ACCURACY OF WINTER STREAMFLOW RECORDS[1]

H. B. Rosenberg[2] and R. L. Pentland[3]

Abstract

The accuracy of winter streamflow records is being examined in a Canada-wide research program. This paper presents interim results of the program; reviews methods of calculating discharge under ice cover; and presents an analysis of various factors contributing to probable error in winter streamflow data. Suggested methods are derived for improving accuracy.

Introduction

With increased interest and activity in the field of hydrology, it is important to examine closely the methods of gathering and assembling the basic data on which hydrologic studies are based. With this object in mind, the Water Resources Branch has undertaken a research program into the accuracy of winter streamflow records. There are two major sources of error in winter streamflow records, one being in field measurement and the second being in the methods of calculating daily mean discharge in the time interval between measurements. This paper deals exclusively with the latter subject, i.e., the accuracy of computational methods.

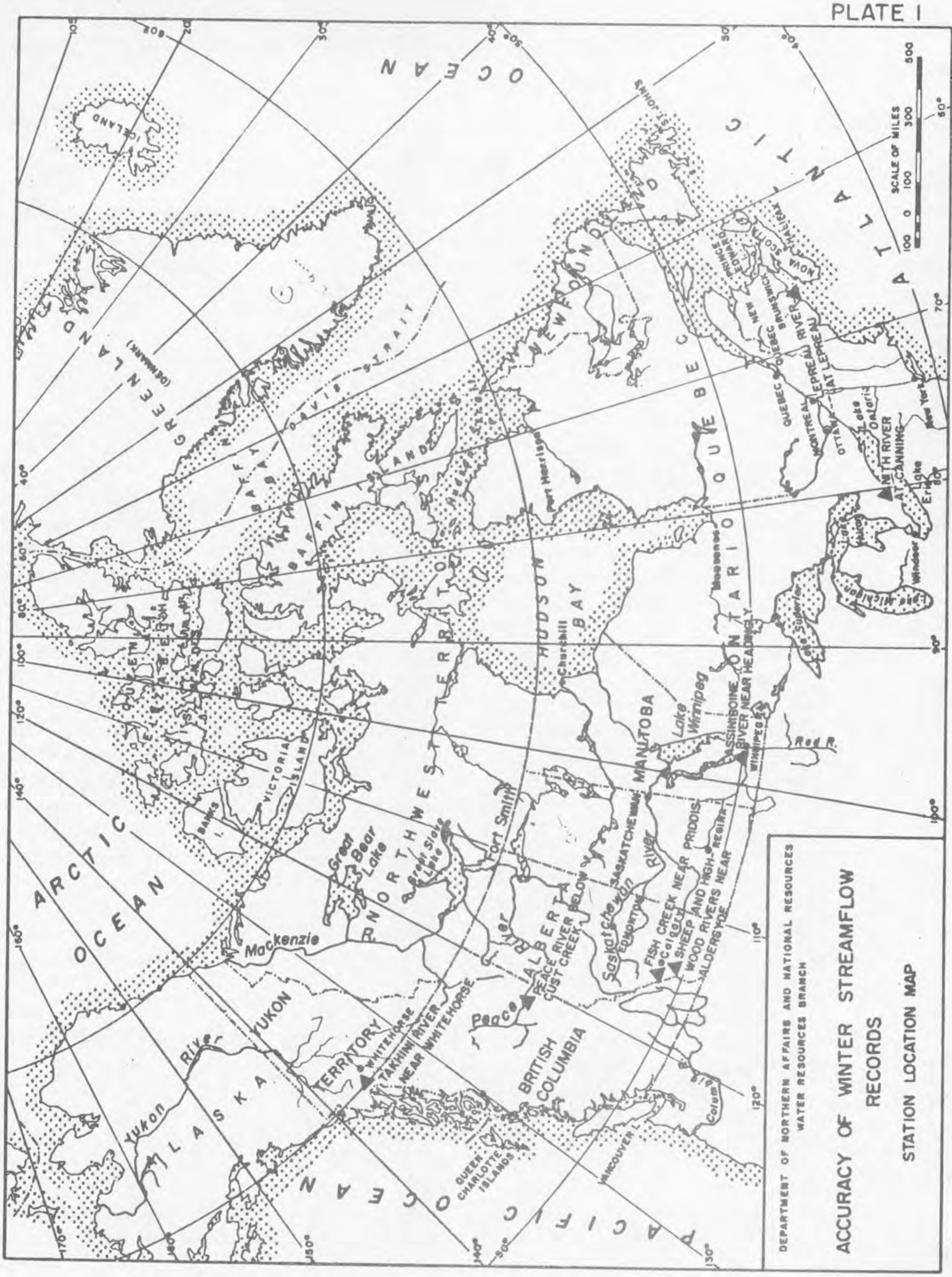
The adequacy of the methods used to compute streamflow under ice conditions is extremely important in Canada, probably more so than anywhere else in the world. Due to the vast number of streams in Canada, the relatively sparse population in remote areas, and the severe winter climate, it is impossible to get as much field coverage as in many other countries. Also, even though streams throughout the whole of the country do experience ice cover to some extent, the type of ice conditions varies greatly because of diverse climatological and topographical factors. With these varying conditions in mind, this investigation was designed to take into account as many different types and sizes of streams as was possible with available funds and personnel.

---

[1]Presented to the Eastern Snow Conference at Hartford, Connecticut - February 10, 1966.

[2]Senior Hydraulic Engineer, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

[3]Hydraulic Engineer, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.


DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH
ACCURACY OF WINTER STREAMFLOW RECORDS
STATION LOCATION MAP
SCALE OF MILES
ARCTIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
GREENLAND (DENMARK)
ICELAND
ALASKA
YUKON TERRITORY
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
HUDSON BAY
BAFFIN BAY
BAFFIN ISLAND
DAVIS STRAIT
HUDSON STRAIT
VICTORIA ISLAND
BANKS I.
QUEEN ELIZABETH ISLANDS
QUEEN CHARLOTTE ISLANDS
VANCOUVER I.
Great Bear Lake
Great Slave Lake
Lake Winnipeg
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Mackenzie R.
Yukon River
Peace River
Saskatchewan River
Red R.
Columbia
Fort Smith
Churchill
Port Harrison
Moosonee
Edmonton
Calgary
Regina
Winnipeg
Windsor
Ottawa
Montreal
Quebec
Halifax
St. Johns
New York
TAKHINI RIVER NEAR WHITEHORSE
PEACE RIVER BELOW CUST CREEK
FISH CREEK NEAR PRIDDIS
SHEEP AND HIGHWOOD RIVERS NEAR ALDERSYDE
ASSINIBOINE RIVER NEAR HEADINGLY
SOUTH RIVER AT CANNING
LEPREAU RIVER AT LEPREAU

2-6075

In the past, an assessment of the adequacy of computational methods was hampered by the limited number of measured discharges with which to compare computed values. This problem could be overcome by obtaining discharge measurements every day for an entire winter on representative streams. The investigation was initiated in the Calgary District Office of the Water Resources Branch during the winter of 1957-58 by Mr. E. P. Collier, then District Engineer, on the Sheep and Highwood Rivers. Preliminary statistical analysis of the data for these rivers showed that computed flows under ice conditions could be subject to serious errors and that more research was needed on a broader scale. During the winters of 1963-64 and 1964-65, the investigation was extended to include six additional streams representing different regions across the country. The 1963-64 program included the Nith River in Southern Ontario, the Assiniboine River in Manitoba, Fish Creek in Alberta, and the Peace River in British Columbia. The Takhini River in the Yukon Territory and the Lepreau River in the Maritimes concluded the field-work in 1964-65.

