IMPLICATIONS OF ALTERNATIVE MISSOURI RIVER FLOWS FOR POWER PLANTS

FAPRI-UMC Report #04-04
April 23, 2004

Prepared by the Food and Agricultural Policy Research Institute

101 South Fifth St.
Columbia, MO 65201
573-882-3576
www.fapri.missouri.edu

FAPRI
At the University of Missouri
Food and Agricultural
Policy Research Institute

IMPLICATIONS OF ALTERNATIVE MISSOURI RIVER FLOWS FOR POWER PLANTS

By John R. Kruse and Abner Womack
FAPRI – University of Missouri-Columbia

Introduction

The purpose of this paper is to discuss the potential impacts of low Missouri River flows on the power plants operating along the Missouri River and using the Missouri River for cooling water. There are nine power companies that operate the eighteen power plants using water from the Missouri River for cooling purposes. Of these nine companies, seven agreed to participate in this study including plants in Missouri, Kansas and Nebraska. Mid American Energy, who operates the three power plants in Iowa that use the Missouri River for cooling water, and Nebraska Public Power Division declined to participate in the study. The results discussed in this paper apply only to the seven participating companies.

Much of current discussion of Missouri River flows is focused on changes in the summer flows. For this reason, the primary focus of this study is the summer flow period which we have defined as June – September. Summer river flows are particularly relevant for power plants because the summer period corresponds to a peak demand period for electrical power.

Each power plant's specific situation is different. This paper presents the aggregate results for all plants on the Missouri River in order to protect the confidentiality of each of the plants that provided information for this study. The information used in this analysis was gathered from the power plants from September 2003 through April 2004 using surveys, personal interviews, and numerous meetings. The power companies reviewed the information presented in this study prior to its final release.

Power Plants on the River

A detailed list of power plants that use the Missouri River for cooling water was obtained using the online databases maintained by the Energy Information Agency. The list was further refined by individual conversations with each of the listed power plants. The power plants at some locations also include combustion turbine generators which do not use Missouri River water for cooling. The capacity of these generators has been deducted from the total power generation capacity for the river cooled plants. Table 1 lists the power plants below Gavins Point utilizing the Missouri River for cooling water and the capacity of each plant. A total summer generation capacity of 11,253.8 megawatts is supplied by power plants that use the Missouri River for cooling water across the states of Iowa, Nebraska, Kansas and Missouri. These plants represent about 25 percent of total power generation capacity in the four states (Table 2).

Table 1. Summer Capacity of Power Plants Below Gavins Point Using the Missouri River For Cooling Water in 2002*

Company	Plant Name	Summer Capacity
		Megawatts Per Hour
Missouri		
Central Electric Power Coop	Chamois	66.0
Ameren UE	Labadie	2,421.0
Ameren UE	Callaway**	1,143.0
Kansas City Power & Light Co	Hawthorn	865.0
Kansas City Power & Light Co	Iatan	670.0
UtiliCorp United Inc	Lake Road	97.0
UtiliCorp United Inc	Sibley	523.0
City of Independence	Missouri City	38.0
Missouri Subtotal		***5,823.0***
Kansas		
Kansas City Board of Public Utilities	Nearman Creek	225.0
Kansas City Board of Public Utilities	Kaw***	55.0
Kansas City Board of Public Utilities	Quindaro	208.0
Kansas Subtotal		***488.0***
Nebraska		
Nebraska Public Power District	Cooper	758.0
Omaha Public Power District	Fort Calhoun	476.0
Omaha Public Power District	Nebraska City	646.0
Omaha Public Power District	North Omaha	662.8
Nebraska Subtotal		***2,542.8***
Iowa		
MidAmerican Energy Co	Council Bluffs	806.0
MidAmerican Energy Co	George Neal North	950.0
MidAmerican Energy Co	Neal South	644.0
Iowa Subtotal		***2,400.0***
Four State Total		**11,253.8**

Data Source: Energy Information Administration
Consultation with the power companies excluding MidAmerican Energy

* The Corps reports 4,026 megawatts of power generation capacity from the dams on the Missouri River above Gavins Point.

** The Callaway plant has cooling towers, but still requires water from the Missouri River to support the cooling towers.

