SNOWMELT OBSERVATIONS IN ALBERTA 1/

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Introduction

In the Alberta plains (or most Prairie areas), runoff from snowmelt is generally responsible for a large portion of the total annual runoff and most of the major spring flood peaks. Therefore, the ability to understand the mechanism of formation of snowmelt flood peaks and the ability to forecast their magnitudes are very important to streamflow forecasters.

Because of the great difficulty and costs involved in observing snowmelt data there have been a lack of observed snowmelt data for Alberta in the past--snowmelt lysimeters are generally quite expensive or difficult to maintain and observations of snowmelt by means of snow samplers are very crude and inaccurate during the period of active melt.

Since 1970 there have been several snowpillows in operation at various locations in Alberta that were used for this study (see Figure 1). More have since been installed and more are planned. Snowpillows provide a good indication of a shallow snowpack water equivalent under prairie conditions, mainly because they provide estimates of the losses from the snowpack during the active melt season (E. Kerr, 1976). Figure 2 shows a portion of the actual trace from a snowpillow chart during May-June 1974, at Marmot Creek, Alberta.

Temperature-Index Approach and Snowmelt Variability

Since temperature is one of the most easily obtainable parameters it is generally used in the calculation of snowmelt for operational streamflow forecasting. However, it is known that the temperature-index approach to streamflow forecasting can lead to significant errors. In snowmelt simulation models which use the temperature-index approach, it has been found that relatively good results can be obtained for some snowmelt events but not for others. Sometimes, in the modeling of snowmelt events, the snowmelt rate is modified until a "fit" is obtained for the particular runoff event. This approach is good for design purposes or in the analyses of historical events, however, in streamflow forecasting it is not very useful where a hydrologist must predict the snowmelt hydrograph in advance.

Figure 3 is a plot of observed snowmelt against mean daily temperature. It can be seen that for a given temperature the snowmelt may vary over a wide range of values. Selected data, presented in Table 1, shows the variability of the observed snowmelt, mean daily temperature and radiation. It can be seen that neither radiation nor temperature data by itself can be used to accurately predict the amount of snowmelt.

TABLE 1

SELECTED RADIATION, TEMPERATURE AND SNOWMELT DATA OBSERVED AT MARMOT CREEK, ELEVATION 5870 feet (1973-1977)

Date	Incoming Solar Radiation (Langleys)	Mean Daily Temperature (^{o}F)	Observed Snowmelt (inches)
May 14, 1973	768	50.5	1.18
May 15, 1973	758	52.0	1.43
May 16, 1973	544	50.5	1.18
June 1, 1974	727	42.0	1.30
June 2, 1974	755	50.5	1.18
May 14, 1975	670	45.5	0.98
May 15, 1975	397	45.5	0.50
May 16, 1975	557	41.0	0.71
May 7, 1976	704	46.0	1.22
April 25, 1977	655	52.0	1.07

1/ Presented at the 48th Annual Western Snow Conference, April 15-17,1980, Laramie, WY