To provide homogeneity in the analysis so that results for all rivers would be directly comparable, all office studies were carried out in the Hydraulics Division in Ottawa. This presentation includes the preliminary results of the program as well as a description of the methods used in Canada for computing streamflow under ice conditions.

STREAM CHARACTERISTICS

The location of the stations used in this study is shown on the location map (Plate 1) and the characteristics of each stream in terms of drainage area, flow, winter temperature and slope are summarized on Table 1. The most southerly location was the Nith River, Ontario and the farthest north (and farthest west), the Takhini River in the Yukon Territory. The most easterly station was the Lepreau River in New Brunswick. The largest river, in terms of flow, was the Peace River in British Columbia and the smallest, Fish Creek in Alberta.

The Assiniboine River at Headingley is located in South Central Canada, an area which experiences a relatively low unit runoff during the winter season. Climatic conditions are quite severe with temperatures almost constantly below the freezing point. This results in very stable flow and ice conditions. The Takhini River, with sub-zero mid-winter temperatures, also has quite stable conditions, although slight thaws do occur occasionally throughout the winter due to the influence of the nearby Pacific Ocean. Both the Assiniboine and Takhini Rivers are approximately the same size, and because both have stable winter conditions, they react quite similarly under ice cover.

The Peace River in British Columbia was by far the largest river investigated. While mean winter temperatures in the region of the Peace River are relatively low, stretches of this river remain open for the greater part of the winter season where high river slopes occur. Because of these open water stretches, slush or frazil ice passing under ice-covered sections creates a problem for the hydrometric field man on this stream. At the measuring section below Cust Creek, slush as deep as 20 feet was encountered during 1963-64 when the Peace River was investigated. Due to the

TABLE 1

ACCURACY OF WINTER STREAMFLOW RECORDS

STREAM CHARACTERISTICS

	Year Studied	Latitude	Longitude	Drainage Area (sq.mi.)	Approximate Mean Discharge (Dec.-Feb.) in Winter of Study (cfs)	Minimum Recorded Discharge and Date (cfs)	Dec. °F	Jan. °F	Feb. °F	Approximate Slope (Ft./Mi.)
Assiniboine River at Headingly, Man.	1963-64	49°52'	97°24'	62,510	200	20 (Dec/ 1936)	3	6	9	1- 2
Fish Creek near Priddis, Alta.	1963-64	50°53'	114°20'	103	2	0 (Various Times)	17	21	32	15-20
Highwood River near Aldersyde, Alta.	1957-58	50°42'	113°51'	906	70	10 (Feb/ 1918)	29	30	16	20-40
Lepreau River at Lepreau, N.B.	1964-65	40°10'	66°28'	92	120	1 (Sept/ 1960)	23	13	16	20-40
Nith River at Canning, Ont.	1963-64	43°11'	80°27'	398	125	16 (Sept/ 1914)	17	22	20	6- 8
Peace River below Cust Creek, B.C.	1963-64	56°05'	122°17'	27,000	10,000	3480 (Dec/ 1952)	4	2	18	2- 3
Sheep River near Aldersyde, Alta.	1957-58	50°43'	113°53'	660	35	11 (Jan/ 1960)	29	30	16	10-20
Takhini River near Whitehorse, Y.T.	1964-65	60°37'	136°07'	1,650	410	128 (April/ 1956)	-12	- 3	- 2	1- 2

presence of the slush, some doubt exists as to the accuracy of the field discharge measurements obtained for this station. On the other hand, because of the large size of the stream, sharp variations in winter flow are damped out, which results in the problem of estimating flows between the measurements being a fairly simple one.

In Alberta, one very small stream was studied, Fish Creek, one slightly larger, the Sheep River, and one intermediate in size, the Highwood River. As the size of stream decreases, the problem of estimating winter flows becomes increasingly more difficult. This is partly due to greater variability in discharge, but also to the fact that the ice effect becomes a large component of the total gauge height so that gauge height becomes meaningless on very small streams. With three different sizes of streams in the same climatological region, it was possible to determine the effect of stream size on the accuracy of streamflow records. Weather in the area of the three streams is characterized by 10 to 20 degrees of frost each night in the early winter, becoming successively colder in mid-winter, but with many days having maximum temperatures well above the freezing point. These weather conditions, combined with high river slopes, lead to a tendency toward frazil and anchor ice formation.

The Nith River in Southern Ontario has mean winter temperatures similar to those in Southern Alberta, but with less sudden changes from day to day. Major thaws in mid-winter are quite common. During the winter of 1963-64 when this stream was studied, a thaw, accompanied by rain in late January, caused an increase in discharge from about 100 cfs to about 600 cfs in five days. Accompanying the rise in discharge was partial ice break-up and ice jams in the vicinity of the gauging station.

The Lepreau River in New Brunswick has quite unstable conditions. Ice forms late in the year and may break up during a thaw only to form again. Due to a thaw in late December 1964, it was necessary to discontinue measurements on this stream for a month during the season of investigation. The gap in daily measurements eliminated the possibility of analyzing the Lepreau River in a manner similar to that of the other streams.

Collection of Field Data

The technical staffs in the District Offices of the Water Resources Branch were responsible for collecting the field data. Metering at the same station each and every day during the winter demands more stamina and patience than is generally required for routine ice measurements. Some of the problems encountered were: long cold spells at all stations, particularly for the Takhini, Peace and Assiniboine Rivers; mid-winter ice jams on the Nith and Lepreau Rivers and extreme slush conditions on the Peace River. The field staff deserves commendation for carrying out their part of the investigation with only a relatively small amount of missing data.

Generally, discharge measurements were taken once a day, but at some stations a measurement was obtained two or three times a day during the freeze-up period.

During this period, discharge tends to drop for a short period while the gauge height rises and then to increase with falling gauge heights. This is caused in part by water going into and out of storage in the form of surface ice. Care was therefore taken to get a good discharge record during the period of freeze-up. For Fish Creek, measurements were required less frequently because an artificial control section was established by constructing a 90° sharp-edged triangular weir. The weir was kept completely free from ice and enough measurements taken to rate the weir accurately. This method was made possible because of the small size of Fish Creek and the relatively mild weather conditions.

Temperature records were obtained from meteorological stations closest to the gauging sites. Table 2 gives the period for which daily discharges are available for each stream, and the corresponding meteorological station used for each hydrometric station.

METHODS OF COMPUTATION

The Water Resources Branch uses three different methods to compute discharges under ice conditions. Presented hereunder are detailed descriptions of the three methods, with examples, as well as brief descriptions of the three other known methods.

