Stream Flow Changes in the Southern Red River Valley of North Dakota

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Climatic events in recent years have had major impact on the economic well-being of many North Dakotans. The summer flood of 1975 destroyed thousands of acres of crops in the southern Red River Valley, caused major soil erosion, destroyed bridges, and damaged homes, farmsteads, and other property. The statewide spring and summer drought of 1980 was comparable to that of 1934 and 1936, resulting in complete crop failure in some areas. These events are directly attributable to extreme climatic situations.

At the same time, flooding has occurred in recent years when the climatic conditions would not be regarded as extreme and in areas where flooding previously has not been a serious problem. Old time residents of Enderlin, along the Maple River, state that flooding had never been a problem until about 20 years ago. Now, houses in a major section of the town have been abandoned because of repeated flooding.

The problem of flooding is a controversial and emotional issue. There are charges and statements as to causes and solutions for the problem. Many are unsubstantiated and erroneous. In this report the authors address three conditions frequently discussed in relation to flooding problems. These are:

1. Have stream and river flow increased?
2. Has there been a climatic change that can be related to increased stream and river flow?
3. Has agricultural land drainage affected stream and river flow?

Changes in Flow

Discharge data from nine gaging stations were analyzed to determine if changes in flow over time have occurred. Locations are shown in Figure 1. There were three comparisons of flow with time using linear regression. This simple statistical test will tell if flow rates are increasing, decreasing or unchanged over the time period measurements have been made. These comparisons were:

1. Mean annual flow for the water year (Oct. 1 of one year through Sept. 30 of the following year) versus time in years.
2. The maximum daily flow in a given water year versus time in years.
3. The mean spring flow (for March, April and May) in a given water year versus time in years.

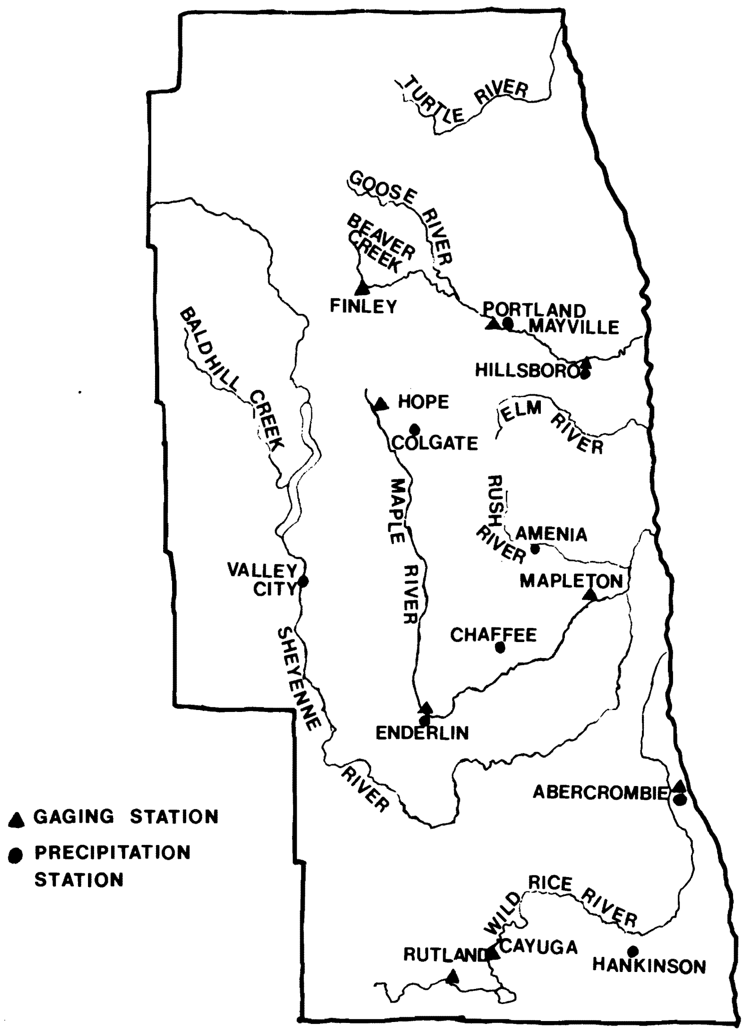

FIGURE 1. Locations of stream gaging stations and precipitation stations used in stream flow analysis.

