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EVALUATION OF PRECIPITATION FORECASTS FOR THE SAINT JOHN RIVER VALLEY

by

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ABSTRACT

One-day and two-day forecasts of precipitation amounts prepared for the New Brunswick Electric Power Commission for the Saint John River Valley are evaluated over a one year period for degree of absolute error and bias. Forecast errors were less than 0.10 inches for the first 24-hour period but slightly higher for the second day for the areas selected for verification. Forecast bias was negligible for the first day, but indicated a slight underestimate - 0.04 inches and 0.02 inches - of the actual precipitation for the second day, despite a pronounced negative bias for the few occasions of higher forecasts. "Skill score" analysis indicated positive factors for both periods.

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ÉVALUATION DES PRÉVISIONS DE PRÉCIPITATION POUR LA VALLÉE DU SAINT-JEAN

par

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et

R. B. B. Dickison

RÉSUMÉ

Les auteurs évaluent, au cours d'une période d'un an, le degré d'erreur absolu et d'écart des prévisions d'un jour et de deux jours des hauteurs de précipitation dans la vallée du Saint-Jean, préparées pour la New Brunswick Electric Power Commission. Les erreurs de prévision relatives aux régions choisies pour vérification ont été inférieures à 0.10 pouce pour la première période de 24 heures, mais légèrent supérieures pour le deuxième jour. L'écart des prévisions du premier jour, a été négligeable mais il a indiqué une légère sous-estimation (0.04 et 0.02 pouce) de la précipitation réelle pour le deuxième jour, malgré un écart négatif prononcé pour les quelques occasions de prévisions supérieures. L'analyse de "l'indice de comparaison" a indiqué des facteurs positifs pour les deux périodes.

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1. Introduction

Forecasts of precipitation amounts are of substantial value to a number of operational agencies, principally hydro-electric utilities which depend largely on stream runoff for power generation. The New Brunswick Electric Power Commission has been provided with general weather forecasts by the Fredericton Weather Office for the past several years. Recently this forecast has contained quantitative forecasts of precipitation for specific areas:

Upper Saint John River Valley,

Lower Saint John River Valley,

Eastern New Brunswick Counties.

The forecasts, issued about 10:00 a.m. daily (except week-ends and holidays), are divided into a first 24-hour period, 1200Z-1200Z, and a second, or outlook, 24-hour period. It may be noted that two hours of the first forecast period has already elapsed at the time of issue, a decided advantage to the forecaster, but not a serious delay to the user. Inasmuch as the main river requires 2-3 days to reach a crest, the fact that the forecast is issued about 2 hours after the beginning of the forecast period is of little or no consequence so far as the user is concerned.

Utilization of the forecasts by the New Brunswick Electric Power Commission is principally in connection with runoff into storage reservoirs and along the main stream of the Saint John River where the Commission operates hydro-electric dams at Grand Falls, Beechwood, Mactaquac and the mouth of the Tobique

River, and to a lesser extent for similar plants at Milltown and Musquash. (See Figure 1). The operation of the power generating systems along the Saint John River and the climate, water balance and physical characteristics of the basin have been described by Bruce and Sporns (1963). A method for converting rainfall to runoff was outlined in an appendix to the study by Bruce and Sporns (Bateman and Arsenault, 1963).

Winter precipitation, with the exception of small basins near the Bay of Fundy, rarely generates any stream runoff. The Commission is still interested in precipitation forecasts at this time of year however, because of the effects on power demand and on maintenance operations.

2. Forecast Techniques

The Fredericton Weather Office is not staffed to provide independent professional input to forecasts on a regular basis. The preparation of forecasts for the New Brunswick Electric Power Commission operations consequently leans heavily on support from the Maritime Weather Office (MWO), the Atlantic Weather Central (AWC) and the Central Analysis Office (CAO). Although there were yet no Canadian quantitative precipitation forecasts (QPF's) available as a regular service, general estimates of expected precipitation amounts may be obtained or inferred from the following sources:

1. Statements of expected precipitation amounts contained in regular FP's or storm warnings issued by the MWO, particularly in the snowfall season.