1. Methods Presently Used

(a) Backwater Method

This method requires four known values: the discharge as measured; the related gauge reading for the measurement; the mean daily gauge height; and the open-water stage-discharge curve. These are shown in the sketch below:

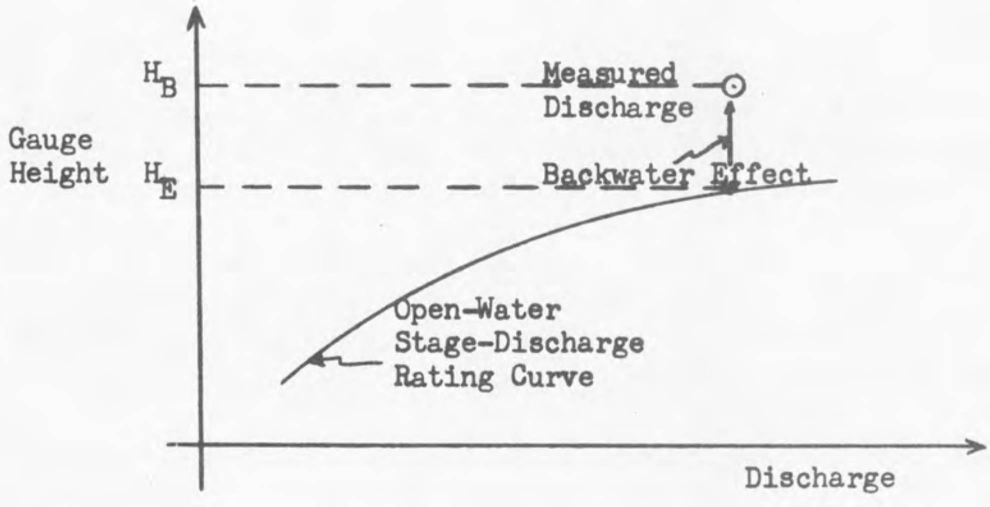


TABLE 2

ACCURACY OF WINTER STREAMFLOW RECORDS

COLLECTION OF DATA

Station Investigated	Corresponding Meteorological Station	Period of Investigation
Assiniboine River	Winnipeg, Manitoba	December 1963 - March 1964
Fish Creek	Calgary, Alberta	December 1963 - February 1964
Highwood River	High River, Alberta	November 1957 - February 1958
Lepreau River	Lepreau, New Brunswick	December 1964 and February 1965 (January missing)
Nith River	Guelph, Ontario	December 1963 - February 1964
Peace River	Hines Creek, B. C.	February 1964 - March 1964
Sheep River	High River, Alberta	November 1957 - February 1958
Takhini River	Whitehorse, Y. T.	January 1965 - February 1965

The difference between the gauge height, as read at the time of the measurement (H_B) and the stage that would occur for the measured discharge if open water conditions existed (H_E) is termed the "backwater effect". The backwater effect and mean daily temperatures are plotted against time and a "backwater" curve drawn with reference to the temperature curve as shown in the example for the Nith River on Plate 2. The backwater effect derived from daily discharge measurements and gauge height readings for the Nith River is also plotted on Plate 2 for comparison. Daily effective gauge heights are computed by subtracting the daily backwater effect, as indicated by the backwater curve, from the recorded daily gauge heights. Daily discharges are produced by application of the open-water rating table or curve to the effective gauge height. Table 3 shows a sample month of daily discharges calculated by the backwater method.

(b) Interpolated-Discharge Method

This method requires only the measured discharges and auxiliary information such as temperature at a nearby meteorological station and measurements in nearby streams. The measured discharges during the winter are plotted on the appropriate days and a hydrograph of daily discharge for the winter season produced by joining the plotted points, using temperature records and any other supplemental information, such as the flow in adjacent streams, as a guide in shaping the hydrograph. An example of this method is shown on Plate 3, along with the hydrograph of measured flows for the stream used in the example. Table 4 shows how the estimated discharges compared to the measured flows for a typical month.

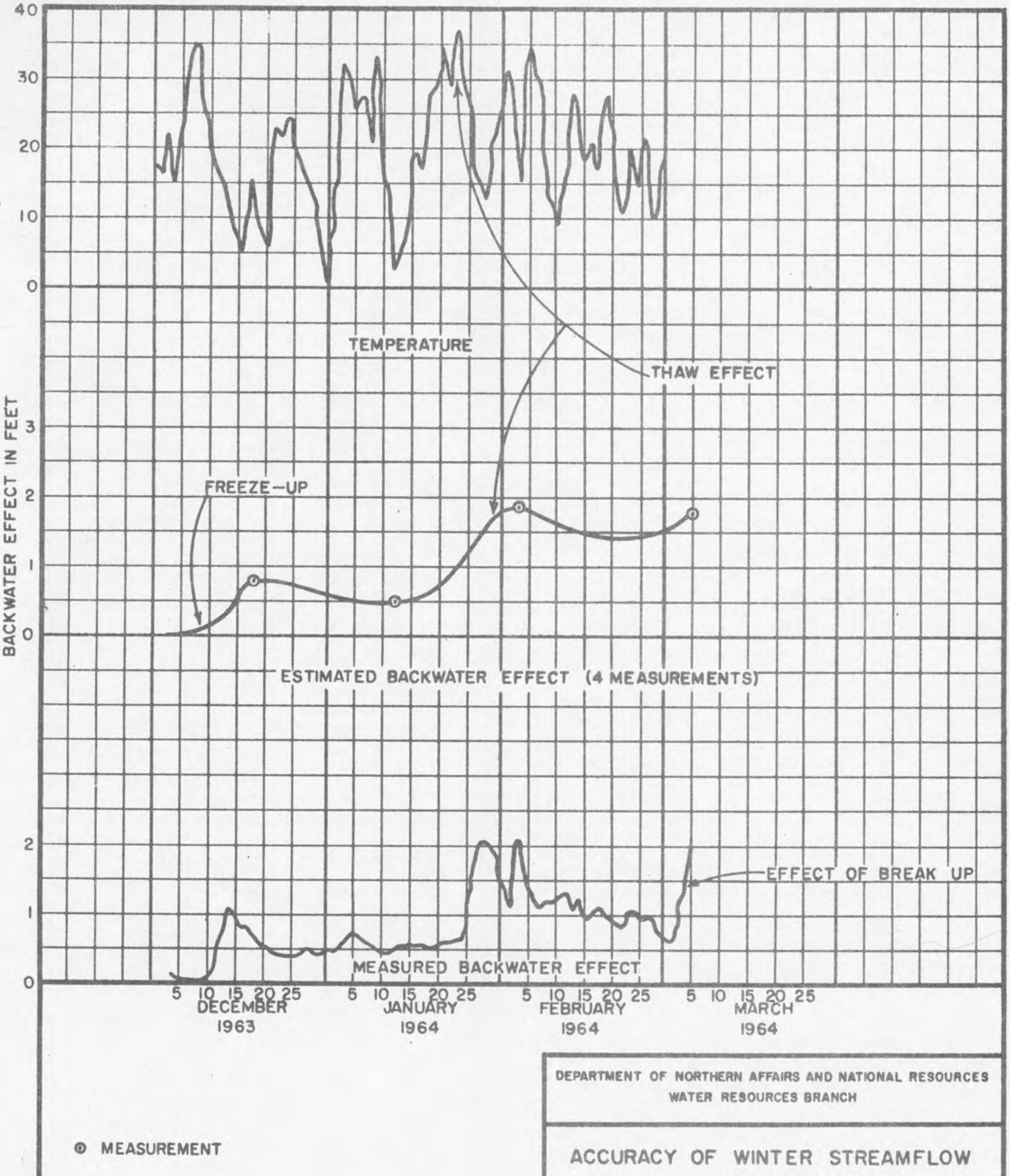
(c) Adjusted-Discharge Method

This method required exactly the same amount of information as the backwater method. The "equivalent open-water discharges" are obtained by using the gauge readings under ice conditions and the open-water stage-discharge curve. A hydrograph of "equivalent open-water discharges" is plotted and the measured discharges plotted below it on the appropriate days. The winter discharges are then estimated by joining the plotted measurement points, using the equivalent open-water hydrograph as a guide, and supplemented by reference to temperature. An example of this method is presented on Plate 4 and Table 5.

