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MISSOURI RIVER AND MISSISSIPPI RIVER FORECAST VERIFICATION FOR THE GREAT MIDWEST FLOOD OF '93

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1. Introduction

The greatest flood to ever impact the United States occurred during the spring and summer of 1993. The entire Midwest was subject to record rainfall and record floods. Flood related deaths approached 50 and flood damages exceeded $15 billion. All or parts of nine states were involved. Nearly 100 river locations had record crests. Every location on the mainstem Missouri River from Rulo, Nebraska, downstream to St. Charles, Missouri, and every location on the mainstem Mississippi from Davenport, Iowa, downstream to Chester, Illinois, had record crests (Figure 1).

The National Weather Service (NWS) is responsible for producing river and flood forecasts. The forecasts are made for about 1,000 specific locations on rivers in the Central Region. In the case of the '93 Midwest Flood, the NWS was producing daily forecasts for about 500 separate river locations.

Verification of river forecasts is generally difficult because historical forecast data are limited for most locations. However, on the mainstem Mississippi and mainstem Missouri Rivers, daily forecasts are made year round and a significant historical data base has been accumulated over the past 12 to 14 years. Therefore, the quality of forecasts for the Flood of '93 can be compared with historical data to produce a quantitative evaluation.

2. Procedures and Data

Flood forecasts for the Mississippi River from the headwaters downstream to Chester, Illinois, are made by the North Central River Forecast Center in Minneapolis, Minnesota. Flood forecasts for the entire Missouri River are made by the Missouri Basin River Forecast Center in Pleasant Hill, Missouri. Each day, these two NWS offices produce forecasts for 12 locations on the Missouri River, and for 10 locations on the Mississippi River for 24-, 48- and 72-hours into the future (Table 1).

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MISSOURI AND MISSISSIPPI RIVERS
DAILY FORECAST POINTS

Figure 1

TABLE 1

Forecast Locations

Missouri River	Mississippi River
Sioux City, IA	St. Paul, MN
Omaha, NE	Guttenburg, IA
Nebraska City, NE	La Crosse, WI
Rulo, NE	Burlington, IA
St. Joseph, MO	Quad Cities
Kansas City, MO	Hannibal, MO
Waverly, MO	Grafton, IL
Glasgow, MO	Alton, IL
Booneville, MO	St. Louis, MO
Jefferson City, MO	Chester, IL
Hermann, MO	
St. Charles, MO	

Bias, variance, standard deviation and mean absolute error can be calculated by comparing forecast stages for each location for 24-, 48- and 72-hour forecasts with actual observed crests for the given time. Similar statistics can be calculated for the entire Mississippi or Missouri Rivers by combining forecasts for all points on the river.

The statistics for the entire river are good indicators for long-term trends in hydrologic forecast capabilities. The mainstem river forecasts for the Mississippi or the Missouri Rivers are a summary or integrator of the forecasting skills for the entire region. As our skills and capabilities improve on the headwaters and tributaries, our skills on the mainstem rivers will improve also. This will be reflected in the forecast statistics for the mainstem rivers.

3. Results

Table 2 shows forecast statistics for the entire Mississippi River, ten locations for the entire period of forecast statistics, February of 1981 through August of 1993. Table 2 also shows the forecast statistics for one forecast point, St. Louis, for its period of record, April 1981 through August of 1993. Table 3 shows the same statistics except for the period of the Great Midwest Flood, June through August, 1993.

Table 4 shows forecast statistics for the entire Missouri River, 12 locations for its period of forecast verification, October 1979 through August 1993. It also shows similar statistics for one forecast point on the river, St. Charles, Missouri, for the same verification period. Table 5 shows similar statistics for the Missouri River for the period of the Great Midwest Flood, June through August, 1993.

TABLE 2

Mississippi River - Monthly Forecast Statistics (150 months)

Location	Period	Bias	Variance	Standard Deviation	Abs. Error	Forecast Period
Entire River	2/81-	0 ft.	.3 ft.	.5 ft.	.3 ft.	24 hrs
(10 Locations)	8/93	-.1	.8	.9	.5	48 hrs
		-.2	1.5	1.2	.7	72 hrs
St. Louis	4/81-	0 ft.	.5	.7	.5	24hrs
	8/93	-.2	1.5	1.2	.8	48 hrs
		-.4	3.0	1.7	1.1	72 hrs

TABLE 3

Mississippi River - Monthly Forecast Statistics (3 months)

Location	Period	Bias	Variance	Standard Deviation	Abs. Error	Forecast Period
Entire River	6/93-	0	.2	.4	.2	24 hrs
(10 Locations)	8/93	-.1	.5	.7	.5	48 hrs
		-.2	1.0	1.0	.7	72 hrs
St. Louis	6/93-	.1	.2	.5	.3	24 hrs
	8/93	.1	.7	.8	.7	48 hrs
		0	1.2	1.1	.9	72 hrs

The forecast statistics for the 1993 record flood for the entire Mississippi River and for the Mississippi River at St. Louis are excellent. From Tables 2 and 3, it can be seen that all forecast statistics actually improved during the three month flood period (June, July, August 1993) as compared to the long term forecast statistics.

