraph Creek Formation comprise the Eagle aquifer and consists of up to 500 feet of interbedded layers of sandstone and sandy shale and is overlain by the Claggett Shale Formation (Lopez, 2000). In central Montana, the Eagle Formation outcrops at Bull Mountains, Cat Creek anticline, Judith Mountains, Little Rocky, and Bears Paw Mountains. Flowing Eagle aquifer wells are common at these outcrop locations (Osterkamp, 1968; Reiten and Hanson, 2008). Well yield is probably directly related to primary porosity and permeability of the sandstone units and secondary porosity related to fracturing in the sandstone, with better yields associated with increased fracturing (Reiten and Hanson, 2008). Where the Eagle Formation dips into the subsurface and is overlain by the Claggett Shale, the aquifer contains highly mineralized water that is not suitable for most uses. Both the Eagle aquifer

and Judith River aquifer is a source of domestic and stock water with well yields generally less than 50 gpm.

Sandstone aquifers in the Kootenai Formation and Swift Formation outcrop in the surrounding mountains, dipping gently beneath the relatively low permeability of the Colorado Shale across the LMRB. The Kootenai Formation and Swift Formation are sandstone aquifers that overlie the Madison Group aquifer. The Kootenai aquifer is one of the most productive and widespread aquifers in the Judith River watershed (Levings, 1983). The Kootenai Formation is estimated to be 330 feet to 400 feet thick in the Judith River watershed and generally flow at the surface and produce moderate volumes of water (Lindsey, 1982). The upper portion of the Kootenai Formation is generally non-productive (up to 10 gpm), while zones known as the second and third Cat Creek Sands in the lower portion of the Kootenai Formation tend to be more productive with well yields up to 300 gpm (Perry, 1933, Levings, 1983). Swift Formation sandstone thickness ranges from 40-150 feet in western Montana, to less than 50 feet in eastern Montana. Well yields can be as great as 50 gpm for the Swift Formation when thicknesses exceed 100 feet.

Recharge to sandstone aquifers is primarily derived from seepage from the streams, infiltration of precipitation, snowmelt in topographically high outcrop areas, and leakage through confining units. Other recharge sources include irrigation water lost by percolation through fields and leakage from ditches. On a regional scale, potentiometric surface mapping shows that groundwater in the bedrock often is in hydraulic communication with alluvial aquifers. Places where shallow aquifers discharge are springs and seeps along the valley bottom and active channel of the Yellowstone River and its tributaries. Groundwater from the Fox Hills–lower Hell Creek aquifer and other sandstone aquifers discharge in topographically lower areas by upward leakage to shallower aquifers and streams (Smith et. al., 2000).

Limestone aquifers

Hydraulic conductivity of the Madison Group aquifer is relatively high where geologically young karst and/or fracturing permeability associated with Laramide and younger orogenesis are encountered. However, the hydraulic conductivity is low where karst processes are absent outside recharge areas or in areas where the Madison Group limestone is largely structurally undeformed (Huntoon, 1993). The Little Belt and Big Snowy Mountains are the recharge area for the Madison Group aquifer and the aquifer discharges along fractures through overlying strata to the Missouri River. The Madison Group aquifer is the source for Big Spring on the north flank of the Big Snowy Mountains south of Lewistown, Warm Spring between North Moccasin, and South Moccasin Mountains north of Lewistown, and a flowing well near Hanover, MT north of Lewistown, MT. Each of these aquifer discharge areas are associated with dome uplifts where the Madison Group is exposed at or brought close to the land surface. This aquifer is present throughout most of the state, but its depth, variable well yields, and water quality are factors in its production potential (EQC, 1983). There is no designated Madison Group aquifer monitoring well with a period of record greater than five years in the LMRB. There are three Madison Group aquifer wells being monitored by MBMG (GWIC # 257040; GWIC # 269262; GWIC # 275370). Figure D shows the groundwater level response to seasonal trends and recharge. Notice the large seasonal changes in water level related to the magnitude of recharge. It is expected that the seasonal "rolling" shape of

the hydrograph will continue, with its magnitude being proportional to recharge and future development.

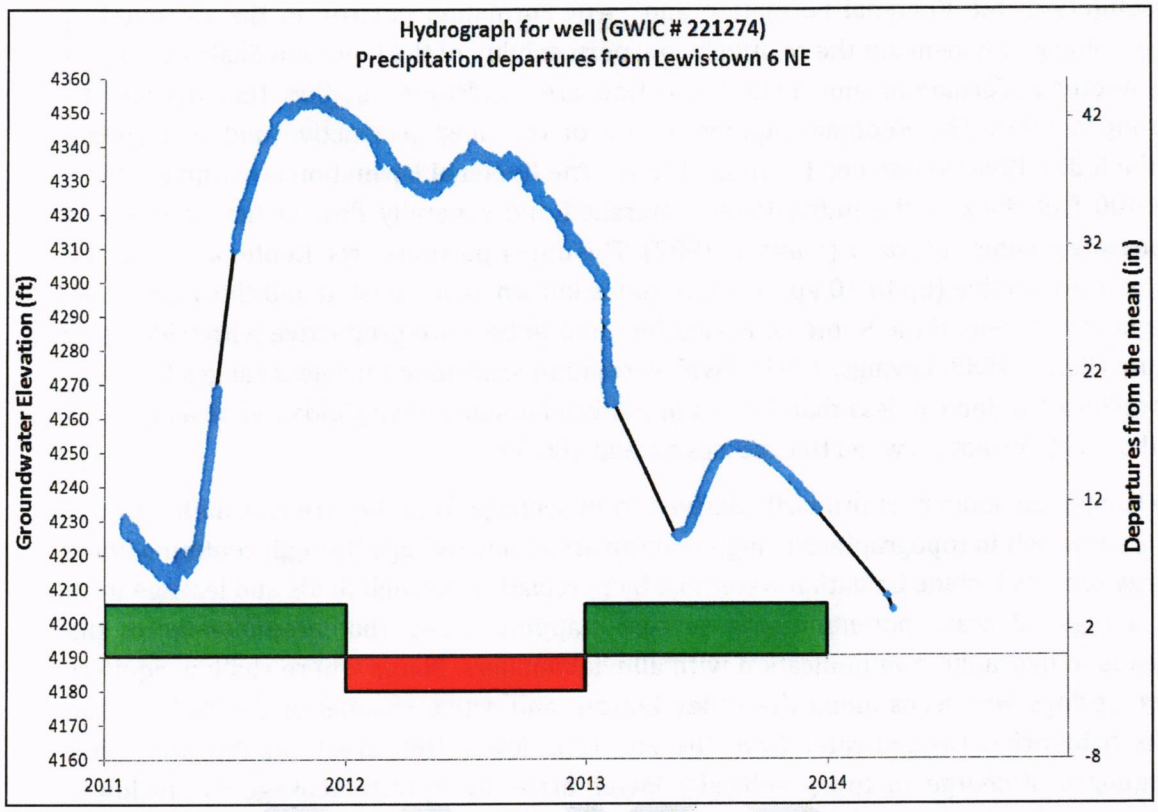


Figure D: Water level in a well (GWIC # 257040) completed in the Madison Group aquifer near Utica, MT that responds to above average years of precipitation and shows seasonal trends. Note: short period of record.

Base flow contribution

With regard to estimating the contribution of groundwater to surface water base flow, groundwater recharge estimates presented in Figure E are the base flow index (BFI) values estimated by the USGS by automated hydrograph separation (Wolock, 2003-146). This assumes that the BFI, an estimated ratio of base flow to annual flow, reasonably represents the long-term percentage of groundwater discharge. It may, in some cases, underestimate recharge if a portion of the recharge flows into regional aquifer systems. Alternatively, streams affected by reservoir regulation or snowmelt dominated flow regimes are likely to have inflated BFIs (Wolock, 2003-311). Data from one gaged site is used to determine a representative BFI for each 8-Digit/4th Code HUC subbasin. The BFI value for the selected gage is used if the USGS dataset includes a BFI value at the location selected for a subbasin and that location was determined to be free of reservoir effects. Otherwise, a BFI value from an interpolated grid of BFI values is used to estimate BFIs at ungaged sites (Wolock, 2003-263).

Recharge estimates in USGS (2003) are based on surface water base flow estimates and, therefore, rely on assumptions that recharge is equal to long-term discharge and that groundwater does not

leave a basin through regional groundwater flow. The first assumption is valid where development is small relative to the basin water balance or relatively recent and not reflected in reduced base-flow discharge. Furthermore, estimates of recharge do not represent the amount of water legally available for appropriation. Ultimately, the availability of groundwater for appropriation depends on any impacts to existing water users which is largely independent of recharge.

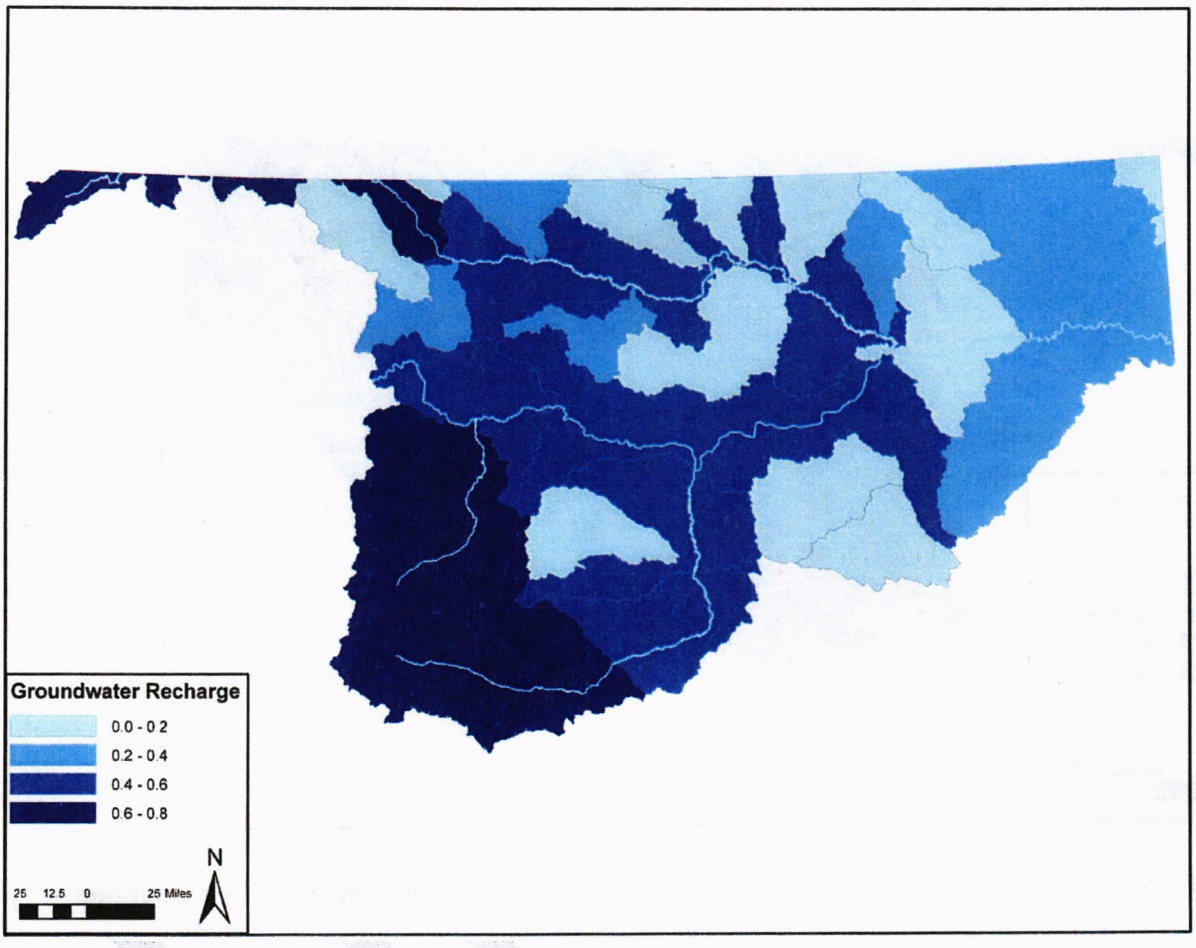


Figure E: Groundwater recharge estimates as a ratio of base flow to annual flow.

Groundwater Storage

The groundwater storage capacity (Figure F) of the upper 50 feet saturated thickness of alluvial and Tertiary basin fill aquifers is estimated from the areal extent of aquifers and their storage capacities. The areal extent of alluvium, alluvial terraces, and Tertiary basin fill sediments with the primary rock type identified as coarse grained is obtained from a digital geologic map available from the USGS (2005). Aquifer storage is assigned a uniform specific yield value of 0.20.

The value of 50 feet for saturated thickness used in calculations is representative of the typical thickness of coarse grained unconfined portions of aquifers and the thickness that accounts for the majority of groundwater circulation. Although an alluvial aquifer may store a considerable quantity of water, pumping cannot remove groundwater in aquifer storage without reducing discharge or inducing recharge, often to the detriment of surface water flows and rights of surface water users. Removal of

even small amounts of groundwater resulting in much less than 50 feet of drawdown will deplete flows and impact existing users, thereby limiting new appropriations of groundwater. Figure F shows the variability of alluvial aquifer storage throughout the LMRB.

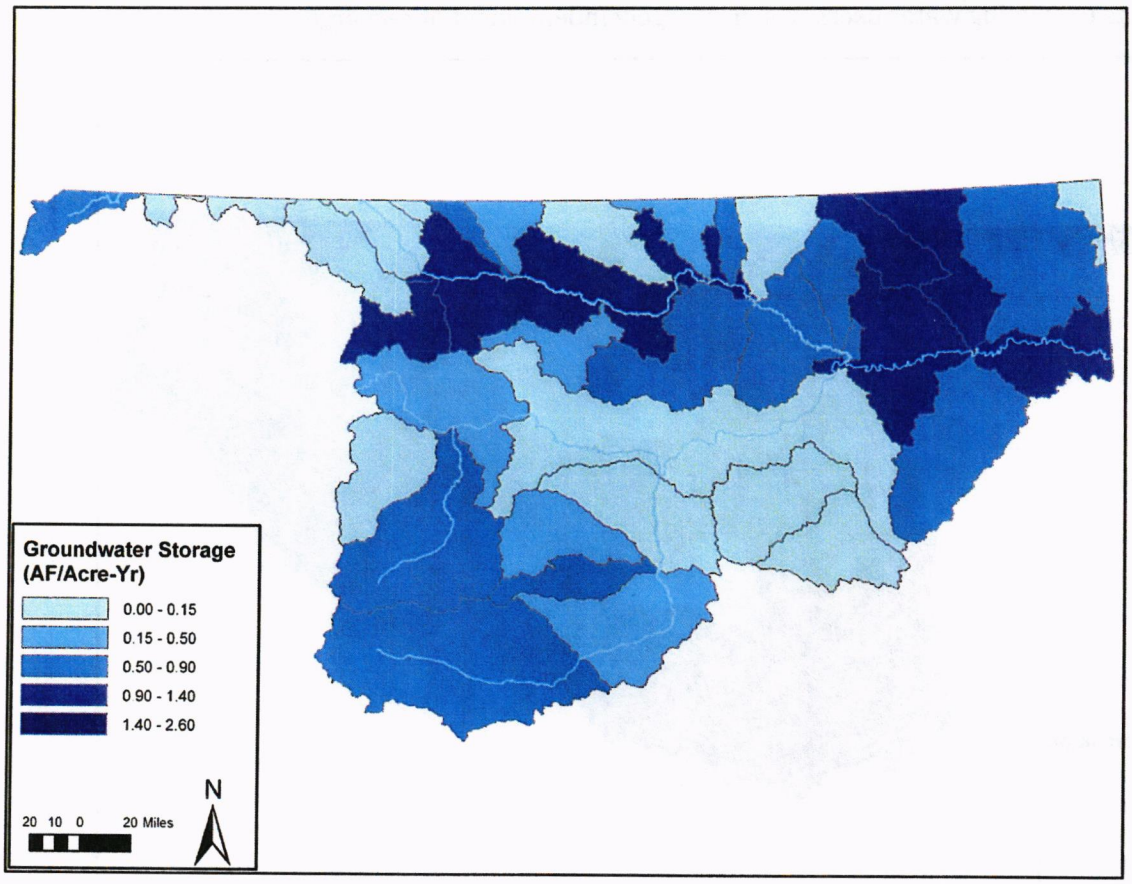


Figure F: Groundwater storage (AF per acre per year) estimates in the upper 50 feet saturated thickness of alluvium / basin fill aquifer.

Surface Water Depletion

Though the individual relationships are varied and complex, groundwater aquifers in most of Montana are hydrologically connected to streams. Connections between groundwater and surface water often control the sustainability of groundwater development. The connection may not be obvious and the interaction diffuse; however, groundwater provides important natural water storage and contributes base flow to surface water during periods of low flow. Groundwater pumped (Q) is ultimately offset by increased recharge to surface water, decreased discharge to surface water or reduced evapotranspiration by phreatophyte vegetation, a process first described by Theis (1941) and defined by the term capture by Lohman (1972). Hydrologic equilibrium is re-established when the amount pumped is balanced by capture (Bredehoeft, 1997).

Shallow alluvial aquifers are typically unconfined and connected to surface water where alluvium is saturated beneath stream beds. Figure G is an example of examining the potential for groundwater/surface water interaction by looking at wells less than 100 feet deep with a static

water level less than 20 feet. The location of such wells do not just occur around large river systems but also up on the plateaus suggesting that the past glacial activity influenced many of the groundwater flow systems in the LMRB. The connection to surface water in tertiary sediments, glacial outwash, confined sandstone aquifers, or confined limestone aquifers depends on the continuity and hydraulic properties of confining layers. Continuous confining layers across the LMRB may transmit only small volumes per a unit area, but they can transmit large volumes over large areas. Therefore deep confined aquifers are often connected to shallow alluvial aquifers through areas where the confining unit is thin or discontinuous. Pumping from a confined aquifer also can deplete surface water by propagation of drawdown through the source aquifer to a subcrop/outcrop in the vicinity of a surface water source.

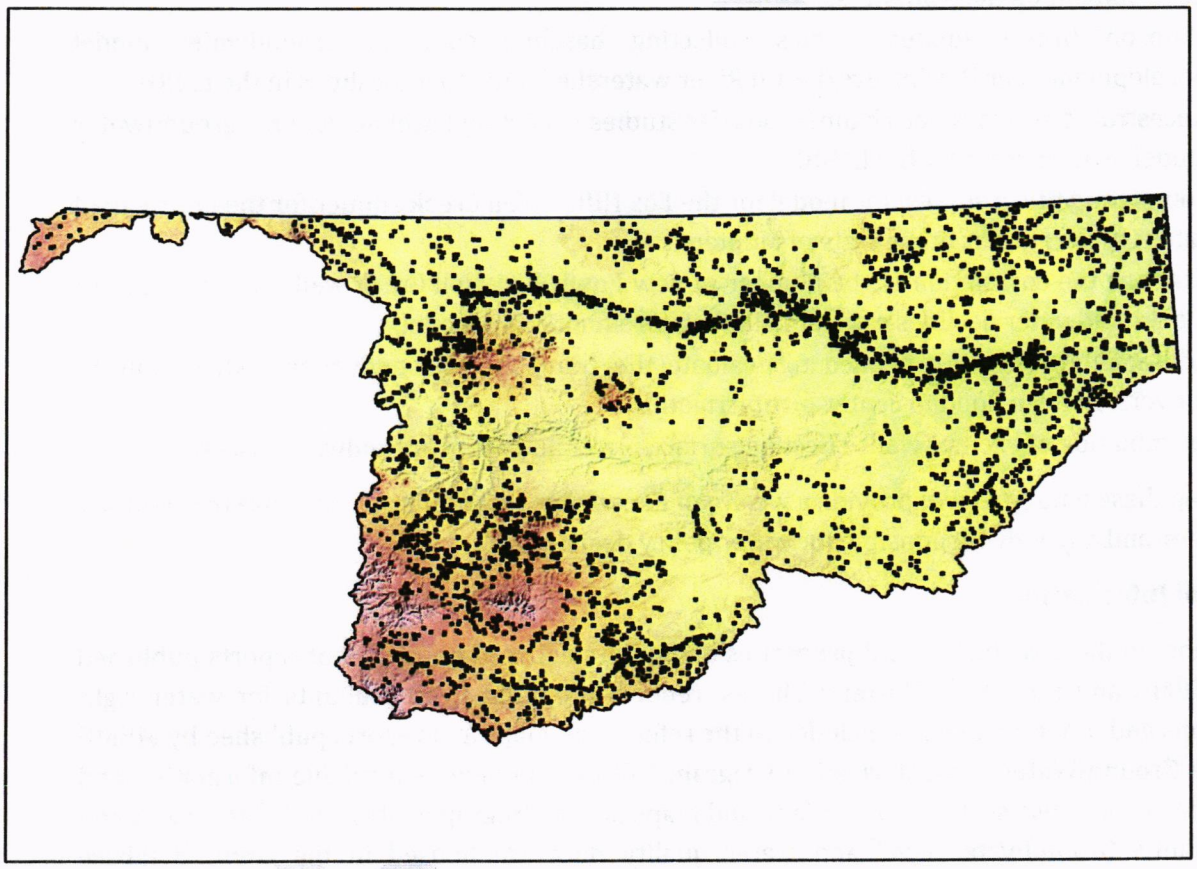


Figure G: Areas where static water levels in wells less than 100 feet deep are less than 20 feet indicating potential for connection between groundwater and surface water.

Data Gaps and Areas of Uncertainty

Groundwater

The following groundwater data gaps and areas of uncertainty were found.

- Groundwater/surface water interaction studies are needed in the LMRB to examine how groundwater production effects surface water flows in the Milk River, Musselshell River, Judith River and Lower Missouri River
- More information (baseline data of water levels and quality, additional long-term monitoring wells, and increased model accuracy) is needed for the development of deep groundwater sources for irrigation purposes and to understand the implications of such development on deep aquifers.
- Madison Group aquifer studies collecting baseline data for groundwater model development near Big Springs/Judith River watershed and other localities in the LMRB.
- Ancestral Missouri River channels aquifer studies collecting baseline data for groundwater model development for the LMRB.
- Completing the groundwater model for the Fox Hills – Hell Creek aquifer for the entire areal extent of the aquifer in the state of Montana.
- Examine the correlation of the number of new Fox Hills – Hell Creek wells and their use to the groundwater declines estimated in the aforementioned model.
- Additional studies are needed to evaluate the changes in groundwater systems due to conversion from flood to center pivot irrigation.
- Examination of exempt wells effect on surface water and other groundwater users.

Addressing these data gaps will provide a wealth of knowledge that will be of great use to scientists, water users, and anybody responsible for water policy decisions.

Sources of Information

Information on the distribution and properties of aquifers is based on review of reports published by the MBMG and the USGS, Master's Theses, reports prepared by consultants for water right applications and other documents included in the references. Maps and reports published by MBMG under the Ground-Water Characterization Program (GWCP) summarize available information and present maps and cross-sections of aquifers, and maps and hydrographs of groundwater levels and water quality. Groundwater level and water quality data are housed in the GWIC database developed and managed by MBMG or the National Water Information System (NWIS) housed with USGS. Table A lists the main data and interpretive products pertinent to the LMRB and their availability by subbasin. Summaries by watershed and references for these products follow.

Table A. Data sources and important reference types.

	Lower Missouri
Data Compilations	✓
Geologic Maps	✓
Geologic Cross-sections	✓
Potentiometric Maps	✓
Hydrographs	✓
Water Quality Maps	✓
Resource Development	✓
Groundwater/surface water interaction reports	

The Groundwater Investigations Program (GWIP), also administered by MBMG, is a potential source of hydrogeologic information at the scale of a few square miles Current projects are ongoing in the Clear Lake aquifer in Sheridan county within the LMRB. Additional prospective GWIP projects can be proposed and are ranked for consideration by the Groundwater Assessment Steering Committee.

Water Use in the LMRB

Historic Water Use in the LMRB

The earliest non-Indian settlers in the Montana territory were fur traders, prospectors, and those wishing to escape service in the Civil War. Irrigation began almost as soon settlers arrived in the area. Early irrigation was practiced beginning in 1841 at the St. Mary's Mission in the Bitter Root Valley. Farmers in the Missoula Valley began irrigating their lands in 1864, and along the Flathead River in western Montana, irrigation systems were be constructed as early as 1885.

During the last 30 years of the 19th century, mining and smelting were the primary industries in much of Montana, with farming and ranching acting in a secondary economic role. But by the turn of the century, the silver boom had tapered off, and agriculture replaced mining as the region's primary industry. As agriculture increased in economic importance, irrigation became increasingly important to Montana.

The Milk River Valley in north-central Montana was one of the last areas in the West to be settled. During the 1880s, several small private irrigation systems had been constructed which diverted water directly from the Milk River. In the mid-1890s, several farmers joined together and constructed a small diversion dam to provide additional water to their system. Other dams soon followed, and before long, upwards of a dozen small dams where spread out along the river. While

their systems functioned sufficiently during periods of high river flows, the inconsistent nature of the supply threatened the stability of the area. Unless a way could be found to ensure a stable and reliable water supply, the future of the region would be in question. Establishment of the Reclamation Service in 1902 was the first step to providing a secure future for farmers of the Milk River Valley.

The initial plans for the Milk River Project were prepared by the Reclamation Service and submitted for approval by the Secretary of the Interior on July 8, 1902, only a few weeks following the formation of the Reclamation Service. This submission relied on information developed during ongoing work within the USGS. The initial approval authorized the allotment of funds for additional surveys and administrative costs. On March 14, 1903, the Secretary of Interior authorized construction of Reclamation's first five projects, including the Milk River Project. On March 25, 1905, $1,000,000 was allocated for construction of storage works on the St. Mary River and facilities to divert water from the St. Mary River to the head of the Milk River. This authorization was limited by the condition that prior to the start of construction, a suitable agreement between the United States and Canada would have to be negotiated that would allow the stored waters of the St. Mary River to be transported through Canadian territory without interference.

By early 1906, even though the governments of the United States and Canada had been unable to reach an agreement, the Reclamation Service was authorized to draw up specifications and advertise for bids to construct the St. Mary Canal from the St. Mary River to the Milk River. It was believed that construction of the canal would help to solidify the United States' claims to the waters of the St. Mary River and, that if no agreement could be reached, the canal could be used to irrigate some 100,000 acres in the eastern part of the Blackfeet Indian Reservation and surrounding areas.

Consumptive Water Use

Overview

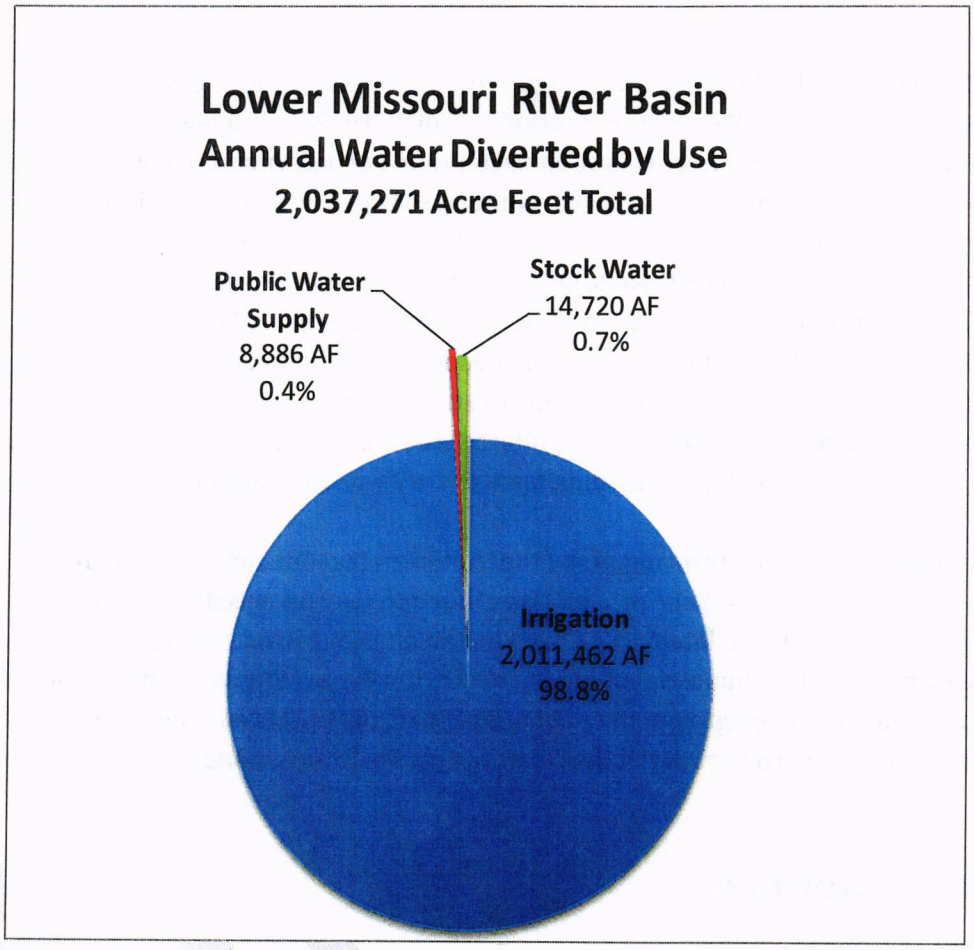
DNRC first published summaries of water use by county and HUC in 1986. Consumptive use of water in Montana has been most recently quantified by the USGS in the document Estimated Water Use in Montana (USGS, 2000. Scientific Investigations Report 2004-5223). The USGS is currently producing an updated version of estimated water use in Montana.

Consumptive use of water has been broken down by the USGS into the following categories: Irrigation, Livestock, Thermoelectric, Self-supplied industrial, Self-supplied domestic and Public Supply. Consumptive use data compiled by the USGS includes both surface water and ground water.

Surface water consumed is presented in Figure U2 for the LMRB. Approximately 96%, or 454 KAF (thousand acre-feet), of water consumed in the basin is consumed by irrigation. The other 4% or 18 KAF is consumed by public water supply, domestic water, livestock watering and industrial uses.

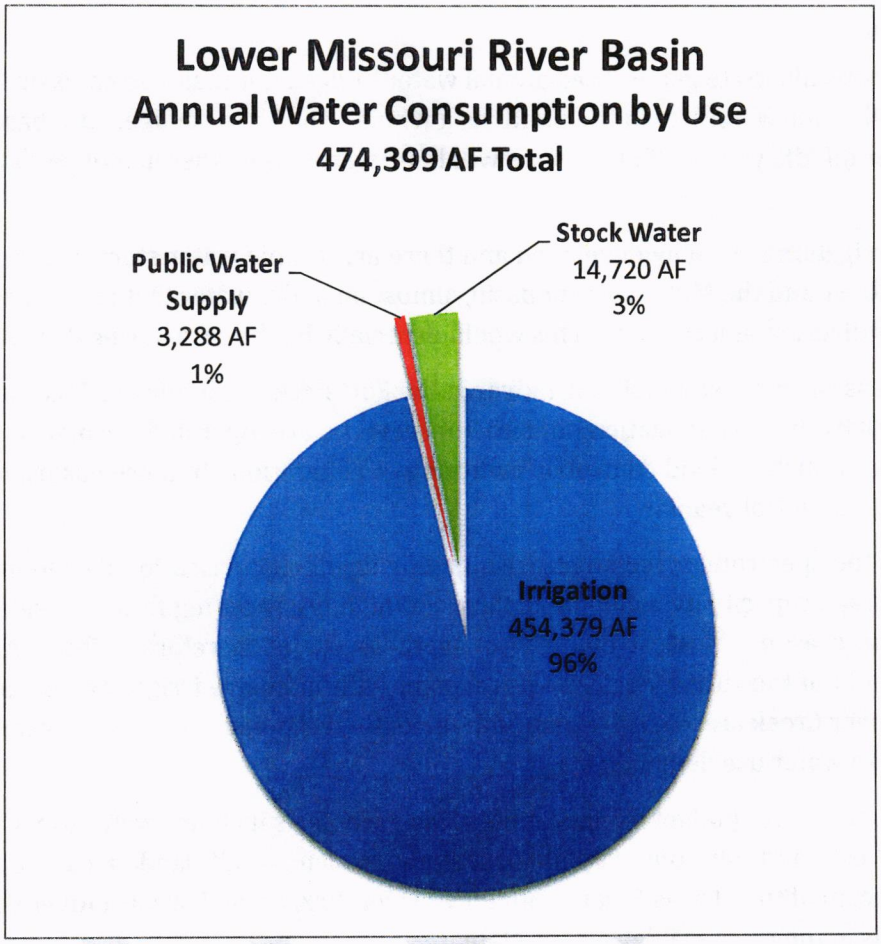
About 2.04 million acre feet is diverted annually in the LMRB for irrigation, livestock watering, industrial, municipal and domestic use (Figure U1). By far the largest consumptive use is irrigation, which accounts for almost 99% of all water diverted in the LMRB.

Figure U1. LMRB Annual Surface Water Diverted by Use.



Only a fraction of the total diverted water is actually consumed; about 474,399 acre feet, which is slightly more than 23 percent of the originally diverted volume. Irrigation accounts for 96% of the total consumption of diverted water in the LMRB (Figure U2). Stock watering is the second largest consumptive use in the LMRB, amounting to about 3% (15,000 acre feet) of water consumed annually. Water consumed by municipal and domestic supply constitutes a very small amount in the basin, less than one percent of the total diverted amount.

Figure U2. LMRB Annual Water Consumption by Use.



Most of the diverted water eventually returns to surface water sources or percolates deeper into groundwater aquifers. Some of the diverted irrigation water is consumed by plants through evapotranspiration, and some of the diverted water that is not consumed by plants is also evaporated into the atmosphere during water application.

Following irrigation, livestock watering is the second largest use of water in the LMRB, although it accounts for a relatively small amount of the total. Most livestock water is diverted to tanks or ponds where it is retained for cattle to drink. The water that isn't actually consumed evaporates to the atmosphere, is consumed by surrounding plants, or returns to surface or groundwater sources.

Most water used for municipal or domestic purposes flows back through waste-water systems and may return to the original source or another downstream surface source or aquifer after treatment. There is currently very little water consumption by industrial uses in the LMRB.

Reservoir evaporation is another consumptive component of water budgets. Although evaporation is not technically a "diverted" water use, it is still a significant factor or loss in total water budgets of the LMRB, and is one cost of storing water in reservoirs and ponds.

Basin Water Budgets

The following diagrams illustrate generalized annual water budgets for major streams or subbasins in the LMRB, as well as for water use in the LMRB as a whole. The water budgets are based on the flow for a median or middle year: half of all years would be wetter, the other half of years would be drier.

For basins where irrigation is heavily developed and there are sizable water storage projects, such as the Musselshell River and the Milk River subbasin, almost all of the water that is produced by the basin is captured or diverted at least once. This would especially be the case during dry years.

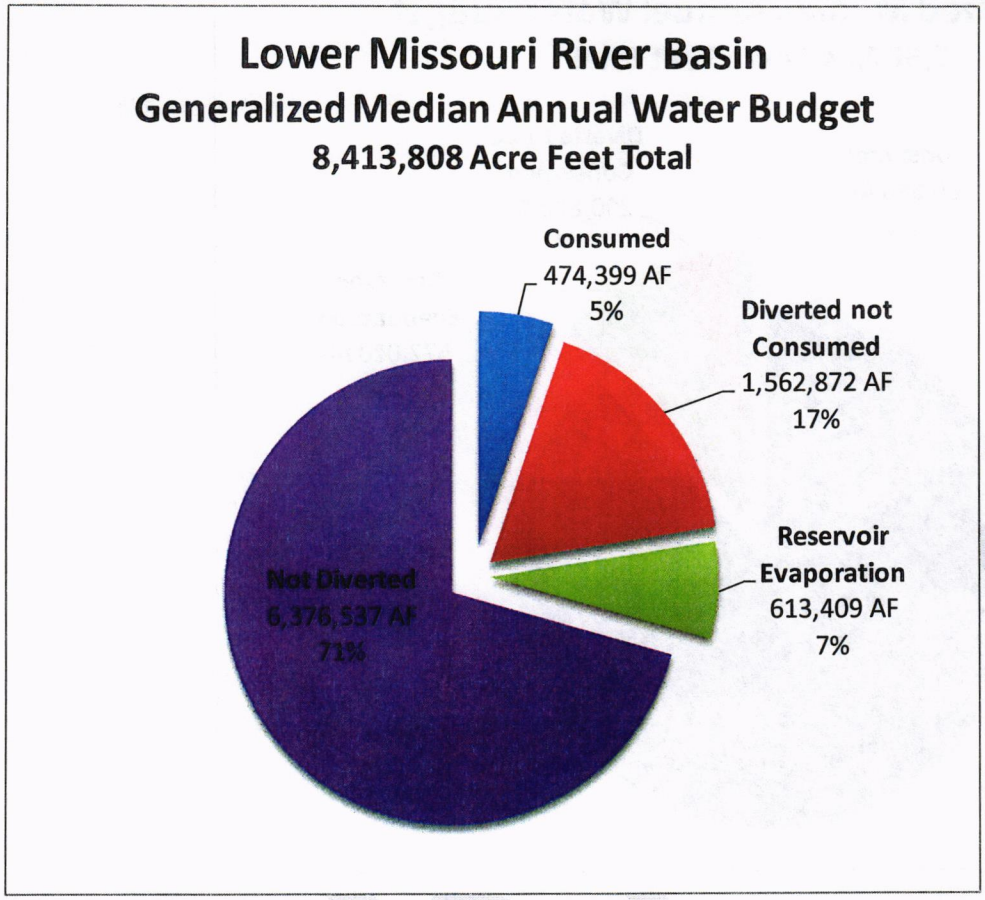
Some streams, such as the main stem Missouri River in the Fort Peck Reservoir and Missouri-Poplar subbasins, have relatively less irrigation and the reservoirs are operated primarily for non-consumptive purposes, such as flood control or hydropower generation. In these basins, most flow is not diverted during a typical year.

At the other end of the spectrum, some streams supplying significant irrigation development may have little or no storage capacity available to capture the high, early spring flows for release later during the irrigation season. Most of the flow in these basins is therefore neither stored nor diverted since the bulk of the runoff does not correspond with intensive irrigation demands. The Judith River and Beaver Creek are such streams, both watersheds having very limited water storage capabilities relative to water use demands.

Figure U3 illustrates the water budget for the LMRB as a whole. This includes water use in the Milk, Musselshell, Fort Peck and Missouri-Poplar subbasins, which is all land area contributing streamflow downstream of the Marias River confluence. Over 70% of the Missouri River flow is not diverted and remains in the river as it leaves the state.

Water actually consumed by beneficial uses within the LMRB is only about 5% of the total water budget of the basin. Only 23% of the amount diverted is actually consumed, leaving 77% of the diverted water to return to surface or groundwater sources. Reservoir evaporation is much greater than the amount of water consumed by all beneficial uses in the LMRB, totaling over 613,000 acre feet, or about 7% of the overall water budget. Fort Peck Reservoir accounts for the vast majority of the evaporative loss.

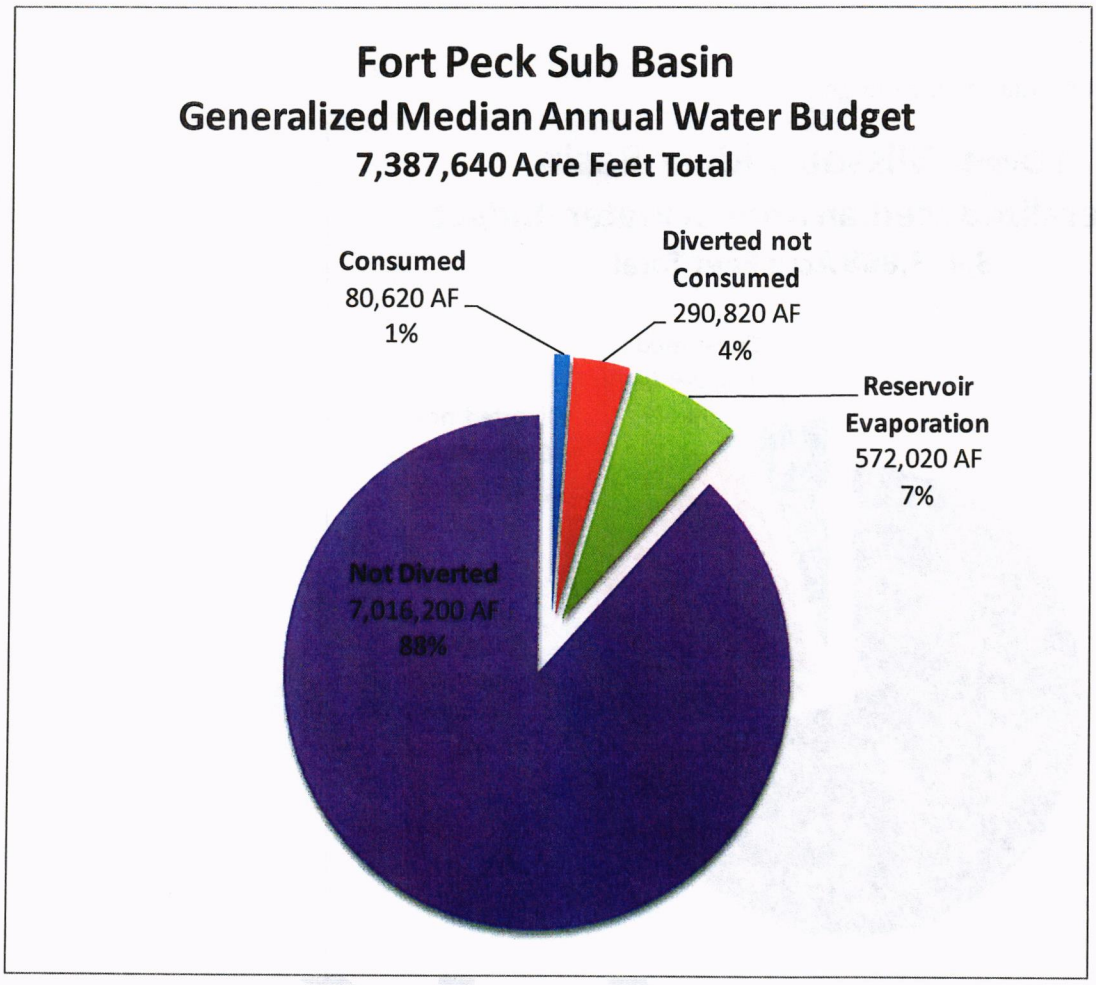
Figure U3. LMRB Annual Water Budget.



Fort Peck Reservoir Sub Basin

Very little water is actually consumed in the Fort Peck Reservoir subbasin (Figure U4). Consumed water equals only about 80,620 acre feet, or 1% of the sub basin total water budget. Of the diverted amount, only 21% is consumed by beneficial uses. 88% of the water is not diverted, remaining instream. Fort Peck Reservoir evaporation is a significant factor in the sub basin and, at 7% of the total water budget, far outweighs other consumptive uses in this subbasin.

Figure U4. Fort Peck Reservoir Subbasin Annual Water Budget.



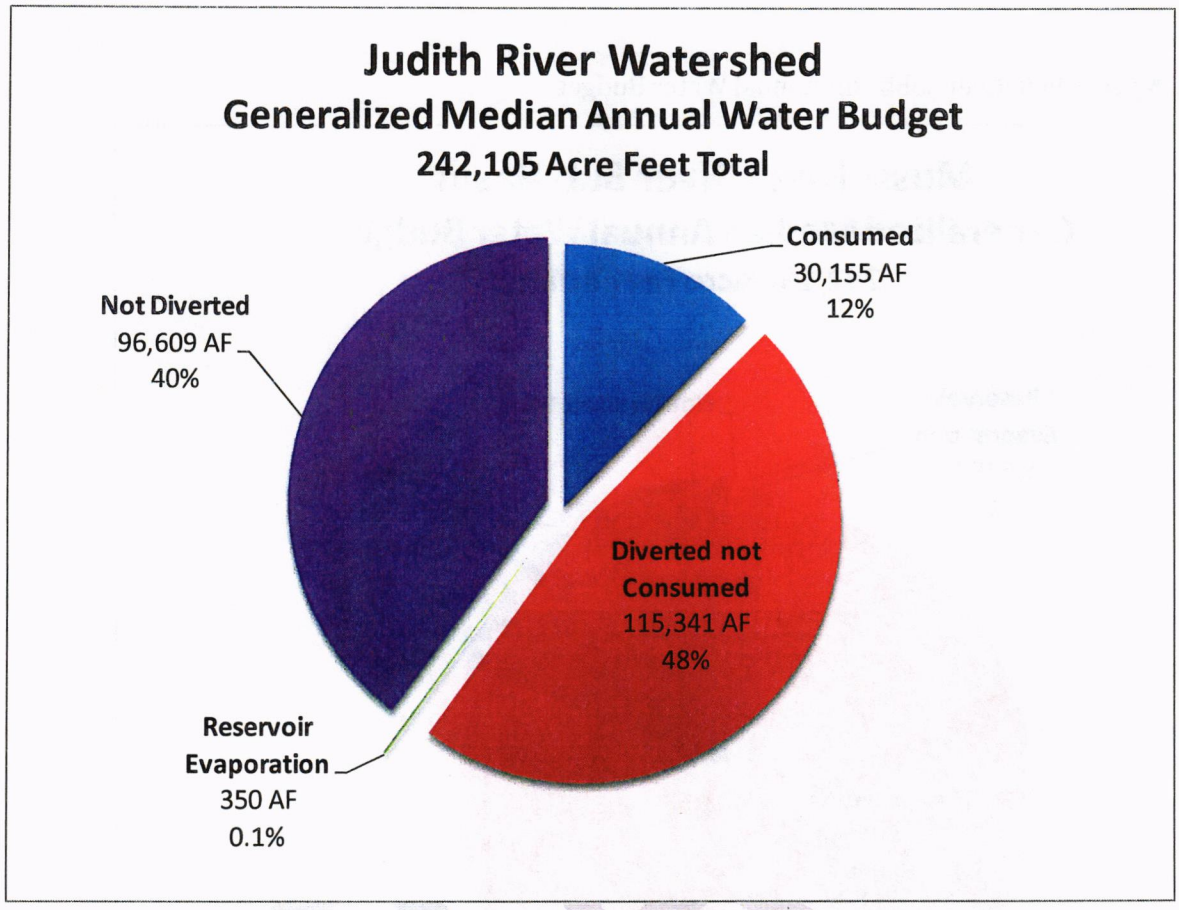
Judith River Watershed

The Judith River watershed is located at the upstream end of the Fort Peck Reservoir subbasin and drains much of the north slope of the Little Belt Mountains, the Moccasin and Judith Mountains and the north slopes of the Big Snowy Mountains including Big Spring Creek, which runs through Lewistown. The Judith River is one of the few major tributaries to the Missouri River mainstem in the LMRB.

The Judith River water budget (Figure U4) shows that 40% of the water remains instream during the median water supply year. Reservoir storage is very limited in the Judith watershed, and high springtime flows are therefore not retained by dams. Since the high spring flows generally occur before the time of heavy irrigation demand, little of the total water supply is diverted.

Reservoir evaporation amounts to a very small portion of the total Judith River water budget. In this 2,758 square mile watershed, water consumed is slightly more than 12% of the total water diverted for consumption.

Figure U4. Judith River Annual Water Budget.



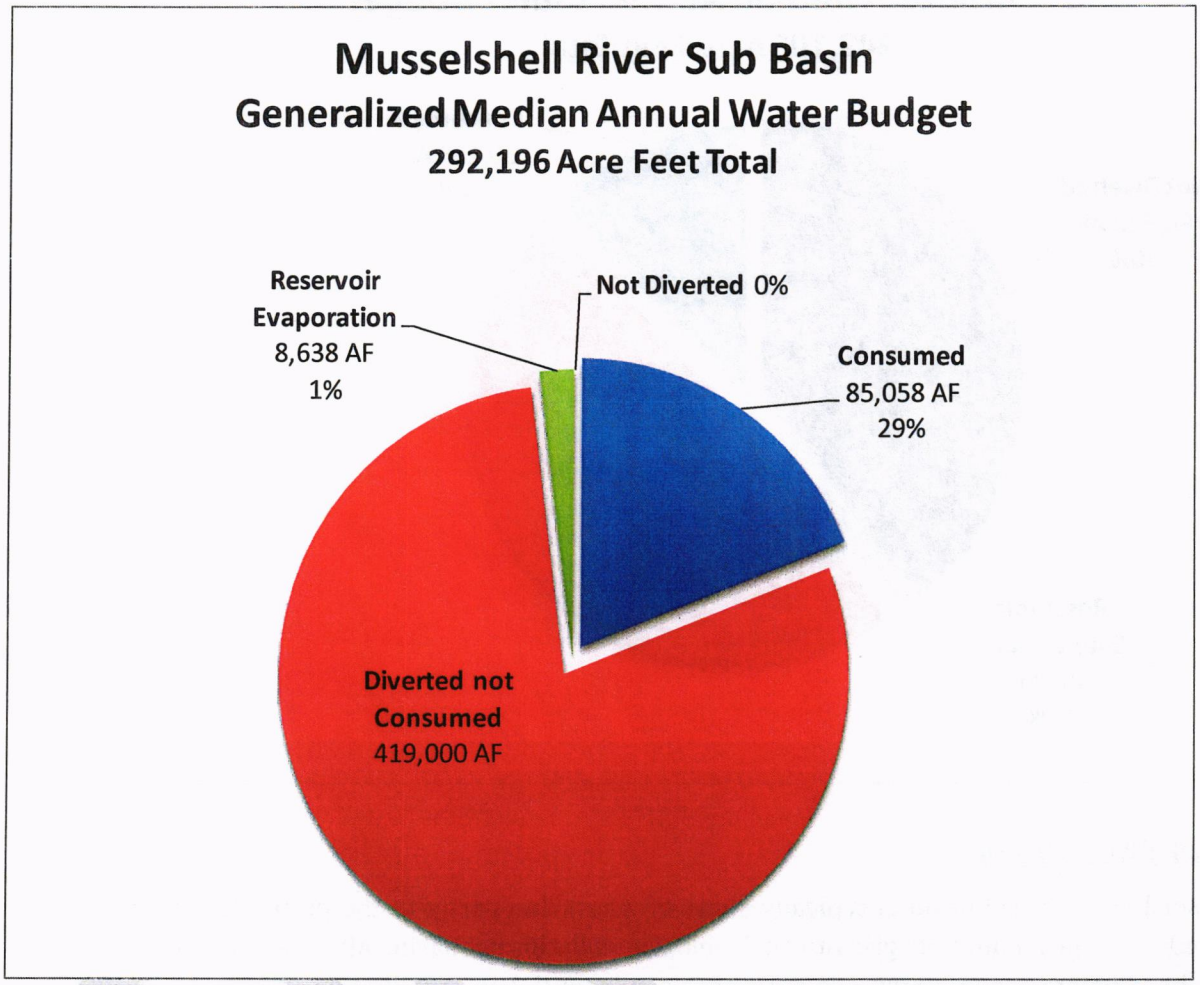
Musselshell River Subbasin

The Musselshell River subbasin is typically short of water due partly to the prairie nature of the system and the large amount of agricultural development in this subbasin. Although portions of the subbasin headwaters are mountainous and receive substantial snowpack, this is mainly a prairie environment. It is estimated that there is a shortage of 110,000 AF during the median water supply year (USBR, DNRC, 1998).

Figure U5 shows more water "diverted and not consumed" than exists in the entire Musselshell River water supply. A substantial amount of the Musselshell subbasin water is diverted more than once during the median (or less than median) water year. Water is diverted for irrigation, a small portion is actually consumed, and the rest is returned to the stream. Farther downstream the water is again diverted for further use, and the pattern repeats. This may happen several times in subbasins such as the Musselshell River and Milk River.

Reservoir evaporation is a relatively small part of the overall Musselshell River water budget, although there is substantial storage in the subbasin.

Figure U5. Musselshell River subbasin Annual Water Budget.



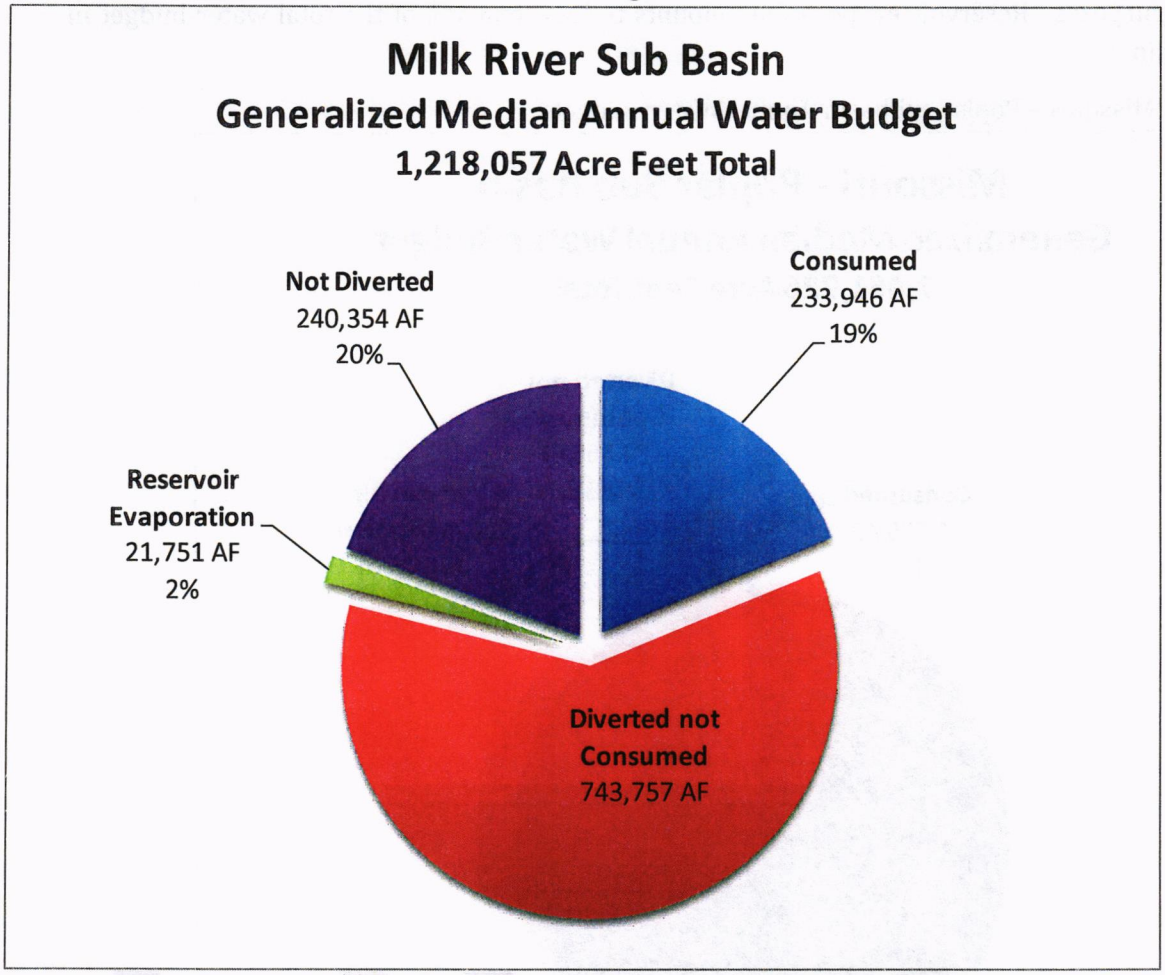
Milk River Subbasin

The Milk River subbasin is also short of water during the median water year. Except for the extreme upper parts of the subbasin and some isolated island mountain ranges, this is entirely a prairie environment which naturally lacks a dependable snowpack for water supply. Figure U6 shows that about 19% of diverted water is consumed. As in the Musselshell River subbasin, water in the Milk River subbasin is diverted more than once during most years.

A substantial portion of water in the Milk River subbasin is imported from the St. Mary River watershed, through a trans-basin diversion canal. This water amounts to approximately 178,000 acre feet annually and is extremely important to the overall system. It has been estimated that the Milk River would dry up completely in 6 years out of 10 without this imported water (USBR, DNRC, 2012). Even so, there is an estimated shortage of 70,000 acre feet annually in the Milk River subbasin (Milk River Internation Alliance, USBR, 1999).

Reservoir evaporative loss amounts to almost 22,000 AF per year, but constitutes a relatively small percentage of the total water budget. The majority of the evaporation occurs at Fresno and Nelson reservoirs.

Figure U6. Milk River subbasin Annual Water Budget.



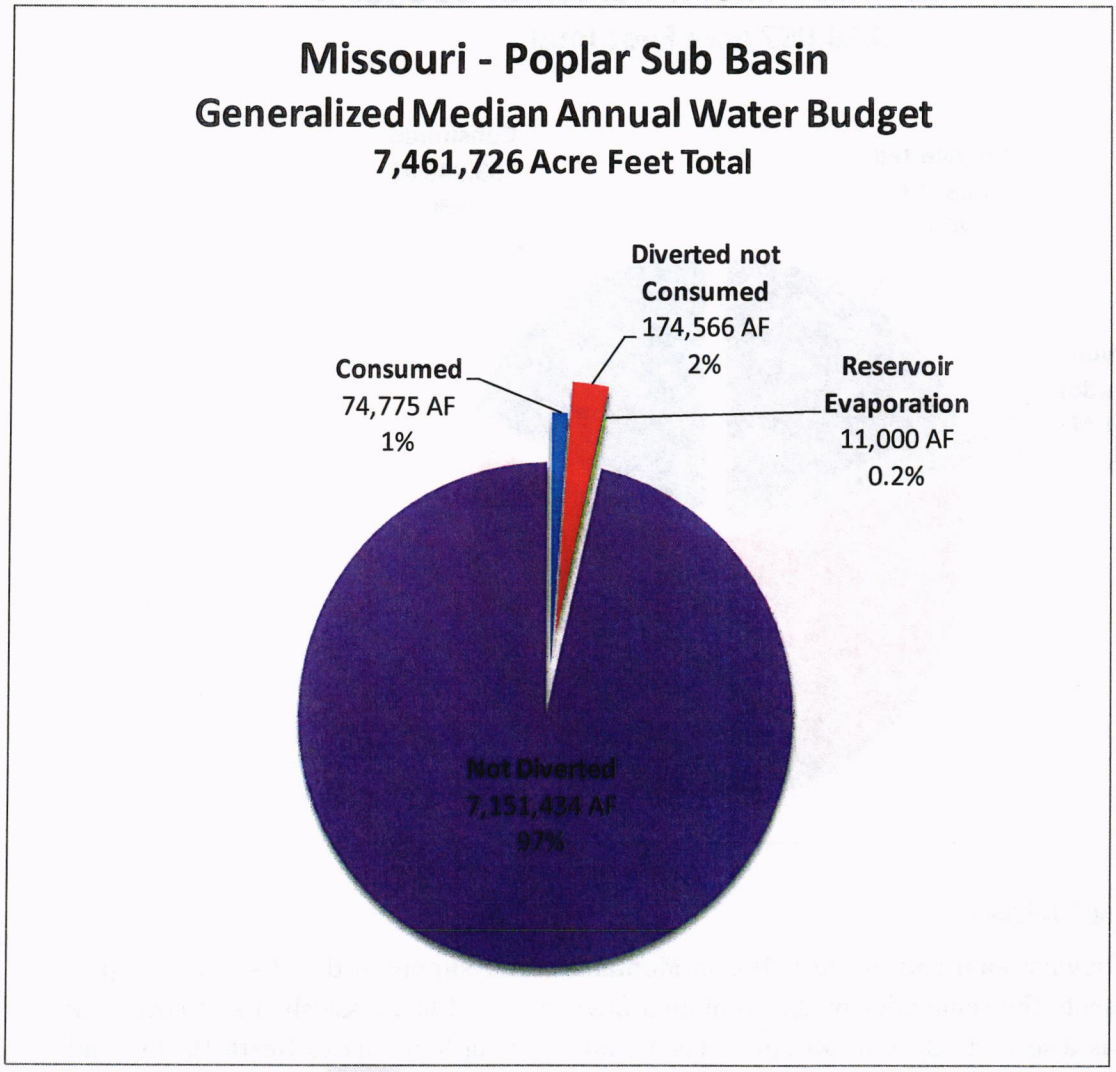
Missouri – Poplar Subbasin

Located at the downstream end of the LMRB in Montana, water supply in the Missouri – Poplar subbasin represents the remainder of the combined flows of the Milk, Musselshell and Fort Peck subbasins, and is also a measure of Missouri Basin water leaving Montana to North Dakota and other downstream states. There are a few locally important tributaries in the subbasin, such as the Poplar River and Big Muddy Creek, which contribute additional flow to the main stem Missouri River.

The vast majority of Missouri River flow remains instream through this subbasin. Water that is not diverted accounts for 93% of the annual water budget, which is nearly 7.5 million AF during the median water supply year. Slightly more than 3% of the total water supply is diverted and of the water that is diverted, about 28% is actually consumed.

Storage facilities are very limited in the subbasin, consisting of small stock or irrigation ponds. There are a number of naturally-occurring shallow lakes, typical of the prairie pothole environment. Medicine Lake, Homestead Lake and Clear Lake are all examples of this type of water body. The lakes provide important habitat for waterfowl and wildlife, but are not used for irrigation purposes. Reservoir evaporation amounts to less than 1% of the total water budget in this subbasin.

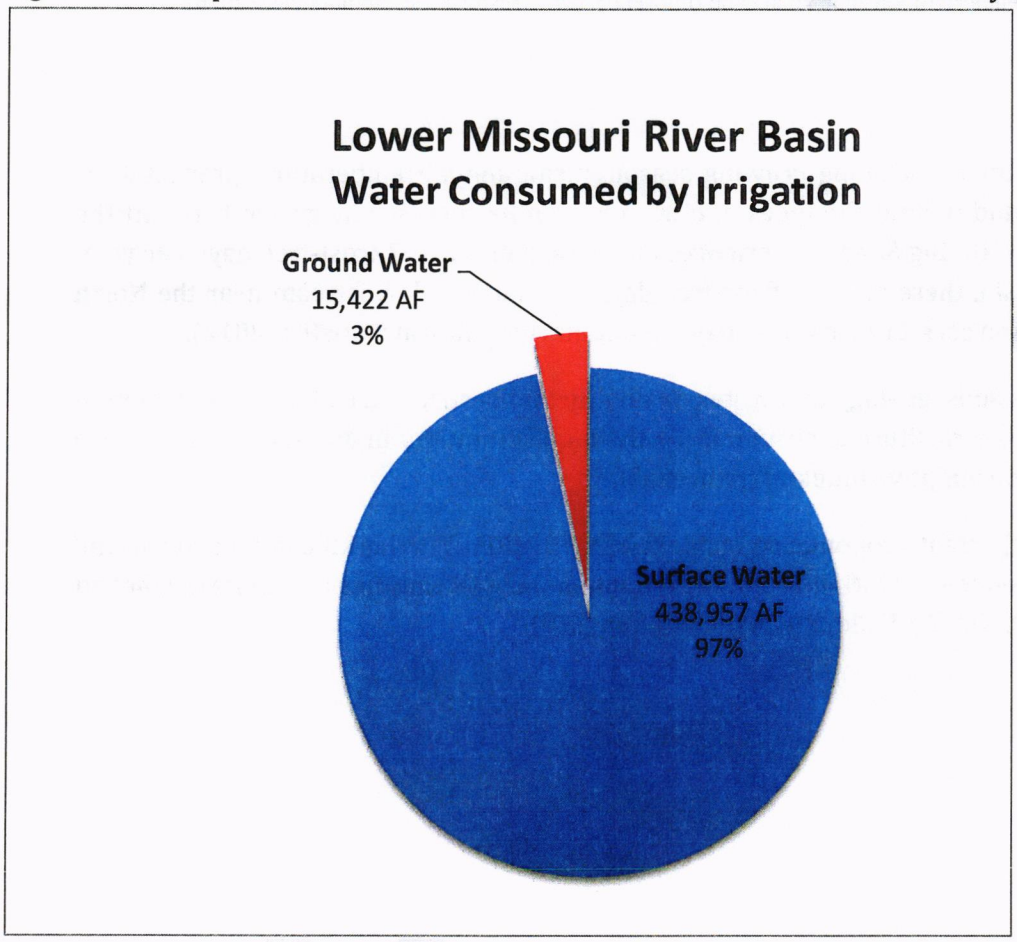
Figure U7. Missouri – Poplar subbasin Annual Water Budget.



Irrigation

The majority of crop land in the LMRB is non-irrigated, and the vast majority of the irrigated parcels in the receive water supply from surface sources (Figure IR1). Ground water supplies only about three percent of the water used for irrigation within the basin. But groundwater can be important locally, especially with the lack of major perennial streams or major storage projects in the LMRB.

Figure IR1. Comparison of Surface and Ground Water Consumed in the LMRB by Irrigation.



Irrigated acreage is listed by subbasin in Table IR1, and for the LMRB as a whole. Also shown is the volume of water diverted, the volume of water consumed, and the percent of diverted water that is consumed. For the LMRB as a whole, 23% of water diverted for beneficial use is actually consumed. The Milk and Lower Missouri-Poplar subbasins exhibit the highest percent of consumption, while the Musselshell and Fort Peck Reservoir subbasins exhibit the lowest.

Table IR1. LMRB Irrigation Water Use by subbasin (DNRC, 2013)

Subbasin	Acres Irrigated	Volume Diverted (acre-feet)	Volume Consumed (acre-feet)	Volume Consumed (percent)

Musselshell River	84,968	433,792	80,688	19%
Milk River	267,812	970,159	228,585	24%
Fort Peck Reservoir*	62,057	363,952	74,562	20%
Judith River watershed	24,468	177,582	36,448	21%
Missouri - Poplar	74,745	243,559	70,544	29%
LMRB Total	**489,582**	**2,011,462**	**454,379**	**23%**

*Figures include the Judith River watershed.

(Data sources include Water Conservation and Salvage Report for Montana (SCS, 1978), DNRC Water Resources Surveys, Montana Department of Revenue 2010 Revenue Final Land Unit (FLU), DNRC Historic Use Methodology (2010).

Irrigated Crops

Climatic factors of Montana, including growing season, mean annual temperature, precipitation, frost-free days, and humidity limit the types of crops that can be successfully grown here. At the upper reaches of the LMRB, Big Sandy experiences an average of only 97 frost-free days per year. At Malta, about mid-basin, there are 122 frost-free days, and farther downstream near the North Dakota border, Culbertson sees 117 frost-free days (Montana Agricultural Statistics, 2012).

Physical factors such as soils, geology and water quality further restrict agricultural production in parts of the LMRB. Still, agriculture is economically the largest industry in Montana, and it is also by far the most water-consumptive industry in the state.

Agriculture is a very important economic component of the LMRB. The LMRB contains five of the top ten agricultural revenue-generating counties in Montana. Those counties are Choteau (ranked number 2), Richland (3), Hill (6), Valley (9), and Sheridan (10).

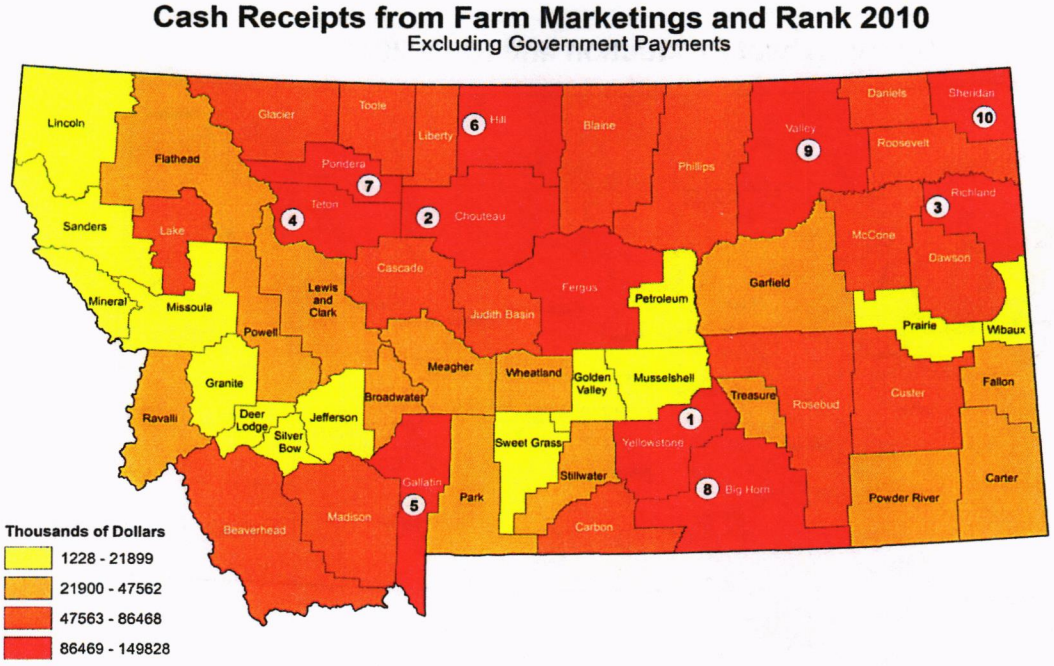


Figure Ag1: Top Ten Revenue Generating Counties in Montana (Montana Ag Stats, 2012).

Wheat accounts for almost 39% of all agricultural cash receipts in Montana, and Montana ranks 3rd nationally in terms of wheat production by state (Montana Agricultural Statistics, 2012). Livestock and Livestock products account for another 40% of the total, and the remaining 21% comes from other assorted crops, led by Hay (7.6%), Barley (4%) and sugar beets (2%).
Winter Wheat, Spring Wheat and Durum Wheat are all grown extensively in the LMRB, and Montana overall produces just under nine percent of all wheat in the U.S. (Montana Agricultural Statistics, 2012). Several of the top ten wheat producing counties of Montana are located within the LMRB, as shown in Figure Ag2.

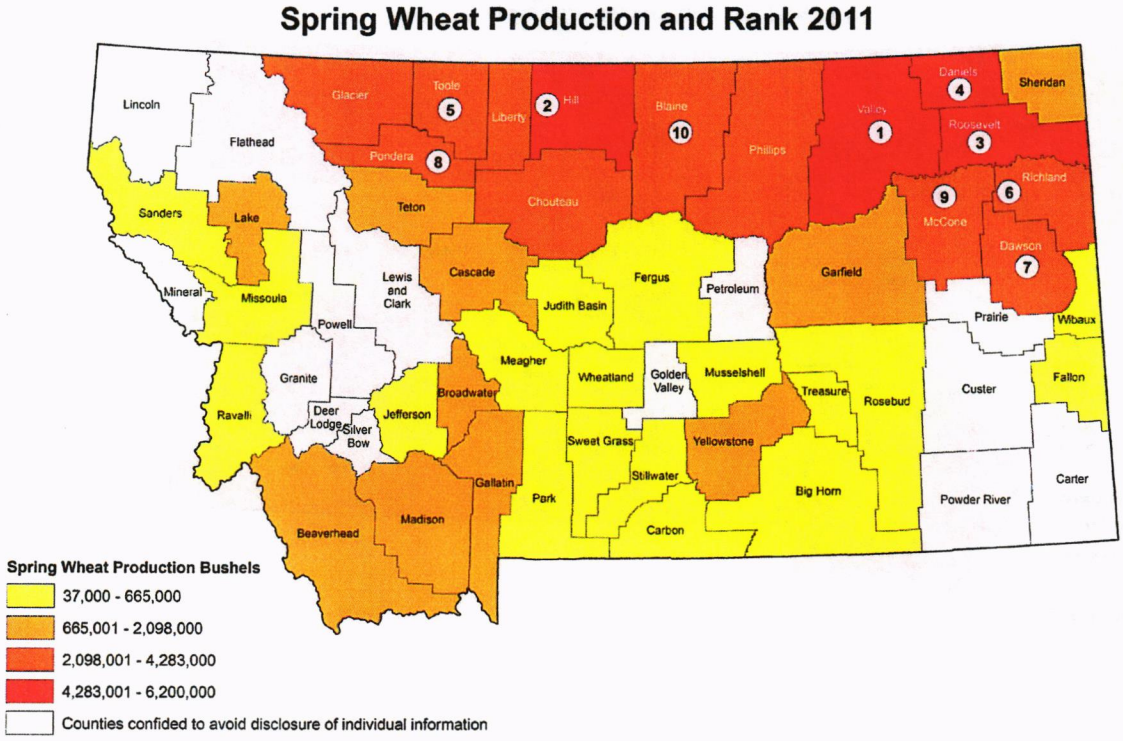


Figure Ag2. Leading Spring Wheat producing counties of Montana.

The vast majority of Spring Wheat grown in the LMRB in on non-irrigated lands. For example, in 2011 in the North Central agricultural region (includes Glacier, Pondera, Toole, Teton, Liberty, Hill, Blaine, Choteau, Philips and Valley counties) Spring Wheat was planted on 912,000 acres of non-irrigated land (95% of total), and on only 51,000 acres of irrigated crop land (5% of total).

Livestock

The number of livestock (Cows, Sheep, Hogs) was derived from NASS data for 2010. Water withdrawn for stock was estimated using the assumptions applied in the USGS 2000 Water Use report (USGS, 2004), and all water withdrawn for livestock was assumed to be consumed.

Beef Cattle: 15 gallons per day (gpd)/head
Dairy Cattle: 23 gpd/head
Hogs and Pigs: 5 gpd/head
Sheep: 2 gpd/head

Assignment of source was based on county percentages of groundwater and surface water originally assigned in the 1986 DNRC water use document. These percentages originated from water rights permits issued at the time of that report.

Livestock consume about 14,720 acre feet of water annually in the LMRB. About three-quarters of the water consumed are supplied by surface water, and the remainder is supplied by ground water sources (Figure LS1). Livestock use by subbasin is summarized in Table LS1.

Figure LS1. Comparison of Surface and Ground Water sources for Livestock in the LMRB.

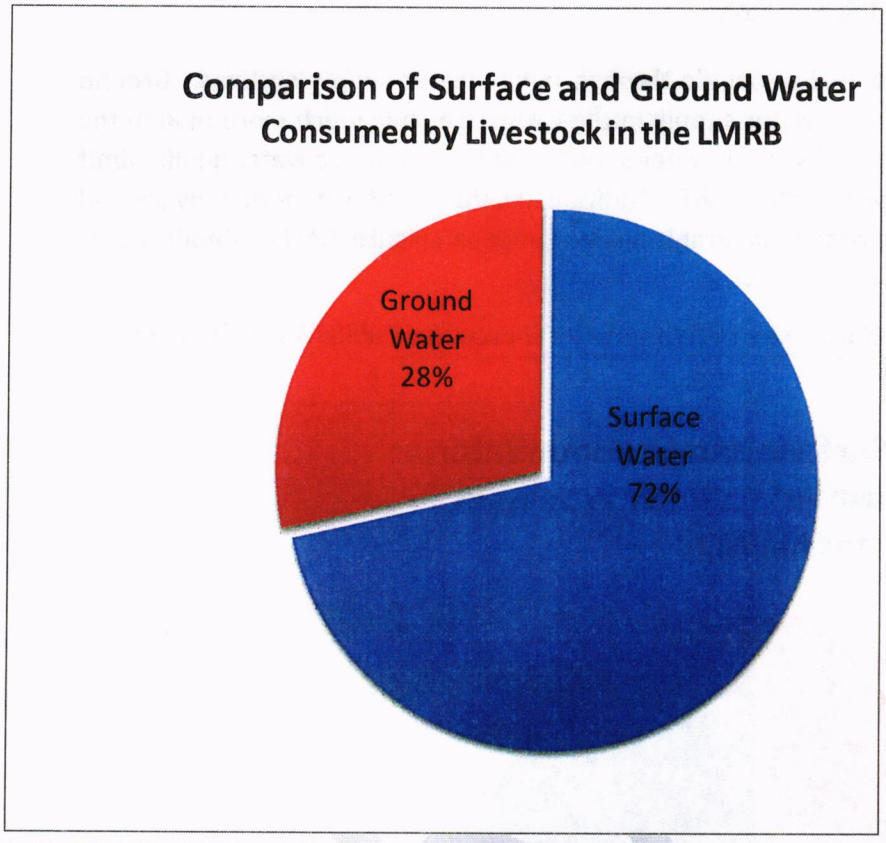


Table LS1. LMRB Stock Water consumed by subbasin.

Subbasin	Volume Consumed (acre-feet)
Milk River	3,761
Fort Peck Reservoir*	4,667
Musselshell River	3,480
Missouri - Poplar	2,811
Judith River	1,430
LMRB Total	**16,149**

*Includes Judith River watershed figures.
Data sources: USGS 2004, NASS 2010 data.

Public and Domestic Water Supplies

Public water supplies (PWS) were identified by combining data from two sources: 1) the Montana Public Water System Sources database (MT- DEQ, accessed through the Montana GIS portal – data published 9/19/2012); and 2) the EPA Safe Drinking Water Information System (SDWIS). The

resulting dataset identifies the number of users, source, county, and HUC for each PWS. Water withdrawn by each PWS was estimated using values of per capita day use reported by county in the USGS (2004) document applied to the number of resident users. An additional 10 gallons per day was applied to cover non-resident users of the PWS. Consumptive use by PWS was assumed to be 37% of withdrawals (DNRC, 1975; USGS, 1986).

LMRB water is delivered to about 49,268 people through public water supply systems. Ground water provides over 63% of the public water supply in the LMRB, which is much more than in the other Montana planning basins. Lack of surface water supplies and poor surface water quality limit surface water use for domestic supply in the LMRB. Additionally, the LMRB is underlain by several high-quality aquifer units which produce favorable water supplies (Figure DM1). Public water supply use is listed by subbasin in Table DM2.

Figure DM1. Comparison of LMRB Surface and Ground Water sources for Public Water Supplies

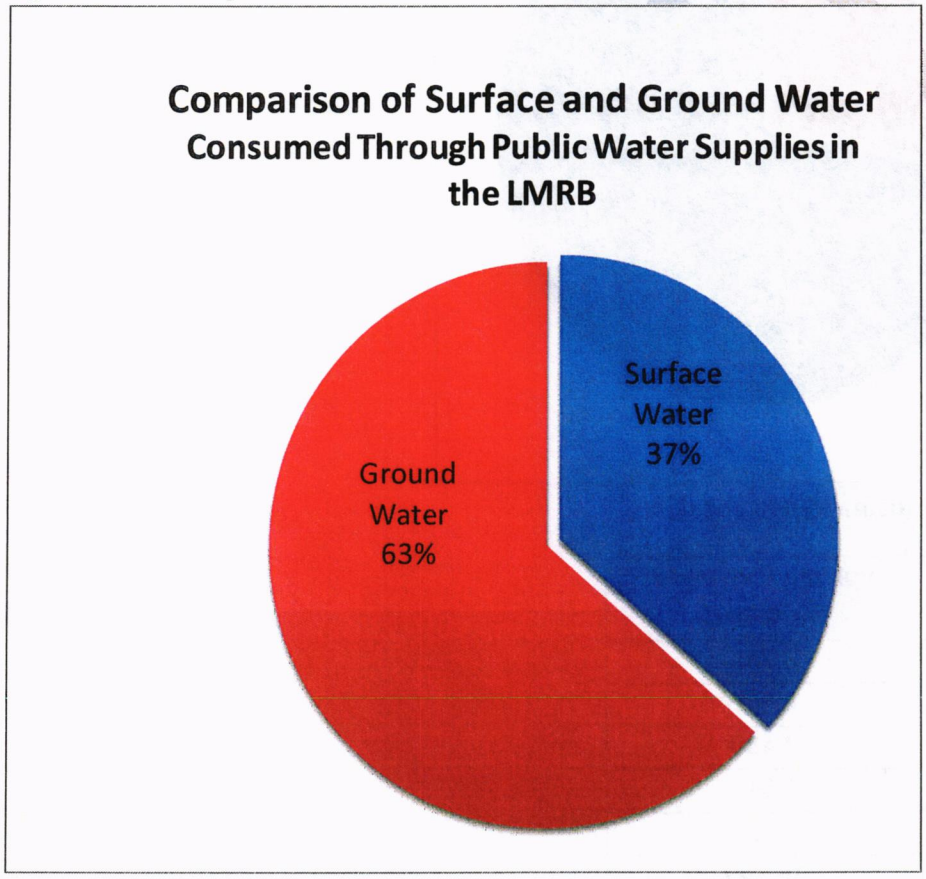


Table DM2. Water Consumed through Public Water Supplies in the LMRB.

Subbasin	Population Served	Volume Diverted (acre-feet)	Volume Consumed (acre-feet)
Milk River	22,806	3,359	1,243
Fort Peck Reservoir	8,784	2,133	789
Musselshell River	4,327	993	367
Missouri - Poplar	13,351	2,402	889
LMRB Total	**49,268**	**8,887**	**3,288**

Self Supplied Domestic Water

The number of self-supplied domestic users was calculated by subtracting PWS resident users from 2010 population estimates (U.S. Census Bureau). The amount of water withdrawn by domestic users was assumed to be 78 gpd per person (DNRC, 1986; DNRC, 1975). Per the 1986 document, this estimate of water use was originally derived from statistics of municipal systems serving less than 55 users. All self supplied domestic water use was assumed to be from groundwater and 50% of the water withdrawn is assumed to be consumed.

Assignment of domestic users to HUCs was performed by assuming uniform distribution of residential users - consistent with the 2010 USGS documentation.

Self-supplied domestic water systems serve the needs of over 30,000 people in the LMRB and these uses are summarized by subbasin in Table DM2.

Table DM2. LMRB water diverted through self-supplied domestic water systems, by subbasin.

Subbasin	Users Served	Volume Diverted (acre-feet)
Milk River	9,518	834
Fort Peck Reservoir	6,281	550
Musselshell River	5,235	459
Missouri - Poplar	9,252	811
LMRB Total	**30,286**	**2,654**

Industrial

Direct estimates of uses considered "industrial" were not possible in 2010. Instead, past USGS estimates (1985 through 2000 - where both HUC and county estimates were provided, and 2005 - which provided only usage by county) were analyzed to determine HUC assignment of those counties where the majority of industrial water use occurred. Then for those counties with the largest share (representing 90% of statewide industrial use), the 2005 USGS estimates were used as the best estimate for 2010 water use. All other industrial use estimates remain as reported in the 2000 water use document.

Other than for oil and gas exploration and production, there is very little industrial water use in the LMRB study area, and all water supplied for industrial uses in the LMRB is derived from ground water sources. All industrial water use in the Fort Peck Reservoir subbasin takes place within the Judith River watershed. Industrial water use in the upper Missouri River basin is summarized by subbasin in Table IN1, and does not include uses for oil and gas exploration and production, which are treated separately.

Table IN1. LMRB Industrial Water Use summary.

Subbasin	Volume Diverted (acre-feet)	Volume Consumed (acre-feet)
Milk River	79	12
Fort Peck Reservoir	101	15
Musselshell River	0	0
Missouri - Poplar	45	7
LMRB Total	**225**	**34**

Oil and Gas Development

Oil and gas exploration have been present in Montana for decades. Most recently, advancements in hydraulic fracture and horizontal drilling technology have allowed for increased, widespread exploration and development in the LMRB. The exploration and production of oil wells requires the use of fresh water, and subsequently produces water that must be disposed of or recycled. Concerns therefore center on both the volume of water needed and the quality of the water resulting from the operations. Both concerns may be serious factors that affect local water supplies in the LMRB.

In Montana, attention for the past 10 years has centered on the Bakken shale oil fields in the northeast part of the state. However, according to the Montana Board of Oil and Gas Conservation (BOAC) 2012 Annual Review, drilling permits and total well completions have steadily decreased from a peak in 2006, even as total oil production has continued to increase (http://bogc.dnrc.mt.gov/PDF/AnnualReview/AR_2012.pdf). According to the Montana Petroleum Association, there were only 3 oil drilling rigs operating in the state as of early 2014 (http://www.montanapetroleum.org/assets/PDF/statistics/RMOJ-Rig-Counts.pdf). Figure OG1 shows the 2006 peak in oil well completions in Richland, Roosevelt and Sheridan counties. Note the smaller peak in completions during 2012. Roosevelt and Sheridan counties are entirely within the LMRB, however Richland County spans part of both the LMRB and the Lower Yellowstone River Basin.

The BLM estimates that hydraulically fracturing (fracking) a Bakken formation oil well to the production stage typically requires 420,000 to 630,000 gallons of water, about 1.3 to 1.9 AF of water (BLM cite). An oil well in the Bakken shale typically requires a total of 2.2 million gallons of fresh water, or about 6.75 AF, though its productive life of 20 to 40 years (Ceres).

During 2012 in the entire Bakken region, including both Montana and North Dakota, 5.5 billion gallons of fresh water were used for oil exploration and production purposes (Ceres). That

amounts to about 16,900 AF of water. One estimate of maximum oil well population suggests that water demand will continue to grow for oil field activities for another 10 to 20 years, to approximately double the 2012 water amount (Ceres). However, the majority of that development is expected to occur in North Dakota.

Oil activity just over the border in North Dakota is much more intense than in Montana, as the shale is much more extensive in that area. However, the activity in North Dakota can affect local water supply in Montana in several ways. Due to the North Dakota permitting process, it is very difficult at this time to acquire the water necessary to meet oil field activities. As a result, several water depots have been developed in Montana in order to supply water to North Dakota oil activities. Domestic and municipal water supplies are also need to meet the needs of an increasing worker population in the region.

Other locations in the LMRB may experience oil exploration and production booms in the future. Central Montana, including parts of the Musselshell Basin and the Judith watershed, have seen recent oil exploration interest. However, at this time, production from these areas is not considered economically feasible.

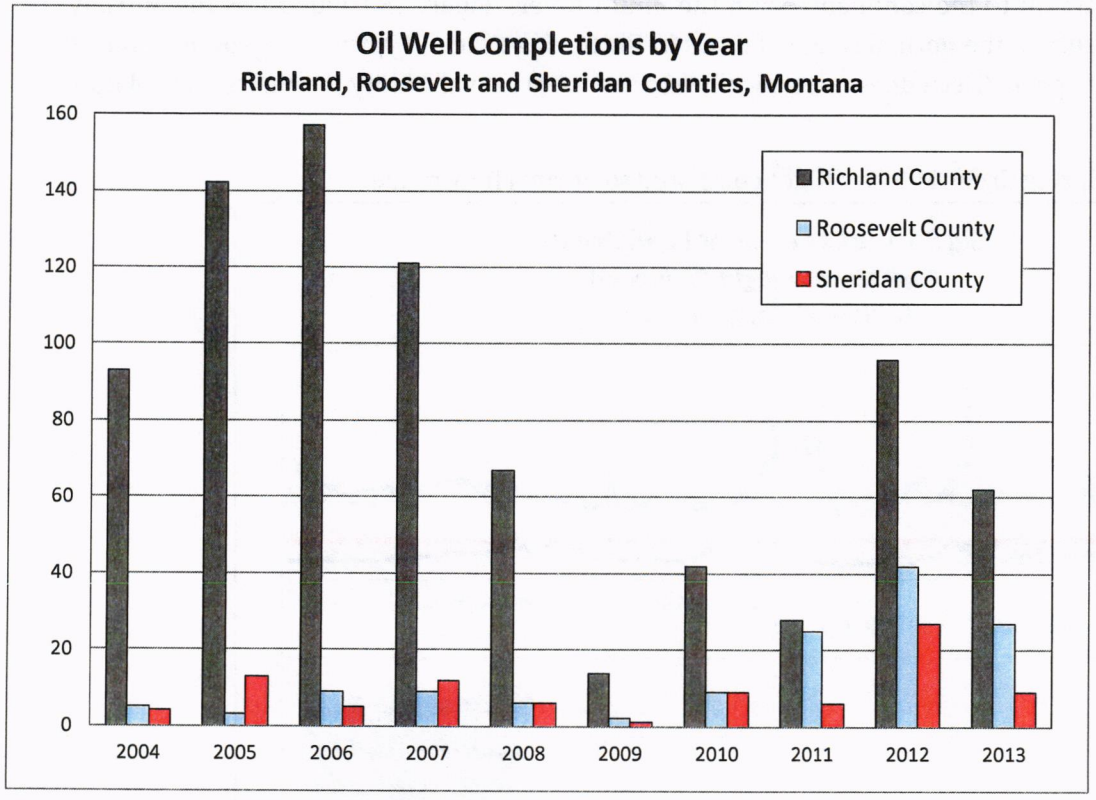


Figure OG1. Number of Oil Well completions by year in Richland, Roosevelt and Sheridan Counties, Montana.

Non-Consumptive Water Use

Recreational and Environmental Uses

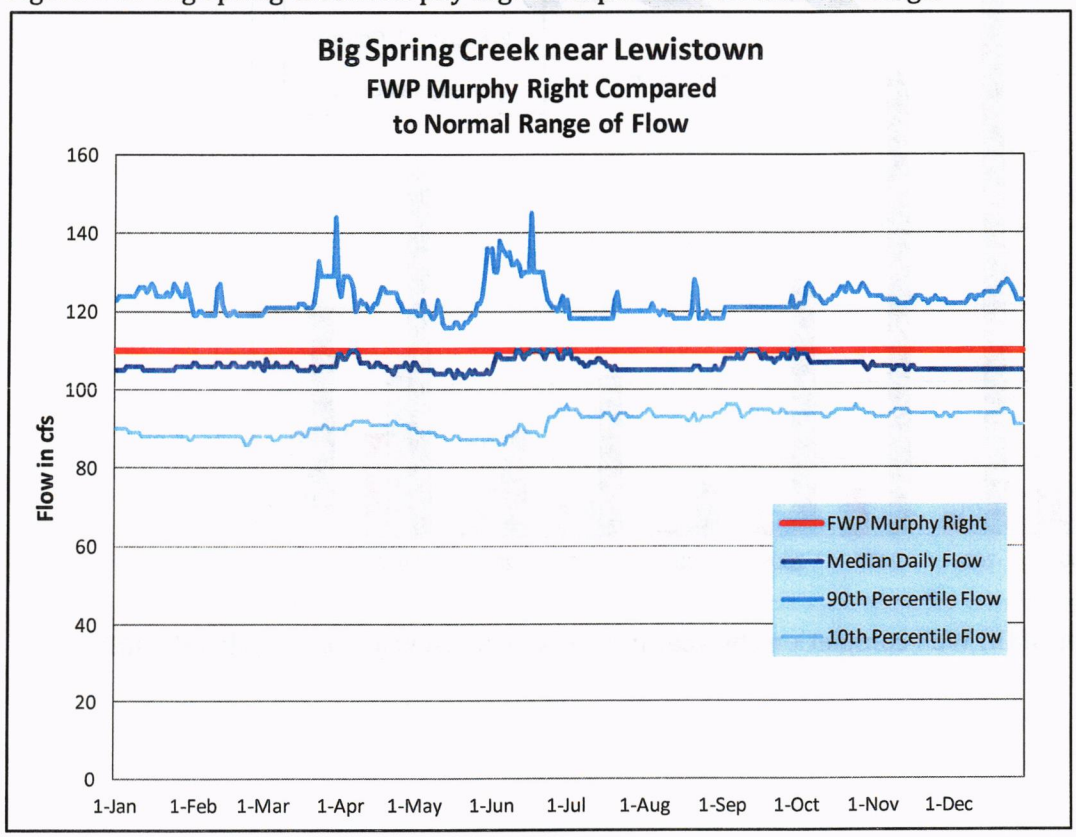
Montana Department of Fish, Wildlife and Parks

Murphy Rights

In 1969, the Montana Legislature authorized the Montana Department of Fish, Wildlife and Parks (FWP) to file for instream rights to protect flows on blue ribbon trout streams for fish and wildlife habitat. FWP filed on only one stream in the LMRB, Big Spring Creek near Lewistown. These "Murphy Rights", named after their legislative author, have December, 1970 priority dates and are therefore subordinate to the many senior, earlier water rights.

Big Spring Creek has a year-round Murphy Right of 110 cfs, enforceable from the State Fish Hatchery downstream to the confluence with the Judith River. Figure IN1 illustrates the Murphy Right in relationship to the normal range of flows in Big Spring Creek. Typical of a groundwater or spring origin, Big Spring Creek does not typically experience great variability within its normal flow range.

Figure IN1. Big Spring Creek Murphy Right compared to normal flow range.



Water Reservations

The Montana Water Reservations process granted instream flow rights to FWP in two separate proceedings; the UMRB Reservations (1992), and the LMRB Reservations (1994). In this case, the upper basin was defined as all drainage area located upstream of Fort Peck Dam, including the Musselshell River subbasin. The lower basin was defined as the drainage area below the dam, including the Milk River subbasin.

FWP was granted reservation water for minimum instream flows for several streams or stream reaches in the UMRB and LMRB. Both sets of water reservations have a priority date of July 1, 1985.

Most of the FWP reservations are based on flow rates required to minimally cover riffle areas of streams, therefore they may be considered a "base flow" level, providing just enough water for species survival. Figures I2 and I3 compare FWP water reservations to the normal range of flows at select locations for some of the major streams which were included in the Upper and Lower Missouri River Reservations process. A summary of all FWP reservations in the UMRB is presented in Table IN1, and a summary for LMRB FWP reservations is listed in Table IN2.

Figure I2. FWP Instream Flow Reservation compared to normal range of flows for the Missouri River below Fort Peck Dam to the Milk River confluence.

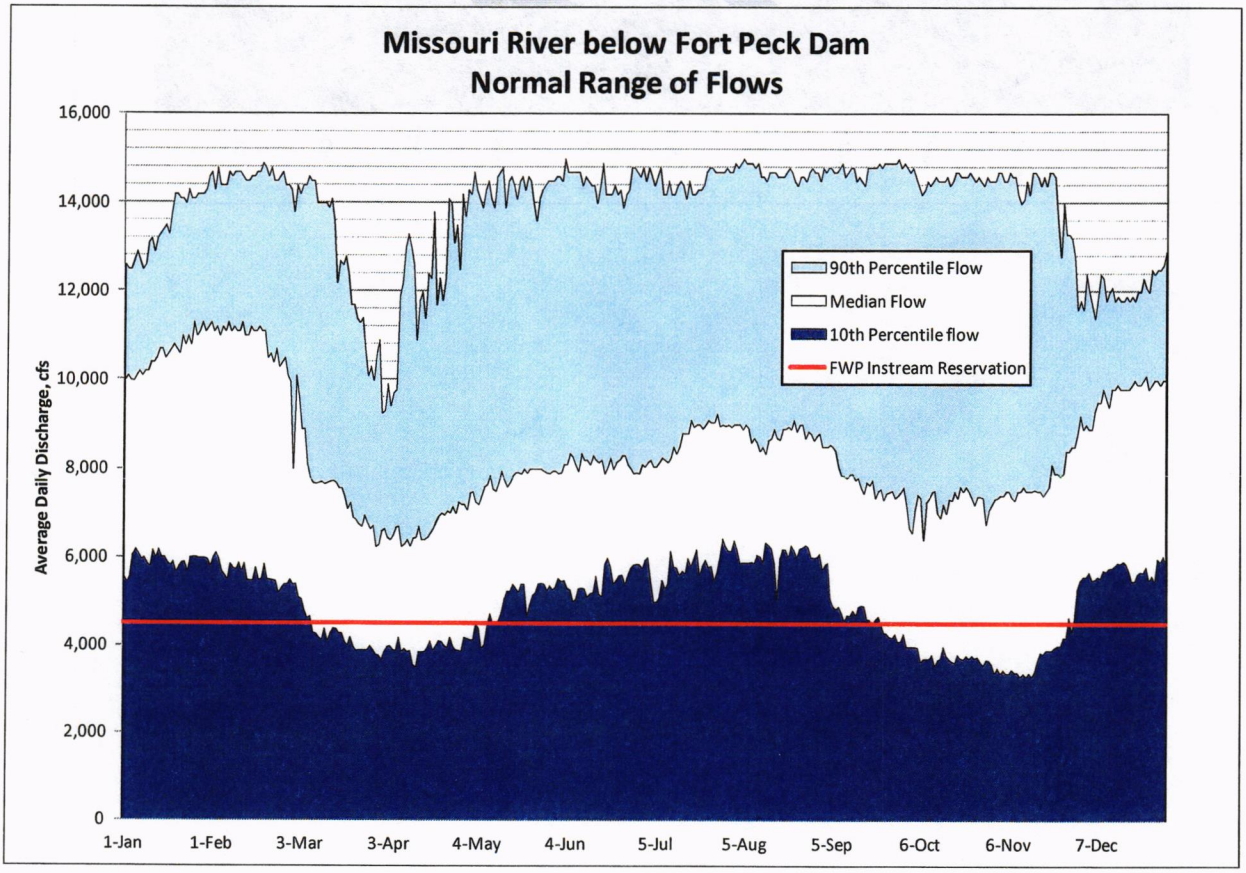
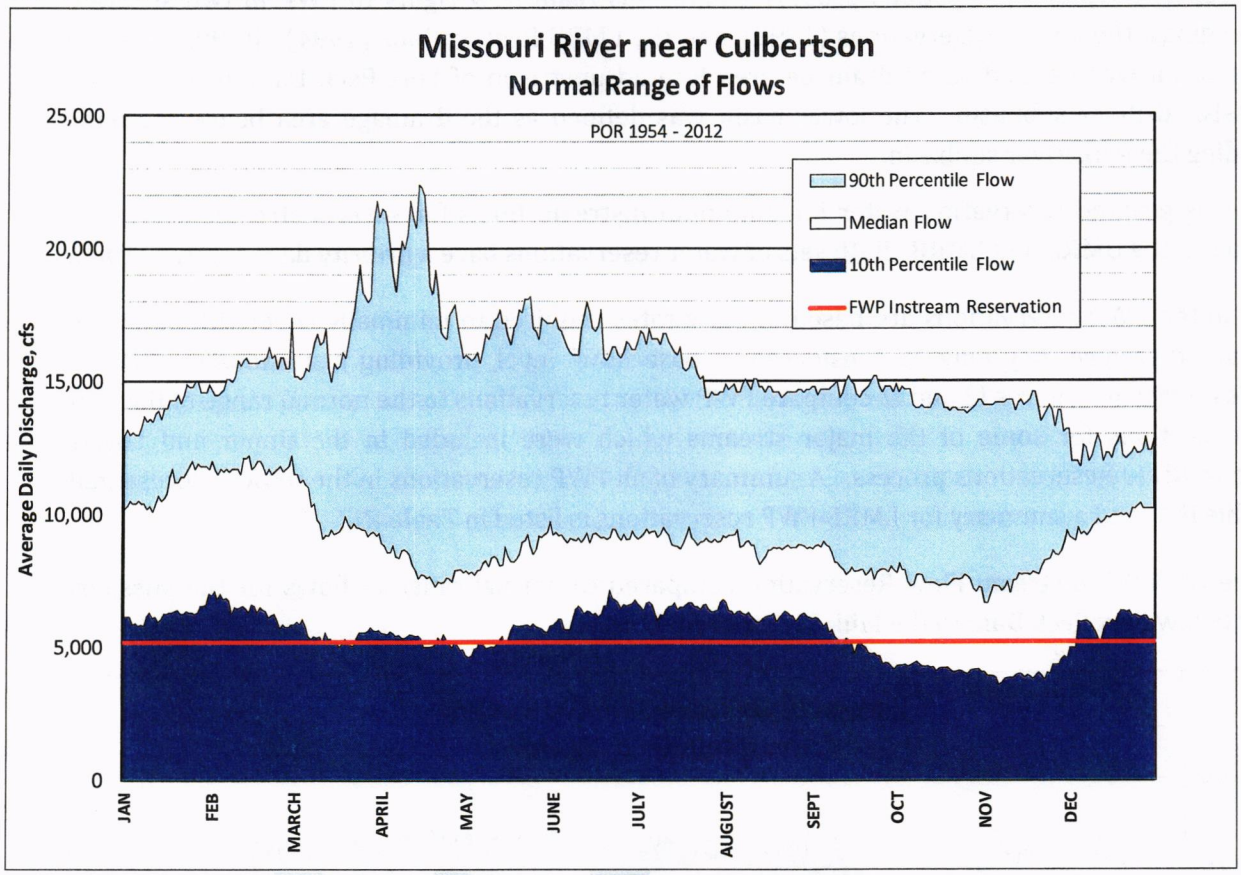


Figure I3. FWP Instream Flow Reservation compared to normal range of flow for the Missouri River below the Milk River confluence, to the state line.



Water Compacts

A water compact between the State of Montana and U.S. Bureau of Land Management (BLM) quantifies the instream flow rights for the Upper Missouri National Wild and Scenic River which is administered by the BLM. The water right is for the amount of remaining flow in the river after all water appropriations before December 31, 1987 are accounted for, and then allows for additional depletions of water by month as specified in Table 4. Additionally, small uses such as domestic and stock wells, lawn and garden watering, and instream stock uses are allowable and not subtracted from the volumes in Table IN4.

Table IN4. Available water supply (depletion) amounts by month under the Compact for the Upper Missouri National Wild and Scenic River.

Month	AF
January	104,000
February	121,000
March	124,000
April	185,000
May	219,000
June	62,000
July	82,000
August	66,000
September	40,000
October	35,000
November	57,000
December	98,000

Another BLM compact recognizes the reserved water rights for the Upper Missouri River Breaks National Monument. The compact reserves a 160 cfs instream flow right on the Judith River, and runs concurrently with the FWP instream flow right of the same specifications. Arrow Creek is also protected in this compact with an instream right of 5 cfs, measured where the creek crosses the monument boundary. These rights have a priority date of January 17, 2001, but are subordinate to state-based permits with a priority date before June 1, 2012.

U.S. Fish and Wildlife Service Compacts

A negotiated compact between the US Fish and Wildlife Service (FWS) and the Montana Reserved Water Rights Compact Commission has been finalized, settling reserved water rights for the Charles M. Russell, Black Coulee, Benton Lake, and Bowdoin national wildlife refuges. (Priority Date?)

The Charles M. Russell refuge occupies a huge portion of the Fort Peck Reservoir subbasin, basically surrounding the reservoir and including many small or intermittent tributaries. The compact recognizes an instream right of one-half or 1 cfs in 68 named streams draining into the refuge, to benefit stock, wildlife, and wildlife habitat.

Additionally, the compact reserves an instream right of 70 cfs for the Musselshell River where the river enters the refuge. The annual period of use for these instream rights is March 1 to June 30 and runs concurrently with the FWP right of the same magnitude.

Lakes and Reservoirs

Physical Characteristics

The LMRB in Montana generally lacks the snowmelt fed tributary streams that are so numerous in the UMRB. As a result, the LMRB possesses only a few major storage reservoirs over its large area. The reservoirs that do exist are vital to the variable water supply in this mainly prairie basin. In addition, there are hundreds of smaller private stock water and irrigation ponds which are of local importance.

Dams in the LMRB are typically multipurpose and provide several benefits, although they are usually constructed and operated for one or more primary purposes. Some of the dams were built to divert river flow into irrigation canals or for off-stream storage projects. Other purposes include waterfowl habitat, irrigation water storage, recreation, flood control, municipal supply, electric power generation and water quality mitigation. Table S1 below provides a summary of the larger storage facilities in the LMRB.

The combined storage capacity of these larger LMRB dams totals 18,850,740 acre feet, which includes the huge capacity of Fort Peck. Not including Fort Peck, the storage capacity is only 350,740 acre feet. That is only about six percent of the average annual Missouri River flow volume measured at Virgelle, which is the dividing point between the UMRB and LMRB.

Table S1: Summary of larger dams in the LMRB.

Dam	Stream	Approximate Total Reservoir Capacity (Acre-Feet)	Owner	Primary Purposes
Fresno	Milk River	91,000	Bureau of Reclamation	Flood control, irrigation, recreation, municipal
Beaver Creek	Beaver Creek	8,700	Bureau of Indian Affairs	Irrigation
Nelson	Milk River	79,000	Montana DNRC	Irrigation
Frenchman	Frenchman River	3,750		Irrigation
East Fork	East Fork Spring Creek	1,100	City of Lewistown	Flood control recreation
Ackley	Judith River	5,800	Montana DNRC	Irrigation, recreation
Fort Peck	Missouri River	18,500,000	US Army Corps of Engineers	Flood control, hydropower, recreation
Bair	North Fork Musselshell River	7,300	Montana DNRC	Irrigation
Martinsdale	South Fork Musselshell River	23,348	Montana DNRC	Irrigation, recreation
Deadman's Basin	Musselshell River	72,000	Montana DNRC	Irrigation, recreation
Yellow Water	Yellow Water Creek	3,842	Montana DNRC	Irrigation, wildlife
Petrolia	Flatwillow Creek	14,000	Montana DNRC	Irrigation, recreation

Management and Operations

Fort Peck Reservoir Subbasin

Fort Peck Dam is the only Missouri River main stem dam in the LMRB. The dam and the reservoir it impounds are significant features of the state. This huge reservoir stores 18.5 million AF and is 130 miles long. Storage is roughly three times the annual inflow to the reservoir as measured near Landusky. Fort Peck is operated by USACE and was constructed originally as a flood control facility during the 1930's.

Each year, USACE develops an operating plan based on forecasted snow and precipitation conditions. The operating plan must also consider the Missouri River Basin downstream of Montana because of the system of USACE dams operated through North and South Dakota, and

because of further downstream concerns. Fort Peck Reservoir is a very important recreational center for fishing, boating, hunting, and other outdoor recreation. Fort Peck Dam also generates 185 megawatts of electricity.

Figure S1 illustrates Fort Peck Reservoir month-end stored water contents for the past 25 years. The large swings in storage are evident through the severe drought periods of the late 1980's and the mid 2000's, and the high water episodes of the late 1990's and 2011. A reservoir of this capacity can take years to stabilize stored contents after extremely dry or wet periods.

Figure S1. Fort Peck Reservoir Storage Contents through time.

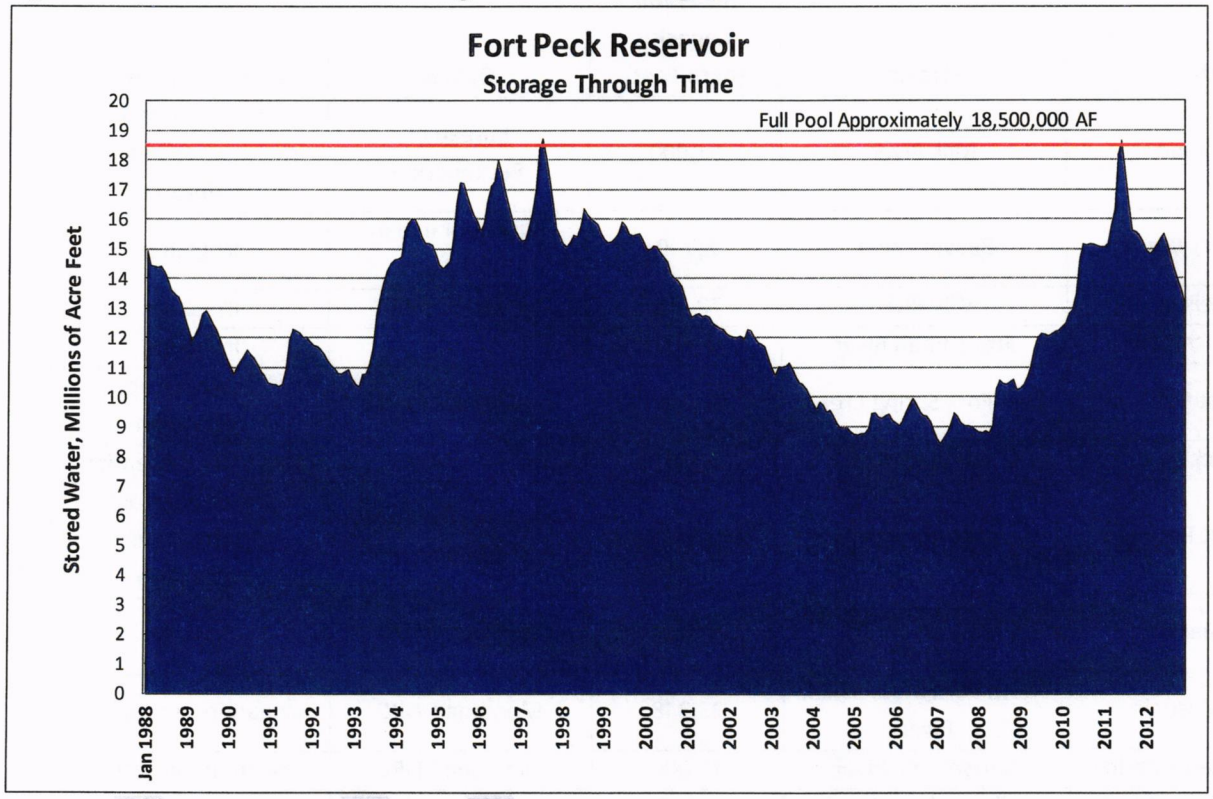
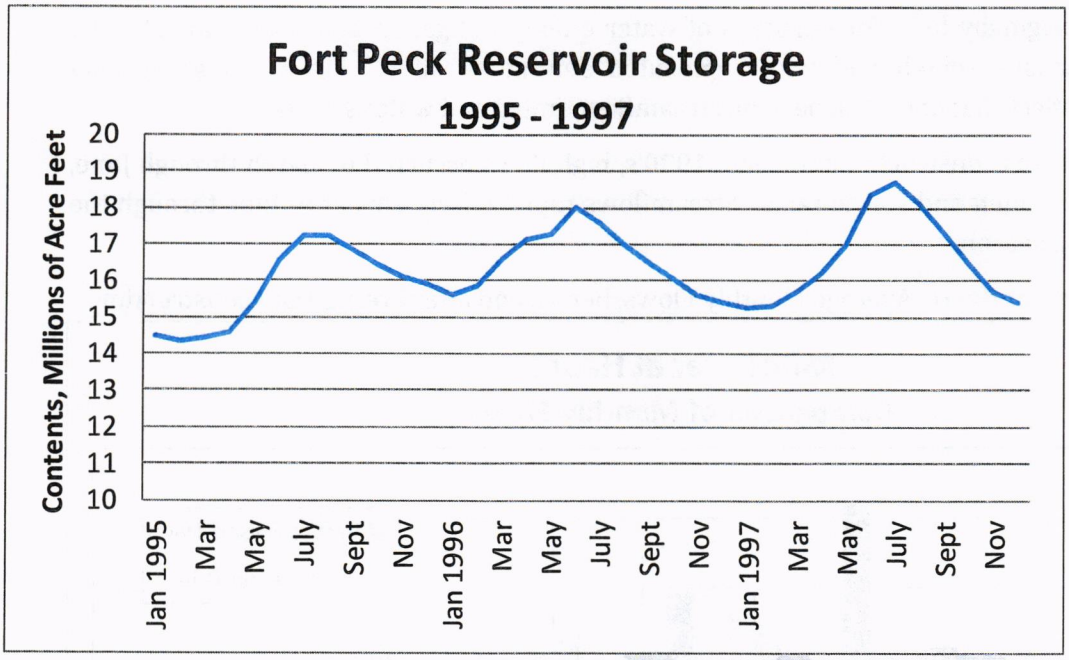


Figure S2 displays a typical Fort Peck Reservoir annual operating pattern, from 1995 through 1997. Storage typically peaks in June or July and is then gradually reduced to an annual low volume in January or February. The record snowpack for Montana occurred in 1997. Figure S3 shows that in 1997, the stored contents grew from a January low of 15.3 million AF to a July high of 18.7 million AF.

Figure S2. Fort Peck Reservoir Storage Contents, 1995 through 1997.



There are also a few small but locally important impoundments in the Fort Peck Reservoir subbasin. Ackley Lake, located in the upper Judith River watershed, is owned by DNRC and is leased for recreational use by FWP. The lake supplies water for irrigation, fish and wildlife and recreation. East Fork Dam, located a few miles south of Lewistown, MT provides some flood control capacity and recreation benefits, however this reservoir exhibits diminished storage capacity due to natural siltation.

Missouri-Poplar Subbasin

There are no artificial water impoundments of significant size in the Missouri – Poplar subbasin below Fort Peck Dam. North of Culbertson, the mainly natural Medicine Lake is a component of the National Wildlife Refuge system, and holds 67,000 acre feet of water for waterfowl and wildlife habitat. There are many small, locally important ponds and wetlands scattered throughout the subbasin, which supply stock water or other small needs.

