A RECENT HISTORY OF FLOODING IN THE MASSAWIPPI DRAINAGE BASIN

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Introduction

Flooding occurs when the flow of a stream increases to the point where the stream channel no longer can contain the discharge of water. The excess water spreads out on to the adjoining floodplain. This is a natural event common to all rivers, often being extremely beneficial to soil and vegetation development. In Canada flooding occurs regularly in all regions, often associated with spring runoff, but not necessarily restricted to that time of year. Although spring snowmelt is the most common cause of flooding in Canada (Andrews, 1993), other causes include intense rainstorms, ice jams and other obstructions, and glacier outburst floods. In Quebec spring snowmelt during frontally generated rainstorms is the major cause of flooding in general; spring ice jams and intense summer convectional storms are other specific causes.

Little work has been completed on flooding in the Eastern Townships or in the Massawippi drainage basin in particular. This is despite the fact that, in an anecdotal sense, flooding is a well-known phenomenon throughout the region. The Massawippi River and its tributaries are excellent examples of streams that are known to flood; yet there exists little documentation of the periodicity or severity of these events. This paper is an attempt to alleviate this situation by contributing to the knowledge of flooding in the Massawippi River drainage basin during the period 1964 to 1994 inclusive. This time period was chosen because adequate stream discharge records for the basin are available starting in 1964. A thirty-one year period is considered extensive enough for general conclusions on flood behaviour to be made. The paper focuses on the recent history, timing, location and magnitude of locally hazardous floods. In addition, the relevance of both the climatic and geomorphic characteristics of the basin to flood initiation is analyzed.

Data collected for this study were obtained from various sources.

Geographic data on the physical and topographic character of the drainage basin were obtained primarily from 1988 1:20,000 scale topographic maps provided by the Gouvernement du Québec, ministère de l'Énergie et des Ressources, Service de la cartographie, and secondarily from field reconnaissance; meteorological and stream discharge data were provided by the Gouvernement du Québec, ministère de l'Environnement et de la Faune, Direction de la météorologie et Direction du milieu atmosphérique; land cover data were obtained from the Gouvernement du Québec, Ressources naturelles, Bureau régional de Sherbrooke (forêts).

Study Area

The Massawippi drainage basin is a sub-basin of the St. Francis drainage basin in southern Quebec covering an area of approximately 1,670 km^2 (Fig. 1 and Table 1). The basin receives an average annual precipitation of 104 cm, measured at Lennoxville (Boisvert, 1972). Approximately 46% of this precipitation falls from May to September, approximately 28 cm of the total, or 27%, as snow. (Note, this latter figure refers to the water equivalent depth of snowfall, not the resulting snowcover depth.) Thus, a relatively rich supply of water is available locally and this rich input has created numerous stream channels of various lengths in the Massawippi basin. In total the basin drainage network is composed of over 2,061 km of stream channels (Table 1). The longest, that of the Coaticook River, exceeds 82 km from its origin at Horton Pond in northern Vermont, to its confluence with the Massawippi River just south of Lennoxville (Fig. 1). However, most stream channels present in the basin, over 76%, are comparatively short often measuring less than 4 km. These first-order streams, that is streams without tributaries, are the primary suppliers of water to the drainage network because of their high frequency. Thus, they are of importance in terms of flooding.

The surficial geology, or physical character of the landscape, is an important control in the development of the drainage network. A history of the development of the natural landscape over the past 100,000 years is provided by Dubois and Parent (1989). The basin is part of a dissected plateau surface known as the New England Upland (Cooke, 1950). A general northwest slope of the plateau surface influences a northward flow of streams to the St. Francis River, and ultimately to the St. Lawrence. Stream valleys are cut through relatively soft sedimentary rocks, principally impure limestones overlain by sandstones, while the hills of the basin represent more resis-

