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Indicators of Climate Warming in Water Resources Data from Minnesota

by

Stephanie L. Johnson and Heinz G. Stefan

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Stephanie L. Johnson and Heinz G. Stefan

St. Anthony Falls Laboratory
Department of Civil Engineering
University of Minnesota
Minneapolis, Minnesota 55414

Abstract

Records of water resources parameters, which are directly dependent on air temperature can serve as indicators of climate warming over both the long and short-term. Ice-out and ice-in dates on lakes, spring runoff timing and discharge in streams, and stream water temperatures recorded in the State of Minnesota up to 2002 were selected for study. The analysis was conducted by linear regression on all or parts of the record and by extreme event sorting.

With the exception of spring stream flow rates all parameters examined show trends, and sometimes quite variable trends, over their period of record. Most trends point towards a warming climate over the last decades. Although hidden among strong variability from year to year, ice-out dates on 73 lakes have been shifting to an earlier date at a rate of –0.13 days/year over the last 38 years of record (1965-2002), while ice-in dates have been delayed by 0.75 days/year over a 24-year period (1979-2002). Trends since 1990 show an acceleration in the rate of change to –0.25 days/year for ice-out and 1.44 days/year for ice-in. Trend analyses also show that spring runoff occurs earlier. First spring runoff (due to snowmelt) averages -0.30 days/year earlier and first spring peak runoff averages –0.23 days/year earlier over a 39-year period (1964-2002). Stream

water temperature records from 26 years (1977-2002) show warming by 0.11°C/year on the average.

The correlation of these trends with climate warming is shown by the correlation with air temperatures, which was also obtained from recent records. Ice-out dates correlated most strongly with average March air temperatures shifting by –2.41 days for a 1°C increase in that temperature. Ice-in dates also show a correlation with air temperatures; they shift at a rate of 2.37 days for a 1°C increase in average November air temperature. Spring runoff dates move –2.8 days for a 1°C minimum daily March air temperature rise; annual average water temperatures at 7 metropolitan stream sites show an average rise of 0.67°C river temperature per 1°C mean annual air temperature rise.

In conclusion, records of five water resources parameters that are closely linked to air temperature show a trend that suggests climate warming in Minnesota in the last 25 to 40 years, and especially since 1990. Analysis of spring runoff rates was inconclusive, probably because it is linked as much to precipitation as to air temperature.

1. Introduction

> "An increasing body of observations gives a collective picture of a warming world and other changes in the climate system ... Globally it is very likely that the 1990s was the warmest decade, and 1998 the warmest year, in the instrumental record (1861–2000)" (IPCC, 2001)

A change in the earth's climate has many consequences for the natural systems that depend on climate, especially air temperatures, in their functions. For example, vegetation, wildlife, and water resources adapt to warmer climate. Numerous models and

studies have been developed and used to project how, where, and when these adaptations will take place, both on a global and regional scale.

Signs that global climate change is, in fact, having an influence on the natural systems surround us. The purpose of this paper is to analyze recent water resources records from Minnesota for signs of climate warming. Records of annual air temperatures since the mid-1800s for the Twin Cities metropolitan area are shown in Figure 1 along with long-term trend lines. The data, plotted as annual data in the first panel, illustrate the strong variability from year to year, which is typical of Minnesota's continental climate; they also show a very weak warming trend of 0.004°C/year. To eliminate the interannual variability, the data are averaged over 10-, 30-, and 50-year periods (each period is plotted at the terminating year of the period). All these panels show that the trend is not uniform over the 110-year period. Depending on the interpretation, there are anywhere from 3 to 7 periods with strongly different, often opposing, trends. All these panels agree, however, that the last portion of the record has a strong, if not the strongest, warming trend. Progressive urbanization as well as global climate change may be a cause. Ten-year running average data (third panel) support that three distinct periods of temperature fluctuation may have occurred since the early 20th century (warming from 1915 to 1935, cooling to 1970, and warming to present). Air temperature increases in Minnesota are not evenly distributed throughout the course of the year (Seeley, 2003). Historical records show that recent air temperatures are increasing more rapidly during the winter months than other times of the year. Of the top twenty warmest January to March periods observed since 1895, eleven occurred within the last twenty years. Also, minimum daily winter temperatures show a greater increase

than maximum daily temperatures (For example, data from Southeast Minnesota show that minimum temperatures observed in February have risen by more than 3°C when comparing 30-year normals from 1891-2000).

As air temperatures change, precipitation patterns are also expected to vary. Most models of the Midwestern United States project an overall increase in annual precipitation over the twenty-first century. These projections are supported by Minnesota data showing a recent increase in precipitation and snowfall across the state (Minnesota State Climatology Working Group, 2003). Figure 2 shows an increase in precipitation for the Twin Cities area. Similar to the air temperature data, there are periods of distinct, opposing trends. On a global or continental scale more extreme rainfall events are expected to alter the magnitude and timing of runoff, ultimately affecting the intensity and frequency of floods and droughts. (DeStasio et al., 1996; Schindler et al., 1996; Mulholland and Sale, 1998; GCRP, 2001; IPCC, 2001)

2. Scope

In this study, and as a complement to climate scenario and response modeling results, we will focus on consequences of global climate change on a regional scale, focusing on the state of Minnesota. Due to the importance of water to the state, our scope is to examine both long-term and recent trends in a few water resource parameters that would be expected to respond to a change in climate, specifically an increase in air temperature. The timing of ice break up in lakes, for example, is dependent on many factors, including snow and cloud cover, and anthropogenic factors (e.g. warm water discharges into the lake), but the main factor has been shown to be air temperature

(Robertson, 1989; Fang and Stefan, 1998). Therefore, trends that we find in ice-out dates can most likely be attributed to a warming climate. Similarly, ice-in dates, spring runoff timing and discharge in streams, and surface water temperatures are dominated by climate, especially air temperature. These are the parameters, therefore, that will be analyzed in this study.

3. Data Sources

Observation and measurement records, of the chosen parameters, were obtained from the following sources:

(1) Lake ice-in and -out dates were provided by Dr. Edward Swain at the Minnesota Pollution Control Agency (MPCA) for 43 lakes from the Citizen Lake Ice Monitoring Program (CLMP). The CLMP is a cooperative program between the MPCA and citizens who volunteer to monitor and collect water quality data on their lakes. (MPCA, 2004) These records range from 11 to 61 years in length and are current through the year 2002. The CLMP lakes are scattered throughout the state of Minnesota.

(2) Ice-out dates were obtained from Greg Spoden at the Minnesota State Climatology Office (Climatology) for 36 lakes statewide. Similar to the MPCA, the State Climatology office relies on citizen volunteers to record and report ice events on their lakes. The history of some of these records go back much further than the MPCA data, with five lakes having records longer than 100 years (the longest is 148 years; the shortest record is 13 years). Many of these records, however, are current only through the late 1990s.

(3) Historic stream flow records (at 21 gaging stations) were obtained from the U.S. Geological Survey (USGS) National Water Information System (NWIS) website (http://waterdata.usgs.gov/nwis). Several employees at the Minnesota USGS office, including James Fallon, Thomas Winterstein, and Greg Mitton, provided technical assistance and guidance.

(4) River temperatures for 43 recording sites on 6 Minnesota rivers were obtained from Terrie O'Dea at the Metropolitan Council Environmental Services Division (MCES). Each of these sites is located within the Twin Cities metropolitan area.

(5) Temperature and precipitation data was retrieved from the Minnesota State Climatology Office website (http://www.climate.umn.edu).

4. Data Screening and Analysis Methods

4.1 Screening

Lake ice event records were screened for length and data quality. In order to show trends up to recent time, only records with data through at least the year 2000 were used. In total, 79 ice records were available. Two lakes had records duplicated between the MPCA and MN State Climatology Office; in both cases the MPCA records were more complete and, therefore, were used. Four lake records were disregarded because of large gaps in data. After these deletions, 73 lake records remained for analysis. Figure 3 shows the location of these lakes; Table 1 provides a summary of lake characteristics.

Two screening criterion were used for spring runoff data. To reflect the natural flow of rivers, any stream gages that were affected by lakes, reservoirs, or manmade regulation were omitted (Flow regulations include dams, diversions, e.g. for irrigation,

and wastewater discharges). This site selection ensures that natural hydrologic conditions are represented in the record. The second criterion for gage selection was data quality. The USGS assigns a quality rating to each of the data sets (daily, monthly and yearly averages, etc.) that it reports at each gage (this quality rating is based on numerous considerations, which can be found in any of the Water Resources Data reports released by the agency). Because it was difficult to find daily discharge values that were rated "good" or "fair", the selection was based on the average discharge rating. Sites that reported "good" data for average discharges were included in this study; daily measurements at these sites ranged from "poor-fair" to "fair".

In order to get a picture of recent shifts in spring runoff events, data records were retrieved back to January 1, 1960. Only 9 sites were found that met the quality criteria and had complete records for the period of 1960 to present. In order to expand the number of sites analyzed, additional gages with shorter or incomplete records were included. In all, 21 sites were included in the analysis, 9 with 43 years of complete data and 12 with slightly limited records. Figure 3 gives the location of these stream gaging stations and Table 2 shows average station characteristics.

The river temperature data included records ranging in length from less than one month to 27 years. Only sites that had at least 20 years of data were included in the study. Average monthly values were computed from the average daily temperatures. Monthly values were than combined to calculate annual averages; averages were calculated only for years that had 12 monthly values. For many records monthly readings were only available for ice-free months; these records were not included in the final analysis. Ultimately 15 sites were used in this study; 7 had 27 years of complete record.

To correlate air temperature with study parameters, historic records were retrieved from the Minnesota State Climatologist website. Records were collected from the weather stations nearest each of the lakes and river gaging stations; the Twin Cities metropolitan area temperature data (Figure 1) were used for comparison with all of the MCES river temperature data. Climatological weather data are reported as daily maximum and minimum air temperature and average daily precipitation. Maximum and minimum air temperatures were combined to obtain a daily average; monthly, yearly and multi-year running averages were also computed for each of these sites. Precipitation records were manipulated in a similar method.

4.2 Analysis Methods

4.2.1 Parameter Definition

There is no steadfast definition of ice-in or ice-out for a lake. Is "ice-out" when the lake is completely free of ice or when one can no longer see the ice from the viewpoint of a family room window? In order to reduce errors due to bias, the MPCA and State Climatology data collection programs rely on the same citizen reporters from year to year for each lake. If comparing intra-lake trends the use of consistent reporters should eliminate bias due to definition of ice events. When comparing ice events between lakes, however, this bias may be a factor (with differences of several days). In some years there will be multiple ice-in or ice-out dates; the lake surface may thaw and then refreeze. If two ice-out dates were reported, the later date was retained; conversely, the earlier of multiple ice-in dates was analyzed.

The first spring runoff date, first spring peak runoff date, and maximum spring peak runoff date were retrieved for each year. The first spring runoff event was defined as the date when the river discharge first showed a noticeable deviation from winter base flow (generally an order of one magnitude increase in flow), typically followed by a return to winter flow rates. The first spring peak runoff was defined as the first peaking event occurring after March 1 and before May 31. This parameter was subject to analyzer interpretation. When the exact date was questionable, the peak dates and flows of previous years were taken into consideration when choosing the peak that would represent the current first spring peak. This practice could influence the resulting spring peak trends, tending to smoothen out major deviations. The maximum spring peak runoff date was defined as the day on which the maximum spring discharge, at a given station, occurred. Examples of these date selections are shown in Figure 4. Spring months were defined to include February, March, April, and May. (The most current data available from the USGS, for daily discharges, was complete through September 30, 2002. Therefore, yearly average analyses were only performed through the year 2001.)

4.2.2 Statistics and Trends

Average values were computed for each parameter and each site, as well as an overall average value for all lakes or stations analyzed. The natural variations from year to year are expressed by the standard deviation around the mean. Trend analyses were performed on the data using linear regression against time. As an indication of predictability, the root mean square error (RMSE) was calculated; RMSE measures the difference between the predicted and reported value for each parameter. The coefficient

of variation, r^2, relates RMSE to standard deviation. Each of these statistical measures (average, RMSE, standard deviation, and r^2) is reported.

Ice events, runoff dates, and surface water temperatures are highly variable from year to year due to natural fluctuations in weather patterns. Trends are easily hidden in large natural variations, making statistically significant trends difficult to see. In order to smoothen out the natural fluctuations, multi-year running averages were calculated for records longer than 15 years. As was shown in Figure 1, running averages also give a new perspective on trends.

Linear regression analysis was performed on annual data for each parameter. Slopes and r^2 values were calculated for the complete record in each of these cases. To view trends occurring in more recent time periods, ice records were split into shorter time spans and linear regression was performed on each of the sub-records. The shorter time spans chosen were 1970 to present, 1980 to present, and 1990 to present. More recent time periods should show trends during greater temperature increase across the state.

4.2.3 Event Sorting Analysis

Event sorting analysis was used to examine the distribution of extreme events over the course of each parameter's record. Only lakes/stations with complete records could be used in this analysis. Sixteen lakes had such records for 30-years of ice-out events; 6 lakes had ice-in events for this length of time and 9 river gaging stations had sufficient runoff data. Years were ranked (ordered) from the year of the earliest event to the latest. The years of the earliest 3, 6, 10, and 15 events were than plotted against time in order to view any groupings. Ice-in events were processed according to latest events.

Six lakes had complete ice-out records for at least 60 years. The analysis was, therefore, repeated for these lakes using a 60-year time span and plotting the years corresponding to the earliest 3, 6, 12, 20, and 30 ice-out events. The analysis was also performed for 2 lakes with 80-years of record and 1 lake with 110-years of record.

A numerical event sorting analysis was done by breaking the 30-year (60-year, 80-year, 110-year) time period of record into spans of 5, 10, 15, 20, 30, and 40 years. It was then calculated how many of the given events should occur in each time span on the average, if the time series were random and stationary. For example, one of the earliest 6 ice-out events in a 30-year record would occur every 5 years if the distribution were uniform. This process was repeated for each time span and each grouping of event occurrences. (The expected number of ice events for each time frame was rounded to the nearest whole number). The calculated number was then compared to the number of extreme events that was actually observed in the last 5, 10, 15, 20, 30, and 40-year time span; the number and percent of lakes with observed events in excess of the expected number was calculated.

4.2.4 Correlations with Air Temperatures

In order to make a direct connection between study parameters and air temperatures, ten-year running averages of the longest records for each water parameter were plotted against ten-year running averages of regional air temperature (retrieved from the nearest weather station). Six lake ice-in and ice-out records, 9 stream flow gaging stations, and 7 water temperature monitoring stations were thus analyzed. Records were normalized to one another by calculating the variation from the average for each event.

For example, the average ice-out date for the 1960-2002 10-year running averages was found for each record. The variation from this average (in days) was than calculated for each year. Yearly variations at each lake were averaged to give an overall variation from average ice-out date; this value was plotted. Air temperature data was processed in the same manner.

Plotting average annual ice event, runoff event, and stream temperature data versus average annual air temperature provided a linearized cause-effect estimate of the influence that air temperature has on each parameter. This allowed us to develop a per degree estimate of how parameters will respond to average annual air temperature fluctuations. In order to determine the effect of average and minimum monthly air temperature on each parameter, the data for these relationships were also analyzed.

5. Results

5.1 Ice-Out Events

The average ice-out date, for the 73 Minnesota lakes investigated was April 17 (standard deviation of 7.05 days). There is a large difference in ice-out date from north to south ranging from April 1 for West Jefferson Lake (44.3° latitude) to May 1 for Rainy Lake (48.6° latitude). Intra-lake standard deviations of ice-out dates averaged 8.75 days, indicative of a large natural variability of ice-out events from year to year (Figure 5). Individual lake values ranged from 6.37 days for Lake Kabekona to 13.29 days for Richardson Lake. Average ice-out dates for more recent time periods are fairly consistent with the long-term average (Table 3). RMSE values for complete ice-out record analysis had an average of 8.47 days, with individual lakes values ranging from

6.23 days for Johnson Lake to 11.73 for Lake Virginia. Average RMSE values are also consistent for the recent periods. (Table 3)

Whole record linear regression analysis was performed on all 73 available lake ice-out records. The average slope for these 73 lakes was -0.132 days/year (standard deviation of 0.189 days). Sixty-one of these slopes (84 %) were negative (indicating earlier ice-out dates in recent times).

Thirty, of the original seventy-three, lakes had long enough records to perform an analysis from 1970 to the present. All 30 lake records showed a trend toward earlier ice-out dates after 1970. The average slope of these records was -0.237 days/year (standard deviation of 0.095 days), nearly twice that calculated for the complete record analysis. The analysis from 1980 forward included 39 ice-out records and resulted in an average slope of -0.002 days/year (standard deviation of 0.174 days). Only 17 of these 39 lake records showed a negative slope for ice-out dates. Of the 22 records that showed a positive slope, however, 14 regained a negative slope when analyzed from 1990 forward. The original 73 lakes were again analyzed for the period from 1990 to present showing an average slope similar to that of 1970 to present at -0.250 days/year (standard deviation of 0.318 days). Fifty-eight of the 73 lakes (80 %) had negative slopes during this time period. Linear regression results for ice-out dates are summarized in Table 3.

The data plots in Figure 5 do not provide a visual impression of any trends, and the calculated regression line, that is also shown, would not be easily guessed from the data plot. The shift to an earlier ice-out date from about 1980 on is, however, readily apparent in Figure 6, where the same data have been plotted as 10-year running averages. Since each data point represents the preceding 10-years, the trend seems to have actually

started in the 1970s. The consistency among lakes is no coincidence, and becomes even more convincing in a plot of data from 12 lakes in Figure 7. Although there is a difference among lakes, primarily because of different latitudes, the trends in ice-out date are very consistent and must be caused by a common physical forcing: the climate over 10-year periods. The appearance of trends in Figure 6 depends, of course, on the length of the "running" or averaging period (Figure 8). At Bone Lake, for example, the overall trend (slope) is increased from -0.076 days/year for annual data to -0.121 days/year for 10-year running averages. Where this period is extended from 10 to 30-years, trends over the 10- and 20-year periods are attenuated, but the overall trend (slope) remains the same. Further reduction of the 60-year long record reduces the slope to -0.09 days/year for the 50-year running average, and eventually 0 at a 60-year average.

Sixteen lake records of ice-out dates over a thirty-year time period were analyzed by event sorting. Approximately half of these lakes showed disproportionate accumulation of ice-out dates late in the analysis period (i.e. more recent years). Results of the ice-out event sorting analysis are summarized in Table 4; the normal number of ice-out events in each time frame is compared with the actual data. The statistics confirm the visual impression of the graphs (Figure 9). In the time frame 1998-2002 (representing 5 years of record), 59% of the records show more early ice-out events than are statistically expected for that period. The time frame 1993-2002 (the most recent 10 years of record) shows that 41% of the records have more early ice-out events than expected.

Ice-out event grouping analysis of the 60-year records (1943-2002) shows a similar trend of event grouping (Table 4). In this case, however, the numerical data

reveals that, in the most recent 5 years of the 60-year record, there are 67% more early ice-out events than expected; this percent is increased to 73% when analyzing the most recent 20 years of the 60-year records. The 80 and 110-year record analyses show similar trends in early ice-out groupings. Regardless of the record length, these findings lead to the conclusion that lake ice-out has occurred earlier in the more recent period of record.

5.2 Ice-In Events

The ice-in records from 34 lakes analyzed show an overall average date of November 24 (standard deviation of 6.58 days); individual lake averages range from November 12 at Portage Lake (46.97° latitude) to December 8 at Lake Kabekona (47.16° latitude). The effect of latitude is obviously not nearly as strong as for ice-out dates. A significant dependence on lake water volume (represented by maximum lake depth), however, is shown in Figure 10; lake water must cool in the fall before ice formation can occur and deeper lakes take longer to cool. Intra-lake standard deviations of ice-in dates average 10.40 days, showing a large natural variability. Standard deviations range from 6.77 days for Lake Siseebakwet to 14.99 days for Island Lake. RMSE values also show this variability with an average RMSE of 9.74 days for complete record analysis. Average ice-in RMSE values fluctuated slightly as shorter time periods were analyzed. (Table 5)

Linear regression trend analysis on the complete records of all 34 lakes showed an average slope of 0.754 days/year (standard deviation of 0.752 days). Thirty-two of the 34 lakes analyzed (94%) showed a positive trend, indicating later ice formation. Only 8 of the 34 original records had enough data to be included in the 1970 to present analysis.

Each of these 8 lakes showed a positive slope for ice-in dates with an average value of 0.150 days/year (standard deviation of 0.173 days). The analysis from 1980 to present included 16 ice-in records; each of these records also showed a positive trend for ice-in dates, the average slope of these records was 0.353 days/year (standard deviation of 0.215 days). All 34 ice-in records were included in the analysis of data from 1990 forward. Linear regression provided an average slope of 1.441 days/year (standard deviation of 0.86 days), with 33 of the 34 lakes (97 %) showing a positive slope. Table 5 gives a summary of all of these results.

Annual ice-in data (dates of ice-in) are illustrated in Figure 11 for 6 lakes. Inter-annual variations are large and mask trends, which have been computed from linear regression and added to Figure 11. Trends are made apparent by 10-year running averages, which eliminate much of the interannual variability (Figure 12). While the overall trends over the 30 to 40-year record lengths differ, all 6 lake records in Figure 12 show a strong trend towards later ice-in dates after about 1997. Since the data points are plotted at the end of the 10-year period, this would indicate a strong warming trend in the early 1990s, except for Crow Wing Lake where the trend started already in the 1970s. The synoptic behavior of all 6 lakes in the 1990s is shown in Figure 13.

Similar to ice-out events, there is a distinct trend in the occurrence of the latest ice-in events: they occur more recently in the record (Figure 14). Due to restrictions in record length, ice-in records were analyzed for only the 30-year time period. Within this analysis, 4 of the 6 lake records analyzed show a disproportionate occurrence of lake ice-in events in more recent time spans. Considering the most recent 5 years of record, 88% of the analyses show more late ice-in events occurring during the specified time period

than would statistically be expected; this statistic is reduced to 75% when looking at the most recent 10 years of record. Results are shown in Table 6.

5.3 Spring Runoff Date

Latitude has a strong effect on the timing of spring runoff. *First spring runoff* dates show considerable variability from year to year (Figure 15). An overall average date for the 21 stations investigated is March 22. Averages for individual stations range from March 9 at station 05317200 (44.23° latitude) to May 7 at station 05124480 (47.92° latitude). The overall average date for the *first spring peak runoff* is March 26. Individual stream averages range from March 15 at station 05353800 (44.25° latitude) to May 9 at station 05124480 (47.92° latitude). Similarly, *maximum spring peak runoff* averages for individual streams range from March 26 at station 05353800 (44.25° latitude) to May 9 at station 05124480 (47.92° latitude), resulting in an overall average date of April 6 (Table 7).

Spring runoff analysis results have larger RMSE values than ice event results reflecting higher natural variability in the timing of runoff versus that of ice-in or -out events. The average RMSE value for first spring runoff date was 14.82 days, with individual station values ranging from 6.99 to 17.80 days. First spring peak date shows RMSE values ranging from 7.79 to 16.49 days, with an overall average of 13.87 days. Maximum spring peak runoff date RMSE values vary widely with a minimum value of 7.97 days and maximum of 21.12 days; the overall average RMSE is 17.62 days (Table 7).

Trend analysis at river gaging stations was done only over the long-term. Nineteen of the 21 river gaging sites (91%) showed a trend of first spring runoff to occur earlier in the year for the time period of analysis (1964 to 2002). The average slope of all 21 records was computed to be -0.300 days/year (standard deviation of 0.235 days). First spring peak date showed an average trend of -0.228 days/year with a standard deviation of 0.193 days. Sixteen stations (76%) exhibited a negative trend for this parameter (peak date moving earlier into the year). The average slope for maximum spring peak runoff was 0.009 days/year with values varying from -0.524 to 1.145 days/year (standard deviation of 0.341 days). Results of runoff date trend analyses are summarized in Table 7.

The trends obtained by linear regression of the time series and shown in Figure 15 for 6 stream sites are surprisingly similar, with one exception. These trends are accentuated when 10-year running averages are plotted and analyzed (Figure 16). They remain consistent among the 6 stations; beginning in the 1960s and moving toward an earlier date for first spring runoff. The synchronization in runoff timing is illustrated in Figure 17 for the nine stream gaging stations with complete records back to 1960. Surprisingly the data in Figures 16 and 17 suggest that the trends leveled off or even reversed in the 1990s. Data for the first spring peak date are shown in Figures 18 to 20. Variability is higher and trends are less consistent between the stream gaging stations than shown in Figures 15 to 17, especially after 1990 (Figure 20). Maximum spring peak dates are even more variable and show almost no overall trend (Table 7). The degradation in consistency from first spring runoff event to spring peak date is attributed to the increasing complexity of physical forcing that cause these events. First spring

runoff in Minnesota is usually from the first snowmelt caused by rising air temperature, while spring peak runoff depends on cumulative effects of snow pack, air temperature, and rainfall over a much longer time period.

The event sorting analysis was performed on 30-years of record of the first spring runoff date and first spring peak date for 9 river gaging stations. Figures 21 and 22 show examples of the graphs created; numerical results are summarized in Table 8. This analysis shows early spring runoff events occurring disproportionately late in the available record. The earliest first spring runoff dates exceed the expected number by 44% during the most recent 5 years of record and by 64% during the most recent 10 years. Statistics for first spring peak date give 39% earlier first peak events during the most recent 5 years and 44% earlier events during the most recent 10 years.

5.4 Spring Runoff Flow Rates

Spring runoff flow rates are ambiguous indicators of climate trends because they combine effects of both air temperatures and precipitation. Flow rates vary immensely from year to year (Figures 23 and 24), showing a trend towards smaller flow rates in spring. The average first spring runoff flow was calculated to be 4350 cfs (Table 9). First spring peak flow averages 5324 cfs and maximum spring peak flow had an average value of 6212 cfs. These values are substantially higher than average monthly flows, which range from 626 cfs in February to 3117 cfs in April; the overall yearly average flow at the 21 analyzed stream gaging stations was 1481 cfs. Spring river discharges show large variability within their records, with intra-station standard deviations averaging about 5,000 cfs for first spring, first spring peak, and maximum spring peak

flows; RMSE values show a similar average of approximately 7,400 cfs. Intra-station standard deviations for mean monthly flows in spring are lower, ranging from 300 cfs in February to 2402 cfs in April; yearly standard deviations average 662 cfs.

Spring river discharge rates show highly variable trends. The average slope for first spring runoff was -44.2 cfs/year (standard deviation of 83.7 cfs), or about 1% of the average flow of 4350 cfs at the 21 gaging stations investigated. Trends ranged from -328 to 72 cfs/year. First spring peak flow shows an average trend of -13.7 cfs/year (standard deviation of 59.8 cfs); trends ranged from -107 to 185 cfs/year. Similarly, trends for maximum spring peak flow show a large variability (from -201 to 101 cfs/year), averaging at -17.5 cfs/year (standard deviation of 58.5 cfs). Spring discharge rates are summarized in Table 9.

5.5 River Temperature

Annual average river temperatures at 15 river stations ranged from 10.75°C to 13.20°C, with an overall average value of 12.32°C (standard deviation 0.76°C). Values from 5 stations on the Mississippi River and one on the Minnesota River are shown in Figures 25 and 26. Standard deviations of individual stations had an average of 1.25°C, with an RMSE value of 0.93°C. Linear regression analysis on the complete record of water temperatures at the 15 stations showed a trend of 0.107°C/year (standard deviation 0.031°C). Each of the stations showed a positive (warming) trend, ranging from 0.064 to 0.159°C/year. Average record length at these stations was 26 years (1977-2002). Results are summarized in Table 10.

6. Discussion

6.1 Trends

The purpose of this study was to identify trends in water resource parameters, which are directly dependent on air temperature, over both the long and short-term record. The majority of parameters analyzed showed recent trends that are associated with an air temperature increase or climate warming. The strongest trends were found in the recent occurrence of ice-in dates on 73 Minnesota lakes, which showed an average shift of 0.754 days/year over an average record length of 24 years (1979-2002). Spring river runoff from snowmelt (expressed as first spring runoff and first spring peak runoff dates) and lake ice-out dates showed a slightly weaker trend than ice-in date. These events are moving earlier into the year at rates of -0.30, -0.23, and -0.13 days/year, respectively. Average annual river temperatures were found to be increasing at an average rate of 0.11°C/year over the last 26 years. Each of these parameters is directly associated with air temperature, therefore these trends are all to be expected during a warming period. No conclusive results were found in the calculated trends of maximum spring peak date or in the spring river discharge records. Because these parameters are not solely dependent on air temperature, but are closely linked to other climate parameters, such as precipitation, distinct trends are not expected.

Analysis of shorter time periods within the lake ice records shows a strengthening of trends during the last ten to twenty years (1982-2002). This strengthening was apparent in both overall average trends and within individual lake records. A doubling of both average ice-in and ice-out date trends is shown when the most recent 13-years are compared to the complete record. Eight-eight percent of individual lake ice-in records

have a stronger trend toward later ice-in dates during the period from 1990-2002 than over the complete record. Ice-out records show a similar result, i.e. 62% of individual lake trends are stronger in the 1990-2002 period. These ice-out trends are more noticeable in lakes with longer records; of the 14 lakes that have at least 50 years of ice-out record 73% show an increase in trend during recent times.

Each of the water resource parameters that is directly dependent on air temperature shows a trend that is consistent with an increase in regional air temperature. A factor, not specifically addressed in this study, that may play a role in recent trends, is urbanization and the effects that it may have not only on regional air temperatures, but other factors affecting water resource parameters (i.e. impacts from increased runoff or wastewater discharges). Urbanization would, however, only be inherent in data from the Minneapolis/Saint Paul metropolitan area.

Similar studies, looking at the effects of increasing air temperatures on water resource parameters, have produced varying findings for ice-out trends. Analysis of 20 lakes (from 1968-1988), in the state of Wisconsin, showed an average trend of –0.59 days/year for ice-out events, more than twice that calculated here (Anderson et al. 1996). A study of 29 lakes in the northern hemisphere, during the 1846-1995 time period, showed an average ice-out trend of 0.058 days/year and an average ice-in trend of 0.065 days/year (Magnuson et al., 2000). Studies focusing on the timing of stream runoff produced results of closer magnitude to those found here. Analysis of 110 stream stations in the high basins of the western United States showed the "spring pulse" date moving earlier into the year at –0.24 days/year over the 1957-1994 period (Cayan et al., 2001); this finding is nearly identical to this study's trend for first spring peak runoff date

computed at –0.228 days/year. A study performed on 84 west-central Canadian rivers showed trends ranging from 0.625 to –0.875 days/year for the timing of peak river runoff due to spring snowmelt (Burn, 1994). As was found in this study, Burn reports a strengthening of these trends in the time period since 1970. A U.S. Geological Survey study on the Piscataquis River in central Maine reported trends for river water temperature, ice-out date, and seasonal-center-of-volume-date (SCVD; defined as the "Julian date on which half of the stream runoff volume" has occurred between January 1 and May 31). (Huntington et al., 2003) Trends for the river water temperature were similar to those calculated in this study, showing an increasing trend of 0.09°C/year over the years from 1966-2001. Ice-out dates were found to be shifting at a rate of –0.21 days/year for the period from 1931-2002; SCVD trends showed this parameter to be shifting earlier into the year at a rate of –0.11 days/year during the years from 1903-2000 with a much steeper trend beginning at 1970.

6.2 Connection to Air Temperature

To see the correlation between water resource parameters and regional air temperatures, data for both were plotted against each other. Direct comparison of ten-year running averages for the 6 lakes with the longest records of lake ice-out date, for example, are shown in Figure 27. Periods of strong inverse correlation between mean annual air temperature and ice-out date are shown in these plots; it is clear, however, that trends are not consistent across the complete record. Averaging the ice event and weather data for these 6 lakes provides a summary (Figure 28), and shows a stronger correlation during recent time periods. Plots of running average data for ice-in events,

river runoff dates, and river water temperatures give similar results; an example of this analysis for first spring runoff date is shown in Figures 29 and 30.

In order to develop an estimated per degree effect of air temperature fluctuation on each of the water resource parameters studied, a linear relationship was developed between parameter data and regional air temperatures at those lakes or stations that had complete records. In order to develop a more complete comparison, average annual, average monthly, and minimum monthly air temperatures were used in this analysis. Six lakes were analyzed for ice-out date; the strongest correlation was found between ice-out date and average air temperature during the month of March. Because most of the ice-out dates occur in April, the correlation between ice-out date and the March air temperature is expected. Calculated trends range from -1.19 days/1°C average March air temperature for Lake Vermillion to -2.13 days/1°C average March air temperature for Lake Minnetonka; the combined trend is -2.41 days/1°C average March air temperature (r^2=0.511). Using 143 freshwater lakes in the United States and Canada, Layman predicted that ice-out dates would shift 4 days earlier into the year for each 1°C increase in mean annual air temperature (Layman, 2000). In this study, the finding of -4.26 days/1°C mean annual air temperature is very similar.

Annual ice-in dates are shown to be shifting at a rate of 2.94 days/1°C mean annual air temperature (r^2=0.138). For this parameter Layman found a trend of 2.3 days/1°C; again, our findings are nearly the same. Further analysis, however, showed a stronger correlation between ice-in dates and average November air temperatures (r^2=0.390). Trends range from 1.98 days/1°C average November air temperature for Lake Siseebakwet to 2.88 days/1°C average November air temperature for Crow Wing

Lake; with a combined trend of 2.37 days/1°C increase in average November air temperature.

First spring runoff and first spring peak runoff dates show the best correlation with minimum March air temperature (r^2 of 0.396 and 0.389). Given the fact that the majority of these runoff events are due to snowmelt in the month of March, this dependence is expected. Individual trends range from -1.50 days/1°C at Station 05313500 to -3.41 days/1°C at Station 05280000 with a combined trend of -2.94 days/1°C for first spring runoff date. First peak runoff date trends range from -1.95 days/1°C at Station 05313500 to -2.79 days/1°C at Station 05280000, giving a combined shift of -2.72 days/1°C increase in minimum March air temperature.

Analysis of average annual river temperatures suggests that these temperatures will increase at a rate of 0.671°C/1°C increase in surrounding air temperature (r^2 of 0.228). This trend ranges from 0.206 °C/1°C at Mississippi River Mile 815.6 to 0.859 °C/1°C at Mississippi River Mile 839.1.

7. Summary

1) Lake ice-out and spring runoff event timing show a strong dependence on latitude. Lake ice-in dates were shown to be dependent on lake volume (expressed as maximum depth).
2) Records from 73 Minnesota lakes showed that ice-out dates are moving to earlier dates with an average trend of -0.13 days/year for complete record analysis (1965-2002). This trend toward earlier ice-out date is strengthening in the 1990s. Overall

average ice-out trends for the time period since 1990 are -0.25 days/year, double that of the complete record.

3) Averaging of ice-out events shows periods of opposing trends with strong trends toward earlier ice-out occurring since the 1980s and also during the 1940s.
4) A direct correlation between annual air temperature and ice event date was shown. A linearization of this dependence (for 6 lakes) shows that ice-out dates are most dependent on average March temperatures and shift at a rate of –2.41 days/1°C average March air temperature. Ice-in dates depend on average November air temperatures, shifting 2.37 days/1°C increase.
5) Ice-in dates were found to be shifting to later dates with a general trend of 0.75 days/year calculated for the complete record of 34 lakes. This trend for ice-in dates moving later in the season has been stronger during the 1990s than for the complete record. The trend for the 1990s is 1.44 days/year, double the trend of the complete record, which averages 24 years in length.
6) A trend of -0.30 days/year was calculated for first spring runoff dates, showing that spring runoff events have been moving to earlier dates over the analysis period (1960-2001). First spring peak dates are moving at a rate of -0.23 days/year.
7) First spring runoff dates and first spring peak dates show a strong correlation with regional air temperatures. The strong dependence of runoff date is with minimum March temperature; dates were calculated to shift approximately 2.8 days earlier into the year for each 1°C increase in air temperature.
8) River temperatures at 15 metropolitan river stations were found to be rising at a rate of 0.11°C/year over the average record period from 1977 to 2002. A strong

correlation between average annual river temperatures and average annual air temperatures is shown. Analysis of 7 river sites shows an annual increase in river temperature of 0.67°C per 1°C increase in air temperature.

9) No consistent trends were found in 39 years (1964-2002) of data for spring runoff flows, probably because they are linked as much to precipitation as to as to air temperature.

8. Conclusion

In conclusion, records of five water resources parameters that are closely linked to air temperature show a trend that suggests climate warming in Minnesota in the last 30-years. A direct correlation was noted between air temperature and these five parameters, resulting in ice-out and spring runoff dates shifting earlier into the year, stream water temperatures rising, and ice-in dates moving later into the year. Analysis of ice-out and -in records since 1990 show trends to be twice as strong over the past 13-years when compared to the complete record analysis. Trend analysis of spring runoff flows was inconclusive, probably because this parameter is linked as much to precipitation as to air temperature.

Recommendations for Further Study

1) Analysis of temperatures at river stations located outside of the metropolitan area would provide for a more controlled study of the effects of air temperature without the concern of the effects of urbanization.

2) Retrieving longer records at river gaging stations would allow for an analysis of recent versus long term trends in spring river runoff timing (similar to those done with lake ice events).
3) Analysis of both deep and shallow groundwater temperatures would provide further data on the effects of air temperature changes.

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Figure 1: Record of mean annual air temperature in the Minneapolis-Saint Paul metropolitan area (weather station located in Downtown Minneapolis 1891-1938; at Twin Cities International Airport 1939-2003)

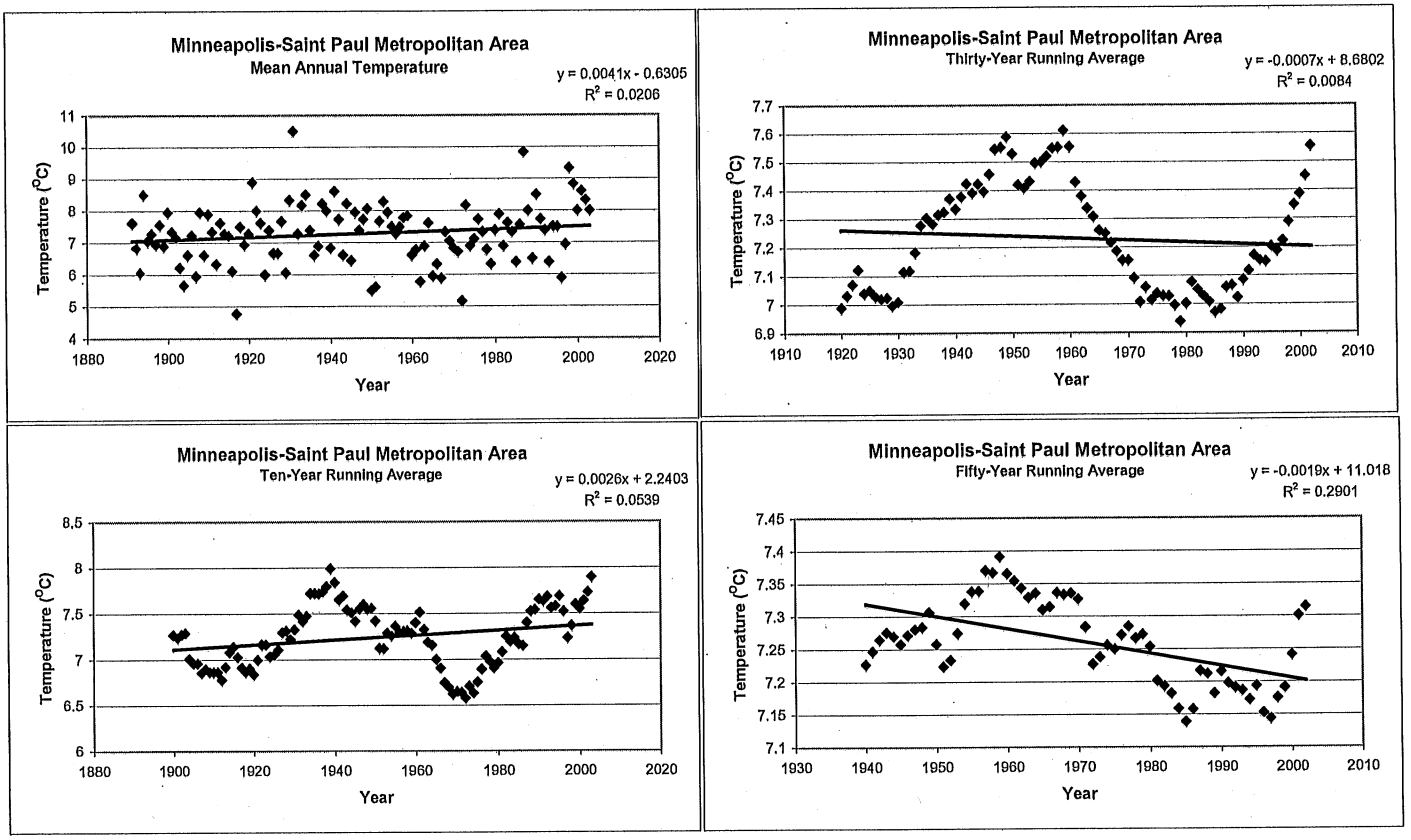


Figure 2: Record of annual precipitation in the Minneapolis-Saint Paul metropolitan area (weather station located in Downtown Minneapolis 1891-1938; at Twin Cities International Airport 1939-2003)

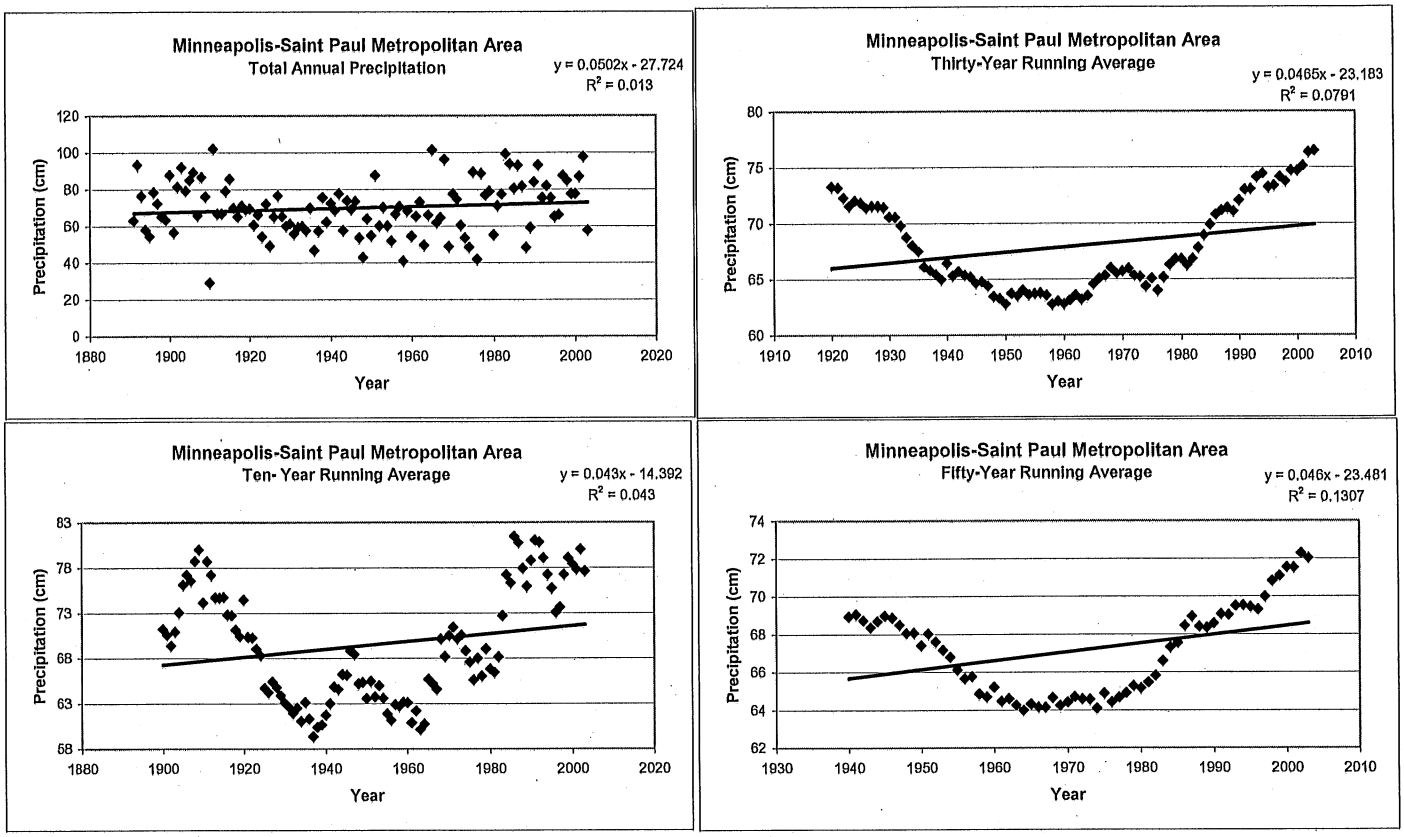


Figure 3: Lake and stream gaging locations in Minnesota, USA

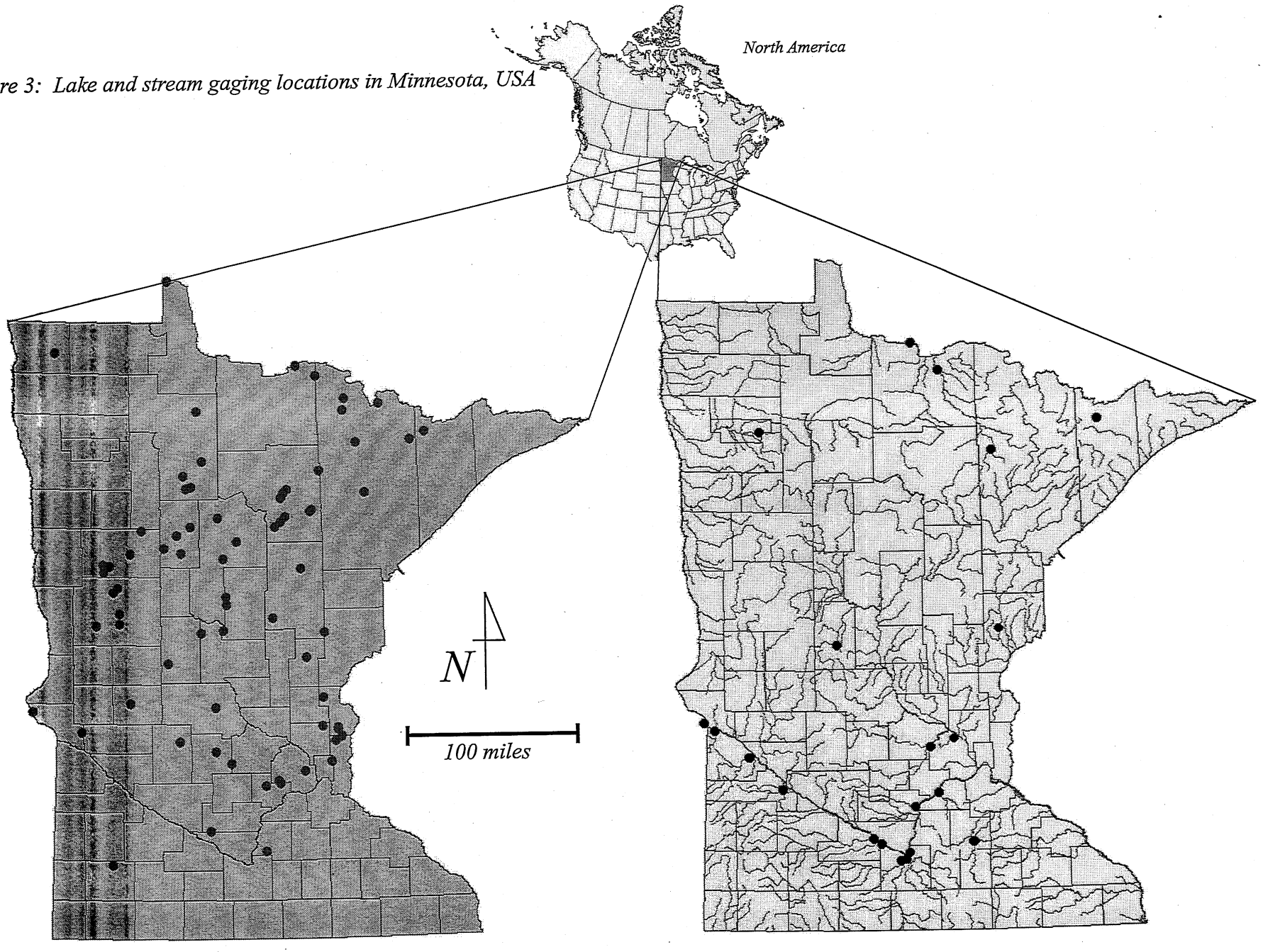
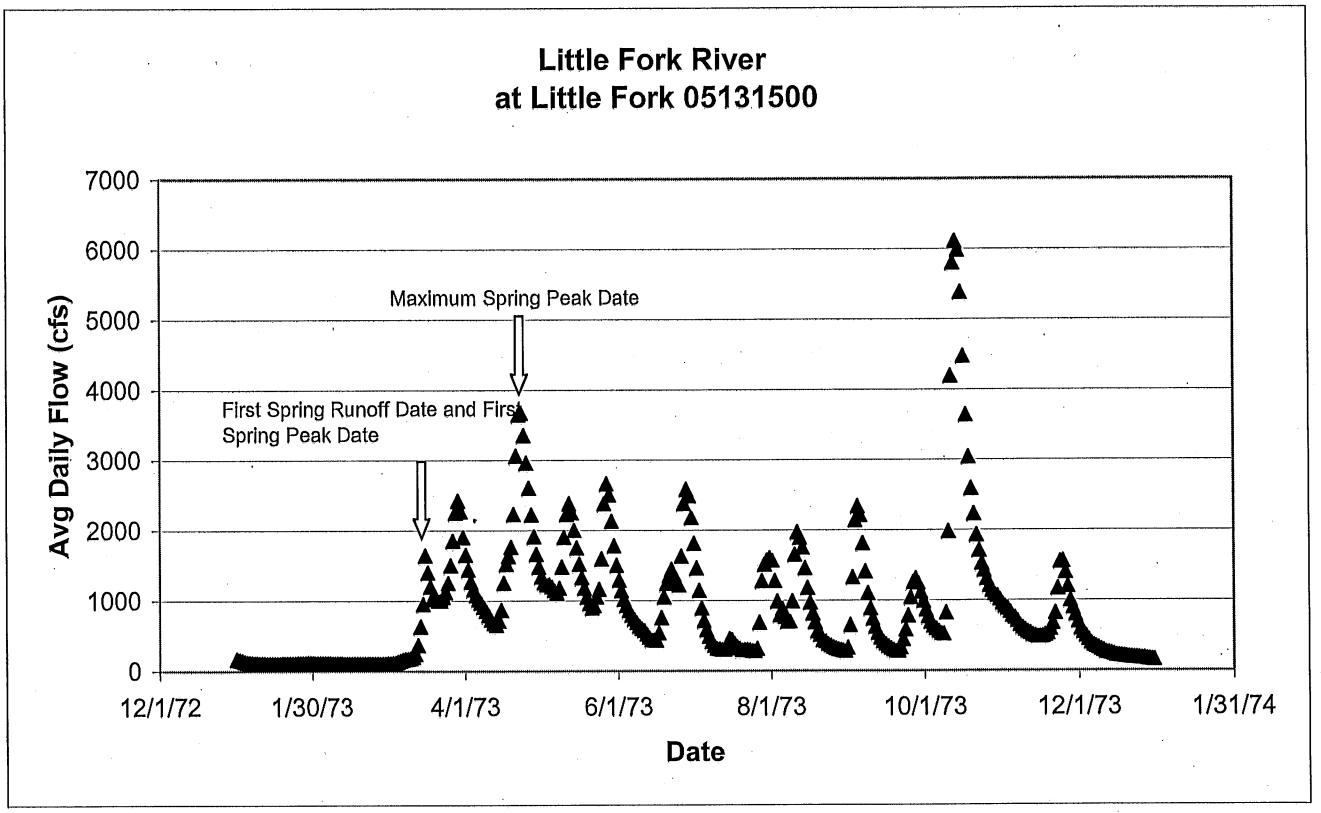


