PERFORMANCE OF SSARR MODEL

SAINT JOHN RIVER BASIN

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ABSTRACT

An evaluation of the forecasting accuracy of the SSARR (Streamflow Synthesis and Reservoir Regulation) model in determining flood flows and levels on the Saint John River Basin, New Brunswick, has been completed. The forecasted values, at an equal number of water level and discharge monitoring stations, were compared with measured values. The statistics used to compare the model performance are the mean, standard deviation, absolute and relative error between measured and computed values. The stations are at strategic locations along the Saint John River Basin. The performance of the model was analyzed during the Springs of 1973 to 1976, inclusive. This evaluation does not provide conclusive evidence of the model's success, due to its short history on this Basin, however, the results do show increasing success from one year to the next.

INTRODUCTION

(1) The Objective

The objective of this paper is to evaluate the forecasting accuracy (error analysis) of the SSARR (Streamflow Synthesis and Reservoir Regulation) model in determining flood flows and levels on the Saint John River Basin, New Brunswick.

(2) The Model

The SSARR model, a computerized flood forecasting program, was developed by the North Pacific Division of the United States Army Corps of Engineers. SSARR is a mathematical-hydrologic model of a river basin system which synthesizes streamflow by evaluating snowmelt and rainfall runoff. The river basin is divided into a number of sub-basins for which the basic snowmelt and rainfall runoff relations are established. The runoff generated is distributed by user-specified functions to surface flow, subsurface flow and base flow. All three components are routed through variable volumes and times of storage before being combined as streamflow. When used as a predictive tool, the model relies on meterological forecasts of temperature and precipitation as input data and the flood forecasts can be continuously updated as recorded streamflow and precipitation data are reported. The SSARR watershed model is extremely versatile and offers many options (backwater computations, etc.) as choices to simulate streamflow from a basin.

The Corps of Engineers SSARR Model was obtained in early February, 1973, by the New Brunswick Electric Power Commission, and the task of applying this model to the Saint John River Basin began immediately.

(3) The Basin

The Saint John River Basin lies across southeastern Quebec, northern Maine and western New Brunswick (see Figure 1). The drainage area of the Basin