In particular, it can be seen that the absolute error improved, or in two categories, stayed the same. For example, the absolute forecast error for the entire river went from .3 ft to .2 ft for a 24-hour forecast. At St. Louis, the absolute error for a 24-hour forecast stage dropped from .5 ft to .3 ft for a 24-hour forecast, from .8 ft to .7 ft for a 48-hour forecast and from 1.1 ft to .9 ft for a 72-hour forecast.

TABLE 4

Missouri River - Monthly Forecast Statistics (166 months)

Location	Period	Bias	Variance	Standard Deviation	Abs. Error	Forecast Period
Entire River	10/79-	-.1 ft.	.4 ft.	.6 ft.	.3 ft.	24 hrs
(12 Locations)	8/93	-.2	1.1	1.1	.5	48 hrs
		-.5	2.0	1.4	.8	72 hrs
St. Charles, MO	10/79-	-.1	.5	.6	.4	24 hrs
	8/93	-.2	1.2	1.1	.6	48 hrs
		-.4	2.1	1.4	.9	72 hrs

TABLE 5

Missouri River - Monthly Forecast Statistics (3 months)

Location	Period	Bias	Variance	Standard Deviation	Abs. Error	Forecast Period
Entire River	6/93-	-.1	.8	.9	.5	24 hrs
(12 Locations)	8/93	-.6	2.4	1.6	1.1	48 hrs
		-1.2	4.8	2.2	1.8	72 hrs
St. Charles, MO	6/93-	.0	.7	.8	.5	24 hrs
	8/93	-.3	1.5	1.2	.8	48 hrs
		-.6	2.5	1.6	1.3	72 hrs

On the Missouri River, forecast statistics did increase somewhat during the 1993 Midwest floods, but certainly stayed well within reasonable and expected bounds. For example, the absolute forecast error for the entire Missouri River increased from .3 ft to .5 ft for a 24-hour forecast, from .5 ft to 1.1 ft for a 48-hour forecast and from .8 ft to 1.8 ft for a 72-hour forecast for the June through August '93 period, as compared to the long term averages.

At St. Charles, Missouri, forecast errors for the Missouri River increased from .4 ft to .5 ft for a 24-hour forecast, from .6 ft to .8 ft for a 48-hour forecast and from .9 ft to 1.3 ft for a 72-hour forecast. However, bias at St. Charles decreased from -.1 ft to 0 ft for 24-hour forecasts during the 1993 flood.

A natural question for the Missouri River would be, what would be an acceptable increase in forecast errors during a record flood such as occurred in 1993? One way to approach this would be to simply examine the ability to measure actual river flows during high flow conditions.

The U.S. Geological Survey states that "good" measurements during major flows are accurate within ± 5 percent. The peak flow at St. Charles at the 1993 crest was about 670,000 cubic feet per second (stage of 39.5 ft on August 2, as compared to the previous stage of record of 37.5 ft on October 7, 1986). Measurement of flows near the 1993 crest at St. Charles could have been in error by as much ± 33,500 cfs (.05 (670,000)). The stage-discharge relationship, Figure 2, which had to be extended past the previous record stage of 37.5 ft, shows that a ± 33,500 cfs at the record crest at St. Charles would equal about ± .5 ft difference in stage. A flow forecast at St. Charles near the record crest could result in an error of up to ± .5 ft in stage just in the conversion of flows to stage. The extension of stage/discharge relationships at record flows is risky at best and introduces significant but unavoidable errors. This is only one example of a possible error when forecasting record crests.

Thus, an increase of average absolute forecast error at St. Charles of .1 ft for a 24-hour forecast, .2 ft for a 48-hour forecast and .4 ft for a 72-hour forecast is well within the ± .5 ft or more potential error just due to flow measurement and rating extension errors.