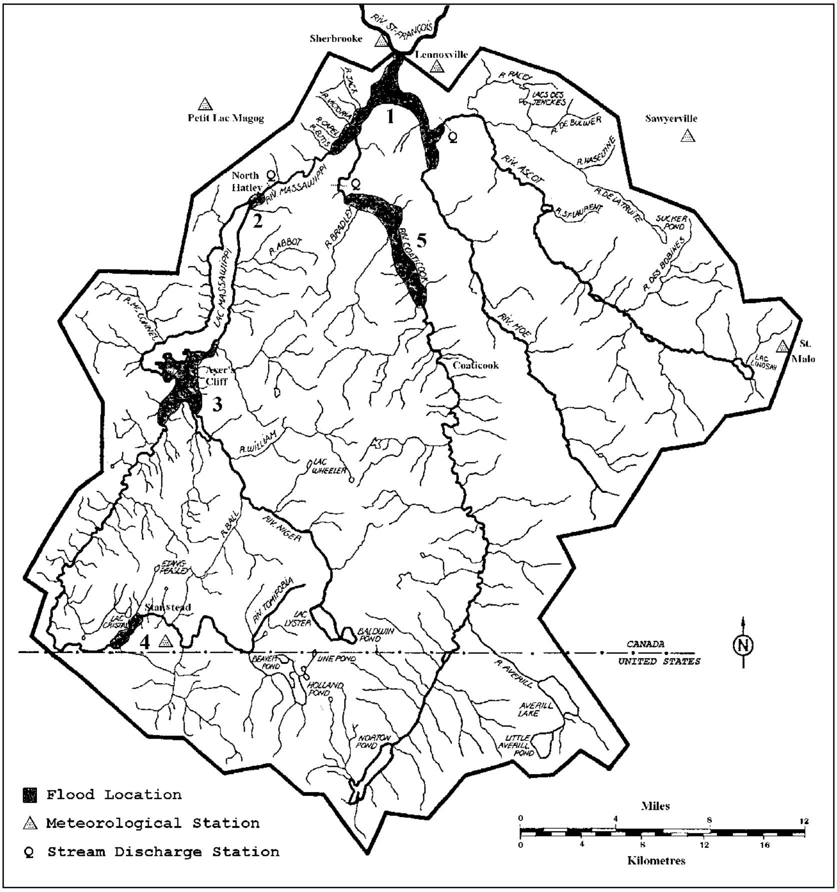

Figure 1.
Massawippi River Drainage Basin – Principal Locations

tant monadnocks of granite and quartzite. It is the widespread presence of these hills and the gradual, continuous land slope which contribute to the creation of numerous short streams, a low number of long streams, and very few lakes. Lake Massawippi, which has been enlarged somewhat by the dam near its north end, is the only relatively large lake present. Smaller water bodies, such as Lake Lyster, Norton Pond and Averill Lake, clustered in the extreme south of the basin (Fig. 1), act as water collection areas and stream sources.

Most small streams are consequent of post-glacial age. Their valleys are poorly developed, cut in glacial sediments for the most part (cf. Larocque et al., 1985). Large streams occupy preglacial valleys cut approximately 100 m into the general plateau level (Cooke, 1950). Examples of the large type include the Coaticook, Moe and

MASSAWIPPI DRAINAGE BASIN GEOMORPHIC CHARACTERISTICS

Linear Aspects:

Total Stream Length:	2061.0 km
Basin Length:	52.3 km
Basin Width:	49.9 km
Length of Longest Channel:	82.2 km
Average Bifurcation Ratio:	3.7

Areal Aspects:

Drainage Basin Area:	1670.5 km^2
Drainage Density:	1.23 km/km^2
Basin Form Factor:	0.61
Length/Width Ratio:	1.05
Stream Frequency:	1.35/km^2

Relief Aspects:

Basin Relief:	737.7 m
Relief Ratio:	0.36
Circularity:	0.88
Slope:	0.014 m/m
Ruggedness Number:	0.91

Land Cover:

A) 1970-1971:		**B) 1990-1991:**	
Forest	53.2%	Forest	61.7%
Agriculture	41.9%	Agriculture	33.1%
Water	4.7%	Water	4.3%
Other	0.2%	Other	0.9%

Table 1

Land Cover Data Source: Gouvernement du Québec,
ministère des Ressources naturelles, Bureau régional de Sherbrooke (forêts)

Ascot Rivers. In all cases the large valleys are graded with few falls or rapids, valley bottoms are moderately wide and flat with moderate meander development. Overall, the large streams in the basin follow the general slope of the land and are little influenced by the strike of the underlying bedrock. They are superimposed. However, a few anomalous characteristics do occur. Deep, narrow gorges are present at Coaticook, Dixville and Moe River villages. These are recent features where glacial sediment blocked wide channels forcing the streams to develop their present channels past the obstructions.