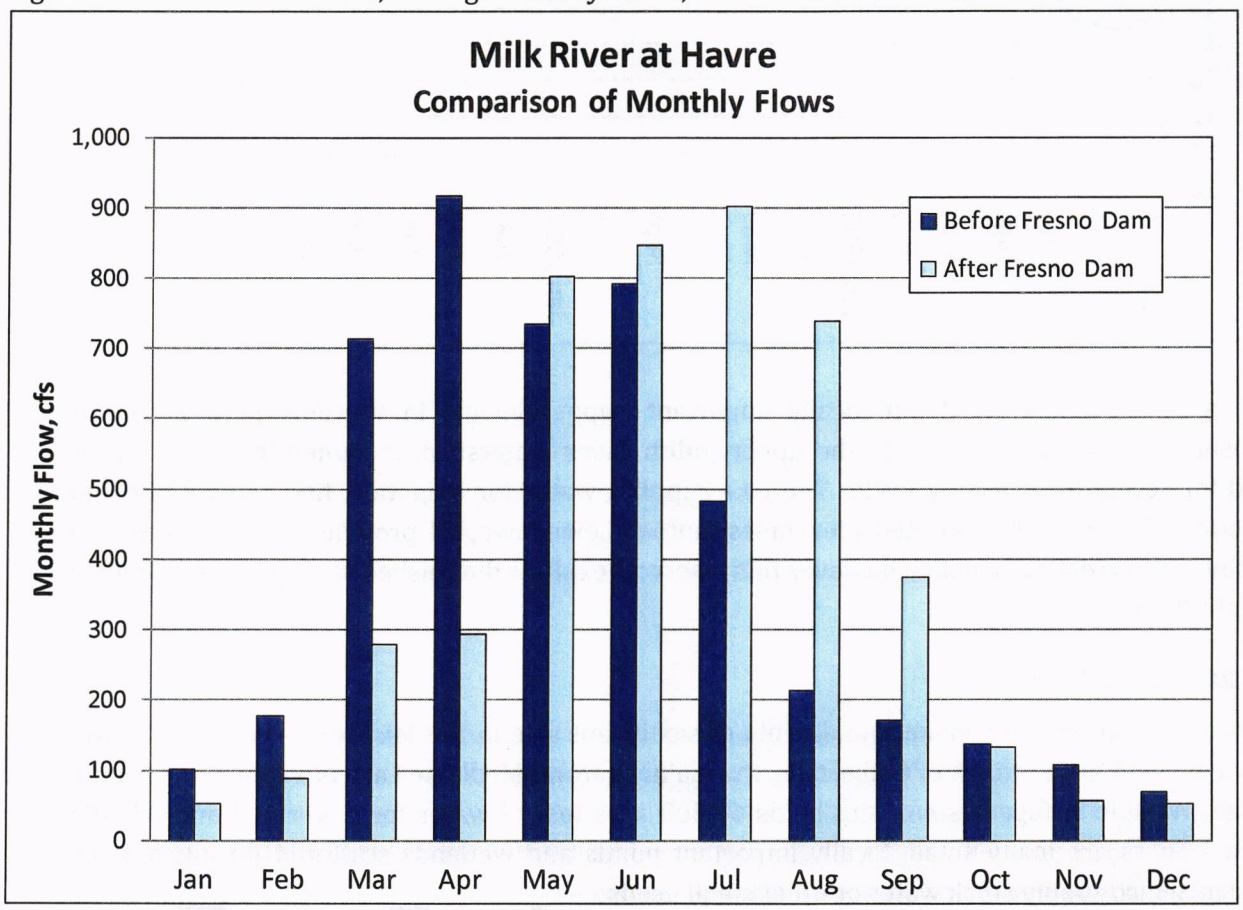
Milk River Subbasin

Fresno Dam has a recently mapped capacity of approximately 93,000 acre feet, and is the only main stem impoundment in the Milk River subbasin. Nelson Reservoir is another substantial off-stream reservoir in the subbasin, with a capacity of approximately 72,000 acre feet. Sherburne Dam is not actually located in the Milk River subbasin, but is an impoundment of Swiftcurrent Creek in the St. Mary River drainage, which flows north into Canada from Montana's Glacier National Park. Sherburne Dam has a storage capacity of 68,000 acre feet, some of which is combined with St. Mary River flow and sent via pipeline as a trans-basin diversion into the North Fork Milk River. Sherburne, Fresno, and Nelson dams are all part of the Bureau of Reclamation (USBR) Milk River Project.

Fresno Dam was originally built for purposes of water quality mitigation and flood control. The dam has been partially rebuilt and with augmented storage capacity. Figure S3 graphically demonstrates the effect that dams can have on streamflow timing and water supply.

Before Fresno Dam was constructed in the late 1930's, high flows occurred in March through June, during times of snow melt and spring rains. Streamflows rapidly decreased after June through the rest of the irrigation season.

Figure S3. Milk River at Havre, Average Monthly Flows, before and after Fresno Dam construction.

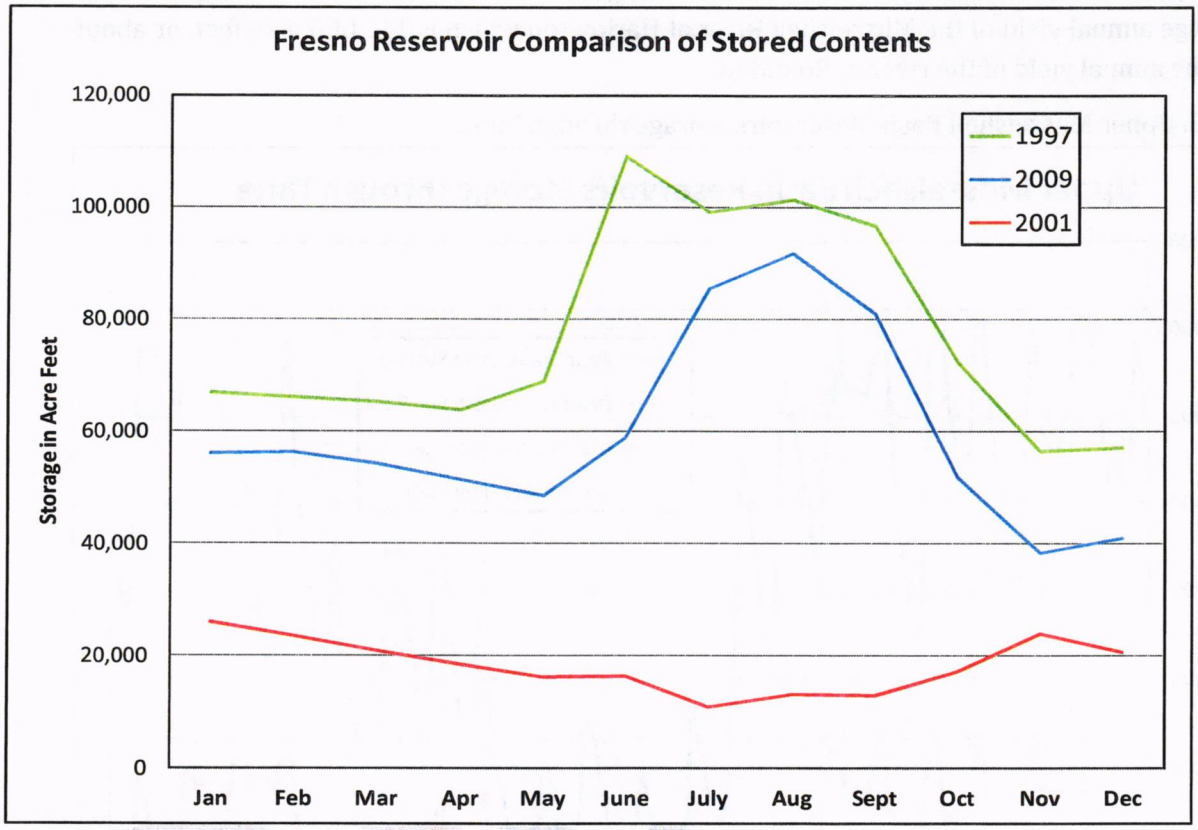


Fresno Dam allows water to be stored during naturally high flow periods before irrigation season for use later in the summer when it is most needed. The post-construction hydrograph shows highest river flows below the dam during May, June, July and August: the heart of the irrigation season. Fresno is also a good example of a multi-purpose impoundment, as the stored water provides the City of Havre with municipal supply, and is a regionally important recreational fishing and boating destination.

Figure S4 graphically compares Fresno Reservoir stored contents between a relatively normal water year (2009), an extremely dry water year (2001), and an abnormally wet water year (1997). Typical operation calls for storage of high spring inflows, May through July, with peak storage usually occurring in July. Storage content drops through the remainder of the irrigation season as releases are made to satisfy downstream demands.

A recent study by the USBR examined the loss of storage capacity in Fresno Reservoir from sediment deposition over the past 80 years (Ferrari, 2013). According to the study, which employed state-of-the-art bathymetric technology, the reservoir capacity has declined by approximately 26,000 acre feet since its original construction.

Figure S4. Comparison of Fresno Reservoir Stored Contents.



Musselshell River Subbasin

In the Musselshell River subbasin, the DNRC operates a well developed system of reservoirs, used in coordination to provide contract water throughout the subbasin. At the upper end of the subbasin, Bair Reservoir stores over 7,000 acre feet on the North Fork Musselshell River. Across the valley on the South Fork Musselshell River, Martinsdale Reservoir stores an additional 23,000 acre feet off-stream.

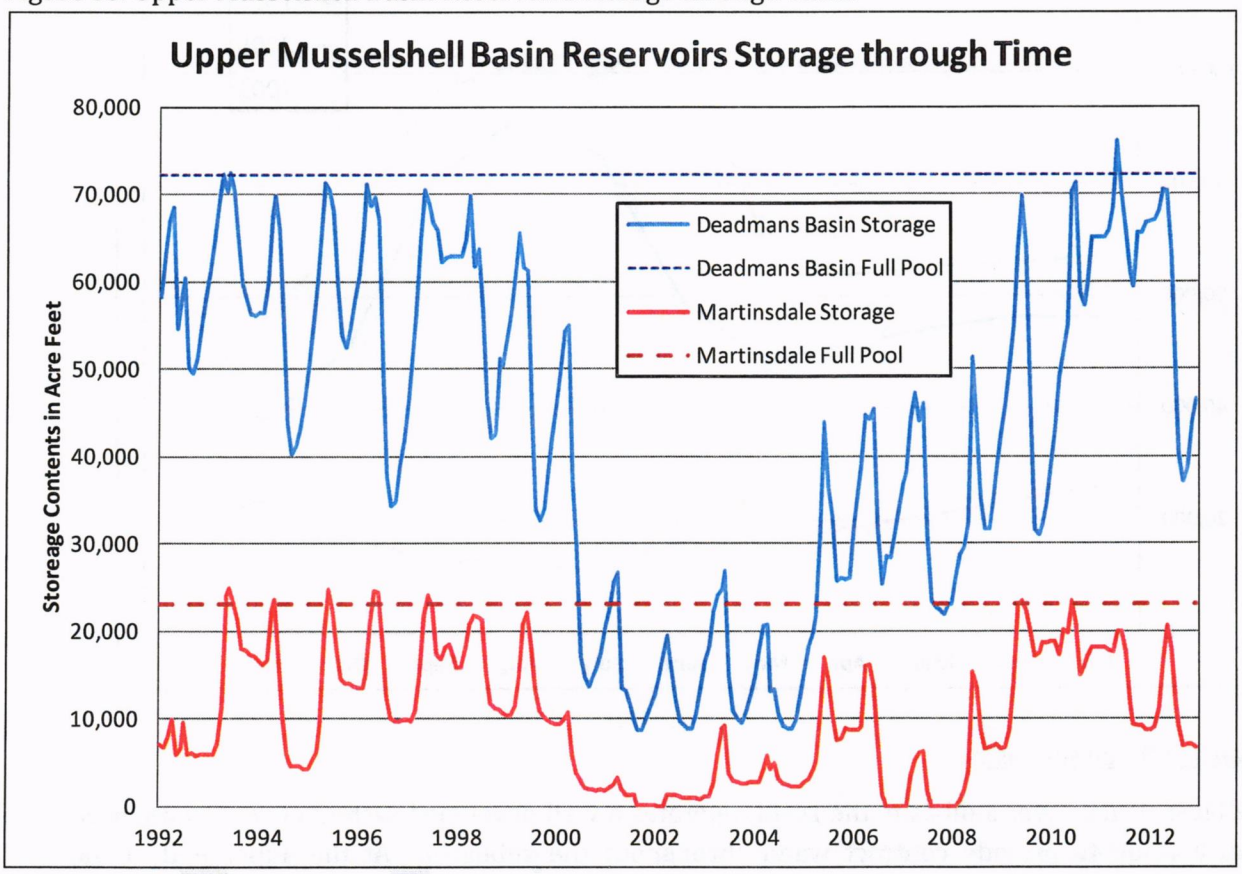
Downstream of Harlowton, Deadman's Basin Reservoir is an off-stream facility, filled directly from the main stem Musselshell River by a 600 cfs capacity supply canal (DNRC, 2008). This reservoir has a storage capacity of 72,000 acre feet and provides much needed contract water to the middle portion of the Musselshell subbasin.

These three reservoirs are operated as part of the Musselshell River Distribution Project. The project was ordered by the District Court as a means of more effectively distributing decreed and contract water within the water short Musselshell River subbasin. The effort requires that water users have properly installed water measuring devices so that the water can be properly

apportioned. Several Water Commissioners and Water User Associations are involved in this effort, which is generally regarded as an overall success.

Figure S5 shows the stored contents of Martinsdale and Deadmans Basin reservoirs over the past 20 years. Together the reservoirs have a capacity of about 95,000 acre feet. Bair Reservoir adds another 7,000 acre feet to the system, for a total of 102,000 acre feet. This is almost equivalent to the average annual yield of the Musselshell River at Harlowton which is 111,000 acre feet, or about 70% of the annual yield of the river at Roundup.

Figure S5. Upper Musselshell Basin Reservoirs Storage through Time.



The two reservoirs generally follow the same annual pattern, storing water during winter and spring for release during the summer. The peak of stored contents is typically in May, declining through June and July and often out of water before August begins.

The drought of the early 2000's was severe in the Musselshell subbasin, as evidenced by the large trough of depleted storage in both reservoirs. Martinsdale Reservoir storage also dropped to zero in 2007 and 2008 when DNRC completed a rehabilitation project of Martinsdale dam (DNRC State Water Projects Bureau, 2009).

Located much further downstream in the Musselshell subbasin, Petrolia Reservoir is privately owned and has a capacity of 14,000 acre feet of storage on the South Fork of Flatwillow Creek. This is an extremely important resource to the lower subbasin, and enters the main stem just upstream from Mosby.

Yellow Water Reservoir is owned by DNRC and managed by the Yellow Water Water Users Association. This small reservoir has a storage capacity of 3,800 acre feet and is located on Yellow Water Creek, which is an upstream tributary to Petrolia Reservoir.

Wild Horse Lake and Warhorse Lake are two large lakes in the upper reaches of Box Elder Creek near Winnett. Although these lakes formerly provided some local irrigation water, they are no longer used as storage reservoirs. These lakes are important for migratory waterfowl production and are part of the National Wildlife Refuge system.

Consumptive Use (Evaporation)

Evaporation is a considerable loss to the hydrologic system of the LMRB, and could be considered a cost of storing water for later use. As part of the permitting process, evaporation from small reservoirs and ponds is usually considered a consumptive component. The prairie or grassland environment is conducive to high evaporation because of persistent winds and a semi-arid or arid climate.

In the Milk River subbasin, Fresno Reservoir has a full pool surface area of 5,757 acres and evaporates an average of 35 inches per year. Twelve inches of the evaporated amount are offset by the average annual precipitation, leaving a net evaporative loss of 23 inches, or 1.92 feet. For the entire surface area then, annual evaporative loss totals 11,034 acre feet from Fresno Reservoir (Cannon and Johnson, 2004).

Similarly, Nelson Reservoir receives equivalent annual precipitation and evaporates the same amount per acre. Having a surface area of 4,560 acres, Nelson Reservoir loses 8,740 AF annually to evaporation (Cannon and Johnson, 2004).

With 245,000 acres of surface area, Fort Peck Reservoir experiences a huge evaporative loss of approximately 571,670 acre feet per year (Cannon and Johnson, 2004). Most of the loss occurs during the summer months which are warm, dry and breezy.

Higher elevation reservoirs within the LMRB receive more precipitation annually and typically experience less evaporation than their prairie counterparts. Air temperatures are usually cooler, and warm weather is more intermittent at higher elevations. For example, in the Musselshell River subbasin, Martinsdale and Bair reservoirs receive 16 inches of precipitation annually, and evaporate 30 inches annually for a net loss of 14 inches, or 1.17 feet. This is quite a bit less than the 2.33 feet evaporated at Fort Peck Reservoir or the 1.92 feet at Fresno Reservoir.

Hydropower

Fort Peck Dam is operated by the USACE and is the only hydroelectric facility within the LMRB. Total generating capacity of the five units at Fort Peck is 185 megawatts.

A. Existing Water Quality Impairments in the Lower Missouri Basin.

Montana Water Quality Law

Numerous laws and regulatory programs in Montana control activities to protect water quality. There are laws that regulate discharges to surface water, discharges to groundwater, streambed disturbance, mining operations, hazardous waste, underground storage tanks, septic systems, and almost every other activity that poses a threat to water quality. Most of these laws are administered by DEQ, with a handful administered by other state and local entities.

The Montana Water Quality Act (MCA §75-5-101) is the primary water pollution control authority in Montana. The Act state that it is public policy to:

> *Conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses; [and] provide a comprehensive program for the prevention, abatement, and control of water pollution; and balance the inalienable rights to pursue life's basic necessities and possess and use property in lawful ways with the policy of preventing, abating, and controlling water pollution.*

Water quality standards, adopted by the Montana Board of Environmental Review, establish the level of water quality necessary to support existing and future beneficial uses of rivers, lakes and groundwater resources. The standards establish a basis for limiting discharges of pollutants.

The 1972 federal Clean Water Act (CWA) established a national framework for protecting and improving water quality. Sections of the CWA passed in 1987, Sections 303(d) and 305(b), require states to monitor and assess statewide water quality conditions, identify and list waterbodies that fail to meet water quality standards, and prepare Water Quality Improvement Plans (WQIPs) for restoring water quality. These WQIPs must include quantitative limits, known as Total Maximum Daily Loads (TMDLs), for each of the pollutants of concern. Most of Montana's water quality impairments reflected on the 303(d) list are a result of nonpoint source (NPS) pollution.

Surface Water Quality Protection

Nonpoint water pollution comes from contaminants (originating from a variety of land-use activities over generally large areas) that are transported to streams, lakes, wetlands, and groundwater by precipitation, snowmelt, and stormwater runoff. Nonpoint pollution also comes from substances that erode directly into surface waters or from aerially transported substances deposited on land and water. Common nonpoint pollutants include sediment, nutrients (nitrogen and phosphorus), temperature changes, metals, pesticides, pathogens, and salt.

Nonpoint pollution is a significant problem in Montana, comprising the single largest cause of water quality impairment on a statewide basis. More than 75% of Montana's assessed rivers and streams and 45% of its lakes, reservoirs, and wetlands fail to meet state water quality standards largely as a result of the effects of NPS pollution (from Table 4-1, Montana Department of Environmental Quality, 2012). DEQ estimates that approximately 37% of the state's perennial river and stream miles, and 72% of the lake and reservoir acres, have been assessed.

The NPS management program is a voluntary program of land, soil and water conservation practices designed to prevent pollution from land-use activities. DEQ works with Conservation Districts, watershed groups, nonprofit organizations, local/state/federal agencies, and individual Montanans to provide training, monitoring support, and project funding. For those waters not meeting standards, total maximum daily loads (TMDLs) are developed, followed by voluntary implementation of best management practices for nonpoint sources, and potentially, point source permit waste load allocations. The TMDL program establishes the maximum amount of a pollutant that a water body may receive and still be expected to achieve applicable water quality standards. TMDLs are designed to achieve and protect designated beneficial uses. Regarding TMDL activity in the Yellowstone River Basin:

Insert current TMDL development activity.

Besides nonpoint pollution, there is point source pollution. Point source pollution comes from a single point, commonly thought of as an end-of-pipe discharge. DEQ maintains a point source pollution control program known as the Montana Pollutant Discharge Elimination System (MPDES), which is aimed at protecting water quality in waterbodies receiving point source discharges from sewage, industrial, or other wastes.

Other water quality protection laws include Section 310 of the Montana Stream Protection Act which requires Conservation Districts to regulate private activities that disturb the bed or banks of rivers and streams. Similarly, government activities that disturb the bed or banks of streams are regulated by the Montana Dept of Fish, Wildlife and Parks. Such activities include temporary disturbances, such as construction or maintenance activities for irrigation diversions. In addition, the Legislature provided for creation of local water quality protection districts. Such districts have limited regulatory authority, and are primarily intended to provide funding to locally monitor and plan for the protection of water quality resources of particular concern to the people within the district.

Groundwater Quality Protection

The Montana Ground Water Pollutant Control System (MGWPCS) (Chapter 17.30, subchapter 10, ARM) is a regulatory program to control all otherwise unregulated sources of groundwater pollution. Important aspects of the MGWPCS rules are groundwater quality standards, a non-degradation requirement, and a discharge permit system. A wide variety of activities are exempt from having to obtain MGWPCS permits (see 75-5-401 MCA and 17.30.1022 ARM). Discharges from the exempted activities are typically covered under other permitting programs or regulations.

Groundwater quality is also addressed in the Agricultural Chemical Ground Water Protection Act. Under this Act, DEQ is responsible for developing and enforcing groundwater quality standards for agricultural chemicals. DEQ is also charged under this Act with monitoring, promoting research, and providing public education in cooperation with universities and other state agencies. The Montana Department of Agriculture (DOA) is to develop and enforce agricultural chemical groundwater management plans aimed at preventing groundwater contamination from agricultural chemicals. Both DEQ and DOA have rules to implement their respective responsibilities under this Act.

1. **Point Sources**
2. **Non-Point Sources**

   TMDLs and 303(d) listed streams

   Nutrients (P and N and SPARROW results)

   Salinity
3. **Data Gaps and Areas of Uncertainty**

B. Existing Flow Impairments in the Lower Missouri Basin

1. **DEQ lists**
2. **FWP lists**
3. **Data Gaps and Areas of Uncertainty**

IV. Administration

A. Institutional and Legal Framework for Water Use in Montana

1. Federal Agencies with a Role in Managing Montana's Water Resources.

Federal authority for water management is implied in the U .S . Constitution, although water is never mentioned by name . The federal role comes from several specified powers:

- Commerce power –U .S . Congress has jurisdiction over all navigable waters of the United States. The commerce power includes flood protection and watershed development .
- Proprietary power – Congress has unlimited authority to control the use of federal public lands . The property clause allows construction of federal reclamation projects and regulates electrical power generated at federal dams .
- Treaty-making power – Only the federal government has authority to enter into treaties with foreign nations and American Indians . The treaty-making power is one basis for the reserved water rights of Indian tribes in Montana .
- General welfare power – The federal government has authority to provide for the general welfare of the Unites States and its citizens "for the common benefit," rather than for only "local purposes ."
- Equitable apportionment – When controversies arise among states over water, the U .S . Supreme Court has the power to decide the controversy .
- Interstate compacts – These negotiated agreements or compacts appropriate water that cross state boundaries . The compacts must be ratified by Congress .

In Montana, the federal government is involved with water management in multipurpose projects such as Hungry Horse, Yellowtail and Canyon Ferry Dams (Bureau of Reclamation) and Fort Peck Reservoir (Army Corps of Engineers); irrigation projects like the Yellowstone and Milk River Irrigation Districts (Bureau of Reclamation); wildlife refuges such as the Charles Russell National Wildlife Refuge (U .S . Fish and Wildlife Service); and water and wastewater treatment facilities managed by municipal governments (regulated by the Environmental Protection Agency)

Federal Laws

The primary federal laws that influence Montana water management are:

- Clean Water Act (CWA) – The CWA, enacted in 1972, gave states the authority to protect the chemical, biological and physical aspects of the nation's water bodies . CWA regulates the discharge of pollutants into waters by establishing national standards and permit

guidelines . The federal Environmental Protection Agency (EPA) oversees the act's implementation .

- Safe Drinking Water Act (SDWA) – The SDWA was passed in 1974 to protect drinking water from contamination . The purpose of SDWA is to establish national enforceable standards for the quality of drinking water distributed by public water systems, and to guarantee that they monitor to ensure compliance with these standards .

- Some overlap exists between these two statutes . However, the SDWA is concerned with public health associated with safe drinking water while the CWA has a broader goal of clean, fishable, and swimmable waters . Both statutes set minimum standards for water quality that must be met by all states . In Montana, both laws are administered by the Montana Department of Environmental Quality (DEQ) on
- non-reservation lands . The federal EPA or tribe administers the laws on tribal lands .

- Flood Cntrol Act (FCA) –This refers to a series of federal laws, all of which grew out of the need for a national response to the impacts of costly floods . The FCA has been amended and supplemented over time from the first Act passed in 1917 . The FCA of 1944 granted authority to Army Corps of Engineers to seek Congressional authorization for water development projects for purposes such as navigation, flood control and irrigation .

- Endangered Species Act (ESA) – The ESA was enacted in 1973 to protect and restore imperiled species and the ecosystems upon which they depend . The ESA provides a program for the conservation of threatened and endangered plants and animals and habitats . In Montana, the lead federal agency for implementing the ESA is the U.S. Fish and Wildlife Service.

The State Role

The framers of Montana's 1972 Constitution made it clear that a close relationship exists between the state's natural resources and a high quality of life . Article IX of the Constitution identified this important relationship by designating the state government as custodian of Montana's water resources . Section One of Article IX assigned shared responsibility for protection and improvement of Montana's water to "the state and each person...for present and future generations ." The Montana legislature bears responsibility for "the administration and enforcement of this duty," including protection of "environmental life support systems" and for preventing "unreasonable depletion and degradation of natural resources ." In addition, the Constitution established the governmental framework for water use, appropriation, channelization, damming, conveyance, regulations, protection, treatment, and monitoring .

Water rights, which regulate water use, are singled out in Section Three of Article IX: "All existing rights to the use of any waters for any useful or beneficial purpose are hereby recognized and confirmed ." It clarifies that all uses of water, regardless the nature, are considered public uses . Further, it declares all waters within state boundaries (groundwater, surface water, flood waters, and atmospheric waters) are the property of the state "for the use of its people ."

Montana Water Use Act of 1973

The 1972 Montana Constitution envisioned strong state supervision of water rights, with language to provide for their administration, control, and regulation, and to establish a system of centralized records.

In response, the Legislature enacted Title 85, Chapter 2, Montana Code Annotated (MCA), generally referred to as the Montana Water Use Act of 1973 . The act changed the water rights administration in several significant ways:

1. All water rights existing prior to July 1, 1973 are to be finalized through a statewide adjudication process in state courts.
2. A permit system was established for obtaining water rights for new or additional water developments.
3. An authorization system was established for changing water rights.
4. A centralized records system was established.
5. A system was provided to reserve water for future consumptive uses and to maintain minimum instream flows for water quality and fish and wildlife . (MT DNRC. Water Rights in Montana, April 2012.)

State Agencies with a Role in Managing Montana's Water Resources.

Montana Department of Agriculture
Monitors groundwater and surface water for pesticides and fertilizer as mandated by the Montana Agricultural Chemical Groundwater Protection Act . http://agr .mt .gov

Montana Fish, Wildlife & Parks
Administers programs to protect and restore fish habitat, instream flows, and water quality for support of fishing opportunities; works to protect and improve wildlife habitat; maintains state parks and recreation sites; provides educational programs to adults and young people, including "Aquatic Project WILD ." http://fwp .mt .gov

Department of Environmental Quality
Administers federal pollution control programs that protect public health; issues permits for municipal, industrial and agricultural discharges; monitors chemical and geological quality of streams and lakes; administers funds for municipal wastewater treatment improvements; administers a non-point source
water pollution management program; promotes wellhead protection program; reviews sanitary and environmental aspects of proposed housing subdivisions. http://deq .mt .gov

Department of Natural Resources and Conservation
Maintains a centralized record of water rights; assists the Montana Water Court with its statewide adjudication of water rights; develops the state water plan; prepares technical studies on surface and groundwater availability; administers the state water reservation statute; administers the state dam safety act; rehabilitates and operates state-owned water storage projects; conducts a floodplain management program; trains water commissioners; manages state trust lands for timber and other uses; represents Montana in interstate and international proceedings regarding water use and allocation; and administers numerous grant programs . http://dnrc .mt .gov

Department of Transportation
Secures floodplain permits from counties when crossing waters of the US that pass through delineated floodplains; designs, installs and maintains structures dealing with surface water runoff (culverts, bridges, storm drains, etc .) and irrigation; mitigates for erosion from roadways into waterways; secures water rights and permits when mitigating wetlands . http://www .mdt .mt .gov

State Historic Preservation Office
Monitors impacts of water-related development on cultural history .
http://www .mhs .mt .gov/shop

Montana Bureau of Mines and Geology
Established in 1919 as a non-regulatory agency within the Montana University Billings . Collects and publishes information relative to the geology and minerals of Montana . In addition to geologic mapping, the Ground Water Investigation Program (GWIP) gathers hydro geologic data on groundwater
in areas of high concern and the Ground Water Assessment Program (GWAP)
maps distribution and quality of state aquifiers . www .mbmg .mtech .edu

Montana Environmental Quality Council
A 17-member council created by the 1971 Montana Environmental Policy Act . Oversees state environmental programs for the Montana legislature; analyzes and interprets environmental trends; and advises the legislature on the adequacy of the state's water policy . http://www .leg .mt .gov/lepo .asp

Montana State Library's Geographic Information Program
Mandated by the Montana Land Information Act, the mission is to create, record, acquire, store and disseminate geographic information for the state of Montana . The Natural Resource Information System and the Water Information System are segments of the program . http://www .geoinfo .montanastatelibrary .org

Montana Water Court
The 1979 Legislature created the Montana Water Court to expedite and facilitate the statewide adjudication of over 219,000 state law-based water rights (generally rights with a pre-July1, 1973 priority date) and Indian and Federal reserved water rights claims . The Water Court has exclusive jurisdiction over the adjudication of water rights claims . http://courts .mt .gov/water

Water Policy Interim Committee
Studies topical water quality and quantity issues to develop policy direction and necessary legislation to guide Montana's water policy .
http://leg .mt .gov/css/Committees/interim/2013-2014/Water-Policy/

Local Government and Non-Governmental Organizations with a Role in Managing Montana's Water Resources

The geography and communities of Montana are diverse . No uniform approach to water management dictated from above would be appropriate across the state . Consequently a large number of decisions that directly or indirectly affect water resources have devolved to local government . Some are legal requirements; for example, conservation district boards review proposals for activities that would affect streams, and issue "310 permits" under state law . Other local actions are more discretionary . In adopting their growth policies, for example, county commissions can choose to incorporate various kinds of measures to protect water resources in the development process . Water management is an important responsibility for local governments . The information below is a synopsis of local government or local group responsibilities towards water.

Local Health Departments
Responsible for protecting public health from communicable disease, including water-borne disease that can be transmitted through ground and surface water . Assess potential public health problems, adopt policies and practices to prevent pollution and clean up contamination . Enforce public health standards, including some regarding drinking water and wastewater .

City & County Commissions and Boards
Direct local water management through shaping and administering county growth policies, subdivision regulations and other land use/protection measures .

Conservancy Districts
Formal political subdivisions of state formed by public petition and governed by an elected Board of District Directors . Conservancy Districts can cross county boundaries to promote and manage the conservation, development, and utilization of land and water for beneficial uses including but not limited to prevention and control of flooding, erosion and sedimentation, domestic, irrigation, livestock,
and industrial water supply, recreation, and fish and wildlife . They have authority to adopt rules, isuse bonds to finance works, collect fees for services, enter into contracts and agreements, and participate in federal programs . See MCA 85-9-101 to 85-9-632 for more information .

Conservation Districts (CD)
Exist in all Montana counties to address local water resource needs . Guided by a locally-elected board of directors, a CD addresses special water problems, regulates stream management, issues 310 Permits and educates citizens about land-use practices and pollution prevention . http://www .macdnet .org
Regional Resource Authorities (RRA's) Similar to Conservancy Districts, these may be created through public petition and election process, with a governing body appointed by county commissioners . RRA's
have the power to, among other things, issue bonds or notes for the purpose of funding projects, purchase and hold lands, make grants and loans of money, property, and services for public purposes, impose fees or assessments for services provided, enter into inter-local agreements or other greements with the federal government .

Water Quality Districts
Local water quality districts (LWQD) serve to protect, preserve, and improve the quality of surface and groundwater within the district . LWQD's operate with a board of directors and funding from county fees . LWQD's research local water quality, answer citizen inquiries and conduct public outreach programs . Under some circumstances, they can take on regulatory authority . Four LWQD's operate in Montana today: Lewis and Clark, Gallatin and Missoula Counties, and Butte/ Silver Bow . Flathead, Lake, and Ravalli counties have explored the possibility of district formation .

County Water and Sewer Districts
Districts with taxing authority, operate under the authority of county government, established for the purpose of developing and operating public water or sewer systems, or both .

Water Commissioners
Local water users can petition for a water commissioner after the water rights in a basin have been verified by the Montana Water Court . The commissioner ensures that daily water allocations in the basin occur in accordance with the users' rights . The local district court appoints the commissioner, and oversees his work.

Irrigation Districts
Subdivisions of government that supply water to irrigators within a specified region . Citizens may establish one by petitioning the court . Members of the district elect a Board of Directors to make policy, hire, manage, and make management decisions based on legal regulations and self-adopted bylaws . All district members pay taxes to construct and maintain the water project, usually a storage reservoir or canal system, supplying their district . Most federal irrigation projects are managed by irrigation districts.

Water User Associations
Non-profit corporations that manage mostly state or local irrigation projects . If they manage state-owned projects, they are bound to terms of water-use contracts prepared by the DNRC . The State of Montana holds the water rights of these projects . If not associated with state-owned projects, water user associations (sometimes called Ditch or Canal Companies) develop their own operating rules . The Middle Creek Water Users' is an example of at state owned project near Bozeman. The Livingston Ditch Association, near Livingston, is not associated with a state-owned project

Ditch or Canal Companies
Private companies set up by local irrigators to share the cost and maintenance of the ditch system servicing their collective lands . Ditch companies vary greatly in membership and acreage, and often address the water needs of many individual water rights holders .

Non-Governmental Organizations
In addition to legal processes and government agencies, less formal efforts bring a variety of people together to resolve conflicts over water and to explore creative solutions to problems of quality and flow .

- Coalitions for Local Watershed Planning: People across Montana have created coalitions of local governments, state and federal agencies, businesses, and local citizens to deal with water quality and quantity issues . One example is The Blackfoot Challenge, a forum that promotes cooperative resource management of the Blackfoot River, its tributaries and adjoining lands .

- Watershed Groups: These citizen groups are as diverse as the communities they serve, and participate directly in watershed level decision making and problem solving, as well as initiating local cleanups, conservation and watershed education, and data gathering/ecosystem research projects .

- Montana Watershed Coordination Council: This council serves to build and unite watershed communities by bringing people and information together . The council is comprised of private organizations and staff from many local, state, and federal natural resource agencies . http://www .mtwatersheds .org

- Montana Wetland Council: This advisory group, whose membership is open to the public, agencies, and interest groups, seeks to direct the development and implementation of a Montana wetlands strategy . Its mission is to conserve and restore Montana's wetlands and riparian ecosystems through the cooperation of public and private interests . http://www.deq.mt.gov/wqinfo/wetlands/wetlandscouncil.mcpx

- Special Interest Groups: Agriculture, recreation, industry and fisheries have a stake in how water is managed . Reflecting this diversity, a variety of special interest groups develops creative solutions related to issues that affect Montana's water .

Water Right Basics

Prior Appropriation Doctrine

Beneficial use and priority are the two key attributes of a water right under the prior appropriation doctrine. In order to use water in Montana you must have a water right. A water right is the right to use the water, not to the ownership of the water. The state actually owns the water which can be used multiple times in a variety of ways during its course through Montana.

Under prior appropriation, the first person to use water from a source established the first right; the second person could establish a right to the leftover water, and so on. A water user with early priority date (senior water user) has priority over water users with later priority dates (junior water users) when there is insufficient water available to meet all demands. The senior water right holder can "call" a junior water right holder and request they curtail their use. This system protects the earliest water users during shortages while maximizing use when water is plentiful. There are no preferences among beneficial uses other than priority.

The elements of one's water right are priority date, source, point of diversion, place of use, and rate and volume of diversion. Beneficial use is the basis, measure and the limit of one's water right and one cannot exercise their right regardless of priority, if they cannot use the water beneficially.

Montana Water Use Act

The Montana Water Use Act of 1973 codified in Title 85, chapter 2, MCA set up Montana's modern way of dealing with water use in the state. It provided a comprehensive revision and update to

Montana water law and the most comprehensive change in Montana's water rights laws in the state's history. Prior to 1973, water rights were considered "use rights" which meant that if you wanted water, you put it to a beneficial use and filed at the county level. The Montana Water Use Act legally recognized all existing rights prior to July 1 1973, set the stage for Adjudication (verification of the statements of claims), established administrative, control and regulation of water rights, created a centralized water rights record system, and established DNRC authority for permitting new water rights and changes to existing water rights.

Any person planning a new or expanded development for a beneficial use of water from surface water or ground water after June 30, 1973, must obtain a permit to appropriate water or file a Notice of Completion of Ground Water Development to get a Certificate of Water Right. There are exceptions to permitting requirements for small livestock pits or reservoirs located on non-perennial flow streams. Also, a person is not required to apply for a permit to develop a well or a ground water spring with an anticipated use of 35 gallons a minute or less, not to exceed 10 acre-feet a year (section 85-2-306, MCA).

Criteria for Issuance of a Permit
Section 85-2-311(1), MCA
The applicant for a water use permit to appropriate less than 4,000 acre-feet a year and 5.5 cfs has the initial burden to prove by a preponderance of the evidence that the criteria for issuance of a permit are met. The criteria include:

1. Water is physically available at the proposed point of diversion in the amount that the applicant seeks to appropriate.
2. Water can reasonably be considered legally available during the period in which the applicant seeks to appropriate, in the amount requested.
3. The water rights of a prior appropriator under an existing water right, a certificate, a permit, or a state WATER RESERVATION will not be adversely affected. Adverse effect is based on a consideration of the applicant's plan to exercise the water right so that prior water rights will be satisfied.
4. The proposed means of diversion, construction, and operation of the appropriation works are adequate.
5. The proposed use of water is a beneficial use.
6. The applicant has a possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use.

A water right owner must obtain a change authorization by meeting criteria under 85-2-402, MCA before work begins on a project that will result in a change to the point of diversion, place of use, purpose of use, or place of storage. An applicant submitting a change in purpose or place of use of an appropriation to divert 4,000 or more acre-feet of water a year and 5.5 or more cubic feet a second will be required to prove the criteria set out in section 85-2-402(4), MCA. If a proposed change in purpose or place of use for a diversion results in 4,000 or more acre-feet and 5.5 or more cubic feet a second of water being consumed, the applicant must prove the criteria in section 85-2-402(5), MCA. If the change involves the transport of water out of state, the applicant must prove the criteria listed in section 85-2-402(6), MCA, and obtain legislative approval.

Criteria for Issuance of a Change Authorization
Section 85-2-402, MCA
The applicant for a change in an appropriation water right has the burden to prove by a preponderance of the evidence that the criteria for issuance of an authorization are met. The criteria include:

1. The proposed use will not adversely affect the use of other water rights or other planned developments for which a permit or certificate has been issued or water has been reserved.
2. The proposed means of diversion, construction, and operation of the appropriation works are adequate.
3. The proposed use of the water is a beneficial use.
4. The applicant owns or has permission from the person who owns the property where the water is to be used.

An applicant may change up to the historic amount of water diverted and the historic consumptive use. In a change proceeding, it must be emphasized that other appropriators have a vested right to have the stream conditions maintained substantially as they existed at the time of their appropriations. Also, the DNRC in administrative rulings has held that a water right in a change proceeding is defined by actual beneficial use, not the amount claimed or even decreed.

Basin Closures in the Clark Fork Basin

Montana has closed some of its river basins to certain types of new water appropriations because of water availability problems, over-appropriation, and a concern for protecting existing water rights. Section 85-2-319, MCA, legislatively authorizes the closure of basins to certain new appropriations through the adoption of administrative rules and negotiation of reserved water rights compacts. The law also provides for the closure of highly appropriated basins through the adoption of administrative rules.

A person wanting to appropriate groundwater in a closed basin must complete a hydrogeologic assessment and must meet requirements of 85-2-360, 85-2-361, and 85-2-362, MCA. If the hydrogeologic assessment predicts that the appropriation would have no net depletion of surface water, the application moves through the permitting process. If the assessment predicts net depletion of surface water, it must be determined if net depletion would have an adverse effect on prior appropriators. If not, the application moves through the permitting process. If there would be an adverse effect, the applicant must submit a plan for mitigation or aquifer recharge.

There are two DNRC-designated basin closures in the Lower Missouri Basin: the Mainstem of the Milk River and the Southern Tributaries of the Milk River. The mainstem Milk closure extends from the Eastern Crossing at the Canadian border to the Vandalia diversion dam and prohibits new direct diversions without storage for any consumptive uses and provides varying periods of closure. The southern tributaries of the Milk closure includes Miners Coulee, Halfbreed Coulee, Bear Creek, and

their respective tributaries in Toole and Liberty counties. The southern tributaries closure prohibits new appropriations for direct diversions without storage for any consumptive uses accept for applications up to 3 acre-feet per year for domestic or stock. Applicants for groundwater greater than 35 gpm up to 10 acre-feet annually in any basin closure area must prove criteria for issuance of a permit under §§85-2-311, MCA and are subject to the requirements of HB-831 found in §§85-2-360, 85-2-361, and 85-2-362, MCA.

Controlled Groundwater Areas in the Lower Missouri Basin

In addition to basin closures for surface water, controlled ground water areas may be designated to protect water quality or quantity (section 85-2-506, MCA). An area for designation may be proposed by the DNRC on its own motion, by petition of a state or local public health agency, municipality, county, conservation district, or local water quality district. An area also may be proposed upon petition of at least one-third of the water rights holders in the proposed controlled ground water area.

[SUMMARIZE CONTROLLED GROUNDWATER AREAS]

[TABLE OF BASIN CLOSURES AND CONTROLLED GROUNDWATER AREAS IN THE LOWER MISSOURI]

Water Rights Administration

Seven state entities play a role in administering Montana water rights and the statewide water adjudication: the Montana Department of Natural Resources and Conservation (DNRC), the Montana Water Court, the District Courts, the Reserved Water Rights Compact Commission, the Attorney General, and two legislative committees, the Water Policy Interim Committee and the Environmental Quality Council (EQC). The EQC contributes policy oversight to the administration of state water rights. The Water Policy Interim Committee (WPIC) coordinates with the Environmental Quality Council (EQC) to avoid duplication of efforts.

Status of Adjudication in the Lower Missouri Basin

Introduction

Adjudication is a process for resolving problems or issues with water right claims for uses that existing previous to July 1, 1973. For existing water right claims the process involves the examination of claims, the issuance of decrees, and the resolution of claim issues. When a judge hears a case and makes a decision, the matter is said to have been *adjudicated*. *Water rights* adjudication refers to the settling of *statements of claim* filed for water rights. Adjudication establishes all *existing water rights* in the state, and provides essential protection to all Montana water users. The adjudication process establishes the *priority date* and the amount of water claimed by users for *beneficial use*. It does not, however, provide any information regarding water supply or guarantee the availability of water.

Purpose and Need

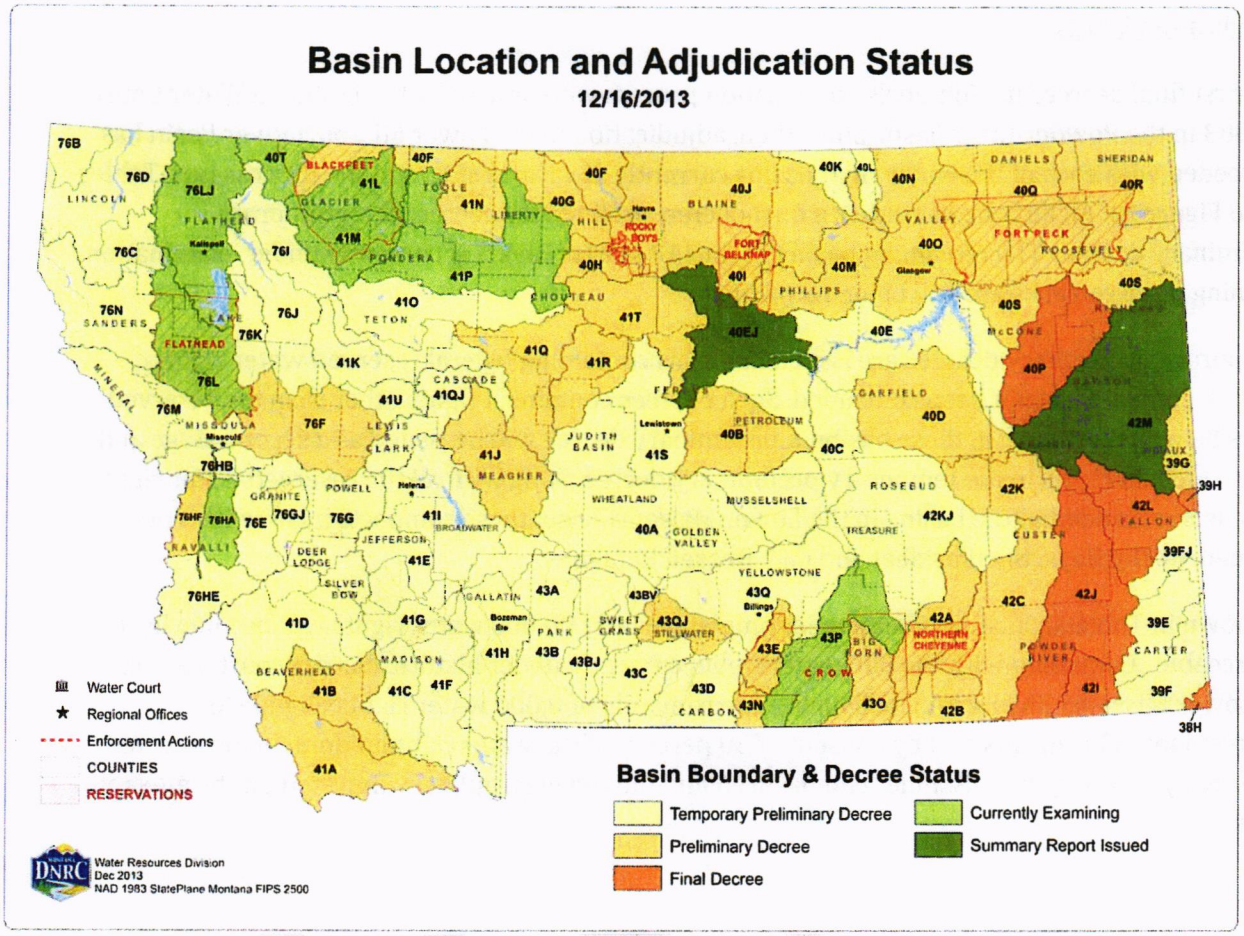
Adjudication of Montana's water rights provides knowledge of available water resources, important to the state's growth and economic development. Montana water users are also better protected and able to defend historical usage against the increasing demands for water from downstream states. Enforcement of water rights in Montana is one way the adjudication program helps protect water users. Since 2001, the number of requests before the district courts calling for enforcement of water rights on streams has been increasing. Until the adjudication of a stream is completed by the Water Court and until all the objections are settled, water commissioners must rely on historical decrees, which are limited, to enforce water use. Water rights on streams without decrees cannot be enforced.

History

Prior to 1973, a person could gain a right to use water simply by putting that water to beneficial use. As a result, no one knew how many water rights there were or exactly how much water had been claimed by users. In passing the 1973 *Montana Water Use Act*, (Act) the Legislature recognized that the amounts, ownership, and priority dates for all existing water rights needed to be more clearly defined. To accomplish this, the Act required that all water rights existing prior to July 1, 1973, were to be adjudicated in state courts. The Act also established a permit system for obtaining new water rights, and an authorization system for changing water rights. In addition, the Act established a central system for all water rights records.

In 1979, the Act was modified to establish a special court, known as the *Water Court* to adjudicate all existing water rights in a statewide proceeding. In June of 1979, the Montana Supreme Court issued an order requiring every person declaring ownership of an existing water right to file a statement of claim with the Department of Natural Resources and Conservation (DNRC) no later than January 1, 1982. The Court later extended the deadline to April 30, 1982. Existing water rights not filed by the deadline were assumed to have been abandoned. Certain stock and domestic water claims were exempt from the Court's order.

By the April 30, 1982, deadline, over 200,000 claims for existing water rights were received. Because adjudication of these claims cannot occur at once, the claims are being handled systematically for each of Montana's 85 river basins (Figure 1). The adjudication process starts with DNRC staff examining each statement of claim for completeness and accuracy according to rules established by the Montana Supreme Court. Discrepancies are then reported to the claimants and the Water Court. The reports are also made available to the public.



The water judge, with the help of a *water master*, hears and decides all objections to the filed claims. After all objections have been resolved, the water judge issues a *decree* or ruling. Once a final decree is issued, DNRC will release a Certificate of Water Right to each person decreed an existing water right. Water rights dated after July 1, 1973, are administered through the DNRC water rights permitting process and are therefore not subject to the adjudication process. By 1985, the first 20 water basins had been decreed.

The 2005 Montana Legislature passed House Bill 22 to help speed up the adjudication process. The bill called for the DNRC to evaluate the remaining 57,000 claims by June 30, 2015. As of June 2013, fewer than 4,000 claims remained for examination by the DNRC.

The Bill also set a target date for the Water Court to issue an initial degree for all basins in Montana by June 30, 2020. To assist the Water Court in meeting this target, DNRC must provide the Court summary reports on the remaining basins to be decreed. In addition, the Bill requires the Water Court and the DNRC provide progress reports to the Environmental Quality Council on a regular basis.

Adjudication Status

The first final decrees in Montana's adjudication process were issued by the Montana Water Court in 1983 in the Powder River basin. Since then, adjudication in the Lower Missouri River Basin has proceeded with each of the water right basins currently at various stages in the process (see Tables X and Figure X). All but one has either a final decree, preliminary decree, or a temporary preliminary decree. The remaining basin (Basin 41P Marias RIver) is currently under examination meaning issue remarks are still being reconciled.

Temporary preliminary decrees are issued in basins containing federal reserved water rights where a compact has not been concluded. Such decrees contain all rights other than the reserved rights being negotiated. In these basins, a preliminary decree will be issued as a second stage and will include all rights in the temporary preliminary decree along with all the reserved water right compacts concluded in the basin. In the Lower Missouri Basin these compacts include the Fort Belknap, Rocky Boys, the Blackfeet and C.M. Russell Refuge.

As shown in Table X, once adjudication is complete, nearly 00,000 water rights will become legally enforceable. Combined with the 000 water rights currently under historic district court decrees, the Lower Missouri River Basin will have approximately 000,000 water rights eligible for enforcement. This means that by consent of 50 percent of the water right holders on the affected water body, a water commissioner can be hired and funded via a mill levy imposed on the affected users.

Water Reservations

When the Montana Water Use Act was passed in 1973, the option to reserve water became a major component of the law. Policy makers recognized the need to create a mechanism for preserving the potential for future diversionary uses and for maintaining instream flows to protect aquatic life, recreation, and water quality. The law established a process for the reservation of waters by public entities for beneficial uses that serve the public interest. The reservation process is unique since it allows the claimant to appropriate water for future use. The reservation establishes a current priority date even if the water is not actually used until a later time. Three classes of water reservations emerged from the 1973 legislation: municipal reservations to serve domestic and industrial needs, conservation district reservations to serve irrigation and stockwater demands, and instream flow reservations to protect fish and aquatic wildlife habitat, recreation, and water quality.

In 1985, the Montana Legislature directed DNRC to initiate a water reservation proceeding for the Missouri River Basin. The legislature felt that implementation of a water reservations would encourage more coordinated development of the basin's water resources and help form a stronger and more unified basis for protecting Montana's share of the Missouri River from downstream states. Due to the size of the basin, DNRC split the Missouri reservation process into upper and lower basins. The upper basin encompassed the area above Fort Peck Dam, and the lower basin encompassed the area below Fort Peck Dam which included the Milk River and Little Missouri Sub-

basins. The reservation process in the Upper Missouri Basin was completed in June, 1992. Shortly thereafter, DNRC began preparation of a draft environmental impact statement to consider the applications in the Lower Missouri River Basin.

DNRC received twenty-six applications for reservations in the lower basin. Fourteen municipalities applied for 46,167 acre-feet of water per year to meet future growth demands. Eleven conservation districts requested 276,407 acre-feet for 472 proposed irrigation projects covering 157,994 acres. The Montana Department of Fish, Wildlife, and Parks applied to reserve instream flows on 21 streams or stream reaches to protect fish, aquatic habitat, recreation, and water quality.

On December 30, 1994, the Board of Natural Resources and Conservation (BNRC) published the order establishing water reservations in the Lower and Little Missouri River Basins. The BNRC granted all of the municipal applications except those applications for surface waters in the Milk River sub-basin (Chinook, Harlem, Havre, and the Hill County Water District) which were summarily denied. The BNRC did approve a groundwater reservation for the city of Havre. Reservations in the Lower Missouri Basin received a priority date of July 1, 1985. Reservations in the Little Missouri River Basin received a priority date of July, 1 1989. Contrary to most water rights that have a priority date and do not reflect any relative preference to other water rights, the BNRC subordinated the reservations for instream flows. Even though all of the reservations in the Lower Missouri Basin carry the same priority date, the BNRC explicitly gave a preference to the municipal, irrigation and stockwater reservations over instream flow in the event of conflicts among the rights secured through the reservation process in the future. A comprehensive list indicating the status of the development of the Conservation District Reservations in the Lower Missouri Basin is set forth below.

LOWER MISSOURI RIVER BASIN CONSERVATION DISTRICT WATER RESERVATION BALANCE as of December 31, 2012							
		PROJECTS	VOLUME	VOLUME	REMAINING	FLOW	FLOW
CONSERVATION DISTRICT	SOURCE OF WATER SUPPLY	APPROVED	GRANTED (AF)	ALLOCATED (AF)	VOLUME (AF)	GRANTED (cfs)	ALLOCATED (CFS)
LOWER BASIN							
BLAINE	Battle Creek, Little Coulee	0	18,934.00	0.00	18,934.00	0.00	0.00
CARTER	Little Missouri River & tribs, Little Beaver Creek & tribs, Boxelder Creek & tribs, 1 groundwater well	0	4,684.00	0.00	4,684.00	26.30	0.00
DANIELS	South Fork Whitetail Creek, Groundwater, Poplar River, UT Middle Fork Poplar River, Pit, Police Creek, East Fork Poplar River, Sprinks, Olson Coulee, Coal Creek, UT of Butte Creek	0	3,047.00	0.00	3,047.00	16.90	0.00
LITTLE BEAVER	Beaver Creek & named tribs, Named tribs of Little Beaver Creek	0	1,548.00	0.00	1,548.00	0.00	0.00
LIBERTY	Lost Coulee	0	310.00	0.00	310.00	0.84	0.00
McCONE	Mainstem Missouri River	7	14,299.00	3,793.30	10,505.70	99.50	62.11
RICHLAND	Mainstem Missouri River	22	25,349.00	9,392.00	15,957.00	186.90	107.50
ROOSEVELT	Mainstem Missouri River	21	73,115.00	9,475.60	63,639.15	558.80	101.83
SHERIDAN	Groundwater	20	15,479.00	5,648.00	9,831.00	0.00	0.00
VALLEY	Groundwater	0	7,668.00	0.00	7,668.00	54.10	0.00
WIBAUX	Beaver Creek & named tribs	0	1,509.00	0.00	1,509.00	0.00	0.00
TOTAL		70	165,942.00	28,308.90	137,632.85	943.34	271.44

Of the ten municipal reservations approved in the process, only the city of Culbertson has utilized their reservation. The Dry Prairie Rural Water System (DPRWS) temporarily used Culbertson's water reservation pending approval of their own application for a water right from the Missouri River. With the town of Plentywood set to receive water from DPRWS it is unlikely that their groundwater reservation will be developed in the future.

In the 20 years since the water reservations in the Lower Missouri River were established, MFWP has never made a call against a junior claim. With a 1989 priority date, the number of junior users on the affected stream reaches is extremely limited. These reservations are more important for the limitations they create for future claims. In keeping with the larger policy goals of protecting instream flows, these reservations are important for establishing a minimum that protects fish, wildlife habitat, recreational values, and water quality from depletions caused by new consumptive uses.

2. Federal and Tribal Reserved Water

The doctrine of reserved water rights evolved to ensure that Indian reservations and public lands set aside by the federal government would have sufficient water to fulfill the purposes for which they were established. Whereas most western water rights (state-based appropriative rights) have a priority date based on when water was first put to beneficial use, federal reserved water rights have a priority date that goes back at least as far as the date on which the lands were set aside.

The reserved water rights doctrine is rooted in a number of judicial decisions, beginning with a U.S.

Supreme Court decision now known as the Winters Doctrine. The case of Winters vs United States involved a dispute between Native Americans of the Ft. Belknap Reservation and nonnative settlers over the use of the Milk River. When the water use of the settlers upstream from the reservation interfered with the Indians' water need for large Irrigation diversions, the U.S. government filed a lawsuit on the reservation's behalf.

The Winters decision held that when Congress created the Ft. Belknap Reservation, sufficient water to make the Indians a "pastoral and civilized People" was implicitly set aside. Therefore, although the normative settlers had perfected their water rights under Montana state law, the water right of the Indians of Ft. Belknap was prior, or senior in use.

The rationale used in the Winters decision on behalf of Native Americans also applies to public lands held by the federal government for national parks, wildlife refuges, national forests, military bases, wilderness areas, or other Public purposes. It holds that when Congress authorized the establishment of federal land, it implicitly intended to reserve enough water to fulfill congressional purposes. This idea of "implied rights" serves as the basis and foundation for tribal and federal claims to state waters embodied in the many compacts negotiated by the state of Montana and its many tribal and federal partners.

DRAFT

TRIBAL COMPACTS IN THE LOWER MISSOURI RIVER BASIN

FORT PECK COMPACT

The Fort Peck Tribal Executive Board and Montana Legislature ratified the Fort Peck Montana Compact in April 1985. Unlike the other compacts negotiated by the state of Montana and other tribes in the state, the Fort Peck Compact did not include any federal funding and corresponding state contribution to assist the tribes of the Fort Peck Reservation in the development of water rights and other resources identified in the compact. Since there was no federal appropriation associated with the compact, it was determined that approval and ratification by the U.S. Congress was unnecessary for implementation.

INTRODUCTION

The Fort Peck Reservation is located in northeastern Montana. It is about 110 miles long (east to west) and 40 miles wide (north to south) encompassing slightly over two million acres. Over 5,000 tribal members live on the Reservation, as well as several hundred Indians belonging to other tribes. Reservation Lands were allotted to the Indians beginning in 1908, and then opened to settlement by non-Indian homesteaders. Today, about half the lands of the Reservation are owned by non-Indians. About 550,000 acres are held in trust by the United States for Indian allottees, and another 400,000 held in trust for the Tribes. Trust and fee lands are commonly interspersed in a "checkerboard" pattern.

The southern boundary of the Reservation is the Missouri River, the major interstate stream system of the Northern Great Plains. The western boundary is the Milk River and, farther north, its tributary, Big Porcupine Creek. The northern boundary of the Reservation is about thirty miles south of the United States – Canadian border. The Reservation's eastern boundary, Big Muddy Creek, joins the Missouri River about 20 miles west of the North Dakota state Line.
The climate is semi-arid, with average annual precipitation between 12 and 13 inches. The major water resource of the Reservation is, of course, the mainstem Missouri, with an average annual flow of over seven million acre feet. Fort Peck Dam, a major Missouri Basin hydroelectric project constructed by the Corps of Engineers, lies about five miles upstream of the Reservation, on the Missouri. Its Reservoir, about one hundred miles long, holds over 20 million acre feet. A number of much smaller tributaries of the Missouri originate on or flow through the Reservation in a generally north to south direction. The major run-off in these streams is in March and April; flows are often intermittent in the late summer, and the water quality is poor.

SUMMARY OF PROVISIONS

PROTECTION OF EXISTING USES IN MISSOURI RIVER TRIBUTARIES.

The Tribes agree in the Compact to make no use of the mainstem of Milk River, which is the western boundary of the Reservation for only a few miles above its confluence with the Missouri. This is because their engineers advised the Tribes that the lands in this area could better be served from the Missouri, which is a dependable, high-quality source.

The Compact also protects all existing Indian and non-Indian uses on the other streams that flow through, and the ground water basins that underlie, the Reservation. About 33,000 acres are presently irrigated from these streams or ground water basins, mostly by non-Indians. About half the irrigation is from ground water. Most of the acres irrigated from surface flow are by means of "water spreading" – capturing high stream flows during the early spring runoff. These irrigation uses are protected, as are present and future domestic uses and future stock watering impoundments not in excess of 20 acre feet per year. All new non-Indian uses, however, will be subordinate to future exercise of the Tribes' reserved rights.

Had the controversy been litigated, the Tribes could of course have "cut off" these junior uses on the tributaries, since the Tribes enjoy a much earlier priority date. The Tribes, however, agreed to protect those uses in return for the State's agreement to the quantification determined by the Tribes' experts, tribal jurisdiction, resolution of disputes by a Compact Board and tribal water marketing.

QUANTIFICATION

The Compact determines finally and forever the quantity of water reserved for the Assiniboine and Sioux Tribes by federal law as 1,050,472 acre feet of diversions, or a consumptive use of 525,236 acre feet, per year. A maximum of 950,000 acre feet may be diverted and 475,000 acre feet may be used, from surface water each year. The rest would have to come from ground water, and the Compact recognizes the Tribes' ground water rights.

The Tribes can use this water for irrigation, or for any other purpose determined by them on the Reservation. Part of the Tribes' water rights may be used to establish instream flows to protect fish and wildlife resources on various tributary streams on the Reservation.

The Compact provides that nonuse of the Tribal Water Right does not abandon or forfeit the Tribes' right, which is a standard component of reserved water rights.

JURISDICTION OVER TRIBAL WATER RIGHTS AND RESOLUTION OF DISPUTES

The United States will continue to administer and settle disputes concerning water use on the Fort Peck Irrigation Project, which presently serves less than 20,000 acres of Indian and non-Indian lands on the Reservation with water from the Missouri River. The Tribes administer all other uses or water of the Reservation by itself, by Indians, or by non-Indians who either lease water from the Tribes or claim a water right under federal law because they purchased a former trust allotment. The Tribes will eventually adopt a water code, and resolve all water disputes among these persons. The Interior Department has approved the tribal water code.

The State administers all water rights established pursuant to state law, including by non-Indians on the Reservation, and resolve all disputes among state water users.

These separate administrative systems will make it less likely that a dispute will arise between the Tribes and the State, or between tribal and state water users. If a dispute does occur, it will be determined by a Joint Tribal-State Board established by the Compact. This Board has one

representative from the State, one from the Tribes, and a third selected by neutral means. It has the power to subpoena witnesses, to hold hearings and take testimony. All decisions must be by majority vote.

Appeals of the Board's decisions may be had in a court of competent jurisdiction, but the scope of review is limited in a fashion very similar to that of an award in binding arbitration. Decisions of the Board must be enforced by any court of competent jurisdiction unless an appeal is timely filed.

TRIBAL WATER MARKETING

The Compact recognizes that the Tribes may market water within the Reservation to non-Indians without complying with any state law or administrative regulation. The permanent sale of tribal water is not authorized. The Compact also provides that the Tribes may market their water outside the Reservation by leasing or otherwise transferring it for up to 50 years, so long as the following requirements are met.

- Water must be diverted from Fort Peck Reservoir or the mainstem of the Missouri River downstream from Fort Peck Dam.

- Outside the Reservation, water must be used for a beneficial purpose as that term is defined by valid state law at the time the Tribes propose the use.

- Aany export of the Tribal Water Right outside Montana must comply with the valid state laws at the time the export is proposed. The Federal Constitution imposes limits on state restrictions against exporting water.

- Industrial facilities or pipelines using or transporting water marketed by the Tribes or constructed by the Tribes outside the Reservation must comply with valid state laws such as Montana's Major Facilities Siting Act that regulate the construction or operations of such facilities.

- The quantity of water marketed by the Tribes outside the Reservation in any year is limited in a complex fashion by reference to the amount of water authorized to be transferred by the State. If the State is authorized to market 50,000 acre feet or more, the amount the Tribes can market is a varying percent of the State total. If total State water marketing is less than 50,000 acre feet per year, the Tribes can market any quantity permitted by federal law or – if federal law has no limits – any quantity state law allows private water users to market. In all events, the Tribes may market at least 50,000 acre feet per year.

- The Tribes must give notice to the State showing that:

  (a) the means of diversion and construction and operation of diversion works for tribal water marketing are adequate,

  (b) the diversion will not adversely affect any federal or state water right actually in use at the time the diversion is proposed,

  (c) the proposed use does not cause any unreasonable significant environmental impact, and

  (d) that certain large diversions will not be made that significantly impair the quality of water for existing uses, use high-quality water where low-quality water is legally and physically available to the Tribes for the use, create or contribute substantially to saline seep or substantially injure fish or wildlife populations.

- In a unique provision, the Tribes agree to offer the State the opportunity to participate in any marketing proposal the Tribes develop outside the Reservation. The State in return must do the same for the Tribes for opportunities in Fort Peck Reservoir or the mainstem Missouri River below Fort Peck Dam.

Although tribal water marketing is not limited by state law, the above criteria do somewhat resemble present state law.

FORT BELKNAP WATER RIGHTS COMPACT

INTRODUCTION

The Fort Belknap Reservation was established in north central Montana for members of the Gros Ventre and Assiniboine Tribes. Historically, the area was part of the large territory north of the Missouri and Musselshell Rivers designated in the treaty of 1855 for the Blackfeet Nation, including the Gros Ventre. On May 1, 1888, this large reserve was split into the smaller separate reservations of the Blackfeet, Fort Peck, and Fort Belknap. On October 9, 1895, 14,900 acres on the southern boundary of the Fort Belknap Reservation was ceded and the Reservation took the form we see today. Land outside of the southwest boundary of the Reservation has been purchased for the Tribes and is held in either trust or fee status. The Fort Belknap Reservation lies partially within four water court subbasins: the Milk River, Peoples Creek, Beaver Creek, and a small tributary to the Missouri River. Within the Milk River Basin is a large Reclamation Project built after establishment of the Reservation. The Milk River Project includes the diversion of water from the St. Marys River to the Milk River.

SUMMARY OF PROVISIONS

Quantification of the Tribal water right is summarized below.

Milk River

- 645 cubic feet per second (cfs) of water from the Milk River mainstem, limited by:
- 125 cfs of natural flow for direct use to irrigate a maximum of 10, 425 irrigated acres;
- 520 cfs of direct use and/or off-stream storage up to 60,000 afy, for historic and future irrigated acres and non-irrigation uses.
- Tributary water use
- Small impoundments for stockwater use
- Existing non-irrigation use

Water use on tributaries upstream from the Reservation is protected from the seniority of the Tribes' October 17, 1855 priority date by an agreement with the Tribes to seek satisfaction of their water use from the Milk River Project when upstream water use affects Tribal ability to divert water. The Project will be made whole through mitigation measures discussed below.

Peoples Creek

The Tribes are entitled to all the water in the stream after satisfaction of upstream water rights. A reservoir proposed on Peoples Creek on the Reservation is proposed to help keep water in the stream for stockwatering, fisheries and recreation.

Beaver Creek

The Tribes are entitled to historic senior irrigation of 2,241 acres, which uses 8,024 afy, plus new small impoundments for stock watering and 180 acres of new irrigation.

Missouri River Basin

The Tribes are entitled to historic senior stock and domestic uses and new small impoundments for stock watering on the Reservation. The Tribes have the right to divert up to 1135 afy for irrigating 297 historically irrigated acres and 18 acres of other land. They may divert 1290 afy for conveyance to Peoples Creek Basin. Water rights acquired with land purchased off the Reservation are recognized and will be administered pursuant to State law.

Groundwater

* Development of groundwater that is connected to surface water is counted within the limits on surface water use as listed above.
* Existing groundwater use is recognized.
* Groundwater that is not connected to surface water may be developed without adverse effect on other water uses
* Small wells of 35 gallons per minute (gpm) or less may be developed.

IMPLEMENTATION

* The Tribes administer the Tribal Water Right
* The Tribes establish a process for recognizing water rights allocated to allotted land.
* The Tribes establish a process for recognizing water use on fee land within the Reservation.
* The U.S. Bureau of Indian Affairs administers BIA Projects. Irrigation companies administer BIA projects quit claimed to them.
* The U.S. Bureau of Reclamation administers its contracts in the Milk River Project.
* The State administers state-based water rights.

To coordinate between these entities in the Milk River Basin, the Compact establishes the Milk River Coordinating Committee composed of representatives of the Tribes, the Milk River Joint Board of Control, the U.S. Bureau of Reclamation, the U.S. Bureau of Indian Affairs, and the Montana Department of Natural Resources and Conservation. The purpose of the Milk River Coordinating Committee is to:

(1) coordinate storage and release of water between the various entities; and

(2) implement a grant and loan program for funding of watershed and efficiency improvements in the Milk River basin and establishment of a water bank during periods of extreme drought.

The parties will seek appointment of water commissioners in state court for the distribution of water from the mainstem of the Milk River to ensure enforcement of water rights.

The Compact establishes a process for assuring that change in use of either a portion of the Tribal Water Right or a state-based right, does not adversely impact any other water right in the basin.

A Compact Board is established to resolve disputes within the Milk River Basin that are not within the authority of the water commissioner, and within the other three basins.

DEVELOPMENT OF THE TRIBAL WATER RIGHT

The Compact contemplates new development of water by the Tribes. Funding and authorization for specific projects must occur in federal legislation which will be negotiated following State and Tribal approval of the Compact.

MITIGATION

To keep the Milk River Project "whole" after development of the Tribal Water Right, the Compact contemplates improvements to the Project including increased storage and improved utilization of existing storage. The Milk River Project is a federal project, thus Congressional authorization is necessary to accomplish mitigation. State and Tribal approval of a Compact is necessary prior to drafting of a federal bill. Cost share between the State and United States cannot be negotiated until that time. The Compact allows the Governor, on behalf of the State, to withdraw from the Compact if mitigation measures are not ultimately agreed to, authorized, funded, and built.

The importation of water from the St. Marys River as part of the Milk River Project is recognized as key to continuation of the Project and to the ability of the Project to satisfy the Tribal Water Right. The St. Marys diversion is in need of rehabilitation. It is not clear that Compact legislation is the best means to accomplish rehabilitation of St. Marys. The parties to the Compact have agreed to work together and with the Blackfeet Tribe and the Milk River Irrigation Districts to determine the most appropriate means to ensure the integrity of the St. Marys diversion.

BLACKFEET WATER RIGHTS COMPACT

INTRODUCTION

The Blackfeet Indian Reservation is located east of Glacier National Park and borders the Canadian province of Alberta. Cut Bank Creek and Birch Creek make up part of its eastern and southern borders. The reservation contains 3,000 square miles (7,800 km2), half again the size of the national park and larger than the size of the state of Delaware. It is located in parts of Glacier and Pondera Counties.

Elevations in the reservation range from a low of 3,400 feet (1,000 m) to a high of 9,066 feet (2,763 m) at Chief Mountain. The eastern part of the reservation is mostly open hills of grassland, while a narrow strip along the western edge is covered by forests of fir, spruce and aspen. Free-ranging cattle are present in areas throughout the reservation.

Several waterways drain the area with the largest being the St. Mary River, Two Medicine River, Milk River, Birch Creek and Cut Bank Creek. There are approximately 175 miles (282 km) of streams and eight major lakes on the reservation.

After 20 years of negotiations, a compact settlement between the Blackfeet Tribe, the United States and the Montana Reserve Compact Commission passed the Montana legislature in 2009. The

compact will provide water and economic development for the Blackfeet while protecting the rights of water users locally and downstream on the Milk River. The compact was first introduced in Congress in 2010. More recently, Montana Senator Max Baucus introduced SB 434 to the Senate Committee on Indian Affairs on March 4, 2013. On May 8, 2013, a hearing was held to consider the bill, but no action has occurred since that time.

SUMMARY OF PROVISIONS

- Provides water for the existing and future needs of the Blackfeet Tribe.
- Protects all current holders of non-irrigation water rights, such as domestic and stock water uses, from the Tribe's future exercise of its water right.
- Provides protection for all current irrigation and non-irrigation uses in Birch Creek and the Badger Creek and Two Medicine River basins and a grace period before Tribal development in Cut Bank Creek and Milk River drainages.
- Provides a process for the Tribe to lease a portion of its water right to off-reservation water users.
- Settles Tribal claims in the St. Mary River basin by providing the Tribe with an allocation of 50,000 acre-feet of water with protections for the Milk River Project downstream.
- Closes on-reservation portions of streams to new water appropriations under state law.
- Provides for Tribal administration of the Tribal Water Right, and State administration of water rights arising under state law.
- Creates a Compact Board with an administrative process for the resolution of any future disputes between Tribal and non-Tribal water users.
- Provides for an allocation of water stored in Tiber Reservoir (in an amount to be determined by Congress) for the Tribe to use or market.

Mitigates the impacts of the Tribe's water rights on Birch Creek water users through a separate Birch Creek Agreement that commits the State to pay the Tribe $14.5 million in exchange for the Tribe deferring new development of its Birch Creek water rights for 15 years and providing 15,000 acre-feet of water per year to Birch Creek water users from on-reservation storage for at least 10 more years, the total deferral and provision of water not to exceed 25 years.

BIRCH CREEK

- 100 cfs from the natural flow of Birch Creek for irrigation use in the Upper Birch Creek Drainage.
- Instream flow of 25 cfs from April 1 to Sept. 1 and 15 cfs from Oct. 1 to March 31.
- Any additional water remaining after satisfaction of existing rights arising under State law
- A management plan is attached as an Appendix to the Compact, which provides for coordinated management of Birch Creek Tribal and non-Tribal water use.

BADGER CREEK/TWO MEDICINE RIVER

- The Tribe has a water right to all currently unappropriated surface water and groundwater. Current non-Tribal water uses are not subject to a call from new Tribal development.
- Instream flow of 20 cfs in both Badger Creek and Two Medicine River.
- Blackfeet Irrigation Project will be supplied water from the Tribal water right and will be administered by the Bureau of Indian Affairs (or as otherwise provided by Congress).

CUT BANK CREEK AND MILK RIVER

- The Tribe has a water right to all currently unappropriated surface water and groundwater. Current non-Tribal non-irrigation water uses are not subject to a call from any new Tribal development.
- Irrigation uses on Cut Bank Creek and the Milk River are subject to a call from Tribal water uses. The Tribe will not develop new irrigation uses on Cut Bank Creek or the Milk River, except projects using exclusively stored or imported water, for 10 years from the effective date of the Compact.
- Instream flow of 2 cfs in the on-reservation portions of both Cut Bank Creek and the Milk River.

ST. MARY RIVER

- 50,000 acre-feet from the United States' share of the St. Mary River. ,
- The Tribe also has a right to all unappropriated water from the U.S. share of Lee Creek, Willow Creek and groundwater in the St. Mary River drainage on the Reservation and any additional water remaining after satisfaction of existing rights arising under State law.
- Current non-Tribal water uses within the Basin are not subject to a call from new Tribal development.

CONTRIBUTIONS TO THE SETTLEMENT

The Montana legislature appropriated $15 million for mitigation during the 2007 regular session. Of these funds, $14.5 million will eventually be paid to the Tribe as part of the Birch Creek Agreement negotiated between the State and the Tribe in 2007. $500,000 was appropriated to the DNRC for engineering studies for the Four Horns Project.

- HB 161 appropriates $4 million toward the State's $20 million cost share commitment to the repair and enlargement of the Four Horns Reservoir system.
- Federal cost share will be determined during Congressional ratification of the settlement.

FEDERAL COMPACTS IN THE LOWER MISSOURI RIVER BASIN

BOWDOIN NATIONAL WILDLIFE REFUGE COMPACT

INTRODUCTION

Bowdoin National Wildlife Refuge, located in Phillips County near Malta, was established in 1936 and expanded in 1940 to be a refuge and breeding ground for migratory birds. The now-15,551 acre Refuge is utilized by nearby communities as an environmental education resource and it draws in tourist dollars for sightseeing and hunting. Most of the Refuge lands were originally part of the Bureau of Reclamation's Milk River Project.

The lands comprising the Refuge sit in a low-lying area alongside the floodplain of Beaver Creek in what is thought to be an old oxbow of the pre-ice age Missouri River. Historically, these lands were fed by large floods that spilled out of the banks of Beaver Creek, creating wetlands. With the development of the Milk River Project, these lands began to receive irrigation return flows from the Project along with some direct deliveries via the Dodson Canal. Diking installed after the creation of the Refuge reduced the ability of the Refuge lands to receive flood flows from Beaver Creek. At the same time, water development upstream has contributed to a reduction of those flows on Beaver Creek, further diminishing the supply of fresh water available to the Refuge. In the early years of the Refuge, FWS managers tried to conserve their water supply by limiting the volume of water released from the Refuge. This in turn caused a buildup of salts, which, for a time, was desirable because it created a saline ecosystem that was very good for waterfowl. But as salts continued to increase and water quality laws became more stringent, the Refuge was prohibited by law from releasing any water at all. Irrigation return flows have also become a source of additional salt which continue to accumulate in the Refuge. Currently, the only way salts can escape the Refuge is when winds blow salt crusts away, or when large Beaver Creek floods enter the refuge wetlands and push some of the saline water downstream into Beaver Creek. Neither of these are sustainable management strategies, especially as large salt/dust storms and occasional releases of saline water have caused problems on neighboring properties. The Refuge is presently embarking on a comprehensive planning process to determine how best to address its long-term management options. Quantifying the Refuge's federal reserved water rights in the proposed Compact is a first step toward ensuring the sustainability of the Refuge as positive rather than negative part of its community.

SUMMARY OF PROVISIONS

The Compact recognizes federal reserved water rights for the Bowdoin National Wildlife Refuge from three sources – surface flows from Beaver Creek, surface flows that drain naturally into the Refuge (predominantly from Black Coulee), and ground water. These water rights may be used for the purposes of the Refuge, including wildlife maintenance and enhancement, stock watering, and administrative, institutional, dust suppression and emergency fire suppression uses. These federal reserved rights are subordinated to all water rights existing under State law as of the Effective Date of the Compact, as well as to all future development excepted from State permitting law (such as small domestic and stock uses). The Refuge's federal reserved rights are also conditioned on the

execution of a Memorandum of Understanding (still being developed) that will establish additional restrictions on the use of these rights to ensure that they do not exacerbate the Refuge's salt problems. It is also worth bearing in mind that the Water Court basin in which the Refuge is located (Basin 40M) was closed to new surface appropriations by the Legislature in 2001 as part of its ratification of the Ft. Belknap Water Rights Compact. Below is a summary of the key provisions of the Compact.

Subject to the subordination requirement, the Compact assigns the FWS federal reserved water rights for:

- 24,714 acre-feet per year from Beaver Creek;
- Surface flows in Basin 400 that drain naturally into the Refuge;
- 223 acre-feet per year of ground water extracted from any source from wells located on the Refuge;
- 5300 acre-feet per year of deep ground water extracted from wells located on the Refuge that must be drilled into geologic formations dating to the Jurassic Period or older

DEEP GROUND WATER

A relatively unique aspect of this Compact is the manner in which it addresses the Refuge's ground water rights. In the negotiations, FWS made a request for recognition of a significant ground water right. The RWRCC was concerned about the potential impacts of such a right for two reasons. First, the RWRCC wanted to ensure that any such right would not harm existing users. Second, RWRCC worried about the risk to those who might develop a ground water right in the future who could potentially still be displaced by the FWS by virtue of the senior priority of an undeveloped federal reserved right. At the same time, the RWRCC recognized that the introduction of new water into a water short area would be of benefit to both the FWS and the off-Refuge community. The Compact's subordination provisions addressed the RWRCC's first concern. The second concern is addressed by requiring that the bulk of FWS' ground water right may only be satisfied with water extracted from such a deep aquifer that the FWS would not to be able to deplete it unilaterally. For legal purposes, this depth requirement is defined in the Compact as a requirement that the FWS may only exercise the right by drilling wells into geologic formations of the Jurassic Period or older. Such formations are likely located at least 2600 feet beneath the Refuge's surface, and are relatively straightforward for a well driller to identify. The Compact also requires the FWS to comply with State permitting requirements (including water quality standards) prior to developing its deep ground water right.

The Compact settles all federal reserved water rights of the FWS on behalf of the Refuge. FWS and the RWRCC remain in negotiation over FWS federal reserved water rights claims for the C.M. Russell National Wildlife Refuge and the National Bison Range. FWS also retains one claim on behalf of the Refuge based in state law that is in the adjudication process and is not part of this agreement. Nothing in this Compact recognizes a federal reserved water right for the Refuge from the Milk River or from water claimed by the U.S. Bureau of Reclamation or other water users on behalf of the Milk River Project.

UPPER MISSOURI NATIONAL WILD AND SCENIC RIVER

The Compact between the State of Montana and the U. S. Department of the Interior, Bureau of Land Management (BLM) settles the reserved water rights for the Upper Missouri National Wild and Scenic River and the Bear Trap Canyon Public Recreation Site. The Compact passed the Montana legislature in 1997 and was signed by federal officials on September 10, 1997. Mont. Code Ann. § 85-20-501 (2007).

UPPER MISSOURI NATIONAL WILD AND SCENIC RIVER

Designated by Congress as a component of the Wild and Scenic River System on October 12, 1976, the designation includes 149 miles of the Missouri River corridor from Fort Benton downstream to Fred Robinson Bridge.

The RWRCC and the BLM were unable to agree on primary purposes for quantification of the reserved water right, but agreed that when Congress designated the Wild and Scenic River it anticipated that future State development would occur.

SUMMARY OF PROVISIONS

- The Compact sets aside a large volume of water by month to meet future State demands. This volume is sufficient to irrigate approximately 100,000 acres of new direct-flow full-service irrigation and municipal and industrial needs plus approximately 500,000 acre-feet of new storage. Domestic, small groundwater, non-consumptive, supplemental, lawn and garden, instream stock uses, late claims, and other federal and Indian reserved water rights are not counted against the State's available water supply. Once the State has exhausted the available water supply, the basin above the downstream boundary of the Upper Missouri National Wild and Scenic River will be closed to new appropriations for that month. The reserved water right for instream flow is limited to the water left after the State's future development.
- The Compact protects all existing water rights, permits and water reservations.
- No new impoundments are allowed on the Missouri River mainstem without U.S. consent.
- BLM does have not standing to object to new appropriations or changes in appropriation.
- No appropriations prior to October 12, 1976 will have terms, conditions, or limitations as result of this agreement.
- BLM cannot make a call on the Missouri River to require junior users to let water pass.

UPPER MISSOURI BREAKS NATIONAL MONUMENT COMPACT

INTRODUCTION

In January 17, 2001, the Upper Missouri River Breaks National Monument was officially added to the Department of the Interior's National Landscape Monument System. This national monument includes an ecosystem that parallels the Upper Missouri National Wild and Scenic River through north-central Montana. Much of the land in this area (375,000 acres) is public land managed by the Bureau of Land Management. In some areas, these BLM acres are intermingled with State of Montana lands and private property. This designation applies only to the BLM managed lands.

The monument contains essential winter range for elk, pronghorn antelope, sage grouse as well as habitat for prairie dogs. The lower reach of the Judith River, just above its confluence with the Missouri, contains one of the few remaining fully functioning cottonwood gallery forest ecosystems on the Northern Plains. Arrow Creek, originally called Slaughter River by Lewis and Clark, contains important spawning habitat for the endangered pallid sturgeon and is a critical seed source for cottonwood trees for the flood plain along the Missouri.

SUMMARY OF PROVISIONS

1. **No reduction in the amount of water available for future development** in the Judith Basin as a result of this compact.

2. **Continued exception to permitting for domestic wells, stock ponds,** and other uses that meet the requirements for exception to permitting as listed in 85-2-306 MCA. These uses will not be subject to call by the BLM under the specifications of this compact.

3. **Water Right:** In settlement of the Monument's Reserved Water Right claim, a water right is granted on both the Judith River and Arrow Creek.
   a. Judith River: The Judith River water right is in the amount of 160 cubic feet per second (cfs) measured at the USGS gaging station near the confluence of the Judith River with the Missouri River. The period of use is January 1 through December 31 of each year. This right shall run concurrently and junior in priority to a Montana Fish, Wildlife & Parks right for the same source, flow rate, and period of use.
   b. Arrow Creek: The Arrow Creek water right is in the amount of 5 cfs measured where the Monument boundary intersects with Arrow Creek. The period of use is March 1 through July 31 of each year. A proportionally lower flow rate at the may be determined at an alternate measurement point.

4. **Priority Date:** The reserved water right will have a priority date of January 17, 2001, but this reserved right will be subordinate to state-based permits with a priority date before June 1, 2012.

5. **Restriction on Mainstem Impoundments:** New mainstem impoundments under this Compact not otherwise excepted from permitting requirements under Montana law will not be permitted on the following reaches of the Judith River and Arrow Creek. Off stream impoundments will continue to be permitted under DNRC permitting procedure.
   a. Judith River: from the confluence of the Middle and South Forks of the Judith River downstream to its confluence with the Missouri River.
   b. Arrow Creek: from its confluence with Hay Creek downstream to its confluence with the Missouri River.

6. **Ramped Diversion Requirement:** Flows on both the Judith River and Arrow Creek that have not already been appropriated as of the date of this Compact will be available for future state-based development, subject to the Reserved Water Right and applicable permit restrictions. New permits issued after the date on which this Compact is ratified will be subject to a ramped diversion requirement for diversions greater than 20 cfs capacity. Direct from source diversions from the Judith River and Arrow Creek that have a diversion capacity greater than 20 cfs will be allowed an increase in diverted water of no more than 20cfs per 24 hour period.

CHARLES M. RUSSELL NATIONAL WILDLIFE REFUGE COMPACT

INTRODUCTION

Extending 125 miles up the Missouri River from the Fort Peck Dam in north-central Montana, the Charles M. Russell National Wildlife Refuge (CMR) is approximately 1,100,000 acres in size and includes the 245,000-acre Fort Peck Reservoir. The Refuge was established in 1936 and sharp-tailed grouse and pronghorn antelope were identified as the primary species in need of conservation. The overall management goal at Charles M. Russell NWR Complex is to promote biological diversity and maintain the natural abundance of native flora and fauna.

The negotiated compact was ratified by the 2013 Montana Legislature and signed by the Governor. The ratified compact quantifies a federal reserved water right consisting of base flows in sixty-nine streams draining onto the refuge, and implements limitations on larger on-stream impoundments on selected streams.

SUMMARY OF PROVISIONS

1. **Priority Date** - The ratified compact subordinates the United States' 1936 priority date to 2013.

2. **Water Right**. In settlement of the Refuge's federal reserved water right, the following rights will be recognized:

   a. A quantified right of ½ or 1 cfs in 68 named streams draining onto the refuge for instream use to benefit stock, wildlife, and wildlife habitat. The place of use is from the point where

the Refuge boundary crosses each named stream to its confluence with Ft. Peck Lake or the Missouri River. The period of use is March 1 to June 30.

b. A minimum instream flow right of 70 cfs in the Musselshell River measured where the mainstem river enters USFWS owned land within the Refuge. The place of use is from the point where the mainstem river channel enters USFWS land on the refuge to its confluence with Fort Peck Lake. The period of use is from March 1 to June 30. This right shall run coextensively with and junior to the Montana Fish, Wildlife & Parks right for the same source and flow rate. This right will be enforceable when the flow on the Musselshell falls below 70 cfs for 5 consecutive days.

c. Filed rights to wells, ponds, and developed springs. The claims that are consistent with the purposes for which the Refuge was established will be incorporated into the Reserved Right and withdrawn from the adjudication.

3. **Conditions to be applied to permits issued after the Effective Date of the compact**. On streams with a quantified right, the DNRC may issue new permits subject to the Reserved Right. On the stream reaches identified in Appendix 5 on the map titled "Article IV.C. Protected Reaches for On-Stream Impoundment Limitations," no new on-stream impoundments may be constructed after the Effective Date of this compact, with the following exceptions:

    a. On-stream impoundments less than 15 AF capacity allowed;

    b. On-stream diversion works to serve off-stream impoundment 15 AF or larger allowed;

    c. On-stream impoundments 15 AF or larger allowed upstream of restricted reach;

    d. On-stream impoundments 15 AF or larger allowed on tributaries of restricted reach.

3. Interstate Compacts and International Treaties,

Description

BOUNDARY WATERS TREATY OF 1909

The Milk River originates in the Montana Foothills and flows north east into Alberta. Once in Alberta, the Milk river travels parallel to the Montana border for about 100 miles before turning south east and crossing back into Montana. The St. Mary River originates in the high mountain areas of Glacier Park in Montana and flows north into Alberta. The St. Mary continues north for about 60 miles before emptying into the Oldman River and becoming part of the Saskatchewan River system.

As the St. Mary and Milk Rivers both originate in western Montana and flow north into Alberta, the origin and path of the flow mean that water negotiations concerning the two rivers are international. When the Boundary Waters Treaty of 1909 between Canada and the United States was signed the division of the flow of the St. Mary and Milk Rivers between Canada and the United States was specified in Section VI.

The Treaty also established the International Joint Commission (IJC) composed of three members from Canada, and three from the United States, to examine and report on any issues referred to it by the member nations.

1917 DIVERSION OF THE ST. MARY RIVER

In 1917 the United States constructed a canal to divert water from the St. Mary River in western Montana to the Milk River. The diverted water flows in the Milk River channel into Alberta and is conveyed across southern Alberta for irrigation in eastern Montana. The project's objective was to provide a stable source of water for irrigation in the lower Milk River Valley. The plan to divert water from the St. Mary's river to augment flows in the Milk River emerged to become the largest and most ambitious trans-basin diversion project of the time.

1921 ORDER OF THE INTERNATIONAL JOINT COMMISSION (IJC)

Tthe United States and Canada could not agree on how the Treaty of 1909 should be interpreted nor could they agree on how water was to be measured or apportioned with regard to the St. Mary and Milk Rivers. The Canadian position was that the prior apportionment specified in the Treaty should be subtracted from the total flow of the two rivers prior to their equal sharing and river flow to be shared should be based on the flow at the mouth of the two rivers.

In 1921, after six years of hearings in Canada and the United States, and a legal reconstruction of intent, the IJC issued an order with rules clarifying how measurement and apportionment would take place.

- Prior appropriations could be excluded from being shared equally.
- The flow to be shared is the flow at the final border crossing of each river.

ST. MARY RIVER AND MILK RIVER: ONGOING ISSUES

In 2003 Montana wrote to the International Joint Commission stating the 1921 Order was unfair and requested it be opened for review. In 2004 the International Joint Commission held public hearings to determine if the 1921 Order should be reviewed regarding the interpretation of how the water from the two rivers is shared.

- In 2005, the IJC established a Joint Task Force of technical staff from Canada and the United States, as well as specifically from Alberta, and Montana, to review Administrative

Measures. These Measures are the actual calculation methods used to determine each countries' share of water based on the entitlement defined in the 1921 Order.

- Because the Joint Task Force was unable to reach consensus, they recommended that Alberta and Montana work together at a watershed level to address the issue. The IJC then approached the governments of Alberta and Montana with the request they work together to address how each country could get better access to their respective entitlements.

MONTANA – ALBERTA WATER MANAGEMENT INITIATIVE

The purpose of the Initiative is to explore and evaluate options for improving Alberta's and Montana's access to their respective share of the water of the St. Mary and Milk Rivers and make a joint recommendation on preferred options to provincial and state governments for their consideration and approval. The Premier of Alberta and the Governor of Montana have approved the Terms of Reference for the initiative. A joint initiative team has been appointed to explore options and make recommendations to the premier and governor. As of 2014, the issues addressed in the Montana/Alberta Water Management Initiative remain unresolved.

4. **Water Quality Laws**

Surface Water

Ground Water

Potential Future Demands for Water in the Lower Missouri River Basin

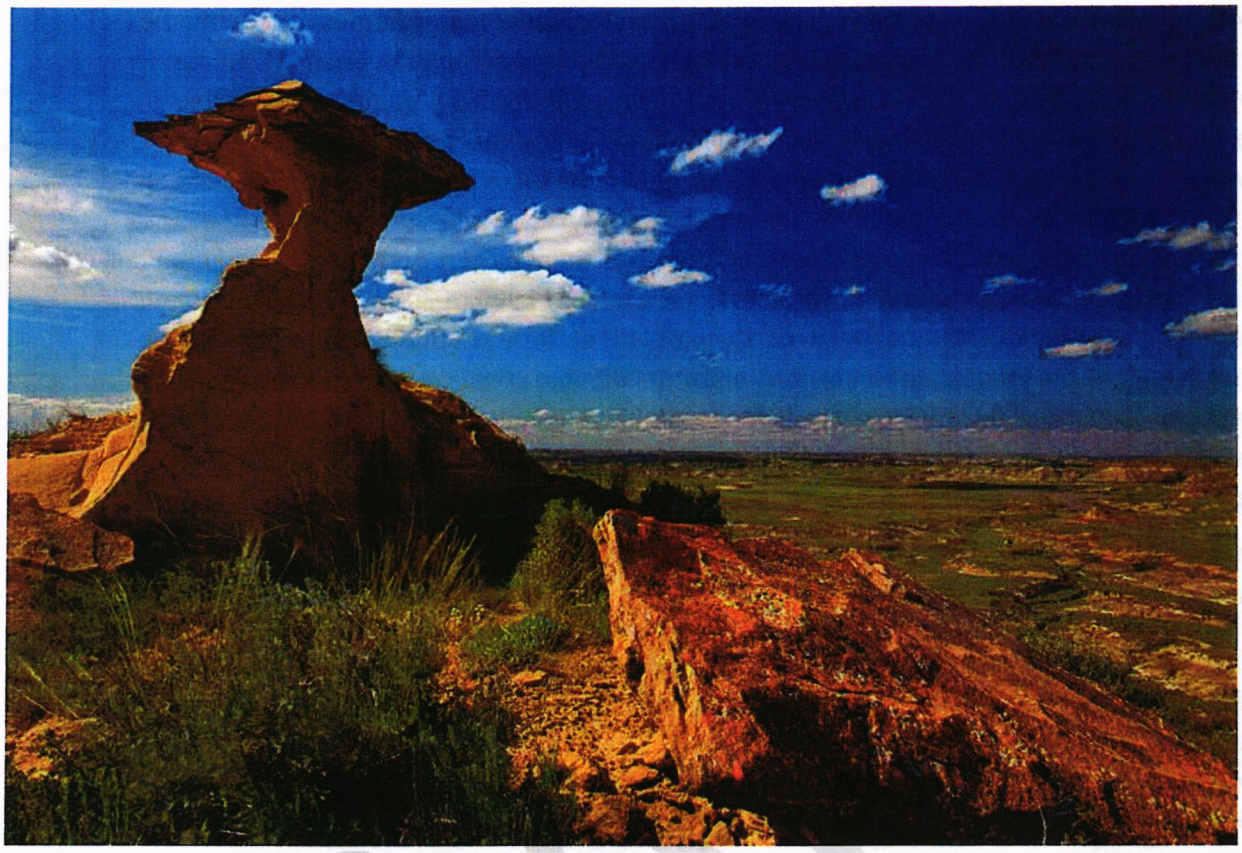
Overview of Planning Scenarios (assumptions, time horizon, etc.)

Estimates of water demand for public water supplies and self-supplied domestic for the twenty-year planning period ending in 2035 are based on population trends extrapolated from the 1990 and 2010 censuses and per-capita use rates. Population projections are provided at the state, county, planning basin, and sub-basin (4th-code, 8-digit HUC) levels. In those HUCs where negative growth was historically observed (54 HUCS, primarily located in the Lower Missouri and Yellowstone planning basins), zero population growth is assumed for planning purposes. The intent of these projections is not to predict or forecast precise population levels at particular points in time and locations in Montana; the purpose, rather, is to offer reasonable estimates of magnitudes of population growth that would presumably relate to the supply and demand for water in various ways over the course of the planning period. Extrapolating state-wide population growth at the average annual rate of population change for the period between 1990 and 2010 would result in 302,923 additional residents in 2035. If Montana's rate of growth were to continue at this rate, the state's population would reach 2 million in 2077.

Another set of population projections developed by the Montana Department of Commerce (MT Commerce) are available for comparison to the extrapolated census values. The MT Commerce projections are at the state and county levels developed using eREMI, a population projection product of Regional Economic Models, Inc. (REMI). Rather than extrapolate recent trends, the MT Commerce projections forecast declining rates of population increase through 2035, reflecting assumptions about Montana's age structure, natality and survival rates, and migration patterns over the period. Population increases forecast by the MT Commerce population are about half of the projections obtained by extrapolating census trends from 1990 to 2010. While the courses of population change in Montana and in particular parts of the state are highly uncertain from the perspective of the present, these projections offer two distinct scenarios for consideration when regarding prospects for future water use in Montana. They should be viewed as potentially useful tools in examining various factors affecting—and consequences affected by— the supply and demand of Montana's waters.

Scenarios of future demand for agricultural irrigation are based on trends in irrigation water use, and agricultural production statistics.

- Projections of future irrigated acres, by watershed, will be developed using extrapolation of historic trends from National Agricultural Statistics Service (NASS) data, and possibly other sources
- Future crop-type trends also will be assessed using trends from NASS data; water-use characteristics will vary as crop-type ratios change
- Trends in irrigation system types (for instance: sprinkler versus flood) also will be used to predict future irrigation efficiencies, and resulting required per-acre diversions and per-acre water consumption rates. Irrigation system types also will affect return flow patterns and potential changes to these patterns also will be taken into consideration
- Changes in the timing of irrigation demands and monthly crop irrigation requirements will be estimated for future scenarios and compared to historic conditions. Modeled temperature and precipitation projections will be used along with crop consumptive use equations to project future per-acre irrigation demands



Agricultural Demand Projections

Scenario 1: Less warming, wetter

Scenario 2: Median warming

Scenario 3: More warming, dryer

Tribal Future Agricultural Projects

Scenario 1: Less warming, wetter

Scenario 2: Median warming

Scenario 3: More warming, dryer

Municipal and Domestic Demand Projections

Population growth projections correspond directly to increased (or decreased) demands for domestic and municipal water uses. In order to estimate future domestic water demands, population projections were created for the LMRB to the year 2035. The projections were made for each HUC and were based on population trends during the period 1990 – 2010.

Much of the LMRB has exhibited a declining population. However, to avoid underestimation of future domestic water demand, stable populations were assumed and negative growth trends were eliminated. Because negative growth trends (declining populations) were replaced with zero loss or zero growth figures, the 2035 population projections, and therefore domestic water use, should be considered a maximum.

The LMRB is comprised of 34 HUCs, with a total 2010 population of 79,030 people. This represents only 8% of the total population of Montana, within a land area of about 34% of the state. Of the 34 HUCs, 27 lost population and only 7 gained population between 1990 and 2010. Based on these trends, total LMRB population is projected to drop to 70,871 people by 2035; a reduction of over eight percent (US Census Bureau).

The seven HUCs showing projected population increases are:

Battle Creek: a tributary to the Milk River located just north and east of Chinook.
Big Sandy Creek: a Milk River tributary located south of Havre on the west slope of the Bearpaw Mountains. This HUC includes a large portion of the Rocky Boy's Indian Reservation.
Flatwillow Creek: a major tributary of the Musselshell River in the lower basin.
Box Elder Creek: a tributary of Flatwillow Creek located east of Lewistown.
Milk River Headwaters: located on the Blackfeet Indian Reservation, north of Browning.
Peoples Creek: drains part of the Bears Paw and Little Rocky mountains and joins the Milk River near Dodson. This HUC contains a large portion of the Fort Belknap Indian Reservation.
Upper Musselshell River: this large HUC contains the towns of Harlowton, Ryegate and Lavina.

Figure PG1 shows the projected population growth for HUCs with increasing populations in the LMRB. The Big Sandy and Peoples Creek HUCs show the largest increases in population at the year 2035. Both of these HUCs contain large portions of Indian Reservations, for which reserved water compacts have been completed.

The Big Sandy Creek projection shows a gain of 2,654 people, which represents a 67% population increase by 2035. The Peoples Creek projection shows a gain of 317 people, representing an increase of 23%. In the Upper Musselshell River HUC, the projected increase is 252 people, or a 5% gain above the 2010 population.

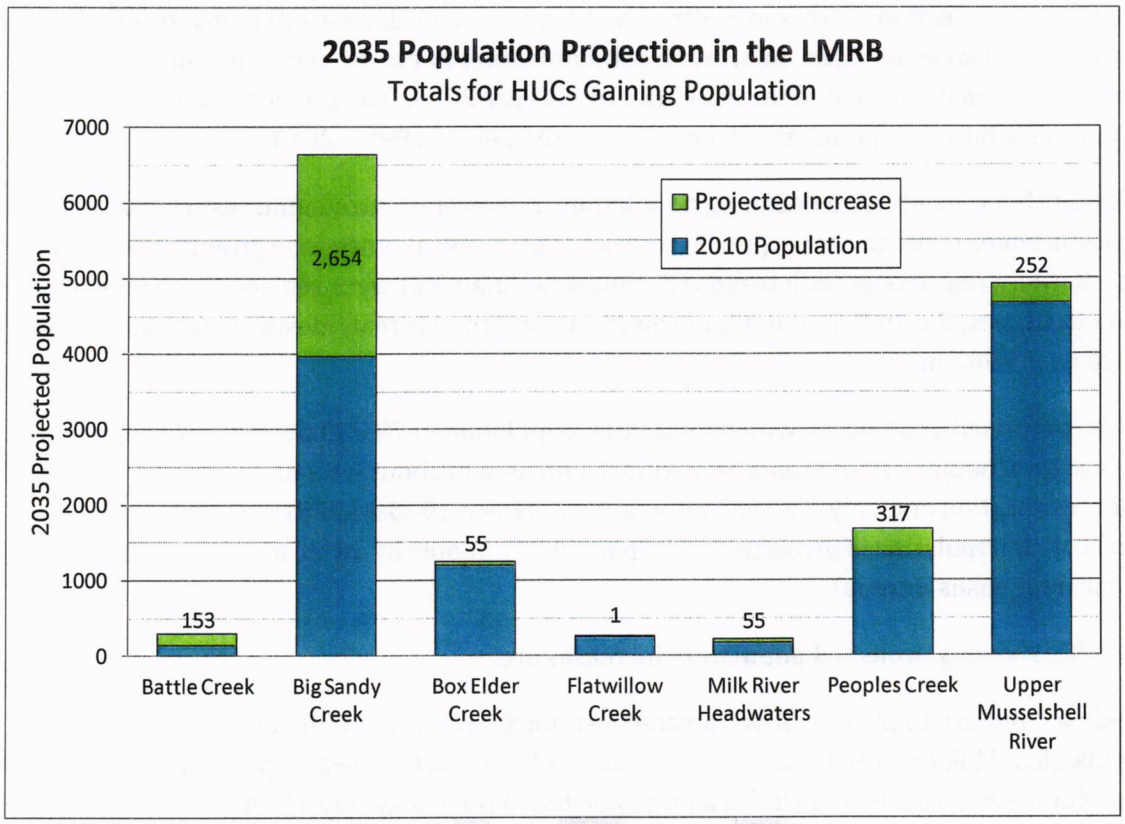


Figure PG1. Projected Population Growth for HUCs gaining population in the LMRB.

Based on the 2035 population estimate, the following assumptions were used to estimate future water demand in the LMRB:

1) Percentages of population by HUC served by Public Water Supply (PWS) and individual wells were assumed to be constant over time.
2) Percentages of PWS supplied by groundwater in each HUC are assumed to be constant over time.
3) Gallons per Capita Daily (gpcd) for PWS users in each HUC is assumed to be constant over time.
4) 37% of water diverted for PWS is consumed. This is consistent with present day (2010) estimates.
5) Self-Supplied Domestic Water (SSD) users = the total population in a HUC minus those served by PWS.
6) New SSD water use is assumed to be supplied entirely by groundwater.
7) SSD water use = 75 GPCD, of which 50% is assumed to be consumed. This is consistent with present day (2010) estimates.

Figure PG2 shows the current (2010) Public Water Supply demand, the projected increase in demand and the total demand of PWS at 2035 in LMRB HUCs that have a positive population growth trend. The figures are in acre-feet annually.

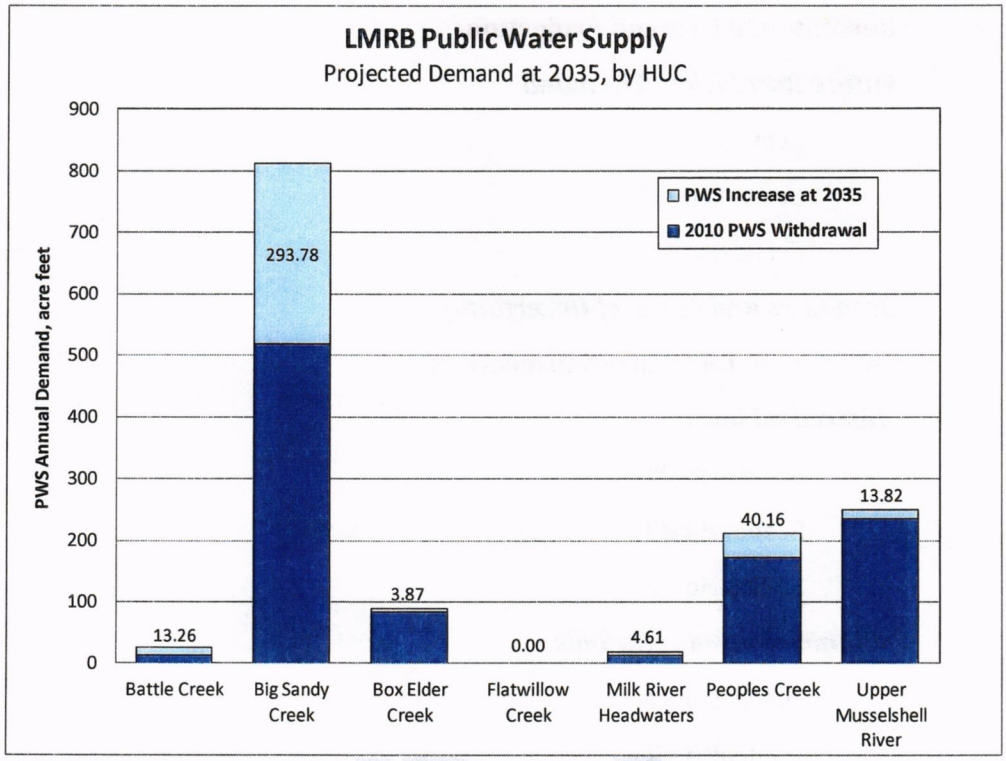


Figure PG2. Projected PWS Demand in 2035.

5. **Recreational Demand Projections**

Future Recreational Demand

Sceneario #1

Sceneario #2

Sceneario #3

Data Gaps and Areas of Uncertainty

6. **Environmental Demand Projections**

Instream Flows

Sceneario #1

Sceneario #2

Sceneario #3

Minimum Reservoir Pools

Sceneario #1

Sceneario #2

Sceneario #3

Minimum Releases and Reservoir Bypasses

Sceneario #1

Sceneario #2

Sceneario #3

Data Gaps and Areas of Uncertainty

7. **Identification of Potential New and Expanded Water Uses Unallocated Water to Meet Future Demand** *(Hydro - legal water availability analysis per Tim D.)*

8. **Availability of Water Supply Development Under Interstate Compacts, Decrees, Tribal Water Compacts, Federal Reserved Water Rights, and International Treaty's,** *(Impact of full development, Compact, Treaty , and Reserved water rights)This would be a smaller section in which issues would be considered and dismissed section would reference data presented under Part IV administration.*

Surface Water

Groundwater

Data Gaps and Areas of Uncertainty

9. Effects of New or Increased Depletions on the Availability of Future Surface Water Supplies.

Climate Variability

Climate may be defined as a prevailing set of environmental conditions in a region over a relatively long period of time. Meteorological variables, such as temperature, precipitation, wind, and snowfall describe average regional climatic conditions and their variability over time. Weather, on the other hand, may describe these same climatic conditions, but over the much shorter time scale of days, weeks or months. Atmospheric records indicate that the LMRB experiences large changes of weather in the short term and significant climatic variability over the long term.

A regional climate may be influenced by factors at the global scale, including climatic fluctuations connected to Pacific Ocean temperatures. Phenomena such as the El Nino Southern Oscillation (ENSO) can affect regional air temperature and precipitation for a series of years. Other dynamics, such as the Pacific Decadal Oscillation (PDO) can have effects that persist for decades. All of these factors can lead to variability in air temperatures and precipitation patterns, which affect regional water supply and demand. Drought cycles and periods of excessive moisture in Montana and in the LMRB are affected by these large-scale factors.

The El Nino Southern Oscillation (ENSO) can influence the timing and extent of wet and dry cycles in Montana. ENSO is attributed to changes in the near-surface ocean temperature of the South Pacific off the coast of South America, and can be characterized by warm, cool and neutral phases. The oscillation of these ENSO phases generally affects Montana and the Lower Missouri Basin as follows: (1) El Nino or warm phases are characterized by below average precipitation; (2) La Nina or cool phases are characterized by above average precipitation; and (3) ENSO neutral conditions have about an equal chance of above or below average precipitation. The Lower Missouri River Basin is highly dependent on snowfall and streamflow conditions in the upper basin, which are in turn influenced by ENSO.

The Multivariate ENSO Index (NOAA) presented in Figure 1 below uses several oceanic parameters to create an index of El Nino, La Nina or neutral conditions. In general, positive numbers (red) represent the warm El Nino conditions and the negative numbers (blue) represent the cold La Nina conditions. The strength of the El Nino or La Nina is indicated by a greater positive or negative number. Neutral conditions are indicated by values near zero.

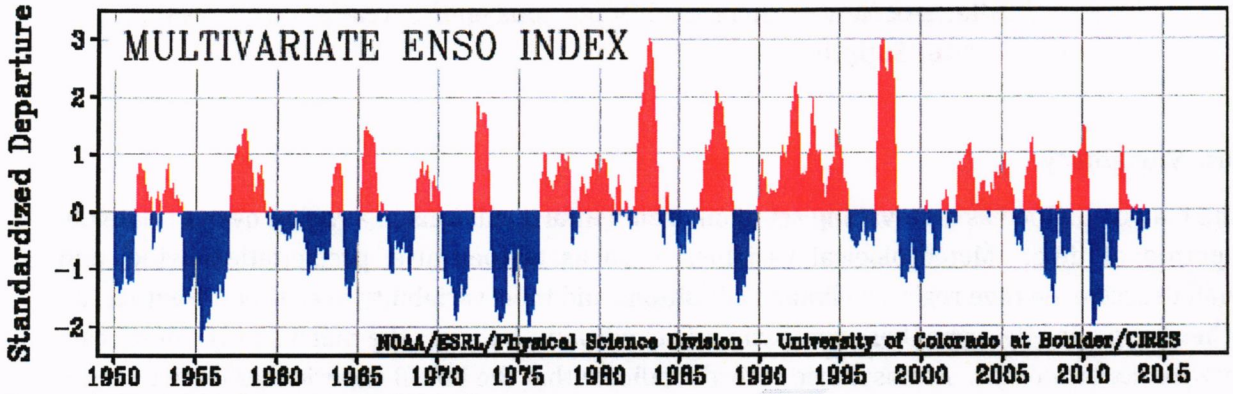


Figure 1: NOAA Multivariate ENSO Index.

The Pacific Decadal Oscillation (PDO) is described as changes in water temperature of the North Pacific Ocean, north of about 20 degrees latitude. The warm and cool phases of the PDO occur on an inter-decadal time scale, typically lasting 20-to-30 years. During the warm or positive phase, the west Pacific Ocean (near Japan and Korea) becomes cool, and the eastern Pacific (near the west coast of the US) warms. During the cool or negative phase, the opposite is true. The PDO index is shown in Figure 2 (JISAO). The strength of the warm or cool phase is indicated by the magnitude of the positive or negative index.

For the Lower Missouri River Basin, the warm phase (positive) of the PDO generally results in drier conditions and the cool (negative) phase typically results in wetter conditions. The data indicate that the PDO recently changed to the cool negative phase.