2. Intensification or dissipation, rate of motion and path of weather systems as indicated by regular prognostic charts issued by AWC and CAO.

3. Statements of expected precipitation amounts occasionally contained in forecast discussions (FXs) issued by AWC.

4. American QPFs, which frequently extend into the area of interest.

5. Historical precipitation measurements to the beginning of the forecast period, plus current weather.

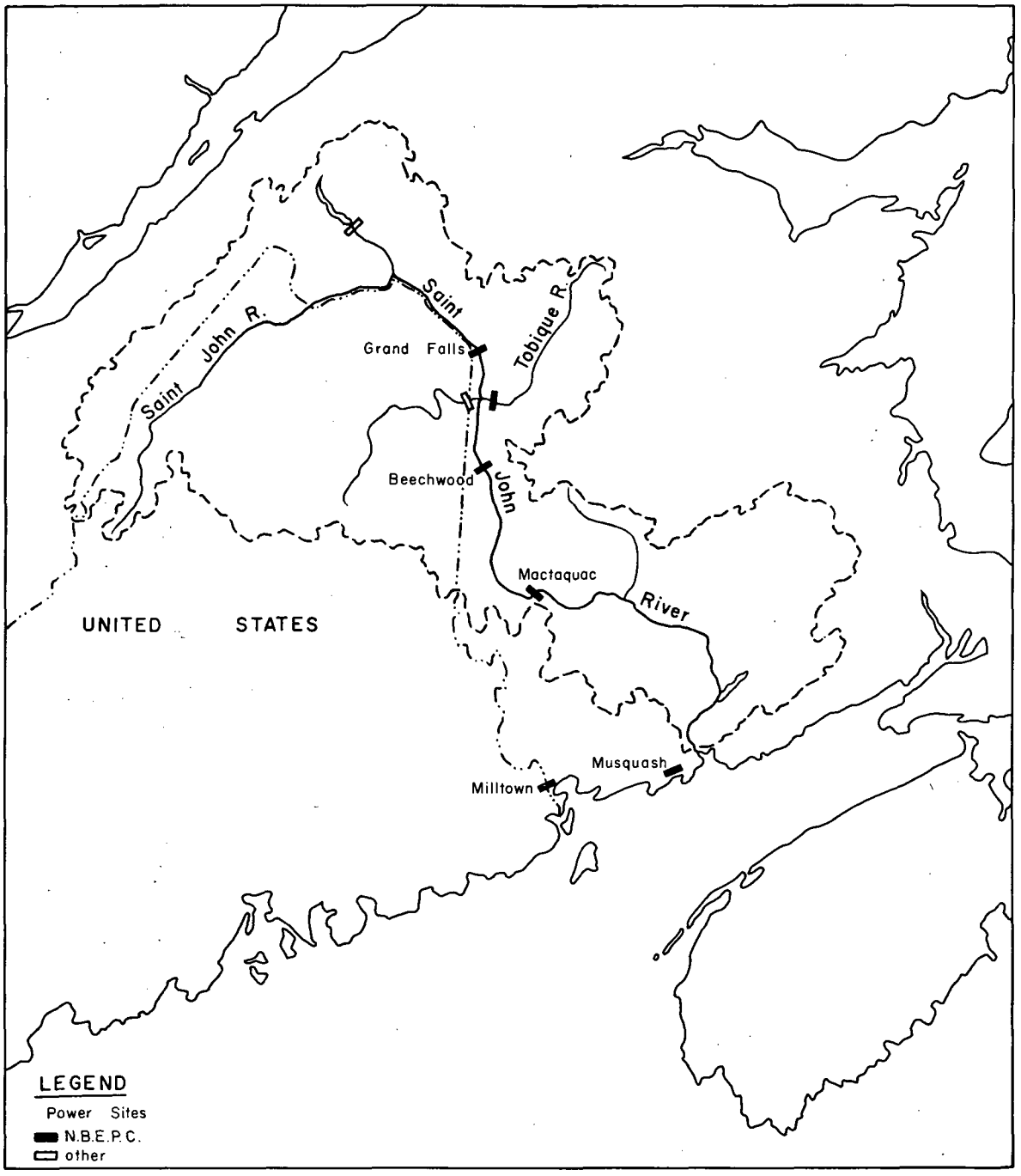

Figure 1.
Locations of Hydro-Electric Dams on the Saint John River

The last source of information is one which can normally be incorporated into the final product at the local level, immediately prior to release to the consumer, a "fail-safe" procedure that avoids some of the embarrassment occasionally resulting from changes during the lapse of time between the issue of a forecast by a major office and its reception by the consuming agency. Since the forecasts are communicated by telephone, it is also possible to convey feelings of low or high confidence in the forecast situation, and to pass amendments as warranted.

3. Objective

The principal objective was to analyze the accuracy of the precipitation forecasts in order to assess the value to the user. The secondary objective was to reveal any biases which would indicate the requirement for a new approach to precipitation forecasting for the two areas.

4. Data

The two regions, (Upper Saint John River Valley and Lower Saint John River Valley), were analyzed separately. The Eastern New Brunswick Counties' forecast was not evaluated since the application of the forecast in that region was of relatively little importance. In the Upper Saint John River Valley the amount of precipitation that fell daily was calculated by taking an areal mean of five stations: Aroostook, Beechwood, Edmundston, Grand Falls and Houlton, Maine. The mean precipitation ($\overline{P}$) was taken as the arithmetic average of the five stations used.

In the Lower Saint John River Valley, ten stations were used to determine the amount of daily precipitation that fell and an areal mean was calculated from: Saint John Airport, Musquash, Milltown, Sussex, Gagetown, Mc Adam, Fredericton (Canada Department of Agriculture), Minto, McGivney and Culliton. Locations of the stations used for verification are shown in Figure 2.

The actual precipitation for each Canadian station used was taken from the published Monthly Record of Meteorological Observations in Canada, and the Monthly Climatological Station Reports were used for the months not yet published in the Monthly Record. The data from Houlton was taken from the U. S. ESSA publication "Climatological Data - New England".