Factors Affecting Flooding

Climatic factors:

As in most regions of Canada, the principal climatic factors affecting flooding in the Massawippi basin are rain and snowmelt. Rain is able to affect a flood event in two ways. First, simply a large amount of rain over a continuous, extended period of time, usually days, can initiate widespread, long duration flooding. As introduced above, the study area receives greater than 73% of its total precipitation as rain, usually over 75 cm per year. Extended rain events are therefore not unusual in this region. Second, rainfall intensity, usually measured in centimetres per hour, can initiate a flood event. Most intense falls of rain result in "flash floods," flood events that occur in a relatively short period of time, with sharp hydrograph peaks and with a minimal spatial effect. In the Massawippi basin these occur as frontal storms in all seasons, and convectional storms in summer.

Snowmelt becomes a major factor in flood initiation when the air temperature remains above freezing for an extended period of time during winter or early spring. In order for flood events to be considered snowmelt-initiated rather than rainfall-initiated events there must be less than 25 mm of rainfall and a maximum temperature of greater than 0° C over four days, the three days preceding the flood event and the event day (Irvine and Drake, 1987). Of course this assumes an existing snowcover, with a positive relationship existing between annual average snowfall and the frequency of snowmelt initiated floods (Irvine and Drake, 1987). By comparison with the peakiness of rain floods, the runoff generated by snowmelt is quite lethargic. Stream hydrographs tend to have less sharp peaks and longer duration. The high amounts of snowfall received by the Massawippi basin means it is prone to snowmelt floods, especially in late winter and early spring when air temperatures fluctuate around the freezing point.

The warm temperatures associated with snowmelt also influence the break-up of river ice and the increased possibility of ice jams. These occur preferentially upstream of built obstructions, such as bridges and dams (see Plate 1), but also can occur at meander bends and narrow reaches of river channel. Ice jams are often associated with snowmelt-initiated flood events since the warm temperatures, which cause snowmelt also, lead to river ice melt and break-up.

Geomorphic factors:

There exist six principal geomorphic factors influencing the degree of flooding a drainage basin might experience: drainage basin area, basin circularity, length of longest channel, bifurcation ratio, drainage density, and basin ruggedness. In addition, the land cover and use have both direct and indirect influences on flood potential and yet are not solely related to the geomorphology; climate and human activity play roles. See Table 1 for a summary of various geomorphic characteristics of the Massawippi basin.

The drainage basin area reflects the volume of water generated from rainfall and snowmelt. Primarily, the larger the basin the greater the volume of water available for stream flow and the greater the discharge of water from the basin. Secondarily, the larger the drainage basin the more temporally extended flood events will be. In the case of the Massawippi basin, at over 1,670 km^2 it is the second largest sub-basin of the St. Francis drainage basin; only the Magog drainage basin at approximately 2,023 km^2 is larger. Thus the Massawippi River has a relatively large source of water and a high potential for long-duration flooding based on this factor.

Basin circularity is a measure of basin shape, an instrumental factor in determining the rate at which water is delivered to the main streams and the basin outlet. Circular basins result in runoff from various parts of the watershed reaching the outlet simultaneously. A shorter time from flood initiation to peak flood will occur. A long, narrow basin of equal area will exhibit a hydrograph with a longer time lag to peak and the resulting flood crest will be more subdued. The Massawippi drainage basin is near circular with a length/width ratio of 1.05. That is, the basin is only slightly longer than it is wide when measured at maximums. Thus, the study basin shape should increase the severity of the local flood hazard, especially at the basin outlet. Also, the Massawippi basin's near-circular shape decreases the duration of flood events, lessening the prolonging effect of a large basin size.

