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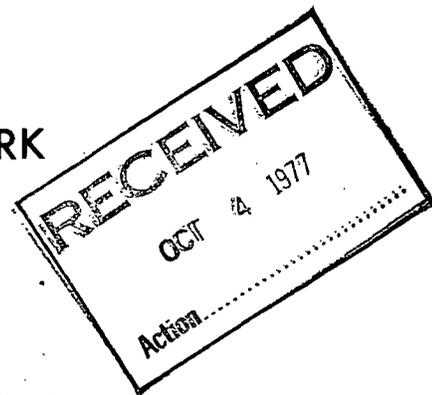
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Technical Memoranda

EFFECT OF LENGTH OF AVERAGING
PERIOD OF INPUT DATA ON
COMPUTED EVAPORATION

by

H.F. CORK



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ABSTRACT

The validity of using an evaporation equation of the form $E = K_u (e_s - e_a)$, which had been empirically derived for daily data for periods up to 32 days, is examined using data for Lake Diefenbaker, Saskatchewan. Errors in evaporation due to extended computation periods are found to be usually overestimates and generally small. Analysis of the errors in the component factors of the evaporation formula indicate that they are generally larger than errors in the computed evaporation, but tend to be compensatory. For other lakes the degree of compensation may be less, resulting in errors in computed evaporation which are larger than for Lake Diefenbaker. Either overestimates or underestimates can occur.

INFLUENCE SUR L'ÉVAPORATION CALCULÉE DE LA LONGUEUR DE
LA PÉRIODE DE CALCUL DES MOYENNES DES DONNÉES

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RÉSUMÉ

L'auteur étudie, à l'aide de données pour le lac Diefenbaker (Saskatchewan), la validité d'une équation de l'évaporation de la forme $E = K_u (e_s - e_a)$ établie empiriquement pour les données quotidiennes de périodes allant jusqu'à 32 jours. Il ressort de l'étude que les erreurs sur l'évaporation dues à la longueur des périodes pour lesquelles s'effectuent les calculs sont en général de légères erreurs par excès. L'analyse des erreurs sur les facteurs de la formule de l'évaporation indique qu'elles sont généralement plus importantes que l'erreur sur l'évaporation calculée mais qu'elles ont tendance à se compenser. Le degré de compensation risque d'être inférieur pour d'autres lacs, ce qui se traduirait par de plus grandes erreurs sur l'évaporation calculée que dans les cas du lac Diefenbaker. Il peut s'agir soit d'erreurs par excès, soit d'erreurs par défaut.

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(Manuscript received July 19, 1976)

1. Introduction

Formulae of the form $E = Ku(e_s - e_a)$, where E is depth of water evaporated, u is wind speed and $(e_s - e_a)$ is the vapour pressure difference between the water surface and some higher level, have been widely used in evaporation computations. Probably the best known are the Lake Hefner formulae (Bruce, 1966). The constant K for each formula of this type has been found for a specific set of circumstances. These include a specific water body, wind measured at a specific height and at a specific position relative to the lake, and atmospheric vapour pressure measured at a specific height. The period of computation is also specified; for example it is one day in the case of the Lake Hefner formulae. Jobson (1972), using Lake Hefner data, identified two sources of error: (1) correlation of wind speed with vapour pressure difference, and (2) the non-linear relationship between vapour pressure and dew-point, but did not attempt to separate the two effects. Using a 30 minute period as a basis for comparison he found no significant bias for three hour and one day averaging periods. For monthly averaging periods he found computed evaporation larger for all 13 months examined, the median error being 4%, the largest error 23%. The variance of the errors for the one day periods was considerably greater than for the three hour periods but there was no significant additional increase in variance for the monthly periods. Jobson concluded that averaging periods of one day or less were satisfactory but that periods of one month - unless a correction factor was known - were not. Periods between one day and one month were not examined. Hage (1975), using Edmonton data, found that monthly mean values of e_a , computed from monthly mean values of temperature and relative humidity, differed little during the summer months from monthly mean values computed from the mean of three-hour vapour pressure data.

The purpose of this paper is to find what errors resulted from using the Lake Hefner formula for computation periods greater than one day, as applied to Lake Diefenbaker data.

The location and configuration of Lake Diefenbaker are shown on Figure 5. Wind and atmospheric vapour pressure measurements are made at 10 metres and screen height, respectively, over flat prairie. The instruments are approximately 30 m higher than the water surface. A table of symbols used may be found on the last page.