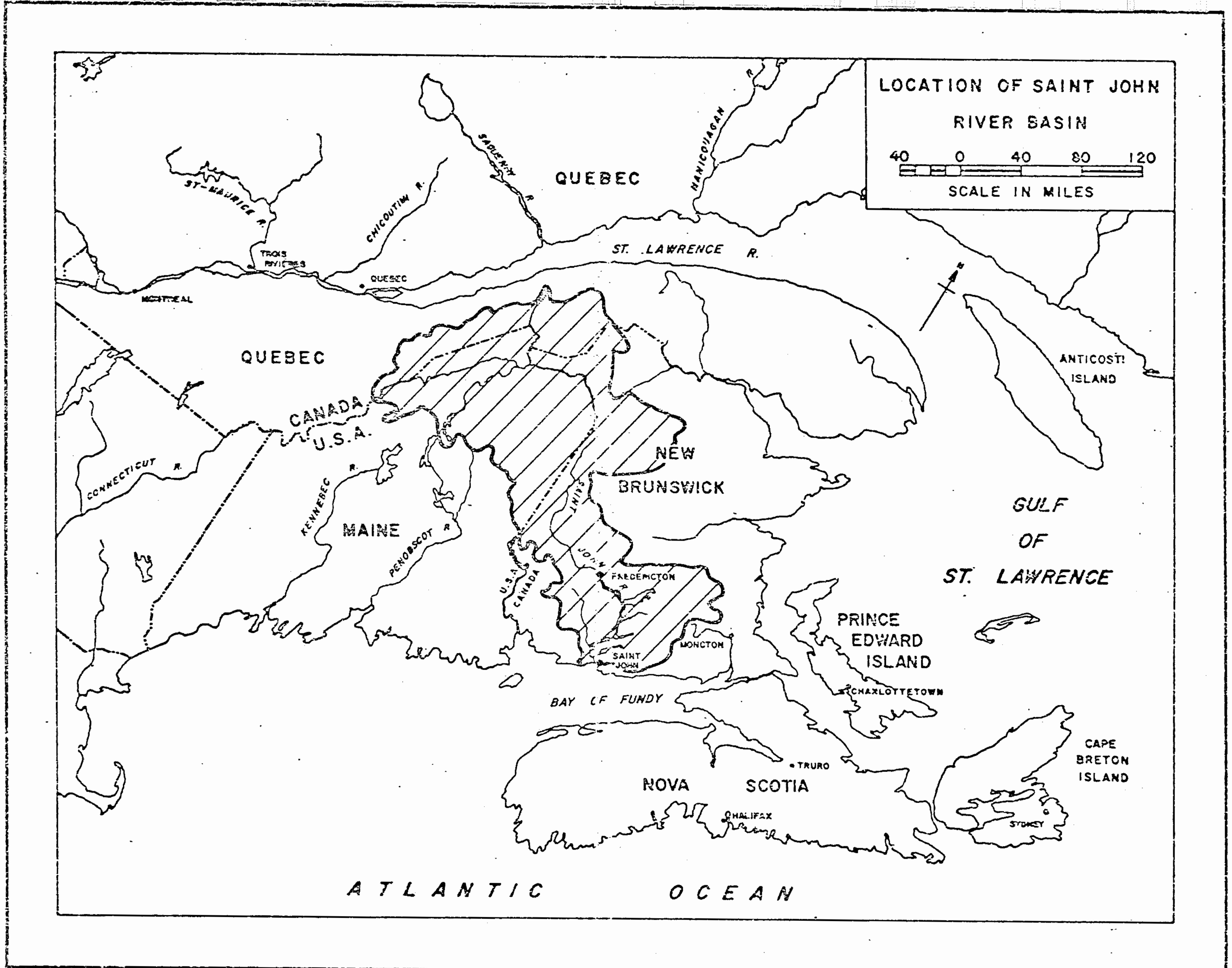

FIGURE 1

DEPARTMENT OF THE ENVIRONMENT, DECEMBER 1971 is 21,300 square miles, of which 51 per cent or 10,950 square miles lie in New Brunswick, 13 per cent or 2,750 square miles in Quebec and the remaining 36 per cent or 7,600 square miles in Maine. A map of the Basin is shown on Figure 2.

The Saint John River above Little Saint John Lake, its point of origin, flows northeastward for about 100 miles through the Chaleur Uplands and then swings in a broad arc to the southeast to Grand Falls, New Brunswick. The river turns south and flows through the Uplands for another sixty miles until it enters the New Brunswick Highlands near Woodstock. Below Woodstock, the Saint John River flows southeastward and enters the New Brunswick Lowland about ten miles upstream of Fredericton and continues southeastward through the Lowland until it enters the Caledonia Highlands where it turns southward to the Reversing Falls at Saint John, and empties into the Bay of Fundy.

Along its 435 miles long streambed, the Saint John River has a total fall of 1,580 feet between Little Saint John Lake and the tide waters of the Bay of Fundy. River slopes gradually decrease from about 8 feet per mile near the headwaters to 3 feet per mile in the vicinity of Grand Falls and 2 feet per mile in the reach above Fredericton.

In the section between Edmundston and Fredericton, the Saint John River has been developed for hydro-electric power. The New Brunswick Electric Power Commission has three developments on this part of the river. The hydro-

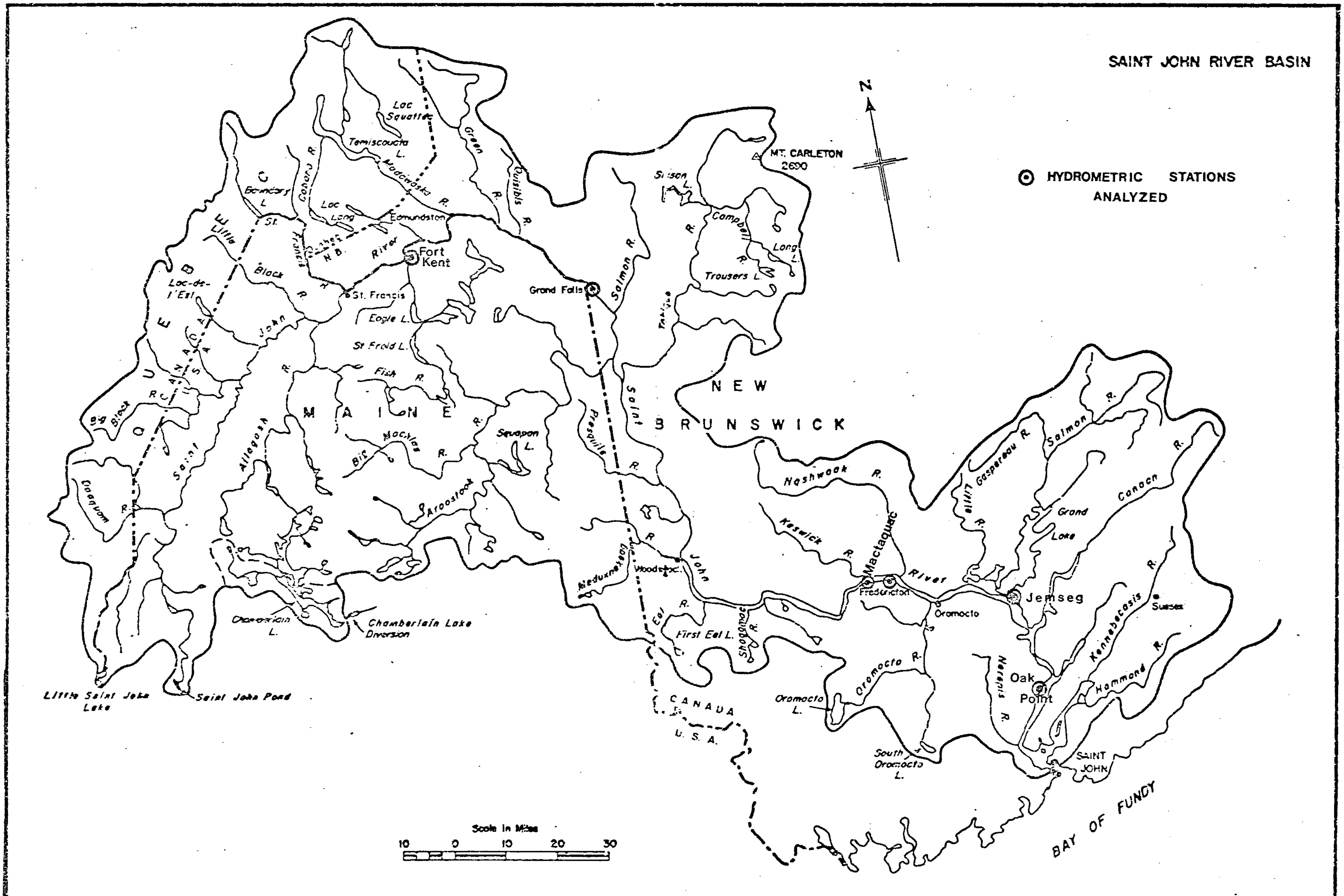

FIGURE 2

DEPARTMENT OF THE ENVIRONMENT, DECEMBER 1971 electric plants are at Grand Falls, with a head of 125 feet; Beechwood, located between Woodstock and Grand Falls, with a head of 57 feet and Mactaquac, which is located a few miles upstream of Fredericton and utilizes a head of about 110 feet.