Similar to the basin shape, the length of the longest channel is related to water travel time. The shorter the longest channel, and

Plate 1:
An ice jam along the Massawippi River at the railway bridge near Lennoxville, April 1992.
(Source: J.D. Booth)

channels in general, the faster water is delivered to the basin outlet and the greater the flood crest will be. The combined length of the Coaticook and Massawippi Rivers at 82 km represents the farthest distance runoff would have to travel in the study basin, from the origin of the Coaticook in northern Vermont to the mouth of the Massawippi where it joins the St. Francis River. This is a relatively short distance for a basin of this size. Assuming a constant water velocity of approximately 1.0 ms^{-1}, or 86 km/day, typical for the two rivers, runoff would take less than 24 hours to travel from basin source to outlet. Travel times on most other channels would be reduced, except for the main branch of the Massawippi River where the presence of Lake Massawippi would cause water storage. Lakes and wetlands tend to decrease flood potential by storing large volumes of water and influencing subdued flood peaks. Analysis of large-scale topographic maps and data collected by the Bureau régional de Sherbrooke (forêts) indicate that in 1990–1991 approximately 4.3% of the Massawippi basin was covered by lakes and wetlands, a slight decrease from the 4.7% measured for 1970–1971. The transformation of small areas of wetlands around Lake Massawippi may account for this slight decrease. However, overall, the Massawippi basin has a relatively quick response to water input and, again, a short time period to flood peak.

The next geomorphic factor, the bifurcation ratio, is a measure of how many times stream channels split, or conversely, how many times two channels come together to create a larger one. It is a measure of the number and internal arrangement of stream channels. Bifurcation ratio is usually discussed with basin shape to determine their combined effect on flood severity. Strahler (1964) suggested two extremes: circular basins with low bifurcation ratios and approximately equal runoff channel lengths would have dramatic flood peaks, whereas elongate basins with unequal channel lengths would yield longer duration, more subdued flood peaks. A low bifurcation ratio would be 2.25, a moderate one 4.0 and a high one 17.0 (Strahler, 1964). The Massawippi basin, therefore, with its circular shape and moderate bifurcation ratio of 3.7, must be expected to demonstrate a moderately dramatic flood peak.

Drainage density represents the length of stream channel per unit area in a drainage basin, usually measured in $kmkm^{-2}$. An increase in drainage density means an increase in the severity of flooding, since there exists more stream channel available to transport water. Basins with low drainage density either have low water input in the form of precipitation or a higher soil infiltration rate; precipitated water is routed to the soil not the stream channels. In humid regions of the world, such as southern Quebec, drainage densities usually range from 0.55 to 2.09 $kmkm^{-2}$, with an average of about 1.03 (Langbein, 1947). Based on measurements taken from large-scale topographic maps, the Massawippi basin has a drainage density of 1.23 $kmkm^{-2}$, slightly higher than average. A slightly higher severity of flooding can be expected here than in basins of comparable climate. It should be noted that, since most Canadian floods occur in spring when infiltration and interception rates are low, humid basins such as the Massawippi receive proportionally more runoff at this time of year than any other. In fact, drainage density may be temporarily increased in spring because of the creation of short-lived, first-order streams that cease to flow after complete snowmelt. Taking into consideration the timing of flood events, drainage density may be an even larger influence on flood potential in the Massawippi basin than at first assumed.

Basin ruggedness is a product of drainage density and basin relief. Often referred to as the Ruggedness Number (Patton, 1988), this variable is especially useful because it summarizes the interaction between maximum basin relief and basin dissection. Maximum relief is defined as the difference in elevation between the highest and lowest points, and dissection refers to erosion by streams. Thus, a highly dissected basin of low relief is as rugged as a moderately dissected basin of high relief. An increase in the basin ruggedness is accompanied by an increase in peak discharge. The Massawippi basin with a Ruggedness Number of 0.91 is characterized by relatively moderate ruggedness due to its moderate drainage density and relatively moderate maximum relief of 738 m. Taken together with the relative scarcity of lakes on this terrain, basin ruggedness will influence a slightly higher than average potential for flooding.

In general, an increase in vegetative cover, especially in forest cover with its high density, means less severe flooding because of the effect vegetation has in intercepting rainfall and utilizing relatively large amounts of infiltrated water for photosynthesis and growth. For example, in the Massawippi basin, data from the analysis of large-scale topographic maps and the Bureau régional de Sherbrooke (forêts) show the percentage of land covered by forest increased from 53% in 1970–1971 to 62% in 1990–1991. This increase was matched by a decrease in agricultural land from 42% to 33% during the same 20-year period. Yet, no obvious change in flood frequency occurred during this time period (Table 1). Thus, although an increase in forest cover should result in fewer, less severe floods, in early spring, when most Canadian floods occur, the ground is frozen, infiltration is essentially zero, vegetation are mostly dormant and the land cover factor is less important. Most precipitation is routed to the streams as runoff at this time of year.