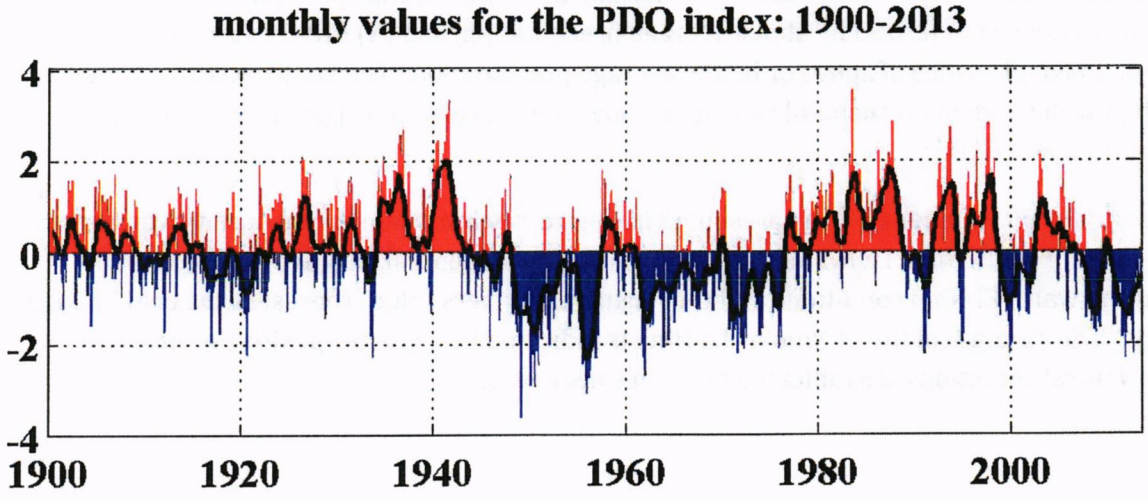


Figure 2. PDO index from 1900 to 2013.

Drought

Montana has experienced several periods of drought over the past century. Drought is a prolonged period of dryness or lack of precipitation that causes extensive damage to crops, forest and range resources, urban water supplies and other water-dependent resources. Duration is an important measure of drought severity, as the negative effects are magimified with longer-lasting droughts. Drought duration can range from a year or two to several continuous years, or even several years interrupted by a high water year. Aerial extent is also an important measure, since some droughts may be fairly localized while other droughts affect huge land areas.

Non-irrigated croplands, which are widespread in the LMRB, are highly susceptible to moisture shortages. Rangelands and irrigated crop lands are less susceptible to short term droughts, but all moisture related resources are eventually affected by longer duration moisture deficits.

Depending on location within the LMRB, recent drought periods include several years within the 2000's, the 1980's, the 1960's, the 1950's, and of course the 1930's Dust Bowl, which is regarded as the most severe, widespread and lost-lasting drought of recent history. But drought severity and duration during these time periods was not uniform across the state.

Figure D1 shows total annual precipitation at Culbertson for the 1930's, 1980's and 2000's, compared to the period of record annual average of 13.39 inches (WRCC, 2014). At Culbertson, several of the 1930's received near-average precipitation, but four years were well below normal, and 1934 received only 4.63 inches. During the 2000's, which harshly affected much of western Montana, Culbertson actually received above average precipitation during all but two years.

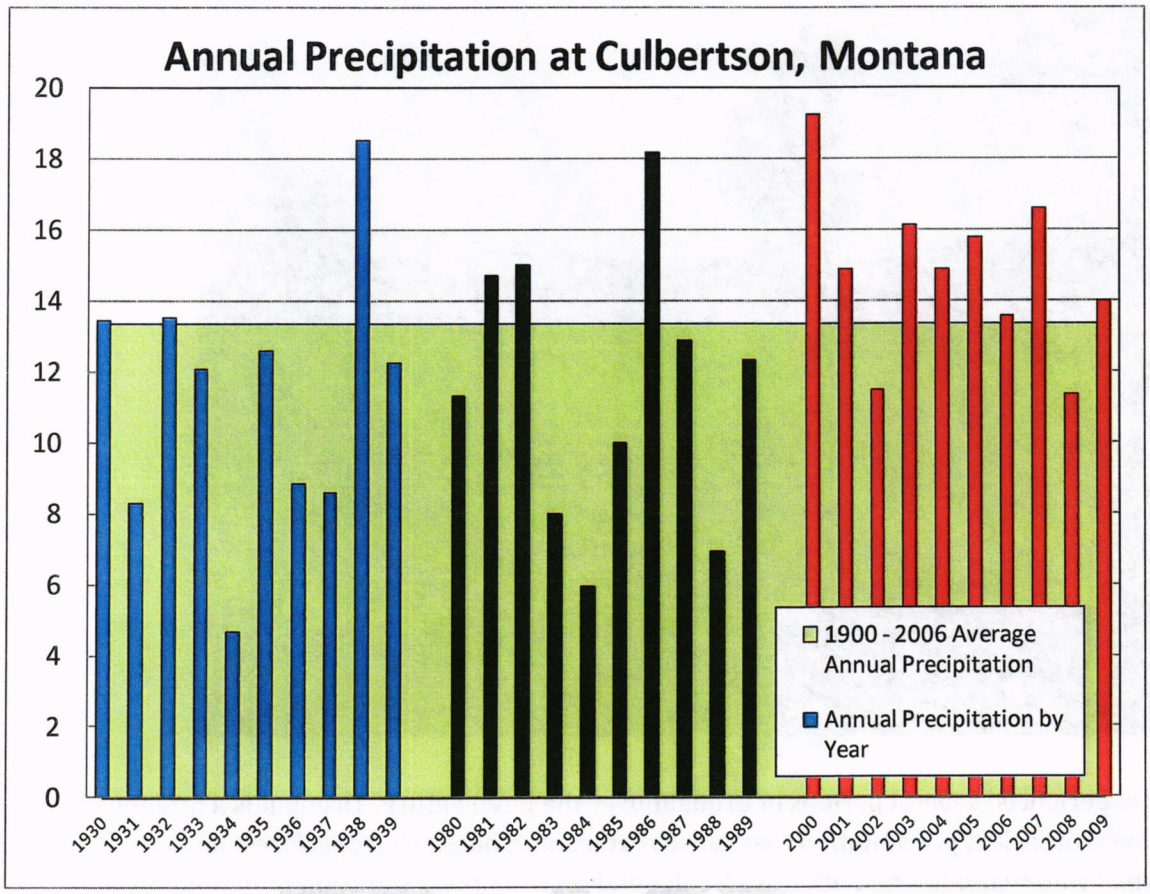


Figure D1. Comparison of Drought Period Annual Precipitation at Culbertson, Montana.

In the LMRB, it is difficult to compare the 1930's drought to that of more recent periods, especially in terms of surface water supply. The LMRB lacks stream gaging records from the 1930's. Reservoirs and other drought-mitigating infrastructure, as well as additional irrigation and other water-depleting uses, have been developed in the interim. However, an examination of existing precipitation records, reservoir operations and limited stream gage records may provide some insights.

Figure D2 compares the period of record monthly average flows against monthly average flows of the Poplar River at the International Boundary for the severe drought years of 1934, 1988, and 2003. The graph shows that 1988 was possibly the worst year on record in terms of summer water supply, and was much worse in this area than in the summers of 1934 and 2003. However, the drought in this area only lasted one or two years.

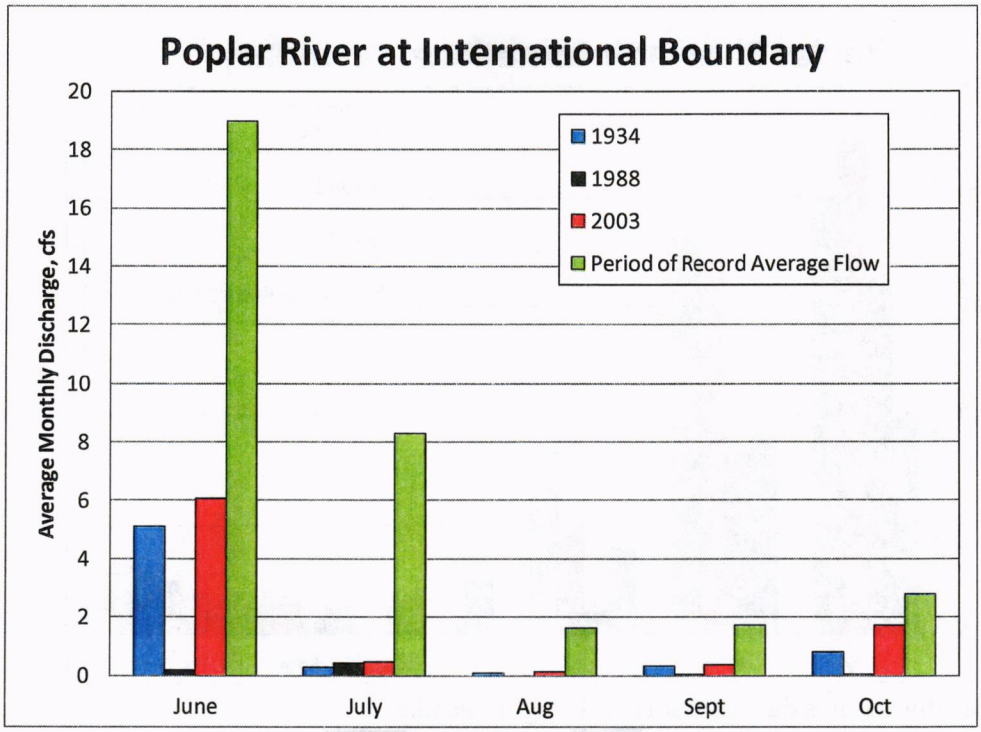


Figure D2. Comparison of average monthly flows for Poplar River at International Boundary.

A limited drought of even one year can be quite harmful to crops, forest resources, cattle or wildlife. However, multi-year droughts compound the damaging effects by further reducing soil moisture and groundwater supplies. Groundwater that is hydrologically connected to the surface supply is strongly influenced by climate and may take years to recover to normal levels following an extended drought period.

Figure D3 shows a more complete picture of Poplar River drought conditions over prolonged periods. In this graph, monthly flows are averaged over each decade.

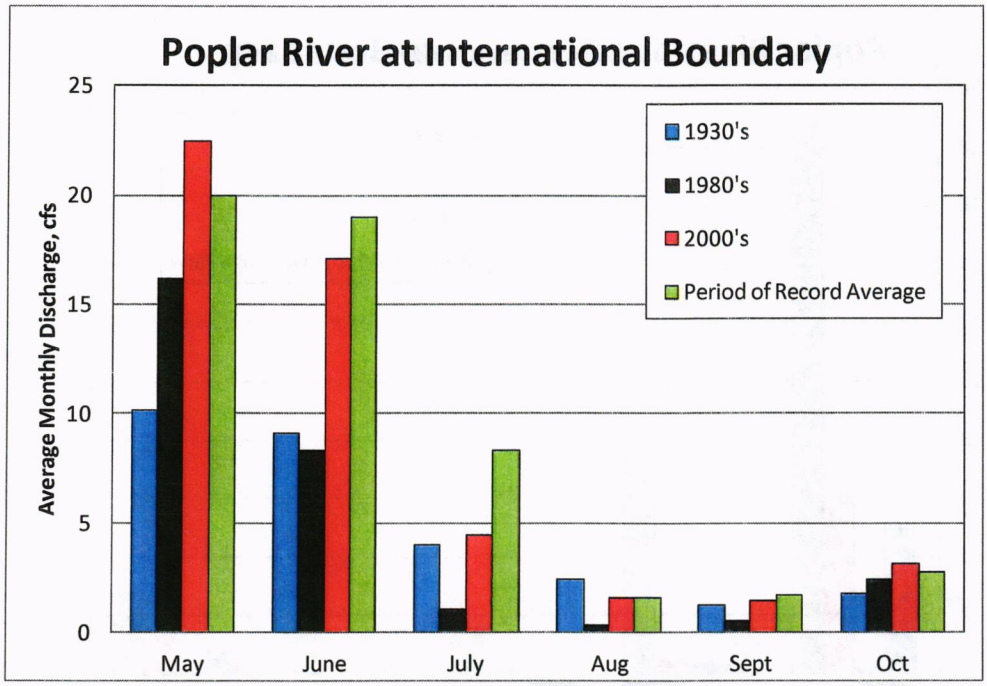


Figure D3. Poplar River flows during assorted drought decades.

The 1930's and 1980's drought periods show depleted flows during the spring and summer months, resulting from a lack of precipitation in the watershed. But except for a few years during the decade, the 2000's experienced relatively close to normal conditions at this location.

Prolonged drought can be very disruptive to reservoir management and to stored water contents. Figure D3 shows month-end contents at Fresno Reservoir for the 1980's and 2000's drought periods, compared to the period of record average month-end stored contents. For each decade, the averaged storage figures were well below the long term normal. Total deficit below normal stored content for the 1980's amounted to 195,000 acre feet, a shortfall of about 25%. The storage deficit for the 2000's totaled 236,000 acre feet, a shortfall of about 30%.

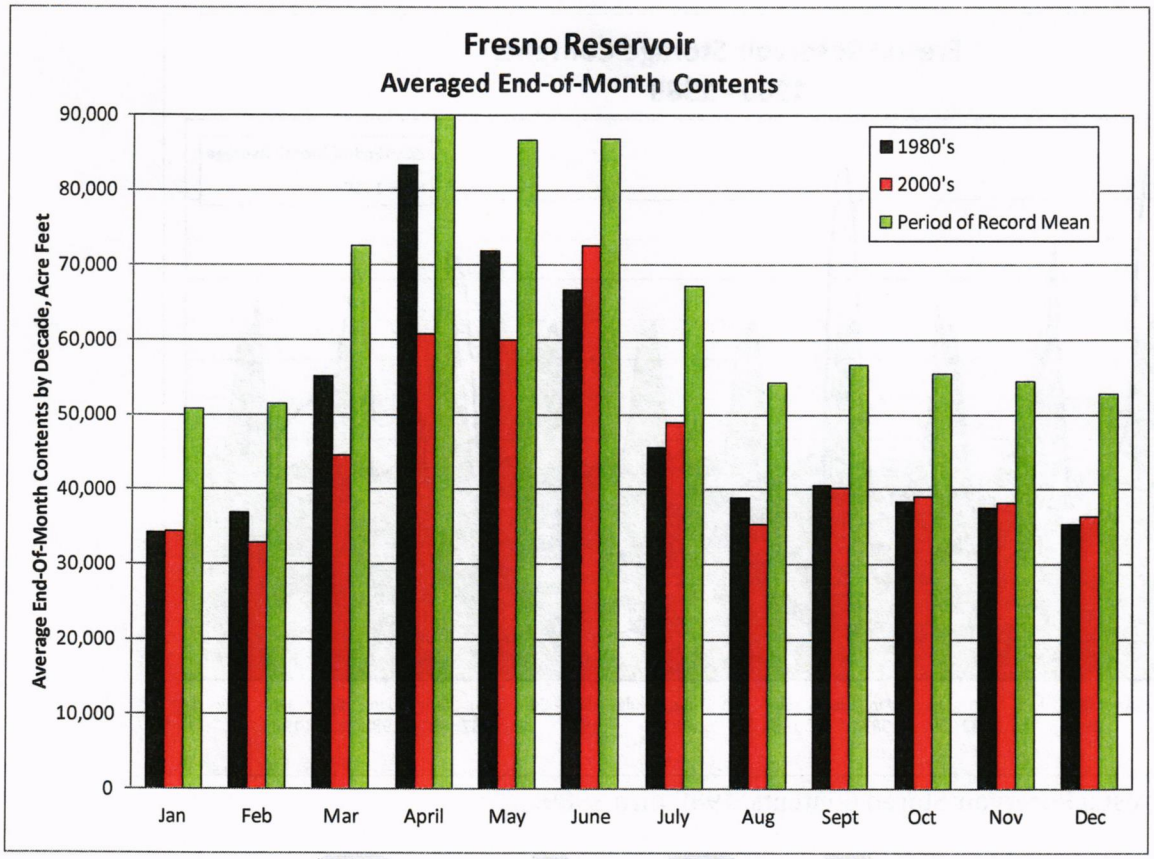


Figure D3. Comparison of Fresno Reservoir Contents during drought periods.

More revealing is the monthly record of stored contents for the reservoir. Figure D4 shows the monthly record for the 1980's compared to the historic average storage pattern. Storage deficits can be seen in the early 1980's mainly during August through February. With the drought progressively worsening, the mid-1980's were especially dry. Fresno Reservoir has a newly-mapped capacity of about 90,000 acre feet. But in February of 1990, stored contents dropped to only 5,124 acre feet. After recovering during the generally water-rich late 1990's, the reservoir again receded, dropping to 3,699 acre feet in March of 2002.

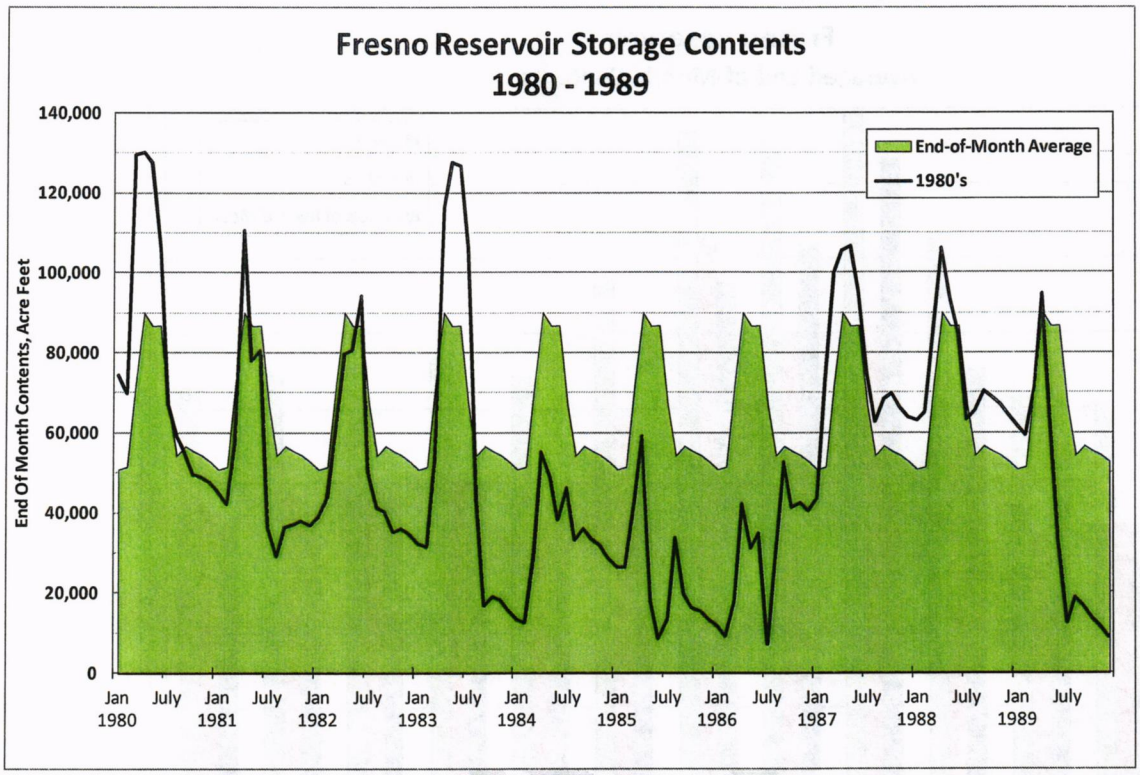


Figure D4. Fresno Reservoir Stored Contents, 1980 thru 1989.

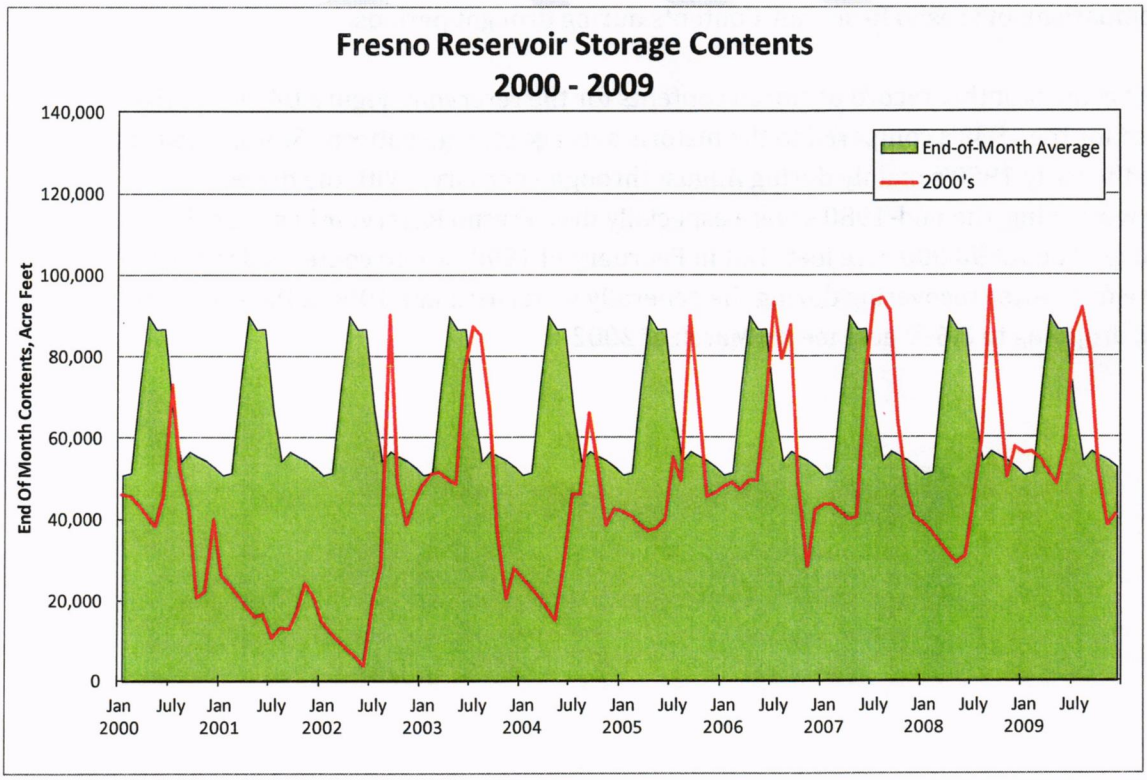


Figure D5. Fresno Reservoir Stored Contents, 2000 thru 2009.

According to the USBR reservoir allocation diagram (Figure D5 below), stored water contents below 59,898 acre feet are allocated to the Active Conservation pool, and are used to satisfy a variety of needs including fisheries, recreation, irrigation and municipal uses. The worst drought years of the mid 1980's and early 2000's saw stored contents much below 30,000 acre feet and impacts on supply were compounded by consecutive drought years.

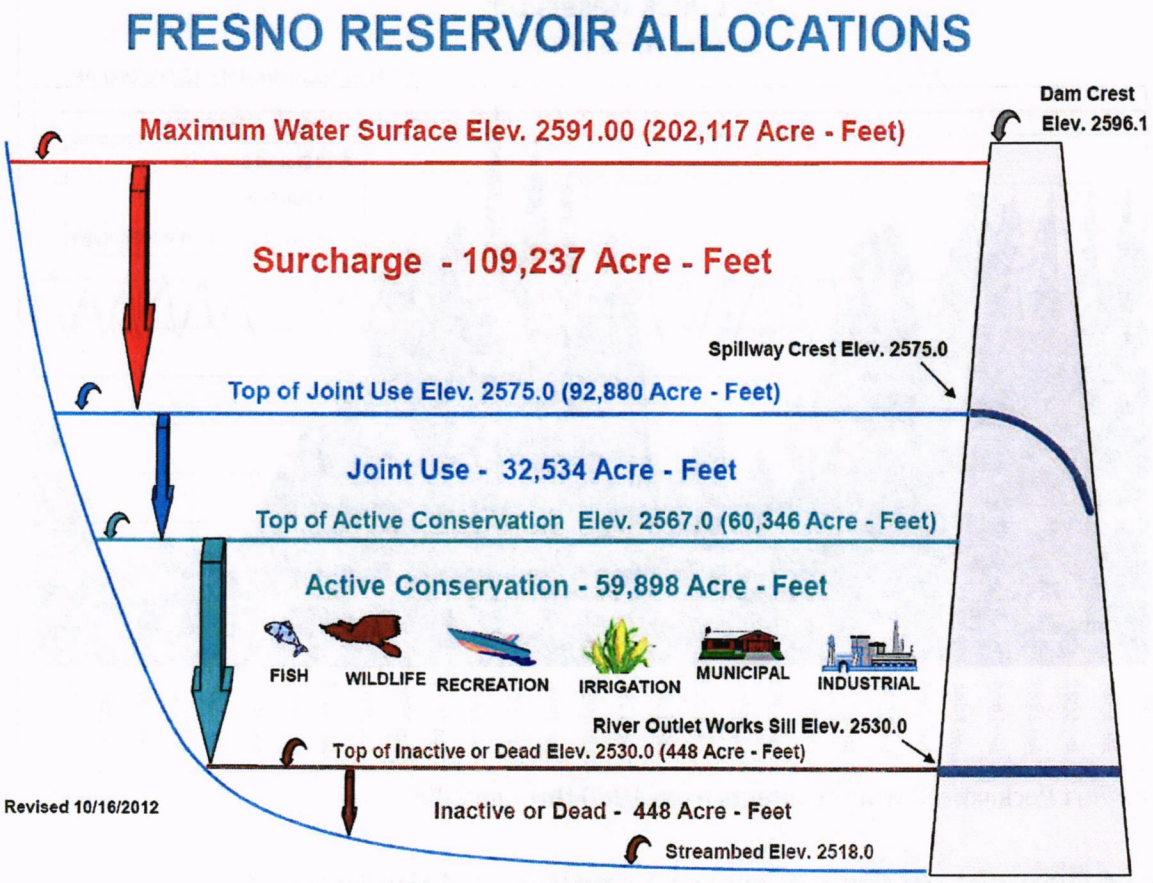


Figure D5. USBR Fresno Reservoir Allocation diagram.

Larger storage projects, such as Fort Peck Reservoir can exhibit massive impacts from prolonged drought. With a full pool of 18,500,000 acre feet, drought effects may not be as immediate, and may take a longer time from which to recover. Figure D6 shows monthly storage at Fort Peck for the 1980's through the 2000's, compared to the average monthly storage for the period 1967 - 2013.

Drought effects from the late 1980's are obvious in the graph, showing a large deficit of storage well into the 1990's. Storage recovered with high water years in the mid and late 1990's, then steadily and drastically declined during the 2000's drought. The largest stored water deficit shown during this time period was in July 2007, with a stored water shortfall of 5,742,000 acre feet; approximately 38% below the normal stored content for July.

The drought of the 2000's was severe and prolonged throughout western Montana, and heavily impacted the mainstem Missouri River, all its tributaries, and reservoirs in the Upper Missouri River Basin above the reservoir. Fort Peck Reservoir being located downstream inherited drought effects from the upper basin. Water shortages such as these typically reduce power generating capacity at hydroelectric facilities such as Fort Peck.

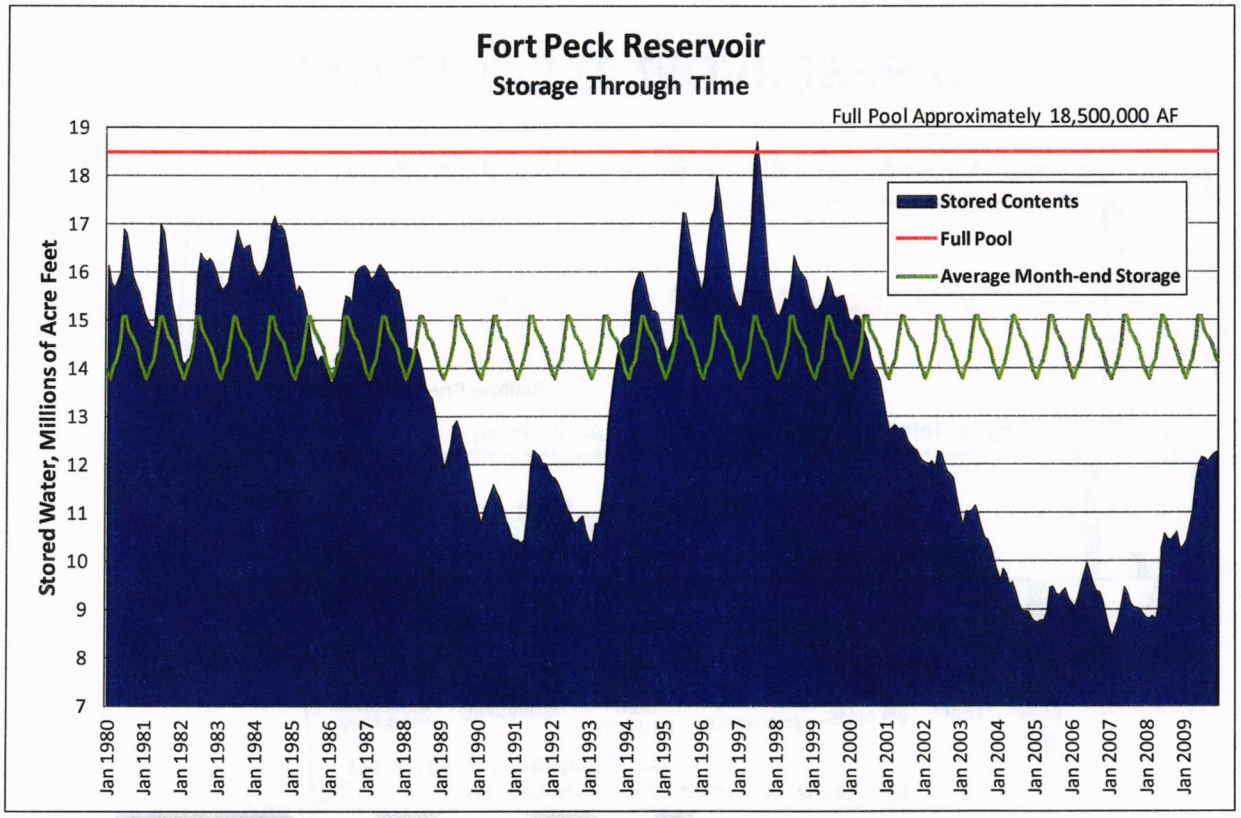


Figure D6. Fort Peck stored water contents from 1980 through 2009.

Effects of Drought on Groundwater Supplies and the Role of Groundwater in Sustaining base flow during Droughts

Drought reduces the quantity of water available to recharge groundwater resulting in declining water levels. At the same time, groundwater is an important storage reservoir that supports base flow during dry years and, at least in the early years of, extended droughts. Support of base flow by release of water from groundwater storage diminishes during extended droughts as the delayed impact of reduced recharge manifests itself in reduced groundwater levels and available storage. As with surface storage, prolonged drought stretches the limit of carry-over groundwater storage resulting in reduced base flows.

Groundwater sensitivity to drought varies throughout the LMRB and is correlated to the groundwater systems ability to transmit and store water, location to surface water (recharge), and depth below ground surface. The Groundwater Information Center (GWIC) statewide monitoring

network provides long-term water-level records that show change in groundwater storage or pressure. Upward trends (increasing elevation and decreasing distance to water) show increased groundwater storage or pressure. Most hydrograph traces portray concurrent high- and low-frequency signals that illustrate the local balance between the numerous signal sources. The high-frequency signals are related to seasonal/annual trends, while the low-frequency, slowly-varying signals are characteristic of climate sensitive wells (Patton, 2013).

The water levels in the alluvium well (GWIC # 3766) near Plentywood show water level responses to climate variability such as the 2000s drought. Figure D7 shows water level changes in the alluvium that are related to extended periods of dry and wet cycles. The hydrograph shows the impact of annual water level fluctuations superimposed on a low-frequency cycle that is likely climate related.

Monitoring wells (GWIC # 3977) in the Flaxville gravels near Turner show a response to yearly changes superimposed on a declining long-term cyclic trend. Figure D8 shows groundwater levels responding to multi-year trends in climate variability. For example, water levels fell approximately 7 feet from 1985 to 2010. Water levels rose during the start of this decade due to a wetter period.

A monitoring well (GWIC # 1575) in the Fort Union Formation near Roundup show annual changes and multi-year trends related to climate variability. Figure D9 shows a declining cyclic trend with water levels falling approximately 6 feet from 1981 to 2006. Since 2006, water levels have risen 4 feet.

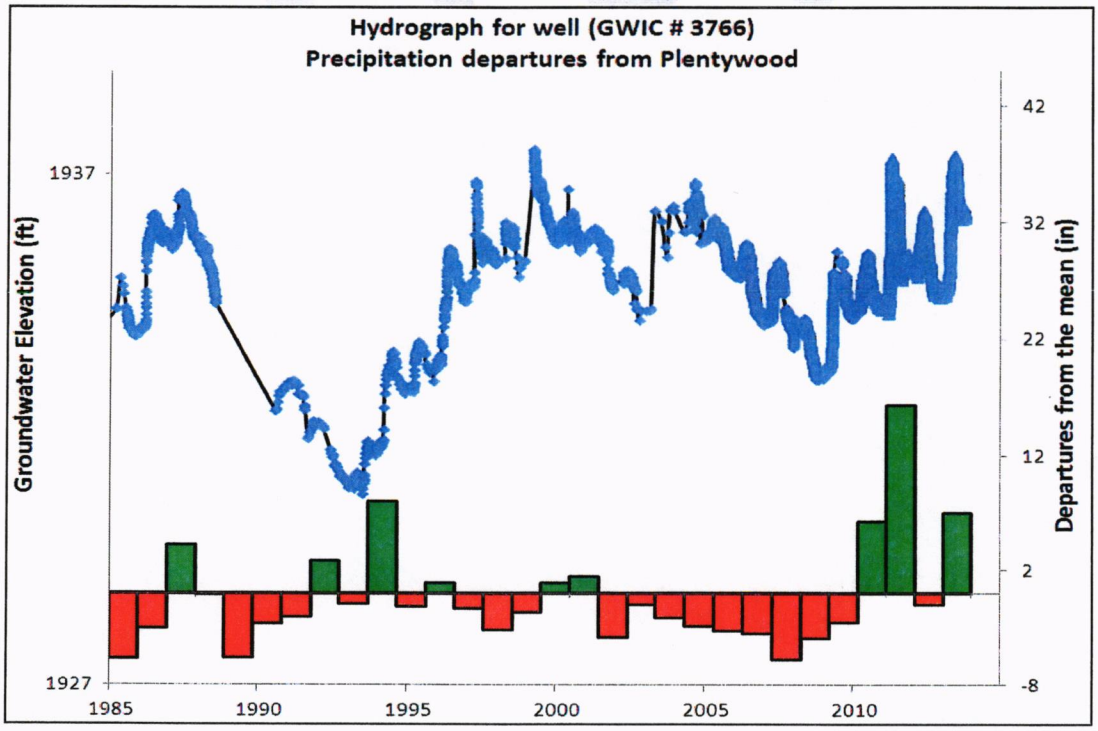


Figure D7: Groundwater levels in the alluvium aquifer near Plentywood showing the effects of drought in the 2000s and recovery during wetter periods (GWIC # 3766).

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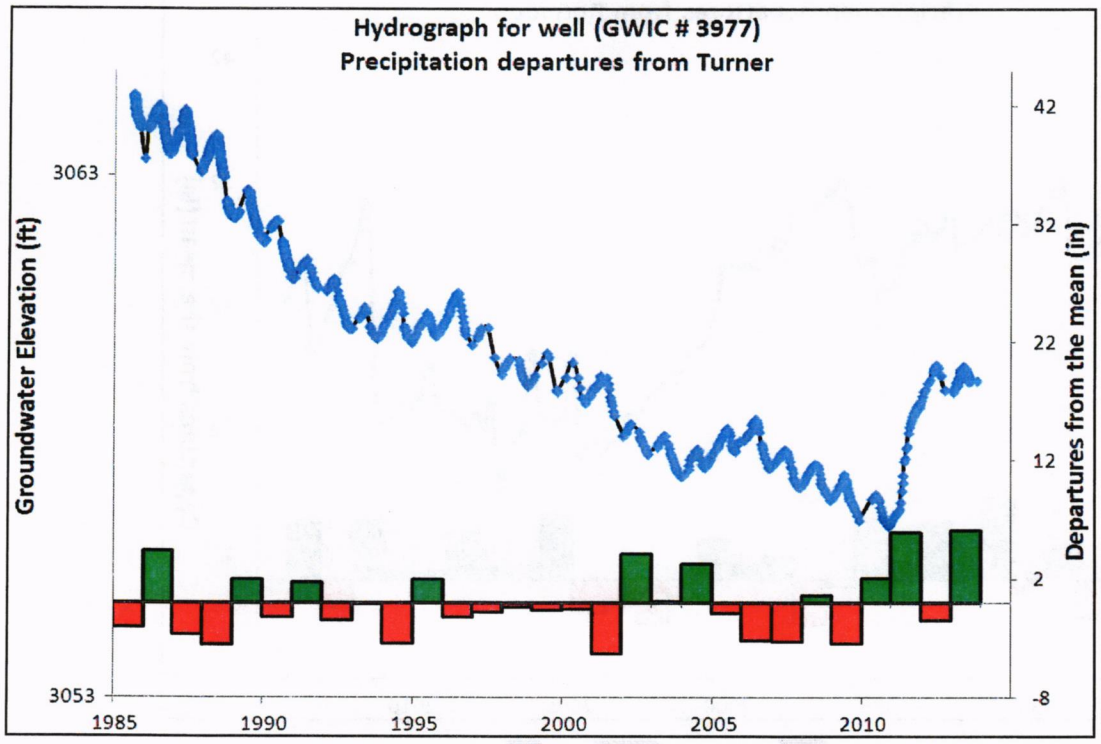

Figure D8: Groundwater levels in the Flaxville gravels near Turner showing the effects of wet periods, dry periods and long-term cyclic decline (GWIC # 3977).

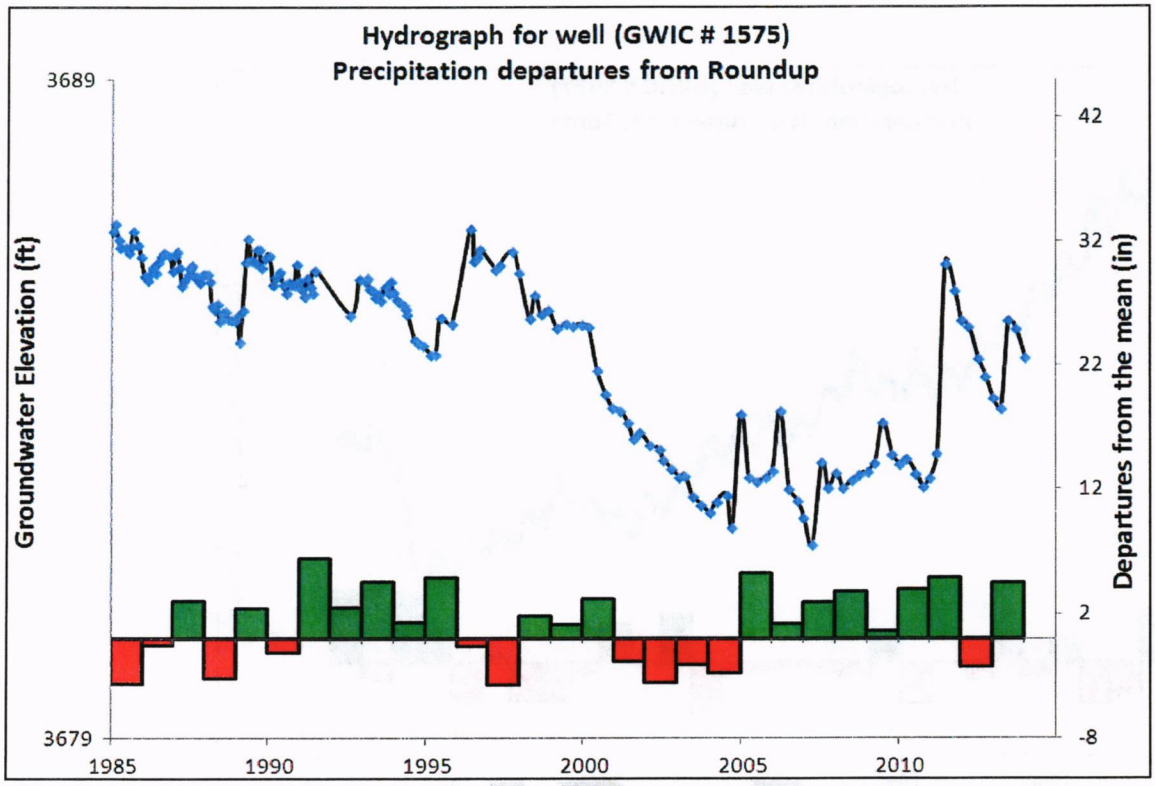

Figure D9: Fort Union Formation groundwater levels near Roundup showing multi-year trends and responses to above average years of precipitation (GWIC # 1575).

Lower Missouri River Basin:
Potential Effects of Climate Change on Future Water Supplies and Demands
[Author Note: highlighted segments are place holders "borrowed" from the Upper Missouri DRAFT and will be reworked to become specific to the Lower Missouri Basin]
Introduction

Water planning assessments have typically assumed that future water supply conditions will be similar to past water supply conditions, within a familiar range of annual fluctuation. The sequencing of past flow patterns cannot be exactly repeated, of course, since we can't cross the same river twice. Recent analysis of climate information suggests that the future limits of streamflow variability may differ from the historic.

Analysis of climatic records shows that much of the US has experienced warming during the 20th century, and projections indicate that warming is likely to continue in the 21st century. This warming will affect the amount, distribution, and form of precipitation as either rain or snow. Warming will also affect evaporation rates and evapotranspiration rates by natural vegetation and irrigated crops. Streamflow is likely to change in volume, timing and distribution.

This section discusses climate change in the Musselshell River Sub Basin, focusing on how these projected climate changes might affect water supplies and demands. This information can be used

to evaluate the ability to meet future water demands within the basin and to identify adaptation strategies to solve future challenges to supply.

Methods

The general procedures used in this section are similar to those described in the US Bureau of Reclamation (2011) West-Wide Climate Risk Assessments. Future temperature and precipitation projections were obtained from the Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections archive site maintained by the US Bureau of Reclamation at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/. The root climate data sources for this archive are the World Climate Research Program Coupled Model Intercomparison Project3 (WCRP CMIP3) phase 3 multi-model climate projections (Meehl et al. 2007). The CMIP3 dataset consists of results from coupled atmosphere and ocean general circulation models, which simulate global climate responses to future greenhouse gas emissions (primarily carbon dioxide). A range of modeled scenarios were available, based on how potential green house gas emission rates and atmospheric concentrations might vary with global technological and economic developments during the 21st Century.

A total of 112 climate projections, based on projections by 16 different CMIP3 models, were used for this analysis. The CMIP3 and CMIP5 Climate and Hydrology Projections archive site contains statistically down-scaled global-scale climate projections to a 12-kilometer (km) square grid (1/8° latitude by 1/8° longitude), which were used because raw CMIP3 dataset and climate models projections are too coarse for basin-scale water resources planning.

Hydrology projections were also downloaded from the same Reclamation Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections archive website, for the same 112 CMIP3 projections. The projections were developed using the University of Washington Variable Infiltration Capacity (VIC) hydrology model (Liang et al. 1994; Liang et al. 1996; Nijssen et al. 1997) to translate climate data to streamflow runoff, and the VIC model also produces evapotranspiration and snow water equivalent output data. Input data to the VIC model is spatially downscaled precipitation, temperature, and wind speed data. Output includes runoff (both surface and subsurface runoff), evapotranspiration, and snow water equivalent over a grid corresponding to the selected watershed area. The model solves the water balance for each grid cell, the gridded runoffs are then linked and hydraulically routed to a watershed outflow point.

The 112 downscaled CMIP3 temperature, precipitation, and hydrologic projections were obtained from the Reclamation website for the period 1950-2099. Since the Montana State Water Plan is updated each 20 years, discussions here will generally compare model results that represent the recent past (1950-1999), to those for a future period centered on the year 2035 (years 2010-2059).

Temperature

Figure 1 displays simulated mean annual temperatures for the Musselshell River Sub Basin, which is within the LMRB. The central heavy line represents the median predicted average annual temperature provided by the entire ensemble of 112 projections. The thin black lines represent the

upper and lower limits of variability for the individual model projections. The consensus message for all of these projections is that temperatures in the Musselshell River Sub Basin will continue to warm into the future, although the rate of the projected warming varies among models and scenarios.

For the period 2010-2059, the increases in average annual temperature above the period 1950-1999 ranged from 1.3° to 4.6° Fahrenheit with the median increase being 2.8°. According to model output, the 2014 mean annual temperature for the Musselshell River Basin is 44.8 degrees. The median ensemble projection line indicates that the mean annual temperature will increase 1.5 degrees between 2014 and 2035, to 46.3 degrees.

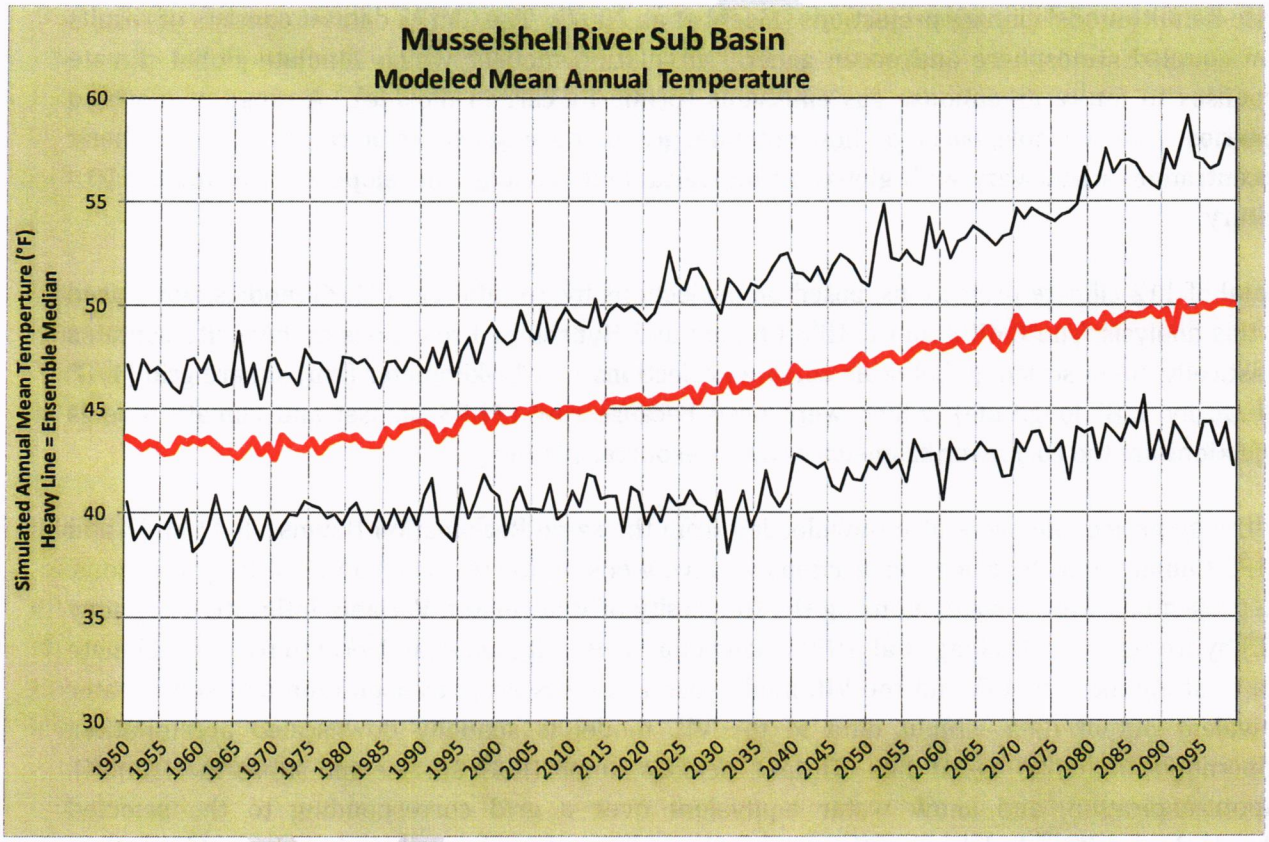

Figure 1. Musselshell River Sub Basin, mean annual temperature simulations based on downscaled projections from 112 GCM models.

Precipitation

Precipitation projections are more mixed, with scenario trends varying from somewhat wetter to slightly drier, with most depicting a slight wetting trend but perhaps increased variability over time (Figure 2). For the Musselshell River Sub Basin, only 18 of the 112 projections indicated a decline in precipitation between the periods 1950-1999 and 2010-2059.

The median projected increase in precipitation for the period 2010-2059 above the period 1950-1999 was 0.67 inches or 4.4%. The maximum projected increase was 3.26 inches (21.5%), and the maximum projected decrease was for 1.50 inches less precipitation (9.9%).

The ensemble median estimate for 2014 Musselshell Basin precipitation is 15.5 inches. The estimate climbs to 15.6 inches by 2035, to 15.9 inches by 2059, and to 17.0 inches by 2099. An increase to 17.0 inches of average annual precipitation would represent a 9.7% gain above current precipitation conditions.

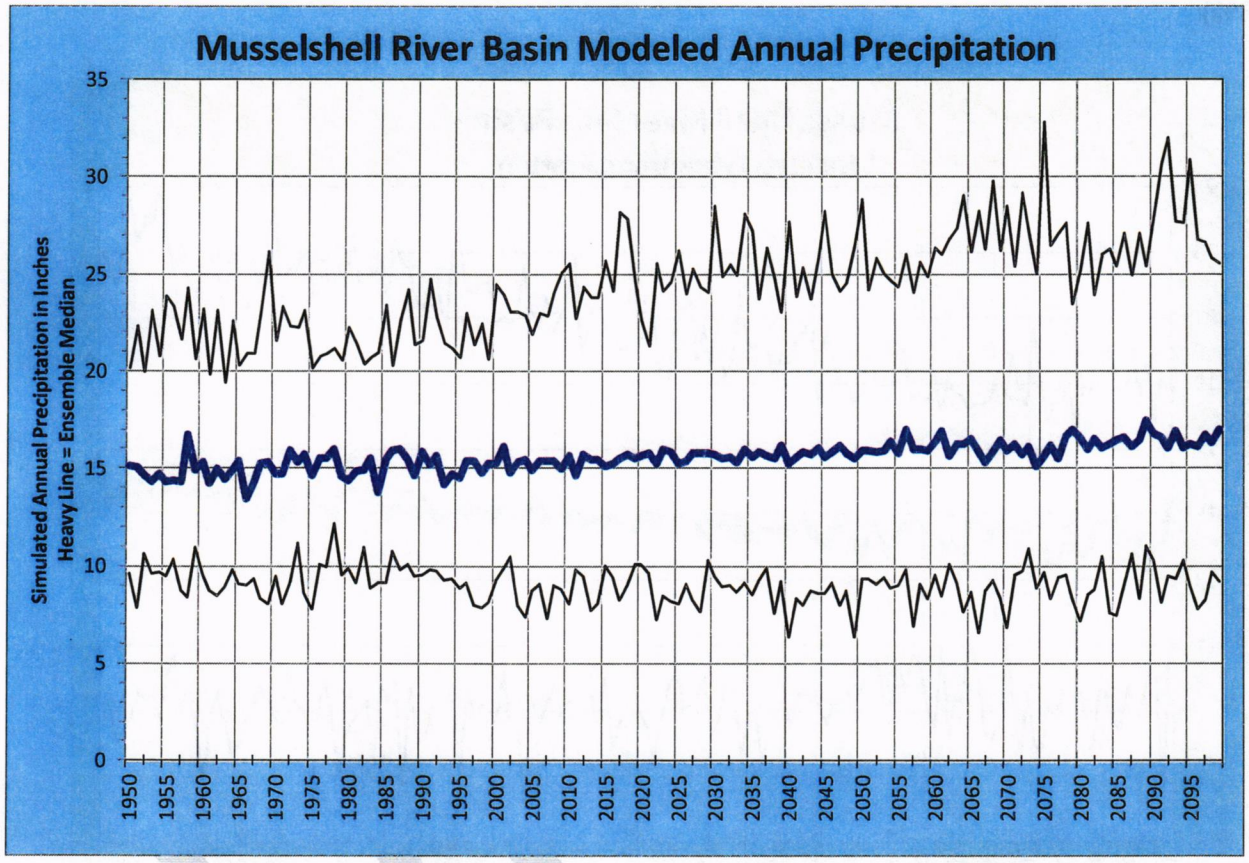

Figure 2. Annual precipitation simulations for the Upper Missouri Basin based on downscaled projections from 112 GCM models.

Evapotranspiration

As described in the Streamflow section of this report, only about 18 percent (about 3.5 inches) of the precipitation that falls on the Musselshell River Sub Basin ultimately leaves the basin as streamflow. Most precipitation will infiltrate into the soil profile to be consumed by plants, or evaporated from the soil surface through the process of evapotranspiration (ET).

Evapotranspiration is projected to increase under most scenarios as air temperatures increase and growing season lengthens. However, some of the modeled scenarios projected a decrease in ET due

to projected drier conditions. Figure 3 depicts modeled ET by natural vegetation in the Musselshell River Sub Basin for the period 1950-2099. ET is projected to increase under most modeled scenarios for the 2010-1959 period compared to the 1950-1999 period. The modeled median increase in annual ET was 0.59 inches (4.1%). The maximum modeled increase in annual ET was 1.5 inches (10%), and the maximum decrease was 0.10 inches (0.7%).

The model ensemble lists the Musselshell River Basin 2014 ET at 14.56 inches. By 2035, the median forecast is 14.86 inches (2.0%), and by 2099, projected ET has risen to 16.13 inches (10.8%).

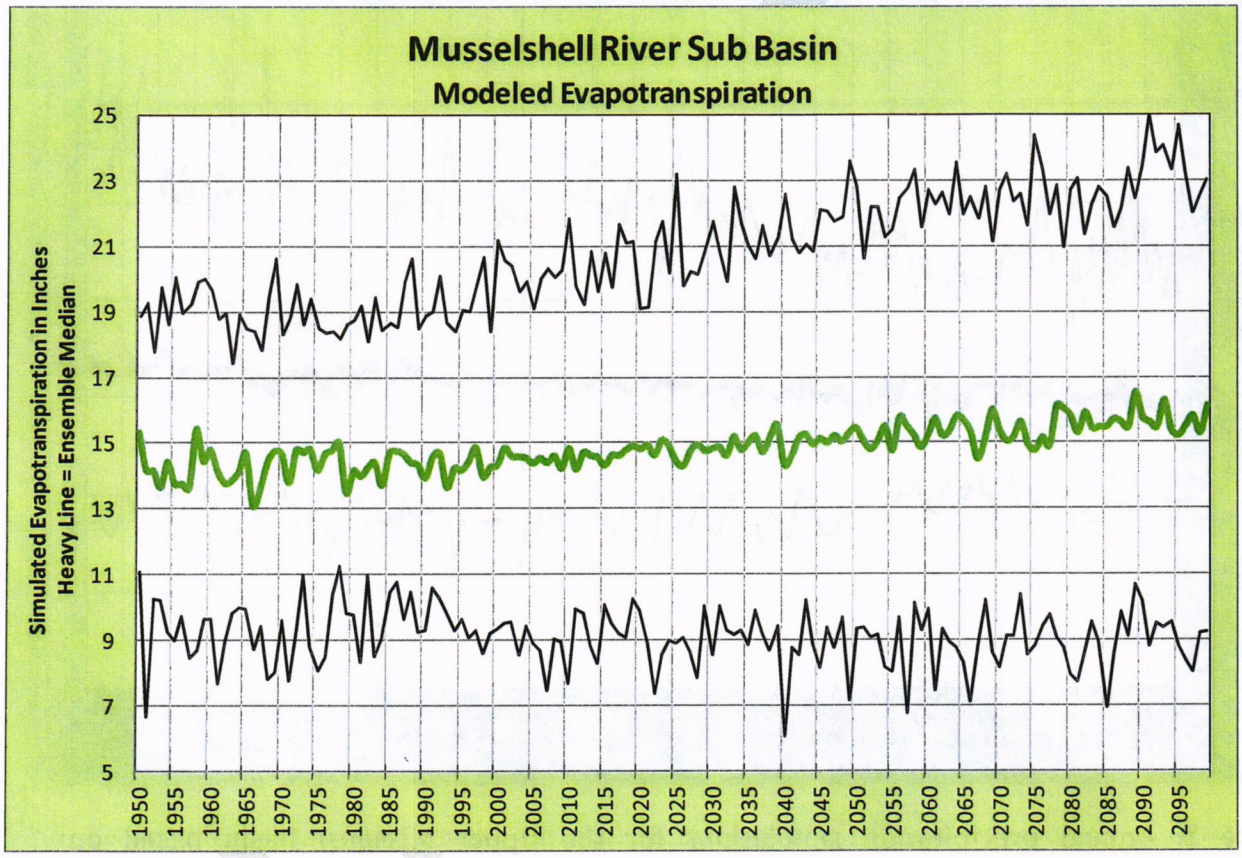

Figure 3. Annual evapotranspiration by natural vegetation simulations for the Musselshell River Sub Basin, based on VIC model results and downscaled projections from 112 GCM models.

Runoff (Annual Volume)

Annual total runoff produced in the Musselshell River Basin is dependent on several, or perhaps all, other climatic factors. Annual runoff is the volume of water that is not consumed by evaporation and evapotranspiration and is then exported from the basin as surface outflow. This runoff or outflow is also dependent on annual precipitation, and therefore fluctuates annually.

Figure 4 depicts the modeled annual runoff volumes for the Musselshell River Basin at the basin outflow point, at the confluence of the Musselshell River and impounded waters of Fort Peck Reservoir. For this graph, unique colors have been assigned to each of the 112 model simulation trace lines, with the dark line depicting the ensemble median. Although most scenarios project modest increases in precipitation for the Upper Missouri River Basin, the projected ET increases seem to offset these. Annual runoff volume is projected to be similar under most modeled scenarios for the 2010-2059 period compared to the 1950-1999 period, with a few scenarios projecting substantial increases and a few others projecting substantial decreases. The modeled annual runoff ensemble median was an increase of 24,218 acre-feet (6.2%). The maximum modeled runoff increase was an additional 81,011 acre-feet (20.6%), and the maximum decrease was -15,889 acre-feet (-4%). These runoff volumes are for "natural" flow, before irrigation depletions and other consumptive uses, including reservoir operations and evaporation. The median gaged annual flow volumes at Virgelle are about 1,000,000 acre-feet lower than the modeled volumes for the historic period, due to these depletions associated with human uses.

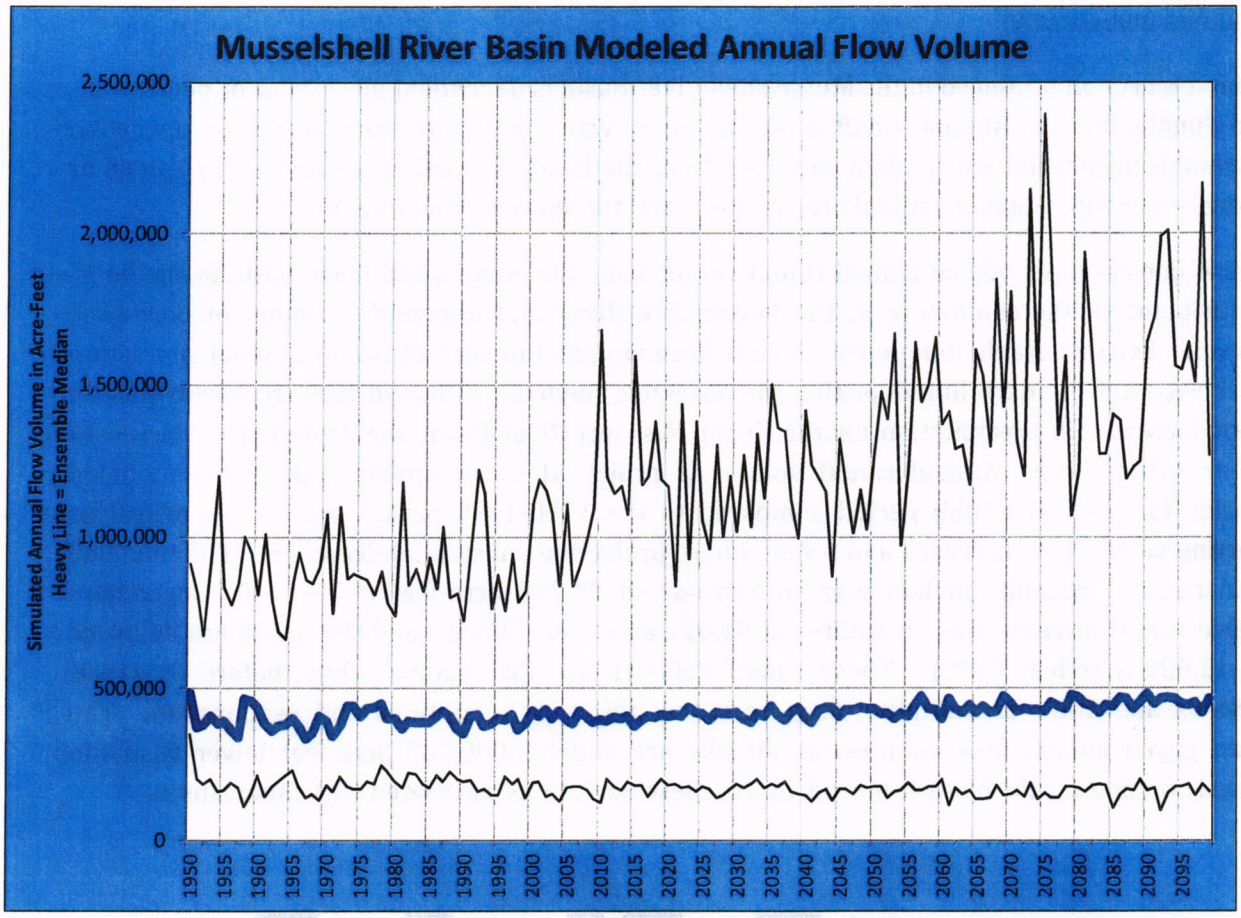

Figure 4. Simulated annual natural flow volumes for the Upper Missouri Basin based on VIC model results and downscaled projections from 112 GCM models.

Snow

The snow accumulation season at mountainous, higher elevation areas of Montana is October through May. Warming temperatures affect the accumulation of mountain snow by shortening the accumulation period. Warmer temperatures occurring earlier in the spring season further affect the timing of the snow melt and the availability of melting snow to sustain runoff later into the summer season.

The hydrology of the Upper Missouri River Basin is snow-melt dominated and warmer temperatures would likely lead to proportionally more rain and less snow, a shorter snow accumulation period, and an earlier spring snow melt runoff. The Lower Missouri River Basin is strongly influenced by factors and occurrences in the upper basin, and will generally inherit these effects on the Missouri River mainstem.

However, the Milk River and Musselshell River Sub basins are not directly linked to the Upper Missouri River Basin, and are therefore not influenced by conditions in the upper basin. Both of these basins have limited snow accumulation zones, and rely heavily on stored snow melt water to provide for summer season irrigation water. Even with storage, both basins experience chronic shortages of supply. Because existing facilities store snow melt water in the spring before irrigation

season, increasing air temperatures may have less effect in these basins in terms of water supplied by snow melt. A bigger concern with warmer temperatures might be less snow water, and therefore a reduction in water volume available to store in reservoirs.

April 1 Snow Water Equivalent (SWE) is a valuable index for assessing snowpack conditions and forecasting spring–summer runoff volumes in snowmelt dominated basins. SWE is a variable computed and used by the VIC hydrology model for each grid cell in a defined basin area. Figure 5 depicts modeled April 1 SWE conditions for the Musselshell River Basin above Roundup, for the 112 simulations.

The Musselshell Basin is a large area, but with limited snowpack accumulation zones. Therefore, SWE numbers are very small when averaged over the entire basin. Since snow water contributions are almost entirely limited to the basin above Roundup, the model runs and resultant projections of SWE were limited to this upper portion of the basin, thus distributed over a smaller, yet still large, area. Doing this provides an easier look at the very small numbers, yet retains the relative differences between them.

The goal of the models is to illustrate projected changes in April 1 SWE, relative to past and current conditions. April 1 SWE was averaged over all grid cells in the area above Roundup to calculate the basin-wide SWE for each simulation year from 1950–2099. The model results show an obvious decreasing trend.

From 2014 to 2035, the model-predicted ensemble median SWE drops by 3.3%. From 2014 to 2059, the ensemble median indicates a SWE reduction of 58%; about 58% less SWE in the April 1 mountain snowpack that currently supplies the Musselshell River Basin. A best-fit curve through the ensemble median data points (Figure 5, black line) illustrates a slightly less alarming long-term trend in SWE, and would forecast a 2035 SWE reduction of 20% below 2014, and a reduction of 37% by 2059.

Of the 112 model scenarios, only 16 of them show a trend of increasing April 1 SWE for the years 2010-2059 relative to the 1950-1999 base period. The median SWE decrease was .06 inches, or 38 percent. The largest decrease for the 2010-2059 period relative to the 1950-1999 base was 0.12 inches of SWE, a 68 percent decrease. The vast majority of modeled scenarios indicate increased precipitation overall, mostly in the form of rain. The increased rain may offset snow water declines.

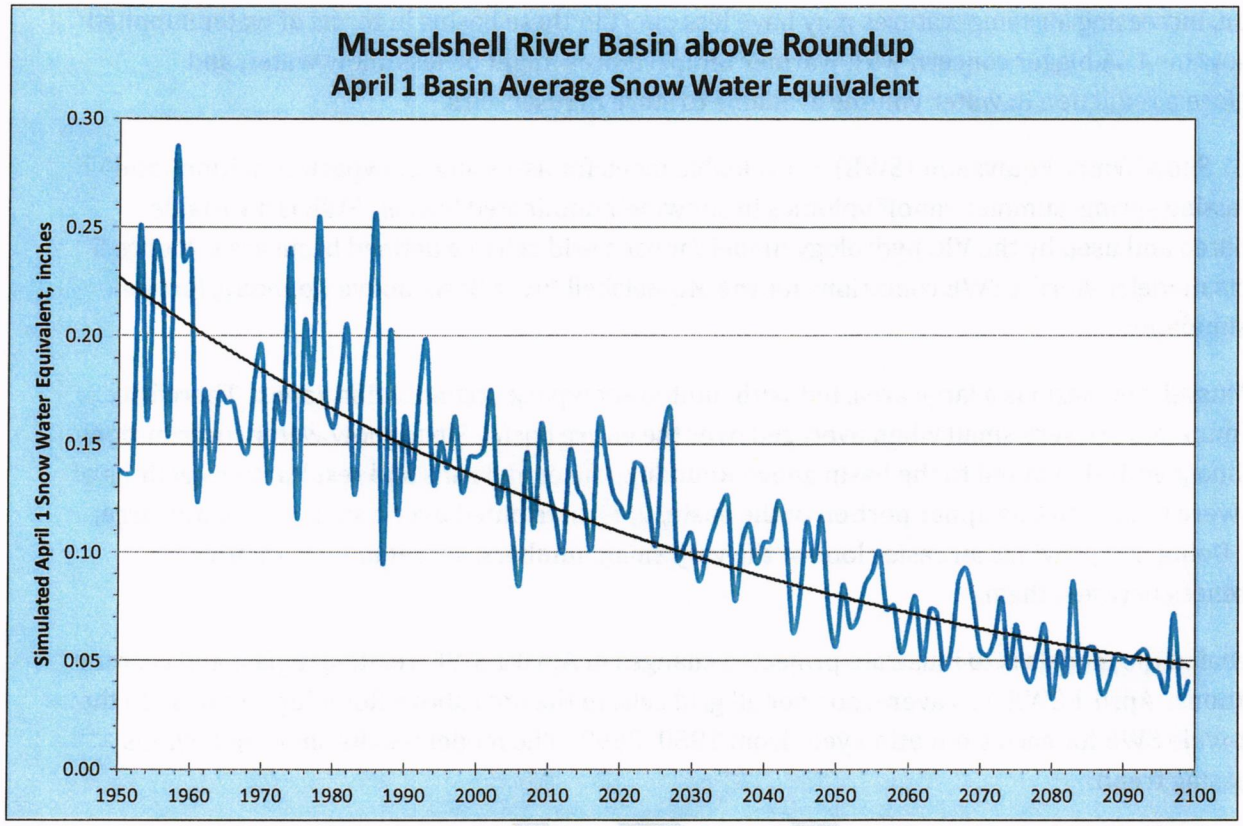

Figure 5. Modeled April 1 Snow Water Equivalent for the Musselshell River Basin based on VIC model results and downscaled projections from 112 GCM models.

Streamflow

Figure 6 and 7 compare simulated median Missouri River streamflow for the future 2010-2059 period to the historic 1950-1999 period for the headwaters area (Missouri River near Toston) and the entire Upper Missouri River basin (Missouri River near Virgelle). The results depicted are for groupings (ensembles) of VIC modeled runoff using the 112 CMIP3 climate scenarios using methods similar to those described by the U.S. Bureau of Reclamation (2010). The groupings partitioned the 112 scenarios into four quadrants that bracketed the climate-change scenario range based on relative changes in mean annual temperature and precipitation, with a fifth "central tendency" grouping. For simplicity, only the results for the quadrant scenario groupings that produce the highest runoff values and the lowest runoff values, and the middle grouping are graphed. Also note that these graphs are for the modeled "natural" flow produced by the basins: they do not include the effects of water development such as reservoirs and irrigation.

In the future, the flow produced in the Upper Missouri Basin might be of similar volume to what it has been produced in the past, with shifts in streamflow timing and the wetter scenarios showing increased overall runoff. The timing shifts would be due to an earlier snowmelt and an increase in the rain fraction of the precipitation during the later winter and early spring. Earlier runoff is projected with December through March showing an increasing trend while late season runoff (June through November) shows a decreasing trend. The earlier shift in runoff timing is more predominant for the warmer scenario groupings.

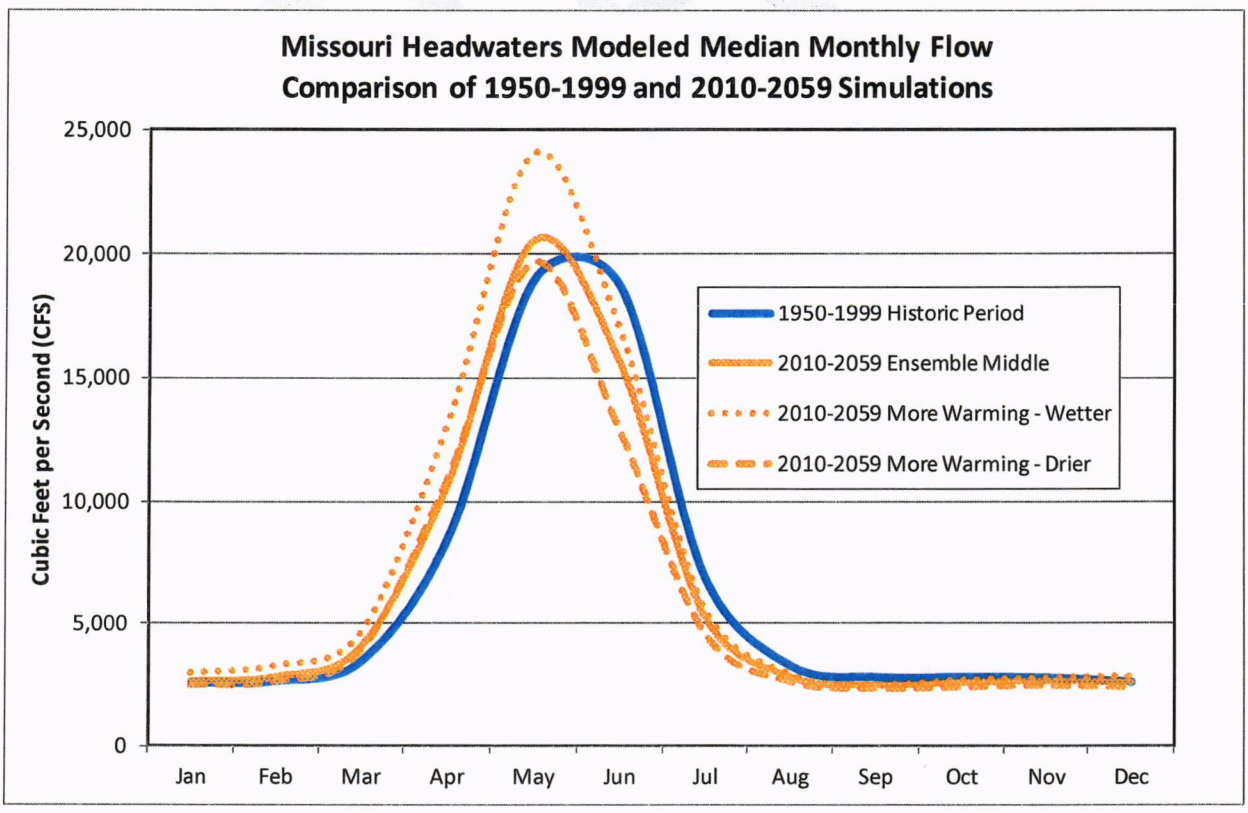

Figure 6. Modeled median monthly flow for the Missouri River Headwaters under historic conditions and future climate scenarios.

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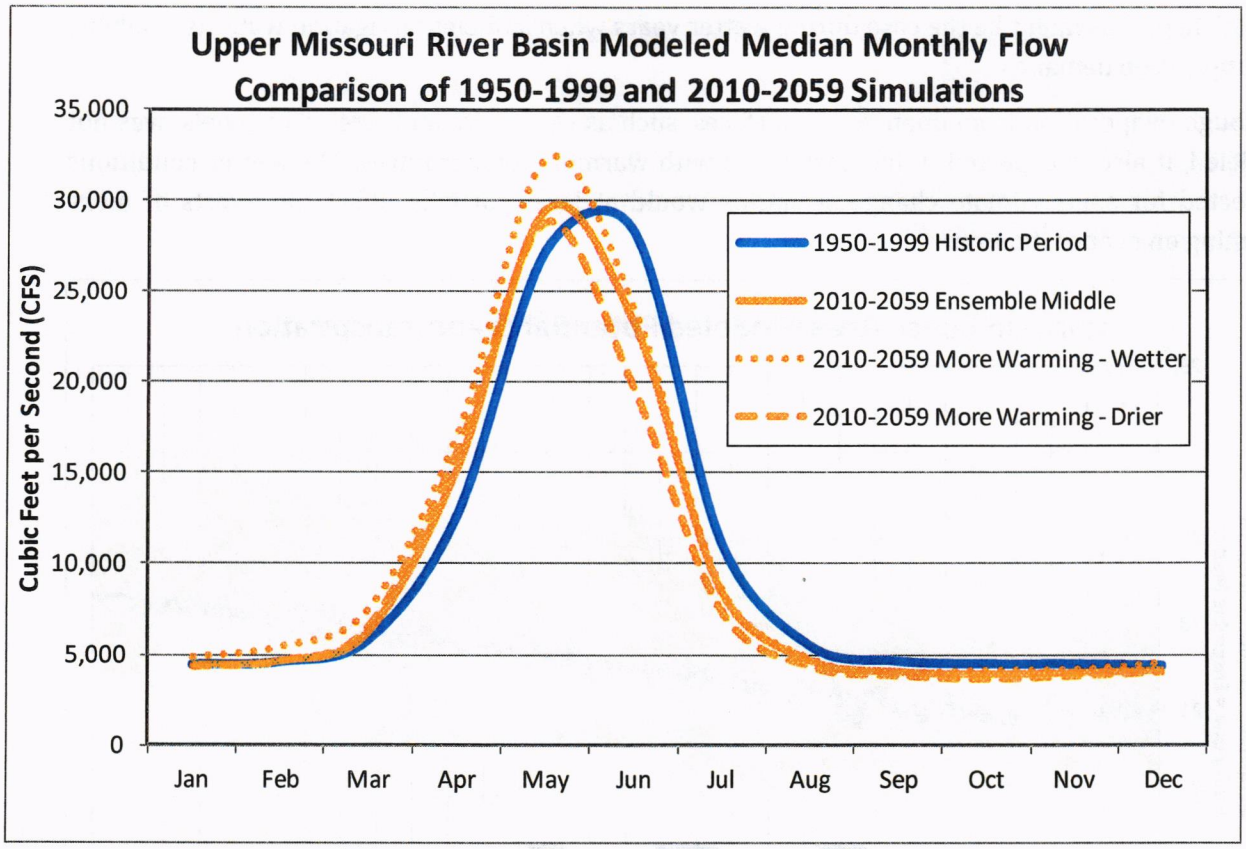

Figure 7. Modeled median monthly flow for the Upper Missouri River Basin under historic conditions and future climate scenarios.

Future Water Demands

All of the 112 simulations project increased temperature in the upper Missouri basin and most show modest precipitation increases. The increase in temperature could result in increased water demands, especially for irrigation. Figure 7 depicts modeled potential evapotranspiration for natural vegetation for the Greenfields Bench agricultural area north of Great Falls. Potential evapotranspiration is the maximum amount of water that could be evaporated and transpired from the landscape at a given temperature, if there were a sufficient supply of water. Although this graph depicts potential ET for natural vegetation, it could be used to infer how water requirements might change for irrigated crops. The VIC model uses a Penman-Montieth formulation to compute Potential ET (reference here), which also can be used to predict ET for agricultural crops.

Potential evapotranspiration is projected to increase during the 2010-2059 period when compared to the 1950-1999 historic period under all but one of the 112 scenarios modeled. The maximum projected increase was 2.2 inches (10.7%), the minimum was the scenario with 0 increase, and the median modeled increase was 1.2 inches (5.5%). Increased ET would result in increased consumption and increased diversion requirements for irrigated crops. The projected increasing ET irrigation requirements might suggests that there could be an increase in crop production, if the increased water demand could

be satisfied. This might be the case during wetter years when sufficient irrigation water is available to supply crop demands.

Although evaporation from open water surfaces, such as reservoirs and stream channels, was not modeled, it also is expected to increase some with warming temperatures. The wetter conditions projected for some climate change scenarios would at least partially offset the effects of more warming on evaporation rates.

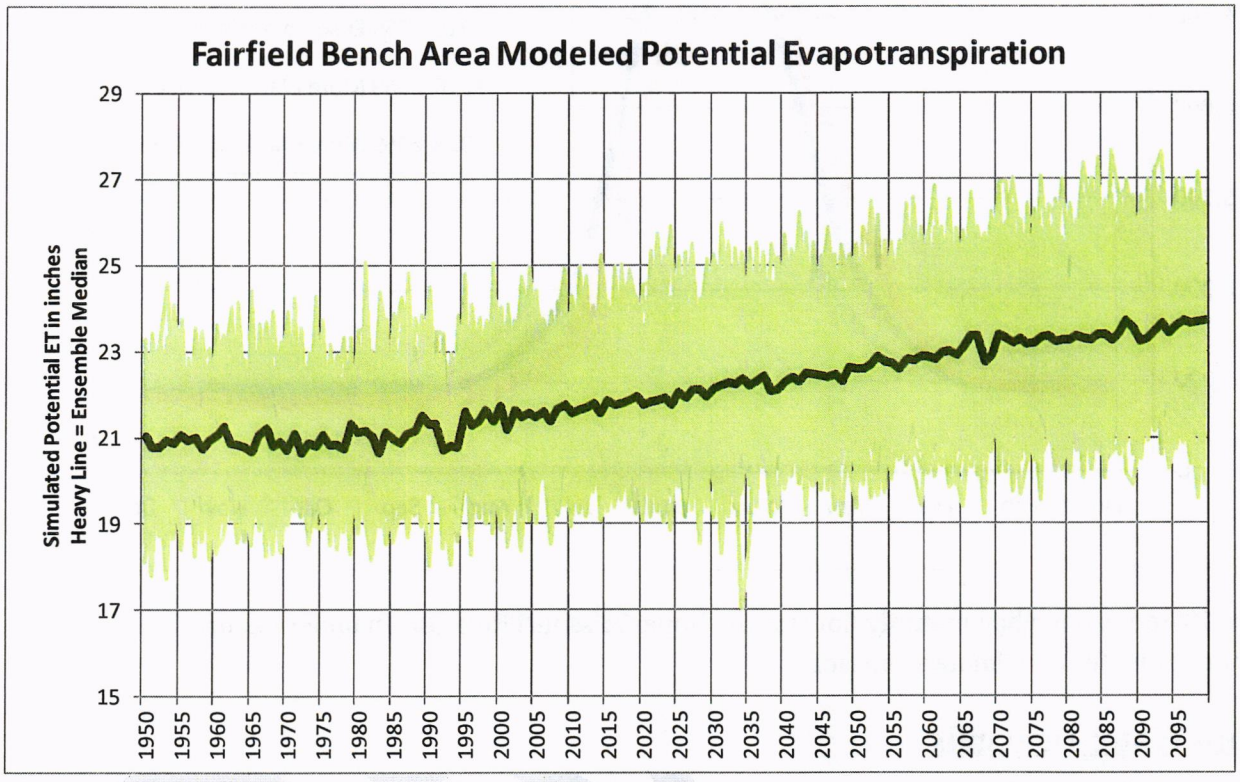

Figure 7. Simulated Annual potential evapotranspiration for natural vegetation simulations for the Fairfield Bench Area based on VIC model results and downscaled projections from 112 GCM models.

Uncertainties

The current scientific understanding of physical processes that affect climate and how to model such processes is not complete. Atmospheric circulation, clouds, ocean circulation, deep ocean heat uptake, ice sheet dynamics, sea level, land cover effects from water cycle, vegetative, and other biological changes are some important factors in climate modeling that are not fully understood. There are uncertainties relevant to the statistically down-scaling of global-scale climate models to the finer scale used in basin planning. For this investigation, global-scale model results were downscaled using temperature and precipitation patterns from historic weather-station data. And the future projections assume that these historic local climate patterns at the finer-scale and their relationships to the climate at the larger scale will still hold in the future, although that may not be the case.

References

Liang, X., D.P. Lettenmaier, E.F. Wood, and S.J. Burges. 1994. —A simple hydrologically based model of land surface water and energy fluxes for general circulation models,|| *Journal of Geophysical Research*, 99(D7), 14415–14428.

Liang X., E.F. Wood, and D.P. Lettenmaier. 1996. —Surface soil moisture parameterization of the VIC-2L model: Evaluation and modifications,|| *Glob Planet Chang* 13: 195–206.

Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. Mcavaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor. 2007. —THE WCRP CMIP3 MULTIMODEL DATASET – A New Era in Climate Change Research,|| *Bulletin of the American Meteorological Society*, 88(9), 1383–1394.

Nijssen, B., D.P. Lettenmaier, X. Liang, S.W. Wetzel, and E F. Wood. 1997. —Streamflow simulation for continental-scale river basins,|| *Water Resour. Res*, 33, 711–724.

U.S. Bureau of Reclamation. 2010. *Climate Change and Hydrology Scenarios for Oklahoma Yield Studies*, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver Colorado. April 2010. 71 pp.

U.S. Bureau Reclamation, 2011. 'West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections', Technical Memorandum No. 86-68210-2011-01, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 138pp.

We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modeling (WGCM) for their roles in making available the WCRP CMIP3multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

Options for Meeting New Water Demands

Basins with Unallocated Water

Water availability and appropriation of water are very important, and often contentious, issues in Montana and other western states. Montana has the authority to restrict or close river basins and groundwater aquifers to future withdrawals, based on concerns to protect existing uses, water quality issues, and additional water shortages. Montana is a "prior appropriations" state, and must first protect existing senior water uses before allowing additional demands on water resources. Physical water availability, if any, is based on surplus water above and beyond existing, valid water uses. An applicant for water use must prove that their proposed future use of water does not impact existing users surface or groundwater uses.

Applicants for a new groundwater appropriation that depletes surface water may need to implement a mitigation or aquifer recharge plan in order to obtain a new permit. "Mitigation" means the reallocation of surface water or ground water through a change in appropriation right or other means that does not result in surface water being introduced into an aquifer through aquifer recharge to offset adverse effects resulting from net depletion of surface water. "Aquifer recharge" means either the controlled subsurface addition of water directly to the aquifer or controlled application of water to the ground surface for the purpose of replenishing the aquifer to offset adverse effects resulting from net depletion of surface water.

The purpose of mitigation and aquifer recharge plans is to offset net depletion to surface water from a groundwater appropriation in order to provide water for legal demands by senior water users and to prevent adverse effects. Mitigation plans involve a change of an existing surface water or groundwater right whereas aquifer recharge plans involve infiltration of surface water to groundwater in addition to a water use change. Mitigation by changing a surface water right is accomplished by stopping the existing use (e.g. drying up irrigated acreage) and leaving water that was previously diverted in-stream and possibly protecting it through a depleted stream reach. This type of mitigation is appropriate where net depletion and adverse effects are predicted to occur within the period of historic use of the existing water right which may occur where a well is located very close to a stream or where water shortages are limited to the irrigation season. Simple mitigation with surface water generally requires a water right with an early priority date.

In contrast, changing an existing ground-water right by stopping use of another well and eliminating its associated purpose may mitigate adverse effects outside the historic period of use of the existing right. This occurs because wells that are not very close to a stream typically have year-round depletion effects; therefore, eliminating an existing well is essence provides year-round mitigation effects. The feasibility of a mitigation plan involving a change of a ground water right depends on consumption of the historic and new uses and on whether the adverse effects of the new use are similar to the historic effects of the retired use.

An aquifer recharge plan or project accomplishes essentially the same thing as retiring use of a well by diverting surface water and allowing it to infiltrate ground water through a well or other means. Again, the viability of a plan depends on a comparison of the historic and new consumptive uses, and an evaluation that indicates whether mounding from aquifer recharge offsets drawdown from the new use. The existing water right may be relatively junior if recharge is conducted in early summer.

A summary of the general legal availability of surface water available for appropriation in the LMRB is summarized in the following table. The summary is based on past permitting records and experience. New appropriations from aquifers hydraulically connected to these streams and rivers also may be subject to limitations.

Lewistown Region

Water Source	Legally Available	Not Legally Available	Comments
Judith River	Lower reaches	Upper reaches	Judith is chronically dewatered above the confluence of Big Spring Creek. Only potential ability to get water above Big Spring is during high spring flows AND if heavy conditions could be met (lack of a gauge decreases chances of new permitting). Below Big Spring and Warm Spring Creek, water is legally available most of the time. Surface water permits could be issued with minor trigger flow conditions.
Big Spring Creek	Potentially – During non-irrigation and runoff season, and in lower reaches after irrigation return flows	Not likely during irrigation season.	There could be potential for new permitting subject to trigger flow conditions, however, since no gage exists on Big Spring Creek, there is no way to monitor streamflows. The lack of a gauge decreases chances for new permitting.
Musselshell River	Only during high spring flows on lower half of river	Most of year water is not legally available (Legislative Closure during irrigation season)	Water only legally available during high spring flows, and from a practical standpoint, probably only in the lower reaches of the river. River is administratively closed during irrigation season. DFWP water reservation exists on entire river, complicating legal availability. Any new permit would be heavily conditioned with trigger flow points.

Lewistown Region (Cont)			
Water Source	**Legally Available**	**Not Legally Available**	**Comments**
Warm Spring Creek	Potentially – During non-irrigation season and in lower reaches after irrigation return flows	Not likely during irrigation season	There could be potential for new permitting subject to trigger flow conditions, however, since no gage exists on Warm Spring Creek, there is no way to monitor streamflows. The lack of a gauge decreases chances for new permitting.
Flatwillow Creek	Potentially, with trigger flow conditions	No – Much of the time	Petrolia reservoir exists on lower Flatwillow Creek. If Petrolia is not full, then water is not legally available. DFWP water reservation exists on entire river, complicating legal availability. The lack of a gauge decreases chances for new permitting.
McDonald Creek	Not Likely	Water probably not legally available	USGS records from 1930-1956 yield a maximum median monthly flow of 13.1 CFS in June. With the exception of July at 5.7 CFS, every other month has less than 2.17 CFS physically available. Legal demands likely exceed flow.

Havre Region			
Water Source	**Legally Available**	**Not Legally Available**	**Comments**
Battle Creek		No Basin Closure	No new water rights issued since the state ratification of the Fort Belknap Compact. Basin closure became effective April 06, 2001. No water rights issued since 1995 Exceptions to this closure are small groundwater developments and small impoundments for stock watering purposes
Big Sandy Creek and tributaries		Basin Closure	No new water rights issued since the Rocky Boy's compact became effective December 09, 1999. No water rights issued since 1995. Exceptions to this closure are small groundwater developments or larger appropriations of groundwater that is not hydrologically connected to surface water and small impoundments for stock watering purposes.
Cut Bank Creek		No Basin Closure	No water rights issued since 1995 Blackfeet Reservation Boundary stream. No new water rights issued since the state ratification of the Blackfeet Compact. Closure became effective April 08, 2011. Exceptions to this closure are small groundwater developments and small impoundments for stock watering purposes
Milk River		Basin Closure	Subject to DNRC ordered mainstem basin closure authorized under §85-2-321, MCA. No water rights issued since 1995 in addition to the basinwide Fort Belknap Compact Closure effective April 06, 2001. Exceptions to this closure are small groundwater developments or larger appropriations of groundwater that is not hydrologically connected to surface water and small impoundments for stock watering purposes.

Havre Region (Cont)			
Water Source	**Legally Available**	**Not Legally Available**	**Comments**
Missouri River		Tributaries limited to small uses	Wild and Scenic Compact has large in-stream rights below Fort Benton, but there is substantial remaining water beyond their rights. Tributaries are limited to small uses due to limited and fluctuating flows.
Sage Creek		Basin Closure	Rocky Boy's compact. No water rights issued since 1995. Exceptions to this closure are small groundwater developments or larger appropriations of groundwater that is not hydrologically connected to surface water and small impoundments for stock watering purposes.
Southern Tributaries of the Milk River		Basin Closure	Department ordered surface water closure of Miners Coulee, Halfbreed Coulee (aka. Breed Creek), Bear Creek, and all their respective tributaries in Toole and Liberty counties. This closure became effective on September 01, 1991.

Glasgow Region			
Water Source	**Legally Available**	**Not Legally Available**	**Comments**
Beaver Creek		Basin Closure	Fort Belknap Compact Closure
Big Muddy Creek		Compact restriction	Fort Peck Compact
Big Dry Creek		No	No water rights issued since 1995
Charlie Creek			Permitting possible on intermittent and ephemeral tributaries.
Fort Peck Reservoir	Yes		CMR compact only effects the tribes surrounding the reservoir by having restrictions
Frenchman Creek		Basin Closure	Fort Belknap Compact Closure
Milk River		Basin Closure	Fort Belknap Compact Closure
Missouri River	Yes		
Poplar River and tributaries		Compact Restriction	Fort Peck Compact
Porcupine Creek		Compact Restriction	Fort Peck Compact, No water rights issued since 1995
Redwater Creek			Permitting possible on intermittent and ephemeral tributaries.
Rock Creek		Basin Closure	Permitting possible on intermittent and ephemeral tributaries. Fort Belknap Compact Closure
Whitewater Creek		Basin Closure	Permitting possible on intermittent and ephemeral tributaries. Fort Belknap Compact Closure

Conservation District Water Reservations

Conservation Districts in the LMRB also have a significant volume of Water Reservations water allocated for future project use. The table below lists water volume available by Conservation District.

MISSOURI RIVER BASIN							
CONSERVATION DISTRICT WATER RESERVATION BALANCE							
as of December 31, 2012							
CD	SOURCE OF WATER SUPPLY	VOLUME GRANTED (AF)	VOLUME ALLOCATED (AF)	REMAINING VOLUME (AF)	FLOW GRANTED (cfs)	FLOW ALLOCATED (CFS)	REMAINING FLOW (CFS)
CHOUTEAU	Mainstem Missouri River, Shonkin Creek, HighwoodCreek, Big Sag Spring, Marias River, Teton River	33,123.00	2,481.00	30642.00	218.80	34.84	183.96
FERGUS	Mainstem Missouri River, Wolverine Creek, Lincoln Ditch, E Fork Big Spring Creek, Little Casino Creek, Olsen Creek, UT of Olsen Creek, UT Ross Fork Creek, Warm Springs Creek	3,914.00	237.00	3677.00	33.70	2.23	31.47
JUDITH BASIN	Louse Creek, Otter Creek, Little Otter Creek, Running Wolf Creek	731.00	0.00	731.00	6.04	0.00	6.04
LOWER MUSSEL SHELL	Groundwater Mines	600.00	0.00	600.00	90.00	0.00	0.00
VALLEY	Fort Peck Reservoir	92,000.00	0.00	92000.00	499.00	0.00	499.00
BLAINE	Battle Creek, Little Coulee	18,934.00	0.00	18934.00	0.00	0.00	0.00
DANIELS	South Fork Whitetail Creek, Groundwater, Poplar River, UT Middle Fork Poplar River, Pit, Police Creek, East Fork Poplar River, Sprinks, Olson Coulee, Coal Creek, UT of Butte Creek	3,047.00	0.00	3047.00	16.90	0.00	16.90
McCONE	Mainstem Missouri River	14,299.00	3,793.30	10505.70	99.50	62.11	37.39
RICHLAND	Mainstem Missouri River	25,349.00	9,392.00	15957.00	186.90	107.50	79.40
ROOSEVELT	Mainstem Missouri River	73,115.00	9,475.60	63639.15	558.80	101.83	456.97
SHERIDAN	Groundwater	15,479.00	5,648.00	9831.00	0.00	0.00	0.00
VALLEY	Missouri River, Milk River, Groundwater	7,668.00	0.00	7668.00	54.10	0.00	54.10
TOTAL		**288,259.00**	**31,026.90**	**257,231.85**	**1,763.74**	**308.51**	**1,365.23**

Note: AF = Acre Feet; CFS = Cubic Feet per Second; volume and flow amounts granted to Conservation District by the Board of Natural Resources

Basins With Hydrology That Could Potentially Support New Storage

The storage of water for future use can be an invaluable component of water management. In Montana, greatest water demand typically occurs during July and August when irrigation is at its seasonal peak. However the time of greatest natural water supply occurs in May and June, when rivers are highest with snow melt runoff. Storing water for times of future use changes the dynamics of supply and demand.

The LMRB contains hundreds of small impoundments that are locally important for stock watering, fish and wildlife habitat, and some irrigation. However, there are very few large reservoirs within the LMRB. Absence of large storage in the LMRB is likely due to several factors, including lack of water demand, lack of major streams to provide firm water yield for storage, high reservoir siltation rates, and the economics of building water storage projects.

Most streams in the LMRB are prairie streams of relatively low elevation which exhibit erratic flow characteristics. These streams are more often supplied by rainfall than by snowmelt, and typically do not produce a large yield. Most other LMRB streams are dependent on upstream inflows from more water rich areas, such as the Upper Missouri River Basin. However, there are streams which drain snow melt from the limited mountainous areas of the LMRB and which could possibly support additional storage.

Fort Peck Reservoir Sub Basin

The Judith River is an example of a snow-dominated stream that drains part of the Little Belt and Big Snowy mountains, near Lewistown. Figure H1 shows the median daily flow of the Judith River near its mouth, downstream of almost all water use in this watershed, and downstream of tributary inflows from Big Spring Creek and Warm Spring Creek. The period of record for this gage site is 2001 through 2013 and therefore includes the 2000's drought era. The diagram shows a conceptual example of when water might be stored (high flows during May and June), and then released for use (July through September). Ackley Lake, an offstream storage facility located high in the watershed, is the only significant storage facility in the Judith River Basin, and has a modest 5,800 acre foot capacity.

Strictly from a hydrologic standpoint, the Judith River and several other smaller streams in the LMRB exhibit hydrologic characteristics suitable for storage projects. Conceptually, there are periods of early high snowmelt streamflows that could be stored for release later in the irrigation season of peak demand.

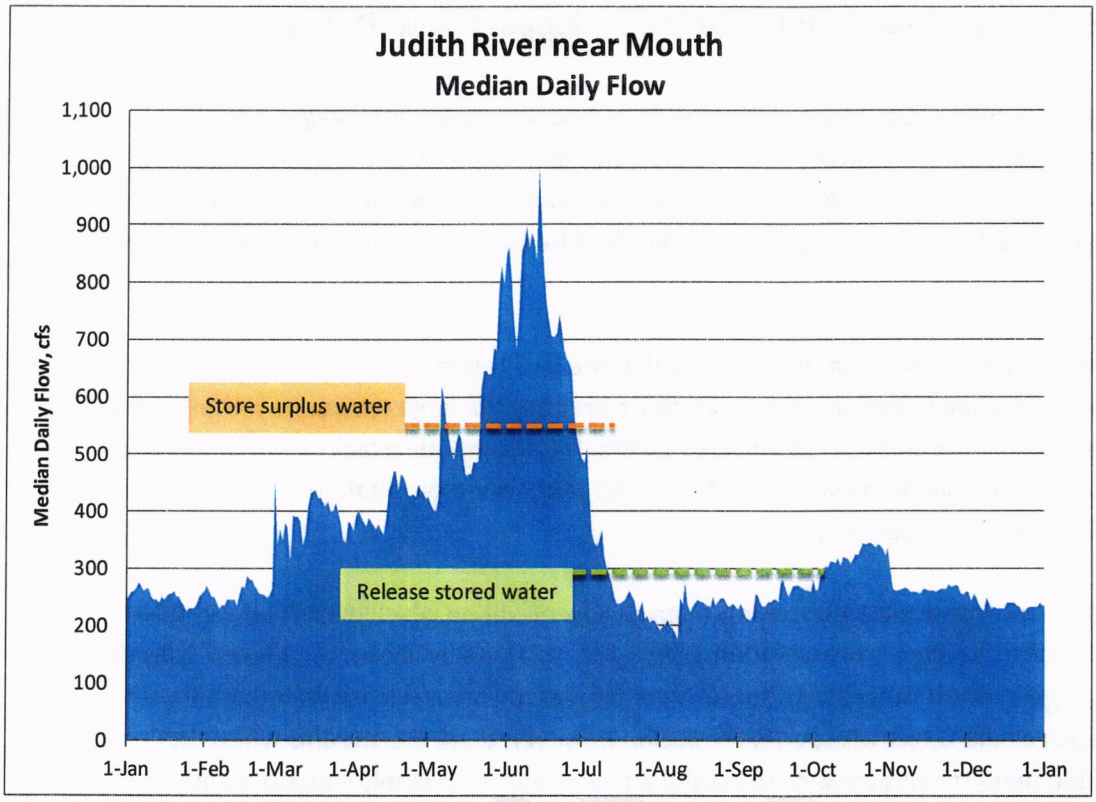

Figure H1. Median Daily Flow of the Judith River near mouth.

Musselshell River Basin

The Musselshell River Basin contains a succession of storage reservoirs beginning high in the watershed with Bair Reservoir on the North Fork Musselshell River, and Martinsdale Reservoir on the South Fork Musselshell River. Deadman's Basin Reservoir, located downstream between Harlowton and Roundup, is an offstream facility with a storage capacity of 76,900 acre feet.

Horse Creek Coulee

In 2010, two provisional permits were issued to the Petroleum County Conservation District for a water marketing project located below Roundup, near the town of Musselshell. The project includes a 4,464 acre foot storage reservoir on Horse Creek, which is tributary to the Musselshell River. According to DNRC documents, the maximum annual appropriation from Horse Creek would be 560 acre feet, and the maximum diversion from the Musselshell River mainstem would be an additional 3950 acre feet. Water would be marketed through contracts for irrigation use in the lower basin. The deadline for project completion is December 31, 2020.

Flatwillow Creek

Flatwillow Creek is a major tributary of the Musselshell River, contributing substantial flow to the mainstem, just upstream of Mosby. The USGS gage is located very near the confluence of these streams, downstream of Yellow Water and Petrolia reservoirs. Yellow Water Reservoir has a capacity of 3,840 acre feet, and Petrolia has a capacity of 9,190 acre feet, for a combined capacity of 13,030 acre feet. According to the USGS, average annual runoff at this gage site is 73,710 acre feet,

so current storage is only about 12% of the average runoff at the site. Strictly from a hydrologic or water supply perspective, it would appear that Flatwillow Creek could accommodate additional water storage.

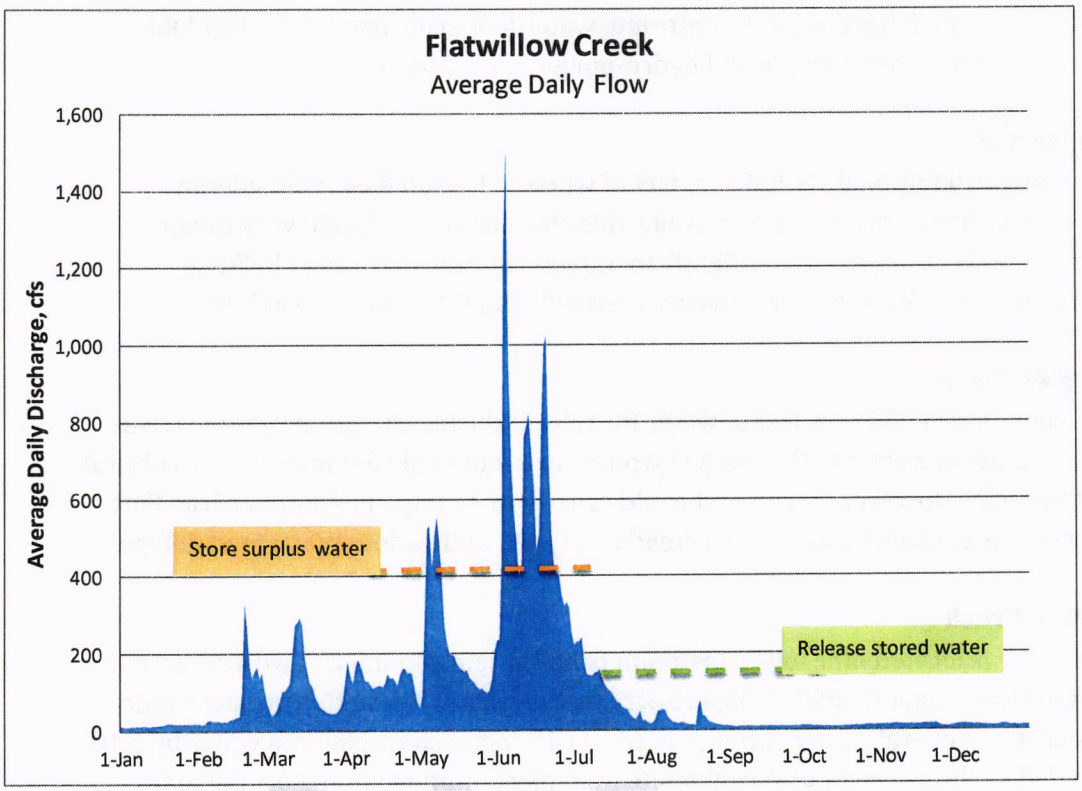

Figure H2. Flatwillow Creek average daily flow hydrograph.

St. Mary River – Milk River Basins

A USBR feasibility study was conducted to identify present and potential water supplies, water uses and management, major water issues and alternatives to address these issues, including potential storage projects (USBR, 2003. North Central Montana Alternatives, Scoping Document). The following alternatives were examined within this document.

Babb Dam

One alternative was the construction of a large dam and reservoir on the St. Mary River near Babb, Montana. According to the study, the conceptual Babb Dam could store 297,000 acre feet of water and would add water slightly to the St. Mary River supply, and add water significantly to the Milk River supply. Strictly from a hydrologic perspective, the St. Mary River exhibits characteristics favorable for additional storage projects. This dam and reservoir would sit entirely on the Blackfeet Indian Reservation.

Enlarge Fresno Reservoir

Another alternative examined in the feasibility study is the enlargement of Fresno Reservoir. Storage capacity of Fresno has been reduced by siltation at the rate of about 500 acre feet per year.

Originally constructed with a storage capacity of 130,000 acre feet, the current capacity is at around 93,000 acre feet (USBR, 2003. North Central Montana Alternatives, Scoping Document). According to the study, alternatives of increasing storage of Fresno Reservoir have very modest effects to the Milk River water supply. Increasing storage at Fresno Reservoir could contribute to implementation of the Fort Belknap Compact, contribute water more consistently to Bowdoin Waterfowl Refuge and improve recreational and hydro-power opportunities.

Enlarge Nelson Reservoir

This option would store an additional 16,000 acre feet of water in Nelson Reservoir, adding flexibility to operation of the reservoir. Agriculturally, this alternative would add very minor amounts to the supply, and could contribute slightly to implementation of the Fort Belknap Compact. Benefit to Cost ratio for this alternative was estimated at 0.10, marginal at best.

Reservoir on Peoples Creek

This option would impound 34,900 acre feet of water for release during irrigation season. It was determined that alternatives relating to this project would contribute only modestly to agricultural water supplies in the basin. However this project could contribute to implementation of the Fort Belknap Compact, and water could be more consistently supplied to Bowdoin Waterfowl Refuge.

Reservoir on 30 Mile Creek

This Milk River tributary is located nine miles upstream from Harlem, Montana. Two alternatives for this project would store either 47,850 or 80,490 acre feet of water. Again, this project would contribute only modestly to overall water supplies in the basin, increasing delivered water by 1.10 inches per acre annually. This project could contribute to implementation of the Fort Belknap Compact.

Reservoir on Beaver Creek

This particular Beaver Creek enters the Milk River several miles to the east of Malta in Phillips County. Storage capacity of a reservoir here would be a maximum of 9,800 acre feet and contribute a small benefit of 0.27 inches per acre annually. This project could contribute to implementation of the Fort Belknap Compact.

US – Canada Joint Storage Alternative

Past discussions and investigations have examined the possibility of a joint US – Canada storage project on the Milk River in Canada. The storage facility would be constructed just below the confluence of the North Fork and Milk River mainstem in southern Alberta, and would have a theoretical capacity of 237,000 acre feet of water (USBR and DNRC, 2012. St. Mary River and Milk River Basins Study Summary Report).

Lower Missouri – Poplar Sub Basin

Frenchman Dam and Reservoir

Frenchman Dam is on Frenchman Creek located north of Saco, and was constructed in 1951 with a storage capacity of 7,010 acre feet of water. Since construction, the reservoir has lost more than half of its capacity to siltation, and now has a capacity of only 2,800 acre feet. The DNRC State Water Projects Bureau is currently investigating alternatives to rebuild or remove the dam, or to restore the lost storage capacity without dam removal (DNRC, 2014. Frenchman Dam Technical Feasibility Study: Enlarging Frenchman Reservoir).

Modeling of Frenchman Dam reconstruction alternatives was also presented in a previous study by the USBR (USBR and DNRC, 2012. St. Mary River and Milk River Basins Study Summary Report). Various storage capacities were modeled which would provide a reliable water supply for irrigation interests, and possibly mitigate impacts of implementing the Fort Belknap Compact. One modeled alternative was for a 50,000 acre foot facility, which would significantly reduce water shortages for Frenchman River water users in most years. A reservoir of this size would also reduce irrigation shortages downstream on the Milk River during dry years.

Non-Structural Storage

Natural or augmented storage in flood plains and associated alluvial aquifers are important sources of non-structural storage. Flood plains with healthy riparian areas slow runoff and promote groundwater recharge to effectively store water when there is a surplus for release later during times of shortage, functioning similarly to constructed reservoirs. Disturbances that can limit connectivity and access of flood waters to flood plains include impervious surfaces, degraded vegetation, stream incision, stream channelization, and subsurface drains. Drought and floods that damage vegetation, cause avulsions, or otherwise disturb the connection between a steam and its flood plain also can reduce the storage capacity of flood plains and alluvial aquifers. Eliminating disturbances and restoring health to riparian areas provides the greatest opportunity for increasing storage to supply or offset the effects of future water demands. Urban encroachment, livestock and wildlife grazing, forest practices, and storm water discharge are areas where improved management can augment flood plain storage. Storage in flood plains and alluvial aquifers, and base flow of streams they feed depend on regular seasonal influx of flood waters that is interrupted during droughts. Severe floods like occurred in 2011 can cause avulsions that disconnect a stream from its flood plain, thereby reducing the storage capacity. Healthy riparian areas are adapted to and recover quickly from drought and flood cycles.

Artificial recharge to alluvial aquifers can increase storage during spring runoff or through aquifer recharge plans implemented to offset depletion by new groundwater uses. Irrigation infrastructure and wetlands provide ready means for augmenting storage in flood plains and associated alluvial aquifer systems. Montana has more than 3,000 miles of irrigation canals from which ditch loss often far exceeds natural recharge. For example, the East Bench Irrigation Canal in the lower Beaverhead River may lose as much as 398 acre-feet per season; with a length of about 17 miles between Dillon and Beaverhead Rock, the seasonal ditch loss would be about 6,800 acre-feet. Additional recharge occurs from direct flood irrigation. The groundwater flow systems in nearly all of the watersheds of western Montana and the large watersheds of eastern Montana have been substantially altered by recharge from irrigation canals. The significance of this is two-fold: 1. significant volumes of water

recharged from irrigation conveyance and application are stored in alluvial aquifers and released to support base flow, and 2. irrigation infrastructure provides the means for augmenting non-reservoir storage to store water in flood plains and alluvial aquifers.

** The importance of groundwater storage and potential for augmenting natural storage could be illustrated using a map of HUCs where stream discharge is most dependent on groundwater. The data would be the ratio of mean base flow to mean annual discharge. Other potential metrics include density of seeps and springs, and groundwater dependent vegetation (examples in the document Mapping Groundwater Dependent Ecosystems in California by Howard and Merrifield, 2010).**

DRAFT

10. Effects of Changes in Timing and Location of Precipitation and Snowpack Runoff.

V. Major Findings and Key Recommendations

A. Introduction

B. Major Findings (Issues)

C. Key Recommendations

1. Issue Statement
2. Goal of Recommendation
3. Objective
4. Implementation Tasks

a) -- Short Term (0-2 years)

b) -- Medium Term (2-10 years)

c) -- Long Term (10-20 years)

VI. References

DNRC, 2008. State Water Projects Bureau, Deadman's Basin Dam Fact Sheet.

Ferrari, 2013. Fresno Reservoir 2010, Sedimentation Survey, U.S. Bureau of Reclamation Technical Report No. SRH-2013-01.

Cannon, M.R. and Johnson, Dave R., 2004. Estimated Water Use in Montana in 2000, U.S. Geological Survey Scientific Investigations Report 2004-5223.

WRCC, 2013. Montana Climate Summaries, Western Regional Climate Center http://www.wrcc.dri.edu/summary/climsmmt.html

U.S. Bureau of Reclamation, and Montana DNRC, 1998. Musselshell River Basin Water Management Study.

Milk River International Alliance, and U.S. Bureau of Reclamation, 1999. The Milk River:

International Lifeline of the Hi-Line, A Guidebook.

U.S. Bureau of Reclamation, and Montana DNRC, 2012. St. Mary River and Milk River Basins Technical Report. Milk river Project, Montana.

GROUNDWATER REFS

Alverson, D. C., 1965. Geology and hydrology of the Fort Belknap Indian Reservation, Montana: U.S. Geological Survey Water-Supply Paper 1576-F,p. F1-F59. http://pubs.usgs.gov/wsp/1576f/report.pdf.

Bowen, C.F., 1919. Contributions to economic geology, 1918, Part II, Mineral fuels--Anticlines in a part of the Musselshell Valley, Musselshell, Meagher, and Sweet Grass counties, Montana, USGS Bulletin: 691-F, http://pubs.usgs.gov/bul/0691f/report.pdf.

Bredehoeft, J.,1997. Safe Yield and the Water Budget Myth. Groundwater, 35: 929. doi: 10.1111/j.1745-6584.1997.tb00162.x

Cannon, M. R., 1987. Water resources and potential effects of surface coal mining in the area of the Woodson Preference Right Lease Application, Montana, USGS Water-Resources Investigations Report: 87-4027, http://pubs.er.usgs.gov/publication/wri874027.

Clayton, L., Moran, S.R., and Bluemle, J.P., 1980. Explanatory text to accompany the geologic map of North Dakota, North Dakota Geologic Survey, Report of Investigations 69, 93 p.

Davis, N.K., Locke III, W.W., Pierce, K.L., Finkel,R.C., 2006. Glacial Lake Musselshell: Late Wisconsin slackwater on the Laurentide ice margin in central Montana, USA, Geomorphology, Volume 75, Issues 3–4, Pages 330-345, http://dx.doi.org/10.1016/j.geomorph.2005.07.021.

Environmental Quality Council (EQC; Groundwater Advisory Council), 1983. Montana Groundwater Status Report, http://www.leg.mt.gov/content/publications/environmental/1983groundwater.pdf.

Fields, R.W., Rasmussen, D.L., Tabrum, A.R., and Nichols, Ralph, 1985. Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho a summary, *in* Flores, R.M., and Kaplan, S.S., eds., Cenozoic paleogeography of west-central United States: Denver, Colo., Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 9-36.

Freeze, R. A., and Cherry, J. A., 1979. Groundwater, Englewood Cliffs, N.J: Prentice-Hall Print.

Huntoon, P.W., 1993. The influence of Laramide foreland structures on modern ground-water circulation in Wyoming artesian basins, in Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., editors, Geology of Wyoming: Geological Survey of Wyoming Memoir No. 5, p. 756-789.