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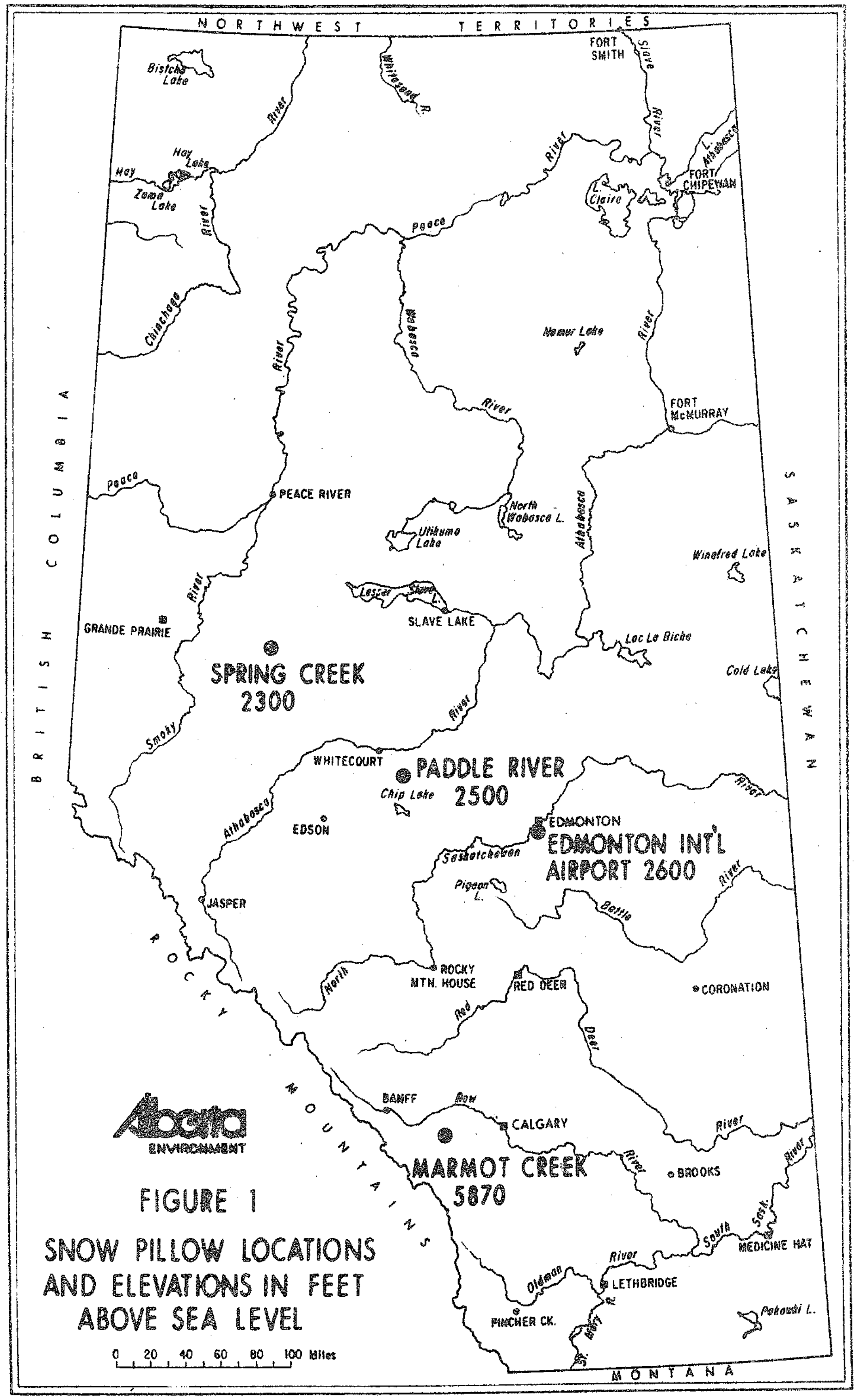