*** The Kaw plant is on the Kansas River but summer cooling water is supplied by the back flow of the Missouri River.

Table 2. 2002 Summer Power Generation Capacity Comparison
Power Plants Cooled by the Missouri River versus Total Power Generation

State	Plants Cooled by MO River	All Plants	Percent of Total
	(Megawatts Per Hour)		
Missouri	5,823.0	19,740.7	29.5%
Kansas	488.0	10,459.1	4.7%
Nebraska	2,542.8	6,033.7	42.1%
Iowa	2,400.0	9,277.5	25.9%
Four State Total	11,253.8	45,510.9	24.7%

Data Source: Energy Information Administration

Sources of Power Plant Impacts

Over the summer months power plants are primarily impacted by river flow rate and river water temperature. It is important to note that power plants are not uniformly affected by flow rate and river water temperature. Lower flow rates will reduce the amount of water available for compliance with thermal effluent limitations and will generally result in higher ambient river temperatures. Extreme low flows may also result in water accessibility problems for individual power plants. Water access problems occur when a plant simply cannot pump sufficient quantities of water to support full operation. Water access problems may force a plant to reduce load or completely shut down.

Each plant has a water intake positioned to withdraw water from the river. These water intakes are usually very large, fixed. As the flow rate falls the water intakes may not be able to pull enough water into the power plants to maintain cooling, causing the plant to de-rate from its summer capacity rating. The affected power plants have a very limited ability to compensate for intake problems since the pump suction elevations are fixed within the intake structure. Through the use of auxiliary pumps and other operations, low flows lasting only a few days can sometimes be compensated for, but usually not without damage to pumps and/or other equipment. Not all power plants on the Missouri River are affected by water intake problems.

Low river flows also affect the efficiency with which plants operate. The first efficiency loss is associated with the physical movement of the water from the river to the plant. When the river flow is low it takes more energy to pump the water into the power plant. In addition, low river flows result in increased accumulation of debris around the screens protecting the intake area, reducing efficiency.

River water temperature can also impact power plants significantly due to the thermal regulations. Each plant has a different set of regulations depending on its state and the specific profile of the Missouri River at its location. Under the Clean Water Act, thermal regulations were initially tied to the temperature of the water released into a mixing zone of the river. Occasionally, States established more rigorous regulations by shrinking the mixing zone area, which effectively reduced thermal releases. Power plants can apply for a “variance” from the thermal regulation if they can show that the river ecosystem is not affected by exceeding their thermal regulations. Several of the power plants are now operating with a variance from their original regulations. Under alternative water control plans that include lower summer river flows, it is more difficult for the power plants to show that the river ecosystem is unaffected and the power plants may not be able to obtain a variance in the future under a low flow water control plan. For purposes of this study, the current variances that have been granted are assumed to be continued. This could significantly understate the impacts the power plants may realize under a low flow water control plan.

Economic Analysis

To determine the economic impacts on power plants, FAPRI developed a model for each plant, a Missouri River flow model, and river water temperature relationships. These models were designed to evaluate the daily economic impacts of flow and river water temperature over the June through September period.

The first stage of this study involved gathering information on the de-rating process and shutdown parameters for each of the plants. The power plants were surveyed for level of river flow required for intakes and any thermal regulations pertaining to river water temperature as well as the de-rating process the plant might undergo if a critical point was reached. The plants were also asked to provide information on their fuel costs as well as the prices they have paid for purchasing electrical power from the grid. Due to the sensitive nature of this information, FAPRI agreed to keep each plant's information confidential.

The second stage of the study involved the development of a Missouri River flow model to simulate the flow from Gavins Point to St. Louis. The flow model calculates Missouri River flows at Sioux City, Omaha, Nebraska City, Rulo, St. Joseph, Kansas City, Waverly, Booneville, Hermann, and St. Louis under alternative releases from Gavins

Point. The historical data on river flows and inflows was compiled from Corps data and the United States Geological Survey data.

In the third stage of the study, a relationship between river water temperature, air temperature, flow, and inflows was estimated for those plants with binding thermal regulations. An investigation into secondary data sources for Missouri River water temperature revealed sporadic observations from the USGS in their water quality data set for a few locations. With only a couple of observations per month, the data set was not used. The power plants were asked to help provide data on the daily river water temperature at their intakes. The data provided was daily, and no data was available prior to 1996. Since some of the plants regarded the data as proprietary information, it will not be reported in this study. Data on flow rates and inflow were taken from the Corps and USGS databases and were measured in cubic feet per second. Air temperature data was assembled from the National Weather Service's online database in units of degrees Fahrenheit.

