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WATER AND EASTERN MONTANA COAL DEVELOPMENT

by Bob Anderson
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November, 1973

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EQC ENERGY/LAND USE REPORT NO. 1

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WATER AND EASTERN MONTANA

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Abstract

Water may be the limiting resource in eastern Montana coal development. Since the public has a major ownership in the water, coal, and associated land resources, and the public will absorb most of the benefits and costs of development, the public should have the major role in determining how that development takes place. Analysis shows that there is adequate water in the Yellowstone Basin for maximum projected diversions of up to 2.7 million acre-feet per year, but only if the main stem of the free-flowing Yellowstone is regulated (by Allenspur Dam) because of critical seasonal low flows. Incremental "nondecisions" could lead to the trading of the free-flowing Yellowstone for coal development.

However, if a water-conservative philosophy is adopted, the Yellowstone may remain free-flowing and the mode of coal development may be determined by other constraints. Several water-conservative alternatives are presented.

Introduction

The potential magnitude of coal-water development in the Fort Union region has been glorified by some and damned by others. Whether the full potential will be realized is questionable. The fact remains that eastern Montana coal will be mined and water will be consumed in the conversion of coal to other forms of energy. The questions are: how much development, at what rate, and in what manner.

It might appear that those with the most at stake in eastern Montana are the energy companies that may reap large profits, but at the risk of large capital investment, and the ranchers who, depending on their land patents or points of view, may either profit from the sale or lease of land and coal or be forced out of a cherished way of life. But others in eastern Montana have an important stake. In a 26-county area the federal government owns almost 25 percent of the land surface, the state owns 6 percent, and Indians own 7 percent (3). Of the mineral estate in the same area, federal ownership accounts for 55 percent and state ownership is about 6 percent (5).

Ownership of Montana water is a fundamental question that can be a controlling factor in coal-energy development. But the legal question of water ownership in Montana is unclear. In its 1972 constitution, the state asserts its rights to all waters within Montana, whereas federal claims to ownership are based on long-established authority to reserve waters. In addition, Indians claim all waters that flow across or adjacent to reservations, as supported by recent court decisions. Private individuals cannot own water but can merely obtain the rights to the use of water. Therefore, the water belongs essentially to the public.

The public has the most to gain and the most to lose from eastern Montana coal-water development: the public will consume most of the energy and the public will suffer most of the social and environmental impacts. Because it owns most of the resources involved, the public has the right, the responsibility, and the opportunity to be the dominant voice in determining how development should proceed.

Unless Montana can assert clear authority to regulate all non-Indian uses of water, it will be almost impossible for the people of the state to control or even influence use of the state's coal resources for energy conversion.

This report is aimed at providing a systematic analysis of water development--the potential and the constraints. An overview of the water resource picture in eastern Montana is followed by an elementary hydrologic analysis. Based on the analysis, questions are posed, conclusions drawn, and recommendations made.

Appended are a directory of involved federal and state government agencies and an explanation of the development of the low-flow probability hydrographs for the Yellowstone River. Also available upon request is a bibliography of pertinent water resource literature.

Water Availability

Some factor will limit the development of coal in eastern Montana. It may be extraction technology or the ability of the land to be reclaimed from surface mining. It may be the ability of the atmosphere to assimilate air pollutants or the willingness of society to accept drastic cultural changes. Or it may be the availability of water--water to cool coal-fired steam generating plants, water to transport coal, water to process coal into gases and liquids, water to assimilate wastes, water to supply expanding populations, and water to assist mined land reclamation.

Because eastern Montana is a semiarid region that produces little runoff, it has been termed a "water-short" area. Yet large quantities of water originate in adjacent mountain ranges and flow through or past the region, mostly as spring runoff from snowmelt. During the summer, large withdrawals are made by irrigators. During the winter, flows would often be insufficient to sustain large industrial withdrawals.

The average annual discharges of rivers in the region are shown in Table 1 (12).

TABLE 1
Annual Average Discharge of Eastern Montana Rivers

	Discharge	
	Million acre-feet per year (mafy)*	Cubic feet per second (cfs)*
Missouri River near Culbertson	7.4	10,260
Yellowstone River near Sidney	9.4	12,980
Powder River near Locate	0.4	609
Yellowstone River at Miles City	8.1	11,250
Tongue River at Miles City	0.3	417
Bighorn River at Bighorn	2.8	3,805
Yellowstone River at Billings	4.9	6,820

Note that about 16.8 million acre-feet of water leave the state via the Missouri-Yellowstone system in an average year.