Levings, J.F., 1983. Hydrogeology and simulation of water flow in the Kootenai aquifer of the Judith Basin, central Montana. U.S. Geological Survey Water-Resources Investigations Report 83-4146, 39 p., http://pubs.usgs.gov/wri/1983/4146/report.pdf.

Lindsey, D.A., 1982. Geologic map and discussion of selected mineral resources of the North and South Moccasin mountains, Fergus County, Montana, United States Geological Survey: Miscellaneous Geologic Investigation 1362, 1 sheet(s), 1:24,000. http://pubs.usgs.gov/imap/1362/plate-1.pdf.

Lohman, S.W., 1972. Definitions of selected ground-water terms: Revisions and conceptual refinements, U.S. Geological Survey Water Supply Paper, 1988, 21 p. http://pubs.usgs.gov/wsp/wsp_1988/pdf/wsp_1988.pdf.

Lopez, D.A., 2000. Geologic map of the Billings 30' x 60' quadrangle, Montana, Montana Bureau of Mines and Geology: Geologic Map 59, 1 sheet(s), 1:100,000, http://www.mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=10214&.

Maxey, G. B. and T. E. Eakin, 1949. Ground Water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada. Nevada Department of Conservation and Natural Resources Water-Resources Bulletin No. 8, 59 pp.

Montana Bureau of Mines and Geology (MBMG), United States Geological Survey, 1978. Ground water of the Fort Union coal region, eastern Montana, MBMG: Special Publication 80, 47 p.

Nimick, D.A, and Thamke, J.N., 1998. Extent, magnitude, and sources of nitrate in the Flaxville and underlying aquifers, Fort Peck Indian Reservation, northeastern Montana: U.S. Geological Survey Water- Resources Investigations Report 98-4079, 45 p., http://pubs.usgs.gov/wri/1998/4079/report.pdf.

Osterkamp, W. R., 1968. Occurrence of ground water in the Judith River Formation, north-central Montana: U.S. Geological Survey Hydrologic Investigations Atlas HA-308, scale 1:250,000, http://pubs.usgs.gov/ha/308/plate-1.pdf.

Patton, T., 2013. Climate 2013: Groundwater level response in wells, Presentation to Governors drought and water supply committee, http://drought.mt.gov/Committee/Presentations/2013/mbmg_july.pdf

Perry, E.S., 1931. Ground water in eastern and central Montana, Montana Bureau of Mines and Geology: Memoir 2, 59 p.

Perry, E.S., 1933. Possibilities of ground-water supply for certain towns and cities of Montana, Montana Bureau of Mines and Geology: Miscellaneous Contribution 2, 49 p.

Reiten, J.C., Hanson, J., 2008. Developing a viable water supply for the town of Broadview, south-central Montana, Montana Bureau of Mines and Geology: Open-File Report 567, 89 p. http://www.mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=10214&.

Seaber, P.R., Kapinos, F.P.,Knapp, G.L., 1987. Hydrologic Unit Maps, U.S. Geological Survey Water Supply Paper 2294, http://pubs.usgs.gov/wsp/wsp2294/pdf/wsp_2294.pdf.

Slagle, S. E., 1983. Water resources of the Fort Union coal region, east-central Montana: U.S. Geological Survey Water- Resources Investigations Open-File Report 83-4151, 111 p., http://pubs.usgs.gov/wri/1983/4151/plate-1.pdf.

Smith, L.N., LaFave, J.I., Patton, T.W., Rose, J.C., McKenna, D.P., 2000. Ground-water resources of the Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana. Part A- Descriptive overview and basic data, Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 1A, 43 p. http://www.mbmg.mtech.edu/pdf/groundwateratlas1.pdf.

Theis, C.V. 1941. The effect of a well on the flow of a nearby stream. *American Geophysical Union Transactions*, 22(3), 734-738.

USGS, 2005. Preliminary integrated geologic map databases for the United States: Central states: Montana, Wyoming, Colorado, New Mexico, North Dakota, South Dakota, Nebraska, Kansas,

Oklahoma, Texas, Iowa, Missouri, Arkansas, and Louisiana, Open-File Report 2005-1351 http://pubs.usgs.gov/of/2005/1351/.

Vine, J. D., 1956. Geology of the Stanford-Hobson area, central Montana, Contributions to economic geology, 1955, USGS Bulletin: 1027-J, http://pubs.er.usgs.gov/publication/b1027J.

Whitehead, R.L., 1996. Ground Water Atlas of the United States: Segment 8, Montana, North Dakota, South Dakota, Wyoming, Ground Water Atlas of the United States: 730-I, http://pubs.usgs.gov/ha/730i/report.pdf.

Wolock, David, 2003. Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States. USGS Open-File Report: 2003-146, http://pubs.er.usgs.gov/publication/ofr03146.

Wolock, David M., 2003. Base-Flow Index Grid for the Conterminous United States. USGS Open-File Report: 2003-263, http://pubs.er.usgs.gov/publication/ofr03263.

Wolock, David M., 2003. Estimated Mean Annual Natural Ground-Water Recharge in the Conterminous United States. USGS Open-File Report: 2003-311, http://pubs.er.usgs.gov/publication/ofr03311.

Zelt, R.B., Boughton, G. K., Miller, K. A., Mason, J. P., Gianakos, L. M., 1999. Environmental setting of the Yellowstone River basin, Montana, North Dakota, and Wyoming, USGS Water-Resources Investigations Report: 98-4269, http://pubs.usgs.gov/wri/wri984269/wri984269.pdf.

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Groundwater Recharge by HUC/planning basin

Groundwater Storage by HUC/planning basin

Consumptive Use by HUC/planning basin

- Irrigation
- Public Water Supply
- Domestic
- Stock
- Industrial
- Thermoelectric Power Generation (none for Upper Missouri)

Instream flow rights by HUC/planning basin

Data Gaps and Uncertainty

FWP instream flow reservations in the LMRB.

MISSOURI RIVER AND FORT PECK RESERVOIR TRIBUTARIES

STREAM	REACH DESCRIPTION	DATES GRANTED	AMOUNT ALLOWED (cfs)
Missouri River #5	Marias River to Judith River	Jan 1 – Dec 31	4,280
Missouri River #6	Judith River to upper end of Fort Peck Reservoir	Jan 1 – Dec 31	4,652
Big Dry Creek	Highway 200 Bridge to mouth	Mar 15 – Mar 31	300
		Apr 1 – Apr 30	100
		May 1 – May 31	35
		June 1 – Oct 31	5.5
Little Dry Creek	Whiteside Ranch house to Big Dry Creek	Mar 15 – Mar 31	110
		Apr 1 – Apr 30	42
		May 1 – May 31	17
		June 1 – Oct 31	3.5

JUDITH RIVER DRAINAGE

STREAM	REACH DESCRIPTION	DATES GRANTED	AMOUNT ALLOWED (cfs)
Beaver Creek	West Fork to Cottonwood Creek	Jan 1 – Dec 31	5
Big Spring Creek #1	Fish Hatchery to Cottonwood Creek	Jan 1 – Dec 31	53.5
Big Spring Creek #2	Cottonwood Creek to mouth	Jan 1 – Dec 31	100
Cottonwood Creek	Spring Branch Cottonwood Cr to Big Spring Cr	Jan 1 – Dec 31	4.5
East Fork Big Spring Cr	Headwaters to Big Spring Cr	Jan 1 – Dec 31	7.5
Judith River #1	SF and MF to Big Spring Creek	Jan 1 – Dec 31	25
Judith River #2	Big Spring Creek to Missouri River	Jan 1 – Dec 31	160
Lost Fork Judith River	SF and WF to MF Judith River	Jan 1 – Dec 31	14
Middle Fork Judith River	Headwaters to South Fork	Jan 1 – Dec 31	22
South Fork Judith River	Headwaters to Middle Fork	Jan 1 – Dec 31	3.5
Warm Spring Creek	Springs to Judith River	Jan 1 – Dec 31	110
Yogo Creek	Headwaters to MF Judith River	Jan 1 – Dec 31	3

MUSSELSHELL RIVER DRAINAGE

STREAM	REACH DESCRIPTION	DATES GRANTED	AMOUNT ALLOWED (cfs)
Alabaugh Creek	Headwaters to mouth	Jan 1 – Dec 31	12
American Fork Creek	South Fork to mouth	Jan 1 – Dec 31	5.5
Big Elk Creek	Origin at Lebo Fork to mouth	Jan 1 – Dec 31	9.5
Careless Creek	Headwaters to Roberts Creek	Jan 1 – Dec 31	2
Checkerboard Creek	East and West Forks to mouth	Jan 1 – Dec 31	6
Collar Gulch Creek	Headwaters to mouth	Jan 1 – Dec 31	0.6
Cottonwood Creek	WF, MF and Loco Creek to mouth	Jan 1 – Dec 31	16
Flatwillow Creek	NF and SF to Petrolia Reservoir	Jan 1 – Dec 31	15
Musselshell River #1	NF and SF to Deadmans Basin Diversion	Jan 1 – Dec 31	80
Musselshell River #2	Deadmans Basin Div to Musselshell Div	Jan 1 – Dec 31	80
Musselshell River #3	Musselshell Div to mouth	Jan 1 – Dec 31	70
NF Musselshell River #1	Headwaters to Bair Reservoir	Jan 1 – Dec 31	3
NF Musselshell River #2	Bair Reservoir to SF Musselshell River	Jan 1 – Dec 31	16
SF Musselshell	Headwaters to North Fork	Jan 1 – Dec 31	30
Spring Creek	Headwaters to mouth	Jan 1 – Dec 31	8
Swimming Woman Creek	Headwaters to Rd crossing 8 miles up from mouth	Jan 1 – Dec 31	2.5

MILK RIVER DRAINAGE

STREAM	REACH DESCRIPTION	DATES GRANTED	AMOUNT ALLOWED (cfs)
Battle Creek	International Boundary to mouth	Jan 1 – Mar 31	2
		Dec 1 – Dec 31	2
		Apr 1 – Nov 31	5
Beaver Cr (Hill County)	Reservation boundary to Beaver Cr Reservoir	Jan 1 – Dec 31	7
Beaver Cr #1 (Phillips Co)	Headwaters to Reservation boundary	Jan 1 – Dec 31	0.2
Beaver Cr #2 (Phillips Co)	Highway 191 to mouth	Jan 1 – Mar 31	7
		Dec 1 – Dec 31	7
		Apr 1 – Nov 31	11
Clear Creek	Headwaters to Clear Creek Rd.	Jan 1 – Dec 31	5
Frenchman River	International boundary to mouth	Jan 1 – Mar 31	2
		Dec 1 – Dec 31	2
		Apr 1 – Nov 31	5
Little Box Elder Creek	Headwaters to Clear Creek Rd.	Jan 1 – Dec 31	1
Peoples Creek	Headwaters to Barney Olson Rd	Jan 1 – Dec 31	1
Rock Creek	International boundary to mouth	Jan 1 – Mar 31	2
		Dec 1 – Dec 31	2
		Apr 1 – Nov 31	8

MISSOURI – POPLAR DRAINAGE

STREAM	REACH DESCRIPTION	DATES GRANTED	AMOUNT ALLOWED (cfs)
Missouri River #7	Fort Peck Dam to Milk River	Jan 1 – Dec 31	4,508
Missouri River #8	Milk River to state line	Jan 1 – Dec 31	5,178
East Fork Poplar River	International boundary to Middle Fork	Jan 1 – Mar 31	3
		Dec 1 – Dec 31	3
		Apr 1 – Apr 30	15
		May 1 – May 31	10
		June 1 – Nov 30	4
Middle Fork Poplar River	International boundary to East Fork	Jan 1 – Mar 31	1
		Dec 1 – Dec 31	1
		Apr 1 – Apr 30	30
		May 1 – May 31	20
		June 1 – Nov 30	2
Poplar River	Junction of MF and EF to Reservation boundary	Jan 1 – Mar 31	8
		Dec 1 – Dec 31	8
		Apr 1 – Apr 30	70
		May 1 – May 31	50
		June 1 – Nov 30	11
West Fork Poplar River	Bridge south of Peerless to Reservation boundary	Jan 1 – Mar 31	3
		Dec 1 – Dec 31	3
		Apr 1 – Apr 30	30
		May 1 – May 31	20
		June 1 – Nov 30	4
Redwater River #1	Circle to East Redwater Creek	Jan 1 – Mar 31	2
		Dec 1 – Dec 31	2
		Apr 1 – Nov 30	3
Redwater River #2	East Redwater Creek to mouth	Jan 1 – Mar 31	2
		Dec 1 – Dec 31	2
		Apr 1 – Nov 30	4

SOCIOECONOMIC PORTRAIT
LOWER MISSOURI BASIN
STATE WATER PLAN

POPULATION

Recent Estimates

Between the 2010 census and July 1, 2013, the population of the Lower Missouri Basin increased 2.4 percent to 76,209. During the same period Montana's population increased 2.6 percent to 1,015,165. The Lower Missouri Basin is the only of Montana's four major basins with neither a "Metropolitan" nor a "Micropolitan" Statistical Area. According to the White House Office of Management and Budget (OMB 2013), a "Metropolitan Statistical Area" is considered to have "at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties." "Micropolitan Statistical Areas" are defined similarly with the exception that the area's core consists of "at least one urban cluster" with a population between 10,000 and 50,000.

Populations of counties in the Lower Missouri Basin for 2013 are listed in Figure 1. Nearly one-fifth of the Basin's residents lived in Hill County. More than half of the Basin's population resides in the three largest counties, Hill, Fergus, and Roosevelt. The populations of six of the Basin's 15 counties declined between 2010 and 2013. Between 2010 and 2013, Roosevelt County ranked 90th among the fastest growing U.S. counties with populations of at least 10,000 after growing by 6.7 percent to 11,125 during the period. The fastest growing county in the nation was Roosevelt County's neighbor across the North Dakota border, Williams County, which grew by 32.1 percent between 2010 and 2013.

Lower Missouri Basin Counties Populations - 2013

Blaine	6,604
Daniels	1,791
Fergus	11,501
Garfield	1,290
Golden Valley	859
Hill	16,568
Judith Basin	2,016
McCone	1,709
Musselshell	4,629
Petroleum	506
Phillips	4,179
Roosevelt	11,125
Sheridan	3,668
Valley	7,630
Wheatland	2134

Figure 1

Reservations	Population 2010	% Change 2000-10
Fort Belknap	2,851	-3.7
Fort Peck	10,008	-3.0
Total	12,859	-3.2

Figure 2 Source: U.S. Census Bureau, Population Division

The populations of Montana's seven Indian reservations totaled 66,598 in 2010 with one-fifth residing in the Lower Missouri Basin. Figure 2 displays the populations of Indian reservations in the Basin and the percentage change in population between 2000 and 2010. The Fort Belknap and Fort Peck Reservations saw population declines during the period.

Population estimates from the 2010 Census were aggregated by 8-digit hydrologic unit code (HUC) sub-basins for the Lower Missouri Basin. Population estimates for these sub-basins are presented in Figure 3. One quarter of the Basin population resided in the Middle Milk River sub-basin in the vicinity of Havre.

LOWER MISSOURI BASIN POPULATION by SUB-BASIN - 2010

SUB-BASIN	2010 POPULATION
Arrow Creek	993
Battle Creek	147
Beaver Creek (Milk R)	843
Big Dry Creek	766
Big Muddy Creek	3,936
Big Sandy Creek	3,978
Box Elder Creek (Musselshell R)	1,197
Brush Lake	307
Bullwhacker-Dog Creeks	1,435
Charlie-Little Muddy Creeks	3,797
Cottonwood Creek	372
Flatwillow Creek	249
Fort Peck Reservoir	785
Frenchman Creek	57
Judith River	11,331
Little Dry Creek	185
Lodge Creek	556
Lower Milk River	5,408
Lower Musselshell River	240
Middle Milk River	19,350
Middle Musselshell River	3,096
Milk River Headwaters	170
Peoples Creek	1,361
Poplar River	3,036
Porcupine Creek	298
Prarie Elk-Wolf Creeks	6,153
Redwater River	1,728
Rock Creek	84
Sage Creek	1,217
Upper Milk River	765
Upper Musselshell River	4,669
West Fork Poplar River	339
Whitewater Creek	170
Wild Horse Lake	12

Figure 3

Source: U.S. Census Bureau, Population Division;
Montana Department of Natural Resources and Conservation

Trends

Between 1990 and 2013, the population of the Lower Missouri Basin decreased by 6.6 percent while Montana's population increased by 27 percent (Figure 4). Musselshell and Roosevelt Counties were the only counties in the Basin with increasing populations during the period. Their populations increased by 12.8 percent and 1.5 percent, respectively. The populations of McCone, Sheridan, and Daniels Counties each decreased by more than 20 percent. Between 2000 and 2010, Musselshell County, with growth of 1.6 percent, was the only county in the Basin increasing in population. The changes in population for Lower Missouri Basin counties for the periods 1990 to 2010 and 2000 to 2010 are displayed in Figure 5.

Montana's population increased by 24 percent between 1990 and 2010 and by 10 percent between 1990 and 2010.

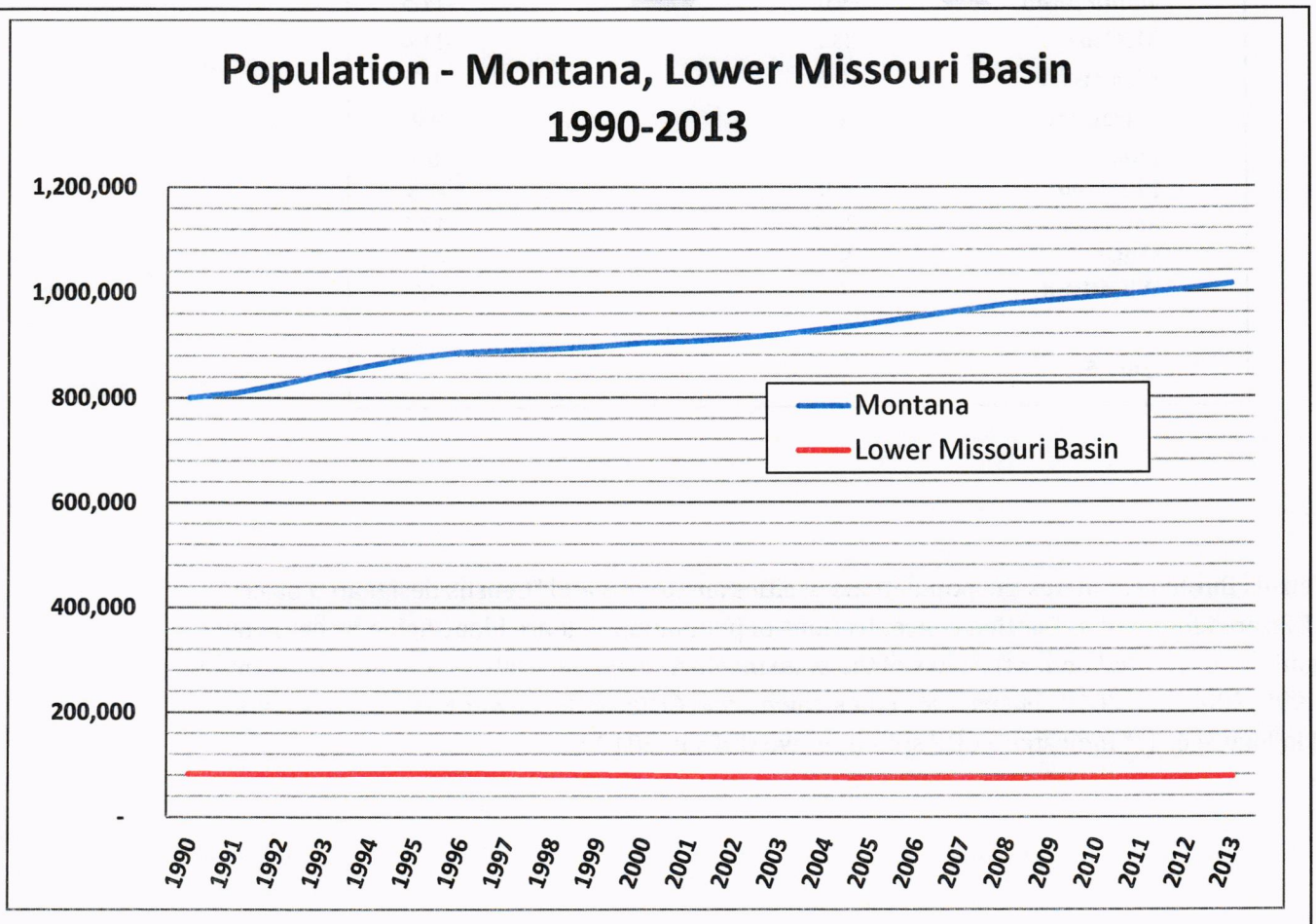


Figure 4

Population Change - Lower Missouri Basin Counties

County	Percent Change 1990-2010	2000-2010
Blaine	-2.9	-7.1
Daniels	-22.0	-13.1
Fergus	-4.1	-2.7
Garfield	-23.9	-6.5
Golden Valley	-3.0	-13.3
Hill	-8.9	-2.7
Judith Basin	-9.0	-11.5
McCone	-23.2	-11.4
Musselshell	10.5	1.6
Petroleum	-4.8	0.0
Phillips	-17.4	-6.7
Roosevelt	-4.9	-1.6
Sheridan	-27.9	-17.3
Valley	-9.9	-3.7
Wheatland	-3.5	-3.7

Figure 5

The U.S. Census Bureau estimates the populations of cities and towns and "Census designated places" (CDPs). CDPs are identified as "settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state in which they are located." Population estimates from the 1990, 2000, and 2010 censuses for cities, towns, and CDPs in the Lower Missouri Basin are presented in Figure 6. (** indicates a CDP split into two CDPs in 2010.)

Figure 6 Estimated Populations for Lower Missouri Basin Cities, Towns, and CDPs

	Census Population 2010	Census Population 2000	Census Population 1990	Percent Change 2000-2010
Blaine County				
Chinook city	1,203	1,386	1,512	-13.2%
Fort Belknap Agency CDP	1,293	1,262	422	2.5%
Harlem city	808	848	882	-4.7%
Hays CDP	843	702	333	20.1%
Lodge Pole CDP	265	214	--	23.8%
Turner CDP	61	--	--	
Daniels County				
Flaxville town	71	87	88	-18.4%
Scobey city	1,017	1,082	1,154	-6.0%
Fergus County				
Denton town	255	301	350	-15.3%
Grass Range town	110	149	159	-26.2%
Lewistown city	5,901	5,813	6,097	1.5%
Lewistown Heights CDP	407	365	--	11.5%
Moore town	193	186	211	3.8%
Roy CDP	108	--	--	
Winifred town	208	156	188	33.3%
Garfield County				
Jordan town	343	364	494	-5.8%
Golden Valley County				
Lavina town	187	209	151	-10.5%
Ryegate town	245	268	260	-8.6%
Hill County				
Agency CDP *	--	324	--	
Azure CDP	286	253	--	13.0%
Beaver Creek CDP	271	291	--	-6.9%
Gildford CDP	179	185	--	-3.2%
Havre city	9,310	9,621	10,201	-3.2%
Havre North CDP	716	973	1,110	-26.4%
Herron CDP	116	100	--	16.0%
Hingham town	118	157	181	-24.8%
Inverness CDP	55	103	--	-46.6%
Kremlin CDP	98	126	--	-22.2%

Figure 6 (cont'd) Estimated Populations for Lower Missouri Basin Cities, Towns, and CDPs

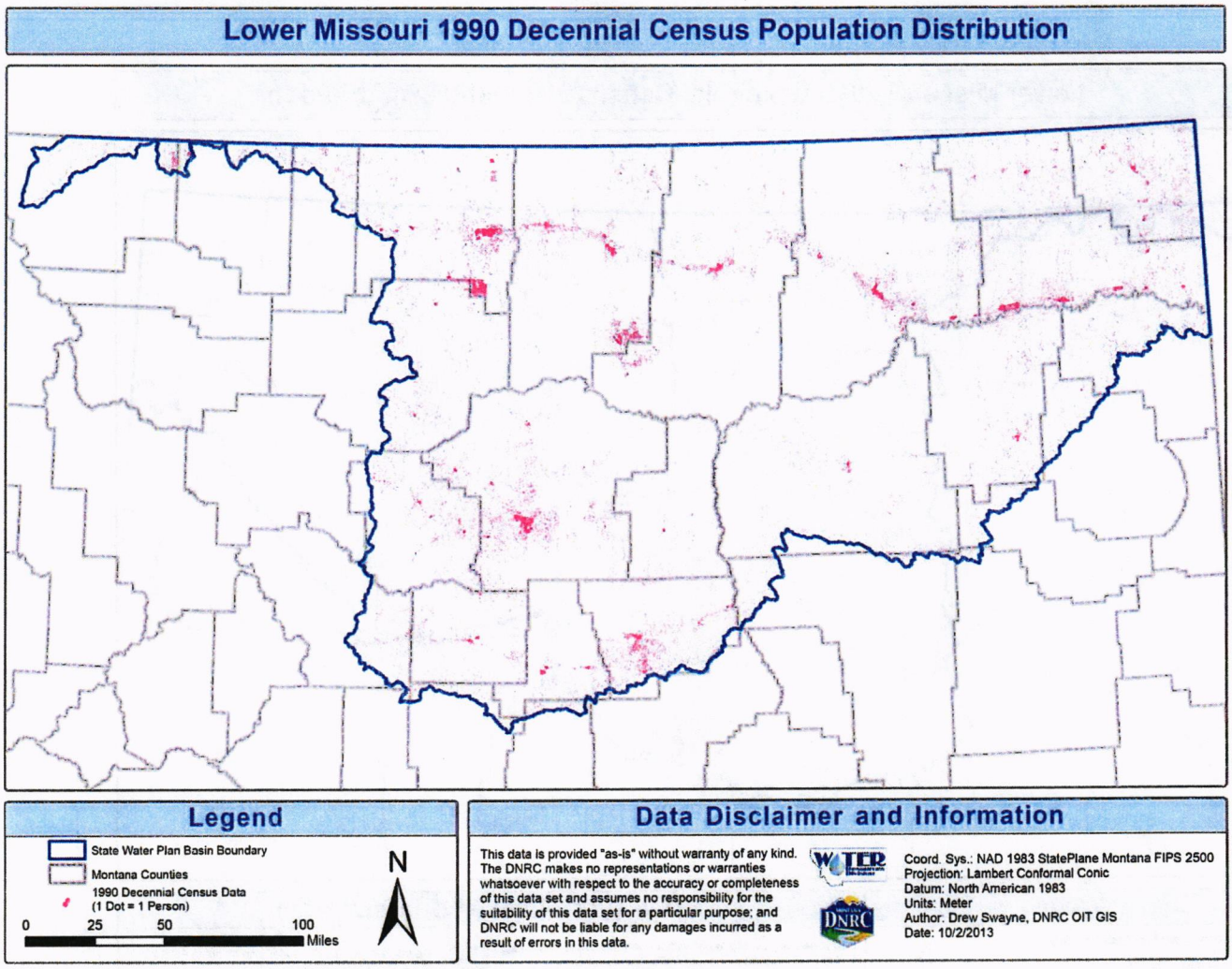
	Census Population 2010	Census Population 2000	Census Population 1990	Percent Change 2000-2010
Hill County (Cont.)				
Rocky Boy's Agency CDP *	355	--	--	
Rudyard CDP	258	275	--	-6.2%
Saddle Butte CDP	128	138	--	-7.2%
Sangrey CDP	306	263	--	16.3%
St. Pierre CDP	350	289	--	21.1%
West Havre CDP	316	284	--	11.3%
Judith Basin County				
Geyser CDP	87	--	--	
Hobson city	215	244	226	-11.9%
Stanford town	401	454	529	-11.7%
McCone County				
Circle town	615	644	805	-4.5%
Musselshell County				
Camp Three CDP	173	138	--	25.4%
Klein CDP	168	188	--	-10.6%
Melstone town	96	136	166	-29.4%
Musselshell CDP	60	60	--	0.0%
Roundup city	1,788	1,931	1,808	-7.4%
Petroleum County				
Winnett town	182	185	--	-1.6%
Phillips County				
Dodson town	124	122	137	1.6%
Malta city	1,997	2,120	2,340	-5.8%
Saco town	197	224	261	-12.1%
Whitewater CDP	64	--	--	
Zortman CDP	69	--	--	
Roosevelt County				
Bainville town	208	153	165	35.9%
Brockton town	255	245	365	4.1%
Culbertson town	714	716	796	-0.3%
Froid town	185	195	195	-5.1%
Poplar city	810	911	881	-11.1%
Wolf Point city	2,621	2,663	--	-1.6%

Figure 6 (cont'd) Estimated Populations for Lower Missouri Basin Cities, Towns, and CDPs

	Census Population 2010	Census Population 2000	Census Population 1990	Percent Change 2000-2010
Sheridan County				
Antelope CDP	51	43	--	18.6%
Medicine Lake town	225	269	357	-16.4%
Outlook town	47	82	109	-42.7%
Plentywood city	1,734	2,061	2,136	-15.9%
Reserve CDP	23	37	--	-37.8%
Westby town	168	172	253	-2.3%
Valley County				
Fort Peck town	233	240	226	-2.9%
Frazer CDP	362	452	403	-19.9%
Glasgow city	3,250	3,253	3,572	-0.1%
Hinsdale CDP	217	--	--	
Nashua town	290	325	375	-10.8%
Opheim town	85	111	145	-23.4%
St. Marie CDP	264	183	--	44.3%

Figures 7 and 8 display maps of the population distributions for the Lower Missouri Basin as reported in the censuses of 1990 and 2010.

DRAFT


Lower Missouri 1990 Decennial Census Population Distribution
Legend
State Water Plan Basin Boundary
Montana Counties
1990 Decennial Census Data
(1 Dot = 1 Person)
0
25
50
100
Miles
N
Data Disclaimer and Information
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Coord. Sys.: NAD 1983 StatePlane Montana FIPS 2500
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Meter
Author: Drew Swayne, DNRC OIT GIS
Date: 10/2/2013

Figure 7

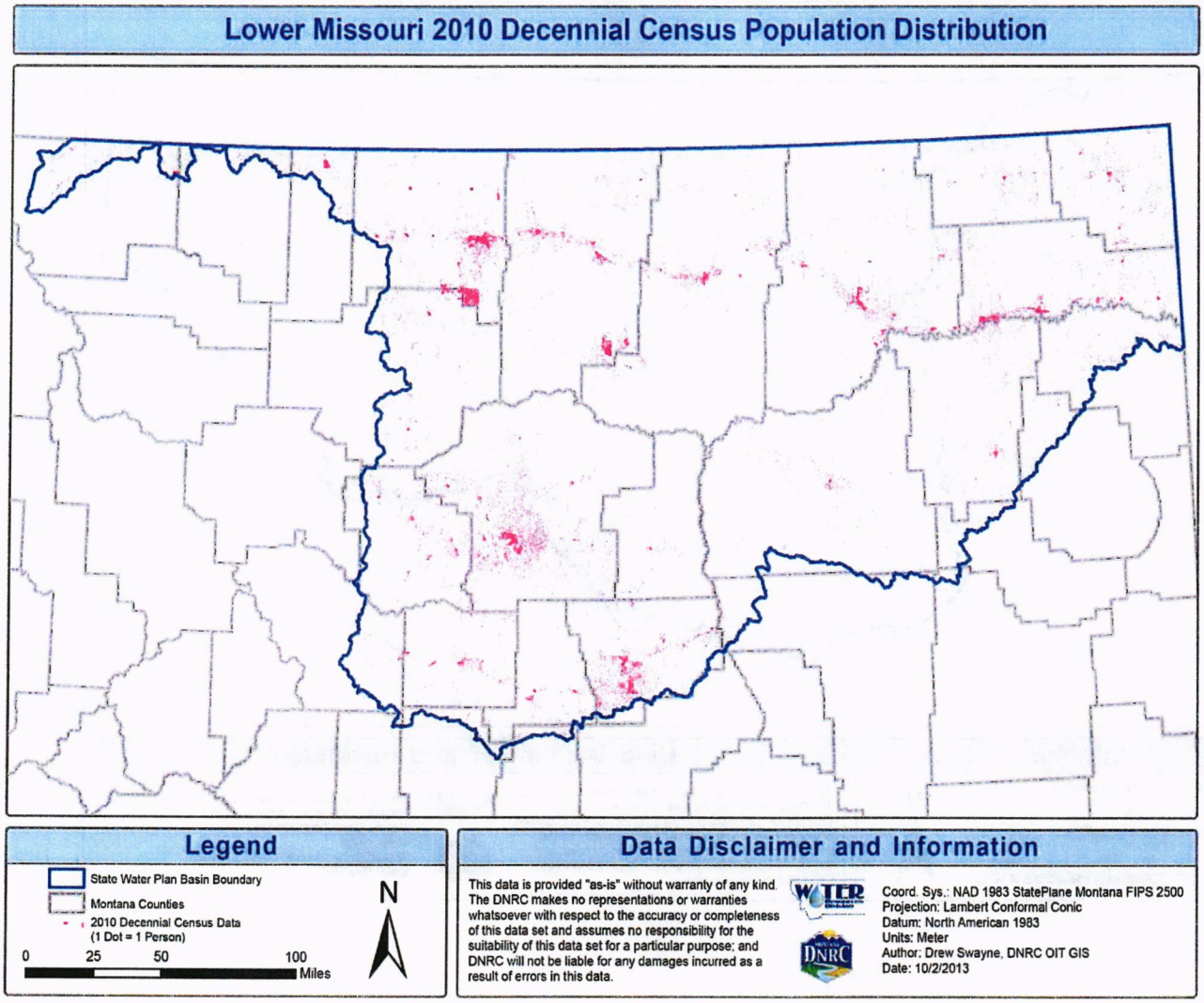
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Figure 8

Population Trends - Lower Missouri Sub-Basins – 1990-2010

SUB-BASIN	1990	2000	2010	Percent Change 1990-2010	Percent Change 2000-2010
Arrow Creek	1,168	1,154	993	-15.0	-14.0
Battle Creek	83	132	147	77.1	11.4
Beaver Creek (Milk R)	923	849	843	-8.7	-0.7
Big Dry Creek	958	792	766	-20.0	-3.3
Big Muddy Creek	5,369	4,783	3,936	-26.7	-17.7
Big Sandy Creek	2,643	3,378	3,978	50.5	17.8
Box Elder Creek (Musselshell R)	1,155	1,300	1,197	3.6	-7.9
Brush Lake	504	372	307	-39.1	-17.5
Bullwhacker-Dog Creeks	1,702	1,566	1,435	-15.7	-8.4
Charlie-Little Muddy Creeks	3,913	3,757	3,797	-3.0	1.1
Cottonwood Creek	487	424	372	-23.6	-12.3
Flatwillow Creek	248	290	249	0.4	-14.1
Fort Peck Reservoir	1,015	828	785	-22.7	-5.2
Frenchman Creek	85	76	57	-32.9	-25.0
Judith River	11,954	11,635	11,331	-5.2	-2.6
Little Dry Creek	284	244	185	-34.9	-24.2
Lodge Creek	788	650	556	-29.4	-14.5
Lower Milk River	5,901	5,444	5,408	-8.4	-0.7
Lower Musselshell River	282	264	240	-14.9	-9.1
Middle Milk River	21,506	20,613	19,350	-10.0	-6.1
Middle Musselshell River	3,153	3,214	3,096	-1.8	-3.7
Milk River Headwaters	136	143	170	25.0	18.9
Peoples Creek	1,151	1,425	1,361	18.2	-4.5
Poplar River	3,710	3,467	3,036	-18.2	-12.4
Porcupine Creek	419	384	298	-28.9	-22.4
Prarie Elk-Wolf Creeks	6,468	6,274	6,153	-4.9	-1.9
Redwater River	2,322	1,969	1,728	-25.6	-12.2
Rock Creek	90	94	84	-6.7	-10.6
Sage Creek	1,350	1,247	1,217	-9.9	-2.4
Upper Milk River	1,133	859	765	-32.5	-10.9
Upper Musselshell River	4,477	4,909	4,669	4.3	-4.9
West Fork Poplar River	595	439	339	-43.0	-22.8
Whitewater Creek	209	226	170	-18.7	-24.8
Wild Horse Lake	47	9	12	-74.5	33.3

Figure 9

The Lower Missouri was the only major basin in Montana with a decreasing population, declining by 8.4 percent between 1990 and 2010. The population of the Middle Milk, the most populous sub-basin, fell by 10 percent. Figure 9 displays population trends over recent decades for the sub-basins in the Lower Missouri Basin.

Components of Population Change

The Lower Missouri Basin's population change of -4,901 between 2000 and 2010 was the result of a natural increase of 1,567 and net migration of -6,140. The components of population change for the Basin's counties are displayed in Figure 10. (The components of population change do not reconcile with the total population change due to the variance in estimation methods applied to different demographic characteristics.) Of the two components of population change, net migration accounts for approximately 125 percent and reflects the substantially larger number of people moving out of the Lower Missouri to other parts of Montana and to other states compared to the number moving in. The level of natural increase—or the number of births in excess of the number of deaths—amounted to -32 percent of the change in the Basin's population. The composition of population change for counties within the Basin varies significantly. Only Musselshell and Golden Valley experienced positive levels of net migration during the decade. In only five counties, the number of births exceeded the number of

Components of Population Change – Lower Missouri Basin Counties 2000-2010

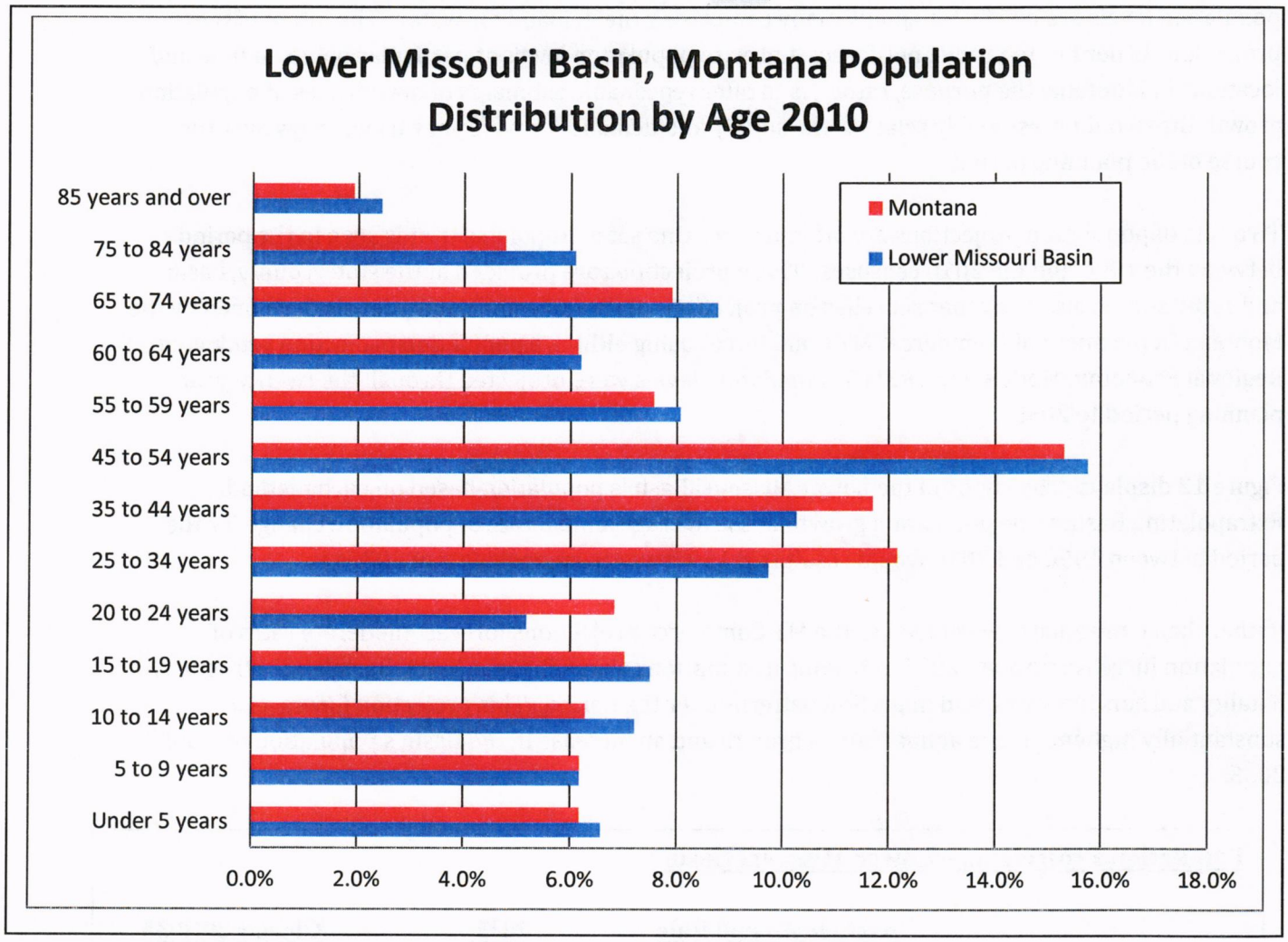
	Births	Deaths	Natural Increase	Percent Natural Increase	Int'l Migration	Domestic Migration	Net Migration	Percent Migration
Blaine	1,191	631	560	-114.3	1	-1,024	-1,023	208.8
Daniels	138	260	-122	41.5	25	-188	-163	55.4
Fergus	1,057	1,567	-510	80.7	92	-152	-60	9.5
Garfield	168	126	42	-30.9	6	-177	-171	125.7
Golden Valley	82	84	-2	-6.3	6	31	37	115.6
Hill	2,786	1,454	1,332	864.9	-3	-1,086	-1,089	-707.1
Judith Basin	156	181	-25	8.4	6	-272	-266	89.3
McCone	151	178	-27	9.2	6	-261	-255	87.0
Musselshell	447	584	-137	-95.1	0	301	301	209.0
Petroleum	38	32	6	-12.2	6	-62	-56	114.3
Phillips	405	510	-105	14.8	-2	-594	-596	84.1
Roosevelt	2,192	1,138	1,054	-442.9	-1	-1,252	-1,253	526.5
Sheridan	222	582	-360	38.8	1	-556	-555	59.9
Valley	805	907	-102	10.9	2	-813	-811	86.4
Wheatland	222	259	-37	16.4	6	-186	-180	79.6
TOTAL	10,060	8,493	1,567	-32.0	151	-6,291	-6,140	125.3

Figure 10

deaths. The substantial level of emigration from Roosevelt County has been reversed since 2010.

In 2010, the median age of residents of counties in the Lower Missouri Basin ranged from 31 years in Roosevelt County to 51.2 years in Judith Basin County. The median age for Montana was 39.7 years and 36.9 for the U.S.

The distributions of population by age for the Lower Missouri Basin and for Montana are presented in Figure 11. Compared to the state as a whole, the Lower Missouri Basin has proportionately fewer people between the ages of 20 and 45 years old. The Basin's lack of a metropolitan or micropolitan area or of a large college are the likely reason for the small number of residents in this age group.



Projections

Population trends can be somewhat mysterious. States have experienced various trends reflecting each state's particular natural endowments and historical circumstances. Those circumstances arise from

unique, complex national, regional, and local dynamics that determine the geography of socioeconomic development and patterns of population change over time. For example: Iowa has seen consistent, low levels of population growth broken only by negative growth in the 1980s; California experienced very high levels of growth throughout the twentieth century, tapering off in recent decades at lower, but still high, levels; North Dakota's pattern of low levels of alternating population increases and declines is now being broken by rapid growth since 2010.

Predicting population changes is an undertaking that grows increasingly speculative as the time horizon expands and the region under consideration diminishes in size. For the purposes of this planning effort, population projections are provided to inform deliberations of water management issues in which population levels are one factor among many comprising the demand for water. The intent of these projections is neither to predict nor forecast precise population levels at particular points in time and locations in Montana; the purpose, rather, is to offer reasonable estimates of magnitudes of population growth that would presumably relate to the supply and demand for water in various ways over the course of the planning period.

Two sets of population projections are offered here. One set extrapolates trends seen in the period between the 1990 and the 2010 censuses. These projections are provided at the state, county, basin, and sub-basin levels. The other set relies on projections at the state and county levels developed by the Montana Department of Commerce (MT Commerce) using eREMI, a population projection product of Regional Economic Models, Inc. (REMI). Population levels were projected through the twenty-year planning period to 2035.

Figure 12 displays projections of the Lower Missouri Basin's population based on each method. Extrapolating Basin-wide population growth at the average annual rate of population change for the period between 1990 and 2010 would result in 8,159 fewer Basin residents in 2035.

Rather than extrapolate recent trends, the MT Commerce projections forecast moderate rates of population increase through 2035, reflecting assumptions about changes in the Basin's age structure, natality and survival rates, and migration patterns over the period. This projection forecasts a substantially higher average annual rate of growth and an increase in the Basin's population of 7,508 by 2035.

Population Projections – Lower Missouri Basin

	Average Annual Rate	2035	Change 2010-35
1990-2010 Extrapolation	-0.43%	70,871	-8,159
MT Commerce	0.38%	82,070	7,508

Figure 12

Figure 13 displays estimated populations for the Basin's counties in 2035 as projected by each method. The MT Commerce forecasts predict reductions in population decline in the Basin and higher populations than those that would result from the continuation of trends of recent decades. The sum of the county projections does not equal the basin population projected due to compounding effects related to the basin and county projection calculations.

Population Projections – 2035
Lower Missouri Basin Counties

	1990-2010 Extrapolation	MT Commerce
Blaine	6,640	7,236
Daniels	1,343	1,981
Fergus	10,897	11,338
Garfield	920	1,513
Golden Valley	811	846
Hill	14,697	18,674
Judith Basin	1,817	2,312
McCone	1,257	1,968
Musselshell	5,234	5,618
Petroleum	483	834
Phillips	3,312	4,156
Roosevelt	10,309	11,033
Sheridan	2,458	3,719
Valley	6,652	8,093
Wheatland	2,020	2,749
	69,446	82,070

Figure 13

Figure 14 presents the projected populations for the Lower Missouri Basin sub-basins in 2035 based on extrapolating trends for the period 1990 to 2010. The populations of the largest sub-basins, the Middle Milk River and Judith Basin, would be projected to decrease by 2,394 and by 733 residents, respectively, if the trends of recent decades were to continue.

While the courses of population change in the Upper Missouri Basin and in particular parts of the state are highly uncertain from the perspective of the present, these projections offer two distinct scenarios for consideration when regarding prospects for future water use in the Basin. They should be viewed as potentially useful tools in examining various factors affecting—and consequences affected by— the supply and demand of the Upper Missouri's waters.

Population Projections – Lower Missouri Sub-Basins 2035
1990-2010 Trends

SUB-BASIN	2010	Estimated Population 2035	Estimated Change 2010-35
Arrow Creek	993	811	-182
Battle Creek	147	300	153
Beaver Creek (Milk R)	843	753	-90
Big Dry Creek	766	579	-187
Big Muddy Creek	3,936	2,670	-1,266
Big Sandy Creek	3,978	6,632	2,654
Box Elder Creek (Musselshell R)	1,197	1,252	55
Brush Lake	307	165	-142
Bullwhacker-Dog Creeks	1,435	1,159	-276
Charlie-Little Muddy Creeks	3,797	3,657	-140
Cottonwood Creek	372	266	-106
Flatwillow Creek	249	250	1
Fort Peck Reservoir	785	569	-216
Frenchman Creek	57	35	-22
Judith River	11,331	10,598	-733
Little Dry Creek	185	108	-77
Lodge Creek	556	360	-196
Lower Milk River	5,408	4,849	-559
Lower Musselshell River	240	196	-44
Middle Milk River	19,350	16,956	-2,394
Middle Musselshell River	3,096	3,026	-70
Milk River Headwaters	170	225	55
Peoples Creek	1,361	1,678	317
Poplar River	3,036	2,363	-673
Porcupine Creek	298	195	-103
Prarie Elk-Wolf Creeks	6,153	5,781	-372
Redwater River	1,728	1,194	-534
Rock Creek	84	77	-7
Sage Creek	1,217	1,069	-148
Upper Milk River	765	468	-297
Upper Musselshell River	4,669	4,921	252
West Fork Poplar River	339	168	-171
Whitewater Creek	170	131	-39
Wild Horse Lake	12	2	-10
TOTAL	**79,030**	**70,871**	**-8,159**

Figure 14

HOUSING

The number of households in the Lower Missouri Basin in 2010 was 29,129 with an average size of 2.4 people (U.S. Census Bureau; 2007-2011 American Community Survey Profile Report). The total number of housing units was 37,629 with 29,129 occupied and 2,555 for seasonal, recreational, or occasional use.

INCOME and EMPLOYMENT

Total personal income (TPI) is comprised of: net earnings in the forms of wages and salaries, supplemental earnings, and proprietors' income; transfer payments; and income from dividends, interest, and rent. In 2012, TPI in the Lower Missouri Basin was $3.1 billion, 8 percent of TPI for Montana of $39.3 billion.[2] Between 1990 and 2012, TPI in the Lower Missouri Basin increased by 49 percent, compared to an increase for Montana of 80 percent.

Per capita personal income (PCPI) in the Lower Missouri Basin in 2012 was reported to be $40,528, compared to $39,126 for Montana. Personal income in 2012 (adjusted to 2013 $s) for the major basins in Montana is displayed in Figure 18. With $13.0 billion, the Clark Fork Basin was the basin with the highest amount of total personal income, but the lowest per capita personal income by a substantial margin. The sparsely populated Lower Missouri had the lowest TPI by a considerable amount, but the Basin nearly matched the Upper Missouri's $40,676 for the highest PCPI among the state's four major basins.

Personal Income – Major Basins 2012

	Total	Per Capita
Clark Fork	13.0 billion	35,896
Lower Missouri	3.1 billion	40,528
Upper Missouri	12.8 billion	40,676
Yellowstone	10.4 billion	41,448
Montana	39.3 billion	39,126

Adjusted to 2013 $s.

Figure 18

[2] Figures are from the U.S. Department of Commerce, Bureau of Economic Analysis, Table CA30, adjusted for inflation to 2013 dollars. Estimates are based on administrative records and survey and census data collected by various agencies.

Figure 19 presents similar upward trends in PCPI for each of the major basins over the period. PCPI in the Lower Missouri and the Yellowstone Basins increased at rates greater than the statewide increase with increases of 61 percent and 58 percent, respectively. Between 2007 and 2012, PCPI in the Lower Missouri increased by 19 percent while PCPI in the Clark Fork declined by 1 percent. The impacts of the recent recession are evident from the graph as are the contributions of strong prices for agricultural commodities and activity in the energy sector.

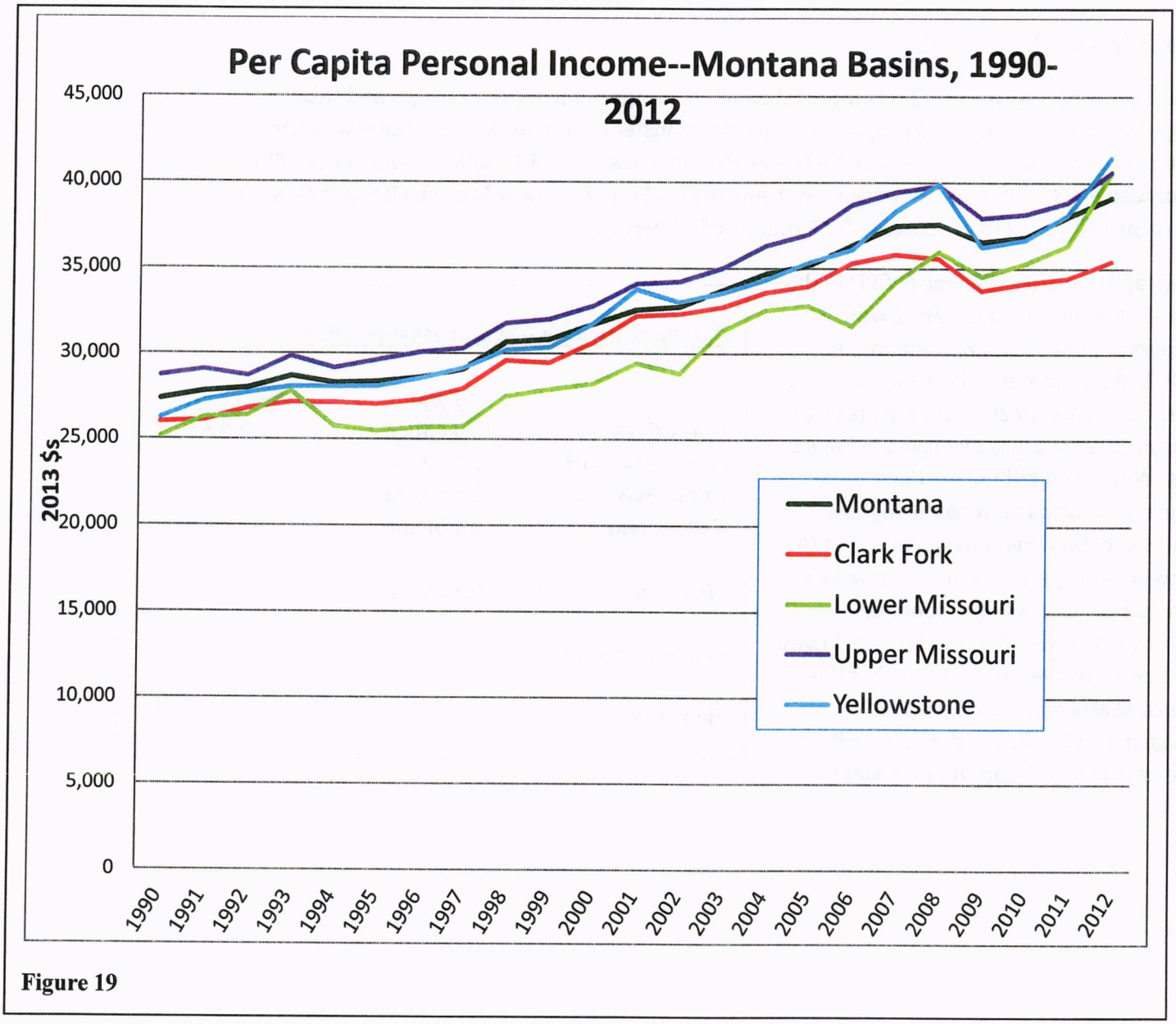


Figure 19

Figure 20 displays TPI and PCPI for Lower Missouri Basin counties for 2012. Hill County accounted for nearly one-quarter the Basin's TPI. Daniels County had the highest PCPI among Montana's 56 counties with PCPI of $65,789. Sheridan, Valley, and Golden Valley ranked, respectively, third, seventh, and eighth on the list.

Personal Income—Lower Missouri Basin Counties—2012

County	TPI ($billion)	PCPI ($)
Blaine	0.210	31,455
Daniels	0.117	65,789
Fergus	0.432	37,802
Garfield	0.043	34,238
Golden Valley	0.039	46,661
Hill	0.696	42,556
Judith Basin	0.088	43,691
McCone	0.068	40,270
Musselshell	0.170	36,380
Petroleum	0.020	38,922
Phillips	0.170	41,236
Roosevelt	0.366	33,479
Sheridan	0.208	58,212
Valley	0.358	47,751
Wheatland	0.072	34,404

Adjusted to 2013 $s.

Figure 20

The composition of personal income in Montana has changed over time. The portion of personal income derived from net earnings—primarily in the form of wages and salaries—has declined to 59 percent in 2012. The portion of income from retirement programs and other transfer payments has increased to 18 percent and income derived from dividends, interest, and rent accounted for 22 percent in 2012. For the U.S. in 2012, 65 percent of personal income was derived from net earnings and income from transfer payments and from dividends, interest, and rent comprised, respectively, 17 percent and 18 percent of personal income. Figure 21 displays the derivation of personal income in 2012 for Montana's four major basins. For Montana's major basins in 2012, net earnings comprised the largest portion of personal income in the Yellowstone at 63 percent. Transfer receipts were lowest in the Upper Missouri and Yellowstone Basins with approximately 16 percent of personal income for each basin. The portion of personal income provided by dividends, interest, and rent ranged between 21 percent and 24 percent across the basins. For the Lower Missouri Basin, 57 percent of net income was derived from net earnings, 20 percent from transfer payments, and 23 percent from dividends, interest, and rent.

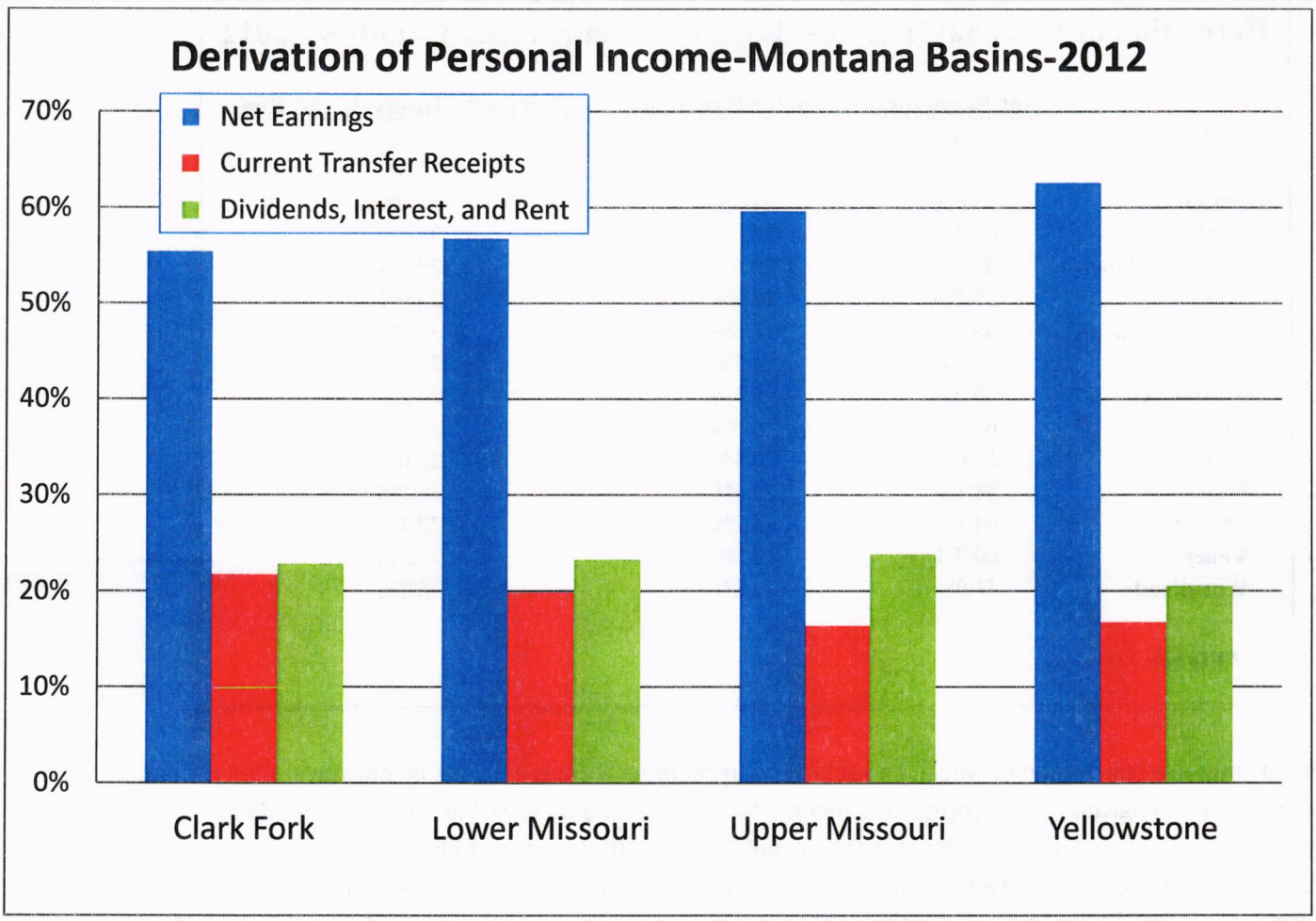


Figure 21

The derivation of personal income for Lower Missouri Basin counties is presented in Figure 22. For five Basin counties, net earnings comprised more than 60 percent of personal income. The portion of income derived from transfer payments was above 25 percent for Roosevelt and Musselshell Counties. Income from dividends, interest, and rent was greater than 30 percent in Wheatland, Garfield, and Judith Basin Counties.

Derivation of Personal Income—Lower Missouri Basin Counties - 2012

	Net Earnings	Transfer Payments	Dividends, Interest, and Rent
Blaine	53.0%	24.0%	23.0%
Daniels	69.8%	12.7%	17.5%
Fergus	51.9%	21.1%	27.0%
Garfield	47.4%	18.0%	34.5%
Golden Valley	47.8%	22.6%	29.6%
Hill	57.7%	18.3%	24.0%
Judith Basin	49.7%	18.5%	31.7%
McCone	61.7%	14.3%	24.0%
Musselshell	50.5%	25.3%	24.2%
Petroleum	62.5%	14.6%	22.8%
Phillips	56.6%	20.4%	23.0%
Roosevelt	58.1%	25.4%	16.5%
Sheridan	64.1%	13.2%	22.7%
Valley	60.7%	18.0%	21.3%
Wheatland	41.0%	22.8%	36.2%

Figure 22

Net earnings are comprised of wages and salaries, supplemental contributions by employers for pension and insurance programs, and proprietors' income for owners of businesses and farms. Trends for earnings in the Lower Missouri Basin for the period 1990 to 2012—adjusted for inflation—are presented in Figure 23. Total earnings for wages and salaries increased by nearly 34 percent to $1.0 billion and income in the form of supplemental employer contributions increased 44 percent to $294 million. Non-farm proprietors' income dropped about 1 percent over the period to $161 million. Farm proprietors' income increased 209 percent in real terms, fluctuating between $7 million and $403 million and averaging $160 million since 1990.

Between 1990 and 2011, average wages and salaries in the Lower Missouri Basin rose 21 percent to $33,741, just below the state average of $36,652. State-wide, wages and salaries, adjusted for inflation, increased 19 percent over the period. Over the same period, average non-farm proprietors' income in the Basin decreased 3 percent to $15,070, exceeding the state-wide average that declined by 2 percent to $21,057.

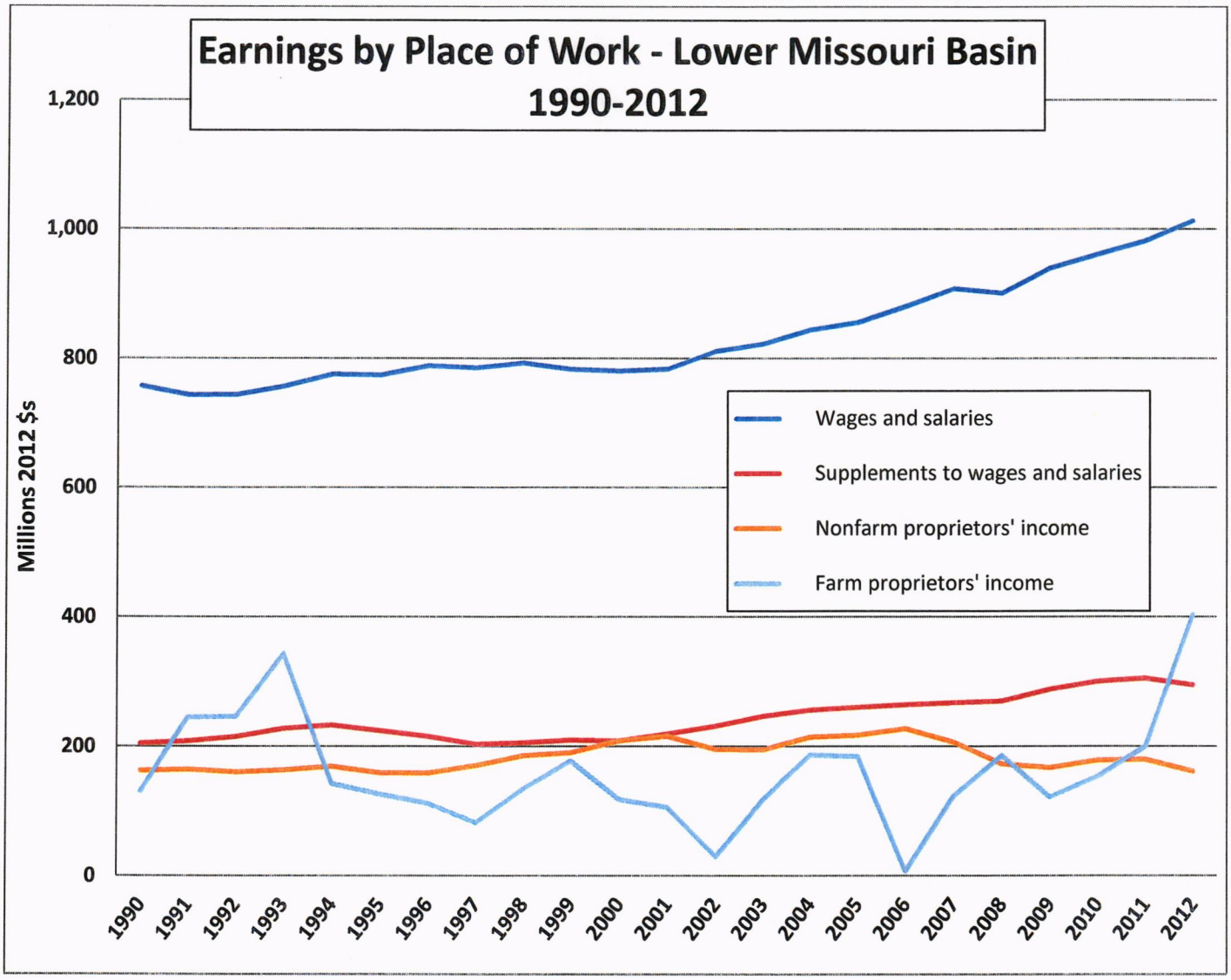

Earnings by Place of Work - Lower Missouri Basin
1990-2012
Millions 2012 $s
1,200
1,000
800
600
400
200
0
Wages and salaries
Supplements to wages and salaries
Nonfarm proprietors' income
Farm proprietors' income
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

Figure 23

Preliminary Working Draft

Montana Water Supply Initiative

Yellowstone River Basin Water Plan

Photo by Ann Marie Reinholt, MSU-Bozeman

Yellowstone River Basin Advisory Council

&

Montana Department of Natural Resources & Conservation

Water Resources Division

Prepared for Montana Water Policy Interim Committee
May 12, 2014

Preliminary Working Draft

Montana Water Supply Initiative – State Water Plan 2015
75% Draft Report for the Yellowstone River Basin Plan

I. Executive Summary
- A. Preface
- B. Yellowstone River Basin Council and Stakeholder Process
- C. Role of DNRC
- D. Major Findings
- E. Recommendations from the Yellowstone BAC
- F. Overview of Report

II. Introduction
- A. Background
- B. Purpose and Need
- C. Statutory Authority for Water Planning

The Montana Legislature recognizes that in order to achieve the public policy objectives specified in § 85-1-101 MCA "*and to protect the waters of Montana from diversion to other areas of the nation, it is essential that a comprehensive, coordinated multiple-use water resource plan be progressively formulated to be known as the 'state water plan'*" (§ 85-1-101(10) MCA).

Responsibility and statutory authority for developing the state water plan is given to DNRC in § 85-1-203 MCA with instructions to "*gather from any source reliable information relating to Montana's water resources and prepare from the information a continuing comprehensive inventory of the water resources of the state.*" As directed by the Legislature in § 85-1-203(2) MCA, "*the state water plan must set out a progressive program for the conservation, development, utilization, and sustainability of the state's water resources, and propose the most effective means by which these water resources may be applied for the benefit of the people, with due consideration of alternative uses and combination of uses".*

Sections of the state water plan must be completed for the Missouri, Yellowstone, and Clark Fork River basins, submitted to the 2015 legislature, and updated at least every 20 years. Montana citizens are given a formal role in the planning process through water user councils established in accordance with the instructions given by the legislature in § 85-1-203(4) MCA. The role of the water user councils is to make recommendations to DNRC on the basinwide plans.

In developing and revising the state water plan, DNRC is instructed to consult with, and solicit advice from, the Environmental Quality Council. The Legislature, by joint resolution, may revise the state water plan.

D. History of Water Planning in MT

1. State-wide Planning History

Water is arguably Montana's most valuable natural resource. The rivers, streams, lakes, and groundwater have shaped the stories of our rich history of settlement, agriculture, mining, industry and recreation, and quality of life. As the physical and economic needs of the state evolve, planning for the conservation and development of our water resources also evolves.

Initial efforts at water resources planning in Montana centered on the development of irrigated agriculture to promote settlement of the west. Water development projects were seen not just as desirable, but as essential to the economic viability of the state. In 1895 the Montana Legislature created the Arid Land Grant Commission to manage the reclamation of lands granted to the State under the federal Carey Land Act of 1894. In 1903, the Commission was abolished and replaced by the Carey Land Act Board. 1903 also saw the U.S. Congress authorize construction of the Milk River Project as one of the first five reclamation projects built by the newly created Reclamation Service (now Bureau of Reclamation) under the Reclamation Act of 1902.

In the 1920's, the Montana Irrigation Commission produced county-by-county plans for irrigation development. In addition, the Commission assisted in organizing and management of irrigation districts around the state. It also had jurisdiction over the sale of water, water rights, and the contracting of water for irrigation. The Commission was abolished in 1929.

The precarious position of agriculture and the livestock industry in Montana during the early 1930's promoted extensive individual and group effort towards seeking ways to put Montana's water resources to beneficial use. Late in 1933, a special session of the state legislature passed House Bill No. 39 creating the State Water Conservation Board. The Act creating the Board declared that the public interest, welfare, convenience and necessity required the construction of a system of works for the conservation, development, storage, distribution and utilization of water. Broad powers were given to the Board allowing it to cooperate and enter into agreements with all federal and state agencies, investigate, survey, construct, operate and maintain, and to finance the construction of projects.

Between 1934 and 1960, the Board built 181 water conservation projects. These included; 141 dams and reservoirs, 815 miles of canals, 23 miles of domestic water supply pipelines, and 24 miles of transmission lines to bring power to pumping stations. All told, the Boards actions created 438,017 acre-feet of storage and developed 405,582 acres of irrigated land (R. Kingery, personal communication 12 July 2013.). This period also saw Congressional approval of all the major federal water projects in Montana. These include Fort Peck, Canyon Ferry, Hungry Horse, Tiber, Yellowtail, and Libby dams.

When Montana began to negotiate the Yellowstone Compact with Wyoming and North Dakota in 1939, the need for cataloging the state's water resources and its use became apparent. As a result, the 1939 Legislature authorized the collection of data pertaining to water use. Between 1942 and 1971, Montana undertook a comprehensive county-by-county assessment of water use. The resulting reports, known collectively as the Montana Water Resources Survey, contain an examination of water rights, water uses and irrigation development in almost every county in Montana. This information was collected and published from 1943 thru 1965 by the State Engineer's Office and from 1966 through 1971 by the Water Conservation Board. The historical information contained in the survey's are an invaluable tool in today's efforts to adjudicate Montana's water rights.

In 1967, the Montana Legislature recognized the need for a comprehensive state water plan with passage of the Montana Water Resources Act of 1967 (89-101.2 R.C.M. 1947). The Act abolished the Water Conservation Board and transferred its powers and duties to the Water Resources Board. The 1967 Act stated that the *"public policy of the state is to promote the conservation, development, and beneficial use of the state's water resources to secure maximum economic and social prosperity for its citizens."* The Act also designated the Water Resources Board as the state agency with responsibility to *"coordinate the development and use of the water resources of the state as to effect full utilization, conservation, and protection of its water resources."* The Board was empowered to prepare a *"continuing comprehensive inventory of the water resources of the state"*, and prepare a *"comprehensive, coordinated multiple-use water resources plan known as the 'state water plan'."*

The responsibilities given to the Board reflect a change in direction and purpose of water resource planning – from "conservation" of water through irrigation to a total concern for full utilization of our water resources through comprehensive multiple-use planning. In 1971, the Water Resources Board became the Water Resource Division of the Montana Department of Natural Resources and Conservation (DNRC).

Between 1972 and 1981, DNRC conducted a number of reconnaissance-level planning studies in each of Montana's major river basins in conformance with federal principals and guidelines and with federal grant assistance. While these plans produced volumes of valuable technical information, inadequate consideration was given to the institutional and political feasibility of implementing the plan recommendations. Consequently, the plans had little effect on water management decision making. These plans were also ineffective vehicles for addressing the state's most critical water management problems such as interstate water allocation, quantification of federally reserved water rights, water use efficiency, instream flow protection and groundwater management. Federal funding to support state water planning ended in 1981.

In 1987, DNRC embarked on a new approach to developing the state water plan. After reviewing the water planning processes of other western states, DNRC adopted an approach similar to that used in Kansas. Under this approach, the state water plan provided a forum for all affected parties, including those affected by, but without jurisdictional responsibility, to collaboratively work together on resolving water management issues. This new approach included the formation of a

State Water Plan Advisory Council and issued-focused Steering Committees. The resulting state water plan focused on the following nine water resource issues:

1. Agricultural Water Use Efficiency (1989)
2. Instream Flow Protection (1989)
3. Federal Hydropower and State Water Rights (1989)
4. Water Information System (1989)
5. Water Storage (1990)
6. Drought Management (1990)
7. Integrated Water Quality and Quantity Management (1992)
8. Upper Clark Fork Basin Water Management (1994)
9. Groundwater (1999)

Between 1999 and 2009, DNRC water planning resources were focused on assisting irrigation districts, conservation districts and local watershed groups with water supply studies and drought management plans.

In 2009, the Montana Legislature amended the state water planning statute to direct DNRC to update the state water and report to the 2015 Legislature. The 2009 amendments also specify a number of items that the state water plan must address including:

- Inventory of consumptive and non-consumptive uses associated with exiting water rights.
- An estimate of the amount of GS and SW needed to satisfy new future demands;
- An analysis of the effects of frequent drought and new or increased depletions on the availability of future water supplies.
- Proposals for the best means to satisfy existing water rights and new demands.
- Possible sources of water to meet the needs of the state; and
- Legislation necessary to address water resource concerns in the Yellowstone, Missouri and Clark Fork basins.

2. Yellowstone Basin Planning History

Water Resource Surveys

Early water planning activities in the Yellowstone Basin were focused on developing irrigation projects to distribute water across the landscape to support and promote agricultural production. During the 1930-1940s, the state and federal government spent much of their time and money on designing and implementing water conservation projects. Following the construction and development of these projects was an effort to produce and publish comprehensive surveys of all of the irrigation projects in Montana. Between 1943 and 1965, the Montana Water Conservation Board and the State Engineer's office developed comprehensive Water Resource Surveys for most of the counties in the Yellowstone River Basin. These surveys were developed from court house records, individual contacts, state and federal agency data, field surveys and aerial photographs. They contain an historic summary of the settlement, water use and survey maps of current water

use at the time of publication. These important documents are still used for historical reference and provide the basis for understanding water use, development, water planning and adjudication in each county. These water resource surveys remain a valuable tool for characterizing and understanding the communities and water distribution systems in the basin.

Drought and Floods Combine to Set the Stage

The 19th and early 20th century history of water planning in the Yellowstone Basin is essentially a history of national politics surrounding settlement of the American West. Large river basin planning emerged post-World War II after decades of political struggle over what federal entity would oversee development. In the Missouri River basin, social politics and the drought of the 1930's combined with the great flood of 1943 to set the political stage: The result: the Flood Control Act of 1944, with its Pick-Sloan Plan and O'Mahoney-Milliken Amendment. This legislation was significant to Montana and other upstream states in the Missouri basin because it codified protection for future increases in water usage in the upper portions of the basin like the Yellowstone, and it gave the states some control with regard to federal water development. In the Yellowstone, a wide variety of planning efforts aimed at estimating the water development potential of the basin and assessing the impacts of such development on existing beneficial uses ensued.

Federal Planning in the 1960's

Some of these studies, such as the Comprehensive Framework Study (1967) produced by the Missouri Basin Interagency Committee, were federal endeavors intended to estimate future water demand basin-wide and propose development projects under the goal of the Pick-Sloan Plan: *"secure the maximum benefits for flood control, irrigation, navigation, power, domestic and sanitary purpose, wildlife and recreation."* Others, such as the Wind, Bighorn, Clarks Fork Type IV Study (1974) or the Wild and Scenic River Study (1975), sought to assess the effects of an individual project such as a new Billings water supply system, or determine eligibility for programs operated by the U.S. Department of Agriculture. Once the Montana Water Resources Act of 1967 provided authority for development of a state water plan, DNRC began to develop and evolve a water planning strategy at the state-level that emphasized economic development, conservation, and utilization of land and water resources.

Federal Planning in the 1970's

The energy crisis of the 1970's combined with renewed environmental awareness ushered in an era of energy-related water planning in the Yellowstone. In 1975, as a result of concerns regarding expanded coal and irrigation development, DNRC produced the Yellowstone River Basin Water Resources Situation Report, which concluded that the basin did not have enough water to satisfy all existing uses, reservation requests, and projected demands. Two large federally-sponsored interdisciplinary studies ensued: the Yellowstone Level B Study (1977) and the Yellowstone Impact Study (1979). The Level B study was a reconnaissance-level evaluation of water and related land resources for the Yellowstone River Basin and Adjacent Coal Area. Its objective was to recommend a near-term plan for development, as well as for environmental preservation of the resources,

compatible with the long-term goals of the nation, the region, and the state. It included the entire Yellowstone River Basin in Montana, Wyoming and North Dakota. This federally funded and managed study identified a wide variety of development proposals: new reservoirs, irrigation infrastructure, highway improvements, land treatments, wild and scenic river designations, etc. and attempted to assess their efficacy in achieving national economic development goals using a cost versus benefit approach.

Happening almost concurrently with the Yellowstone Level B Study was the Yellowstone Impact Study. Funded by the Old West Regional Commission and managed by DNRC, the study was a manifestation of a growing concern for water availability in the Yellowstone. Passage of the Water Use Act of 1973, which among other things, mandated adjudication of existing water rights and made possible the reservation of water for future beneficial use, was followed by the Water Moratorium Act of 1974, which delayed actions on major applications for Yellowstone Basin water for three years; that period was later extended by legislative and court action and expired in December of 1978 when the Board of Natural Resources and Conservation acted on the received water reservation applications.

Citing a need to examine the individual and cumulative impacts of future water development, DNRC took advantage of the moratorium to study the basin's water and related land resources, as well as existing and future need for the basin's water. The study projected future agricultural, industrial, and municipal development and calculated stream flow depletions associated with the development. Then, based on those results, researchers assessed the effects of those depletions on various components of the Yellowstone's aquatic ecology: hydrology, river channel morphology, water quality, migratory birds, fish, aquatic invertebrates, furbearers, recreation, and existing human water users. The study concluded that the Yellowstone mainstem and the Bighorn River would be able to meet even the demands of high-level development, although summer and fall flows would be extremely low in the mainstem as a result. The study also concluded that neither the Tongue nor the Powder rivers would be able to supply the water demanded of them under the high-level development scenario.

Events Surrounding the 1996 and 1997 Floods

It wasn't until the late 1990's that a renewed emphasis on conservation and planning for Yellowstone River resources began anew. This time, however, it wasn't concern about the paucity of water that initiated the planning effort, but rather its abundance. One-hundred-year floods in 1996 and 1997 caused extensive erosion and sedimentation along the Yellowstone River, particularly in its upper reaches. Within the floodplain, large areas of agricultural land were eroded and existing bank protection in many areas was damaged. A significant amount of riparian habitat, crucial for many river-dependent species was destroyed. As a result, significant public interest emerged, due in primarily to the widespread damage and the resulting bank stabilization and flood protection projects.

The controversy surrounding these projects, and the regulatory process through which they were approved (§310 program operated by Montana Conservation Districts and §404 program operated

by the U.S. Army Corps of Engineers), precipitated the formation of two citizen-based Yellowstone River resource management groups: the Upper Yellowstone River Task Force (Task Force) and the Yellowstone River Conservation District Council (Council). Operating from 1997 until 2003, the governor-appointed Task Force consisted of citizens representing a broad array of Yellowstone River interests from Park County. The Task Force, using a combination of state and federal funds, undertook a wide-ranging effort to collect and disseminate scientific information about the upper Yellowstone River in Park County. They produced a set of consensus-based recommendations on a wide variety of issues specific to the Yellowstone River in Park County. It was upon this work that a special federal regulatory designation called a Special Area Management Plan (SAMP) was instituted by the Corps of Engineers to review and authorize projects seeking to alter the bed and/or banks of a critical segment of the Yellowstone River in Park County under the §404 program.

In 1999, a coalition of environmental organizations filed suit against the U.S. Army Corps of Engineers alleging inadequate assessment of the cumulative effects of bank stabilization authorized under the §404 program. Also in 1999, the Yellowstone Conservation District Council formed, in part to demonstrate local resource management primacy in the face of increasing national attention. The Council is a coalition of conservation districts that comprise the Yellowstone River in Montana and North Dakota. Its purpose is to provide local leadership, assistance, and guidance for the wise use and conservation of the Yellowstone River corridor's natural resources to sustain and improve social, environmental, and economic values. As a result of the successful lawsuit, Congress authorized the Yellowstone River Corridor Comprehensive Study, also known as the Cumulative Effects Study (CES) under §431 of the Water Resources Development Act of 1999 (WRDA, 1999). WRDA 1999 provides for a comprehensive study of the Yellowstone River from Gardiner, Montana, to its confluence with the Missouri River to determine the hydrologic, biological, and socioeconomic cumulative impacts on the river. In 2004, Custer County Conservation District, fiscal agent for the Council, entered into a cost sharing agreement with the U.S. Army Corps of Engineers (USACE) for this study. The study is scheduled for completion in 2015.

Montana Water Supply Initiative 2015

And so the Yellowstone water planning saga continues. Prized for the cultural heritage it embodies and the natural resources it provides, the Yellowstone basin and the water it generates is and will continue to be the subject of planning efforts intended to ensure its sustainability for present and future uses. To this day, even though the Yellowstone River is no longer used for commercial transportation and Montana's adjudication process has strengthened its claim over water originating within its borders, control over Yellowstone water for uses both within and downstream of the basin is still very much an issue for many basin water users. Although the Yellowstone contributes over half the average annual flow at its confluence with the Missouri, the basin comprises one of the most sparsely populated areas of the country. Montana and Wyoming rank 44 and 50 amongst the states in population. Water users in the Yellowstone are acutely aware that despite the basin's disproportionate hydrologic and ecologic importance, a significant political

disparity exists between upstream and downstream uses. As the need for control and protection of Yellowstone water has increased, so has the need to achieve the primary, yet elusive goal of water planning: ensuring and expanding water availability for present and future uses.

Yellowstone Basin Planning Methodology

The 2015 Montana Water Supply Initiative (MWSI) is a public water planning process that promotes awareness and understanding of the dynamic nature of Montana's water supply and engages citizens in planning for our future water needs. For the Yellowstone River Basin, the MWSI occurred in three primary phases that occurred over a two-year period *(see Figure ___ - Yellowstone River Basin Plan Timeline)*: *Phase 1 (Issue Identification); Phase 2 (Information Transfer); and Phase 3 (Recommendation Development).* Phase 1 included a messaging campaign that promoted public awareness of water issues and the planning process for the Yellowstone River Basin. Phase 1 also included establishment of the Yellowstone Basin Advisory Council (Yellowstone BAC). Phase 2 included a series of presentations during the fall of 2013 from subject matter experts on issues raised during Phase 1, while Phase 3 focused on the BAC's development of recommendations to address priority issues.

Phase 1 - Establishing the BAC, Public Scoping Process, and Issue Identification

Establishing the Yellowstone Basin Advisory Council. In January 2013, a contract was established with Montana State University-Billings to provide assistance with formation and coordination of the Yellowstone BAC activities for Phase 1 (Issue Identification). To establish the Yellowstone BAC, citizen involvement was solicited from a variety of water interests including agriculture, conservation, industry, municipal, recreation, and tribal. In the Yellowstone River Basin there are 15 conservation districts and 9 watershed groups. Each of these organizations was asked to supply a single nominee who is knowledgeable about water resource issues and interests within their district or watershed. Other key water interest organizations within the Yellowstone River Basin in Montana were asked to submit nominees. From this pool of potential members, DNRC selected a 20-member Yellowstone BAC that, to the extent possible, is geographically distributed and representative of water interests throughout the basin. Figure 1 is a photo of the Yellowstone BAC.

(see Figure ___ - Yellowstone River Basin Plan Timeline): Phase 1 (Issue Identification); Phase 2 (Information Transfer); and Phase 3 (Recommendation Development).

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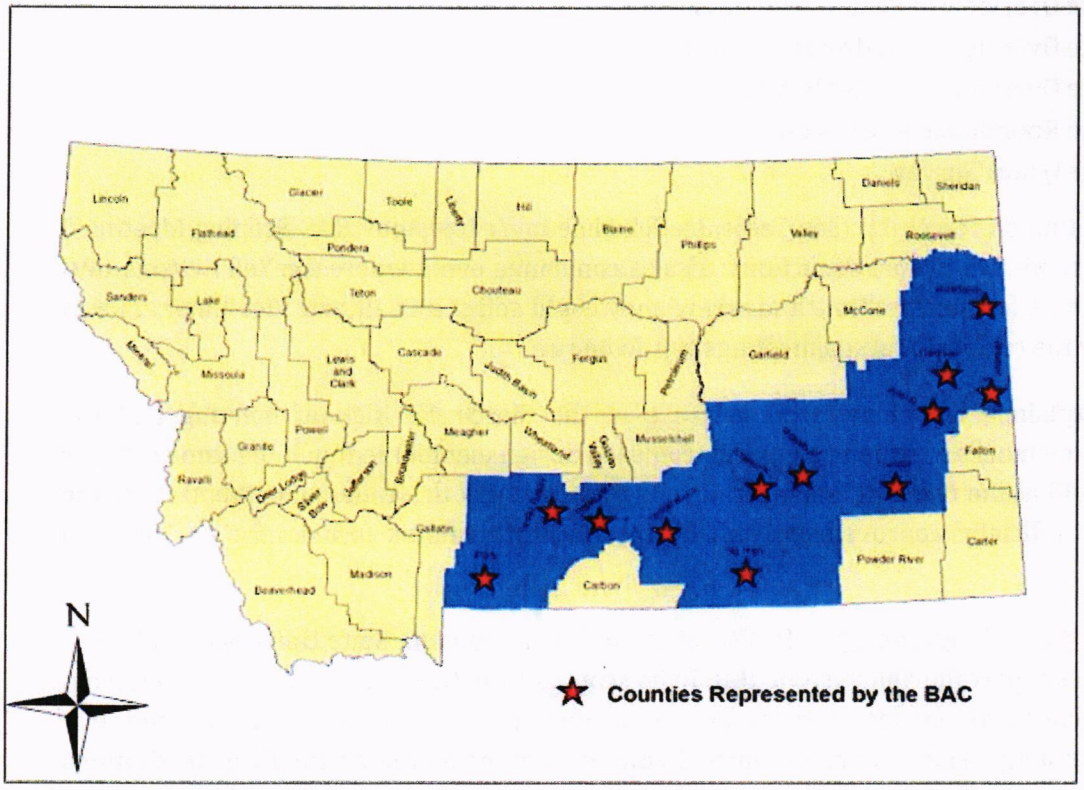
Figure 1: Photo of Yellowstone BAC on May 8, 2013

Back Row--Left to Right: Dan Rostad, Dave Mumford, Greg Lackman, Steve Pust, Cal Cumin, Bobbi Blankenship, Paul Gatzemaier, Jerry O'Hair, Nick Golder.
Front Row-Left to Right: Dan Lowe , Roger Muggli, Shanny Spang Gion, Mack Cole, Mike Penfold, John Pulasky, Dave Galt.
(Photo by MSUB Research Team)

The Yellowstone BAC includes people with a broad array of water interests, ranging from irrigation, to petroleum production, to instream flows. Two entities requested alternates who could attend some of the designated meetings. In both cases the request was approved, thus Boris Krizek was named as an alternate for David Mumford (City of Billings Municipal Water Supply) and Nick Golder was named as an alternate for Brad Sauer (Northern Plains Resources Council). Mack Cole and John Moorhouse were elected as Chair and Vice Chair, respectively, at the March 18, 2013 meeting in Billings. In August, Kay Petermann was named as the new representative for the Wibaux conservation district (in place of Bobbi Blankenship who served the BAC from March through August).

The BAC also provides broad geographic representation. The map below (Figure 2) illustrates the counties with representation on the Yellowstone BAC.

Figure 2: Yellowstone BAC Representation Map



(Blue county with red star indicates BAC representation served by at least one person)
Map by: Matthew Anderson, MSUB

Attention was also given to the need for technical advice throughout the planning process. At the request of the DNRC, eight individuals were named as ex-officio members of the Yellowstone BAC (Table 1). These individuals attend the meetings and provide input, however, per the BAC guidelines (Appendix A) they are not voting members.

Table 2: Yellowstone Basin Advisory Council Ex-officio Members Spring 2013

	Last Name	First	Agency
1	Brummond	Andy	Montana Department of Fish Wildlife and Parks (Lewistown)
2	Duberstein	Lenny	US Bureau of Reclamation
3	Frankfurter	Jill	US Geological Survey
4	Frazer	Ken	Montana Department of Fish Wildlife and Parks (Billings)
5	LaFave	John	Montana Bureau of Mines and Geology
6	Ockey	Mark	Montana Department of Environmental Quality
7	Opitz	Scott	Montana Department of Fish Wildlife and Parks (Livingston)
8	Philbin	Mike	US Bureau of Land Management

Scoping Process/Issue Identification

Design of the Public Scoping Meetings. In general, the scoping meetings were designed to take two hours. At the regional locations, two sessions were scheduled: a morning session (10-noon) and an afternoon session (1-3). The sessions included:

- 20-minute Overview of Planning Process
- 20-minute Overview of Hydrologic Issues
- 20-minute Overview of Water Rights
- 45-minute Roundtable Discussion
- 20-minute Q Sort Survey

The Kick-off meeting on March 18 (see Table 3 - Schedule of Yellowstone BAC Scoping Meetings) was designed to serve two primary functions: 1) as a convening event where the Yellowstone BAC members could meet for the first time and where they could select a Chair and Vice-Chair; 2) as a "preview" of how the regional scoping meetings would be run.

The elements explained below were all in place at the March 13 Kick-off meeting and the Yellowstone BAC members themselves experienced each design element in much the same manner as the public would at the regional meetings. Having gone through these elements themselves, the Yellowstone BAC officially approved each of the meeting elements as formats for the regional meetings.

Staff Support for the Yellowstone BAC. DNRC contracted with Montana State University – Billings, to coordinate and support the Yellowstone BAC in its scoping activities. MSUB under the leadership of Dr. Susan Gilbertz assembled a team of five professors, one graduate student and five undergraduate students. The team represented a concerted effort on the part of three institutions to support interdisciplinary/inter-institutional studies that that encourage citizen-based natural resource management models. Faculty from Montana State University-Billings, Rocky Mountain College (of Billings), and Saint Louis University Center for Sustainability were involved.

In addition, a DNRC support team was created for the Yellowstone BAC. This team attended every regional meeting and each member of the team provided a brief overview of water issues in the basin. Jim Robinson explained that water planning, per se, had not occurred in the Yellowstone River Basin since 1976. He also explained the goals and mandates of the 2015 MWSI and the Yellowstone BAC. Chuck Dalby provided an overview of Yellowstone River Basin hydrologic information. Kim Overcast (with Kerri Strasheim) provided an overview of water rights. As summarized in Appendix B, each of the DNRC team members had key points to emphasize. After each briefing, time was allowed for questions from the BAC and the public.

Once the DNRC briefings were completed, over one hour of time at each session of the public scoping meetings was dedicated to gathering inputs from the attending public. Three types of opportunities were created in each session for the public: 1) roundtable discussions, 2) demographic surveys, and 3) Q Sort surveys (see Appendix D for details).

Regional Public Scoping Meetings. To provide a variety of regional opportunities for public input, four meetings were held in four different communities along the Yellowstone River. The meetings

in Glendive, Big Timber and Forsyth included morning and afternoon sessions to expand opportunities for public comment at any single location. Also, as a means of accommodating people unable to attend a daytime meeting, one evening session was conducted in Billings. The public meetings were all held in settings that were politically neutral and readily accessible (see Table 3).

Table 3: Schedule of Yellowstone BAC Meetings
March-May 2013

DATE	LOCATION	VENUE
March 18*	Billings	MSU-Billings Downtown Campus
March 27	Glendive	Dawson College
April 12	Big Timber	Big Timber Public Library
April 24	Forsyth	Forsyth Public Library
May 7	Billings	MSU-Billings Downtown Campus
May 8**	Billings	MSU-Billings Downtown Campus

*Primarily an organizational meeting.
**Primarily for review of public inputs and to begin prioritization of issues.

Publicity for the meetings involved four primary avenues: 1) radio, 2) newspaper, 3) direct mail, and 4) personal solicitation. Some local outlets such as conservation districts and Farm Bureau newsletters offered free announcements, while others required advertising space to be purchased (see Table 4).

Table 4: Print Advertising of Yellowstone BAC Regional Meetings

Newspaper	Run Dates					
Miles City Star	3/22	3/25	4/16			
Glendive Ranger Review	3/21	3/24				
Sidney Herald	3/24	3/27	4/17			
Billings Gazette	3/24	4/5	4/17	4/30	5/2	5/5
Bighorn County News			4/11	4/18		
Livingston Enterprise		4/3	4/10			
Carbon County News			4/18			
Big Timber Pioneer		4/4	4/11			
Forsyth Independent Press			4/11	4/18		
Powder River Examiner		4/11	4/18			
A Cheyenne Voice		4/12	4/19			

Numerous local radio stations were engaged as a primary means of announcing the meetings. The radio "spots" were primarily handled by one Yellowstone BAC member, John Pulasky. Local print media were also engaged as primary modes of announcing the public meetings. A third means of encouraging attendance at the regional meetings included sending meeting notices to all of the groups and organizations that received the original invitations to provide Yellowstone BAC

nominations. Finally, the MSUB team placed approximately 200 telephone calls to citizens throughout the basin informing them of nearby meetings and encouraging their participation.

Scoping Results

The public scoping efforts were well received in each location. As shown in Table 5, nearly 150 public attendees participated in the meetings.

Table 5: Public Attendance at Yellowstone BAC Meetings March-May 2013

Meeting Site and Date	Number of Public Attendees
Billings, March 18	08
Glendive, March 27	24
Big Timber, April 12	43
Forsyth, April 24	32
Billings, May 7	30
Billings, May 8	11
TOTAL	**148**

Public Comment via Roundtable Discussions. Each discussion resulted in a list of concerns and an audio-recording. These materials were reviewed in a five-step process. First, the listed concerns were transcribed into sets of notes organized by meeting and discussion table. Second, the audio – recordings were carefully reviewed by a research associate and explanatory details were added to the transcribed notes. Third, the various sets of notes were reorganized into question-by-question documents. Fourth, the content was organized into thematically arranged elements. Finally, the thematically arranged elements were distilled into a set of primary concerns which were edited for continuity, clarity and primacy as concerns.

As a result, the roundtable data revealed 28 primary concerns voiced by the public. These were not discrete concerns as there is certain overlap among them. They are summarized below in alphabetical order, not by order of importance:

1. **Availability:** Do we know how much water is available?
2. **Beneficial Uses:** Should we rethink what constitutes a "beneficial use?"
3. **Current Allocations:** To what extent are we appropriated or over-appropriated?
4. **Drought Readiness:** Are we ready to address water shortages?
5. **Enforcement/Protecting Senior Rights:** What can be done to better enforce our water right administrative system based on the Prior Appropriation Doctrine?
6. **Exempt Wells/Groundwater Wells**: Are wells impacting surface water availability in this basin?

7. **Federal Reserved Rights:** Can the BAC better address the failure of water supplies to support fish and wildlife (especially as defined by federal rights that protect the fisheries, endangered species and flow regimes)?
8. **Fisheries and Wildlife:** Can we determine how much water is truly needed to support wildlife and fisheries?
9. **Future Allocations/Additional Rights:** How many new users can be supported? Are "closures" of sub-basins eminent? Can we avoid over-allocating?
10. **Gauges/Monitoring**: Do we really know how much water is being drawn? Do we need a comprehensive system that links all monitors in the basin to one database or system of analysis? What would it take?
11. **Hydrologic Models to Explore "Full Development":** Can we find a way to think about how much water is really in the system, how much is being drawn off and what it would look like if all of the existing rights were fully developed? Do we know what will happen if all water right holders develop their full shares?
12. **Hydrologic Models to Explore Variability:** Can we anticipate what it will mean to experience extremely variable episodes of available snowpack or rainfall?
13. **Incentives and Support for New Technologies and Conservation Practices:** Should we seek governmental support to encourage water use technologies that maximize efficiencies? Should we reward conservation?
14. **Industrial Uses of Water:** Do we know how much water industry is using? How do we ensure the needs of industrial users? How much water does fracking (hydraulic oil well fracturing) really use?
15. **Irrigation Technologies and Growth:** Do we know the circumstances when flood irrigation is preferable to sprinkler irrigation?
16. **Instream Flows:** What are the instream flow requirements? Can we devise management plans that work to serve all needs?
17. **Invasive Species:** To what extent are invasive species, such as salt cedar and Russian olive, reducing our available water? Can we reduce the problem?
18. **Montana as Priority:** Have we done all we can to get our share from Wyoming? Have we done all we can to keep water in Montana? To what extent are we beholden to barge traffic on the Missouri or Mississippi? Are we prepared to fully protect our water rights from parties located outside the state?
19. **Municipal Uses, Urban Development and Population Growth:** To what extent might significant growth in municipal draws impact availability?
20. **Planning for Water Demands:** Can the BAC better match water supplies to demands, especially where shortages currently occur? Can the BAC look further down the road than 20 years? Can we revisit the planning process every few years instead of every few decades? How should future planning be financed?
21. **Recreational Uses:** Do we know how to value recreational uses? If recreational demands increase, how will that impact other user groups? Will river access issues be addressed by this plan? Are recreational uses fully developed?

22. **Stock Water Ponds and Tanks/Fishing Ponds:** How much water is retained? How much is lost to evaporation? Should these practices be addressed? Might more creeks be dammed to store water?
23. **Tribal (Reserved) Rights:** To what extent are tribal rights already developed? What is the impact if tribal rights are fully developed?
24. **"Use it or Lose it" Principle:** Is this the best model for encouraging water conservation? Should this be modified? Are ditch companies intentionally wasting water as insurance against "losing it?"
25. **Water Market Transfers:** Should Montana stop allocating and start a new transfer system? Is water already in a "loose" market system that needs to be watched over more carefully? What are other states doing in terms of water markets?
26. **Water Quality:** To what extent is quality a concern within issues of availability? Do we monitor quality in a satisfactory manner? Can we better address non-point source pollution, especially agricultural run-off? Do we understand "natural pollutants" in the Montana water system?
27. **Water Reservations:** Is it possible to honor all of the Yellowstone Water Reservations and not impact existing senior users? What if they are fully developed? How can we maintain instream flow reservations?
28. **Water Storage:** What are the options for storing more water? How will projects be paid for? Can smaller projects help individuals and the state? Are off-stream reservoirs a viable option?

Preliminary Ranking of Issues. At the May 8th Wrap-up Meeting, the Yellowstone BAC members were provided a list of issues that had been brought forward by the public and were given approximately two weeks to make their rankings and to return them to Gilbertz who would separately calculate overall rankings for the BAC voting members and for the BAC Ex-Officio members. See the final Yellowstone BAC scoping report for the methodology.

Table 7 documents the calculated rankings for the Yellowstone BAC. Issues for which no ranking was offered by any member of the BAC have been left off the list. In the third column, the list also indicates the number of respondents that ranked each issue as #1 (most important).

Table 7 - Yellowstone BAC Issue Rankings

CONCERN	# with this as #1 Rank	# who ranked this as 1-7
Availability	10	13
Drought Readiness	1	11
Enforcement/Protecting Senior Rights	1	7
Water Quality	1	7
Instream Flows	0	6
Shifting Practices: Irrigation Technologies	0	6
Future Allocations/Additional Rights	0	5
Incentives and Support for New Technologies and Conservation	0	5
Storage Capacities	0	5
Reservations (Protected MT Rights)	0	4
Current Allocations	1	4
Planning	0	4
Beneficial Uses	1	3
Montana as Priority	1	3
Gauges/Monitoring	0	4
Municipal Needs, Urban Dev & Pop	0	3
Shifting Practices: Water to Industry	0	4
Water Market Transfers	1	3
Hydrologic Model –Variability	0	2
Hydrologic Model—Full Development	0	3
Recreational Uses	0	2
Exempt Wells/Groundwater Wells	0	2
Fisheries and Wildlife	0	1
Invasive Species	0	2
Stock Ponds and Tanks/Fishing Ponds	0	1
Use It or Lose It Principle	0	1
Hydraulic Fracturing (Fracking)	0	1
Tribal (Reserved) Rights	0	1

Public Input—Written Comments. MSUB faculty (Gilbertz) served as the primary contact during the scoping process. All written comments, including those gathered at meetings, via email or by postal delivery, were directed to her office. A complete record of all written comments is found in Appendix G of the Scoping Report.

Phase 2 - Information Transfer

The Yellowstone BAC met twice in Billings, on November 14-15 and December 13, 2013, to complete the work of Phase 2. The technical analyses phase was designed to provide the BAC members with the most current science and information on the topics of importance identified by the Phase 1 scoping. This was accomplished by inviting technical experts on the various issues to make presentations to the BAC and be available for follow-up questions and discussion. The presentation topics covered during this phase were initially identified by DNRC staff based on the results of Phase 1 and then approved by the BAC members.

The BAC members heard presentations from state and federal experts, legal and non-profit interests, and an experienced on-the-groundwater commissioner. Taken together, the presentations provided everything from a scientific background to practical advice on what is working on the ground now, and thoughts on enhancing water management in the future. The overarching topics addressed were; water administration, reallocation tools, and drought management; climate science and water information tools; water quality and beneficial use; reservoir operations, tribal compacts, and the hydrological effects of present-day water development; instream flow programs; groundwater-surface water nexus; and the executive and legislative process for recommendations.

Yellowstone Basin Advisory Council Technical Presentations

Date	Speaker	Topic
11/14/2013	Peter Marchi, Chief Water Commissioner	Musselshell Water Distribution Project
11/14/2013	Mike Roberts, Hydrologist Montana DNRC, Water Resources	Water Management and Candidate Conservation Agreements—Bighole Basin
11/14/2013	Jennifer Schoonen, Blackfoot Challenge Water Steward	Blackfoot Drought Response Plan
11/14/2013	Patrick Byorth, Attorney, Trout Unlimited	Instream Flow Leasing and Forbearance Agreements
11/14/2013	Chuck Dalby, Hydrologist Montana DNRC, Water Resources	Introduction to Climate Science and Policy Development in Other States
11/14/2013	Greg Pederson, Climate Scientist U.S. Geological Survey	Yellowstone River Basin Climate: Past, Present and Future
11/14/2013	Troy Blandford, Water Information System Manager, Montana State Library	Montana's Water Information System
11/14/2013	Peter McCarthy, Hydrologist U.S. Geological Survey	StreamStats-an Internet Accessible Hydrological Statistics Application for Hydrologists, Engineers, and Water Right and Water Quality Specialists
11/14/2013	Rusty Merritt, President Geospatial Solutions, Inc.	Water Information Systems for Irrigation District Operations
11/15/2013	Jill Frankforter, Hydrologist U.S. Geological Service	Water Quality in the Yellowstone, A Basin-wide Perspective
11/15/2013	Mark Ockey, Water Quality Specialist, Montana DNRC	TMDLs and Beneficial Use Criteria in the Yellowstone
11/15/2013	Jim Bauder, Soil Scientist and Professor Emeritus MSU-Bozeman and Broadus, MT	Water Quality, Soils, and Beneficial Use in the Tongue and Powder River Basins
11/15/2013	Lenny Duberstein, Chief Planner U.S. Bureau of Reclamation Montana Area Office	Water Planning for Federal Reservoir Operations in the Bighorn Basin
11/15/2013	Clayton Jordan, Engineer, U.S. Bureau of Reclamation Montana Area Office	Bighorn Reservoir Operations
11/15/2013	Doug Ollerman, Engineer, U.S. Bureau of Reclamation Great Plains Regional Office	Status of the Crow Water Compact
11/15/2013	Chris Murray, Hydrologist, U.S. Bureau of Reclamation Great Plains Regional Office	Missouri River Depletions Model
11/15/2013	Kathy Chase, Hydrologist, U.S. Geological Survey	Streamflow Statistics for Unregulated and Regulated Conditions for the Yellowstone River
12/13/2013	Tim Davis, Division Administrator Montana DNRC Water Resources Division	Executive and Legislative Process for Recommendations
12/13/2013	John LaFave, Montana Bureau of Mines and Geology	Aquifers, Wells, and Groundwater Use
12/13/2013	Tim Bryggman, Economist Montana DNRC Water Resources	Economics of Water Resources
12/13/2013	Andy Brummond, Fishery Biologist Montana Fish, Wildlife, and Parks	Instream Flow in the Yellowstone River Basin

The BAC did not develop any formal input during Phase 2. There was brief discussion following the presentations and during selection of the issues to advance for recommendations. The BAC discussed among other topics:

- the importance of information from monitoring,
- the difficulty of placing a monetary value on the water resource,
- the amount and use of water for hydraulic fracturing for petroleum extraction,
- water quality and the relationship between water quality and quantity,
- the roles of the various agencies in water management (DNRC, DEQ, etc.),
- the tools available for instream flow protection, their uses, and some of their limitations,
- the impacts of climate change on water availability,
- the benefits of local watershed groups,
- the water information that is currently available to the public,
- the operations of Yellowtail Dam in the Bighorn watershed,
- what to expect with the Crow Compact settlement,
- the relatively minor impact of groundwater withdrawals (for all uses) compared to surface water uses on water availability,
- the artificial aquifer situations created by human activity, and
- the need for communication on water management between Montana and Wyoming (especially in the Tongue watershed.)

During Phase 2 the Yellowstone BAC members heard from experts on a wide range of water-related topics and were given opportunity to request clarification and additional information on any of the topics. BAC members, while not necessarily experts in all aspects of water science themselves, appeared comfortable with their level of understanding related to the task of developing recommendations. They also appeared comfortable relying on DNRC staff and ex-officio agency experts for answers to questions that arise during discussion of specific issues. Ex-officio members with expertise in subjects under discussion related to the recommendations will likely be present during those discussions and able to answer questions as they surface.

The BAC's input and feedback was gathered at the series of meetings held during Phase 2 and between meetings by working closely with the Chair and Vice Chair of the BAC. During the three days of meetings, presentations were made and questions and discussion followed.

Patrick Byorth, attorney for Trout Unlimited, addresses the Yellowstone Basin Advisory Council

Phase 3 - Recommendation Development

During the last day of Phase 2 meetings, the stage was set for Phase 3. Several things were done to prepare for the recommendation development phase. The list of all scoping issues and their previous ratings by the BAC was revisited and validated, key decisions previously made by the BAC were revisited, and proposed screening criteria for recommendations were revisited and validated.

BAC facilitator, Barb Beck, proposed a process to the BAC members for developing recommendations. The recommendations will be the ultimate and most important product of the BAC's work and will be provided to the DNRC for the MWSI. Beck explained the multi-step process and then the BAC agreed to take one of their priority issues and try the process. The process was acceptable to the BAC members and recommendations will be developed in Phase 3 using the steps below;

- Define the issue under consideration
- Describe the ideal situation with respect to that issue (desired future condition)
- Ask the following questions,
- What did we learn about this issue during scoping in Phase 1?
- What did we learn about this issue from the experts in Phase 2?
- Who is affected and how?
- Do we need to make a recommendation on this issue? If yes,
- What do we want to recommend?
- How does this recommendation meet the criteria we have agreed upon? And, do we understand the consequences of this recommendation?

DNRC staff developed a summary of the scoping issues across all of the major basins to update the Environmental Quality Council standing legislative committee and the Water Interim Policy Committee in January 2014. Prior to the legislative committee presentation, the Yellowstone BAC Chair, Mack Cole and Vice Chair, John Moorhouse reviewed and commented on the draft summary of scoping issues document for the Yellowstone Basin. *The Yellowstone Basin Advisory Committee Summary of Scoping Issues* (January 2014) and the *Montana Water Supply Initiative Summary of Phase 1-Public Scoping Process* (January 2014) were e-mailed to the BAC members in mid-January.

The summary of scoping issues addresses the eight priority issues for the Yellowstone Basin and will provide the foundation for recommendation development in Phase 3. The eight issues are:

- Drought readiness
- Water information
- Integrated water quality and quantity management
- Water administration and beneficial use
- Watershed planning
- Groundwater/surface water nexus
- Instream flow maintenance, and
- Water storage

Next Steps (steps, activities, and tasks). Note: This will be revised to reflect current circumstances. The first Phase 3 BAC meeting is scheduled for February 25, 2014, in Billings. The BAC will develop recommendations on water information and water storage at the February meeting. Recommendations on the remaining topics (above) will be developed during the two additional meetings scheduled on March 12 and April 9.

The February meeting agenda and a flyer for posting and forwarding by e-mail will be sent to the BAC members, ex-officio members, conservation districts, and interested parties the first week in February. With this advance notice, it is hoped that members of the public will be aware of and choose to attend and offer comments during the public comment period on the agenda.

Based on previous discussions, the BAC members understand and take seriously their responsibility to talk with constituents between meetings both to impart information about the work of the BAC and to gather input on issues and recommendations. Each meeting begins with the opportunity for BAC members to share "what I've heard" since the last meeting.

All BAC members are clear on the progression of the three-phase process and that the February meeting will be devoted to work in earnest developing recommendations. "Preliminary recommendations" will be developed at one meeting, BAC members will seek input from their constituents between meetings and then the recommendations will be finalized at the following meeting considering any comments received. At the BAC's final meeting (April 9) the entire package of recommendations will be reviewed.

As explained above, the goal of the BAC is to produce consensus recommendations. Recommendations for which consensus has not been reached will be discussed further in an attempt to gain consensus. Lacking consensus, the BAC will vote and recommendations forwarded will be accompanied by information that explains the outstanding concerns and why consensus was not reached.