The relationship between river water temperature, air temperature, flow, and inflows was estimated using Ordinary Least Squares. The functional form of the model specified river water temperature as a function of the seven day moving average of air temperature, the reciprocal of the flow rate, the ratio of inflows to flows, and intercept shifters for June, July, and August. The regression equation was estimated only over the summer months (June – September) in order to focus on the period of interest. Since the river water temperature is more impacted at low flows than high flows, the reciprocal of the flow rate was used in the specification. Because air temperatures vary more than water temperatures, a seven day average of air temperatures (including the current day's temperature) was used to smooth out the day to day variances. Precipitation is also believed to cool the temperature of the river water. As a proxy for precipitation, the river inflow as a portion of the total flow was used. Inspection of the data suggests that this ratio has an impact for low flows and hot air temperatures, but little or no impact during high flows or low air temperatures. Therefore, this ratio was set to 0 during period of high flows or low air temperatures.

The final phase of the study involved the development of a model for each plant that calculated the economic damages. By using the flow and temperature requirements for each plant, the number of days and average de-rating for each month during the summer was calculated. Based on the capacity of the power plant and the average de-rating, the number of megawatt hours of reduced power production was calculated for each month. Each non-holiday weekday was assumed to have 16 hours of peak power demand and 8 hours of non-peak power demand with different power purchase prices from the grid for each period. Holidays and weekends were also assumed to have 16 hours of peak power demand and 8 hours of off peak demand with different power prices from the grid for each period. For each month the number of hours of weekday on peak, holiday and weekend on peak, and off peak hours was calculated. The total number of megawatt hours lost to de-ratings was then distributed to each of the three categories based on the share per month. The number of megawatt hours of de-rating in each category was then multiplied by the purchase price of power from the grid to calculate a gross economic damage. Since the power plant is not consuming fuel during the de-rate period, the fuel cost savings are then subtracted from the gross economic damage to determine a net economic damage.

The economic impacts in this study have been generalized to reflect consistent assumptions regarding the cost of replacement energy across all plants. Based on the power plant surveys and discussions with power industry experts, replacement energy prices on the grid were assumed to increase when power demand from all river power plants increases simultaneously. Table 3 presents the grid prices used in this study.

Table 3. Average Power Prices

	June	July	August	September
Megawatts Demanded	*Dollars Per Megawatt*			
Weekday On-Peak				
0 - 500 Megawatts	42	49	49	39
500 - 1000 Megawatts	45	52	52	42
1000 - 2000 Megawatts	54	62	62	50
2000 - 3000 Megawatts	65	74	74	60
3000 - 4000 Megawatts	78	89	89	72
4000 - 5000 Megawatts	94	107	107	86
5000 - 12,000 Megawatts	105	120	120	96
Weekend and Holiday On-Peak				
0 - 500 Megawatts	32	37	37	29
500 - 1000 Megawatts	34	39	39	32
1000 - 2000 Megawatts	41	47	47	38
2000 - 3000 Megawatts	49	56	56	45
3000 - 4000 Megawatts	59	67	67	54
4000 - 5000 Megawatts	71	80	80	65
5000 - 12,000 Megawatts	79	90	90	72
Off-Peak				
0 - 500 Megawatts	21	25	25	20
500 - 1000 Megawatts	23	26	26	21
1000 - 2000 Megawatts	27	31	31	25
2000 - 3000 Megawatts	33	37	37	30
3000 - 4000 Megawatts	39	45	45	36
4000 - 5000 Megawatts	47	54	54	43
5000 - 12,000 Megawatts	53	60	60	48

Source: Industry estimates.

Since river flow and water temperature vary with weather events as well as the Corps' water control plan, it was necessary to simulate alternative weather events through the model. In order to establish the weather variation experienced over a 100-year period (1898 through 1997), the daily weather conditions over the summer period in each year were simulated under alternative water control plans. This created 100 years of economic impacts for each plant for each alternative water control plan. For this study, the GP2021 scenario and the Corps' new master manual policy, formerly known as the Preferred Alternative, were simulated over the 100 year period. The GP2021 scenario includes a spring rise of 20,000 cubic feet per second (cfs) over navigation requirements for the May 15 – June 15 period, a flat 25,000 cfs release over the June 16 – July 15 period, a flat 21,000 cfs release over the July 16 – August 15 period, and a 25,000 cfs release over the August 16 – September 1 period. The exceptions to policy occur when the system is in a flood control mode or when there has been a severe drought in the upper reservoirs that might reduce flows over the May 15 to July 15 period. The Preferred Alternative does not include a spring rise, but does attempt to support navigation over the May 15 through September 1 period. As water levels in the upper reservoir allow, Gavins Point releases over the June to September period would typically vary from 28,500 to 35,000 cfs depending on whether minimum or full service navigation was supported and the downstream flood conditions. Under the new Master Manual, in severe droughts where navigation is not supported, flow levels fall to as low as 18,000 cfs during the May to August period and as low as 9,000 cfs during the September to November period.