*Throughout the text, million acre-feet per year is abbreviated "mafy" and cubic feet per second is abbreviated "cfs."

Some eastern Montana water originates in Wyoming and is allocated to Wyoming under the Yellowstone River Compact of 1951. Terms of the compact are shown in Table 2, as are average annual discharges at the pertinent locations (2, 12).

TABLE 2
Conditions of the Yellowstone River Compact

Tributary	Percent Allocation Montana	Percent Allocation Wyoming	Average Annual Discharge: Million acre-feet per year (mafy)	Average Annual Discharge: Cubic feet per second (cfs)
Bighorn River at Bighorn	20	80	2.8	3,805
Clarks Fork at Edgar*	40	60	0.7	941
Tongue River at Miles City	60	40	0.3	417
Powder River at Locate	58	42	0.4	609

*Flow records near Edgar have been kept only since October 1969. The discharge reported here is at Belfry, some 25 miles upstream from Edgar.

Flows in the Missouri River are heavily regulated by Fort Peck and other upstream dams. The Bighorn River is impounded by Yellowtail Dam (Bighorn Lake), the Wind River (the upper portion of the Bighorn in Wyoming) by Boysen Reservoir, and the Tongue River by Tongue River Reservoir.

The Yellowstone River, however, is virtually free-flowing in its main stem. Because it is one of the few free-flowing rivers in a land of dams, reservoirs, and canals, the Yellowstone is both fortunate and threatened. It is a unique natural phenomenon and therefore offers diverse values. But its free-flowing state also makes it attractive for development. Its uniqueness is continually threatened by development proposals. The proposed Allenspur site on the Yellowstone near Livingston is the best remaining damsite in Montana and could firm up 1.7 mafy (2,350 cfs) for downstream industrial or agricultural use (2). Construction of Allenspur Dam would be one of the most massive impacts that could result from coal development, with perhaps the greatest spectrum of environmental costs. Accordingly, public opposition to the project is vehement and widespread.

Water Consumption and Demand

Current industrial water use in eastern Montana is slight, probably less than 10,000 acre-feet per year (11). The primary use of water is for agriculture; in the Yellowstone Basin about 1.25 million acres are irrigated (12). Unfortunately, precise information about the quantities diverted is sparse and information about the amount of diverted water that returns to the streams is nonexistent.

The Montana Water Use Act (1973) provides for centralized filing of water rights so that a single agency--the Water Resources Division of the Department of Natural Resources and Conservation--will now administer all water rights. The act also reaffirms existing water rights and provides for basinwide adjudication of these rights. Such adjudication will improve the quality of information about diversions.

The question of the magnitude of impending coal-water development in the Fort Union region is perplexing. Plans and decisions are being made by private individuals, corporations, and the federal government with little public review. Because of competition in the private sector, these plans and decisions are often secretive.

An indication of the scope of the potential development may be seen from the options and applications for water as shown in Table 3 (4):

TABLE 3
Industrial Options and Applications for Fort Union Water

Water Source	Acre-feet per year: Option in effect or pending	Acre-feet per year: Additional Applications
Boysen Reservoir, Wyoming	85,000	59,000
Bighorn Lake, Montana, Wyoming	623,000	630,000
Tongue River Reservoir, Montana	4,175	---
Moorhead Reservoir, Wyoming, Montana (Proposed)	---	220,000
Fort Peck Reservoir, Montana	---	310,000
Lake Sakakawea, North Dakota	---	124,000
Lake Tschida, North Dakota	---	18,000
Yellowstone River, Montana	---	630,000
	712,175	1,991,000

Total, options and applications: 2,703,175 acre-feet per year (3,734 cfs).

Most of the water sought for industrial use in the Fort Union region is in Montana. The total of 2.7 mafy optioned or applied for tends to support earlier estimates of maximum water use. The Bureau of Reclamation's Appraisal Report on Montana-Wyoming Aqueducts suggested that up to 2.6 mafy would be diverted (2). Persse and Willard of the U.S. Bureau of Mines estimated maximum use of up to 2.2 mafy (11). To what extent the options will be exercised is not known. These maximum use estimates are based on combinations of wet-cooled steam generation plants and gasification-liquefaction plants.

Of interest is the probable cost of water delivered to coal fields. In the aqueduct report the cost of delivered water to the various proposed pipelines was estimated to be $30 to $100 per acre-foot (2). These calculations assumed a discount rate of 3.502 percent and a project life of 50 years. On August 3, 1973, President Nixon approved the Water Resources Council Principles and Standards, which require a discount rate of 6.875 percent (13). This rate change will substantially increase the estimated costs of delivered water. It may also make private water development competitive with public development and reduce the government's role in coordinating the projects.