Figure 4: Spring runoff event timing



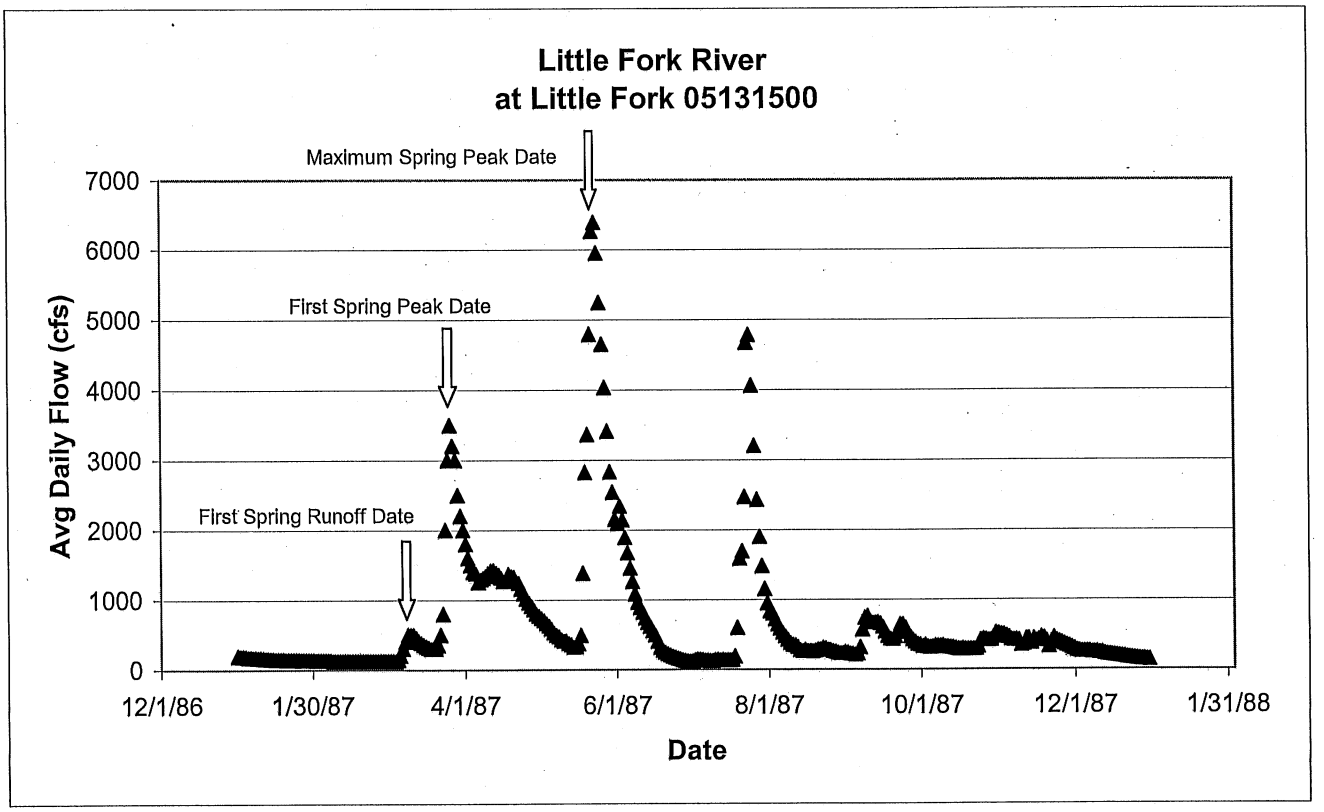


Figure 5: Example of annual ice-out dates

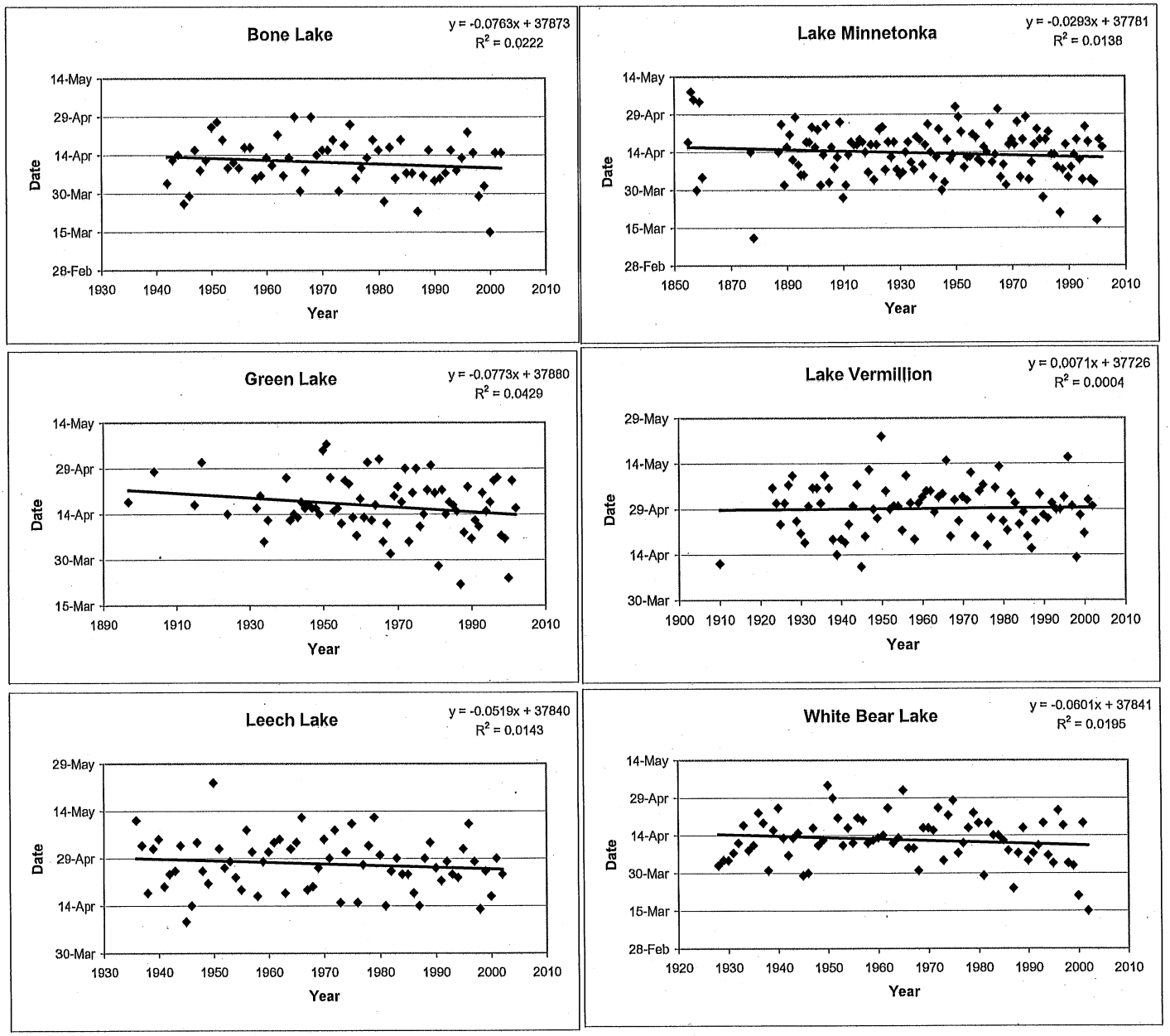


Figure 6: Example of ten-year running average ice-out dates

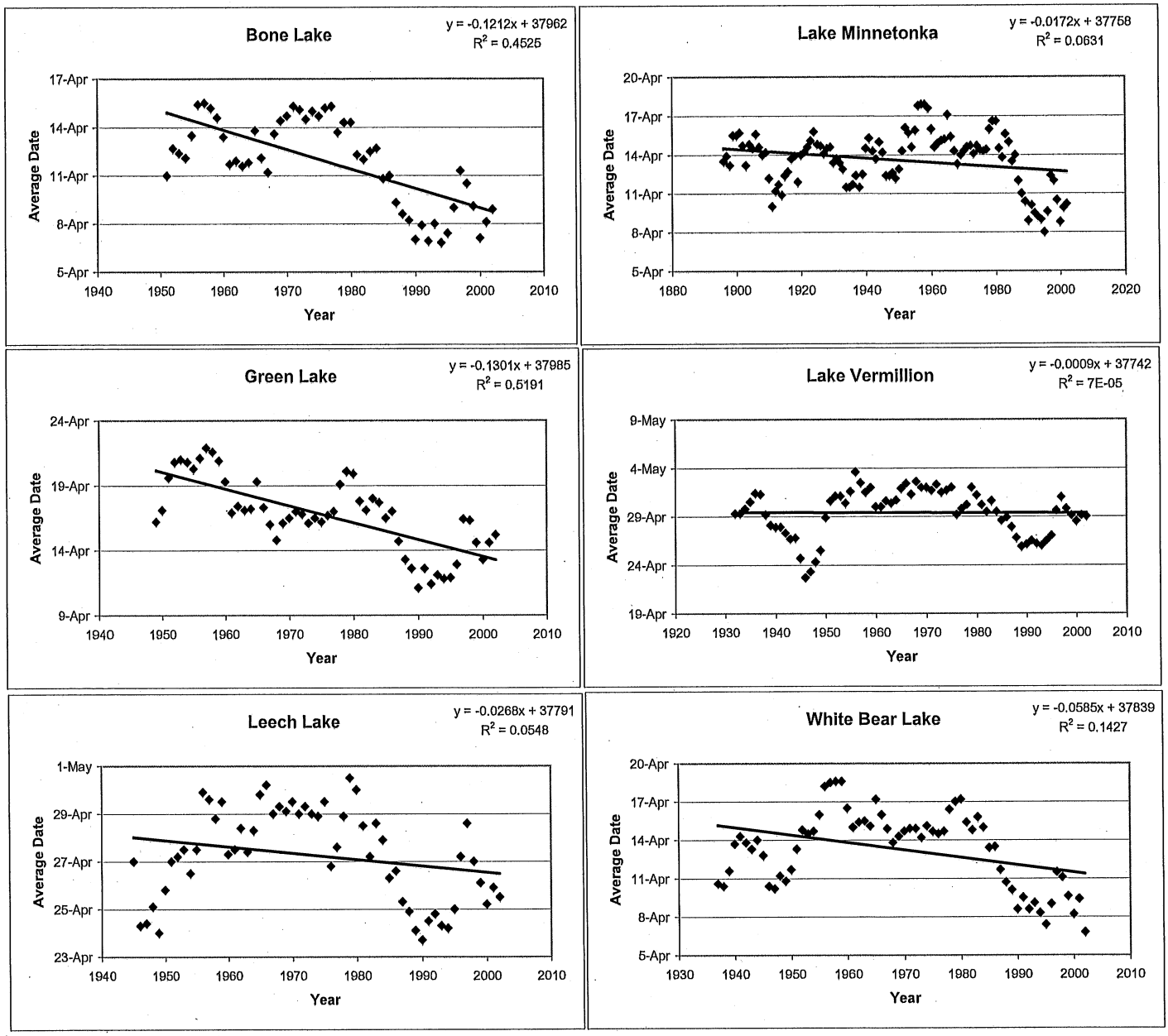


Figure 7: Comparison of ten-year running averages for ice-out dates

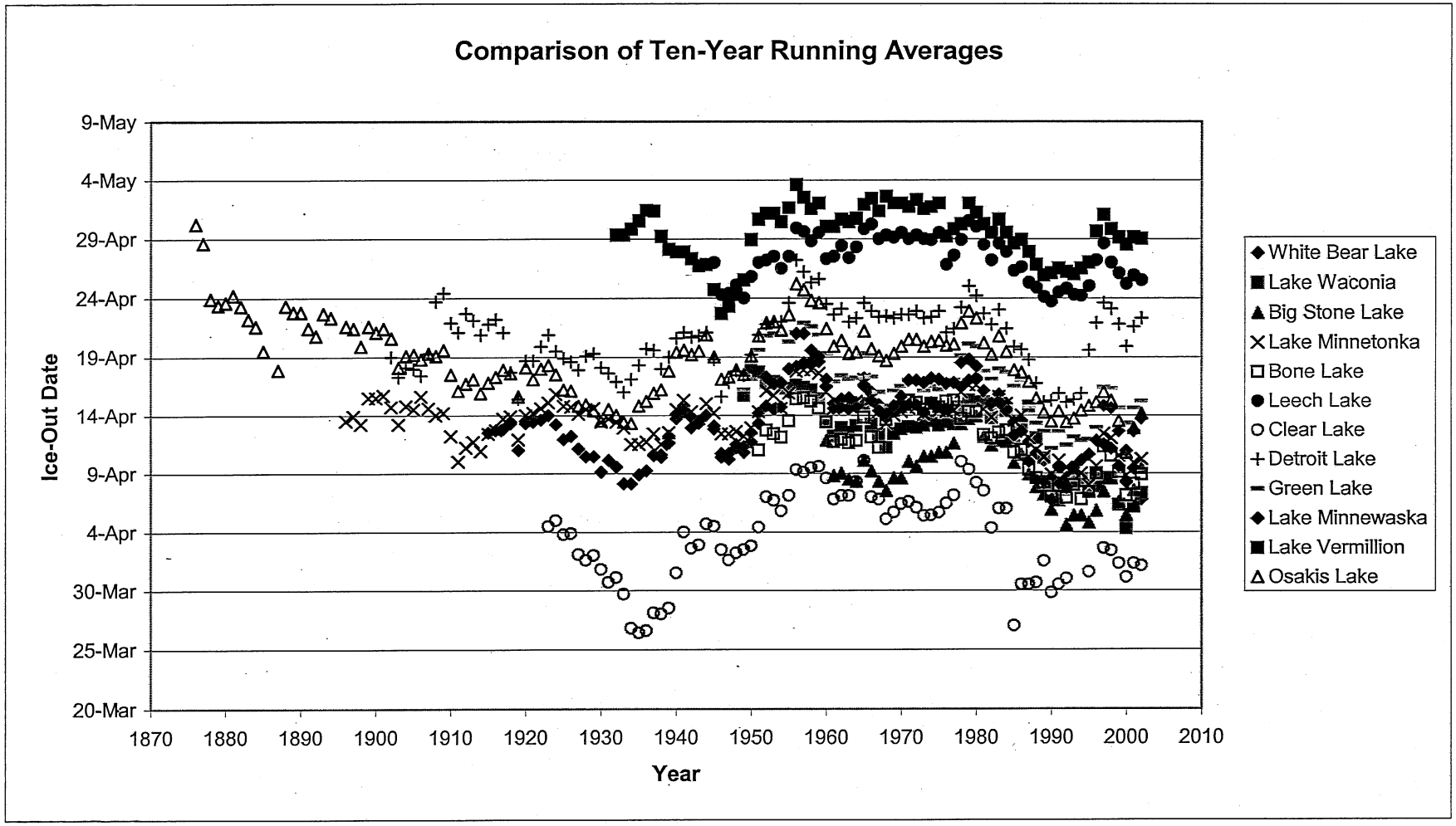


Figure 8: Various averaging periods for ice-out dates

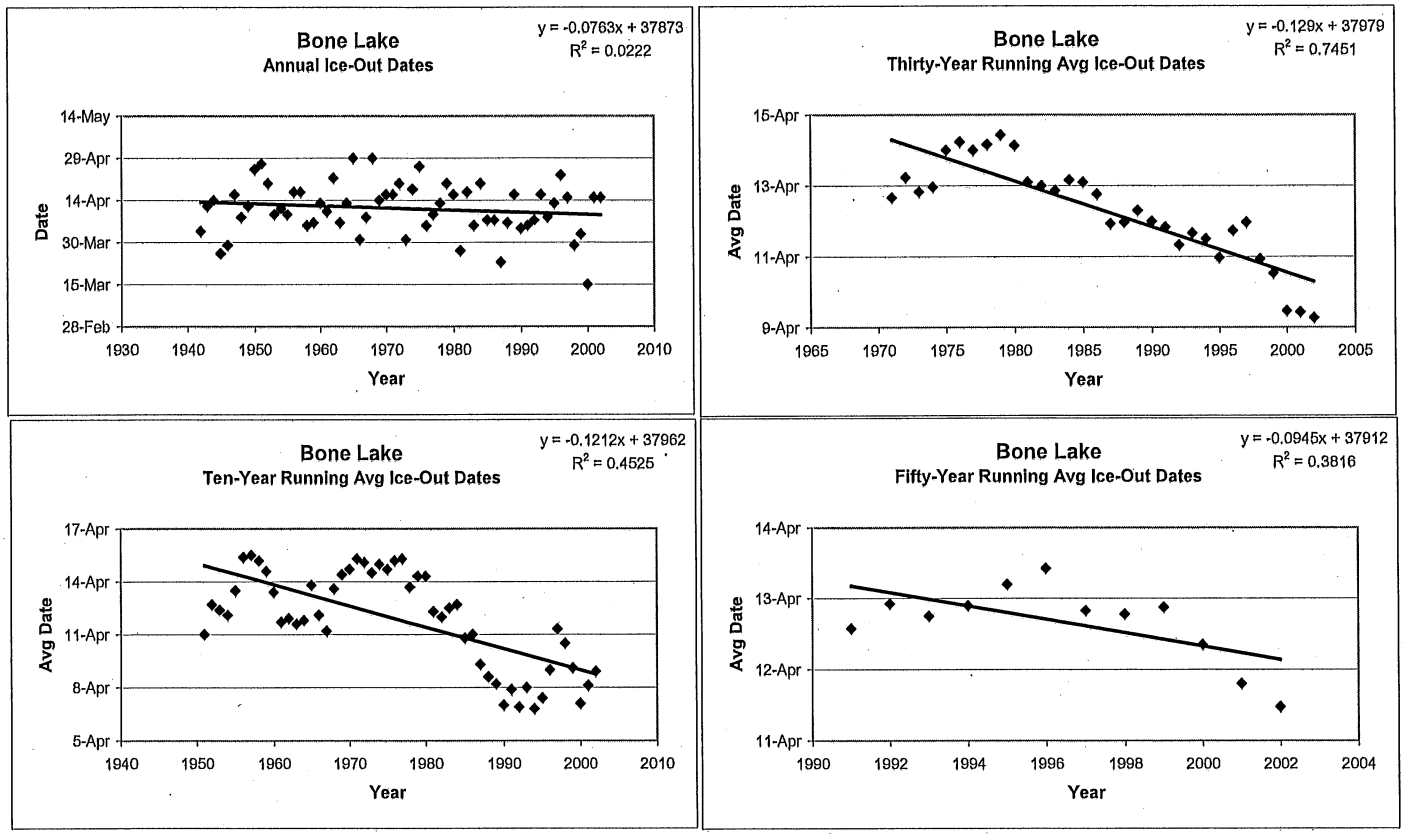


Figure 9: Sorting (ranking) of 60 years (1943-2002) of ice-out data for six lakes

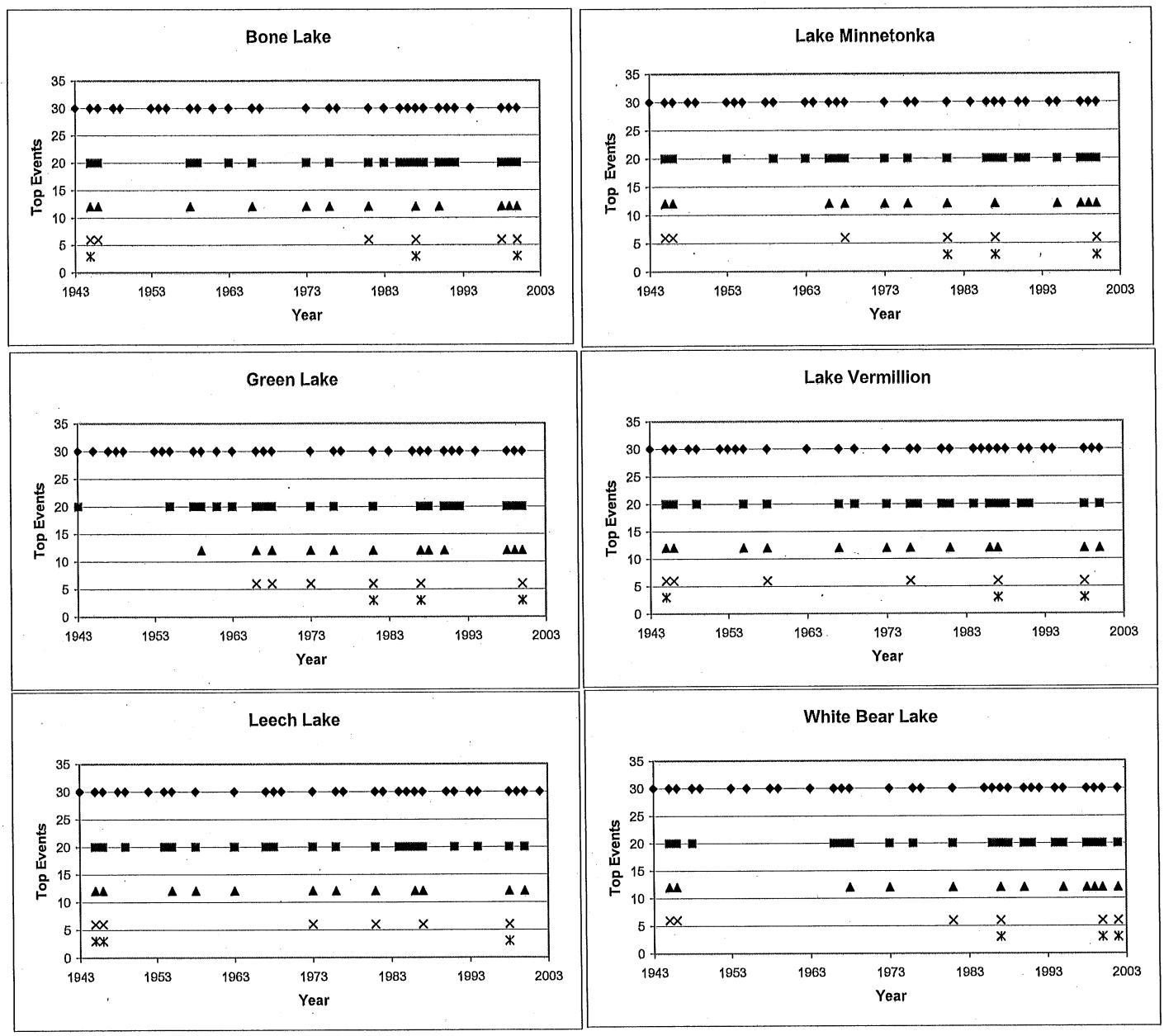
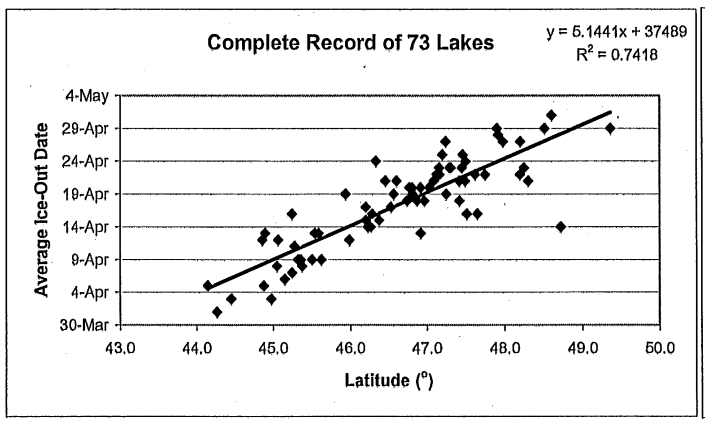
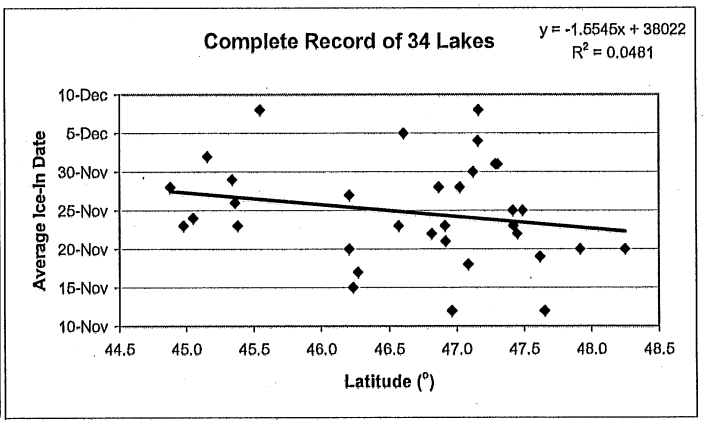
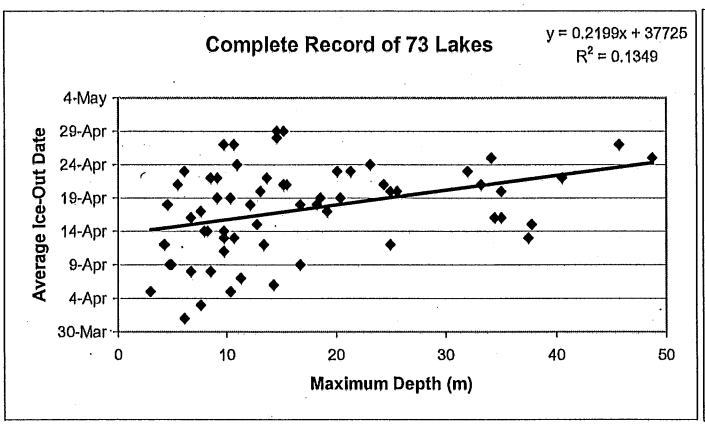


Figure 10: Influence of latitude and maximum depth on lake ice-out and ice-in dates







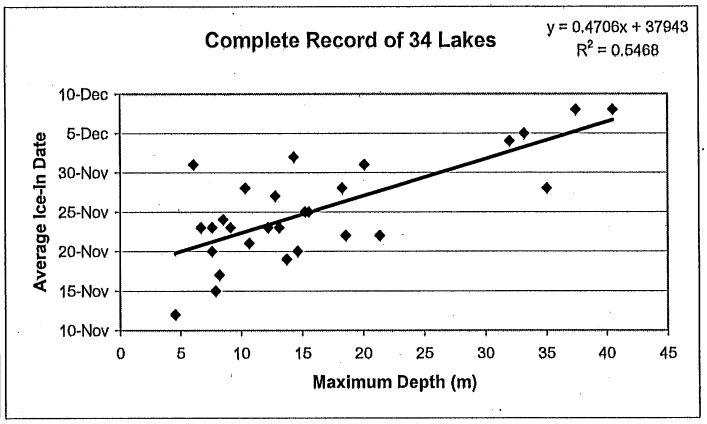


Figure 11: Example of annual ice-in dates

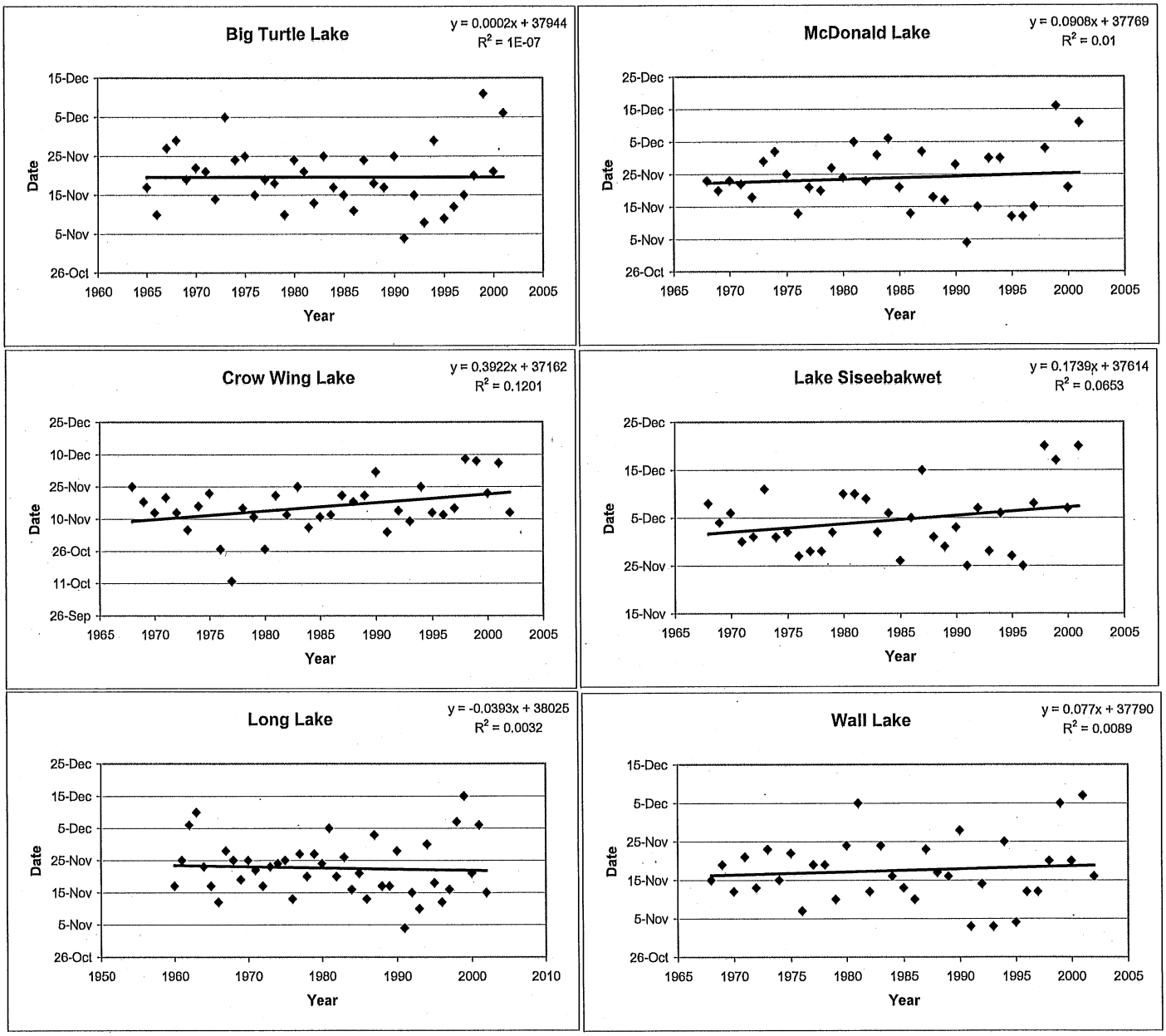


Figure 12: Example of ten-year running average ice-in dates

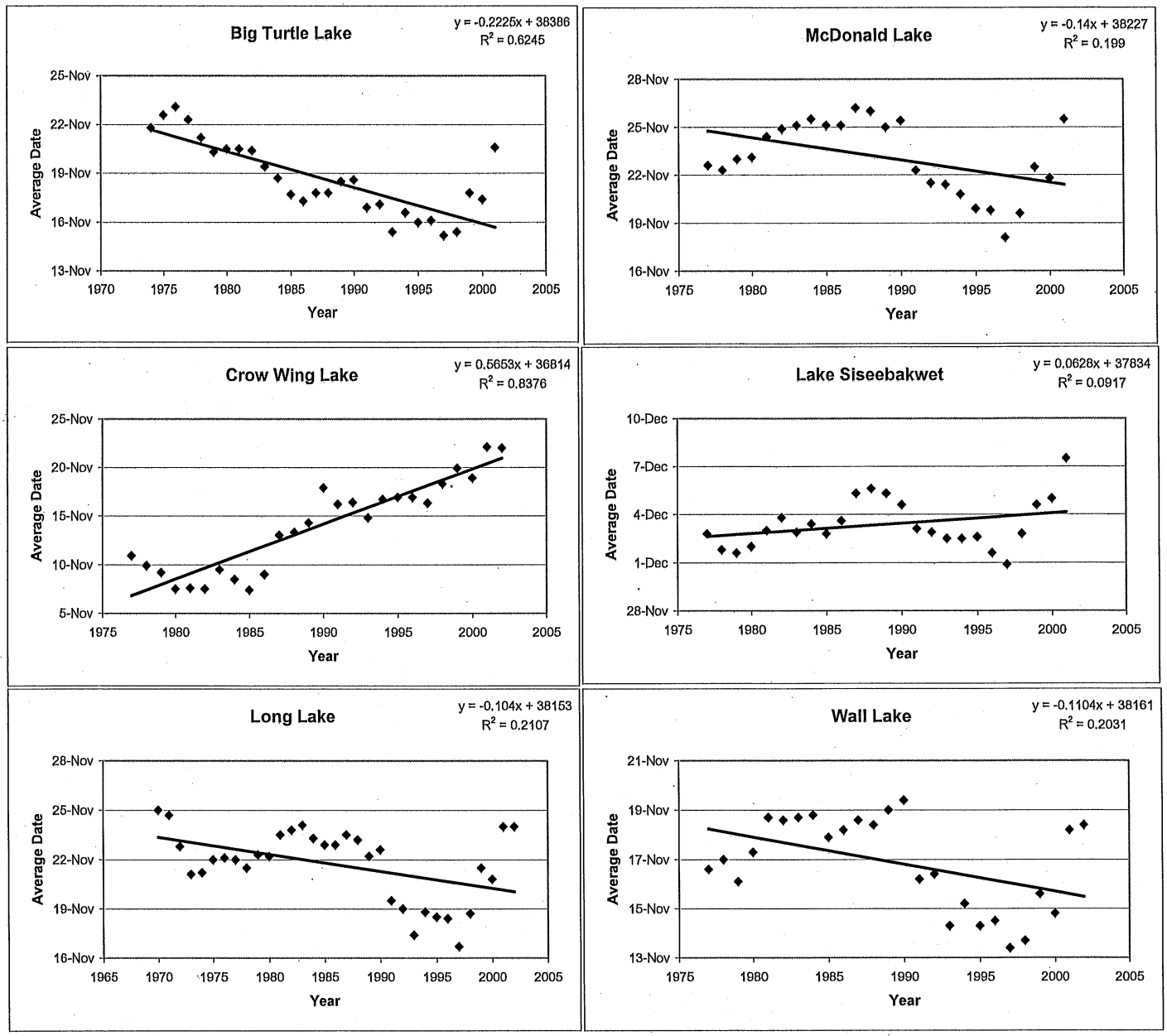


Figure 13: Comparison of ten-year running averages for ice-in dates

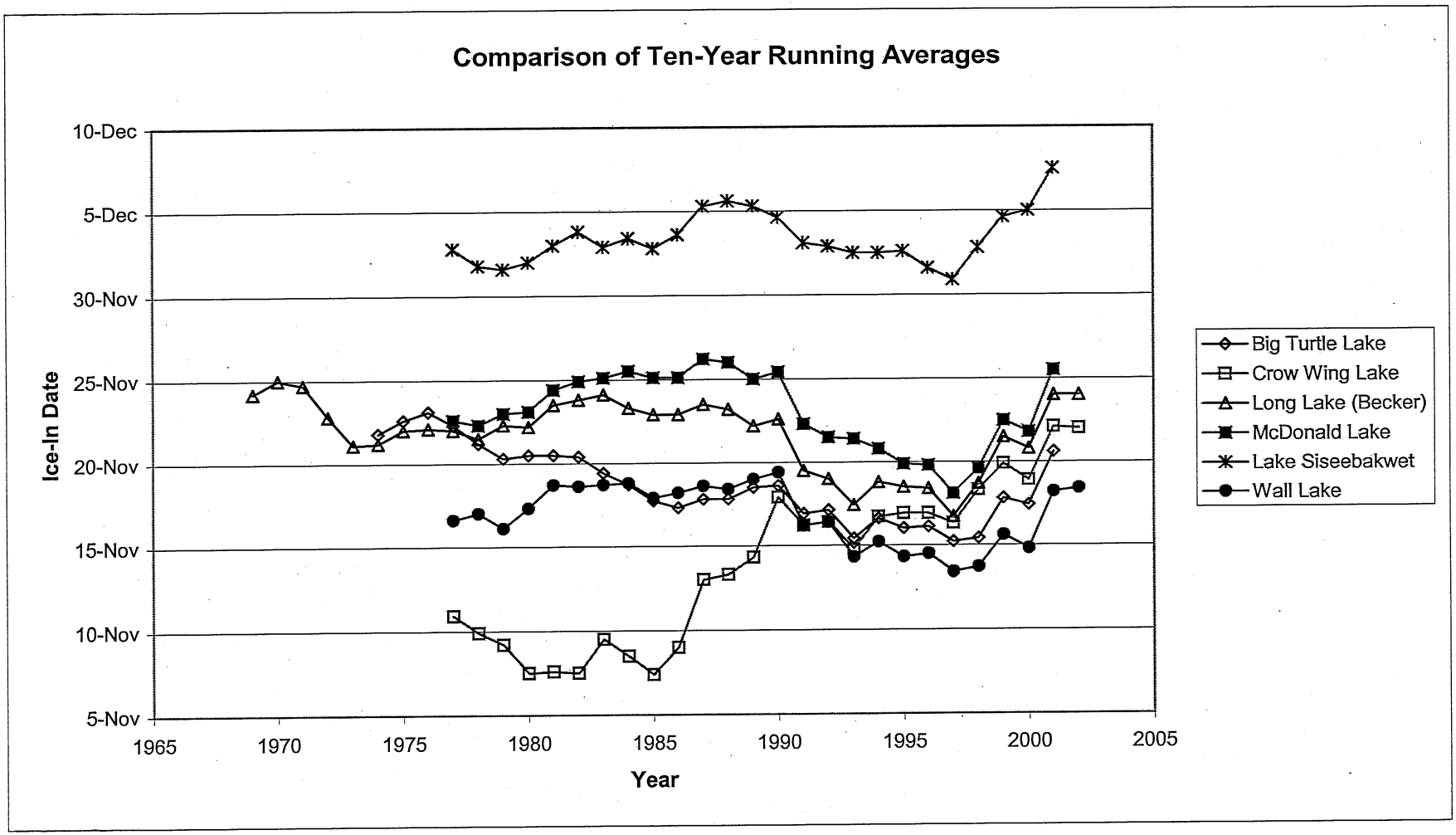


Figure 14: Sorting (ranking) of 30 years of ice-in data for six lakes

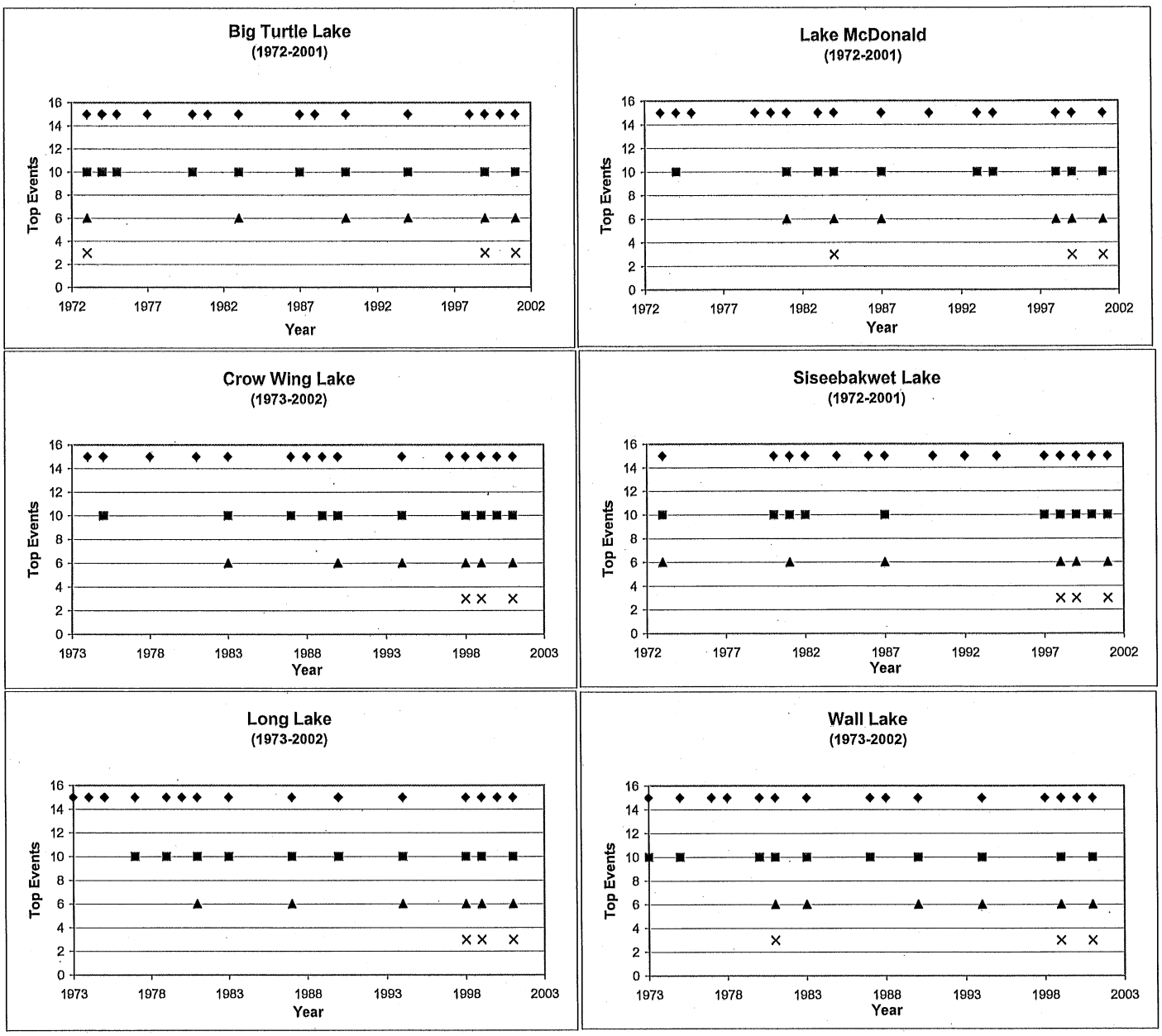


Figure 15: Example of annual first spring runoff dates

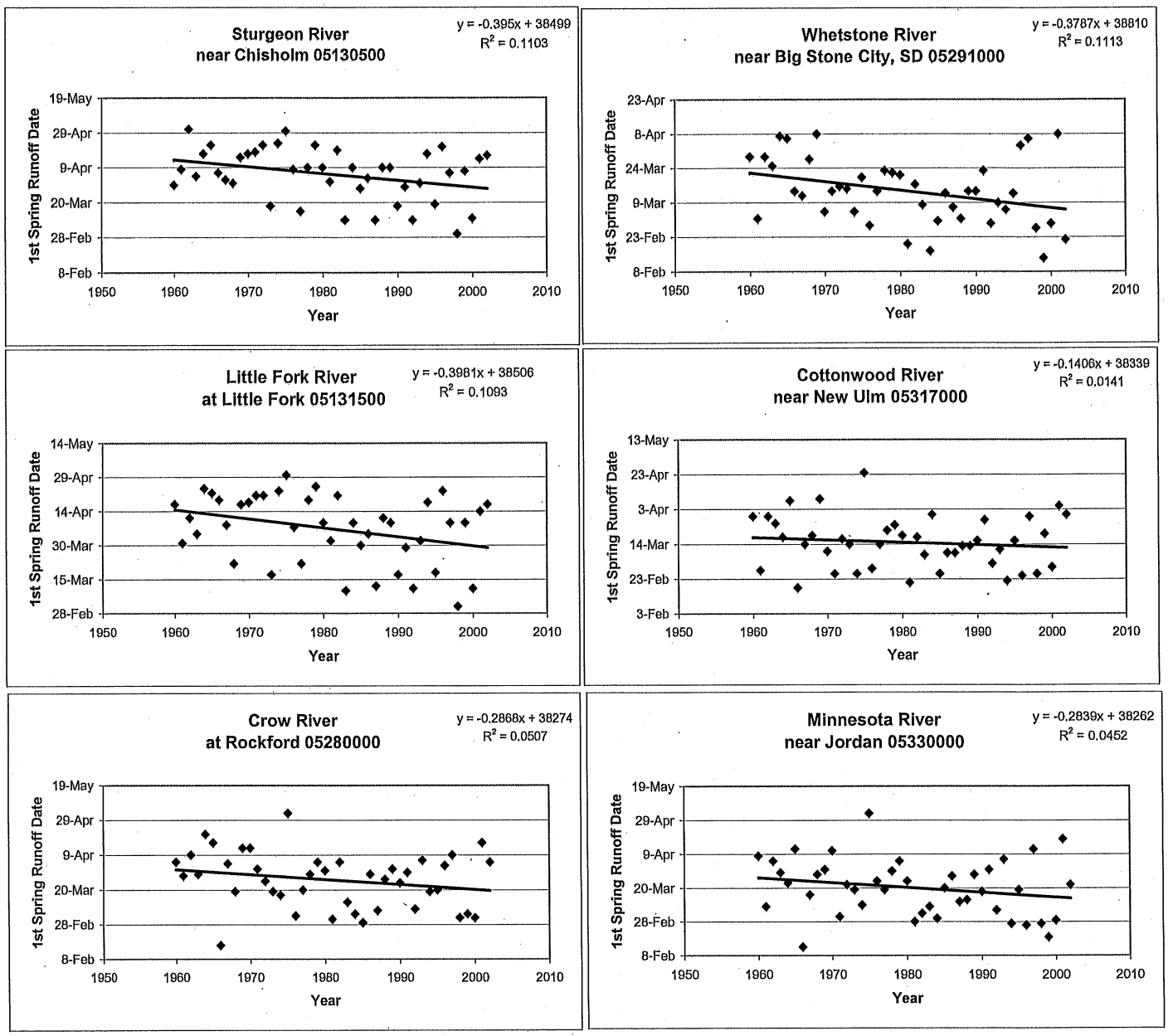


Figure 16: Example of ten-year running average first spring runoff dates

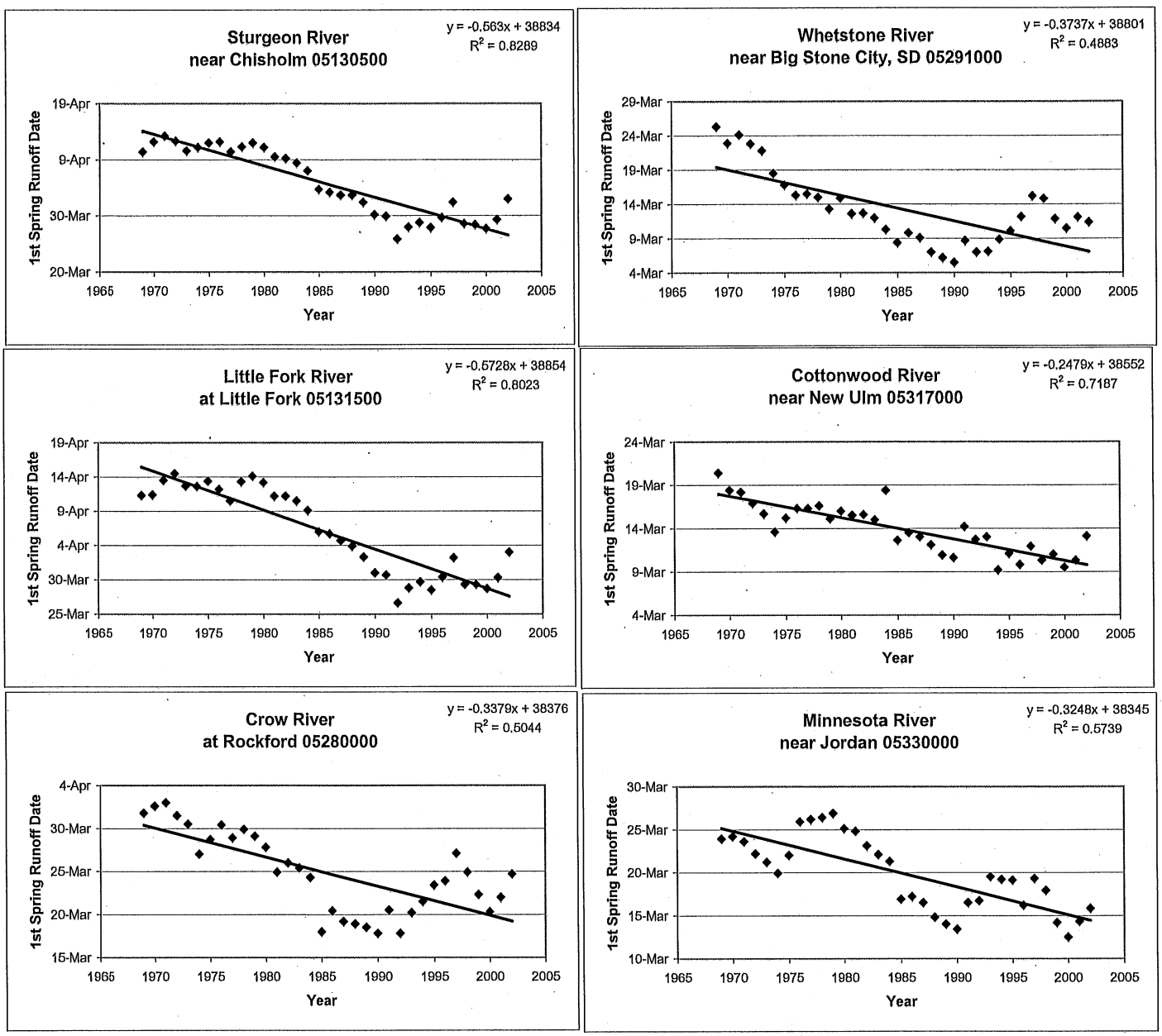


Figure 17: Comparison of ten-year running averages for first spring runoff dates

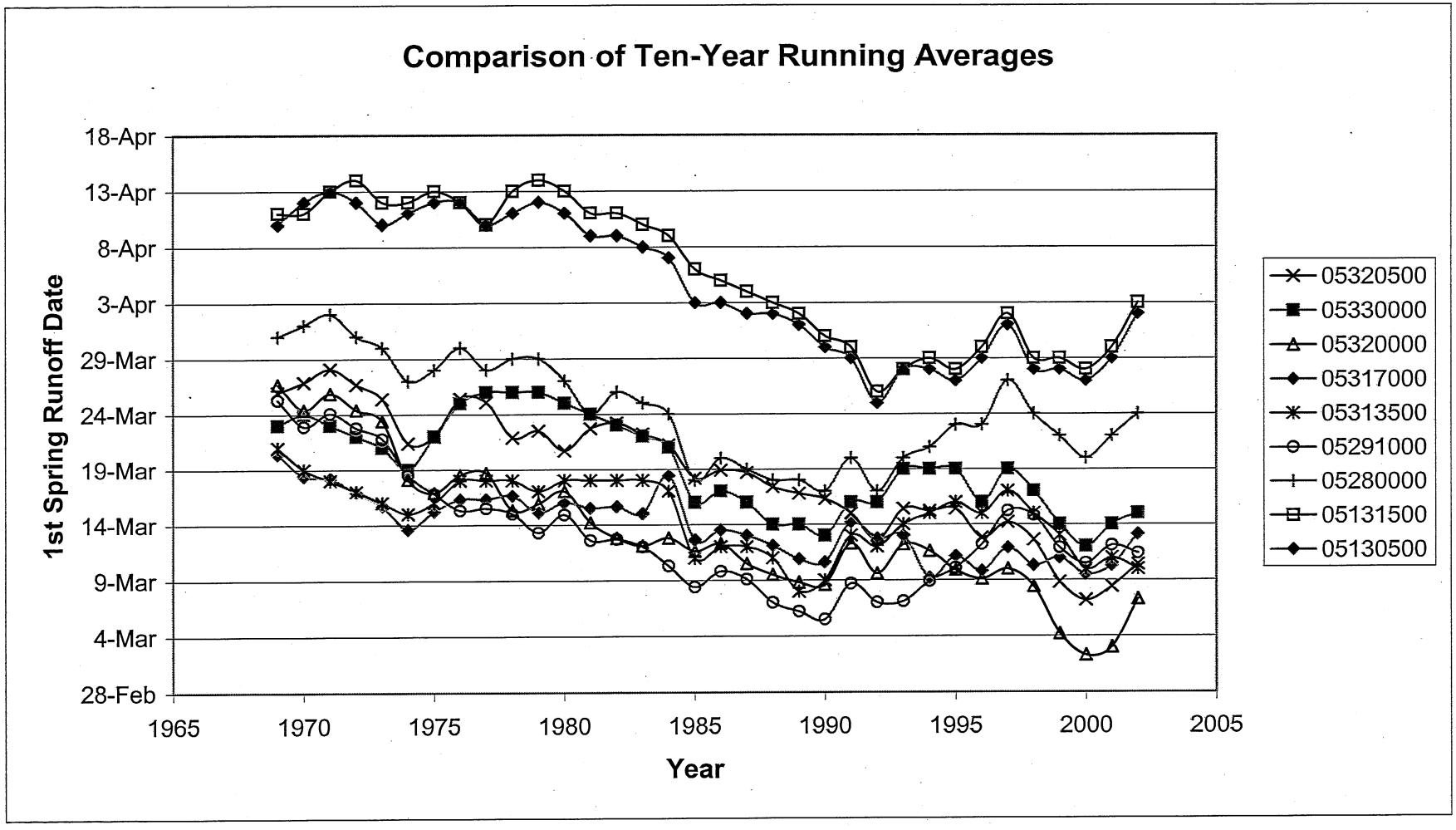


Figure 18: Example of annual first spring peak dates

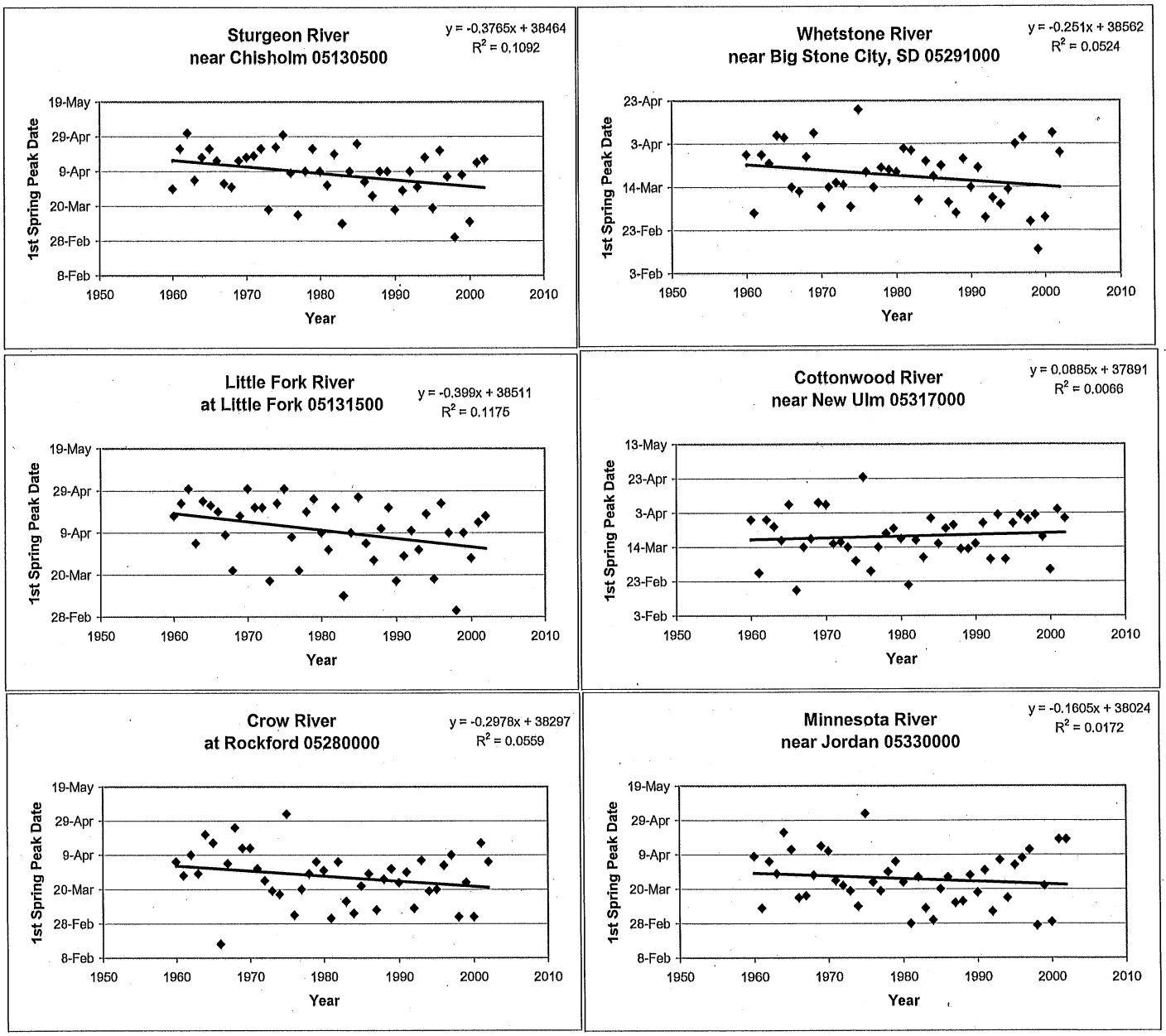


Figure 19: Example of ten-year running average first spring peak dates

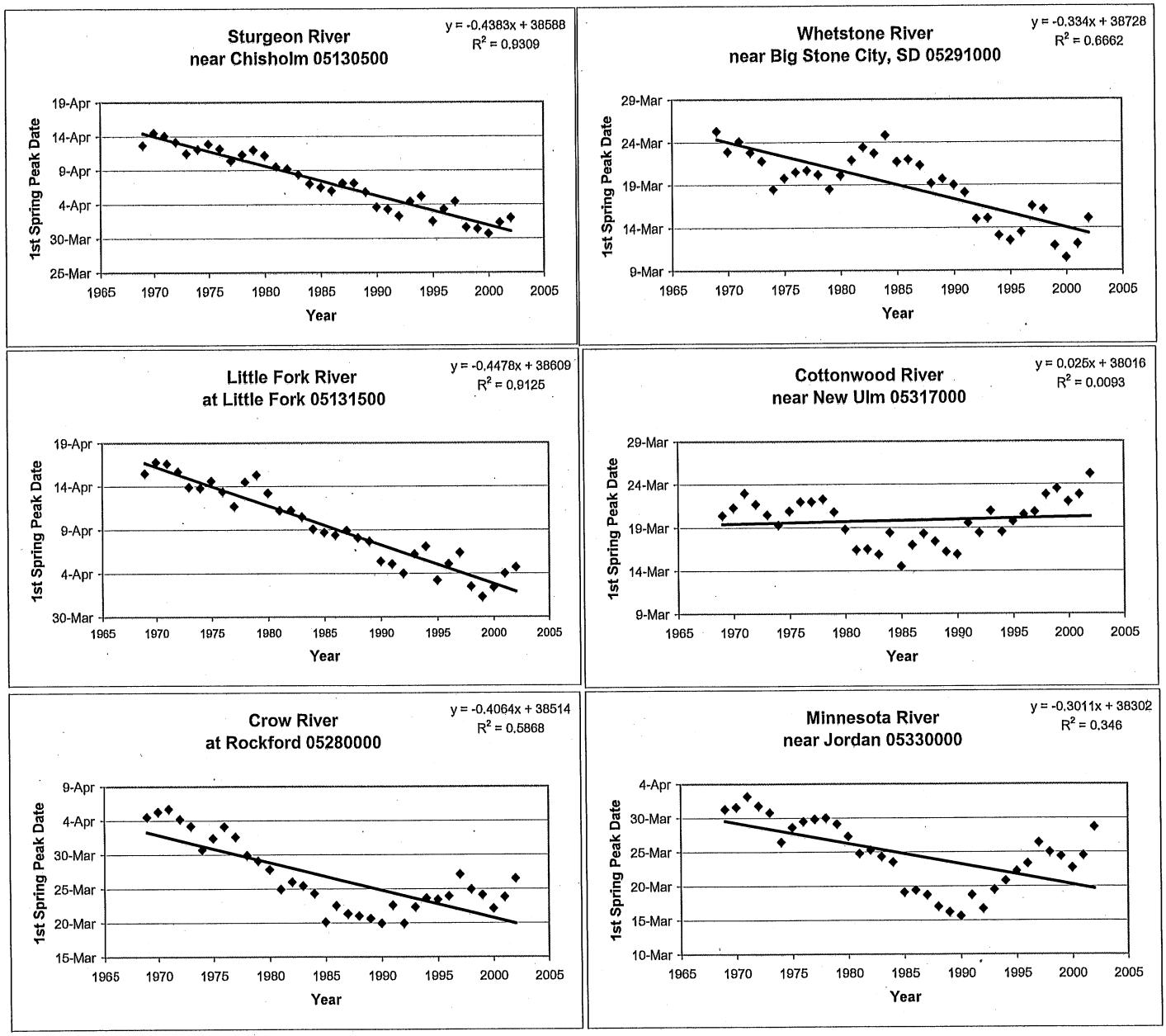


Figure 20: Comparison of ten-year running averages for first spring peak dates

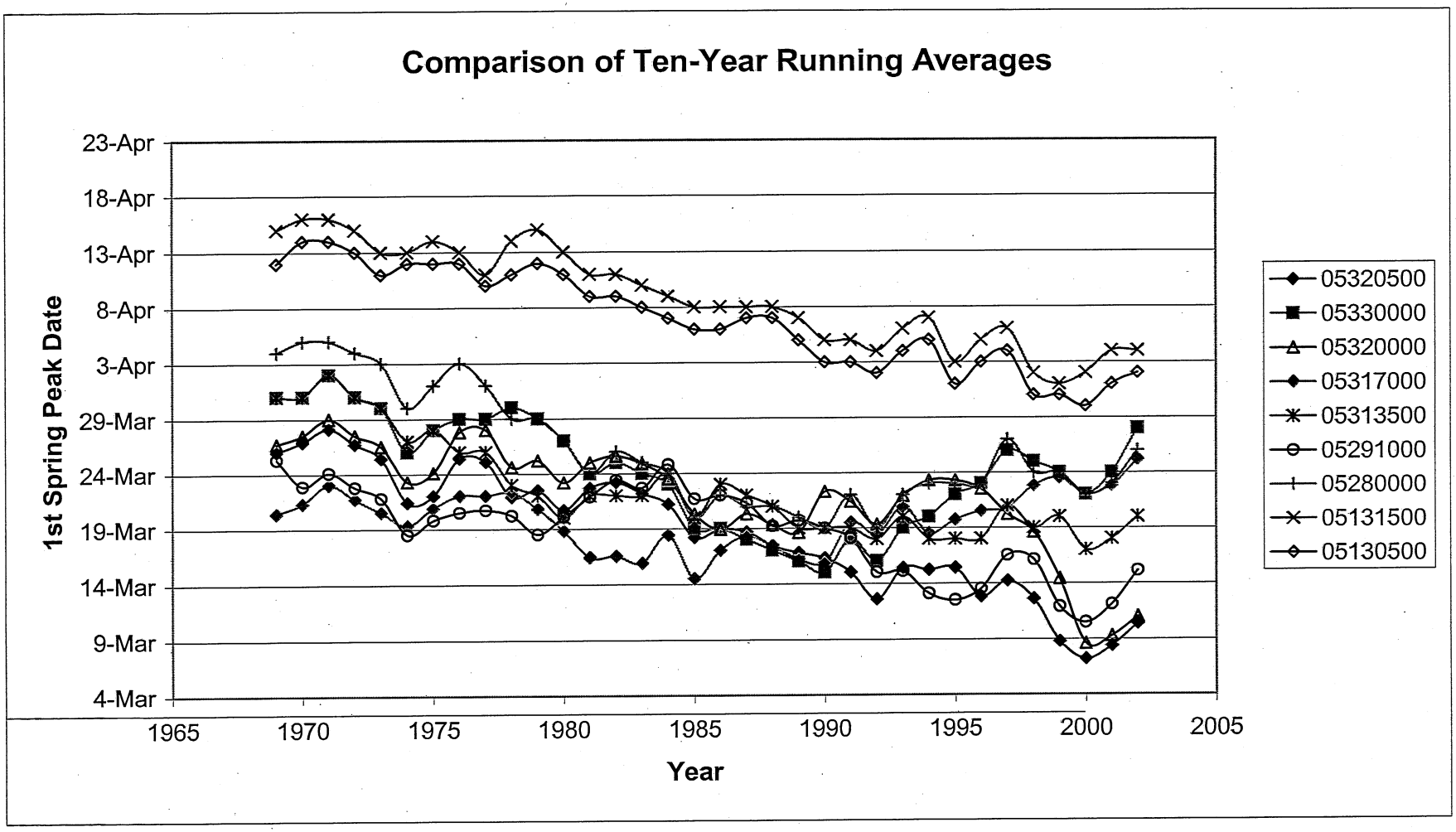
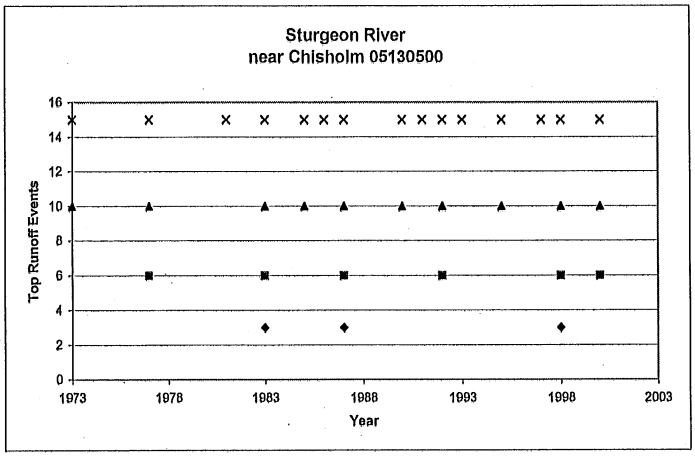
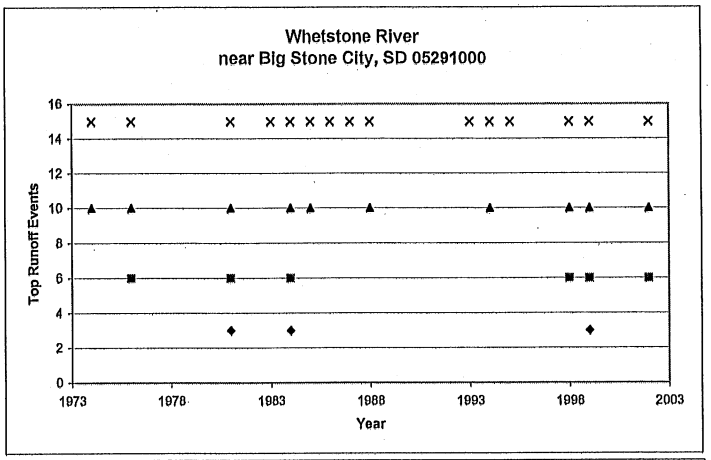
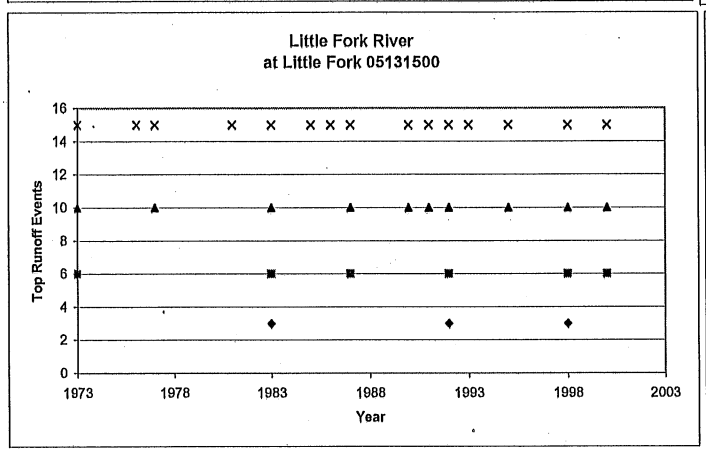
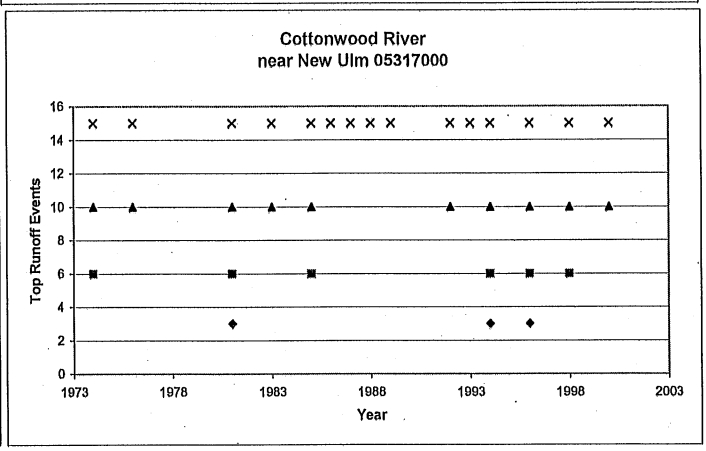