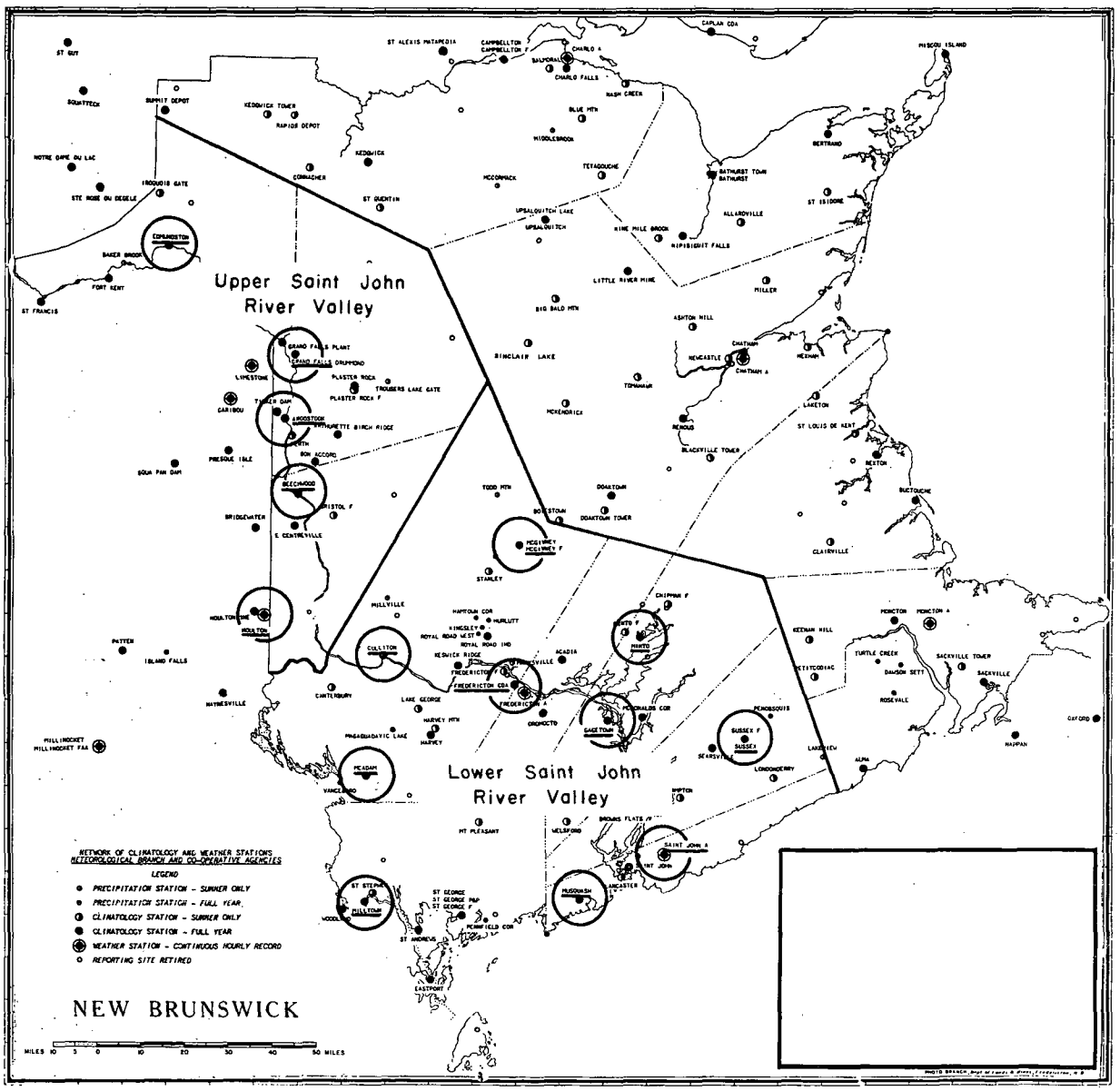

Figure 2.
Precipitation Forecast Regions and Stations Used in Verification

In each area an analysis of the first 24-hour, second 24-hour and total 48-hour forecast was done, comparing each with the areal mean. The analysis was done for 13 months from mid-April 1967 to the end of April 1968. Forecasts were not prepared for holidays and week-ends. The period was not broken into sub-periods of expected light, moderate or heavy precipitation to further analyze the forecast accuracy.

5. Evaluation Procedure and Results

Definition of a "correct" forecast requires a very subjective decision. A first evaluation was prepared on the basis of forecast errors of zero, $\leq$ .10 inches and $\leq$ .20 inches, (Table I). When a range of measureable precipitation was forecast, e.g. "less than .10 inches", "one-quarter to one-half inch", the mid-point of the range was used for evaluation. The frequent use of a range of values may be interpreted as implying an accuracy in the order of $\pm$.10 inches. On this basis forecasts could be considered accurate 73-77% of the time during the first period and 70-72% of the time during the second period. When the two periods were combined into a 48-hour forecast there was a significant drop in accuracy to 57%.

Forecasts were in all cases better for the first period than for the second. There appeared to be no difference in accuracy between forecasts for the two regions. When errors were related to the forecast depth of precipitation, it was apparent that errors increased as the forecast depth increased, (Table III). Forecast bias, which was generally small with small forecast amounts, became negative - indicating over estimation - with larger amounts, although with only 18 cases of forecast amounts .75 inches or more, it is difficult to draw valid conclusions. The bias averaged for all forecasts was small and positive.

When the forecasts were evaluated on a simple "rain-no rain" basis (Table II), verifications were 73-76% for the first period, 62-66% for the second and 71-77% for the two-day period treated as a whole.