Estimates for water consumption by energy conversion plants vary widely. The figures in Table 4 are typical (2, 11):

TABLE 4
Estimated Water Consumption by Energy Conversion Plants

Process	Water Consumption acre-feet per year
1000-megawatt (mw) coal-fired steam generation, wet-cooling tower	9,500 - 17,000
1000-mw coal-fired steam generation, dry-cooling tower	1,500
Gasification, 250 million cubic feet daily	20,000 - 30,000
Liquefaction, 100,000 barrels synthetic crude oil daily	20,000 - 65,000
Combined products; 50,000 barrels crude daily 250 million cubic feet gas daily, 1000-mw	50,000 - 75,000
1000-mw stream-ammonia, wet-cooling tower	13,500
1000-mw stream-ammonia, dry-cooling tower	1,300
1000-mw magnetohydrodynamic (mhd), hot gas to atmosphere	---
1000-mw mhd, steam auxiliary, wet-cooling tower	7,800
1000-mw mhd, steam auxiliary, dry-cooling tower	800
1000-mw mhd, steam-ammonia auxiliary, wet-cooling tower	7,000
1000-mw mhd, steam-ammonia auxiliary, dry-cooling tower	600
1000-mw fuel cells	No cooling

Note that many of the processes in the above table are not yet technologically feasible, such as 1000-mw fuel cells.

Table 4 shows that the amount of water required for energy conversion processes varies widely; the largest differences are between wet-and dry-cooling systems. Right now there is little incentive to install dry-cooling towers. Water is essentially free at the point of diversion and the delivery cost is small. Montana law encourages the diversion, appropriation, and beneficial use of water, but not its conservation. In hot weather, the efficiency of dry-cooled plants is reduced so that additional peaking-power generation may be needed. And dry cooling may be more expensive. But dry cooling has the singular advantage of conserving water, and, as discussed later, this may be the overriding decision factor in its implementation.

In 1969, the Montana legislature recognized the need to maintain minimum flows in certain reaches of high-quality trout streams and authorized the Montana Fish and Game Commission to appropriate water for that purpose (8). Accordingly, the commission appropriated Yellowstone water in varying amounts depending on the location and the season. The furthest downstream appropriation was between the mouth of the Stillwater River and the Carbon-Stillwater County line (S10, T35, R21E), and claimed 1,500 cfs (1.1 mafy) from November 1 to April 15 and 2,600 cfs (1.9 mafy) from April 16 to October 31.

This water right was defined as a second-class right that could be abrogated by a district court in favor of another beneficial use appropriator. However, none of the appropriations was ever challenged. The new Montana constitution and the Montana Water Use Act confirmed existing rights, so it is likely that those appropriations are now valid, prior appropriations notwithstanding.

The Montana Water Use Act allows state and federal agencies to apply to reserve water for existing or future beneficial uses or to maintain a minimum flow, level, or quality of water. In order to preserve and protect the aquatic environment, the Montana Fish and Game Commission is preparing applications for minimum flows in the Yellowstone River downstream from the above mentioned appropriations.

Conflicts

From this overview, it is apparent that eastern Montana has at least two unusual attributes: the free-flowing Yellowstone River and the vast strippable deposit of Fort Union coal. Decisions could be made now that would trade one off for the other. For example, Allenspur Dam could be built to provide industrial water, or development could be prohibited and the Yellowstone included in the National Wild and Scenic River System.

It is more likely, however, that a series of "nondecisions" will be made. Energy conversion plants will be constructed. Each will take "just a little bit" of water and each will pay little attention to water conservation or to its role in the overall scheme. Each little bit of water, diverted steadily, year round, wet years and dry, may create a critical withdrawal situation that in an exceedingly dry year or two will seriously deplete the river. At that point public support may, for lack of a viable alternative, sway toward regulation of the Yellowstone in order to prevent irrigation disruption and widespread unemployment in the energy industry and to maintain a minimum flow in the river. And Allenspur will be built.

But it may not be necessary to sacrifice the free-flowing Yellowstone for industrial development. The Missouri-Yellowstone system may have enough water to provide for both, if the appropriate decisions are soon made. To analyze conditions and capabilities of the Yellowstone, the flow of the river is next examined.

Flow Analysis

Figures 1 and 2 show probability hydrographs developed from daily flow records at Billings and Sidney. (See Appendix A for an explanation of the methodology used to prepare the graphs.)