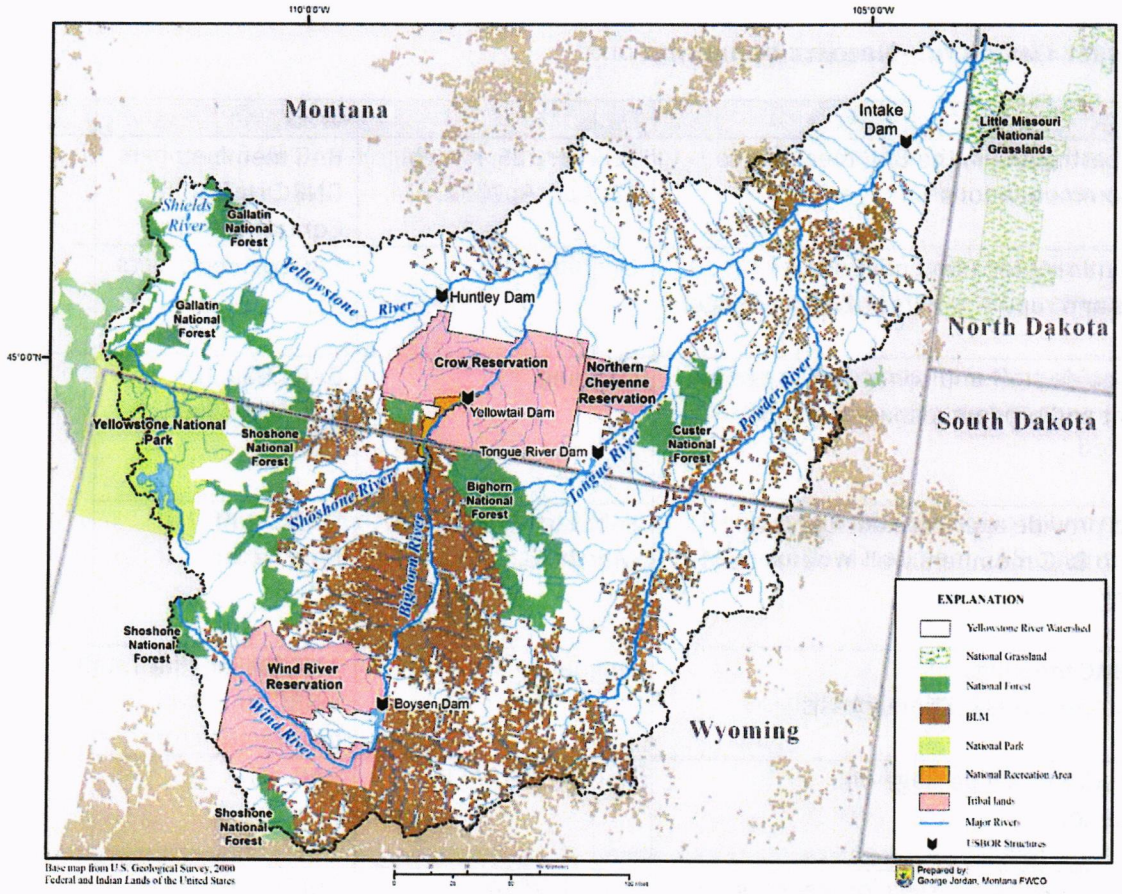
Priority Tasks for Developing Recommendations

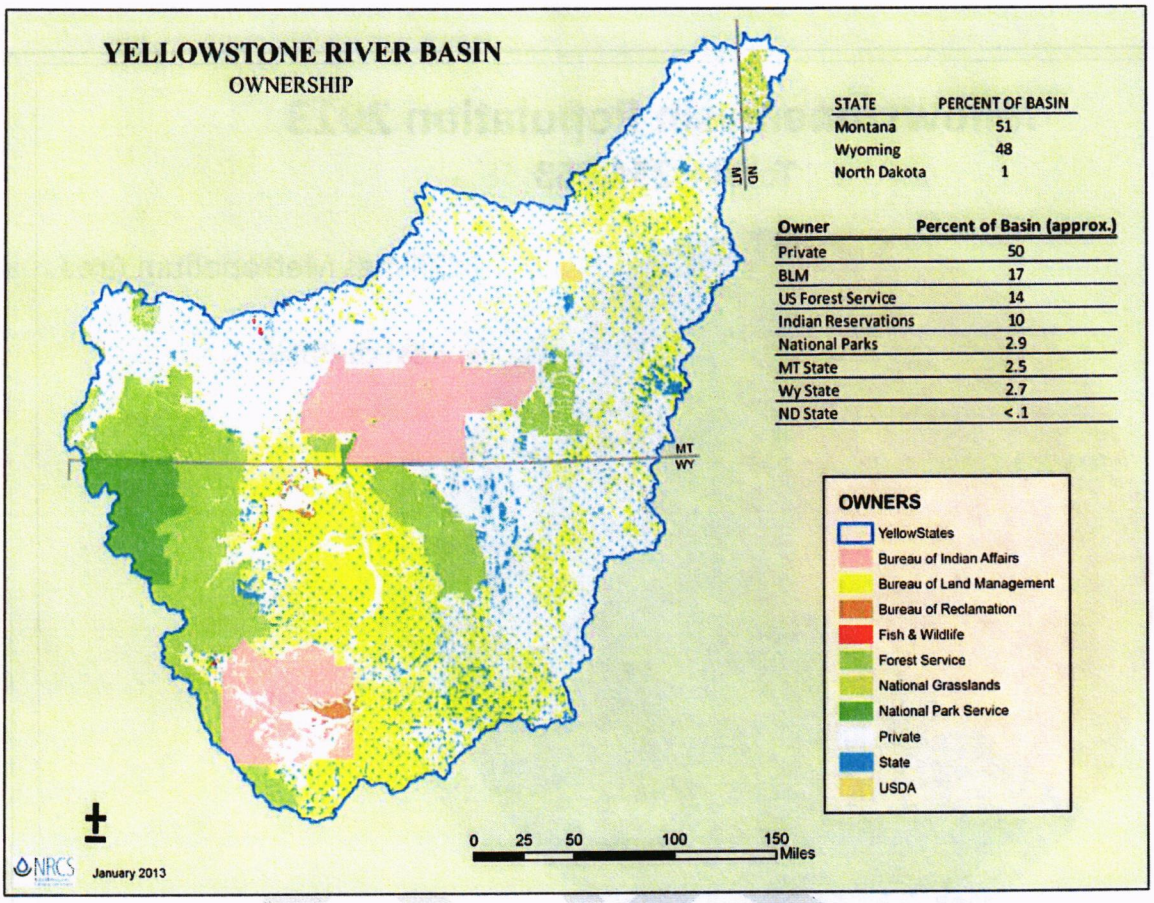
Task	Date	Who
Attend and participate in the BAC meetings to develop recommendations	February 25, March 12, April 9, 2014	BAC members DNRC staff Contractor
Discuss preliminary recommendations with constituents and report results at BAC meetings	Ongoing	BAC members
Review and guide staff and contractor in agenda development and process management as requested	Ongoing	BAC Chair BAC Vice Chair
Develop and provide agendas and supporting documents to BAC members well in advance of each meeting	February 7, March 3, March 28, 2014	DNRC staff Contractor
Document BAC meetings Provide accurate notes on timely basis	Ongoing	MSU-Billings staff DNRC staff Contractor
Review and adopt final package of recommendations	April 9, 2014	BAC
Prepare Recommendation Development Report (RDR) transmitting the recommendations of the BAC to DNRC for the MWSI and 2015 Legislature	June 1, 2014	Contractor (DNRC staff and BAC review)

III. Basin Profile of the Yellowstone Basin

A. Demographic, Economic, and Social Setting

1. Land Use and Ownership





2. Historical and Projected Demographics

POPULATION

Recent Estimates

Between the 2010 census and July 1, 2013, the population of the Yellowstone Basin increased 3.8 percent to 254,858. During the same period Montana's population increased 2.6 percent to 1,015,165.

The Yellowstone Basin contains one area that is considered to be "Metropolitan" or "Micropolitan" by the White House Office of Management and Budget (see Figure 1). According to OMB (OMB 2013), a "Metropolitan Statistical Area" is considered to have "at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties." "Micropolitan Statistical Areas" are defined similarly with the exception that the area's core consists of "at least one urban cluster" with a population between 10,000 and 50,000. The Billings Metropolitan Area is the most populous of these areas in Montana with 162,848 residents. One of every six Montanans lived in the Billings Metropolitan Area in 2013. Thirty-five percent of the Basin's residents lived in areas considered to be "rural" or classified as neither "Metropolitan" nor "Micropolitan" (Figure 1).

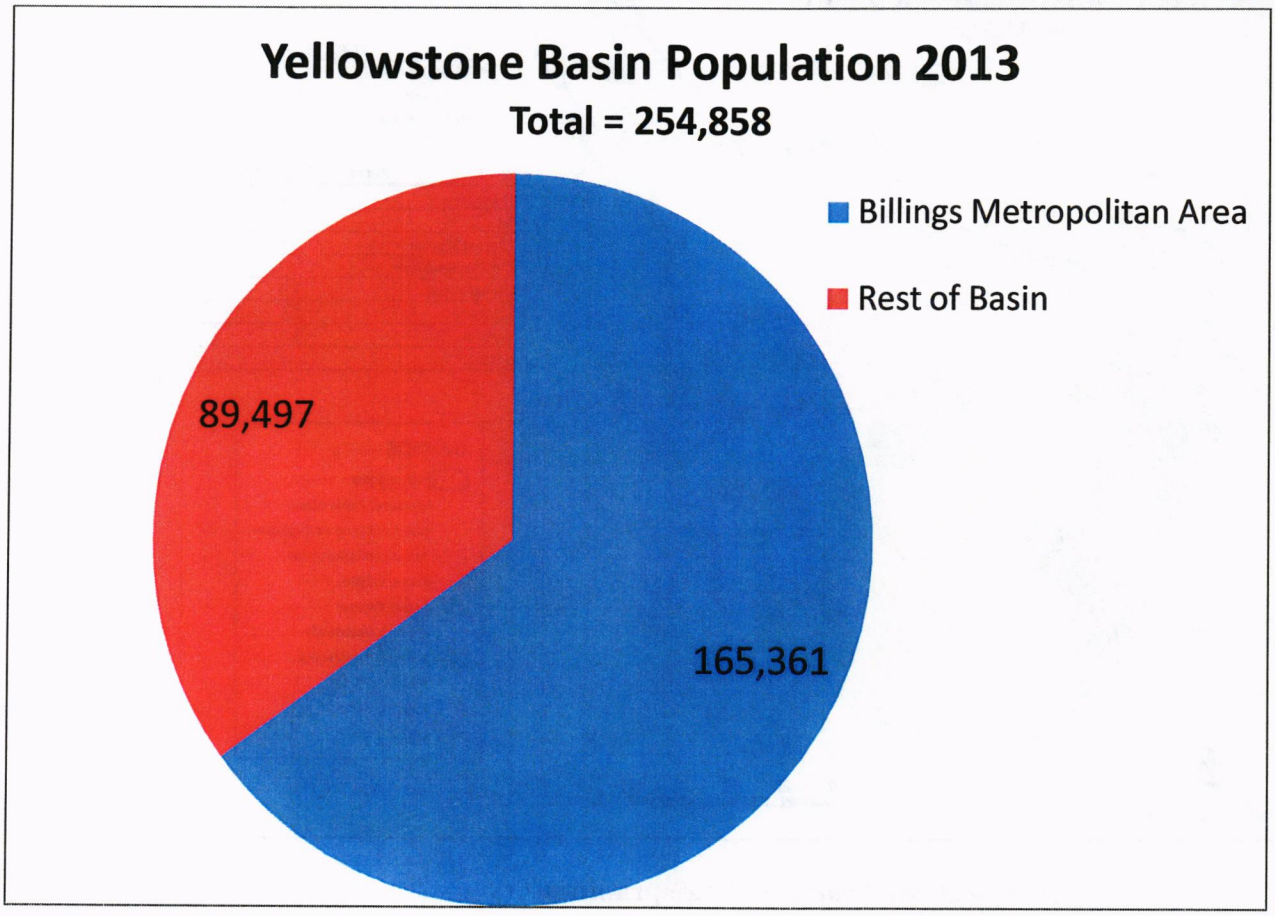


Figure 1

Source: U.S. Census Bureau, Population Division

Populations for the Billings Metropolitan Statistical Area and for the rest of the Yellowstone Basin grew by 4 percent and 3 percent, respectively, between 2010 and 2013. Growth for these parts of the Basin exceeded the Montana's growth rate for the period of 2.6 percent.

Metropolitan Statistical Area, Rest of Basin
Yellowstone Basin

	2010	2013	% Change
Metropolitan Areas			
Billings	158,934	162,848	+4.0
Rest of Basin	86,966	89,497	+2.9
Montana	989,415	1,015,165	+2.6

Figure 2

Source: U.S. Census Bureau, Population Division

Populations of counties in the Yellowstone Basin for 2013 are listed in Figure 3. More than 60 percent of the Basin's residents lived in Yellowstone County.

Among U.S. counties with populations exceeding 10,000, Richland County ranked 19th in population growth between 2012 and 2013, growing by 3.7 percent to 11,214. Richland County's population increased by 15.1 percent between 2010 and 2013.

Carbon County ranked 92nd for population growth between 2012 and 2013, increasing by 2.2 percent to 10,340.

Yellowstone Basin Counties Populations - 2013

Big Horn	13,042
Carbon	10,340
Custer	11,951
Dawson	9,445
Fallon	3,079
Park	15,682
Powder River	1,748
Prairie	1,179
Richland	11,214
Rosebud	9,329
Stillwater	9,318
Sweet Grass	3,669
Treasure	700
Yellowstone	154,162

Source: U.S. Census Bureau, Population Division

Figure 3

The populations of Indian reservations in the Basin totaled 11,652 in 2010 with nearly 60 percent residing on the Crow Indian Reservation. Figure 4 displays the populations of the Crow and Northern Cheyenne Reservations and Off-Reservation Trust Land and the percentage change in population between 2000 and 2010. The population for the Northern Cheyenne Reservation increased by 7 percent while the population of the Crow Reservation declined slightly during the decade.

Reservations	Population 2010	% Change (2000-10)
Crow	6,863	-0.5
Northern Cheyenne	4,789	7.1
Total	11,652	2.5

Figure 4

Source: U.S. Census Bureau, Population Division

Population estimates from the 2010 Census were aggregated by 8-digit hydrologic unit code (HUC) sub-basins for the Upper Missouri Basin. Population estimates for these sub-basins are presented in Figure 5. Nearly two-thirds of the Basin population resided in two sub-basins, the Upper Yellowstone-Big Lake Basin and the Upper Yellowstone-Pompeys Pillar.

YELLOWSTONE BASIN POPULATION by SUB-BASIN - 2010

SUB-BASIN	2010 POPULATION
Big Horn Lake	10
Big Porcupine Creek	108
Clarks Fork Yellowstone River	10,013
Little Bighorn River	4,662
Little Powder River	271
Lower Bighorn River	5,646
Lower Powder River	327
Lower Tongue River	7,139
Lower Yellowstone River	19,143
Lower Yellowstone River-Sunday Creek	12,012
Middle Powder River	796
Mizpah Creek	221
O'Fallon Creek	2,723
Pryor Creek	1,457
Rosebud Creek	4,253
Shields River	1,957
Shoshone River	31
Stillwater River (Yellowstone R)	3,102
Upper Tongue River	148
Upper Yellowstone River	16,455
Upper Yellowstone River-Big Lake Basin	111,086
Upper Yellowstone River-Pompeys Pillar	42,574
Yellowstone Headwaters	928

Source: U.S. Census Bureau, Population Division; Montana Department of Natural Resources and Conservation

Figure 5

Trends

Between 1990 and 2013, the population of the Yellowstone Basin increased by 23 percent while Montana's population increased by 27 percent (Figure 6). Stillwater, Yellowstone, and Carbon Counties were the most rapidly growing counties with populations increasing by 42 percent, 36 percent, and 28 percent, respectively. The populations of four counties in the Basin declined over the period.

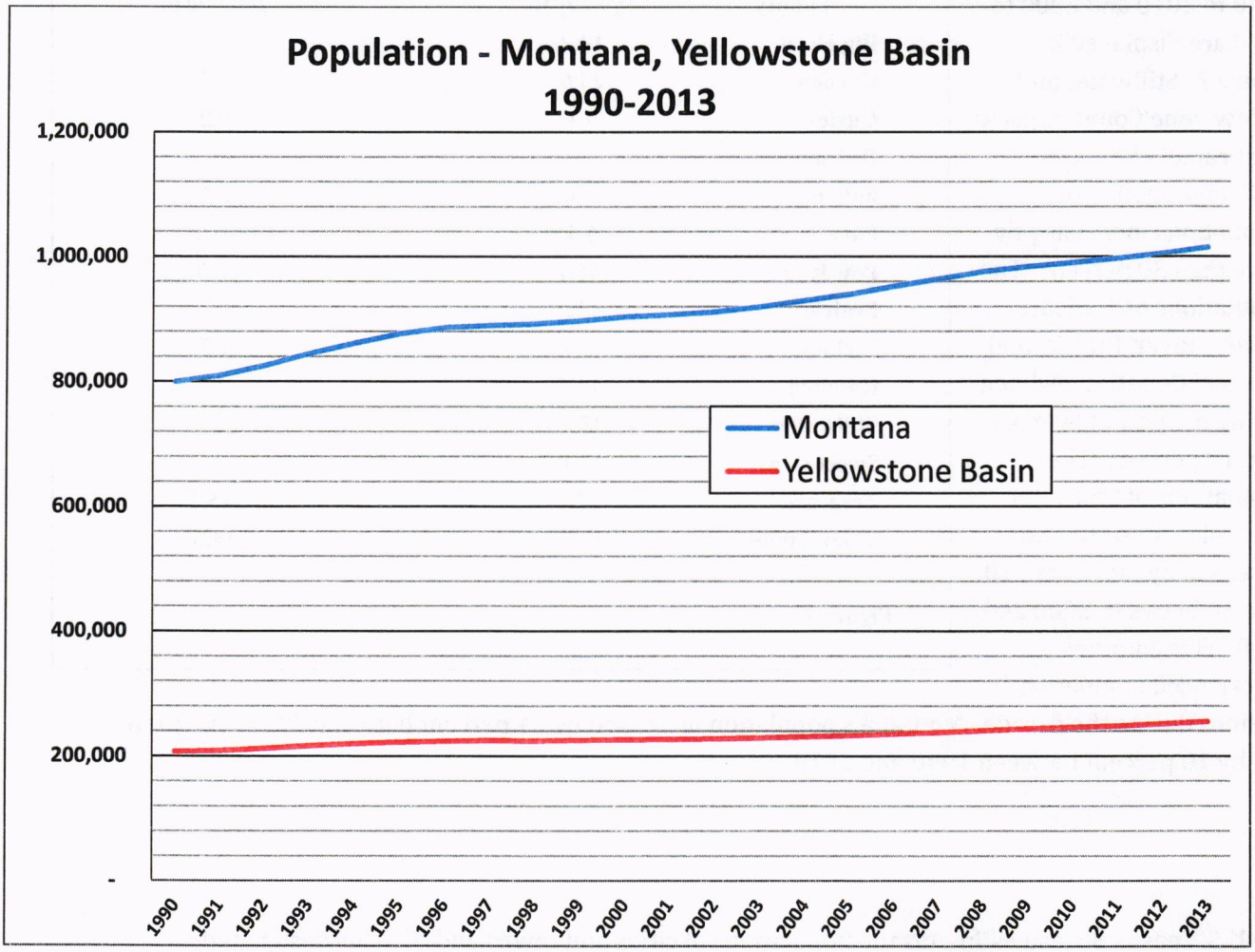


Figure 6

The changes in population for Yellowstone Basin counties for the periods 1990 to 2010 and 2000 to 2010 are displayed in Figure 7. Stillwater and Yellowstone Counties grew most rapidly between 1990 and 2010 with populations increasing by more than 30 percent. The populations of Treasure, Powder River, Prairie, and Rosebud Counties declined during the period by more than 10 percent. The populations of Stillwater and Yellowstone Counties increased by more than 10 percent between 2000 and 2010. Five counties experienced population declines during the decade. Montana's population increased by 24 percent between 1990 and 2010 and by 10 percent between 1990 and 2010.

Population Change - Yellowstone Basin Counties

	% Change	
County	1990-2010	2000-2010
Big Horn	14.2	2.0
Carbon	24.6	5.3
Custer	0.1	0.2
Dawson	-5.1	-1.3
Fallon	-6.0	2.5
Park	6.4	-0.8
Powder River	-16.7	-6.3
Prairie	-13.2	0.7
Richland	-8.4	1.3
Rosebud	-11.6	-1.5
Stillwater	38.5	10.4
Sweet Grass	15.1	-0.3
Treasure	-17.1	-15.8
Yellowstone	30.7	14.6

Figure 7

The U.S. Census Bureau estimates the populations of cities and towns and "Census designated places" (CDPs). CDPs are identified as "settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state in which they are located." Population estimates from the 1990, 2000, and 2010 censuses for cities, towns, and CDPs in the Yellowstone Basin are presented in Figure 8. (** indicates a CDP split into two CDPs in 2010.)

Figure 8 Estimated Populations for Yellowstone Basin Cities, Towns, and CDPs

	Census 2010 Population	Census 2000 Population	Census 1990 Population	% Change 2000 to 2010
Big Horn County				
Busby CDP	745	695	409	7.2%
Crow Agency CDP	1,616	1,552	1,446	4.1%
Fort Smith CDP	161	122	--	32.0%
Hardin city	3,505	3,384	2,940	3.6%
Lodge Grass town	428	510	517	-16.1%
Muddy CDP	617	627	387	-1.6%
Pryor CDP	618	628	654	-1.6%
St. Xavier CDP	83	67	--	23.9%
Wyola CDP	215	186		15.6%
Carbon County				
Bearcreek town	79	83	37	-4.8%
Belfry CDP	218	219	--	-0.5%
Boyd CDP	35	--	--	
Bridger town	708	745	692	-5.0%
Edgar CDP	114	--	--	
Fromberg town	438	486	370	-9.9%
Joliet town	595	575	522	3.5%
Red Lodge city	2,125	2,177	1,958	-2.4%
Roberts CDP	361	--	--	
Roscoe CDP	15	--	--	
Silesia CDP	96	--	--	
Custer County				
Ismay town	19	26	19	-26.9%
Miles City city	8,410	8,487	8,461	-0.9%
Dawson County				
Glendive city	4,935	4,729	4,802	4.4%
Richey town	177	189	259	-6.3%
West Glendive CDP	1,948	1,833	--	6.3%
Fallon County				
Baker city	1,741	1,695	1,818	2.7%
Plevna town	162	138	140	17.4%

Source: U.S. Census Bureau, Population Division; Montana Department of Commerce; Montana Department of Natural Resources and Conservation

Figure 8 (cont'd) Estimated Populations for Yellowstone Basin Cities, Towns, and CDPs

	Census 2010 Population	Census 2000 Population	Census 1990 Population	% Change 2000 to 2010
Park County				
Clyde Park town	288	310	282	-7.1%
Cooke City CDP **	75	--	--	
Cooke City-Silvergate CDP**	--	140	--	
Corwin Springs CDP	109	--	--	
Emigrant CDP	488	--	--	
Gardiner CDP	875	851	--	2.8%
Jardine CDP	57	--	--	
Livingston city	7,044	6,851	6,701	2.8%
Pray CDP	681	--	--	
Silver Gate CDP **	20	--	--	
South Glastonbury CDP	284	--	--	
Springdale CDP	42	--	--	
Wilsall CDP	178	237	150	-24.9%
Wineglass CDP	256	--	--	
Powder River County				
Biddle CDP	41	--	--	
Broadus town	468	451	572	3.8%
Prairie County				
Fallon CDP	164	138	659	18.8%
Terry town	605	611	--	-1.0%
Richland County				
Crane CDP	102	--	--	
Fairview town	840	709	869	18.5%
Fox Lake CDP	158	157	--	0.6%
Knife River CDP	320	297	--	7.7%
Sidney city	5,191	4,774	5,217	8.7%
Rosebud County				
Ashland CDP	824	464	484	77.6%
Birney CDP	137	108	--	26.9%
Colstrip city	2,214	2,346	3,035	-5.6%
Forsyth city	1,777	1,944	2,178	-8.6%
Lame Deer CDP	2,052	2,018	1,918	1.7%
Rosebud CDP	111	--	--	

Figure 8 (cont'd) Estimated Populations for Yellowstone Basin Cities, Towns, and CDPs

	Census 2010 Population	Census 2000 Population	Census 1990 Population	% Change 2000 to 2010
Stillwater County				
Absarokee CDP	1,150	1,234	1,067	-6.8%
Columbus town	1,893	1,748	1,573	8.3%
Park City CDP	983	870	--	13.0%
Reed Point CDP	193	185	--	4.3%
Sweet Grass County				
Big Timber city	1,641	1,650	1,557	-0.5%
Greycliff CDP	112	56	--	100.0%
Treasure County				
Hysham town	312	330	361	-5.5%
Yellowstone County				
Ballantine CDP	320	346	--	-7.5%
Billings city	104,170	89,847	81,125	15.9%
Broadview town	192	150	133	28.0%
Custer CDP	159	145	--	9.7%
Huntley CDP	446	411	--	8.5%
Laurel city	6,718	6,255	5,686	7.4%
Lockwood CDP	6,797	4,306	3,967	57.8%
Shepherd CDP	516	193	--	167.4%

Figures 9 and 10 display maps of the population distributions for the Yellowstone Basin as reported in the censuses of 1990 and 2010. The maps illustrate the increasing population density in the western portion of the Basin--particularly in the vicinities of Billings and Livingston.

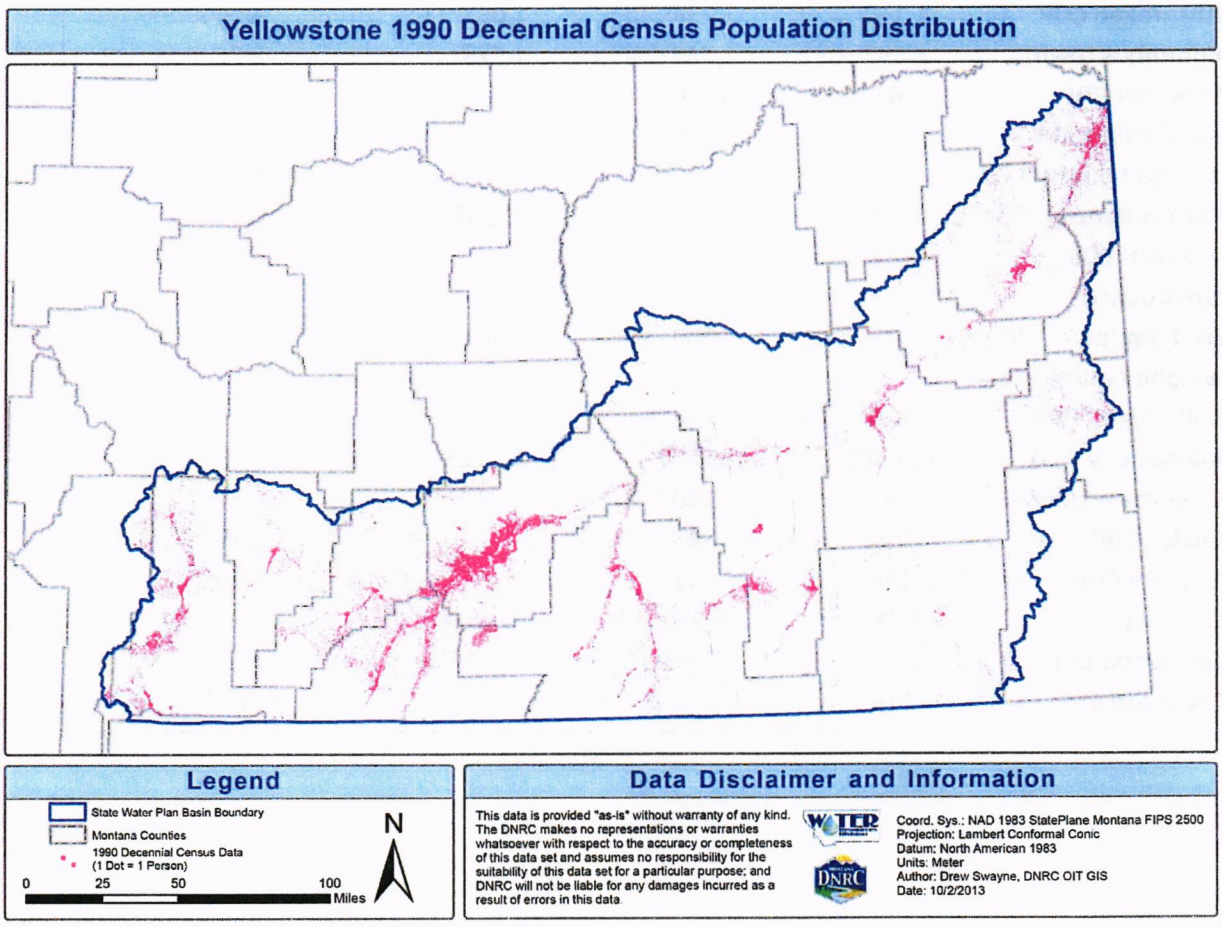


Figure 9

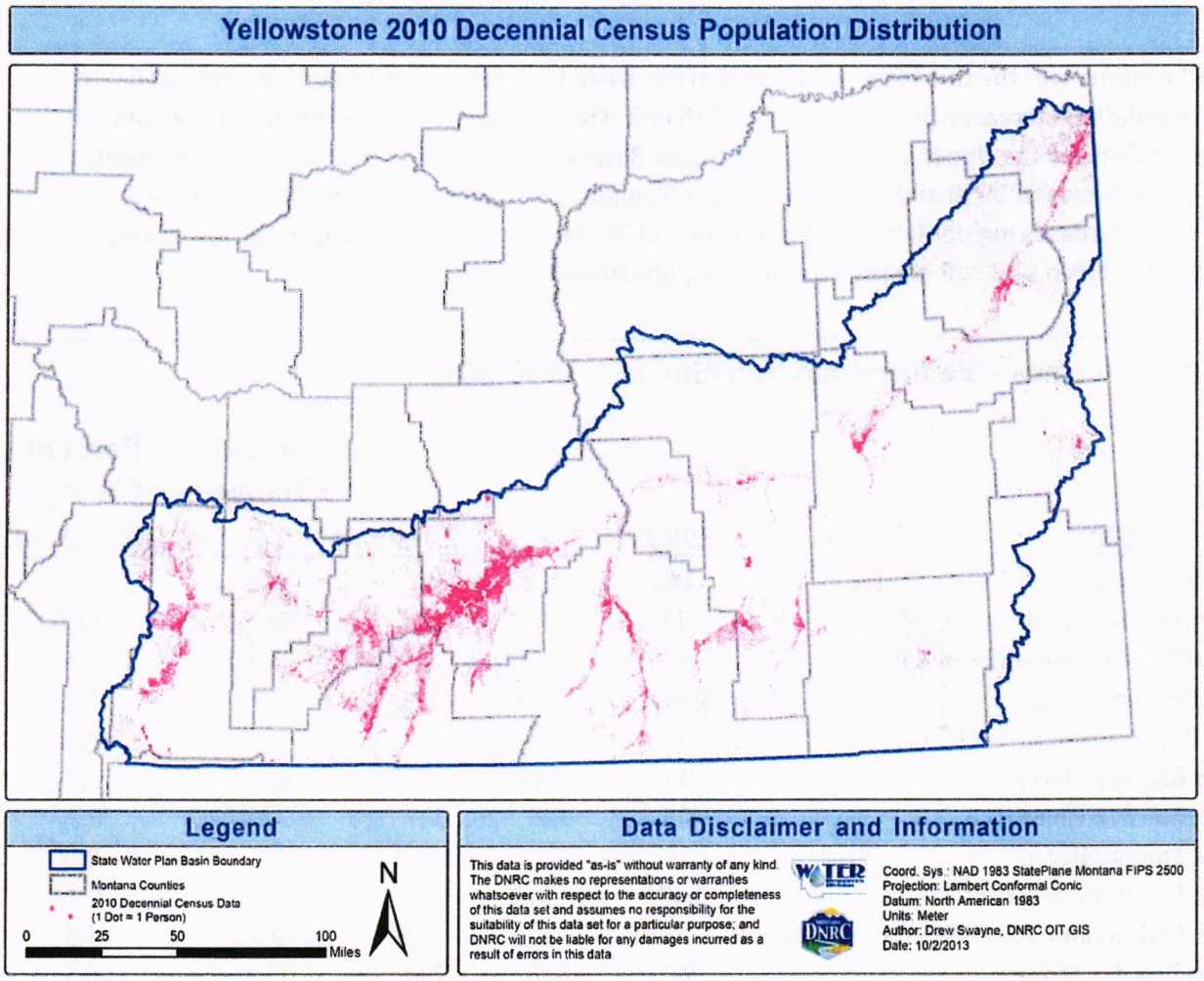

Yellowstone 2010 Decennial Census Population Distribution
Legend
State Water Plan Basin Boundary
Montana Counties
2010 Decennial Census Data
(1 Dot = 1 Person)
0
25
50
100
Miles
N
Data Disclaimer and Information
This data is provided "as-is" without warranty of any kind. The DNRC makes no representations or warranties whatsoever with respect to the accuracy or completeness of this data set and assumes no responsibility for the suitability of this data set for a particular purpose; and DNRC will not be liable for any damages incurred as a result of errors in this data
Coord. Sys : NAD 1983 StatePlane Montana FIPS 2500
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Meter
Author: Drew Swayne, DNRC OIT GIS
Date: 10/2/2013

Figure 10

The Yellowstone was the third fastest growing major basin in Montana between 1990 and 2010, with a population increasing by 19 percent to 245,062. The populations of the Upper Yellowstone-Pompeys Pillar and the Upper Yellowstone-Big Lake Basin increased by 47 percent and 26 percent, respectively, between 1990 and 2010. The Upper Tongue River and Lower Powder River sub-basins saw decreases in population of 33 percent and 25 percent, respectively, during the period. Twelve of the basin's 23 sub-basins experienced population declines.

Population Trends - Yellowstone Sub-Basins – 1990-2010

SUB-BASIN	1990	2000	2010	Percent Change 1990-2010	Percent Change 2000-2010
Big Horn Lake	24	17	10	-58.3	-41.2
Big Porcupine Creek	138	125	108	-21.7	-13.6
Clarks Fork Yellowstone River	7,991	9,467	10,013	25.3	5.8
Little Bighorn River	4,369	4,680	4,662	6.7	-0.4
Little Powder River	435	335	271	-37.7	-19.1
Lower Bighorn River	4,904	5,498	5,646	15.1	2.7
Lower Powder River	435	326	327	-24.8	0.3
Lower Tongue River	7,342	7,344	7,139	-2.8	-2.8
Lower Yellowstone River	20,471	19,015	19,143	-6.5	0.7
Lower Yellowstone River-Sunday Creek	13,308	12,175	12,012	-9.7	-1.3
Middle Powder River	960	842	796	-17.1	-5.5
Mizpah Creek	206	239	221	7.3	-7.5
O'Fallon Creek	2,951	2,695	2,723	-7.7	1.0
Pryor Creek	1,235	1,424	1,457	18.0	2.3
Rosebud Creek	3,526	4,046	4,253	20.6	5.1
Shields River	1,688	2,013	1,957	15.9	-2.8
Shoshone River	36	23	31	-13.9	34.8
Stillwater River (Yellowstone R)	2,541	3,126	3,102	22.1	-0.8
Upper Tongue River	220	172	148	-32.7	-14.0
Upper Yellowstone River	15,013	16,182	16,455	9.6	1.7
Upper Yellowstone River-Big Lake Basin	88,133	99,631	111,086	26.0	11.5
Upper Yellowstone River-Pompeys Pillar	29,067	34,435	42,574	46.5	23.6
Yellowstone Headwaters	1,028	1,093	928	-9.7	-15.1

Figure 11

Components of Population Change

The Yellowstone Basin's population change of 16,752 between 2000 and 2010 was the result of a natural increase of 9,750 and net migration of 8,237. The components of population change are displayed in Figure 12. (The components of population change do not reconcile with the total population change due to the variance in estimation methods applied to different demographic characteristics.) Population change in the Basin is dominated by the relatively large levels of positive net migration and natural increase for Yellowstone County. The composition of population change for counties within the Basin varies significantly. In four Basin counties, the number of deaths exceeded the number of births and for nine counties net migration was negative during the

Components of Population Change – Yellowstone Basin Counties 2000-2010

	Births	Deaths	Natural Increase	% Natural Increase	International Migration	Domestic Migration	Net Migration	Percent Migration
Big Horn	2,760	1,073	1,687	305.1	53	-1,123	-1,070	-193.5
Carbon	838	962	-124	-56.9	80	316	396	181.7
Custer	1,447	1,414	33	-6.9	16	-469	-453	95.0
Dawson	964	1,064	-100	17.6	7	-424	-417	73.5
Fallon	365	313	52	-41.3	-1	-171	-172	136.5
Park	1,664	1,487	177	106.6	98	-22	76	45.8
Powder River	107	188	-81	39.7	-1	-112	-113	55.4
Prairie	83	165	-82	160.8	6	30	36	-70.6
Richland	1,047	1,025	22	-8.0	26	-283	-257	93.8
Rosebud	1,743	734	1,009	-2402.4	51	-1,060	-1,009	2,402.4
Stillwater	987	740	247	38.9	6	424	430	67.7
Sweet Grass	374	366	8	-15.7	25	-67	-42	82.4
Treasure	50	59	-9	3.5	6	-255	-249	96.9
Yellowstone	19,286	12,375	6,911	40.1	484	10,597	11,081	64.3
TOTAL	31,715	21,965	9,750	58.2	856	7,381	8,237	49.2

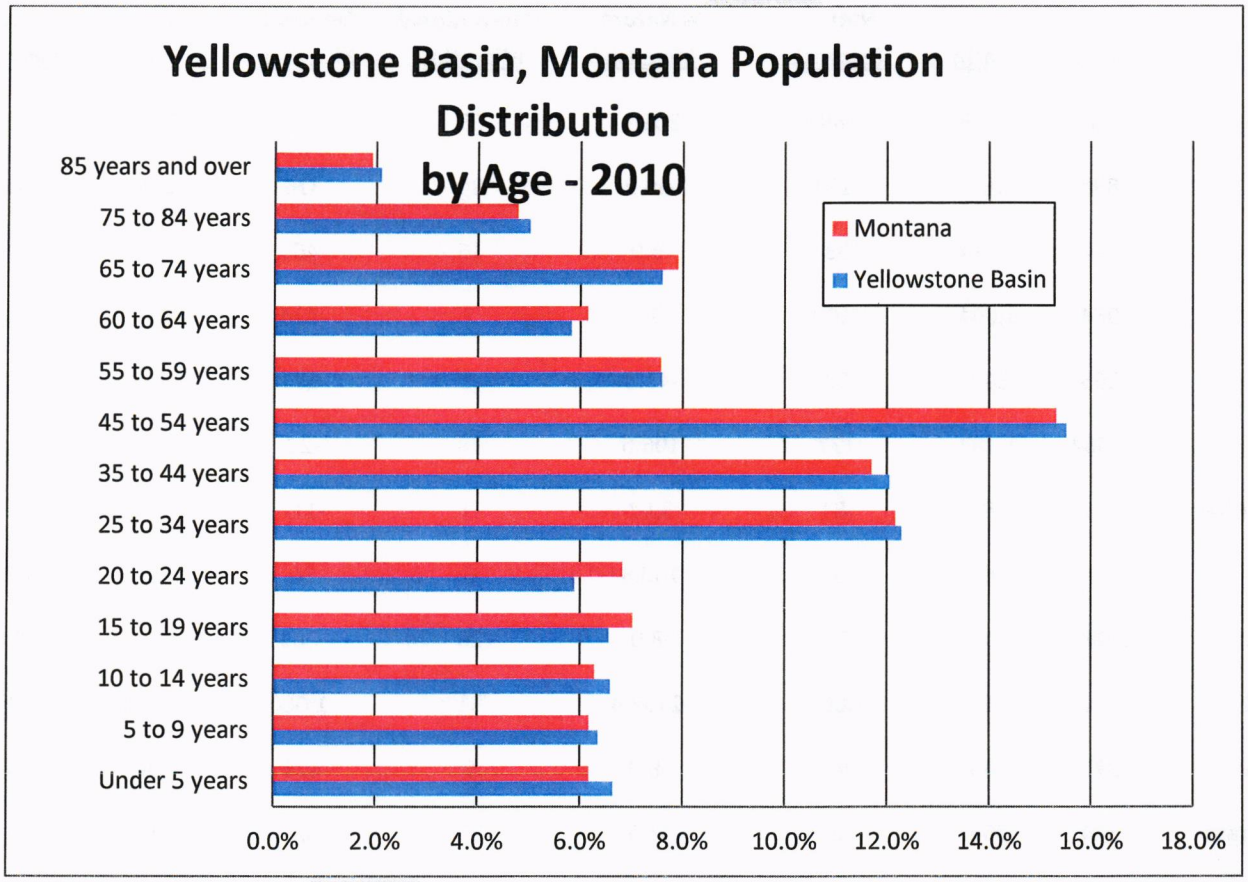
Figure 12

decade. Curiously, for Rosebud County a natural increase of 1,009 was offset by negative net migration in the same amount.

In 2010, the median age of residents of counties in the Yellowstone Basin ranged from 30.1 years in Big Horn County to 56.1 years in Prairie County—the state's youngest and oldest counties. The median age for Montana was 39.7 years and 36.9 for the U.S.

As displayed in Figure 13, the Yellowstone Basin has proportionately more residents than the state that are younger than 15, between the ages of 25 and 55, and older than 75 years old.

Figure 13



Projections

Population trends can be somewhat mysterious. States have experienced various trends reflecting each state's particular natural endowments and historical circumstances. Those circumstances arise from unique, complex national, regional, and local dynamics that determine the geography of socioeconomic development and patterns of population change over time. For example: Iowa has seen consistent, low levels of population growth broken only by negative growth in the 1980s; California experienced very high levels of growth throughout the twentieth century, tapering off in recent decades at lower, but still high, levels; North Dakota's pattern of low levels of alternating population increases and declines is now being broken by rapid growth since 2010.

Predicting population changes is an undertaking that grows increasingly speculative as the time horizon expands and the region under consideration diminishes in size. For the purposes of this planning effort, population projections are provided to inform deliberations of water management issues in which population levels are one factor among many comprising the demand for water. The intent of these projections is neither to predict nor forecast precise population levels at particular points in time and locations in Montana; the purpose, rather, is to offer reasonable estimates of magnitudes of population growth that would presumably relate to the supply and demand for water in various ways over the course of the planning period.

Two sets of population projections are offered here. One set extrapolates trends seen in the period between the 1990 and the 2010 censuses. These projections are provided at the state, county, basin, and sub-basin levels. The other set relies on projections at the state and county levels developed by the Montana Department of Commerce (MT Commerce) using eREMI, a population projection product of Regional Economic Models, Inc. (REMI). Population levels were projected through the twenty-year planning period to 2035.

Figure 14 displays projections of the Yellowstone Basin's population based on each method. The MT Commerce forecasts predict a population increase for the Yellowstone Basin by 2035 that is about three-fourths of the projection that relies on extrapolations of trends from 1990 to 2010. Extrapolating Basin-wide population growth at the average annual rate of population change for the period between 1990 and 2010 would result in 59,364 additional residents in 2035 and an estimated population of 304,426, or one-quarter of the state's projected population. Over 90 percent of the increase would occur in the vicinity of Billings. These projections do not include the notable recent population changes in the lower Yellowstone since 2010.

Rather than extrapolate recent trends, the MT Commerce projections forecast more moderate rates of population change through 2035, reflecting assumptions about the Basin's age structure, natality and survival rates, and migration patterns over the period. This projection forecasts a substantially lower average annual rate of growth and an increase in the Basin's population of 41,223 by 2035.

Population Projections – Yellowstone Basin

	Average Annual Rate	2035	Change 2010-35
1990-2010 Extrapolation	0.87%	304,426	59,364
MT Commerce	0.62%	287,201	41,223

Figure 14

Figure 15 displays estimated populations for the Basin's counties in 2035 as projected by each method. Generally, the MT Commerce forecasts predict more moderate rates of population change for counties compared to the trends of recent decades. That is, rapidly growing counties are predicted to grow less rapidly, counties with very slow rates of growth are expected to see increasing rates of growth, and counties with declining populations are predicted to shrink at decreasing rates. The sum of the county projections does not equal the basin population projected due to compounding effects related to the basin and county projection calculations.

Population Projections – 2035
Yellowstone Basin Counties

	1990-2010 Extrapolation	MT Commerce
Big Horn	15,145	11,135
Carbon	13,061	9,307
Custer	11,908	15,395
Dawson	8,760	9,816
Fallon	2,822	4,273
Park	16,777	15,883
Powder River	1,443	1,859
Prairie	974	1,457
Richland	9,764	13,389
Rosebud	8,116	9,016
Stillwater	13,384	8,341
Sweet Grass	4,273	4,280
Treasure	593	859
Yellowstone	206,018	182,191
TOTAL	313,036	287,201

Figure 15

Figure 16 presents the projected populations for the Yellowstone sub-basins in 2035. Essentially, all of the Basin's population increase would occur in the Basin's two most populous sub-basins in the vicinity of Billings. For the remaining sub-basins, the projected population change would be a net gain of just over 5,000 residents.

Population Projections – Yellowstone Sub-Basins 2035
1990-2010 Trends

SUB-BASIN	2010	Estimated Population 2035	Estimated Change 2010-35
Big Horn Lake	10	3	-7
Big Porcupine Creek	108	79	-29
Clarks Fork Yellowstone River	10,013	13,274	3,261
Little Bighorn River	4,662	5,056	394
Little Powder River	271	150	-121
Lower Bighorn River	5,646	6,733	1,087
Lower Powder River	327	229	-98
Lower Tongue River	7,139	6,893	-246
Lower Yellowstone River	19,143	17,603	-1,540
Lower Yellowstone River-Sunday Creek	12,012	10,568	-1,444
Middle Powder River	796	630	-166
Mizpah Creek	221	241	20
O'Fallon Creek	2,723	2,463	-260
Pryor Creek	1,457	1,791	334
Rosebud Creek	4,253	5,376	1,123
Shields River	1,957	2,354	397
Shoshone River	31	26	-5
Stillwater River (Yellowstone R)	3,102	3,981	879
Upper Tongue River	148	90	-58
Upper Yellowstone River	16,455	18,454	1,999
Upper Yellowstone River-Big Lake Basin	111,086	148,358	37,272
Upper Yellowstone River-Pompeys Pillar	42,574	68,600	26,026
Yellowstone Headwaters	928	817	-111
TOTAL	245,062	304,426	59,364

Figure 16

While the courses of population change in the Yellowstone Basin and in particular parts of the state are highly uncertain from the perspective of the present, these projections offer two distinct scenarios for consideration when regarding prospects for future water use in the Basin. They should be viewed as potentially useful tools in examining various factors affecting—and consequences affected by— the supply and demand of the Yellowstone's waters.

HOUSING

The number of households in the Upper Missouri Basin in 2010 was 98,976 with an average size of 2.4 people (U.S. Census Bureau; 2007-2011 American Community Survey Profile Report). The total number of housing units was 112,705 with 98,976 occupied and 5,191 for seasonal, recreational, or occasional use.

INCOME and EMPLOYMENT

Total personal income (TPI) is comprised of: net earnings in the forms of wages and salaries, supplemental earnings, and proprietors' income; transfer payments; and income from dividends, interest, and rent. In 2012, TPI in the Yellowstone Basin was $10.4 billion, 26 percent of TPI for Montana of $39.3 billion.[1] Between 1990 and 2012, TPI (adjusted to 2013 $s) in the Yellowstone Basin increased by 92 percent, compared to an increase for Montana of 80 percent.

Per capita personal income (PCPI) in the Yellowstone Basin in 2012 was reported to be $41,448, compared to $39,126 for Montana. Personal income in 2012 (adjusted to 2013 $s) for the major basins in Montana is displayed in Figure 17. With $13.0 billion, the Clark Fork Basin was the basin with the highest amount of total personal income, but the lowest per capita personal income by a substantial margin. The sparsely populated Lower Missouri had the lowest TPI by a considerable amount, but the Basin nearly matched the Upper Missouri's $40,676 for the highest PCPI among the state's four major basins. PCPI in the Yellowstone Basin was the highest among the four major basins, exceeding PCPI for Montana by $2,322.

Personal Income – Major Basins 2012

	Total	Per Capita
Clark Fork	13.0 billion	35,896
Lower Missouri	3.1 billion	40,528
Upper Missouri	12.8 billion	40,676
Yellowstone	10.4 billion	41,448
Montana	39.3 billion	39,126

Adjusted to 2013 $s.

Figure 17

[1] Figures are from the U.S. Department of Commerce, Bureau of Economic Analysis, Table CA30, adjusted for inflation to 2013 dollars. Estimates are based on administrative records and survey and census data collected by various agencies.

Between 1990 and 2012, per capita income in the Yellowstone Basin, adjusted for inflation, increased by 58 percent. Figure 18 presents similar upward trends in PCPI for each of the major basins over the period. PCPI in the Lower Missouri and the Yellowstone Basins increased at rates greater than the statewide increase of 43 percent. Between 2007 and 2012, PCPI in the Lower Missouri increased by 19 percent while PCPI in the Clark Fork declined by 1 percent. PCPI in the Yellowstone increased 8 percent during the period. The impacts of the recent recession are evident from the graph as are the contributions of strong prices for agricultural commodities and activity in the energy sector.

Figure 18

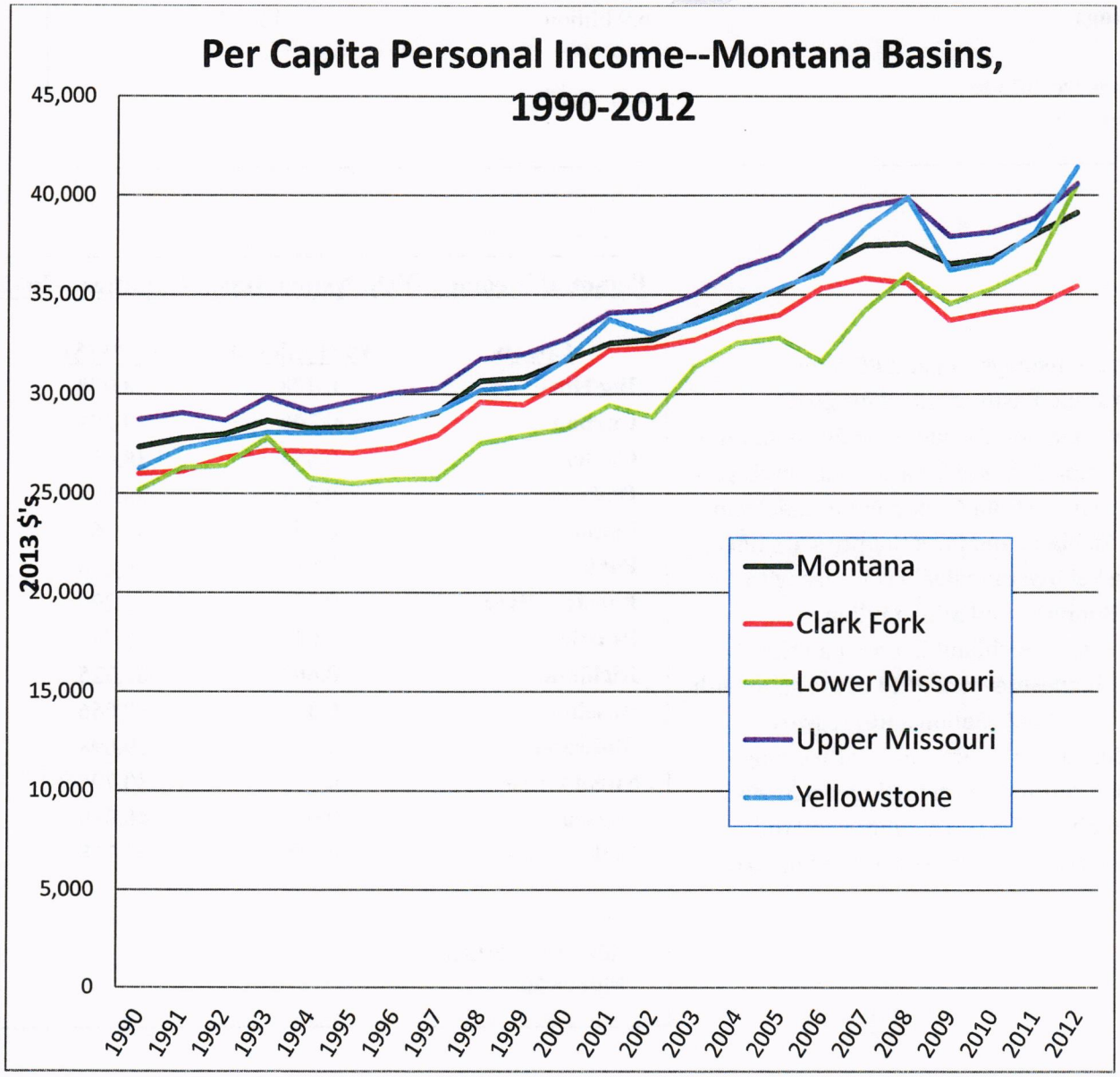


Figure 19 displays TPI and PCPI for the Billings Metropolitan Statistical Area for 2012. TPI totaled nearly $7 billion—two-thirds of TPI for the Basin and over one-sixth of Montana's TPI. Overall, PCPI in the area exceeded PCPI for the other Metropolitan and Micropolitan Statistical Areas—except Butte—and for the state.

Personal Income—Billings Metropolitan Area—2012

Metropolitan Areas	Total Personal Income	Per Capita Personal Income
Billings	6.9 billion	42,161

Adjusted to 2013 $s

Figure 19

Figure 20 displays TPI and PCPI for Yellowstone Basin counties for 2012. Yellowstone County had the highest amount of TPI among all Montana counties with $6.4 billion—more than 61 percent of the Basin total. Richland and Park Counties are next among Yellowstone Basin counties with TPI of $663 million and $617 million, respectively. Richland County had the second highest level of PCPI in the state with $61,325 in 2012. Fallon and Treasure Counties ranked fourth and sixth among Montana counties with the highest levels of PCPI in 2012. Big Horn County had the state's second lowest level of PCPI in 2012.

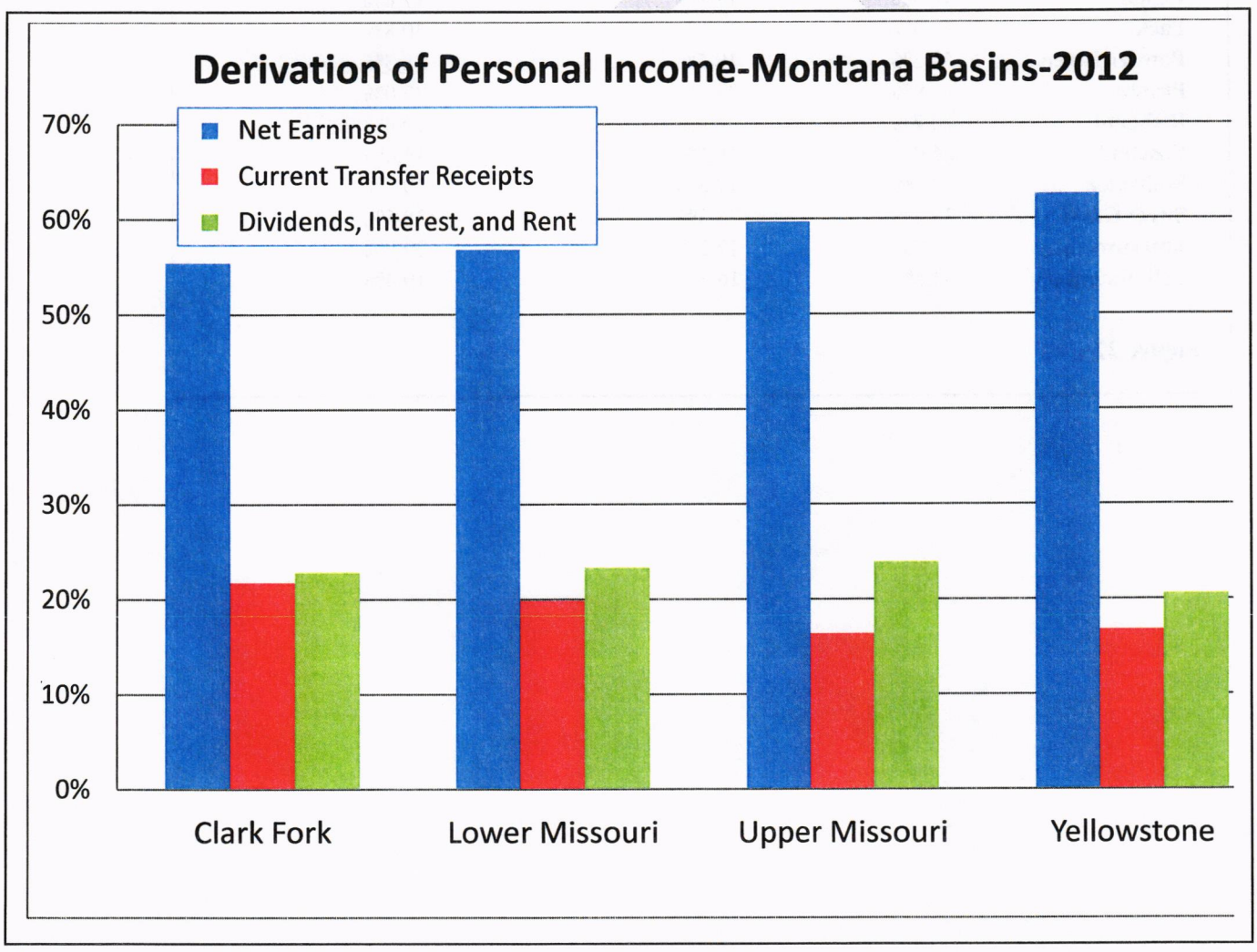
Personal Income—Yellowstone Basin Counties—2012

County	TPI ($ billion)	PCPI ($)
Big Horn	0.378	28,958
Carbon	0.398	39,291
Custer	0.454	38,151
Dawson	0.352	38,103
Fallon	0.161	53,263
Park	0.617	39,628
Powder River	0.057	32,296
Prairie	0.045	38,779
Richland	0.663	61,325
Rosebud	0.358	38,056
Stillwater	0.365	39,698
Sweet Grass	0.111	30,795
Treasure	0.035	48,030
Yellowstone	6.429	42,328

Adjusted to 2013 $s.

Figure 20

The composition of personal income in Montana has changed over time. The portion of personal income derived from net earnings—primarily in the form of wages and salaries—has declined to 59 percent in 2012. The portion of income from retirement programs and other transfer payments has increased to 18 percent and income derived from dividends, interest, and rent accounted for 22 percent in 2012. For the U.S. in 2012, 65 percent of personal income was derived from net earnings and income from transfer payments and from dividends, interest, and rent comprised, respectively, 17 percent and 18 percent of personal income. Figure 21 displays the derivation of personal income in 2012 for Montana's four major basins. For Montana's major basins in 2012, net earnings comprised the largest portion of personal income in the Yellowstone at 63 percent. Transfer receipts were lowest in the Upper Missouri and Yellowstone Basins with approximately 16 percent of personal income for each basin. The portion of personal income provided by dividends, interest, and rent ranged between 21 percent and 24 percent across the basins.

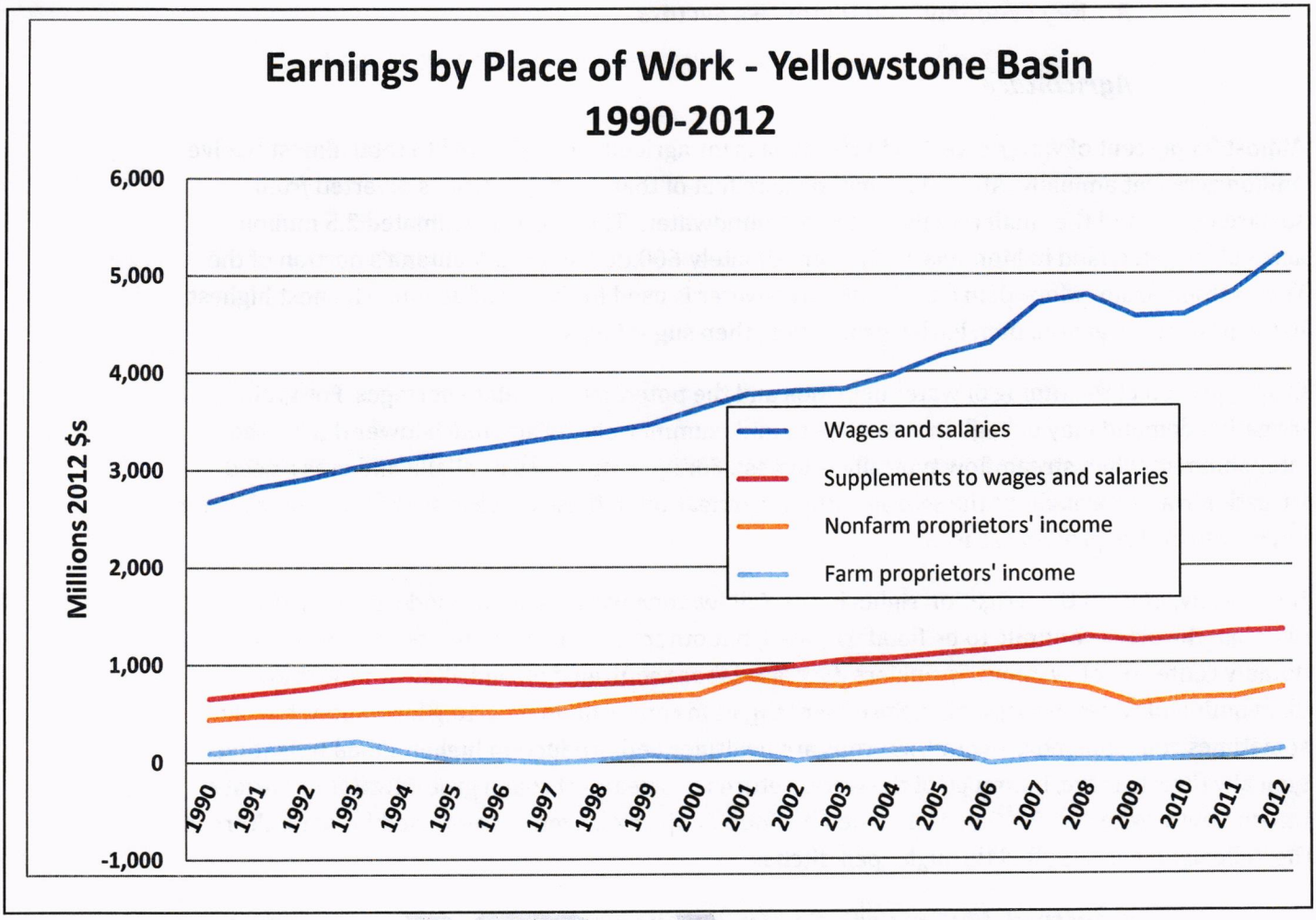


The derivation of personal income for Yellowstone Basin counties is presented in Figure 22. For Fallon and Richland Counties, net earnings comprised more than 70 percent of personal income. The portion of income derived from transfer payments was highest in Big Horn County. Income from dividends, interest, and rent was nearly 40 percent in Sweet Grass County and greater than 30 percent in Park County.

Derivation of Personal Income—Yellowstone Basin Counties - 2012

	Net Earnings	Transfer Payments	Dividends, Interest, and Rent
Big Horn	57.2%	26.9%	16.0%
Carbon	51.6%	18.9%	29.5%
Custer	60.5%	19.1%	20.4%
Dawson	62.0%	18.1%	19.9%
Fallon	70.3%	11.9%	17.8%
Park	50.4%	18.8%	30.8%
Powder River	52.2%	19.5%	28.3%
Prairie	46.9%	26.1%	27.0%
Richland	70.7%	9.3%	20.0%
Rosebud	66.0%	19.6%	14.4%
Stillwater	62.2%	17.6%	20.2%
Sweet Grass	38.2%	23.3%	38.5%
Treasure	52.9%	17.2%	29.9%
Yellowstone	64.6%	16.1%	19.4%

Figure 22



Net earnings are comprised of wages and salaries, supplemental contributions by employers for pension and insurance programs, and proprietors' income for owners of businesses and farms. Trends for earnings in the Yellowstone Basin for the period 1990 to 2012—adjusted for inflation—are presented in Figure 23.

Total earnings for wages and salaries increased by nearly 94 percent to $5.2 billion and income in the form of supplemental employer contributions increased doubled to $1.3 billion. Non-farm proprietors' income increased 70 percent $741 million. Farm proprietors' income increased 24 percent since 1990 in real terms, fluctuating between -$18 million and $216 million and averaging $65 million since 1990.

Between 1990 and 2011, average wages and salaries in the Yellowstone Basin rose 29 percent to $39,220, just below the state average of $36,652. State-wide, wages and salaries, adjusted for inflation, increased 19 percent over the period. Over the same period, average non-farm proprietors' income in the Basin decreased 4 percent to $18,639, below the state-wide average that declined by 2 percent to $21,057.

3. Key Economic and Water Use Sectors

Agriculture

Almost 98 percent of water diverted in Montana is for agriculture, estimated to total almost twelve million acre feet annually. About 11.5 million acre feet of that, or 98 percent, is diverted from surface water, and the small remainder from groundwater. There are an estimated 2.5 million acres of irrigated land in Montana, with approximately 600,000 acres in Montana's portion of the Yellowstone Basin. More than half the diverted water is used for hay production. The next highest use is pasture irrigation, then barley production, then sugar beets.

Crop types affect the timing of water demands and the potential for water shortages. For grain, irrigation demand may be high in the early- to mid- summer period and much lower during the later summer, when streamflow typically is lowest. Forage crops, such as alfalfa and grass, need irrigation water throughout the season, although irrigation to these crops is shut off periodically for haying during the growing season.

Historically, most of the irrigation rights in the Yellowstone were used for flood irrigation. Now, over half the acres continue to be flood irrigated, but others have been converted to sprinklers, notably center pivot systems. Sprinklers decrease labor requirements and allow for more even distribution of water across a field. Sprinkler irrigation can result in diverting less water, but can sometimes consume more overall, as crops are healthier and production higher. Flood irrigation typically diverts more, but much of the water returns to streams through groundwater or surface return flows. Whether the field is irrigated by flood or sprinkler, most water used for agriculture in the Yellowstone is supplied through open ditches.

Industrial, Mineral and Energy Resources

Industrial water uses in the basin include mining, petroleum production and refining, hydropower generation, coal-fired power generation and non-agricultural food production. Coal, oil, metals, and natural gas are natural resources mined in the Yellowstone River watershed. Coal is found underground near Forsyth, Montana, and also in those parts of the basin within Wyoming. Several large active coal mines exist at Decker near the Tongue River reservoir, and two metal mines - the Stillwater Mine near Nye, and the East Boulder Mine near Big Timber produce platinum and palladium. Oil and natural gas production occurs in the east and southeast parts of the basin within the state where some consumptive use occurs for the hydro fracturing process. Two petroleum refineries exist in the basin near Billings: Exxon-Mobil and Conoco-Phillips, as does a sugar beet refining facility. All of these uses are relatively small in comparison to water used for irrigated agriculture.

Water rights are required for all beneficial uses of water, including industrial uses, except where those uses are indirect or collateral to the primary water use (e.g., mine pit dewatering, etc.). Coal-fired electricity is generated from the Colstrip plants located in Rosebud County. The Colstrip plants produce up to 2,094 megawatts (one megawatt can satisfy the average energy needs of 750 households) of electricity from coal using stream created by the burning of the coal. The water for

the steam is pumped 30 miles from the Yellowstone River. The Colstrip facility is the second largest coal-fired project west of the Mississippi. It uses one rail car's worth of coal every five minutes and has a water right for _____.

The Yellowstone's largest hydropower generating facility is associated with Yellowtail Dam on the Bighorn River. Bighorn Lake is the reservoir formed behind the dam, and has a capacity of 1,381,189 acre-feet. The dam's hydroelectric plant has a capacity of 250 megawatts. The other significant hydropower facility in Montana's portion of the Yellowstone basin is located at Mystic Lake Dam on West Rosebud Creek in the Beartooth Mountains. The hydropower facility consists of two generating units that have a total generating capacity of 12 megawatts.

Municipal and Domestic

This water use category includes domestic water use, whether supplied by an individual on-site well, a major municipality's water supply system, a community system in a subdivision, or a system of an intermediate scale. There are approximately ___ municipal water rights recorded in the basin, and about _____ individual domestic well permits (purposes include domestic, lawn and garden, and fire protection). Municipal suppliers have diverse demands they must fulfill, which makes planning challenging. Water quality comes into play as well. Municipal water demand figures vary widely, and may include residential, commercial, industrial, universities and government agencies. In general, in-home water use is not highly consumptive, but lawn and garden uses are. Within the Yellowstone basin, seven cities and the town of Broadus have water reservations for future use.

Recreation and Tourism

Recreation and tourism are major uses of water in the Yellowstone Basin. Of the 54 state parks in Montana, 8 are located in the basin, three being water-based parks. Other major water-related recreational attractions include the 47 fishing access sites along the main stem of the Yellowstone River, the area's many trout streams, the tail water fishery below the Yellowtail Dam, Cooney and Tongue River reservoirs, and the extensive public lands including Yellowstone National Park. Fishing and boating remain popular recreational activities in the Yellowstone basin and Montana residents make frequent use of its rivers, streams, natural lakes and reservoirs, and out-of-state visitors often comment that clean waterways are among the most important attributes to their experience.

IV. Water Resources in the Yellowstone Basin

A. Physical Setting

1. Physiography

The Yellowstone River is the longest free-flowing river in the lower 48 states and drains about 70,000 square miles as it flows more than 700 miles from its origin in Yellowstone National Park to the confluence with the Missouri River in North Dakota (Figure 1). The Yellowstone River mainstem flows into Montana near Gardiner, MT on the southern edge of the Park. Several large tributaries, including the Clarks Fork Yellowstone River, Bighorn River, Tongue River and Powder River also originate in Wyoming and flow north to join the main Yellowstone River in Montana.

Elevations in the drainage basin range from about 13,780 feet in the mountains south of Yellowstone National Park to 1,850 feet at the mouth of the Yellowstone River (Zelt and others, 1999). Major tributaries to the Yellowstone River include the Bighorn, Tongue, and Powder Rivers (Figure1--table 1, figure 2).

Figure 1. The Yellowstone River Basin in Montana, Wyoming and North Dakota (Source: Zeldt and others, 1999)

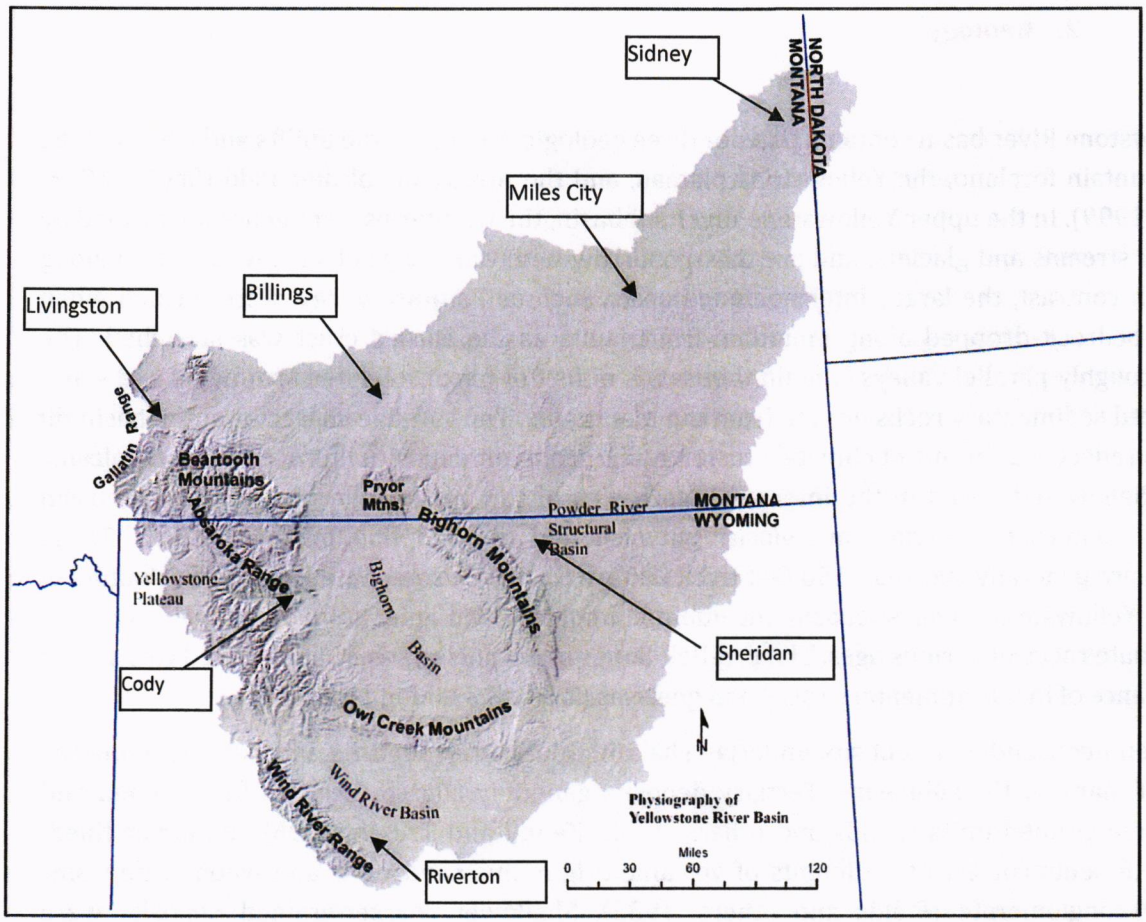


Figure 2. Physiography of Yellowstone River Basin -- Major Mountain Ranges and Runoff Producing Areas.

2. Geology

The Yellowstone River basin contains parts of three geologic provinces: the uplifts and basins of the Rocky Mountain foreland, the Yellowstone plateau, and the Absaroka volcanic field (Snoke, 1993; Zelt et al., 1999). In the upper Yellowstone River subbasin, the tributaries were generally formed by erosion by streams and glaciers, and are mostly narrow with thin strips of shallow alluvium along streams. In contrast, the larger intermontane basins, such as Paradise valley, were formed when blocks of bedrock dropped along mountain-front faults as the earth's crust was stretched. The resulting roughly parallel valleys contain thousands of feet of unconsolidated sediments and semi-consolidated sedimentary rocks eroded from the mountains. The variable character of the basin fill sediments reflects variations of climate, erosion rates, sediment deposition processes, and volcanic activity. Shallow sediments in the intermontane basins of the upper Yellowstone River subbasin consist of Quaternary alluvial fans, glacial outwash and till, and floodplain alluvium. These sediments are generally less than 150 feet thick but are thicker in some locations. Bedrock units in the upper Yellowstone River subbasin, include metamorphic and igneous rocks as well as clastic and carbonate rocks of various ages. The pre-Belt Supergroup gneiss, schist, and related rocks are a thick sequence of metasedimentary rocks and gneisses (2.5 to 3.3 billion years old).

Tertiary semi-consolidated deposits underlay shallow Quaternary deposits and outcrop along the margins of many of the subbasins. Tertiary deposits generally consist of lower fine-grained and upper coarse-grained units (Fields and others, 1985; Kendy and Tresch, 1996).The lower fined-grained sediments consist of sediments of volcanic origin, fine sandstone, and wetland deposits, with local conglomerate (Fields and others, 1985). Shallower coarser-grained deposits were deposited as mud and debris flows and channel fills on alluvial fans (Fields and others, 1985). In the Powder River subbasin, sediment shed from the adjacent Laramide uplifts of the Big Horn and Pryor Mountains were transported and deposited primarily by fluvial processes (Curry, 1971).

Surficial bedrock geology in the middle Yellowstone River subbasin includes the Upper Cretaceous to lower Tertiary rocks of the Eagle Sandstone, Claggett Shale, Judith River Formation, Bearpaw Shale, Fox Hills Formation, Hell Creek Formation, and the Tullock Member, Lebo Member, and Tongue River Member of the Fort Union Formation. Where the Yellowstone River crosses eroding shale, the valley is on the order of miles wide. When the Yellowstone River encounters resistant sandstone the river valley narrows to less than a quarter mile in some places.

Surficial bedrock geology in the lower Yellowstone River subbasin includes the Upper Cretaceous to lower Tertiary rocks of the Bearpaw Shale, Fox Hills Formation, Hell Creek Formation, and the Tullock Member, Lebo Member, and Tongue River Member of the Fort Union Formation. The lower Yellowstone has been periodically covered by seas during geologic time. When inland seas covered eastern Montana, mud and sand were transported into the seas by streams. The mud and sand deposited during the last marine inundation now make up the Bearpaw Shale and Fox Hills Formations, respectively. When the seas receded, streams continued to carry sediment into the basin. On recession of the last sea from what is now Montana, streams deposited sand and mud that

later became the Hell Creek Formation and Fort Union Formation (LaFave et al., 2000). Near the western extent of the Lower Yellowstone River subbasin, stresses associated with mountain building uplifted rocks along two smaller structures: the northwest southeast–oriented Cedar Creek Anticline and Poplar dome. Regional uplift of the Great Plains and Rocky Mountain area and drainage adjustments, resulting from glaciation, caused streams to downcut and develop the modern landscape of broad valley floors and low-relief uplands (LaFave et. al., 2000).

The Yellowstone River basin contains numerous faults, crustal folds, arches and troughs that buckled the rocks underneath the plains. These structures may exist sub-regionally and locally and consist of geologic folds and fault/fracture zones that play a role in defining the limits of groundwater boundaries in the Yellowstone River basin. These features can be either barriers to, or pathways for, groundwater flow. Faults that are barriers have the type of displacement that grinds up rock and creates very low permeability fault gouge along the fault plane, isolating the aquifers on each side. Additionally, faults with significant vertical displacements may offset the interflow zones that host the aquifers on each side of the fault. Significant water level differences have been identified in wells near such hydrostructures in the Yellowstone River basin (e.g. Bull Mountain aquifer system). Folds and their associated faults can create linear zones of low permeability that affect the lateral continuity of groundwater flow in aquifers.

The distribution and physical properties of geologic units affect the availability, movement, and quality of groundwater. The geologic units in eastern Montana that contain usable groundwater are unconsolidated alluvial and terrace deposits within the major stream valleys and the sedimentary strata that lie above the Claggett Shale. Deep regional aquifers are present beneath the Claggett Shale; however, the water in these aquifers is too saline to be used as a potable supply.

ADD PARAGRAPH ON GLACIAL AND QUATERNARY GEOLOGY

3. Hydrography

The diverse physiography of the Yellowstone River Basin is an important factor in determining surface water hydrology. From its headwaters at the Continental Divide in northwestern Wyoming, the Yellowstone River flows out of the mountains and across the plains of south-central and eastern Montana to the confluence with the Missouri River in western North Dakota (Figures 1 and 2)). Approximately 80% if the runoff (measured near Sidney, MT), originates in the mountains of Wyoming and enters Montana from the four major tributary basins: the Clarks Fork Yellowstone, Wind/Bighorn, Tongue, and Powder Rivers. The higher elevations of the Beartooth Mountains, Wind River Range, Absaroka Range, and Bighorn Mountains are the headwaters of most of the perennial streamflow in the basin (Figures (Wahl, 1970).

Basin relief is large; headwaters elevations exceed 13,000 feet above sea level for streams originating in the mountains, while the mouth (where it joins the Missouri River in North Dakota) of the mainstem Yellowstone River is only 1,850 feet above sea level. The mainstem is more than

700 miles long. The combination of large relief in the mountainous areas and long stream lengths across the basins and plains results in a large range in stream and precipitation gradients for the major tributaries.

Water that originates through snowfall and precipitation is stored in mountain snowpack and watershed soils and is consumed through evaporation and transpiration (Figure 3.). Some water is stored as groundwater in aquifers, and later recharges fall and winter base flow.

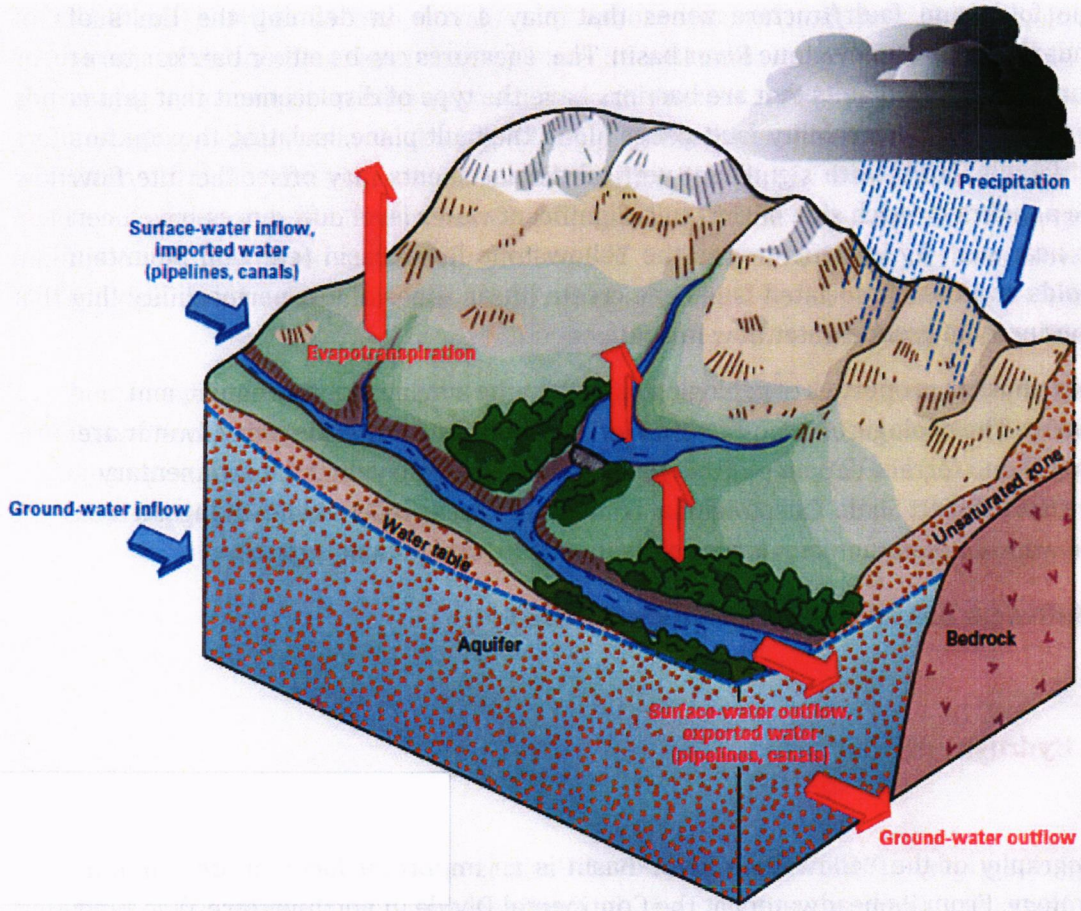


Figure 3. Hydrologic cycle for a part of a watershed (USGS_____)

4. Sub-basins

The Yellowstone River basin has been sub-divided in to 23 hydrologic units by the USGS (in cooperation with other federal, state, and public entities) (Figure3.) for the purposes of measuring and monitoring streamflow, water quality, and other natural resource attributes. For the State Water Plan, these hydrologic units (HUC's)s were aggregated into upper, middle, and lower basins for information presentation and analysis.(Figure 4.). The location of stream gaging stations and drainage basin characteristics, for the water-planning units, are given in Table 2

The Upper Yellowstone subbasin extends from the headwaters in Yellowstone Park to Billings, Montana. In addition to receiving flow, mainly in the form of snowmelt from the headwaters, the mainstem Yellowstone receives runoff from mountain tributaries in the Paradise valley upstream from Livingston; the Shields, Boulder and Stillwater Rivers contribute a smaller amount. The Clarks Fork Yellowstone River , which drains the Beartooth Plateau in Wyoming, enters the mainstem approximately 13 miles upstream from Billings and contributes significant runoff. The Upper Yellowstone Basin contains minor dams and reservoirs that do not significantly influence annual runoff.

The Middle Yellowstone Subbasin extends from Billings to Miles City, and receives most additional flow from the Big Horn River, which enters the mainstem approximately 50 miles downstream from Billings; other tributaries including Pryor Creek, Rosebud Creek, Porcupine Creek and the Tongue River, contribute less flow. The Middle Yellowstone Subbasin contains a significant number of storage projects including Yellowtail Dam (located in Montana) and Bighorn Lake (located primarily in Wyoming). Three other large reservoirs in Wyoming influence the flow of the Big Horn River and Yellowstone mainstem in Montana—Boysen, Buffalo Bill and Bull Lake Reservoirs. The Tongue River Dam and Reservoir, located about 15 miles south of the Wyoming stateline, influences the seasonal distribution of streamflow in the Tongue River, but has little effect on mainstem river flow.

The Lower Yellowstone Subbasin extends from Miles City to Sidney, Montana and drains a semi-arid plain and with the exception of the Powder River streams entering the mainstem Yellowstone are primarily intermittent and contribute little streamflow. Streamflow in the Powder River is generated almost entirely by snowmelt runoff from tributaries that drain the eastside of the Big Horn Mountains in Wyoming—Clear Creek, Crazy Woman Creek, and the Middle Fork Powder River.

For water accounting purposes and creation of generalized partial water budgets, showing water inflows and consumptive water use in each subbasin, the downstream point in each subbasin is included in that subbasin. For example in the Upper Yellowstone Subbasin, Billings is the

downstream location and the mean annual streamflow at Billings is used to represent the total depleted inflow to that subbasin—in other words, the amount of streamflow left in the channel after losses from consumptive use are accounted for. Estimated consumptive uses are then added to the depleted mean annual flow to arrive at an undepleted or "natural" flow. The depleted flow at Billings then becomes the inflow to the next basin downstream—the Middle Yellowstone Basin. In order to show how consumptive use within a subbasin compares with the inflow generated in only that subbasin, for example the Middle Yellowstone the upstream depleted inflow at Billings was subtracted from the downstream depleted flow at Miles City. This quantity represents the total inflow to the Middle Yellowstone, and with consumptive uses added back in, the undepleted streamflow added to that channel segment. This approach was taken so that consumptive uses in a subbasin can be compared directly with the amount of inflow generated only in that subbasin.

The partial water budgets examine only surface runoff and human consumptive uses of water—primarily from irrigated agriculture. Other aspects of the water budget such as precipitation (snow and rain) and evaporative loss from land surfaces and evapotranspiration from vegetation are not accounted for. Further, effects of water storage on mainstem flow are not included, although the only basin with significant year-to-year, carry-over storage is the Big Horn.

Figure 4. Yellowstone River Basin Hydrologic Unit Code Subbasins (Source: National Hydrography Dataset, USGS and Montana State Library 2013)

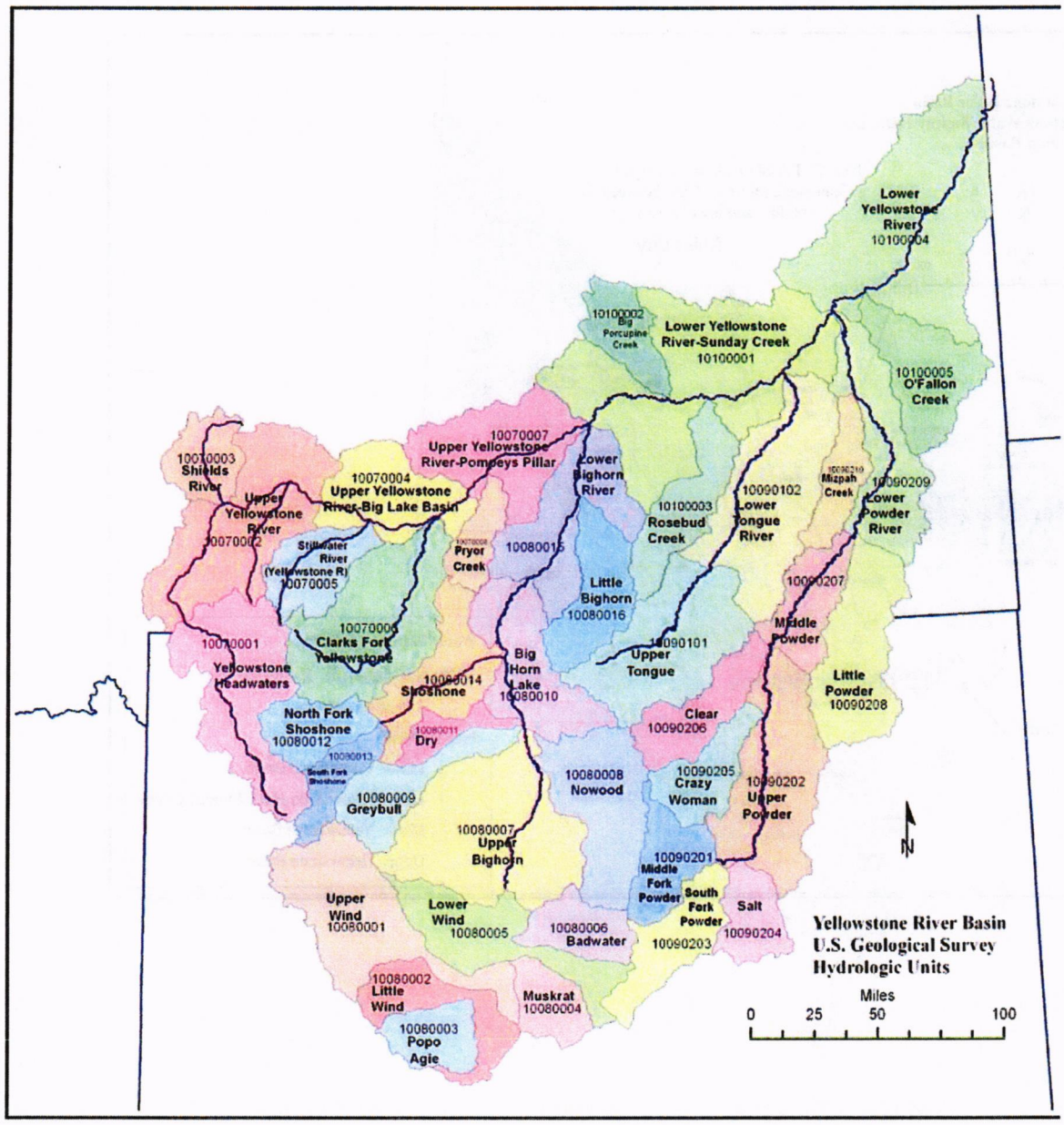


Figure 5. Yellowstone River Subbasins Aggregated into Upper, Middle and Lower Water-Planning Basins.

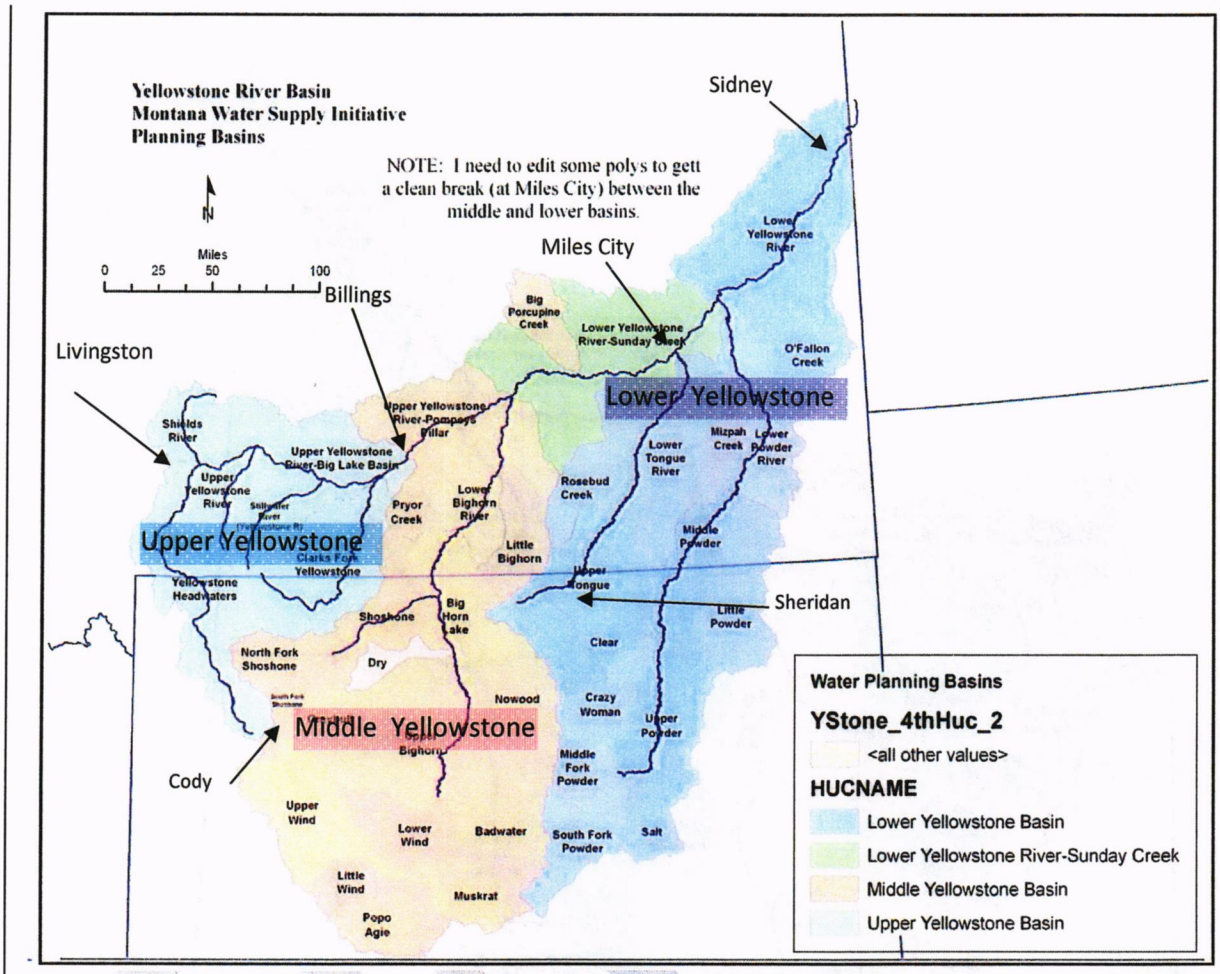


Table 1. Yellowstone River Basin: MWSI Subbasin Divisions and Streamflow Information

Yellowstone River Mainstem Location	Tributary of Yellowstone River	USGS Station ID	Basin Area (mi^2)	Percent of Total Basin Area	Period of record of Annual, Monthly, and Mean-Daily Discharge	Hydrologic Conditions Analyzed by USACE and USGS	MTDEQ TMDL Planning Unit
Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming		6186500	991	1	1922-82, 1983-86, 1988-2010	historic	
Yellowstone River at Corwin Springs		6191500	2619	4	1930-2011	historic, regulated, and unregulated flow conditions (monthly historic 1928 to 2002) USACE Sept 2011)	Upper Yellowstone Sub-Basin
Yellowstone River near Livingston		6192500	3551	5	1930-2011	historic, regulated, and unregulated flow conditions (monthly historic 1928 to 2002) USACE Sept 2011)	
Yellowstone River at Billings		6214500	11805	17	1930-2011	historic, regulated, and unregulated flow conditions (monthly historic 1928 to 2002) USACE Sept 2011)	
	Bighorn River above Tullock Cr near Bighorn, Mont	6294500	22414	34	1945-55, 1956-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
Yellowstone River at Forsyth		6295000	40146	58	1977-2011	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
	Tongue River at State Line near Decker, Mont.	6306300	1,453	2	1960-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	Middle Yellowstone Sub-Basin
	Tongue River at Tongue River Dam near Decker, Mont.	6307500	1,770	3	1939-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
	Tongue River at Miles City, Mont.	6308500	5,397	8	1938-42, 1946-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
Yellowstone River at Miles City		6309000	48253	70	1930-2011	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
	Powder River at Moorhead, Mont.	6324500	8,086	12	1929-72, 1974-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
	Powder River near Locate, Mont.	6326500	13,068	19	1938-2010	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	Lower Yellowstone Sub-Basin
Yellowstone River at Glendive		6327500	66739	97	1930-2011	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	
Yellowstone River near Sidney		6329500	69083	100	1930-2011	regulated and unregulated flow conditions (monthly 1928 to 2002) USGS 2013	

B. Surface Water Resources of the Yellowstone Basin

1. Climate

Climate in the study unit ranges from cold and moist in the mountainous areas to temperate and semiarid in the plains areas. Primarily because of its midcontinent location, the basin's weather is characterized by fluctuations and extremes (Missouri Basin Inter-Agency Committee, 1969). Interaction between air masses originating in the Gulf of Mexico, the northern Pacific Ocean, and the Arctic regions is largely responsible for the seasonal climate regimens found within the study area. Gulf air tends to dominate in spring and early summer, but Arctic air dominates in winter (Missouri Basin Inter-Agency Committee, 1969).

Mean-annual temperatures range from less than 32°F at Yellowstone Lake to about 50°F along the Bighorn River valley in Montana (National Climatic Data Center, digital data, 1994). Annual temperature extremes range from about -40°F during the winter to hotter than 100°F during the summer (Western Regional Climate Center, digital data, 1997). Temperatures generally are coldest in January, when average daily lows range from less than -0.4°F in higher elevations to about 18°F near Livingston, Mont. (Western Regional Climate Center, digital data, 1997), and average monthly temperature ranges from less than 9°F in Yellowstone National Park to about -37?°F near Livingston, Mont. (National Climatic Data Center, digital data, 1994). July normally is the warmest month, with average daily highs ranging from about 72°F in higher elevations to about 90°F in some valleys of the Great Plains and Wyoming Basin Provinces (Western Regional Climate Center, digital data, 1997). Average July temperature ranges from about 54°F in higher elevations to about 75°F in some valley locations (National Climatic Data Center, digital data, 1994). The average frost-free period ranges from less than 10 days at high elevations (Marston and Anderson, 1991) to more than 140 days on the plains and in lower basins (U.S. Department of the Interior, 1965). The climate is cold enough at some sites to form permanent ice (permafrost) in the ground: local permafrost occurs at elevations as low as 7,900 to 8,500 Feet on north slopes near Yellowstone National Park (Pierce, 1979).

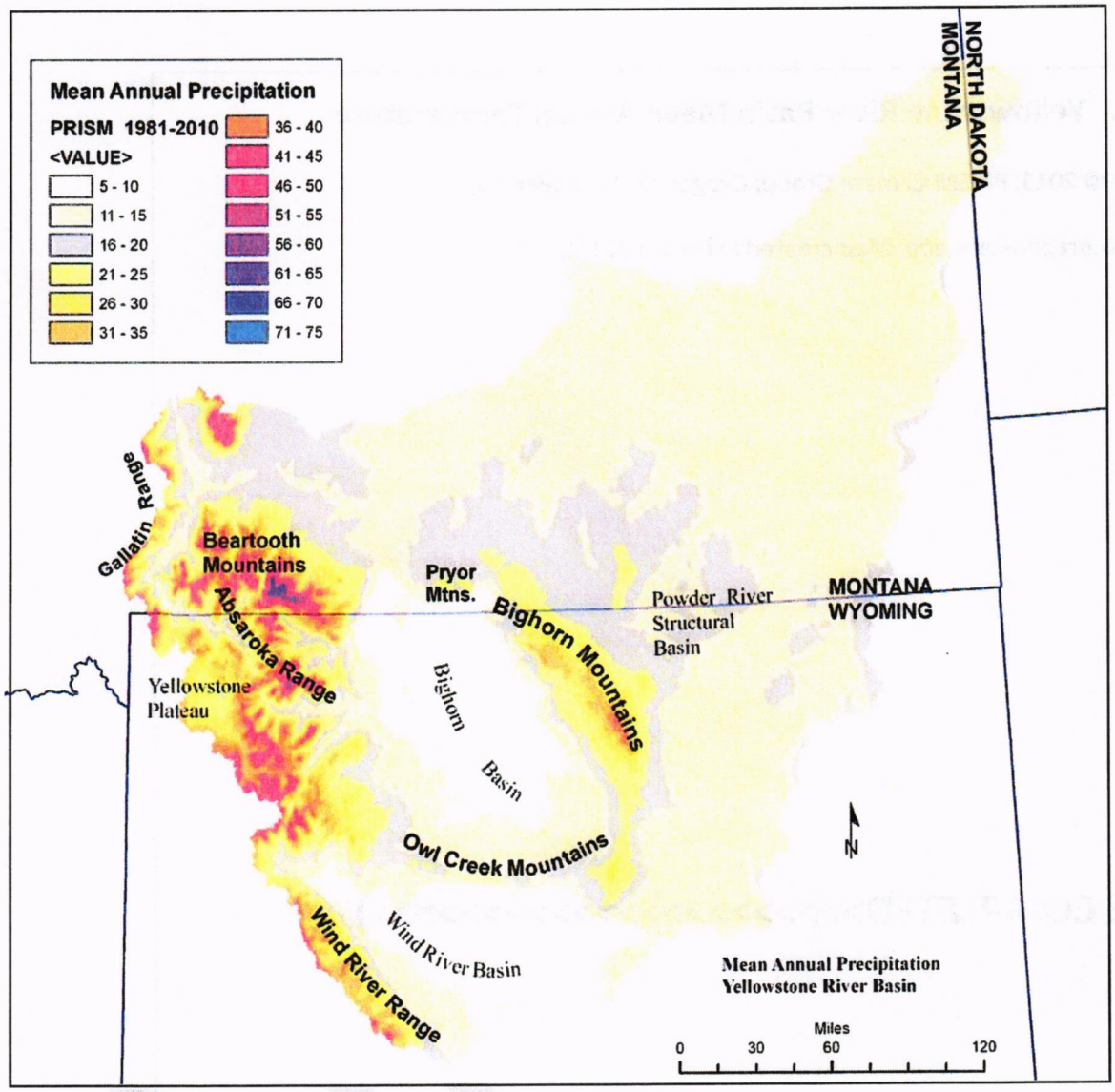


Figure 6 . Yellowstone River Basin Mean Annual Precipitation (Copyright © 2013, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu Map created February 2014).

Figure 7 . Yellowstone River Basin Mean Annual Temperature

(Copyright © 2013, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu Map created February 2014).

(TO BE COMPLETED>>>>>>>>>>>>>>>>>>>>>)

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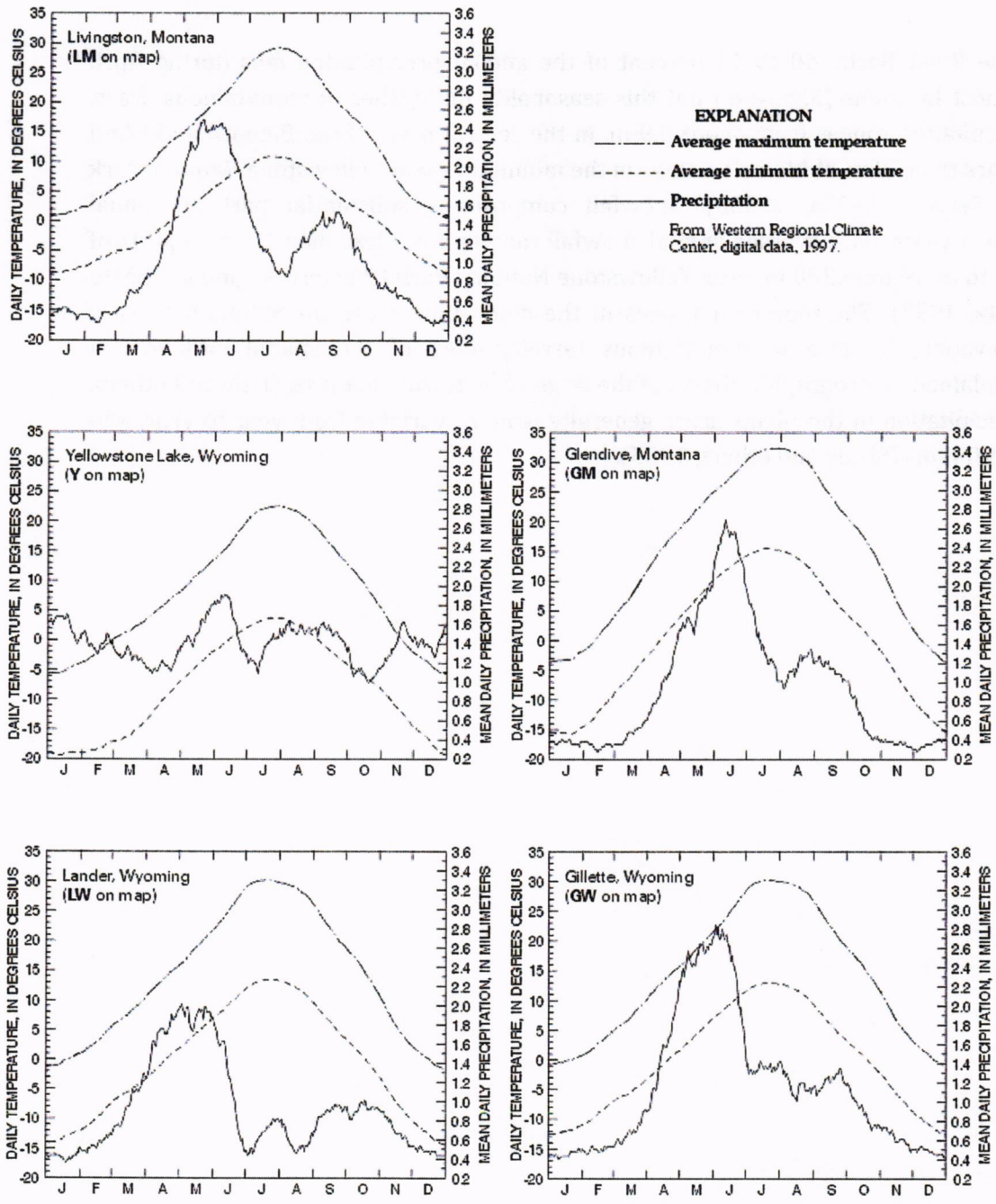


Figure 8. Daily precipitation and temperature for stations in Montana and Wyoming

Author note: These are placeholder graphics. I am in the process of generating my own and have included the HCN stations I will use (HCN stations are those where the climate data has been fully QA/QC'd) in the following examples. Most of the information can be consolidated in a few graphs.

In the Yellowstone River Basin, 40 to 45 percent of the annual precipitation falls during April through June at most locations (Figure 8.) but this seasonality diminishes in mountainous areas. Mean annual precipitation ranges from about 5.9 in. in the central parts of the Bighorn and Wind River Basins to more than 59 in. at high elevations in the mountains near Yellowstone National Park (Oregon Climate Service, 1995a, 1995b). Snowfall composes a substantial part of annual precipitation in most years, with average annual snowfall ranging from less than 12 in. in parts of the Bighorn Basin to more than 200 in. near Yellowstone National Park (Western Regional Climate Center, digital data, 1997). The mountain ranges in the study unit cause precipitation to vary strongly with elevation, because in mountainous terrain, most of the spatial variation in precipitation is explained by orographic effects of the large-scale terrain features (Daly and others, 1994). Annual precipitation in the plains areas generally is more variable from year to year, and less than in the mountains (Slagle and others, 1983).

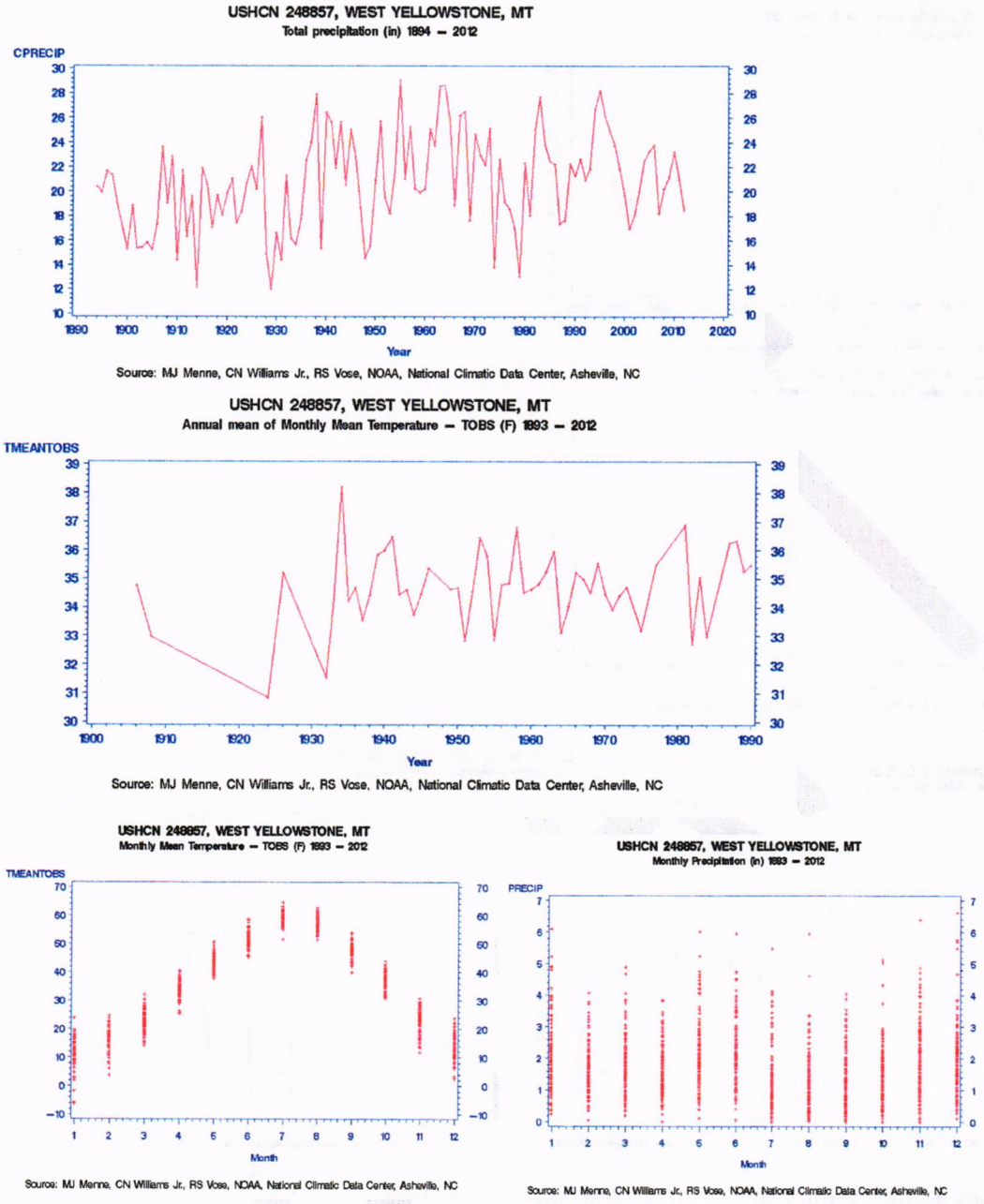
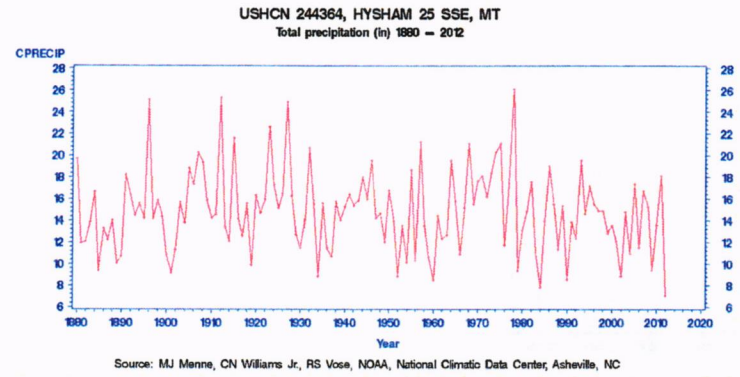
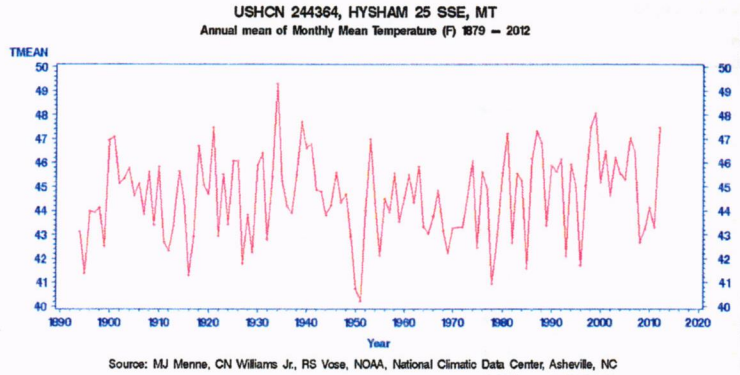
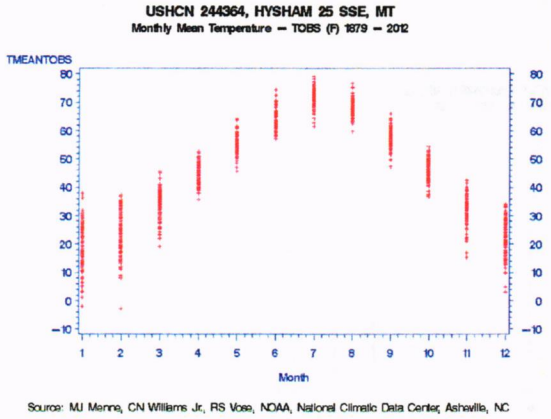


Figure 9.a. West Yellowstone, Montana: Temperature and precipitation 1900-2012







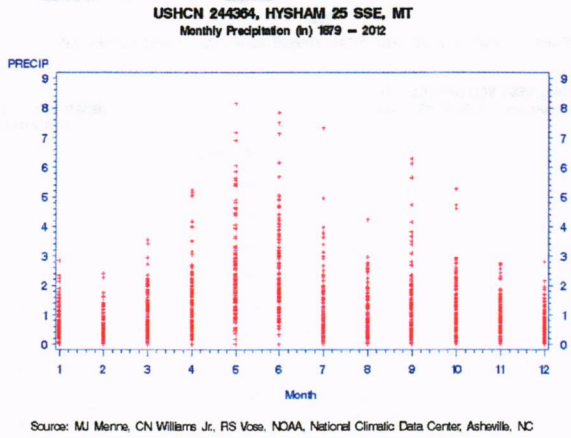


Figure 9.b. Hysham, Montana: Temperature and precipitation 1900-2012

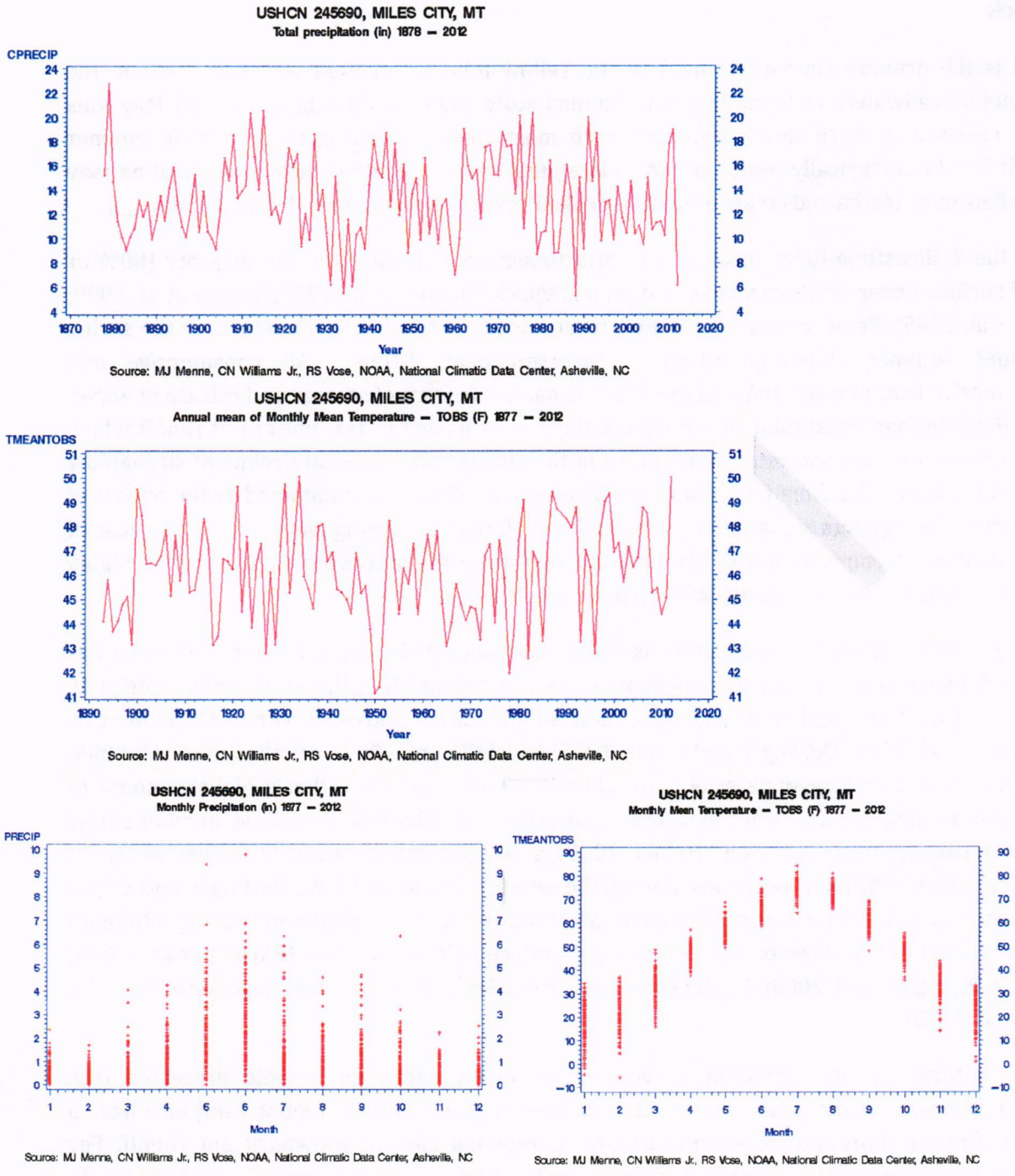


Figure 9.c. Miles City, Montana: Temperature and precipitation 1900-2012

Snowpack

Snowfall is the primary source of runoff to the Yellowstone River. High elevation areas in the mountainous headwaters of Wyoming and Montana store water in November through May; this water is released in April through August, with most runoff occurring in the spring-summer snowmelt flood that typically peaks in mid to late June. Lower elevation snow accumulation may runoff in February-March and create a "double-peaked" hydrograph (Figure _hydrographs____).