Although this form of evaluation is useful to the user in interpreting the forecasts provided, it does not provide an assessment of the degree of skill involved. If, for example, climatological records reveal that an average rainfall of $\leq$.10 inches is

recorded for the Lower Saint John River Valley on 80% of the days, then the forecast accuracies of 77% and 70% would actually indicate a "negative skill", since 80% could be achieved by always forecasting no rain. Therefore the data were further analyzed according to the procedures used by Horne and Boer (1962) and Healey and Harms (1963) in British Columbia.

Contingency tables were set up for each forecast period and each region, (Tables IV A to IX A), for forecasts in .10 inch categories up to .60 inches, and for "rain or no-rain" categories, (Tables IV B to IX B). The data are summarized in Table X, and for comparison a similar table, Table XI, is given for the data of Healey and Harms (1963).

The results of the "skill score" analysis show that a favorable input was achieved to a degree comparable with that achieved in British Columbia by more rigorous and objective techniques.

Table X shows that the first 24-hour forecast gave the best results with 46% and 51% correct in predicting precipitation amount, and skill score of .23 and .31 compared with 35% and .21 for B.C. for the 24-hour test data. The percent correct in predicting rain or no rain was 73% and 76%, and skill scores of .45 and .52 compared with 80% and .52 for B.C. A satisfactory skill score was also maintained for the second day, although with an understandable drop in accuracy.

6. Conclusions

An evaluation of one year's experience in forecasting precipitation amounts for the Saint John River Valley in New Brunswick reveals positive skill scores for both 24-hour and 48-hour forecasts. The extent to which these forecasts may be of value to the New Brunswick Electric Power Commission, to whom they were provided, is indicated by the degree of absolute accuracy achieved, 73-77% within 0.10 inches for 24-hours and 70-73% within 0.20 inches for 48-hours.

The forecasts were prepared by the Fredericton Weather Office with the assistance of normal guidance material from parent offices, plus up-to-the-minute data on current weather. It is suggested

that more elaborate techniques may produce improved forecasts, but the degree of skill should be evaluated against this "ab initio" approach.

APPROVED,

J. R. H. Noble,
Director,
Meteorological Branch.

7. References

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Table I

Distribution of Forecast Errors

	Upper Saint John River Valley			Lower Saint John River Valley		
Forecast Error	1st 24-hour	2nd 24-hour	Total 48-hour	1st 24-hour	2nd 24-hour	Total 48-hour
0	38%	33%	21%	39%	33%	22%
$\leq \lvert .10 \rvert$	73%	72%	57%	77%	70%	57%
$\leq \lvert .20 \rvert$	86%	86%	73%	87%	80%	70%

Table II

Verification of "Rain-no-Rain" Forecasts

	Forecast Accuracy					
	Upper Saint John River Valley			Lower Saint John River Valley		
Forecast	1st 24-hour	2nd 24-hour	Total 48-hour	1st 24-hour	2nd 24-hour	Total 48-hour
Rain	72%	68%	82%	76%	72%	86%
No Rain	74%	58%	49%	77%	60%	59%
Rain(or)No Rain	73%	62%	71%	76%	66%	77%

Table III

Distribution of Forecast Bias and Absolute Error According to Categories of Forecast Precipitation Amount

Table III A-Bias $\left(\frac{\Sigma \text{Precipitation Actual} - \Sigma \text{Precipitation Forecast}}{\text{Number of Forecasts}}\right)$

	Upper Saint John River Valley			Lower Saint John River Valley		
Forecast	1st 24-hour	2nd 24-hour	Total 48-hour	1st 24-hour	2nd 24-hour	Total 48-hour
No of Forecasts	121	139	89	125	142	86
0	.03	.05	.10	.04	.07	.06
	219	220	188	221	231	188
0. - .24	.03	.05	.08	.02	.06	.07
	23	32	35	27	24	40
.25 - .49	.01	0	.01	-.08	.01	-.07
	16	6	24	15	10	18
.50 - .74	-.10	-.01	.16	.01	-.30	-.06
	2	0	8	2	2	15
.75 - .99	-.30	0	-.13	-.20	-.38	.12
	1	0	4	7	4	10
$\geq$ 1.00	-.96	0	-.74	-.06	-.59	-.52
	261	258	259	272	271	271
Total	.01	.04	.06	0	.02	.03

Table III (Cont.)