The graph shows, for example, that at Sidney on January 1 in an average year, the flow will be about 5,000 cfs. About 25 percent of the time, the flow will be 3,500 cfs or less. About 10 percent of the time, the flow will be 2,100 cfs or less.

Figure 1 shows when the critical low-flow periods occur at Billings. From about September 1 to April 15 the average daily flow is less than 4,000 cfs (2.9 mafy), dropping to 2,400 cfs (1.7 mafy) during January. About 25 percent of the time, January flows at this station will probably be less than 2,000 cfs (1.4 mafy). Ten percent of the time, January flows will be about 1,400 cfs (1.0 mafy) or less.

At Sidney, the furthest downstream gauging station on the river, the flow characteristics are quite different from those at Billings. There is an autumn peak, probably caused by recovery from extensive late summer diversions.

The autumn low flow at Sidney averages about 5,700 cfs (4.1 mafy). Twenty-five percent of the time it runs below 3,600 cfs (2.6 mafy); there is 10-percent probability of it being 1,600 cfs (1.2 mafy) or less.

Another critical period at Sidney is in winter. During January, the average daily flow is about 5,000 cfs (3.6 mafy). Twenty-five percent of

Fig.1 LOW-FLOW PROBABILITY HYDROGRAPH, YELLOWSTONE RIVER AT BILLINGS

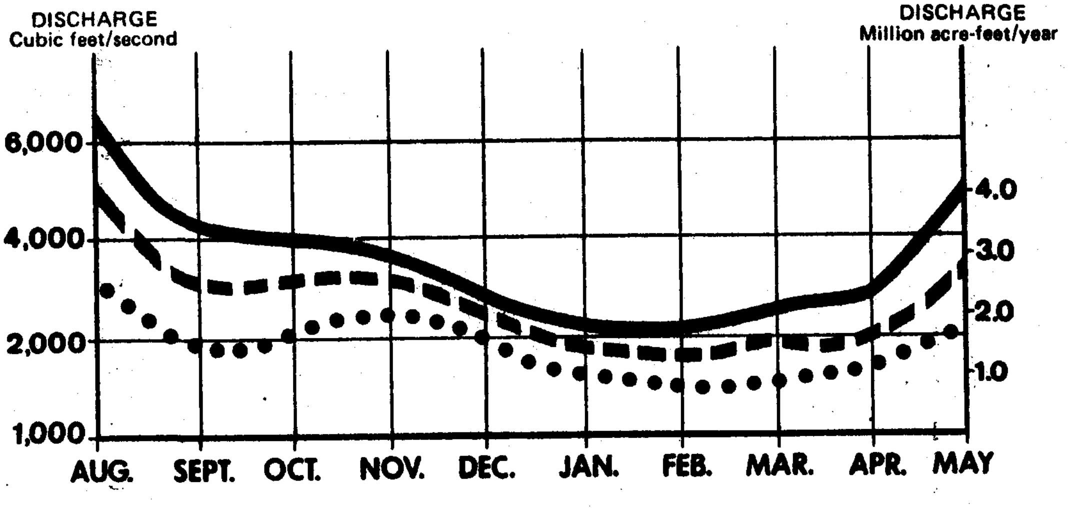
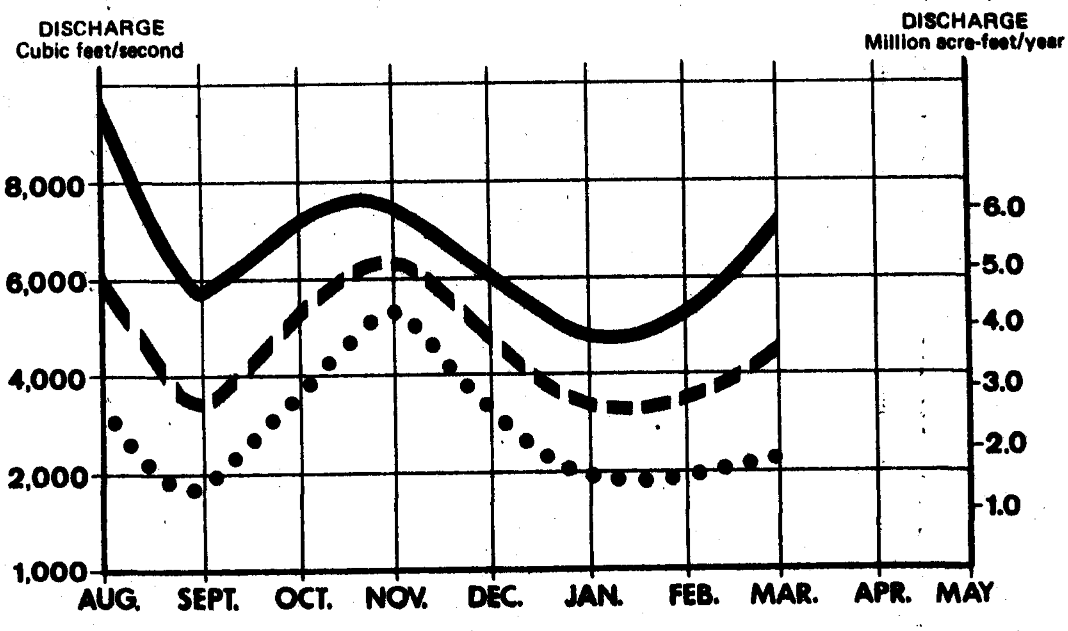