Flood History

Since no official study has been made nor records kept of flood events in the Massawippi drainage basin, it was necessary to compile a history of flooding from a content analysis of local print media, specifically *The Sherbrooke Record*, *La Tribune* and *The Townships Sun*. Newspaper accounts have the advantage of easy accessibility and using three sources increases the chance of a flood event being recorded for inclusion. One major disadvantage of this research method is the propensity for newspapers to cover only major events, overestimate damages and, occasionally, confuse flood damage with erosion damage (Kreutzwiser and Gabriel, 1992). The possibility of the newspapers utilized in this study covering only major events is low; these are local newspapers that attempt to report all local events, large or small. Also, since damage amounts are not specifically analyzed here, this disadvantage is moot. Additionally, general information on the flood history of southern Quebec came from government publications (e.g.: Andrews, 1993).

MASSAWIPPI DRAINAGE BASIN
SUMMARY OF FLOOD EVENTS
1964 - 1994

Date	Effective Rainfall (cm)	Rainfall Intensity (cm/hr)	Water Equivalent Snowmelt (cm)	Peak Discharge (m^3/sec)	Principal Causes	Flood Location (Fig. 1)	Water Equivalent Snowcover Depths Event (cm)	Average (cm)
March 5-6, 1964	3.00	0.50	3.60	239.2	Snowmelt, Rain	1	24.7	15.8
April 11-13, 1969	1.88	0.24	15.30	353.7	Snowmelt, Rain	1, 2, 3	42.0	10.8
April 18-20, 1970	2.42	0.81	7.30	290.6	Snowmelt, Rain	1, 2, 3	14.8	4.7
Dec. 27-28, 1973	1.78	0.08	0.25	172.5	Rain	1	4.5	N/A
Jan. 29-30, 1974	0.64	0.13	3.60	70.3	Snowmelt, Ice Jams	1	7.2	6.8
April 4-5, 1974	1.33	0.11	2.20	295.4	Rain, Snowmelt	1	7.2	10.8
Mar. 21-28, 1976	1.98	0.22	12.00	209.2	Snowmelt, Rain	1, 5	18.1	15.7
April 1-3, 1976	0.81	0.13	4.50	243.0	Snowmelt, Rain	1	6.1	10.8
April 25-26, 1978	0.00	0.00	6.80	120.8	Snowmelt	1	18.1	4.7
Mar. 7-8, 1979	4.17	0.69	1.10	182.1	Rain, Ice Jams	1	19.9	15.8
April 18-20, 1982	8.51	0.72	15.70	394.9	Rain, Snowmelt	1, 2, 3, 4, 5	15.7	4.7
Mar. 19-21, 1983	1.47	0.53	4.30	165.0	Snowmelt, Rain	5	11.4	15.7
Feb. 22-26, 1985	4.91	0.13	2.87	137.6	Rain, Snowmelt	1	5.6	15.8
Mar. 26-27, 1986	0.79	0.09	15.80	146.8	Snowmelt	1	17.5	15.7
April 1, 1987	1.34	0.20	12.80	279.3	Snowmelt, Rain	1, 2, 3, 5	16.7	15.7
Mar. 15-16, 1989	0.07	0.01	1.50	90.2	Snowmelt	1, 5	11.1	15.7
Mar. 29-30, 1989	4.84	0.20	3.34	279.2	Rain, Snowmelt	1, 3	11.1	15.7
Dec. 22-23, 1990	4.91	0.14	0.50	165.1	Rain	1, 2, 3	2.4	N/A
Dec. 31, 1990	2.18	0.13	0.40	163.4	Rain	2	2.2	N/A
April 9-10, 1991	3.07	0.06	5.45	158.0	Snowmelt, Rain	1	5.4	10.8
Mar. 12-13, 1992	0.22	0.11	5.85	216.0	Snowmelt, Ice Jam	1, 5	10.9	15.8
April 11-13, 1993	0.98	0.07	6.68	256.5	Snowmelt, Rain	2	10.6	10.8
April 16-18, 1994	1.91	0.41	13.94	408.1	Snowmelt, Rain	1, 2, 3, 4, 5	19.6	4.7