FIGURE 1

SNOW PILLOW LOCATIONS AND ELEVATIONS IN FEET ABOVE SEA LEVEL

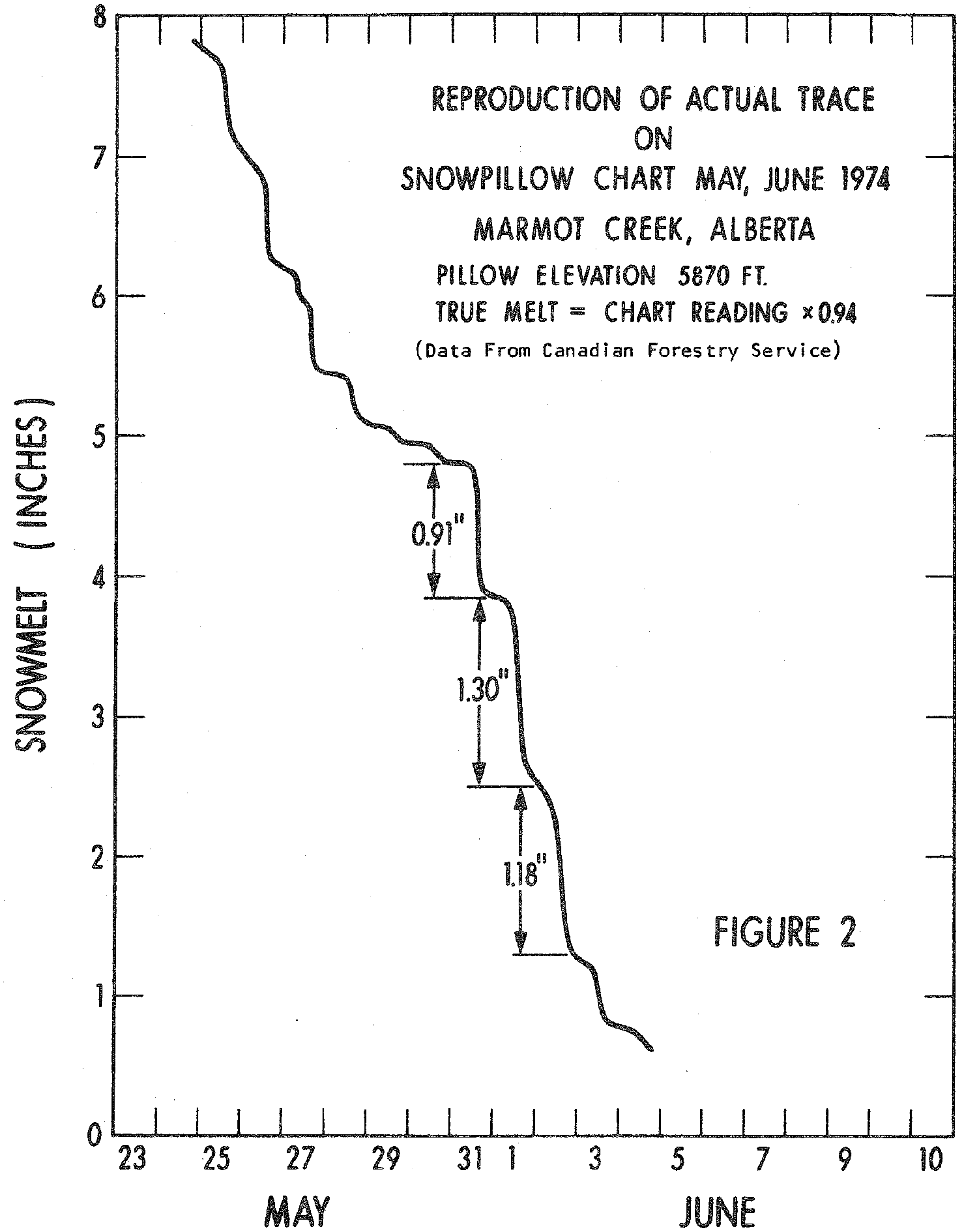
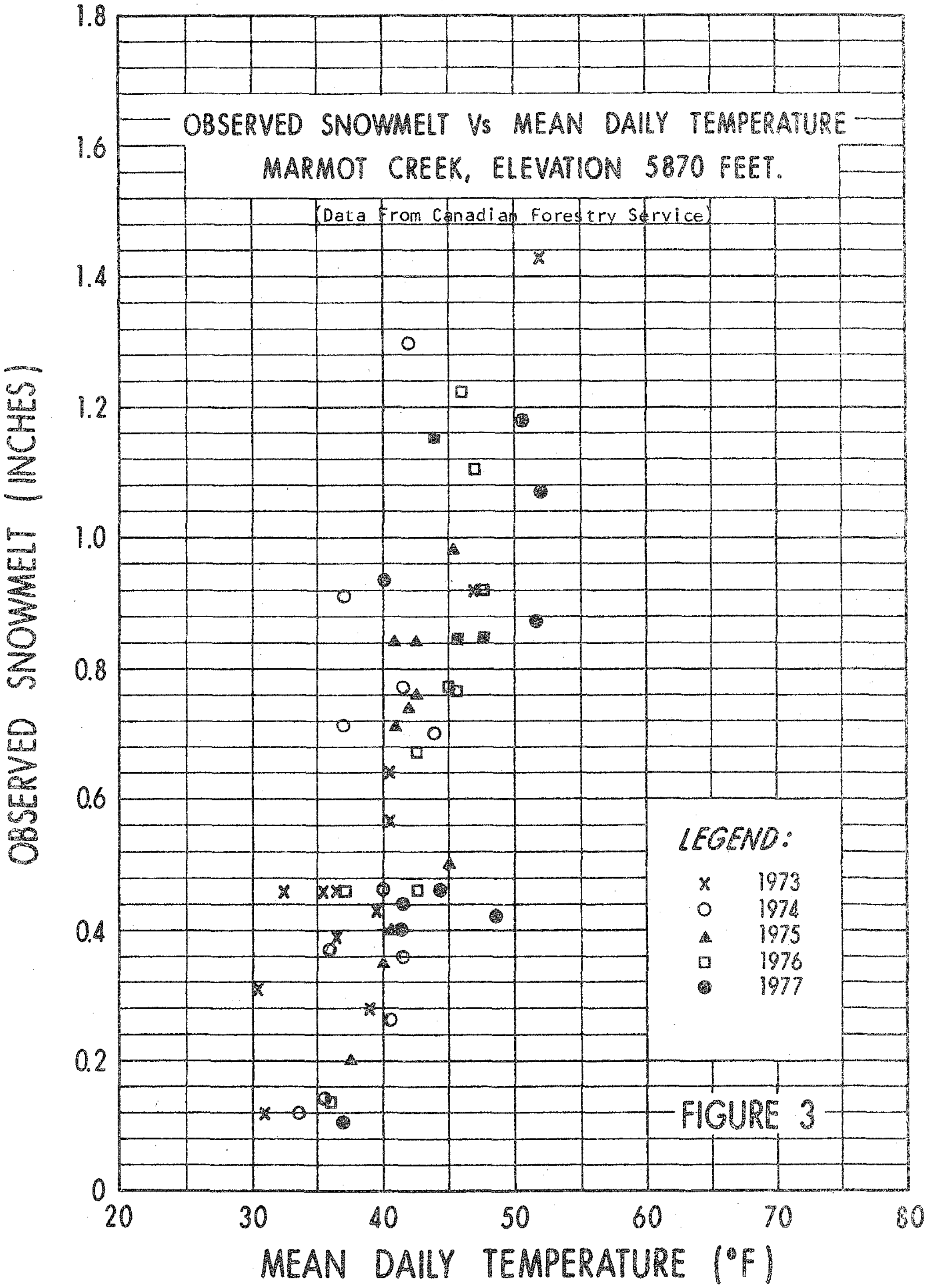