4. Summary

The flood forecasting effort by the NWS during the Great Flood of '93 was outstanding. This is verified by the verification statistics for the Mississippi River. Statistics such as bias, variance, standard deviation and absolute error decreased during the flood period (i.e., June through August, 1993) as compared to the long term forecast averages. This is remarkable considering the unknowns of record rainfall, rating extensions, levee failures and record crests. The record crest at St. Louis exceeded the previous record by over six feet (49.6 in 1993 versus 43.2 in 1973). This puts the magnitude of the flood in perspective when one considers that record crests on major rivers, such as the Mississippi, are usually broken by tenths of a foot, not multiples of feet. The situation on the Missouri River was essentially the same with forecast statistics increasing only slightly during the Great Flood of '93, as compared to long term averages. Certainly increases in absolute errors and 48 and 72-hour bias were well within the expected increased uncertainty when forecasting flows of major rivers during record floods. It should be remembered that nearly 100 locations within the Missouri River drainage and the Upper Mississippi drainage had record crests during this event. Producing thousands of flood forecasts over a nine-state area and a three-month period with overall flood forecast statistics improving or increasing only slightly is an outstanding hydrologic forecasting effort.

Missouri River at
St. Charles, MO
Stage-Discharge Relation

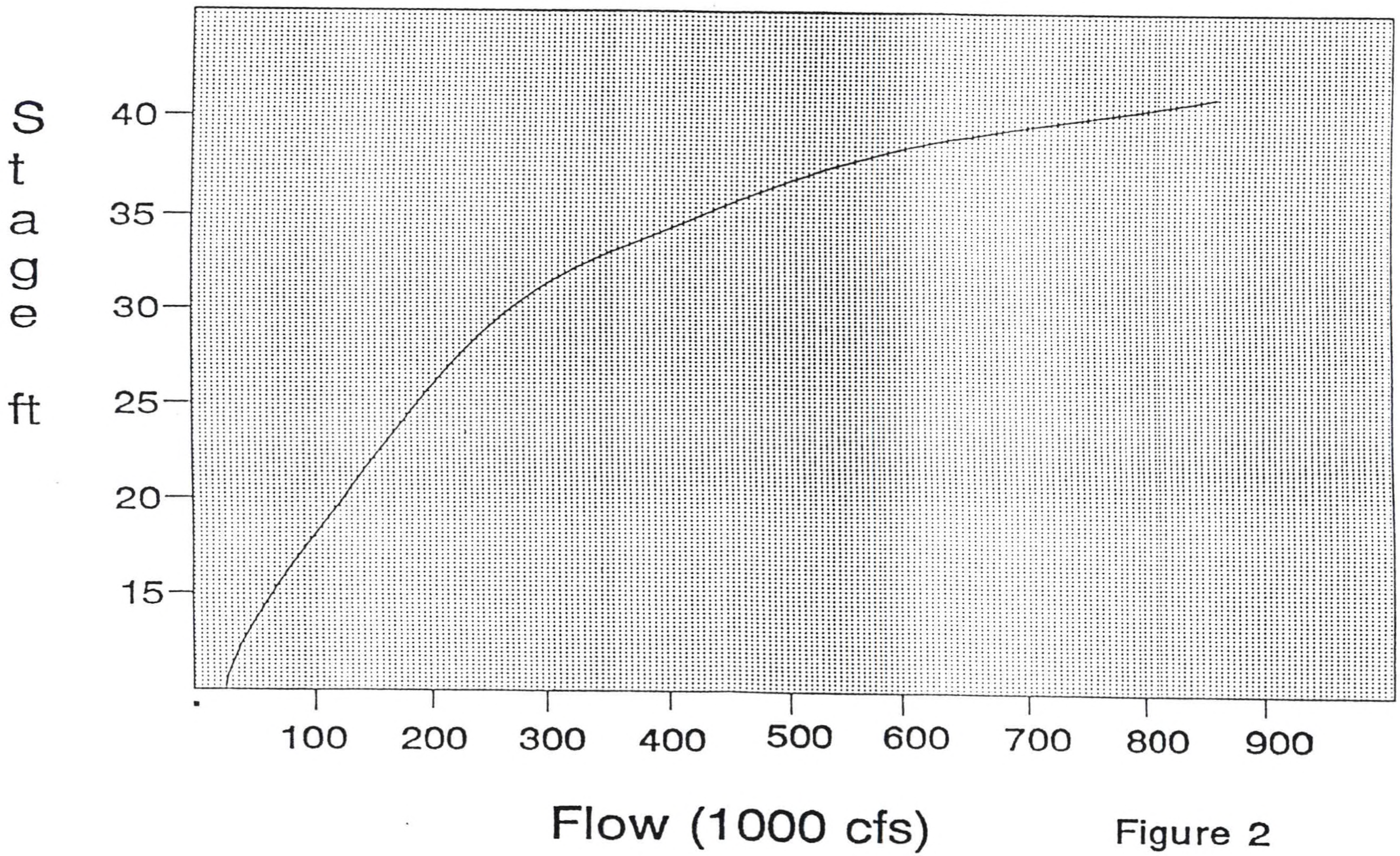

Figure 2