In its last 80 miles, the Saint John River is influenced by tides and is controlled at the outlet by a narrow rocky ledge known as the "Reversing Falls" through which water discharges to the Bay of Fundy at low tide and salt water enters the estuary during high tide. The river is tidal to a point a few miles upstream of Fredericton.

In the upper 200 miles of the Saint John River Basin, the river is fed by numerous tributaries from the west and north such as the Daaquam, Big and Little Black, St. Francis and Madawaska Rivers, which rise in the southeastern slopes of the Notre Dame Mountains. The Allagash and the Fish Rivers enter from the south, from the upland area of Maine. Below Grand Falls, the Saint John River is joined from the west by the Aroostook River, whose drainage basin, combined with those of the Allagash and Fish Rivers, comprises most of the Saint John Basin in Maine. Below Grand Falls, tributaries from the New Brunswick Highlands begin to come in from the north and east. The Tobique, which enters just below the Aroostook, and the Nashwaak, which joins the Saint John at Fredericton, are the two most important of these. The major tributaries below Fredericton are the Omomocto, Salmon, Canaan and Kennebecasis Rivers.

PROCEDURE

Water level and discharge forecasts for six hydrometric stations along the Saint John River were analyzed (see Figure 2 for location of the stations) in this study. The water level forecasts were checked at the Oak Point, Jemseg, and the Fredericton stations to assess the accuracy of the lower estuary part of the model, whereas the discharge forecasts were checked at the Mactaquac, Grand Falls, and Fort Kent stations to assess the upper part of the Saint John River Basin. It should be mentioned that the station at Fort Kent is on the American side of the Saint John River Basin.

The forecasted values (for each of the five-day forecasts) were compared with the measured values at each of the stations mentioned; the actual values (measured values) and the forecasts of these values (one through five-day forecasts) are for the 7:00 a.m. instantaneous water levels or discharges. The one-day forecast is the predicted value of the measured value; for a particular day, one day in advance. The two-day forecast is the predicted value of the actual two days in advance, and similarly, the three-day through five-day forecasts.

The data were taken from the files of the Saint John River Flood Forecasting Unit of the New Brunswick Electric Power Commission Headquarters and are for the spring period, March to May. The period of record was from 1974 to 1976, inclusive, for water levels, and from 1973 to 1976, inclusive, for the discharge forecasts.

The values for the actual and forecasted water levels and discharges are recorded in the Appendix, of Reference 5. It should be noted that some of the forecasted values were estimated for purposes of this analysis, where data gaps existed for various reasons. The missing values were estimated by linear interpretation of values about the missing value(s) for a particular day of forecast.

The main interest in this study is the comparison of the forecasted values with the measured values. The statistics used to compare the model performance (see Tables 1 to 6) are as follows:

Mean: The "average," it is merely the sum of the individual value for each case, divided by the number of cases;

Standard Deviation:

A measure of the dispersion about the mean of a variable; the typical distance between any case and the mean;

Forecast:

The mean and standard deviation of the observed or actual values along with the one through five-day forecasts or simulated values for the number of forecasts checked in each particular year;

Absolute Error:

The mean and standard deviation of the absolute value of the error (residual), e.g.,/computed minus observed/;

Relative Error:

The mean and standard deviation of the error (residual), e.g., (computed minus observed);

Under-Forecast:

The computed value is less than the observed value;

Over-Forecast:

The computed value is greater than the observed value.

A summary of the results are tabulated (see Tables 7 and 8) as follows:

A. The ratio of the absolute error to the mean of the observed values in percentage;

B. The ratio of the relative error to the mean of the observed values in percentage.

RESULTS AND DISCUSSION

The results of the model performance for the six hydrometric stations analyzed are presented in Tables 1 to 6.

(1) Oak Point

For the three years the model has been operational, the number of forecasts checked ranged from 16 to 23, Table 1.

In 1974, the forecasts varied from best forecast on day 1 to worst on day 5. In 1975, the same trend is noticeable but overall, the error tended to be greater. The model tended to over-forecast in all forecast days in 1975; whereas in 1974, the model tended to over-forecast and under-forecast, equally.

In 1976, the model performed best overall. Again, the error increased from day 1 to 5 and the model tended to under-forecast. When the model did over-forecast, the tendency to over-forecast increased from day 1 to day 5.

(2) Jemseg

Examining Table 2, 1974 to 1976, the number of forecasts checked ranged from 15 to 23.

Generally, the forecasts improved from 1974 to 1976, with 1976 being the best forecast year. The forecasts for all years varied from best forecast on day 1 to worst on day 5. The model tended to be under-forecasting in 1974, over-forecasting in 1975, and nearly balanced in numbers in 1976.

(3) Fredericton

Looking at Table 3 for the forecast years, 1974 to 1976, the number of forecasts checked ranged from 17 to 23.