2. Sources of Error

(a) Correlation between wind and vapour pressure difference

If we compute evaporation on a daily basis and sum the daily computed evaporation for n days we have

$$E_n = \sum_{i=1}^{i=n} K u_i (e_{si} - e_{ai}) \quad (1)$$

If we sum the wind and average the vapour pressures for n days and then compute the evaporation we have

$$E'_n = K \sum_{i=1}^{i=n} u_i \sum_{i=1}^n (e_{si} - e_{ai})/n \quad (2)$$

E_n will be greater than E'_n if wind and vapour pressure difference are positively correlated, E_n will be less than E'_n if they are negatively correlated, and they will be equal if there is no correlation.

Correlations between wind and vapour pressure difference at Lake Diefenbaker were found for 32-day "months" from June to October for three years. These are listed in Table 1. The last one or two days from the preceding month have been included to make each month 32 days for reasons which become clearer later.

(b) Methods of finding time-averaged vapour pressure

Two methods are commonly used in finding average vapour pressure. (1) Method (A): dew points are obtained at intervals during the averaging period, the corresponding vapour pressure for each dew point is found, and the mean of these vapour pressures is the required value. Usually, in evaluating e_s , the surface water temperature is considered to represent the atmospheric dew point at the water surface. (2) Method (B): dew points are obtained at intervals during the averaging period,

the mean value of the dew points is found, and the vapour pressure corresponding to the mean dew point is considered to be the required value. This method involves less clerical time than the first and may be necessary where published mean dew point values are the only data available. However method (B) always underestimates average vapour pressure. This may be expected because the dewpoint - vapour pressure relationship is not linear. When plotted as dependent variable the vapour pressure curve is concave upward. Average vapour pressures found by this second method will be differentiated from those found by the first method by the use of double primes: e''_s and e''_a .

Method (B) always underestimates the true average vapour pressure, that is, e''_s is always less than e_s and e''_a is always less than e_a . The magnitude of underestimation is larger for higher vapour pressures and larger for periods of greater dewpoint variability.

If we approximate $(\bar{e}_s - \bar{e}_a)$ by using $(\bar{e}''_s - \bar{e}''_a)$, both \bar{e}_s and \bar{e}_a will be underestimated. However it does not follow that the difference $(\bar{e}_s - \bar{e}_a)$ will be underestimated, since \bar{e}''_s and \bar{e}''_a will both have errors in the same direction. For Lake Diefenbaker it was found that \bar{e}_a was underestimated by \bar{e}''_a to a greater degree than \bar{e}_s was underestimated by \bar{e}''_s in all cases except June 1974. The effect is that $(\bar{e}_s - \bar{e}_a)$ is overestimated by $(\bar{e}''_s - \bar{e}''_a)$ in all other cases.

(c) Effect of Variation in Starting Date of Computation Period

If a 32 day "month" is divided into 8-day computation periods, different results will be obtained depending on the starting dates of the eight day periods. Trial with four different starting dates for each of 15 "months" showed an average mean deviation of only 0.6 mm, approximately 0.5%. It was concluded that the effect of starting date would be ignored.

3. Changes in Computed Evaporation with Change in Computation Period

Daily mean values were the shortest term values available for some of the variables. Also, the Lake Hefner formulae are based on daily values. Periods of computation were, 2, 4, 8, 16 and 32 days. Each 32-day period ended on the last day of a month and was named for that month. Each "month" began one or two days before the first day of the standard month to obtain 32 days. In all, 15 "months" were computed: June to October 1972, 1973 and 1974 for the lower portion of Lake Diefenbaker (below Riverhurst ferry).

Method 1: This is simply the summation of the daily evaporation computed daily mean values of wind and daily difference between daily mean saturation vapour pressure at the water surface and daily mean atmospheric vapour pressure.

For Method 1 the number of days of computation used would make no difference.

Method 2: This computes the evaporation for several days from the mean value of wind for that period and the mean values of the daily vapour pressures for that period.

Method 2 gives an answer which differs from that of Method 1 if there is correlation between wind and vapour pressure difference, as outlined in Section 2(a).

Method 3: This method differs from Method 2 in the manner of obtaining vapour pressure values. The surface vapour pressure for 8-day computation periods is obtained by averaging the surface water temperatures for 8 days and finding the corresponding vapour pressure. Similarly, 8-day atmospheric vapour pressures are found from mean 8-day dew points.

Method 3, compared to Method 1, combines the error outlined in Sections 2(a) and 2(b).