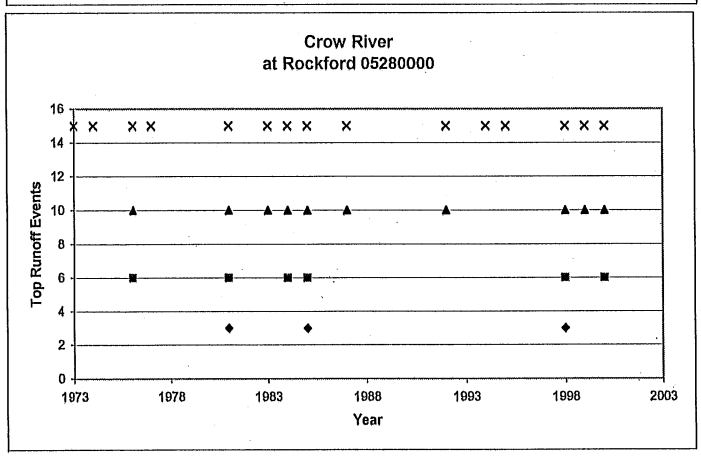
Figure 21: Sorting (ranking) of 30 years (1973-2002) of first spring runoff date











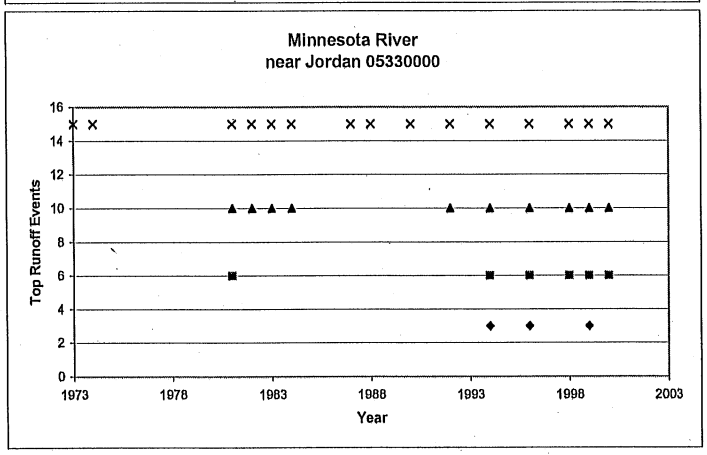


Figure 22: Sorting (ranking) of 30 years (1973-2002) of first spring peak date

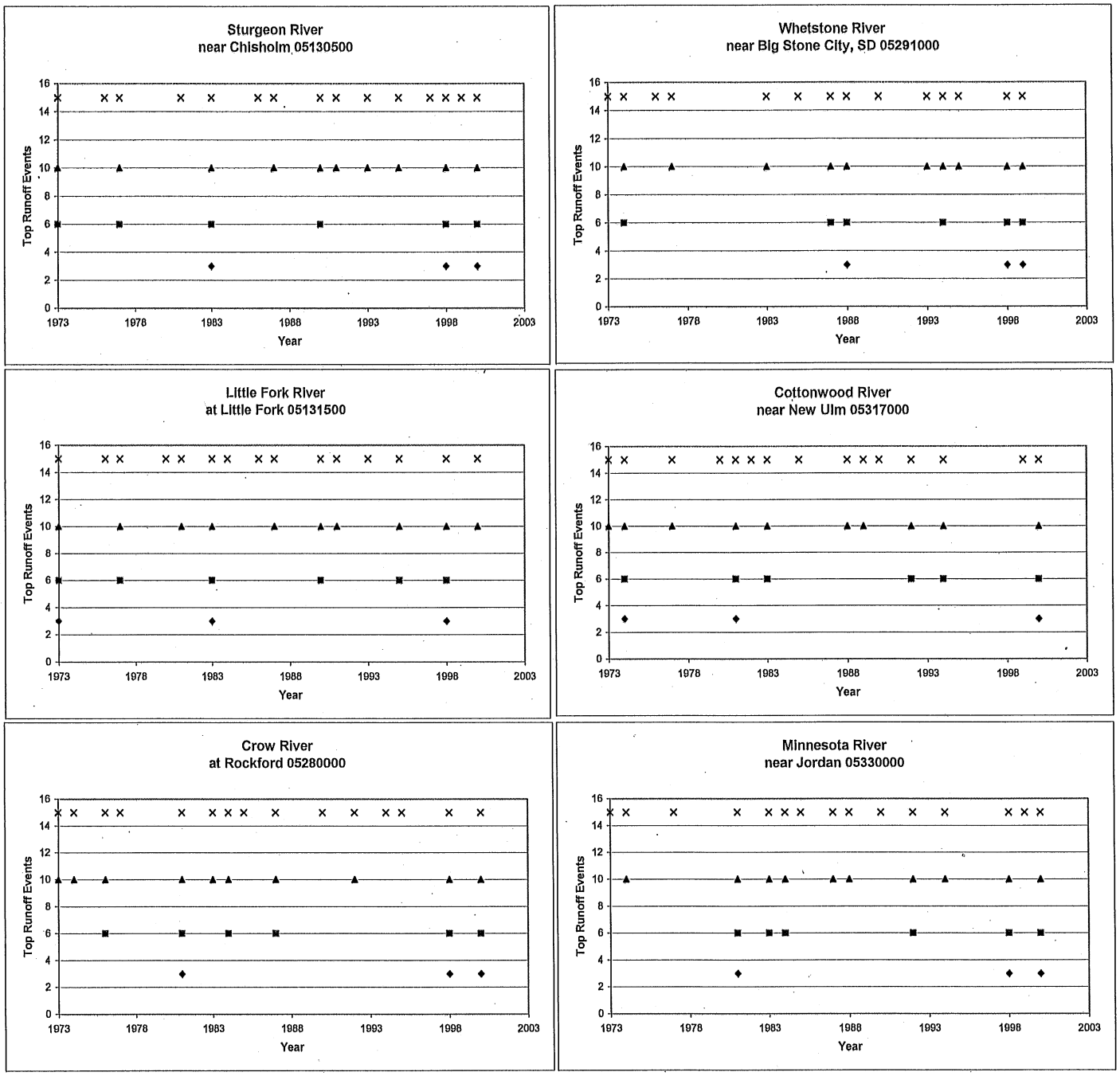


Figure 23: Example of annual first spring runoff flows

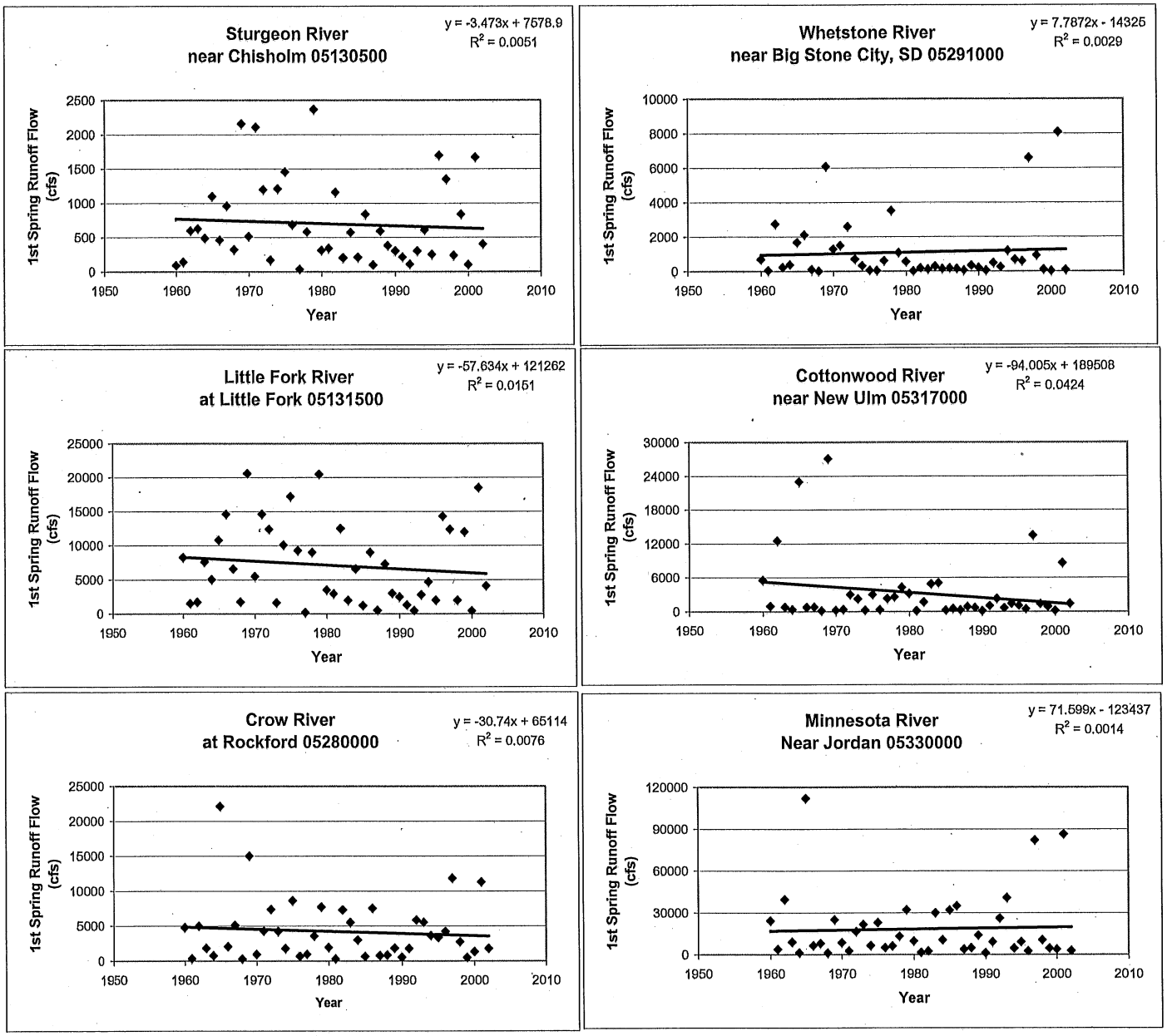


Figure 24: Example of annual first spring peak flows

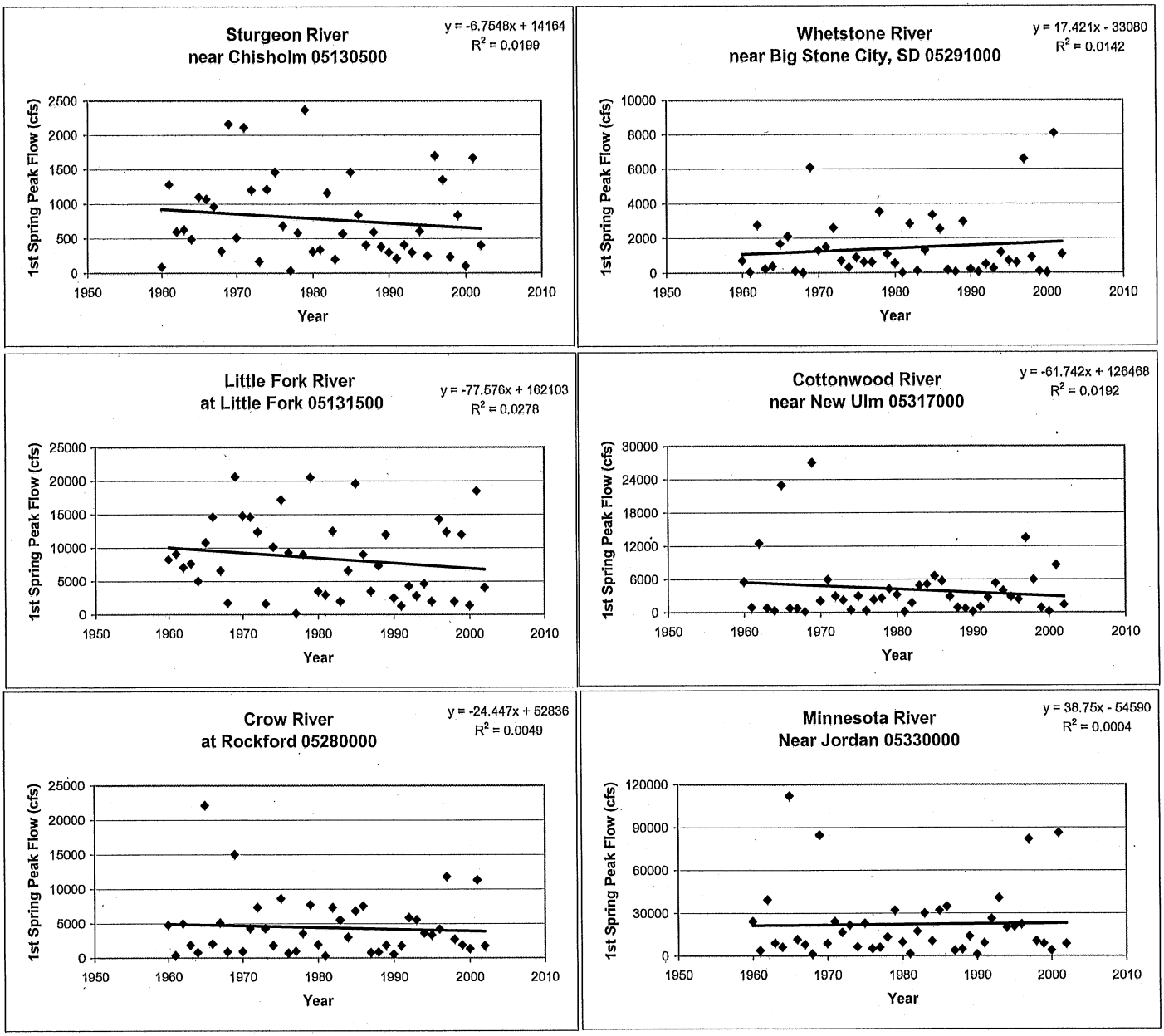


Figure 25: Example of annual average stream temperatures

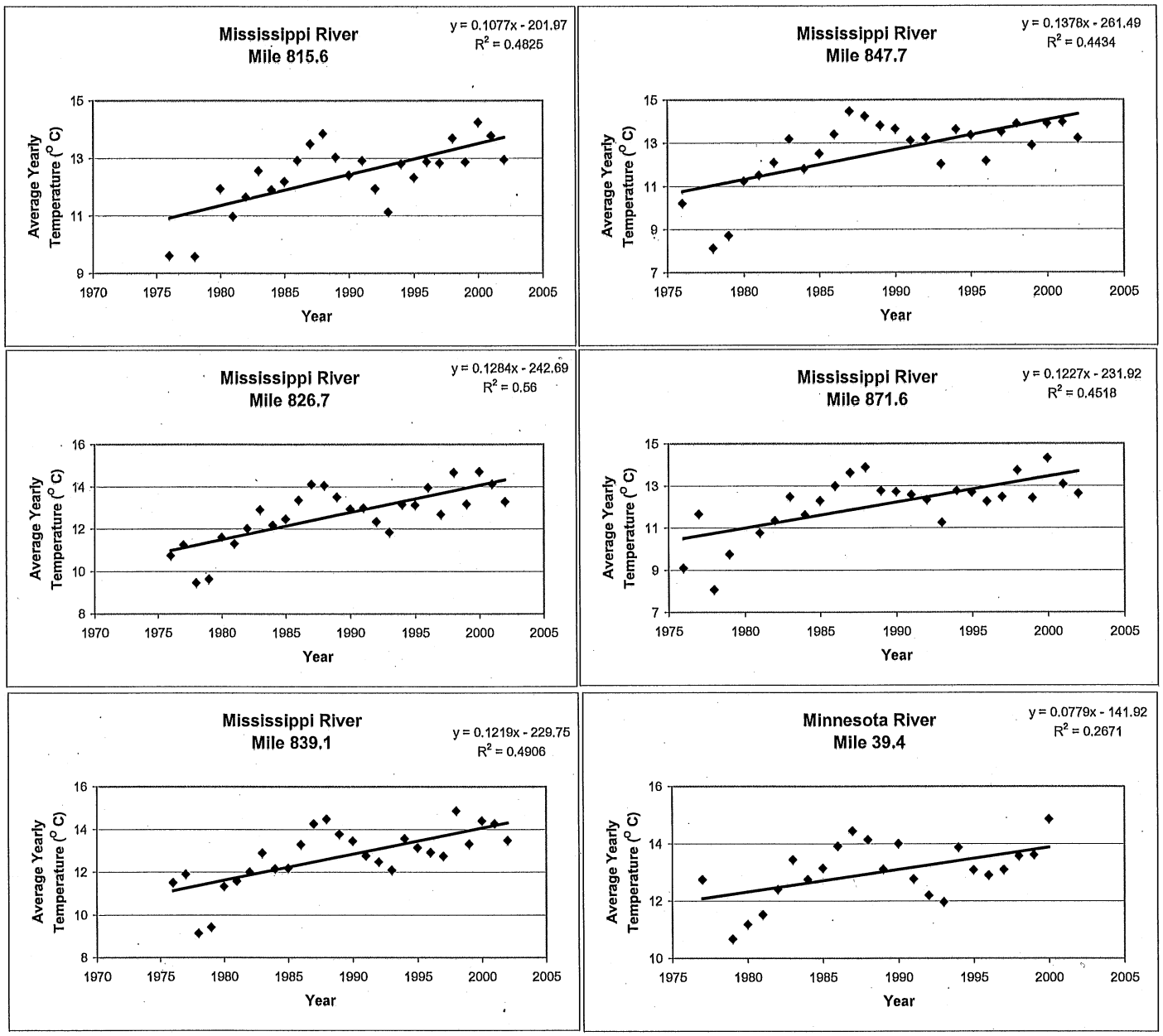


Figure 26: Example of ten-year running average annual stream temperatures

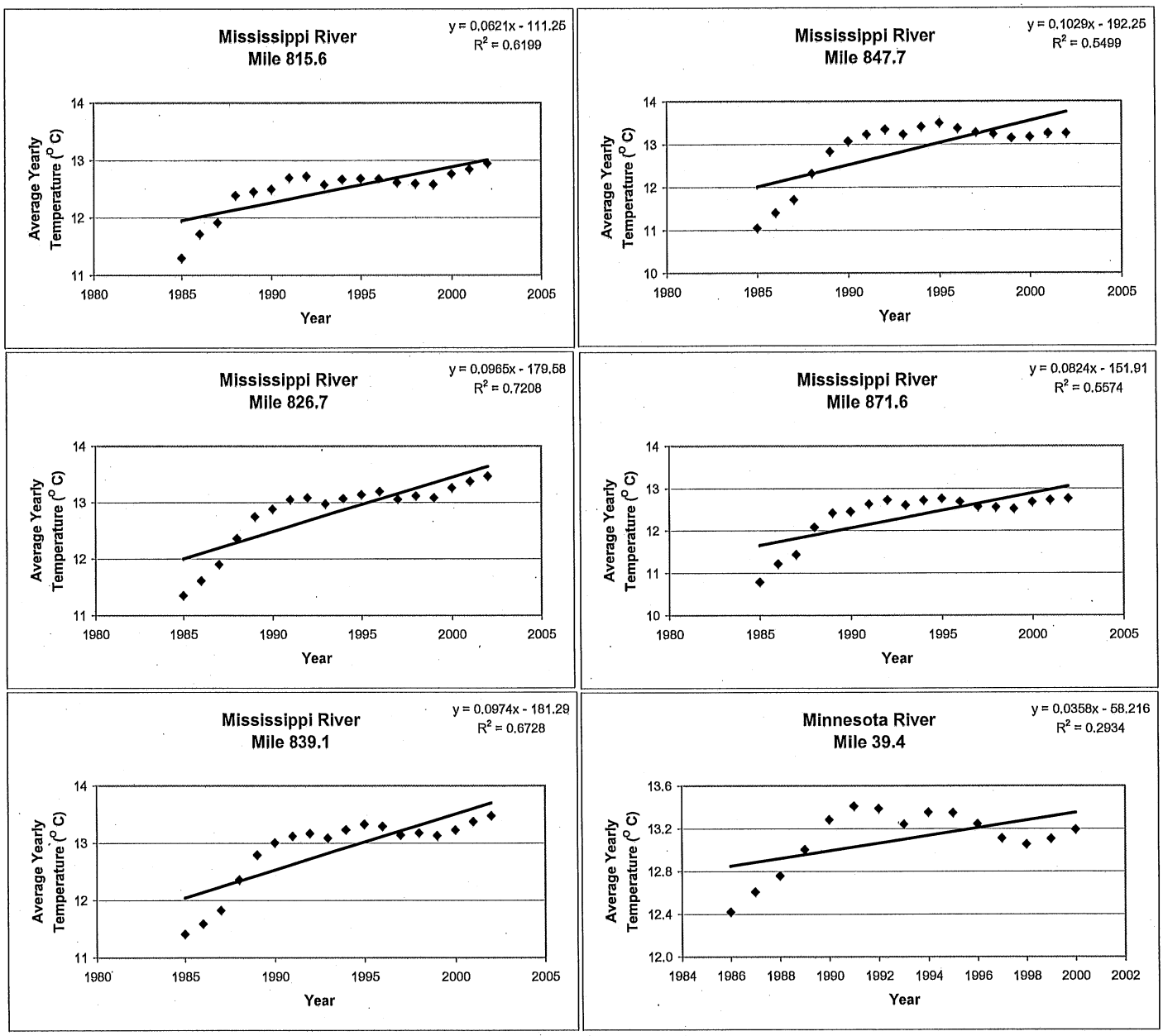


Figure 27: Comparison of ice-out date and average annual air temperature ten-year running averages

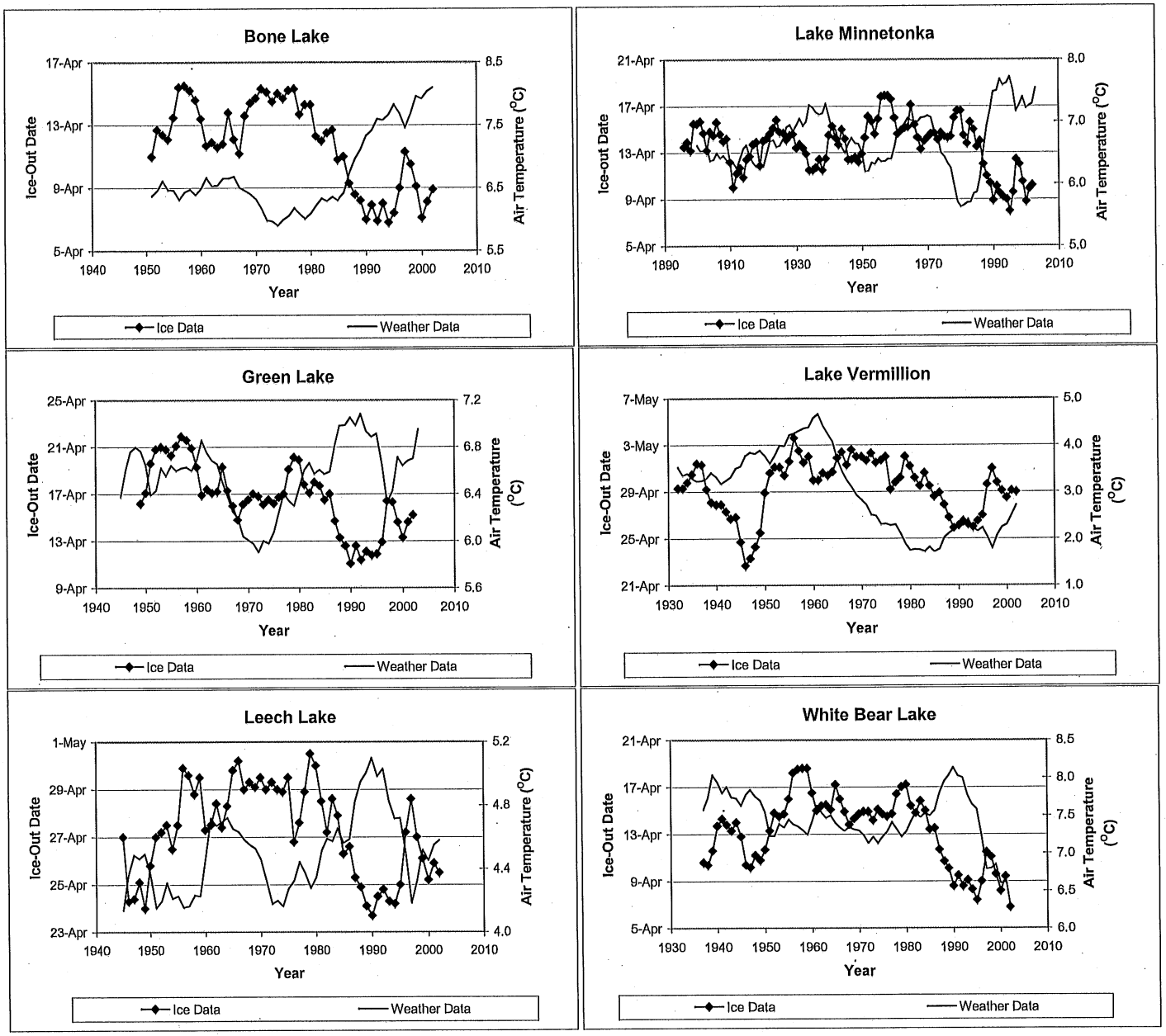


Figure 28: Variations of average ice-out date and average annual air temperature for six lakes (includes Lakes: Bone, Green, Leech, Minnetonka, Vermillion, and White Bear)

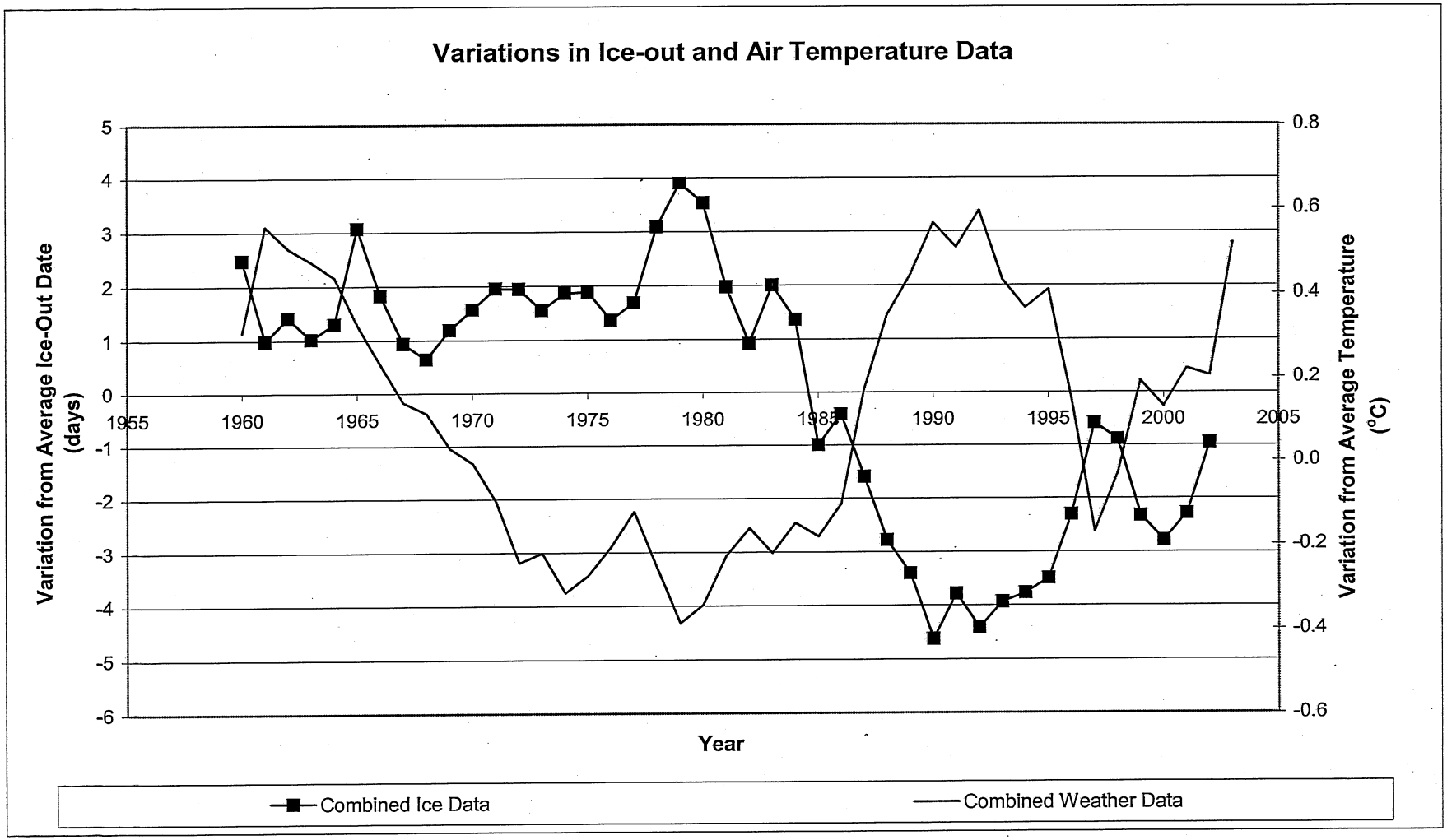


Figure 29: Comparison of first spring runoff date and average annual air temperature ten-year running averages

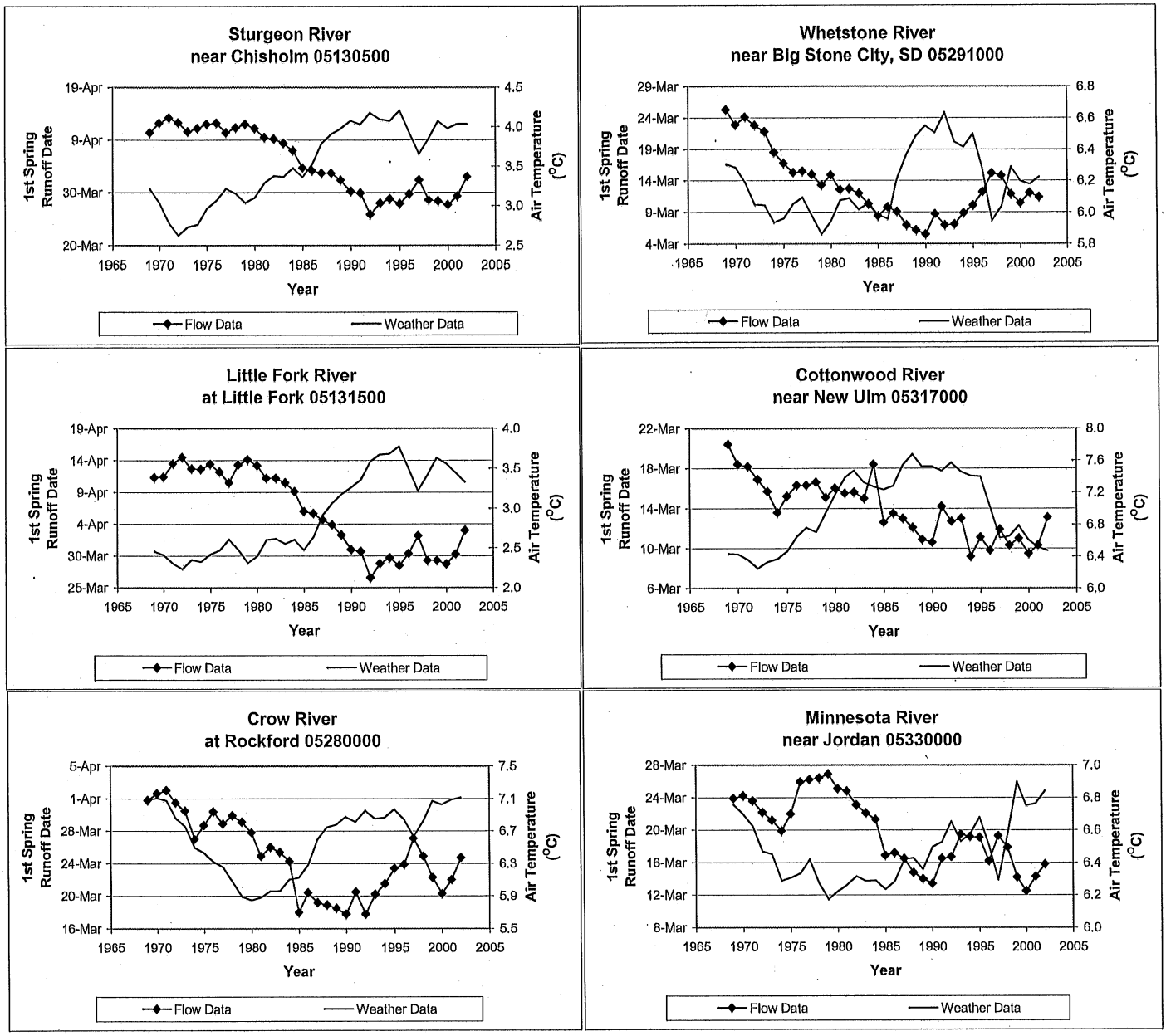


Figure 30: Variations of average first spring runoff date and average annual air temperatures at nine stations (includes Stations: 05130500, 05131500, 05280000, 05291000, 05313500, 05317000, 05320000, 05320500, 05330000)

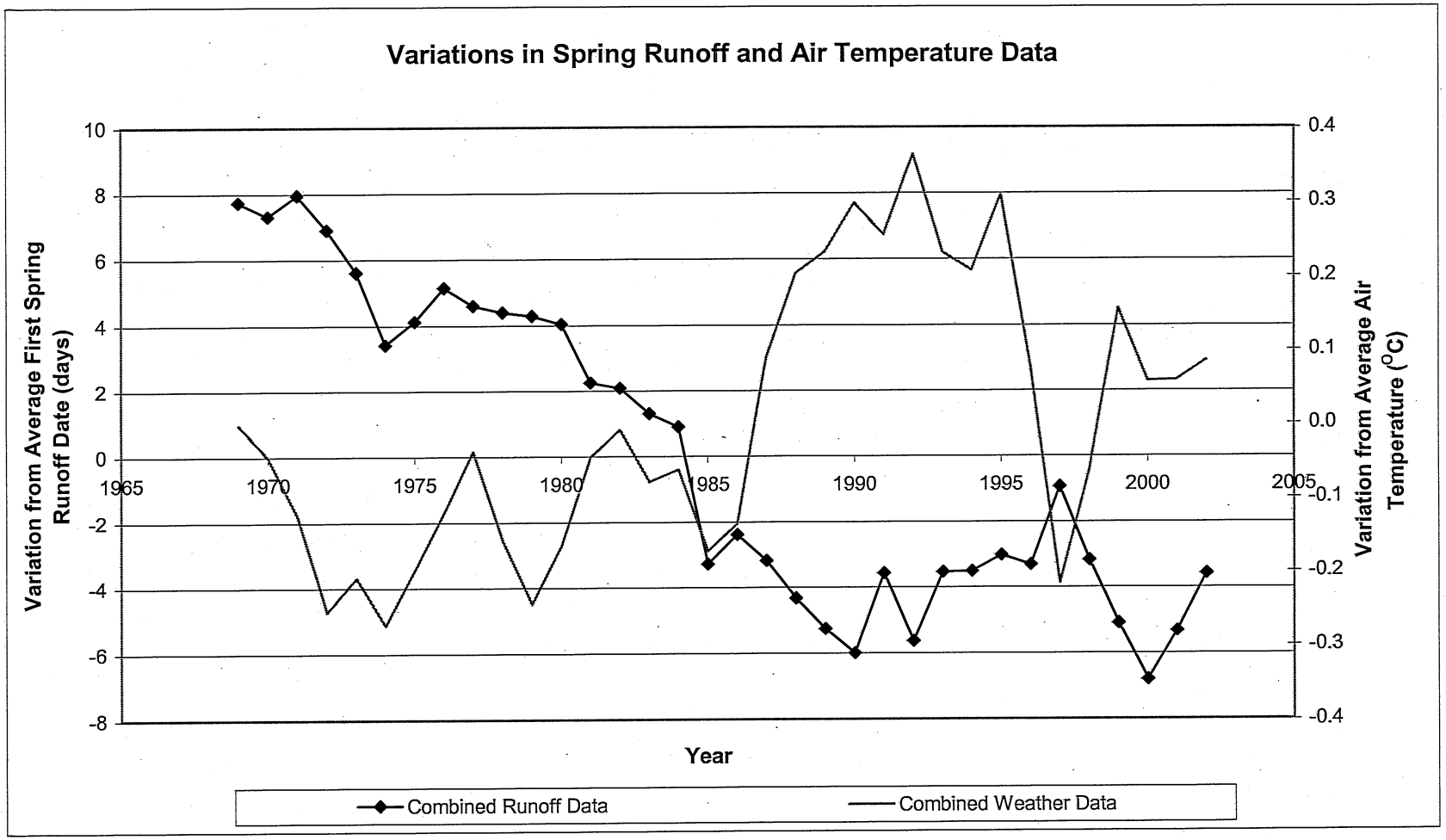


Table 1: Average lake characteristics (73 Lakes)

		Latitude (^{O})	Longitude (^{O})	Surface Area (km^2)	Maximum Depth (m)	Record Length (years)
Ice-Out Data:	**Average Value**	46.6192	94.1695	116.3	16.9	37.7
	Standard Deviation	1.1802	1.1717	501.6	11.3	30.0
Ice-In Data:	**Average Value**	46.6378	94.0821	2.6	16.3	23.2
	Standard Deviation	0.9286	1.1061	2.7	10.2	9.0

Table 2: Average gaging station characteristics (21 Stations)

	Latitude (^{O})	Longitude (^{O})	Record Length (years)	Watershed Area (miles^2)	Mean Annual Flow (cfs)
Average Value	45.5906	94.2192	38.8	3079	1481
Standard Deviation	1.5450	1.2474	5.9	5844	3246

Table 3: Summary of ice-out date statistics and trends for annual data

	Complete Record	1970 to Present	1980 to Present	1990 to Present
Number of Lakes	73	30	39	73
Average Ice-Out Date	17-Apr	17-Apr	15-Apr	16-Apr
Average Standard Deviation of Ice-Out Date	7.05	7.06	7.32	7.32
Average Trend (days/yr)	-0.132	-0.237	-0.002	-0.250
Standard Deviation of Trend (days/yr)	0.189	-0.095	0.174	0.318
Average r^2 of Trend	0.036	0.079	0.021	0.032
Standard Deviation of r^2	0.040	0.055	0.043	0.037
RMSE of Trend (days)	8.47	8.44	8.25	8.86

Table 4: Summary of event sorting analysis for ice-out dates

	30-Year Record (16 Lakes)				60-Year Record (6 Lakes)				80-Year Record (2 Lakes)				110-Year Record (1 Lake)			
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Observed Events		Top Ice-Out Events	Number of Events Expected	Observed Events		Top Ice-Out Events	Number of Events Expected	Observed Events		Top Ice-Out Events	Number of Events Expected	Observed Events	
			Number Above Expected*	% Above Expected			Number Above Expected*	% Above Expected			Number Above Expected*	% Above Expected			Number Above Expected*	% Above Expected
5	3	1	7	44	3	0	6	100	4	0	2	100	5	0	1	100
	6	1	15	94	6	1	2	33	8	1	1	50	11	1	1	100
	10	2	10	63	12	1	6	100	16	1	2	100	22	1	1	100
	15	3	6	38	20	2	4	67	20	1	2	100	36	2	1	100
	-	-	-	-	30	3	2	33	40	3	0	0	55	3	0	0
Average			*10*	*59*			*4*	*67*			*1*	*70*			*1*	*80*
10	3	1	7	44	3	1	1	17	4	1	0	0	5	0	1	100
	6	2	9	56	6	1	2	33	8	1	1	50	11	1	1	100
	10	3	6	38	12	2	4	67	16	2	1	50	22	2	1	100
	15	5	4	25	20	3	2	33	20	3	1	50	36	3	1	100
	-	-	-	-	30	5	2	33	40	5	0	0	55	5	0	0
Average			*7*	*41*			*2*	*37*			*1*	*30*			*1*	*80*
15	3	2	2	13	3	1	1	17	4	1	0	0	5	1	0	0
	6	3	6	38	6	2	0	0	8	2	0	0	11	2	0	0
	10	5	4	25	12	3	4	67	16	3	1	50	22	3	1	100
	15	8	1	6	20	5	4	67	20	4	1	50	36	5	1	100
	-	-	-	-	30	8	1	17	40	8	0	0	55	8	1	100
Average			*3*	*20*			*2*	*33*			*0*	*20*			*1*	*60*
20	-	-	-	-	3	1	5	83	4	1	2	100	5	1	1	100
	-	-	-	-	6	2	2	33	8	2	1	50	11	2	1	100
	-	-	-	-	12	4	4	67	16	4	1	50	22	4	1	100
	-	-	-	-	20	7	6	100	20	5	1	50	36	7	1	100
	-	-	-	-	30	10	5	83	40	10	2	100	55	10	1	100
Average							*4*	*73*			*1*	*70*			*1*	*100*
30	-	-	-	-	3	2	3	50	4	2	1	50	5	1	1	100
	-	-	-	-	6	3	4	67	8	3	1	50	11	3	1	100
	-	-	-	-	12	6	6	100	16	6	1	50	22	6	1	100
	-	-	-	-	20	10	6	100	20	8	1	50	36	10	1	100
	-	-	-	-	30	15	4	67	40	15	2	100	55	15	1	100
Average							*5*	*77*			*1*	*60*			*1*	*100*
40	-	-	-	-	3	2	3	50	4	2	1	50	5	2	1	100
	-	-	-	-	6	4	2	33	8	4	1	50	11	4	1	100
	-	-	-	-	12	8	4	67	16	8	1	50	22	8	1	100
	-	-	-	-	20	13	6	100	20	10	1	50	36	13	1	100
	-	-	-	-	30	20	2	33	40	20	1	50	55	20	1	100
Average							*3*	*57*			*1*	*50*			*1*	*100*

** Number of lakes with more events than expected*

Table 5: Summary of ice-in date statistics and trends for annual data

	Complete Record	1970 to Present	1980 to Present	1990 to Present
Number of Lakes	34	8	16	34
Average Ice-In Date	24-Nov	21-Nov	23-Nov	25-Nov
Average Standard Deviation of Ice-In Date	6.58	5.71	6.99	6.90
Average Trend (days/yr)	0.754	0.150	0.353	1.441
Standard Deviation of Trend (days/yr)	0.752	0.173	0.215	0.859
Average r^2 of Trend	0.142	0.043	0.067	0.314
Standard Deviation of r^2	0.138	0.069	0.056	0.387
RMSE of Trend (days)	9.74	8.44	9.76	10.80

Table 6: Summary of event sorting analysis for ice-in dates

	30-Year Record (6 Lakes)			
Last Years of Record	**Top Ice-Out Events**	**Number of Events Expected**	**Observed Events**	
			Number Above Expected*	**% Above Expected**
5	3	1	6	100
	6	1	6	100
	10	2	4	67
	15	3	5	83
Average			*5*	*88*
10	3	1	6	100
	6	2	6	100
	10	3	4	67
	15	5	5	33
Average			*5*	*75*
15	3	2	3	50
	6	3	6	100
	10	5	3	50
	15	8	2	33
Average			*4*	*58*

** Number of lakes with more events than expected*

Table 7: Summary of statistics and trends in spring runoff dates

	First Spring Runoff Date	First Spring Peak Date	Maximum Spring Peak Date
Number of Stations	21	21	21
Average Date of Event	22-Mar	26-Mar	6-Apr
Average Standard Deviation of Event (days)	13.54	12.68	11.17
Average Trend (days/yr)	-0.300	-0.228	0.009
Standard Deviation of Trend (days/yr)	0.235	0.193	0.341
Average r^2 of Trend	0.077	0.054	0.027
Standard Deviation of r^2	0.057	0.046	0.035
RMSE of Trend (days)	14.82	13.87	17.62

Table 8: Summary of 30-year event sorting analysis for spring runoff dates (9 Stations)

			1st Spring Runoff		1st Spring Peak	
			Observed Events		Observed Events	
Last Years of Record	Top Runoff Events	Number of Events Expected	Number Above Expected*	% Above Expected	Number Above Expected*	% Above Expected
5	3	1	2	22	6	67
	6	1	7	78	7	78
	10	2	5	56	1	11
	15	3	2	22	0	0
Average			*4*	*44*	*4*	*39*
10	3	1	5	56	7	78
	6	2	6	67	3	33
	10	3	7	78	4	44
	15	5	5	56	2	22
Average			*6*	*64*	*4*	*44*
15	3	2	1	11	2	22
	6	3	3	33	3	33
	10	5	4	44	5	56
	15	8	0	0	0	0
Average			*2*	*22*	*3*	*28*

** Number of stations with more events than expected*

Table 9: Summary of statistics and trends in spring runoff flows

	First Spring Runoff Flow	First Spring Peak Flow	Maximum Spring Peak Flow
Number of Stations	21	21	21
Average Event Flow (cfs)	4350	5324	6212
Average Standard Deviation of Event Flow (cfs)	5901	7588	8672
Average Trend (cfs/yr)	-44.20	-13.71	-17.45
Standard Deviation of Trend (cfs/yr)	83.70	59.80	58.50
Average r^2 of Trend	0.028	0.022	0.031
Standard Deviation of r^2	0.039	0.034	0.038
RMSE of Trend (cfs)	4898	5075	5067

Table 10: Summary of statistics and trends in average annual stream temperature (15 Stations)

Average River Temperature (°C)	Average Standard Deviation in River Temperature (°C)	Average Trend (°C/yr)	Standard Deviation of Trend (°C/yr)	Average r^2 of Trend	Standard Deviation of r^2	RMSE of Trend (°C)
12.32	1.247	0.107	0.031	0.416	0.147	0.93

APPENDIX A
LAKE ICE-OUT ANALYSIS

Statistical Analyses of Lake Ice-Out Dates For Whole Record

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
5th Crow Wing	29-0092	Hubbard	14	1989	2002	4/13	4/15	4/18	8.43	03/31/00	05/01/96
Artichoke	6000200	BIG STONE	20	1983	2002	4/9	4/11		10.23	03/22/00	04/22/01
Bad Axe	29-0208	Hubbard	14	1989	2002	4/21	4/19	4/25	7.26	04/11/00	05/06/96
Bad Medicine	03-0088	Becker	30	1973	2002	4/22	4/22	4/28	8.11	04/08/81	05/11/79
Bemidji	4013000	BELTRAMI	20	1983	2002	4/24	4/25	4/25	7.47	04/13/98	05/10/96
Big Green	13-0041-02	Chisago	23	1979	2001	4/9	4/11	4/18	7.98	03/23/00	04/24/96
Big Pine	58-0138	Pine	38	1965	2002	4/17	4/18	4/23	12.96	04/03/81	05/02/75
Big Sandy	1006200	AITKIN	73	1930	2002	4/20	4/21	4/26	7.37	03/31/00	05/04/96
Big Stone	6015200	BIG STONE	52	1951	2002	4/9	4/10	4/12	9.04	03/22/00	04/26/75
Big Trout	31-0410	Crow Wing	46	1957	2002	4/25	4/26	4/29	7.81	04/13/98	05/16/66
Big Turtle	04-0159	Beltrami	38	1965	2002	4/22	4/22	4/23	8.07	04/06/00	05/10/96
Big Watab	73-0102	Stearns	20	1983	2002	4/13	4/14	4/21	8.68	03/24/00	04/25/96
Blackduck	04-0069	Beltrami	16	1987	2002	4/22	4/23	4/23	8.48	04/07/00	05/10/96
Bone	82-0054	Washington	61	1942	2002	4/11	4/12	4/16	9.09	03/15/00	04/29/65
Bronson	35000300	KITTSON	18	1984	2001	4/14	4/13	4/22	6.64	04/01/00	04/27/96
Clear	72008900	Sibley	109	1894	2002	4/3	4/3	4/15	10.70	03/07/00	04/27/51
Collinwood	86-0293	Wright	18	1985	2002	4/8	4/8	4/1	10.47	03/08/00	04/23/96
Crow Wing	18-0155	Crow Wing	35	1968	2002	4/14	4/15	4/18	11.59	03/25/00	04/30/75
Detriot	3038100	Becker	110	1893	2002	4/20	4/20	4/21	10.49	03/23/10	05/23/95
Doan	31-0536	Itasca	18	1984	2001	4/18	4/18	4/18	8.54	03/31/00	05/06/96
Edna	18-0396	Crow Wing	24	1979	2002	4/17	4/17	4/18	6.85	04/02/81	05/02/79
Elephant	69-0810	St. Louis	17	1986	2002	4/22	4/22	4/21	8.67	04/05/00	05/13/96
Ely	69-0660	St. Louis	33	1969	2001	4/23	4/24	4/28	7.66	04/05/00	05/09/96
Fall	38081100	LAKE	68	1935	2002	4/27	4/28	4/30	7.43	04/10/45	05/19/50
Fish Trap	49-0137	Morrison	17	1984	2000	4/15	4/17	4/17	8.45	03/26/00	04/30/96
Forest	82015900	WASHINGTON	23	1980	2002	4/7	4/8	4/18	9.81	03/18/00	04/23/96
Goose	13-0083-02	Chisago	14	1989	2002	4/9	4/11	4/16	8.82	03/24/00	04/23/96
Green	34007900	Kandiyohi	106	1897	2002	4/16	4/16	4/16	9.07	03/22/87	05/07/51
Gull	11030500	Crow Wing	53	1950	2002	4/21	4/22	4/14	8.94	04/02/00	05/18/50
Island	03-0153	Becker	13	1990	2002	4/20	4/19	4/11	7.77	04/11/98	05/08/96
Johnson	31-0586	Itasca	22	1980	2001	4/21	4/22	4/22	6.96	04/09/81	05/08/96
Kabekona	29-0075	Hubbard	27	1976	2002	4/22	4/23	4/23	6.37	04/12/98	05/08/96
Kabetogama	69084500	Koochiching	51	1952	2002	4/29	4/30	4/28	7.68	04/13/98	05/18/96
Knife	33002800	KANABEC	14	1988	2001	4/12	4/13	4/13	7.72	03/27/00	04/23/95
Lake of the Woods	39000200	LAKE OF THE WOOD	18	1985	2002	4/29	5/2	5/2	9.53	04/08/00	05/16/96
Leech	11020300	Cass	67	1936	2002	4/27	4/28	4/24	8.45	04/09/45	05/23/50
Little Bass	04-0110	Beltrami	22	1981	2002	4/16	4/16	4/25	8.42	04/01/81	05/06/96
Little Green	13-0041-01	Chisago	24	1979	2002	4/9	4/11	4/18	8.07	03/22/00	04/24/96
Little McDonald	56-0328	Otter Tail	25	1977	2001	4/21	4/22	4/28	8.12	04/05/00	05/11/96
Long	03-0383	Becker	43	1960	2002	4/19	4/19	4/18	8.24	04/03/00	05/08/79
Long	69-0765	St. Louis	17	1986	2002	4/21	4/20	4/20	9.05	04/02/00	05/12/96
Long (Boy River)	11-0142	Cass	28	1974	2001	4/20	4/20	4/22	8.21	04/04/00	05/05/96
Loon	69-0426	St. Louis	24	1979	2002	4/23	4/23	4/28	7.00	04/09/87	05/08/96
Martin	02-0034	Anoka	21	1982	2002	4/8	4/9	4/8	8.84	03/20/00	04/22/96
McDonald	56-0386-02	Otter Tail	34	1968	2001	4/19	4/20	4/22	8.61	04/01/00	05/06/79
McKinney	31037000	ITASCA	37	1964	2000	4/19	4/19	4/19	8.35	03/31/00	05/06/96
Mille Lacs	48000200	Aitkin	47	1956	2002	4/24	4/24	4/24	7.60	04/02/00	05/08/75
Minnetonka	27013300	Hennepin	148	1855	2002	4/13	4/14	4/18	9.60	3/11/1878	5/8/1856
Minnewaska	61013000	Pope	97	1906	2002	4/13	4/14	4/12	9.23	03/23/00	05/07/50
Osakis	77021500	Todd	136	1867	2002	4/19	4/20	4/22	9.64	3/13/1878	05/14/50
Otter Tail	56024200	OTTER TAIL	13	1988	2000	4/15	4/13	4/10	7.80	04/03/00	04/28/96
Pokegama	31053200	ITASCA	41	1962	2002	4/25	4/27	4/29	8.17	04/06/00	05/10/96
Ponto	11-0234	Cass	17	1986	2002	4/18	4/19	4/9	7.98	04/05/00	05/04/96
Portage	29-0250	Hubbard	28	1974	2001	4/18	4/19	4/25	8.45	04/05/00	05/05/75
Rainy	69069400	KOOCHICHING	20	1983	2002	5/1	5/1	5/1	8.39	04/13/98	05/19/96
Red	4003500	BELTRAMI	20	1983	2002	4/27	4/28	4/29	8.03	04/12/00	05/17/96
Richardson	47-0088	Meeker	13	1989	2001	4/6	4/6	4/1	13.29	03/01/00	04/20/96
Sallie	3035900	BECKER	33	1970	2002	4/18	4/18	4/24	8.47	04/03/00	05/07/79
Sand	31-0438	Itasca	13	1989	2001	4/21	4/21	4/19	8.45	04/03/00	05/09/96
Secret	31-0061	Itasca	24	1979	2002	4/16	4/17	4/17	8.82	03/25/00	05/04/96
Shagawa	69-0069	St. Louis	37	1965	2001	4/28	4/28	4/29	8.31	04/14/98	05/16/96
Shetek	51004600	Murray	42	1960	2001	4/5	4/4	4/13	11.12	03/08/00	04/24/62
Sisseebakwet	31-0554	Itasca	34	1968	2001	4/23	4/23	4/26	7.51	04/05/00	05/13/96
Swan (main)	31-0067-02	Itasca	16	1987	2002	4/23	4/24	4/24	8.02	04/06/00	05/09/96
Swan (west)	31-0067-01	Itasca	16	1987	2002	4/23	4/24	4/24	8.02	04/06/00	05/09/96
Vermillion	11002900	St Louis	93	1910	2002	4/29	4/30	5/1	8.31	04/10/45	05/23/50
Virginia	10-0015	Carver	11	1992	2002	4/5	4/6	4/15	11.90	03/08/00	04/20/96
W Jefferson	40-0092-04	Le Seuer	25	1978	2002	4/1	4/3	4/3	11.43	03/07/00	04/18/79
Waconia	10005900	Carver	63	1940	2002	4/12	4/13	4/7	9.48	03/15/00	05/01/65
Wall	56-0658	Otter Tail	35	1968	2002	4/14	4/14	4/13	8.49	03/24/00	04/28/79
West Battle	56023900	OTTER TAIL	13	1988	2000	4/16	4/18	4/21	9.11	03/31/00	05/05/96
White Bear	82016700	Ramsey	75	1928	2002	4/12	4/12	4/17	9.38	03/15/02	05/04/50
Wirth	27-0037	Hennepin	27	1975	2001	4/3	4/4	4/4	11.17	03/08/00	04/23/75
Average			**38**	**1965**	**2002**	**4/17**	**4/17**	**4/19**	**8.75**		
Standard Deviation			**30.02**	**29.87**	**0.58**	**7.05**	**7.04**	**7.31**	**1.37**		

Statistical Analyses of Lake Ice-Out Dates For 1970 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
Big Pine	58-0138	Pine	38	1965	2002	4/17	4/18	4/23	7.47	04/03/81	05/02/75
Big Sandy	1006200	AITKIN	73	1930	2002	4/20	4/20	4/22	8.08	03/31/00	05/04/96
Big Stone	6015200	BIG STONE	52	1951	2002	4/9	4/11	4/18	9.21	03/22/00	04/26/75
Big Trout	31-0410	Crow Wing	46	1957	2002	4/25	4/26	4/29	7.33	04/13/98	05/14/96
Big Turtle	04-0159	Beltrami	38	1965	2002	4/22	4/22	4/23	8.30	04/06/00	05/10/96
Bone	82-0054	Washington	61	1942	2002	4/10	4/13	4/16	9.31	03/15/00	04/26/75
Clear	72008900	Sibley	109	1894	2002	4/2	4/1	4/15	11.45	03/07/00	04/26/75
Crow Wing	18-0155	Crow Wing	35	1968	2002	4/15	4/15	4/18	9.12	03/25/00	04/30/75
Detriot	3038100	Becker	110	1893	2002	4/20	4/18	4/21	11.14	04/03/00	05/23/95
Ely	69-0660	St. Louis	33	1969	2001	4/23	4/23	4/28	7.62	04/05/00	05/09/96
Fall	38081100	LAKE	68	1935	2002	4/27	4/28	4/28	5.66	04/15/00	05/07/75
Green	34007900	Kandiyohi	106	1897	2002	4/15	4/17	4/18	9.87	03/22/87	04/30/79
Gull	11030500	Crow Wing	53	1950	2002	4/20	4/22	4/28	8.69	04/02/00	05/04/96
Kabetogama	69084500	Koochiching	51	1952	2002	4/28	4/29	4/18	8.10	04/13/98	05/18/96
Leech	11020300	Cass	67	1936	2002	4/26	4/27	4/29	7.87	04/13/98	05/12/79
Long	03-0383	Becker	43	1960	2002	4/19	4/19	4/28	8.56	04/03/00	05/08/79
McDonald	56-0386-02	Otter Tail	34	1968	2001	4/19	4/20	4/28	8.77	04/01/00	05/06/79
McKinney	31037000	ITASCA	37	1964	2000	4/18	4/19	4/19	8.66	03/31/00	05/06/96
Mille Lacs	48000200	Aitkin	47	1956	2002	4/24	4/24	4/24	8.25	04/02/00	05/08/75
Minnetonka	27013300	Hennepin	148	1855	2002	4/12	4/13	4/19	9.90	03/18/00	04/28/75
Minnewaska	61013000	Pope	97	1906	2002	4/13	4/15	4/24	9.97	03/23/00	04/29/75
Osakis	77021500	Todd	136	1867	2002	4/16	4/17	4/15	9.65	03/24/00	05/03/79
Shagawa	69-0069	St. Louis	37	1965	2001	4/27	4/28	5/2	8.05	04/14/98	05/16/96
Shetek	51004600	Murray	42	1960	2001	4/5	4/4	4/13	10.99	03/08/00	04/22/75
Siseebakwet	31-0554	Itasca	34	1968	2001	4/23	4/25	4/26	7.70	04/05/00	05/13/96
Vermillion	11002900	St Louis	93	1910	2002	4/28	4/29	5/3	7.53	04/13/98	05/16/96
Waconia	10005900	Carver	63	1940	2002	4/10	4/12	4/3	9.87	03/15/00	04/27/75
Wall	56-0658	Otter Tail	35	1968	2002	4/13	4/14	4/13	8.59	03/24/00	04/28/79
White Bear	82016700	Ramsey	75	1928	2002	4/10	4/12	4/19	10.35	03/15/02	04/28/75
Average			**64**	**1939**	**2002**	**4/17**	**4/18**	**4/21**	**8.83**		
Standard Deviation			**32.48**	**32.27**	**0.51**	**7.06**	**7.12**	**6.74**	**1.29**		