Table III B - Absolute Error $\left(\frac{\Sigma \left|\text{Precipitation Actual} - \text{Precipitation Forecast}\right|}{\text{Number of Forecasts}}\right)$

Forecast	1st 24-hour	2nd 24-hour	Total 48-hour	1st 24-hour	2nd 24-hour	Total 48-hour
No of Forecasts	121	139	89	125	142	86
0	.03	.05	.10	.04	.07	.06
	219	220	188	221	231	188
0 - .24	.06	.08	.12	.05	.09	.11
	23	32	35	27	24	40
.25 - .49	.26	.23	.25	.17	.25	.19
	16	6	24	15	10	18
.50 - .74	.22	.32	.35	.41	.47	.43
	2	0	8	2	2	15
.75 - .99	.30	0	.44	.20	.38	.43
	1	0	4	7	4	10
$\geq$ 1.00	.96	0	.74	.38	.59	.75
	261	258	259	272	271	271
Total	.09	.10	.18	.09	.13	.19

Table IV A

1st 24-Hour Forecast (Upper Saint John River Valley)

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-.29	.10-.19	.01-.09	No Rain	Total
.60 +	4	1	0	1	3	2	0	1	12
.50-.59	1	3	1	0	1	0	1	0	7
.40-.49	1	1	1	0	4	1	1	0	9
.30-.39	1	0	0	0	1	1	1	4	8
.20-.29	1	1	2	2	0	3	1	1	11
.10-.19	1	2	1	3	0	5	7	8	27
.01-.09	0	2	0	1	9	11	18	18	59
No Rain	0	0	0	0	3	8	28	89	128
Total	9	10	5	7	21	31	57	121	261

Percent Correct 46%

Skill Score .23

Table IV B

Forecast

Observed		Rain	No Rain	
	Rain	101	32	133
	No Rain	39	89	128
		140	121	261

Percent Correct 73%

Skill Score .45

Table V A

2nd 24-Hour Forecast (Upper Saint John River Valley)

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-.29	.10-.19	.01-.09	No Rain	Total
.60 +	0	2	1	0	3	1	2	2	11
.50-.59	0	2	0	1	1	1	0	0	5
.40-.49	0	0	2	0	4	0	1	3	10
.30-.39	0	0	0	1	2	1	1	0	5
.20-.29	0	0	0	0	4	2	2	5	13
.10-.19	0	0	2	2	5	5	2	14	30
.01-.09	0	1	1	1	7	9	12	35	66
No Rain	0	1	0	2	5	10	20	80	118
Total	0	6	6	7	31	29	40	139	258

Percent Correct 41%

Skill Score .15

Table V B

Observed \ Forecast	Rain	No Rain	
Rain	81	59	140
No Rain	38	80	118
	119	139	258

Percent Correct 62%

Skill Score .25

Table VI A

48-Hour Forecast (Upper Saint John River Valley)

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-29	.10-.19	.01-.09	No Rain	Total
.60 +	12	5	2	1	1	2	3	4	30
.50-.59	2	3	1	1	3	1	0	1	12
.40-.49	3	0	1	0	3	0	2	3	12
.30-.39	1	1	3	1	5	3	3	3	20
.20-.29	2	1	1	2	1	3	3	4	17
.10-.19	4	1	1	5	2	3	3	9	28
.01-.09	1	0	0	2	7	17	18	21	66
No Rain	0	0	1	1	4	10	14	44	74
Total	25	11	10	13	26	39	46	89	259