2. Other Known Methods

(a) The Effective Gauge-Height Method

A hydrograph of the observed daily gauge heights is constructed. Effective gauge height at the time of each discharge measurement is computed from the observed gauge height, the measured discharge and the open-water station rating. The effective gauge height for each discharge measurement is then plotted below the gauge height hydrograph.



DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

EXAMPLE OF BACKWATER METHOD

NITH RIVER AT CANNING 1963—64

2-6075

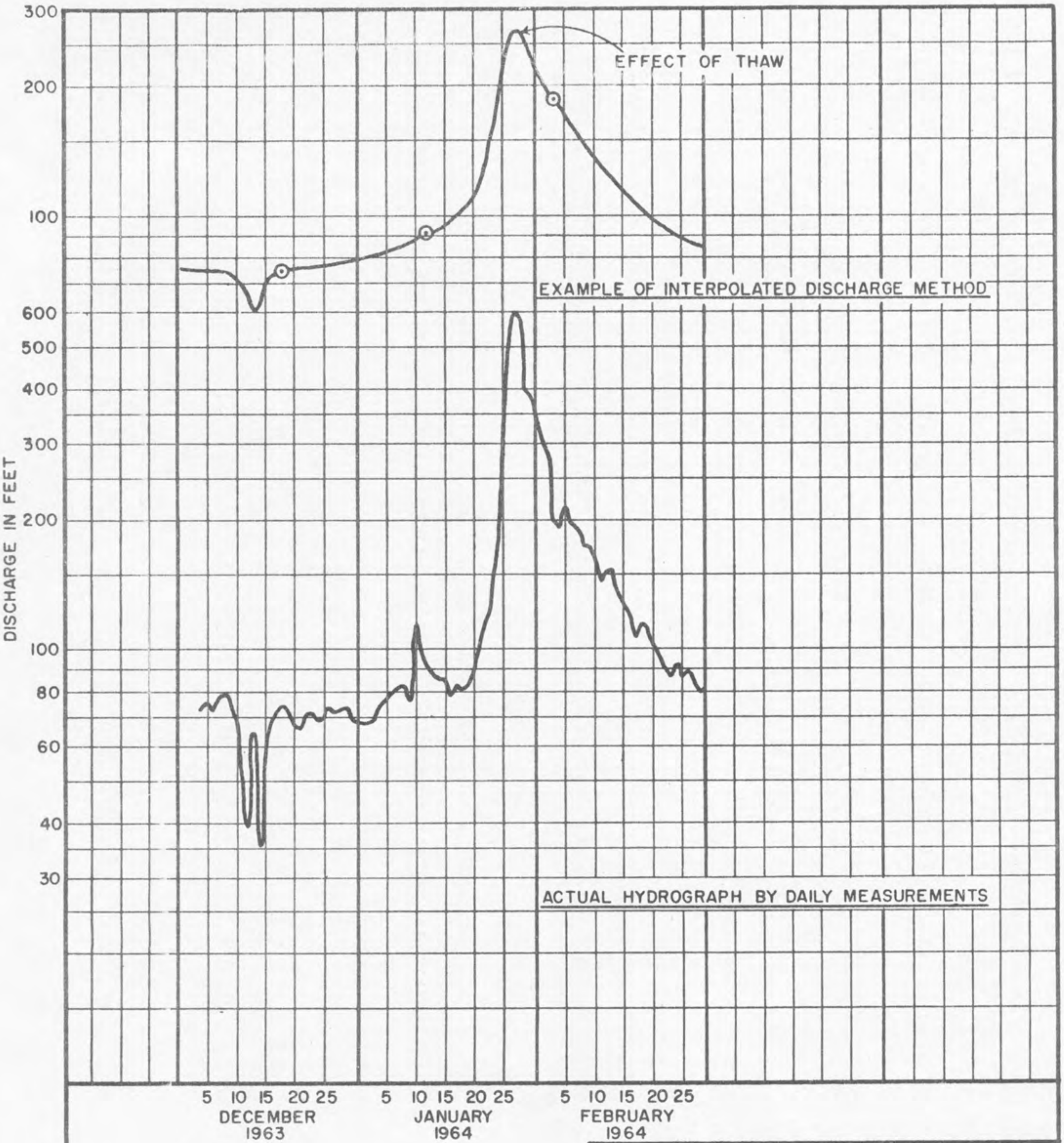
TABLE 3

SAMPLE CALCULATIONS - BACKWATER METHOD - NITH RIVER

Date 1964	Gauge Height feet	Discharge cfs	Effective G.H. feet	Shift or B.W. Corr. feet	Daily Gauge Height feet	Shift or B.W. Corr. feet	Computed Effective G.H. feet	Computed Discharge cfs
January 1					800.94	0.60	800.34	51.0
2					800.96	0.58	800.38	55.0
3					801.02	0.57	800.45	62.2
4					801.28	0.55	800.73	94.7
5					801.35	0.52	800.83	107
6					801.36	0.51	800.85	110
7					801.29	0.50	800.79	102
8					801.30	0.49	800.81	104
9					801.29	0.49	800.80	103
10					801.47	0.49	800.98	128
11					801.28	0.49	800.79	102
12	801.23	92	800.74	0.49	801.23	0.49	800.74	95.9
13					801.10	0.50	800.60	79.1
14					801.10	0.51	800.59	77.9
15					801.25	0.53	800.72	93.5
16					801.18	0.57	800.61	80.3
17					801.25	0.59	800.66	86.3
18					801.26	0.61	800.65	85.1
19					801.26	0.64	800.62	81.5
20					801.34	0.70	800.64	83.9
21					801.56	0.76	800.80	103
22					801.56	0.81	800.75	97.1
23					801.60	0.95	800.65	85.1
24					801.76	1.05	800.71	92.3
25					802.30	1.20	801.10	146
26					803.31	1.32	801.99	350
27					805.04	1.46	803.58	1060
28					804.78	1.60	803.18	840
29					804.10	1.70	802.40	489
30					804.12	1.76	802.46	511
31					803.95	1.81	802.14	396

Note: B.W. Corr. Read from smooth curve Plate 2.