Statistical Analyses of Lake Ice-Out Dates For 1980 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
Bad Medicine	03-0088	Becker	29	1973	2002	4/21	4/22	4/28	7.31	04/08/81	05/09/96
Big Pine	58-0138	Pine	37	1965	2002	4/16	4/17	4/17	7.05	04/03/81	04/26/97
Big Sandy	1006200	AITKIN	72	1930	2002	4/19	4/20	4/17	7.73	03/31/00	05/04/96
Big Stone	6015200	BIG STONE	51	1951	2002	4/7	4/9	4/11	9.20	03/22/00	04/21/01
Big Trout	31-0410	Crow Wing	45	1957	2002	4/24	4/25	4/26	7.24	04/13/98	05/14/96
Big Turtle	04-0159	Beltrami	37	1965	2002	4/20	4/21	4/22	7.69	04/06/00	05/10/96
Big Watab	73-0102	Stearns	20	1983	2002	4/13	4/14	4/21	8.74	03/24/00	04/25/96
Bone	82-0054	Washington	61	1942	2002	4/8	4/7	4/16	9.45	03/15/00	04/23/96
Clear	72008900	Sibley	109	1894	2002	3/31	4/1	3/31	10.24	03/07/00	04/16/96
Crow Wing	18-0155	Crow Wing	35	1968	2002	4/13	4/15	4/18	8.79	03/25/00	04/25/96
Detriot	3038100	Becker	110	1893	2002	4/18	4/16	4/13	11.21	04/03/00	05/23/95
Edna	18-0396	Crow Wing	24	1979	2002	4/16	4/16	4/18	6.20	04/02/81	04/30/98
Ely	69-0660	St. Louis	33	1969	2001	4/22	4/22	4/28	7.41	04/05/00	05/09/96
Fall	38081100	LAKE	68	1935	2002	4/25	4/25	4/28	4.95	04/15/00	05/03/89
Green	34007900	Kandiyohi	106	1897	2002	4/13	4/15	4/21	9.90	03/22/87	04/26/97
Gull	11030500	Crow Wing	53	1950	2002	4/18	4/19	4/19	8.71	04/02/00	05/04/96
Kabekona	29-0075	Hubbard	27	1976	2002	4/21	4/22	4/21	5.95	04/12/98	05/08/96
Kabetogama	69084500	Koochiching	51	1952	2002	4/27	4/28	4/18	7.60	04/13/98	05/18/96
Leech	11020300	Cass	67	1936	2002	4/24	4/25	4/24	6.61	04/13/98	05/10/96
Little McDonald	56-0328	Otter Tail	25	1977	2001	4/21	4/23	4/28	9.12	04/05/00	05/11/96
Long	03-0383	Becker	43	1960	2002	4/17	4/16	4/14	7.36	04/03/00	05/04/96
Long (Boy River)	11-0142	Cass	28	1974	2001	4/19	4/20	4/22	7.87	04/04/00	05/05/96
Loon	69-0426	St. Louis	24	1979	2002	4/22	4/23	4/28	6.70	04/09/87	05/08/96
McDonald	56-0386-02	Otter Tail	34	1968	2001	4/17	4/19	4/14	8.22	04/01/00	05/04/96
McKinney	31037000	ITASCA	37	1964	2000	4/17	4/19	4/19	8.20	03/31/00	05/06/96
Mille Lacs	48000200	Aitkin	47	1956	2002	4/22	4/24	4/24	7.96	04/02/00	05/06/96
Minnetonka	27013300	Hennepin	148	1855	2002	4/10	4/13	4/19	9.96	03/18/00	04/24/96
Minnewaska	61013000	Pope	97	1906	2002	4/10	4/10	4/24	9.96	03/23/00	04/24/96
Osakis	77021500	Todd	136	1867	2002	4/13	4/14	4/22	8.45	03/24/00	04/25/01
Pokegama	31053200	ITASCA	41	1962	2002	4/22	4/22	4/20	8.80	04/06/00	05/10/96
Portage	29-0250	Hubbard	28	1974	2001	4/17	4/18	4/25	7.44	04/05/00	05/03/96
Sallie	3035900	BECKER	33	1970	2002	4/16	4/16	4/19	6.96	04/03/00	04/28/97
Shagawa	69-0069	St. Louis	37	1965	2001	4/26	4/25	4/24	7.23	04/14/98	05/16/96
Shetek	51004600	Murray	42	1960	2001	4/3	4/2	3/27	11.46	03/08/00	04/20/93
Siseebakwet	31-0554	Itasca	34	1968	2001	4/22	4/23	4/26	7.87	04/05/00	05/13/96
Vermillion	11002900	St Louis	93	1910	2002	4/27	4/28	4/25	6.80	04/13/98	05/16/96
W Jefferson	40-0092-04	Le Seuer	25	1978	2002	3/31	4/3	4/3	11.31	03/07/00	04/15/93
Waconia	10005900	Carver	63	1940	2002	4/7	4/7	4/3	9.63	03/15/00	04/20/01
Wall	56-0658	Otter Tail	35	1968	2002	4/12	4/13	4/13	8.04	03/24/00	04/25/96
White Bear	82016700	Ramsey	75	1928	2002	4/8	4/8	4/19	10.32	03/15/02	04/24/96
Wirth	27-0037	Hennepin	27	1975	2001	4/2	4/4	4/4	10.92	03/08/00	04/20/96
Average			**53**	**1949**	**2002**	**4/15**	**4/16**	**4/18**	**8.36**		
Standard Deviation			**32.11**	**31.91**	**0.50**	**7.32**	**7.25**	**7.96**	**1.54**		

Statistical Analyses of Lake Ice-Out Dates For 1990 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
Bad Axe	29-0208	Hubbard	14	1989	2002	4/20	4/19	4/25	7.11	04/11/00	05/06/96
Bad Medicine	03-0088	Becker	30	1973	2002	4/23	4/23	4/25	7.45	04/10/98	05/09/96
Bemidji	4013000	BELTRAMI	20	1983	2002	4/24	4/25	4/13	7.80	04/13/98	05/10/96
Big Green	13-0041-02	Chisago	23	1979	2001	4/8	4/6	4/6	8.98	03/23/00	04/24/96
Big Pine	58-0138	Pine	38	1965	2002	4/16	4/17	4/8	7.07	04/05/98	04/26/97
Big Sandy	1006200	AITKIN	73	1930	2002	4/18	4/19	4/17	9.05	03/31/00	05/04/96
Big Stone	6015200	BIG STONE	52	1951	2002	4/7	4/6	4/2	9.62	03/22/00	04/21/01
Big Trout	31-0410	Crow Wing	46	1957	2002	4/25	4/26	4/26	7.90	04/13/98	05/14/96
Big Turtle	04-0159	Beltrami	38	1965	2002	4/21	4/21	4/23	8.26	04/06/00	05/10/96
Big Watab	73-0102	Stearns	20	1983	2002	4/13	4/14	4/8	8.61	03/24/00	04/25/96
Blackduck	04-0069	Beltrami	16	1987	2002	4/22	4/23	4/23	9.08	04/07/00	05/10/96
Bone	82-0054	Washington	61	1942	2002	4/8	4/8	4/15	10.00	03/15/00	04/23/96
Bronson	35000300	KITTSON	18	1984	2001	4/14	4/12	4/22	7.21	04/01/00	04/27/96
Clear	72008900	Sibley	109	1894	2002	3/31	4/1	3/19	11.67	03/07/00	04/16/96
Collinwood	86-0293	Wright	18	1985	2002	4/8	4/4	4/1	11.84	03/08/00	04/23/96
Crow Wing	18-0155	Crow Wing	35	1968	2002	4/13	4/15	4/18	9.43	03/25/00	04/25/96
Detriot	3038100	Becker	110	1893	2002	4/20	4/18	4/28	13.24	04/03/00	05/23/95
Doan	31-0536	Itasca	18	1984	2001	4/18	4/19	4/22	9.13	03/31/00	05/06/96
Edna	18-0396	Crow Wing	24	1979	2002	4/18	4/18	4/16	5.68	04/09/91	04/30/98
Elephant	69-0810	St. Louis	17	1986	2002	4/23	4/22	4/22	8.76	04/05/00	05/13/96
Ely	69-0660	St. Louis	33	1969	2001	4/23	4/24	4/28	8.42	04/05/00	05/09/96
Fall	38081100	LAKE	68	1935	2002	4/24	4/24	4/22	4.67	04/15/00	05/02/92
Fish Trap	49-0137	Morrison	17	1984	2000	4/15	4/17	4/9	9.54	03/26/00	04/30/96
Forest	82015900	WASHINGTON	23	1980	2002	4/6	4/5		9.85	03/18/00	04/23/96
Goose	13-0083-02	Chisago	14	1989	2002	4/9	4/8	4/16	8.93	03/24/00	04/23/96
Green	34007900	Kandiyohi	106	1897	2002	4/13	4/15	4/6	9.55	03/24/00	04/26/97
Gull	11030500	Crow Wing	53	1950	2002	4/19	4/19	4/19	9.18	04/02/00	05/04/96
Johnson	31-0586	Itasca	22	1980	2001	4/23	4/22	4/22	5.64	04/18/91	05/08/96
Kabekona	29-0075	Hubbard	27	1976	2002	4/21	4/21	4/23	6.22	04/12/98	05/08/96
Kabetogama	69084500	Koochiching	51	1952	2002	4/27	4/29	4/29	8.38	04/13/98	05/18/96
Knife	33002800	KANABEC	14	1988	2001	4/11	4/11	4/6	8.10	03/27/00	04/23/95
Lake of the Woods	39000200	LAKE OF THE WOOD	18	1985	2002	4/27	4/30		10.60	04/08/00	05/16/96
Leech	11020300	Cass	67	1936	2002	4/25	4/25	4/28	6.64	04/13/98	05/10/96
Little Bass	04-0110	Beltrami	22	1981	2002	4/17	4/15	4/15	8.92	04/02/81	05/05/96
Little Green	13-0041-01	Chisago	24	1979	2002	4/8	4/6	4/5	9.10	03/22/00	04/24/96
Little McDonald	56-0328	Otter Tail	25	1977	2001	4/21	4/23	4/28	9.12	04/05/00	05/11/96
Long	03-0383	Becker	43	1960	2002	4/17	4/16	4/16	8.49	04/03/00	05/04/96
Long	69-0765	St. Louis	17	1986	2002	4/22	4/22	4/20	9.10	04/02/00	05/12/96
Long (Boy River)	11-0142	Cass	28	1974	2001	4/19	4/19	4/19	8.51	04/04/00	05/05/96
Loon	69-0426	St. Louis	24	1979	2002	4/23	4/24	4/23	6.45	04/12/98	05/08/96
Martin	02-0034	Anoka	21	1982	2002	4/8	4/8	4/5	8.91	03/20/00	04/22/96
McDonald	56-0386-02	Otter Tail	34	1968	2001	4/18	4/20	4/22	9.74	04/01/00	05/04/96
McKinney	31037000	ITASCA	37	1964	2000	4/16	4/18	4/19	9.44	03/31/00	05/06/96
Mille Lacs	48000200	Aitkin	47	1956	2002	4/22	4/24	4/24	9.19	04/02/00	05/06/96
Minnetonka	27013300	Hennepin	148	1855	2002	4/9	4/11	4/19	9.99	03/18/00	04/24/96
Minnewaska	61013000	Pope	97	1906	2002	4/12	4/15	4/24	9.72	03/23/00	04/24/96
Osakis	77021500	Todd	136	1867	2002	4/12	4/15	4/15	9.65	03/24/00	04/25/01
Otter Tail	56024200	OTTER TAIL	13	1988	2000	4/15	4/12	4/10	8.22	04/03/00	04/28/96
Pokegama	31053200	ITASCA	41	1962	2002	4/25	4/25	5/3	8.78	04/06/00	05/10/96
Ponto	11-0234	Cass	17	1986	2002	4/19	4/21	4/23	8.13	04/05/00	05/04/96
Portage	29-0250	Hubbard	28	1974	2001	4/16	4/18	4/18	8.54	04/05/00	05/03/96
Rainy	69069400	KOOCHICHING	20	1983	2002	5/1	5/1	5/1	8.81	04/13/98	05/19/96
Red	4003500	BELTRAMI	20	1983	2002	4/27	4/27	4/27	8.56	04/12/00	05/17/96
Sallie	3035900	BECKER	33	1970	2002	4/17	4/18		7.66	04/03/00	04/28/97
Secret	31-0061		24	1979	2002	4/16	4/17	4/17	9.86	03/25/00	05/04/96
Shagawa	69-0069	St. Louis	37	1965	2001	4/26	4/26	4/25	8.20	04/14/98	05/16/96
Shetek	51004600	Murray	42	1960	2001	4/3	3/30	3/27	13.32	03/08/00	04/20/93
Siseebakwet	31-0554	Itasca	34	1968	2001	4/22	4/22	4/26	9.19	04/05/00	05/13/96
Swan (main)	31-0067-02	Itasca	16	1987	2002	4/23	4/24	4/21	8.17	04/06/00	05/09/96
Swan (west)	31-0067-01	Itasca	16	1987	2002	4/23	4/24	4/21	8.17	04/06/00	05/09/96
Vermillion	11002900	St Louis	93	1910	2002	4/28	4/29	4/27	7.40	04/13/98	05/16/96
W Jefferson	40-0092-04	Le Seuer	25	1978	2002	4/1	4/3	4/3	11.31	03/07/00	04/15/93
Waconia	10005900	Carver	63	1940	2002	4/6	4/7	4/7	10.83	03/15/00	04/20/01
Wall	56-0658	Otter Tail	35	1968	2002	4/12	4/13	4/16	8.62	03/24/00	04/25/96
West Battle	56023900	OTTER TAIL	13	1988	2000	4/15	4/15	4/21	9.92	03/31/00	05/05/96
White Bear	82016700	Ramsey	75	1928	2002	4/6	4/6	4/19	11.52	03/15/02	04/24/96
Wirth	27-0037	Hennepin	27	1975	2001	4/3	4/4	4/4	12.71	03/08/00	04/20/96
Average			**40**	**1963**	**2002**	**4/16**	**4/17**	**4/17**	**8.92**		
Standard Deviation			**30.45**	**30.29**	**0.59**	**7.32**	**7.73**	**9.19**	**1.64**		

Complete Results of Linear Regression Analysis for Ice-Out Dates

Lake Name	MNDNR Lake ID Number	Latitude	Longitude	Surface Area (acres)	Surface Area (km^2)	Maximum Depth (ft)	Maximum Depth (m)	County	Record Length			Slopes: Complete			Slopes: 1970 to Now		
									Length (years)	From	To	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2
5th Crow Wing	29-0092	46.92222	94.8925	392	1.6	35	10.7	Hubbard	14	1989	2002	-0.1868	8.40	0.0075			
Artichoke	6000200	45.33	96.13	2011	8.1	16	4.7	Big Stone	20	1983	2002	-0.0864	10.22	0.0021			
Bad Axe	29-0208	47.08778	94.95					Hubbard	14	1989	2002	-0.4484	7.01	0.0667			
Bad Medicine	03-0088	47.124	95.404					Becker	30	1973	2002	-0.0586	8.09	0.0038			
Bemidji	4013000	47.5	94.83	6920	28.0	76	23.2	Beltrami	20	1983	2002	0.0735	7.46	0.0027			
Big Green	13-0041-02	45.34389	92.89611	1550	6.3			Chisago	23	1979	2001	-0.1956	7.87	0.0285			
Big Pine	58-0138	46.20833	93.05	387	1.6	25	7.6	Pine	38	1965	2002	-0.0824	7.94	0.0143	-0.1507	7.32	0.0381
Big Sandy	1006200	46.78	93.33	9380	38.0	84	25.6	Aitkin	73	1930	2002	-0.0518	7.28	0.023	-0.1898	7.84	0.0572
Big Stone	6015200	45.51	96.75	6028	24.4	16	4.9	Big Stone	52	1951	2002	-0.1059	8.89	0.0316	-0.2191	8.97	0.051
Big Trout	31-0410	47.46333	93.5475	1659	6.7	160	48.8	Crow Wing	46	1957	2002	-0.0846	7.56	0.0187	-0.0381	7.32	0.0026
Big Turtle	04-0159	47.61861	94.87056	1436	5.8	45	13.7	Beltrami	38	1965	2002	-0.1822	7.99	0.0604	-0.2019	8.07	0.0553
Big Watab	73-0102	45.54722	94.45	227	0.9	123	37.5	Stearns	20	1983	2002	-0.1400	8.63	0.0130			
Blackduck	04-0069	47.75	94.625	2742	11.1	28	8.5	Beltrami	16	1987	2002	-0.2831	8.36	0.0284			
Bone	82-0054	45.28611	92.85972	206	0.8	32	9.8	Washington	61	1942	2002	-0.0763	8.99	0.0222	-0.2650	9.97	0.0758
Bronson	35000300	48.72	96.59	313	1.3	32	9.8	Kittson	18	1984	2001	-0.3127	6.45	0.0553			
Clear	72008900	44.457	94.514					Sibley	109	1894	2002	0.0224	10.68	0.0042	-0.3583	10.81	0.1089
Collinwood	86-0293	45.05278	94.25278	584	2.4	28	8.5	Wright	18	1985	2002	-0.0193	10.47	0.0001			
Crow Wing	18-0155	46.23694	94.34028	373	1.5	26	7.9	Crow Wing	35	1968	2002	-0.1922	8.92	0.0465	-0.2951	8.66	0.098
Detroit	3038100	46.81	95.81	3089	12.5	82	25.0	Becker	110	1893	2002	0.0038	10.49	0.0001	-0.1387	11.06	0.0154
Doan	31-0536	47.42083	93.575	89	0.4	40	12.2	Itasca	18	1984	2001	-0.0172	8.54	0.0001			
Edna	18-0396	46.53444	94.31306	153	0.6	63	19.2	Crow Wing	24	1979	2002	0.1896	6.72	0.0383			
Elephant	69-0810	48.19417	92.74611	742	3.0	30	9.1	St. Louis	17	1986	2002	0.1838	8.62	0.0115			
Ely	69-0660	47.45111	92.48472	57	0.2	70	21.3	St. Louis	33	1969	2001	-0.1663	7.48	0.0487	-0.1184	7.54	0.0212
Fall	38081100	47.98	91.68	2322	9.4	32	9.8	Lake	68	1935	2002	-0.0505	7.36	0.0182	-0.2324	5	0.2197
Fish Trap	49-0137	46.20833	94.625	1303	5.3	42	12.8	Morrison	17	1984	2000	-0.0807	8.44	0.0029			
Forest	82015900	45.25	92.93	2206	8.9	37	11.3	Washington	23	1980	2002	-0.17	9.74	0.0139			
Goose	13-0083-02	45.62917	93.07833	470	1.9	55	16.8	Chisago	14	1989	2002	-0.1890	8.79	0.0080			
Green	34007900	45.25	94.9	5821	23.6	115	35.1	Kandiyohi	106	1897	2002	-0.0773	8.87	0.0429	-0.236	9.61	0.0534
Gull	11030500	46.46	94.3	9541	38.6	80	24.4	Crow Wing	53	1950	2002	-0.1718	8.56	0.0828	-0.1967	8.45	0.0554
Island	03-0153	46.91667	95.54167	1160	4.7	43	13.1	Becker	13	1990	2002	-0.2879	7.68	0.1574			
Johnson	31-0586	47.41667	93.58333	305	1.2	51	15.5	Itasca	22	1980	2001	0.4766	6.23	0.1979			
Kabekona	29-0075	47.16361	94.76583	2252	9.1	133	40.5	Hubbard	27	1976	2002	-0.0665	6.34	0.0074			
Kabetogama	69084500	48.51	93.1	24800	100.4	50	15.2	Koochiching	51	1952	2002	-0.1057	7.52	0.0419	-0.1935	7.88	0.0553
Knife	33002800	45.99	93.28	1127	4.6	14	4.3	Kanabec	14	1988	2001	-0.5735	7.28	0.1093			
Lake of the Woods	39000200	49.36	95.1	950400	3846.1			Lake of the Wood	18	1985	2002	-0.5232	9.16	0.0758			
Leech	11020300	47.24	94.41	109415	442.8	150	45.7	Cass	67	1936	2002	-0.0519	8.39	0.0143	-0.1845	7.67	0.0513
Little Bass	04-0110	47.51611	94.76694	343	1.4	22	6.7	Beltrami	22	1981	2002	0.2309	8.28	0.0317			
Little Green	13-0041-01	45.36472	92.8975	280	1.1			Chisago	24	1979	2002	-0.2052	7.95	0.0306			
Little McDonald	56-0328	46.60833	95.7	1174	4.8	109	33.2	Otter Tail	25	1977	2001	-0.1368	8.05	0.0166			
Long	03-0383	46.81917	95.89306	357	1.4	61	18.6	Becker	43	1960	2002	-0.1794	7.92	0.0748	-0.2677	6.38	0.097
Long	69-0765	48.30194	92.72389	409	1.7	18	5.5	St. Louis	17	1986	2002	0.1691	9.01	0.0089			
Long (Boy River)	11-0142	47.02528	94.17194	650	2.6	115	35.1	Cass	28	1974	2001	-0.1746	8.08	0.0306			
Loon	69-0426	48.25	92.267					St. Louis	24	1979	2002	0.0646	6.98	0.0046			
Martin	02-0034	45.38333	93.0875	237	1.0	22	6.7	Anoka	21	1982	2002	-0.2843	8.67	0.0383			
McDonald	56-0386-02	46.57	95.75694			30	9.1	Otter Tail	34	1968	2001	-0.1462	8.48	0.0286	-0.2047	8.56	0.0479
McKinney	31037000	47.25	93.53	178	0.7	34	10.4	Itasca	37	1964	2000	-0.2551	7.88	0.1093	-0.323	8.15	0.115
Mille Lacs	48000200	46.34	93.7	132516	536.3	36	11.0	Aitkin	47	1956	2002	-0.1012	7.45	0.0367	-0.3373	7.68	0.1335
Minnetonka	27013300	44.9	93.66	14310	57.9			Hennepin	148	1855	2002	-0.0293	9.53	0.0138	-0.3031	9.46	0.0876
Minnewaska	61013000	45.59	95.52	7770	31.4	32	9.8	Pope	97	1906	2002	0.0133	9.22	0.0016	-0.2483	9.65	0.0635
Osakis	77021500	45.94	95.05	6768	27.4	67	20.4	Todd	136	1867	2002	-0.0538	9.41	0.0469	-0.4032	8.81	0.1653
Otter Tail	56024200	46.38	95.67	13845	56.0	124	37.8	Otter Tail	13	1988	2000	-0.1932	7.77	0.0082			
Pokegama	31053200	47.2	93.59	15600	63.1	112	34.1	Itasca	41	1962	2002	-0.1801	7.74	0.103	-0.2601	8.18	0.1334

Complete Results of Linear Regression Analysis for Ice-Out Dates

Lake Name	MNDNR Lake ID Number	Latitude	Longitude	Surface Area (acres)	Surface Area (km^2)	Maximum Depth (ft)	Maximum Depth (m)	County	Record Length			Slopes: Complete			Slopes: 1970 to Now		
									Length (years)	From	To	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2
Ponto	11-0234	46.87222	94.34167	724	2.9	60	18.3	Cass	17	1986	2002	0.0417	7.97	0.0007			
Portage	29-0250	46.96583	95.11833	412	1.7	15	4.6	Hubbard	28	1974	2001	-0.2885	8.11	0.0789			
Rainy	69069400	48.6	93.36	220800	893.5			Koochiching	20	1983	2002	-0.0594	8.39	0.0014			
Red	4003500	48.2	94.7	288800	1168.7	35	10.7	Beltrami	20	1983	2002	-0.0412	8.02	0.0008			
Richardson	47-0088	45.15889	94.43917	115	0.5	47	14.3	Meeker	13	1989	2001	-0.1116	9.35	0.0011			
Sallie	3035900	46.75	95.89	1287	5.2	55	16.8	Becker	33	1970	2002	-0.223	8.19	0.0648			
Sand	31-0438	47.49167	93.50417	149	0.6	50	15.2	Itasca	13	1989	2001	-0.4560	10.19	0.0442			
Secret	31-0061	47.6523	93.078						24	1979	2002	-0.0012	8.82	0.0000			
Shagawa	69-0069	47.91667	91.875	2370	9.6	48	14.6	St. Louis	37	1965	2001	-0.1833	8.07	0.057	-0.1815	7.87	0.0447
Shetek	51004600	44.15	95.71	3596	14.6	10	3.0	Murray	42	1960	2001	-0.1653	10.9	0.0383	-0.205	10.78	0.0379
Siseebakwet	31-0554	47.15833	93.66667	1312	5.3	105	32.0	Itasca	34	1968	2001	-0.0927	7.45	0.016	-0.1427	7.58	0.0321
Swan (main)	31-0067-02	47.30611	93.18	9	0.0	66	20.1	Itasca	16	1987	2002	-0.1265	8.00	0.0056			
Swan (west)	31-0067-01	47.28972	93.20833	9	0.0	20	6.1	Itasca	16	1987	2002	-0.1265	8.00	0.0056			
Vermilion	11002900	47.9	92.58	49110	198.7	48	14.6	St. Louis	93	1910	2002	0.0071	8.3	0.0004	-0.1176	7.45	0.0228
Virginia	10-0015	44.88056	93.63972	116	0.5	34	10.4	Carver	11	1992	2002	-0.6091	11.73	0.0288			
W Jefferson	40-0092-04	44.27167	93.82361	441	1.8	20	6.1	Le Seuer	25	1978	2002	-0.1762	11.36	0.0129			
Waconia	10005900	44.86	93.82	3196	12.9	44	13.4	Carver	63	1940	2002	-0.181	8.89	0.12	-0.3855	9	0.1682
Wall	56-0658	46.27222	95.96389	683	2.8	27	8.2	Otter Tail	35	1968	2002	-0.2286	8.16	0.0761	-0.2280	8.28	0.0699
West Battle	56023900	46.29	95.67	5672	23.0	113	34.4	Otter Tail	13	1988	2000	-0.8099	8.51	0.1168			
White Bear	82016700	45.07	92.99	2432	9.8	82	25.0	Ramsey	75	1928	2002	-0.0601	9.28	0.0195	-0.484	9.23	0.2044
Wirth	27-0037	44.98194	93.32222	37	0.1	25	7.6	Hennepin	27	1975	2001	-0.2218	11.01	0.0277			
Average		**46.6192**	**94.1695**	**28734**	**116.3**	**56**	**16.9**		**37.6986**	**1965**	**2002**	**-0.1324**	**8.4732**	**0.0356**	**-0.2370**	**8.4410**	**0.0794**
Standard Deviation		**1.1802**	**1.1717**	**123940**	**501.6**	**37**	**11.3**		**30.0235**	**29.8733**	**0.5787**	**0.1889**	**1.1445**	**0.0396**	**0.0951**	**1.3024**	**0.0553**

Complete Results of Linear Regression Analysis for Ice-Out Dates (Continued)

Lake Name	Slopes: 1980 to Now			Slopes: 1990 to Now			Comments
	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2	
5th Crow Wing				-0.1868	8.40	0.0075	
Artichoke				-0.0182	10.77	3.00E-05	*Missing 1984-1991, 97
Bad Axe				-0.2308	7.05	0.0160	
Bad Medicine				-0.2582	7.12	0.0182	
Bemidji				0.1635	7.77	0.0072	*Missing 1984-1989, 97
Big Green				0.0934	8.97	0.0016	Missing 1987
Big Pine	0.0623	7.04	0.0036	-0.0824	6.94	0.0143	
Big Sandy	-0.2273	7.59	0.0359	-0.3846	8.93	0.0274	*Missing 1934, 39-54, 76-79, 81, 82, 87
Big Stone	0.0601	9.19	0.002	0.5417	9.37	0.0521	*Missing 1973, 97
Big Trout	0.1082	7.20	0.0107	-0.3433	7.78	0.0305	*Missing 1958-59, 61-63, 94
Big Turtle	0.0731	7.67	0.0042	-0.1923	8.22	0.0082	
Big Watab	-0.0731	8.58	0.0032	-0.1758	8.72	0.0063	
Blackduck				-0.6455	8.81	0.0584	*Missing 1990, 92-93
Bone	-0.0741	9.44	0.0028	-0.1978	8.95	0.0059	
Bronson				-0.5629	6.92	0.0792	*Missing 1985-86
Clear	-0.0572	10.24	0.0009	-0.0879	11.66	0.0009	*Missing 1905, 08, 09, 11-13, 74, 77-82, 84, 85 ,87
Collinwood				-0.0418	11.83	0.0002	
Crow Wing	-0.0553	8.78	0.0018	-0.2473	9.38	0.0104	
Detroit	0.3351	10.99	0.0395	-0.1868	13.22	0.003	*Missing 1982, 85
Doan				-0.3392	9.04	0.0180	
Edna	0.3933	5.60	0.1852	0.5220	5.31	0.1279	
Elephant				-0.3022	8.68	0.0181	
Ely	0.0277	7.40	0.0006	-0.7198	7.94	0.1109	Missing 1967-68, 70
Fall	-0.4449	4.52	0.1935	-0.2697	4.44	0.0652	*Missing 1976-1987
Fish Trap				-0.1813	9.52	0.0055	
Forest				-0.0783	9.85	0.001	*Missing 1984, 97
Goose				0.0385	8.93	0.0003	
Green	0.0553	9.89	0.0014	0.022	9.55	8.00E-05	*Missing 1898-1903, 1905-1914, 16, 18-23, 25-31, 36-39
Gull	0.0344	8.71	0.0006	-0.5882	8.86	0.0675	*Missing 1951-54, 80, 82, 84-86, 97
Island				-0.2879	7.68	0.1574	
Johnson				0.4725	5.34	0.1063	
Kabekona	0.0030	5.95	0.0000	-0.1888	6.18	0.0120	Missing 1989-90
Kabetogama	0.0968	7.57	0.0075	-0.2692	8.32	0.0157	
Knife				-0.5196	7.84	0.0641	*Missing 1996-97
Lake of the Woods				-0.425	10.49	0.0214	*Missing 1986-87, 90, 97, 01
Leech	0.0721	6.6	0.0055	-0.2308	6.58	0.0183	
Little Bass				0.4725	8.73	0.0426	
Little Green				0.0879	9.09	0.0014	Missing 1987
Little McDonald	-0.0425	7.67	0.0014	-0.5934	8.82	0.0643	
Long	-0.0074	7.34	0.00005	-0.3451	8.37	0.0289	
Long				-0.3956	8.97	0.0287	
Long (Boy River)	0.0136	7.87	0.0001	-0.3497	8.42	0.0219	
Loon	0.2013	6.54	0.0452	0.0505	6.45	0.0011	
Martin				-0.1484	8.89	0.0042	
McDonald	0.0446	8.22	0.0012	-0.4580	9.60	0.0287	
McKinney	-0.261	8.04	0.039	-0.9636	8.88	0.1147	
Mille Lacs	-0.1334	7.91	0.0129	-0.5824	8.91	0.0609	*Missing 1959, 72-74, 76-78
Minnetonka	-0.1324	9.92	0.0081	-0.1593	9.97	0.0039	*Missing 1861-76, 79-86
Minnewaska	0.284	9.78	0.0352	0.0824	9.71	0.0011	*Missing 1928, 82, 84-85
Osakis	-0.1105	8.42	0.0078	-0.2276	9.6	0.0101	*Missing 1886, 82, 96-97
Otter Tail				-0.4121	8.12	0.0231	*Missing 1989-90
Pokegama				-0.1242	8.79	0.0031	*Missing 1976-1990, 97, 98

Complete Results of Linear Regression Analysis for Ice-Out Dates (Continued)

Lake Name	Slopes: 1980 to Now			Slopes: 1990 to Now			Comments
	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2	
Ponto				-0.2692	8.06	0.0167	
Portage	0.0113	7.44	0.0001	0.0734	8.54	0.001	
Rainy				-0.486	8.63	0.0396	*Missing 1984-1987, 89-90
Red				-0.6109	8.2	0.0828	*Missing 1984-1987, 94, 98, 01
Richardson				-0.1116	9.83	0.0011	Missing 1998
Sallie	0.1509	6.9	0.0163	-0.3687	7.52	0.0384	*Missing 1980, 82, 84-85, 96, 98-99, 01
Sand				-0.4560	10.71	0.0442	
Secret				-0.3846	9.75	0.0231	Missing 1982-83, 85-86
Shagawa	0.1045	7.20	0.0088	-0.3182	8.12	0.0196	
Shetek	0.1036	11.43	0.0017	0.0718	13.32	0.0004	*Missing 1981-86, 94
Siseebakwet	-0.0978	7.84	0.0071	-0.5659	8.92	0.0576	
Swan (main)				-0.3791	8.04	0.0327	
Swan (west)				-0.3791	8.04	0.0327	
Vermilion	0.1433	6.73	0.0204	-0.1813	7.36	0.0091	*Missing 1911-1922
Virginia				-0.6091	11.73	0.0288	
W Jefferson	0.0395	11.31	0.0006	0.0604	11.54	0.0004	
Waconia	-0.2242	9.54	0.0183	0.0789	10.83	0.001	*Missing 1980-82, 84, 85, 87, 96-98
Wall	-0.0261	8.04	0.0005	-0.1604	8.59	0.0061	
West Battle				-1.0152	9.29	0.123	*Missing 1997
White Bear	-0.4407	9.88	0.0838	-1.00	10.84	0.1143	
Wirth	-0.0958	10.90	0.0037	-0.8042	12.37	0.0521	Missing 1990
Average	**-0.0022**	**8.2533**	**0.0208**	**-0.2503**	**8.8618**	**0.0318**	
Standard Deviation	**0.1739**	**1.5977**	**0.0433**	**0.3180**	**1.6653**	**0.0369**	

Analysis of 30 Years of Sorted Ice-Out Dates

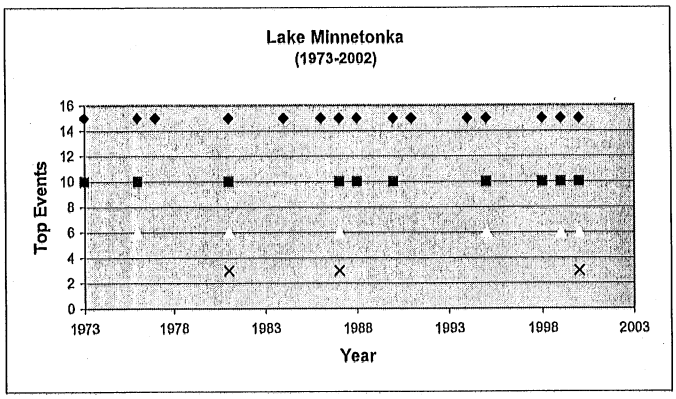
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Actual Number of Years															Analysis		
			McKinney	Kabetogama	Wall	White Bear	Siseebakwet	McDonald	Crow Wing	Bone	Big Pine	Minnetonka	Green	Vermillion	Big Turtle	Leech	Long	Shagawa	# above expected	% above expected	% above per period
5	3	0.5	2	1	1	2	2	2	1	1	1	1	1	1	2	1	3	2	7	43.8	59.4
	6	1.0	3	2	2	3	3	2	3	3	1	2	2	2	2	2	3	2	15	93.8	
	10	1.7	3	2	2	4	3	3	3	3	2	3	3	2	3	2	3	2	10	62.5	
	15	2.5	3	3	4	4	4	3	3	3	4	3	3	3	3	4	4	3	6	37.5	
10	3	1.0	2	1	1	2	2	2	1	1	1	1	1	1	2	1	3	2	7	43.8	40.6
	6	2.0	3	2	3	4	3	3	3	3	1	3	2	2	2	2	4	2	9	56.3	
	10	3.3	4	3	3	6	4	4	3	3	2	4	3	2	3	3	4	2	6	37.5	
	15	5.0	6	4	5	6	5	6	4	4	5	5	4	3	5	6	5	4	4	25.0	
15	3	1.5	2	1	1	2	2	2	1	1	1	1	1	1	2	1	3	3	2	12.5	20.3
	6	3.0	4	2	4	4	3	4	4	3	3	3	3	2	2	2	4	3	6	37.5	
	10	5.0	6	4	5	7	5	5	5	5	4	6	6	3	5	4	5	4	4	25.0	
	15	7.5	8	6	7	9	7	8	7	8	7	8	8	6	8	7	6	7	1	6.3	
20	3	2.0	3	2	2	3	2	2	2	2	2	2	2	2	2	2	3	3	4	25.0	31.3
	6	4.0	5	4	5	5	4	4	5	4	4	4	4	4	3	3	5	3	5	31.3	
	10	6.7	7	7	8	8	6	7	6	6	6	7	7	6	7	7	7	5	2	12.5	
	15	10.0	11	11	10	12	10	11	11	12	11	11	10	10	10	11	8	10	9	56.3	
# above expected			12	2	6	15	7	9	6	4	2	6	3	1	4	4	11	5			
% above expected			75	12.5	37.5	93.75	43.75	56.25	37.5	25	12.5	37.5	18.75	6.25	25	25	68.75	31.25			

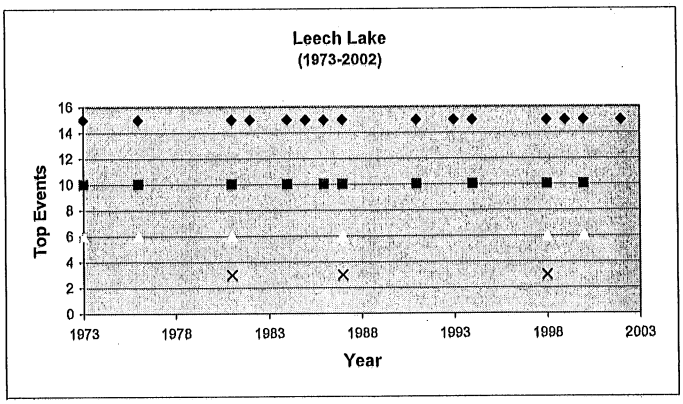
Analysis of 60 Years of Sorted Ice-Out Dates

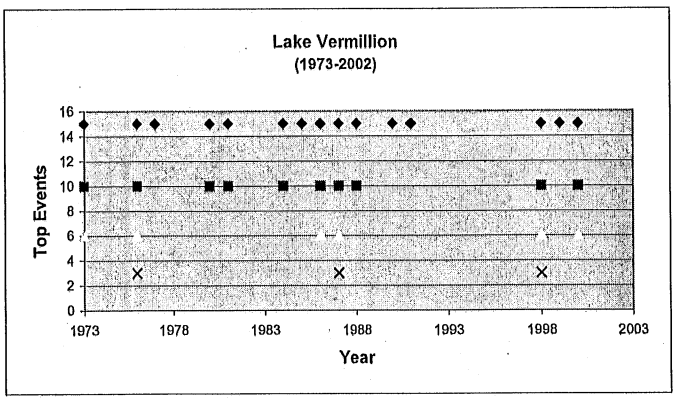
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Actual Number of Years						Analysis		
			White Bear	Bone	Minnetonka	Green	Leech	Vermillion	# above expected	% above expected	% above per period
5	3	0.3	2	1	1	1	1	1	6	100.0	66.7
	6	0.5	2	2	1	1	1	1	2	33.3	
	12	1.0	4	3	3	3	2	2	6	100.0	
	20	1.7	4	3	3	3	2	2	4	66.7	
	30	2.5	4	3	3	3	4	3	2	33.3	
10	3	0.5	2	1	1	1	1	1	1	16.7	36.7
	6	1.0	2	2	1	1	1	1	2	33.3	
	12	2.0	5	3	4	3	2	2	4	66.7	
	20	3.3	6	3	4	3	3	2	2	33.3	
	30	5.0	6	4	5	4	6	5	2	33.3	
15	3	0.8	2	1	1	1	1	1	1	16.7	33.3
	6	1.5	2	2	1	1	1	1	0	0.0	
	12	3.0	6	4	4	5	2	2	4	66.7	
	20	5.0	9	7	7	7	4	5	4	66.7	
	30	7.5	10	7	8	8	8	8	1	16.7	
20	3	1.0	3	2	2	2	1	2	5	83.3	73.3
	6	2.0	3	3	2	2	2	2	2	33.3	
	12	4.0	7	5	5	6	4	4	4	66.7	
	20	6.7	13	11	9	8	8	8	6	100.0	
	30	10.0	13	12	11	10	12	12	5	83.3	
25	3	1.3	3	2	3	3	1	2	5	83.3	66.7
	6	2.5	4	4	3	3	3	2	2	33.3	
	12	5.0	8	6	6	7	5	5	4	66.7	
	20	8.3	12	12	10	9	9	10	6	100.0	
	30	12.5	14	13	12	12	14	14	3	50.0	
30	3	1.5	3	2	3	3	1	2	3	50.0	76.7
	6	3.0	4	4	3	4	4	3	4	66.7	
	12	6.0	9	8	8	9	7	7	6	100.0	
	20	10.0	14	14	12	11	11	12	6	100.0	
	30	15.0	17	17	15	15	17	17	4	66.7	
35	3	1.8	4	2	3	3	1	2	3	50.0	46.7
	6	3.5	5	4	4	5	4	3	2	33.3	
	12	7.0	10	8	9	10	7	7	4	66.7	
	20	11.7	15	14	13	12	12	13	4	66.7	
	30	17.5	18	17	16	16	19	18	1	16.7	
40	3	2.0	4	2	3	3	1	2	3	50.0	56.7
	6	4.0	5	4	4	6	4	3	2	33.3	
	12	8.0	10	9	10	11	8	8	4	66.7	
	20	13.3	17	16	16	15	14	14	6	100.0	
	30	20.0	21	20	20	19	21	20	2	33.3	
# above expected			38	25	23	23	15	13			
% above expected			95	62.5	57.5	57.5	37.5	32.5			

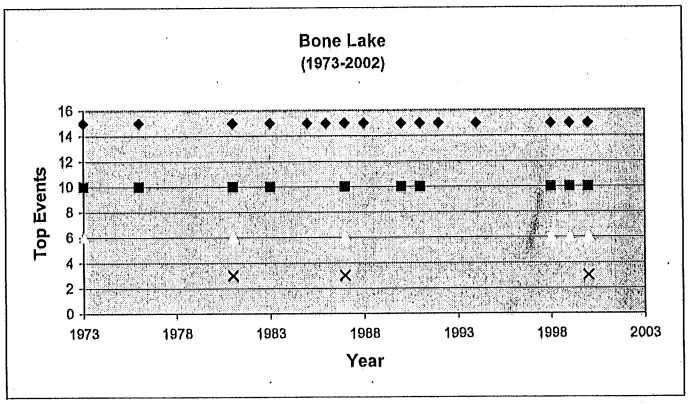
Analysis of 80 Years of Sorted Ice-Out Dates							
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Actual Number of Years		Analysis		
			Minnetonka	Vermillion	# above expected	% above expected	% above per period
5	4	0.3	1	1	2	100.0	70.0
	8	0.5	2	1	1	50.0	
	16	1.0	3	2	2	100.0	
	20	1.3	3	2	2	100.0	
	40	2.5	3	3	0	0.0	
10	4	0.5	1	1	0	0.0	30.0
	8	1.0	2	1	1	50.0	
	16	2.0	4	2	1	50.0	
	20	2.5	4	2	1	50.0	
	40	5.0	5	5	0	0.0	
15	4	0.8	1	1	0	0.0	20.0
	8	1.5	2	1	0	0.0	
	16	3.0	5	2	1	50.0	
	20	3.8	6	2	1	50.0	
	40	7.5	8	8	0	0.0	
20	4	1.0	2	2	2	100.0	70.0
	8	2.0	3	2	1	50.0	
	16	4.0	6	4	1	50.0	
	20	5.0	7	4	1	50.0	
	40	10.0	12	12	2	100.0	
25	4	1.3	3	2	2	100	60.0
	8	2.5	4	2	1	50	
	16	5.0	7	4	1	50	
	20	6.3	8	5	1	50	
	40	12.5	13	14	1	50	
30	4	1.5	3	2	1	50	60.0
	8	3.0	5	3	1	50	
	16	6.0	9	6	1	50	
	20	7.5	10	7	1	50	
	40	15.0	16	17	2	100	
35	4	1.8	3	2	1	50	50.0
	8	3.5	6	3	1	50	
	16	7.0	10	6	1	50	
	20	8.8	11	7	1	50	
	40	17.5	17	18	1	50	
40	4	2.0	3	2	1	50	50.0
	8	4.0	6	3	1	50	
	16	8.0	11	7	1	50	
	20	10.0	12	8	1	50	
	40	20.0	21	20	1	50	
# above expected			32	9			
% above expected			80	22.5			

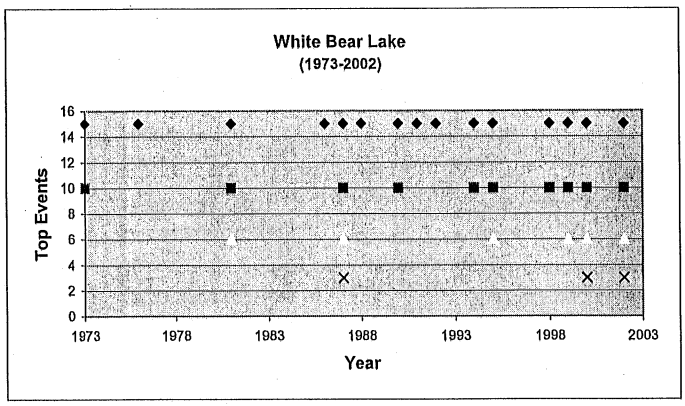
Analysis of 110 Years of Sorted Ice-Out Dates						
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Actual Number of Years	Analysis		
			Minnetonka	# above expected	% above expected	% above per period
5	5	0.2	1	1	100.0	80.0
	11	0.5	2	1	100.0	
	22	1.0	3	1	100.0	
	36	1.6	3	1	100.0	
	55	2.5	3	0	0.0	
10	5	0.5	1	1	100.0	80.0
	11	1.0	2	1	100.0	
	22	2.0	4	1	100.0	
	36	3.3	4	1	100.0	
	55	5.0	5	0	0.0	
15	5	0.7	1	0	0.0	60.0
	11	1.5	2	0	0.0	
	22	3.0	5	1	100.0	
	36	4.9	7	1	100.0	
	55	7.5	9	1	100.0	
20	5	0.9	2	1	100.0	100.0
	11	2.0	3	1	100.0	
	22	4.0	6	1	100.0	
	36	6.5	9	1	100.0	
	55	10.0	13	1	100.0	
25	5	1.1	3	1	100	100.0
	11	2.5	4	1	100	
	22	5.0	7	1	100	
	36	8.2	10	1	100	
	55	12.5	14	1	100	
30	5	1.4	3	1	100	100.0
	11	3.0	4	1	100	
	22	6.0	11	1	100	
	36	9.8	11	1	100	
	55	15.0	17	1	100	
35	5	1.6	3	1	100	80.0
	11	3.5	5	1	100	
	22	7.0	12	1	100	
	36	11.5	13	1	100	
	55	17.5	18	0	0	
40	5	1.8	3	1	100	100.0
	11	4.0	5	1	100	
	22	8.0	13	1	100	
	36	13.1	15	1	100	
	55	20.0	22	1	100	
45	5	2.0	3	1	100	40.0
	11	4.5	5	0	0	
	22	9.0	13	1	100	
	36	14.7	15	0	0	
	55	22.5	23	0	0	
50	5	2.3	3	1	100	60.0
	11	5.0	5	0	0	
	22	10.0	13	1	100	
	36	16.4	16	0	0	
	55	25.0	26	1	100	
55	5	2.5	3	0	0	20.0
	11	5.5	5	0	0	
	22	11.0	13	1	100	
	36	18.0	16	0	0	
	55	27.5	28	0	0	
# above expected			41			
% above expected			74.5			

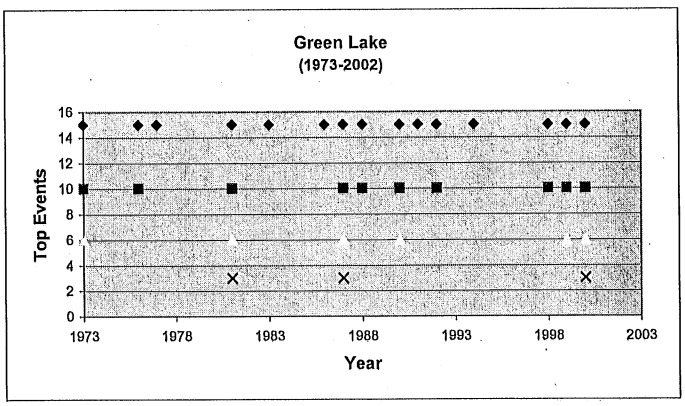

Lake Minnetonka
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

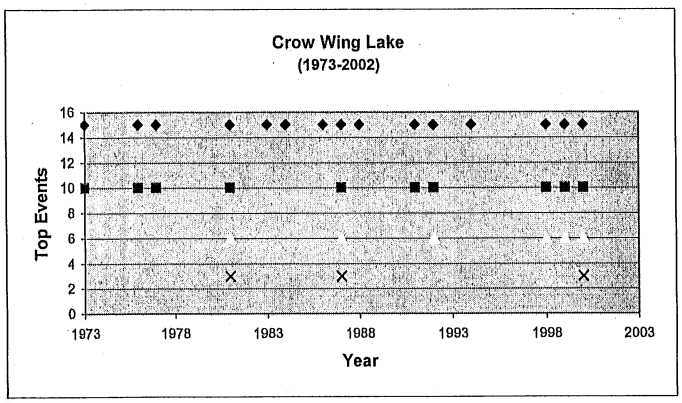

Leech Lake
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

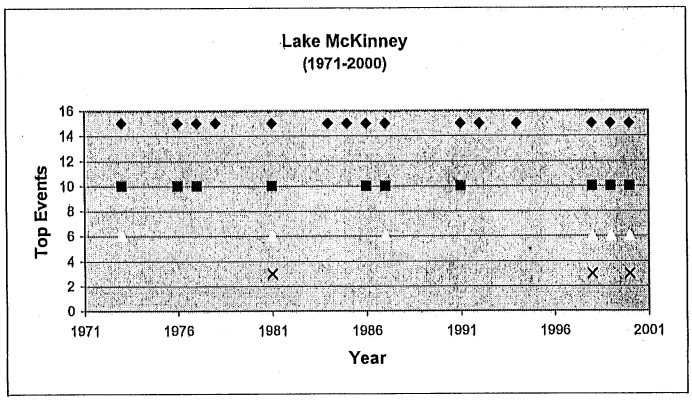

Lake Vermillion
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

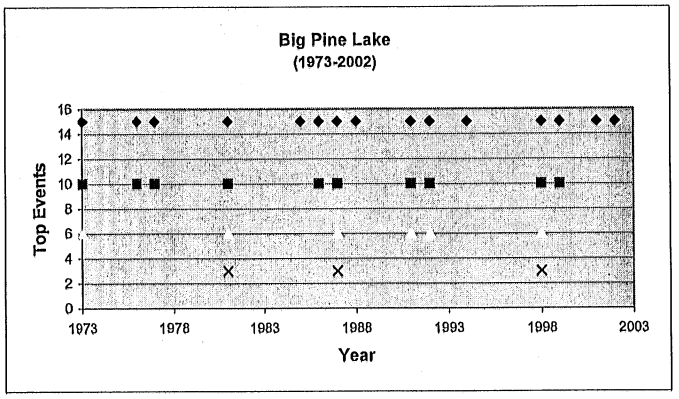

Bone Lake
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

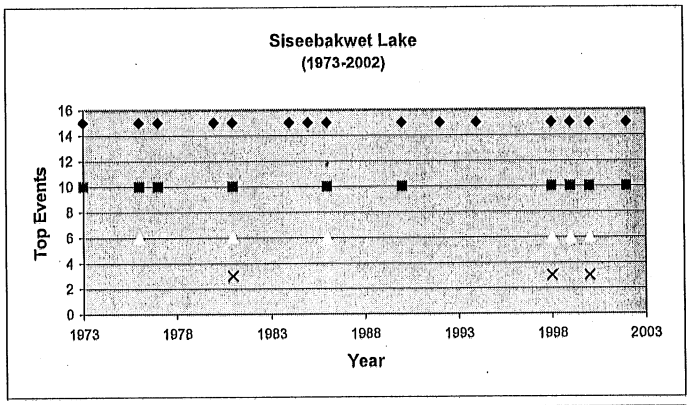

White Bear Lake
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

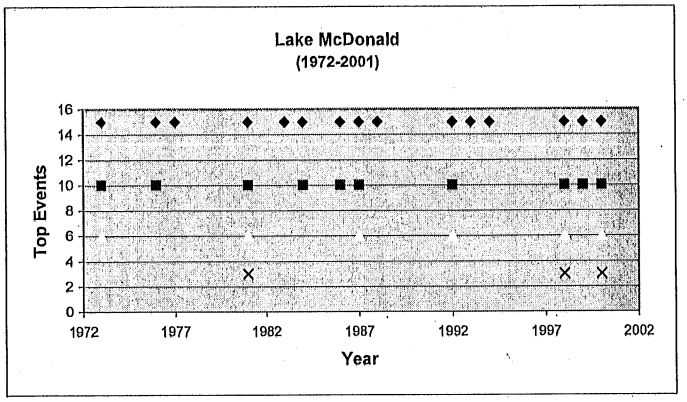

Green Lake
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

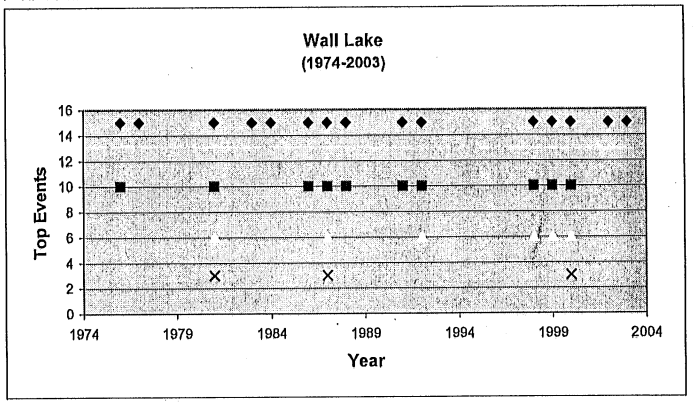

Crow Wing Lake
(1973-2002)
Top Events
Year
0
2
4
6
8
10
12
14
16
1973
1978
1983
1988
1993
1998
2003

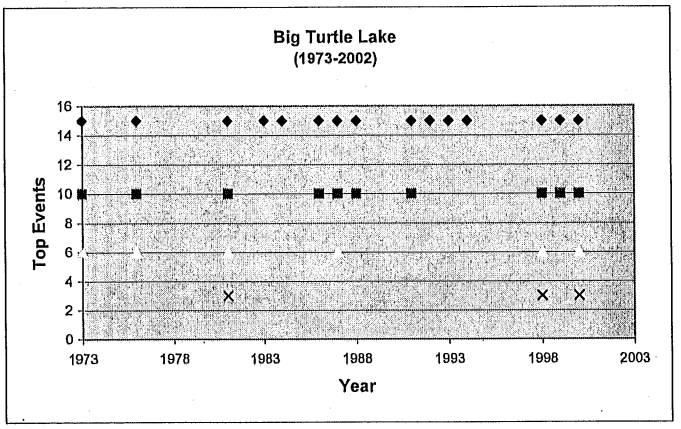

Lake McKinney
(1971-2000)
Top Events
Year
0
2
4
6
8
10
12
14
16
1971
1976
1981
1986
1991
1996
2001

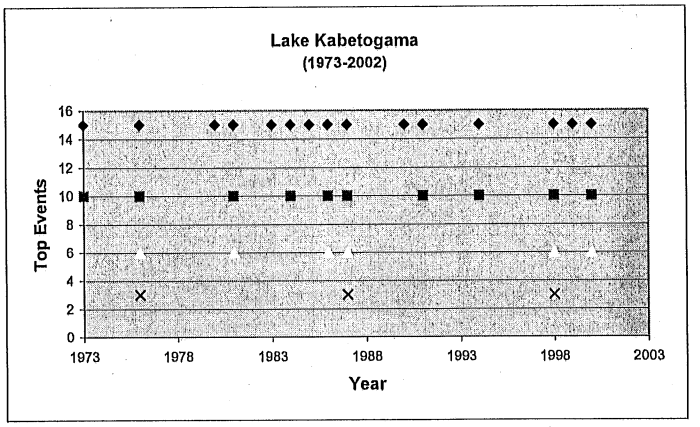

Big Pine Lake
(1973-2002)
Top Events
Year
1973
1978
1983
1988
1993
1998
2003

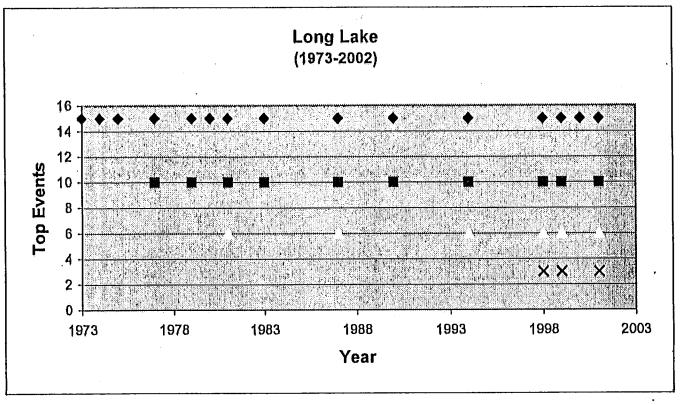

Siseebakwet Lake
(1973-2002)
Top Events
Year
1973
1978
1983
1988
1993
1998
2003

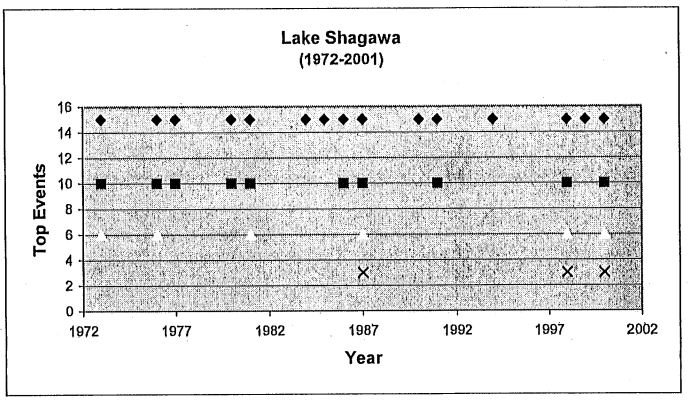

Lake McDonald
(1972-2001)
Top Events
Year
1972
1977
1982
1987
1992
1997
2002


Wall Lake
(1974-2003)
Top Events
Year
1974
1979
1984
1989
1994
1999
2004

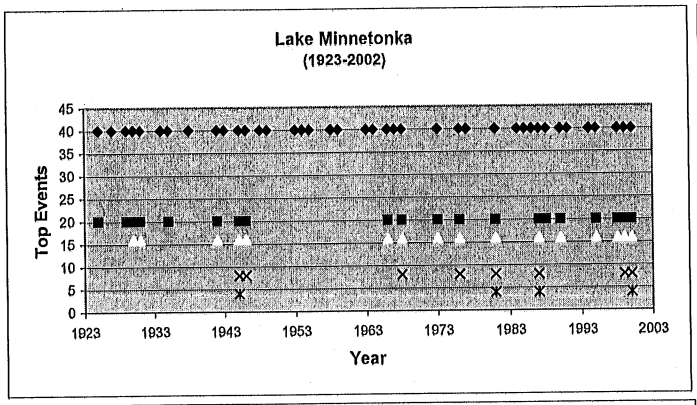

Big Turtle Lake
(1973-2002)
Top Events
Year
1973
1978
1983
1988
1993
1998
2003

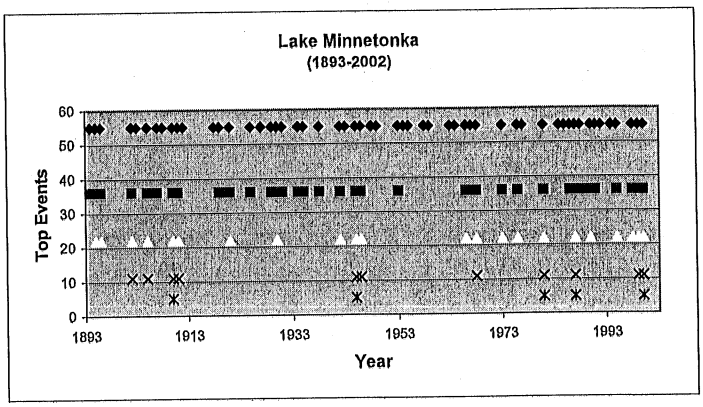

Lake Kabetogama
(1973-2002)
Top Events
Year
1973
1978
1983
1988
1993
1998
2003

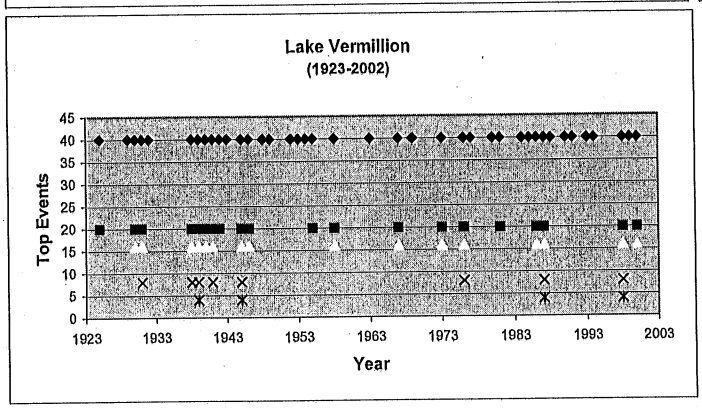

Long Lake
(1973-2002)
Top Events
Year
1973
1978
1983
1988
1993
1998
2003


Lake Shagawa
(1972-2001)
Top Events
Year
1972
1977
1982
1987
1992
1997
2002

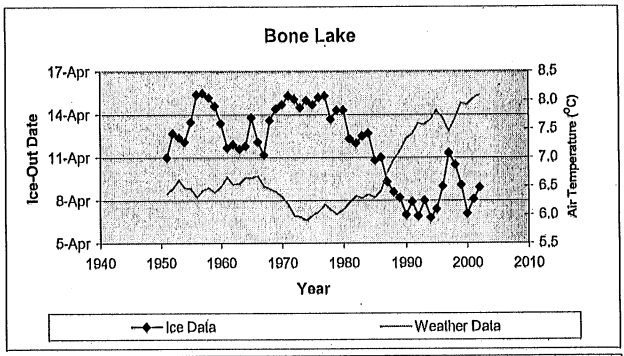
80 and 110-Year Event Sorting of Ice-Out Data