4. Results

Figures 1 to 4 depict the total 32-day evaporation amounts as computed by each of the three Methods. Method 1 is considered as a standard because the constants of the formulae were derived using that method. It yields the value given for the sum of 32 one-day computation periods. The other two methods are identified for the 32 one-day periods but give varying values for:

- (1) the sum of 16-day periods
- (2) the sum of 8 four-day periods
- (3) the sum of 4 eight-day periods
- (4) the sum of 2 sixteen-day periods
- (5) one 32-day period.

Examination of the Figures leads to the following observations:

- (1) From Figure 1 it is seen that the bias in the mean for the five months for three years is not great. From no difference for one-day computation periods, the bias increased with longer

computation periods up to 8 days. There was little increase in bias for 16-day and 32-day computation periods. For a mean evaporation of 123 mm for 32 days Method 2 gave a value about 1 mm too large and Method 3 gave a value about $3\frac{1}{2}$ mm too large.

- (2) Method 3 generally, but not always, gave higher values than Method 2. Largest differences - approximately 5 mm - were for the July 1974 and August 1973 sixteen and thirty-two day computation periods.
- (3) The greatest deviation from the standard (Method 1) values occurred in June 1973. For a 32-day evaporation of 65 mm Method 2 gave values 7-8 mm too high for four to thirty-two day computation periods and Method 3 gave values 9 mm too high. This may be attributed to the correlation of $-.49$ between wind speed and vapour pressure difference for June 1973 (See Table 1). This is the highest correlation for any month.
- (4) June 1974 was unusual in that the computed evaporation for the 32 days was slightly less using Method 2 or Method 3 than for using Method 1. When using 2, 4, 8 or 16 day computations, results showed much the same trend as for other months. However, for the 32-day computation period, Method 3 shows a sharp drop compared to results using the same method but 16 day computation periods. Investigation showed a sharp increase in air temperature beginning about mid-month. This resulted in an average water temperature for the last 16 days which was 5.6°C higher than for the first 16 days (compared with differences of 1.2°C and 3.4°C for 1972 and 1973).

5. Comparison with Results from Babine Lake

Babine Lake is in central British Columbia, (55°N , 126°W) on a tributary to the Skeena River. It is long and narrow and similar in size to Lake Diefenbaker. However it is surrounded by forest and mountainous terrain whereas Lake Diefenbaker is surrounded by flat prairie. Lake Diefenbaker has much greater evaporation.

Spring and Schaefer (1974) reported results obtained using a number of variations of the Hefner formula. Using daily values, the 1972 June to November evaporation was computed to be 127.7 mm. Using monthly average values the evaporation was computed to be 108.6 mm. The monthly method gave 19.1 mm less for the season (approximately 3.34 mm/32 days). The ratio was .85. These results

can be compared with the Method 3 results for Lake Diefenbaker which yielded 3.5 mm more for 32 days and a ratio of 1.03. It is clear that the effect of increasing the averaging period of the input data will be different with dissimilar lakes.

6. Conclusions and Recommendations

- (1) In general, for Lake Diefenbaker, Method 2 gives higher evaporation estimates than Method 1, and Method 3 gives higher evaporation estimates than Method 2. The analysis of the causes of the different values does not lead to any expectation that those findings would be necessarily true of other lakes. The error introduced by either method could be in either direction.
- (2) The errors resulting from using Method 2 or Method 3 instead of Method 1 for Lake Diefenbaker were generally small and could be considered acceptable. The evidence from Lake Diefenbaker should not be considered necessarily applicable to other lakes.
- (3) Since the errors in Method 3 include the errors in Method 2, Method 2 would generally be preferable, as it is for Lake Diefenbaker. However it would be possible that the additional error introduced by Method 3 could be in the opposite direction at some other lake and compensate for the error introduced by Method 2.
- (4) Method 3 has been used for Lake Diefenbaker since 1972. The error introduced by this method has been small for this lake. It is therefore recommended that Method 3 be continued, for consistency with published results for 1972, 1973 and 1974 and for convenience of computation.
- (5) For other lakes it is recommended that, before proceeding to use Method 2 or Method 3 on a routine basis, testing of results against Method 1 be carried out to assure that the error introduced is acceptable.

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3. Jobson, H.E., 1972. Effect of using averaged data on the computed evaporation. Water Resources Research, Vol. 8, No. 2, April, 1972.
4. Spring, K., and D.G. Schaefer, 1974. Mass transfer evaporation estimates from Babine Lake, British Columbia. Canadian Meteorological Research Report 2/74, Toronto, Ontario.
5. Water Loss Investigations. Volume 1 - Lake Hefner Studies Technical Report. (United States) Geological Survey Circular 229.

