

ICE JAMS AND AN ANALYSIS OF THE WINTER CLIMATE AT
TWO SITES NEAR THE WHITE RIVER IN SOUTH DAKOTA

by

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Abstract

Weather records for stations in South Dakota for the winter months from 1921-1984 were examined to detect any long-term trends, and to determine possible relationships between climate and ice-jam occurrence on the White River. Analysis of the observed average monthly winter air temperatures at Kennebec, South Dakota, revealed warmer Decembers and Januarys occurring between 1930 and 1950. Five of the seven ice-jam winters that were studied in detail occurred after 1950, and during this period significantly lower temperatures were recorded in January. However, no consistent pattern between below-normal seasonal freezing temperatures, or above-normal precipitation amounts, and ice-jams was noted.

I. Introduction

A review of hydrological records and a dendrochronologic examination of damaged trees by other investigators revealed specific occurrences of ice jams on the White River in South Dakota. Due to the variability and number of physical and environmental variables involved, the exact causes of these river ice jams are not fully understood. Meteorological conditions, however, certainly would contribute to the formation, jamming, and break-up of the ice cover. Questions arose as to whether there has been any detectable changes in the climate in the area of interest over the past 30 to 60 years, and whether monthly climatic records could be associated with river ice jam occurrences.

The objectives of this paper, then, were to:

- a) Obtain long-term winter air temperature data for two climatic stations, one near the eastern end of the White River and another near the western end, to determine the possible existence of regional short or long-term temperature trends.
- b) Examine the monthly temperature and precipitation weather records at these two stations from November through April and evaluate any significant patterns occurring during major ice jam winters.
- c) Compare similar winter temperature regimes during ice-jam and non-ice-jam events in order to establish any possible associations between the phenomena.

II. Selected Stations and Data Sources

The choice of climatic stations to use in the study was based on a few factors. It was necessary that the climatic record be both lengthy and continuous and that the stations be as close as possible to the White River in South Dakota. Weather records for Kennebec, SD, near the eastern end of the river system, and Oelrichs, SD, near the western end (Fig. 1), showed that average monthly values of the daily maximum and minimum air temperatures (hereafter referred to as T_x and T_m , respectively) were available from January 1921 to April 1984 for Kennebec, and from about January 1949 to April 1984 for Oelrichs.

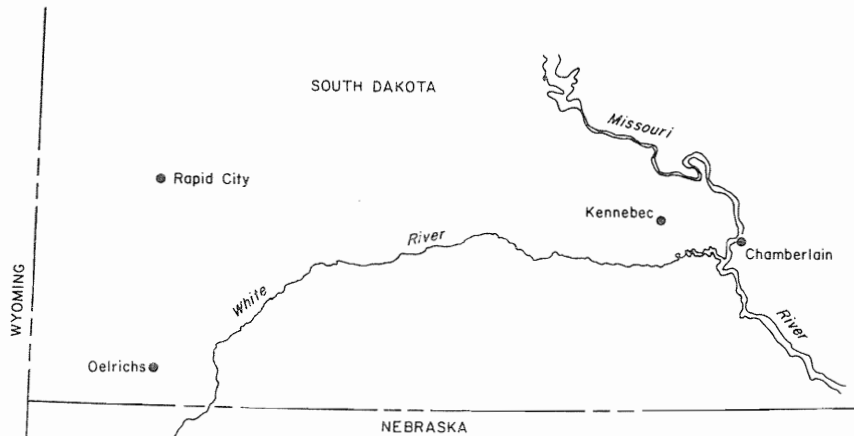


Figure 1. Location map.

These values for November through April for the years of record were obtained and extracted from publications by the U.S. Department of Commerce (1956, 1965, 1973, 1976, 1982, 1982a,b, 1920-1984).

The observers at Kennebec and Oelrichs throughout the years of record were participants in the U.S. National Weather Service cooperative station network. The measurements obtained from this source are quite reliable because the data are continuously reviewed for quality control. Brief missing records did not interfere with the analyses of the study.

III. Graphing the Climatic Data

A historical review of river ice jams requires an investigation of possible regional long-term trends in the winter air temperatures. Since a lengthy record was available for Kennebec, a visual display of the Tx-Tm values was prepared for December through March for the period from 1920 to 1984 (Fig. 2a-d). Maximum and minimum values were used instead of daily average air temperatures because they provide a better indication of the day-night range in the winter temperatures.