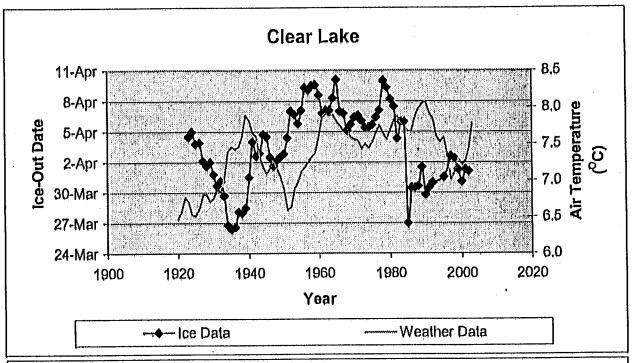


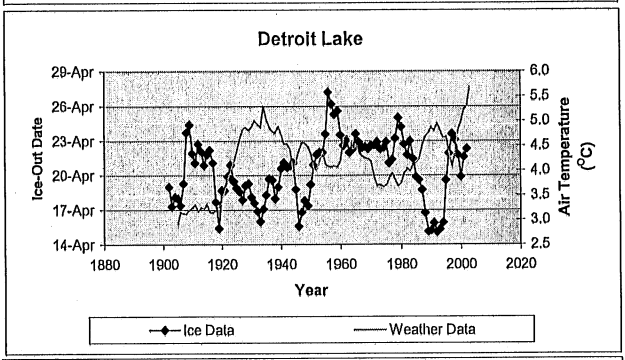


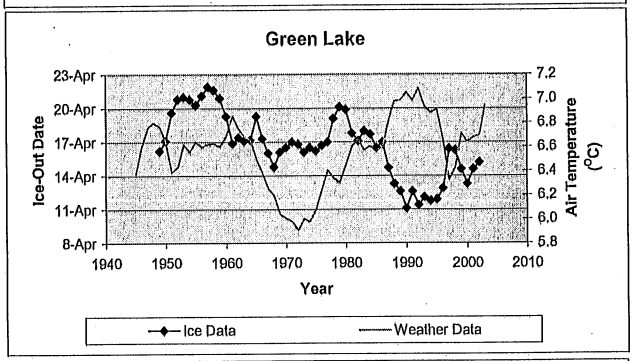


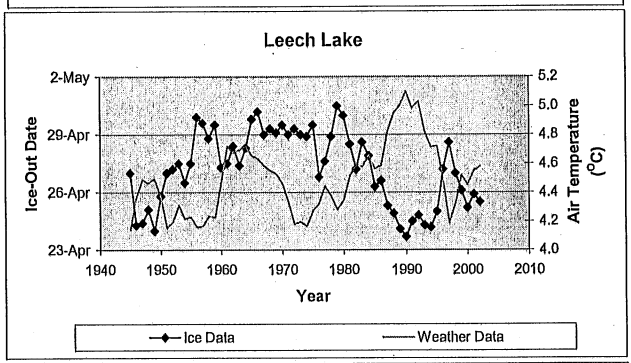
Comparison of Ice-Out and Average Annual Air Temperature Ten-Year Running Averages

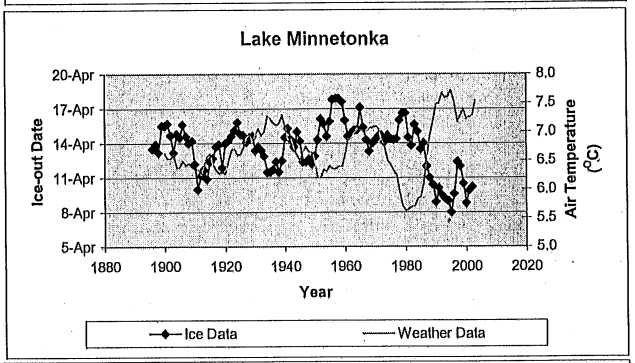


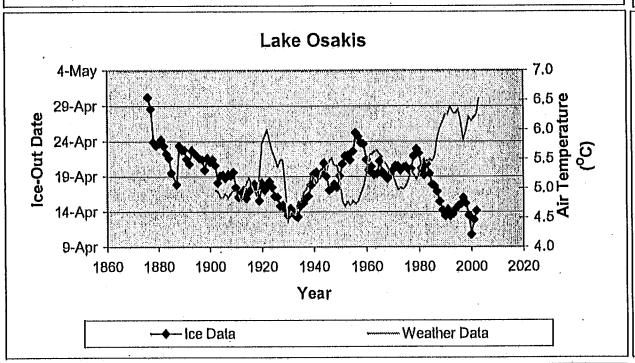


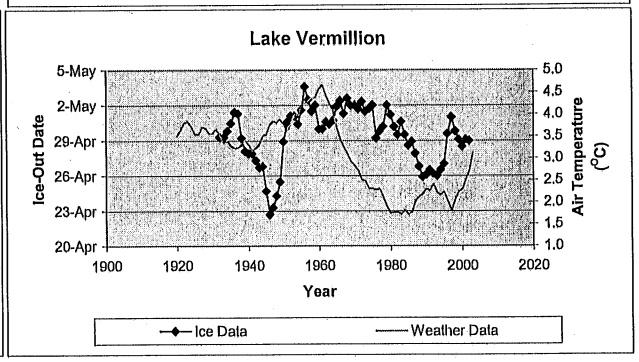


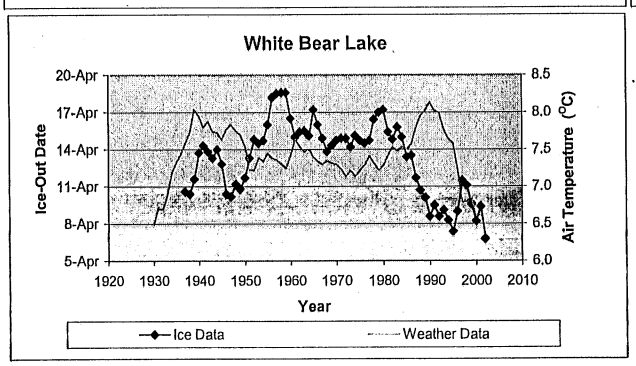




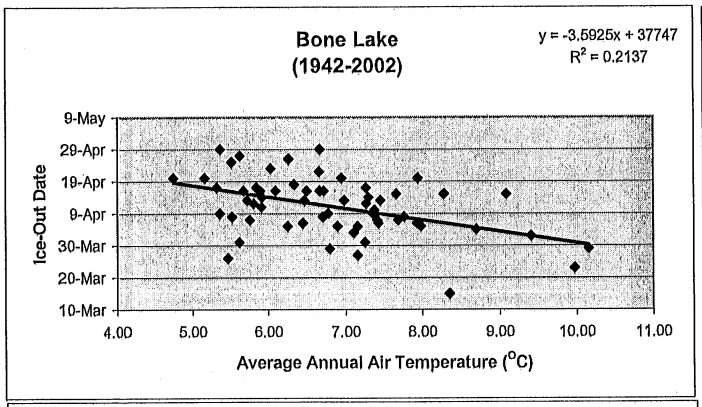


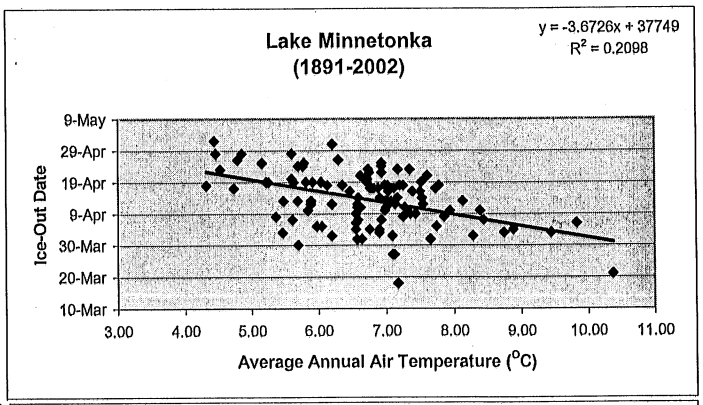


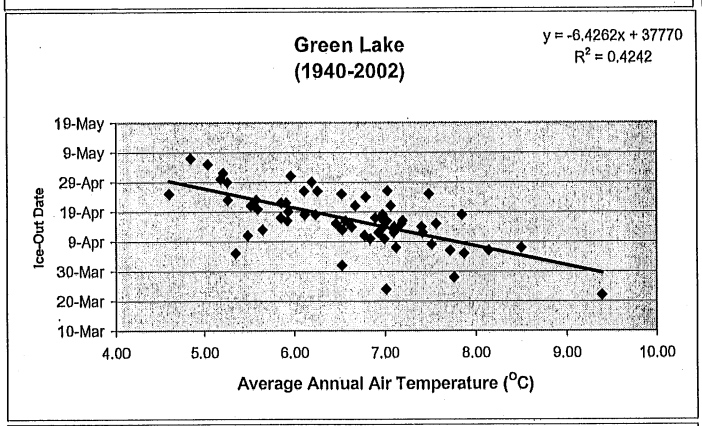


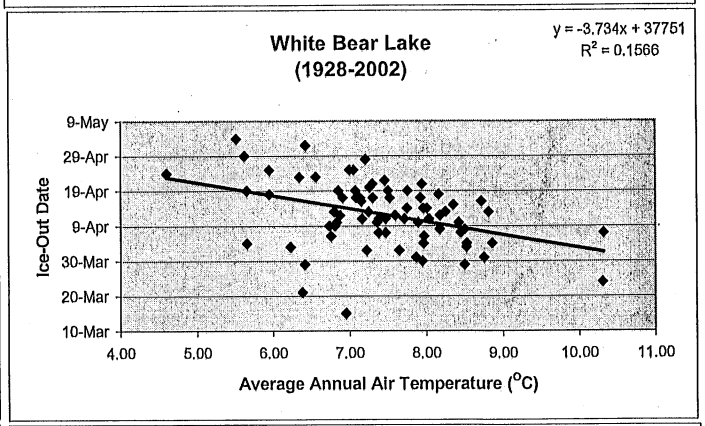


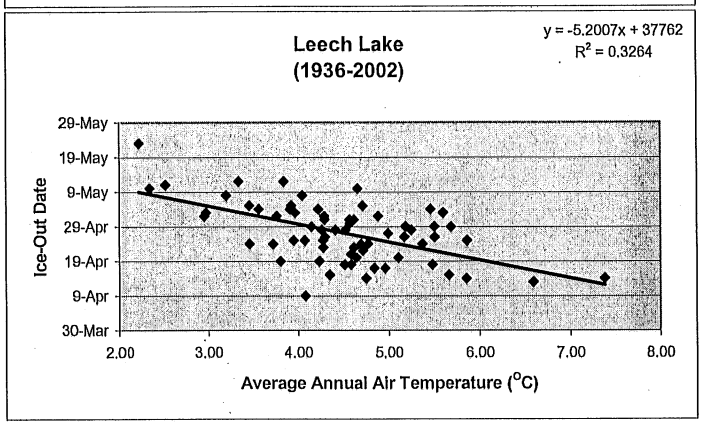
Linearization of ice-out date and average annual air temperature

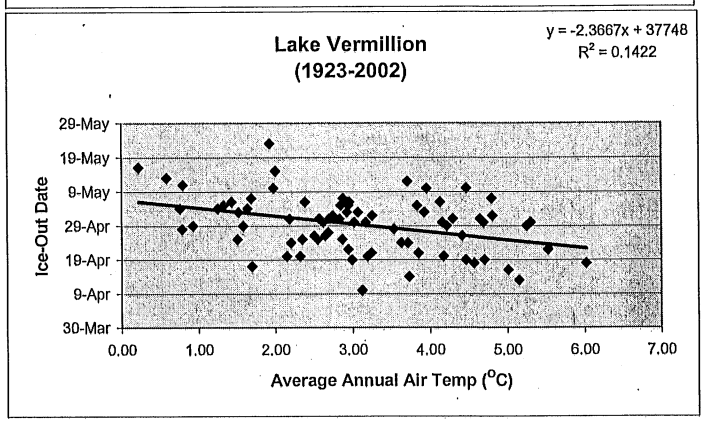




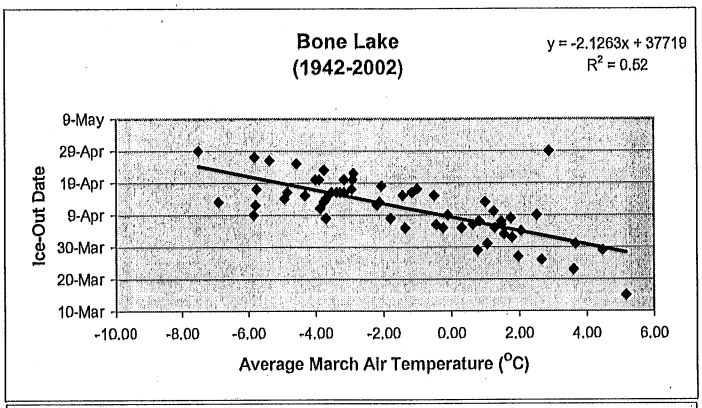


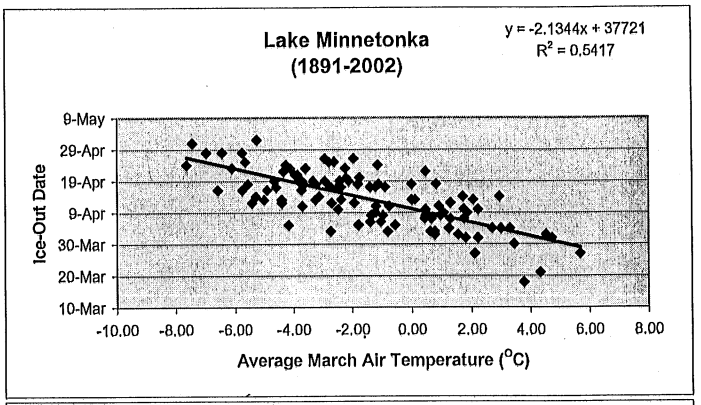


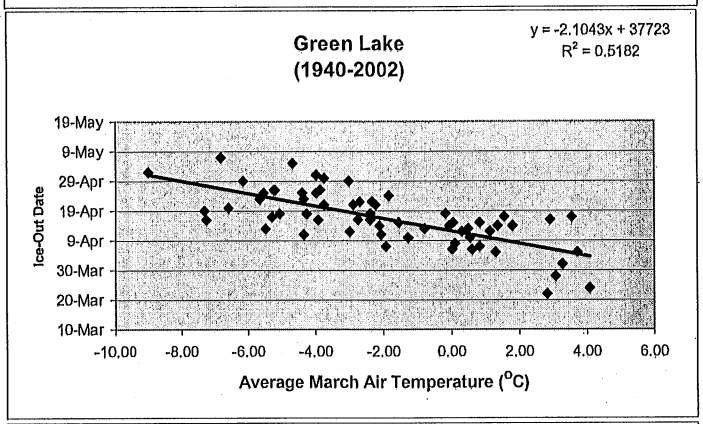


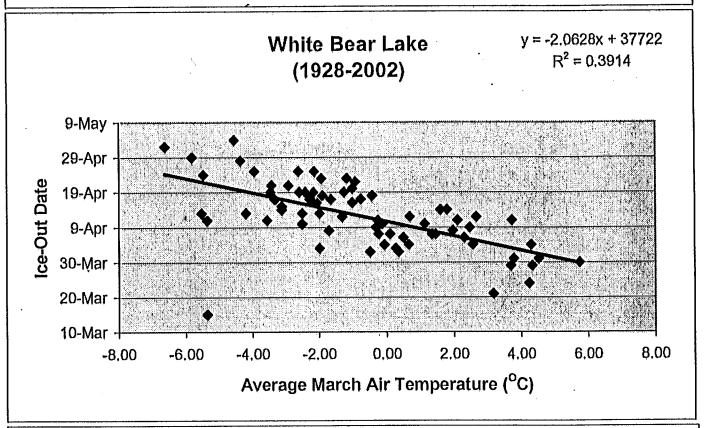


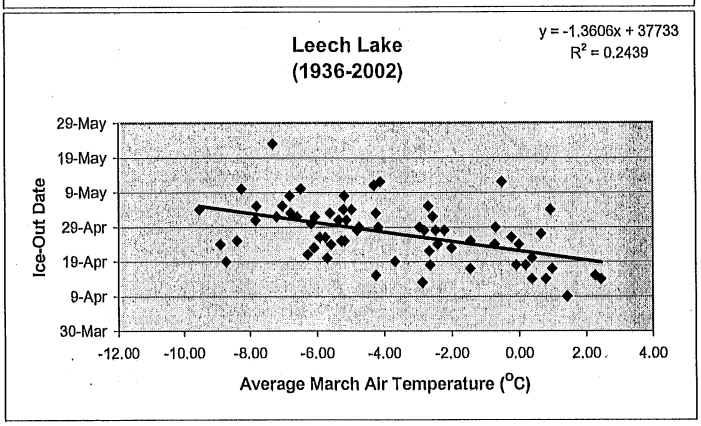
Linearization of ice-out date and average March air temperature

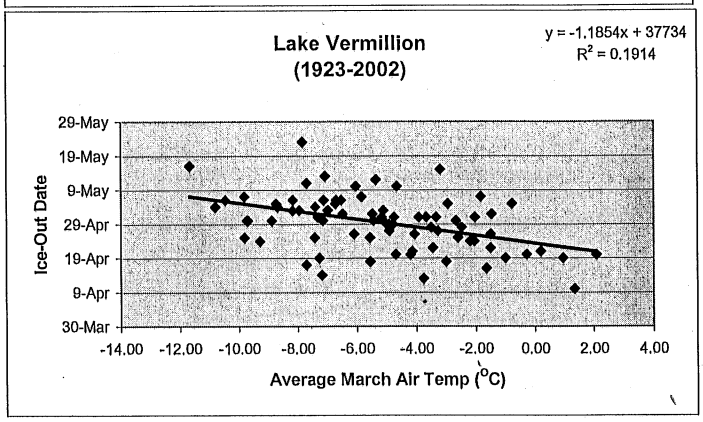




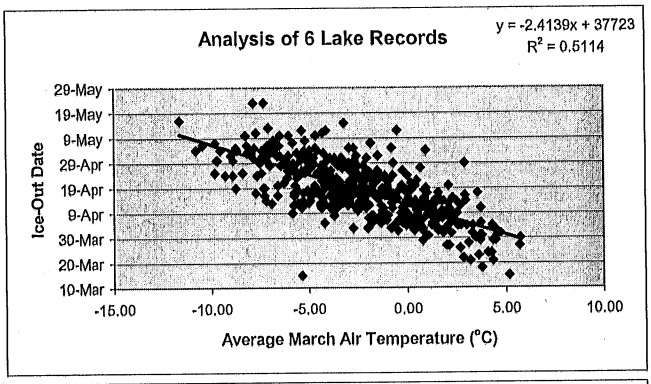


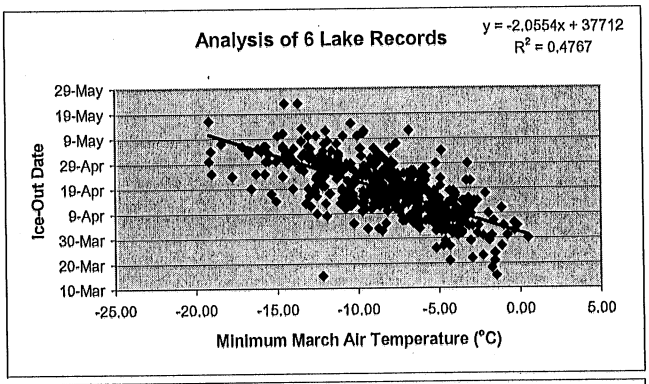


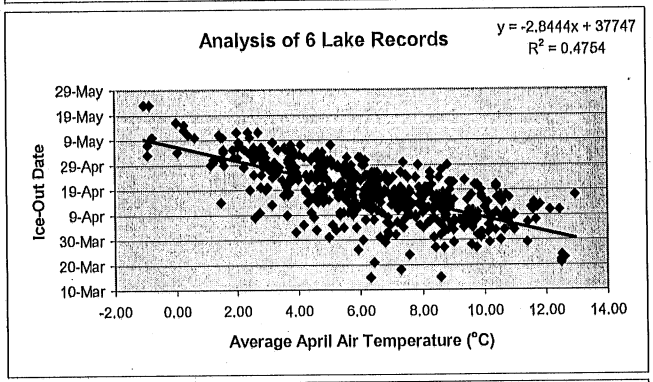


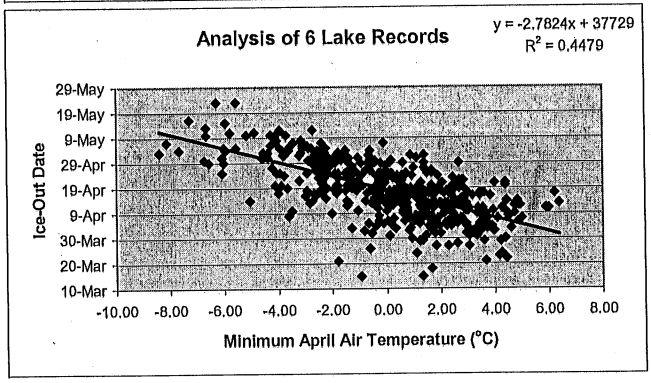


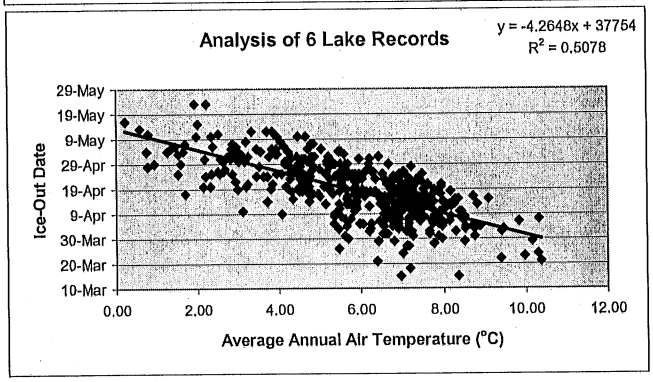
Linearization of ice-out date and various air temperature measurements











APPENDIX B
LAKE ICE-IN ANALYSIS

Statistical Analyses of Lake Ice-In Dates For Whole Record

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
5th Crow Wing	29-0092	Hubbard	14	1989	2002	11/21	11/16	11/11	14.40	11/04/91	12/18/01
Bad Axe	29-0208	Hubbard	14	1989	2002	11/18	11/18	11/20	10.65	11/03/91	12/06/99
Bad Medicine	03-0088	Becker	30	1973	2002	11/30	11/30	12/2	7.74	11/19/96	12/19/98
Big Green	13-0041-02	Chisago	23	1979	2001	11/29	11/25	12/7	14.12	11/04/91	12/22/98
Big Pine	58-0138	Pine	12	1991	2002	11/20	11/17	12/6	7.65	11/03/91	12/12/99
Big Turtle	04-0159	Beltrami	38	1965	2002	11/19	11/19	11/15	8.24	11/04/91	12/11/99
Big Watab	73-0102	Stearns	20	1983	2002	12/8	12/7	12/5	10.54	11/25/91	12/26/97
Collinwood	86-0293	Wright	18	1985	2002	11/24	11/22	11/29	13.04	11/14/91	12/20/98
Crow Wing	18-0155	Crow Wing	35	1968	2002	11/15	11/15	11/13	9.13	11/12/77	12/08/98
Doan	31-0536	Itasca	18	1984	2001	11/23	11/21	11/21	11.14	11/07/91	12/19/01
Ely	69-0660	St. Louis	33	1969	2001	11/22	11/23	11/21	7.12	11/05/91	12/07/01
Fish Trap	49-0137	Morrison	17	1984	2000	11/27	11/24	11/24	11.86	11/12/95	12/22/98
Island	03-0153	Becker	13	1990	2002	11/23	11/18		14.99	11/05/91	12/20/98
Johnson	31-0586	Itasca	22	1980	2001	11/25	11/24	11/13	11.07	11/12/98	12/21/89
Kabekona	29-0075	Hubbard	12	1991	2002	12/8	12/6	12/21	10.79	11/26/91	12/25/97
Little Green	13-0041-01	Chisago	24	1979	2002	11/26	11/22	11/20	13.89	11/03/91	12/21/99
Little McDonald	56-0328	Otter Tail	25	1977	2001	12/5	12/5	12/3	8.42	11/21/96	12/21/98
Long	03-0383	Becker	43	1960	2002	11/22	11/22	11/17	8.66	11/04/91	12/15/99
Long (Boy River)	11-0142	Cass	28	1974	2001	11/28	11/26	11/24	9.38	11/13/95	12/18/01
Loon	69-0426	St. Louis	24	1979	2002	11/20	11/20	11/13	9.86	11/04/91	12/16/98
Martin	02-0034	Anoka	21	1982	2002	11/23	11/22	11/11	11.33	11/04/91	12/20/97
McDonald	56-0386-02	Otter Tail	34	1968	2001	11/23	11/23	11/23	9.04	11/04/91	12/16/99
Ponto	11-0234	Cass	17	1986	2002	11/28	11/25	11/24	10.80	11/11/95	12/20/01
Portage	29-0250	Hubbard	28	1974	2001	11/12	11/12	11/12	8.19	10/29/88	11/29/01
Richardson	47-0088	Meeker	13	1989	2001	12/2	11/27	11/27	12.41	11/19/97	12/22/98
Sand	31-0438	Itasca	13	1989	2001	11/25	11/21	11/17	11.60	11/13/95	12/15/98
Secret	31-0061	Itasca	24	1979	2002	11/12	11/10	11/10	8.18	10/29/88	11/28/87
Shagawa	69-0069	St. Louis	37	1965	2001	11/20	11/20	11/15	8.47	11/06/91	12/09/98
Siseebakwet	31-0554	Itasca	34	1968	2001	12/4	12/3	12/6	6.77	11/25/96	12/20/01
Swan (main)	31-0067-02	Itasca	16	1987	2002	12/1	11/28	12/2	10.47	11/13/95	12/20/98
Swan (west)	31-0067-01	Itasca	16	1987	2002	12/1	11/28	12/2	10.47	11/13/95	12/20/98
Virginia	10-0015	Carver	11	1992	2002	11/28	11/26	11/21	13.56	11/12/96	12/20/98
Wall	56-0658	Otter Tail	35	1968	2002	11/17	11/16	11/12	8.36	11/03/93	12/07/01
Wirth	27-0037	Hennepin	27	1975	2001	11/23	11/23	11/21	11.23	11/04/91	12/20/01
Average			**23**	**1979**	**2002**	**11/24**	**11/23**	**11/22**	**10.40**		
Standard Deviation			**8.97**	**9.05**	**0.56**	**6.58**	**6.36**	**9.83**	**2.22**		

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Statistical Analyses of Lake Ice-In Dates For 1970 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
Big Turtle	04-0159	Beltrami	38	1965	2002	11/19	11/18	11/15	8.23	11/04/91	12/11/99
Crow Wing	18-0155	Crow Wing	35	1968	2002	11/15	11/14	11/13	11.82	10/12/77	12/08/98
Ely	69-0660	St. Louis	33	1969	2001	11/22	11/22	11/21	7.24	11/05/91	12/07/01
Long	03-0383	Becker	43	1960	2002	11/22	11/21	11/17	8.72	11/04/91	12/15/99
McDonald	56-0386-02	Otter Tail	34	1968	2001	11/23	11/23	11/21	9.30	11/04/91	12/16/99
Shagawa	69-0069	St. Louis	37	1965	2001	11/21	11/21	11/21	8.79	11/06/91	12/09/98
Siseebakwet	31-0554	Itasca	34	1968	2001	12/4	12/2	12/6	6.96	11/25/96	12/20/01
Wall	56-0658	Otter Tail	35	1968	2002	11/17	11/16	11/12	8.60	11/03/93	12/07/01
Average			**36**	**1966**	**2002**	**11/21**	**11/20**	**11/19**	**8.71**		
Standard Deviation			**3.23**	**2.97**	**0.53**	**5.71**	**5.46**	**7.60**	**1.49**		

Statistical Analyses of Lake Ice-In Dates For 1980 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
Bad Medicine	03-0088	Becker	30	1973	2002	12/1	11/29	12/2	8.50	11/19/96	12/19/96
Big Green	13-0041-02	Chisago	23	1979	2001	11/29	11/23	12/7	14.65	11/04/91	12/22/98
Big Turtle	04-0159	Beltrami	38	1965	2002	11/19	11/17	11/15	8.88	11/04/91	12/11/99
Crow Wing	18-0155	Crow Wing	35	1968	2002	11/17	11/15	11/21	10.78	10/27/80	12/08/98
Ely	69-0660	St. Louis	33	1969	2001	11/22	11/22	11/21	7.84	11/05/91	12/07/01
Little Green	13-0041-01	Chisago	24	1979	2002	11/26	11/21	11/20	14.29	11/03/91	12/21/99
Little McDonald	56-0328	Otter Tail	25	1977	2001	12/6	12/5	12/3	8.82	11/21/96	12/21/98
Long	03-0383	Becker	43	1960	2002	11/22	11/20	1/16	10.11	11/04/91	12/15/99
Long (Boy River)	11-0142	Cass	28	1974	2001	11/28	11/26	11/24	9.61	11/13/95	12/18/01
Loon	69-0426	St. Louis	24	1979	2002	11/20	11/19	1/13	10.09	11/04/91	12/16/98
McDonald	56-0386-02	Otter Tail	34	1968	2001	11/24	11/23	11/21	10.67	11/04/91	12/16/99
Portage	29-0250	Hubbard	28	1974	2001	11/12	11/12	11/21	8.74	10/29/88	11/29/01
Secret	31-0061	Itasca	24	1979	2002	11/12	11/10	11/10	8.16	10/29/88	11/28/87
Shagawa	69-0069	St. Louis	37	1965	2001	11/21	11/20	11/11	9.65	11/06/91	12/09/98
Siseebakwet	31-0554	Itasca	34	1968	2001	12/5	12/6	12/10	7.64	11/25/96	12/20/01
Wall	56-0658	Otter Tail	35	1968	2002	11/18	11/16	11/12	9.69	11/03/93	12/07/01
Wirth	27-0037	Hennepin	27	1975	2001	11/24	11/23	11/21	12.32	11/04/91	12/20/01
Average			**31**	**1972**	**2001**	**11/23**	**11/21**	**10/16**	**10.03**		
Standard Deviation			**5.93**	**5.88**	**0.51**	**6.99**	**7.08**	**104.34**	**2.05**		

Statistical Analyses of Lake Ice-In Dates For 1990 to Present

Lake Name	DNR Lake ID Number	County	Record Length			Average Date	Median Date	Mode Date	Standard Deviation	Earliest Date	Latest Date
			Length	From	To						
5th Crow Wing	29-0092	Hubbard	14	1989	2002	11/22	11/18	11/11	14.94	11/04/91	12/18/01
Bad Axe	29-0208	Hubbard	14	1989	2002	11/18	11/20	11/20	11.25	11/03/91	12/06/99
Bad Medicine	03-0088	Becker	30	1973	2002	12/1	11/27	11/25	10.54	11/19/96	12/19/96
Big Green	13-0041-02	Chisago	23	1979	2001	12/5	12/18		21.29	11/04/91	12/22/98
Big Turtle	04-0159	Beltrami	38	1965	2002	11/19	11/17	11/15	11.43	11/04/91	12/11/99
Big Watab	73-0102	Stearns	20	1983	2002	12/10	12/14	12/20	11.98	11/25/91	12/26/97
Collinwood	86-0293	Wright	18	1985	2002	11/27	11/27	11/29	14.34	11/04/91	12/20/98
Crow Wing	18-0155	Crow Wing	35	1968	2002	11/20	11/15	11/13	11.67	11/04/91	12/08/98
Doan	31-0536	Itasca	18	1984	2001	11/24	11/21		13.76	11/07/91	12/19/01
Ely	69-0660	St. Louis	33	1969	2001	11/22	11/26	11/13	9.76	11/05/91	12/07/01
Fish Trap	49-0137	Morrison	17	1984	2000	11/30	12/2		15.55	11/12/95	12/22/98
Johnson	31-0586	Itasca	22	1980	2001	11/22	11/20	11/13	10.26	11/12/98	12/09/00
Little Green	13-0041-01	Chisago	24	1979	2002	11/28	11/24	12/20	19.20	11/03/91	12/21/99
Little McDonald	56-0328	Otter Tail	25	1977	2001	12/8	12/8	11/28	10.88	11/21/96	12/21/98
Long	03-0383	Becker	43	1960	2002	11/22	11/18	11/15	12.14	11/04/91	12/15/99
Long (Boy River)	11-0142	Cass	28	1974	2001	11/30	11/29	12/2	11.60	11/13/95	12/18/01
Loon	69-0426	St. Louis	24	1979	2002	11/22	11/21	11/13	12.72	11/04/91	12/16/98
Martin	02-0034	Anoka	21	1982	2002	11/23	11/23		13.47	11/04/91	12/20/97
McDonald	56-0386-02	Otter Tail	34	1968	2001	11/23	11/24	11/15	12.80	11/04/91	12/16/99
Ponto	11-0234	Cass	17	1986	2002	11/30	11/27	11/27	11.51	11/11/95	12/20/01
Portage	29-0250	Hubbard	28	1974	2001	11/14	11/13		9.79	10/31/93	11/29/01
Richardson	47-0088	Meeker	13	1989	2001	12/3	11/29	11/27	12.63	11/19/97	12/22/98
Sand	31-0438	Itasca	13	1989	2001	11/26	11/23	12/6	11.88	11/13/95	12/15/98
Secret	31-0061	Itasca	24	1979	2002	11/13	11/11	11/6	8.43	11/03/91	11/26/01
Shagawa	69-0069	St. Louis	37	1965	2001	11/22	11/19		11.43	11/06/91	12/09/98
Siseebakwet	31-0554	Itasca	34	1968	2001	12/6	12/6	11/25	9.12	11/25/96	12/20/01
Swan (main)	31-0067-02	Itasca	16	1987	2002	12/2	11/29	12/2	11.57	11/13/95	12/20/98
Swan (west)	31-0067-01	Itasca	16	1987	2002	12/2	11/29	12/2	11.57	11/13/95	12/20/98
Wall	56-0658	Otter Tail	35	1968	2002	11/17	11/16	11/3	11.34	11/03/93	12/07/01
Wirth	27-0037	Hennepin	27	1975	2001	11/26	11/26	11/26	15.56	11/04/91	12/20/01
Average			**25**	**1978**	**2002**	**11/25**	**11/25**	**11/23**	**12.48**		
Standard Deviation			**8.47**	**8.49**	**0.57**	**6.90**	**8.55**	**12.18**	**2.74**		

Complete Results of Linear Regression Analysis for Ice-In Dates

Lake Name	MNDNR Lake ID Number	Latitude	Longitude	Surface Area (acres)	Surface Area (km^2)	Maximum Depth (ft)	Maximum Depth (m)	County	Record Length			Slopes: Complete		
									Length (years)	From	To	Ice-In (days/year)	RMSE (days)	r^2
5th Crow Wing	29-0092	46.92222	94.8925	392	1.6	35	10.7	Hubbard	14	1989	2002	2.0659	11.95	0.3121
Bad Axe	29-0208	47.08778	94.95					Hubbard	14	1989	2002	1.0347	9.69	0.1722
Bad Medicine	03-0088	47.124	95.404					Becker	30	1973	2002	0.0959	7.69	0.0119
Big Green	13-0041-02	45.34389	92.89611	1550	6.3			Chisago	23	1979	2001	0.5521	13.47	0.0901
Big Pine	58-0138	46.20833	93.05	387	1.6	25	7.6	Pine	11	1991	2001	3.0909	7.59	0.6252
Big Turtle	04-0159	47.61861	94.87056	1436	5.8	45	13.7	Beltrami	38	1965	2002	0.0002	8.07	0.0000
Big Watab	73-0102	45.54722	94.45	227	0.9	123	37.5	Stearns	20	1983	2002	0.7491	9.66	0.1600
Collinwood	86-0293	45.05278	94.25278	584	2.4	28	8.5	Wright	18	1985	2002	1.3818	10.75	0.3201
Crow Wing	18-0155	46.23694	94.34028	373	1.5	26	7.9	Crow Wing	35	1968	2002	0.3922	10.87	0.1201
Doan	31-0536	47.42083	93.575	89	0.4	40	12.2	Itasca	18	1984	2001	1.0031	9.72	0.2389
Ely	69-0660	47.45111	92.48472	57	0.2	70	21.3	St. Louis	33	1969	2001	0.0242	7.11	0.0010
Fish Trap	49-0137	46.20833	94.625	1303	5.3	42	12.8	Morrison	17	1984	2000	0.8438	10.87	0.1598
Island	03-0153	46.91667	95.54167	1160	4.7	43	13.1	Becker	13	1990	2002	1.5275	13.76	0.0240
Johnson	31-0586	47.41667	93.58333	305	1.2	51	15.5	Itasca	22	1980	2001	-0.4771	10.63	0.0783
Kabekona	29-0075	47.16361	94.76583	2252	9.1	133	40.5	Hubbard	12	1991	2002	1.3636	9.61	0.2015
Little Green	13-0041-01	45.36472	92.8975	280	1.1			Chisago	24	1979	2002	0.3925	13.59	0.0436
Little McDonald	56-0328	46.60833	95.7	1174	4.8	109	33.2	Otter Tail	25	1977	2001	0.4023	7.88	0.1236
Long	03-0383	46.81917	95.89306	357	1.4	61	18.6	Becker	43	1960	2002	-0.0393	8.65	0.0032
Long (Boy River)	11-0142	47.02528	94.17194	650	2.6	115	35.1	Cass	28	1974	2001	0.3905	9.00	0.0793
Loon	69-0426	48.25	92.267					St. Louis	24	1979	2002	0.3814	9.49	0.0731
Martin	02-0034	45.38333	93.0875	237	1.0	22	6.7	Anoka	21	1982	2002	0.3999	11.09	0.0432
McDonald	56-0386-02	46.57	95.75694			30	9.1	Otter Tail	34	1968	2001	0.0908	8.99	0.0100
Ponto	11-0234	46.87222	94.34167	724	2.9	60	18.3	Cass	17	1986	2002	1.1544	9.09	0.2914
Portage	29-0250	46.96583	95.11833	412	1.7	15	4.6	Hubbard	28	1974	2001	0.1178	8.13	0.0130
Richardson	47-0088	45.15889	94.43917	115	0.5	47	14.3	Meeker	13	1989	2001	1.9222	13.28	0.4318
Sand	31-0438	47.49167	93.50417	149	0.6	50	15.2	Itasca	13	1989	2001	1.5170	8.26	0.2284
Secret	31-0061	47.6523	93.078					Itasca	24	1979	2002	0.4162	7.72	0.1105
Shagawa	69-0069	47.91667	91.875	2370	9.6	48	14.6	St. Louis	37	1965	2001	0.2165	8.13	0.0787
Siseebakwet	31-0554	47.15833	93.66667	1312	5.3	105	32.0	Itasca	34	1968	2001	0.1739	6.55	0.0653
Swan (main)	31-0067-02	47.30611	93.18	9	0.0	66	20.1	Itasca	16	1987	2002	1.1250	9.18	0.2311
Swan (west)	31-0067-01	47.28972	93.20833	9	0.0	20	6.1	Itasca	16	1987	2002	1.1250	9.18	0.2311
Virginia	10-0015	44.88056	93.63972	116	0.5	34	10.4	Carver	11	1992	2002	1.7074	12.51	0.1496
Wall	56-0658	46.27222	95.96389	683	2.8	27	8.2	Otter Tail	35	1968	2002	0.0770	8.32	0.0089
Wirth	27-0037	44.98194	93.32222	37	0.1	25	7.6	Hennepin	27	1975	2001	0.4206	10.73	0.0883
Average		**46.6378**	**94.0821**	**646.5**	**2.6**	**53.4**	**16.3**		**23.1765**	**1979**	**2002**	**0.7541**	**9.7415**	**0.1417**
Standard Deviation		**0.9286**	**1.1061**	**654.9**	**2.7**	**33.5**	**10.2**		**9.0066**	**9.0550**	**0.5633**	**0.7516**	**1.9558**	**0.1381**

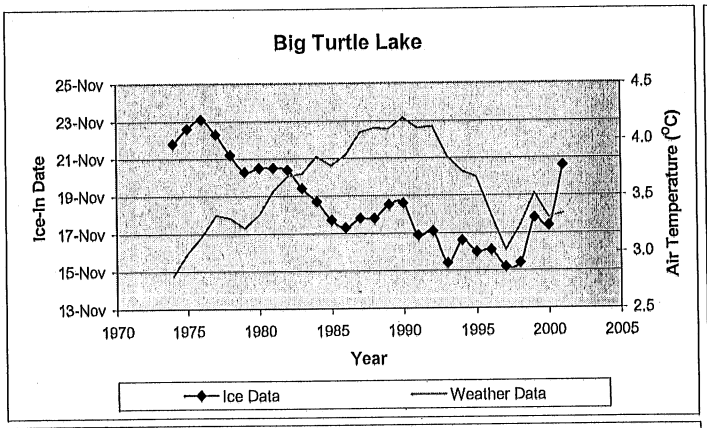
Complete Results of Linear Regression Analysis for Ice-In Dates (Continued)

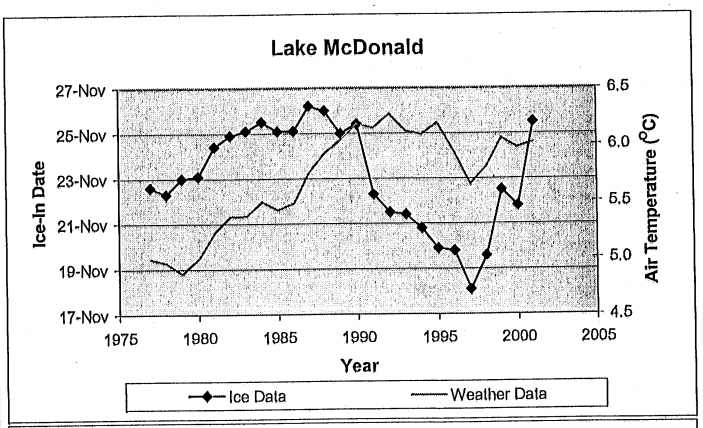
Lake Name	Slopes: 1970 to Now			Slopes: 1980 to Now			Slopes: 1990 to Now			Comments
	Ice-In (days/year)	RMSE (days)	r^2	Ice-In (days/year)	RMSE (days)	r^2	Ice-In (days/year)	RMSE (days)	r^2	
5th Crow Wing							2.3741	12.24	0.3283	
Bad Axe							1.5023	9.94	0.2188	*In: Missing 1990, 92-93, 95
Bad Medicine							1.1758	9.49	0.1887	
Big Green				0.6346	13.86	0.1054	3.9682	14.35	0.5455	*In: Missing 1987, 90, 92-97
Big Pine							0.3407	7.94	0.0352	
Big Turtle	0.0192	8.23	0.0005	0.3015	8.66	0.0486	1.6678	9.72	0.2768	
Big Watab							1.0594	11.36	0.1017	
Collinwood							1.8407	12.42	0.2499	
Crow Wing	0.5374	10.62	0.1932	0.7095	9.65	0.1991	1.0440	10.94	0.1214	
Doan							2.3968	10.36	0.4330	*In: Missing 1996
Ely	0.0316	7.23	0.0015	0.0291	7.84	0.0005	0.7502	9.43	0.0683	*In: Missing 1999-00
Fish Trap							2.0857	13.83	0.2098	*In: Missing 1991-93, 97
Island							1.5275	13.76	0.0240	
Johnson							-1.1643	9.37	0.1673	
Kabekona							1.3636	9.61	0.2015	
Little Green				0.4959	13.84	0.0615	2.6872	15.78	0.3242	*In: Missing 1987, 92-94, 96
Little McDonald				0.5285	8.12	0.1516	1.7552	8.85	0.3385	
Long	0.0431	8.37	0.0023	0.1344	10.07	0.0081	1.2253	11.16	0.1545	
Long (Boy River)				0.4748	9.11	0.1010	1.4825	10.29	0.2124	*In: Missing 1983
Loon				0.4534	9.62	0.0909	0.7460	12.37	0.0539	*In: Missing 1999
Martin							0.8117	13.10	0.0543	
McDonald	0.0805	9.27	0.0066	0.0830	10.66	0.0026	1.6888	11.25	0.2265	
Ponto							1.3352	10.27	0.2039	
Portage				0.2411	8.60	0.0321	1.4266	8.33	0.2761	
Richardson							2.0071	13.28	0.3938	*In: Missing 1994, 96
Sand							1.6970	8.26	0.1871	*In: Missing 1990-91
Secret				0.3571	7.87	0.0712	0.9965	7.62	0.1818	*In: Missing 1981-82
Shagawa	0.1767	8.64	0.0326	0.3478	9.38	0.0548	1.9790	8.93	0.3898	*In: Missing 1969-70, 75-76, 78-79
Siseebakwet	0.2276	6.62	0.0941	0.2484	7.47	0.0446	1.6748	6.83	0.4384	
Swan (main)							0.3004	9.68	1.7587	
Swan (west)							0.3004	9.68	1.7587	
Virginia							1.7074	12.51	0.1496	*In: Missing 1999
Wall	0.0849	8.56	0.0091	0.0316	9.68	0.0005	1.1868	10.36	0.1661	
Wirth				0.5833	11.72	0.0946	2.0350	13.72	0.2224	
Average	**0.1501**	**8.4425**	**0.0425**	**0.3534**	**9.7594**	**0.0667**	**1.4405**	**10.7950**	**0.3136**	
Standard Deviation	**0.1726**	**1.2143**	**0.0686**	**0.2146**	**1.9418**	**0.0561**	**0.8587**	**2.1488**	**0.3866**	

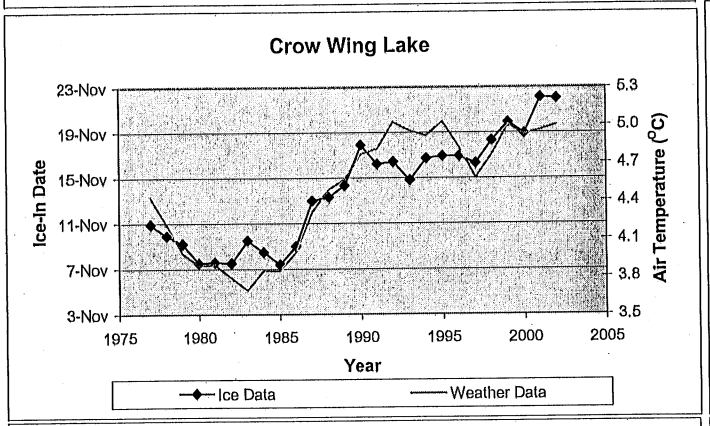
Analysis of 30 Years of Sorted Ice-In Dates

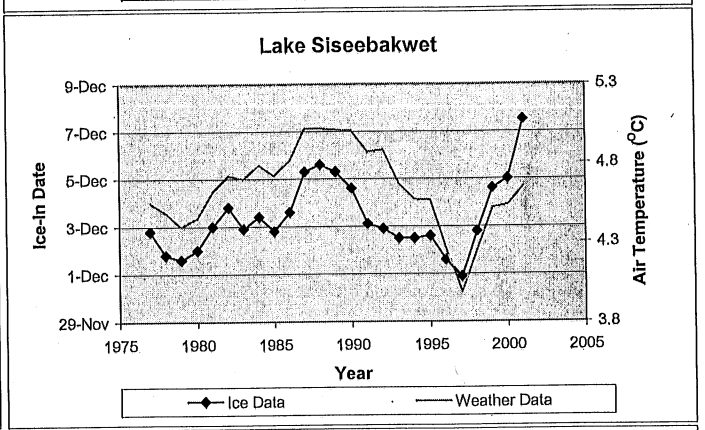
Last Years of Record	Top Ice-Out Events	Number of Events Expected	Actual Number of Years						Analysis		
			Wall	Siseebakwet	McDonald	Crow Wing	Big Turtle	Long	# above expected	% above expected	% above per period
5	3	0.5	2	3	2	3	2	3	6	100.0	87.5
	6	1.0	2	3	3	3	2	3	6	100.0	
	10	1.7	2	5	3	4	2	3	4	66.7	
	15	2.5	4	5	3	4	4	4	5	83.3	
10	3	1.0	2	3	2	3	2	3	6	100.0	75.0
	6	2.0	3	3	3	4	3	4	6	100.0	
	10	3.3	3	5	5	5	3	4	4	66.7	
	15	5.0	5	7	5	6	5	5	2	33.3	
15	3	1.5	2	3	2	3	2	3	3	50.0	58.3
	6	3.0	4	4	4	5	4	4	6	100.0	
	10	5.0	4	6	6	7	5	5	3	50.0	
	15	7.5	7	9	7	9	8	6	2	33.3	
20	3	2.0	2	3	3	3	2	3	4	66.7	54.2
	6	4.0	5	4	5	6	5	5	5	83.3	
	10	6.7	6	7	8	9	6	7	2	33.3	
	15	10.0	9	12	9	11	9	8	2	33.3	
# above expected			7	14	11	16	7	11			
% above expected			43.75	87.5	68.75	100	43.75	68.75			

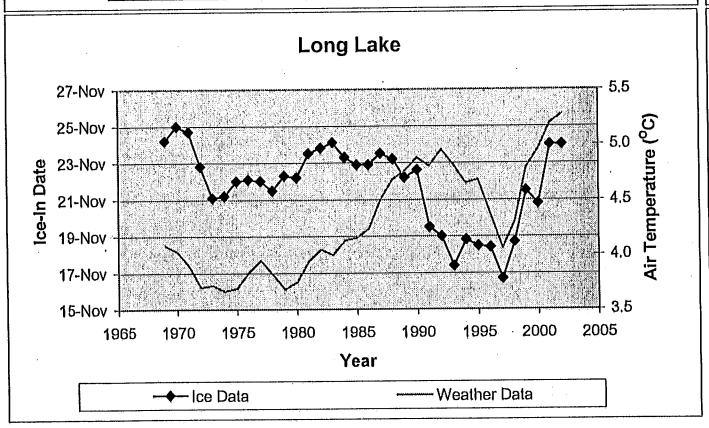
Comparison of Ice-In Date and Average Annual Air Temperature Ten-Year Running Averages

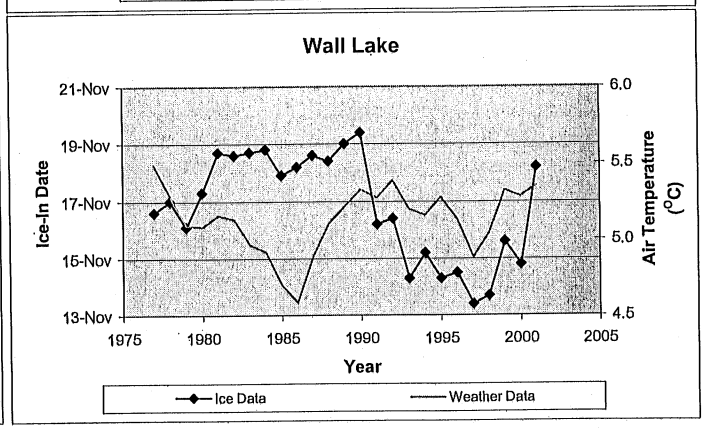




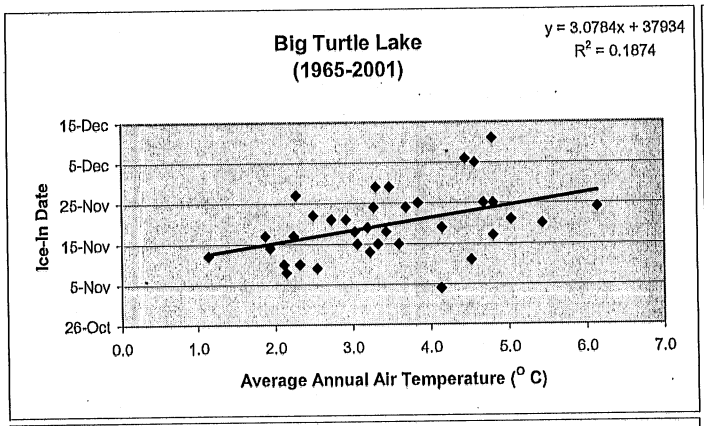


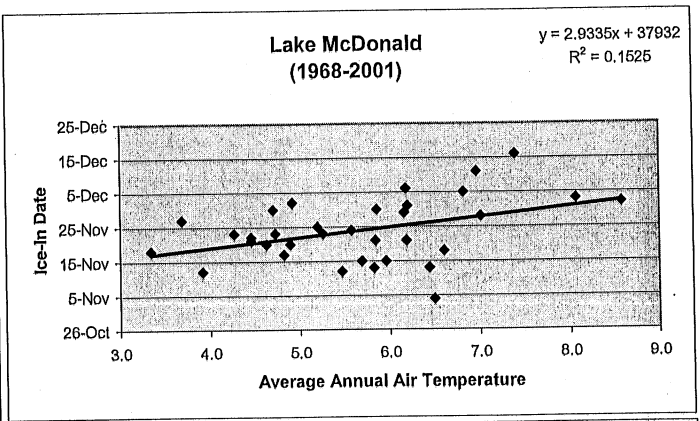


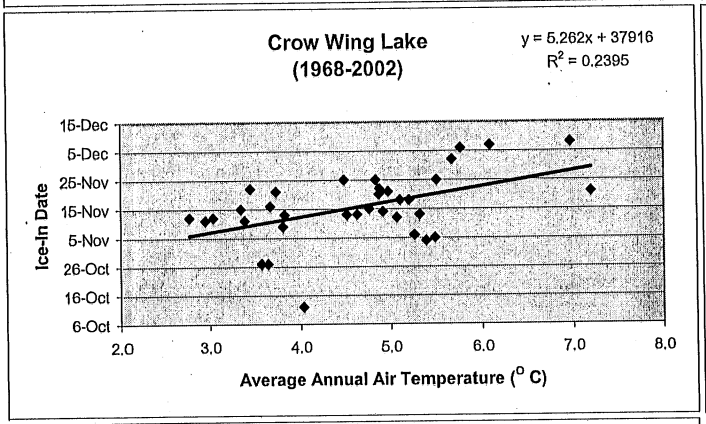


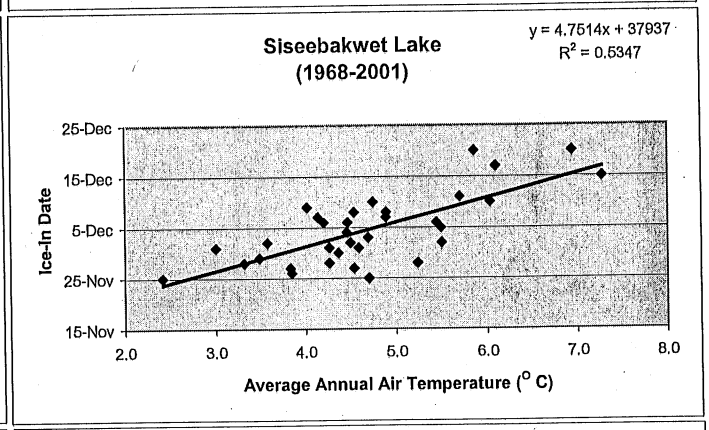


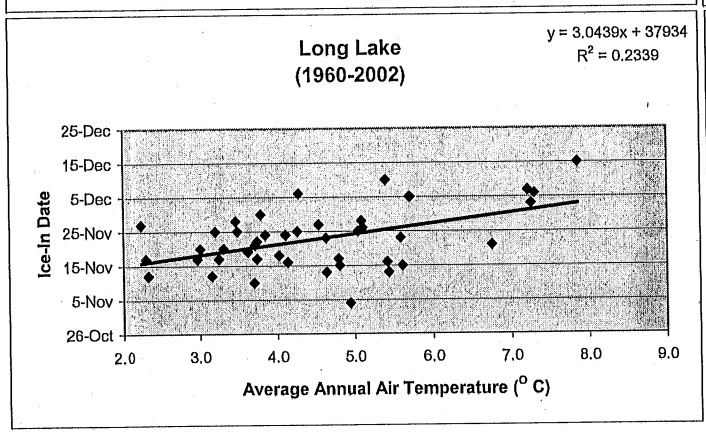
Linearization of ice-in date and average annual air temperature