To facilitate comparison with other Corps reports, the actual daily flows simulated by the Corps for the GP2021 and PA scenarios were used to determine the economic impacts on each power plant. Since the PA scenario was generated before the final Master Manual was completed, minimal flows over the September to November period do get as low as 7,000 cfs in extreme drought years.

In order to simulate over the 1898 to 1997 period, a consistent historical data set of river flows and river water temperatures was required. The Corps had already developed a historical data set of river flows for the period under alternative scenarios. Since river water temperatures are also estimated as a function of air temperatures, a data set of average daily air temperatures was constructed by piecing together air temperature data from the National Weather Service. When air temperature data was not available for a location a regression equation relating temperature at the location to another location with data was estimated. These regressions fit very well explaining 92 percent of the variation or more in all cases. Using the temperature, flow, and inflow data from 1898 to 1997, historical river water temperatures were estimated.

Results

Simulation of the GP2021 and PA scenarios over the 1898 to 1997 summer periods produced the aggregate results presented in Table 4. From Table 4, one can see that the probability of annual summer economic damage exceeding 52 million dollars under the GP2021 scenarios is about 25 percent compared to approximately 10 percent under the PA scenario. The annual summer expected loss generated by the GP2021 scenario is 46 million dollars compared to 21 million dollars under the Preferred Alternative option. The GP2021 option increases economic damages to the power plants over the PA scenario due to the low summer flows which impact power plants during peak periods of demand. The GP2021 also causes large damages with a higher degree of probability. For example, there is a 50 percent chance of damages exceeding 5.2 million dollars per summer under GP2021 while under the PA scenarios there is a 50 percent change of damage exceeding 0.005 million dollars per summer. Further details are available from the cumulative distributions presented in Figures 1 & 2.

Table 4. Probability of Summer Economic Damages

	GP2021	PA
100%	$0 or >	$0 or >
50%	>$5,194,865	>$5,271
25%	>$51,691,831	>$9,919,138
20%	>$75,227,757	>$16,530,691
10%	>$148,884,998	>$48,799,741
5%	>$191,401,985	>$188,150,515
2%	>$249,847,268	>$213,380,519
1%	$598,378,306	$259,042,543
Expected Value	$45,605,785	$21,036,946

Figure 1. Cumulative Distribution Of Power Plant Damages GP2021 Scenario

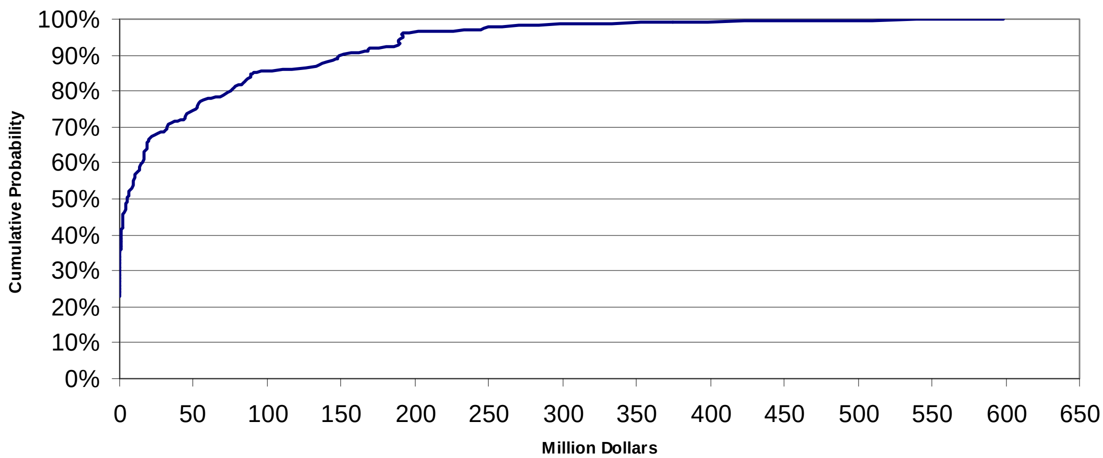
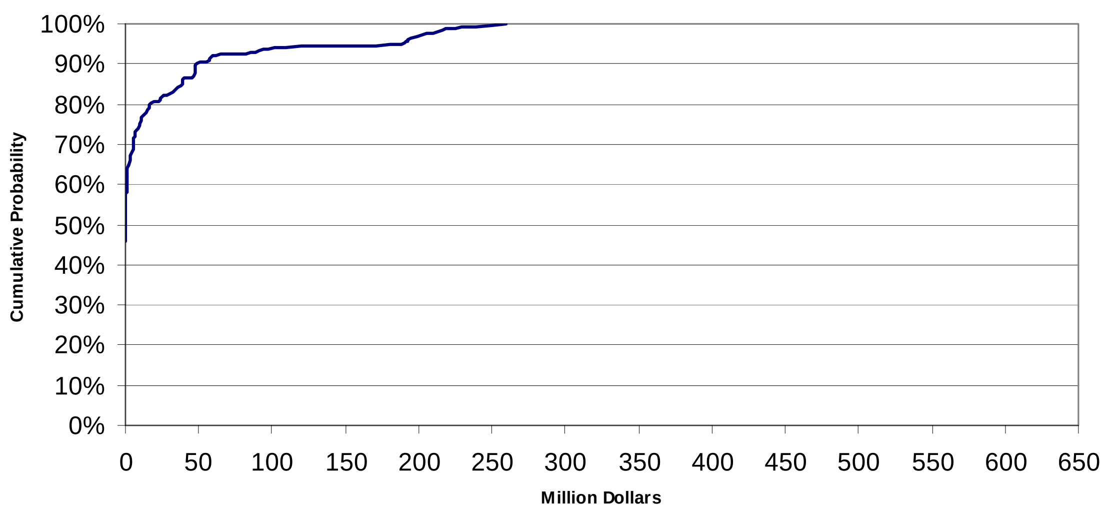