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The analyses were done by indexing the first water year as 1 and incrementing each following water year by 1 through the period of record. Flow was then correlated with the indexed years for the nine gaging stations. Discharge or flow is expressed in cubic feet per second. Results are shown in Table 1.

A consistent pattern for all three comparisons emerged. At nearly all locations, the regression equations indicate that the flow rates have increased with time. They further indicate that the flows have increased faster at stations further downstream. In fact, at the last gaging station on a river the relationship between flow and time is usually statistically significant. For example, this means there is a 99 per cent probability that the mean annual flow at Hillsboro has increased with time and only a 1% probability that these data would have occurred by chance.

The headwaters of the Maple River near Hope show a negative correlation, implying flow has decreased with time. However, the Colgate precipitation data for this short time period also have a negative correlation with time (Table 3) which is the reason for this observation.

The Climate Factor

The flow analyses show flow rates have increased on a year-to-year basis except for the Maple River near Hope. The question is to determine if the increased flows could be due to a climatic factor. To address this question two analyses were performed again, using linear regression. If it can be shown that flow rates are related to climate and also shown that the climatic factor (precipitation) has increased in a fairly regular manner over the last 20 to 40 years, a reasonable explanation would exist for the increase in flow rates.

In Table 2 there is a comparison of Mean Annual Flow with Mean Annual Precipitation (both for the water year) and Mean Spring Flow (based on March, April and May) with Winter plus Spring Precipitation (Nov. through the following May). In all cases a positive correlation exists and in many cases there is a statistically significant relationship indicating flow rates increase as precipitation increases. While Table 2 shows flow rates are related to precipitation, it still leaves much of the observed variation in flow unexplained.

Next is a comparison of Mean Annual Precipitation (for the water year) with time as shown in Table 3. At some stations comparisons were made over different time periods to correspond to the available stream flow data. For example, the precipitation data at Colgate were evaluated for three time periods corresponding to the flow data at Hope, Enderlin and Mapleton. There is no detectable pattern or change with a similar number of positive and negative correlations.

So far our analysis has shown:

1. Flow rates have increased with time.

TABLE 1. Comparison of flow rates (ft^3/s) with time (water year) at nine sites in southeastern ND where r is the correlation coefficient, n the number of years and SIG the level of statistical significance.