REPRODUCTION OF ACTUAL TRACE
ON
SNOWPILLOW CHART MAY, JUNE 1974
MARMOT CREEK, ALBERTA
PILLOW ELEVATION 5870 FT.
TRUE MELT = CHART READING ×0.94
(Data From Canadian Forestry Service)
0.91"
1.30"
1.18"
SNOWMELT (INCHES)
0
1
2
3
4
5
6
7
8
23
25
27
29
31
1
3
5
7
9
10
MAY
JUNE

FIGURE 2


OBSERVED SNOWMELT Vs MEAN DAILY TEMPERATURE
MARMOT CREEK, ELEVATION 5870 FEET.
(Data From Canadian Forestry Service)
OBSERVED SNOWMELT (INCHES)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
20
30
40
50
60
70
80
MEAN DAILY TEMPERATURE (°F)
LEGEND:
1973
1974
1975
1976
1977
FIGURE 3

It is the selection of an appropriate snowmelt rate along with the related meteorologic data forecasts which then becomes important to streamflow forecasters.

The Alberta Experience

Figure 4 illustrates the cumulative snowmelt curves, for 5 years, at one of the Marmot Creek Basin sites (elevation 5870 feet). It can be seen that the snowmelt rates can vary considerably in any given year, or that high snowmelt rates can occur earlier in some years than in other years. Similar types of data are presented for Paddle River Basin (elevation 2500 feet, Figure 5). Figure 6 illustrates how the snowmelt can, in a given year, vary from one location to the next in the Alberta plains.

Theoretical Equation Requirements

Some of the factors influencing snowmelt rates are: depth of the snowpack, cloud cover, albedo and radiation. The theoretical snowmelt equation of the U.S. Army Corps of Engineers considers the following melt components: shortwave radiation, longwave radiation, convection-condensation and rain.

The generalized snowmelt equation developed by the U.S. Army Corps of Engineers (1960) for partly forested areas is as follows:

$$M = k' \ (1-F) \ (0.004K\downarrow) \ (1-a) + 0.029 \ FT'_a + 0.0084kV(0.22T'_a + 0.78'_d) + 0.007RT'_a$$

The factors are defined as:

- M is the total melt in inches per day
- k' is a shortwave radiation melt factor dependent on average slope and aspect of the site in comparison with an unshielded horizontal surface
- F is the average forest canopy cover effective in shading the site from solar radiation, expressed as a decimal fraction
- $K\downarrow$ is the internationally accepted symbol for incoming shortwave radiation on a horizontal surface in langleys (calories/cm^2)
- a is the average snow surface albedo
- T'_a is the difference in degrees Fahrenheit between the air temperature measured at 10 ft and the snow surface temperature
- k is the convection-condensation melt factor which depends on the exposure to the wind
- V is the mean wind speed at 50 ft above the snow (mph)
- T'_d is the difference in degrees Fahrenheit between the dewpoint at 10 ft and the snow surface temperature
- R is the rainfall in inches

A study was done to compare the measured snowmelt quantities from snowpillow data with the snowmelt quantities from the theoretical equation (D. Storr, 1978). This study found that the observed snowmelt from snowpillow data compared extremely well with the theoretical computations for a partly forested site. Some of the results are illustrated in Figure 7. For the investigated location it was found that longwave radiation accounted for approximately 20 percent of the calculated snowmelt and shortwave radiation accounted for about 78 percent of the snowmelt. Furthermore, melt from rainfall was insignificant.