To determine whether the monthly Tx and Tm values were above or below normal, dashed lines indicating long-term mean values were included in Figures 2a-d (Table 1): the earliest refers to 1908-1930, the next to 1931-1952, and the third to 1951-1980. No long-term values were available for the period after 1980, so an extension of the values obtained for 1951-1980 was used for these recent years. Except for the warmer period during December and January between 1931 and 1948, followed by a cooling trend during these months (especially January) between 1950 and 1982, no persistent long-term trends in winter air temperatures for this region are visible. A more detailed analysis of the record, however, for example, using stochastic models may reveal temperature trends.

The diagrams are useful because they show when (and to what extent) the winter air temperatures at Kennebec were above or below normal. The following are some other interesting points derived from Figures 2a-d:

- a) Except for those years when the Tx-Tm values are near normal, the departures for both values are almost always in the same direction (i.e. both above or below the normal);
- b) Large temperature departures from the normal seem to occur most frequently during January (Fig. 2b), but extremely cold periods can occur during any month or year. For example, note the very cold December during 1927 and 1983; January during 1937, 1950, 1978 and 1979; February during 1936, 1978 and 1979; and March during 1960 and 1965; and

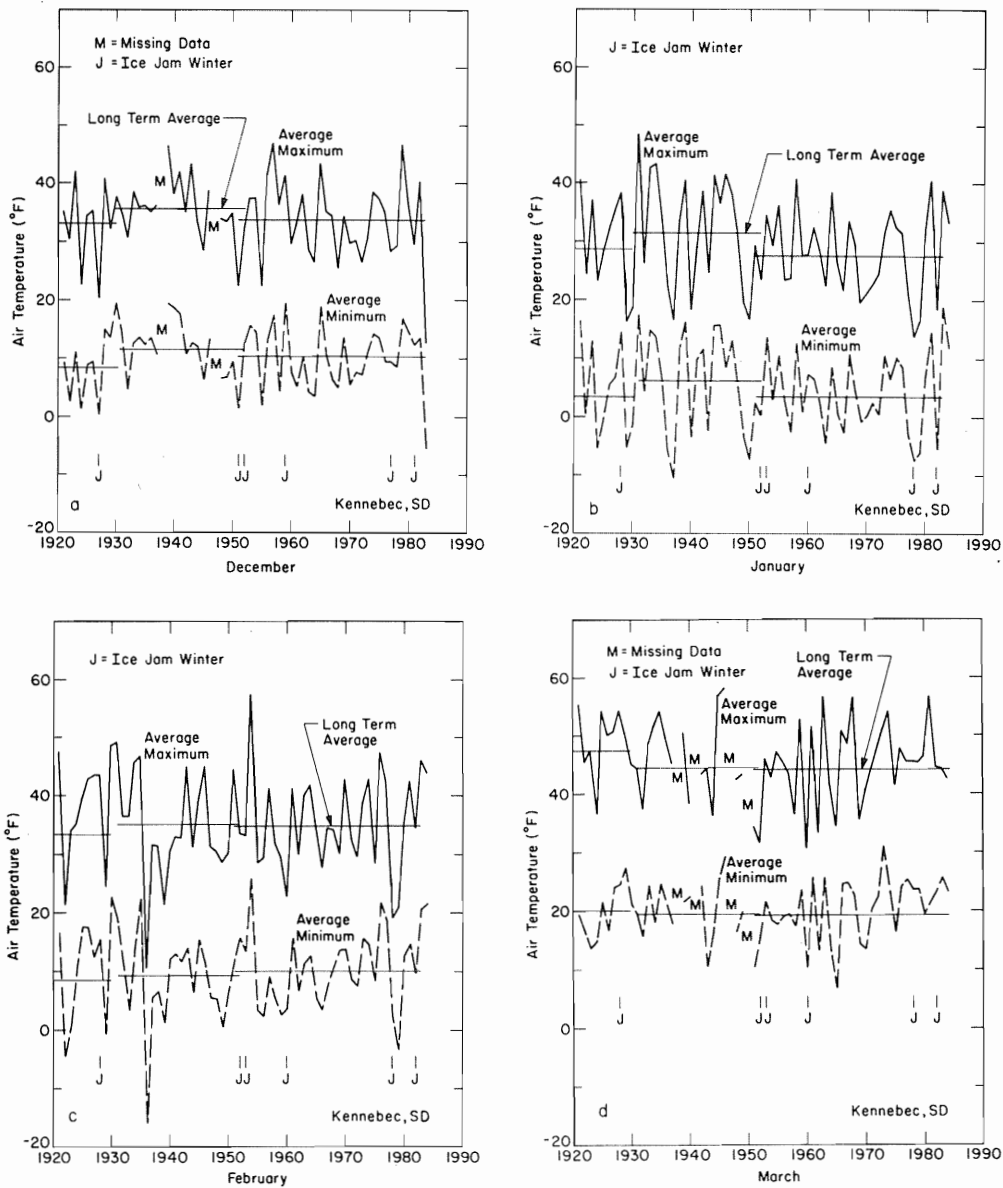


Figure 2. Monthly averages of the daily maximum and minimum air temperatures at Kennebec, SD.