Much of the Yellowstone River Basin has an arid to semiarid climate, and the majority (80% or more) of surface water originates as mountain snowpack (Hamlet et al. 2007;Serreze et al. 1999; Stewart et al. 2005). Snow serves as a natural reservoir for water that is released over the spring (April–June) summer (July–September) (Pederson et.al. 2011). All consumptive and nonconsumptive uses of water have adapted to this natural pattern of storage and release of water. Fish, wildlife, riparian vegetation, and river channels are adjusted to this pattern of runoff which includes a long-duration, snowmelt flood pulse in the spring and a gradual decline of streamflow over the summer months; from fall through early spring, low flows are maintained by the release of groundwater from aquifers recharged by snowmelt runoff over the spring and summer. Because of the limited reservoir capacity in the Montana portion of the basin, Irrigated agriculture is highly dependent on the amount and timing of snowmelt runoff.

A growing number of studies have demonstrated that, since 1950, western North America has experienced a substantial decline in peak snow water equivalent (SWE;Das et al. 2009; Mote et al. 2005;Pierce et al. 2008) and subsequently a reduced and earlier snowmelt runoff (Aguado et al. 1992; Cayan et al. 2001; Dettinger and Cayan 1995; Hidalgo et al. 2009; McCabe and Clark 2005; Rajagopalan et al. 2009; Regonda et al.) In addition, there is evidence that a higher amount of precipitation is falling as rain rather than snow (Knowles et al. 2006); an increasing number of low baseflows during dry years (Luce and Holden 2009), and significant increases in the percentage of total annual water discharge occurring during the winter (Das et al. 2009; Dettinger and Cayan 1995; Stewart et al. 2005). Many studies have identified increases in winter and spring minimum temperatures and linked these to green- house gas–induced global warming (Barnett et al. 20088; Clow 2010; Dettinger et al. 2004; Hamlet et al. 2007; Knowles and Cayan 2004; Regonda et al. 2005; Stewart et al. 2005).

However, natural climatic variation, driven by interaction between oceanic processes (e.g. circulation of ocean currents) and atmospheric processes (e.g. creation of jet stream) also have a significant effect on short and long-term variation in regional climate, snowpack and runoff. For example, over within-decade to multi-decadal periods of time, seasonal controls on variation in climate and runoff, are strongly influenced by natural ocean–atmosphere interactions (e.g., Cayan 1996; Cayan et al. 1998; Dettinger et al. 1994; Rood et al. 2005), with modifying influences associated with the North Atlantic (e.g., Enfield et al. 2001; McCabe et al. 2004). Variations in sea surface temperatures (SSTs) substantially alter air temperature and precipitation patterns across large regions (i.e., at sub- continental scales) by modifying atmospheric circulation patterns and consequently changing the preferential positioning of storm tracks (Cayan 1996; Cayan et al. 1998; Dettingeretal.1994). For the northern Rocky Mountains, the Pacific Decadal Oscillation (PDO;

Mantua et al. 1997) is the dominant interannual-to-decadal-scale index of Pacific basin sea surface temperature variability.

Pederson et. al. (2011) assessed the historic variability and trends in the hydroclimatology of snow-dominated watersheds in the Northern Rocky Region (NRM), (Figure 10) which includes the Upper Yellowstone and Big Horn Basins.

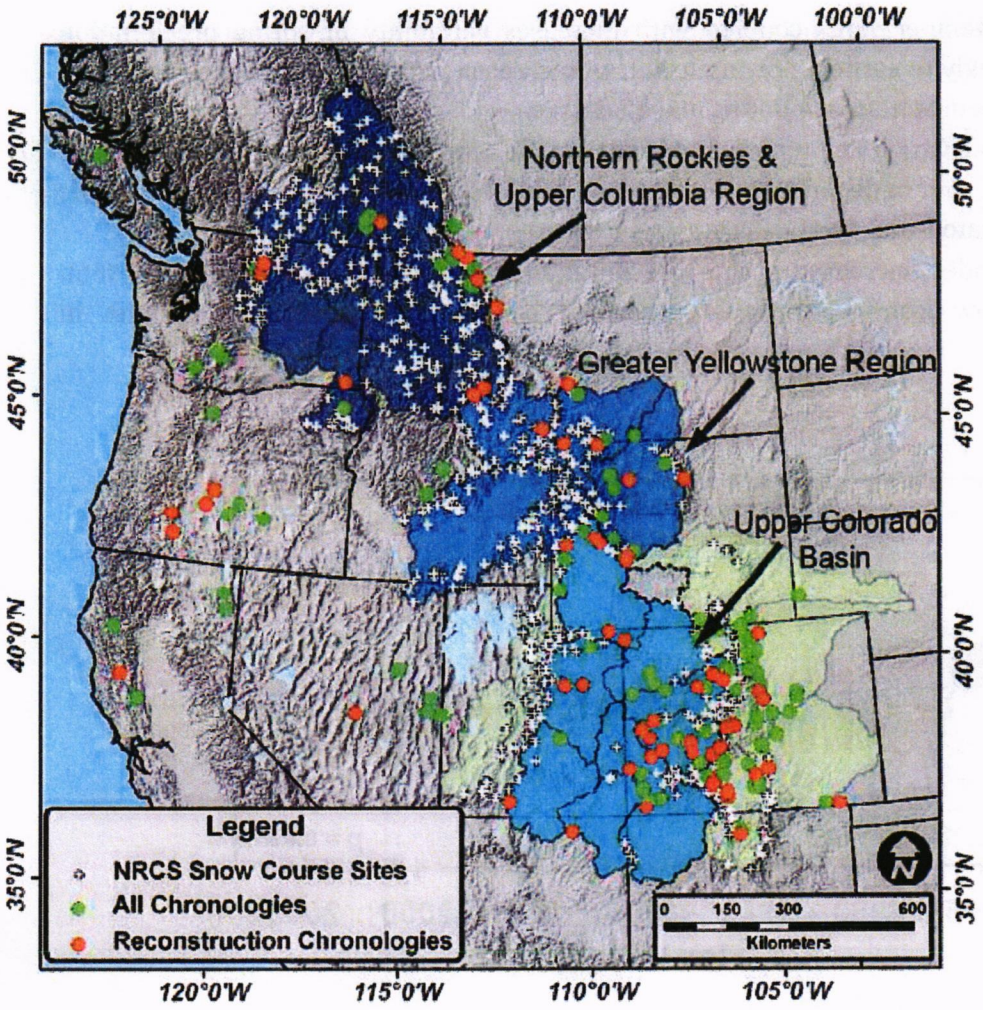


Figure 10.. Northern Rocky Mountain Region (including the Upper Yellowstone and Big Horn Basins) Location Long-term Snowcourse and Tree-Ring Chronology Sites (Pederson et.al. 2013)

Analyses conducted(using records from 25 snow telemetry (SNOTEL) stations, 148 April 1 snow course records, stream gauge records from 14 relatively unimpaired rivers, and 37 valley meteorological stations) showed that:

- Over the past four decades, mid-elevation SNOTEL records show a tendency toward decreased snowpack with peak snow water equivalent (SWE) arriving and melting out earlier.
- Temperature records show significant seasonal and annual decreases in the number of frost days and changes in spring minimum temperatures that correspond with atmospheric circulation changes and surface–albedo (solar reflection from snow cover) feedbacks in March and April.
- Warmer spring temperatures coupled with increases variability of spring precipitation correspond strongly to earlier snow melt-out, an increased number of snow-free days, and observed changes in streamflow timing and discharge.
- The majority of the variability in peak and total annual snowpack and streamflow, however, is explained by season-dependent interannual-to-interdecadal changes in atmospheric circulation associated with Pacific Ocean sea surface temperatures.
- Over recent decades, increased spring precipitation appears to be elevating NRM total annual streamflow from what would otherwise be greater snow-related declines in hydrologic yield.

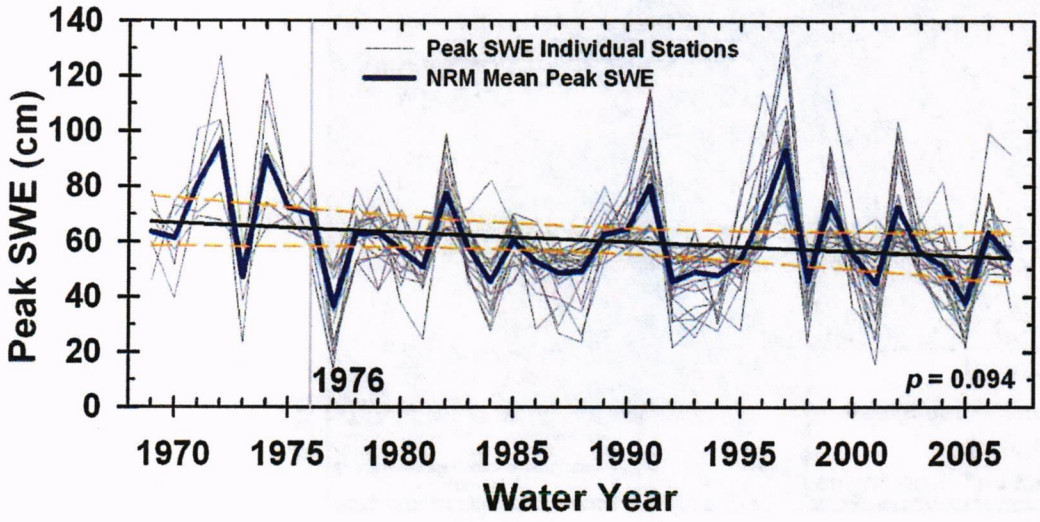


Figure 11. Average peak snow-water equivalent (SWE) calculated from 25 stations (black line) in the Northern Rocky Mountains. A regression line (black solid line) shows trends in SWE and is bounded by 95% confidence intervals (black dashed lines) with significance (p value) shown.

Additional work by Pederson and others (2013) examined how unique these recent declines in snowpack are when compared with historic (paleo) periods extending back in time over 1000 years. Using snowpack reconstructions from 66 tree-ring chronologies in key runoff-generating areas of the Rocky Mountains they found the late 20th century snowpack reductions are almost unprecedented in magnitude across the northern Rocky Mountains (Figure 11 and 12); in addition these declines occurred over the entire area and resulted from unparalleled springtime warming that is due to positive reinforcement of the anthropogenic warming by decadal variability.

In the Upper Yellowstone and Bighorn River Basins (Figure 12) , the April 1 Snow Water Equivalent (SWE) during the 1929-1941 drought was about 30% less than the average value over the period from 1400 to 1950 A.D. April 1 SWE during the drought of the early to mid 2000's was also about 30% less than the long-term mean, however the 1929-1941 drought was more persistent and extended several years longer in duration. A period of extended high snowpack occurred from about 1650 to 1890 that matches a period of cool wet conditions (Little Ice Age) during which local glaciers in the Beartooths , Bighorns and Wind River Mountains advanced and occurrence of fires was low.. While snowpack accumulation is an important variable influencing runoff and water supply, some years with average to slightly below average snowpack have produced extreme low-flow periods in the historic record. These low-flow periods occur in response to elevated summer temperatures that increase demand for and use of water..

Pederson and others(2011) conclude that "The increasing role of warming on large-scale snowpack variability and trends foreshadows fundamental impacts on streamflow and water supplies across the western United States . In much of this region, snow- pack declined since the 1950s, and continued reductions are expected throughout the 21st century and beyond . When coupled with increasing demand, additional warming- induced snowpack declines would threaten many current water storage and allocation strategies and lead to substantial strain on related infrastructure and overall supplies.

Changes in the amount of snowpack accumulation and timing of snowmelt have affected the hydrographs of streams by reducing the overall volume of runoff, and creating earlier spring runoff

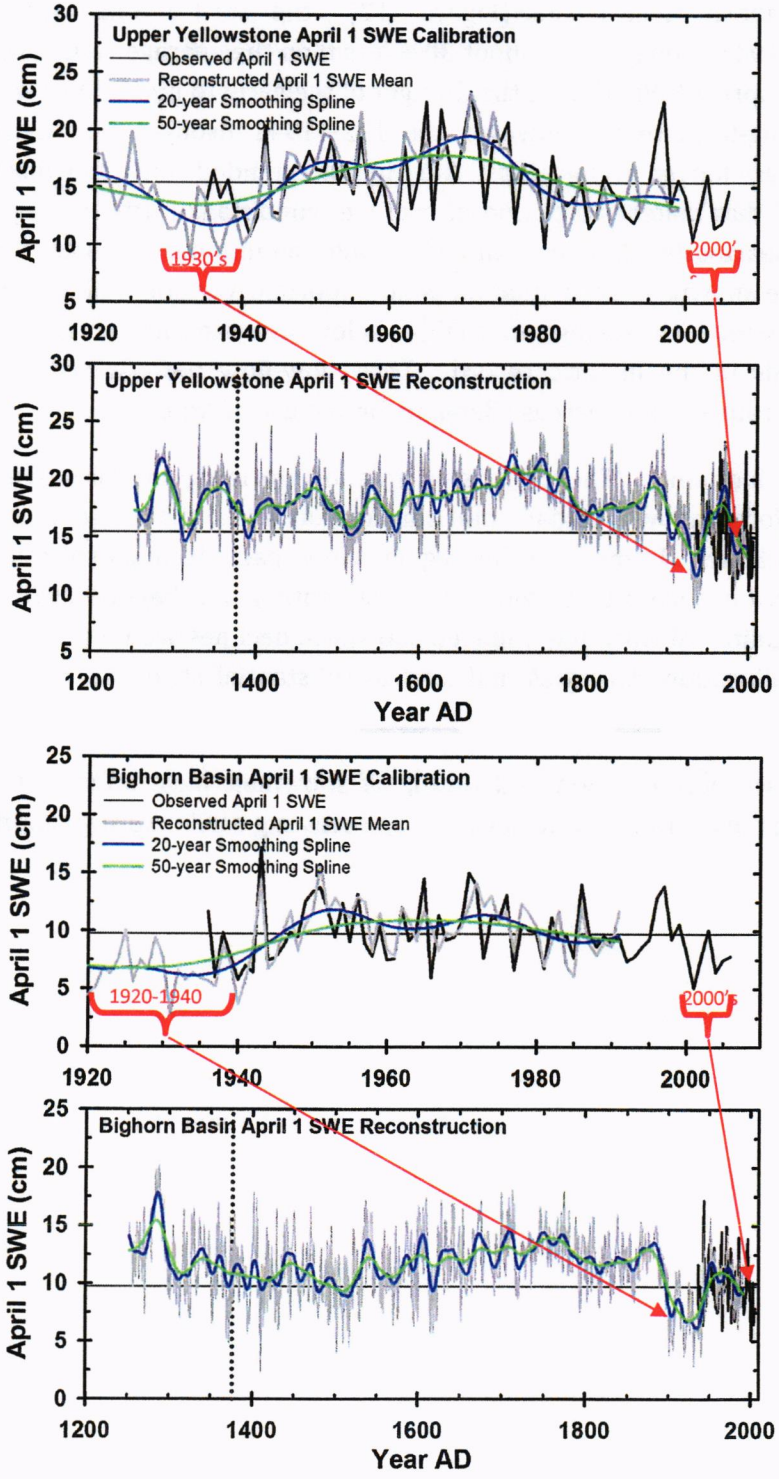


Figure 12. Observed and Estimated April 1 Snow Water Equivalent: Period 1200 to 2010 A.D. Upper Yellowstone and Bighorn River Basins. (Pederson et.al. 2011).

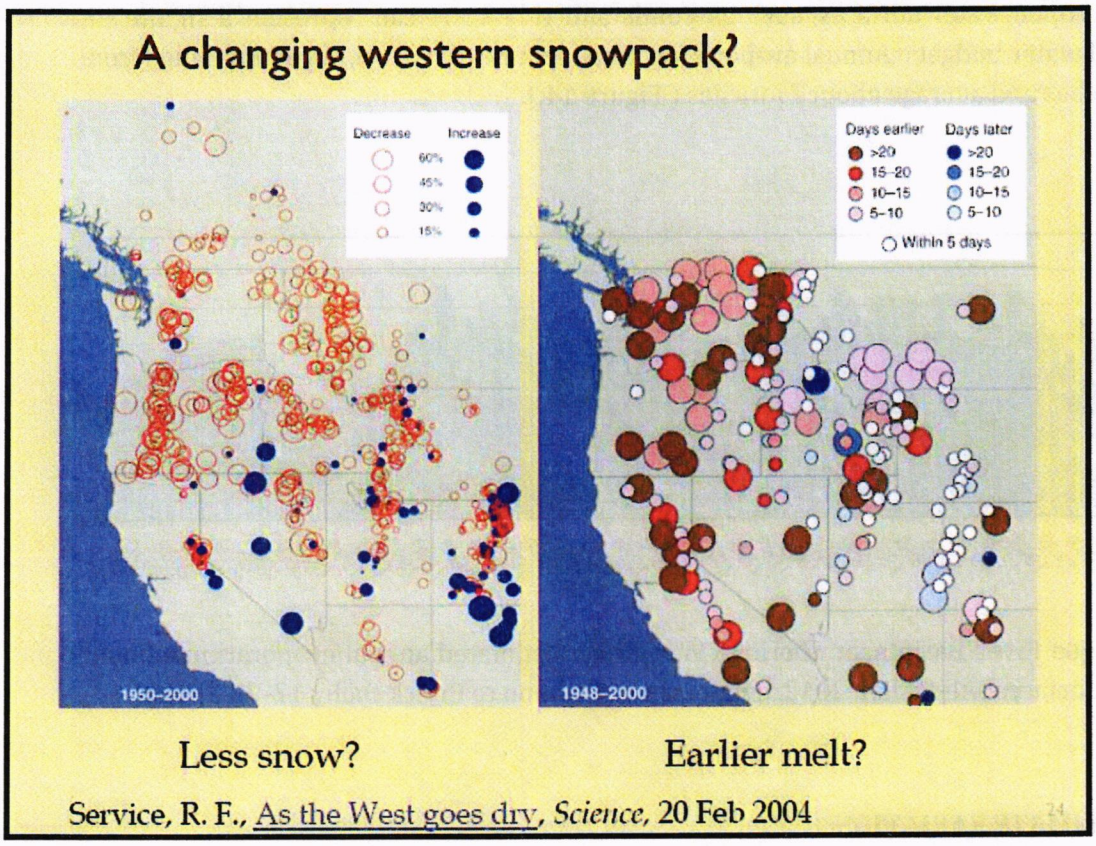


Figure 13. Changes in the amount of snow accumulation and timing of melt in the western United States over the period 1950-2000.

Evaporation

Evaporation varies with temperature, which in turn, is strongly affected by elevation (Reider, 1990). Evaporation in the Yellowstone River Basin is affected more by prevailing wind and sky conditions than by latitude, as shown by published maps of mean annual evaporation for 1956-70 (Farnsworth and others, 1982). Evaporation is greatest in the windswept basins and prairies where the mean annual total generally exceeds 35 inches, and surpasses 43 inches in parts of the Bighorn and Powder River Basins and Yellowstone River valley. In the cool, often cloud-shrouded highlands of the Absaroka and Beartooth Mountains, mean annual evaporation is less than 20 inches (Martner, 1986). Evaporation and precipitation together distinguish the moist, mountain forest ecosystem from the lower-elevation regions where evaporation exceeds precipitation (Ostresh and others, 1990; Marston and Anderson, 1991).

Evaporation from open-water surfaces, such as ponds and reservoirs can represent a significant part of the annual water budget . Annual evaporation amounts near Sheridan, Wyoming range from about 16 to 32 inches and average about 27 inches (Figure 14.).

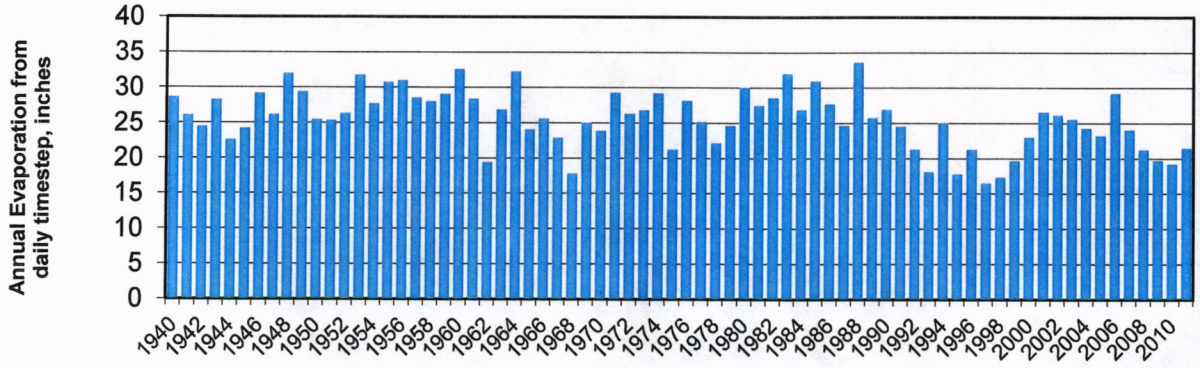


Figure 14 . Tongue River Basin near Sheridan Wyoming: estimated annual evaporation amount from open-water surfaces (Allen, R.A. 2012, email communication to Chuck Dalby 12-28-2012).

DROUGHT and CLIMATE VARIATION

Drought and Effects of Drought

Drought originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water or soil moisture shortage for some activity, group, or environmental sector. Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another.

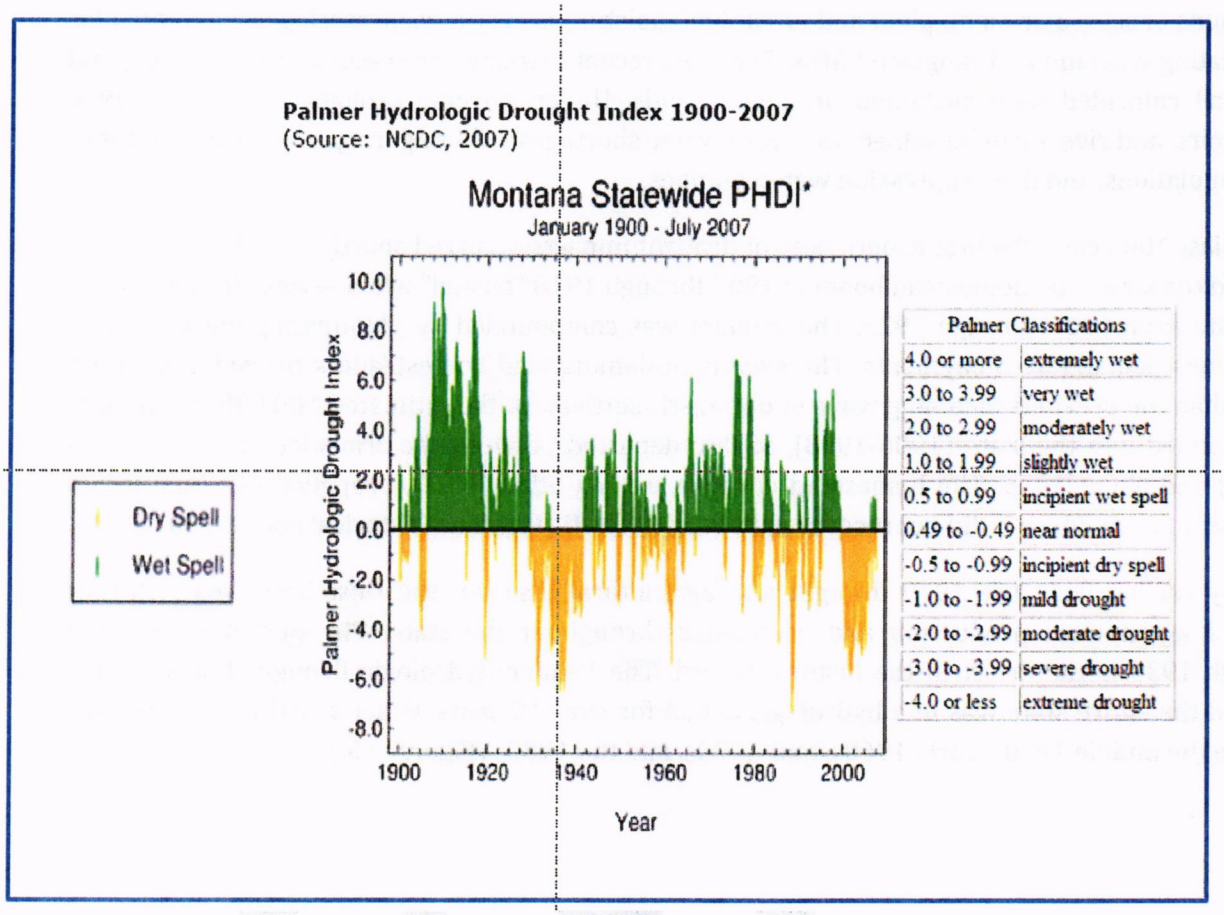
Drought is usually considered relative to some long-term average condition of balance between precipitation and evapo-transpiration perceived as "normal". Drought is related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e., rainfall intensity, number of rainfall events) of the rains.

Effects of drought become apparent with a longer duration because more and more moisture-related activities are affected. Agriculturally, non-irrigated croplands are most susceptible to moisture shortages. Rangeland and irrigated agricultural lands do not feel the effects of drought as quickly as the non-irrigated, cultivated acreage, but their yields can also be greatly reduced due to drought. Reductions in yields due to moisture shortages are often aggravated by wind-induced soil erosion.

In periods of severe drought, plant and forest fuel moisture is very low, increasing the potential for devastating wildland and rangeland fires. The most recent extreme fire seasons in 1988, 2000, and 2003 all coincided with sustained drought periods. Under extreme drought conditions, lakes, reservoirs, and rivers can be subject to severe water shortages, affecting irrigation, drinking water, fish populations, and fire suppression water supplies.

In the last 100 years, the first experiences of drought impacts occurred shortly after homesteaders flooded the state. The homestead boom of 1906 through 1918 "busted" when severe drought swept the state from 1917 through 1923. The drought was compounded by plummeting market prices and banks demanding repayments. The exodus of demoralized homesteaders proved even more rapid than the previous incoming wave of optimistic settlers. Of the estimated 100,000 immigrants who flooded into the state (1906-1918), 65,000 departed between the armistice of World War I (1918) and about 1925. The homestead collapse, among other forces, propelled Montana into a depression from which it did not recover until World War II (Montana Historical Society, 2004).

Already reeling from the 1919 drought and agricultural disaster, the Dust Bowl years further affected agricultural production and economies throughout the state. The period from 1928 through 1939 is the driest in the historic record. The Palmer Hydrologic Drought Index (PHDI) showed the entire state was in a hydrologic deficit for over 10 years. Other sustained dry periods include the middle 1950s, early 1960s, mid-1970s, and the 1980s (Figure 15.).



(Figure 15). The most-recent drought from 2000-2007, suggests the dryness and hydrologic deficit mimics the Dust Bowl years .

According to the Palmer Hydrologic Drought Index, Montana has been in severe and extreme drought between 10 and 20 percent in the time in the last one hundred years (Figure 15.).

Extreme high temperature, low humidity, wind, rainfall, and snowpack can all contribute to drought conditions. Montana's weather extremes can be a factor in compounding an existing drought problem. In Glendive on July 20, 1893 and in Medicine Lake on July 5, 1937, the temperature reached 117°F. During 1960, the community of Belfry only received 2.97 inches of precipitation, another Montana extreme. Although Montana is typically known for its extreme winter weather, summertime extremes can also have an impact.

Severe droughts of several-years duration have occurred in the Yellowstone River Basin. Droughts with recurrence intervals greater than 25 years occurred during the periods 1929-42 and 1948-62 over most of Wyoming and Montana (Druse, 1991; Merritt and others, 1991), including nearly all of the Yellowstone River Basin. Such regional drought conditions are common in the upper parts of the Missouri River Basin (Matthai, 1979).

Drought conditions of the 2000s have been compared to the drought of the 1930s during the Great Depression and Dust Bowl period. In Montana, the Dust Bowl period lasted about 11 years, 1930-40 (inclusive). Below-normal precipitation was experienced during nearly every year of the Dust Bowl. Additionally, the 1930s were warmer than normal, which, again, exhibits some similarities to conditions of the early 2000s.

Historic Droughts in Montana and the West

Studies of ancient climate (paleoclimate) indicate that droughts occurring prior to 1200 A.D. were more frequent and of longer duration than those of the 20th century. Paleoclimate research indicates that regular and persistent droughts existed and were especially pronounced during the years of A.D. 200-370, A.D. 700-850, and A.D. 1000-1200. These drought periods were long and sustained; by comparison, the period from A.D. 1200 to the present is relatively wet (Laird and others, 1996). Examination of more recent paleoclimate, using tree rings to identify dry and wet periods, shows a much wetter period in the United States over the past 300 years. NOAA researchers reconstructed Palmer Drought Severity Indexes from tree-ring data and found that historic droughts, similar to severity and duration of drought during the 1950s, occurred once or twice a century for the past three centuries in the United States (1860s, 1820s, 1730s). The research also showed that there has not been another drought as extensive and prolonged as the 1930s drought in the past 300 years (NOAA, 2003). Recent studies by climate scientists have extended the historic record of climatic variation in the Northern Rocky Mountains (including Montana) to include the past several thousand years; this provides an extended context for understanding natural climatic variation ..

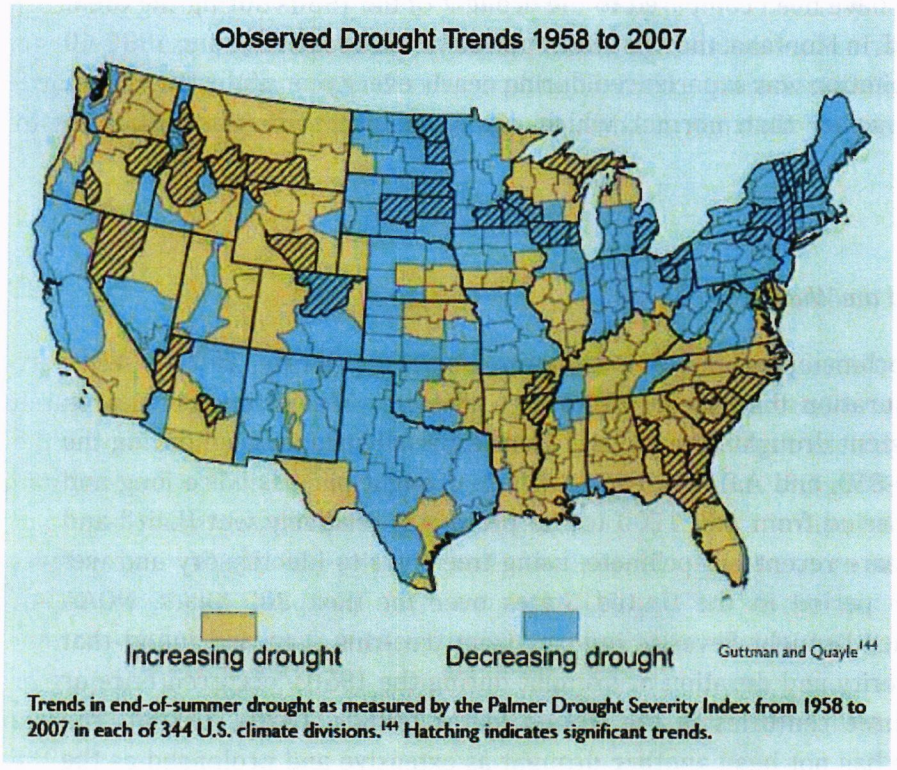


Figure 16 . Observed Drought Trends in the United States from 1958 to 2007.

Effect of Droughts on Water Supply Variability

Variation in precipitation (especially snowpack) and temperature contribute to fluctuations in streamflow on a daily, monthly and annual basis. The Surface-Water Supply Index (based on snowpack, reservoir storage, streamflow and precipitation) describes the degree of drought and availability of water at a point in a watershed (Table 2.).

Table 2 . Surface-Water Supply Index Values

Extremely Dry:	-4.2 to -3.0
Moderately Dry	-2.9 to -2.0
Slightly Dry:	-1.9 to -1.0
Near Average:	-0.9 to 1.0
Slightly Wet:	1.1 to 2.0
Moderately Wet:	2.1 to 3.0
Extremely Wet:	3.1 to 4.2

The Surface-Water Supply Index (SWSI) for the Yellowstone River above Livingston, and above and below the confluence with the Bighorn River are shown in Figure 17.. The pattern of low and high SWSI is remarkably similar across the locations over the 1992-2013 period with the drought of the 2000's extending from 2000 to 2008 clearly defined. The SWSI does not vary much from the Upper

Basin to the Lower Basin which is probably due to the influx of tributary inflow from the Clarks Fork and Bighorn tributaries that significantly replenish flow near the midpoint of the basin.

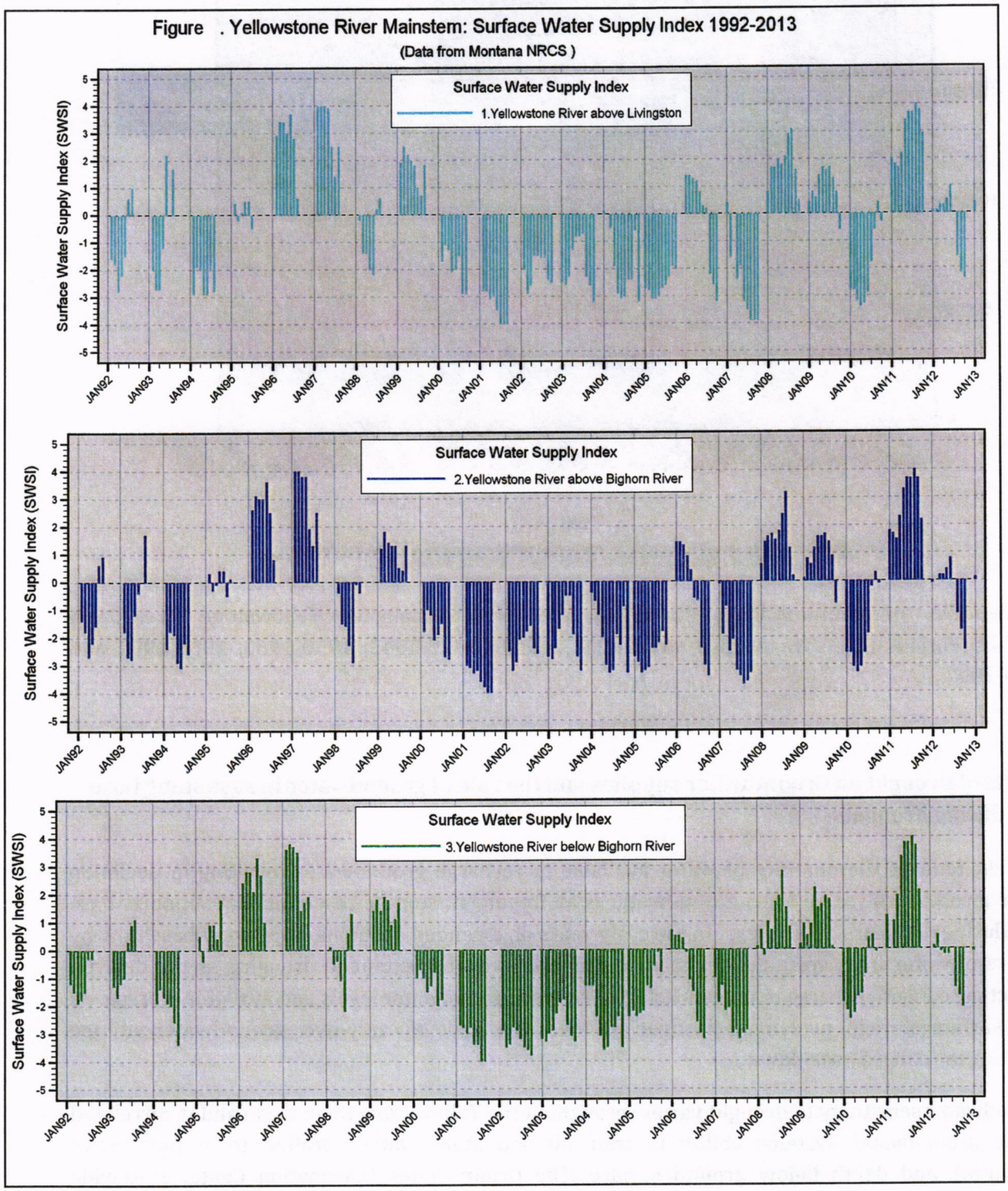


Figure 17. Surface-Water Supply Index (SWSI) 1992-2013 for the mainstem Yellowstone River locations in the Upper, Middle and Lower Basins.

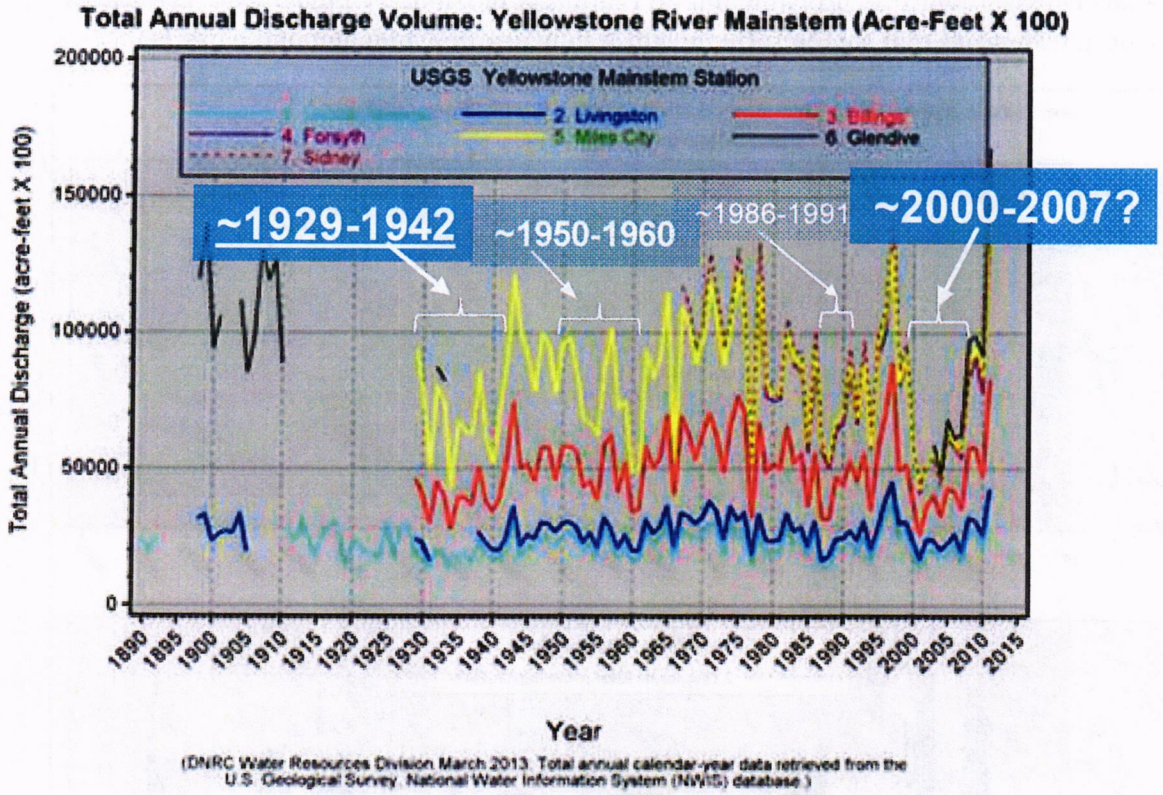


Figure 17b. Annual volume of streamflow measured at mainstem Yellowstone River Basin stations. Periods of below average streamflow include 1929-1942, 1950-1960, 1986-1991 and 2000-2007.

Effects of Drought on Groundwater supplies and the role of groundwater in sustaining base flow during droughts

Drought reduces the quantity of water available to recharge groundwater resulting in declining water levels. At the same time, groundwater is an important storage reservoir that supports base flow during dry years and, at least in the early years of, extended droughts. Support of base flow by release of water from groundwater storage diminishes during extended droughts as the delayed impact of reduced recharge manifests itself in reduced groundwater levels and available storage. As with surface storage, prolonged drought stretches the limit of carry-over groundwater storage resulting in reduced base flows.

Groundwater sensitivity to drought varies throughout the Yellowstone River basin and is correlated to the groundwater systems ability to transmit and store water, location to surface water (recharge), and depth below ground surface. The Groundwater Information Center statewide monitoring network provides long-term water-level records that show change in groundwater storage or pressure. Upward trends (increasing elevation and decreasing distance to water) show increased groundwater storage or pressure. Most hydrograph traces portray concurrent high- and

low- frequency signals that illustrate the local balance between the numerous signal sources. The high-frequency signals are related to seasonal/annual trends, while the low-frequency, slowly-varying signals are characteristic of climate sensitive wells (Patton, 2013).

The water levels in the alluvium well (GWIC # 148500) near Terry show water level responses to climate variability. Figure 19 shows water level changes in the alluvium that are related to periods of dry and wet cycles. The hydrograph shows the impact of annual water level fluctuations superimposed on a low-frequency cycle that is likely climate related.

The water levels in a well (GWIC # 1103) completed in the Fort Union Formation near Bloomfield show a response to yearly changes superimposed on a low-frequency cycle. Figure 20 shows groundwater levels responding to multi-year trends in climate variability. For example, water levels fell approximately 3 feet during the early 2000s drought period. Water levels rose after 2010 by 10 feet and fell 5 feet a year later.

A monitoring well (GWIC # 1103) in the Fort Union Formation near Colstrip shows annual changes and multi-year trends related to climate variability. Figure 21 shows a declining cyclic trend with water levels falling approximately 3 feet prior to 1990. Since 1990, water levels have risen 8 feet.

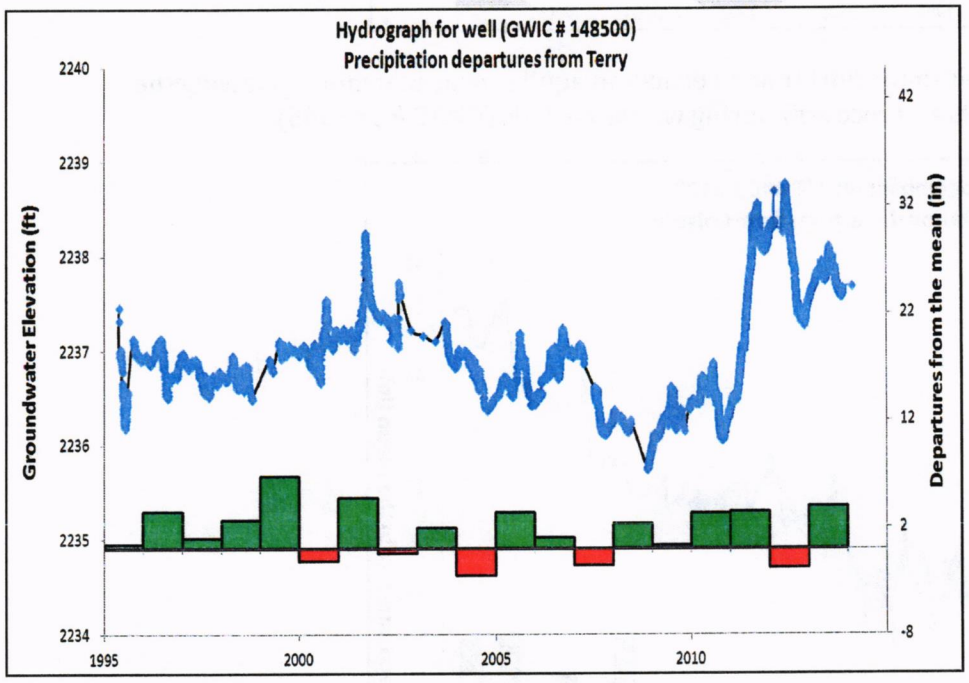


Figure 19. Groundwater levels in the alluvial aquifer near Terry showing the effects of drought in the 2000s and recovery during wetter periods (GWIC # 148500).

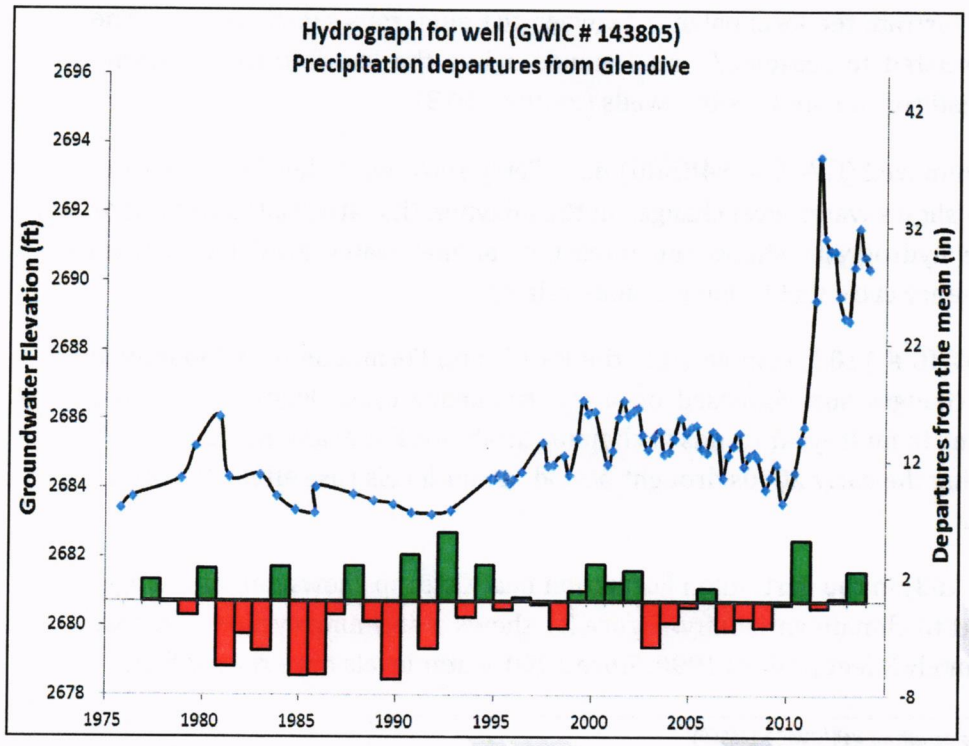


Figure 20. Groundwater levels in the Fort Union Formation aquifer near Bloomfield showing the effects of drought in the 2000s and recovery during wetter periods (GWIC # 143805).

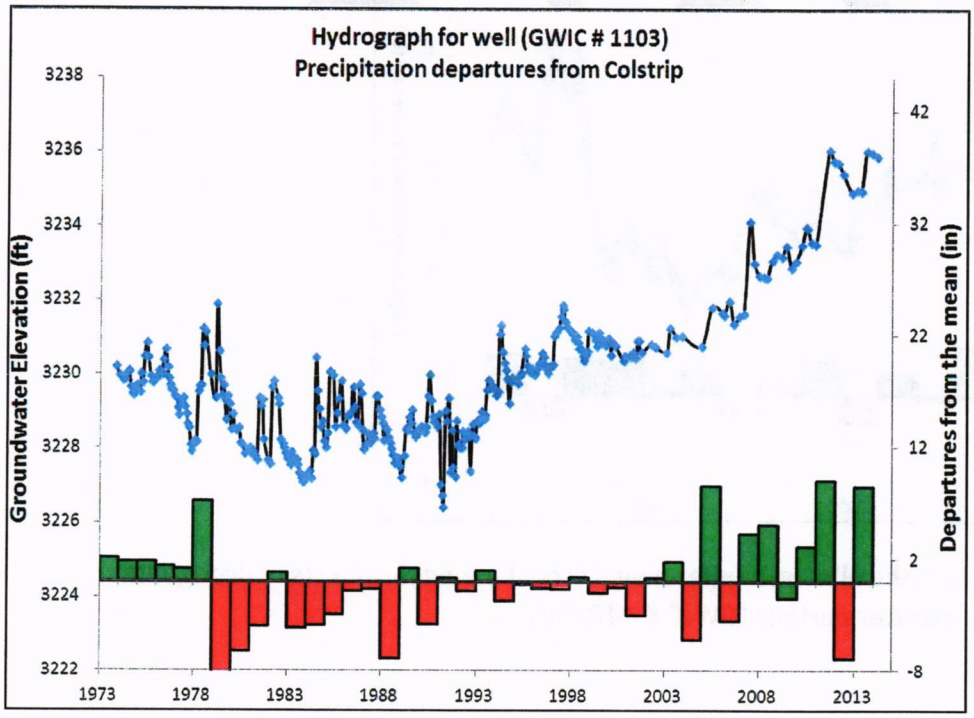


Figure 21. Groundwater levels in the Fort Union Formation aquifer near Colstrip showing responses to above average years of precipitation and long-term cyclic upward trends (GWIC # 1103).

2. Effects of Changes in Timing and Location of Precipitation and Snowpack Runoff.

Seasonal variation in temperature and precipitation produces fluctuations in streamflow over a single year and affects the timing and amount of water measured at a location. Recent studies show that as the temperature has warmed, there is a trend toward earlier melt of the snowpack. For example in 2007 the last day with snow accumulation arrived four to eight weeks earlier than the long-term normal. (Figure 22.).

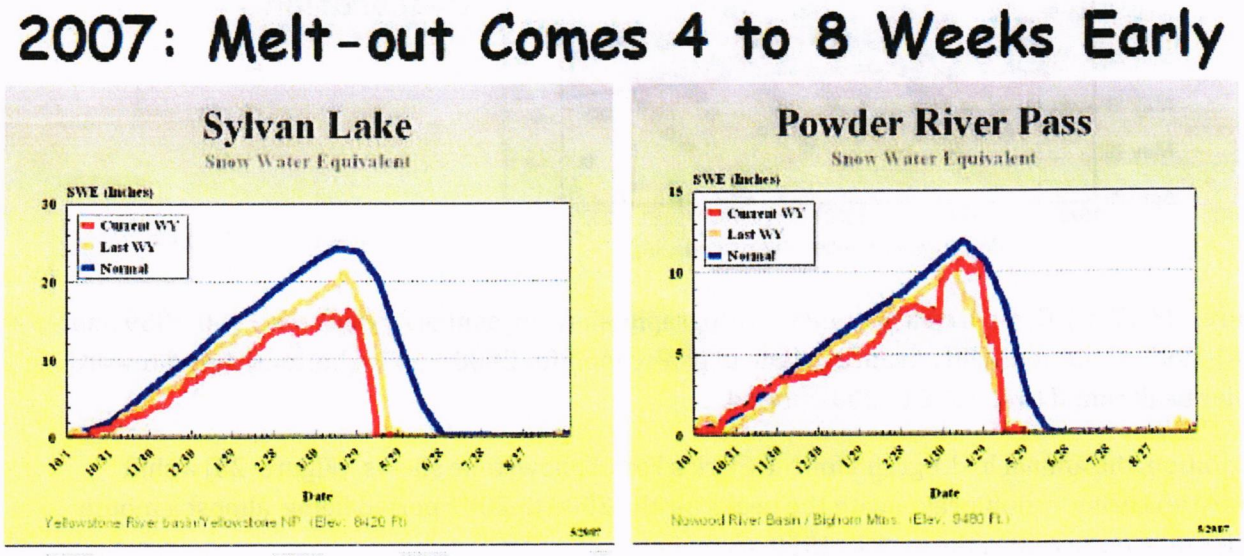


Figure 22. Upper elevation snow courses in Bighorn Mountains showing complete melt of snowpack in 2007 that is four to eight weeks earlier than the long-term normal date.

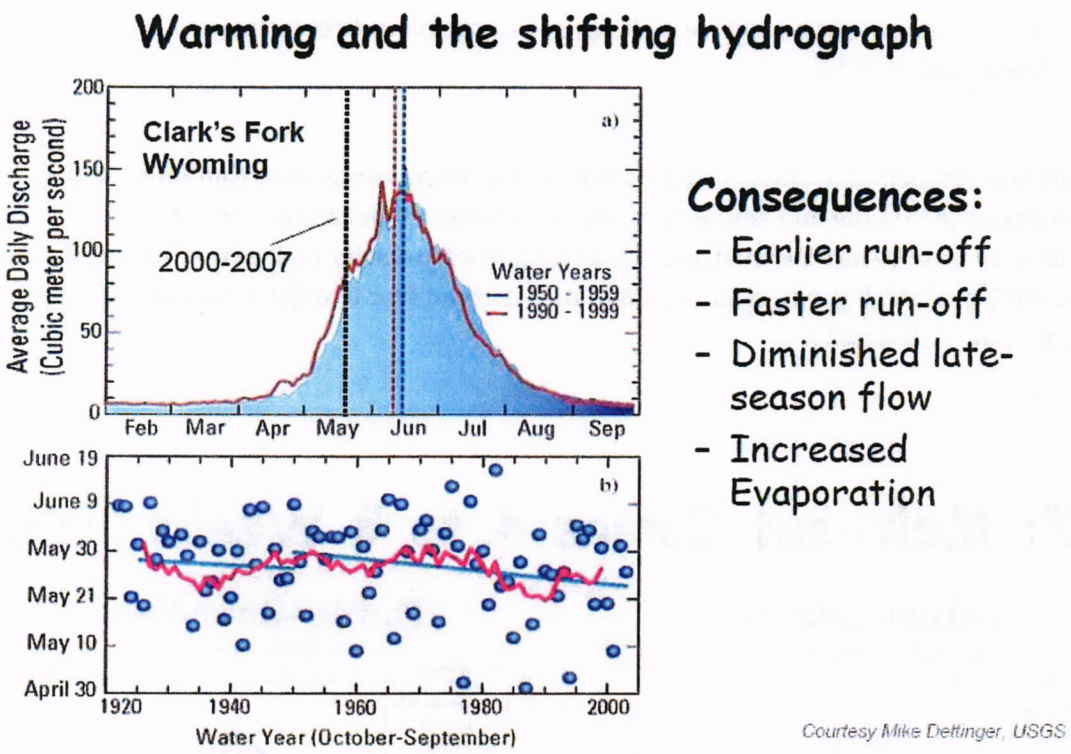


Figure 23. (Top) Comparison of annual hydrographs showing similarity between 1950-1959 and 1990-1999 periods and advance in date of peak runoff for 2000-2007; (bottom) trend toward earlier peak runoff over 1920 to 2007 period.

In addition, the annual hydrograph for the Clark's Fork Yellowstone shows (Figure 23) a shift toward an earlier runoff peak—with the peaks for the 2000 to 2007 period being almost a month earlier than occurring in the period 1950-1999

Streamflow

Most of the annual streamflow from the Yellowstone River Basin originates in the mountainous areas of the upper Yellowstone River and the Clarks Fork Yellowstone River and Wind/Bighorn River Basins. Representing about half of the study unit's total drainage area, the combined mean annual flows from the upper Yellowstone, Clarks Fork Yellowstone, and Wind/Bighorn Rivers equal about 90 percent of the mean annual flow measured near the mouth of the basin at Sidney, Montana (Table 3.). Runoff amounts from the basins and plains areas are lower than those from the mountainous areas. Unit annual runoff in the Yellowstone River Basin ranges from 1.31 cfs/ mi^2 in the mountainous headwaters to 0.007 cfs/ mi^2 in the lower-elevation, semi-arid, plains.

Streams in the mountainous areas of the Yellowstone River Basin generally are perennial (Wahl, 1970; Lowham, 1988). Most of the flow in mountain streams is from snowmelt runoff. Annual streamflow in the mountainous areas are dominated by a single snowmelt peak of moderate duration during late spring/early summer with low variability in daily mean discharge throughout the year (Figures 25-28). Variability in annual flows in streams in the mountainous areas of the basin is generally small--relative to the intense localized convective rainstorms of the basins and plains areas—and mountain snow accumulations are less variable in aerial extent and between years.

Most streams originating in the basins or plains areas of the Yellowstone River Basin are ephemeral, flowing only as a result of local snowmelt or intense rainstorms (Wahl, 1970; Omang, 1992). Intense localized convective rainstorms can produce most of the total flow for any given year in these watersheds. The distribution and occurrence of these events vary between years (Lowham, 1988, p. 18). Because of the localized extent and annual variability of these storms, the resulting flows in any given watershed are variable between years. Annual flow of streams originating in the basin or plains areas often consist of multiple peaks: a lowland snowmelt peak of moderate duration occurring late winter/early spring and several rainstorm peaks of short duration occurring late spring through late summer (Figures 25-28) .

Streamflow characteristics in the Yellowstone River Basin (Table 3a,b,c.) vary by geographic location, time of year, and degree of human influence. For most streams in the basin with little or no flow modifications, streamflow characteristics can be described by annual streamflow and flow duration at representative locations. For streams where human activities have modified the natural drainage, regulation, diversion, and return flows affect streamflow characteristics to varying degrees. Variations in geography and weather cause severe floods and droughts in the basin. The typical annual hydrograph for the Yellowstone River downstream from Billings (Figure 26) , Montana consists of a lowland snowmelt peak during the late winter/early spring followed by a peak from the mountain snowmelt during the late spring/early summer (Zelt and others, 1999). Several short to moderate duration rainstorm peaks usually augment the spring/summer snowmelt peaks and the summer base flows.

The period of observation for mean annual discharge in the Yellowstone basin varies significantly, with mainstem gages in Montana having nearly continuous records since the 1930's. Smaller tributaries tend to have shorter periods of observation and measurements emphasizing recent streamflow. Mean annual discharge for stations with at least 30 years of record was compared with the mean computed for several shorter periods of interest that represent dry conditions: 1929-1941, and 2000-2010 (Table 4.), and with the period currently used as the base for reporting hydrologic observations—1981 to 2010. In general, mean annual discharge was less than the long-term mean for most stations for all three periods. The dry periods from 1929-1941 and 2000-2010 show similar reductions in streamflow, compared with the long-term value.

Eleven stations have complete periods of record from 1929-2010 (Table 5.) . For mainstem stations, the mean difference between the period of record mean and the 1981-2010 mean, is -3.4 percent; for 1929-1941 the difference is -17.5 percent; and for the 2000-2010 the difference is -14.2 percent. For tributary stations, the mean difference between the period of record mean and the 1981-2010 mean, is -11.7 percent; for 1929-1941 the difference is -6.0 percent; and for the 2000-2010 the difference is -26.6 percent. Streamflow over the 1981-2010 period was about -3.4 percent (mainstem) to -11.7 percent (tributaries) less than the long-term 1929-2010 mean. The period 1929-1941 produced the least streamflow for mainstem stations (-17.5 percent compared with period of record), but tributaries were less affected (-6.0 percent compared with period of record). The period 2000-2010 appears to deviate the greatest from the long-term mean for both the mainstem (-14.2 percent) and tributary stations (-26.2 percent.)

Table 3a. . Upper Yellowstone River Basin: Mean Annual Discharge for Various Periods of Measurement:

Mainstem	Tributary	USGS Station	Drainage Area (mi^2)	Period of Record	Period of Record Mean Annual Discharge (cfs)		1929-1941 Mean Annual Discharge (cfs)		2000-2010 Mean Annual Discharge (cfs)		1981-2010 Mean Annual Discharge (cfs)		1981-2010 Unit Annual Runoff (cfs/mi2)
					n	Mean	n	Mean	n	Mean	n	Mean	
Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming		06186500	991	1922-82, 1983-86, 1988-2010	81	1327.0	13	1057.5	11	1197.5	25	1311.8	1.324
	Gardiner River near Mammoth YNP	06191000	200	1984-2010	61	211.9	3	154.8	11	182.6	26	203.3	1.017
Yellowstone River at Corwin Springs, Mont.		06191500	2,619	1889-93, 1910-2010	105	3124.2	13	2493.8	11	2834.4	30	3094.0	1.181
Yellowstone River near Livingston, Mont.		06192500	3,551	1897-1905, 1928-32, 1937-2010	86	3747.5	7	3029.9	11	3347.0	30	3648.0	1.027
	Shields River near Livingston MT	06195600	852		34	271.4			11	204.4	30	259.3	0.304
	Boulder River at Big Timber MT	06200000	523		64	556.3			11	445.6	30	488.2	0.933
	Stillwater River near Absarokee MT	06205000	975		71	923.9	6	719.3	10	778.0	25	1311.8	1.345
	Clarks Fork Yellowstone near Belfry, MT	06207500	1,154	1921-2013	91	934.2	13	804.9	11	827.5	30	879.2	0.762
	Clarks Fork Yellowstone at Edgar, MT	06208500	2,022	1921-2013	73	1029	13	895.1	11	890.2	24	971.2	0.480
	Rock Creek near Red Lodge, MT	06209500	105		61	166.8	7	145.5	10	130.7	13	141.2	1.345
Yellowstone River at Billings, Mont.		06214500	11,805	1904-05, 1928-2010	84	6930.9	13	5409.2	11	5755.2	30	6623.7	0.561

(Note: Only means of annual discharge are reported. Comparison of the mean and median values of annual discharge shows there is no significant difference at p=0.001)

Table 3b. . Middle Yellowstone River Basin: Mean Annual Discharge for Various Periods of Measurement:

Mainstem	Tributary	USGS Station	Drainage Area (mi^2)	Period of Record	Period of Record Mean Annual Discharge (cfs)		1929-1941 Mean Annual Discharge (cfs)		2000-2010 Mean Annual Discharge (cfs)		1981-2010 Mean Annual Discharge (cfs)		1981-2010 Unit Annual Runoff (cfs/mi^2)
					n	Mean	n	Mean	n	Mean	n	Mean	
	Pryor Creek at Pryor MT	06216000	117		41	30.561			9	18.9	28	24.6286	0.211
	Bighorn River at Kane WY	06279500	15,762		83	2130.8	12	2062.3	11	1356.0	30	1906.2	0.121
	Bighorn River near St. Xavier MT	06287000	19,667		78	3386.3	7	3120.4	11	2353.1	30	3026.1	0.154
	Bighorn River above Tullock Cr near Bighorn, Mont.	06294500	22,414	1945-55, 1956-2010	67	3674.4			11	2495.6	30	3300.6	0.147
	Little Bighorn River near Hardin MT	06294000	1,294		59	276.0			11	194.8	30	226.5	0.175
	Sarpy Creek near Hysahm MT	06294940	453		10	7.056					3	3.3267	0.007
Yellowstone River at Forsyth, Mont.		06295000	40,146	1921-23, 1977-2010	35	10434.8			11	8487.1	30	10079.2	0.251
	Tongue River near Dayton WY	06298000	206		81	173.8			11	142.4	30	157.1	0.763
	Tongue River at Stateline near Decker MT	06306300	1,453		53	438.0			11	343.4	30	388.9	0.268
	Tongue River at Dam, near Decker MT	06307500	1,770		74	431.0			11	333.2	30	383.1	0.216
	Hanging Woman Creek near Birney, MT	06307600	470		28	3.1			7	0.8	19	1.6	0.003
	Prairie Dog Creek near Acme, WY	06306250	358	1970-10-01 to 2010-10-01	20	34.09			10	24.89	10	24.89	0.070
	Pumpkin Creek near Miles City MT	06308400	697		20	19.2			6	14.5	10	11.9	0.017
	Tongue River at Miles City, Mont.	06308500	5,397		70	405.2			11	283	30	340.4	0.063
Yellowstone River at Miles City, Mont.		06309000	48,253	1922-23, 1928-2010	80	11247	13	9400.8	11	8820.5	30	10476.2	0.217

(Note: Only means of annual discharge are reported. Comparison of the mean and median values of annual discharge shows there is no significant difference at p=0.001)

Table . Lower Yellowstone River Basin: Mean Annual Discharge for Various Periods of Measurement: Period of Record; 1981-2010; 1929-1941; 2000-2010

Mainstem	Tributary	USGS Station	Drainage Area (mi^2)	Period of Record	Period of Record Mean Annual Discharge (cfs)		1929-1941 Mean Annual Discharge (cfs)		2000-2010 Mean Annual Discharge (cfs)		1981-2010 Mean Annual Discharge (cfs)		1981-2010 Unit Annual Runoff (cfs/mi^2)
					n	Mean	n	Mean	n	Mean	n	Mean	
	Clear Creek near Arvada WY	06324000	1,100		53	177.8			7	159.9	8	157.5	0.143
	Powder River at Moorehead MT	06324500	8,086		81	438.2	12	421.3	11	325.4	30	402.6	0.050
	Little Powder River above Dry Creek,near Weston WY	06324970	1,237		40	21.8			11	16.1	30	19.8	0.016
	Powder River near Locate, Mont.	06326500	13,068	1938-2010	75	563.8	3	552.1	11	368.5	30	468.9	0.036
	O'fallon Creek near Ismay MT	06326600	699		14	10.8							
	Burns Creek near Savage MT	06329200	233		17	5.9			.	.	3	5.5	0.024
Yellowstone River at Glendive MT		06327500	66,788		23	13271.3			8	10130.1	8	10130.1	0.152
Yellowstone River near Sidney, Mont.		06329500	69,083	1910-31, 1933-2010	46	12005.9			11	8726.5	30	10675.3	0.155

(Note: Only means of annual discharge are reported. Comparison of the mean and median values of annual discharge shows there is no significant difference at p=0.001)

Table 4. Yellowstone River Basin: Percent difference in mean annual discharge for various periods compared with long-term mean

Mainstem	Tributary	USGS Station	Drainage Area (mi^2)	Record Length	Period of Record Mean (cfs)	1981-2010 Mean (cfs)	Percent Difference 1981-2010 Mean From Period of Record Mean	1929-1941 Mean (cfs)	Percent Difference 1929-1941 Mean From Period of Record Mean	2000-2010 Mean (cfs)	Percent Difference 2000-2010 Mean From Period of Record Mean
Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming		06186500	991	1922-82, 1983-86, 1988-2010	1327.0	1311.8	-1.1	1097.0	-17.3	1197.5	-9.8
	Gardiner River near Mammoth YNP	06191000	200	1984-2010	211.9	203.3	-4.1	147.3	-30.5	182.6	-13.8
Yellowstone River at Corwin Springs, MT		06191500	2,619	1889-93, 1910-2010	3124.2	3094.0	-1.0	2608.0	-16.5	2834.4	-9.3
Yellowstone River near Livingston, MT		06192500	3,551	1897-1905, 1928-32, 1937-2010	3747.5	3648.0	-2.7	3152.0	-15.9	3347.0	-10.7
	Shields River near Livingston MT	06195600	852	1978-2013	271.4	259.3	-4.5			204.4	-24.7
	Boulder River at Big Timber MT	06200000	523	1947-2013	556.3	488.2	-12.2			445.6	-19.9
	Stillwater River near Absarokee MT	06205000	975	1910-2013	923.9	1311.8	42.0	762.5	-17.5	778.0	-15.8
	Clarks Fork Yellowstone near Belfry, MT	06207500	1,154	1921-2013	934.2	879.2	-5.9	796.3	-14.8	827.5	-11.4
	Clarks Fork Yellowstone at Edgar, MT	06208500	2,022	1921-2013	1029	971.2	-5.6	890.3	-13.5	890.2	-13.5
	Rock Creek near Red Lodge, MT	06209500	105	1932-2013	166.8	141.2	-15.3	145.9	-12.5	130.7	-21.6
Yellowstone River at Billings, MT		06214500	11,805	1904-05, 1928-2010	6930.9	6567.5	-5.2	5469.0	-21.1	5573.0	-19.6
	Pryor Creek at Pryor MT	06216000	117	1968-2008	30.561	24.8	-18.9		16.2		-47.0
	Bighorn River at Kane WY	06279500	15,762	1929-2013	2130.8	1906.2	-10.5	2062.3	-3.2	1356.0	-36.4
	Bighorn River near St. Xavier MT	06287000	19,667	1935-2013	3386.3	2849	-15.9	3426	1.2	2111	-37.7
	Bighorn River above Tullock Cr near Bighorn, Mont.	06294500	22,414	1945-55, 1956-2010	3674.4	3003	-18.3			2229	-39.3
	Little Bighorn River near Hardin MT	06294000	1,294	1953-2013	276.0	222	-19.6			183.8	-33.4
Yellowstone River at Forsyth, MT		06295000	40,146	1921-23, 1977-2010	10434.8	10079.2	-3.4			8487.1	-18.7
	Tongue River near Dayton WY	06298000	206	1919-1926, 1941-2013	173.8	157.1	-9.6			142.4	-18.1
	Tongue River at Stateline near Decker MT	06306300	1,453	1960-2013	438.0	388.9	-11.2			343.4	-21.6
	Tongue River at Dam, near Decker MT	06307500	1,770	1939-2013	431.0	383.1	-11.1			333.2	-22.7
	Hanging Woman Creek near Birney, MT	06307600	470	1973-2013	3.1	1.6	-48.7			0.8	-72.9
	Tongue River at Miles City, Mont.	06308500	5,397	1938-2013	405.2	340.4	-16.0			283	-30.2
Yellowstone River at Miles City, MT		06309000	48,253	1922-23, 1928-2010	11247	10476	-6.9	9400.8	-16.4	8820.5	-21.6
	Clear Creek near Arvada WY	06324000	1,100	1916,1940-2013	177.8	157.5	-11.4			159.9	-10.1
	Powder River at Moorehead MT	06324500	8,086	1929-2013	438.2	402.6	-8.1	421.3	-3.9	325.4	-25.7
	Little Powder River above Dry Creek,near Weston WY	06324970	1,237	1973-2012	21.8	19.8	-9.1			16.1	-26.0
	Powder River near Locate, Mont.	06326500	13,068	1938-2010	563.8	468.9	-16.8	552.1	-2.1	368.5	-34.6
Yellowstone River at Glendive MT		06327500	66,788	1898-1910,2003-2012	13271.3	10130.1	-23.7			10130.1	-23.7
Yellowstone River near Sidney, MT		06329500	69,083	1910-31, 1933-2010	12005.9	10675.3	-11.1			8726.5	-27.3

Table 5. Percent difference in mean annual discharge compared with long-term mean for tributary and mainstem stations with full period of record 1930-2010.

	USGS Station	Drainage Area	Period of Measurement	Number of Years	Percent Difference 1981-2010 Mean From Period of Record Mean	Percent Difference 1929-1941 Mean From Period of Record Mean	Percent Difference 2000-2010 Mean From Period of Record Mean
Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming	06186500	991	1922-82, 1983-86, 1988-2013	81	-1.1	-17.3	-9.8
Yellowstone River at Corwin Springs, Mont.	06191500	2,619	1889-93, 1910-2013	105	-1.0	-16.5	-9.3
Yellowstone River near Livingston, Mont.	06192500	3,551	1897-1905, 1928-32, 1937-2013	86	-2.7	-15.9	-10.7
Yellowstone River at Billings, Mont.	06214500	11,805	1904-05, 1928-2013	84	-5.2	-21.1	-19.6
Yellowstone River at Miles City, Mont.	06309000	48,253	1922-23, 1928-2013	70	-6.9	-16.4	-21.6
				Mean=	-3.4	-17.5	-14.2
Clarks Fork Yellowstone near Belfry, MT	06207500	1,154	1921-2013	91	-5.9	-14.8	-11.4
Bighorn River at Kane WY	06279500	15,762	1929-2013	83	-18.5	-3.2	-47.0
Tongue River near Dayton WY	06298000	206	1919-1926, 1941-2013	81	-9.6		-18.1
Tongue River at Dam, near Decker MT	06307500	1,770	1939-2013	74	-11.1		-22.7
Powder River at Moorehead MT	06324500	8,086	1929-2013	81	-8.1	-3.9	-25.7
Powder River near Locate, Mont.	06326500	13,068	1938-2013	75	-16.8	-2.1	-34.6
				Mean=	-11.7	-6.0	-26.6

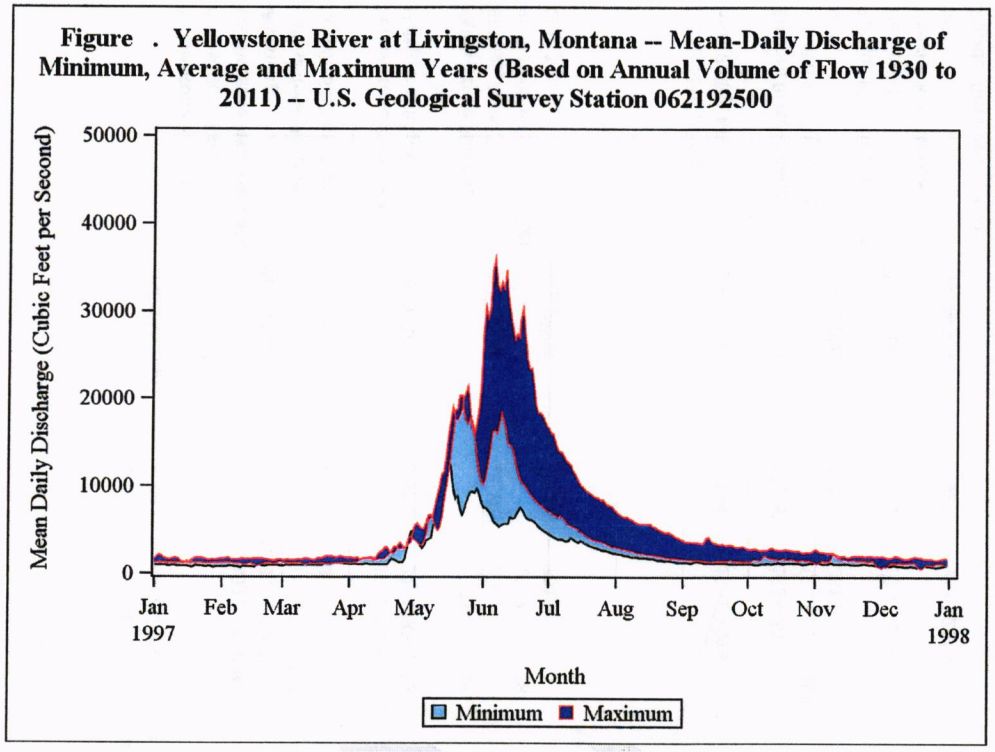


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Figure 25. Yellowstone River at Livingston Montana_Mean Daily discharge of minimum, average and maximum years (Based on annual volume of flow 1930 to 2011).

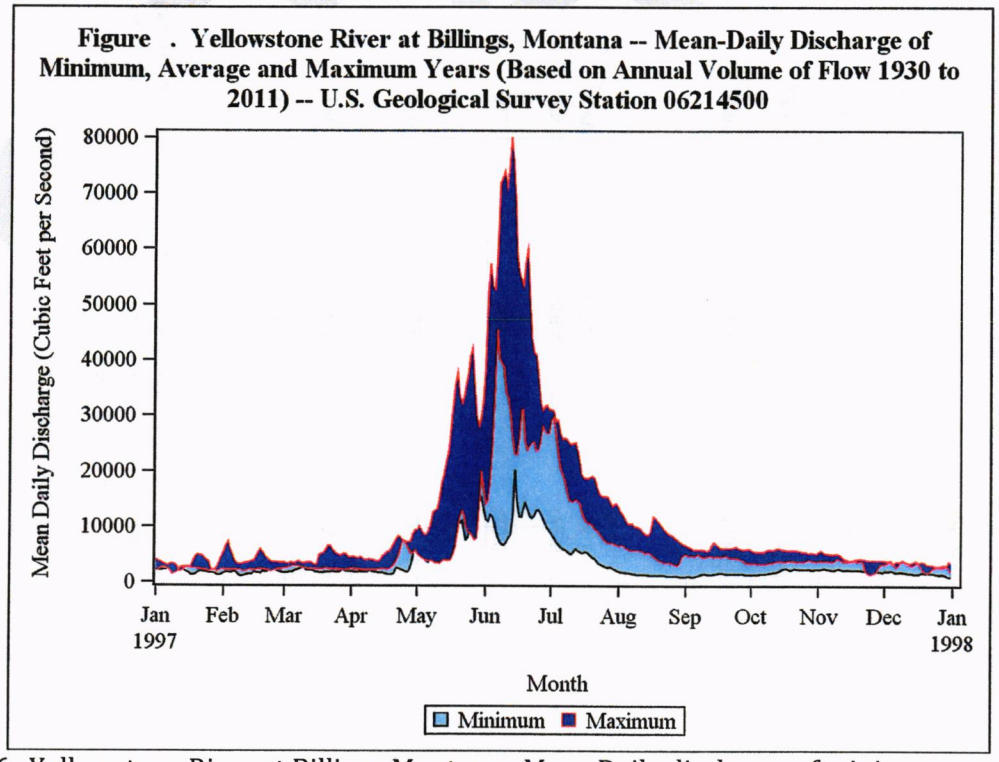

Figure 26. Yellowstone River at Billings Montana_Mean Daily discharge of minimum, average and maximum years (Based on annual volume of flow 1930 to 2011).

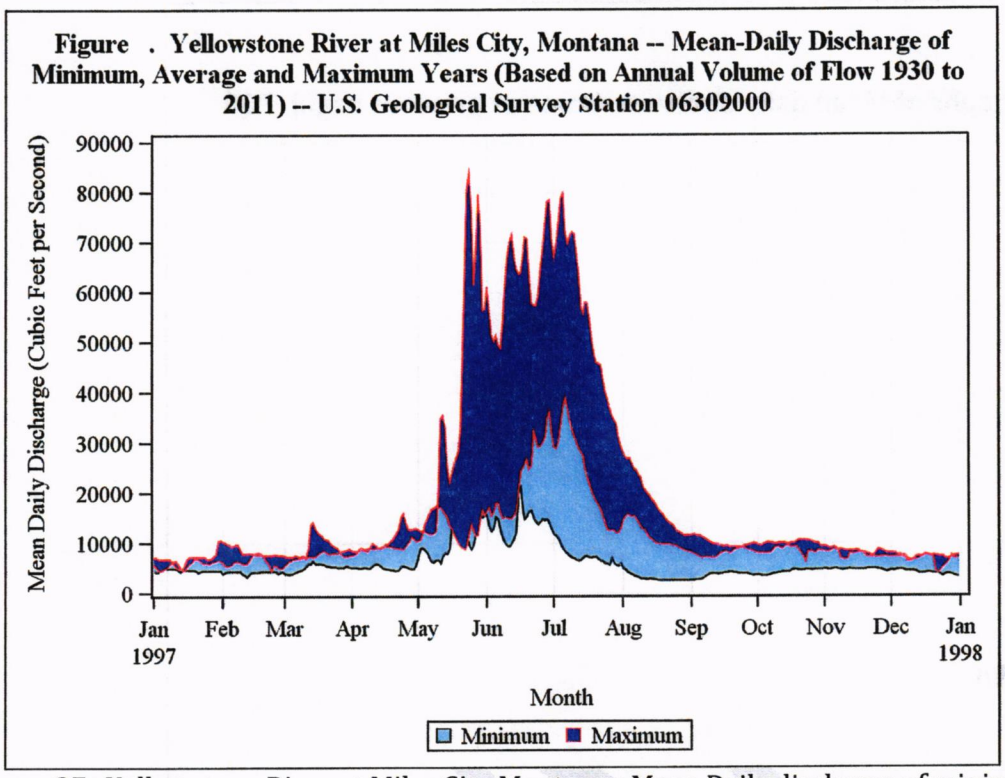

Figure 27. Yellowstone River at Miles City Montana_Mean Daily discharge of minimum, average and maximum years (Based on annual volume of flow 1930 to 2011).

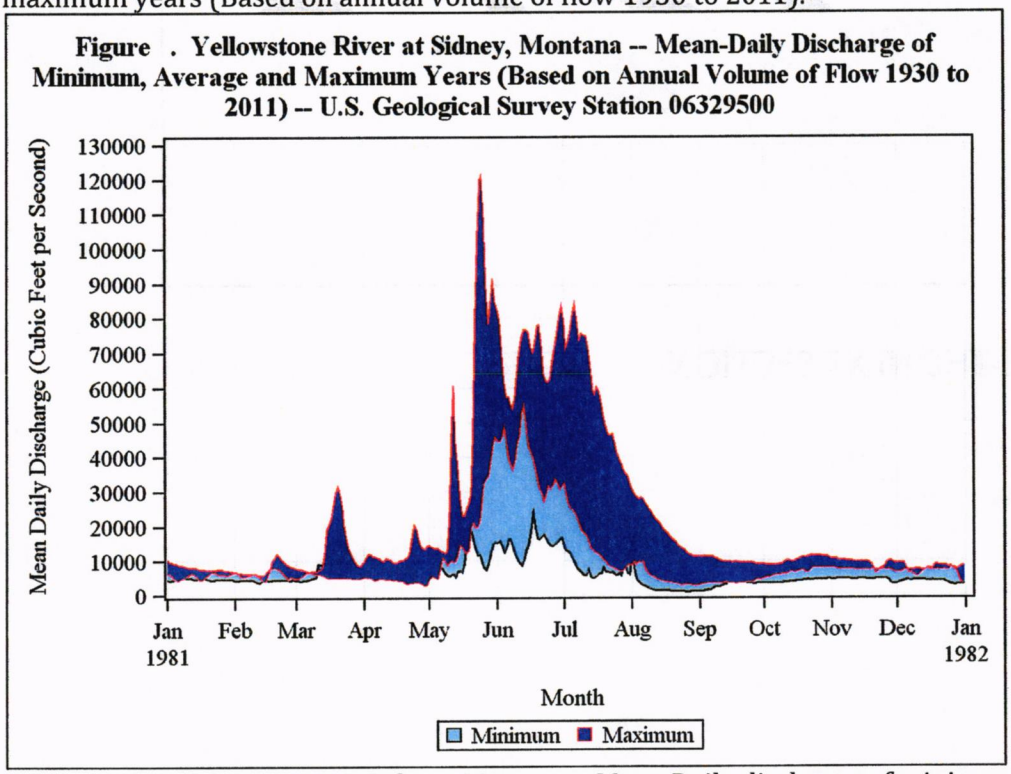

Figure 28. Yellowstone River at Sidney, Montana_Mean Daily discharge of minimum, average and maximum years (Based on annual volume of flow 1930 to 2011).

ADD Annual Hydrographs of Mean daily discharge (same as previous page) FOR

shields river

boulder river

clarks fork

bighorn river

tongue at stateline

tongue at miles city

powder at moorehead

powder at locate

clear creek wy

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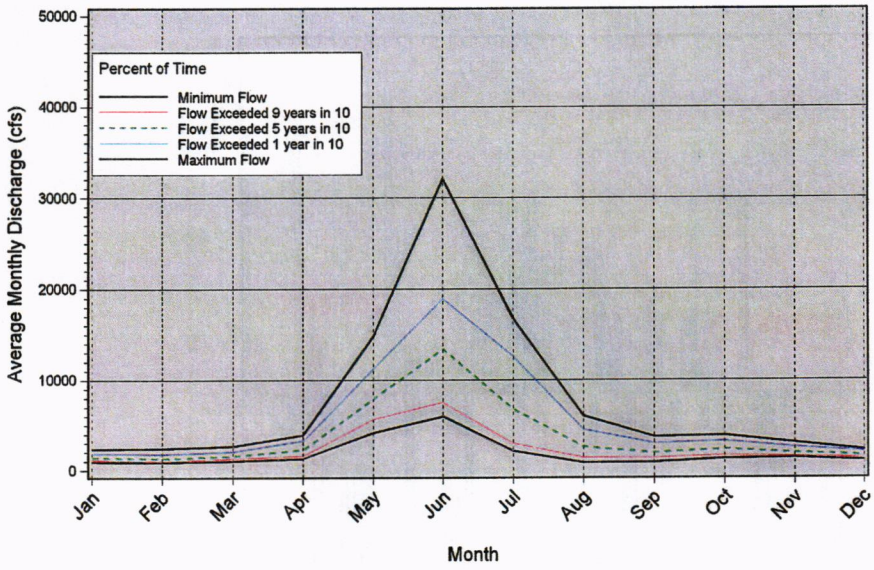
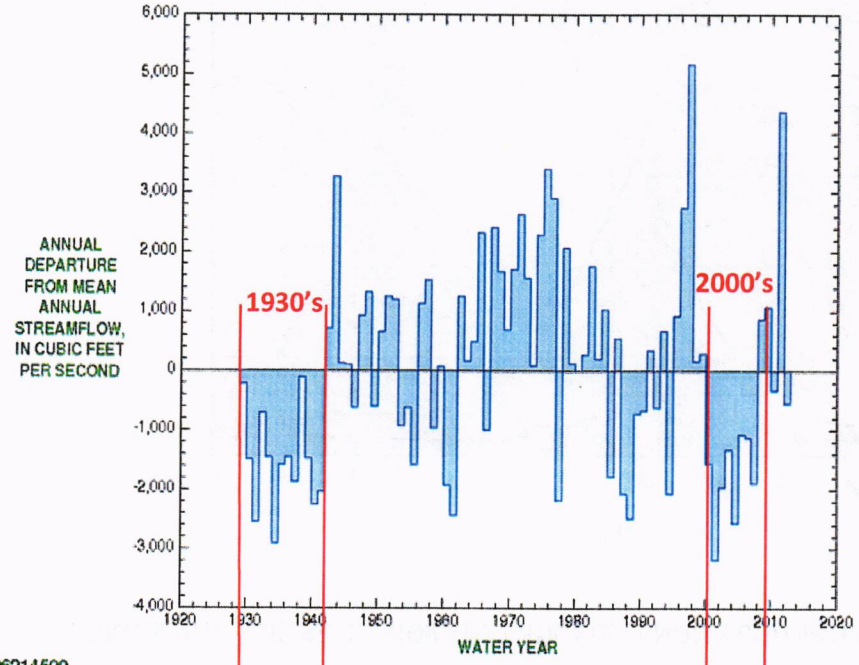
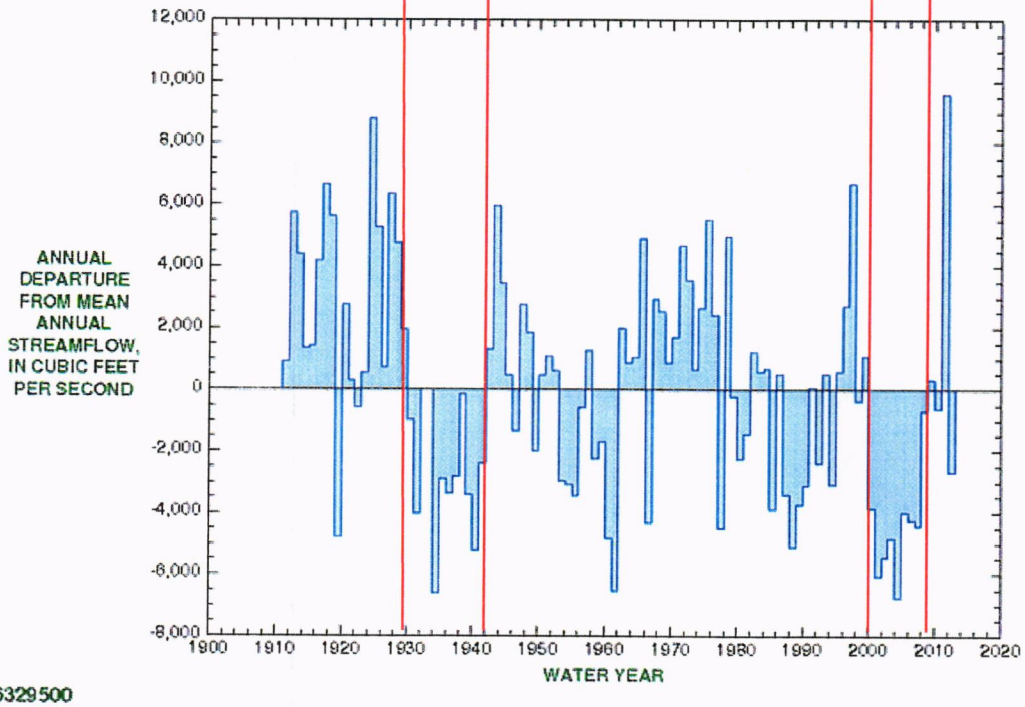
Figure . Yellowstone River at Billings: U.S. Geological Survey Streamflow 1981-2010
Number of Years in Ten That Discharge Has Ocurred



ADD MONTHLY FLOW-DURATION HYDROGRAPHS FOR MILES CITY AND SIDNEY MT

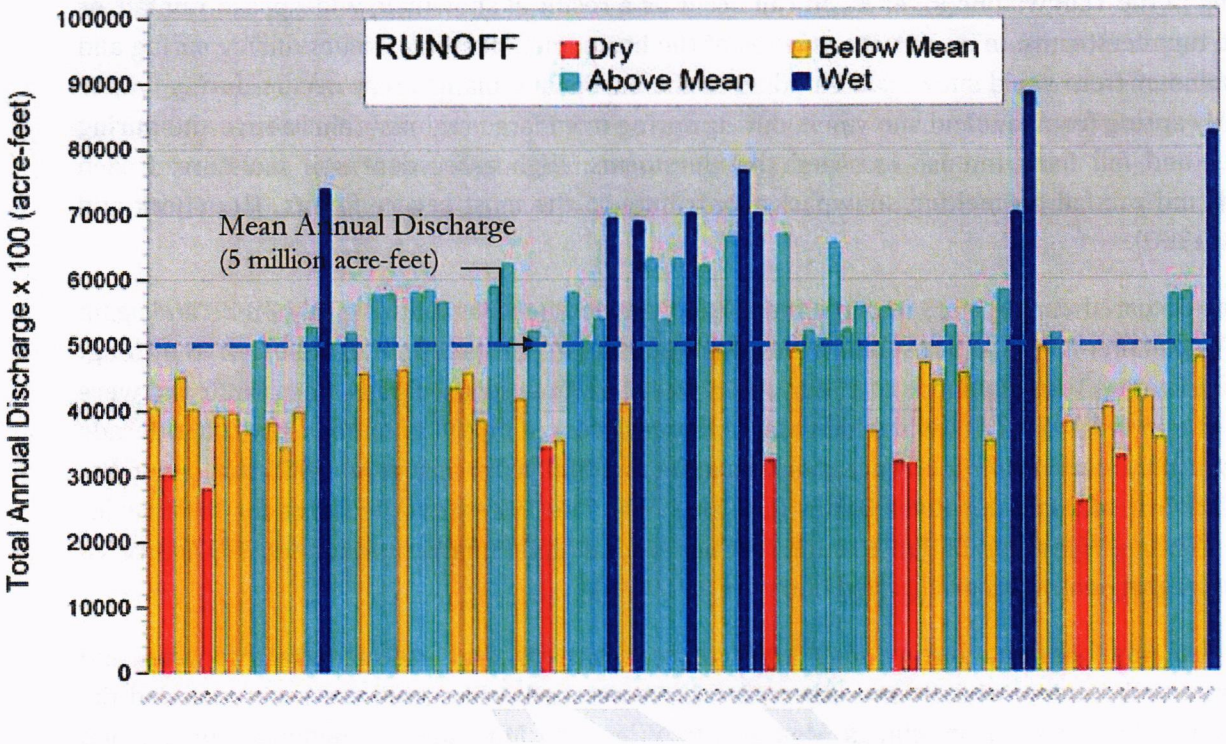


06214500
Yellowstone River at Billings MT

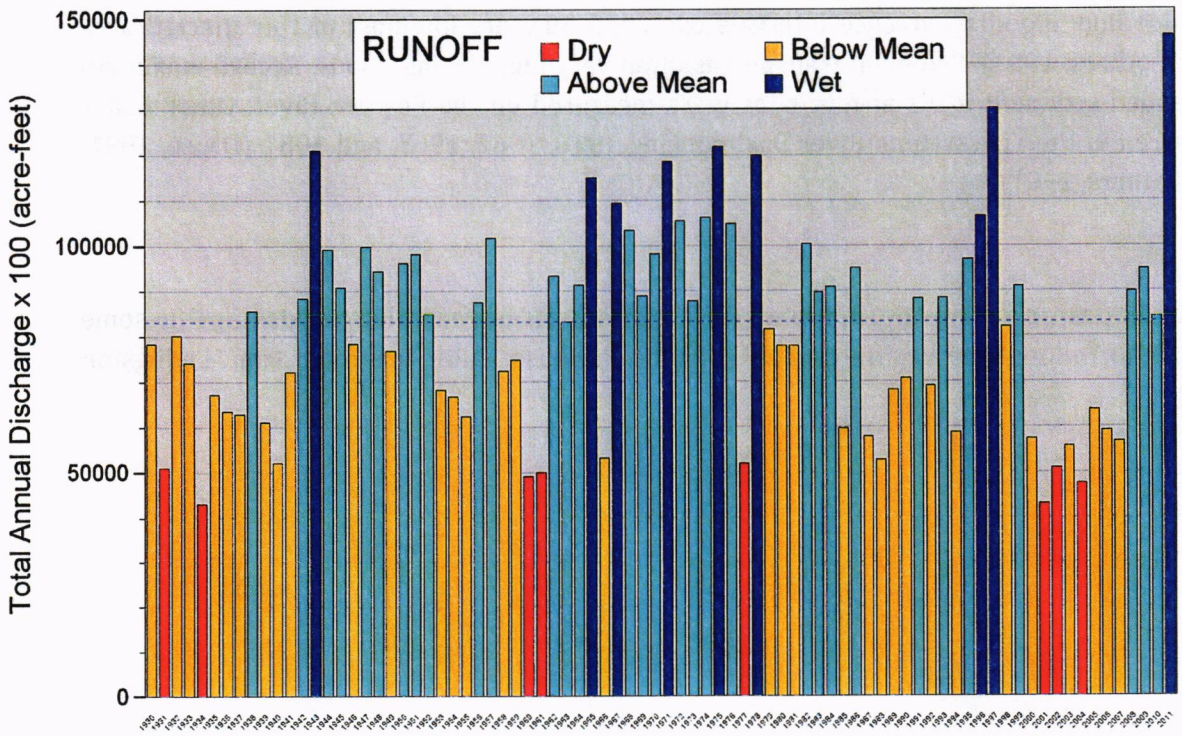


06329500
Yellowstone River near Sidney MT

Yellowstone River at Billings--Historic Annual Total Discharge 1930-2011



Yellowstone River at Miles City--Historic Annual Total Discharge 1930-2011



Floods

Flooding in the Yellowstone River Basin can occur as a result of snowmelt, widespread rainfall, or intense thunderstorms. In mountainous areas of the basin, most flooding occurs during spring and early summer from rapid snowmelt. Flooding in the basins and plains areas occurs during winter and early spring from lowland snowmelt, during spring from large regional rainstorms, and during summer and fall from intense localized thunderstorms. High antecedent soil moisture, frozen ground, and rainfall on melting snowpacks contribute to the most severe floods (Holnbeck and Parrett, 1996).

Flooding occurred during 1923 in parts of the Yellowstone River Basin during July 23-25 and again during September 27-30 as a result of widespread thunderstorms and rainfall. Referred to by long-term residents as "the big floods of 1923," these were the most severe floods since 1880 and were during the period 1918-27 in which more large floods occurred in Wyoming than any other decade (Cooley, 1990). Peak flow recurrence intervals exceeded 100 years at several USGS stations in the Wind, Bighorn, and Powder River Basins (Druse, 1991). The 1923 peak discharge for the Powder River at Arvada, Wyoming) of 99,940 cubic feet per second (cfs) (Smalley and others, 1997) is twice the next largest peak of record (period of record 1919-96).

Severe flooding occurred during May 1978 in southeastern and south-central Montana and northeastern Wyoming (Merritt and others, 1991). Watersheds affected in the basin included the Yellowstone River from near Billings, Montana, to Miles City, Montana; the Bighorn, Tongue, and Powder Rivers; and many smaller tributary watersheds (Parrett and others, 1984). Widespread rain on saturated soils combined with bankfull snowmelt runoff conditions in most streams to cause the flooding. Flood recurrence intervals exceeded 50 years for most of the affected area (Merritt and others, 1991). Sediment transport is often very high during floods. Record maximum daily suspended-sediment loads at four sites were measured on the Powder River. Other major floods occurred in the Yellowstone River Basin during 1918, 1962, 1963, and 1981 (Druse, 1991; Merritt and others, 1991).

More recent floods occurring in 1996 and 1997 caused widespread channel damage in some segments of the Yellowstone Basin—especially in the Paradise Valley upstream from Livingston (Figure 29).

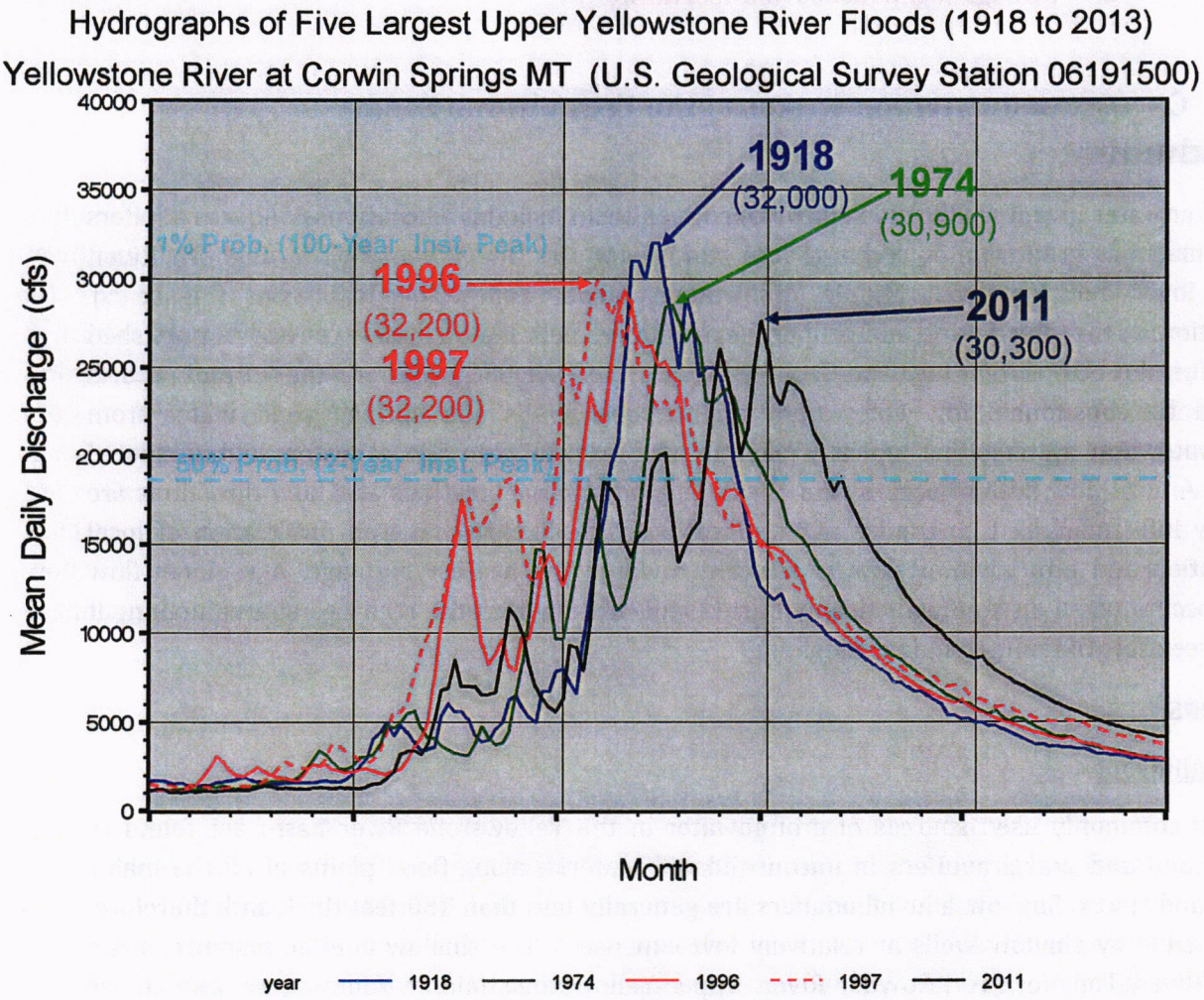


Figure 29. Hydrographs of the Five largest floods (1918 to 2013) measured at Corwin Springs Montana.

C. Groundwater Resources of the Yellowstone Basin

Groundwater

The groundwater inventory for the Yellowstone River basin includes discussions of source aquifers and estimates of groundwater recharge and storage for the Upper Yellowstone, Bighorn River, Tongue River, Powder River, Middle Yellowstone, Lower Yellowstone subbasins (Figure 5). Information on the distribution and properties of aquifers is based on review of reports published by the Montana Bureau of Mines and Geology (MBMG) and the USGS, Master's theses, and reports prepared by consultants for water right applications. Wells and springs yield water from groundwater flow systems that typically take the form of two types, a local system and a regional system. A local flow system occurs near recharge or discharge locations and flow directions are primarily influenced by topography and surface drainage. Recharge is from infiltration of local precipitation and groundwater flow is directed towards the nearest drainage. A regional flow system occurs when an aquifer is deeply buried and further from the recharge source making it more susceptible to groundwater mining.

Aquifers

Shallow Alluvium

The most commonly used sources of groundwater in the Yellowstone River basin are found in shallow sand and gravel aquifers in unconsolidated material along flood plains of all the major streams and rivers. Shallow alluvial aquifers are generally less than 150 feet thick and, therefore, are accessible by shallow wells at relatively low expense. The shallow aquifer systems of the Bighorn River, Tongue River, Powder River, Upper Yellowstone, Middle Yellowstone, and Lower Yellowstone subbasins will be described below.

The alluvial aquifers of the Bighorn River subbasin are composed of approximately 30 feet of sand and gravel beds that may yield as much as 100 gallons per minute (gpm). The terrace deposits are permeable, but their saturation thickness varies and may yield up to 30 gpm. The alluvial fan, colluvial, and eolian deposits yield small volumes of water (Hamilton and Paulson, 1968).

The alluvial aquifers of the Tongue River subbasin are composed of sand and gravel beds (clinker fragments) that yield adequate water for domestic and stock supplies. This alluvium underlies the flood plains and yields as much as 700 gpm and average approximately 50 gpm. The surficial deposits on the upland areas of the Tongue River subbasin yield insufficient water (Hopkins, 1973).

The Powder River subbasin alluvium consists of unconsolidated silt, sand, and gravel and occurs along rivers and major drainages within the Powder River subbasin (USGS, 1973). The Powder River alluvium ranges from 4 feet to 45 feet thick but commonly is 10 to 30 feet thick and about one-half mile wide (Ringen and Daddow, 1990). Local groundwater movement is primarily along the Powder River drainage in a downstream direction (US-BLM, 2002).

In the Paradise valley of the upper Yellowstone River subbasin, the alluvial aquifers are composed of well sorted sand and gravels of the Paradise valley glacial outwash deposits. These glacial

outwash deposits are up to 1,000 feet thick and have extensive clay deposits up to 100 feet thick (Lopez and Reiten, 2003). These clay deposits create semi- to leaky- confined aquifer systems in the valley. Groundwater in the alluvium/outwash aquifer fluctuates from 1 foot to 20 feet throughout the year (MBMG, 2005). In the Emigrant, MT area, the fluctuations appear to be controlled primarily by seasonal infiltration through the Park Branch Canal.

The alluvial aquifers of the middle Yellowstone River subbasin are composed of a heterogeneous mix of interbedded sand, gravel, silt, and clay. Where saturated, these alluvial deposits form productive aquifers. Two-thirds of all the wells are completed in alluvial aquifers and their distribution corresponds to both the deposits aerial extent and the population density. Groundwater from the alluvial aquifers is mostly produced from within 30 feet of the land surface and is a preferred water source because it is shallow and productive. The reported well yields range between 10 gpm and 85 gpm, with a median of 30 gpm (Madison et al., 2014).

The Shallow Hydrologic Unit (SHU) of the Lower Yellowstone River subbasin alluvial terrace deposits varies in thickness and is laterally and vertical discontinuous when separated by non-aquifer material or by topography; however there is sufficient hydraulic continuity and it is considered a single groundwater flow system (Patton et al., 1998). Reported well yields average approximately 35 gpm in the sand and gravel aquifers of the SHU. Records in the MBMG's Groundwater Information Center (GWIC) database show that almost 70% of total wells obtain water from the SHU, making it the most utilized groundwater source in the Lower Yellowstone River subbasin. The SHU is used primarily for domestic potable water, and to a lesser degree for industrial, irrigation, and stock water. The underlying rock type in the Lower Yellowstone River subbasin is usually shale making the alluvium the sole source for groundwater (Olson, 2005).

The Lower Yellowstone Buried Channel aquifer thickness is between 100 feet and 250 feet with the deeper sand and gravel deposits being the most productive. The buried channel aquifer has an approximately width of 2,500 feet and is incised into, and bounded by the Fort Union Formation, which acts as lateral boundaries and the base of the aquifer. Reported well yields range between 500 gpm to 1,500 gpm in the sand and gravel deposits when their saturated thickness is greater than 20 feet. This aquifer is used primarily for irrigation and domestic potable water (Reiten, 2008).

Recharge to the shallow aquifer systems is primarily derived from seepage from the streams/rivers, stored during periods of higher stream flow, and discharged back to the stream/river during low flows. Other recharge sources include infiltration of precipitation, irrigation water lost by percolation through fields, and leakage from ditches. Additional recharge is provided by underlying strata/coal seams that either outcrop along canyon walls forming springs or intersect and discharge into alluvium under the rivers. Places where water discharges are springs and seeps along the valley bottom of the Yellowstone River and its tributaries. Figure 30. shows the seasonal recharge and trends in precipitation and runoff that are typical of shallow aquifer systems. Another trend in shallow wells is of increasing water levels during irrigation season from irrigation or canal leakage.

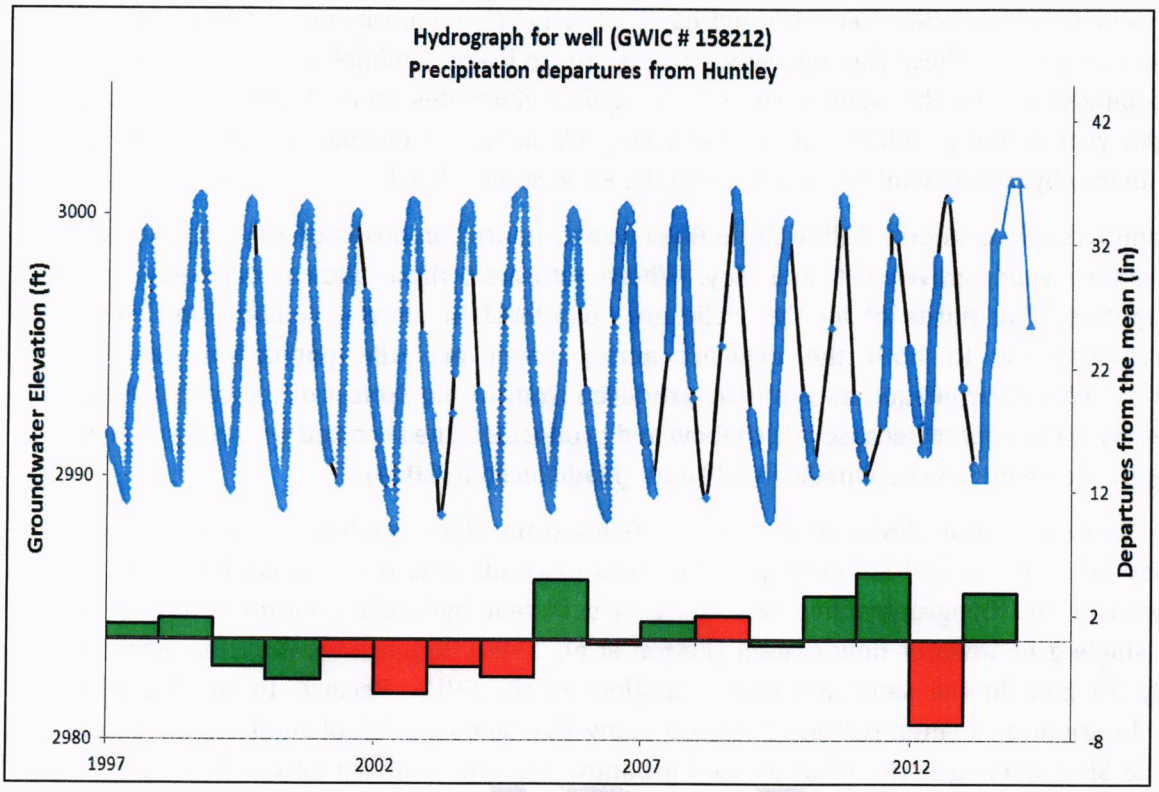


Figure 30. Water level in a well (GWIC # 158212) completed in the Yellowstone River alluvium near Huntley, MT that responds to seasonal recharge from a nearby stream as well as multi-year trends in precipitation and runoff.

Sandstone Aquifers

The major sedimentary rock aquifers consist of multiple sandstone units separated by thick sequences of shale. Sandstone of the Tongue River Member of the Tertiary Fort Union Formation is the shallowest and the most utilized sandstone source of groundwater (MBMG, 1978; Slagle, 1983). The Tullock Member of the Fort Union Formation is semi-productive in the Lower Yellowstone River subbasin. Most of the water from this aquifer system discharges to springs and streams along the Yellowstone River Valley, but part of the water continues downward to the underlying Hell Creek and Fox Hills Aquifers (Slagle, et al., 1983). The Lebo Shale of the Fort Union Formation and Bearpaw Shale are considered regional confining units.