Conclusion

On the basis of the data obtained in Alberta and the studies conducted to-date, it can

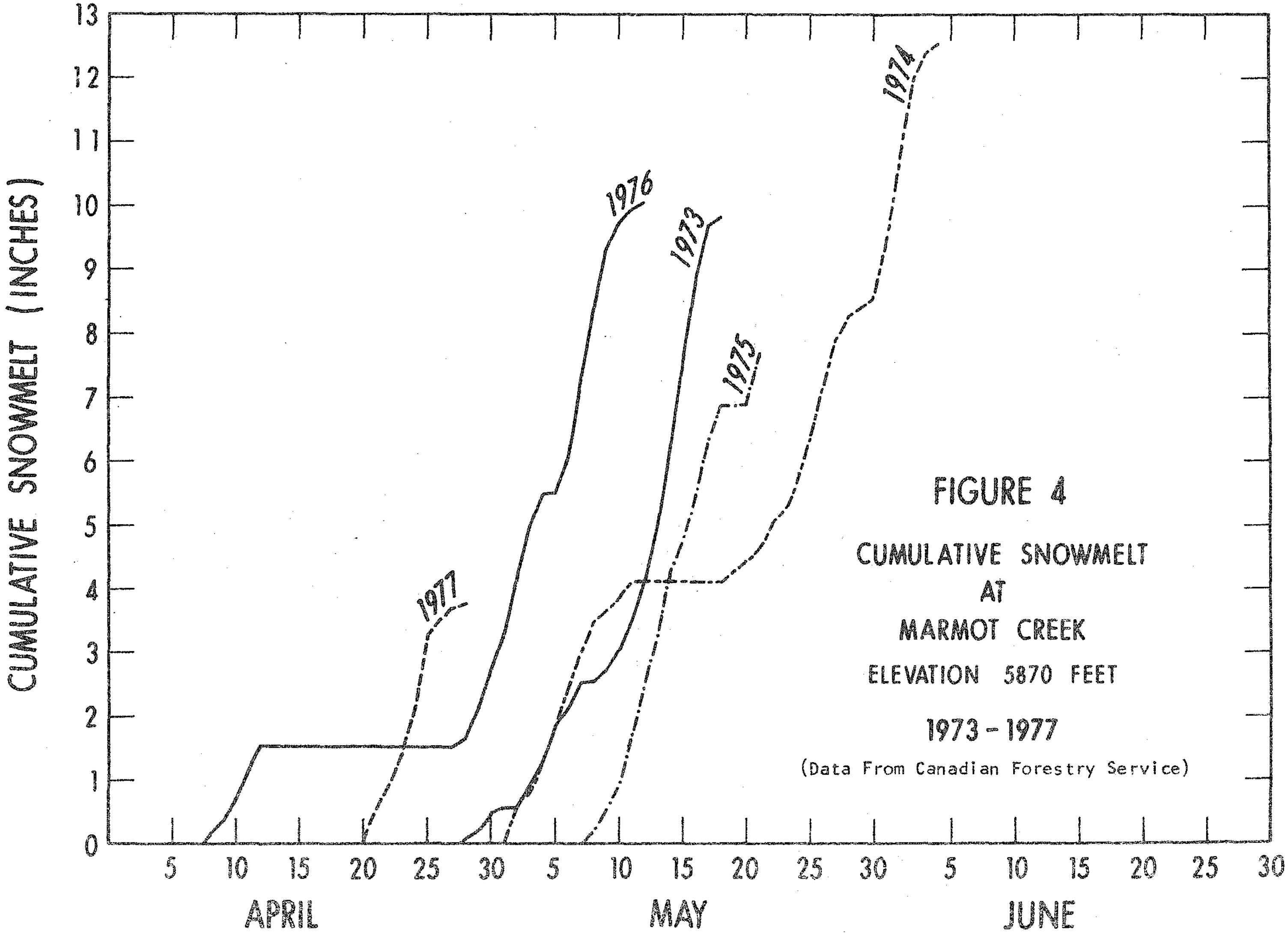


FIGURE 4

CUMULATIVE SNOWMELT
AT
MARMOT CREEK
ELEVATION 5870 FEET

1973 - 1977

(Data From Canadian Forestry Service)