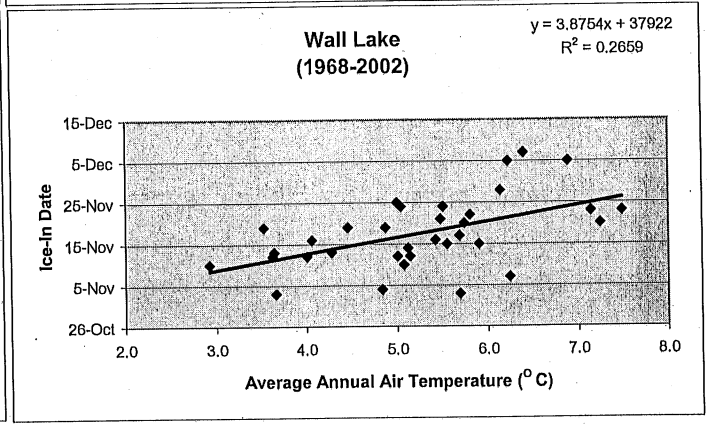




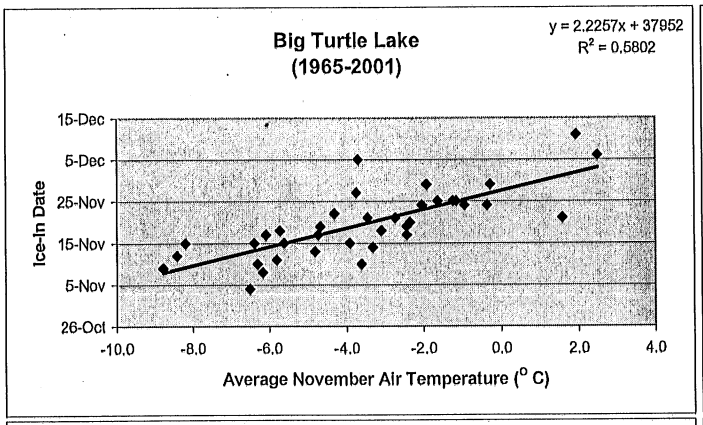


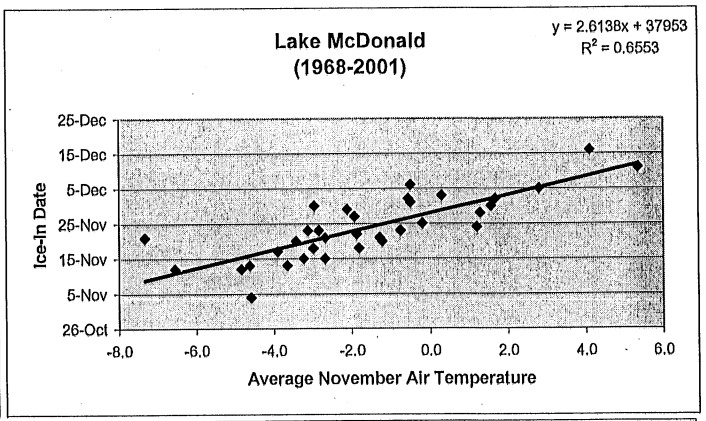


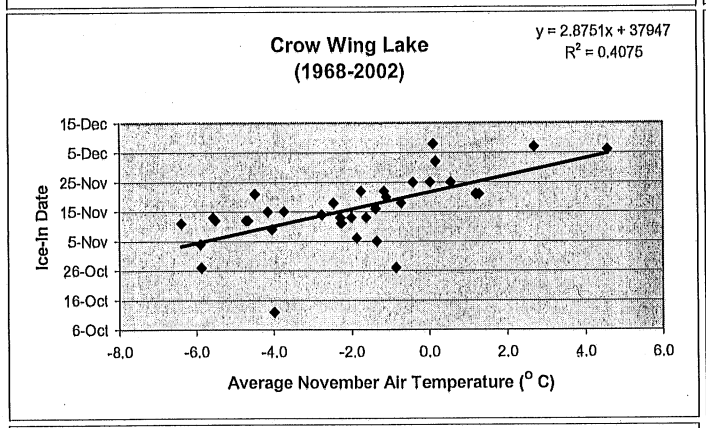


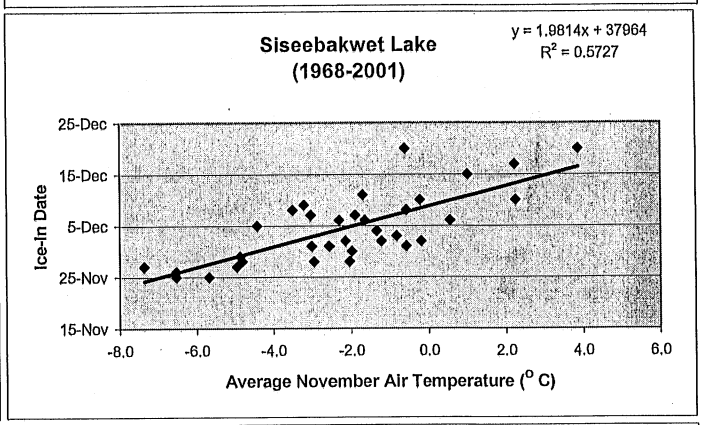


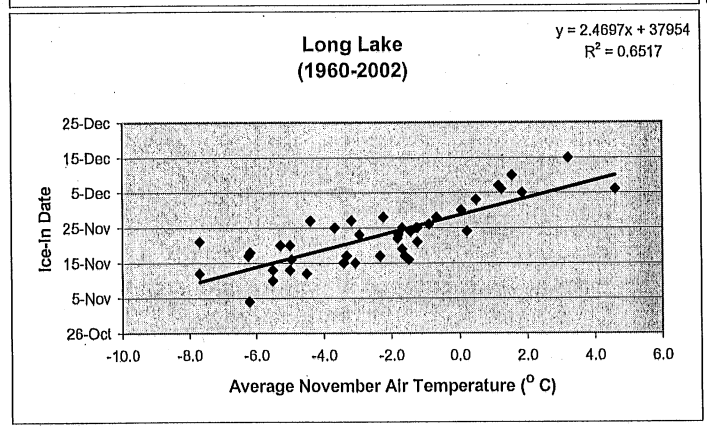
Linearization of ice-in date and average November air temperature

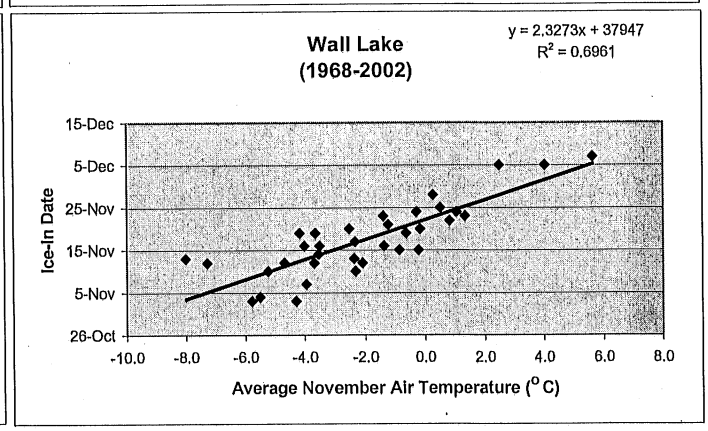




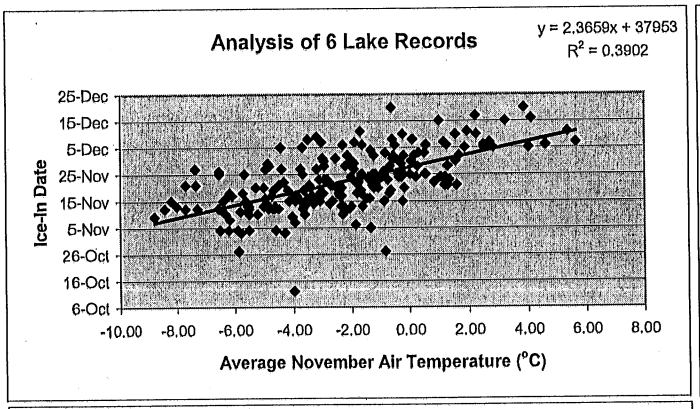


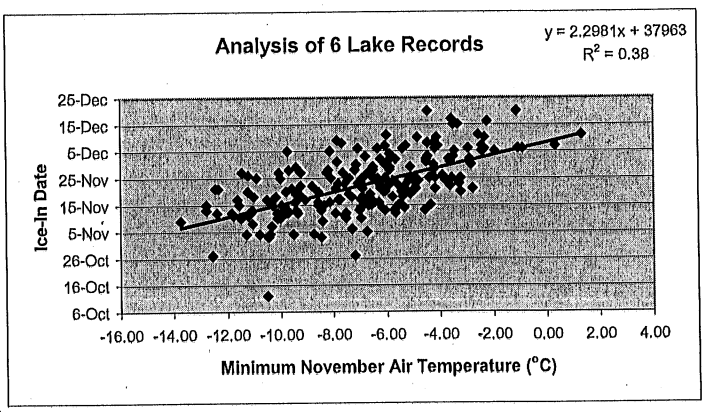


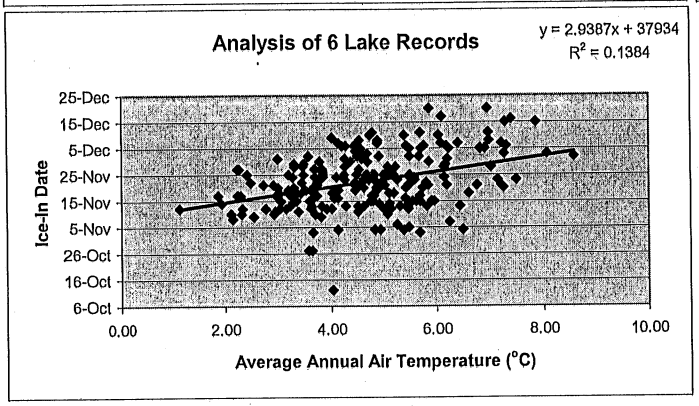




Linearization of ice-in date and various air temperature measurements







APPENDIX C
SPRING RIVER RUNOFF
DATE AND FLOW ANALYSIS

Statistical Data for Spring River Discharge

Station	Name	Record Length			First Peak Date					First Peak Flow (cfs)				
		Length	From	To	Average	Median	St. Dev.	Earliest	Latest	Average	Median	St. Dev.	Minimum	Maximum
05078230	Lost River at Oklee	42	1961	2002	31-Mar	31-Mar	15.02	28-Feb	17-May	991.55	695.00	873.24	45.00	3040.00
05124480	Kawishiwi River near Ely	36	1967	2002	9-May	10-May	7.78	24-Apr	28-May	904.26	903.00	414.30	222.00	1850.00
05130500	Sturgeon River near Chisholm	43	1960	2002	7-Apr	9-Apr	14.30	2-Mar	1-May	783.02	594.00	601.66	35.00	2370.00
05131500	Little Fork River at Little Fork	43	1960	2002	9-Apr	11-Apr	14.61	3-Mar	30-Apr	8423.95	7600.00	5841.13	200.00	20600.00
05133500	Rainy River at Manitou Rapids	43	1960	2002	12-Apr	15-Apr	13.18	10-Mar	1-May	26469.52	21300.00	15276.07	4910.00	60800.00
05245100	Long Prairie River at Long Prairie	31	1972	2002	26-Mar	27-Mar	15.15	25-Feb	22-Apr	781.74	672.00	546.80	88.00	2710.00
05280000	Crow River at Rockford	43	1960	2002	27-Mar	29-Mar	15.81	16-Feb	3-May	4406.88	3350.00	4366.85	307.00	22100.00
05287890	Elm Creek near Champlin	24	1979	2002	21-Mar	21-Mar	13.22	27-Feb	15-Apr	261.70	224.00	200.74	8.90	750.00
05291000	Whetstone River near Big Stone City, SD	43	1960	2002	19-Mar	21-Mar	13.77	14-Feb	19-Apr	1431.37	700.00	1833.18	18.00	8090.00
05293000	Yellow Bank River near Odessa	40	1960	1999	18-Mar	18-Mar	12.04	24-Feb	9-Apr	1202.18	640.00	1508.38	20.00	6640.00
05300000	Lac Qui Parle River near Lac Qui Parle	43	1960	2002	23-Mar	26-Mar	12.57	26-Feb	20-Apr	2204.05	1100.00	3244.56	37.00	16000.00
05313500	Yellow River Near Granite Falls	43	1960	2002	23-Mar	25-Mar	14.15	26-Feb	25-Apr	1754.95	807.00	2857.99	37.00	16400.00
05317000	Cottonwood River near New Ulm	43	1960	2002	19-Mar	19-Mar	13.64	18-Feb	24-Apr	4157.70	2600.00	5588.28	127.00	27100.00
05317200	Little Cottonwood River near Courtland	29	1974	2002	16-Mar	16-Mar	14.58	15-Feb	17-Apr	412.96	243.00	471.93	28.00	2310.00
05320000	Blue Earth River near Rapidan	43	1960	2002	21-Mar	21-Mar	17.14	13-Feb	27-Apr	5374.05	3100.00	7162.83	437.00	42500.00
05320500	Le Sueur River near Rapidan	43	1960	2002	18-Mar	18-Mar	16.54	10-Feb	26-Apr	3754.51	2200.00	4371.00	228.00	23400.00
05325000	Minnesota River at Mankato	39	1964	2002	25-Mar	24-Mar	14.30	26-Feb	27-Apr	18983.08	13000.00	20636.48	1070.00	92700.00
05327000	High Island Creek near Henderson	29	1974	2002	16-Mar	15-Mar	13.56	25-Feb	23-Apr	495.10	379.00	455.18	17.00	1580.00
05330000	Minnesota River Near Jordan	43	1960	2002	25-Mar	25-Mar	15.38	27-Feb	3-May	22173.26	13100.00	24997.52	1180.00	112000.00
05336700	Kettle River below Sandstone	35	1968	2002	31-Mar	2-Apr	15.64	27-Feb	25-Apr	5012.54	3750.00	3722.18	626.00	13000.00
05353800	Straight River near Faribault	37	1966	2002	15-Mar	17-Mar	18.03	8-Feb	24-Apr	1821.32	1350.00	1258.16	236.00	5090.00
	Average	**39**	**1964**	**2002**	**26-Mar**	**27-Mar**	**14.30**	**25-Feb**	**26-Apr**	**5323.80**	**3728.90**	**5058.50**	**470.33**	**22906.19**
	Standard Deviation	**5.93**	**6.00**	**0.65**	**12.68**	**13.13**	**2.10**	**15.47**	**10.54**	**7587.75**	**5538.48**	**6868.06**	**1070.18**	**30561.23**

Statistical Data for Spring River Discharge (Continued)

Station	Max Spring Peak Date					Max Spring Peak Flow (cfs)					1st Spring Runoff Date				
	Average	Median	St. Dev.	Earliest	Latest	Average	Median	St. Dev.	Minimum	Maximum	Average	Median	St. Dev.	Earliest	Latest
05078230	4-Apr	4-Apr	14.87	28-Feb	17-May	1103.98	850.00	893.13	70.00	3040.00	29-Mar	30-Mar	15.76	25-Feb	17-May
05124480	9-May	12-May	7.99	24-Apr	28-May	910.06	903.00	417.76	222.00	1850.00	7-May	8-May	6.99	24-Apr	24-May
05130500	20-Apr	21-Apr	13.75	2-Mar	23-May	916.72	814.00	546.75	85.00	2370.00	5-Apr	8-Apr	14.93	2-Mar	1-May
05131500	22-Apr	21-Apr	13.42	22-Mar	24-May	9362.56	9000.00	5230.43	200.00	20600.00	6-Apr	9-Apr	15.12	3-Mar	30-Apr
05133500	27-Apr	23-Apr	17.95	1-Mar	27-May	29869.29	26650.00	15161.55	4910.00	60800.00	4-Apr	5-Apr	15.71	1-Mar	1-May
05245100	4-Apr	5-Apr	18.85	27-Feb	13-May	808.26	672.00	527.49	95.00	2710.00	21-Mar	23-Mar	14.72	25-Feb	22-Apr
05280000	30-Mar	30-Mar	14.37	3-May	4-Mar	4533.53	3590.00	4299.11	330.00	22100.00	25-Mar	29-Mar	15.99	16-Feb	3-May
05287890	31-Mar	29-Mar	22.04	27-Feb	15-May	342.87	309.50	223.23	8.90	815.00	18-Mar	18-Mar	13.74	26-Feb	12-Apr
05291000	1-Apr	29-Mar	19.16	29-Feb	25-May	1657.49	1080.00	1839.08	57.00	8090.00	13-Mar	14-Mar	14.26	14-Feb	8-Apr
05293000	29-Mar	25-Mar	20.28	24-Feb	20-May	1409.50	1070.00	1480.27	20.00	6640.00	14-Mar	15-Mar	14.05	16-Feb	9-Apr
05300000	6-Apr	31-Mar	19.77	7-Mar	22-May	2507.85	1260.00	3194.98	66.00	16000.00	18-Mar	18-Mar	14.96	15-Feb	20-Apr
05313500	5-Apr	1-Apr	20.66	6-Mar	28-May	2076.16	1160.00	2827.01	37.00	16400.00	15-Mar	14-Mar	15.97	12-Feb	25-Apr
05317000	2-Apr	30-Mar	20.23	21-Feb	20-May	5238.14	2830.00	6167.01	127.00	27100.00	14-Mar	14-Mar	14.62	18-Feb	24-Apr
05317200	26-Mar	28-Mar	13.53	29-Feb	17-Apr	475.64	403.00	465.05	40.00	2310.00	9-Mar	8-Mar	15.71	7-Feb	17-Apr
05320000	6-Apr	2-Apr	20.41	3-Mar	22-May	7436.91	5490.00	7165.52	437.00	42500.00	14-Mar	15-Mar	17.69	6-Feb	26-Apr
05320500	3-Apr	29-Mar	21.85	28-Feb	23-May	5084.70	3480.00	4660.60	310.00	23400.00	15-Mar	15-Mar	17.64	10-Feb	26-Apr
05325000	5-Apr	4-Apr	21.94	19-Feb	24-May	22541.03	15300.00	22171.24	2190.00	92700.00	15-Mar	17-Mar	18.43	9-Feb	27-Apr
05327000	29-Mar	27-Mar	20.48	27-Feb	17-May	742.28	710.00	609.02	35.00	2400.00	11-Mar	8-Mar	16.07	16-Feb	23-Apr
05330000	6-Apr	5-Apr	17.24	1-Mar	17-May	25224.88	20000.00	24056.23	1210.00	112000.00	20-Mar	20-Mar	16.77	13-Feb	3-May
05336700	10-Apr	12-Apr	14.98	8-Mar	7-May	6049.23	5200.00	3633.96	883.00	14200.00	25-Mar	27-Mar	16.40	25-Feb	24-Apr
05353800	26-Mar	24-Mar	20.20	8-Feb	5-May	2156.54	1950.00	1217.02	236.00	5090.00	10-Mar	13-Mar	18.26	5-Feb	24-Apr
	6-Apr	**5-Apr**	**17.81**	**5-Mar**	**14-May**	**6211.79**	**4891.50**	**5085.07**	**550.90**	**23005.48**	**22-Mar**	**22-Mar**	**15.42**	**20-Feb**	**26-Apr**
	11.17	**12.11**	**3.72**	**19.70**	**18.93**	**8672.01**	**7160.65**	**6909.08**	**1126.17**	**30512.34**	**13.54**	**14.16**	**2.35**	**16.73**	**10.85**

Statistical Data for Spring River Discharge (Continued)

Station	1st Spring Runoff Flow (cfs)					February Flow (cfs)					March Flow (cfs)				
	Average	Median	St. Dev.	Minimum	Maximum	Average	Median	St. Dev.	Minimum	Maximum	Average	Median	St. Dev.	Minimum	Maximum
05078230	960.81	625.00	888.97	45.00	3040.00	10.83	8.95	12.34	0.00	76.30	76.04	36.15	73.79	0.19	264.00
05124480	885.46	903.00	440.96	91.00	1850.00	68.26	64.95	24.27	4.77	107.00	56.90	58.65	15.15	5.87	85.20
05130500	698.91	513.00	609.65	35.00	2370.00	26.43	26.40	10.27	4.54	47.70	49.54	42.10	31.81	15.00	131.00
05131500	7087.79	5480.00	5892.60	200.00	20600.00	140.64	136.00	57.49	42.30	271.00	295.81	219.00	228.76	50.20	902.00
05133500	19312.38	14500.00	12939.23	4910.00	57900.00	9212.21	8778.00	2557.75	3661.00	17240.00	9051.93	9194.00	2212.82	3866.00	13769.00
05245100	666.35	589.00	557.28	83.00	2710.00	66.91	64.60	46.68	1.62	208.00	171.58	140.00	124.64	19.80	441.00
05280000	4218.53	3000.00	4421.70	285.00	22100.00	238.00	157.00	251.91	27.30	1115.00	1085.70	671.00	1081.06	31.90	4084.00
05287890	232.33	168.50	196.38	8.90	750.00	9.92	4.04	19.76	0.91	99.10	64.78	39.45	59.54	3.86	185.00
05291000	1101.14	343.00	1819.38	16.00	8090.00	20.19	8.40	31.85	1.85	168.00	184.58	128.00	184.67	2.85	612.00
05293000	1096.98	450.00	1522.65	20.00	6640.00	20.84	7.28	34.14	0.00	147.00	204.21	127.00	198.80	1.59	693.00
05300000	1965.54	722.00	3278.35	18.00	16000.00	30.62	9.88	47.50	0.00	244.00	353.04	214.00	377.42	0.94	1634.00
05313500	1454.79	360.00	2888.72	16.00	16400.00	24.33	9.80	30.49	2.43	149.00	262.73	161.00	275.09	3.67	933.00
05317000	3284.19	1030.00	5729.27	127.00	27100.00	116.89	68.10	135.18	7.26	628.00	747.75	594.00	696.66	13.90	3350.00
05317200	321.18	119.00	482.86	23.00	2310.00	23.22	15.00	28.83	0.38	105.00	122.29	86.90	96.91	11.20	360.00
05320000	4740.77	1800.00	7341.78	222.00	42500.00	296.18	140.00	382.26	18.10	1792.00	1548.57	1051.00	1536.26	92.40	6277.00
05320500	3451.81	1670.00	4445.69	129.00	23400.00	175.35	69.10	273.82	8.89	1298.00	913.40	679.00	861.85	33.00	3464.00
05325000	15428.21	8310.00	20376.14	1040.00	92700.00	1069.29	646.00	1027.04	93.30	4505.00	5400.21	4086.00	4584.64	538.00	18240.00
05327000	416.34	273.00	459.93	17.00	1580.00	22.24	9.80	32.01	1.28	121.00	155.22	93.30	151.56	5.33	547.00
05330000	18400.93	9060.00	23897.71	1180.00	112000.00	1277.65	713.00	1065.81	184.00	3992.00	5832.84	4127.00	5234.46	591.00	21170.00
05336700	4204.80	2590.00	4038.92	241.00	13000.00	185.76	155.00	80.04	98.50	447.00	535.14	381.00	416.34	141.00	1742.00
05353800	1423.70	1030.00	1275.39	137.00	5090.00	117.94	76.60	149.70	12.90	837.00	508.10	461.00	344.05	26.40	1270.00
	4350.14	**2549.31**	**4928.74**	**421.14**	**22768.10**	**626.37**	**531.80**	**299.96**	**198.63**	**1599.86**	**1315.26**	**1075.69**	**894.58**	**259.72**	**3816.82**
	5901.17	**3753.03**	**6515.92**	**1076.06**	**30387.50**	**1995.90**	**1899.36**	**599.54**	**794.66**	**3791.01**	**2395.30**	**2200.91**	**1448.45**	**842.70**	**6141.79**

Statistical Data for Spring River Discharge (Continued)

Station	April Flow (cfs)					May Flow (cfs)					Yearly Flow (cfs)				
	Average	Median	St. Dev.	Minimum	Maximum	Average	Median	St. Dev.	Minimum	Maximum	Average	Median	St. Dev.	Minimum	Maximum
05078230	310.41	201.50	253.30	29.50	904.00	140.45	111.00	121.00	10.50	622.00	76.98	76.80	37.60	17.00	179.00
05124480	242.07	191.50	174.63	8.95	785.00	645.62	712.50	283.89	13.30	1133.00	204.83	198.00	52.62	110.00	343.00
05130500	365.21	332.00	181.34	41.00	801.00	287.40	247.00	139.50	22.90	546.00	128.70	131.50	33.49	61.10	190.00
05131500	3458.14	3037.00	1881.43	292.00	8421.00	2898.26	2545.00	1540.85	173.00	6287.00	1163.05	1121.50	356.82	554.00	1872.00
05133500	16375.69	15884.50	7256.33	4378.00	38100.00	20861.79	19630.00	10875.37	4106.00	43480.00	14134.58	13910.00	3718.44	7175.00	21000.00
05245100	382.15	330.00	220.09	71.80	1062.00	283.62	261.00	156.57	45.50	653.00	164.07	151.50	85.10	43.60	390.00
05280000	2838.30	2162.00	2325.17	211.00	9026.00	1907.33	1591.00	1437.85	211.00	5992.00	1008.29	924.50	657.25	157.00	2713.00
05287890	108.60	101.40	88.58	5.31	414.00	70.32	41.25	64.04	3.54	203.00	37.17	38.80	21.48	4.23	74.30
05291000	268.76	123.00	362.28	9.21	1676.00	107.75	44.40	126.44	6.85	491.00	71.23	47.80	63.21	6.98	229.00
05293000	279.81	128.00	349.95	9.13	1613.00	118.22	64.55	141.18	2.94	652.00	79.11	53.80	69.36	3.81	263.00
05300000	771.50	299.00	1045.07	23.40	5354.00	305.19	229.50	312.73	11.60	1264.00	195.14	135.00	169.54	13.90	647.00
05313500	638.67	340.00	790.08	17.20	3302.00	260.24	175.00	237.88	8.85	933.00	169.60	122.50	146.68	12.10	587.00
05317000	1429.31	765.00	1654.26	54.70	7075.00	785.81	524.00	772.16	28.20	3497.00	467.91	316.50	372.09	62.10	1769.00
05317200	208.82	166.00	205.09	9.64	980.00	136.83	109.00	104.89	4.17	418.00	73.76	62.05	56.52	9.13	233.00
05320000	3237.44	2198.00	3199.06	142.00	13230.00	2073.51	1634.00	1526.32	144.00	5775.00	1228.36	1045.50	785.39	130.00	4229.00
05320500	1638.49	1253.00	1560.13	66.00	6563.00	1114.98	938.00	884.44	55.40	3706.00	639.57	621.00	364.76	64.80	1812.00
05325000	14040.47	9597.00	12973.00	916.00	52910.00	8631.19	7748.00	6052.88	869.00	25740.00	4727.90	3659.00	3037.42	744.00	14560.00
05327000	273.85	245.00	260.66	6.69	1104.00	158.40	118.00	136.86	3.32	478.00	105.19	105.30	76.74	8.88	274.00
05330000	15489.65	11190.00	13839.34	997.00	59030.00	9971.72	8643.00	7053.52	1163.00	31480.00	5417.12	4488.50	3410.65	923.00	16700.00
05336700	2429.03	2208.00	1307.78	435.00	6459.00	1236.77	1193.00	651.56	222.00	3168.00	720.56	710.50	240.75	275.00	1344.00
05353800	661.84	550.00	523.05	70.20	2365.00	464.40	370.00	344.13	58.10	1322.00	293.98	276.50	144.73	44.00	696.00
	3116.58	**2442.95**	**2402.41**	**371.13**	**10532.10**	**2498.09**	**2234.72**	**1569.72**	**341.10**	**6563.81**	**1481.29**	**1342.69**	**661.94**	**496.17**	**3338.30**
	5217.91	**4306.97**	**3999.22**	**960.93**	**17211.31**	**4994.37**	**4638.72**	**2845.83**	**913.19**	**11814.81**	**3245.81**	**3111.08**	**1163.87**	**1551.92**	**6069.04**

Station	Name	Latitude	Longitude	Watershed Area (miles^2)	Watershed Area (km^2)	Mean Annual Flow (cfs)	Mean Annual Flow (m^3/s)	Record Length			Data Quality		First Peak Date			First Peak Flow		
								Length (years)	From	To	Averages	Daily	Slope (days/yr)	r^2	RMSE (days)	Slope (cfs/yr)	r^2	RMSE (cfs)
05078230	Lost River at Oklee	47°50'35"	95°51'30"	254	657.9	77.0	2.2	42	1961	2002	Good	Fair	-0.2907	0.0564	14.68	-8.755	0.0151	859.53
05124480	Kawishiwi River near Ely	47°55'22"	91°32'06"	254	657.9	204.8	5.8	36	1967	2002	Good	Good	0.0578	0.0062	7.79	-15.581	0.1592	385.15
05130500	Sturgeon River near Chisholm	47°40'25"	92°54'00"	180	466.2	128.7	3.6	43	1960	2002	Good	Fair	-0.3765	0.1092	13.40	-6.7548	0.0199	587.18
05131500	Little Fork River at Little Fork	48°23'45"	93°32'57"	1680	4351.2	1163.0	32.9	43	1960	2002	Good	Fair	-0.399	0.1175	13.89	-77.576	0.0278	5821.67
05133500	Rainy River at Manitou Rapids	48°38'04"	93°54'47"	19400	50245.8	14134.6	400.2	43	1960	2002	Good	Fair	-0.2639	0.0619	12.92	-106.74	0.0075	15227.30
05245100	Long Prairie River at Long Prairie	45°58'30"	94°51'56"	434	1124.1	164.1	4.6	31	1972	2002	Good	Poor-Fair	-0.2391	0.0206	15.21	3.0016	0.0025	553.99
05280000	Crow River at Rockford	45°05'12"	93°44'02"	2640	6837.6	1008.3	28.6	43	1960	2002	Good	Fair	-0.2978	0.0559	15.55	-24.447	0.0049	4408.78
05287890	Elm Creek near Champlin	45°09'48"	93°26'11"	86	222.7	37.2	1.1	24	1979	2002	Good	Poor	0.0809	0.0019	12.99	-2.7132	0.0091	204.31
05291000	Whetstone River near Big Stone City, SD	45°17'30"	96°29'14"	398	1030.8	71.2	2.0	43	1960	2002	Good	Poor-Fair	-0.251	0.0524	12.94	17.421	0.0142	1812.07
05293000	Yellow Bank River near Odessa	45°13'37"	96°21'12"	459	1188.8	79.1	2.2	40	1960	1999	Good	Poor-Fair	-0.2899	0.0793	11.66	8.0534	0.0039	1524.67
05300000	Lac Qui Parle River near Lac Qui Parle	44°59'42"	95°55'09"	960	2486.4	195.1	5.5	43	1960	2002	Good	Poor-Fair	-0.0973	0.0087	12.64	-28.128	0.0109	3267.79
05313500	Yellow River Near Granite Falls	44°43'18"	95°31'07"	259	670.8	169.6	4.8	43	1960	2002	Good	Fair-Poor	-0.2591	0.0529	13.93	-19.122	0.0071	2877.24
05317000	Cottonwood River near New Ulm	44°17'29"	94°26'24"	1300	3367.0	467.9	13.2	43	1960	2002	Good	Poor-Fair	0.0885	0.0066	13.63	-61.742	0.0192	5601.30
05317200	Little Cottonwood River near Courtland	44°14'47"	94°20'19"	170	440.3	73.8	2.1	29	1974	2002	Good	Fair	0.0342	0.0004	14.61	9.0122	0.0263	472.89
05320000	Blue Earth River near Rapidan	44°05'44"	94°06'33"	2430	6293.7	1228.4	34.8	43	1960	2002	Good	Fair	-0.4219	0.0956	16.49	-96.148	0.0284	7139.35
05320500	Le Sueur River near Rapidan	44°06'40"	94°02'28"	1110	2874.9	639.6	18.1	43	1960	2002	Good	Fair-Poor	-0.4625	0.1234	15.67	-40.671	0.0137	4384.46
05325000	Minnesota River at Mankato	44°10'10"	94°00'15"	14900	38590.8	4727.9	133.9	39	1964	2002	Good	Fair-Poor	-0.2996	0.057	13.74	184.59	0.0104	20743.94
05327000	High Island Creek near Henderson	44°34'19"	93°55'18"	237	613.8	105.2	3.0	29	1974	2002	Good	Fair-Poor	0.0143	8.00E-05	13.58	10.359	0.0375	452.56
05330000	Minnesota River Near Jordan	44°41'35"	93°38'30"	16200	41957.8	5417.1	153.4	43	1960	2002	Good	Fair-Poor	-0.1605	0.0172	15.34	38.75	0.0004	25291.46
05336700	Kettle River below Sandstone	46°06'20"	92°51'50"	868	2248.1	720.6	20.4	35	1968	2002	Good	Fair	-0.6064	0.1579	14.32	-71.309	0.0385	3676.40
05353800	Straight River near Faribault	44°15'29"	93°13'51"	442	1144.8	294.0	8.3	37	1966	2002	Good	Fair	-0.339	0.0414	16.32	0.5443	2.00E-05	1273.10
	Average			**3079.10**	**7974.8**	**1481.3**	**41.9**	**39**	**1964**	**2002**			**-0.2275**	**0.0535**	**13.87**	**-13.7122**	**0.0217**	**5074.53**
	Standard Deviation			**5844.14**	**15136.3**	**3245.8**	**91.9**	**5.93**	**6.00**	**0.65**			**0.1932**	**0.0463**	**1.88**	**59.8025**	**0.0335**	**6919.83**

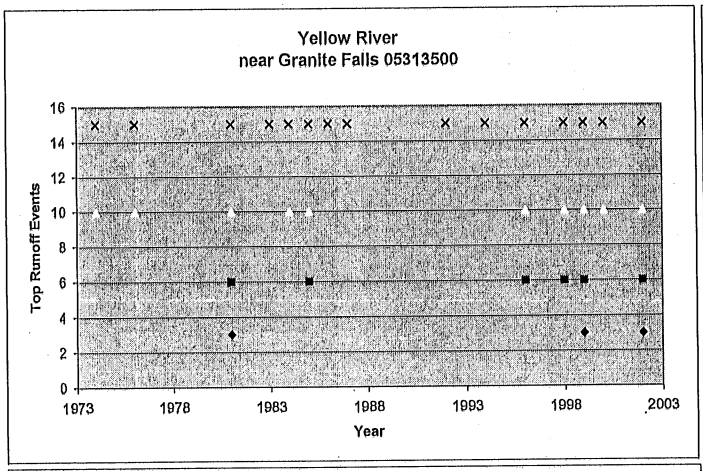
Trends in Spring River Discharge (Continued)

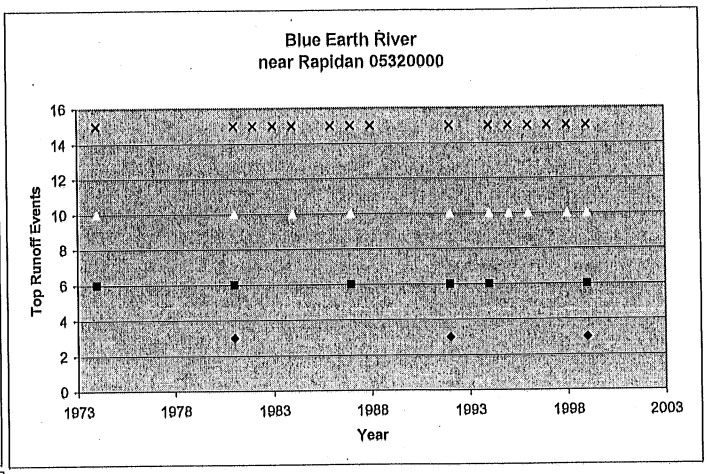
Station	Max Spring Peak Date			Max Spring Peak Flow			1st Spring Runoff Date			1st Spring Runoff Flow			February Flow			March Flow		
	Slope (days/yr)	r^2	RMSE (days)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (days/yr)	r^2	RMSE (days)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)
05078230	-0.2518	0.0432	14.55	-9.119	0.0157	881.19	-0.2736	0.0453	15.53	-7.8397	0.0117	878.85	0.4798	0.233	10.95	1.5904	0.0699	72.03
05124480	0.0957	0.0162	7.97	-15.053	0.1461	391.42	-0.0114	0.0003	6.99	-16.63	0.1601	409.78	-0.1152	0.0025	24.54	-0.0349	0.0006	15.34
05130500	-0.0734	0.0045	13.85	-8.5677	0.0387	538.76	-0.395	0.1103	14.06	-3.473	0.0051	605.26	0.3664	0.2009	9.25	1.0383	0.168	29.30
05131500	0.1311	0.015	13.47	-88.781	0.0454	5149.18	-0.3981	0.1093	14.44	-57.634	0.0151	5918.87	1.7858	0.1521	53.52	5.4277	0.0888	219.97
05133500	-0.0009	4.00E-07	18.09	-201.05	0.0271	14790.52	-0.5743	0.2062	14.17	-328.13	0.0992	12284.12	-33.185	0.026	2550.03	-30.938	0.0302	2187.01
05245100	-0.2633	0.0161	18.80	3.5351	0.0037	534.25	-0.2778	0.0294	14.75	5.5581	0.0082	560.02	1.4609	0.081	44.79	-0.1223	8.00E-05	119.05
05280000	-0.3351	0.0851	13.91	-31.044	0.0082	4332.77	-0.2868	0.0507	15.75	-30.74	0.0076	4458.19	4.4909	0.0501	247.93	17.573	0.0417	1068.14
05287890	1.1448	0.1349	20.54	8.9381	0.0802	218.53	0.2257	0.0135	13.14	-1.3902	0.0025	200.25	-0.3364	0.0145	19.90	-1.5665	0.0346	58.76
05291000	0.0764	0.0025	19.33	22.488	0.0236	1839.13	-0.3787	0.1113	13.55	7.7872	0.0029	1838.36	1.0846	0.1829	29.12	2.6275	0.0319	183.78
05293000	-0.5239	0.0912	19.58	9.6212	0.0058	1495.05	-0.4505	0.1406	13.14	-0.3631	8.00E-06	1542.32	1.5679	0.2882	29.12	6.2891	0.1368	186.60
05300000	0.1557	0.009	19.93	-14.906	0.0032	3230.52	-0.4482	0.1306	14.12	-40.461	0.0222	3283.03	1.8794	0.2279	42.24	6.6802	0.0456	373.36
05313500	0.1909	0.0135	20.77	-6.503	0.0008	2855.42	-0.2939	0.0534	15.63	-27.168	0.0139	2896.79	0.8249	0.1154	29.02	5.2997	0.0585	270.15
05317000	0.1235	0.0056	21.00	-2.0923	2.00E-05	6241.55	-0.1406	0.0141	14.81	-94.005	0.0424	5674.12	3.1148	0.0837	130.91	12.637	0.0519	686.33
05317200	0.2252	0.02	12.98	13.495	0.0607	457.56	-0.1757	0.009	15.82	8.7527	0.0237	485.73	0.8283	0.0483	28.58	-1.7129	0.0183	94.70
05320000	0.111	0.0047	20.60	-73.525	0.0166	7169.58	-0.5177	0.1349	16.61	-113.73	0.0378	7284.10	8.7509	0.0826	370.55	17.906	0.0214	1533.45
05320500	-0.3301	0.036	20.57	-72.597	0.0383	4141.44	-0.5761	0.1682	16.28	-54.513	0.0237	4436.93	5.6795	0.0678	267.57	3.4546	0.0025	865.51
05325000	-0.3508	0.0332	21.12	11.549	4.00E-05	22401.34	-0.4856	0.0903	17.80	-168.14	0.0089	20348.61	29.859	0.1333	967.71	97.65	0.0715	4458.55
05327000	0.1951	0.0066	20.49	22.039	0.0949	589.97	0.3005	0.0253	16.15	12.875	0.0568	454.38	0.5618	0.0223	32.17	1.4556	0.0067	152.85
05330000	-0.0751	0.003	17.42	101.08	0.0028	24313.26	-0.2839	0.0452	16.45	71.599	0.0014	24140.68	29.51	0.1209	1011.37	102.89	0.0609	5115.86
05336700	-0.1779	0.0148	14.94	-47.794	0.0182	3609.60	-0.3997	0.0624	15.60	-89.205	0.0512	3870.52	2.4487	0.0983	76.72	7.6583	0.0355	414.45
05353800	0.1302	0.0049	20.11	11.848	0.0111	1227.40	-0.463	0.0753	16.43	-1.4035	0.0001	1293.27	2.3685	0.0293	145.56	-1.681	0.0028	348.40
	0.0094	**0.0267**	**17.62**	**-17.45**	**0.0305**	**5067.07**	**-0.3002**	**0.0774**	**14.82**	**-44.20**	**0.03**	**4898.29**	**3.02**	**0.1077**	**291.50**	**12.10**	**0.0466**	**878.74**
	0.3413	**0.0353**	**3.64**	**58.45**	**0.0376**	**6950.49**	**0.2347**	**0.0573**	**2.18**	**83.69**	**0.04**	**6509.27**	**11.91**	**0.0807**	**591.79**	**30.84**	**0.0437**	**1414.37**

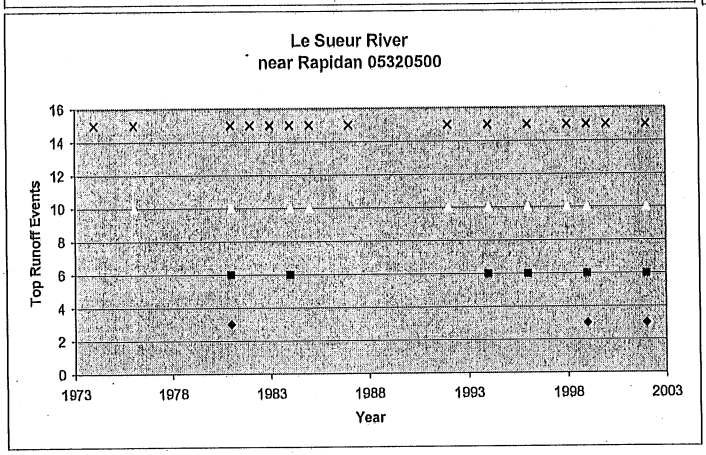
Trends in Spring River Discharge (Continued)

Station	April Flow			May Flow			Yearly Flow			Comments
	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)	
05078230	-2.9705	0.0207	250.05	-0.7335	0.0058	121.22	0.1581	0.0027	37.03	Data from 1961-2002 only
05124480	-3.2751	0.039	172.46	-6.9566	0.0667	278.26	-1.7535	0.1166	48.72	Data from 1967-2002 only; no peak in 1977
05130500	-2.0956	0.0211	181.06	-3.6153	0.1059	133.22	0.3701	0.0184	33.28	
05131500	-15.01	0.01	1878.00	-25.866	0.0444	1506.48	-1.1289	0.0015	350.67	
05133500	-38.145	0.0043	7247.35	-25.021	0.0008	10798.05	-8.8436	0.0008	3653.19	Missing daily data for 1998
05245100	3.6827	0.0231	214.42	5.6485	0.1076	144.56	1.6502	0.0291	73.20	Data from 1972-2002 only
05280000	18.962	0.0105	2340.67	28.584	0.0623	1407.82	18.308	0.1168	624.07	
05287890	2.993	0.0571	86.69	3.4171	0.1424	60.61	0.5148	0.0264	21.68	Data from 1979-2002 only
05291000	7.272	0.0635	354.21	1.3936	0.0192	126.35	1.9116	0.1376	59.43	
05293000	5.6506	0.0356	347.24	1.8548	0.0236	139.62	2.7669	0.2069	62.50	Daily up to 1999 with some 2001 data; Annual up to 1998 only; Monthly to 1999
05300000	15.051	0.0302	1036.81	10.025	0.1567	290.74	6.9238	0.2168	151.64	Missing data for 2000, 2001
05313500	9.673	0.0236	781.32	6.5086	0.118	226.04	4.1778	0.1221	138.93	
05317000	17.101	0.0168	1657.88	20.593	0.1121	736.24	11.013	0.1318	350.85	
05317200	6.7589	0.0635	201.61	3.1499	0.0528	102.91	2.6823	0.1488	53.05	Daily data from 1974-2002 only (missing 1997);Yearly 1974-2001;Monthly 1977-2002
05320000	12.477	0.0024	3232.74	28.12	0.0535	1415.24	20.963	0.1072	750.13	
05320500	8.5899	0.0048	1575.01	11.552	0.0269	751.39	9.2485	0.0968	349.17	
05325000	189.85	0.0338	12878.82	174.05	0.1304	5624.35	106.26	0.1842	2773.42	Daily data from 1964-2002 only
05327000	6.6081	0.0466	259.07	3.7994	0.0559	135.37	2.7951	0.0898	74.34	Data from 1974-2002 only
05330000	192.01	0.0304	13763.76	190.6	0.1151	6615.86	116.69	0.1762	3129.71	
05336700	-0.1342	1.00E-06	1307.42	-5.9493	0.0088	658.44	-1.675	0.0048	242.54	Data from 1968-2002 only
05353800	7.8418	0.0263	523.43	9.5207	0.0897	332.18	4.9078	0.1276	136.81	Data from 1966-2002 only
	21.09	**0.0268**	**2394.76**	**20.51**	**0.0714**	**1505.00**	**14.19**	**0.10**	**624.49**	
	57.76	**0.0192**	**3976.70**	**55.52**	**0.0481**	**2762.92**	**33.07**	**0.07**	**1097.94**	

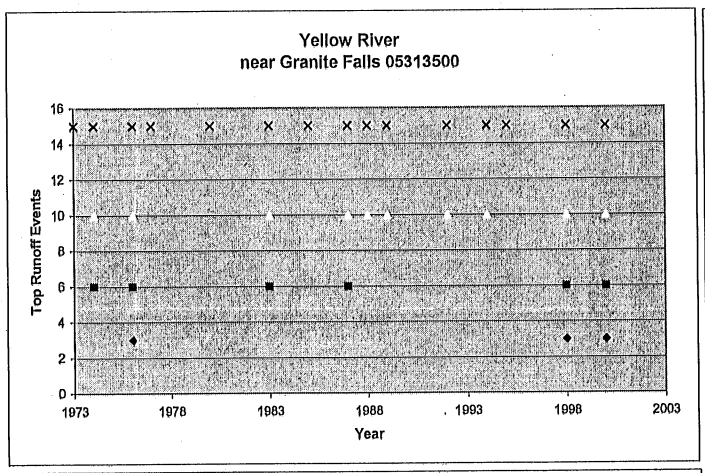
Sorting (Ranking) of 30 years (1973-2002) of First Spring Runoff Date

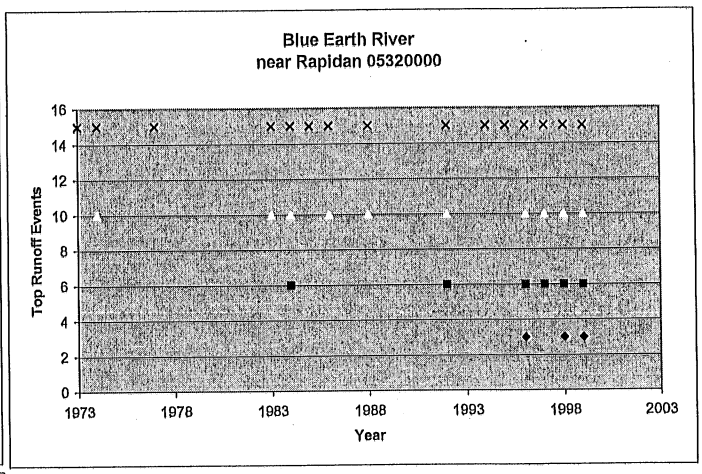


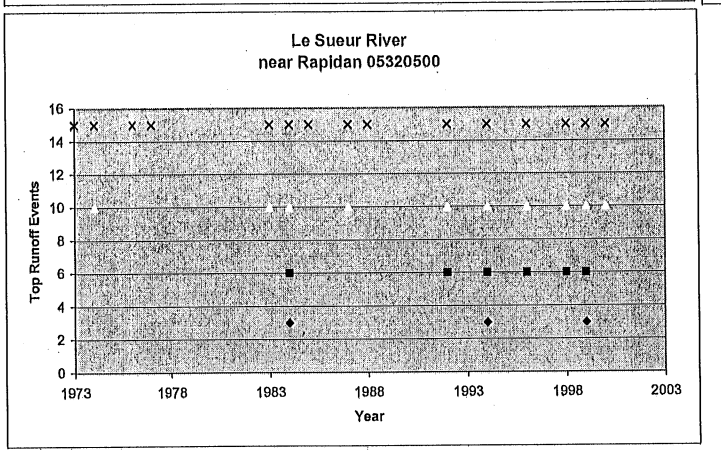




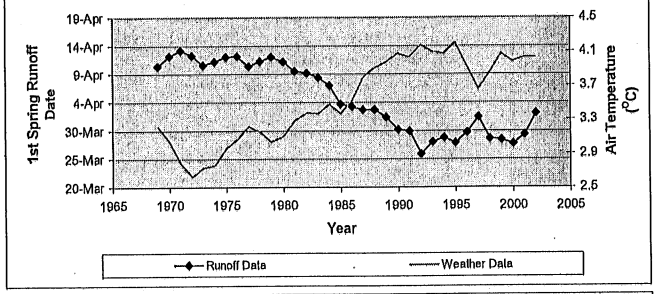
Sorting (Ranking) of 30 years (1973-2002) of First Spring Peak Date



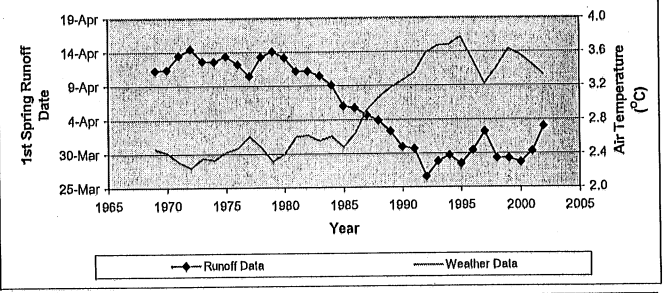




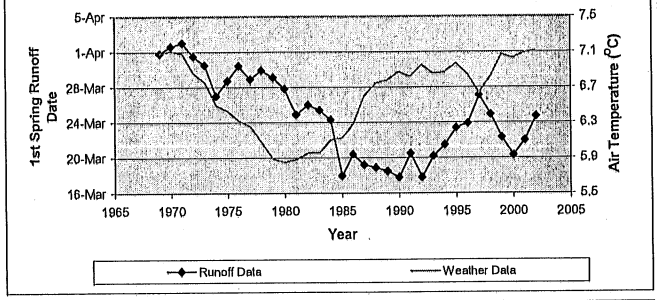
Sturgeon River near Chisholm 05130500



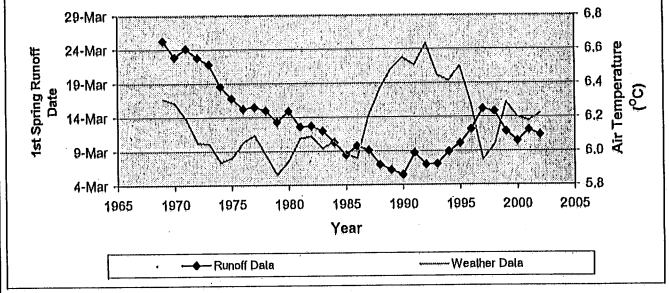
Little Fork River at Little Fork 05131500



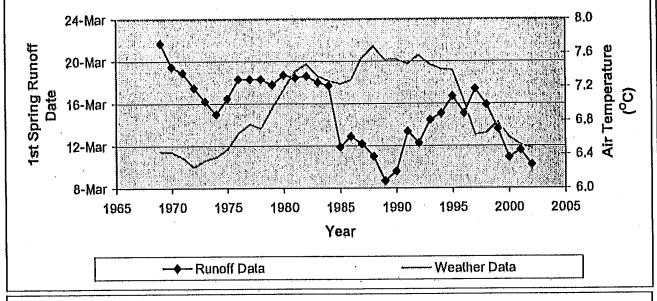
Crow River at Rockford 05280000



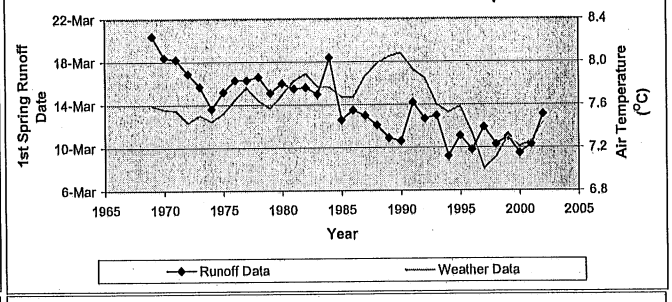
Whetstone River near Big Stone City, SD 05291000



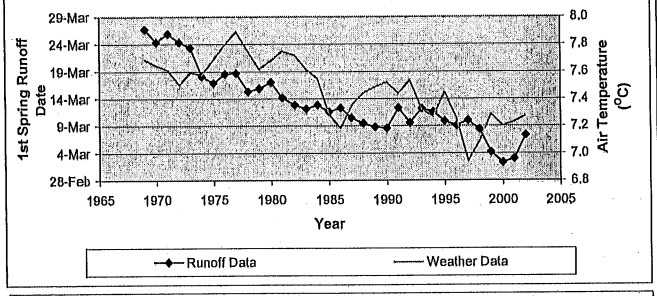
Yellow River near Granite Falls 05313500



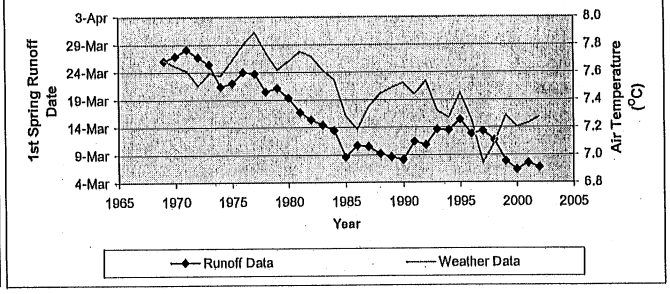
Cottonwood River near New Ulm 05317000



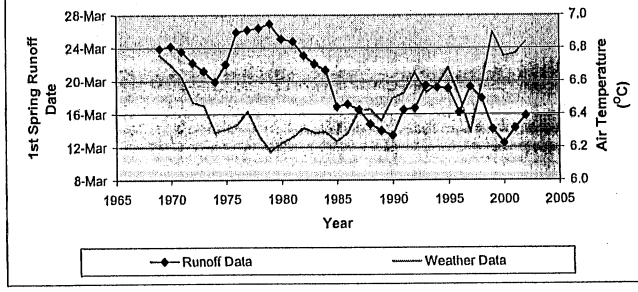
Blue Earth River near Rapidan 05320000



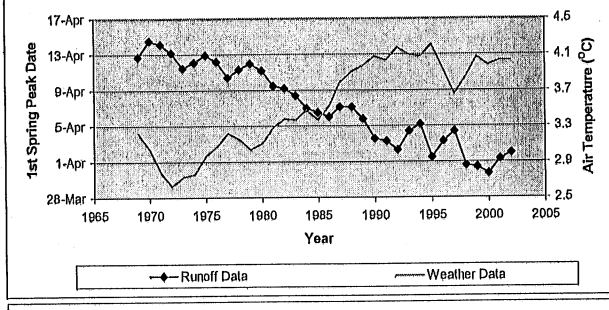
Le Sueur River near Rapidan 05320500



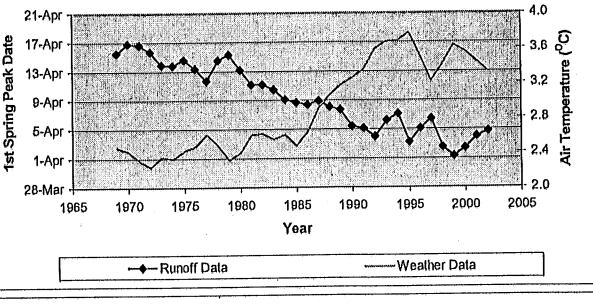
Minnesota River near Jordan 05330000



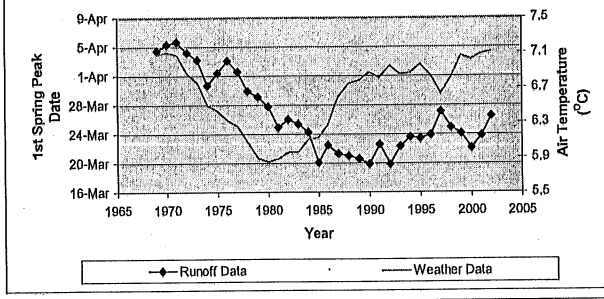
Sturgeon River near Chisholm 05130500



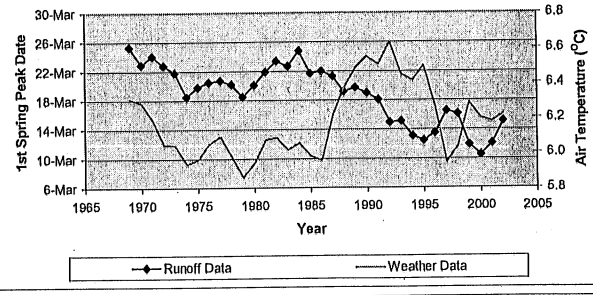
Little Fork River at Little Fork 05131500



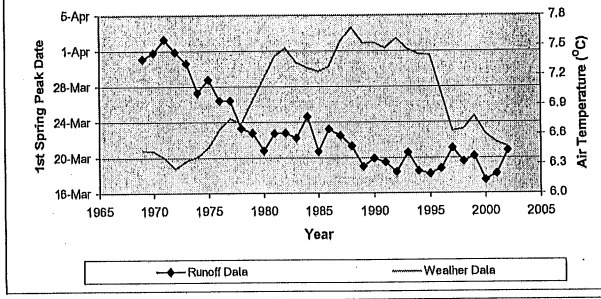
Crow River at Rockford 05280000



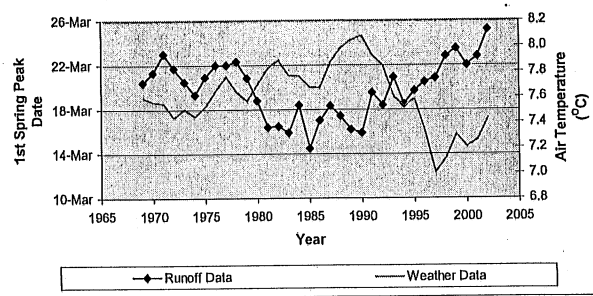
Whetstone River near Big Stone City, SD 05291000



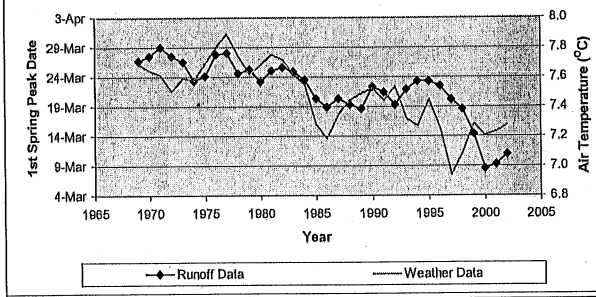
Yellow River near Granite Falls 05313500



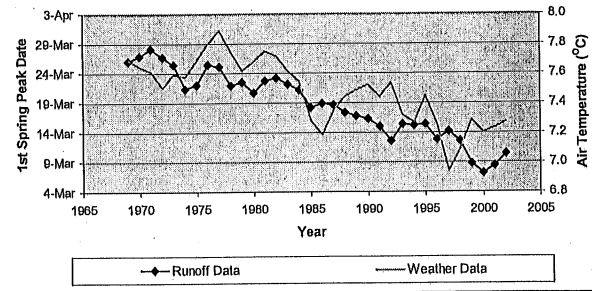
Cottonwood River near New Ulm 05317000



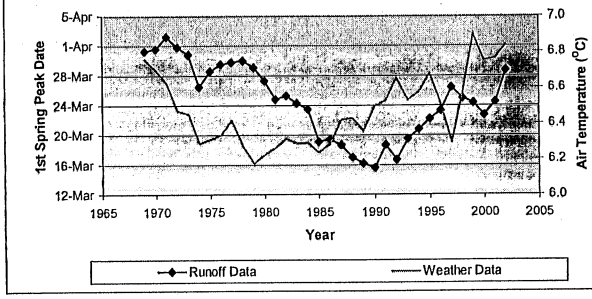
Blue Earth River near Rapidan 05320000

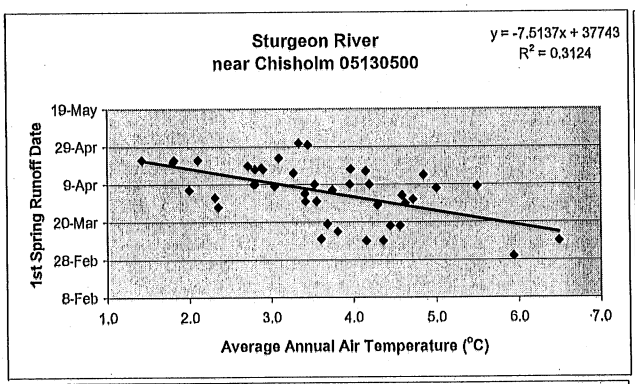


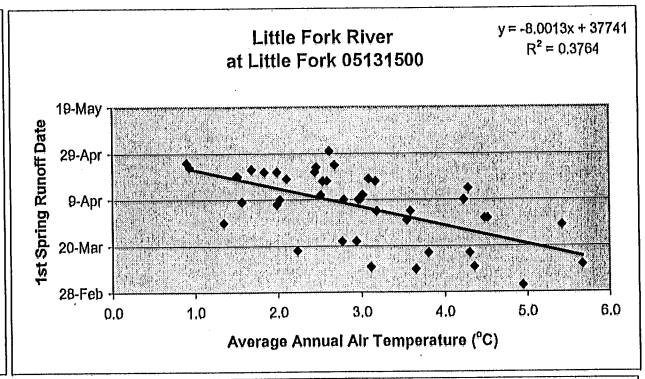
Le Sueur River near Rapidan 05320500

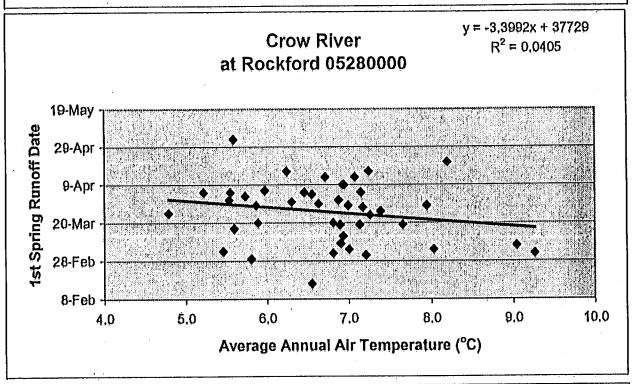


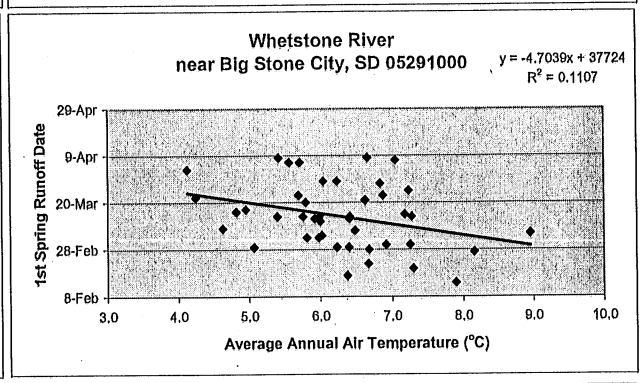
Minnesota River near Jordan 05330000

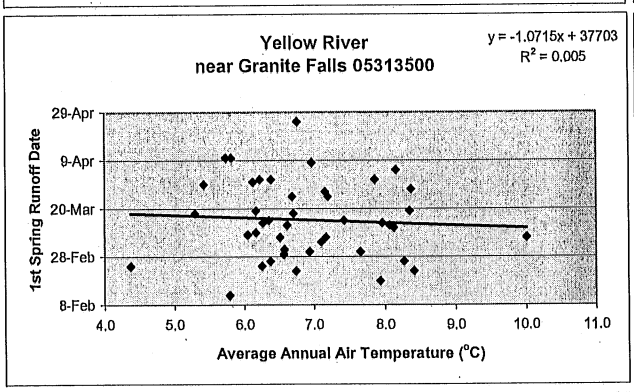


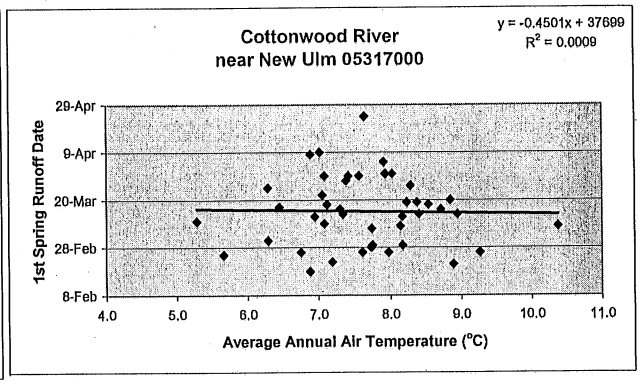

Sturgeon River
near Chisholm 05130500
y = -7.5137x + 37743
R² = 0.3124
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Average Annual Air Temperature (°C)