Another sandstone aquifer is the lower portion of the Cretaceous Hell Creek Formation and the entire Cretaceous Fox Hills Formation. This is a regional aquifer and occurs at depths from 600 feet to 1,600 feet below land surface throughout most of the Lower Yellowstone River subbasin area (Smith et. al., 2000). Flowing Fox Hills–lower Hell Creek aquifer wells are usually found in the valley bottoms of large streams/rivers and have potentiometric surfaces that are 50 feet to 100 feet above land surface. 31 shows a water level decline of approximately 1 foot per year. Declines of 1 to 3 feet a year are observed in monitoring wells throughout the Yellowstone River basin. Stable groundwater level trends exist in Fox Hills–lower Hell Creek monitoring wells in areas where the Fox Hills crops out at land surface and near Fort Peck Reservoir.

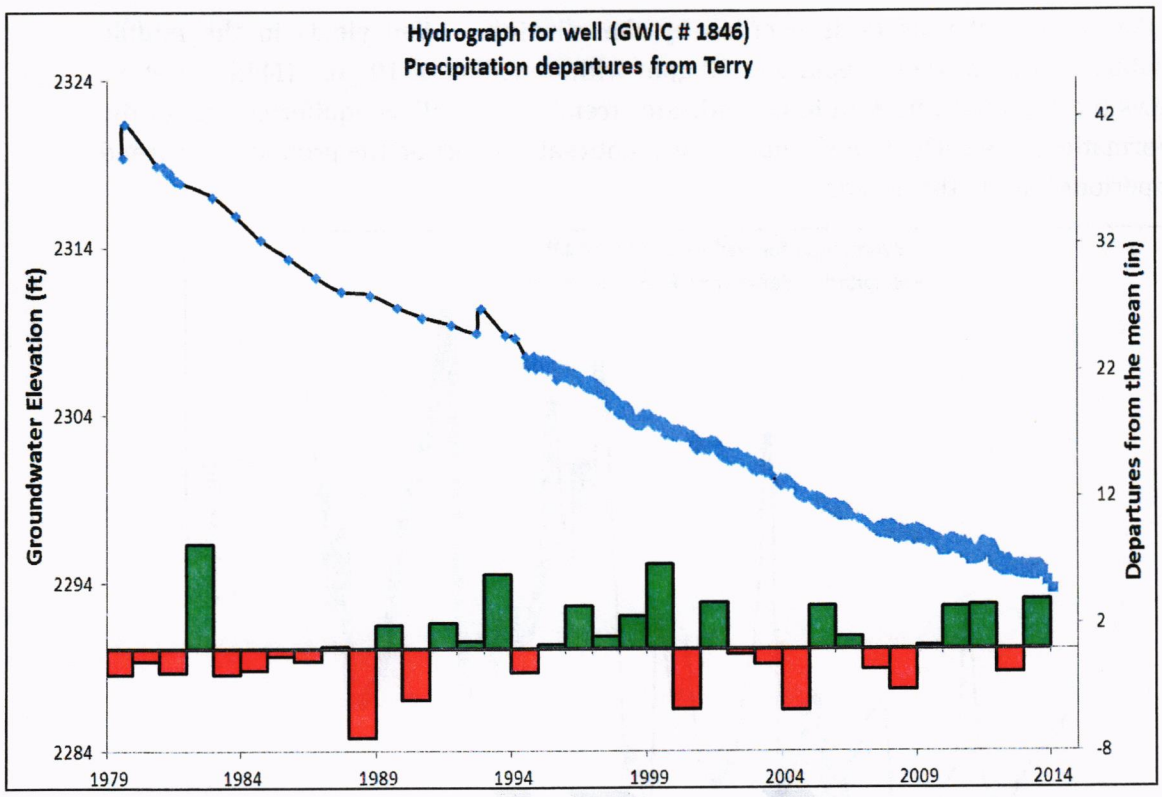


Figure 31: Water level in a well (GWIC # 1846) completed in the Fox Hills–lower Hell Creek aquifer near Terry, MT that has a water level decline during the period of record.

The Bull Mountain aquifer system is a composite of several hydrologically similar formations, including the Fort Union Formation, Fox Hills Formation, and Lance Formation (Hell Creek Formation equivalent in southern Montana), that act as a single aquifer on a regional scale (Olson et al., 2007; Madison et al., 2014). This groundwater flow system is underlain by the Bearpaw Shale which separates it from the Judith River aquifer system. The extent, thickness, and depth of aquifer are controlled by the Bull Mountain basin with formations dipping toward the center of the basin. The only regionally continuous sandstone unit in the aquifer is the Fox Hills Formation with the Lebo Shale acting as the regional confining layer. The remainder of the aquifer is generally composed of discontinuous channel-shaped sandstone lenses deformed by folds and faults. The aquifer is as much as 2,400 feet thick as determined from oil and gas well logs with typical domestic and stock water well depths of 100 feet to 250 feet. Water in the Bull Mountain aquifer system is generally of marginal quality. The Bull Mountain aquifer system is a source for domestic and stock water with well yields between 2 gpm and 30 gpm with a median of 8 gpm (Madison et al., 2014).

The Judith River Formation is characterized by relatively high porosity and permeability and is 400 feet thick in the lower Yellowstone River subbasin (Lopez, 2000). Water quality in most of the Judith River aquifer in the lower Yellowstone River subbasin is highly mineralized and marginal for many uses due to the Judith River Formation dipping into the subsurface and being overlain by the Bearpaw Shale (800 feet thick). The Judith River aquifer is a source for domestic and stock water with well yields between 5 gpm and 15 gpm in the lower Yellowstone subbasin (Olson and Svingen, 2006). In the middle Yellowstone subbasin, the most suitable water quality is found where the

Judith River Formation outcrops or is overlain by the alluvium. Well yields in the middle Yellowstone subbasin are between 7 gpm and 20 gpm with a median of 10 gpm (Madison et al., 2014). 32 shows the seasonal variation in groundwater trends in a shallow aquifer system of the Judith River Formation. The early 2000s drought has a noticeable effect on the groundwater trend as well as wet periods later in the decade.

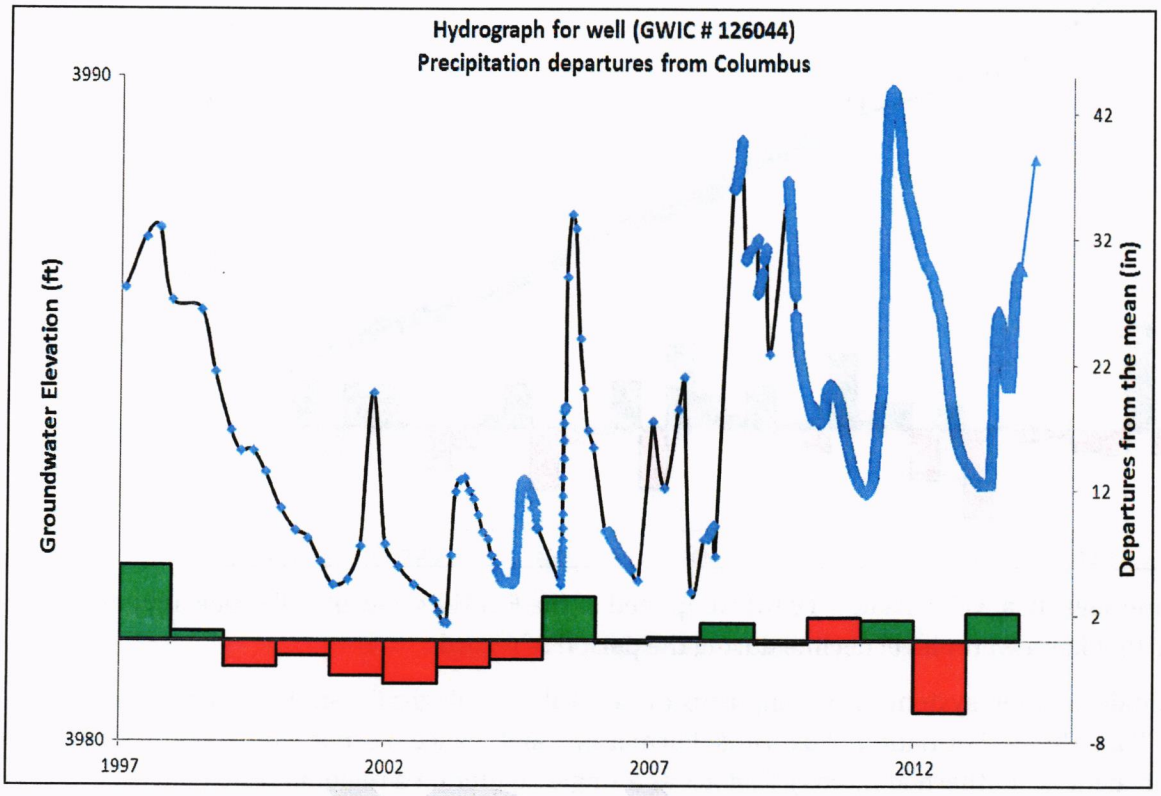


Figure 32 Water level in a well (GWIC # 126044) completed in the Judith River aquifer near Columbus, MT that responds to seasonal recharge as well as multi-year trends in precipitation and runoff.

The saturated sandstone of the Eagle Formation and Telegraph Creek Formation comprise the Eagle aquifer and consists of up to 500 feet of interbedded layers of sandstone and sandy shale overlain by the Claggett Shale Formation (Lopez, 2000). In central Montana, the Eagle Formation outcrops at Bull Mountains, Cat Creek anticline, Judith Mountains, Little Rocky, and the Bears Paw Mountains. Flowing Eagle aquifer wells are common at these outcrop locations (Reiten and Hanson, 2008). The Eagle aquifer is a source for domestic and stock water with well yields between 5 gpm and 16 gpm with a median of 10 gpm (Olson and Reiten, 2003; Madison et al., 2014). Well yield is probably directly related to primary porosity and permeability of the sandstone units and secondary porosity related to fracturing in the sandstone, with better yields associated with increased fracturing (Reiten and Hanson, 2008). Where the Eagle Formation dips into the subsurface and is overlain by the Claggett Shale, the aquifer contains highly mineralized water that is not suitable for most uses. A similar groundwater flow pattern towards the Yellowstone River valley exists in both the Judith River aquifer and Eagle aquifer (Olson and Svingen, 2006).

Recharge to sandstone aquifers is primarily derived from seepage from the streams/rivers, infiltration of precipitation, snowmelt in topographically high outcrop areas, and leakage through confining units. Other recharge sources include irrigation water lost by percolation through fields and leakage from ditches. On a regional scale, potentiometric surface mapping shows that groundwater in the bedrock often is in hydraulic communication with alluvial aquifers. Places where shallow aquifers discharge are springs and seeps along the valley bottom and active channel of the Yellowstone River and its tributaries. Groundwater from the Fox Hills–lower Hell Creek aquifer and other sandstone aquifers discharge in topographically lower areas by upward leakage to shallower aquifers and streams (Smith et. al., 2000).

Other Bedrock

Other geologic formations that are aquifers in other parts of the state but are deeply buried, have very limited surface exposure, and therefore are utilized minimally or not at all in the Yellowstone basin include the Wasatch Formation, Falls River Formation, Kootenai Formation, Swift Formation, Chugwater Formation, Tensleep Formation, Amesden Formations, and the Madison Group.

Groundwater occurrence within bedrock aquifers (pre-Belt Supergroup metasedimentary and related rocks, Madison Group, Cretaceous Livingston Group, Absaroka volcanics, Elkhorn Mountain volcanics, and other volcanic material aquifers) are primarily found in discontinuous fractures and faults resulting in large variations in well yield, often over short distances. Fracture generally is not sufficiently continuous to create regional-scale aquifers; however, fracturing often is sufficient to provide yield adequate water supplies for individual residential or small public water supplies that utilize multiple wells. On a regional scale, potentiometric surface mapping shows that groundwater in the bedrock often is in hydraulic communication with alluvial aquifer. Figure 33 shows the seasonal variation in groundwater trends in a shallow aquifer system of the Livingston Group. These groundwater trends are related to groundwater pumping, recharge, and climate variability.

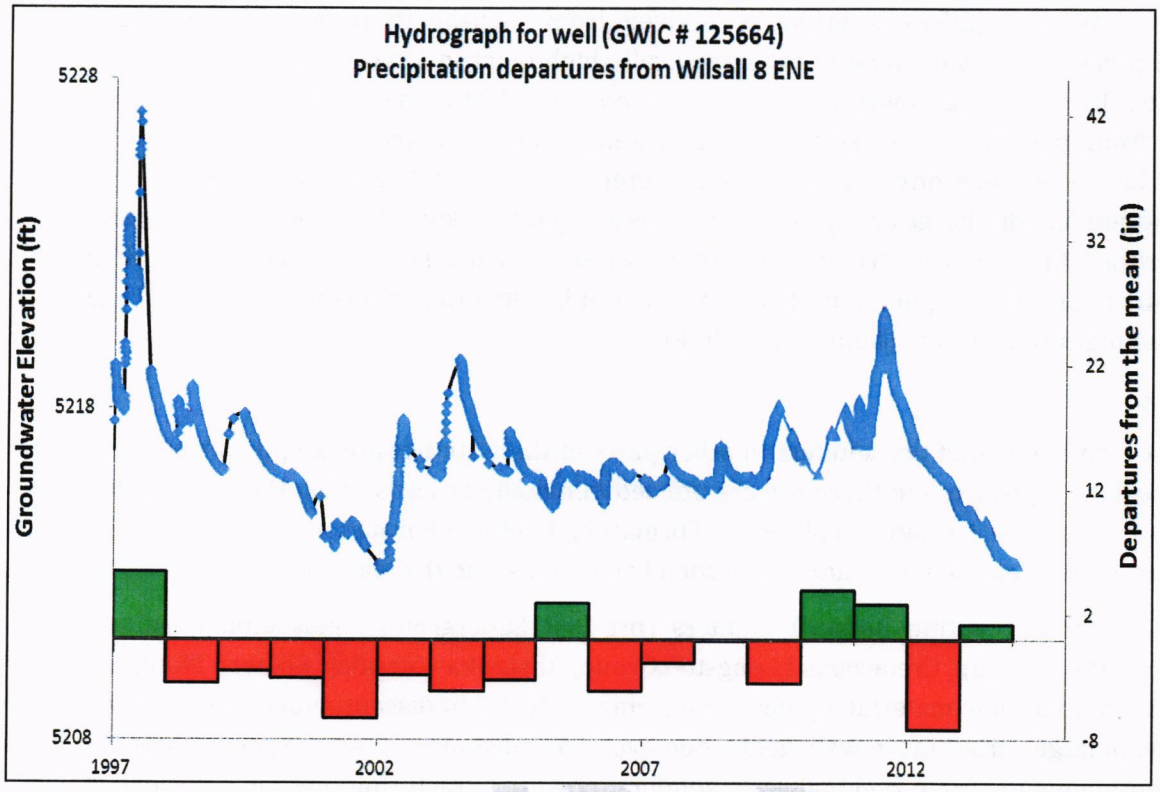


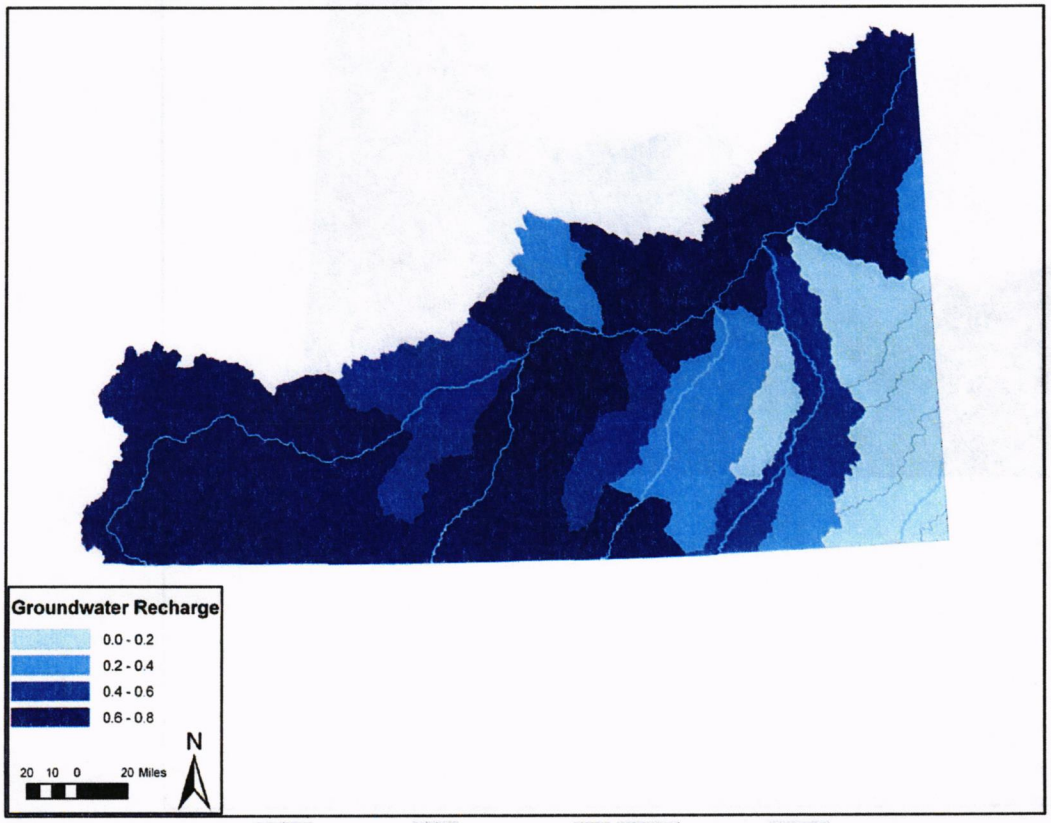
Figure 33. Water level in a well (GWIC # 125664) completed in the Livingston Group aquifer near Wilsall, MT that responds to seasonal recharge as well as multi-year trends in precipitation and runoff.

Base flow contribution

With regard to estimating the contribution of groundwater to surface water base flow, groundwater recharge estimates presented in 34. are the base flow index (BFI) values estimated by the USGS by automated hydrograph separation (Wolock, 2003-146). This assumes that the BFI, an estimated ratio of base flow to annual flow, reasonably represents the long-term percentage of groundwater discharge. It may, in some cases, underestimate recharge if a portion of the recharge flows into regional aquifer systems. Alternatively, streams affected by reservoir regulation or snowmelt dominated flow regimes are likely to have inflated BFIs (Wolock, 2003-311). Data from one gaged site is used to determine a representative BFI for each 8-Digit/4th Code HUC subbasin. The BFI value for the selected gage is used if the USGS dataset includes a BFI value at the location selected for a subbasin and that location was determined to be free of reservoir effects. Otherwise, a BFI value from an interpolated grid of BFI values is used to estimate BFIs at ungaged sites (Wolock, 2003-263).

Recharge estimates in USGS (2003) are based on surface water base flow estimates and, therefore, rely on assumptions that recharge is equal to long-term discharge and that groundwater does not leave a basin through regional groundwater flow. The first assumption is valid where development is small relative to the basin water balance or relatively recent and not reflected in reduced base flow discharge. Furthermore, estimates of recharge do not represent the amount of water legally

available for appropriation. Ultimately, the availability of groundwater for appropriation depends on any impacts to existing water users which is largely independent of recharge.



34. Groundwater recharge estimates as a ratio of base flow to annual flow.

Groundwater Storage

The groundwater storage capacity (35.F) of the upper 50 feet saturated thickness of alluvial and Tertiary-age basin fill aquifers is estimated from the areal extent of aquifers and their storage capacities. The areal extent of alluvium, alluvial terraces, and Tertiary-age basin fill sediments with the primary rock type identified as coarse grained is obtained from a digital geologic map available from the USGS (2005). Aquifer storage is assigned a uniform specific yield value of 0.20.

The value of 50 feet for saturated thickness used in calculations is representative of the typical thickness of coarse grained unconfined portions of aquifers and the thickness that accounts for the majority of groundwater circulation. Although an alluvial aquifer may store a considerable quantity of water, pumping cannot remove groundwater in aquifer storage without reducing discharge or inducing recharge, often to the detriment of surface water flows and rights of surface water users. Removal of even small amounts of groundwater resulting in much less than 50 feet of drawdown will deplete flows and impact existing users, thereby limiting new appropriations of groundwater. Figure F shows that the majority of the alluvial aquifer storage is in the upper Yellowstone River subbasin and Powder River subbasin.

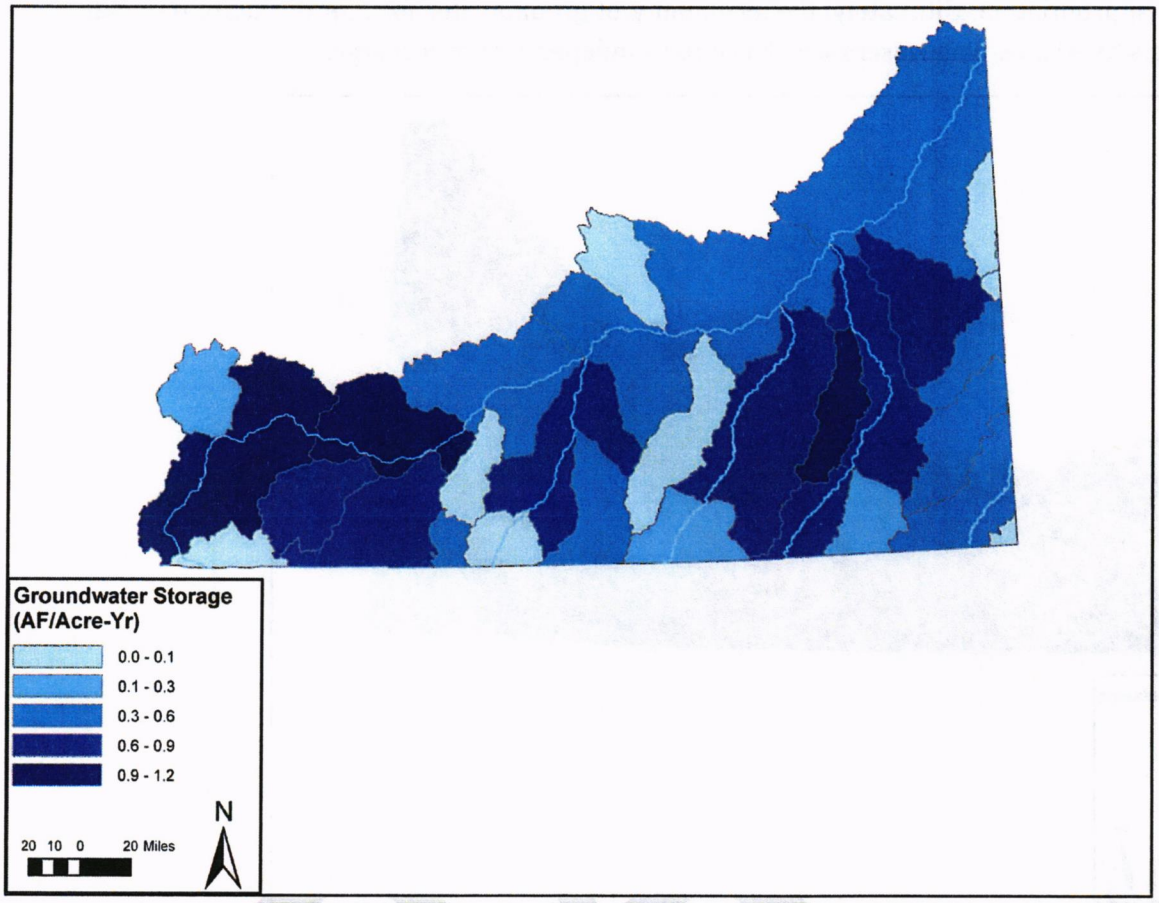


Figure 35. Groundwater recharge estimates as a ratio of base flow to annual flow.

Surface Water Depletion

Though the individual relationships are varied and complex, groundwater aquifers in most of Montana are hydrologically connected to streams. Connections between groundwater and surface water often control the sustainability of groundwater development. The connection may not be obvious and the interaction diffuse; however, groundwater provides important natural water storage and contributes base flow to surface water during periods of low flow. Groundwater pumped (Q) ultimately is offset by increased recharge to surface water, decreased discharge to surface water or reduced evapotranspiration by phreatophyte vegetation, a process first described by Theis (1941) and defined by the term capture by Lohman (1972). Hydrologic equilibrium is re-established when the amount pumped is balanced by capture (Bredehoeft, 1997).

Shallow alluvial aquifers are typically unconfined and connected to surface water where alluvium is saturated beneath stream beds. Figure 36 is an example of examining the potential for groundwater/surface water interaction by looking at wells less than 100 feet deep with a static water level less than 20 feet. The location of such wells do not just occur around large river systems but also up on the plateaus suggesting that the past glacial activity influenced many of the groundwater flow systems in the Yellowstone River basin. The connection to surface water in tertiary sediments, glacial outwash, confined sandstone aquifers, or confined limestone aquifers depends on the continuity and hydraulic properties of confining layers. Continuous confining layers

across the Yellowstone River basin may transmit only small volumes per a unit area, but they can transmit large volumes over large areas. Therefore deep confined aquifers are often connected to shallow alluvial aquifers through thin areas. Pumping from a confined aquifer also can deplete surface water by propagation of drawdown through the source aquifer to a subcrop/outcrop in the vicinity of a surface water source.

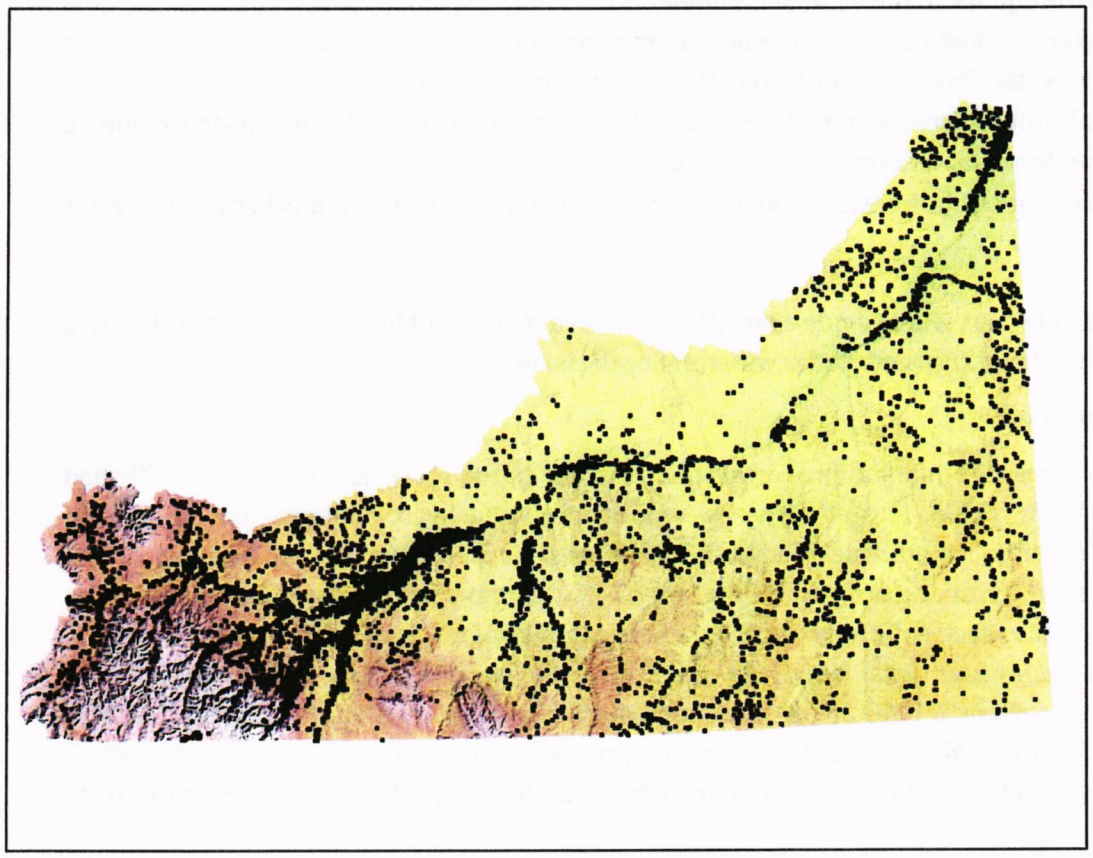


Figure 36. Areas where static water levels in wells less than 100 feet deep are less than 20 feet indicating potential for connection between groundwater and surface water.

Data Gaps and Areas of Uncertainty

Groundwater

The following groundwater data gaps and areas of uncertainty were found.

- Groundwater/surface water interaction studies are needed in the Yellowstone River basin and its tributaries to examine how groundwater production effects surface water flows in these watersheds.
- More information (baseline data of water levels and quality, additional long-term monitoring wells, and increased model accuracy) is needed for the development of deep groundwater sources for irrigation purposes and to understand the implications of such development on deep aquifers.

- Ancestral Yellowstone River channels aquifer studies collecting baseline data for groundwater model development for the Yellowstone River basin.
- Fort Union Formation aquifer studies collecting baseline data for groundwater model development for the Lower Yellowstone River subbasin.
- Completing the groundwater model for the Fox Hills – Hell Creek aquifer for the entire areal extent of the aquifer in the state of Montana.
- Examine the correlation of the number of new Fox Hills – Hell Creek wells and their use to the groundwater declines estimated in the aforementioned model.
- Additional studies are needed to evaluate the changes in groundwater systems due to conversion from flood to center pivot irrigation.
- Examination of exempt wells cumulative impacts on surface water and other groundwater users.

Addressing these data gaps will provide a wealth of knowledge that will be of great use to scientists, water users, and anybody responsible for water policy decisions.

Sources of Information

Information on the distribution and properties of aquifers is based on review of reports published by the MBMG and the USGS, Master's Theses, reports prepared by consultants for water right applications and other documents included in the references. Maps and reports published by MBMG under the Ground-Water Characterization Program (GWCP) summarize available information and present maps and cross-sections of aquifers, and maps and hydrographs of groundwater levels and water quality. Groundwater level and water quality data are housed in the GWIC database developed and managed by MBMG or the National Water Information System (NWIS) housed with USGS. Table 6. lists the main data and interpretive products pertinent to the Yellowstone River basin and their availability by subbasin. Summaries by watershed and references for these products follow.

Table 6: Data sources and important reference types.

	Yellowstone River
Data Compilations	✓
Geologic Maps	✓
Geologic Cross-sections	✓
Potentiometric Maps	✓
Hydrographs	✓
Water Quality Maps	✓
Resource Development	✓
Groundwater/surface water interaction reports	

The Groundwater Investigations Program (GWIP), also administered by MBMG, is a potential source of hydrogeologic information at the scale of a few square miles to address specific issues such as surface water depletion by groundwater development and water quality. Current projects are ongoing in the buried Yellowstone River channel aquifer near Sidney, Springs and Coalbed Methane Groundwater model in southeastern Montana within the Yellowstone River basin. Additional prospective GWIP projects can be proposed and are ranked for consideration by the Groundwater Assessment Steering Committee.

DRAFT

V. Water Use in the Yellowstone Basin

A. Historic Water Use in the Yellowstone Basin

From *Greenfields of Montana - A Brief History of Irrigation* by Stanley W. Howard

Pre-1900

The early 1880s found settlers moving into the Yellowstone and Lower Yellowstone Valleys, and along its tributaries. The fear of hostile Native Americans and long distances from placer gold activity probably had delayed settlement.

A typical early settler that made use of Yellowstone water was John Young. He built his log cabin in 1877 on the bank of the Yellowstone River at Young's Point, about four miles west of present-day Park City. Several others moved into the area between Park City and Billings at about the same time. Little did they realize that the area would someday become one of the most productive irrigated valleys of Montana. Young's site was sub-irrigated and he grew potatoes.

The area around Billings settled rapidly, according to historical reports. In 1873, the land had no white residents; by 1883, a population claimed to be several thousand having property with and assessed valuation of nearly $2M supported the request for county designation, and Yellowstone County was formed.

George Mace settled west of Forsyth in present-day Rosebud County in 1876. He enter into a government contract near the mouth of Reservation Creek in about 1881, and developed one the first irrigation projects in Rosebud County. He built a diversion dam on Reservation Creek and constricted a canal to divert water to irrigate his claim. He grew alfalfa hay from seed imported from California.

Emmett Dunlap had settled on Dunlap Creek in the Lower Yellowstone Valley near present-day Savage. An issue of the *Glendive Times* in 1889 described Dunlap's ranch as an illustration of what could be obtained by irrigation. The ditch provided water for 160 acres of hay. Testimony at the Senate Irrigation and Reclamation Committee hearing in Glendive on August 6, 1889 indicates that Dunlap's farm produced corn, potatoes, oats, and all kinds of vegetables.

An early example of private construction was provided by the Minnesota and Montana Land and Improvement Company, a subsidiary of Northern Pacific Railway. Its purpose was to irrigate the town site of Billings and land adjacent to or near the Clarks Fork and Yellowstone Rivers. This project diverted 20,000 miner's inches of water from the Yellowstone River. The canal's construction required a great number of structures, all built of wood, including the head gate and nine flumes. Because the canal system was large for that era, it was later called the "Big Ditch". Eventually, between 30,000 and 35,000 acres were irrigated.

The Miles City Irrigation and Ditch Company was incorporated in 1885 under the laws of the Territory of Montana to divert water from the Tongue and Yellowstone Rivers. The company was incorporated for 20 years and its purpose was "irrigation, milling or town supply."

Post- 1900

Two projects under the Newlands Reclamation Act were built by the USBR: The Lower Yellowstone and Huntley Projects. The Lower Yellowstone Project, authorized in 1904, diverts about 1,500 CFS from the Yellowstone River below Glendive at Intake. The diversion dam and 67-miles canal were begun in 1905, with project lands receiving water in 1909. Today, the project irrigates about 60,000 acres. Construction of Huntley project east of Billings was begun in the year of authorization, 1905, and the first water was delivered in 1909. That portion of the canal that crosses Pryor Creek has been washed out by floods on Pryor Creek and rebuilt three times. Presently, the Huntley Project waters about 30,000 acres of alfalfa and other hay crops, sugar beets, silage, irrigated pasture, and small grains.

Get the rest from WRS

B. Inventory of Consumptive Water Use in the Yellowstone Basin Associated with Exiting Water

1. Overview of Consumptive Use

Water falls on the basin as precipitation and either runs off into the rivers (Figure top next page), infiltrates into the ground or is returned to the atmosphere through evapotranspiration. It is commonly captured and stored for later use in storage projects or aquifers. Water is subsequently withdrawn from either the river or surface storage to meet demands which can be divided into two components: consumptive demand and non-consumptive demand.

Consumptive demand permanently removes water from the basin—examples include, evaporation from open water or cooling systems and evapotranspiration from crops and plants.

Non-consumptive demand is water that is either withdrawn for use but returned without being consumed (hydropower), or used instream without any means of diversion (fish and wildlife).—examples include hydropower generation, and instream flow

Water that is not consumed is returned to the basin; depending on the soil, geology and aquifer properties, this water may return rapidly (days) or slowly (months).

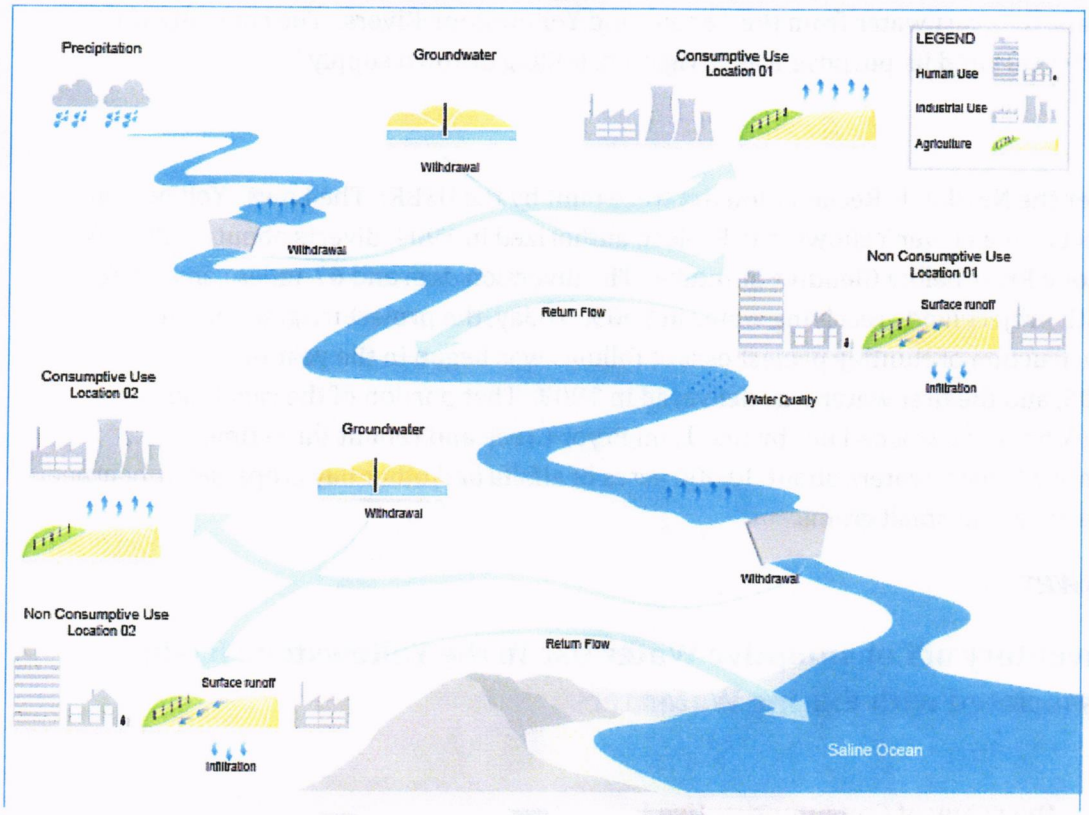


Figure 37 . Hydrologic cycle and consumptive and non-consumptive uses of water.

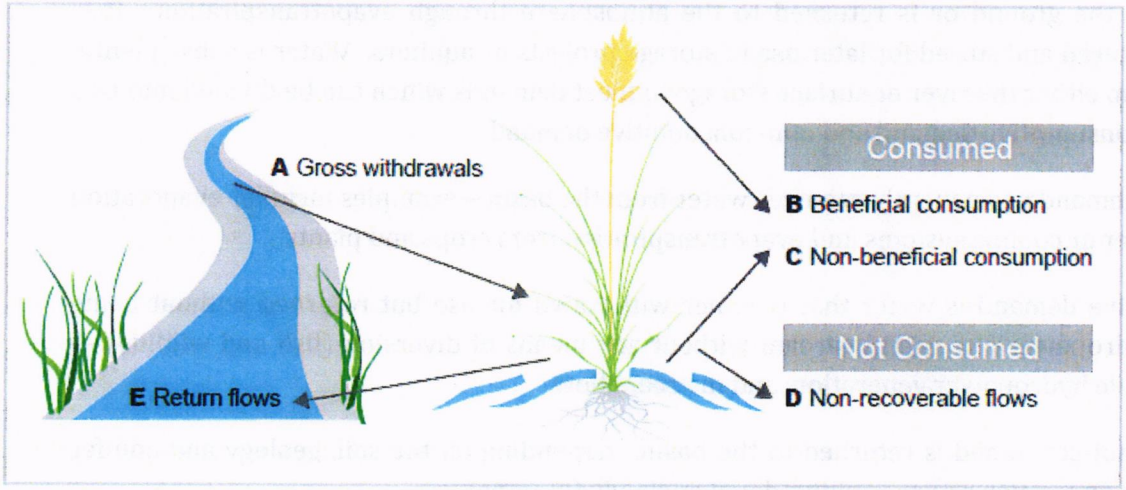


Exhibit 2: Illustrative overview of the components of water withdrawals in irrigation (Source : Adapted from 2030 Water Resources Group).

Figure 38. Withdrawal (diversion) of water for consumptive and non-consumptive use.

Previous and Current efforts to estimate water use

Water use in the Yellowstone River basin has been estimated in several previous investigations (Table next). The Department of Natural Resources and Conservation estimated consumptive use throughout the Yellowstone Basin in the early 1980's as part of a water avaialbility study conducted in support of the Yellowstone Water Reservations (Sobashinski 1982). The Wyoming State Engineer's Office consultants estimated consumptive and non-consumptive uses of water in the Powder, Tongue and Wind-Clarks Fork-Bighorn Basins of Wyoming (2000-2002). The USGS publishes estimates of water use in Montana every ten years (USGS xxxx -- Figure 39).

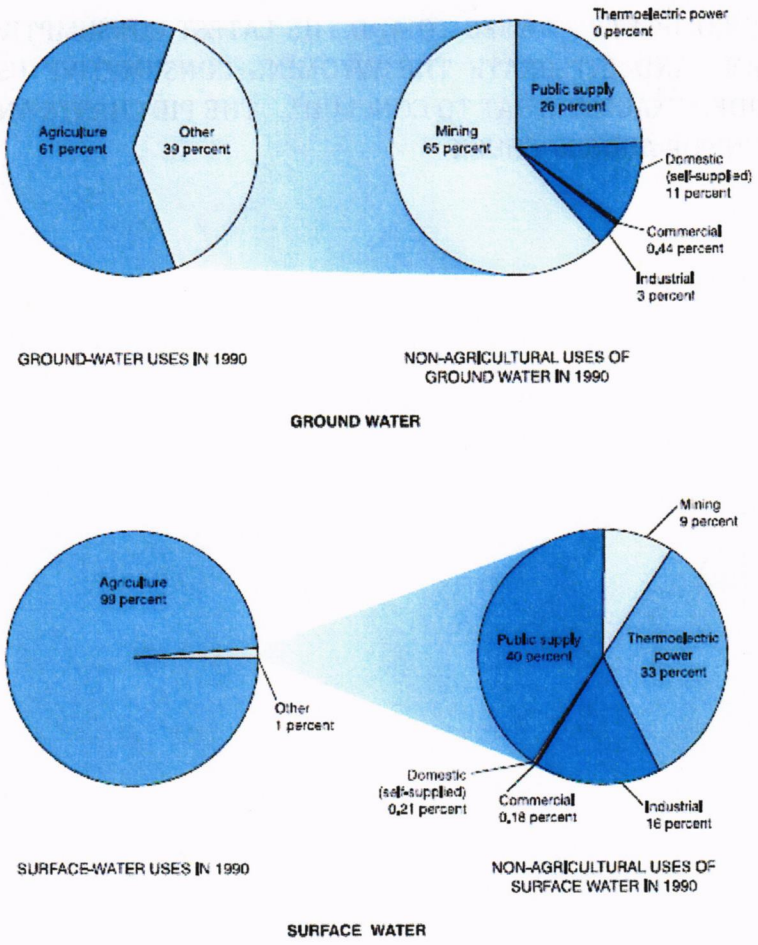


Figure 22. Estimated water use, 1990, Yellowstone River Basin.

Figure 39.. Yellowstone River Basin -- Estimated water use in 1990 (USGS XXXX)

Methodology, scope and purpose of water use estimates

For the Montana State Water Plan, consumptive use of water was estimated by application of the Water Resource Division's Consumptive Use Rules, to irrigated acreage mapped in a geographic information system (see supporting working paper: Estimating Consumptive Use of Water for the Montana State Water Plan 2015)[2]. From this analysis and streamflow data for the period 1981-2010, partial water budgets.

NOTE_THIS SECTION IS LARGELY INCOMPLETE . I NEED TO ADD THE LATEST CONSUMPTIVE USE INFORMATION FROM GREIMAN AND INTEGRATE THE WYOMING CONSUMPTIVE USE INORMATION WHEN WE HAVE DECIDED EXACTLY WHAT TO CONCLUDE. THE PIE CHARTS AND NARRATIVE WILL NEED TO BE REDONE OR ADDED.--CHUCK

[2] Data sources: water volumes are based on USGS streamflow data, 1955-2012 period; irrigation water use data sources include Water Conservation and Salvage Report for Montana (SCS, 1978), DNRC Water Resources Surveys, Montana Department of Revenue 2010 Revenue Final Land Unit (FLU), DNRC Historic Use Methodology (2010); data sources for other uses include Montana Public Water System Sources Database, USGS Estimated Water Use in Montana 2000 report (2004), DNRC Montana Water Use in 1980 report (DNRC 1986).

Summary of withdrawals and consumption by use

The following pie-charts show generalized partial, annual water budgets for the major subbasins in the Yellowstone River Basin. The water budgets are based on the streamflow at USGS gaging for an average (or median) year. For subbasins where irrigation is heavily developed and there are sizable water storage projects, such as the Bighorn Basin, almost all of the water that is produced by the basin is captured or diverted at least once-- especially during dry years. In the Upper Yellowstone Basin above Livingston, where there is relatively less irrigation and no storage, most flow is never diverted and during a typical yea, flows downstream. Note that the partial water budgets account for only human withdrawal and consumption of water and do not consider water consumed by other uses (e.g. nonirrigated vegetation, evaporation from bare soil or natural lakes).

Annually, about 4.80 mllion acre-feet is estimated to be diverted from the Yellowstone River and tributaries for irrigation, stock, industrial, and municipal and domestic use (Figure –Below). By far the largest of these uses is irrigation, which accounts for about 98% of all diversions.

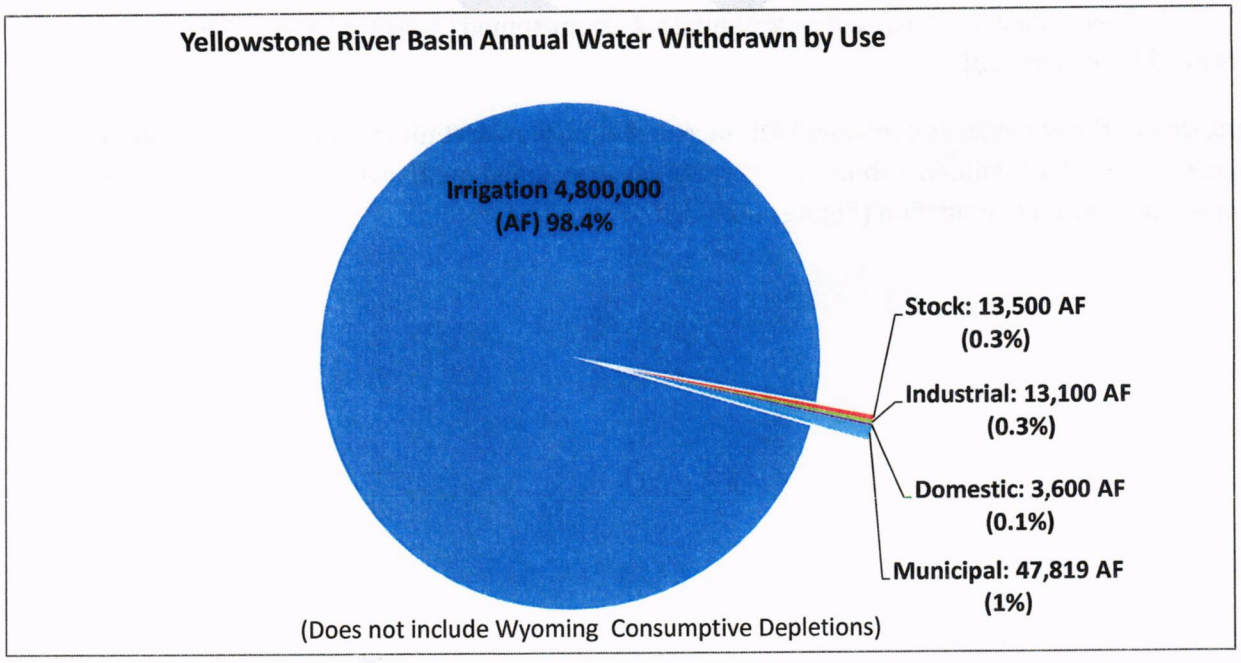


Figure . Yellowstone River Basin average annual water withdrawn by sector.[NOTE: These numbers need to be updated]

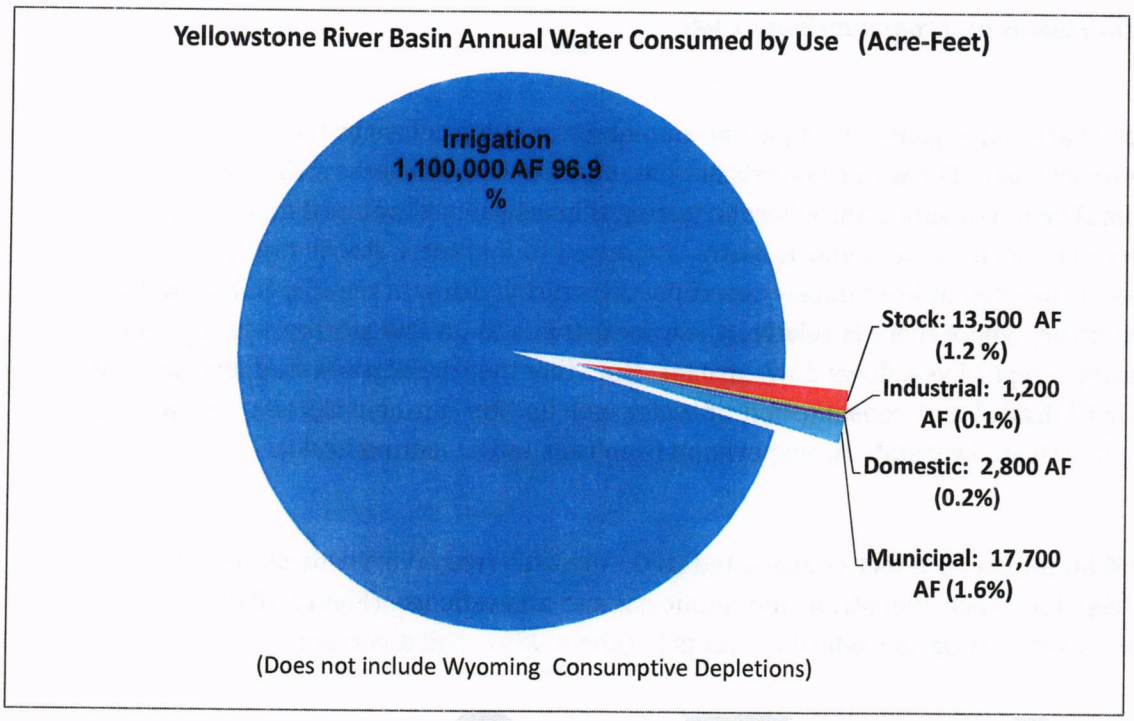


Figure . Yellowstone River Basin average annual water consumed by sector.[NOTE: These numbers need to be updated]

Only a portion of the diverted is consumed. Of the 4.8 million acre-feet diverted in the Yellowstone River Basin, about 1.14 million (about 25 percent) is consumed with over 96 percent of the consumption attributed to irrigation (Figure Above).

2. Irrigated Agricultural Water Use

Irrigated Acreage

Irrigated Crops

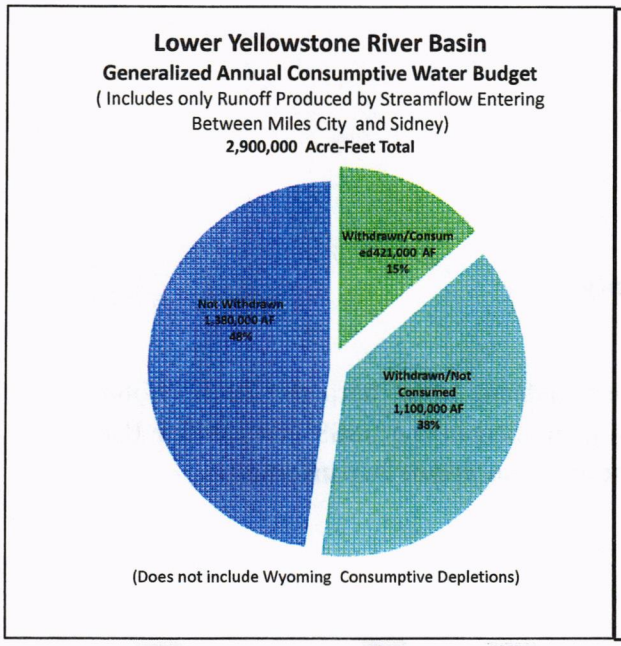
Consumption Estimates

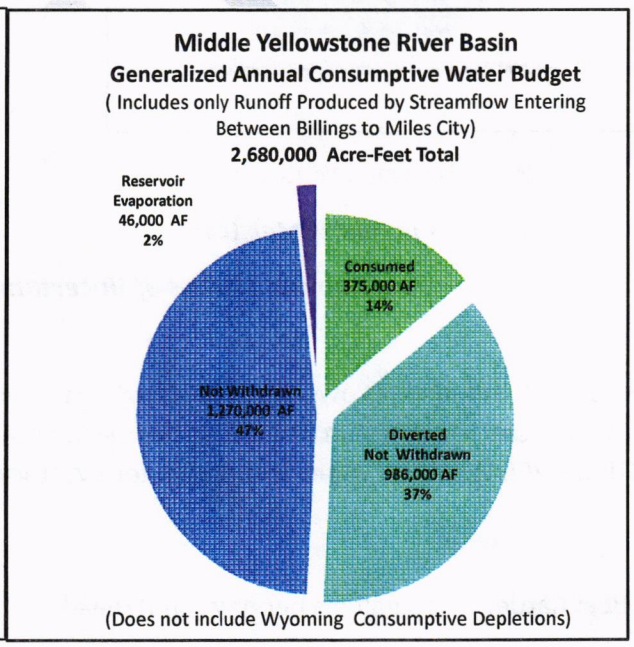
Diversion Estimates

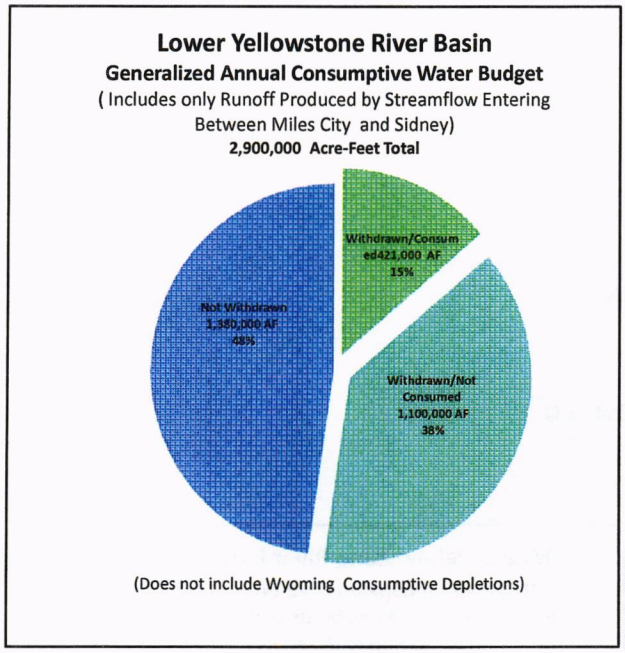
Data Gaps and Areas of Uncertainty

Irrigation

NOTE: Section in progress—not yet written up







3. Livestock Water Use

Current Water Use

Data Gaps and Areas of Uncertainty

The number of livestock (Cows, Sheep, Hogs) was derived from NASS data for 2010. Water withdrawn for stock was estimated using the assumptions applied in the USGS 2000 Water Use report (USGS, 2004), and all water withdrawn for livestock was assumed to be consumed.

Beef Cattle: 15 gallons per day (gpd)/head

Dairy Cattle: 23 gpd/head

Hogs and Pigs: 5 gpd/head

Sheep: 2 gpd/head

Assignment of source was based on county percentages of groundwater and surface water originally assigned in the 1986 DNRC water use document. These percentages originated from water rights permits issued at the time of that report.

In the Yellowstone River basin, about _____ acre-feet of water is consumed in a typical year by livestock. About two-thirds of the water needed by livestock is supplied by surface water, with the remainder by groundwater .. Livestock use by subbasin is summarized in Table _____.

4. Municipal and Domestic Water Use

Current Water Use

Data Gaps and Areas of Uncertainty

Public Water Supply

Public water supplies (PWS) were identified by combining data from two sources: 1) the Montana Public Water System Sources database (MT- DEQ, accessed through the Montana GIS portal – data published 9/19/2012); and 2) the EPA Safe Drinking Water Information System (SDWIS). The resulting dataset identifies the number of users, source, county, and HUC for each PWS. Water withdrawn by each PWS was estimated using values of per capita day use reported by county in the USGS (2004) document applied to the number of resident users. An additional 10 gallons per day was applied to non-resident users of the PWS. Consumptive use by PWS was assumed to be 37% of withdrawals (DNRC, 1975; USGS, 1986).

Self Supplied Domestic

The number of self-supplied domestic users was calculated by subtracting PWS resident users from 2010 county population estimates (U.S. Census Bureau). The amount of water withdrawn by domestic users was assumed to be 78 gpd per person and all water withdrawn is assumed to be consumed (DNRC, 1986; DNRC, 1975). Per the 1986 document, this estimate of water use was originally derived from statistics of municipal systems serving less than 55 users. All self supplied domestic water use was assumed to be from groundwater.

Assignment of domestic users to HUCs was performed by assuming uniform distribution of residential users - consistent with the 2010 USGS documentation.

5. Industrial Water Use

Current Water Use

Data Gaps and Areas of Uncertainty

Direct estimates of industrial use in 2010 were not possible. Instead, past USGS estimates (1985 through 2000 - where both HUC and county estimates were provided, and 2005 - which provided only usage by county) were analyzed to determine HUC assignment of those counties where the majority of industrial water use occurred. Then for those counties with the largest share (representing 90% of statewide industrial use), the 2005 USGS estimates were used as the best estimate for 2010 water use. All other industrial use estimates remain as reported in the 2000 water use document.

Thermoelectric

Thermoelectric generators were identified from Energy Information Administration reporting (EIA923 – Power Plant Operations Report, Schedule 8D: Cooling System information). Six projects were identified in the report, three of which reported withdrawals and consumptive use for cooling in 2010:

- Colstrip (Rosebud County)
- J E Corette Plant (Yellowstone County)
- Hardin Generator Project (Big Horn County)

X acre-feet was reported withdrawn in the Yellowstone River subbasins for thermoelectric cooling in 2010. This does not necessarily imply, however, that there isn't any additional thermoelectric generation in these basins.

Oil and Gas Development

6. Summary of Consumptive Water Use

C. Inventory of Non-Consumptive Water Use in the Yellowstone Basin Associated with Exiting Water Rights.

1. Recreational Water Use

Current Water Use

Montana Department of Fish, Wildlife and Parks

Murphy Rights

Water Reservations

United States Bureau of Land Management

Water Reservations

Water Compacts

Montana Department of Environmental Quality

Water Reservations

Overview of Consumptive Use

Data Gaps and Areas of Uncertainty

2. Environmental Water Use

Current Water Use

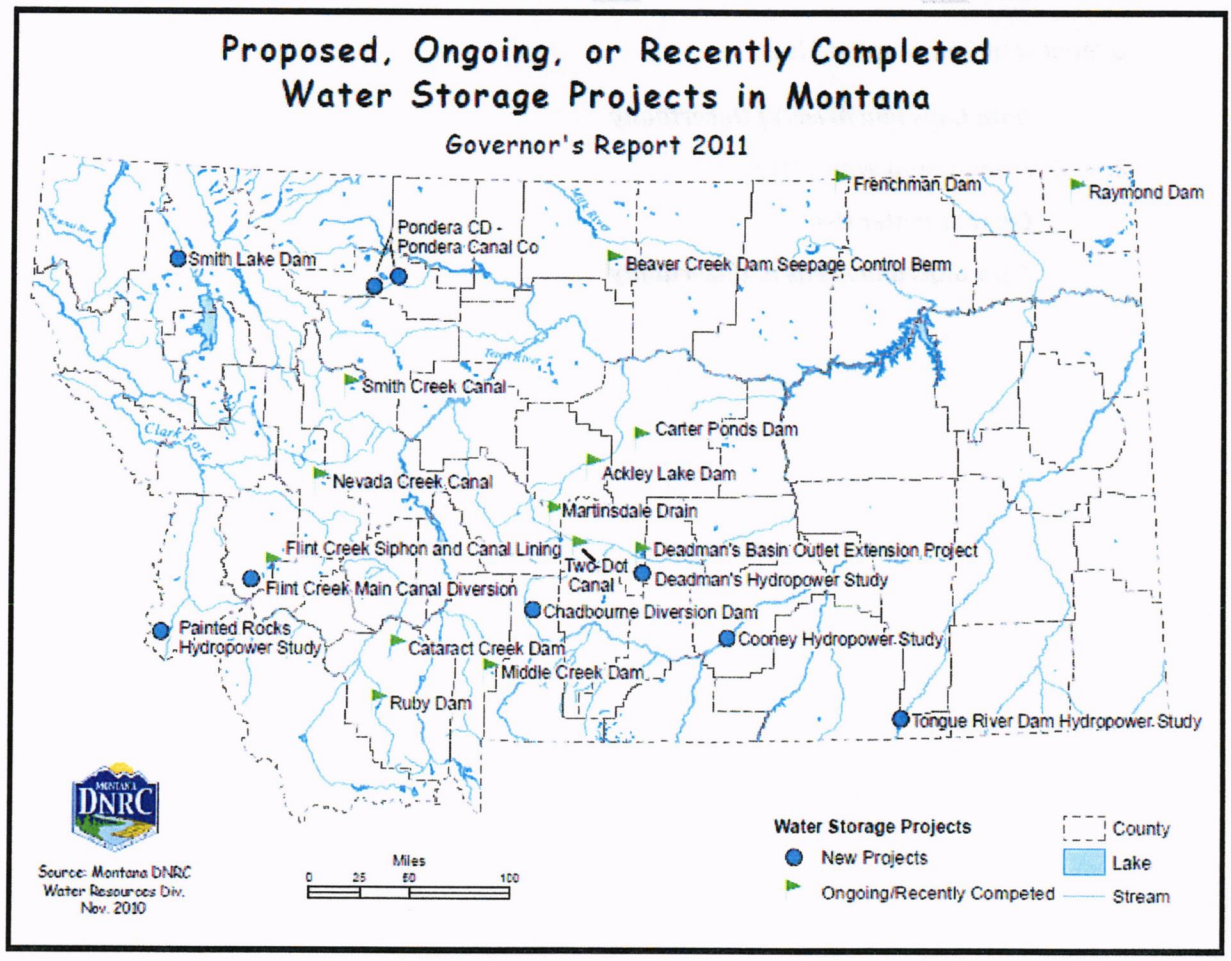
Data Gaps and Areas of Uncertainty

3. Lakes and Reservoirs

Surface Water Storage

Physical Characteristics

Montana and Wyoming watersheds contain a variety of types of surface-water storage projects, ranging from small impoundments (for example, stock watering and fish ponds), to large multi-purpose dams and reservoirs that provide flood control; water storage for irrigation, municipal, and industrial use; and generation of hydropower. Larger projects typically have a federal partner --for example, Yellowtail Dam and Bighorn Lake operated by the U.S. Bureau of Reclamation in Cooperation with both adjoining states. The state of Montana oversees operation of several state water projects constructed between 1930 and 1950 (Figure Below). These projects are less than 100,00 acre-feet in size and constructed primarily for irrigation water supply. Many of the aging projects are in need of maintenance and repair to meet current-day dam safety standards.



Total storage in the Yellowstone River basin is about 3,450,000 acre-feet (Montana 1,446,400 ac-ft and Wyoming 2,010,000 ac-ft). Yellowtail Dam and Bighorn Lake, which extends into Wyoming, account for most of Montana's storage (1,300,00 ac-ft) capacity (Tables Below). With the

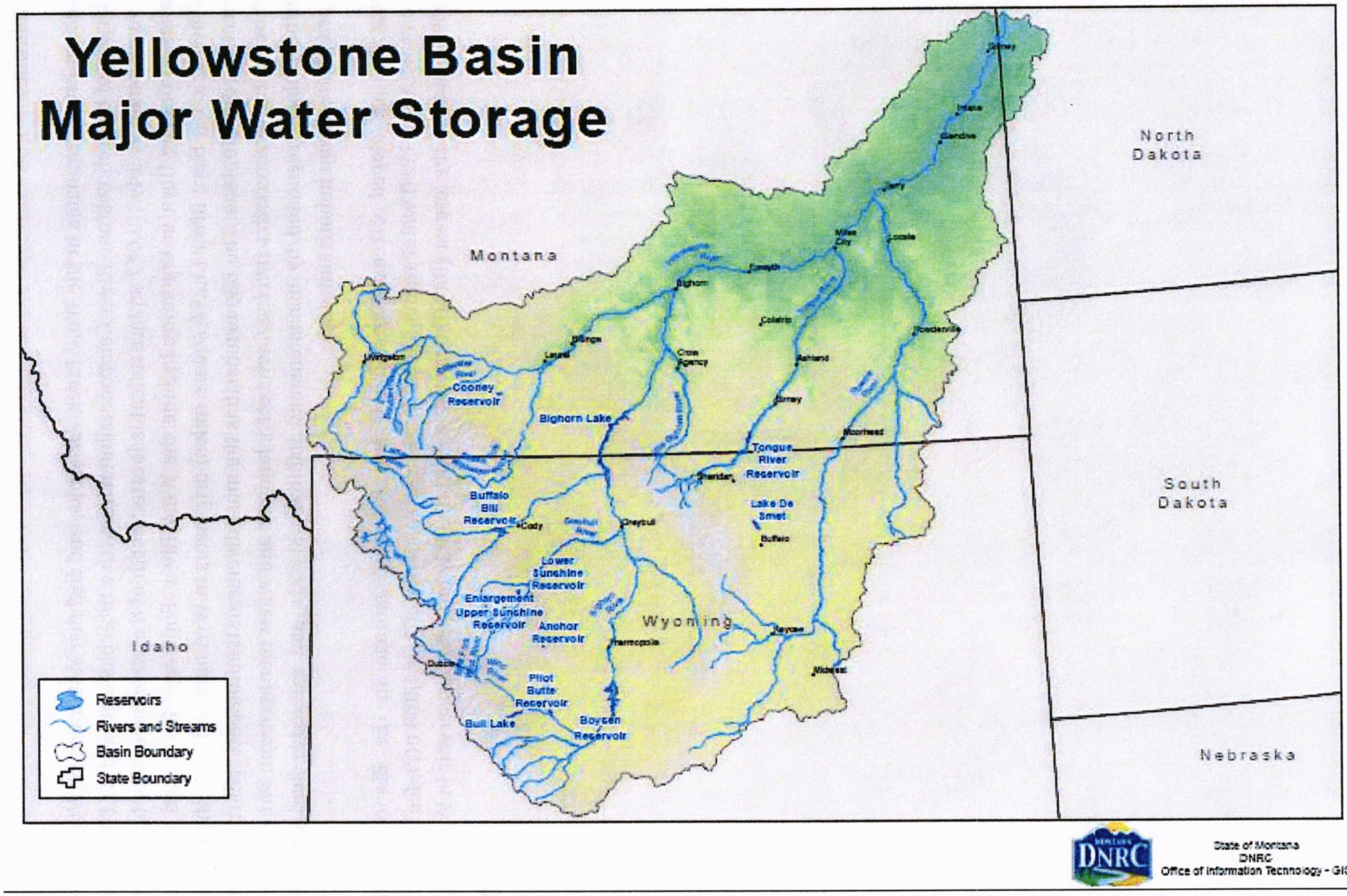
exception of the Tongue River Dam, most of the larger storage projects are located in the western headwaters of the basin, and most of the storage capacity is developed in the Bighorn Basin (2,791,440 ac-ft).

Table . Yellowstone River Basin Lakes and Reservoirs with Capacity Greater Than 1000 Acre-Feet

Upper Yellowstone River Basin (in progress.....)

	Yellowstone River Compact Tributaries		
Reservoir or Lake	Pre-compact 1950 Water Right	Post-compact 1950 Water Right	Usable Capacity (Acre-Feet)
	Clarks Fork Yellowstone River Basin		
Cooney Reservoir	28,230	0	28,230
Glacier Lake	4,200	0	4,200
	Bighorn River Basin		
(Lake) Adelaide Reservoir	1,450	3,320	4,770
Anchor Reservoir	--	9,250	17,410
Bighorn Lake	--	1,312,000	1,312,000
Boysen Reservoir	757,900	--	757,900
Buffalo Bill Reservoir	456,600	187,900	644,500
Bull Lake	77,040	--	77,040
Greybull Valley Reservoir	33,170	33,170	9,390
Pilot Butte Reservoir	34,600	--	34,600
Sunshine Reservoir	52,990	--	52,990
Lower Sunshine Reservoir	--	58,750	58,750
Christina Reservoir	3,860	--	3,860
Corral Reservoir	--	1,030	1,030
Diamond Creek Dike Reservoir	--		18,380
Enterprise Reservoir	1,490	204	1,700
Fairview Extension Reservoir	791	620	1,410
Harrington Reservoir	315	887	1,200
Lake Cameahwait Reservoir	--	6,680	6,680
Lake Creek Reservoir	1,370	--	1,370
Newton Lakes	4,520	--	4,520
Perkins and Kinney Reservoir	1,200	--	1,200
Sage Creek Reservoir	440	2,340	2,780
Shell Reservoir	1,950	--	1,950
Shoshone Lake Reservoir	9,740	--	9,740
Teapot Reservoir	1,580	--	1,580
Tensleep Reservoir	3,510	--	3,510
Wiley Reservoir	689	331	1,020
Worthen Meadow Reservoir	--	1,500	1,500
	Powder River Basin		
Cloud Peak Reservoir	3,400	172	3,570
Dull Knife Reservoir	--	4,320	4,350
Healy Reservoir	--	5,140	5,140
Kearney Reservoir	1,850	4,470	6,320
Lake DeSmet	37,520	197,500	235,000
Muddy Guard Reservoir	--	2,340	2,340
Tie Hack Reservoir	1,650	788	2,440
Willow Park Reservoir	4,460	--	4,460
Posy No.1 Reservoir	--	1,540	1,540
	Tongue River Basin		
Bighorn Reservoir	2,750	1,880	4,630
Dome Reservoir	1,840	188	2,030
Park Reservoir	7,350	3,020	10,360
Sawmill Lakes Reservoir	--	1,280	1,280
Tongue River Reservoir	79,070	--	79,070
Twin Lakes Reservoir	1,180	2,220	3,400
Willow Creek Reservoir	--	22,900	22,900

Yellowstone River Basin Lakes and Reservoirs with Capacity Greater Than 1000 Acre-Feet		
Lake or Reservoir	**MT**	**WY**
	Clarks Fork Yellowstone River Basin	
Cooney Reservoir	28,230	
Glacier Lake	4,200	
	Bighorn River Basin	
(Lake) Adelaide Reservoir		4,770
Anchor Reservoir		17,410
Bighorn Lake	1,312,000	
Boysen Reservoir		757,900
Buffalo Bill Reservoir		644,500
Bull Lake		77,040
Greybull Valley Reservoir		9,390
Pilot Butte Reservoir		34,600
Sunshine Reservoir		52,990
Lower Sunshine Reservoir		58,750
Christina Reservoir		3,860
Corral Reservoir		1,030
Diamond Creek Dike Reservoir		18,380
Enterprise Reservoir		1,700
Fairview Extension Reservoir		1,410
Harrington Reservoir		1,200
Lake Cameahwait Reservoir		6,680
Lake Creek Reservoir		1,370
Newton Lakes		4,520
Perkins and Kinney Reservoir		1,200
Sage Creek Reservoir		2,780
Shell Reservoir		1,950
Shoshone Lake Reservoir		9,740
Teapot Reservoir		1,580
Tensleep Reservoir		3,510
Wiley Reservoir		1,020
Worthen Meadow Reservoir		1,500
	Powder River Basin	
Cloud Peak Reservoir		3,570
Dull Knife Reservoir		4,350
Healy Reservoir		5,140
Kearney Reservoir		6,320
Lake DeSmet		235,000
Muddy Guard Reservoir		2,340
Tie Hack Reservoir		2,440
Willow Park Reservoir		4,460
Posy No.1 Reservoir		1,540
	Tongue River Basin	
Bighorn Reservoir		4,630
Dome Reservoir		2,030
Park Reservoir		10,360
Sawmill Lakes Reservoir		1,280
Tongue River Reservoir	79,070	
Twin Lakes Reservoir		3,400
Willow Creek Reservoir	22,900	
	1,446,400	2,007,640


Yellowstone Basin
Major Water Storage
Montana
North Dakota
South Dakota
Nebraska
Wyoming
Idaho
Cooney Reservoir
Bighorn Lake
Tongue River Reservoir
Buffalo Bill Reservoir
Lake De Smet
Lower Sunshine Reservoir
Enlargement Upper Sunshine Reservoir
Anchor Reservoir
Pilot Butte Reservoir
Bull Lake
Boysen Reservoir
Reservoirs
Rivers and Streams
Basin Boundary
State Boundary
State of Montana
DNRC
Office of Information Technology - GIS

Bighorn Basin

The Bighorn River originates in the Wind River, Absaroka, and Bighorn Mountains of Wyoming. It is the largest of the Yellowstone River Compact tributaries with a total basin area of 22,885 square miles. Approximately 14% (3,067 square miles) is located north of the stateline in Montana. Major tributaries to the Big Horn in Wyoming include the Wind River, Popo Agie River, and Shoshone River. The Little Big Horn River (1,294 square miles) originates in Wyoming and joins the Bighorn River near Hardin, Montana. The Bighorn basin is the most diverse of the Compact tributaries with respect to basin characteristics (geology, soils etc.), land use and water management. Streamflow in the basin is highly regulated by mainstem and tributary storage and extensive land has been developed for irrigation in both states.

Wyoming has developed extensive mainstem and tributary storage in the Bighorn basin. Reservoirs with pre-1950 water rights have a total capacity of about 1,766,000 acre-feet. Of these the Boysen project is the largest (829,000 acre-feet) and the only mainstem reservoir in Wyoming.

DRAFT

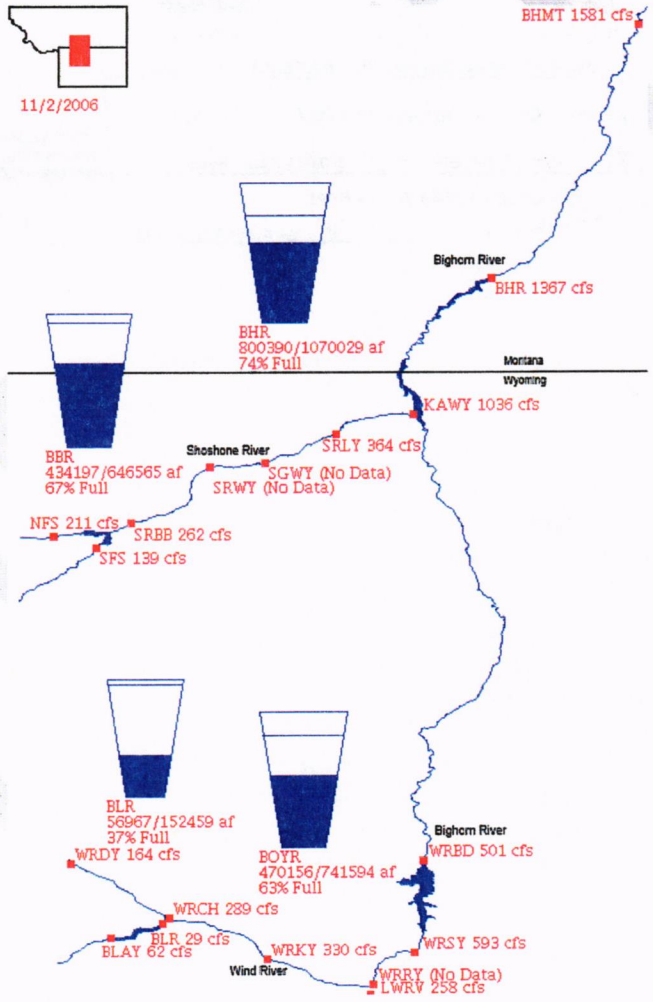
Management and Operations

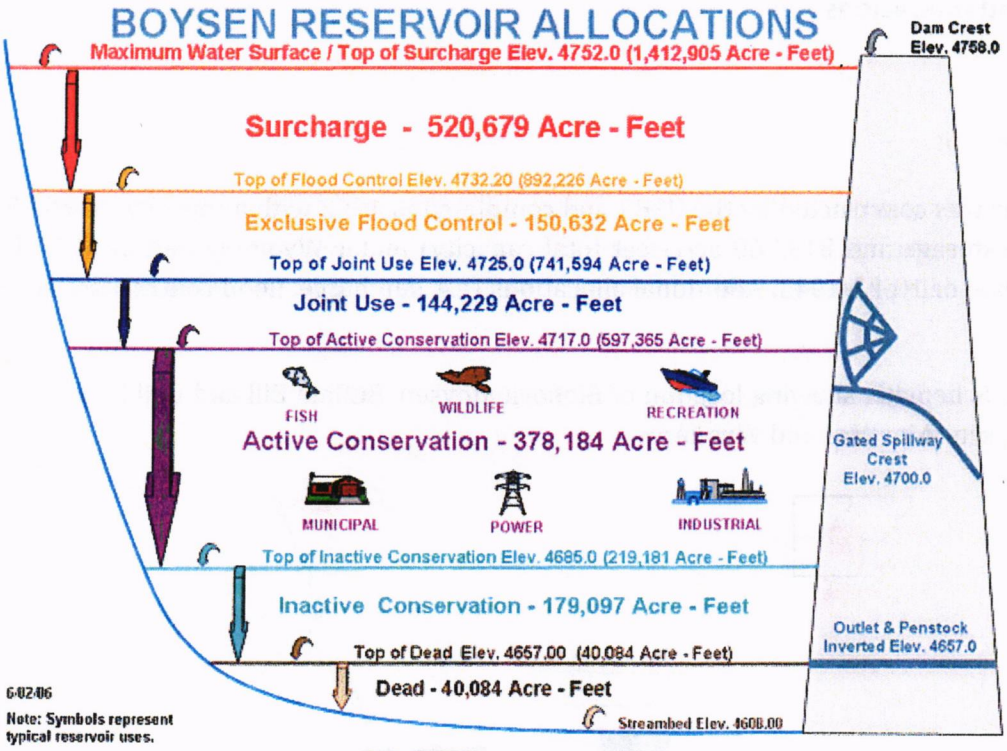
Bighorn Basin

Boysen Reservoir

Boysen Reservoir was constructed by the USBR and completed in 1952 with a capacity of 757,000 acre-feet (active storage and 819,760 acre-feet total capacity) under Wyoming Permit 5576 Res. with a priority date of 10-22-1945. Additional allocations (e.g. surcharge, flood control) are shown below.

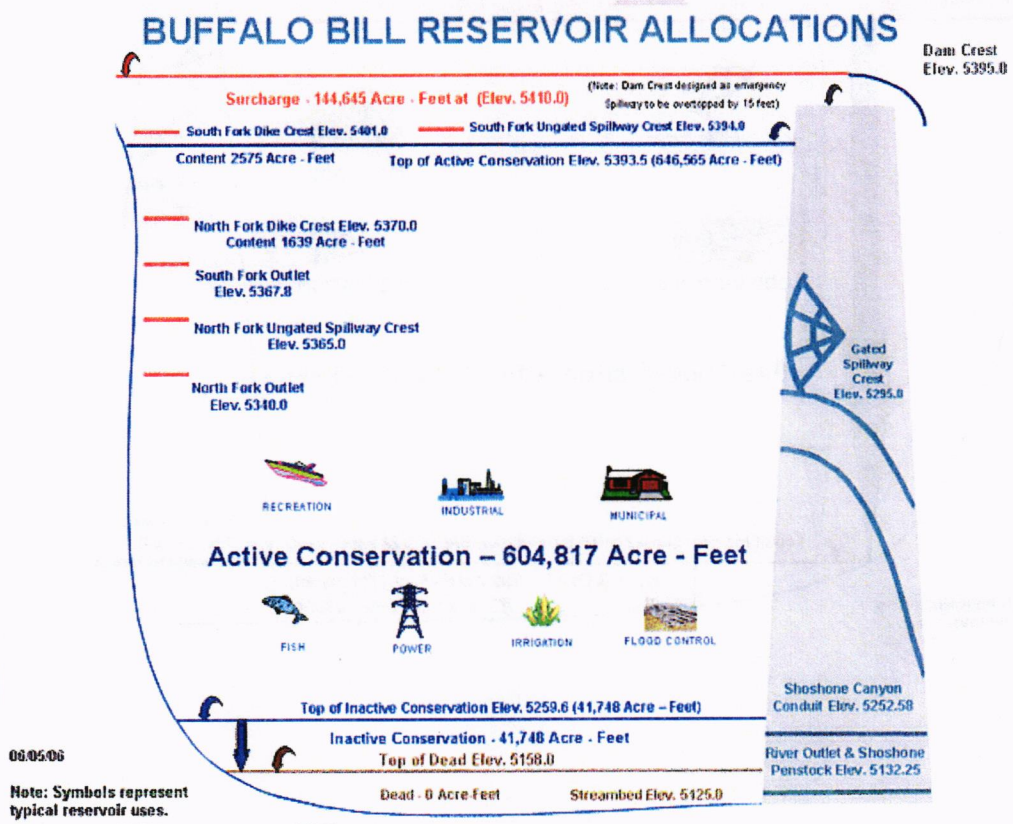
Figure 1. Schematic showing location of Bighorn, Boysen, Buffalo Bill and Bull Lake Reservoirs in Montana and Wyoming.




BOYSEN RESERVOIR ALLOCATIONS
Maximum Water Surface / Top of Surcharge Elev. 4752.0 (1,412,905 Acre - Feet)
Dam Crest Elev. 4758.0
Surcharge - 520,679 Acre - Feet
Top of Flood Control Elev. 4732.20 (892,226 Acre - Feet)
Exclusive Flood Control - 150,632 Acre - Feet
Top of Joint Use Elev. 4725.0 (741,594 Acre - Feet)
Joint Use - 144,229 Acre - Feet
Top of Active Conservation Elev. 4717.0 (597,365 Acre - Feet)
FISH
WILDLIFE
RECREATION
Active Conservation - 378,184 Acre - Feet
MUNICIPAL
POWER
INDUSTRIAL
Gated Spillway Crest Elev. 4700.0
Top of Inactive Conservation Elev. 4685.0 (219,181 Acre - Feet)
Inactive Conservation - 179,097 Acre - Feet
Outlet & Penstock Inverted Elev. 4657.0
Top of Dead Elev. 4657.00 (40,084 Acre - Feet)
Dead - 40,084 Acre - Feet
Streambed Elev. 4608.00
6-02-06
Note: Symbols represent typical reservoir uses.

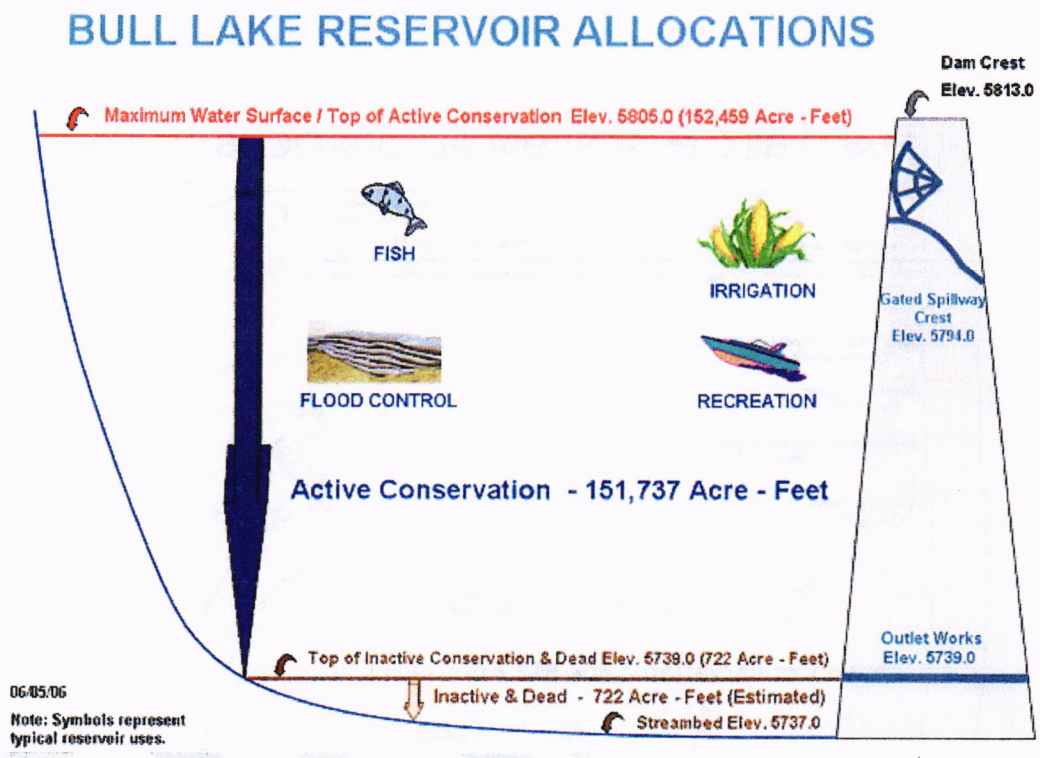
Buffalo Bill Reservoir

Buffalo Bill Reservoir was constructed by USBR between 1905 and 1910 and has several water rights with priority dates as follows: 3-5-1904 =159,00acre-feet, 9-?-1905=297,100 acre-feet, 6-?-1980=187,940 acre-feet; Total active reservoir capacity is approximately 604,817 acre-feet (due to capacity loss from sedimentation ??). Buffalo Bill's power generation capacity was upgraded in 1993 or 1994 ?



Bull Lake Reservoir

Bull Lake Reservoir was constructed by USBR with a priority date of 12-26-1906 for 151,191 acre-feet.



Bighorn Reservoir and Yellowtail Dam

Yellowtail dam was constructed in the mid-1960's and began storing water in 1967. Pertinent facts about the dam and reservoir are summarized in Table 1. (Yellowtail Dam & Bighorn Lake Water Supply & Operations Meeting, 2006). The storage project is multi-purpose and USBR coordinates with numerous entities in an attempt to meet project objectives; in a series of low-water years, the various uses given in Table 1 compete for allocation of water. Inflow to the project is generated primarily from snowmelt runoff in the Bighorn/Wind River basin, and USBR coordinates reservoir management with two other large upstream storage projects in the basin--Boysen Dam on the Wind River and Buffalo Bill Dam on the Shoshone River (Figure 1). Based on 1967 to 2005 data, USBR has estimated that about 30 % of the annual inflow to Bighorn Reservoir is from unregulated gains downstream of the Boysen and Buffalo Bill projects. Of the remaining inflow Boysen supplies about 42% and Buffalo Bill supplies 28% (Yellowtail Dam & Bighorn Lake Water Supply & Operations Meeting, 2006). The).

USBR's general operating objectives are summarized in Table 2 and Figure 2. Priority of stored allocations (e.g. uses) was not examined, but they may actually follow the order listed in Table 2. Figure 1 appears to represent reservoir storage allocations as idealized in the original design and operation plan. Bighorn Reservoir operations management (e.g. regulating outflow to store water for subsequent release and maintaining various reservoir pool elevations) is a shared responsibility of the USBR and U.S. Army Corps of Engineers (USACE).

Table 2. USBR GENERAL OPERATING OBJECTIVES: Bighorn Reservoir

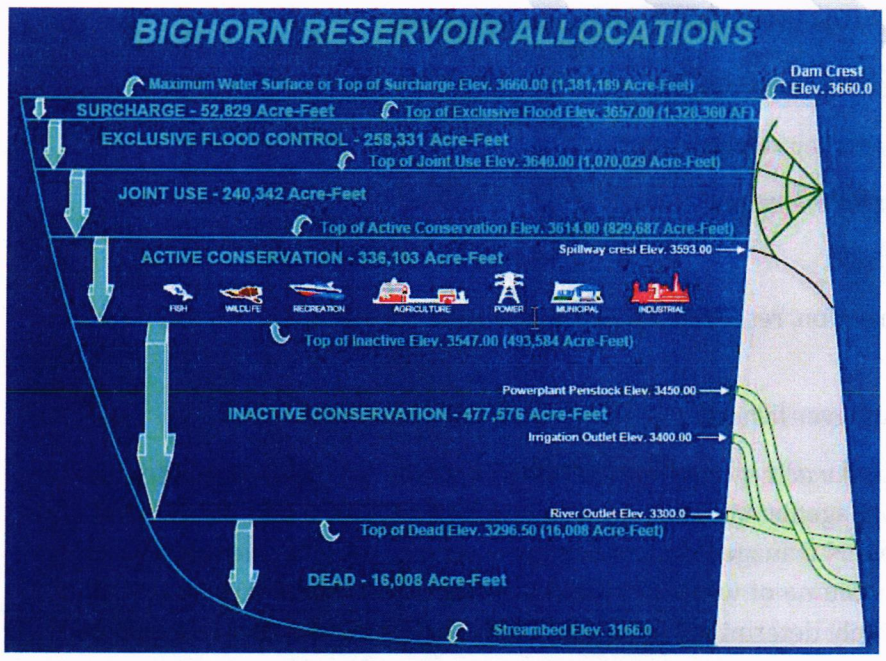
- Recognize all downstream senior water rights.
- Meet contractual commitments for stored water.
- Maintain adequate storage space for flood control.
- Maximize the power benefits.
- Maintain lake levels for recreation, reservoir fishery, and waterfowl interests.
- Maintain river flow levels for river fishery.

USBR manages water up to the top of the *active conservation* pool (elevation 3,614 ft.) At that point, USACE participates with USBR in management of the *joint use pool* (3,614 ft. to 3,640 ft.). Beyond elevation 3640.0 ft, the reservoir pool is managed exclusively for flood control. The *exclusive flood control pool* represents a dedicated volume of water (259,000 acre-feet) allocated for storage and regulation of flood water, and was likely determined by design hydrology studies of flood duration, size, and frequency. The flood control pool is managed (as to an extent, are other allocations) based on knowledge of downstream constraints (e.g. mandated or preferred maximum and minimum outflows), and forecasts of seasonal runoff. For example, if the precipitation and snowpack information from the early spring indicate the chance of certain volume of runoff within a specified period of time, then the exclusive flood control pool must be drawn down to an elevation that will store the predicted runoff. Runoff forecasts are generally tracked through the fall, winter and

spring, and the operating plan is modified by increasing or decreasing outflows to meet target reservoir pool elevations on certain dates.

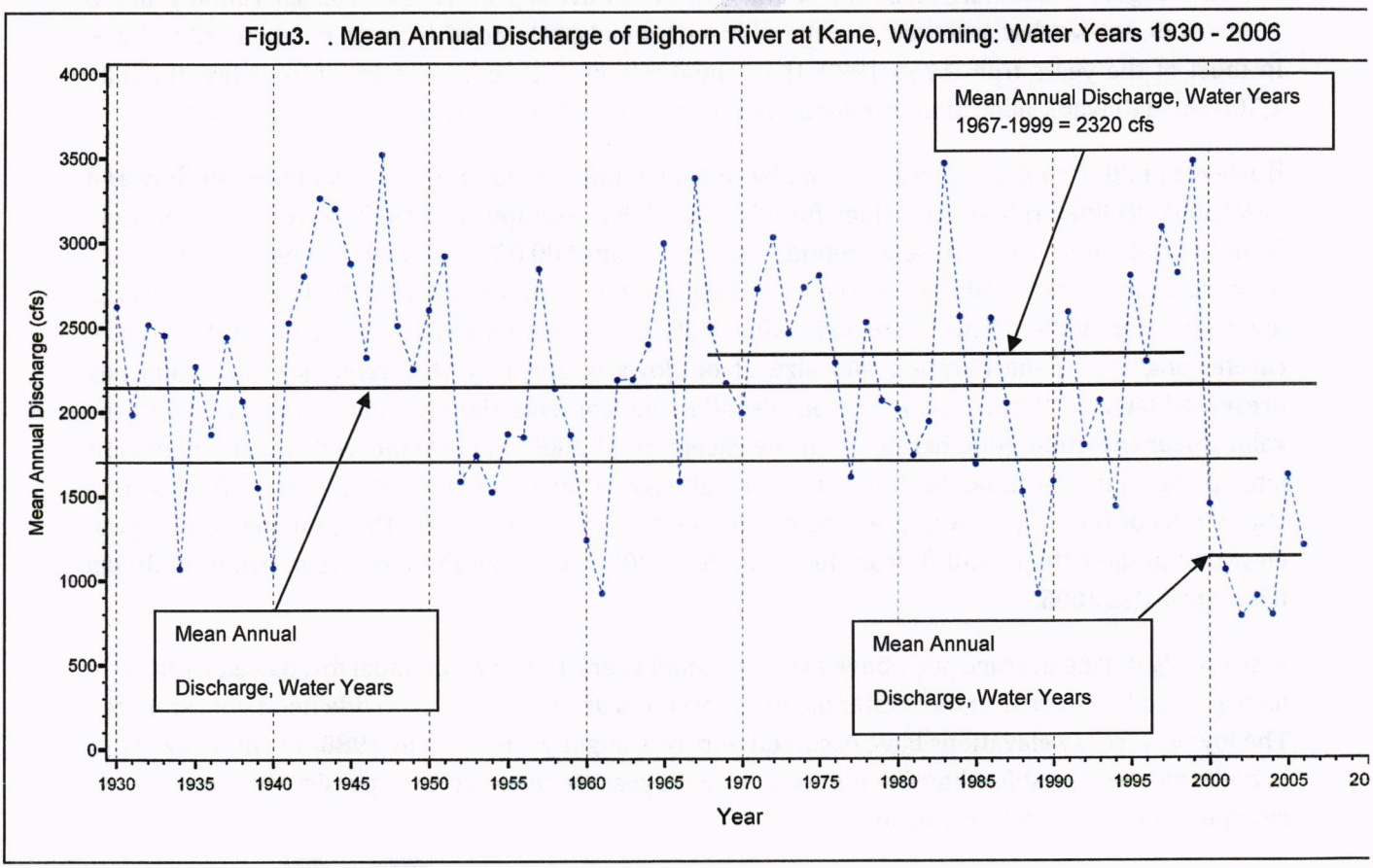
In general, it is easier meet the objectives listed in Table 2 during a series of average and above average years of runoff. This is due to the obvious reason that more water is normally better than less water, but also because the reservoir includes flood control as a primary objective, and this partially constrains the amount of carry over storage possible from year-to-year. A further complication is that regulated outflows from upstream reservoirs (primarily Boysen and Buffalo Bill) contribute roughly 70% of the inflow to Bighorn Reservoir. Each reservoir is operated with a separate set of constraints (e.g. Table 2) and associated target pool elevations and outflows, and these are modified, in part, based on forecasts of seasonal inflows. Although Boysen, Buffalo Bill and Bighorn Reservoir operations are coordinated through a joint management effort, in a series of dry years it would be difficult, if not impossible, to meet all of the established beneficial uses of stored water[3]. Another joint-reservoir management problem concerns errors in forecast inflows. Bighorn Reservoir pool levels are managed, in part, based on forecast inflows and outflows from the upstream reservoirs, and errors in these forecasts may accumulate in a downstream direction; consequently in a series of dry years it may be difficult to adjust Bighorn Reservoir operations to compensate for erroneous inflow forecasts.

Figure 2. Bighorn Reservoir Storage Allocation



Historic Bighorn Reservoir Operations

Bighorn Reservoir inflow, outflow, end-of-month contents, and forebay[4] elevation data (USBR Hydromet website, accessed [date]) were used to examine how USBR has historically operated the reservoir. Comparing general trends in inflow, outflow, contents, and elevation, over the 1966 to 2006 period, it is evident that beginning in 2000 the pattern of variation changed largely due to the onset of a persistent drought in the Bighorn drainage. This is especially evident in a graph showing long-term average annual flow of the Bighorn River at Kane, WY, which is representative of historic inflow to Bighorn Reservoir (Figure 3).



[4] Forebay elevation is the water-surface elevation of the reservoir pool measured just upstream of the dam. With the exception of spring runoff conditions, when backwater effects may increase water-surface elevation in the upstream end of the pool, forebay elevation is representative of water-surface elevation throughout the pool.

Average mean annual discharge for the 77-year period, 1930-2006 is 2,156 cfs; at the same station, average mean annual discharge for the period 1967 (when Bighorn Reservoir began significant water storage) to 1999 was 2,320 cfs. Over the most recent 6 years, 2000-2006, the average mean annual discharge was only 1,112 cfs[5], or about 47% of the 1967 to 1999 value. Water years 2000-2004 are the most persistent sequence of low annual flows that has occurred in the 77-year record.

Historic and Recent Variation:

Inflow, Outflow, Contents and Elevation

Monthly Bighorn Reservoir inflow, outflow, end-of-month contents, and forebay elevation are shown in Figure 4. Comparison of inflow and outflow for average and above average runoff years in 1966-1999, shows that reservoir storage reduced annual peak monthly flows by about 30 to 50%. In most of the years from 1966-1999, the annual inflow (Figure 3) was equal to or greater than 1,500 cfs[6] and water allocation problems were minimal--even in below average water years.

However in 2000 to 2006, there were no large annual inflows, and reservoir contents, outflow and elevations declined relative to values for 1966-1999. For example, the monthly volume of outflow from 2000 to 2006 varied closely around a value of about 100,000 acre-feet, an amount equivalent to a constant mean daily discharge of 1,680 cfs for a month[7]. [Note that this is a rough approximation and outflows were somewhat higher in spring months and in 2005-2006; a more careful analysis of the duration and size of outflows is given by the frequency curve analysis presented later in this memo). Reservoir elevation and contents show similar trends toward lower values over the 2000-2006 period, with the exception of 2005 due to improved runoff (significant late spring rain). Annual 2005 runoff, although significant relative to 2004 and 2006, was only about 75% of the 77-year average--yet, this amount was sufficient to fill the pool, maintain a pool elevation greater than 3630 ft. from June-October 2005, and maintain outflows of about 3,000 cfs from April-Dec 2005.

Historically during average and above average runoff years, the lowest annual forebay elevations have generally occurred in the winter as the reservoir is drawn down to provide flood pool storage. The lowest forebay elevations have occurred during drought years, such as 1988-89 and 2002-04; in addition, the lowest forebay elevations in drought years tend to occur, or persist, through the summer and fall recreation season.

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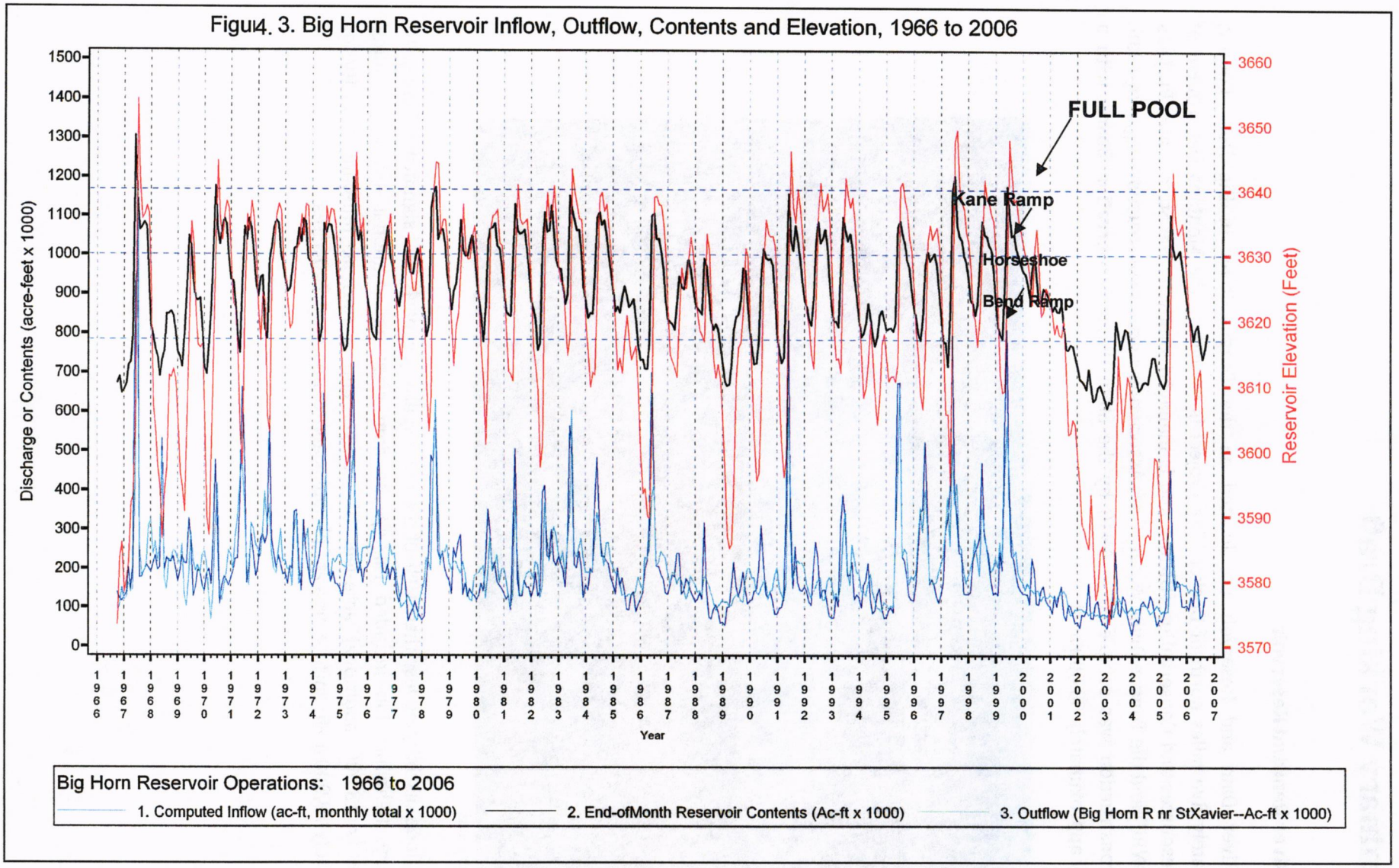
[5] Expressed as a total volume of water these values amount to 1,560,500 ac-ft; 1,679,200 ac-ft; and 804,860 ac-ft, respectively.

[6] A year-round, constant discharge of 1500 cfs is equivalent to the reservoir contents at full pool (e.g. el. 3640 ft.; 1,070,000 acre-feet).

[7] Discharge values shown in the figures are given in monthly volumes of runoff, to convert these to an average daily discharge (for a given month) in cubic feet per second (cfs), divide the monthly volume by ~59.5.


Figu4. 3. Big Horn Reservoir Inflow, Outflow, Contents and Elevation, 1966 to 2006
Discharge or Contents (acre-feet x 1000)
Reservoir Elevation (Feet)
FULL POOL
Kane Ramp
Horseshoe
Bend Ramp
Year
Big Horn Reservoir Operations: 1966 to 2006
1. Computed Inflow (ac-ft, monthly total x 1000)
2. End-ofMonth Reservoir Contents (Ac-ft x 1000)
3. Outflow (Big Horn R nr StXavier--Ac-ft x 1000)

Tongue River Dam and Reservoir

Tongue River Dam and Reservoir are located on the Tongue River in Big Horn County, approximately five miles north of Decker. The project is owned by the Montana Department of Natural Resources and Conservation (DNRC), and is managed jointly by the State Water Projects Bureau (DNRC) and the Tongue River Water Users Association since its construction began in 1938. Original construction was completed in 1940 by the State Water Conservation Board, with a capacity of approximately 68,000 ac-ft.

Tongue River Dam

In 1978, a flood discharging less than 10% of the rated spillway capacity did significant damage to the spillway. Rehabilitation included raising the dam crest an additional 4-feet, providing approximately 13,000 additional acre-feet of storage, and a normal, full-pool capacity of approximately 79,000 ac-ft; surface area at full pool is approximately 3,700 acres.

Effects of Flow Regulation

Placeholder for Kathy Chase (USGS) work on regulated and unregulated flows in Basin

Annual and seasonal flow-duration data for station 06308500 (Tongue River at Miles City, Mont.) for unregulated and regulated streamflow conditions, 1928-2002.
[Abbreviations: ft^3/s, cubic feet per second]

Streamflow condition	Streamflow, in ft^3/s, which was equaled or exceeded for indicated percent of time																
	1	2	5	10	15	20	30	40	50	60	70	80	85	90	95	98	99
	ANNUAL																
Unregulated	3880	3040	2100	1450	1120	922	667	487	339	241	181	135	110	80	41	15	0
Regulated	3430	2590	1620	1010	699	549	379	280	233	198	161	124	103	78	52	27	16
	WINTER (JANUARY-MARCH)																
Unregulated	2780	1720	930	546	428	342	255	208	180	155	133	111	95	80	61	42	33
Regulated	2800	1740	944	559	440	360	270	226	199	178	151	129	114	99	80	61	52
	SPRING (APRIL-JUNE)																
Unregulated	4730	4250	3230	2590	2140	1900	1470	1190	980	817	647	452	352	266	195	107	65
Regulated	4280	3840	2770	2050	1650	1370	978	714	552	425	327	218	183	128	63	30	19
	SUMMER (JULY-SEPTEMBER)																
Unregulated	2990	2880	1700	1250	1050	940	807	685	606	521	441	358	305	258	193	130	109
Regulated	2430	1790	1110	719	530	426	317	254	217	180	146	96	72	50	25	13	6
	FALL (OCTOBER-DECEMBER)																
Unregulated	763	642	493	368	309	268	212	170	150	120	88	51	34	18	4	0	0
Regulated	828	681	540	415	360	320	264	225	198	167	135	106	90	70	54	38	29

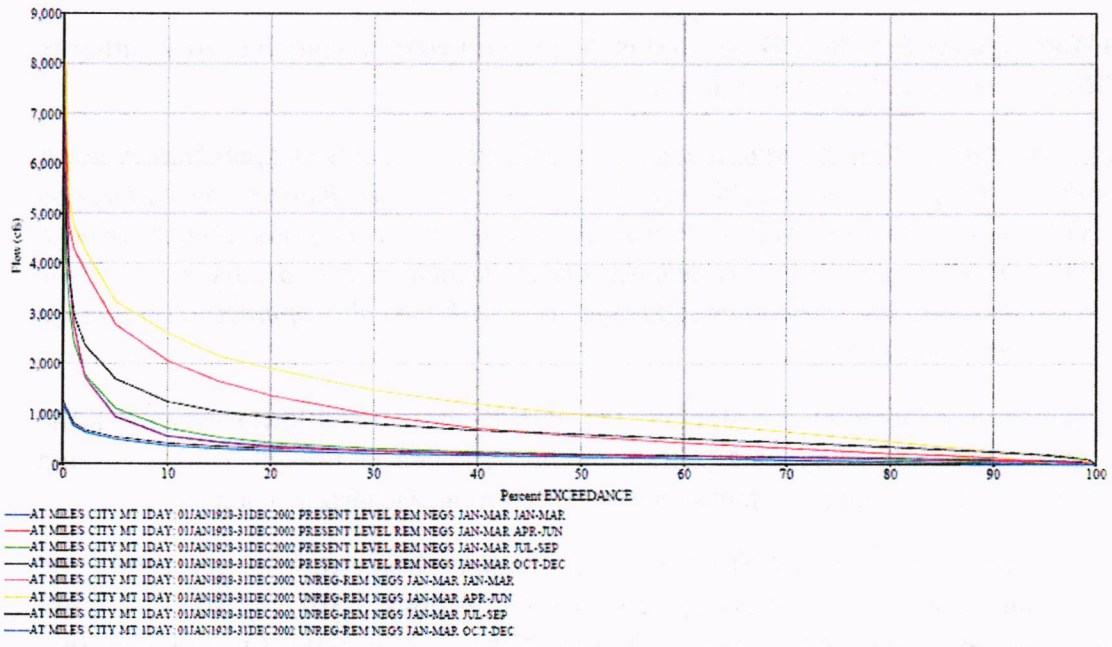


Figure 2-5-21. Annual and seasonal flow-duration data for station 06308500 (Tongue River at Miles City, Mont.) for unregulated and regulated conditions, 1928-2002.

4. Hydropower

Current Water Use

Data Gaps and Areas of Uncertainty

5. Summary of Non-Consumptive Water Use

D. Existing Water Quality Impairments in the Yellowstone Basin.

Montana Water Quality Law

Numerous laws and regulatory programs in Montana control activities to protect water quality. There are laws that regulate discharges to surface water, discharges to groundwater, streambed disturbance, mining operations, hazardous waste, underground storage tanks, septic systems, and almost every other activity that poses a threat to water quality. Most of these laws are administered by DEQ, with a handful administered by other state and local entities.

The Montana Water Quality Act (MCA §75-5-101) is the primary water pollution control authority in Montana. The Act state that it is public policy to:

> *Conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses; [and] provide a comprehensive program for the prevention, abatement, and control of water pollution; and balance the inalienable rights to pursue life's basic necessities and possess and use property in lawful ways with the policy of preventing, abating, and controlling water pollution.*

Water quality standards, adopted by the Montana Board of Environmental Review, establish the level of water quality necessary to support existing and future beneficial uses of rivers, lakes and groundwater resources. The standards establish a basis for limiting discharges of pollutants.

The 1972 federal Clean Water Act (CWA) established a national framework for protecting and improving water quality. Sections of the CWA passed in 1987, Sections 303(d) and 305(b), require states to monitor and assess statewide water quality conditions, identify and list waterbodies that fail to meet water quality standards, and prepare Water Quality Improvement Plans (WQIPs) for restoring water quality. These WQIPs must include quantitative limits, known as Total Maximum Daily Loads (TMDLs), for each of the pollutants of concern. Most of Montana's water quality impairments reflected on the 303(d) list are a result of nonpoint source (NPS) pollution.

Surface Water Quality Protection

Nonpoint water pollution comes from contaminants (originating from a variety of land-use activities over generally large areas) that are transported to streams, lakes, wetlands, and groundwater by precipitation, snowmelt, and stormwater runoff. Nonpoint pollution also comes from substances that erode directly into surface waters or from aerially transported substances deposited on land and water. Common nonpoint pollutants include sediment, nutrients (nitrogen and phosphorus), temperature changes, metals, pesticides, pathogens, and salt.

Nonpoint pollution is a significant problem in Montana, comprising the single largest cause of water quality impairment on a statewide basis. More than 75% of Montana's assessed rivers and streams and 45% of its lakes, reservoirs, and wetlands fail to meet state water quality standards largely as a result of the effects of NPS pollution (from Table 4-1, Montana Department of Environmental Quality, 2012). DEQ estimates that approximately 37% of the state's perennial river and stream miles, and 72% of the lake and reservoir acres, have been assessed.

The NPS management program is a voluntary program of land, soil and water conservation practices designed to prevent pollution from land-use activities. DEQ works with Conservation Districts, watershed groups, nonprofit organizations, local/state/federal agencies, and individual Montanans to provide training, monitoring support, and project funding. For those waters not meeting standards, total maximum daily loads (TMDLs) are developed, followed by voluntary implementation of best management practices for nonpoint sources, and potentially, point source permit waste load allocations. The TMDL program establishes the maximum amount of a pollutant that a water body may receive and still be expected to achieve applicable water quality standards. TMDLs are designed to achieve and protect designated beneficial uses. Regarding TMDL activity in the Yellowstone River Basin:

- Currently (03/20/2014), the only active TMDL projects in the Yellowstone are within the Tongue and Powder watersheds. That work is mostly involved with detailed salinity modeling to help inform future TMDL development activities, with higher priority within the Tongue and specifically within Otter Creek (tributary to the Tongue). The work in Otter Creek also involves development of an iron TMDL and removal of a sediment impairment due to a non-impairment determination jointly determined via DEQ and EPA coordination. This work is scheduled for completion in 2014.

- TMDLs have been completed for parts of the Cooke City area, the Shields River watershed, and the Boulder River. TMDL documents may be downloaded from DEQ's TMDL website: http://www.deq.mt.gov/wqinfo/tmdl/default.mcpx

- Site-specific nutrient standards for the Yellowstone River are complete or nearing completion. This will assist with future nutrient assessment updates and any resulting TMDL activity.

- DEQ is in the process of prioritizing TMDL activity for the next 2 to 5 years. The Tongue – Powder – Rosebud watersheds are currently identified as TMDL development priority areas. No other areas within the Yellowstone watershed are currently identified as a priority, but that could change and DEQ is interested in hearing from stakeholders regarding areas where there is interest in implementing the type of water quality protection activities typically recommended within a TMDL document.

Besides nonpoint pollution, there is point source pollution. Point source pollution comes from a single point, commonly thought of as an end-of-pipe discharge. DEQ maintains a point source pollution control program known as the Montana Pollutant Discharge Elimination System (MPDES), which is aimed at protecting water quality in waterbodies receiving point source discharges from sewage, industrial, or other wastes.

Other water quality protection laws include Section 310 of the Montana Stream Protection Act which requires Conservation Districts to regulate private activities that disturb the bed or banks of rivers and streams. Similarly, government activities that disturb the bed or banks of streams are regulated by the Montana Dept of Fish, Wildlife and Parks. Such activities include temporary disturbances, such as construction or maintenance activities for irrigation diversions. In addition, the Legislature provided for creation of local water quality protection districts. Such districts have limited regulatory authority, and are primarily intended to provide funding to locally monitor and plan for the protection of water quality resources of particular concern to the people within the district.