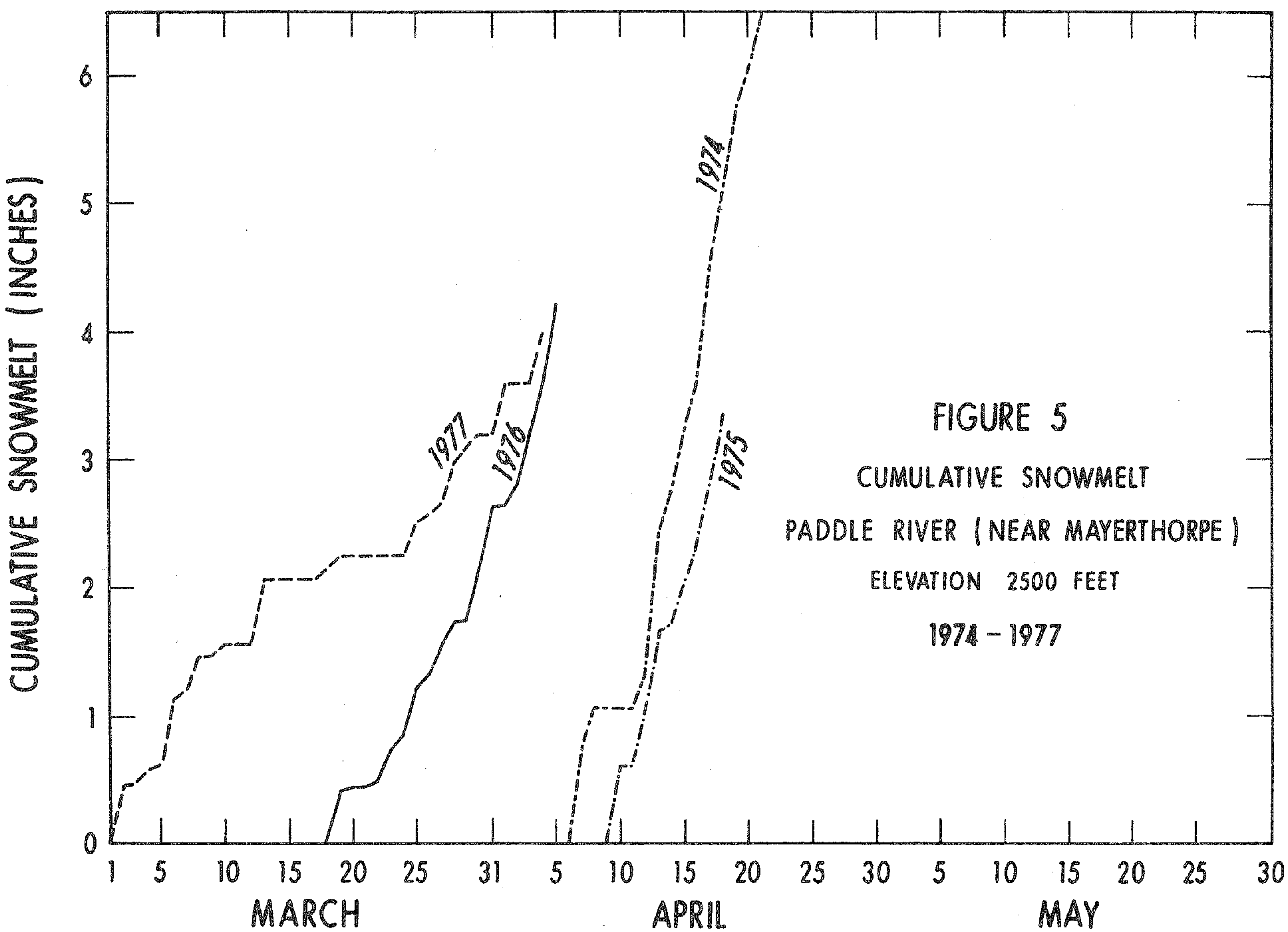
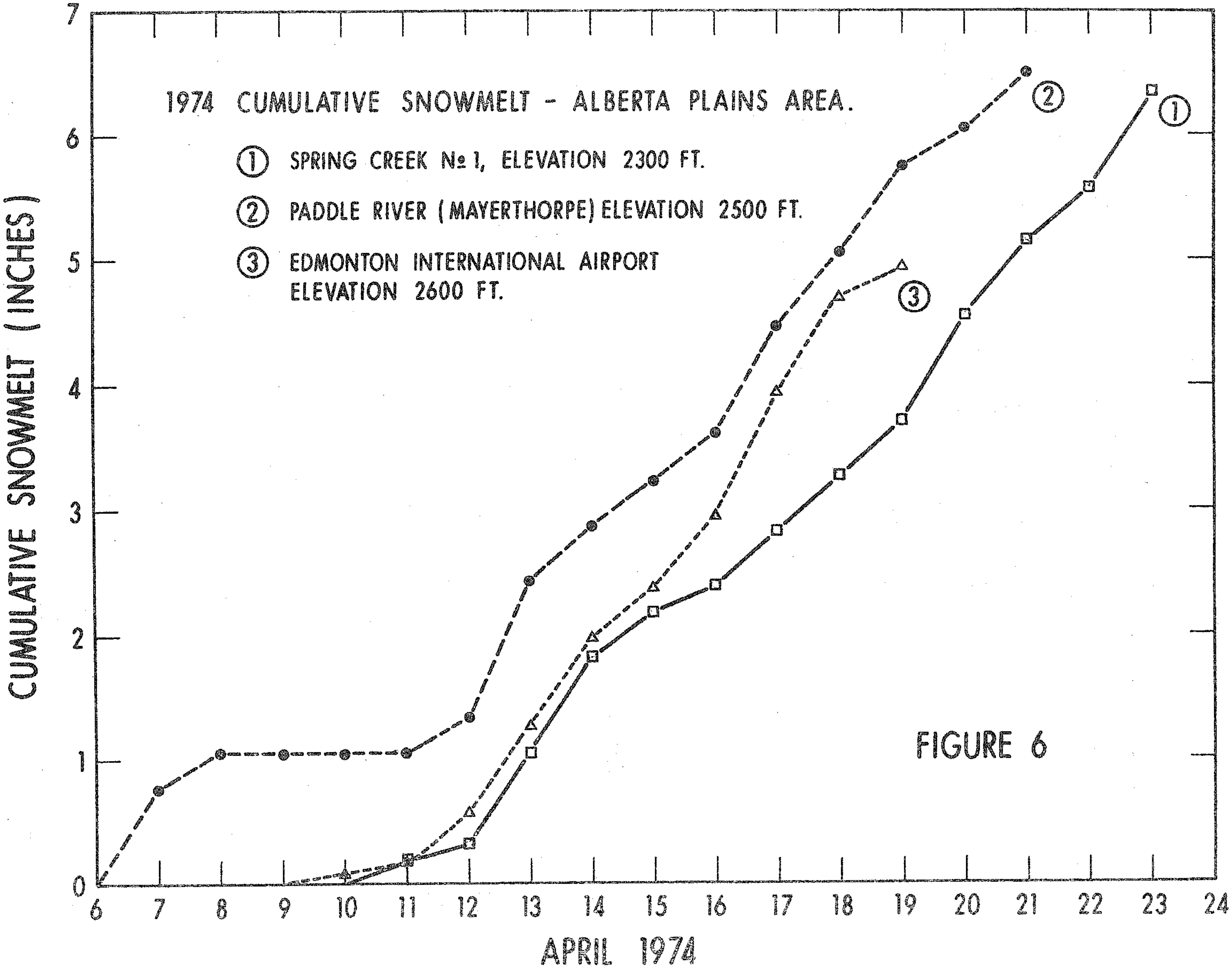