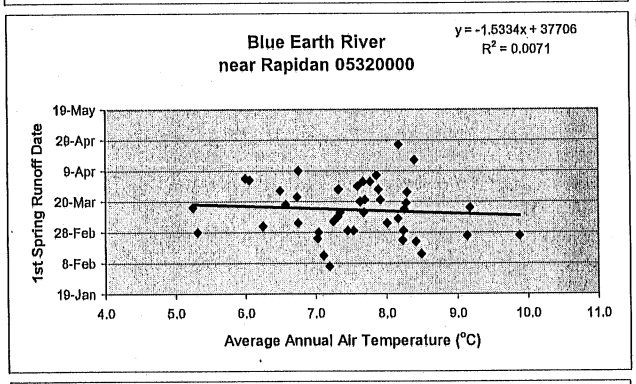

Little Fork River
at Little Fork 05131500
y = -8.0013x + 37741
R² = 0.3764
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Average Annual Air Temperature (°C)

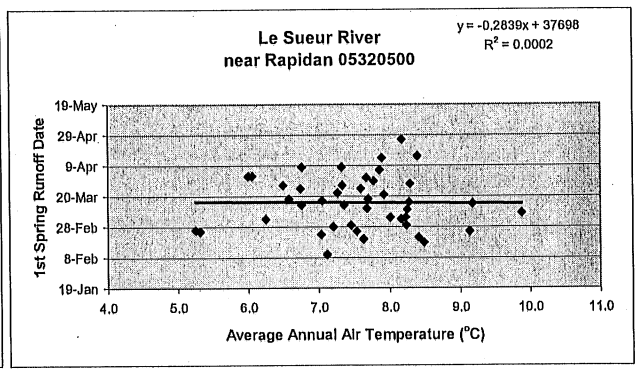

Crow River
at Rockford 05280000
y = -3.3992x + 37729
R² = 0.0405
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Average Annual Air Temperature (°C)

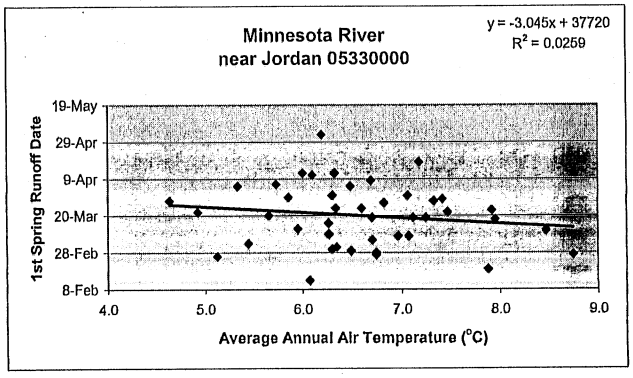

Whetstone River
near Big Stone City, SD 05291000
y = -4.7039x + 37724
R² = 0.1107
1st Spring Runoff Date
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Average Annual Air Temperature (°C)

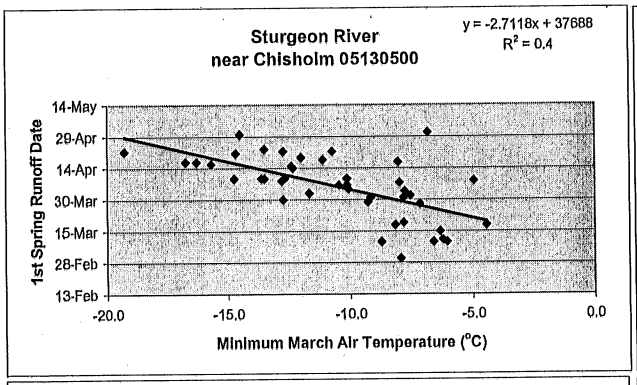

Yellow River
near Granite Falls 05313500
y = -1.0715x + 37703
R² = 0.005
1st Spring Runoff Date
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

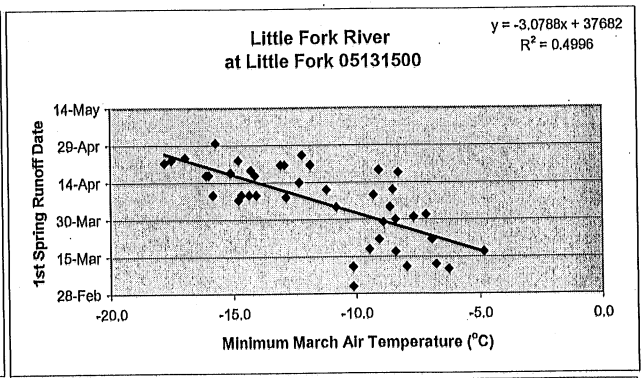

Cottonwood River
near New Ulm 05317000
y = -0.4501x + 37699
R² = 0.0009
1st Spring Runoff Date
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

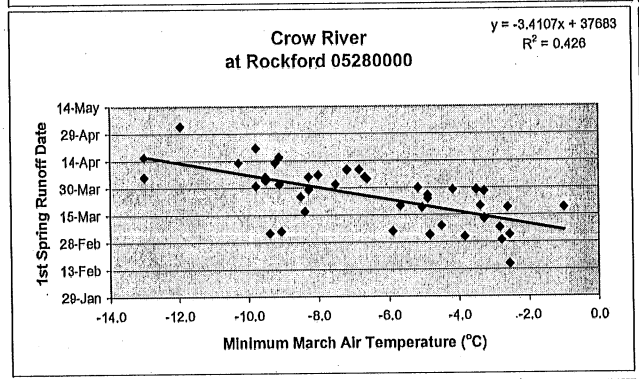

Blue Earth River
near Rapidan 05320000
y = -1.5334x + 37706
R² = 0.0071
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
19-Jan
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

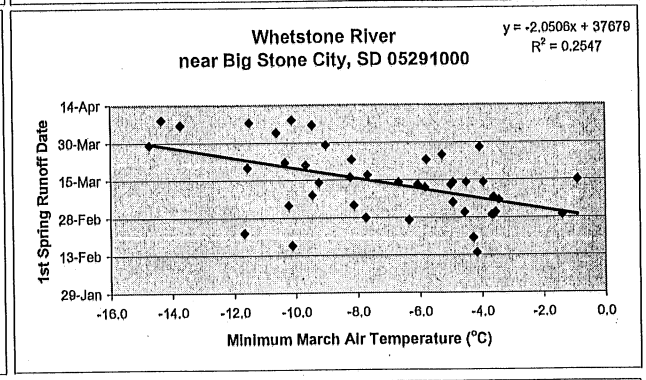

Le Sueur River
near Rapidan 05320500
y = -0.2839x + 37698
R² = 0.0002
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
19-Jan
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

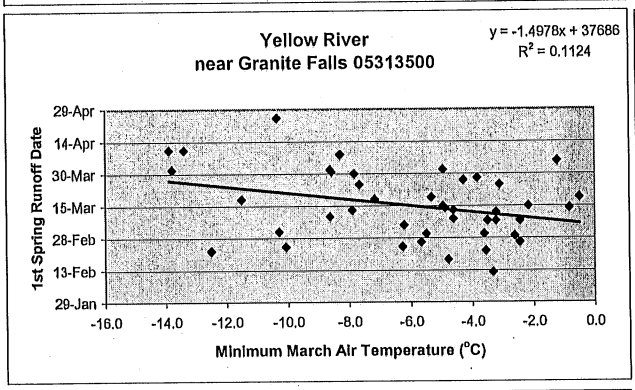

Minnesota River
near Jordan 05330000
y = -3.045x + 37720
R² = 0.0259
1st Spring Runoff Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
Average Annual Air Temperature (°C)

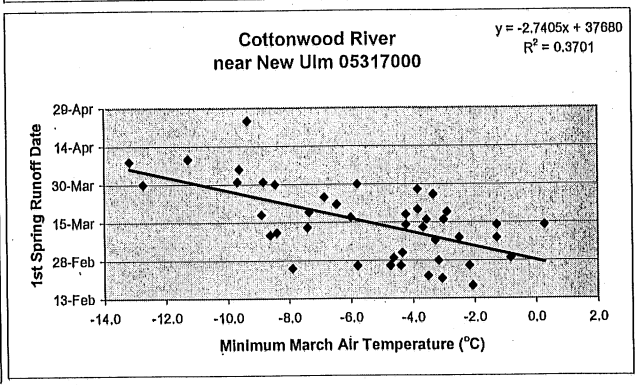

Sturgeon River
near Chisholm 05130500
y = -2.7118x + 37688
R² = 0.4
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-20.0
-15.0
-10.0
-5.0
0.0
Minimum March Air Temperature (°C)

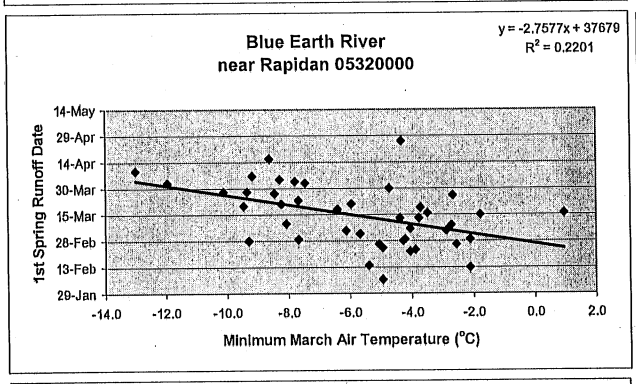

Little Fork River
at Little Fork 05131500
y = -3.0788x + 37682
R² = 0.4996
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
-20.0
-15.0
-10.0
-5.0
0.0
Minimum March Air Temperature (°C)

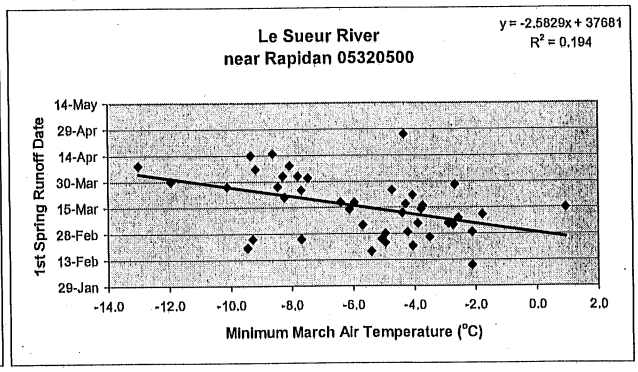

Crow River
at Rockford 05280000
y = -3.4107x + 37683
R² = 0.426
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
Minimum March Air Temperature (°C)

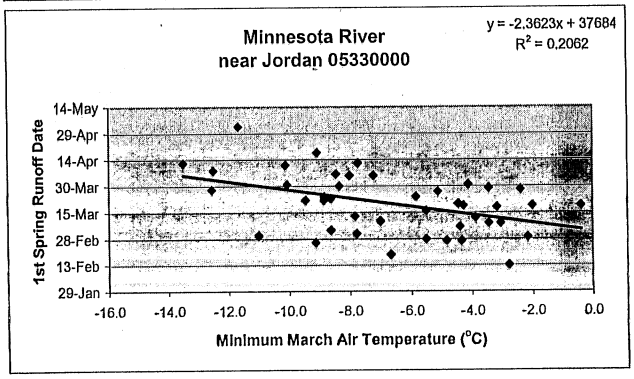

Whetstone River
near Big Stone City, SD 05291000
y = -2.0506x + 37679
R² = 0.2547
1st Spring Runoff Date
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
Minimum March Air Temperature (°C)


Yellow River
near Granite Falls 05313500
y = -1.4978x + 37686
R² = 0.1124
1st Spring Runoff Date
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
Minimum March Air Temperature (°C)

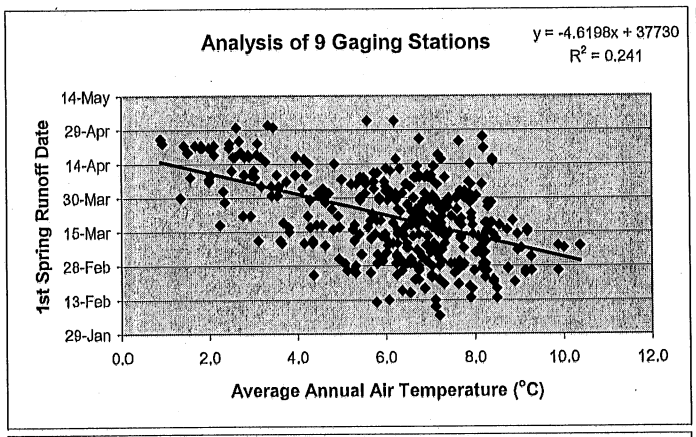

Cottonwood River
near New Ulm 05317000
y = -2.7405x + 37680
R² = 0.3701
1st Spring Runoff Date
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
Minimum March Air Temperature (°C)

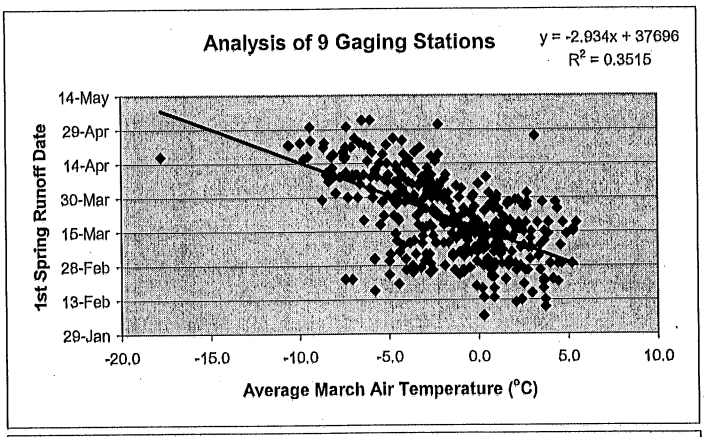

Blue Earth River
near Rapidan 05320000
y = -2.7577x + 37679
R² = 0.2201
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
Minimum March Air Temperature (°C)

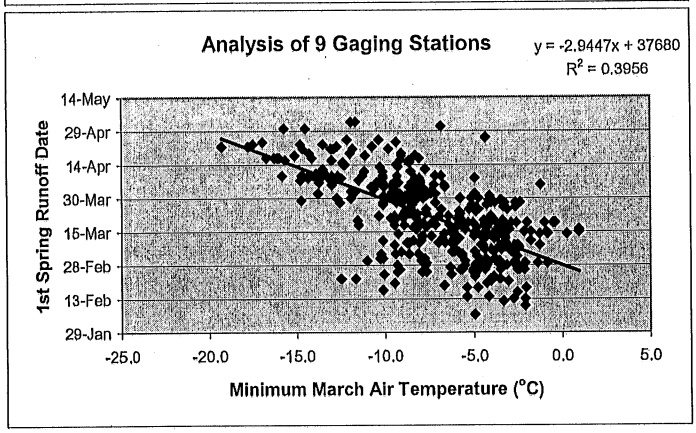

Le Sueur River
near Rapidan 05320500
y = -2.5829x + 37681
R² = 0.194
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
Minimum March Air Temperature (°C)

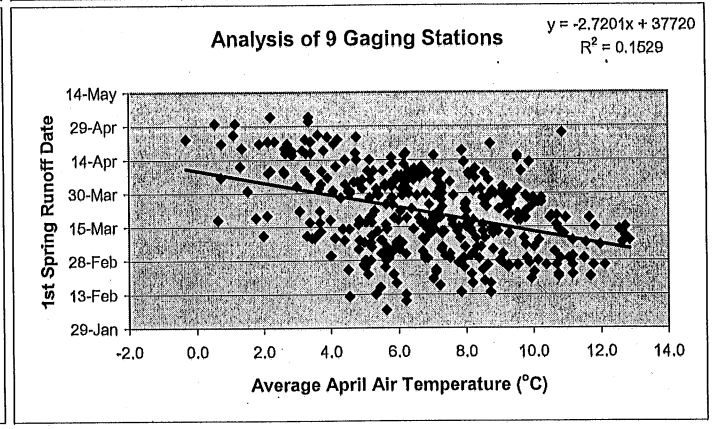

Minnesota River
near Jordan 05330000
y = -2.3623x + 37684
R² = 0.2062
1st Spring Runoff Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
Minimum March Air Temperature (°C)

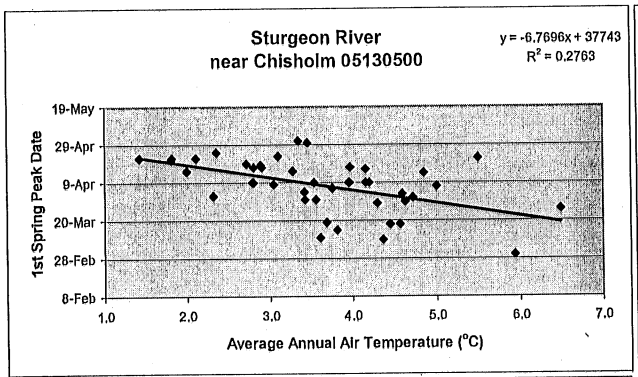
Linearization of First Spring Runoff Date and Various Air Temperature Measurements

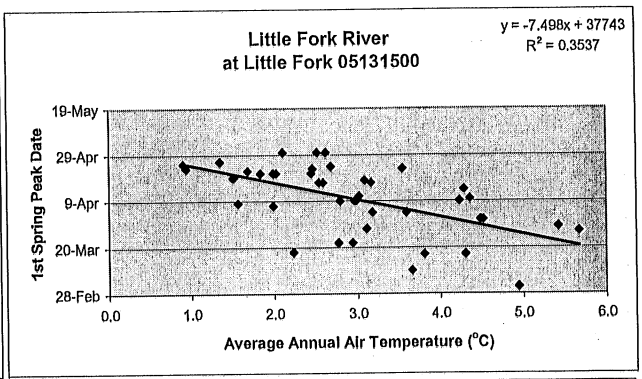


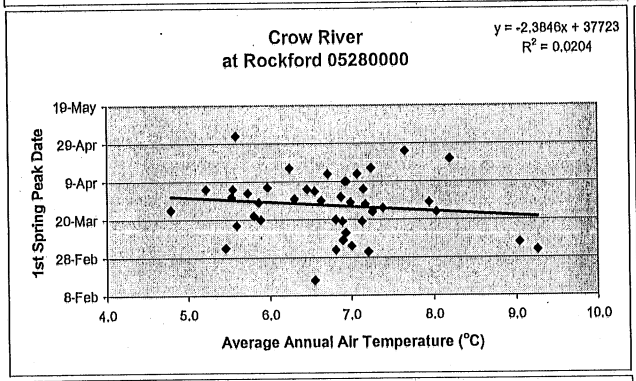


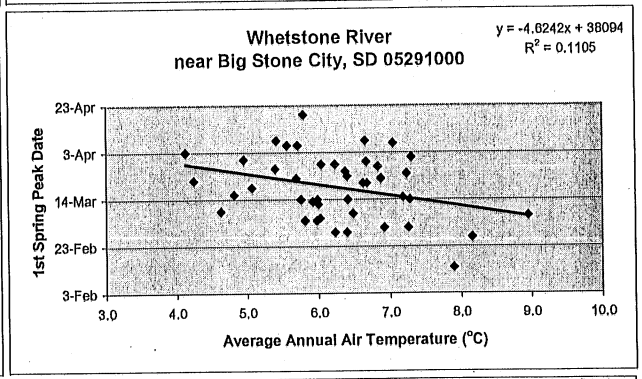


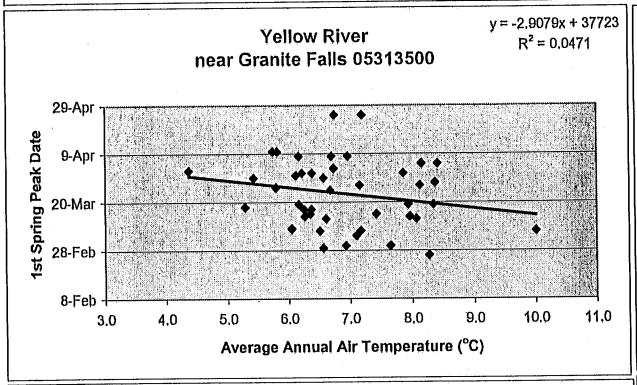


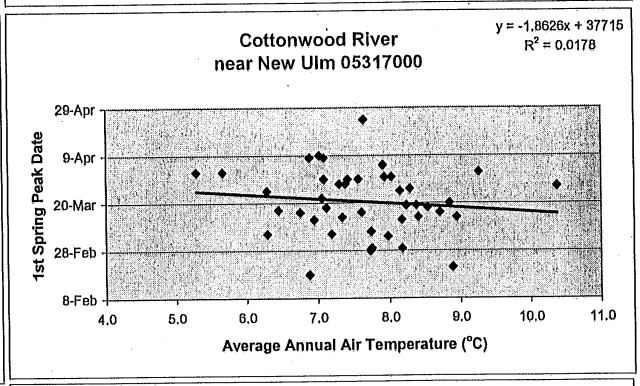

Sturgeon River
near Chisholm 05130500
y = -6.7696x + 37743
R² = 0.2763
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Average Annual Air Temperature (°C)

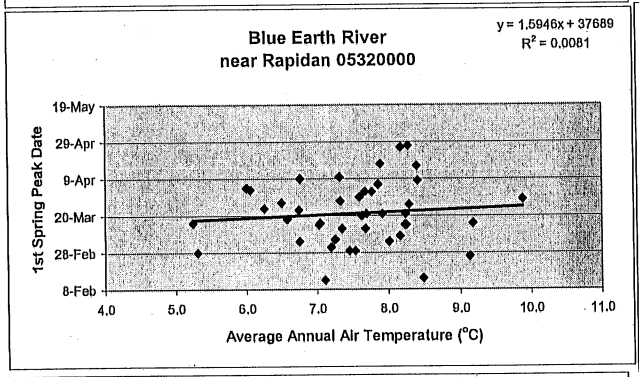

Little Fork River
at Little Fork 05131500
y = -7.498x + 37743
R² = 0.3537
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Average Annual Air Temperature (°C)

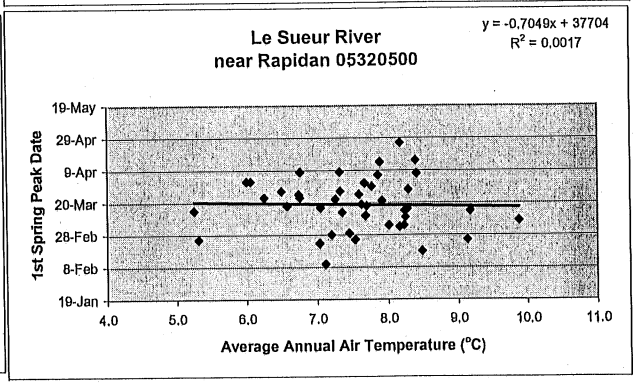

Crow River
at Rockford 05280000
y = -2.3846x + 37723
R² = 0.0204
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Average Annual Air Temperature (°C)

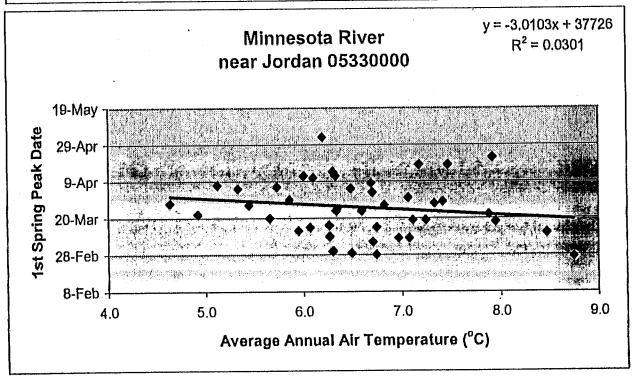

Whetstone River
near Big Stone City, SD 05291000
y = -4.6242x + 38094
R² = 0.1105
1st Spring Peak Date
23-Apr
3-Apr
14-Mar
23-Feb
3-Feb
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Average Annual Air Temperature (°C)

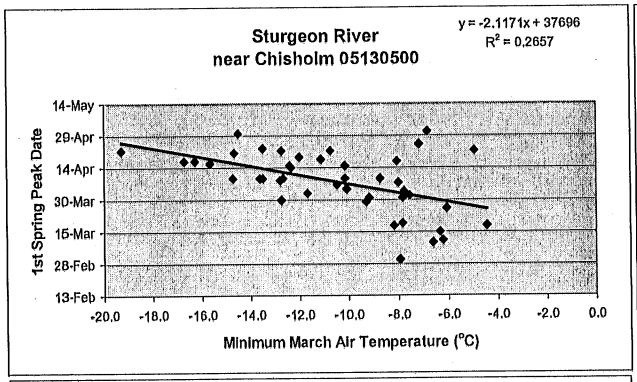

Yellow River
near Granite Falls 05313500
y = -2.9079x + 37723
R² = 0.0471
1st Spring Peak Date
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

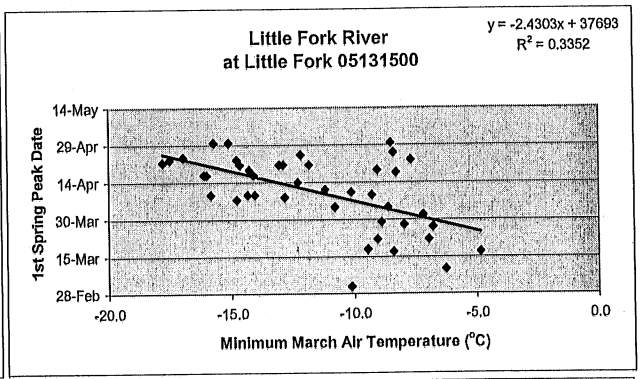

Cottonwood River
near New Ulm 05317000
y = -1.8626x + 37715
R² = 0.0178
1st Spring Peak Date
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

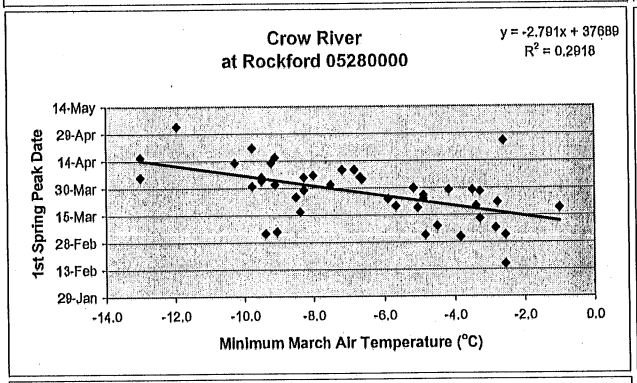

Blue Earth River
near Rapidan 05320000
y = 1.5946x + 37689
R² = 0.0081
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

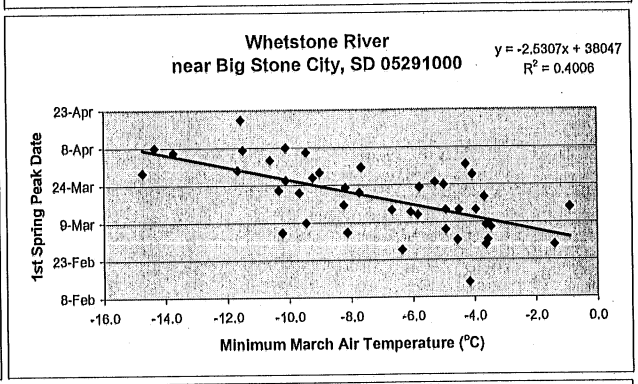

Le Sueur River
near Rapidan 05320500
y = -0.7049x + 37704
R² = 0.0017
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
19-Jan
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Average Annual Air Temperature (°C)

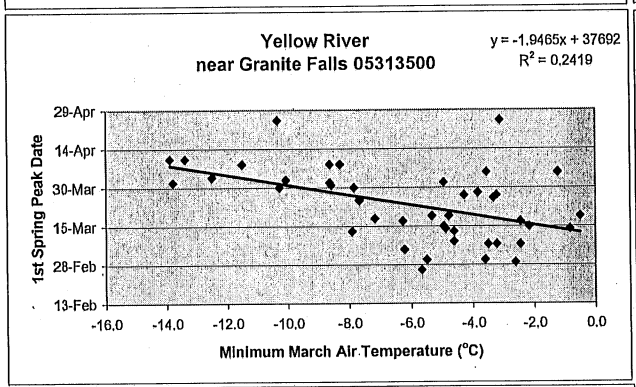

Minnesota River
near Jordan 05330000
y = -3.0103x + 37726
R² = 0.0301
1st Spring Peak Date
19-May
29-Apr
9-Apr
20-Mar
28-Feb
8-Feb
4.0
5.0
6.0
7.0
8.0
9.0
Average Annual Air Temperature (°C)

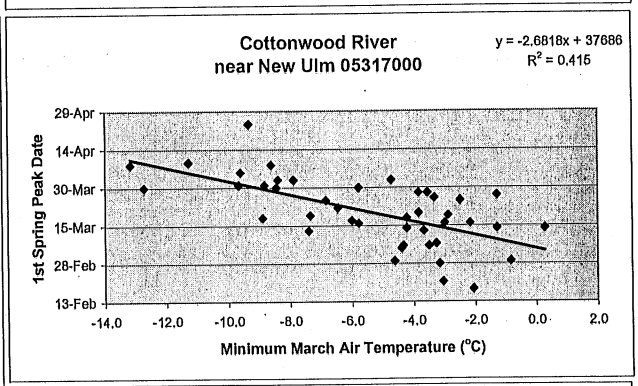

Sturgeon River
near Chisholm 05130500
y = -2.1171x + 37696
R² = 0.2657
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-20.0 -18.0 -16.0 -14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0
Minimum March Air Temperature (°C)

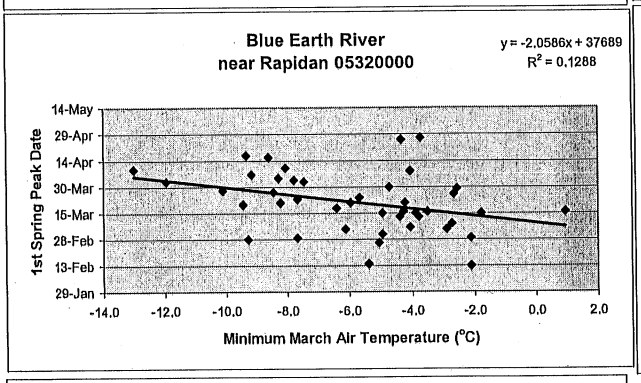

Little Fork River
at Little Fork 05131500
y = -2.4303x + 37693
R² = 0.3352
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
-20.0 -15.0 -10.0 -5.0 0.0
Minimum March Air Temperature (°C)

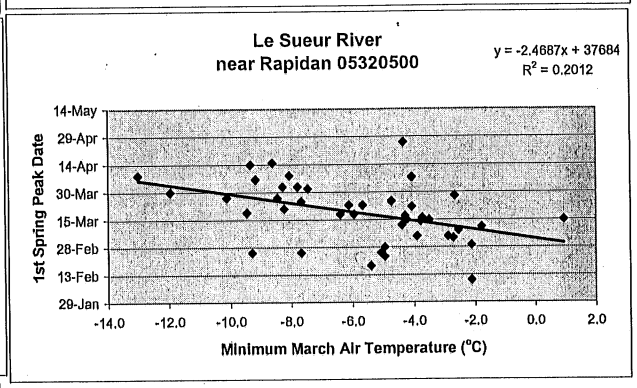

Crow River
at Rockford 05280000
y = -2.791x + 37689
R² = 0.2918
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0
Minimum March Air Temperature (°C)

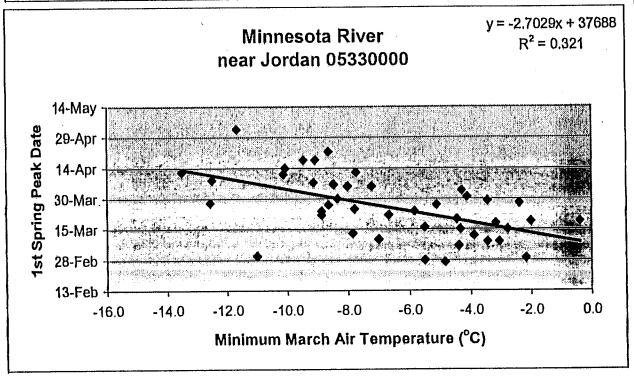

Whetstone River
near Big Stone City, SD 05291000
y = -2.5307x + 38047
R² = 0.4006
1st Spring Peak Date
23-Apr
8-Apr
24-Mar
9-Mar
23-Feb
8-Feb
-16.0 -14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0
Minimum March Air Temperature (°C)

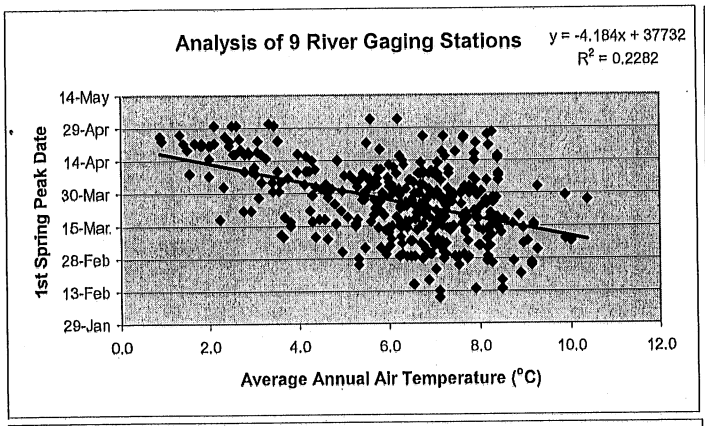

Yellow River
near Granite Falls 05313500
y = -1.9465x + 37692
R² = 0.2419
1st Spring Peak Date
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-16.0 -14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0
Minimum March Air Temperature (°C)

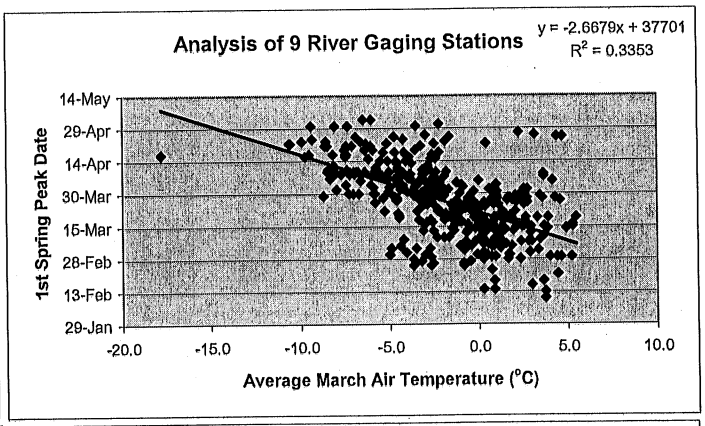

Cottonwood River
near New Ulm 05317000
y = -2.6818x + 37686
R² = 0.415
1st Spring Peak Date
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0 2.0
Minimum March Air Temperature (°C)

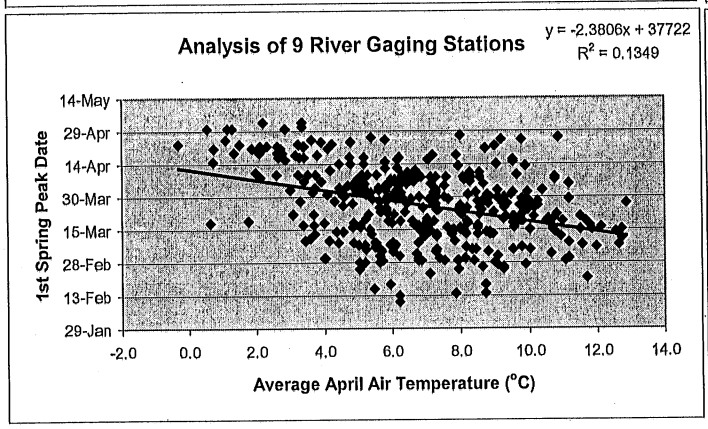

Blue Earth River
near Rapidan 05320000
y = -2.0586x + 37689
R² = 0.1288
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0 2.0
Minimum March Air Temperature (°C)

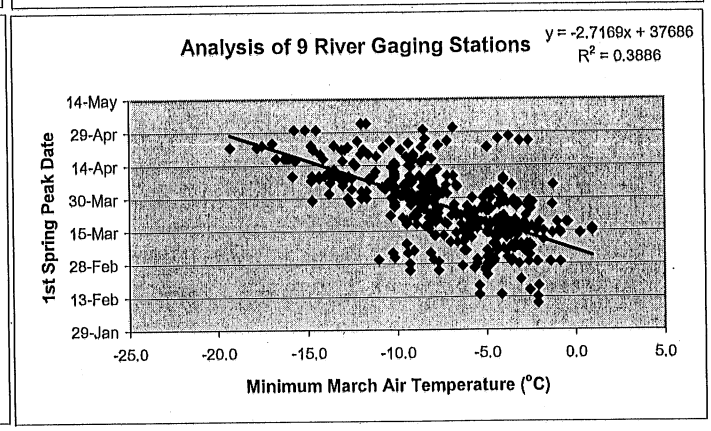

Le Sueur River
near Rapidan 05320500
y = -2.4687x + 37684
R² = 0.2012
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0 2.0
Minimum March Air Temperature (°C)


Minnesota River
near Jordan 05330000
y = -2.7029x + 37688
R² = 0.321
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
-16.0 -14.0 -12.0 -10.0 -8.0 -6.0 -4.0 -2.0 0.0
Minimum March Air Temperature (°C)


Analysis of 9 River Gaging Stations
y = -4.184x + 37732
R² = 0.2282
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Average Annual Air Temperature (°C)


Analysis of 9 River Gaging Stations
y = -2.6679x + 37701
R² = 0.3353
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-20.0
-15.0
-10.0
-5.0
0.0
5.0
10.0
Average March Air Temperature (°C)

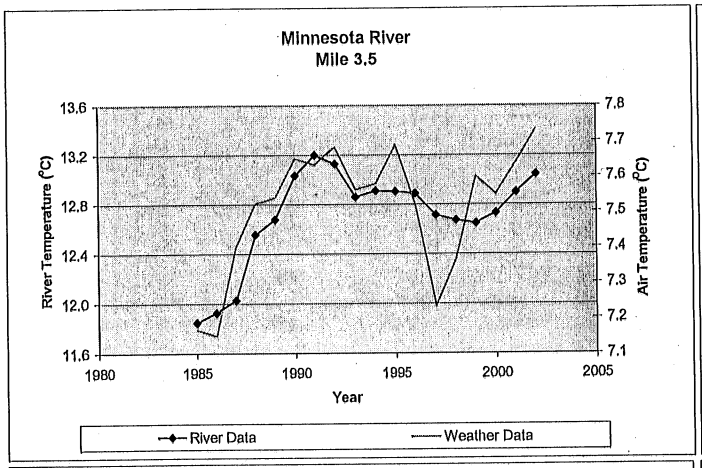

Analysis of 9 River Gaging Stations
y = -2.3806x + 37722
R² = 0.1349
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-2.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Average April Air Temperature (°C)

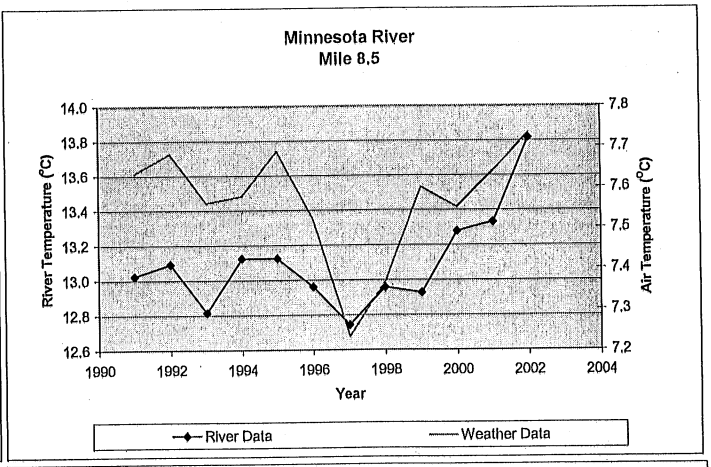

Analysis of 9 River Gaging Stations
y = -2.7169x + 37686
R² = 0.3886
1st Spring Peak Date
14-May
29-Apr
14-Apr
30-Mar
15-Mar
28-Feb
13-Feb
29-Jan
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
5.0
Minimum March Air Temperature (°C)

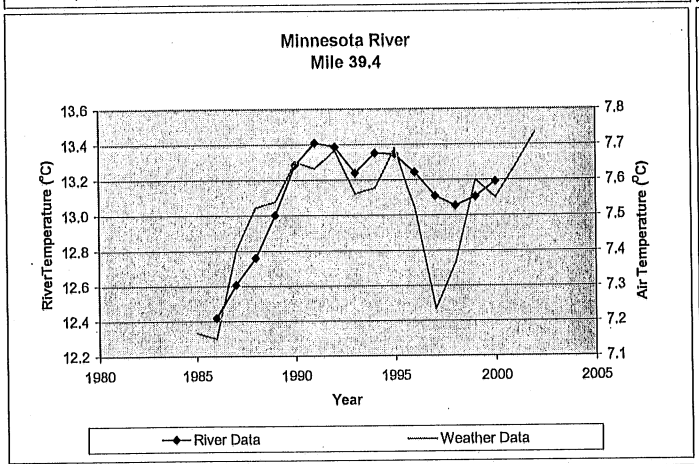
APPENDIX D
SURFACE WATER TEMPERATURE ANALYSIS

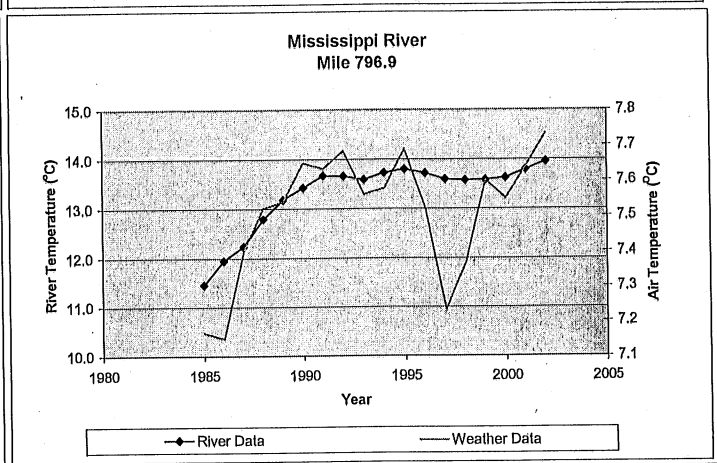
Results of River Temperature Trend Analysis

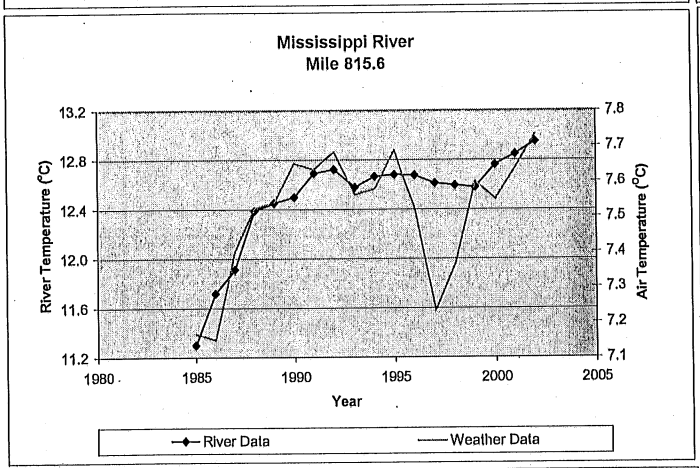
Station			Record Length			Average	Standard Deviation	Yearly Average			10-Year Running Average			Comments
River Name	River Mile	Sample Method	Length (years)	From	To	(°C)	(°C)	Slope (°C/year)	r^2	RMSE (°C)	Slope (°C/year)	r^2	RMSE (°C)	
Vermillion	2.7	Grab	23	1980	2002	11.43	0.842	0.082	0.454	0.574	0.048	0.731	0.073	Missing: 82, 86, 93, 97
	15.6	Auto	26	1977	2002	11.19	1.075	0.096	0.440	0.821	0.072	0.739	0.191	Missing: 78
	20.6	Grab	23	1980	2002	10.75	0.921	0.080	0.346	0.664	0.032	0.472	0.130	Missing: 97
St. Croix	0.3	Grab	27	1976	2002	12.30	1.321	0.132	0.590	0.855	0.098	0.798	0.212	Missing: 77
	23.3	Grab	27	1976	2002	11.58	1.496	0.146	0.573	0.986	0.105	0.746	0.272	Missing: 77, 96
Mississippi	796.9	Grab	27	1976	2002	13.05	1.644	0.159	0.559	1.072	0.105	0.628	0.360	Missing: 77, 97
	815.6	Auto	27	1976	2002	12.42	1.174	0.108	0.483	0.807	0.062	0.620	0.195	Missing: 77, 79
	826.7	Auto	27	1976	2002	12.65	1.362	0.128	0.560	0.920	0.097	0.721	0.276	
	831.0	Auto	22	1981	2002	13.20	0.860	0.066	0.251	0.703	0.021	0.478	0.089	
	839.1	Auto	27	1976	2002	12.71	1.381	0.122	0.491	1.002	0.097	0.673	0.329	
	847.7	Grab	27	1976	2002	12.61	1.597	0.138	0.443	1.210	0.103	0.550	0.437	Missing: 77
	871.6	Grab	27	1976	2002	12.14	1.439	0.123	0.452	1.042	0.082	0.557	0.323	Missing: 80
Minnesota	3.5	Auto	27	1976	2002	12.67	1.299	0.077	0.225	1.165	0.042	0.320	0.305	Missing: 79, 86, 97
	8.5	Grab	21	1982	2002	13.12	1.258	0.064	0.101	1.220	0.046	0.328	0.241	Missing: 85, 95, 96, 01
	39.4	Grab	24	1977	2000	13.01	1.034	0.078	0.267	0.892	0.036	0.293	0.218	Missing: 78
Average			26	1977	2002	**12.32**	**1.247**	**0.107**	**0.416**	**0.929**	**0.070**	**0.577**	**0.243**	
Standard Deviation						**0.76**	**0.256**	**0.031**	**0.146**	**0.197**	**0.030**	**0.167**	**0.101**	

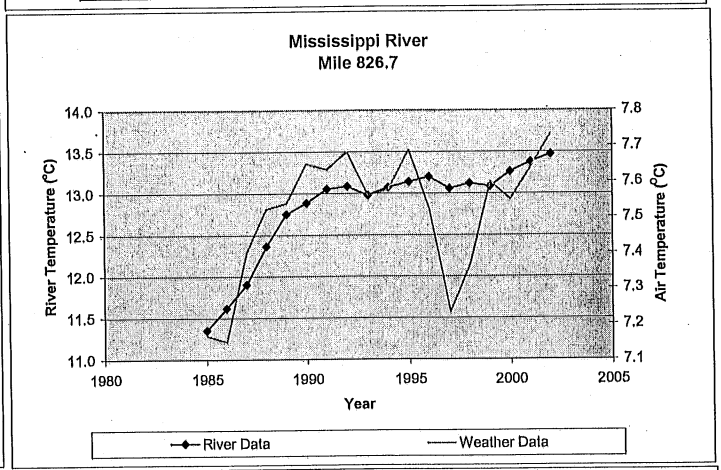

Minnesota River
Mile 3.5
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

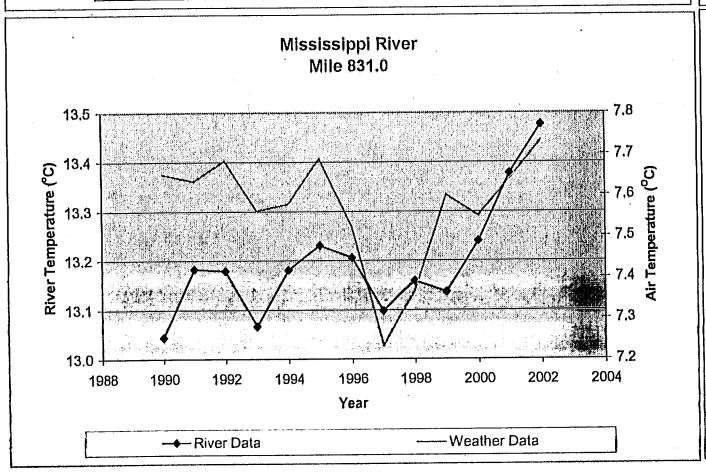

Minnesota River
Mile 8.5
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

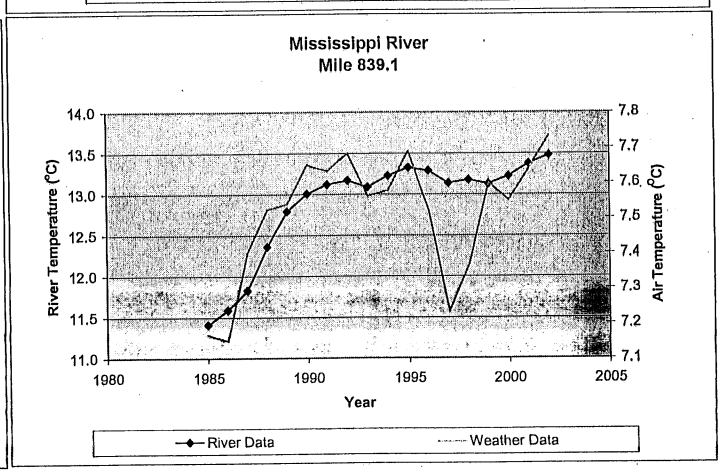

Minnesota River
Mile 39.4
RiverTemperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

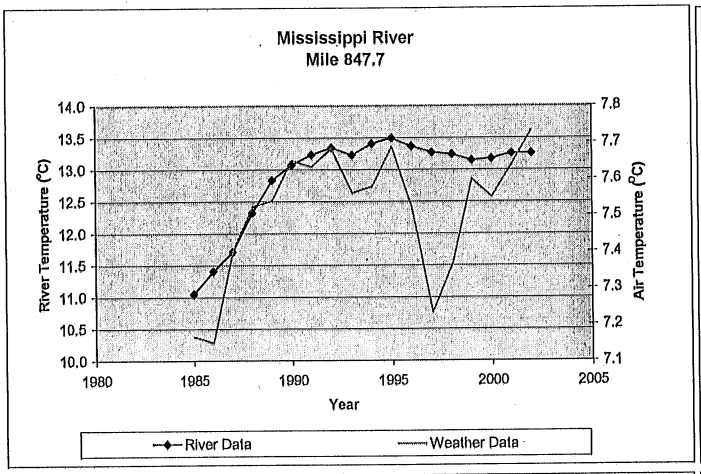

Mississippi River
Mile 796.9
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

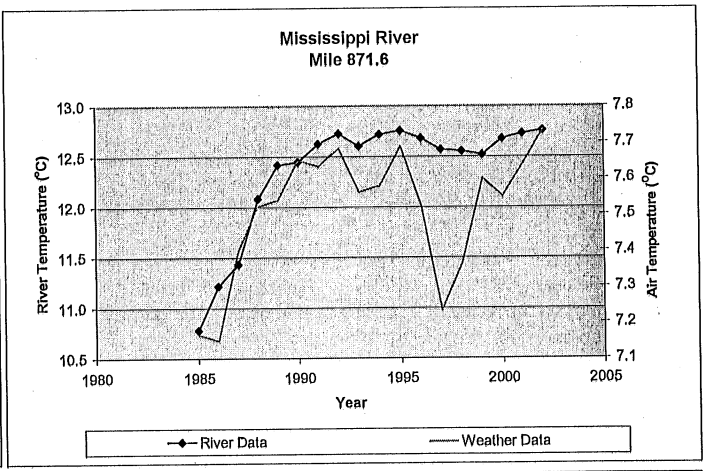

Mississippi River
Mile 815.6
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

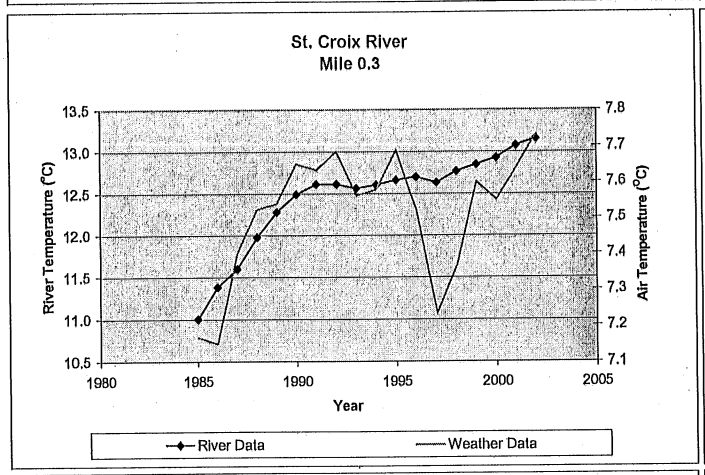

Mississippi River
Mile 826.7
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

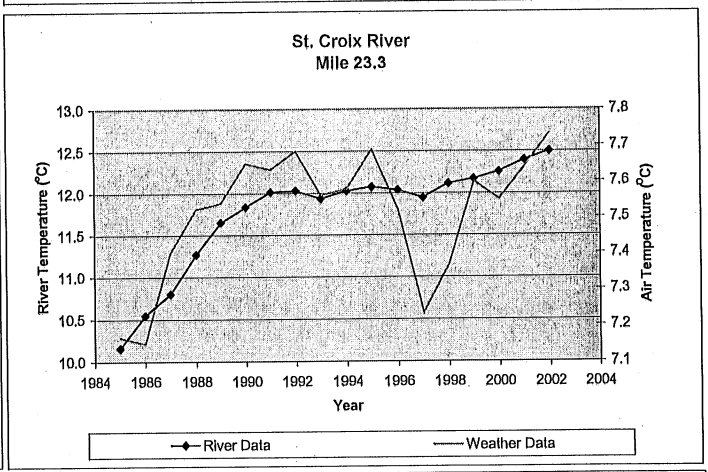

Mississippi River
Mile 831.0
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

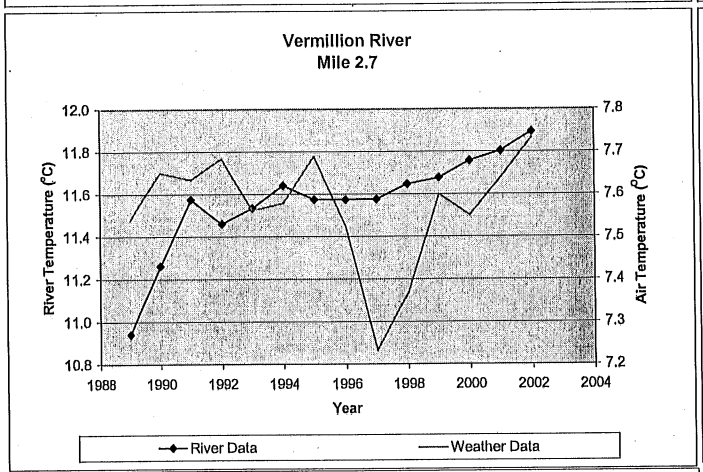

Mississippi River
Mile 839.1
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

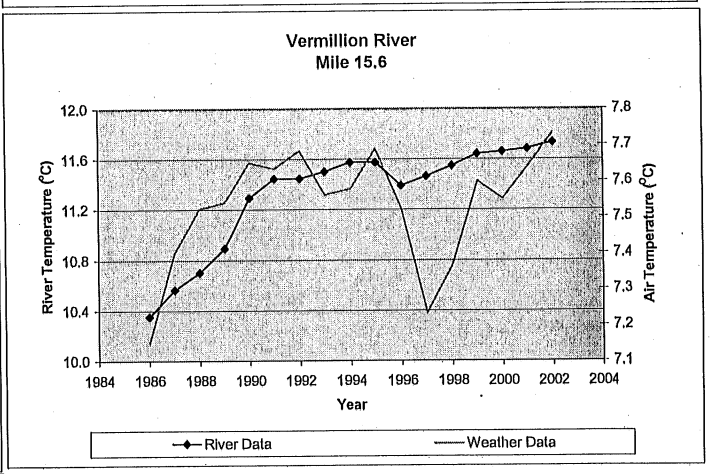

Mississippi River
Mile 847.7
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

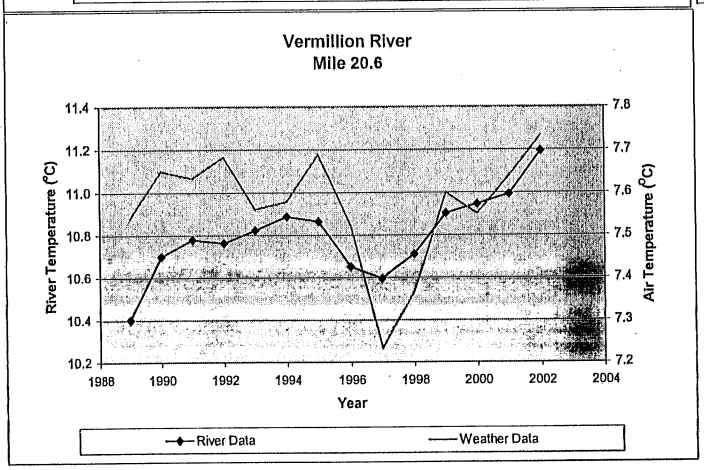

Mississippi River
Mile 871.6
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