The forecasts in 1975 are not as accurate as those computed in 1974 and 1976, which are about equal in terms of absolute error. Generally, the forecasts for all years varied from best forecast on day 1 to worst on day 5.

The model tended to over-forecast in 1975 and 1976, and nearly balanced (over- and under- forecast) in numbers in 1974.

(4) Mactaquac

Looking at Table 4 for the forecast years, 1973 to 1976, the number of forecasts checked ranged from 36 to 43.

Generally, in 1973 to 1975, the forecasts seem to vary from best forecasts in 1973 to worst in 1975. In 1976, the forecasts appear to be the best overall. The forecasts for all years varied from best forecast on day 1 to worst on day 5.

The model tended to be over-forecasting in 1973 to 1975 and nearly balanced (over - and under-forecast) in numbers in 1976.

(5) Grand Falls

Examining Table 5, 1973 to 1976, the number of forecasts checked ranged from 34 to 43.

From 1973 to 1976, the forecasts do not tend to show a trend of getting better or worse. In 1973 and 1976, the forecasts appear better than those in the years 1974 and 1975, with 1975 being the worst year of all, although the one-day forecast in 1975 is the best. The forecasts for all years varied from best forecast on day 1 to worst on day 5.

The model tended to be over-forecasting in 1973 to 1975, and under-forecasting in 1976.

(6) Fort Kent

Looking at Table 6, 1973 to 1976, the number of forecasts checked ranged from 32 to 43.

From 1973 to 1976, the forecasts do not tend to show a trend of getting better or worse. In 1973 and 1976, the forecasts appear better than those in the years 1974 and 1975, with 1975 the worst year of all, although again (as found with Grand Falls), the one-day forecast in 1975 is the best overall. Generally, the forecasts for all year varied from best forecast on day 1 to worst on day 5.

The model tended to be over-forecasting in the years 1973 to 1975, and under-forecasting in 1976.

(7) Summary

Tables 7 and 8 summarize the results of the forecast errors of the water level and discharge stations, respectively. The tables represent the one-day to five-day forecasts in terms of absolute "A" and relative "R" errors in percentages.

Table 7 shows that, overall, ranking the water level stations from best to worst, they were: Oak Point, Jemseg, and Fredericton. Ranking the forecast years from best to worst, they were: 1976, 1974, and 1975, except for Fredericton, which had the best forecasts in 1974, and the worst in 1975. At all stations and for each particular year, the values ranged from best forecast on day 1 to worst on day 5. The tendency to under-forecast was prevalent at Oak Point in 1976, and Jemseg in 1974. Over-forecasting was prevalent at Oak Point in 1975, Jemseg in 1975, and Fredericton in 1975 and 1976, and nearly balanced in numbers and magnitude, the rest of the time. Overall, the model had a tendency of over-forecasting the actual values in all years. Generally, the model tended to improve with time and 1976 was the best forecast year. The one to three-day forecasts, for the most part, were within ± 10% error in all years and at all water level stations; these stations were by far the superior when compared to the discharge forecasts in terms of percentage error.

Table 8 presents the summary of the discharge errors. Ranking the stations from best to worst, they were: Grand Falls, followed very closely by Mactaquac, and Fort Kent. When ranking the forecast years from best to worst, they were: 1973, 1976, 1974, with 1975 being the worst by far. At all stations and for each particular year, the values ranged from best forecast on day 1 to worst on day 5. The tendency to under-forecast was prevalent at all stations in 1976; over-forecasting was prevalent at all stations in the years 1974 and 1975, and nearly balanced in numbers in 1973. Overall, the model has a tendency to over-forecast. The model did not tend to improve with time, although 1976 appears to be best forecast year and 1975 the worst. The error for the day 1 forecasts is generally within $\pm$ 15% at all stations and forecast years. Beyond the one-day forecast, the accuracy deteriorates rapidly.

An analysis of seasonal peak values was performed (found in Reference 5) in terms of the model predicting the actual maximum instantaneous (peak) values. It was found from this analysis that the model mis-timed (lagged) and over-estimated the seasonal peak values at all stations.

CONCLUSIONS

In terms of flood forecasting of the Saint John River, the SSARR model tended to be reasonably accurate in determining water levels, at best up to three days in advance of their occurrence, whereas beyond day one of the discharge forecasts, the accuracy deteriorated considerably.

It should be noted that there always remains some uncertainty as to the exact conditions within a basin, no matter how complete the reporting network; a five to ten percent residual error is, therefore, associated with even the best rainfall-runoff relationship. Under average conditions, water level forecasts cannot be expected to be consistently reliable to within less than 0.5 feet. Using this criterion, it would seem apparent that the SSARR model was quite accurate in forecasting water levels, whereas beyond day one of the discharge forecasts, the results were unreliable. The SSARR model could be subject to further calibrations on the Saint John River Basin. In addition, the information on the hydrometric network should be assessed to ensure that all regimes in the basin are accounted for.