Table 1

	<u>1972</u>	<u>1973</u>	<u>1974</u>
"June"	-.36	-.49	+ .07
"July"	-.36	+ .02	+ .06
"August"	+ .10	+ .00	-.03
"September"	-.21	-.07	-.05
"October"	-.15	-.26	+ .12

Correlation coefficients between daily values of wind speed and vapour pressure difference ($e_s - e_a$) at Lake Diefenbaker. For those "months" when correlations are large, use of mean values of more than one day results in an overestimate of the sum of daily evaporation if the coefficients are negative, an underestimate if the coefficients are positive. For correlations near zero there is no error from this cause.

Table of Symbols

$E = Ku (e_s - e_a)$ (Basic formula)

E_{32} is the evaporation in millimetres for 32 days computed by method 1

E'_{32} is computed by method 2

E''_{32} is computed by method 3

K is a constant

u is the average daily wind speed (mph)

e_s is the saturation vapour pressure (mb) at the mean daily surface water temperature

\bar{e}_s is the mean of the daily saturation vapour pressures for 32 days

e''_s is the saturation vapour pressure (mb) for a period of more than one day derived from the mean surface water temperature

\bar{e}''_s is the saturation vapour pressure for a 32 day period, derived from the mean surface water temperature for the whole period

e_a is the atmospheric vapour pressure (mb) derived from the mean daily atmospheric dew point

\bar{e}_a is the mean of the daily atmospheric vapour pressures for 32 days, each daily value derived from the mean dew point for that day

e''_a is the atmospheric vapour pressure (mb) for a period of more than one day derived from the mean atmospheric dew point for the whole period

\bar{e}''_a is the atmospheric vapour pressure for a 32 day period, derived from the mean atmospheric dew point for the 32-day period