Fig.2 LOW-FLOW PROBABILITY HYDROGRAPH, YELLOWSTONE RIVER AT SIDNEY



LEGEND: MEAN ▬▬▬▬; 25% ▬ ▬ ▬ ▬ ▬ ▬; 10% ● ● ● ● ● ● ● ● ●

Note: Low-flow data for abnormally high flow periods is not depicted in Figures 1 and 2 because the assumption of a normal distribution of data is poor for these periods.

the time the flow is 3,600 cfs (2.6 mafy) or less; 10 percent of the time it is less than about 2,000 cfs (1.4 mafy).

The two low-flow periods at Sidney are quite different. In autumn, the low flow lasts only a short time. The average daily flow is not unusually low, but the variation in flow is large so that extremely low flows often occur.

In winter at Sidney the low flows last much longer. Flows about equal to the average daily flow are likely to last for about a month; flows about equal to the 10-percent flow are likely to last for about two months. Even though the average daily flow in winter is lower than the average daily flow in autumn, the winter flows vary less and the most extreme lows occur in autumn.

Diversion, regulation, and conservation

What effect will massive diversions have on these flow regimes? If all of the options and applications for water are realized, about 2.7 mafy (3,730 cfs) will be diverted; presumably most or all of this water would be consumed. A glance at Figures 1 and 2 clearly shows that the Yellowstone often does not even have that much water. Therefore, if diversions are to be made on the order of the maximum proposed, the Yellowstone River would have to be heavily regulated. In fact, the extreme low flows at Sidney and Billings may already be approaching critical levels. The 10-percent low flow at Sidney in the fall is considerably less than the 2,600 cfs that the Montana Fish and Game Commission has reserved upstream at the Carbon-Stillwater county line.

What is the potential of the Yellowstone River to be regulated? The most promising site (in terms of capacity) and the most ominous (in terms of environmental values) is Allenspur, near Livingston. Allenspur would flood Paradise Valley with four million acre-feet of water and assure 1.7 mafy (2,350 cfs) for downstream industrial use (2). Other proposed sites on the Yellowstone main stem, in downstream order, and their total (not active) storage capacities include: Yankee Jim (280,000 acre-feet), Wanigan (1,320,000), Lower Canyon (1,384,000), Absaroka (892,000), and Lisa (1,600,000) (9).

Of all the above, Allenspur was the only one listed as a potential site in the Bureau of Reclamation's aqueduct report (2). According to the report, Allenspur and Bighorn Lake could provide the necessary water for maximum diversion.

What is the outlook for offstream regulation? The aqueduct report lists three possible sites near the Yellowstone: Buffalo Creek Reservoir, Cedar Ridge Reservoir, and Sunday Creek Reservoir. Total storage capacity of these offstream reservoirs would be about 630,000 acre-feet (2). Water resource inventories for the Crow and Northern Cheyenne Indian Reservations (6, 7) list potential reservoirs with total active capacities of 171,700 and 345,750 acre-feet respectively. Many of these sites are not included in the 1969 inventory by the Montana Water Resources Board (9).

Without main stem or offstream Yellowstone regulation, about 1.5 mafy of firm industrial water would become available, according to the aqueduct study (2). Offstream storage could probably increase the firm yield to about 2.0 mafy--enough for large-scale coal development but not enough for the maximum diversion mentioned previously (up to 2.7 mafy if options and applications are realized).

How much regulation would be needed if intense water conservation were practiced? This depends on the type and extent of development (see Table 4).