- c) The plot of the air temperatures by year and month made it possible to select specific winters for use in an investigation of the weather that occurred during ice-jam and non-ice-jam events.

Since the White River extends from its confluence with the Missouri River near Chamberlain, SD, to near the northwest corner of Nebraska, a distance of over 240 miles (Fig. 1), it becomes necessary to determine how representative the weather records for one station (i.e. Kennebec) would be for the entire region under study. A plot, therefore, of the Tx-Tm values was also done for Oelrichs, SD (Fig. 3a-d). These temperatures for December through March from 1951 through 1984 were sufficient to obtain the following comparisons between the two stations:

- a) Although missing data were more prevalent for the Oelrichs record, a gradual cooling trend is noted during December and January between 1950 and 1982. This observation agrees with what was found for Kennebec.

Table 1. Long-term monthly averages of the daily maximum and minimum air temperature (°F) for Kennebec and Oelrichs, S.D.*

Period of Record	Max. and Min. Temp.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.
<u>Kennebec, S.D.</u>							
1907-1930	Max.	28.7	33.4	47.6	61.8	47.6	33.1
	Min.	3.5	8.6	20.1	32.9	20.9	8.7
1931-1952	Max.	31.4	35.1	44.7	62.1	48.1	35.8
	Min.	6.1	9.1	19.7	33.4	21.7	11.7
1951-1980	Max.	27.7	34.9	44.3	61.5	47.1	33.9
	Min.	3.5	10.0	19.5	33.1	21.3	10.2
<u>Oelrichs, S.D.</u>							
1951-1980	Max.	34.1	40.8	48.2	60.6	48.3	38.4
	Min.	9.5	14.7	20.8	31.7	21.9	14.3

* These long-term averages were taken from the following references: U.S. Department of Commerce (1956) and U.S. Department of Commerce (1982a).

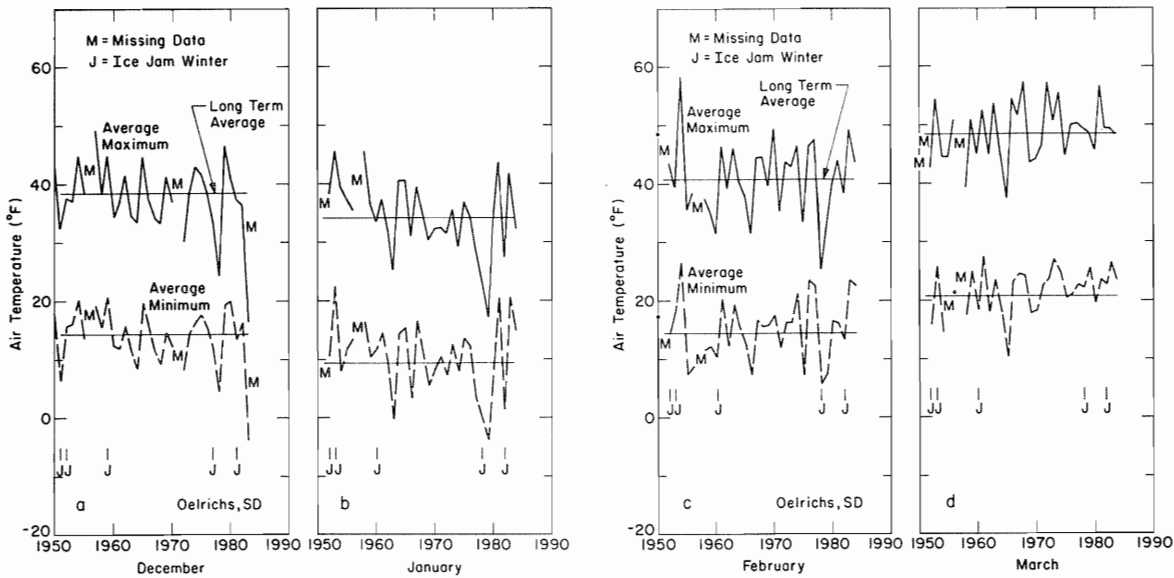


Figure 3. Monthly averages of the daily maximum and minimum air temperatures at Oelrichs, SD.