TABLE 1. RESULTS OF MODEL PERFORMANCE

WATER LEVEL FORECASTS

OAK POINT

Year	Forecast	No. of Forecasts Checked	Forecast Mean (Feet)	Forecast Standard Deviation (Feet)	Absolute Error Mean (Feet)	Absolute Error Standard Deviation (Feet)	Relative Error Mean (Feet)	Relative Error Standard Deviation (Feet)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1974	Actual Value	22	11.96	1.74								
	1 Day	22	12.14	1.67	0.27	0.23	0.19	0.30	5	22.7	17	77.3
	2 Day	22	12.02	1.61	0.38	0.19	0.06	0.43	9	40.9	13	59.1
	3 Day	22	11.97	1.58	0.54	0.35	0.01	0.65	10	45.5	12	54.5
	4 Day	22	12.03	1.70	0.84	0.58	0.07	1.04	9	40.9	13	59.1
	5 Day	22	12.15	1.95	1.11	0.87	0.19	1.42	9	40.9	13	59.1
									TOTAL 42		TOTAL 68	
									% 38.2		% 61.8	
1975	Actual Value	23	10.22	1.34								
	1 Day	23	10.54	1.32	0.32	0.28	0.32	0.28	1	4.3	22	95.7
	2 Day	23	10.85	1.49	0.63	0.43	0.63	0.43	0	0.0	23	100
	3 Day	23	11.18	1.64	0.96	0.61	0.96	0.61	0	0.0	23	100
	4 Day	23	11.58	1.85	1.36	0.77	1.36	0.77	0	0.0	23	100
	5 Day	23	12.02	2.08	1.80	0.94	1.80	0.94	0	0.0	23	100
									TOTAL 1		TOTAL 114	
									% 0.9		% 99.1	
1976	Actual Value	16	11.60	0.99								
	1 Day	16	11.29	0.94	0.36	0.17	-0.31	0.25	15	93.8	1	6.3
	2 Day	16	11.22	0.88	0.45	0.26	-0.39	0.35	14	87.5	2	12.5
	3 Day	16	11.22	0.76	0.44	0.39	-0.38	0.45	14	87.5	2	12.5
	4 Day	16	11.25	0.51	0.42	0.58	-0.36	0.62	13	81.3	3	18.8
	5 Day	16	11.40	0.52	0.58	0.67	-0.21	0.87	6	37.5	10	62.5
									TOTAL 62		TOTAL 18	
									% 77.6		% 22.5	

TABLE 2. RESULTS OF MODEL PERFORMANCE

WATER LEVEL FORECASTS

JEMSEG

			Forecast		Absolute Error		Relative Error					
Year	Forecast	No. of Forecasts Checked	Mean (Feet)	Standard Deviation (Feet)	Mean (Feet)	Standard Deviation (Feet)	Mean (Feet)	Standard Deviation (Feet)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1974	Actual Value	22	14.02	2.24								
	1 Day	22	13.45	1.80	0.74	0.47	-0.58	0.67	19	86.4	3	13.6
	2 Day	22	13.37	1.79	0.85	0.64	-0.66	0.85	18	81.8	4	18.2
	3 Day	22	13.33	1.76	1.05	0.68	-0.69	1.05	16	72.7	6	27.3
	4 Day	22	13.44	1.95	1.29	0.89	-0.58	1.48	13	59.1	9	40.9
	5 Day	22	13.61	2.25	1.54	1.20	-0.41	1.93	15	68.2	7	31.8
									TOTAL 81		TOTAL 29	
									% 73.6		% 26.4	
1975	Actual Value	23	11.90	1.68								
	1 Day	23	11.74	1.53	0.31	0.19	-0.15	0.33	16	69.6	7	39.4
	2 Day	23	12.06	1.64	0.26	0.25	0.16	0.33	9	39.1	14	60.9
	3 Day	23	12.47	1.79	0.59	0.43	0.58	0.45	2	8.7	21	91.3
	4 Day	23	13.00	2.00	1.10	0.58	1.10	0.58	0	0.0	23	100
	5 Day	23	13.52	2.22	1.63	0.78	1.63	0.78	0	0.0	23	100
									TOTAL 27		TOTAL 88	
									% 23.5		% 76.5	
1976	Actual Value	15	13.09	1.26								
	1 Day	15	12.83	1.17	0.31	0.23	-0.25	0.30	12	80.0	3	20.0
	2 Day	15	12.99	1.12	0.29	0.20	-0.10	0.34	9	60.0	6	40.0
	3 Day	15	13.16	0.92	0.40	0.30	0.07	0.50	8	53.3	7	46.7
	4 Day	15	13.39	0.84	0.73	0.49	0.30	0.84	5	33.3	10	66.7
	5 Day	15	13.69	1.02	1.04	0.70	0.60	1.12	4	26.7	11	73.3
									TOTAL 38		TOTAL 37	
									% 50.7		% 49.3	