WATER YEAR	LOCATION	EQUATION	r	n	SIG.
		MEAN ANNUAL FLOW (MAF)-TIME (T)			
OCT 64-SEP 65 TO OCT 77-SEP 77	MAPLE RIVER NR HOPE	MAF = −0.32 (T) + 5.36	−0.73	14	1%
OCT 56-SEP 57 TO OCT 77-SEP 78	MAPLE RIVER NR ENDERLIN	MAF = 1.56 (T) + 20.8	0.27	22	25%
OCT 44-SEP 45 TO OCT 74-SEP 75	MAPLE RIVER NR MAPLETON	MAF = 3.46 (T) + 18.1	0.40	31	2.5%
OCT 59-SEP 60 TO OCT 78-SEP 79	WILD RICE RIVER NR RUTLAND	MAF = −0.017 (T) + 9.60	−0.01	20	--
OCT 56-SEP 57 TO OCT 78-SEP 79	WILD RICE RIVER NR CAYUGA	MAF = 0.16 (T) + 17.2	0.05	23	--
OCT 32-SEP 33 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE	MAF = 1.34 (T) + 41.7	0.21	46	20%
OCT 64-SEP 65 TO OCT 78-SEP 79	BEAVER CREEK NR FINLEY	MAF = 0.11 (T) + 9.12	0.08	15	--
OCT 39-SEP 40 TO OCT 74-SEP 75	GOOSE RIVER NR PORTLAND	MAF = 0.71 (T) + 17.5	0.19	36	25%
OCT 31-SEP 32 TO OCT 78-SEP 79	GOOSE RIVER AT HILLSBORO	MAF = 2.24 (T) + 12.8	0.38	46	1%
		MAXIMUM DAILY FLOW (MDF)-TIME (T)			
OCT 64-SEP 65 TO OCT 77-SEP 78	MAPLE RIVER NR HOPE	MDF = −21.1 (T) + 33.8	−0.63	14	2.5%
OCT 56-SEP 57 TO OCT 78-SEP 79	MAPLE RIVER NR ENDERLIN	MDF = 69.4 (T) + 364	0.29	22	20%
OCT 44-SEP 45 TO OCT 74-SEP 75	MAPLE RIVER NR MAPLETON	MDF = 84.6 (T) + 585	0.34	31	5%
OCT 59-SEP 60 TO OCT 78-SEP 79	WILD RICE RIVER NR RUTLAND	MDF = 5.59 (T) + 140	0.12	20	--
OCT 56-SEP 57 TO OCT 78-SEP 79	WILD RICE RIVER NR CAYUGA	MDF = 7.24 (T) + 217	0.13	23	--
OCT 32-SEP 33 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE	MDF = 28.5 (T) + 851	0.21	46	20%
OCT 64-SEP 65 TO OCT 78-SEP 79	BEAVER CREEK NR FINLEY	MDF = −2.75 (T) + 484	−0.03	15	--
OCT 39-SEP 40 TO OCT 74-SEP 75	GOOSE RIVER NR PORTLAND	MDF = 13.0 (T) + 883	0.10	36	--
OCT 31-SEP 32 TO OCT 78-SEP 79	GOOSE RIVER AT HILLSBORO	MDF = 75.3 (T) + 54.2	0.39	46	1%
		MEAN SPRING FLOW (MSF)-TIME (T)			
OCT 64-SEP 65 TO OCT 77-SEP 78	MAPLE RIVER NR HOPE	MSF = −0.75 (T) + 15.1	−0.50	14	10%
OCT 56-SEP 57 TO OCT 78-SEP 79	MAPLE RIVER NR ENDERLIN	MSF = 4.66 (T) + 55.1	0.27	22	25%
OCT 44-SEP 45 TO OCT 74-SEP 75	MAPLE RIVER NR MAPLETON	MSF = 6.87 (T) + 86.6	0.34	31	10%
OCT 59-SEP 60 TO OCT 78-SEP 79	WILD RICE RIVER NR RUTLAND	MSF = 0.38 (T) + 22.4	0.07	20	--
OCT 56-SEP 57 TO OCT 78-SEP 79	WILD RICE RIVER NR CAYUGA	MSF = 1.54 (T) + 33.7	0.15	23	--
OCT 32-SEP 33 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE	MSF = 3.41 (T) + 120	0.18	46	25%
OCT 64-SEP 65 TO OCT 78-SEP 79	BEAVER CREEK NR FINLEY	MSF = 0.73 (T) + 30.4	0.13	15	--
OCT 39-SEP 40 TO OCT 74-SEP 75	GOOSE RIVER NR PORTLAND	MSF = 2.24 (T) + 66.6	0.16	36	--
OCT 31-SEP 32 TO OCT 78-SEP 79	GOOSE RIVER AT HILLSBORO	MSF = 7.57 (T) + 42.6	0.34	46	2.5%

2. Flow rates increase as precipitation increases.
3. There has been no significant increase or decrease in precipitation over the period in which flow rates have increased.

Land Drainage

Considerable surface drainage of agricultural land in North Dakota has occurred within the last 30 to 40 years. Water that once was held in fields, depressions and sloughs now is free to drain into streams and rivers. However, little information can be found on the magnitude of change due to drainage. To evaluate this question the natural drainage basin and the drained land in the Maple River and Goose River catchment basins above the Glacial Lake Agassiz Plain were determined. United States Geological Survey maps were used to calculate the total acreage in each catchment basin. A ground survey was conducted during the summer of 1979 to determine the acreage in the natural drainage basin and the additional acreage that now drains in the basin as a result of land drainage. These data, shown in Table 4, indicate the current drainage basin is much greater due to land drainage.