- b) Agreement during those winter months between 1951 and 1984 with extreme cold conditions were also found at the two sites. For example, similarities in below-normal temperatures at both stations occurred during December of 1951 and 1983; January of 1963, 1978 and 1979; and February of 1978 and 1979. and
- c) A comparison of the departures of the average monthly winter temperatures from the normal at the two sites provided the following results: of the 125 possible comparisons included in the survey, 81 showed very good agreement in the departures of $T_x - T_m$ values, 22 showed fair agreement, 13 indicated slightly colder conditions at Oelrichs, and 9 slightly warmer conditions at Oelrichs.

Table 2. Approximate time periods of Ice Jam Events on the White River, S.D.

1982	15 February - 31 March
1978	5 March - 31 March
1960	15 March - 31 March
1953	11 March - 13 March
1952	25 March - 31 March
1928	Time Period Uncertain

The preceding review provided two main points that are pertinent to this investigation. One, the long-term winter temperature records at Kennebec and Oelrichs are sufficiently similar so that the data at either location could be assumed to be representative for the region under study. The second point is that except for the slightly warmer values at Oelrichs in February 1952 and March 1960, the Tx-Tm values recorded at these stations during the ice jams in 1952, 1953, 1960, 1978 and 1982 were in good or fair agreement. Consequently, only the Kennebec temperature data are used in the subsequent analysis.

IV. Air Temperature Regimes During Ice Jam Events

A list of the approximate time periods when significant ice jams occurred on the White River in South Dakota since 1928 is given in Table 2. The events were principally determined from hydrographic records (U.S. Geological Survey, 1928-1982), and in some cases supported by tree scar dating (Mogren, 1984).

Although approximate starting and ending dates for the ice jam events are given in Table 2, details on the exact location, duration, or method of development of these jams on the river were not available for this study. However, since this investigation is a broad review of the phenomenon, precise information is not required.

Graphs of the winter temperature regimes at Kennebec from November through April during the six ice jam years listed in Table 2 are shown in Figures 4a-f. The observed and long-term monthly precipitation amounts (in inches of water equivalent) for the six ice jam winters are also given in this figure.

Figures 4a-f show that five of the six seasons with ice jams had below-average air temperatures during significant portions of each winter. For example, during January 1982, January and February 1978 and February and March 1960, it was much colder than normal. During the winters of 1951-1952 and 1927-1928, the significant colder periods occurred earlier in the season (i.e. November and December). Since no specific information on the time when the ice jam occurred during 1927-1928 was available it is possible that the event may have taken place during January or February 1928, i.e. soon after the extremely cold period in December 1927.

The only ice jam winter that recorded above- or near-normal Tx-Tm values from November through April was during 1952-1953 (Fig. 4d). However, the average daily minimum air temperatures throughout the season remained below freezing. The average daily maximum values during December and February for this winter also were near 32°F, so conditions were sufficiently cold to cause ice to form on the White River.

Unfortunately, attempts to discern repetitive patterns (or associations) between the temperature records and ice jams proved indecisive. A possible exception is for the winters from 1950 to 1982, when five of the six reported ice jams (Table 2) occurred concurrently with the cooling trend during December and January at Kennebec and Oelrichs