TABLE 3. RESULTS OF MODEL PERFORMANCE

WATER LEVEL FORECASTS

FREDERICTON

		Forecast			Absolute Error		Relative Error					
Year	Forecast	No. of Forecasts Checked	Mean (Feet)	Standard Deviation (Feet)	Mean (Feet)	Standard Deviation (Feet)	Mean (Feet)	Standard Deviation (Feet)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1974	Actual Value	22	19.82	2.75								
	1 Day	22	19.46	2.72	0.69	0.71	-0.36	0.94	12	54.5	10	45.5
	2 Day	22	19.62	2.82	1.13	1.02	-0.20	1.53	12	54.5	10	45.5
	3 Day	22	19.91	3.14	1.54	1.51	0.09	2.18	10	45.5	12	54.5
	4 Day	22	20.19	3.40	2.13	2.15	0.37	3.04	10	45.5	12	54.5
	5 Day	22	20.50	3.46	2.66	2.67	0.68	3.75	12	54.5	10	45.5
									TOTAL 56		TOTAL 54	
									% 50.9		% 49.1	
1975	Actual Value	23	16.05	2.84								
	1 Day	23	16.67	2.52	0.70	0.46	0.62	0.56	2	8.7	21	91.3
	2 Day	23	17.33	2.83	1.31	0.83	1.28	0.88	1	4.3	22	35.7
	3 Day	23	18.13	2.98	2.16	1.17	2.08	1.31	1	4.3	22	95.7
	4 Day	23	19.07	2.88	3.19	1.51	3.02	1.84	1	4.3	22	95.7
	5 Day	23	19.84	2.81	4.07	1.89	3.79	2.41	1	4.3	22	95.7
									TOTAL 6		TOTAL 109	
									% 5.2		% 94.8	
1976	Actual Value	17	17.22	2.75								
	1 Day	17	17.82	2.24	0.73	0.64	0.60	0.78	2	11.8	15	88.2
	2 Day	17	18.53	2.26	1.37	1.21	1.31	1.27	2	11.8	15	88.2
	3 Day	17	19.20	2.68	2.14	1.63	1.98	1.83	4	23.5	13	76.5
	4 Day	17	19.43	2.81	2.64	1.82	2.21	2.35	3	17.6	14	82.4
	5 Day	17	19.28	2.67	2.52	1.93	2.06	2.43	3	17.6	14	82.4
									TOTAL 14		TOTAL 71	
									% 16.5		% 83.5	

TABLE 4. RESULTS OF MODEL PERFORMANCE

DISCHARGE FORECASTS

MACTAQUAC

Year	Forecast	No. of Forecasts Checked	Forecast Mean (cfs)	Forecast Standard Deviation (cfs)	Absolute Error Mean (cfs)	Absolute Error Standard Deviation (cfs)	Relative Error Mean (cfs)	Relative Error Standard Deviation (cfs)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1973	Actual Value	36	146,000	82,000								
	1 Day	36	148,000	85,400	19,800	19,800	2,480	28,100	14	38.9	22	61.1
	2 Day	36	150,000	83,400	27,300	24,600	4,610	36,700	16	44.4	20	55.6
	3 Day	36	155,000	82,100	34,700	29,700	9,580	45,000	14	38.9	22	61.1
	4 Day	36	155,000	76,700	39,400	36,700	9,310	53,400	15	41.7	21	58.3
	5 Day*	–	–	–	–	–	–	–	–	–	–	–
									TOTAL 59		TOTAL 85	
									% 41.0		% 59.0	
1974	Actual Value	36	114,000	67,500								
	1 Day	36	122,000	78,100	16,000	15,500	7,990	20,900	15	41.7	21	58.3
	2 Day	36	129,000	82,600	22,400	25,800	14,300	31,100	14	38.9	22	61.1
	3 Day	36	132,000	82,900	27,300	28,100	17,300	35,300	12	33.3	24	66.7
	4 Day	36	138,000	83,100	33,400	36,300	23,900	43,300	9	25.0	27	75.0
	5 Day	36	144,000	81,800	37,200	38,800	29,300	45,300	8	22.2	28	77.8
									TOTAL 58		TOTAL 122	
									% 32.2		% 67.8	
1975	Actual Value	39	78,100	57,700								
	1 Day	39	82,400	64,500	8,350	8,890	4,300	11,500	18	46.2	21	53.8
	2 Day	39	92,800	75,600	17,400	20,800	14,700	22,800	11	28.2	28	71.8
	3 Day	39	101,000	84,500	26,000	30,200	22,900	32,700	12	30.8	27	69.2
	4 Day	39	108,000	91,500	33,900	38,000	29,600	41,500	12	30.8	27	69.2
	5 Day	39	114,000	96,400	38,800	45,300	36,000	47,600	14	35.9	25	64.1
									TOTAL 67		TOTAL 128	
									% 34.4		% 65.6	
1976	Actual Value	43	119,000	45,600								
	1 Day	43	119,000	44,800	9,890	6,920	-135	12,200	17	39.5	26	60.5
	2 Day	43	119,000	44,700	17,500	16,200	-433	24,000	19	44.2	24	55.8
	3 Day	43	120,000	54,000	26,800	26,600	693	37,900	24	55.8	19	44.2
	4 Day	43	119,000	59,700	31,500	30,000	-686	43,800	23	53.5	20	46.5
	5 Day	43	115,000	57,000	32,100	30,400	-3,830	44,300	22	51.2	21	48.8
									TOTAL 105		TOTAL 110	
									% 48.8		% 51.2	