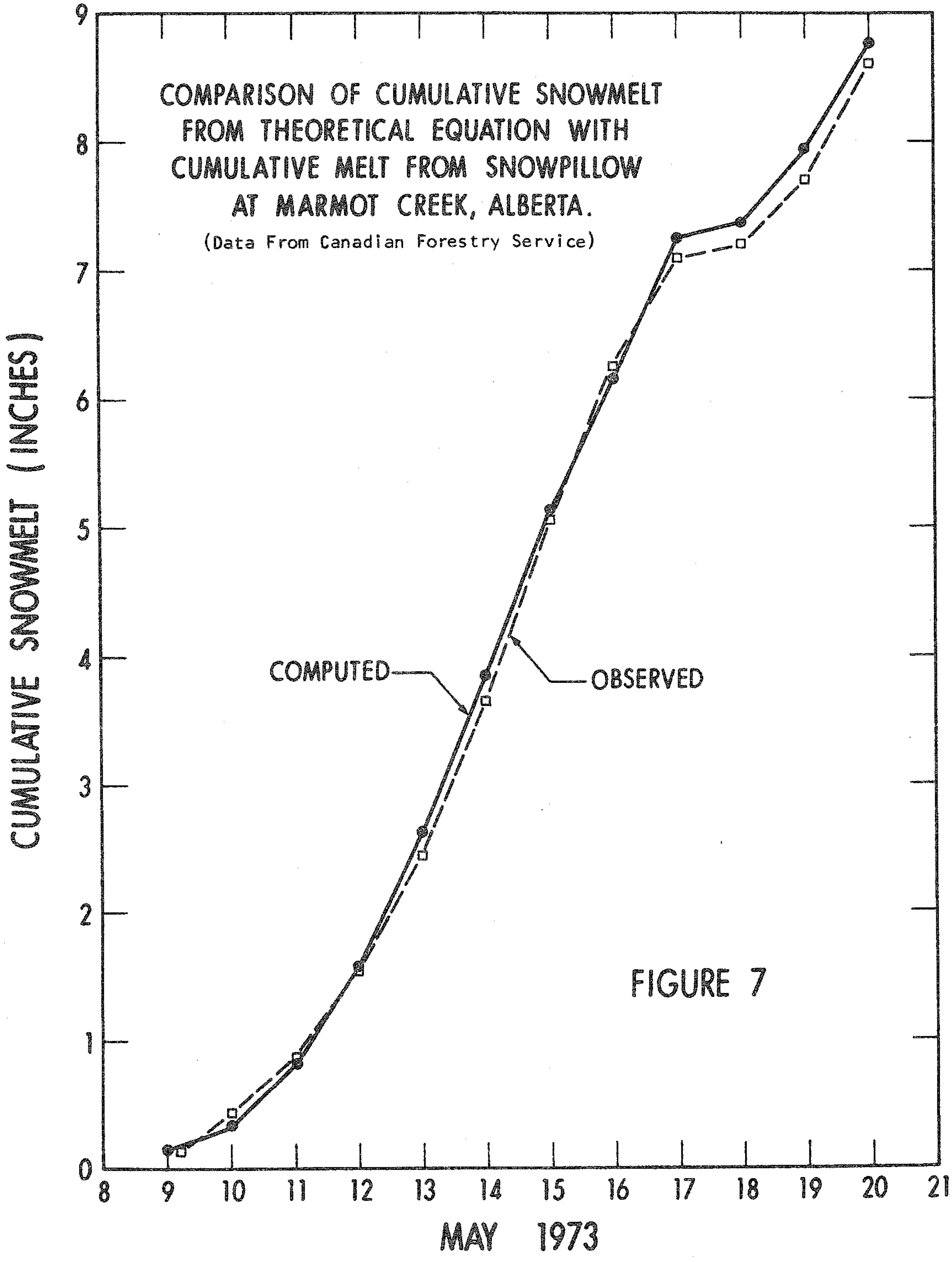