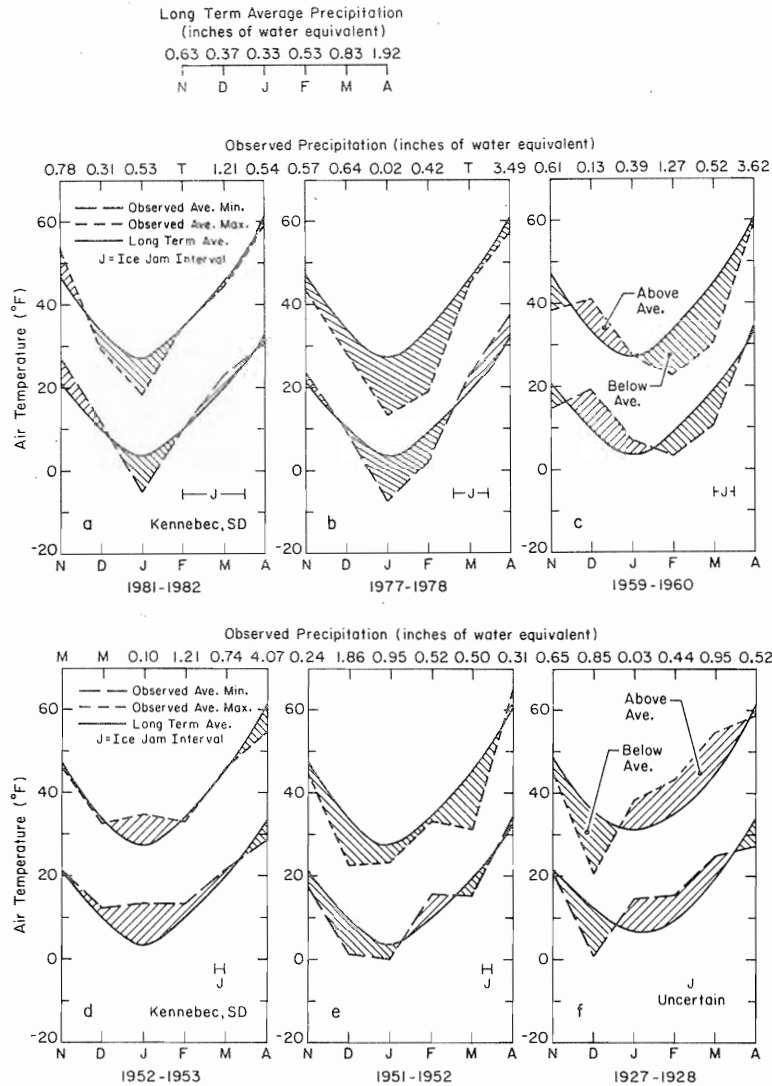


Figure 4. Monthly averages of the daily maximum and minimum air temperatures and the departures from normal for November through April at Kennebec, ND, for six years when there were ice jams.

(Fig. 2a, 2b, 3a and 3b). Freezing conditions undoubtedly play an important part in the problem, but other meteorological factors, such as rapid thaws and/or excessive rainfalls, also need to be considered.

A review of the total monthly precipitation amounts (Fig. 4a-f) was therefore conducted. Although greater than normal amounts of precipitation occasionally occurred during those months prior to or when ice jams were recorded, e.g. in March 1982 (Fig. 4a) and February 1960 (Fig. 4c), no association between the two events was evident. Of course, the problem might be that the monthly precipitation amounts would mask any brief but heavy rainfalls that could cause ice jams and flooding. This confirms the need for subsequent work in which specific ice jams are investigated in conjunction with a very detailed evaluation of the meteorological conditions during the event.

V. Comparison of Similar Winter Temperature Regimes During Ice-Jam and Non-Ice-Jam Events

During this study two questions were asked:

- a) Were there examples of two winters with similar Tx-Tm values when an ice jam occurred during one of the winters but not the other, and
- b) Were there examples of two winters with similar temperature regimes when an ice jam occurred prior to the construction of a dam on the Missouri River in 1951 but not after?

The first question is answered by comparing the winter temperature regimes for the 1977-1978, season when an ice jam was observed on the White River, and the 1978-1979 season, when no ice jams were recorded on the river. The records for Kennebec and Oelrichs showed that the temperature regimes during these two winters were similar throughout the White River region. The 1977-1978 temperature graph for Kennebec (Fig. 4b), therefore, was compared with Figure 5b, which shows the temperature regime during the following winter; temperatures were similar.

These results indicate that monthly values of temperature alone will not determine the occurrence of ice jams, and suggest that a combination of the temperature influences as well as weather and hydrological factors such as rainfall, thawing temperatures and river discharge need to be considered. Examination of the monthly precipitation amounts during the ice-jam winter (1977-1978) compared to the non-ice-jam winter (1978-1979) also proved inconclusive. It is assumed that because the ice jam reached its critical stage in March 1978 that above normal precipitation during February and March would be a crucial input to the event. However, precipitation totals were near normal (0.42 in.) for February 1978 and much below normal (trace) for March 1978 at Kennebec (Fig. 4b). Since heavy rainfalls are generally expected to cause or accompany major ice jam events (Bates and Brown, 1981), it is essential to review additional causes that may explain the March 1978 ice jam.

To answer the question regarding the occurrence of ice jams prior to and after the construction of a dam on the Missouri River, the temperature regimes during two winters were investigated: the winter of 1927-1928 (Fig. 4f), when an ice jam occurred prior to the construction of the dam, and the winter of 1983-1984 (Fig. 5a), when no ice jam occurred.