The U.S. Bureau of Mines, an agency with an interest in chemical conversion, projects the following onstream plant capability in the Powder River Basin (11):

TABLE 5
Estimated Number of Coal Conversion Plants in the Powder River Basin

Plant	1990 Low	1990 Medium	1990 High	2020 Low	2020 Medium	2020 High
1000-mw electric generation	3	3	4	3	4	5
Synthetic gas 500 minimum cubic feet per day	-	7	31	5	19	31
Synthetic crude oil 100,000 barrels per day	-	10	4	-	16	4

The above projection is obviously slanted toward gasification and liquefaction, which provide less opportunity for water conservation than coal-fired steam generation.

The North Central Power Study, a report slanted toward coal-fired steam generation, identified 21 sites in Montana with a total generating potential of 69,000 mw (10). Such a scheme would allow greater water conservation through dry cooling than would the above.

The spectrum of water-conservative alternatives for development include:

1. Transportation of coal to the point of use.
2. Transportation of coal to the already regulated Missouri River for conversion.

3. Transportation of water from the Missouri to coal field conversion plants.
4. Transportation of water from the Missouri to the Yellowstone for flow augmentation.
5. Use of offstream and onsite water storage.
6. Installation of dry-cooling technology.
7. Limiting development by the constraints of a free-flowing Yellowstone with minimum flows assured.
8. Altering energy demand through conservation.
9. Prohibiting coal and water development.

Unanswered Questions

Study of the eastern Montana coal-water situation and the existing hydrologic literature reveals a number of serious information gaps.

The first concerns the hydrology of the Yellowstone Basin, a thorough understanding of which is a prerequisite to intelligent decision making. This hydrology is complicated by unknown diversions and returns; by regulations large and small; by ephemeral streams; by unknown interactions between surface and groundwater; by ice jamming in the winter; and by evaporation from storage. In the future it may be further complicated by massive withdrawals, additional regulation, and weather modification. Understanding could be advanced by simulating the hydrologic regime under a variety of hypothetical watershed manipulations. Application of the State Water Planning Model would make this possible (1).

The groundwater resource in eastern Montana is poorly understood. Most existing information concerns alluvial aquifers or specific aquifers.

Information is needed on:

1. Interactions between surface and groundwater (recharge and discharge);
2. Potential of aquifers, especially the Madison carbonates, for development; and
3. Effect of surface mining on groundwater movement and quality.

Surface water questions are equally important: What are the minimum acceptable flows in the Yellowstone? How much, if any, attrition of the free-flowing river can be justified? Also needed is information on:

1. The effect of changing flow regimes on water quality;
2. Effect of changing flow regimes on aquatic biology;
3. Effect on water quality of effluents from mines, energy conversion plants, and new human habitation;
4. Quantities of irrigation and other diversions and returns;
5. Changes in ice jamming due to flow changes;
6. Hydrology and water quality of ephemeral streams;
7. Effect of lowered surface water levels on existing diversion structures; and
8. Adverse impacts of new storage reservoirs.

Many of these questions may be answered by traditional research, and some are being investigated. Researchers at the University of Montana, Montana State University, and the Montana College of Mineral Sciences and Technology are cooperating in a multidisciplinary proposal which, if funded, will address many of the important social, economic, and environmental issues related to coal-water development. The Water Resources Research Centers of Montana, Wyoming, and North Dakota have jointly acquired funds from the Office of Water Resources Research to study research needs and capabilities in the Fort Union region. The Montana Energy Advisory Council is also seeking funds for a coal-water study.

Economics research is essential in order to determine the optimal cost and benefit allocation from coal-water development. Included must be an analysis of the opportunity costs of water withdrawn and consumed. These costs involve natural amenities, wildlife habitat, recreation, and down-stream power production.

Means of conserving developed water must be investigated, including the technology of process modification (dry cooling) as well as the institutional means of encouraging conservation (regulations and consumption taxes).

Conclusions and Recommendations

1. The sector of society with the largest stake in eastern Montana coal-water development is the public. The public should play the key role in determining the course of events. Involved government agencies should inform the public and seek opinions on the issues. An agency such as the Montana Energy Advisory Council should accept the lead role in that task.

2. Only if the main stem is regulated would the Yellowstone River have sufficient water to allow maximum diversion. However, regulation of the main stem is not necessary for large-scale coal development, but further tributary regulation would be required. The Yellowstone River should remain in its free-flowing condition. Other merits and issues may then determine the mode of coal development.