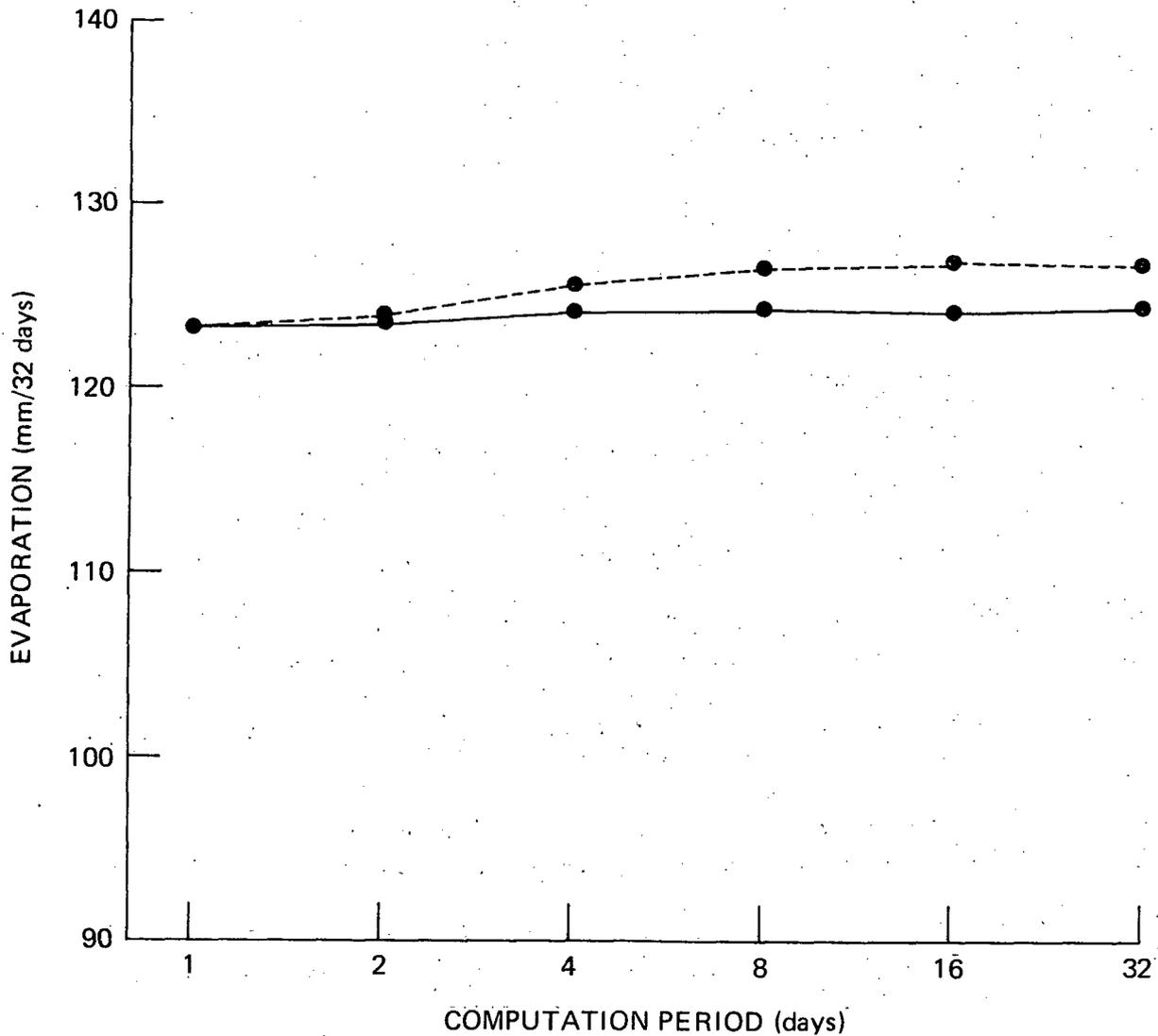


Figure 1

Mean evaporation (June to October, 1972, 1973, 1974) for 1, 2, 4, 8, 16 and 32 day computation periods. Values are shown for the three Methods described under Section 3. All three Methods give the same result for the one-day period. Method 1 gives the same result for any period and is shown only for the one day period. E' values are computed by Method 2 and are joined by a solid line. E'' values are computed by Method 3 and are joined by a dashed line (See Section 4).