* Note: No 5 Day Forecast for 1973

TABLE 5. RESULTS OF MODEL PERFORMANCE

DISCHARGE FORECASTS

GRAND FALLS

Year	Forecasts	No. of Forecasts Checked	Forecast Mean (cfs)	Forecast Standard Deviation (cfs)	Absolute Error Mean (cfs)	Absolute Error Standard Deviation (cfs)	Relative Error Mean (cfs)	Relative Error Standard Deviation (cfs)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1973	Actual Value	34	83,800	48,700								
	1 Day	34	82,400	43,800	8,560	7,820	-1,420	11,600	12	35.3	22	64.7
	2 Day	34	86,100	46,700	13,400	11,300	2,250	17,500	12	35.3	22	64.7
	3 Day	34	89,400	49,600	18,800	14,300	5,640	23,100	12	35.3	22	64.7
	4 Day	34	88,900	48,000	22,700	21,400	5,090	31,000	11	32.4	23	67.6
	5 Day*	-	-	-	-	-	-	-	-	-	-	-
									TOTAL 47		TOTAL 89	
									% 34.6		% 65.4	
1974	Actual Value	36	75,300	56,200								
	1 Day	36	72,500	55,100	10,000	14,900	-2,840	17,800	27	75.0	9	25.0
	2 Day	36	76,300	57,200	15,300	18,600	940	24,200	17	47.2	19	52.8
	3 Day	36	79,000	56,000	16,700	15,900	3,680	22,800	15	41.7	21	58.3
	4 Day	36	85,300	56,900	21,300	21,600	9,960	28,900	13	36.1	23	63.9
	5 Day	36	91,300	57,500	26,700	23,200	16,000	31,800	9	25.0	27	75.0
									TOTAL 81		TOTAL 99	
									% 45.0		% 55.0	
1975	Actual Value	40	44,900	39,500								
	1 Day	40	44,900	41,200	3,330	3,810	14.0	5,090	17	42.5	23	57.5
	2 Day	40	51,200	48,400	9,120	9,810	6,300	11,900	11	27.5	29	72.5
	3 Day	40	55,600	53,200	14,100	15,000	10,700	17,700	12	30.0	28	70.0
	4 Day	40	59,600	57,100	18,200	20,500	14,700	23,300	13	32.5	27	67.5
	5 Day	40	63,100	59,600	21,000	25,100	18,200	27,200	12	30.0	28	70.0
									TOTAL 65		TOTAL 135	
									% 32.5		% 67.5	
1976	Actual Value	43	70,500	30,200								
	1 Day	43	68,000	27,100	7,430	6,670	-2,500	9,730	26	60.5	17	39.5
	2 Day	43	68,600	30,000	13,000	13,800	-1,920	19,000	29	67.4	14	32.6
	3 Day	43	70,200	37,500	19,100	18,800	-357	26,900	30	69.8	13	30.2
	4 Day	43	69,400	40,900	20,400	20,100	-1,140	28,800	27	62.8	16	37.2
	5 Day	43	67,900	38,900	19,500	18,400	-2,600	26,800	24	55.8	19	44.2
									TOTAL 136		TOTAL 79	
									% 63.3		% 36.7	

* Note: No 5 Day Forecast for 1973

TABLE 6. RESULTS OF MODEL PERFORMANCE

DISCHARGE FORECASTS

FORT KENT

Year	Forecast	No. of Forecasts Checked	Forecast Mean (cfs)	Forecast Standard Deviation (cfs)	Absolute Error Mean (cfs)	Absolute Error Standard Deviation (cfs)	Relative Error Mean (cfs)	Relative Error Standard Deviation (cfs)	Under-Forecast No.	Under-Forecast %	Over-Forecast No.	Over-Forecast %
1973	Actual Value	32	60,600	31,900								
	1 Day	32	63,300	33,900	6,280	5,340	2,730	7,840	12	37.5	20	62.5
	2 Day	32	67,600	36,900	10,600	8,240	7,020	11,500	8	25.0	24	75.0
	3 Day	32	69,500	39,100	15,200	12,700	8,920	17,800	10	31.3	22	68.8
	4 Day	32	67,000	34,900	17,200	14,800	6,410	22,000	10	31.3	22	68.8
	5 Day*	-	-	-	-	-	-	-	-	-	-	-
									TOTAL 40		TOTAL 88	
									% 31.3		% 68.8	
1974	Actual Value	36	52,000	41,500								
	1 Day	36	52,100	39,600	8,130	12,800	113	15,300	16	44.4	20	55.6
	2 Day	36	56,200	41,300	12,700	14,600	4,150	19,000	14	38.9	22	61.1
	3 Day	36	59,400	41,100	15,500	14,900	7,380	20,300	8	22.2	28	77.8
	4 Day	36	64,600	41,600	20,500	16,400	12,600	23,200	6	16.7	30	83.3
	5 Day	36	69,900	41,900	24,500	18,000	17,900	24,800	6	16.7	30	83.3
									TOTAL 50		TOTAL 130	
									% 27.8		% 72.2	
1975	Actual Value	40	30,900	27,900								
	1 Day	40	32,400	29,400	2,520	2,940	1,500	3,590	16	40.0	24	60.0
	2 Day	40	36,800	33,800	7,210	8,170	5,900	9,190	11	27.5	29	72.5
	3 Day	40	39,700	36,800	10,500	12,000	8,800	13,400	10	25.0	30	75.0
	4 Day	40	42,600	39,600	13,100	17,000	11,600	18,100	12	30.0	28	70.0
	5 Day	40	45,300	41,300	15,500	20,800	14,400	21,600	11	27.5	29	72.5
									TOTAL 60		TOTAL 140	
									% 30.0		% 70.0	
1976	Actual Value	43	46,800	23,000								
	1 Day	43	46,200	21,100	4,760	5,870	-602	7,570	26	60.5	17	39.5
	2 Day	43	46,700	23,800	9,280	11,400	-68.8	14,700	30	69.8	13	30.2
	3 Day	43	47,600	28,400	12,600	14,000	805	18,900	30	69.8	13	30.2
	4 Day	43	46,700	29,600	12,600	14,400	-37.9	19,200	26	60.5	17	39.5
	5 Day	43	45,900	27,600	12,800	12,800	-849	18,200	24	55.8	19	44.2
									TOTAL 136		TOTAL 79	
									% 63.3		% 36.7	