PLATE 3



⊙ - MEASUREMENT

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

EXAMPLE OF INTERPOLATED DISCHARGE METHOD

ACTUAL HYDROGRAPH BY DAILY MEASUREMENTS

NITH RIVER AT CANNING 1963 — 64

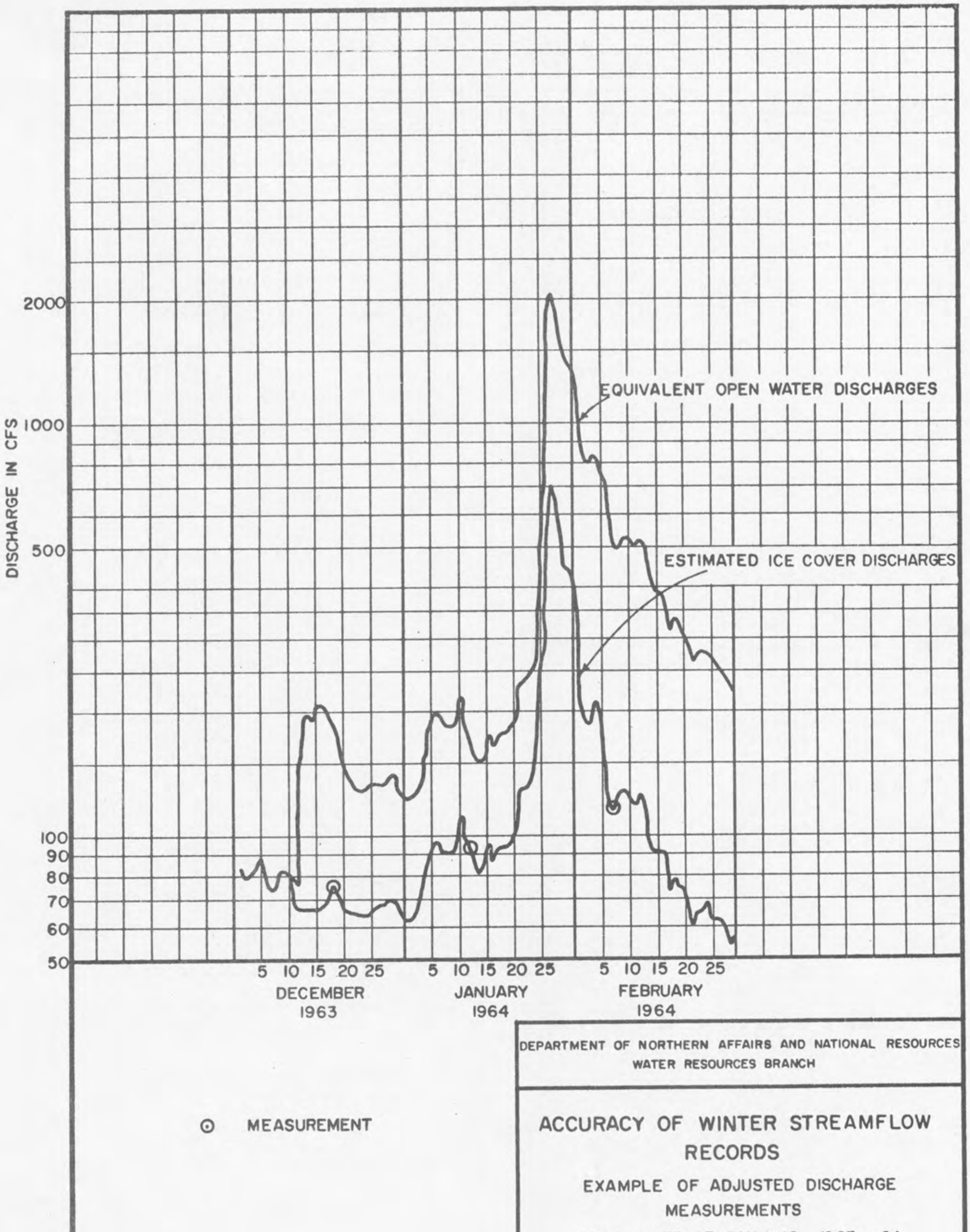
2-6075

TABLE 4

SAMPLE CALCULATIONS FOR INTERPOLATED DISCHARGE METHOD - NITH RIVER

Date 1965	Discharge in cubic feet per second Calculated (from plate 3)	Measured	Error	% Error
January 1	80	68	+ 12	+17.65
2	81	68	+ 13	+19.12
3	82	69	+ 13	+18.84
4	83	75	+ 8	+10.67
5	83	78	+ 5	+ 6.41
6	84	80	+ 4	+ 5.00
7	85	82	+ 3	+ 3.66
8	86	83	+ 3	+ 3.61
9	87	76	+ 11	+14.47
10	88	115	- 27	-23.48
11	90	100	- 10	-10.00
12	92	92	0	0.00
13	94	88	+ 6	+ 6.82
14	95	86	+ 9	+10.47
15	96	85	+ 11	+12.94
16	98	78	+ 20	+25.64
17	101	83	+ 18	+21.69
18	104	82	+ 22	+26.83
19	108	82	+ 26	+31.71
20	114	87	+ 27	+31.03
21	122	98	+ 24	+24.49
22	137	112	+ 25	+22.32
23	160	124	+ 36	+29.03
24	190	161	+ 29	+18.01
25	220	257	- 37	-14.40
26	255	358	-103	-28.77
27	270	595	-325	-54.62
28	265	584	-319	-54.62
29	250	395	-145	-36.71
30	230	390	-160	-41.03
31	215	343	-128	-37.32
Total	4145	5074	-929	-18.31
Average	134	164		

PLATE 4



DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

EXAMPLE OF ADJUSTED DISCHARGE MEASUREMENTS

NITH RIVER AT CANNING 1963—64

2-6075

TABLE 5

SAMPLE CALCULATIONS - ADJUSTED DISCHARGE METHOD - NITH RIVER

Date 1965	Discharge in cubic feet per second Calculated (from plate 4)	Measured	Error	% Error
January 1	62	68	- 6	- 8.82
2	64	68	- 4	- 5.88
3	72	69	+ 3	+ 4.35
4	88	75	+ 13	+17.33
5	94	78	+ 16	+20.51
6	96	80	+ 16	+20.00
7	90	82	+ 8	+ 9.76
8	90	83	+ 7	+ 8.43
9	90	76	+ 14	+18.42
10	110	115	- 5	- 4.35
11	98	100	- 2	- 2.00
12	92	92	0	0.00
13	80	88	- 8	- 9.09
14	80	86	- 6	- 6.98
15	94	85	+ 11	+ 8.97
16	85	78	+ 7	+ 8.97
17	92	83	+ 9	+10.84
18	94	82	+ 12	+14.63
19	94	82	+ 12	+14.63
20	100	87	+ 13	+14.94
21	130	98	+ 32	+32.65
22	130	112	+ 18	+16.07
23	135	124	+ 11	+ 8.87
24	170	161	+ 9	+ 5.59
25	260	257	+ 3	+ 1.17
26	400	358	+ 42	+11.73
27	700	595	+105	+17.64
28	600	584	+ 16	+ 2.74
29	420	395	+ 25	+ 6.33
30	420	390	+ 30	+ 7.69
31	350	343	+ 7	+ 2.04
Total	5480	5074	+406	+ 8.0
Average	177	164		

A curve of the daily effective gauge height for the season is then produced by joining the plotted points, using the hydrograph of observed gauge heights as a guide, with some reference to the temperature records.

(b) The Recession-Curve Method

Slopes of mean recession curves for various periods of the winter season are estimated from a study of open-water recession curves at the station and from winter measurements over the period of record. The curves are then plotted on semi-logarithmic paper and the measurements for the winter under study plotted on the same chart. The discharge hydrograph for the winter is constructed by drawing a curve through the plotted points, using the recession curves and temperature records as guides. The method has not been developed to the point where it has practical application in the area under study.