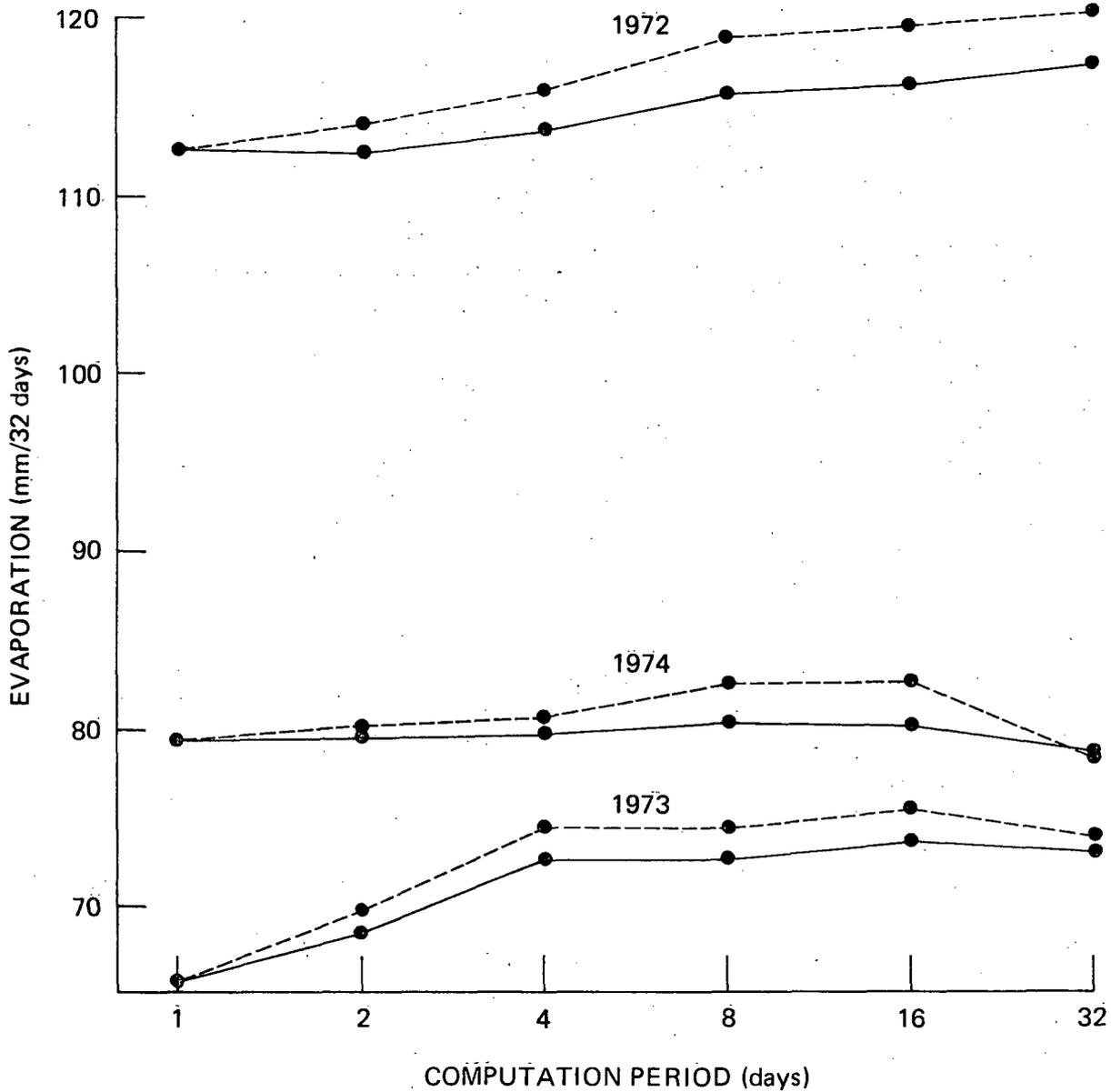


Figure 2

June evaporation for 1, 2, 4, 8, 16 and 32 day computation periods. Values are shown for the three Methods described under Section 3. All three Methods give the same result for the one-day period. Method 1 gives the same result for any period and is shown only for the one day period. E' values are computed by Method 2 and are joined by a solid line. E'' values are computed by Method 3 and are joined by a dashed line (See Section 4).