3. Unless proper steps are taken, incremental "nondecisions" will result in development that will create critically low flows in the Yellowstone, thus increasing the need for main stem regulation (Allenspur Dam). To avoid the pitfall of incremental "nondecisions" a state agency such as the Department of Natural Resources and Conservation should have centralized decision and planning authority. The Montana Legislative Assembly should enact the necessary legislation empowering such an agency and insuring free public access to the workings of the agency.

4. Montana law encourages the diversion, appropriation, and beneficial use of water, but not its conservation. The constraint of water availability on development could be eased by requiring conservative use of water. A conservative water philosophy should be adopted to maximize the social benefits from development and to maintain options in the public interest. Each development proposal should consider the net social and environmental benefits and costs of the full set of water-conservative alternatives. The legislature should encourage water conservation by statute.

5. Rational decision making on Montana coal-water development is hampered by a serious lack of knowledge, including information about Yellowstone Basin hydrology, impacts of development on the Yellowstone, and the socioeconomic costs of water withdrawn and consumed. Coal-water development should proceed only when the crucial questions on Montana water resources have been answered sufficiently to enable Congress and the legislature to act in the best interest of the people. Proceeding without the answers to these questions is a continuation of the dangerous nondecision approach that, one by one, forecloses intelligent options.

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Appendix A

Development of the Low-Flow Probability Hydrographs

Figures 1 and 2 are low-flow probability hydrographs for the Yellowstone River at Billings and Sidney. The graphs were developed from data gathered and published by the U.S. Geological Survey.

The top line in each graph shows the flow rate that can be expected to pass the station on any given day in an average year. The middle line shows the rate of flow that exceeds the flow that can be expected 25 percent of the time on any given day. The bottom line shows the rate of flow that exceeds the flow that can be expected 10 percent of the time on any given day.

Forty-eight evenly spaced days of the year (the 1st, 9th, 17th, and 25th of each month) were chosen for the analysis. On each of these days of the year, the daily flow was tabulated for all the years of record (28 years at Billings, 38 years at Sidney). On each of the days, the mean (average) daily flow was calculated. The mean daily flows are plotted in Figures 1 and 2 and smooth lines were drawn through the points. These are the top lines in each figure. These lines show the flow rate at the gauging station, on the average, on any given day of the year.

Flows with probabilities of occurrence of 25 percent and 10 percent were calculated for each selected day, assuming a normal distribution of events. (The assumption of a normal distribution is poor for peak flows but is acceptable for low flows).

The "student t" statistic was used to calculate the 25 percent low flow on each of the selected days. On a given calendar day, about 25 percent of the time the daily flow will be equal to or less than the amount calculated.

These flows were plotted and smooth lines drawn through the points. So, a glance at the figures shows, for any given day of the year, the daily flow that can be expected 25 percent of the time. The 10 percent lines were developed in the same way.

For example, at Billings on September 1, the average daily flow is about 4,000 cfs. About 25 percent of the time, the daily flow at Billings on September 1 has been 2,800 cfs or less. About 10 percent of the time, the daily flow at Billings on September 1 has been 1,800 cfs or less.

The hydrograph for Sidney is less exact than the one for Billings. Figure 2 reflects 38 years of record. Part of that time the flows were essentially unregulated. However, the Tongue River Reservoir, built in 1939, regulates about 0.3 mafy (417 cfs). Boysen Reservoir (1952) and Yellowtail Dam (1967) regulate about 2.5 mafy (3,495 cfs) in the Bighorn River. About 30 percent of the flow at Sidney is now regulated.

If it may be assumed that the future will be like the past, Figures 1 and 2 show the low flows and the approximate probabilities of their future occurrences.

Appendix B

Directory of State and Federal Agencies Involved in Water Resources Related to Eastern Montana Coal Development

Federal

Bureau of Indian Affairs
Billings Area Office
Federal Building
316 N. 26th St.
Billings, Mt. 59101

The BIA is assisting some Montana tribes, including the Crow and Northern Cheyenne, by financing water resources inventories. A private consulting firm, Hurlbut, Kersich, and McCullough of Billings, has completed Phase I - Water Resource Base for both reservations. Three other phases will follow, leading to detailed recommendations for water resource development.

Bureau of Land Management
Federal Building
316 N. 26th St.
Billings, Mt. 59101

The BLM, with the U.S. Forest Service, is conducting an intensive resource study in the Decker-Birney area. The study has progressed to the point of offering arrays of alternative recommendations for public review and comment.

In addition, BLM is cooperating with the U.S. Geological Survey in the establishment of two water quality monitoring stations on the Tongue River and is a participant in the Northern Great Plains Resource Program (NGPRP). (See below).