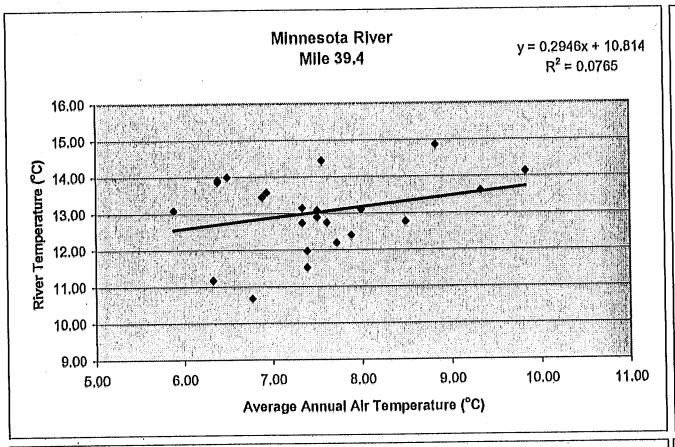

St. Croix River
Mile 0.3
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

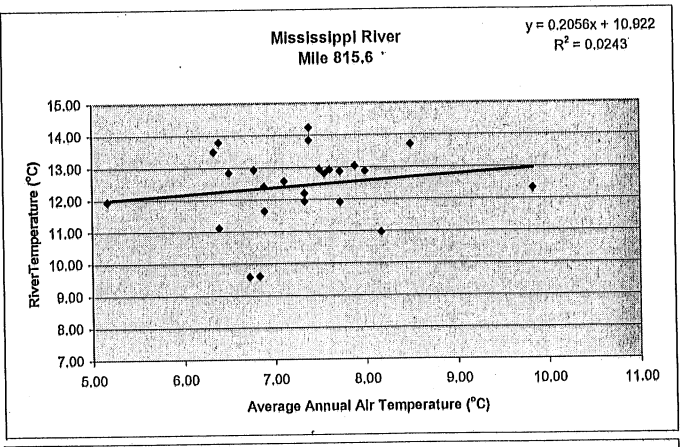

St. Croix River
Mile 23.3
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

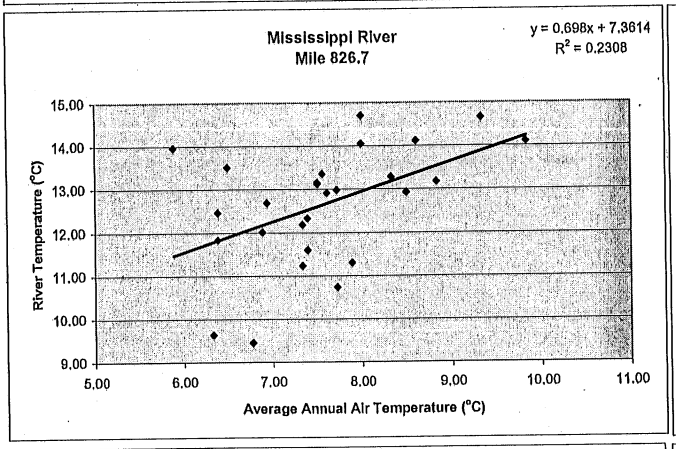

Vermillion River
Mile 2.7
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

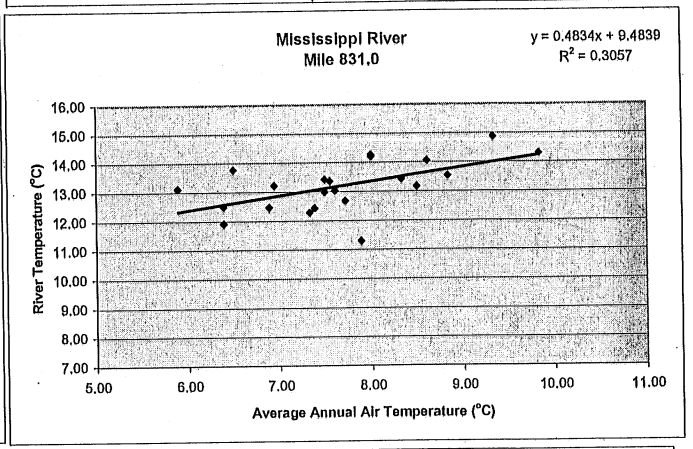

Vermillion River
Mile 15.6
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

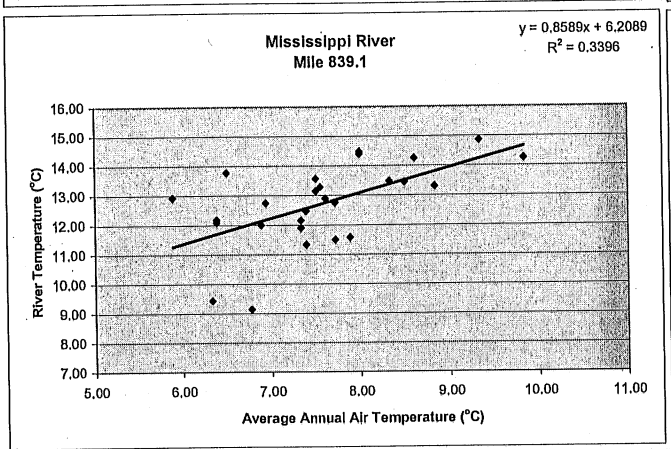

Vermillion River
Mile 20.6
River Temperature (°C)
Air Temperature (°C)
Year
River Data
Weather Data

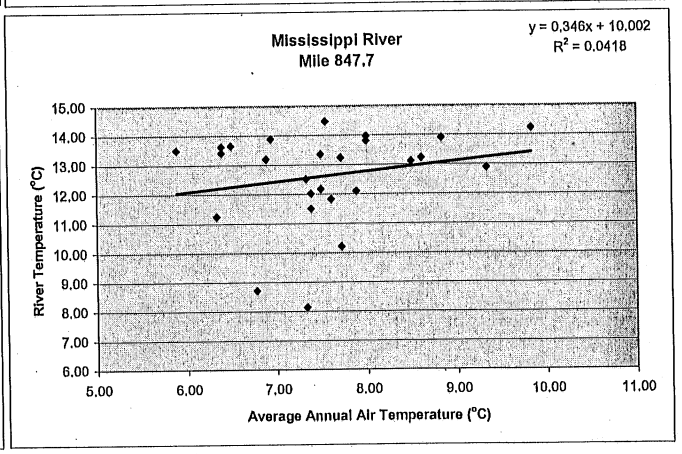

Minnesota River
Mile 39.4
y = 0.2946x + 10.814
R² = 0.0765
River Temperature (°C)
Average Annual Air Temperature (°C)

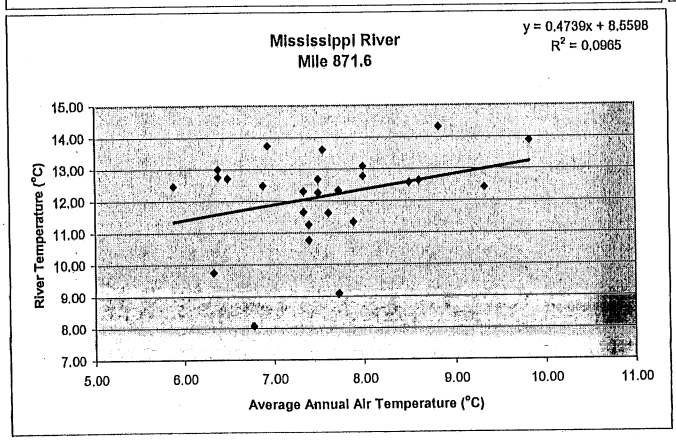

Mississippi River
Mile 815.6
y = 0.2056x + 10.922
R² = 0.0243
RiverTemperature (°C)
Average Annual Air Temperature (°C)


Mississippi River
Mile 826.7
y = 0.698x + 7.3614
R² = 0.2308
River Temperature (°C)
Average Annual Air Temperature (°C)

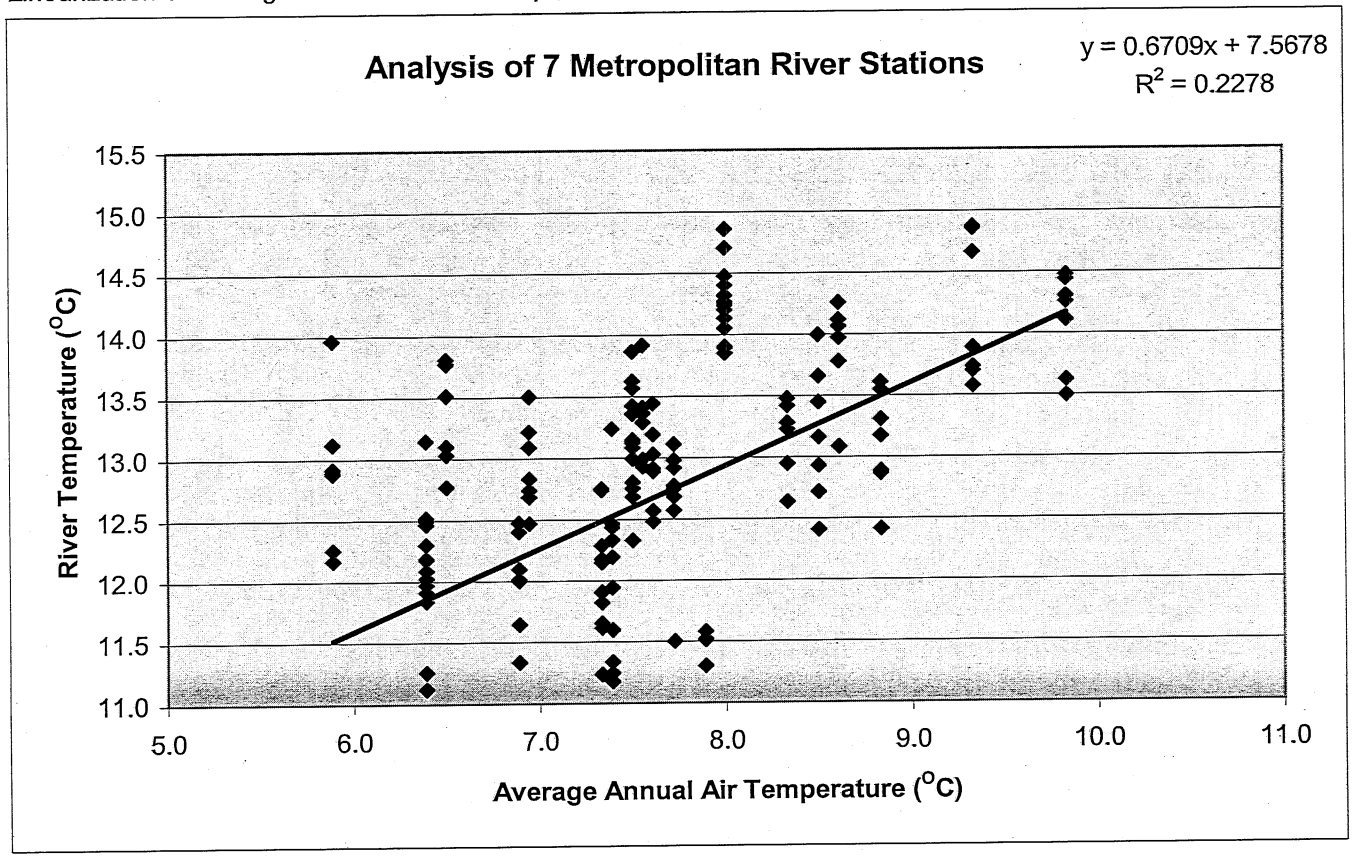

Mississippi River
Mile 831.0
y = 0.4834x + 9.4839
R² = 0.3057
River Temperature (°C)
Average Annual Air Temperature (°C)


Mississippi River
Mile 839.1
y = 0.8589x + 6.2089
R² = 0.3396
River Temperature (°C)
Average Annual Air Temperature (°C)


Mississippi River
Mile 847.7
y = 0.346x + 10.002
R² = 0.0418
River Temperature (°C)
Average Annual Air Temperature (°C)

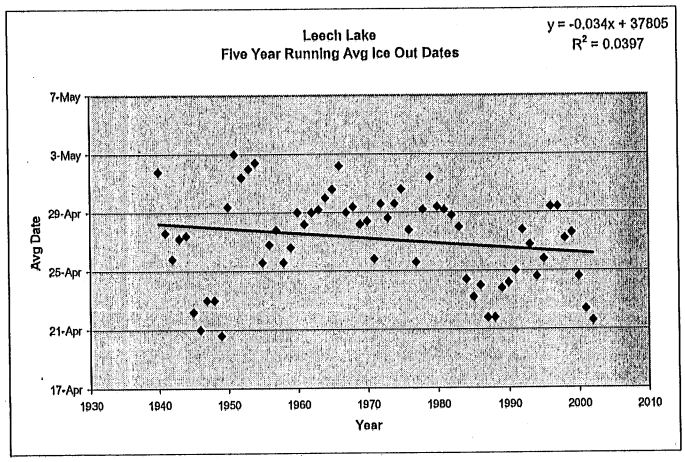

Mississippi River
Mile 871.6
y = 0.4739x + 8.5598
R² = 0.0965
River Temperature (°C)
Average Annual Air Temperature (°C)

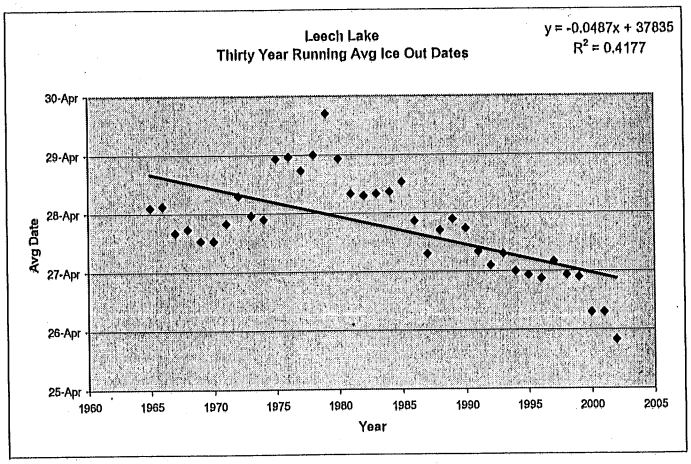
Linearization of Average Annual Stream Temperature and Average Annual Air Temperature

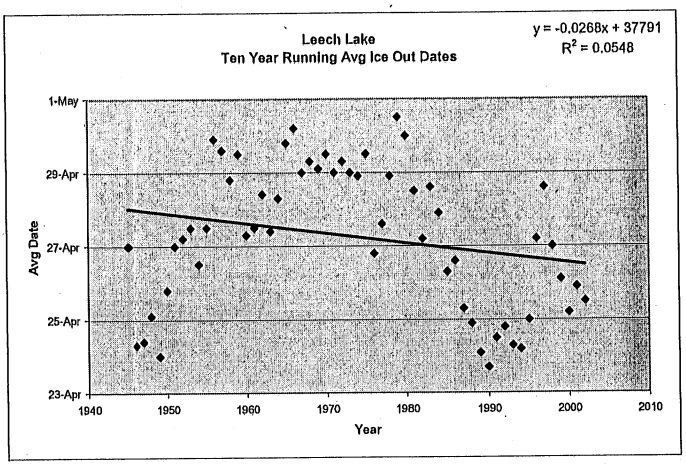


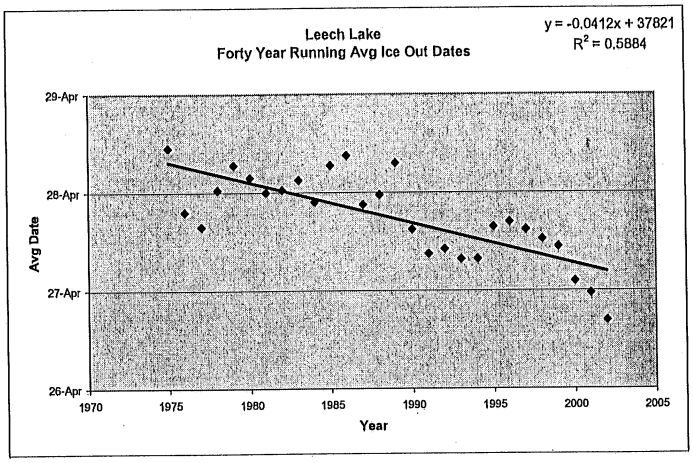
APPENDIX E
RUNNING AVERAGE ANALYSIS

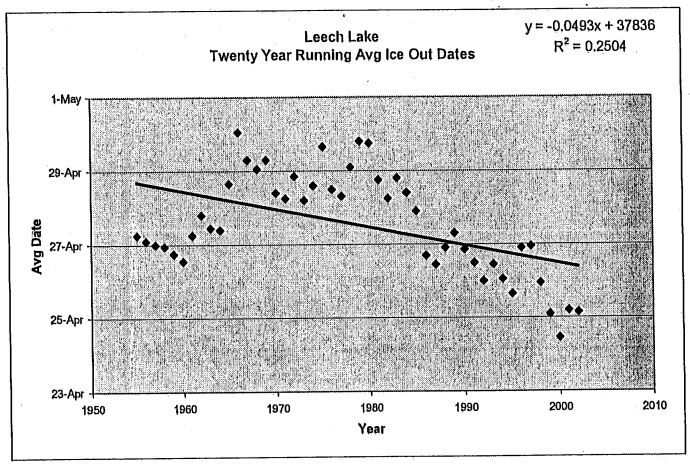
Various Averaging Periods

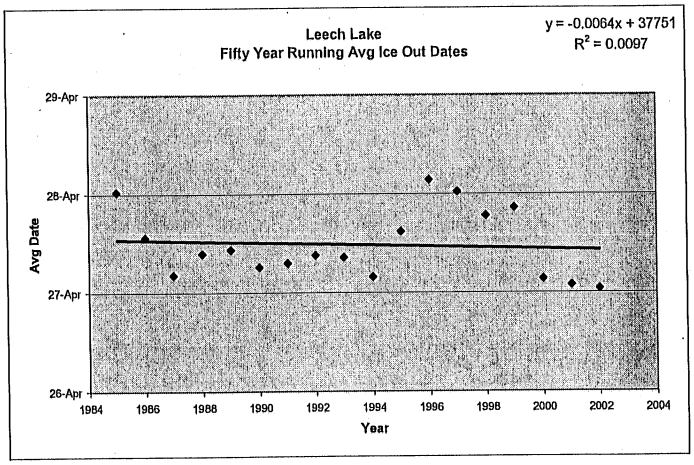




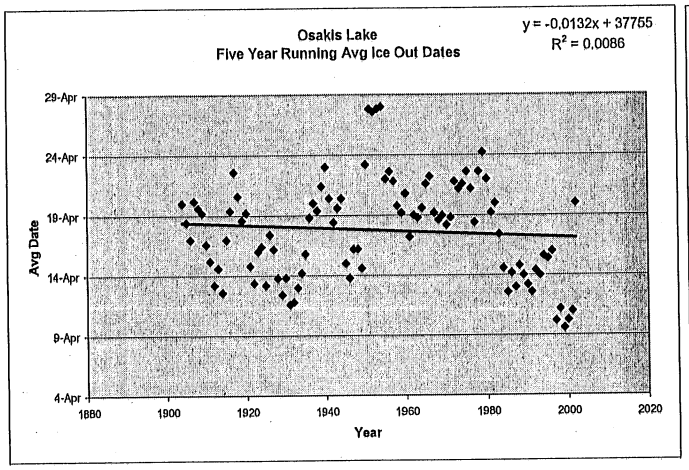


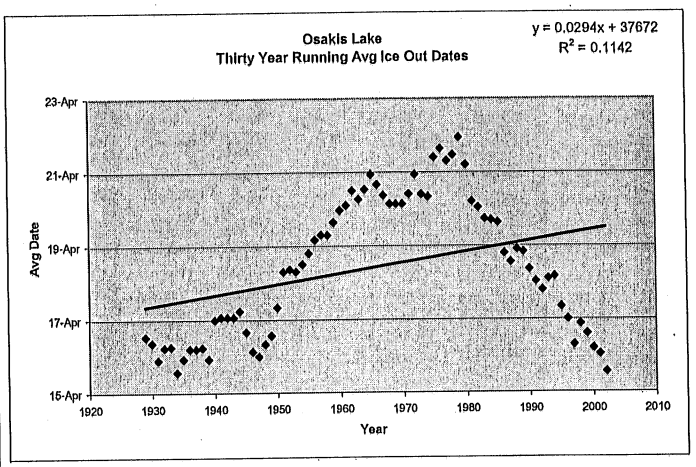


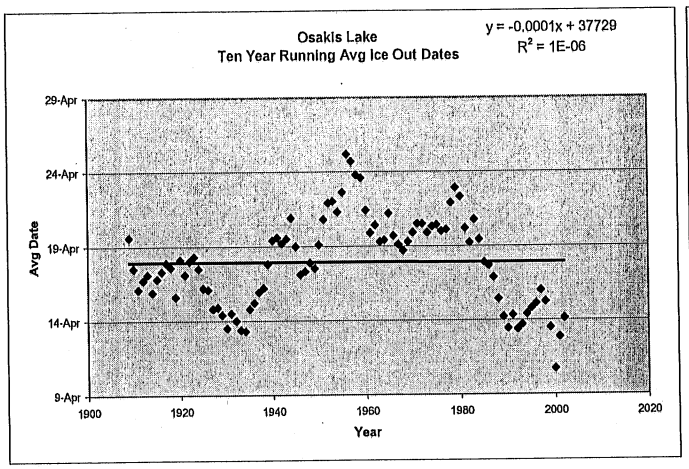


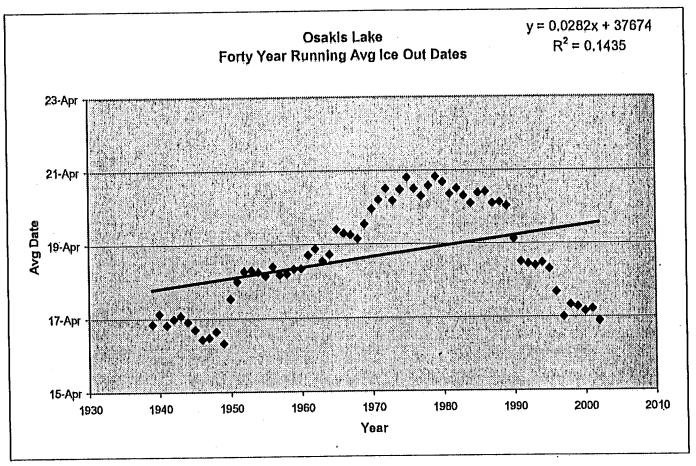


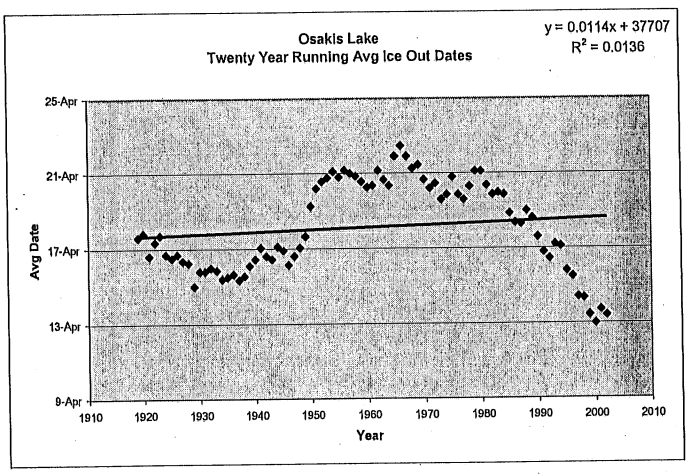
Various Averaging Periods

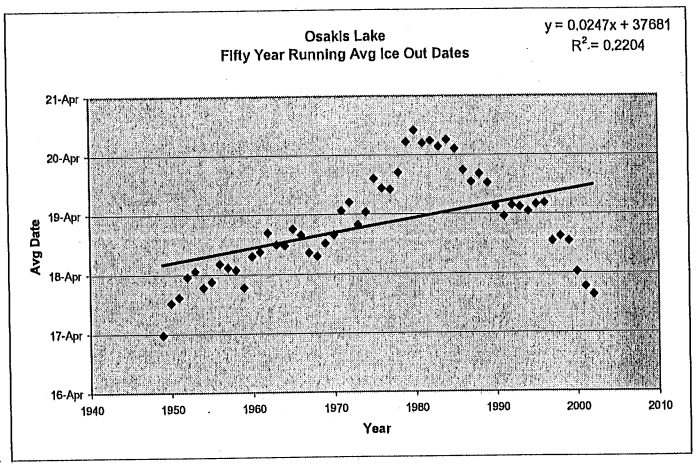




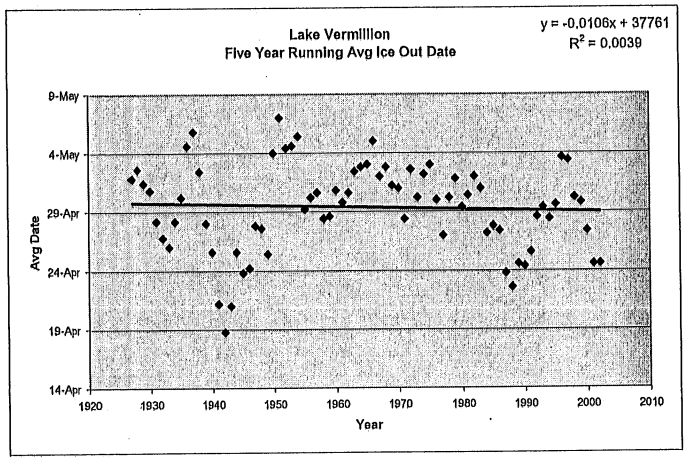


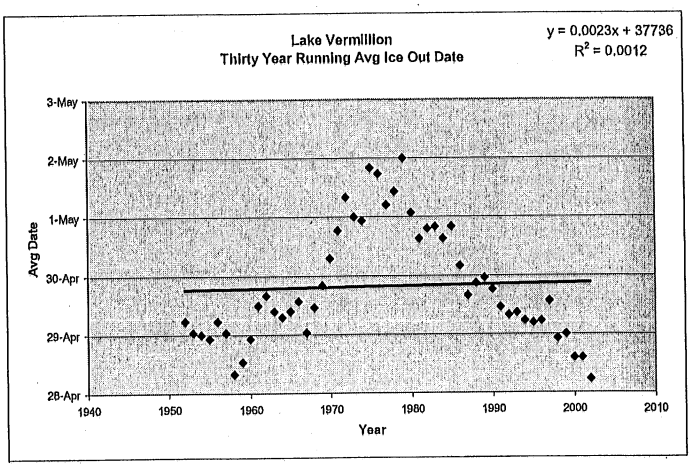


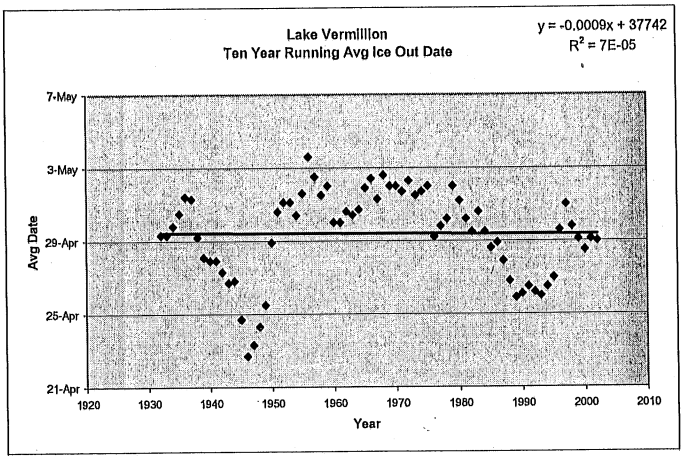


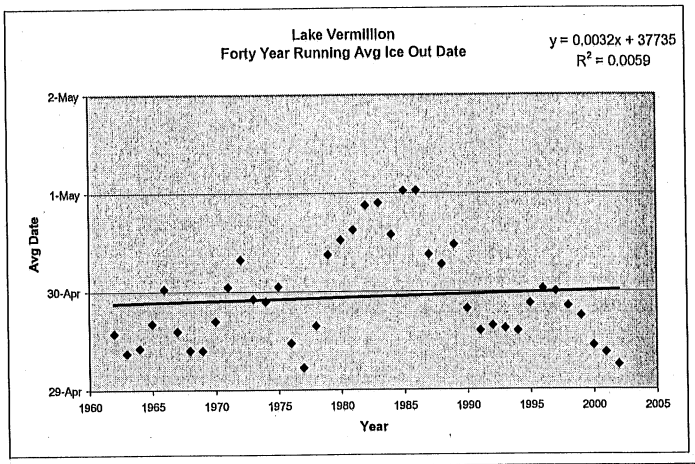


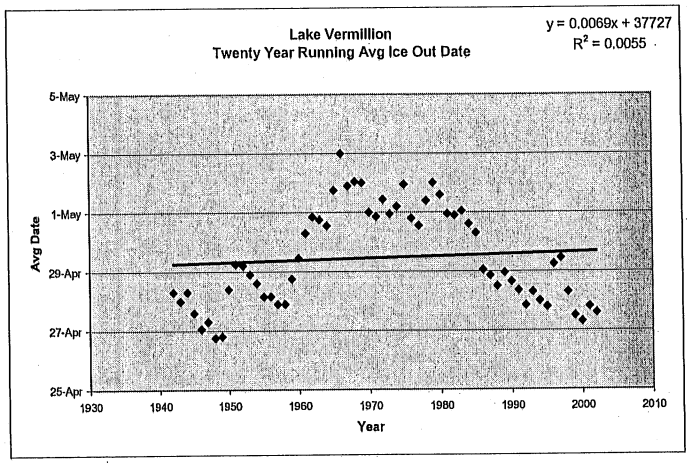
Various Averaging Periods

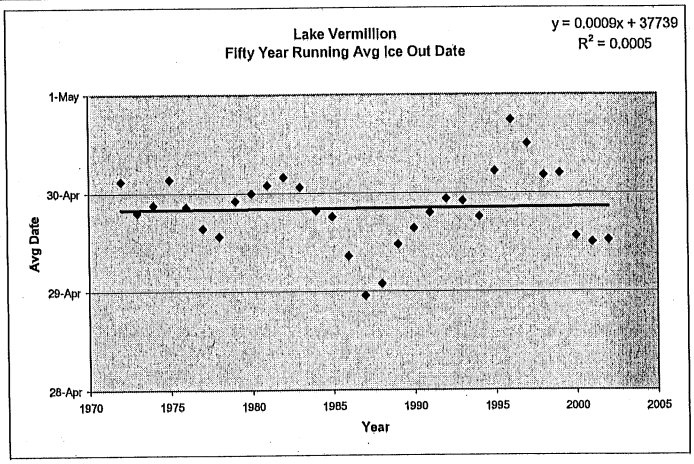




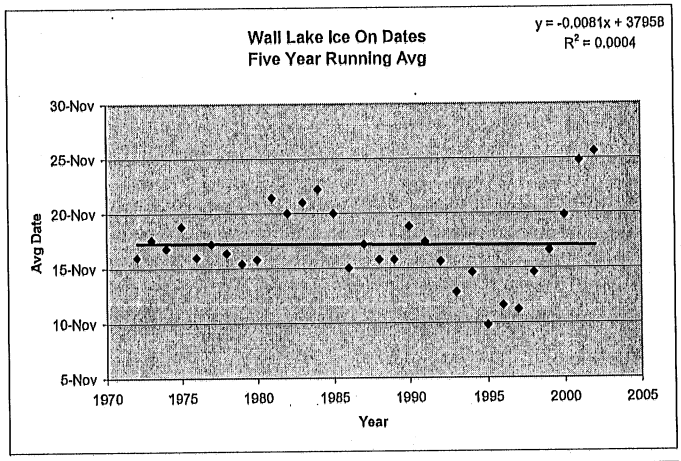


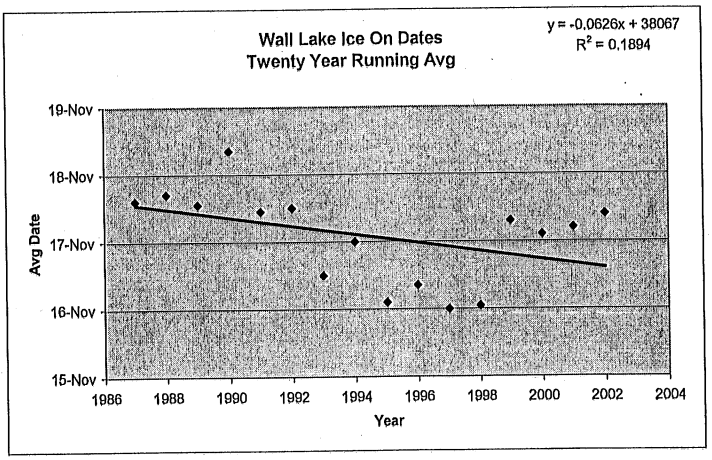


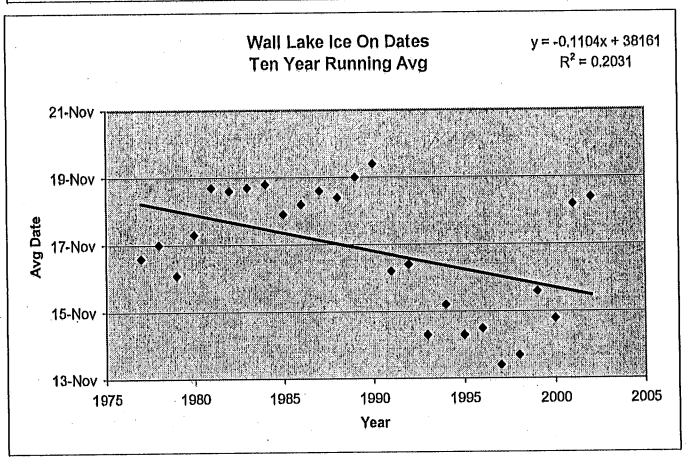


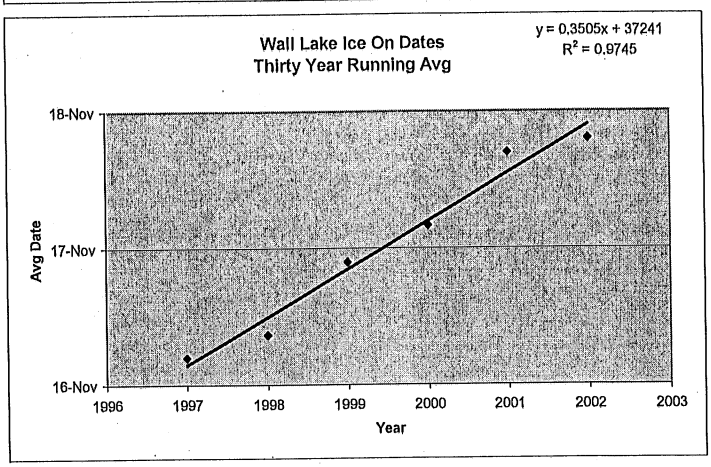


Various Averaging Periods

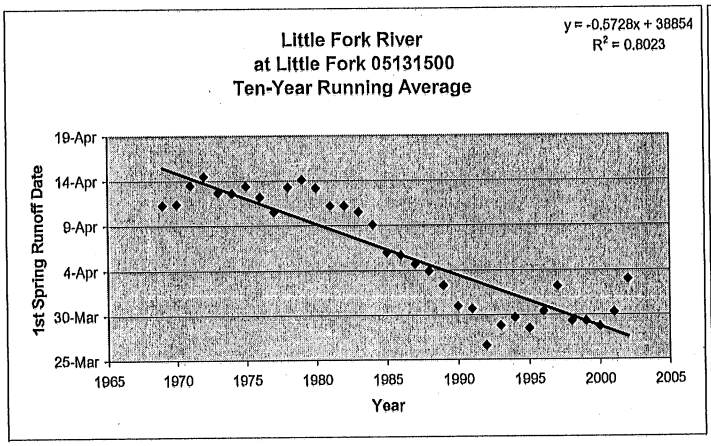


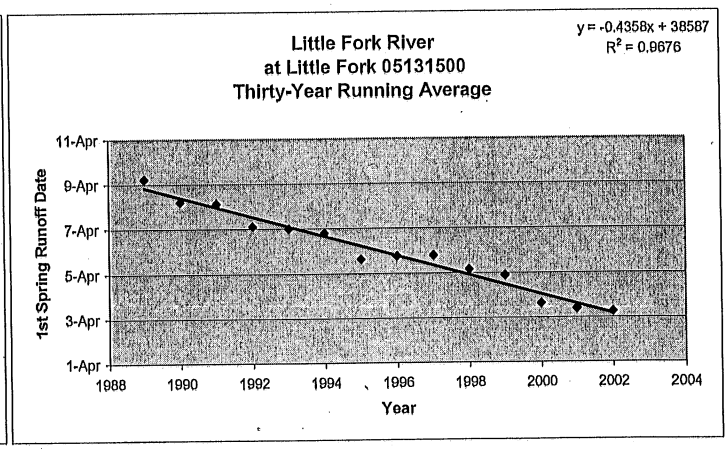


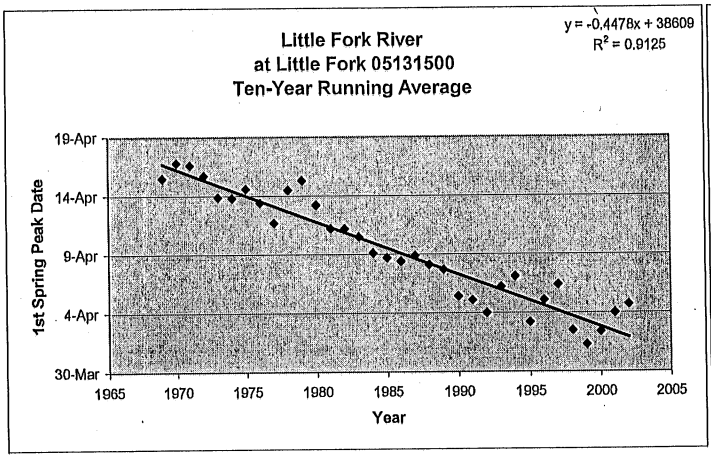


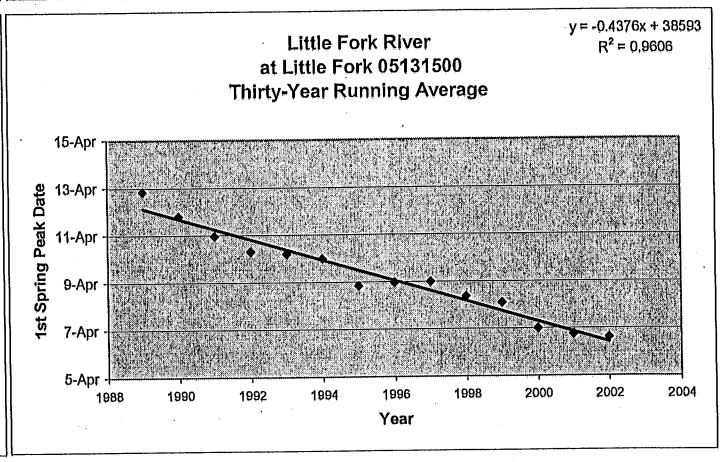


Various Averaging Periods









Complete Results of Ten-Year Running Average Analysis for Ice-Out Dates

Lake Name	County Name	Record Length			Slopes: Complete			Slopes: 1970 to Now			Slopes: 1980 to Now			Slopes: 1990 to Now			Comments
		Length (years)	From	To	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2	Ice-Out (days/year)	RMSE (days)	r^2	
Big Pine	Pine	29	1974	2002	-0.1297	1.28	0.4276				-0.1144	1.31	0.259	0.1681	1.07	0.2724	
Big Stone	Big Stone	43	1960	2002	-0.0853	2.16	0.1969	-0.1837	2.02	0.4348	-0.2757	1.94	0.4817	0.2272	1.17	0.3645	*Missing 1973, 97
Big Trout	Crow Wing	30	1973	2002	0.0117	1.49	0.0049				0.0222	1.63	0.0088	0.2489	1.48	0.3122	
Big Turtle	Beltrami	28	1974	2001	-0.1671	1.47	0.4852				-0.138	1.48	0.2856	0.1049	1.24	0.0975	
Bone	Washington	52	1951	2002	-0.1212	2.02	0.4525	-0.2727	1.54	0.7467	-0.2061	1.68	0.4094	0.1527	1.28	0.1786	
Clear	Waseca	80	1923	2002	0.0219	3.80	0.0171	-0.2494	2.69	0.4499	-0.1832	2.86	0.1731	0.1809	0.93	0.4109	*Missing 1974, 77-82, 84, 85 ,87
Crow Wing	Crow Wing	26	1977	2002	-0.2473	1.70	0.5532				-0.2217	1.69	0.4424	0.0951	1.47	0.0598	
Detroit	Becker	101	1902	2002	0.0156	2.69	0.0281	-0.1121	2.76	0.1337	-0.0118	3.11	0.0007	0.7028	1.91	0.6722	*Missing 1982, 85
Green	Kandiyohi	54	1949	2002	-0.1301	1.97	0.5191	-0.1509	2.01	0.345	-0.1901	2.16	0.2625	0.3473	1.23	0.5457	
Gull	Crow Wing	39	1964	2002	-0.0972	1.29	0.4257	-0.1009	1.37	0.3354	-0.075	1.55	0.0973	0.07	1.46	0.0337	*Missing 1980, 82, 84-86, 97
Kabetogama	Koochiching	42	1961	2002	-0.1412	1.63	0.5305	-0.1741	1.66	0.5061	-0.0884	1.77	0.1033	0.2159	1.33	0.2858	
Leech	Cass	58	1945	2002	-0.0268	1.88	0.0548	-0.1418	1.45	0.4707	-0.1036	1.58	0.1656	0.1868	1.19	0.2709	
Long	Becker	34	1969	2002	-0.1945	1.72	0.5584				-0.2156	1.87	0.3997	0.1358	1.26	0.1682	
Long	Cass	28	1974	2001	-0.0247	1.36	0.0104							0.1343	1.36	0.1127	
Mc Donald	Otter Tail	25	1977	2001	-0.1824	1.64	0.4017				-0.163	1.65	0.2908	0.158	1.45	0.1337	
McKinney	Itasca	28	1973	2000	-0.1885	1.18	0.6339				-0.1445	1.26	0.3358	0.0273	1.45	0.0039	
Mille Lacs	Aitkin	38	1965	2002	-0.1306	2.23	0.2978	-0.1806	2.24	0.3774	-0.2518	2.09	0.4013	0.0841	1.47	0.0471	*Missing 1959, 72-74, 76-78
Minnetonka	Hennepin	107	1896	2002	-0.0172	2.06	0.0631	-0.2144	1.58	0.6327	-0.2723	1.65	0.5558	0.1005	1.18	0.0995	
Minnewaska	Pope	88	1915	2002	0.0157	3.19	0.0156	-0.234	2.72	0.4091	-0.1164	2.93	0.0677	0.5455	1.49	0.671	*Missing 1928, 82, 84-85
Osakis	Todd	127	1876	2002	-0.0381	3.07	0.1711	-0.2978	1.64	0.7543	-0.3594	1.59	0.7005	-0.0632	1.29	0.0354	*Missing 1886, 82, 96-97
Portage	Hubbard	18	1984	2001	-0.227	1.47	0.4297							0.0549	1.21	0.0261	
Shagawa	St. Louis	28	1974	2001	-0.1404	1.61	0.3405				-0.0673	1.58	0.0707	0.2913	1.15	0.4556	
Shetek	Murray	33	1969	2001	-0.1607	2.15	0.3433	-0.1647	2.18	0.3343	0.274	2.43	0.3496	0.3538	1.23	0.5199	*Missing 1981-86, 94
Siseebakwet	Itasca	25	1977	2001	-0.0396	1.15	0.0644				-0.0331	1.18	0.0347	0.0022	1.43	4.00E-05	
Vermillion	St. Louis	71	1932	2002	-0.0009	2.40	7.00E-05	-0.1271	1.60	0.37	-0.0399	1.69	0.0251	0.3269	1.13	0.5588	
Waconia	Carver	54	1949	2002	-0.1784	1.87	0.693	-0.2785	1.83	0.6846	-0.4515	1.42	0.8229	-0.1595	1.05	0.2574	*Missing 1980-82, 84, 85, 87, 96-98
Wall	Otter Tail	25	1978	2002	-0.2017	1.44	0.5341				-0.1695	1.41	0.4209	0.069	1.20	0.0545	
White Bear	Ramsey	66	1937	2002	-0.0585	2.75	0.1427	-0.2606	1.70	0.6926	-0.3819	1.66	0.7288	-0.0387	1.30	0.0159	
Wirth	Hennepin	19	1984	2002	-0.0492	1.41	0.0367							0.0353	1.46	0.0091	
Average		**48.14**	**1955**	**2002**	**-0.1005**	**1.9338**	**0.2908**	**-0.1965**	**1.9369**	**0.4798**	**-0.1530**	**1.8142**	**0.3036**	**0.1641**	**1.3059**	**0.2301**	
Standard Deviation		**28.63**	**28.40**	**0.54**	**0.0816**	**0.6521**	**0.2283**	**0.0630**	**0.4626**	**0.1767**	**0.1443**	**0.5059**	**0.2307**	**0.1765**	**0.1886**	**0.2131**	

Questionable results due to number of data points analyzed

Complete Results of Ten-Year Running Average Analysis for Ice-In Dates

Lake Name	County Name	Record Length			Slopes: Complete			Slopes: 1980 to Now			Slopes: 1990 to Now			Comments
		Length (years)	From	To	Ice-In (days/year)	RMSE (days)	r^2	Ice-In (days/year)	RMSE (days)	r^2	Ice-In (days/year)	RMSE (days)	r^2	
Big Turtle	Beltrami	28	1974	2001	-0.2225	1.42	0.6245	-0.148	1.41	0.3167	0.0955	1.52	0.049	
Crow Wing	Crow Wing	26	1977	2002	0.5653	1.90	0.8376	0.6691	1.54	0.8963	0.4505	1.40	0.6124	
Long	Becker	34	1969	2002	-0.104	1.95	0.2107	-0.1594	2.16	0.1997	0.2659	2.15	0.1879	
Long	Cass	14	1988	2001	0.1473	1.41	0.1599				0.232	1.44	0.251	*Missing 1983
Mc Donald	Otter Tail	25	1977	2001	-0.14	2.07	0.199	-0.2247	1.98	0.3517	-0.0476	2.21	0.006	
Portage	Hubbard	18	1984	2001	-0.1105	1.90	0.0877				0.2787	1.62	0.2777	
Shagawa	St. Louis	28	1974	2001	-0.0673	2.21	0.0588	-0.1879	2.19	0.2368	0.1248	2.40	0.034	*Missing 1969-70, 75-76, 78-79
Siseebakwet	Itasca	25	1977	2001	0.0628	1.45	0.0917	0.0379	1.51	0.0259	0.1979	1.63	0.1614	
Wall	Otter Tail	25	1978	2002	-0.1104	1.67	0.2031	-0.1703	1.62	0.3369	-0.0132	1.91	0.0007	
Wirth	Hennepin	19	1984	2002	0.0725	2.15	0.0314				0.4406	2.14	0.3552	
Average		**24.20**	**1978**	**2001**	**0.0093**	**1.8130**	**0.2504**	**-0.0262**	**1.7729**	**0.3377**	**0.2025**	**1.8420**	**0.1935**	
Standard Deviation		**5.77**	**5.65**	**0.52**	**0.2257**	**0.3055**	**0.2658**	**0.3179**	**0.3279**	**0.2705**	**0.1685**	**0.3636**	**0.1920**	

Questionable results due to number of data points analyzed

Trends in Ten-Year Running Averages of Spring River Discharge

Station	Name	Lat	Long	Record Length: Length (years)	Record Length: From	Record Length: To	Data Quality: Averages	Data Quality: Daily	First Peak Date: Slope (days/yr)	First Peak Date: r^2	First Peak Date: RMSE (days)	First Peak Flow: Slope (cfs/yr)	First Peak Flow: r^2	First Peak Flow: RMSE (cfs)
05078230	Lost River at Oklee	47°50'35"	95°51'30"	33	1970	2002	Good	Fair	-0.405	0.5869	3.29	-23.899	0.541	212.84
05124480	Kawishiwi River near Ely	47°55'22"	91°32'06"	27	1976	2002	Good	Good	-0.0342	0.0133	2.34	-17.36	0.7602	77.39
05130500	Sturgeon River near Chisholm	47°40'25"	92°54'00"	34	1969	2002	Good	Fair	-0.4383	0.9309	1.19	-16.405	0.6893	109.69
05131500	Little Fork River at Little Fork	48°23'45"	93°32'57"	34	1969	2002	Good	Fair	-0.4478	0.9125	1.38	-162.6	0.7691	887.33
05133500	Rainy River at Manitou Rapids	48°38'04"	93°54'47"	34	1969	2002	Good	Fair	-0.3718	0.7584	2.09	-391.01	0.6459	2883.01
05245100	Long Prairie River at Long Prairie	45°58'30"	94°51'56"	22	1981	2002	Good	Poor-Fair	-0.3408	0.418	2.61	-2.357	0.0236	98.44
05280000	Crow River at Rockford	45°05'12"	93°44'02"	34	1969	2002	Good	Fair	-0.4064	0.5868	3.40	-57.386	0.3908	713.52
05287890	Elm Creek near Champlin	45°09'48"	93°26'11"	15	1988	2002	Good	Poor	0.0911	0.0686	1.50	-5.2487	0.4335	26.83
05291000	Whetstone River near Big Stone City, SD	45°17'30"	96°29'14"	34	1969	2002	Good	Poor-Fair	-0.334	0.6662	2.35	-7.7377	0.0746	271.40
05293000	Yellow Bank River near Odessa	45°13'37"	96°21'12"	31	1969	1999	Good	Poor-Fair	-0.2266	0.5687	1.79	-11.921	0.1305	279.79
05300000	Lac Qui Parle River near Lac Qui Parle	44°59'42"	95°55'09"	34	1969	2002	Good	Poor-Fair	-0.1738	0.3609	2.20	-60.139	0.3908	712.81
05313500	Yellow River Near Granite Falls	44°43'18"	95°31'07"	34	1969	2002	Good	Fair-Poor	-0.4011	0.769	6.26	39.34	0.3353	511.25
05317000	Cottonwood River near New Ulm	44°17'29"	94°26'24"	34	1969	2002	Good	Poor-Fair	0.025	0.0093	2.57	-87.726	0.3215	1269.01
05317200	Little Cottonwood River near Courtland	44°14'47"	94°20'19"	40	1963	2002	Good	Fair	-0.1798	0.1254	2.81	-1.964	0.0207	79.87
05320000	Blue Earth River near Rapidan	44°05'44"	94°06'33"	34	1969	2002	Good	Fair	-0.4194	0.6703	2.93	-80.217	0.2733	1302.45
05320500	Le Sueur River near Rapidan	44°06'40"	94°02'28"	34	1969	2002	Good	Fair-Poor	-0.5557	0.9194	1.64	-53.5	0.4069	643.25
05325000	Minnesota River at Mankato	44°10'10"	94°00'15"	30	1973	2002	Good	Fair-Poor	-0.2188	0.3265	2.77	375.36	0.4587	3589.86
05327000	High Island Creek near Henderson	44°34'19"	93°55'18"	20	1983	2002	Good	Fair-Poor	-0.0026	1.00E-04	1.47	9.48	0.4668	59.95
05330000	Minnesota River Near Jordan	44°41'35"	93°38'30"	34	1969	2002	Good	Fair-Poor	-0.3011	0.346	4.12	-81.279	0.0189	5824.98
05336700	Kettle River below Sandstone	46°06'20"	92°51'50"	26	1977	2002	Good	Fair	-0.6531	0.7893	2.58	-103.91	0.4123	948.99
05353800	Straight River near Faribault	44°15'29"	93°13'51"	28	1975	2002	Good	Fair	-0.5224	0.4587	4.67	-6.4429	1.05E-01	154.87
	Average			**31**	**1972**	**2002**			**-0.3008**	**0.4898**	**2.665**	**-35.57**	**0.3652**	**983.7**
	Standard Deviation			**5.88**	**5.92**	**0.65**			**0.1994**	**0.3134**	**1.209**	**130.0**	**0.2384**	**1445**

Trends in Ten-Year Running Averages of Spring River Discharge (Continued)

	Max Spring Peak Date			Max Spring Peak Flow			1st Spring Runoff Date			1st Spring Runoff Flow			February Flow			March Flow		
Station	Slope (days/yr)	r^2	RMSE (days)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (days/yr)	r^2	RMSE (days)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)	Slope (cfs/yr)	r^2	RMSE (cfs)
05078230	-0.3867	0.6133	2.97	-28.26	0.4889	279.40	-0.4164	0.4392	4.55	-22.737	0.4881	225.17	0.353	0.642	2.55	1.8519	0.559	15.91
05124480	0.1029	0.1307	2.11	-16.483	0.7249	80.59	-0.0538	0.0666	1.60	-18.51	0.7204	91.55	-0.2032	0.1258	4.25	0.022	0.0032	3.07
05130500	0.05	0.0408	2.41	-16.344	0.7642	90.40	-0.563	0.8269	2.55	-16.651	0.5119	161.92	0.3604	0.8402	1.56	1.2578	0.8442	5.38
05131500	0.2778	0.4304	3.18	-154.15	0.8391	672.33	-0.5728	0.8023	2.83	-180.52	0.5799	1530.08	1.059	0.5734	9.10	6.0984	0.6695	42.67
05133500	0.0461	1.35E-02	3.92	-404.99	0.8366	1782.67	-0.7521	0.912	2.33	-571.92	0.8287	2589.24	-71.214	0.7216	440.53	-50.796	0.7199	315.51
05245100	-0.702	0.8394	1.99	-2.2234	0.0253	89.55	-0.1238	0.1009	2.40	5.4844	0.2011	70.99	1.4706	0.4547	10.46	3.6365	5.56E-01	21.12
05280000	-0.521	0.719	3.24	-68.241	0.4732	716.95	-0.3379	0.5044	3.34	-65.379	0.3942	807.05	5.2289	0.5137	50.66	23.879	0.5132	231.60
05287890	1.3204	0.8976	1.99	7.3277	0.4915	33.33	0.275	0.5202	1.81	-0.7713	0.0274	20.56	-0.5344	0.4803	2.49	-1.0289	0.3198	6.71
05291000	0.2207	0.1558	5.12	3.7564	0.0202	260.65	-0.3737	0.4883	3.81	-21.42	0.1487	510.29	1.0902	0.8135	5.20	3.8606	0.6093	30.78
05293000	-0.5527	0.5763	4.31	-11.513	0.1381	261.48	-0.384	0.3536	4.72	-17.599	2.38E-01	286.30	1.2055	0.8296	4.97	5.6321	0.7874	26.61
05300000	0.082	0.028	4.62	-45.917	0.2919	678.92	-0.3451	0.4367	3.72	-75.708	0.4272	832.29	1.6644	0.7868	8.22	8.78	0.5162	80.69
05313500	0.252	0.1386	2.19	-21.713	0.1517	551.55	-0.2162	0.4236	2.51	-48.215	0.3328	679.88	0.7429	0.6022	6.01	8.5773	0.5562	76.29
05317000	0.2696	0.2904	4.20	-23.945	2.76E-02	1415.87	-0.2479	0.7187	1.54	-132.87	0.5606	1171.53	3.342	0.6834	22.65	21.214	0.6857	143.02
05317200	-0.0465	0.032	1.51	4.0704	0.0868	78.09	-0.1248	0.2398	1.31	-1.0266	0.0052	84.22	1.1329	0.705	3.70	-1.1583	0.2319	10.65
05320000	-0.1386	0.0952	4.26	-56.89	0.0826	1887.67	-0.5837	0.8561	2.38	-111.09	0.3793	1415.03	11.874	0.751	68.08	34.043	0.6139	168.83
05320500	-0.102	0.0305	5.73	-25.723	0.0626	991.21	-0.599	0.777	3.20	-68.524	0.5102	668.60	7.0203	0.5079	68.82	6.3046	0.1003	188.07
05325000	0.0386	0.0043	5.18	240.71	2.02E-01	4214.90	-0.528	0.8191	2.18	-201.44	0.3802	2264.16	33.046	0.7348	197.68	140.94	0.7186	878.26
05327000	0.6029	0.7143	2.26	25.64	0.5925	125.80	0.3527	0.5419	1.92	13.631	0.6417	60.26	0.3094	0.1169	5.03	0.8489	0.0355	26.18
05330000	-0.1035	0.1073	2.97	13.072	0.0004	6593.35	-0.3248	0.5739	2.79	65.489	0.0257	4017.49	31.468	0.7194	195.73	142.81	0.6588	1023.38
05336700	0.1273	0.1121	2.74	-67.112	0.5611	453.95	-0.5347	0.5628	3.60	-118.99	0.5583	809.56	3.0563	0.736	14.00	12.237	0.6968	61.74
05353800	0.2501	0.1577	4.76	10.518	0.2478	150.74	-0.6096	0.5802	4.27	-5.9652	0.0587	196.53	3.3338	0.2583	46.47	2.2557	0.0762	64.61
	0.0518	**0.2918**	**3.412**	**-30.40**	**0.3385**	**1019**	**-0.3364**	**0.5497**	**2.827**	**-75.94**	**0.3818**	**880.6**	**1.705**	**0.5998**	**55.63**	**17.68**	**0.4986**	**162.91**
	0.4288	**0.3042**	**1.247**	**110.7**	**0.2938**	**1602**	**0.2839**	**0.2385**	**0.9978**	**131.7**	**0.2387**	**1020**	**19.17**	**0.2152**	**105.3**	**44.10**	**0.2613**	**276.06**

Trends in Ten-Year Running Averages of Spring River Discharge (Continued)

Station	April Flow Slope (cfs/yr)	April Flow r^2	April Flow RMSE (cfs)	May Flow Slope (cfs/yr)	May Flow r^2	May Flow RMSE (cfs)	Yearly Flow Slope (cfs/yr)	Yearly Flow r^2	Yearly Flow RMSE (cfs)	Comments
05078230	-7.6075	0.5499	66.55	-1.2271	0.1318	31.36	-0.4874	0.1397	11.35	Data from 1961-2002 only
05124480	-3.4458	0.4558	29.89	-3.2886	0.2329	47.38	-1.1798	0.6595	9.45	Data from 1967-2002 only; no peak in 1977
05130500	-5.4451	0.6312	41.45	-4.3937	0.7079	28.11	-0.2451	0.0621	9.21	
05131500	-49.386	0.6704	344.82	-33.81	0.5986	276.74	-9.3909	0.656	65.75	
05133500	-167.47	0.4939	1688.17	-130.01	0.2466	2263.01	-91.599	0.3924	1102.21	
05245100	2.2555	0.1222	39.25	5.831	0.6731	26.39	1.5808	0.2444	17.25	Data from 1972-2002 only
05280000	1.5691	0.0013	434.84	28.811	0.7899	147.97	21.745	0.7479	122.07	
05287890	2.8762	0.376	16.57	2.3959	0.7328	6.47	0.8036	0.661	2.41	Data from 1979-2002 only
05291000	5.0606	0.2957	77.86	1.3105	0.1163	35.98	1.9902	0.6297	14.76	
05293000	1.1216	0.0317	56.33	0.0005	1.00E-08	38.24	1.8151	0.4629	17.21	Daily up to 1999 with some 2001 data; Annual up to 1998 only; Monthly to 1999
05300000	10.223	0.1653	218.06	9.7203	0.473	100.26	5.2958	0.5959	38.39	Missing data for 2000, 2001
05313500	5.9004	0.115	163.01	7.4682	0.7091	47.63	5.4046	0.7636	29.08	
05317000	7.2729	0.038	364.42	29.638	0.7794	157.02	14.092	0.7146	86.11	
05317200	4.161	0.2647	35.02	3.8415	0.7844	10.17	2.9959	0.8917	5.88	Daily data from 1974-2002 only (missing 1997);Yearly 1974-2001;Monthly 1977-2002
05320000	12.577	0.0341	666.46	46.933	0.7696	255.69	27.803	0.726	165.14	
05320500	2.9176	0.008	323.20	20.634	0.781	108.82	10.073	0.5595	86.43	
05325000	150.66	0.1916	3081.55	211.78	0.7643	1171.22	124.98	0.7453	706.55	Daily data from 1964-2002 only
05327000	0.8328	0.0077	55.85	4.4002	0.7529	14.91	2.7017	0.6972	10.02	Data from 1974-2002 only
05330000	143.03	0.1561	3310.98	229.8	0.7459	1335.57	136.54	0.739	784.66	
05336700	-7.4275	6.97E-02	207.57	-1.9169	0.0138	123.78	0.8407	0.0315	34.28	Data from 1968-2002 only
05353800	5.008	0.1731	90.03	7.9326	0.7492	37.75	5.2516	0.8218	19.41	Data from 1966-2002 only
	5.461	**0.2310**	**538.7**	**20.75**	**0.5501**	**298.3**	**12.43**	**0.5687**	**158.9**	
	60.67	**0.2162**	**957.9**	**74.61**	**0.2902**	**576.4**	**45.36**	**0.2517**	**305.4**	