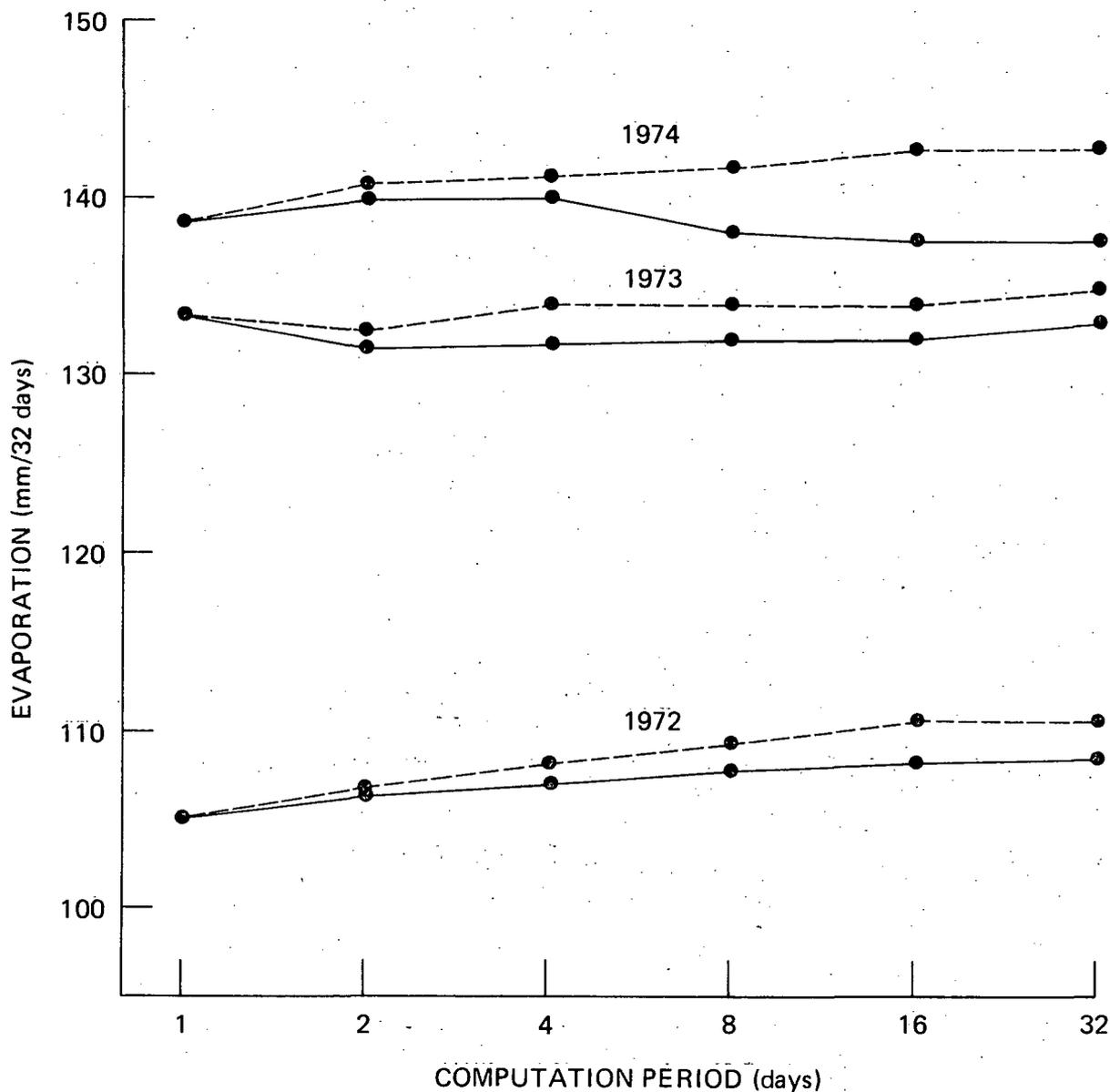


Figure 3

July evaporation for 1, 2, 4, 8, 16, and 32 day computation periods. Values are shown for the three Methods described under Section 3. All three Methods give the same result for the one-day period. Method 1 gives the same result for any period and is shown only for the one day period. E' values are computed by Method 2 and are joined by a solid line. E'' values are computed by Method 3 and are joined by a dashed line (See Section 4).

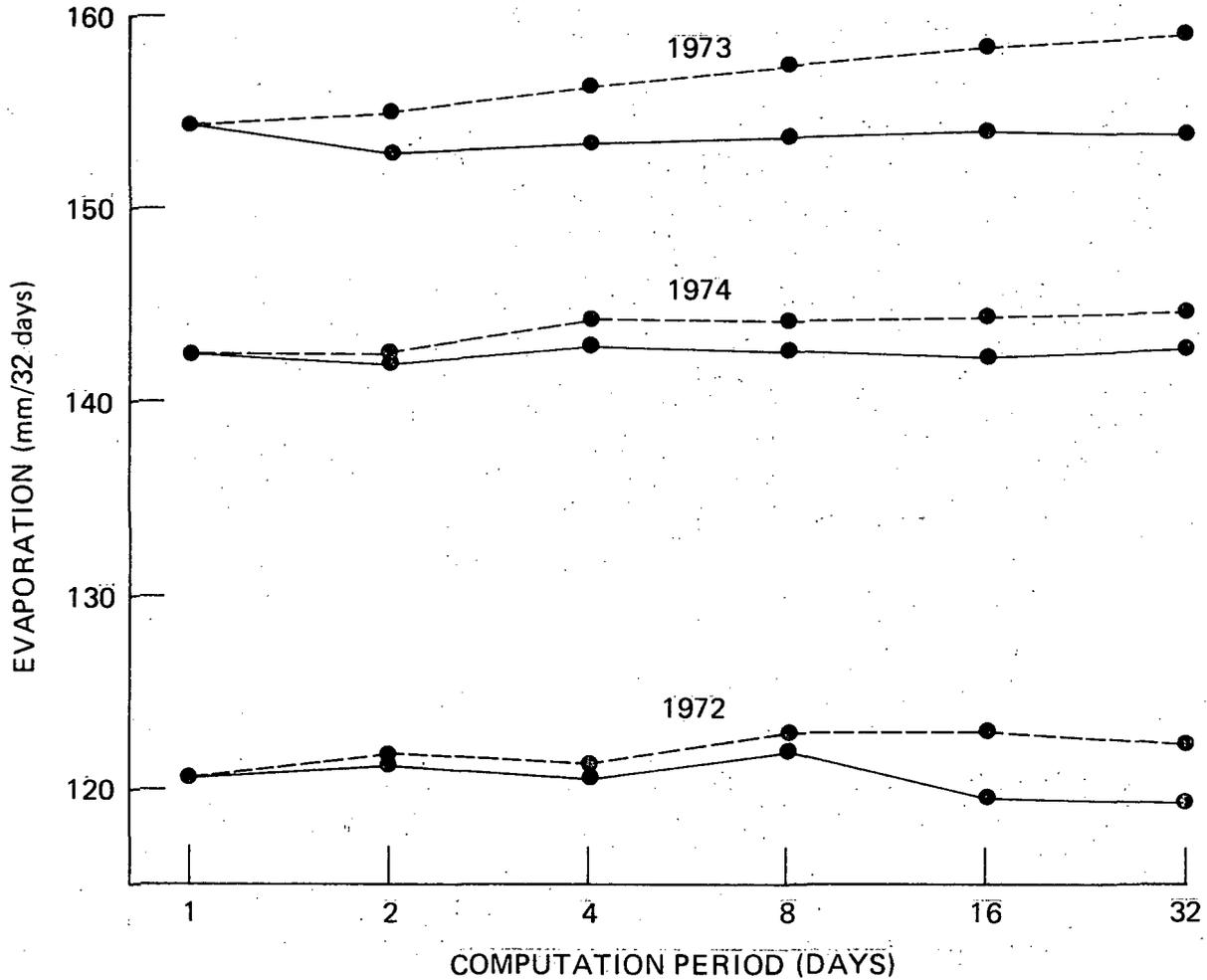


Figure 4

August evaporation for 1, 2, 4, 8, 16 and 32 day computation periods. Values are shown for the three Methods described under Section 3. All three Methods give the same result for the one-day period. Method 1 gives the same result for any period and is shown only for the one day period. E' values are computed by Method 2 and are joined by a solid line. E'' values are computed by Method 3 and are joined by a dashed line (See Section 4).