Table 2

Data Source: Gouvernement du Québec, ministère de l'Environnement et de la Faune

The principal locations of floods in the Massawippi basin are shown on Figure 1. All of these locations are susceptible to flooding primarily because of their low elevations, less than 150 metres above sea level. Secondarily, Locations 1 and 3 are areas of major river confluence, with ice jams being influential at Locations 1, 2 and 3. At Location 1 bridges over the Massawippi River and the confluences of the Massawippi with the Moe and Coaticook Rivers are key points of channel constriction and water and ice build-up; the confluence of the Moe and Ascot Rivers is also susceptible. At Location 2 a dam present immediately downstream of Lake Massawippi provides a constriction point, as does the confluence of the Massawippi and Niger Rivers at Ayer's Cliff, Location 3. Location 5 represents a highly meandering reach of the Coaticook River, each meander bend providing a possible point of water build-up and overflow. Location 4 at Stanstead is the least flooded one, simply being an area of low elevation.

A total of twenty-three flood events were reported in the thirty-one-year study period at these locations (Table 2). A comparison of the peak stream discharges experienced during these events to the mean, or average, discharge calculated for the same dates is provided in Figure 2. Note the large difference between the peak and mean discharge for each event. On average, the peak discharge is approximately 3.6 times the average discharge for the same dates. In extreme cases, such as the December 1973 and 1990 events, the peak discharge is over eight times larger than the normal one. These large differentials are caused by the very low average discharges on those dates, not extreme peaks. It is interesting to note that the three largest peak discharges all occurred in the month of April: 1969, 1982 and 1994. It is during this month that the combined effect of heavy rainstorms, either extended or sudden intense storms, and warm temperatures leading to rapid snowmelt and ice jams, can create the most dangerous flood conditions.

Of the twenty-three total flood events noted on Table 2, eighteen events were rainfall influenced. Examples when rainfall was the principal causal factor include the early March 1979, late March 1989 and late December 1990 events. In these cases extended rainfall that occurred over several days preceding flooding initiated and sustained flooding. Due to the timing of the rainstorms, that is in winter and early spring, very little of the water input was blocked by vegetation interception, or routed to soil or groundwater storage. Most vegetation would be dormant and frozen ground would block any infiltration. Minor amounts of water may have been stored in the snowpack, although in December the snowpack is usually relatively thin reducing the effectiveness of this storage location during this month. The precipitation input flowed directly into runoff, quickly filling then overtopping the stream channels.

Intense rainfalls in the Massawippi basin were the primary cause of flooding in several instances, including, for example, the April 1970, March 1979 and April 1982 events. These floods occurred due to a sudden input of rain over a short period of time, usually less than 24 hours; thus they could be termed "flash floods." Again, because these events occurred in early spring little precipitation was intercepted or infiltrated.

A detailed view of the April 1982 flood is provided in Figure 3; all data are relevant to the Massawippi River outlet at Lennoxville. Note that there are actually two flood peaks present. On April 1 the river rises to a discharge of approximately 178 m^3s^{-1}, well over the average discharge for that date of approximately 105 m^3s^{-1}, as a consequence of four days of above freezing temperatures causing increased snowmelt, and two days of rainfall. However, for the next ten days the river discharge drops and stays below average until April 17. On this date relatively high temperatures begin to cause high rates of snowmelt and an increased discharge, over two times the average. Then, on April 18, a sudden, intense rainstorm of 59.6 mm initiates an unusually high discharge of 395 m^3s^{-1} and extensive flooding throughout the Massawippi basin. Warm temperatures, and attendant snowmelt, keep river discharges dangerously high until April 23. After this, even though temperatures remain relatively high, the snowpack has been almost exhausted and river discharge drops to around average by April 30.

Snowmelt played at least a partial role in the initiation of 16 flood events, including the 1982 event, and snowmelt alone was responsible for 3 of the 23 flood events analyzed: April 1978, March 1986 and early March 1989 (Table 2). In those instances only minor amounts of rain were recorded while warm temperatures caused rapid snowmelt. Note that on 12 other occasions rapid snowmelt was the primary cause of flooding, secondary factors being rain or ice jams (Table 2). In each instance a rapid snowpack melt was accompanied by rain or ice jams. Rain was the secondary factor on 10 occasions, ice jams added significantly to the flood hazard on three occasions (Table 2). Plate 2 shows the Massawippi River near Lennoxville druring the April 1992 flood, an event in part initiated by ice jamming.