The effects of drainage on flow rates at Enderlin and Portland were evaluated. The acreage in the natural drainage basin and the acreage in the current drainage basin were compared with the mean annual flow, the maximum daily flow and the mean spring flow obtained from the prediction equations in Table 1. In using the flow prediction equations we have assumed drainage started near the time when flow records began and has proceeded annually in a fairly uniform manner.

The regression analysis shows the increase in predicted flow is strongly related to increase in drainage area in each basin (Table 5). The analysis indicates that approximately 50 per cent of the increase in predicted mean annual flow, 36 per cent of the increase in predicted maximum daily flow, and 70 per cent of the increase in predicted mean spring flow is due to increased drainage area. In the second part of Table 5 we assumed the same proportion of land drainage upstream from Mapleton and Hillsboro as there was upstream from Enderlin and Portland, respectively. Any error in

TABLE 2. Comparison of flow rates (ft^3/s) with precipitation (in) at six sites in southeastern ND where r is the correlation coefficient, n the number of years and SIG the level of statistical significance.

WATER YEAR	LOCATION	EQUATION	r	n	SIG.
	MEAN ANNUAL FLOW (MAF) - MEAN ANNUAL PRECIPITATION (MAP)				
OCT 64-SEP 65 TO OCT 77-SEP 78	MAPLE RIVER NR HOPE-COLGATE	MAF = 0.10 (MAP) + 1.13	0.25	14	--
OCT 56-SEP 57 TO OCT 77-SEP 78	MAPLE RIVER NR ENDERLIN-ENDERLIN	MAF = 2.62 (MAP) − 17.15	0.42	22	5%
OCT 32-SEP 33 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE-HANKINSON	MAF = 8.23 (MAP) − 91.52	0.45	46	1%
OCT 56-SEP 57 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE-ABERCROMBIE	MAF = 8.57 (MAP) − 98.82	0.45	22	5%
OCT 39-SEP 40 TO OCT 74-SEP 75	GOOSE RIVER NR PORTLAND-MAYVILLE	MAF = 3.50 (MAP) − 37.57	0.34	36	5%
OCT 32-SEP 33 TO OCT 77-SEP 78	GOOSE RIVER AT HILLSBORO-HILLSBORO	MAF = 2.11 (MAP) + 26.29	0.11	41	--
	MEAN SPRING FLOW (MSF) - WINTER + SPRING PRECIPITATION (PWS)				
OCT 64-SEP 65 TO OCT 77-SEP 78	MAPLE RIVER NR HOPE-COLGATE	MSF = 0.05 (PWS) + 9.06	0.01	14	--
OCT 56-SEP 57 TO OCT 77-SEP 78	MAPLE RIVER NR ENDERLIN-ENDERLIN	MSF = 9.01 (PWS) + 39.73	0.17	22	--
OCT 32-SEP 33 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE-HANKINSON	MSF = 26.11 (PWS) − 7.56	0.26	46	10%
OCT 56-SEP 57 TO OCT 77-SEP 78	WILD RICE RIVER NR ABERCROMBIE-ABERCROMBIE	MSF = 33.99 (PWS) − 52.61	0.30	22	20%
OCT 39-SEP 40 TO OCT 74-SEP 75	GOOSE RIVER NR PORTLAND-MAYVILLE	MSF = 41.82 (PWS) − 188.51	0.65	36	1%
OCT 32-SEP 33 TO OCT 77-SEP 78	GOOSE RIVER AT HILLSBORO-HILLSBORO	MSF = 52.53 (PWS) − 146.53	0.37	41	2.5%

TABLE 3. Comparison of precipitation (in) with time (water year) at nine sites in southeastern ND where r is the correlation coefficient, n the number of years and SIG the level of statistical significance.