Percent Correct 32%

Skill Score .19

Table VI B

Forecast

Observed		Rain	No Rain	
	Rain	140	45	185
	No Rain	30	44	74
		170	89	259

Percent Correct 71%

Skill Score .33

Table VII A

1st 24-Hour Forecast (Lower Saint John River Valley)

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-.29	.10-.19	.01-.09	No Rain	Total
.60 +	3	4	0	1	2	1	0	0	11
.50-.59	3	0	0	1	0	0	0	1	5
.40-.49	2	1	3	0	1	0	0	0	7
.30-.39	0	1	1	4	4	2	0	0	12
.20-.29	2	0	2	1	1	4	2	3	15
.10-.19	2	0	2	1	2	4	5	2	18
.01-.09	1	0	1	0	8	10	29	23	72
No Rain	0	1	1	1	1	5	27	96	132
Total	13	7	10	9	19	26	63	125	272

Percent Correct 51%

Skill Score .31

Table VII B

Forecast

Observed		Rain	No Rain	
	Rain	111	29	140
	No Rain	36	96	132
		147	125	272

Percent Correct 76%

Skill Score .52

Table VIII A

2nd 24-Hour Forecast (Lower Saint John River Valley)

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-.29	.10-.19	.01-.09	No Rain	Total
.60 +	1	1	2	0	1	3	1	4	13
.50-.59	1	0	0	1	0	1	0	1	4
.40-.49	0	0	1	1	1	2	1	2	8
.30-.39	1	1	0	1	2	2	2	4	13
.20-.29	2	1	0	0	5	2	3	3	16
.10-.19	2	1	1	0	4	3	4	6	21
.01-.09	2	2	0	1	8	9	16	37	75
No Rain	0	1	1	0	10	7	17	85	121
Total	9	7	5	4	31	29	44	142	271

Percent Correct 41%

Skill Score .16

Table VIII B

Observed \ Forecast	Rain	No Rain	
Rain	93	57	150
No Rain	36	85	121
	129	142	271

Percent Correct 66%

Skill Score .32

Table IX A

48-Hour Forecast (Lower Saint John River Valley

Observed	.60 +	.50-.59	.40-.49	.30-.39	.20-.29	.10-.19	.01-.09	No Rain	Total
.60 +	15	3	0	3	2	4	2	2	31
.50-.59	5	0	1	0	0	1	0	0	7
.40-.49	4	0	2	1	3	3	1	1	15
.30-.39	0	2	3	2	1	4	3	3	18
.20-.29	3	1	3	2	2	2	6	2	21
.10-.19	3	4	2	0	4	5	7	3	28
.01-.09	3	0	0	3	13	8	23	24	74
No Rain	0	0	1	1	4	8	12	51	77
Total	33	10	12	12	29	35	54	86	271

Percent Correct 37%

Skill Score .23

Table IX B

Forecast

Observed		Rain	No Rain	
	Rain	159	35	194
	No Rain	26	51	77
		185	86	271

Percent Correct 77%

Skill Score .46

Table X

Summary of Percentages Correct and Skill Scores

April 1967 April 1968	Upper Saint John River Valley			Lower Saint John River Valley		
	1st 24-hour	2nd 24-hour	Total 48-hour	1st 24-hour	2nd 24-hour	Total 48-hour
Precipitation Forecast Amount Percent Correct	46%	41%	32%	51%	41%	37%
Skill Score	.23	.15	.19	.31	.16	.23
Rain (or) No Rain Percent Correct	73%	62%	71%	76%	66%	77%
Skill Score	.45	.25	.33	.52	.32	.46

Table XI

Quantitative Forecasting of Winter Precipitation for the Fraser Valley and Georgia Strait of British Columbia

(After Healey and Harms, 1963)

1952-1957	Developmental Data	Test Data	Developmental Data	Test Data
	24-Hour Forecast		18-Hour Forecast	
Precipitation Forecast Amount Percent Correct	52%	35%	40%	29%
Skill Score	.36	.21	.24	.13
Rain (or) No Rain Percent Correct	81%	80%	77%	75%
Skill Score	.60	.52	.51	.36

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