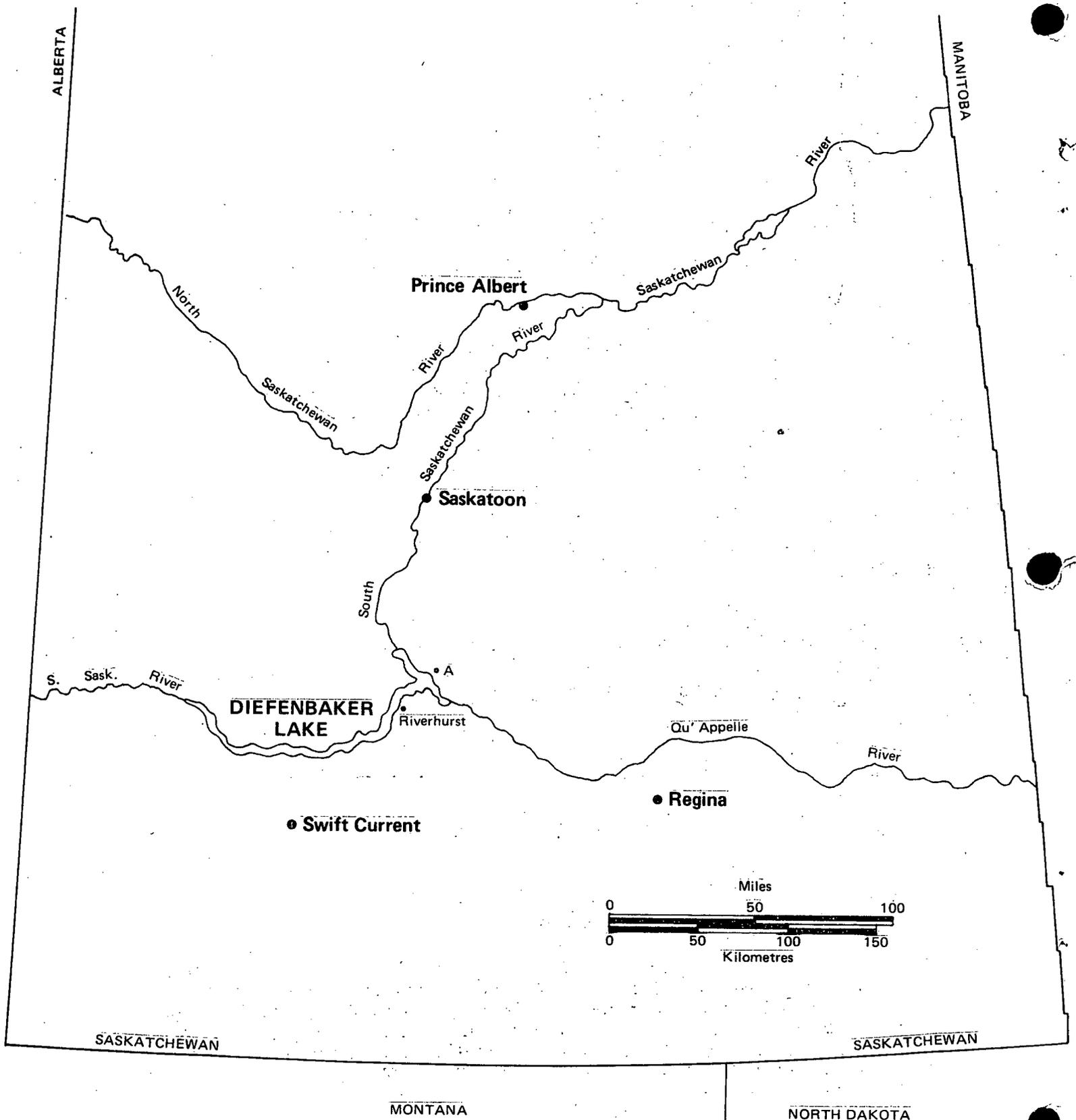


Figure 5

Location of Lake Diefenbaker. Instruments for measuring wind and vapour pressure are at A

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