Groundwater Quality Protection

The Montana Ground Water Pollutant Control System (MGWPCS) (Chapter 17.30, subchapter 10, ARM) is a regulatory program to control all otherwise unregulated sources of groundwater pollution. Important aspects of the MGWPCS rules are groundwater quality standards, a non-degradation requirement, and a discharge permit system. A wide variety of activities are exempt from having to obtain MGWPCS permits (see 75-5-401 MCA and 17.30.1022 ARM). Discharges from the exempted activities are typically covered under other permitting programs or regulations.

Groundwater quality is also addressed in the Agricultural Chemical Ground Water Protection Act. Under this Act, DEQ is responsible for developing and enforcing groundwater quality standards for agricultural chemicals. DEQ is also charged under this Act with monitoring, promoting research, and providing public education in cooperation with universities and other state agencies. The Montana Department of Agriculture (DOA) is to develop and enforce agricultural chemical groundwater management plans aimed at preventing groundwater contamination from agricultural chemicals. Both DEQ and DOA have rules to implement their respective responsibilities under this Act.

1. Point Sources
2. Non-Point Sources

TMDLs and 303(d) listed streams

Nutrients (P and N and SPARROW results)

Salinity

3. Data Gaps and Areas of Uncertainty

E. Existing Flow Impairments in the Yellowstone Basin

1. DEQ lists
2. FWP lists
3. Data Gaps and Areas of Uncertainty

VI. Administration

A. Institutional and Legal Framework for Water Use in Montana

1. Federal Agencies with a Role in Managing Montana's Water Resources.
2. State Agencies with a Role in Managing Montana's Water Resources.
3. Local Government and Non-Governmental Organizations with a Role in Managing Montana's Water Resources

Local Government

Conservation Districts, Irrigation Districts, etc.

Non-Governmental Organizations

Local Watershed Groups

4. Water Right Basics

Montana Water Use Law

Water Use in Montana is guided by the Prior Appropriation Doctrine - that is, first in time is first in right. A person's right to a specific quantity of water is prioritized depending on when the use of water began and is limited to the amount of water that is beneficially put to use. The 1973 Montana Water Use Act significantly changed water right law in a number of ways. First, all water rights existing prior to July 1, 1973 were to be finalized through an adjudication process in state courts. Second, a permit system was established for obtaining water rights for new or additional water development. Third, a centralized record system for all water rights was established. Finally, a system was provided for public entities to reserve water for future beneficial uses or to maintain minimum stream flows.

In 1979, the Legislature modified the statutes that governed how pre-1973 water rights would be adjudicated. The law required that everyone claiming existing water rights had to submit those claims to the DNRC. More than 200,000 claims were received. Since all of the claims cannot be adjudicated at once, the claims are being decreed systematically by drainage basin. Each claim is examined by DNRC and the Montana Water Court for completeness and accuracy prior to issuance of a decree. As of 2014, all of these claims have been examined at least once. However, not all of the claims have been examined according to standards established by the Montana Supreme Court in 2005.

New water users must apply for a permit from DNRC, with certain exceptions. The permit must be applied for and be received before construction of diversion begins or water is diverted from any surface water source. The applicant must provide evidence concerning the proposed system design and operation, water availability, and the effects on existing water rights. The exceptions to the general permitting requirements have to do with the amount of water being used. Small livestock reservoirs or pits holding less than 15 acre-feet of water and located on non-perennial streams may be constructed first and applied for within 60-days of completion. A permit will then be issued. Also, no permit is required to develop a well or spring producing 35 gallons per minute (or 10-acre-feet per year) or less; however, a notice of completion must be filed on these wells to establish a water right.

Large new appropriations have to meet more stringent approval requirements. Ground water appropriations of more than 3000 acre-feet per year, except for municipal or other public water supplies or for irrigation of cropland owned and operated by the applicant, must be approved by the Legislature. Applications to appropriate 4,000 acre-feet a year and 5.5 cubic feet per second or more assume a higher burden of proof and, in addition to being a beneficial use, must be a "reasonable" use, subject to more stringent criteria.

It is also possible to change a water right to a new or different use and transfer it to another person. Changes in water rights must be approved by DRNC, with that approval dependent on the applicant proving that criteria similar to those for a new appropriation will be met. Except for very large new appropriations or changes, those criteria do not include a consideration of water quality effects.

Public entities, such as DEQ, can apply for water reservations for future uses, including maintaining a minimum instream flow for water quality dilution purposes. Such water reservations have priority as of the date a correct and complete application is received, unless special legislative provisions apply. Instream flow reservations are also subject to a statutory limit of one-half the average annual stream flow on gauged streams such as the Yellowstone River.

As water supplies become fully appropriated, there are mechanisms in the law to limit new appropriations further. Basins can be "closed" to new appropriations by the Legislature or through rulemaking by DNRC upon receipt of a petition by the current water users. The petition must show, and DNRC must determine, that there are no unappropriated waters in the source of supply, the rights of prior appropriators will be adversely affected by further appropriations, or that further uses will interfere unreasonable with other planned uses or developments for which a permit has been issued or for which water has been reserved.

The second mechanism for placing greater controls over heavily appropriated waters is through controlled groundwater areas. It is possible to close an aquifer to further appropriations or restrict or condition water allocations. Controlled groundwater areas can be created by DNRC by petition of the water users. Controlled groundwater areas may be created if groundwater withdrawals are in excess of recharge, excessive withdrawals are expected in the future because of recent consistent and significant increases in withdrawals, disputes in priority rights or amounts of use are in progress, groundwater levels are declining or have declined excessively, or if contaminant migration and degradation of groundwater quality are occurring because of excessive withdrawals.

5. Status of Adjudication in the Yellowstone Basin

Yellowstone River Adjudication Status

(Need Yellowstone Basin Map showing adjudication status)

Introduction

Adjudication is a process for resolving problems or issues with water right claims for uses that existing previous to July 1, 1973. For existing water right claims the process involves the examination of claims, the issuance of decrees, and the resolution of claim issues. When a judge hears a case and makes a decision, the matter is said to have been *adjudicated. Water rights* adjudication refers to the settling of *statements of claim* filed for water rights. Adjudication establishes all *existing water rights* in the state, and provides essential protection to all Montana water users. The adjudication process establishes the *priority date* and the amount of water claimed by users for *beneficial use.* It does not, however, provide any information regarding water supply or guarantee the availability of water.

Purpose and Need

Adjudication of Montana's water rights provides knowledge of available water resources, important to the state's growth and economic development. Montana water users are also better protected and able to defend historical usage against the increasing demands for water from downstream states. Enforcement of water rights in Montana is one way the adjudication program helps protect water users. Since 2001, the number of requests before the district courts calling for enforcement of water rights on streams has been increasing. Until the adjudication of a stream is completed by the Water Court and until all the objections are settled, water commissioners must rely on historical decrees, which are limited, to enforce water use. Water rights on streams without decrees cannot be enforced.

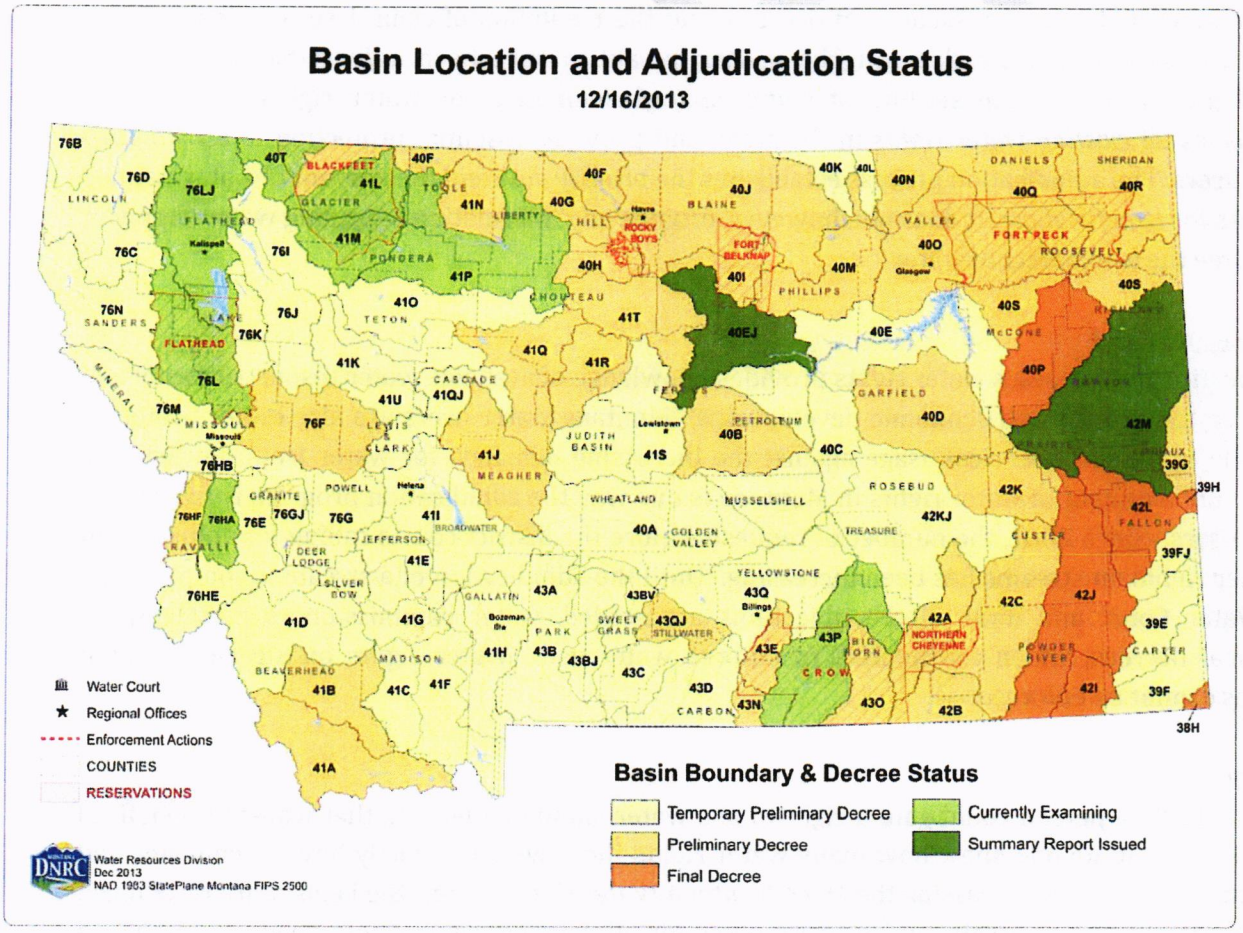
History

Prior to 1973, a person could gain a right to use water simply by putting that water to beneficial use. As a result, no one knew how many water rights there were or exactly how much water had been claimed by users. In passing the 1973 *Montana Water Use Act,* (Act) the Legislature recognized that the amounts, ownership, and priority dates for all existing water rights needed to be more clearly defined. To accomplish this, the Act required that all water rights existing prior to July 1, 1973, were to be adjudicated in state courts. The Act also established a permit system for obtaining

new water rights, and an authorization system for changing water rights. In addition, the Act established a central system for all water rights records.

In 1979, the Act was modified to establish a special court, known as the *Water Court* to adjudicate all existing water rights in a statewide proceeding. In June of 1979, the Montana Supreme Court issued an order requiring every person declaring ownership of an existing water right to file a statement of claim with the Department of Natural Resources and Conservation (DNRC) no later than January 1, 1982. The Court later extended the deadline to April 30, 1982. Existing water rights not filed by the deadline were assumed to have been abandoned. Certain stock and domestic water claims were exempt from the Court's order.

By the April 30, 1982, deadline, over 200,000 claims for existing water rights were received. Because adjudication of these claims cannot occur at once, the claims are being handled systematically for each of Montana's 85 river basins (Figure 1). The adjudication process starts with DNRC staff examining each statement of claim for completeness and accuracy according to rules established by the Montana Supreme Court. Discrepancies are then reported to the claimants and the Water Court. The reports are also made available to the public.



The water judge, with the help of a *water master*, hears and decides all objections to the filed claims. After all objections have been resolved, the water judge issues a *decree* or ruling. Once a final decree is issued, DNRC will release a Certificate of Water Right to each person decreed an existing water right. Water rights dated after July 1, 1973, are administered through the DNRC water rights permitting process and are therefore not subject to the adjudication process. By 1985, the first 20 water basins had been decreed.

The 2005 Montana Legislature passed House Bill 22 to help speed up the adjudication process. The bill called for the DNRC to evaluate the remaining 57,000 claims by June 30, 2015. As of June 2013, fewer than 4,000 claims remained for examination by the DNRC.

The Bill also set a target date for the Water Court to issue an initial degree for all basins in Montana by June 30, 2020. To assist the Water Court in meeting this target, DNRC must provide the Court summary reports on the remaining basins to be decreed. In addition, the Bill requires the Water Court and the DNRC provide progress reports to the Environmental Quality Council on a regular basis.

Adjudication Status

The first final decrees in Montana's adjudication process were issued by the Montana Water Court in 1983 in the Powder River basin. Since then, adjudication in the Yellowstone has proceeded with each of the 27 water right basins currently at various stages in the process (see Tables X and Figure X). All but one has either a final decree, preliminary decree, or a temporary preliminary decree. The remaining basin (Basin 43P - Bighorn River below Greybull River) is currently under examination meaning issue remarks are still being reconciled.

Temporary preliminary decrees are issued in basins containing federal reserved water rights where a compact has not been concluded. Such decrees contain all rights other than the reserved rights being negotiated. In these basins, a preliminary decree will be issued as a second stage and will include all rights in the temporary preliminary decree along with all the reserved water right compacts concluded in the basin. In the Yellowstone these compacts include the Crow, Northern Cheyenne, USFS, Fort Keogh and the NPS

As shown in Table X, once adjudication is complete, nearly 96,000 water rights will become legally enforceable. Combined with the 3,800 water rights currently under historic district court decrees, the Yellowstone Basin will have approximately 100,000 water rights eligible for enforcement. This means that by consent of 50 percent of the water right holders on the affected water body, a water commissioner can be hired and funded via a mill levy imposed on the affected users.

Table X: Yellowstone Adjudication Status showing basin decrees, district court decrees, and number of pre- and post-1973 claims.

BASIN	DECREE	DECREE DATE	Number of Pre-1973 Claims	Number of Post-1973 Claims	Number of water rights included in historic decrees
BELLE FOURCHE RIVER, ABOVE CHEYENNE RIVER	FINL	3/27/1984	210	27	0
BOXELDER CREEK	TEMP	2/1/1985	2451	493	0
LITTLE MISSOURI RIVER, ABOVE LITTLE BEAVER CREEK	TEMP	2/1/1985	2956	497	1
LITTLE BEAVER CREEK	TEMP	1/31/1985	976	309	0
BEAVER CREEK, TRIBUTARY TO LITTLE MISSOURI RIVER	PRLM	1/31/1985	706	397	0
LITTLE MISSOURI, BELOW LITTLE BEAVER CREEK	FINL	3/27/1984	203	29	0
ROSEBUD CREEK	PRLM	5/23/2013	1220	317	1
TONGUE RIVER, ABOVE & INCLUDING HANGING WOMAN CREEK	PRLM	2/28/2008	1349	397	18
TONGUE RIVER, BELOW HANGING WOMAN CREEK	PRLM	2/28/2008	4712	1276	18
LITTLE POWDER RIVER	FINL	5/31/1983	2273	427	6
POWDER RIVER, BELOW CLEAR CREEK	FINL	5/31/1983	8855	1617	28
YELLOWSTONE RIVER, BETWEEN TONGUE & POWDER RIVERS	PRLM	9/19/1985	1467	792	1
YELLOWSTONE RIVER, BETWEEN BIGHORN & TONGUE RIVERS	TEMP	11/14/2003	4808	1587	10
O'FALLON CREEK	FINL	4/17/1985	2751	850	0
YELLOWSTONE RIVER, BELOW POWDER RIVER	PRLM	1/24/2014	5290	3610	4
SHIELDS RIVER	TEMP	8/3/1988	3299	952	1176
YELLOWSTONE RIVER, ABOVE & INCLUDING BRIDGER CREEK	TEMP	1/16/1985	4884	3729	1317
BOULDER RIVER, TRIBUTARY TO YELLOWSTONE RIVER	TEMP	4/3/1985	817	459	43
SWEET GRASS CREEK	TEMP	12/19/1984	714	197	242
STILLWATER RIVER	TEMP	11/7/1985	1720	1752	58
CLARKS FORK YELLOWSTONE RIVER	TEMP	6/9/1993	2613	3303	829
PRYOR CREEK	PRLM	2/25/2010	631	250	0
SHOSHONE RIVER	PRLM	6/13/2013	165	63	19
LITTLE BIGHORN RIVER	PRLM	3/25/2010	1177	195	8
BIGHORN RIVER, BELOW GREYBULL RIVER			2111	724	17
YELLOWSTONE RIVER, BETWEEN CLARKS FORK YELLOWSTONE & BIGHORN RIVER	TEMP	12/29/1998	2480	7781	21
YELLOWSTONE RIVER, FROM BRIDGER CREEK TO CLARKS FORK YELLOWTONE	PRLM	7/23/1985	1071	1869	1
TOTAL			61909	33899	3818

6. Water Reservations

Yellowstone Water Reservations

Introduction

The first order to establish water reservations on any river in Montana was issued in December 1978 by DNRC. This order reserved water in the Yellowstone River Basin for municipal use, irrigation, off-stream storage, and instream flow. Tables X through X lists these reservations known collectively as the Yellowstone Water Reservations. An annual total of 716,237 acre-feet was reserved for future consumption by Montana irrigators and municipalities in the basin. The largest instream flow reservation was granted by the Board of Natural Resources for 5,578,890 acre-feet per year at Miles City. The reservations have a significant effect on the amount of water that can be appropriated through-out the Yellowstone River Basin.

Purpose and Need

In the years prior to 1974, a substantial number of applications for water use permits for drawing large amounts of water from the Yellowstone River were received by the DNRC. Many of these applications requested significant amounts of water for energy-related industrial development. Reacting to concerns that industrial water development would impair municipal, agricultural, and instream water use, the Montana Legislature passed the Water Moratorium Act of 1974, which suspended all applications for water use permits for diversions larger than 20 cfs or storage over 14,000 acre-feet in the Yellowstone Basin until March 10, 1977. During this period, the state determined the amount of water available for allocation and quantified instream flow requirements for the Yellowstone River and its tributaries. The moratorium also allowed local, state and federal agencies to assess their future water requirement and submit applications for the reservation of water.

History

The moratorium on new appropriations encouraged applicants to submit applications for reservations before November 1, 1976. Between 1973 and 1976, DNRC prepared an environmental impact statement that analyzed the effects the water reservations and increased water use would have on the basin's hydrology, geomorphology, water quality, wildlife, existing uses, recreation, and economics (DNRC final EIS, 1976). The moratorium was extended for one year in order for federal agencies to apply for off-stream storage reservations and to allow DNRC enough time to gather and analyze the data necessary for decisions on the granting of reservations.

By November 1, 1976, 30 applications for water reservations were filed with DNRC for Yellowstone River water. A total of 1,181,559 acre-feet per year was requested for irrigation. This total included thirteen requests from conservation districts, two from irrigation districts, and three from the Montana Department of State Lands. Table Z shows the conservation district water reservation balance as of December 31, 2013. Eight municipalities filed applications totaling 391,500 acre-feet per year for domestic and municipal use. Two reservations, for a total of 1,600,000 acre-feet per

		YELLOWSTONE RIVER BASIN							
		CONSERVATION DISTRICT WATER RESERVATION BALANCE							
		as of December 31, 2013							
		NO. PROJECTS	VOLUME	VOLUME	REMAINING	% VOLUME	FLOW	FLOW	REMAINING
CONSERVATION DISTRICT	SOURCE OF WATER SUPPLY	APPROVED	GRANTED (AF)	ALLOCATED (AF)	VOLUME (AF)	ALLOCATED	GRANTED (cfs)	ALLOCATED (CFS)	FLOW (CFS)
UPPER BASIN									
BIG HORN	Big Horn River	29	20,185	12,925	7,260	64.03%	144	127	17
CARBON	Yellowstone River & tribs, Clarks Fork of Yellowstone	5	22,676	1,424	21,252	6.28%	131	11	120
PARK	Yellowstone River	6	64,125	1,586	62,539	2.47%	446	12	434
STILLWATER	Yellowstone River & tribs,Stillwater River	9	16,755	1,018	15,737	6.07%	122	14	108
SWEET GRASS	Yellowstone River, Southern Tributaries	9	46,245	5,734	40,512	12.40%	363	53	310
YELLOWSTONE	Yellowstone River	15	57,963	5,999	51,964	10.35%	378	60	318
Upper Basin Subtotal		**73**	**227,949**	**28,685**	**199,264**	**12.58%**	**1,584**	**277**	**1,307**
LOWER BASIN									
CUSTER	Yellowstone River, Powder River & tribs	18	28,478	11,045	17,433	38.78%	N/A	N/A	N/A
DAWSON	Yellowstone River	14	45,855	5,525	40,330	12.05%	331	45	286
LITTLE BEAVER	O'Fallon Creek & tribs, Cabin Creek & tribs, Pennel Creek & tribs	39	12,773	1,322	11,451	10.35%	N/A	N/A	N/A
PRAIRIE	Yellowstone River, Powder River	10	68,467	5,711	62,756	8.34%	553	46	513
POWDER RIVER	Powder River	27	13,680	8,123	5,558	59.38%	N/A	N/A	N/A
RICHLAND	Yellowstone River	9	45,620	28,853	16,767	63.25%	354	167	187
ROSEBUD	Yellowstone River	14	87,003	3,754	83,249	4.31%	541	75	466
TREASURE	Yellowstone River, Bighorn River	5	18,361	1,842	16,519	10.03%	119	25	94
Lower Basin Subtotal		**136**	**320,237**	**66,175**	**254,063**	**20.66%**	**1,897**	**357**	**1,547**
Total Yellowstone		**209**	**548,186**	**94,860**	**453,326**	**17.30%**	**3,481**	**634**	**2,854**

year for multipurpose reservoir storage, were filed on the Tongue and Powder rivers by DNRC. In addition, the U.S. Bureau of Reclamation filed for a reservation totaling 729,500 acre-feet per year for three off-stream storage reservoirs on the Yellowstone River between Billings and Miles City.

Requests for major non-consumptive reservations of instream flow, the maximum being 8,206,723 acre-feet per year at Sidney, were filed by the Montana Departments of Health and Environmental Sciences (now DEQ), and Fish, Wildlife and Parks. All of the applications filed by conservation districts mentioned instream flows, although only the North Custer Conservation District's application mentioned a specific figure.

In addition to establishing amounts of water associated with each application, the Board of Natural Resources also established priorities for the use of the water. Municipal use has first priority. Upstream from the mouth of the Bighorn River, instream use has second priority and agriculture third. Below the confluence of the Bighorn and the North Dakota border, agriculture has second priority and instream flow third. Storage reservations have the lowest priority.

Since the reservations were granted two changes have been authorized. The first, authorized in September 1980, increased the reservation for the City of Billings from 41,229 acre-feet per year, with an average diversionary flow rate of 56.9 cfs, to 53,500 acre-feet, with an average diversionary flow rate of 74.0 cfs.

The second change, authorized in November 1980, was a result of a decrease in the instream reservation of the Yellowstone River above the mouth of the Bighorn River (as measured at Billings) held by the Department of Fish, Wildlife and Parks and the Department of Health and Environmental Sciences (now DEQ). The original reservation was established on the basis of the 65th percentile flow, which means that flows in excess of the reservation could be expected in 65 out of 100 years. The change reduced this reservation from the 65th to the approximately 83rd percentile. This change increased the amount of water available for the irrigation reservations.

Effects of Reservations on Senior Water Rights The reservations were made with the stipulation that all senior water rights must be met first. Currently, these senior rights are being quantified by through the water right adjudication process (see Section VI.A.5 - Status of Yellowstone Water Right Adjudication).

Table 1 - Municipal Reservations

Town	Annual Reservation (acre-feet)
Livingston	4,510
Big Timber	365
Columbus	883
Laurel	7,151
Billings	41,229
Miles City	2,889
Glendive	3,281
Broadus	605
TOTAL	60,913

Table 2 - Multipurpose/Storage Reservations

Applicant	Reservoir	Annual Reservation (acre-feet)
DNRC	Tongue River	383,000
USBR	Cedar Ridge	121,800
	Buffalo Creek	68,000
	Sunday Creek	539,000
TOTAL		1,111,800

Table 3 - Instream Flow Reservations

Location	Annual Reservation (acre-feet)
Yellowstone River at Livingston	1,879,013
Shields River near Clyde Park	35,434
Shields River at Wilsall	21,764
Big Timber Creek	28,267
West Boulder River	74,853
East Boulder River at mouth	23,146
Boulder River at Contact	137,120
Boulder River at Big Timber	195,163
Stillwater River at mouth	379,795
Yellowstone River at Billings	3,679,968
Bighorn River at mouth	2,477,987
Yellowstone River at Miles City	5,578,892
Tongue River at Wyoming state line	244,799
Tongue River at mouth	54,289
Powder River at mouth	95,201
Yellowstone River at Sidney	5,429,310

Table X - Irrigation Reservations

Reservation Holder	Annual Reservation (acre feet)	Maximum Diversion (cfs)
Park Co. Conservation District (CD)	64,125	445.9
Sweet Grass Co. CD	46,245	363.4
Stillwater Co. CD	16,755	122.1
Carbon Co. CD	22,676	130.7
Yellowstone Co. CD	57,963	378.2
Bighorn Co. CD	21,239	143.8
Treasure Co. CD	18,361	118.6
Rosebud Co. CD	94,147	540.7
North Custer Co. CD	39,375	---
Powder River Co. CD	13,680	---
Prairie Co. CD	68,467	552.7
Dawson Co. CD	45,855	330.8
Richland Co. CD	45,620	354.2
Little Beaver CD	12,773	---
Buffalo Rapids Project	11,997	16.55
Montana Dept. of State Lands (No.9931-r)	14,679	86.11
Montana Dept. of State Lands (No.9933-r)	25,889	185.2
Montana Dept. of State Lands (No.9934-r)	15,078	---
US-BLM	2,924	12.287
US-BLM	17,476	75.76
TOTAL	655,324	

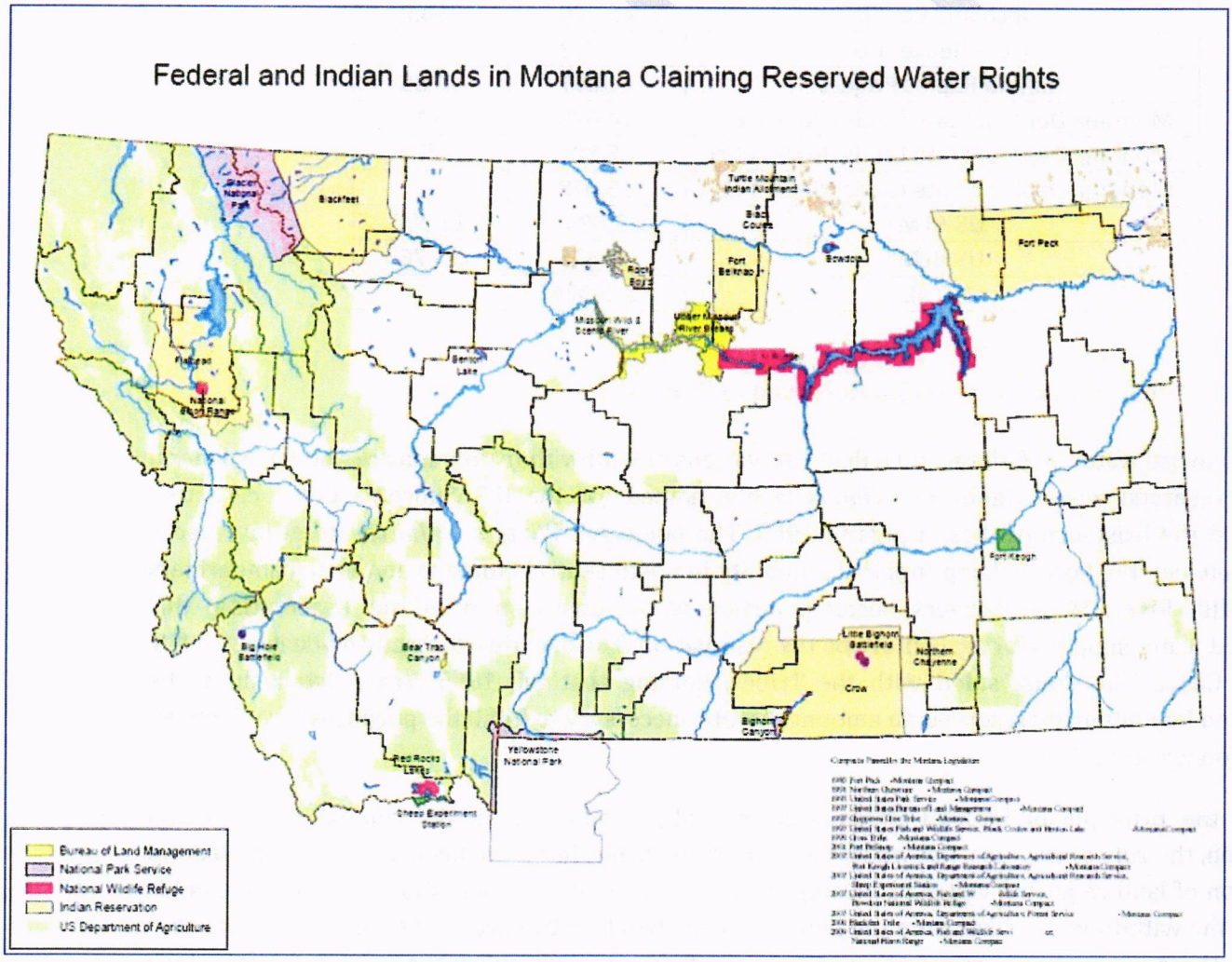
7. Federal and Tribal Reserved Water

The rights to use water on federal and tribal reservations of land within Montana are known as federal or tribal reserved water rights, or *Winters* rights, named for the U.S. Supreme Court case that established the existence of these rights in 1908. The landmark *Winters v. United States* involved a dispute between the Fort Belknap Indian Community in north central Montana and upstream farmers on the Milk River. When farmers began diverting water upstream from the Reservation, this diminished water supplies for agriculture on the reservation. The dispute eventually made it to the U.S. Supreme Court. The Court sided with the Tribes, holding that the 1855 treaty establishing the Reservation had implicitly reserved an amount of water necessary to fulfill the purposes for which the Reservation was established.

Although the principle of implied rights was originally established in the context of an Indian reservation, the rule of the case, known as the *Winters' Doctrine*, has since been applied to any federal reservation of land requiring water to accomplish the purpose of the reservation. The Doctrine holds that with the withdrawal of land from the public domain, whether by executive order, treaty, or Act of Congress, there is an implied reservation of water sufficient to accomplish the purpose(s) for which the land was reserved. Such rights have a *priority date* of the date the reservation was established.

Because the amount of water reserved is determined by the purpose(s) of the reservation, these rights are not established or determined by beneficial use, as State-based rights are. In addition federal and tribal reserved water rights cannot be abandoned through non-use.

In Montana, reserved water rights have been claimed for seven Indian reservations, for national parks, forests, monuments, and wildlife refuges, and for federally designated wild and scenic rivers. Montana's Reserved Water Rights Compact Commission (Commission) was established by the Montana Legislature in 1979 as part of the state-wide general stream adjudication. The Commission is authorized to negotiate settlements with federal agencies and Indian tribes claiming federal reserved water rights within the State of Montana. The Commission includes nine members, each serving a four-year term. Two are appointed by the Speaker of the House, two by the President of the Senate, one by the Attorney General's office and four by the Governor's office. The Commission negotiates on behalf of the Governor's Office and represents the interests of State water users. A five-member legal and technical staff, attached to the Montana Department of Natural Resources and Conservation (DNRC) for administrative purposes, supports the Commission.



The requirement to file claims with the Montana Water Court in state-wide general stream adjudication process is suspended for the tribes and the federal agencies pending the resolution of all negotiations by the Commission. This suspension ends June 30, 2015. Tribes and federal agencies for which no compact has been ratified must file their claims by that date.

Settlements negotiated by the Commission on behalf of Montana must be ratified by the Montana Legislature and the Tribal Councils and approved by the appropriate federal authorities. In some instances, approval by the U.S. Departments of Justice and the Interior are sufficient. In other cases, where federal appropriations are needed to implement provisions of the settlement, congressional approval is required. Once approved, the compacts are sent to the Water Court to be incorporated into a final decree for the basin.

Citizen participation is an essential element of each settlement negotiation. It ensures that the Commission's deliberations on behalf of Montana address the concerns of the public.

So far, there have been 17 compacts negotiated by the Commission and approved by the Legislature. The Legislature has approved compacts for six of the seven Indian reservations in Montana, as well as for five federal agencies administering federal lands in the state. The Flathead Reservation, home to the Confederated Salish and Kootenai Tribes (CSKT), is the only reservation not to have a legislatively approved compact, although the CSKT and the Compact Commission have agreed to a negotiated settlement. The CSKT have until June 30, 2015 to file their water right claims with the Water Court for inclusion in the state-wide adjudication.

Federal and Tribal Reserved Water in the Yellowstone Basin

The Compact entered into by the State of Montana and the Crow Tribe of the Crow Indian Reservation was ratified effective June 23, 1999 by the Montana Legislature. The Crow Compact recognizes water rights for the Crow Tribe in the following basins (need map):

- Basin 42A, the mainstem of Rosebud Creek and its tributaries from its headwaters to its confluence with the Yellowstone River;
- Basin 42B, the mainstem of the Tongue River and its tributaries from the Montana-Wyoming border to above and including Hanging Woman Creek;
- Basin 42KJ, the mainstem of the Yellowstone River and its tributaries between Bighorn River and Tongue River;
- Basin 43D, the mainstem of the Clarks Fork Yellowstone River and its tributaries from the Montana-Wyoming border to its confluence with the Yellowstone River;
- Basin 43E, the mainstem of Pryor Creek and its tributaries from its headwaters to its confluence with the Yellowstone River;
- Basin 43N, the mainstem of the Shoshone River and its tributaries within Montana;
- Basin 43O, the mainstem of the Little Bighorn River and its tributaries from the Montana-Wyoming border to its confluence with the Bighorn River;
- Basin 43P, the mainstem of the Bighorn River, below Greybull River, and its tributaries (exclusive of the Little Bighorn River and its tributaries) within Montana to its confluence with the Yellowstone River; and

- Basin 43Q, the mainstem of the Yellowstone River and its tributaries between Clarks Fork Yellowstone River and Bighorn River.

Article III of the Crow Compact provides the key water rights provisions:

The Tribe has a quantified water right of 500,000 Acre Feet per Year (AFY) to the natural flow of the Bighorn River (Basin 43P) and its tributaries, and groundwater for tribal uses, with a Tribal priority date of May 7, 1868, but agrees to share shortages in natural flow with all water rights recognized under state law with a priority date before the June 22, 1999.

The Tribe is entitled to an allocation of 300,000 AFY of water stored in Bighorn Lake. Of the storage allocation, 150,000 AFY may be put to use in addition to the natural flow right (including 50,000 AFY that may be used outside the Reservation) and 150,000 AFY may be used only to supplement natural flow in times of natural flow shortage.

The Tribe has rights to all surface flow, groundwater and storage in the other eight basins on the Reservation (43O, 43E, 42A, 42B, 42KJ, 43D, 43N, 43Q) with a Tribal priority date of May 7, 1868, but agrees to share shortages in natural flow with all water rights recognized under state law with a priority date before the June 22, 1999 ratification by the Montana Legislature of the Crow Compact.

The Tribe may use 47,000 AFY on the Ceded Strip with a Tribal priority date of May 7, 1868, but agrees to share shortages in natural flow with all water rights recognized under state law with a priority date before the June 22, 1999 ratification by the Montana Legislature of the Crow Compact. Authorized uses include all current uses of the Tribal water right and future uses as limited by the Compact.

The Tribe agrees that any future uses of the Tribal water right cannot adversely affect valid state-based water rights and uses of the Tribal water right in existence before June 22, 1999.

All basins that include the Tribal water right are closed to the issuance of new water rights permits under state law after June 22, 1999.

The parties agree to create a stream flow and lake level management plan for the Bighorn River, from the Yellowtail Afterbay Dam to a point immediately upstream of the Two Leggins diversion, and for Bighorn Lake.

The State will administer all water rights recognized under state law and the Tribe will administer the Tribal water right through a water code adopted by the Tribe and approved by the Secretary of the Interior. A Crow–Montana Compact Board has jurisdiction to resolve disputes between the Tribal water right and water rights recognized under state law.

Northern Cheyenne Water Rights Compact

The Compact entered into by the state of Montana and the Northern Cheyenne tribe of the Northern Cheyenne Indian reservation was ratified effective May 20, 1991. The Compact settles for all time, any and all existing claims of or on behalf of the Northern Cheyenne Tribe to water within the State of Montana. In general, the Northern Cheyenne Compact provides water as follows (need map):

- Existing Non-Agricultural Uses.
    - Tribal and individual Indian stockwater, domestic and municipal water uses on the Reservation and in existence as of the ratification date are recognized and protected as part of the Tribal Water Right,
- Tongue River. The Tribal Water Right in the Tongue River basin consists of the right to divert or use or to permit the diversion or use of up to 32,500 acre-feet per year, from a combination of direct flow, storage, and exchange water.
    - Direct Flow Right: The Tribe has a right to divert or use or permit the diversion or use of up to 12,500 acre-feet of water per year from direct flow of the Tongue River and its tributaries with a priority date of October 1, 1881; provided, that:
        - The Tribe's annual depletion of its direct flow water right in the Tongue River and its tributaries will not exceed 75 percent of the amount diverted, or 9,375 acre-feet per year; and
        - The Tribe's direct flow water right in the Tongue River and its tributaries may not be used in a manner that adversely affects:
            - Miles City Decree water rights, or
            - Water rights from off-Reservation tributaries of the Tongue River, with a priority date of June 30, 1973 or earlier and are based on the use of an irrigation system in place and not abandoned as of June 30, 1973.
    - Storage and Exchange Water. The Tribe has a right to divert or deplete, or permit the diversion or depletion of, up to 20,000 acre-feet per year from a combination of water stored in the Tongue River Reservoir and exchange water. The availability of the 20,000 acre-feet per year depends, as provided in the Tongue River Water Model, upon the annual schedule utilized by the Tribe for diversions of Tongue River direct flows.
- Rosebud Creek.
    - Water Right. The Tribe has a right to divert or use or to permit the diversion or use from Rosebud Creek and its tributaries, for agricultural purposes only, of 1,800 acre-feet of water per year, or enough water to irrigate 600 acres of land per year, whichever is less, with a priority date of October 1, 1881.

- Additional Water Right. The Tribe has a right to divert or use or permit the diversion or use from Rosebud Creek and its tributaries, for any purpose, of up to 19,530 acre-feet of water per year, or enough water to irrigate 6,510 acres of land per year, whichever is less, with a priority date of October 1, 1881.

- Moratorium on the issuance of permits in the Rosebud Creek basin concurrent with the ratification date of the Compact.

- Groundwater.

  - Alluvial Groundwater. The Tribe has a right to withdraw and use, or permit the withdrawal and use of, alluvial groundwater in lieu of surface water diversions of the Tongue River and Rosebud Creek Tribal Water Right, subject to the same terms and conditions of this Compact that apply to such surface water diversions.

  - Non-alluvial Groundwater. Except where a Tribal right to non-alluvial groundwater is established pursuant to Article VII.B. of this Compact, Tribal use or authorization of use of non-alluvial groundwater will, at the election of the Tribe, comply with state law.

- Stockwater Impoundments.

  - The Tribe may construct, or permit the construction of stockwater impoundments on the Reservation, where the capacity of the impoundment is less than 15 acre-feet

- Subirrigation.

  - The Tribe is entitled to take advantage of any natural subirrigation occurring on the Reservation.

- Big Horn Reservoir (Yellowtail) Storage.

  - Tribal Allocation. As a part of the Tribal Water Right, the Secretary of the Interior will allocate 30,000 acre-feet per year of stored water in Bighorn Reservoir

ADMINISTRATION

- Except as otherwise provided in this Compact, the use of the Tribal Water Right will be administered by the Tribe. Administration and enforcement of the Tribal Water Right will be pursuant to a water code, which shall be developed and adopted by the Tribe (code completed in 1999).

- Any use of the Tribal Water Right involving a point of diversion or place of use located off the Reservation will be considered an off-Reservation use; provided, that releases or diversions from Big Horn Reservoir or Tongue River Reservoir for use on the Reservation will not be considered off-Reservation uses.

- The State will administer all rights to the use of surface water and groundwater within the Reservation which are not a part of the Tribal Water Right.

OPERATION OF TONGUE RIVER RESERVOIR

- To provide for Tongue River Reservoir operation procedures that are consistent with the purposes of this Compact, a reservoir operation plan will be developed by a five-member advisory committee. The committee will have representatives from the State of Montana, the Tongue River Water Users Association, the Northern Cheyenne Tribe, the United States, and a fifth member to be selected by the other four. The advisory committee will annually agree upon a reservoir operation schedule setting forth proposed uses of storage and direct flow for the year.

ESTABLISHMENT OF THE NORTHERN CHEYENNE - MONTANA COMPACT BOARD

- The Board will consist of three members: one member appointed by the Governor of the State of Montana; one member appointed by the Northern Cheyenne Tribal Council; and one member selected by the other two members.
- The Northern Cheyenne-Montana Compact Board will have jurisdiction to resolve controversies over the right to the use of water between users of the Tribal Water Right on the one hand and users of state water rights on the other hand.

CONTRIBUTIONS TO SETTLEMENT

- The United States agreed to provide $31,500,000 to repair the Tongue River Dam and spillway and to raise the Tongue River Dam spillway crest.
- The State agreed to provide $16,500,000 to repair the Tongue River Dam and spillway.
- The United States agreed to provide $10,000,000 for a Tribal Development Fund.

Fort Keogh Compact

The United States Department of Agriculture Fort Keogh Livestock and Range Research Laboratory - Montana Compact (Compact) recognizes federal reserved rights for the Fort Keogh Livestock and Range Research Laboratory located in Water Court Basins 42C and 42KJ near Miles City, Montana for existing and future irrigation, stock, and administrative uses and emergency fire suppression.

The Compact quantifies federal reserved water rights for the Fort Keogh Livestock and Range Research Laboratory from the Yellowstone and Tongue Rivers and seeps, naturally-occurring surface flows and groundwater sources arising inside the boundaries of the Fort Keogh Livestock and Range Research Laboratory.

The Compact recognizes federal reserved water rights within the United States Fort Keogh Livestock and Range Research Laboratory lands:

- to withdraw or divert 58 cubic feet per second up to 6,092 acre feet from the Yellowstone River in Water Court Basin 42KJ for current irrigation use on 1,523 acres.
- to withdraw or divert by water spreading on Reservation Creek, a tributary of the Yellowstone River, in Water Court Basin 42KJ for current irrigation use on 450 acres.

- to withdraw or divert by water spreading on an unnamed tributary of the Tongue River in Water Court Basin 42C for current irrigation use on 203 acres.
- to withdraw or divert water up to a total additional flow of 23 cubic feet per second from the Yellowstone River, a tributary, or groundwater in Water Court Basin 42KJ for future irrigation use on an additional 620 acres.
- for consumptive use for stockwatering purposes from the sources, at the volumes and for use at the locations identified in Compact Appendix 5, provided that the total current Stock Use shall not exceed the historic maximum of 3,000 Animal Units (an Animal Unit is a cow-calf pair or other equivalent).
- In addition to the current Stock Use, for consumptive use for stockwatering purposes at the same locations and the same volume of water as described above for future stock use not to exceed an additional 2,000 Animal Units.
- for current administrative uses totaling 26.70 Acre-Feet per year.
- for future administrative uses up to a total additional volume of 18 Acre-Feet per year.

The priority date for these rights shall be April 15, 1924.

U.S. Dept. of Agriculture, Forest Service Compact

INTRODUCTION

Since 1992, the Montana Reserved Water Rights Compact Commission (RWRCC) and the United States Department of Agriculture, Forest Service (Forest Service) have been in active negotiations concerning federal reserved water rights on National Forest System lands in Montana. In the fall of 2005, the RWRCC and the Forest Service hired a mediator to assist with the negotiations and have reached a settlement (Compact) to present to the Legislature. The Yellowstone River Basin in Montana comprises portions of the Custer and Gallatin National Forests.

BACKGROUND

In general, the Compact recognizes reserved water rights for the Forest Service for administrative and emergency fire fighting uses and instream flows for the South Fork Flathead Wild and Scenic River. To resolve major differences between the negotiating parties concerning the existence, nature and extent of any possible reserved water rights for instream flows under federal law, the proposed Compact uses state law to create numerous state-based water rights for instream flow on National Forest System lands and to set up a process for applying for additional instream flows under state law. Below is a summary of what the proposed Compact does.

Federal Reserved Water Rights.

- Recognizes a reserved water right to divert water for the Forest Service for administrative uses (such as for ranger stations, pack stock, road watering) and for emergency fire suppression. Priority date is date of the creation of the National Forest or as specified.

- Recognizes an instream flow right for the South Fork Flathead Wild and Scenic River. Priority date is October 12, 1976, the date this river was designated by Congress.

Instream Flows under State Law.

- Creates, in the Compact, instream flow water rights under state law for 77 streams and one in-place water right for a fen (wetland) all located on National Forest System lands. All of these water rights will have a priority date of 2007.

- Establishes a process that the Forest Service may use in the future to apply for additional instream flows under state law on other streams throughout the National Forest System lands in Montana. Priority date will be the date of application.

- In exchange for water rights created and the means of acquiring instream flows under state law, the Forest Service will withdraw forever all of its existing or possible claims for reserved water rights for instream flows in the ongoing water adjudication.

  As part of the overall agreement, the parties have agreed to seek changes to state law that:

- Continues the ability of the Forest Service to object in the Water Court to any water right claim on or crossing National Forest System lands that adversely affects Forest Service interests.

- Coordinates state and federal permitting processes.

- Allows a change of use from an appropriation to divert or withdraw water on land owned by the Forest Service above or immediately adjacent to the National Forest boundary to an instream flow. This is primarily intended to allow the Forest Service to change irrigation and other rights to instream flow on land that it might acquire in the future.

  This Compact settles all federal reserved water rights of the Forest Service. The Forest Service has other water use claims based on state law that are in the adjudication process and are not part of this agreement (for example, campgrounds are not "specific purposes" for which forest service land was originally reserved).

8. Interstate Compacts and International Treaties,

Description

Yellowstone River Compact

This compact divides unused and unappropriated waters of the interstate tributaries (Clarks Fork of the Yellowstone River, Tongue River, Powder River and Bighorn River) of the Yellowstone River as of January 1, 1950, between Wyoming and Montana. According to the compact, Wyoming and Montana are entitled to the following percentages of *surplus flow* after January 1, 1950 as shown in Table X:

Table X: Percent of surplus flow allocated to Montana and Wyoming by the Yellowstone River Compact

Tributary	Wyoming (percent)	Montana (percent)
Clarks Fork	60	40
Bighorn	80	20
Tongue	40	60
Powder	42	58

Surplus flow is determined on an annual water year basis measured from October 1 of any year through September 30 of the following year. The quantity of water to which the percentage factors (shown in Table X above) shall be applied through a given date in any water year shall be, in acre-feet, equal to the algebraic sum of:

1. The total diversion of irrigation, municipal, and industrial uses developed after January 1, 1950, and above the point of measurement during the period from October 1 to that given date;
2. The net change in reservoir storage in all reservoirs above the point of measurement completed subsequent to January 1, 1950, during the period from October 1 to that given date;
3. The change in storage in existing reservoirs above the point of measurement, which is used for irrigation, municipal, and industrial purposes developed after January 1, 1950, during the period October 1 to that given date;
4. The quantity of water that passed the point of measurement during the period from October 1 to that given date.

(In all cases, the point of measurement is located at the confluence of the interstate tributaries and the Yellowstone River.)

Supplemental water for holders of water rights prior to January 1, 1950, also is subtracted from the tributary flows to determine surplus flows. Supplemental water is defined as that quantity of unused and unappropriated water necessary to fully satisfy the water requirements of pre-1950 water rights in both states and, therefore, cannot be allocated between states in the apportionment.

Wyoming has independently estimated its share of the surplus flow from the four tributaries. However, Montana does not necessarily agree with these estimates. It is obvious that some of the present flow in the tributaries specified in the compact may not be available to Montana in the future

because Wyoming will someday attempt to appropriate a greater share. Wyoming's share of the water in the Yellowstone Basin, as defined in terms of the Yellowstone River Compact, has not been quantified and is pending outcome of litigation currently in progress. The central issue being litigated is.... A decision is expected in 2014...

9. Water Quality Laws

Surface Water

Groundwater

DRAFT

VII. Potential Future Demands for Water in the Yellowstone Basin

1. **Results of Past Efforts to Estimate Future Demand**
2. **Overview of Planning Scenarios (assumptions, time horizon, etc.)**
3. **Agricultural Demand Projections**
4. **Municipal and Domestic Demand Projections**
5. **Industrial Demand Projections**
6. **Recreational Demand Projections**
7. **Environmental Demand Projections**
8. **Identification of Potential New and Expanded Water Uses Unallocated Water to Meet Future Demand** *(Hydro - legal water availability analysis per Tim D.)*
9. **Availability of Water Supply Development Under Interstate Compacts, Decrees, Tribal Water Compacts, Federal Reserved Water Rights, and International Treaty's,** *(Impact of full development, Compact, Treaty , and Reserved water rights)This would be a smaller section in which issues would be considered and dismissed section would reference data presented under Part IV administration.*

   Surface Water

   Groundwater

   Data Gaps and Areas of Uncertainty

10. **Effects of New or Increased Depletions on the Availability of Future Surface Water Supplies.**

11. Effects of prolonged drought and climate variability on the availability of future surface water supplies.

Effects of Drought on Future Water Supply

As Montana's population continues to grow, water usage and demand for water will increase. Available supplies have also increased over the years through a variety of structural (dams) and non-structural (conservation) means, but the ability to create new levels of supply in the Yellowstone Basin is limited; consequently much of Montana is at high risk from the effects of drought.

Figure 3.3.9-6 Hazard Risk Map: Drought

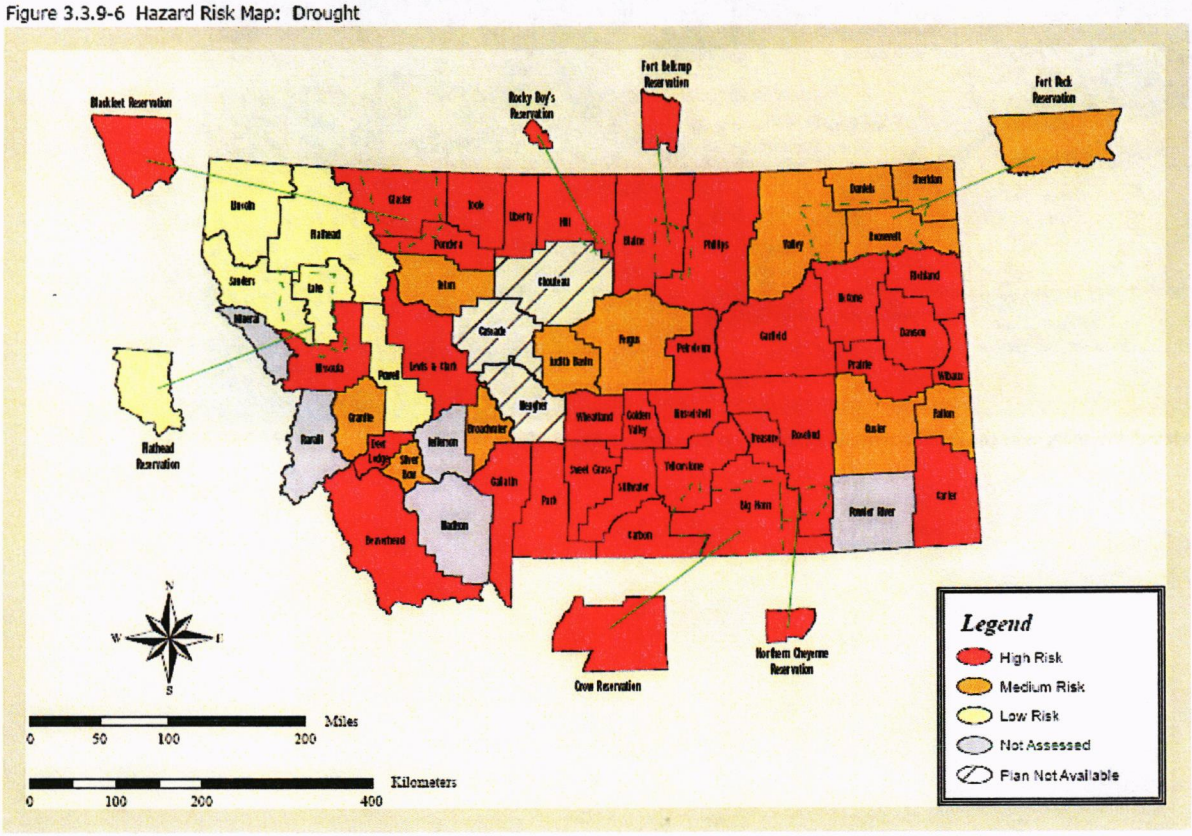
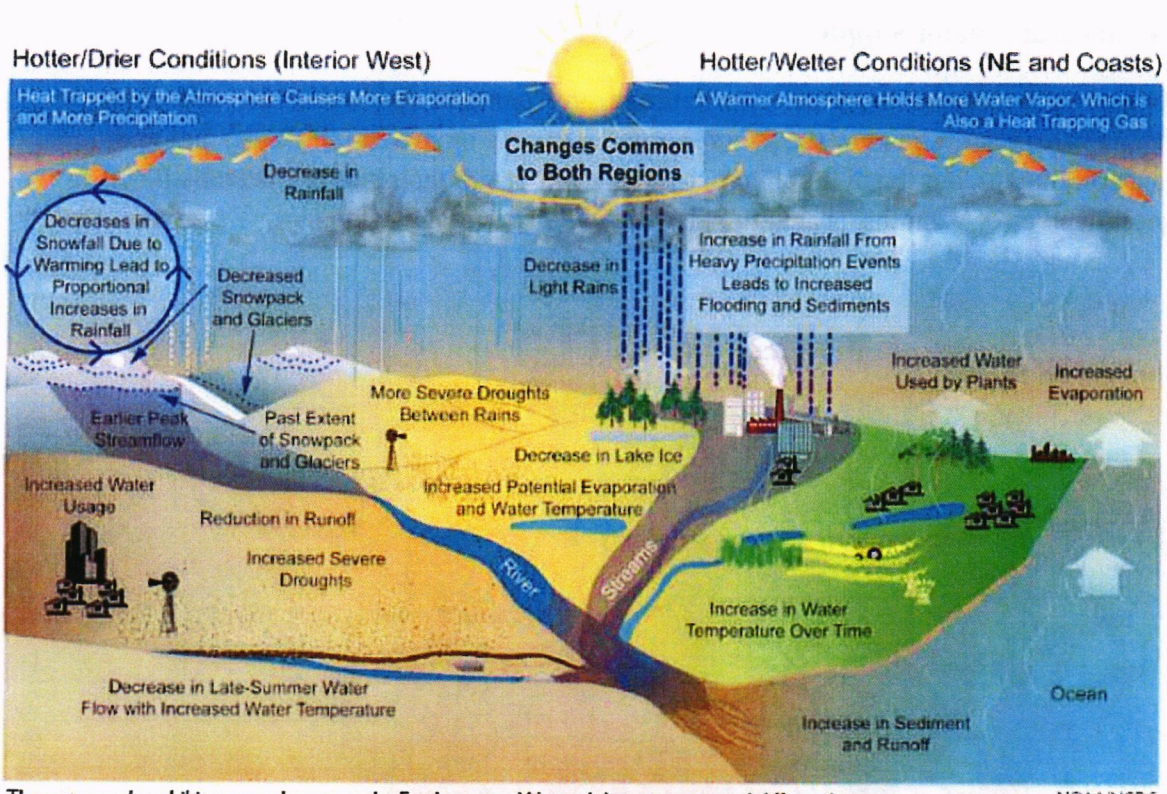


Figure 18. Montana map of relative risk from drought. Most counties in the Yellowstone Basin are at High Risk for drought conditions.

Projected Changes in the Water Cycle



The water cycle exhibits many changes as the Earth warms. Wet and dry areas respond differently. NOAA/NCDC

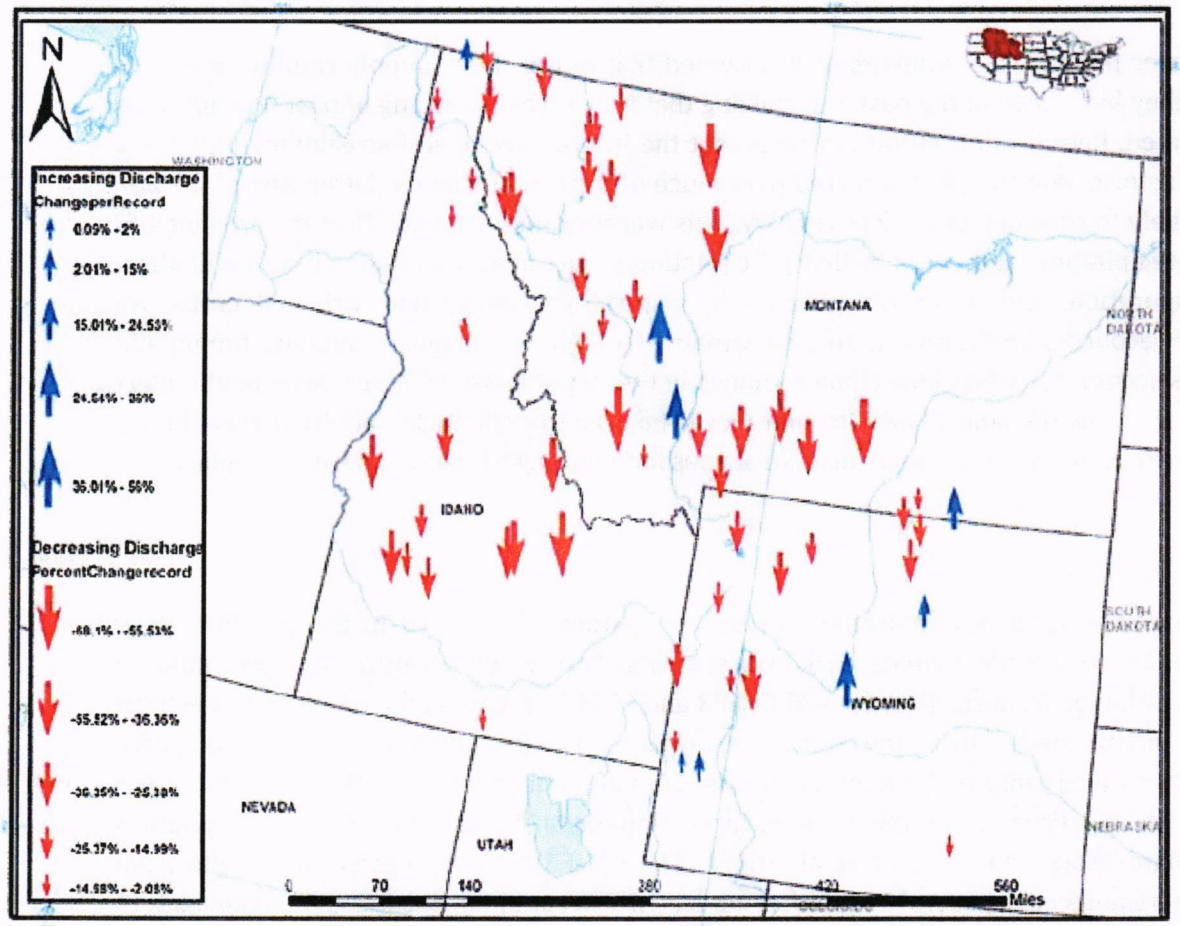


Fig. 5 Amount and type of normalized discharge change per record across the Central Rockies. The downward pointing red arrows signify a decreasing slope and the upward pointing blue arrows signify an increasing slope. The Larger the arrow the larger the discharge change at each gauging station. This figure shows a decreasing trend across the study area with very few positive slopes

PLACEHOLDER—WORK IN PROGRESS---I have inserted Larry Dolan's climate change modeling as a place holder since the Yellowstone version will be nearly identical except with data for Billings, Bighorn and Miles City.

Yellowstone River Basin: Potential Effects of Climate Change on Future Water Supplies and Demands

Introduction

Traditionally, water planning assessments have assumed that future water supply conditions will be similar to what they have been in the past, recognizing that the exact sequencing of past flow patterns will not be repeated. Recent information indicates that the future envelope of streamflow variability will differ from historic. Warming has occurred over much of the U.S. during the latter part of the 20th century and is likely to continue in the 21st century. This warming, in turn, will affect the amount and distribution of precipitation, and whether that precipitation occurs as rain or snow. It also will affect the rate of evaporation, and evapotranspiration by natural vegetation and irrigated crops. An important water-resources implication is that streamflow is likely to change, in amount, timing and distribution. This section discusses how climate change in the Upper Missouri River Basin might affect future water supplies and demands. This information can be used to evaluate the ability to meet future water demands within the basin and to identify strategies for adapting to changing water supplies.

Methods

The general procedures used in this section are similar to those descri-bed in the U.S. Bureau of Reclamation (2011) West-Wide Climate Risk Assessments. Future temperature and precipitation projections were obtained from the Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections archive site maintained by the U.S. Bureau of Reclamation at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/. The root climate data sources for this archive are the World Climate Research Program Coupled Model Intercomparison Project3 (WCRP CMIP3) phase 3 multi-model climate projections (Meehl et al. 2007). The CMIP3 dataset consists of results from coupled atmosphere and ocean general circulation models, which simulate global climate responses to future greenhouse gas (primarily carbon dioxide) emissions. A range of modeled scenarios were available, based on how potential green house gas emission rates and atmospheric concentrations might vary with global technological and economic developments during the 21st Century. In total, 112 climate projections, based on projections by 16 different CMIP3 models, were downloaded and used for this analysis. The CMIP3 and CMIP5 Climate and Hydrology Projections archive site contains global-scale, climate projections, statistically down-scaled to a 12-kilometer (km) square grid (1/8° latitude by 1/8° longitude), which were used because raw CMIP3 dataset and climate models projections are too coarse for basin-scale water resources planning.

Hydrology projections also were downloaded from the same Reclamation Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections archive website, for the same 112 CMIP3 projections. The projections were developed using the University of Washington Variable Infiltration Capacity (VIC) hydrology model (Liang et al. 1994; Liang et al. 1996; Nijssen et al. 1997) to translate climate data to streamflow runoff; the VIC model also produces evapotranspiration and snow water equivalent output data. Input data to the VIC model is spatially downscaled precipitation, temperature, and wind speed data. Output includes runoff (both surface and subsurface runoff), evapotranspiration, and snow water equivalents over a grid corresponding to the watershed selected. The model solves the water balance

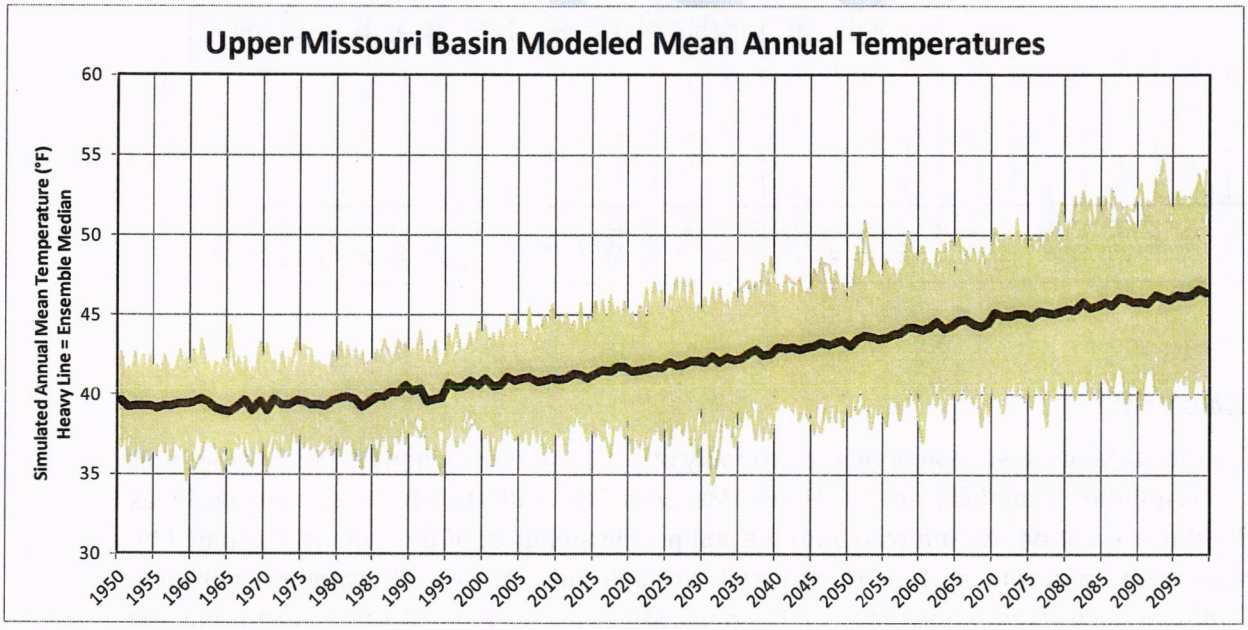
for each grid cell, and then the gridded runoff is linked and hydraulically routed to a watershed outflow point.

The 112 downscaled CMIP3 temperature, precipitation, and hydrologic projections were obtained from the Reclamation website for the 1950-2099 period. Because the period for this State Water Plan cycle is 20 years, discussions here will focus on comparing model results that are representative of the recent past (1950-1999) to those for a look-ahead period centered on the year 2035 (years 2010-2059).

Temperature

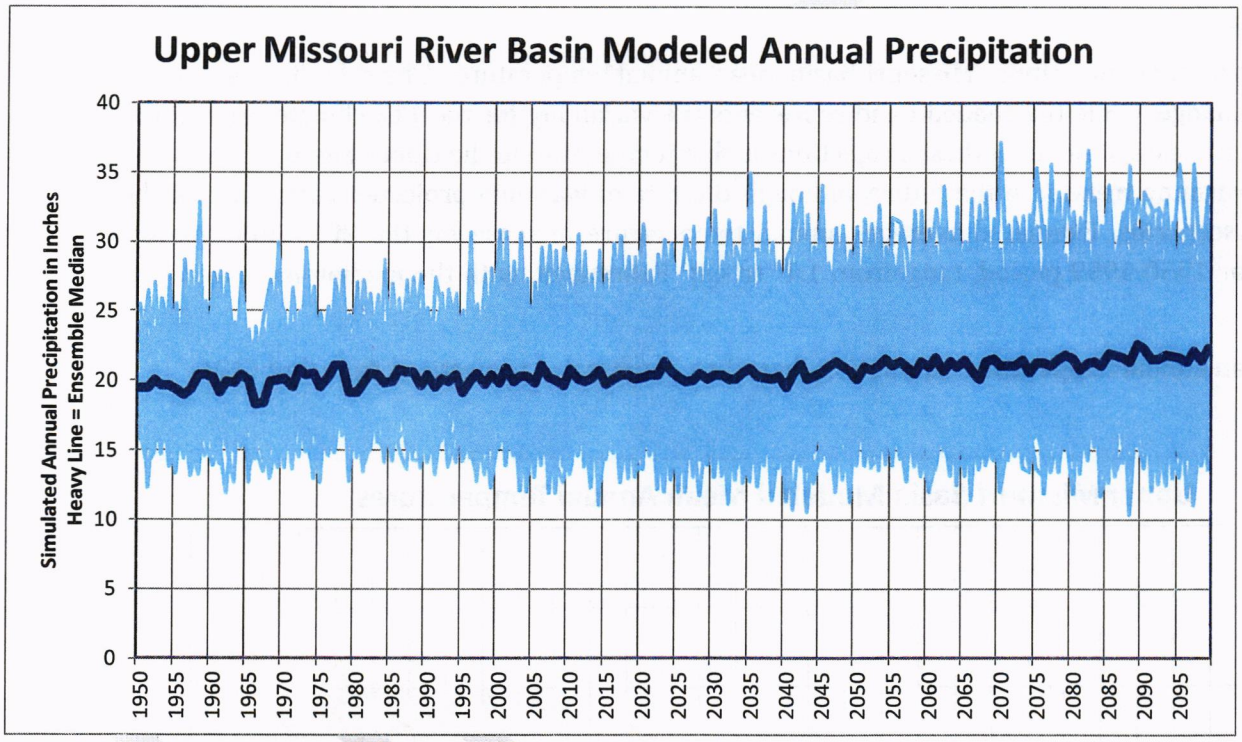
Figure 1 graphs simulated Upper Missouri Basin mean-annual temperature-. The solid line represents the median change, while the shaded band represents the variability for the 112 climate projections. The consensus message for all of these projections is that temperaturein the Upper Missouri Basin will continue a warming trend into the future, although the rate of warming projected varies among the models and scenarios. Estimated average- annual temperature increase for the 2010-2059 period, over those for 1950-1999 period, rangefrom 1.1° to 4.8° Fahrenheit, with the median increase being 2.8°.

Figure 1. Mean annual temperature simulations based on downscaled projections from 112 GCM models.



The projections for precipitation are more variable, with scenario trends varying from slightly wetter to slightly drier, with most depicting a small wetting trend, but possibly increased variability over time (Figure 2). For the Upper Missouri Basin, the maximum projected increase for the 2010-3059 period relative to the 1950-1999 period was 4.6 inches (22.8%) and the minimum was for a decrease of 1.1 inches (5.5%), with a median projected increase of 0.5 inches (2.4%).

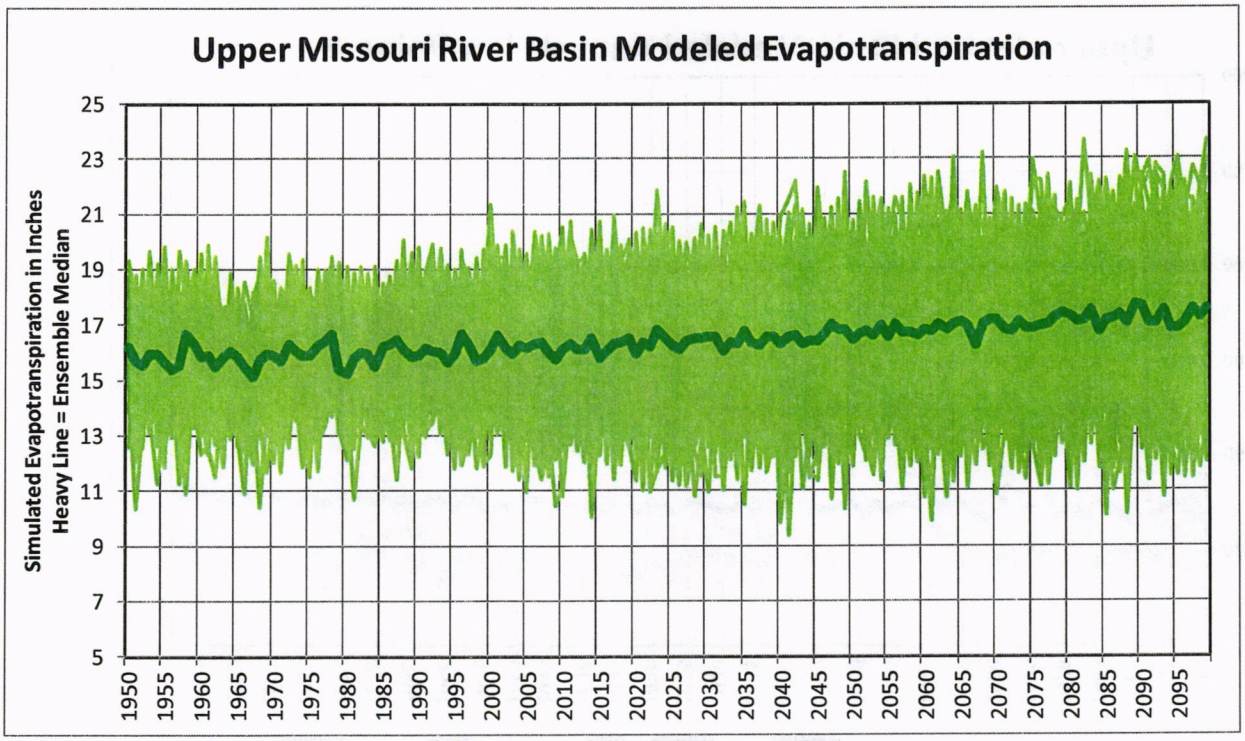
Figure 2. Annual precipitation simulations for the Upper Missouri Basin based on downscaled projections from 112 GCM models.



Evapotranspiration (ET)

As described in the Streamflow section of this report, only about 18 percent (about 3.5 inches/per unit area) of the precipitation that falls on the Upper Missouri Basin ultimately leaves the basin as streamflow. Most precipitation will infiltrate into the soil profile and most of this will be consumed by plants or evaporated from the surface of the soil through the process of evapotranspiration. Evapotranspiration is projected to increase under most scenarios as temperatures warm and the growing season increases, although some of the modeled scenarios show an ET decrease due to projected drier conditions. Figure 3 depicts modeled ET by natural vegetation in the Upper Missouri Basin for the 1950-2099 period. ET is projected to increase under most modeled scenarios for the 2010-1959 period compared to the 1950-1999 period. The maximum modeled increase was 2.6 inches (16%), the maximum decrease 0.8 inches (5%), and the median increase was 0.5 inches (3.1%).

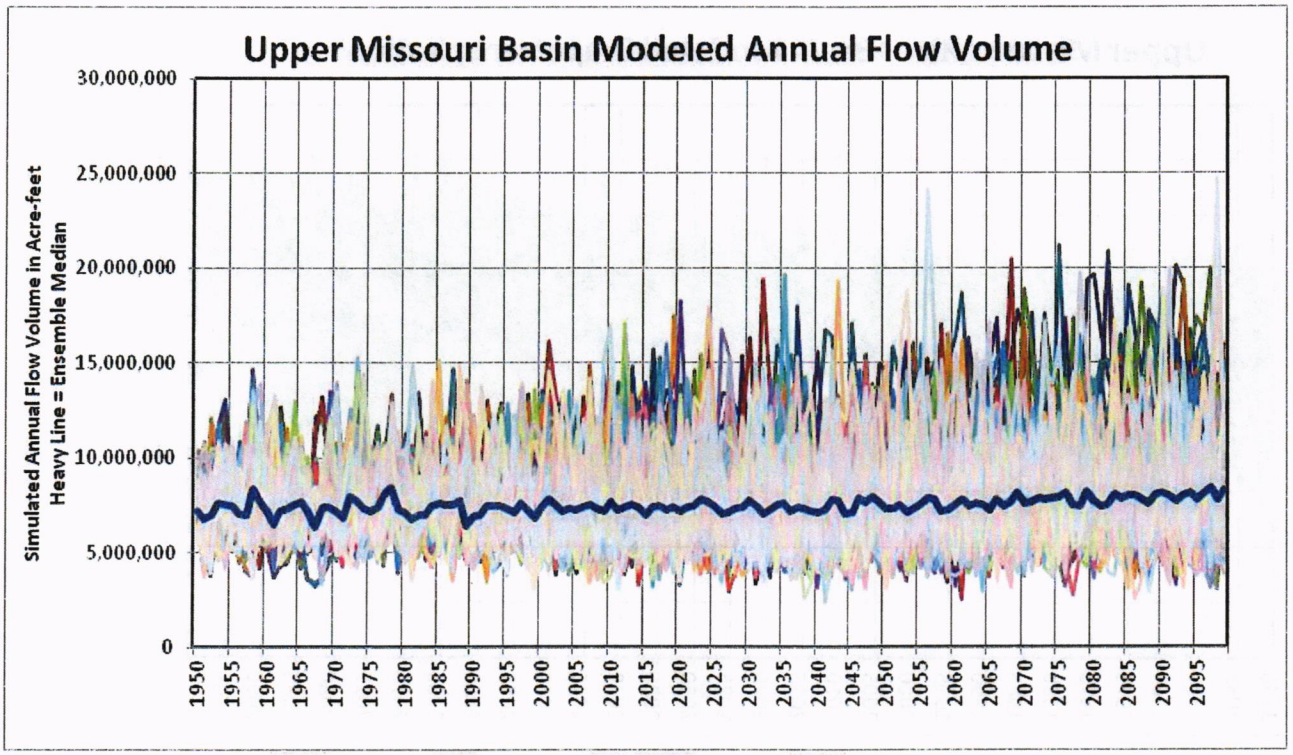
Figure 3. Annual evapotranspiration by natural vegetation simulations for the Upper Missouri Basin based on VIC model results and downscaled projections from 112 GCM models.



Runoff (Annual Volume)

The total amount of flow produced in the Upper Missouri River Basin depends on the amount of precipitation that is received, and how much of that precipitation is not consumed by evapotranspiration and evaporation and can be converted to as runoff. Figure 4 depicts the modeled annual runoff volumes for the Upper Missouri River Basin at the basin outflow point, at the Missouri River near Virgelle. For this graph, unique colors have been assigned to each of the 112 model simulation trace lines, with the dark line depicting the ensemble median. Although most scenarios project modest increases in precipitation for the Upper Missouri River Basin, the projected ET increases appear to offset these. Annual runoff volume is projected to be similar under most modeled scenarios for the 2010-1959 period compared to the 1950-1999 period, with a few scenarios projecting substantial increases and a few others projecting substantial decreases. The maximum modeled increase was 2,630,000 acre-feet inches (37%), the maximum decrease was -1,450,000 acre-feet (-19%), and the median was for a small increase of 4,000 acre-feet (.06%). These runoff volumes are for "natural" flow, before depletions due to irrigation and other uses, and reservoir operations and evaporation. The median gaged annual flow volumes at Virgelle are about 1,000,000 acre-feet lower than the modeled volumes for the historic period, due to these depletions associated with human uses.

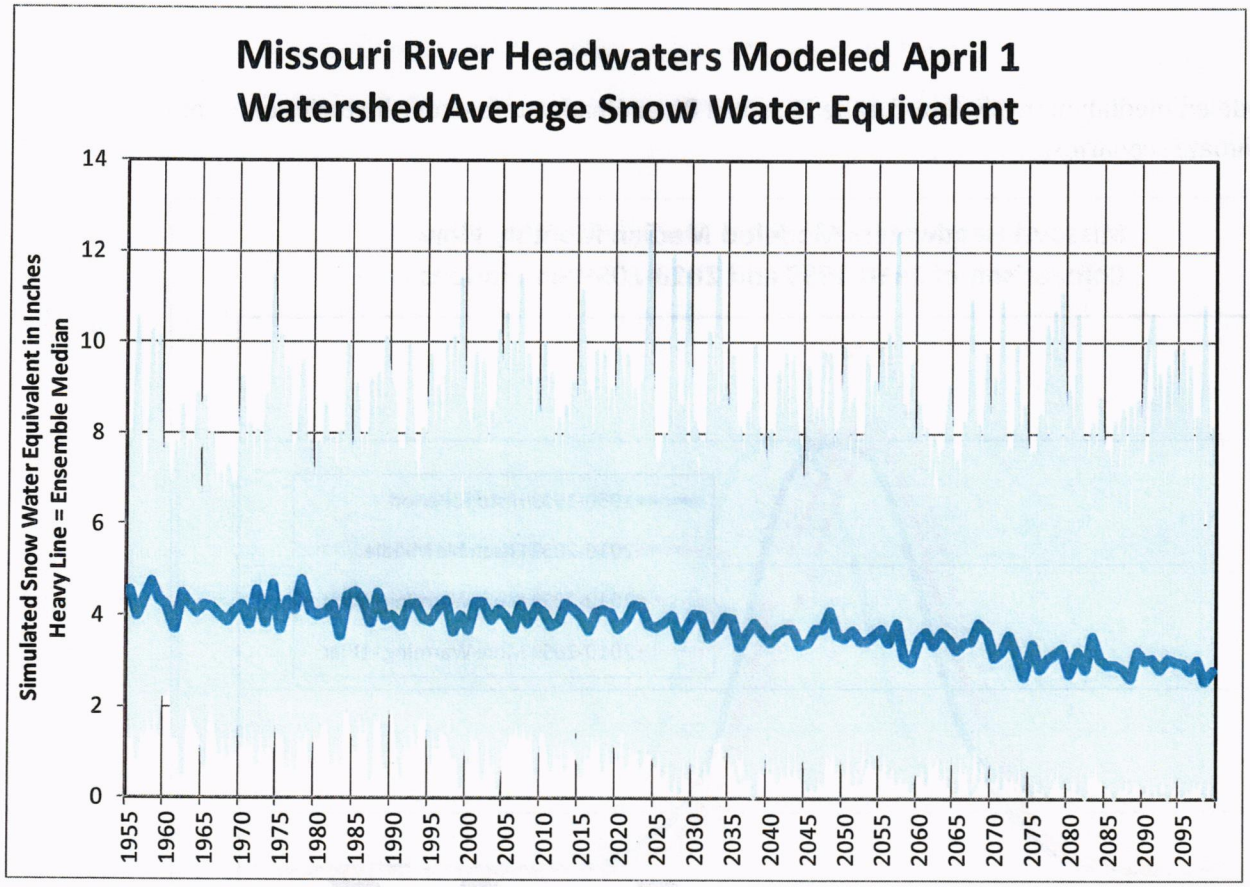
Figure 4. Simulated annual natural flow volumes for the Upper Missouri Basin based on VIC model results and downscaled projections from 112 GCM models.



Snow

Warmer temperatures would affect the accumulation of snow in the mountains during the cooler months and the availability of melting snow to sustain runoff during the spring and summer. The hydrology of much of the Upper Missouri Basin is snow-melt dominated and warming temperatures likely would lead to proportionally more rain and less snow. Snow water equivalent (SWE) on April 1 is a measure for assessing snowpack and subsequent spring–summer runoff conditions in the snowmelt dominated basins. SWE is a variable computed and used by the VIC hydrology model for each grid cell. Figure 5 depicts modeled April 1 snowmelt conditions for the Missouri River headwaters area (upstream of Canyon Ferry Dam) for the 112 simulations. This gridded SWE on April 1st was averaged over all the grid cells in the headwaters area to calculate the basin-wide April 1st SWE in each of the simulation years from 1950–2099. April 1st SWE shows a decreasing trend, although about 20 percent of the modeled scenarios show a trend of increasing April 1 SWE for the years 2010-2059 relative to the 1950-1999 base. The highest decrease for the 2010-2059 period relative to the 1950-1999 base was 1.4 inches SWE (32.4 % decrease) while the largest increase was 1.0 inches (24.4%) and the median SWE decrease was 0.4 inches (8.9%). Under most modeled scenarios, increased precipitation overall, mostly in the form of rain, might somewhat offset the snow decreases.

Figure 5. Modeled April 1 snow water equivalents for the Missouri River headwaters area based on VIC model results and downscaled projections from 112 GCM models.



Streamflow

Figure 6 and 7 compare simulated median Missouri River streamflow for the future 2010-2059 period to the historic 1950-1999 period for the headwaters area (Missouri River near Toston) and the entire Upper Missouri River basin (Missouri River near Virgelle). The results depicted are for groupings (ensembles) of VIC modeled runoff using the 112 CMIP3 climate scenarios using methods similar to those described by the U.S. Bureau of Reclamation (2010). The groupings partitioned the 112 scenarios into four quadrants that bracketed the climate-change scenario range based on relative changes in mean- annual temperature and precipitation, with a fifth "central tendency" grouping. For simplicity, only the results for the quadrant scenario groupings that produce the highest runoff values and the lowest runoff values, and the middle grouping are graphed. Also note that these graphs are for the modeled "natural" flow produced by the basins: they do not include the effects of water development such as reservoirs and irrigation.

In the future, flow produced in the Upper Missouri Basin might be of similar volume to what has been produced in the past, with shifts in streamflow timing and the wetter scenarios showing increased overall runoff. Timing shifts would be due to an earlier snowmelt and an increase in the rain fraction of the precipitation during the later winter and early spring. Earlier runoff is projected with December

through March showing an increasing trend while late season runoff (June through November) shows a decreasing trend. The earlier shift in runoff timing is more predominant for the warmer scenario groupings.

Figure 6. Modeled median monthly flow for the Missouri River Headwaters under historic conditions and future climate scenarios.

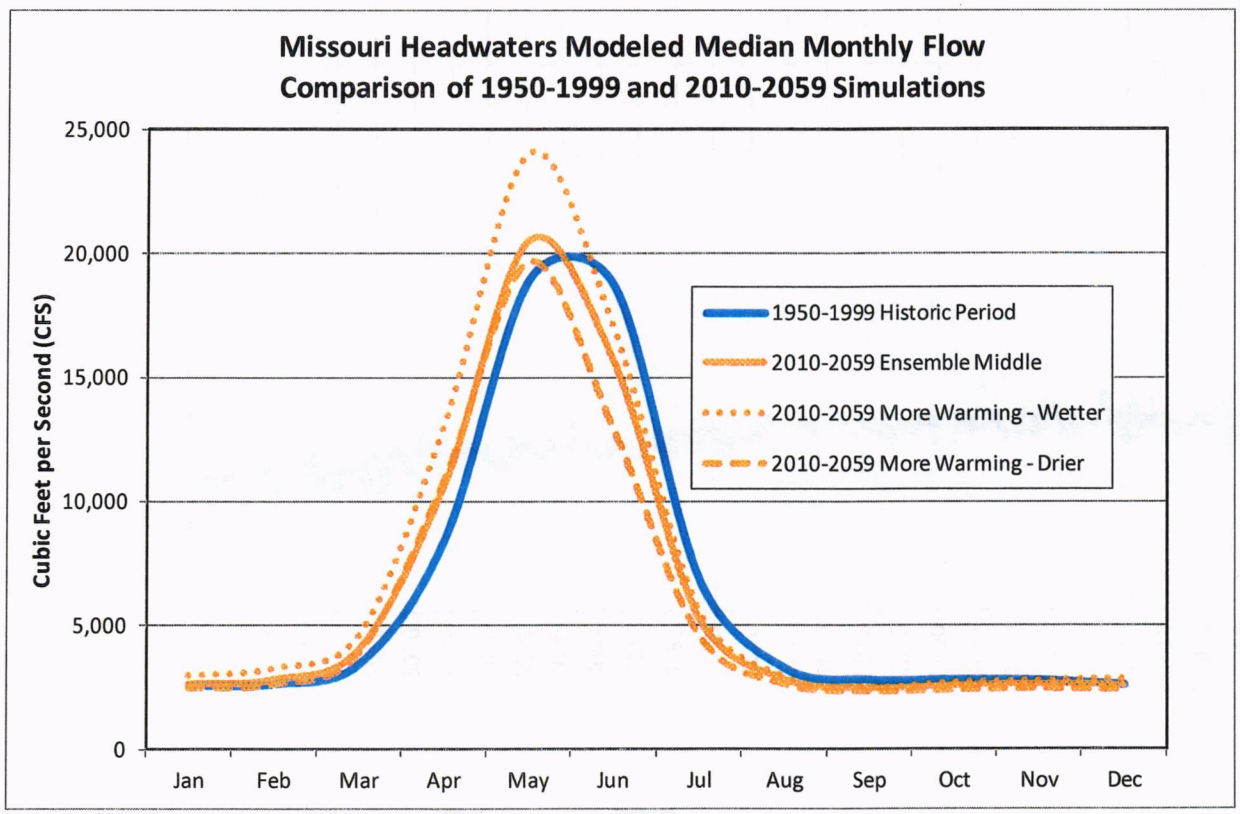
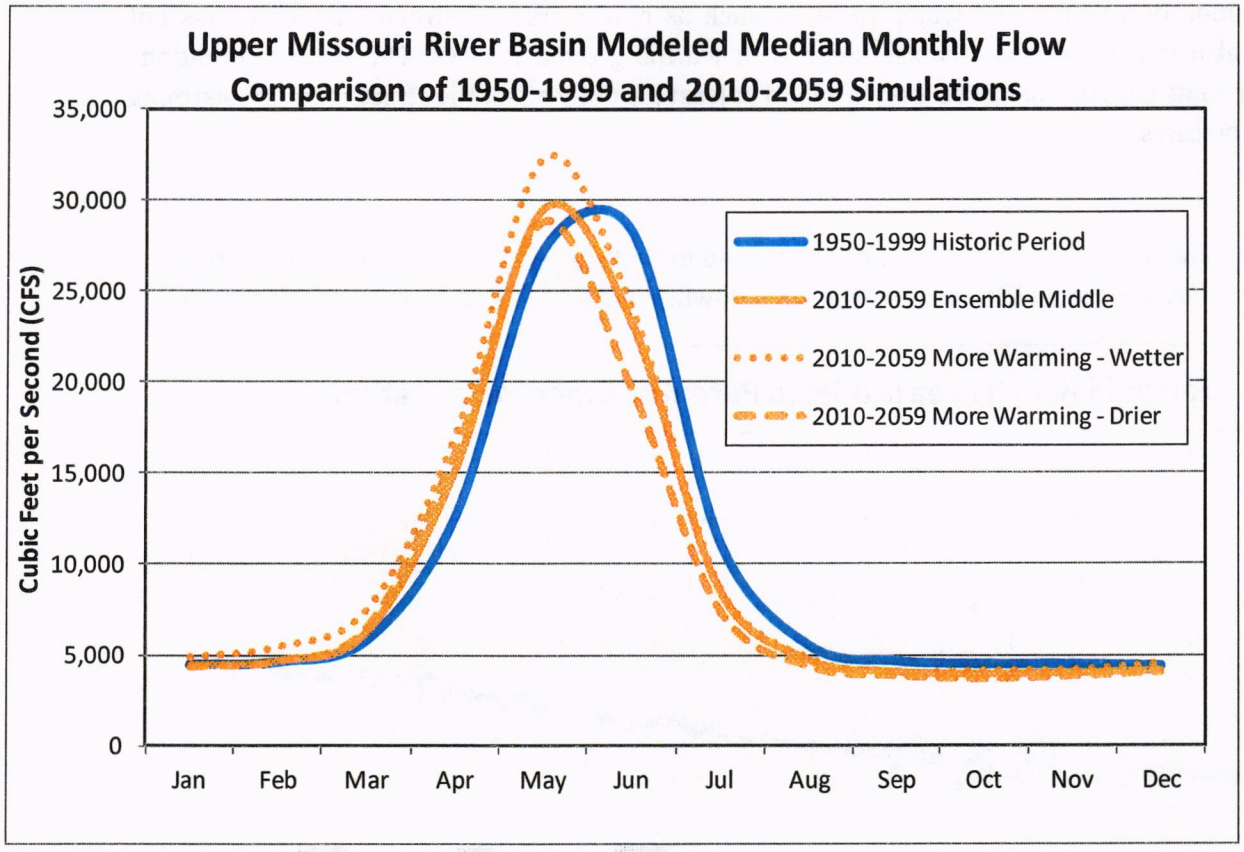


Figure 7. Modeled median monthly flow for the Upper Missouri River Basin under historic conditions and future climate scenarios.



Future Water Demands

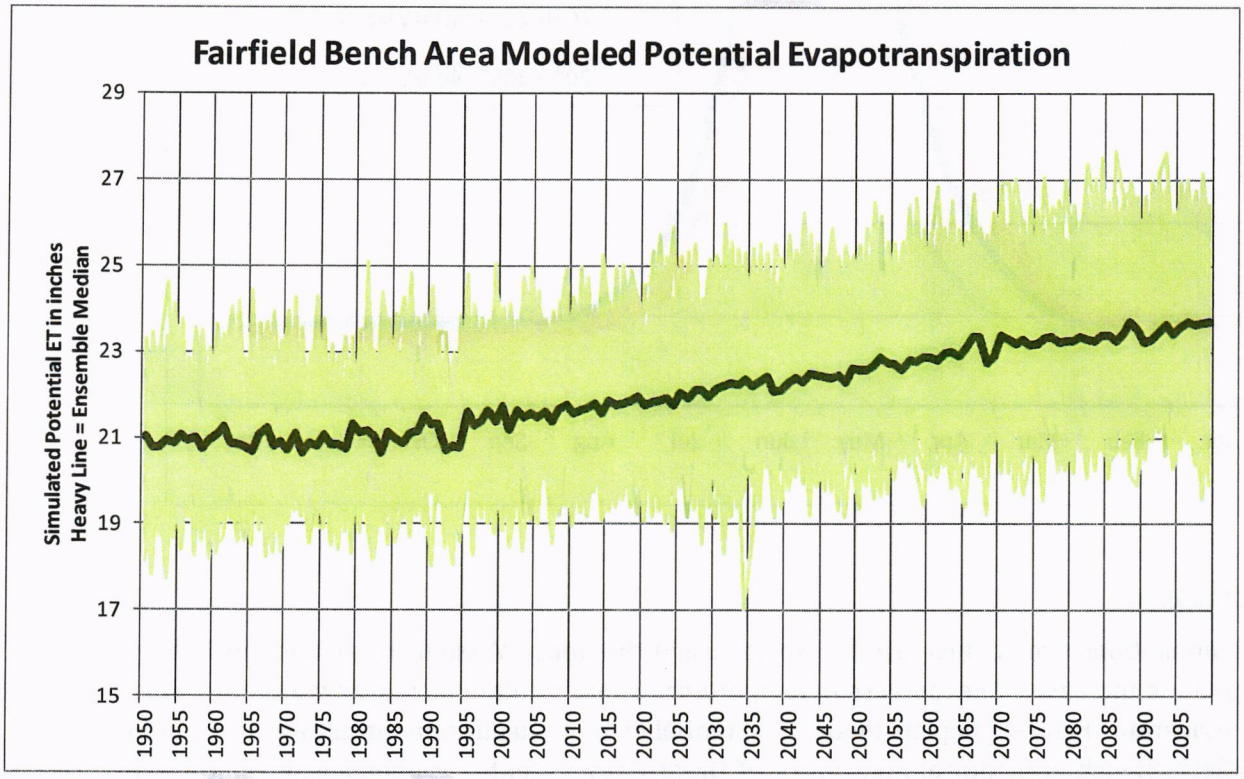
All of the 112 simulations project increased temperature in the upper Missouri basin and most show modest precipitation increases. The increase in temperature could result in increased water demands, especially for irrigation. Figure 7 depicts modeled potential evapotranspiration for natural vegetation for the Greenfields Bench agricultural area north of Great Falls. Potential evapotranspiration is the maximum amount of water that could be evaporated and transpired from the landscape at a given temperature, if there were a sufficient supply of water. Although this graph depicts potential ET for natural vegetation, it could be used to infer how water requirements might change for irrigated crops. The VIC model uses a Penman-Montieth formulation to compute potential ET (reference here), which also can be used to predict ET for agricultural crops.

Potential evapotranspiration is projected to increase during the 2010-2059 period when compared to the 1950-1999 historic period under all but one of the 112 scenarios modeled. The maximum projected increase was 2.2 inches (10.7%), the minimum was the scenario with 0 increase, and the median modeled increase was 1.2 inches (5.5%). Increased ET results in increased consumption and increased diversion requirements for irrigated crops. The projected increasing ET irrigation requirements suggests there could be an increase in crop production, if the increased water demand

could be satisfied. This might be the case during wetter years when sufficient irrigation water is available to supply crop demands.

Although evaporation from open water surfaces, such as reservoirs and stream channels, was not modeled, it also is expected to increase some with warming temperatures. The wetter conditions projected for some climate change scenarios would at least partially offset the effects of more warming on evaporation rates.

Figure 8. Simulated Annual potential evapotranspiration for natural vegetation simulations for the Fairfield Bench Area based on VIC model results and downscaled projections from 112 GCM models.



Uncertainties

The current scientific understanding of physical processes that affect climate and how to model such processes is not complete. Atmospheric circulation, clouds, ocean circulation, deep ocean heat uptake, ice sheet dynamics, sea level, land cover effects from water cycle, vegetative, and other biological changes are some important factors in climate modeling that are not fully understood. There are uncertainties relevant to the statistically down-scaling of global-scale climate models to the finer scale used in basin planning. For this investigation, global-scale model results were downscaled using temperature and precipitation patterns from historic weather-station data. And the future projections assume that these historic local climate patterns at the finer-scale and their relationships to the climate at the larger scale will still hold in the future, although that may not be the case.

References

Liang, X., D.P. Lettenmaier, E.F. Wood, and S.J. Burges. 1994. —A simple hydrologically based model of land surface water and energy fluxes for general circulation models,|| *Journal of Geophysical Research*, 99(D7), 14415–14428.

Liang X., E.F. Wood, and D.P. Lettenmaier. 1996. —Surface soil moisture parameterization of the VIC-2L model: Evaluation and modifications,|| *Glob Planet Chang* 13: 195–206.

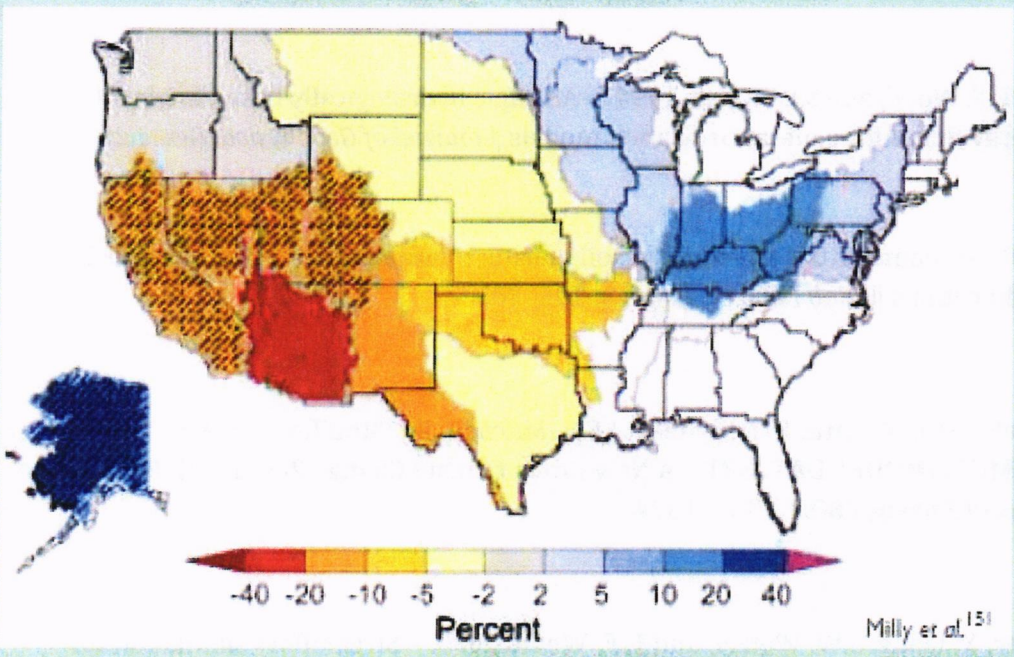
Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. Mcavaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor. 2007. —THE WCRP CMIP3 MULTIMODEL DATASET – A New Era in Climate Change Research,|| *Bulletin of the American Meteorological Society*, 88(9), 1383–1394.

Nijssen, B., D.P. Lettenmaier, X. Liang, S.W. Wetzel, and E F. Wood. 1997. —Streamflow simulation for continental-scale river basins,|| *Water Resour. Res*, 33, 711–724.

U.S. Bureau of Reclamation. 2010. *Climate Change and Hydrology Scenarios for Oklahoma Yield Studies*, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver Colorado. April 2010. 71 pp.

U.S. Bureau Reclamation, 2011. 'West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections', Technical Memorandum No. 86-68210-2011-01, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 138pp.

We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modeling (WGCM) for their roles in making available the WCRP CMIP3multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.



Projected changes in median runoff for 2041-2060, relative to a 1901-1970 baseline, are mapped by water-resource region. Colors indicate percentage changes in runoff. Hatched areas indicate greater confidence due to strong agreement among model projections. White areas indicate divergence among model projections. Results are based on emissions in between the lower and higher emissions scenarios.[91]

VIII. Options for Meeting New Water Demands

Basins with Unallocated Water

Water availability and appropriation of water are very important, and often contentious, issues in Montana and other western states. Montana has the authority to restrict or close river basins and groundwater aquifers to future withdrawals, based on concerns to protect existing uses, water quality issues, and additional water shortages. Montana is a "prior appropriations" state, and must first protect existing senior water uses before allowing additional demands on water resources. Physical water availability, if any, is based on surplus water above and beyond existing, valid water uses. An applicant for water use must prove that their proposed future use of water does not impact existing users surface or groundwater uses.

A summary of the general legal availability of surface water available for appropriation in the Yellowstone is summarized in the following table. The summary is based on past permitting records and experience. New appropriations from aquifers hydraulically connected to these streams and rivers also may be subject to limitations.

Billings Region

Water Source	Legally Available	Not Legally Available	Comments
Bighorn River	Yes		Below the Crow Indian Reservation
Big Porcupine Creek		No	No water rights issued since 1995
Bitter Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Yellowstone River Basin between Clarks Fork Yellowstone River and Bighorn River & Reservation
Blue Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Yellowstone River Basin between Clarks Fork Yellowstone River and Bighorn River & Reservation
Bluewater Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Clarks Fork Yellowstone River Basin & Reservation
Clarks Fork Yellowstone River	Near the mouth		May be available elsewhere on the source, however no water availability analysis has been performed recently

Cottonwood Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Clarks Fork Yellowstone River Basin & Reservation
Dry Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Tongue River Basin & Reservation
Dry Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Yellowstone River Basin between Clarks Fork Yellowstone River and Bighorn River & Reservation
Five Mile Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Clarks Fork Yellowstone River Basin & Reservation
Fly Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Yellowstone River Basin between Clarks Fork Yellowstone River and Bighorn River & Reservation
Little Missouri River			
Little Bighorn River Basin (43O)		Basin Closure	Crow Compact – Effective June 22, 1999
Little Powder River			
Lower Powder River		No	No water rights issued since 1995
Mizpah Creek		No	No water rights issued since 1995
Powder River	Below Broadus		
Pryor Creek Basin (43E)		Basin Closure	Crow Compact – Effective June 22, 1999
Rock Creek		Basin Closure	ARM 36.12.1013 - Effective February 2, 1990 - Diversion from June 1 through September 30 are prohibited
Rosebud Creek		Moratorium /	Northern Cheyenne Compact - Effective May 20, 1991

Basin (42A)		Basin Closure	Crow Compact – Effective June 22, 1999 Applies to Rosebud Creek Basin reservation
Stillwater River			
Sage Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - within Shoshone River Basin & Reservation
Sarpy Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Yellowstone River Basin between Bighorn River and Tongue River & Reservation
Spring Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Tongue River Basin & Reservation
Squirrel Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Tongue River Basin & Reservation
Sage Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - within Shoshone River Basin & Reservation
Stillwater River			
Tanner Creek Drainage		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Tongue River Basin & Reservation
Tongue River		No	No water rights issued since 1995
Yellowstone River	Below Mouth w Bighorn River		Conservation District Water Reservation Water May be Available
Yellowstone River	Below Billings and between Billings and Livingston	At Billings	FWP In-stream flow reservation may limit new appropriations
Youngs Creek		Basin Closure	Crow Compact – Effective June 22, 1999 - Within Tongue River Basin & Reservation

Bozeman Region			
Legally Available	**Legally Available**	**Legally Available**	**Legally Available**
Shields River	Yes, Sometimes		No year round or full season irrigation water available, but high spring flows and other times of year have availability.
Yellowstone River	Yes, Sometimes		No every-year availability left, so would need the ability to turn off at a trigger flow or mitigate when lower flows. Subject to future perfection of water reservations.

IX. Major Findings and Key Recommendations

X. References

Groundwater References

Bredehoeft J.D., 1997, The water budget myth. Groundwater 35(6):929.

Curry, W.H., III, 1971, Laramide structural history of the Powder River Basin, Wyoming, in Renfro, A.R., Madison, L.V., and Jarre, G.A., eds., Symposium on Wyoming tectonics and their economic significance, Wyoming Geological Association, annual field conference, 23rd, Casper, Wyo., September 20-22, 1971, Guidebook: Wyoming Geological Association, pp. 49-60.

Fields, R.W., Rasmussen, D.L., Tabrum, A.R., and Nichols, Ralph, 1985, Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho a summary, *in* Flores, R.M., and Kaplan, S.S., eds., Cenozoic paleogeography of west-central United States: Denver, Colo., Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 9-36.

Freeze, R. A., and Cherry, J. A., 1979, Groundwater, Englewood Cliffs, N.J: Prentice-Hall Print.

Hamilton, L. J., and Paulson, Q. F., 1968, Geology and ground-water resources of the lower Bighorn Valley, Montana: U.S. Geological Survey Water-Supply Paper 1876, 39 p, http://pubs.usgs.gov/wsp/1876/report.pdf.

Hopkins, W. B., 1973, Water resources of the Northern Cheyenne Indian Reservation and adjacent area, southeastern Montana: U.S. Geological Survey Hydrologic Investigations Atlas HA-468, scale 1:125,000, 2 sheets, http://pubs.usgs.gov/ha/468/plate-1.pdf, http://pubs.usgs.gov/ha/468/plate-2.pdf.

Kendy, E. and R.E. Tresch, 1996. Geographic, geologic, and hydrologic summaries of intermontane basins of the northern Rocky Mountains, Montana. U.S. Geological Survey Water Resources Investigations Report 96-4025, 233 p., http://pubs.usgs.gov/wri/1996/4025/report.pdf.
Lohman, S.W., 1972. Definitions of selected ground-water terms: Revisions and conceptual refinements, U.S. Geological Survey Water Supply Paper, 1988, 21 p.
http://pubs.usgs.gov/wsp/wsp_1988/pdf/wsp_1988.pdf.

Lopez, D.A., 2000, Geologic map of the Billings 30' x 60' quadrangle, Montana, Montana Bureau of Mines and Geology: Geologic Map 59, 1 sheet(s), 1:100,000, http://www.mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=10214&.

Lopez, D.A, and Reiten, J.C., 2003, Preliminary Geologic Map of Paradise Valley, South-CentralMontana, MBMG Open-File report 480, Butte, MT., Scale 1:50,000, http://www.mbmg.mtech.edu/pdf-open-files/mbmg480-ParadiseValley.pdf.

Madison, J.P., LaFave, J.I., Patton, T.W., Smith, L.N., Olson, J.N., 2014, Groundwater resources of the Middle Yellowstone River area: Treasure and Yellowstone counties, Montana Part A*—Descriptive Overview and Water-Quality Data, Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 3, 82 p., http://www.mbmg.mtech.edu/pdf-publications/gwaa_3.pdf.

Maxey, G. B. and T. E. Eakin, 1949. Ground Water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada. Nevada Department of Conservation and Natural Resources Water- Resources Bulletin No. 8, 59 pp.

MBMG, USGS, 1978. Groundwater of the Fort Union coal region, eastern Montana, MBMG: Special Publication 80, 47 p.

MBMG, 2005. Impacts of Non-Point source pollution on water resources in the Paradise Valley, MBMG Report for Park County, Contract Number 20091.

Myers, T. 2009. Groundwater management and coal bed methane development in the Powder River Basin of Montana, Journal of Hydrology, Volume 368, Issues 1–4, Pages 178-193, ISSN 0022-1694
Olson, J.L., 2005, Characterization of alluvial aquifers in Treasure and Yellowstone counties, Middle

Olson, J.L., 2005, Characterization of alluvial aquifers in Treasure and Yellowstone counties, Middle Yellowstone River Area, Montana (open-file version), Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 3B-03, 1 sheet(s), 1:50,000,
http://mbmggwic.mtech.edu/gwcpmaps/gwaa03map03untiled.pdf.

Olson, J.L., Svingen, R.R., 2006, Characterization of the Judith River aquifer, Middle Yellowstone River Area, Yellowstone and Treasure counties, Montana (open-file version), Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 3B-05, 1 sheet(s), 1:175,000,
http://mbmggwic.mtech.edu/gwcpmaps/gwaa03map05untiled.pdf.

Olson, J.L., Smith, L.N., LaFave, J., , 2007, Characterization of the Bull Mountain aquifer system in Treasure and Yellowstone Counties, Middle Yellowstone River Area, Montana, Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 3B-04, 1 sheet(s), 1:250,000,
http://mbmggwic.mtech.edu/gwcpmaps/gwaa03map04untiled.PDF.

Patton, T.W., Rose, J.C., LaFave, J.I., Smith, L.N., 1998, Potentiometric surface map for the shallow hydrologic unit, Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana (Superseded by GWAA 1B-05), Montana Bureau of Mines and Geology: Ground-Water Open-File Report 4, 1 sheet(s), 1:250,000.

XI. http://mbmggwic.mtech.edu/gwcpmaps/gwaa01map05untiled.pdf.

Patton, T., 2013. Climate 2013: Groundwater level response in wells, Presentation to Governors drought and water supply committee,
http://drought.mt.gov/Committee/Presentations/2013/mbmg_july.pdf

Reiten, J.C., Hanson, J., 2008, Developing a viable water supply for the town of Broadview, south-central Montana, Montana Bureau of Mines and Geology: Open-File Report 567, 89 p.
http://www.mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=10214&.

Reiten, J.C., 2008, Irrigation potential of groundwater underlying the lower Yellowstone Valley in Richland County, Final report to DNRC, RRG-0601280.

Ringen, B.H. and P.B. Daddow. 1990. Hydrology of the Powder River alluvium between Sussex, Wyoming, and Moorhead, Montana. United States Geological Survey WRIR 89-4002. http://pubs.usgs.gov/wri/1989/4002/report.pdf.

Seaber, P.R., Kapinos, F.P.,Knapp, G.L., 1987, Hydrologic Unit Maps, U.S. Geological Survey Water Supply Paper 2294, http://pubs.usgs.gov/wsp/wsp2294/pdf/wsp_2294.pdf.

Slagle, S. E., 1983, Water resources of the Fort Union coal region, east-central Montana: U.S. Geological Survey Water- Resources Investigations Open-File Report 83-4151, 111 p., http://pubs.usgs.gov/wri/1983/4151/plate-1.pdf.

Slagle, S. E., et al., 1983, Hydrogeology of area 49, northern Great Plains and Rocky Mountain coal provinces, Montana and Wyoming. United States Department of Interior Geologic Survey Water-Resources Investigation Open File Report 82-682, http://pubs.usgs.gov/of/1982/0682/report.pdf.

Smith, L.N., LaFave, J.I., Patton, T.W., Rose, J.C., McKenna, D.P., 2000, Ground-water resources of the Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana. Part A- Descriptive overview and basic data, Montana Bureau of Mines and Geology: Ground-Water Assessment Atlas 1A, 43 p. http://www.mbmg.mtech.edu/pdf/groundwateratlas1.pdf.

Snoke, A.W., 1993, Geologic history of Wyoming within the tectonic framework of the North America Cordillera, in Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds, Geology of Wyoming: Geologic Survey of Wyoming Memoir No. 5, p. 2-56.

Theis, C.V. (1941), The effect of a well on the flow of a nearby stream. *American Geophysical Union Transactions*, 22(3), 734-738.

United State Bureau of Land Management (US-BLM), 2002, Technical Report: Powder River Basin Oil and Gas Environmental Impact Statement- Groundwater Modeling of Impacts associated with Mining and Coal Bed Methane Development, Prepared by Applied Hydrology Associates, Inc. and Greystone Environmental Consultants, Inc. http://www.blm.gov/pgdata/etc/medialib/blm/wy/information/NEPA/prb-feis/groundwater_report.Par.12991.File.dat/groundwater.pdf

USGS, 1973. Water Resources of the Powder River Basin and Adjacent Areas, Northeastern Wyoming.

USGS Hydrologic Investigations Atlas HA-465. Prepared by Warren G. Hodson, Richard H. Pearl, and Stanley A. Druse in cooperation with the Wyoming State Engineer.

USGS, 2005. Preliminary integrated geologic map databases for the United States: Central states: Montana, Wyoming, Colorado, New Mexico, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Iowa, Missouri, Arkansas, and Louisiana, Open-File Report 2005-1351 http://pubs.usgs.gov/of/2005/1351.

Wolock, David, 2003. Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States. USGS Open-File Report: 2003-146, http://pubs.er.usgs.gov/publication/ofr03146.

Zelt, R.B., Boughton, G. K., Miller, K. A., Mason, J. P., Gianakos, L. M., 1999, Environmental setting of the Yellowstone River basin, Montana, North Dakota, and Wyoming, USGS Water-Resources Investigations Report: 98-4269, http://pubs.usgs.gov/wri/wri984269/wri984269.pdf.

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