The possibility that a flood event of a certain size will re-occur can be estimated by calculating its exceedance probability. This statistic measures the probability that a flood of a given size will be exceeded each year. For example, the April 1982 flood has an exceedance probability of 6.3% (Table 2). Thus, there is a 6.3% chance that an event this size could be exceeded in size each year. The 1994 peak discharge, the largest during the study period, has a 3.1% chance of being exceeded each year. Further, by using the exceedance probabilities for all floods of the study period, an estimate of the 100-year flood can be calculated. A flood this size occurs on average only once every 100 years and has a 1% probability of occurring each

Plate 2:
Looking upstream along the ice-clogged Massawippi River to the railway bridge near Lennoxville, April 1992. (Source: J.D. Booth)

year. This is often the maximum flood size used by municipalities for flood hazard planning purposes. In the Massawippi basin, based on the 31 years of data available, the 100-year flood would have an estimated discharge of 422 m^3s^{-1}, exceeding in size all floods recorded during the study period. The 1994 flood had a peak discharge of 408 m^3s^{-1} and represents a 63-year flood; the 1982 event with a peak discharge of 395 m^3s^{-1} represents a 41-year flood.

Summary

This analysis of flooding in the Massawippi drainage basin allows several insights into flood behaviour in this area. A historical analysis based on print media reveals that the 31-year study period experienced 23 floods in 19 of those years. The basin has a rich history of flood events. Only 12 of the 31 years studied did not experience a flood event, with 4 years, 1974, 1976, 1989 and 1990, each experiencing two events. The vast majority of the floods (18) occurred during March and April. The 4 remaining flood events occurred during brief periods of winter thaw and, with the exception of the December 22–23, 1990, event, were limited in extent.

All of these floods but two took place in an extensive area immediately south of Lennoxville. Its location near the basin outlet, on