<u>Bureau of Reclamation</u>
Upper Missouri Region
P.O. Box 2553
Billings, Mt. 59103

The bureau, along with the U.S. Army Corps of Engineers, has been a lead agency in the development of the water resources in the Missouri Basin. At present, the bureau's major activities involve participation in NGPRP. A list of potential reservoir sites is being compiled and a series of operation studies will be developed to predict the effects of various storage and withdrawal schemes on the flow regimes of the rivers in the Fort Union region.

The bureau is responsible for acting on applications for water allocations from Bighorn Lake and Fort Peck Reservoir.

<u>Bureau of Sport Fisheries and Wildlife</u>
P.O. Box 1296
Billings, Mt. 59103

As a participant in NGPRP, the BSF&W is identifying critical stream reaches that might be impacted by coal development. A combination of analytical techniques and field observations will result in an estimation of flow requirements to satisfy instream water needs.

Based on different levels of coal development, the impacts of water withdrawals will be predicted.

<u>Corps of Engineers</u>
Omaha District
6014 U.S. Post Office and Court House
Omaha, Nb. 68102

The Corps, a major water resources development agency, is responsible with the Bureau of Reclamation, for allocating the waters in Fort Peck Reservoir, a Corps project.

Environmental Protection Agency
1860 Lincoln Street
Denver, Co. 80203

The EPA is responsible for administering a permit system for the discharge of industrial and municipal water-borne wastes and is a participant of NGPRP.

Missouri River Basin Commission
10050 Regency Circle, Suite 403
Omaha, Nb. 68114

The Commission, which succeeded the Missouri Basin Inter-Agency Committee, participates in NGPRP but has no current active involvement in eastern Montana water development.

Northern Great Plains Resource Program (NGPRP)

NGPRP, a one-year program, is the official federal effort to guide coal, water and other resource development in the Fort Union region. Participants include all federal agencies involved with the region as well as interested state agencies and private and public groups.

The program is divided into seven work groups: regional geology, mineral resources, water, atmospheric aspects, surface resources, socio-economic and cultural aspects, and national energy considerations.

NGPRP will largely utilize existing information to analyze the Fort Union resource situation and, based on various levels of energy development, attempt to predict and analyze consequences. The scheduled completion date is mid-1974.

Soil Conservation Service
P.O. Box 970
Bozeman, Mt. 59715

The SCS, as a participant in NGPRP, provides information gathered over the years, but currently has no specific hydrologic studies under way in eastern Montana.

U.S. Forest Service
Custer National Forest
Box 2556
Billings, Montana 59103

(See the paragraph on BLM for mention of the joint BLM-USFS study in the Decker-Birney area).

SEAM (Surface, Environment, and Mining), 145 Grand, Billings, Mt. 59101, is a USDA program that is researching strip mining reclamation problems in eastern Montana.

The USFS is a participant in NGPRP.

U.S. Geological Survey
Federal Building
310 N. Park Ave.
Helena, Mt. 59601

The USGS is the major source of hydrologic information in the United States and operates, often in cooperation with other federal, state, and local agencies, a network of gauging stations in eastern Montana. Gauging stations may provide flow and water quality data.

The USGS also performs an inventory of wells and springs to determine water levels and quality.

In cooperation with the Montana Bureau of Mines and Geology, it is studying the Madison formation and shallow aquifers.

A technique for estimating mean annual flows in ungauged streams based on channel geometry is being applied.

RALI (Resources and Land Information) is a USGS program which, although it has no active involvement in Montana, is performing a relevant study near Gillette, Wyoming.

State

Department of Natural Resources and Conservation
Mitchell Building
Helena, Mt. 59601

DNR&C includes the Water Resources Division, mentioned later.

In addition, the Energy Planning Division is responsible for the detailed analysis of impacts, including hydrologic ones, of proposed energy generation and conversion plants and associated facilities.

Department of State Lands
Capitol
Helena, Mt. 59601

The Department of State Lands is responsible for the review of applications for strip mining. That review includes an assessment of hydrologic and water quality impacts.

The Department is also charged with the management of state school lands. This management may include water development.

Environmental Quality Council
Box 215, Capitol Station
Helena, Mt. 59601

As an advisory arm of the state legislature, the EQC is charged with overseeing the physical, biological, and human environments in Montana, all of which have water as a major component.

The 1973 legislature directed the EQC by resolution to undertake detailed studies of land use policy and energy policy. Important aspects of both areas are water resources.