FIGURE 5
CUMULATIVE SNOWMELT
PADDLE RIVER (NEAR MAYERTHORPE)
ELEVATION 2500 FEET
1974 - 1977


1974 CUMULATIVE SNOWMELT - ALBERTA PLAINS AREA.
① SPRING CREEK № 1, ELEVATION 2300 FT.
② PADDLE RIVER (MAYERTHORPE) ELEVATION 2500 FT.
③ EDMONTON INTERNATIONAL AIRPORT ELEVATION 2600 FT.
FIGURE 6
CUMULATIVE SNOWMELT (INCHES)
APRIL 1974
0
1
2
3
4
5
6
7
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
①
②
③


COMPARISON OF CUMULATIVE SNOWMELT
FROM THEORETICAL EQUATION WITH
CUMULATIVE MELT FROM SNOWPILLOW
AT MARMOT CREEK, ALBERTA.
(Data From Canadian Forestry Service)
CUMULATIVE SNOWMELT (INCHES)
COMPUTED
OBSERVED
FIGURE 7
MAY 1973
0
1
2
3
4
5
6
7
8
9
8
9
10
11
12
13
14
15
16
17
18
19
20
21

be concluded that snowpillows are providing useful snowmelt data from the plains in Alberta. However, more analyses have to be done in order to determine generalized meteorologic relationships and forecasts which can be used in operational streamflow forecasting.

Since radiation is not observed at many locations it may be necessary for meteorologists to provide radiation forecasts for cloudy days at given locations. A good estimate can be made of the incoming solar radiation for cloudless days but the hydrologist must also know what is the incoming solar radiation on cloudy days. If solar radiation could be forecasted, with any confidence for sufficiently large areas, then accurate forecasting could be done using the U.S. Army Corps of Engineers snowmelt equation.

The Future

(1) Under prairie conditions good appreciation of day-by-day albedo changes is a necessity so that hydrologists have a good estimate of how much shortwave radiation is being absorbed by the snowpack.

(2) In the Prairies there may be significant energy losses during the night when the temperature drops below freezing. This loss could exceed the gain during the day, thus the energy of the snowpack is lowered. This negative effect, therefore, must be accounted for before the following day's melt can be estimated accurately.

(3) The conversion of point observations to estimates over large areas must be clearly understood in order to estimate the true basin melt for modeling purposes. Since the prairie areas do not have a 'well-defined' snowline like the mountain areas, it is important to know what portions of a basin are snowcovered on a daily basis. Remote sensing techniques offer some promise for operational use here.

(4) The possible use of Figure 5 of the U.S. Army Corps of Engineers Snowmelt Manual (1960) should also be investigated. This is a Nomogram for estimating daily insolation from latitude, date and duration of sunshine.

REFERENCES

Kerr, W.E., 1976: Snowpillow Experiences in a Prairie (Alberta) Environment, Proc. Western Snow Conference. 44:39-47. Calgary, Alberta.

Storr, D., 1978: A Comparison of Snowmelt Rates as Calculated by the U.S. Corps of Engineers Theoretical Model With Measured Rates on a Snowpillow. Prepared for Alberta Environment. 30 p.

U.S. Army Corps of Engineers, 1960: Runoff from Snowmelt Manual EM 1110-2-1406.