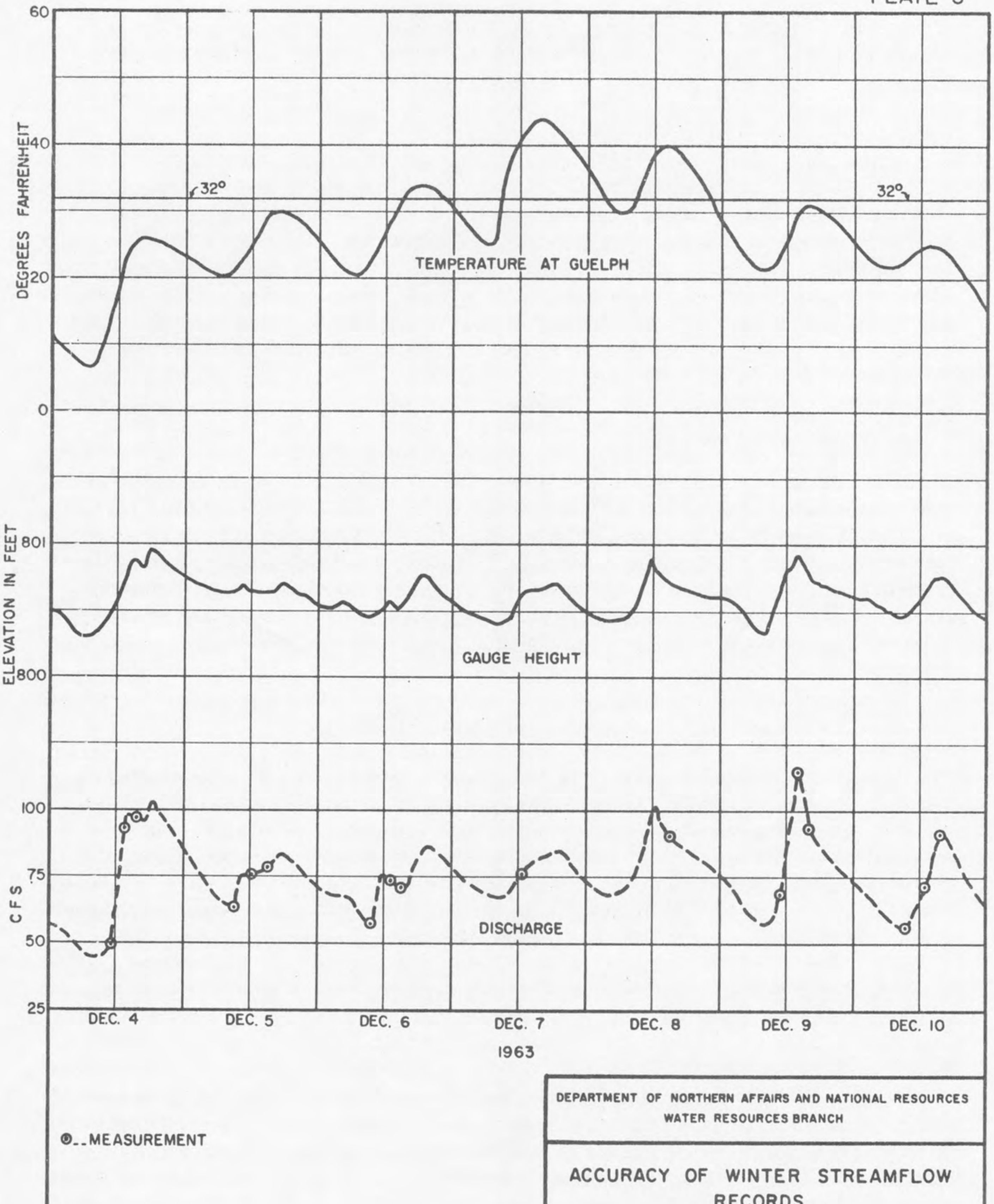
(c) The k-Factor Method

A "k" factor is computed for each winter measurement, "k" being the ratio of the measured discharge to the open-water discharge at the same gauge height. This "k" is almost always less than unity. The value of"k" for each measurement is plotted on the appropriate days, and a curve of "k" for each day constructed by joining the plotted points, using temperature records as a guide. The daily discharge for the winter season is then computed by determining the equivalent open-water discharge from each day's gauge height and multiplying by the appropriate value of "k" from the curve.

ANALYSIS OF TEST DATA

Mean daily discharges were computed for each stream from a consideration of hourly gauge heights, hourly temperature, and the measured discharges which were plotted on a large scale (1 inch = 1 day) graph. The hydrograph of discharge was obtained by joining the points of measurement with reference to gauge height and temperature. A sample discharge hydrograph, plotted for the Nith River for a one-week period during freeze-up is shown on Plate 5. This is an extreme example of the variability of streamflow during the formation of ice cover.

For most hydrometric stations in Canada, field practice is to obtain winter discharge measurements at intervals of about one month. At some of the more important, well-located stations the interval may be as short as two weeks and at remote stations where access is difficult, the interval may be as long as two months. In this investigation, to simulate field practice, an average interval of one month was assumed as a representative period between winter measurements. Where large errors were found to exist, the effect on accuracy of decreasing the interval to a half-month was also determined. In order to apply statistical techniques, various group programs of measurements were established. A nominal one-month interval was assumed to vary from 14 to 42 days in a random fashion. Likewise for a program of two measurements a month, the intervals chosen were between 7 and 21 days. A random numbers table



DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

EXAMPLE OF DETERMINATION OF ACTUAL MEAN DAILY DISCHARGES

NITH RIVER AT CANNING – DECEMBER 1963

2-6075

was used to make the selection of thirty such programs. The necessity of so large a number of programs was the extreme variability of winter flows which are constantly changing with ice jams, slush ice, precipitation, temperature, etc. The date when a specific measurement is taken, can, by pure chance affect the accuracy of published records for a lengthy period. Thirty artificially established programs of measurement were found, by experiment, to fulfil the requirements of this study.

After selecting the thirty normal programs for each stream, it was necessary to select which methods should be compared. There are basically only two different types of solution, one which uses gauge heights and one which does not. The problem was to decide if stream gauge heights do in fact improve the records, and if so which specific method of calculation is the most satisfactory. Of those methods described in "Methods of Computation", the Interpolated Discharge Method and the Recession Curve Method are the only two which do not use gauge heights. Since the Recession Curve Method is not yet developed to the point where it has practical application in this study, the Interpolated Discharge Method was chosen as one of the methods to be studied. The other four methods all use gauge heights but in two different ways. For the Backwater and the Effective Gauge Height Methods, effective gauge heights are estimated before translating them into discharge data, while for the adjusted discharge and "k" factor methods, the estimating is done by using the equivalent open-water discharges as a guide in estimating the discharge hydrograph. Since the Backwater and Adjusted Discharge Methods are now used by the Branch, they were selected for test comparison. A detailed comparison was therefore made of the Interpolated Discharge, Backwater, and Adjusted Discharge Methods, the methods principally used in Canada.