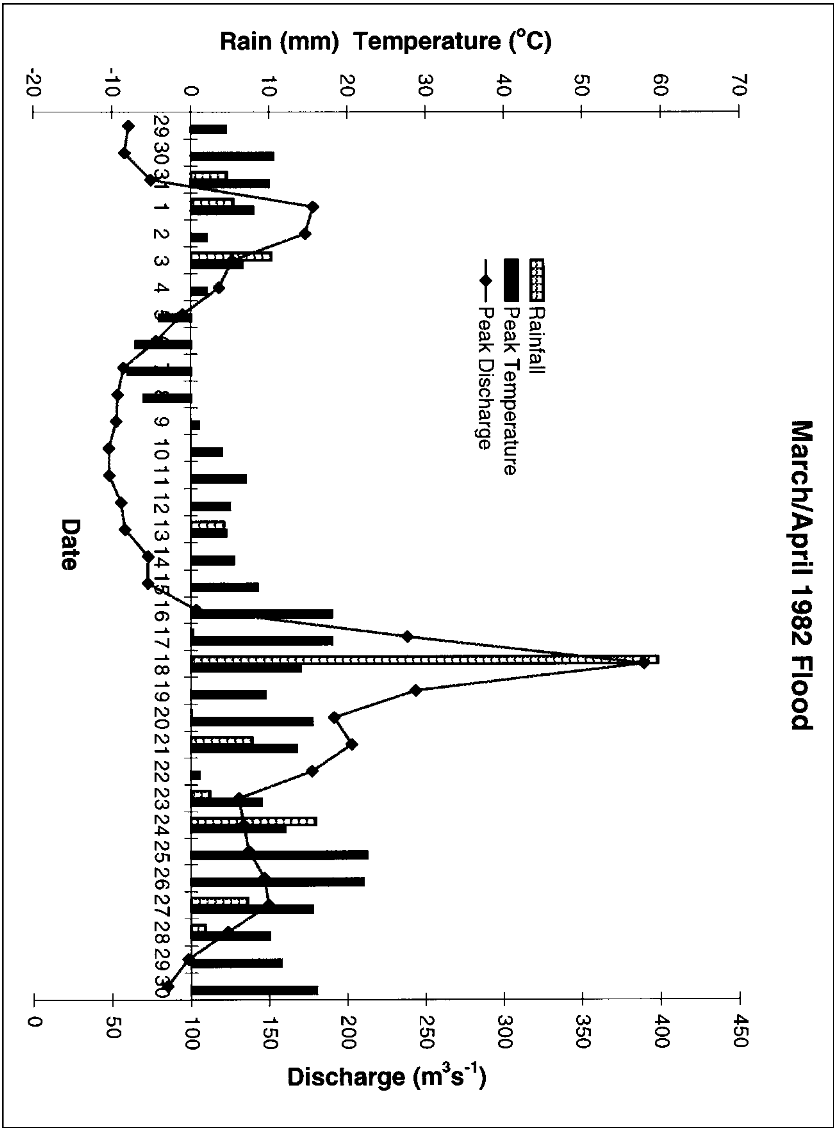

Figure 3

Data Source: Gouvernement du Québec, ministère de l'Environnement et de la Faune

extensive low-lying floodplains, with river constrictions by bridges and the confluence of four rivers, made this a flood-prone area. The dam at North Hatley made this location the next most flooded, although a limited area was actually flooded. Ayer's Cliff, being low-lying and located at a confluence of two rivers, and the intensely meandered lower Coaticook River areas were almost as frequently flooded as North Hatley. Stanstead, with a small local floodplain, experienced floodwaters only during the two largest events.

As might be expected, climate plays a key role in flooding in the Massawippi basin. As evidenced by a detailed look at one of the largest floods on record, April 1982, most floods are initiated by a combination of an extensive melt of a thick snowpack and sudden, intense rainstorms, with ice jamming exacerbating the flood problem in areas of river constriction. Flooding caused by snowmelt alone or rain alone is less probable. On average flood discharges exceeded the average by almost four times; during extreme events this increased to eight-fold. The largest discharge of 408 m^3s^{-1} occurred during April 1994. For the most part, Massawippi basin floods have a tendency to flashiness and are usually short-lived. The 100-year flood would exceed in discharge all recorded events with an estimated discharge of 422 m^3s^{-1}.

Perhaps less expected is the important role played by the geomorphology of the basin. The large drainage area captures a large volume of the water generated by rainfall and snowmelt; the near-circular basin shape, relatively short length of the longest channel and relatively high stream channel bifurcation ratio result in a rapid water travel time, with runoff from various parts of the watershed reaching the outlet at Lennoxville simultaneously. Moderate drainage density and basin ruggedness parameters maintain the flood severity caused by the four preceding parameters. Since floods occur in winter or early spring when the ground is frozen, soil characteristics, and land cover and use are not dominant factors. Flood frequency in the Massawippi drainage basin is climatically based but the severity of these floods is increased by the basin geomorphology.

One important component of flood hazards not investigated extensively during this research project was the human involvement. Obviously, since there would not exist a flood hazard in a drainage basin without the presence of people, they will play a key role in hazard initiation and severity. The Massawippi basin is no exception. The construction of bridges and dams across local rivers has already been indicated as influencing flooding in the basin through the initiation of ice jamming. Thus, the next phase of this research into flood hazards in the Massawippi drainage basin will focus on the human involvement in local flooding, including the role of dam construction and the human response to this hazard.

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RESUME

Le risque d'inondation présent dans le sud du Québec est un phénomène qui, quoique bien connu, n'a jamais été étudié en détail. Cet article rend compte de la nature et de l'histoire des inondations survenues dans le bassin hydrographique de la rivière Massawippi. Les données sur lesquelles repose cette étude ont été tirées de plusieurs sources : analyses cartographiques, levés de terrain et analyse des journaux locaux publiés au cours de la période qui fait l'objet de cette étude, soit de 1964 à 1994. Cette période couvre 31 années, dont 23 ont vu se produire des phénomènes d'inondation. La majorité de ces inondations se sont produites pendant les mois de mars et d'avril. C'est également à ce moment de l'année que sont survenues les inondations les plus graves, alors que des inondations moins importantes se sont produites pendant de brèves périodes de dégel hivernal, particulièrement au mois de décembre. La plupart des inondations se sont produite dans la région située immédiatement au sud de Lennoxville; c'est là qu'a eu lieu la plus importante des inondations étudiées ici, en avril 1994. Les inondations résultent de la combinaison de deux facteurs : une fonte rapide et importante de la neige et l'arrivée soudaine de fortes pluies. La géomorphologie du bassin hydrographique, en particulier sa taille relativement vaste et sa forme presque circulaire, contribue au caractère périodique et à l'intensité des inondations qui s'y produisent.

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