Figure 2. Cumulative Distribution Of Power Plant Damages Preferred Alternative Scenario



In the simulation of the 100-year period, when economic damages exceed 100 million dollars there is a significant chance of a rolling blackout or blackout. While limited power availability from the grid could be a possible cause of a blackout, the more likely cause may be the limited capacity of power transmission lines. When plants de-rate simultaneously, they may be able to purchase power from the grid, but they may not be able to transfer it to their power customers.

Conclusions

Due to the low summer flow included in the GP2021 water control plan, it produced economic damages that were on average twice the level of those incurred by the Preferred Alternative water control plan. In addition, the GP2021 water control plan produces higher economic damages more frequently the Preferred Alternative. While blackouts or rolling blackouts are difficult to precisely predict, the stress on the power transmission system is significant when annual summer economic damages exceed 100 million dollars. The GP2021 scenario produces economic damages of $100 million dollars or more with a 15 percent probability while economic damages from the Preferred Alternative exceed 100 million dollars with a 7 percent probability.

The economic damages calculated in this study pertain only to the summer month period of June through September. Other economic damages may be incurred during the October through May period, but those are not considered in this study.

In reviewing this study, several power plants commented that the grid prices used in this study may be conservative and may not reflect additional price pressure associated with power plant de-ratings in extreme situations.

REFERENCES

Energy Information Administration. http://www.eia.doe.gov, 2004.

Nebraska Power Association Joint Planning Subcommittee. December 2003. "Impacts of Possible Changes in Missouri River Flows on Nebraska's Electric Energy Industry."

National Weather Service. http://nws.noaa.gov, 2004.

US Army Corps of Engineers. July 1994. "Economic Studies Water Supply Economics" Volume 6B: Missouri River Master Water Control Manual, Review and Update Study, Missouri River Division.

US Army Corps of Engineers. July 1994. "Low Flow Studies, Gavins Point Dam to St. Louis, Missouri" Volume 3A: Missouri River Master Water Control Manual, Review and Update Study, Missouri River Division.

US Army Corps of Engineers. August 2001. "Revised Draft Environmental Impact Statement" Volume 1: Main Report, Missouri River Master Water Control Manual, Review and Update, Northwestern Division, Missouri River Basin, Water Management Division.

US Army Corps of Engineers. November 2003. "Final Biological Assessment On The Operation of the Missouri River Mainstream Reservoir System, The Operation and Maintenance of the Bank Stabilization and Navigation Project, and the Operation of Kansas River Reservoir System." Northwestern Division, Missouri River Basin, Water Management Division.

US Army Corps of Engineers. March 2004. "Missouri River Mainstream System 2004 Annual Operating Plan." Draft Final, Northwestern Division, Missouri River Basin, Water Management Division.

US Army Corps of Engineers. March 2004. "Missouri River Mainstream System Master Water Control Manual." Final Draft, Northwestern Division, Missouri River Basin, Water Management Division.

US Geological Survey. http://www.usgs.gov, 2004.