For each stream, the thirty random measurement programs were used to produce thirty independent records of calculated daily mean discharge for the entire winter period for each of the three methods. The calculated discharges were then compared to the discharges determined from the daily field measurements. Standard errors as a percentage of the mean were determined on a monthly and total winter basis. By comparing the percentage standard error obtained for each of the three methods, it was possible to choose the best method for a particular river. In order that the results might be extended to other streams not included in the investigation, a general relationship was sought. After attempting several types of relationships, it was discovered that for any one method, an apparent relationship existed between percentage standard error, (a reflection of relative accuracy), climate as represented by mean winter air temperature and stream size as represented by mean winter discharge.

Preliminary Results

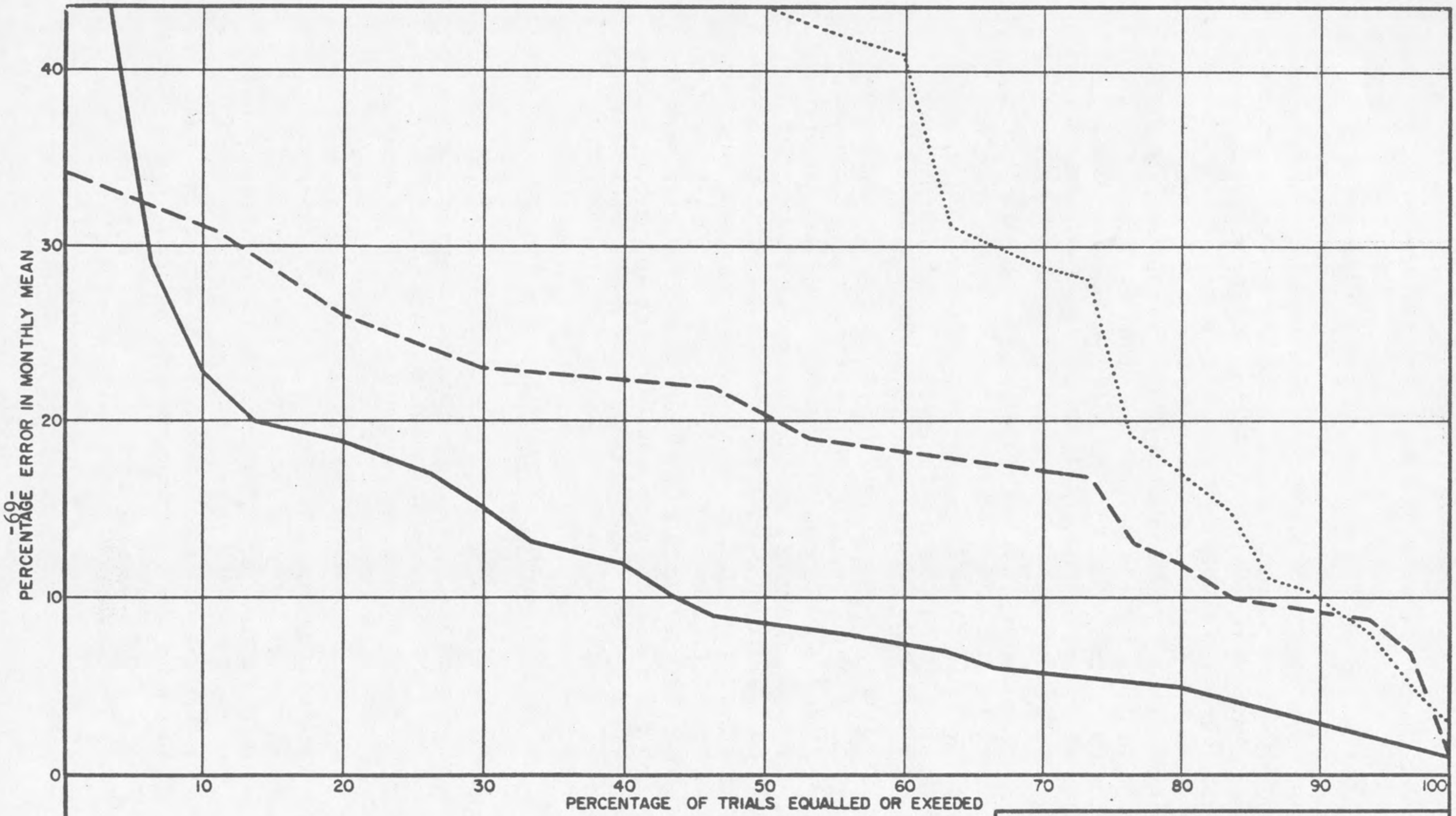
A summary of percentage standard errors on a monthly and total winter basis for each of the streams studied is presented in Table 6. In each case, the standard error was calculated from thirty artificial programs of measurements with random intervals of approximately one or one-half months. Shown on Plate 6 is an example of the error distribution on a frequency basis for each of the three computational methods for the Nith River for the month of January with approximately one measurement per month.

TABLE 6

ACCURACY OF WINTER STREAMFLOW RECORDS

SUMMARY OF RESULTS

Stream	Computational Method	Number of Measurements Per Month	Nov.	Dec.	Jan.	Feb.	March	Total Period
			Standard Errors in Percent					
Assiniboine	Adjusted Discharge	1		11.2	5.3	3.8	5.7	4.2
	Backwater	1		9.3	5.7	8.3	6.4	4.5
	Interpolated Discharge	1		14.2	7.1	3.6	8.9	4.6
Fish	Adjusted Discharge	1		>100	38.3	68.0		74.7
	Backwater	1		>100	>100	>100		>100
	Interpolated Discharge	1		21.8	45.2	31.8		16.8
	Interpolated Discharge	2		10.3	15.3	25.5		8.2
Highwood	Adjusted Discharge	1	13.0	14.6	17.9	15.7		8.5
	Backwater	1	24.3	27.8	22.9	24.3		18.1
	Interpolated Discharge	1	27.6	32.4	18.1	12.4		18.6
Nith	Adjusted Discharge	1		10.8	15.4	20.6		13.2
	Backwater	1		23.7	43.0	37.5		31.9
	Interpolated Discharge	1		14.8	21.3	15.3		14.5
	Adjusted Discharge	2		7.1	9.1	9.7		6.3
	Interpolated Discharge	2		12.1	15.6	6.4		7.9
Peace	Adjusted Discharge	1				6.2	4.7	4.1
	Backwater	1				5.2	5.6	4.1
	Interpolated Discharge	1				5.1	9.8	3.2
Sheep	Adjusted Discharge	1	8.3	57.7	38.7	14.9		18.3
	Backwater	1	14.4	97.5	68.4	>100		38.4
	Interpolated Discharge	1	12.2	30.5	14.5	23.2		8.9
Takhini	Adjusted Discharge	1			4.1	3.6		3.0
	Backwater	1			4.1	3.4		2.4
	Interpolated Discharge	1			7.1	3.4		4.1



LEGEND

.... BACKWATER METHOD

— — INTERPOLATED DISCHARGE METHOD

——— ADJUSTED DISCHARGE METHOD

NOTE:- SEE TABLE 6 FOR THE MAGNITUDE OF ERRORS FOR OTHER MONTHS AND OTHER STREAMS. (DISTRIBUTION OF ERRORS IS SIMILAR TO THOSE SHOWN ABOVE IN MOST CASES)

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

EXAMPLE OF DISTRIBUTION OF ERRORS

NITH RIVER AT CANNING JAN. 1964

2-6075

Similar shaped distributions were found to exist for the other streams.