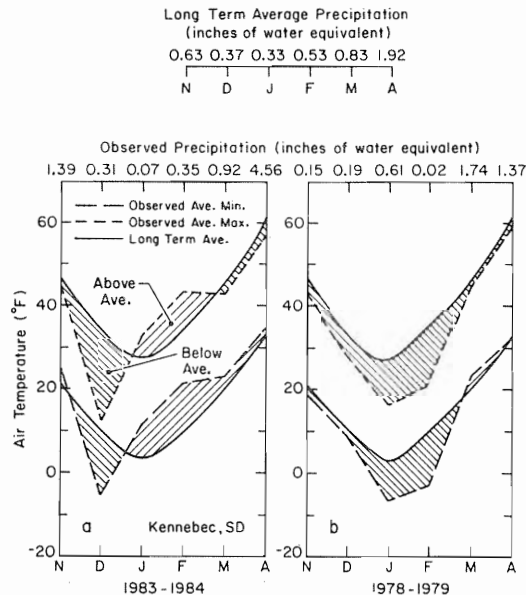


Figure 5. Monthly averages of the daily maximum and minimum air temperatures and the departures from normal for November through April at Kennebec, SD, for two years without ice jams.

The winter temperature regime at Kennebec during 1983-1984 (Fig. 5a) was very similar to that recorded during 1927-1928 (Fig. 4f). In addition, the water equivalent precipitation amounts during January and February, when the jam may have occurred, were also quite similar: 0.03 and 0.44 in. in 1928 (Fig. 4f) and 0.07 and 0.35 in. in 1984 (Fig. 5a). Since the general weather conditions were about the same during both winters, the reason that an ice jam formed during 1927-1928 but not in 1983-1984 (except for the fact that it may be related to the construction of the dam) remains unknown.

VI. Summary and Required Future Studies

An investigation of the average monthly values of the daily maximum and minimum winter air temperatures versus the long-term normal temperature values was conducted for two locations near the eastern and western portions of the White River in South Dakota. The data were analyzed to determine any possible relationships between the temperature regimes and ice jam occurrences on the river.

Although no realistic correlations were obtained from the monthly climatic values, some useful and conclusive statements could be derived from the study. Except for an apparent cooling trend during December and January between 1950 and 1982, a plot of the mid-winter air temperatures from 1920 to 1984 showed no specific trend in the monthly averages at Kennebec, SD. A similar plot for Oelrichs, SD, for the period from 1950 to 1984 provided temperature values similar to those for Kennebec, and also revealed the cooling trend for December and January during the period of record. Five of the six recorded ice jams occurred between 1952 and 1982.

The monthly temperature data for those winters when ice jams were observed were then examined in more detail. During five of the six ice jam winters investigated, the region recorded significant periods during the season with below average air temperatures. Although the sixth ice jam winter (which occurred in 1952-1953) did not record notable colder than normal temperatures, the average daily minimum values remained below freezing from November through April. There was no consistent pattern, however, because there were numerous other winters with extremely cold periods but with no ice jams.

A review of total precipitation amounts recorded during the ice jam winters was also conducted. Although greater than normal amounts were occasionally observed during those months when ice jams occurred, the two events did not coincide frequently enough to establish a firm association between them.

Comparisons between similar winter temperature regimes during ice-jam and non-ice-jam events were also made. The results from consecutive winters (1977-1978 and 1978-1979) revealed that the average monthly maximum and minimum temperature values for both years were very similar, but an ice jam occurred on the White River during the first winter but not the second. The issue becomes even more clouded because the total precipitation was less than 0.09 in. along the White River during the ice jam in March 1978 but ranged from 0.49 at Oelrichs to 1.74 in. at Kennebec during March 1979, when no ice jams were recorded.

Since it was not possible to obtain positive associations between average monthly values of climatic data and occurrences of ice jams on the White River, further studies in which a more detailed (i.e. daily weather observations) evaluation of the meteorological conditions prior to and during ice jam periods, as well as concurrent hydrologic information, are required.

Finally, average monthly weather data for an ice jam winter prior to the construction of a dam on the Missouri River were compared with similar data recorded during a non-ice-jam winter after the dam was built. The investigation revealed very similar average monthly temperature and precipitation conditions during these winters. The results strongly suggest that future studies should include closer examination of the local environmental and physical conditions, and more precise information on characteristics of the ice jam events in order to determine possible cause and effects.

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