PRECIPITATION (PPT) - TIME (T)

WATER YEAR	LOCATION	EQUATION	r	n	SIG.
OCT 64-SEP 65 TO OCT 77-SEP 78	COLGATE	PPT = −0.31 (T) + 21.14	−0.30	14	25%
OCT 56-SEP 57 TO OCT 77-SEP 78	COLGATE	PPT = −0.01 (T) + 18.53	−0.01	22	--
OCT 44-SEP 45 TO OCT 77-SEP 78	COLGATE	PPT = 0.02 (T) + 17.64	0.05	35	--
OCT 44-SEP 45 TO OCT 77-SEP 78	VALLEY CITY	PPT = −0.03 (T) + 19.44	−0.08	35	--
OCT 32-SEP 33 TO OCT 77-SEP 78	HILLSBORO	PPT = 0.02 (T) + 19.41	0.06	43	--
OCT 63-SEP 64 TO OCT 77-SEP 78	CHAFFEE	PPT = 0.00 (T) + 20.10	0.00	15	--
OCT 56-SEP 57 TO OCT 77-SEP 78	ENDERLIN	PPT = −0.11 (T) + 22.56	−0.11	22	--
OCT 39-SEP 40 TO OCT 74-SEP 75	MAYVILLE	PPT = 0.03 (T) + 18.87	0.09	36	--
OCT 32-SEP 33 TO OCT 77-SEP 78	HANKINSON	PPT = 0.05 (T) + 18.83	0.14	46	--
OCT 56-SEP 57 TO OCT 77-SEP 78	AMENIA	PPT = −0.02 (T) + 21.48	−0.03	22	--
OCT 50-SEP 51 TO OCT 77-SEP 78	AMENIA	PPT = 0.10 (T) + 19.13	0.17	28	--
OCT 56-SEP 57 TO OCT 77-SEP 78	ABERCROMBIE	PPT = −0.10 (T) + 22.75	−0.13	22	--

this assumption would be small since the ground survey of the drainage basins above Enderlin and Portland are a large part of the Mapleton and Hillsboro basins, respectively. The current drainage upstream from Mapleton was estimated to be 64 per cent greater than the natural drainage, while the current drainage upstream from Hillsboro was estimated to be 180 per cent greater the natural drainage. This gave even higher correlations of predicted flow to acreage than the previous case (Table 5).

TABLE 4. Acreage in Maple River and Goose River basins and changes due to land drainage.

Total Catchment Basin	Natural Drainage Basin	Drained Land Estimate	Total Current Drainage Basin
	Maple River		
636,000 acres	126,800 acres (19.9%)	80,700 acres (12.7%)	207,500 acres (32.6%)
	Goose River		
609,800 acres	110,700 acres (18.2%)	199,000 acres (32.6%)	309,700 acres (50.8%)

TABLE 5. Comparison of predicted flow rates (ft^3/s) to natural drainage and current drainage area where r is the correlation coefficient.

Flow	Predicted flow rates for:				r
	Enderlin		Portland		
	Natural Drainage	Current Drainage	Natural Drainage	Current Drainage	
	126,800 acres	207,500 acres	110,700 acres	309,700 acres	
	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	
Mean Annual	22.36	55.12	18.21	43.06	0.72
Maximum Daily	433.4	1891	896.0	1351	0.60
Mean Spring	59.76	157.6	68.84	147.2	0.84
	Predicted flow rates for:				
	Mapleton		Hillsboro		
	Natural Drainage	Current Drainage	Natural Drainage	Current Drainage	
	1.00 Weighted acres	1.64 Weighted acres	1.00 Weighted acres	2.80 Weighted acres	
	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)	
Mean Annual	21.56	125.4	15.04	115.8	0.79
Maximum Daily	669.6	3208	129.5	3528	0.86
Mean Spring	93.47	299.6	50.17	390.8	0.93

Conclusions

Significant increases in flow on the Maple, Wild Rice and Goose Rivers have occurred over the last 30 to 40 years. Flow rates were shown to be related to climate (precipitation); however, there appears to be no change in precipitation patterns to account for the increase in flow rates. Predicted flow rates were shown to be closely related to changes in basin size due to land drainage in the Maple River and Goose River basins. It appears that land drainage is a factor aggravating the flooding problem in eastern North Dakota; however, no attempt was made to quantify its overall significance.

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