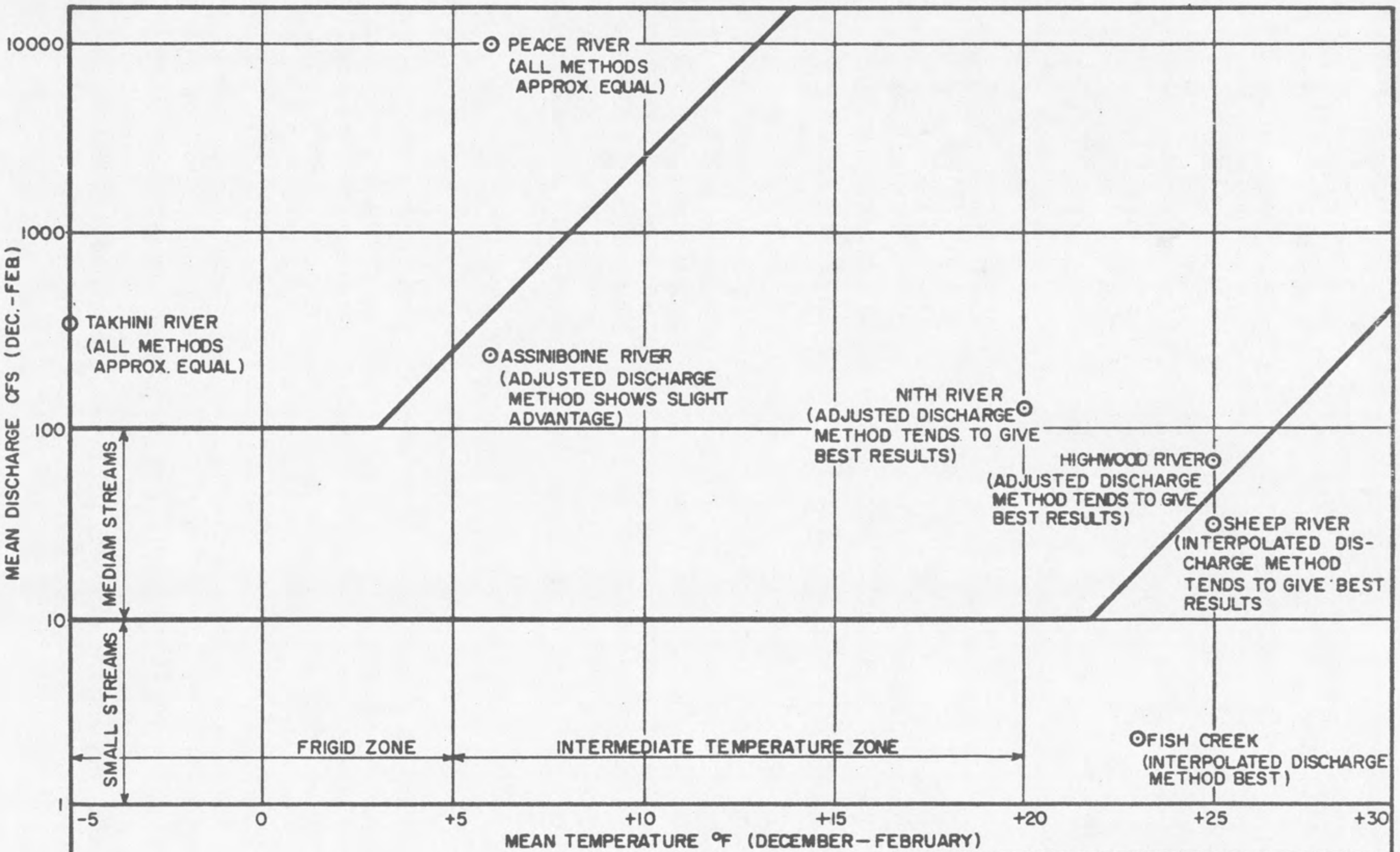
For all three computational methods, standard error as a percentage of the mean tends to decrease as mean discharge increases. This is because minor fluctuations of supply are damped out in large streams. Also, for very large streams, changing ice conditions do not affect the discharge to the same extent as for smaller streams. Climatic conditions tend to have an even greater effect on the magnitude of errors than does stream size. In cold climates, conditions are quite stable. Supply conditions are relatively constant since no melting occurs during the winter and all precipitation is in the form of snow. Another factor which has an effect on errors is the slope of a stream. High slopes lead to high velocities causing more open water and consequently more frazil and anchor ice formation, and more jamming which in turn complicates the problem of estimating discharges.

Shown on Plate 7 is a demonstration of how streams may be categorized using mean winter temperature and discharge. For large streams in frigid zones, all methods give good results. Therefore, in this category, collection of gauge height data could be discontinued where the data are only used for hydrometric purposes. Also, consideration could be given to decreasing the frequency of measurements to less than one per month in this category of stream. This could be done without any serious loss in accuracy. For very small streams, and streams in moderate temperature zones, gauge height data do not improve records. This is particularly true for very small streams where gauge height becomes meaningless in estimating discharge because ice effect is so large a proportion of the total gauge height. As shown on Plate 7, for all other types of streams, gauge height data do give some improvement to published records. In the category where gauge height data do give an improvement, it was found that the adjusted discharge method is far superior to the backwater method. This is mainly due to the fact that the technician is working directly in terms of discharge, which is much easier to understand than the less predictable "backwater effect".

CONCLUSIONS

The winter season is recognized as the season in which discharge records generally have their lowest degree of reliability. As a result of the present program, errors in winter discharge were found to be greater than anticipated. While size of stream and climate are major factors which affect accuracy, computational methods were also found to be important.

For the purpose of choosing the best method for computing daily flows, streams may be placed in three categories, divided approximately as shown on Plate 7. For the category of large streams in frigid zones, gauge heights are unnecessary, and consideration could be given to reducing the frequency of measurements. For small streams and streams in a moderate temperature zone, gauge height data are of little value. For medium and large streams in the intermediate temperature zone, there is some indication



DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES

WATER RESOURCES BRANCH

ACCURACY OF WINTER STREAMFLOW RECORDS

CLIMATIC AND STREAM SIZE EFFECT ON COMPUTATIONAL METHODS

2-6075

that the adjusted discharge method using gauge height data tends to give slightly better results than the interpolated discharge method and much better results than the backwater method. In the warmer part of this category, increased frequency of measurements would also be desirable. The divisions shown on Plate 7 dividing the categories are arbitrary and would require additional data before they could be used operationally.

For most streams included in the program, a diurnal effect in discharge was observed to take place during the freeze-up period and in some cases, the flow changed by as much as 100% in a few hours. This would suggest another area for study. While measurements were taken during the freeze-up period, very little information was obtained during the spring breakup period. Because of its importance, this is an area where future research is necessary.

In conclusions, it should be pointed out that further research on the accuracy of winter streamflow records should be carried on. Although heretofore a simple approach has been taken with respect to computations of ice effect, it is in fact a very complex subject. One of the more important aspects to be considered for the future is the feasibility of application of computer techniques. All the methods now in use by the Water Resources Branch require personal judgment and are thus not directly applicable to solution by electronic computer. Some research has been done towards developing computer methods, but more is needed.