* Note: No 5 Day Forecast for 1973

TABLE 7. SUMMARY OF THE WATER LEVEL ERRORS

OAK POINT				JEMSEG				FREDERICTON			
Year	Forecast	A(%)	R(%)	Year	Forecast	A(%)	R(%)	Year	Forecast	A(%)	R(%)
1974	1 Day	2.26	1.59	1974	1 Day	5.28	- 4.14	1974	1 Day	3.48	- 1.82
	2 Day	3.18	0.50		2 Day	6.06	- 4.71		2 Day	5.70	- 1.01
	3 Day	4.52	0.08		3 Day	7.49	- 4.92		3 Day	7.77	0.45
	4 Day	7.02	0.59		4 Day	9.20	- 4.14		4 Day	10.75	1.87
	5 Day	9.23	1.59		5 Day	10.98	- 2.92		5 Day	13.42	3.43
1975	1 Day	3.13	3.13	1975	1 Day	2.61	- 1.26	1975	1 Day	4.36	3.86
	2 Day	6.16	6.16		2 Day	2.18	1.34		2 Day	8.16	7.98
	3 Day	9.39	9.39		3 Day	4.96	4.87		3 Day	13.46	12.96
	4 Day	13.31	13.31		4 Day	9.24	9.24		4 Day	19.88	18.82
	5 Day	17.61	17.61		5 Day	13.70	13.70		5 Day	25.36	23.61
1976	1 Day	3.10	- 2.67	1976	1 Day	2.37	- 1.91	1976	1 Day	4.24	3.48
	2 Day	3.88	- 3.36		2 Day	2.22	- 0.76		2 Day	7.96	7.61
	3 Day	3.79	- 3.28		3 Day	3.06	0.53		3 Day	12.43	11.50
	4 Day	3.62	- 3.10		4 Day	5.58	2.29		4 Day	15.33	12.83
	5 Day	5.00	- 1.81		5 Day	7.94	4.58		5 Day	14.63	11.96

TABLE 8. SUMMARY OF THE DISCHARGE ERRORS

MACTAQUAC				GRAND FALLS				FORT KENT			
Year	Forecast	A(%)	R(%)	Year	Forecast	A(%)	R(%)	Year	Forecast	A(%)	R(%)
1973	1 Day	13.56	1.70	1973	1 Day	10.21	- 1.69	1973	1 Day	10.36	4.50
	2 Day	18.70	3.16		2 Day	15.99	2.68		2 Day	17.49	11.58
	3 Day	23.77	6.56		3 Day	22.43	6.73		3 Day	25.08	14.72
	4 Day	26.99	6.38		4 Day	27.09	6.07		4 Day	28.38	10.58
	5 Day*	-	-		5 Day*	-	-		5 Day*	-	-
1974	1 Day	14.04	7.01	1974	1 Day	13.28	- 3.77	1974	1 Day	15.63	0.22
	2 Day	19.65	12.54		2 Day	20.32	1.25		2 Day	24.42	7.98
	3 Day	23.95	15.18		3 Day	22.18	4.89		3 Day	29.81	14.19
	4 Day	29.30	20.96		4 Day	28.29	13.23		4 Day	39.42	24.23
	5 Day	32.63	25.70		5 Day	35.46	21.25		5 Day	47.12	34.42
1975	1 Day	10.69	5.51	1975	1 Day	7.42	0.03	1975	1 Day	8.16	4.85
	2 Day	22.28	18.82		2 Day	20.31	14.03		2 Day	23.33	19.09
	3 Day	33.29	29.32		3 Day	31.40	23.83		3 Day	33.98	28.48
	4 Day	43.41	37.90		4 Day	40.53	32.74		4 Day	42.39	37.54
	5 Day	49.68	46.09		5 Day	46.77	40.53		5 Day	50.16	46.60
1976	1 Day	8.31	- 0.11	1976	1 Day	10.54	- 3.55	1976	1 Day	10.17	- 1.29
	2 Day	14.71	- 0.36		2 Day	18.44	- 2.72		2 Day	19.83	- 0.15
	3 Day	22.52	0.58		3 Day	27.09	- 0.51		3 Day	26.92	1.72
	4 Day	26.47	- 0.58		4 Day	28.94	- 1.62		4 Day	26.92	- 0.08
	5 Day	26.97	- 3.22		5 Day	27.66	- 3.69		5 Day	27.35	- 1.81

*Note: No 5 Day Forecast for 1973.

REFERENCES

1. Department of the Environment, Inland Waters Directorate. Hydrology of the Saint John River Basin for the Saint John River Basin Board. Halifax, 1973.

2. Environment Canada, Inland Waters Directorate. Technical Bulletin No. 81 - New Brunswick Flood, April - May, 1973. Halifax, 1974.

3. Kite, G. W. Performance of two deterministic hydrological models. Proceedings of the Bratislava Symposium, September 1975, IAHS-AISH Publ. No. 115, 1975.

4. Montreal Engineering Company Limited. Maritime Provinces Water Resources Study for Atlantic Development Board. Vol. 3, Book 3, New Brunswick, 1969.

5. Pol, R. A. Forecasting Error Analysis, Saint John River, New Brunswick, Spring, 1973-1976. Task 3(b) for the World Weather Watch Project on the Saint John River Basin. Water Survey of Canada, Inland Waters Directorate, Halifax, 1977.

6. U. S. Army Engineer Division, North Pacific (1972). Program Description and User Manual for SSARR Model Streamflow Synthesis and Reservoir Regulation, Program 724-K5-G0010: Portland, Oregon.