Grand River Conservation Authority
Ice Management Plan

Approval Date: October 25, 2024

Table of Contents

References

List of Tables

List of Figures

1.0 Introduction and Overview

River and lake ice formation, break up, jamming, and ablation are natural processes in rivers and lakes in northern climates. Ice processes shape river channels and overbanks and can cause river channels to migrate or shift over time in response to ice processes. Ice processes naturally occur and often go unnoticed unless development has occurred in floodplains adjacent to rivers and water courses in the associated floodplain.

Historic development has occurred in floodplains in Ontario and in the Grand River watershed locally. In some locations throughout the Grand River watershed this historical development may be at risk of flooding from ice jam induced or enhanced floods. Ice jams impede the movement of water obstructing flow in the main channel causing flood water to back up and forcing flood water into the adjacent floodplain resulting in flooding. If historic development is present in the floodplain, flooding of roads and structures may occur. In addition to flooding structures, ice blocks and sheets that leave the main channel may push into structures located in the floodplain and exert ice loading and shearing forces on structures close to the main channel.

Ice is an important consideration when designing infrastructure like bridges and crossings over rivers and watercourses. Where ice is a significant consideration, particularly on large rivers, it is important to span the floodplain to leave room for ice to travel under the bridge and gain relief in the floodplain adjacent to the main channel. It is also important when designing infrastructure to consider ice loading on structures like bridge, dams, floodwalls, and dikes.

The Hurricane Hazel flood event is the flood standard used to map and define the flood hazard limits in the Grand River watershed. This flood standard is sufficiently large enough that in most cases the limits of potential ice jam flooding are within the hazard limits determined by the Hurricane Hazel flood standard. One exception to this is dike reaches; through dike reaches, the floodplain is constrained, and the ability of ice and flood flows associated with an ice jam to gain relief is restricted. The flood hazard limit in some of these reaches may be governed by the ice jam flood hazard. Dike reaches and ice jam considerations for specific dike reaches are addressed later in this document.

Many factors affect the formation, breakup, and ablation of ice in a watershed. The complexity of ice processes makes ice jams impossible to predict whether an ice jam will occur or how severe an ice jam will be. It is possible to anticipate potential for ice jams based on ice conditions in a river system, the watershed conditions, and the weather forecast at the time of ice formation and at the time of breakup. This report includes a discussion of approaches used to monitor ice conditions, anticipate the potential for ice jams, mitigate ice jam potential where possible, and monitor ice conditions during the breakup process.

Later in this report, a discussion of specific communities with a history of ice jam flooding is included. A history of ice jams floods is included for specific communities where information is readily available. This report includes a discussion of the factors or river characteristics affecting the potential for ice jams flooding in communities frequently impacted by ice jams. Recommendations of any further actions to monitor, anticipate, and, if possible, reduce the potential for ice jams is included for each community.

This document is a compilation of current knowledge and experience and is intended to be a living document, updated on a five-year basis as knowledge and experience with ice evolves.

2.0 Watershed Communities Vulnerable to Ice Jam Flooding

Communities vulnerable to ice jam flooding in the Grand River are summarized in Table 1. A qualitative assessment is included in this table of frequency and potential severity of ice jam flooding.

Table 1 Communities Vulnerable to Ice Jam Flooding

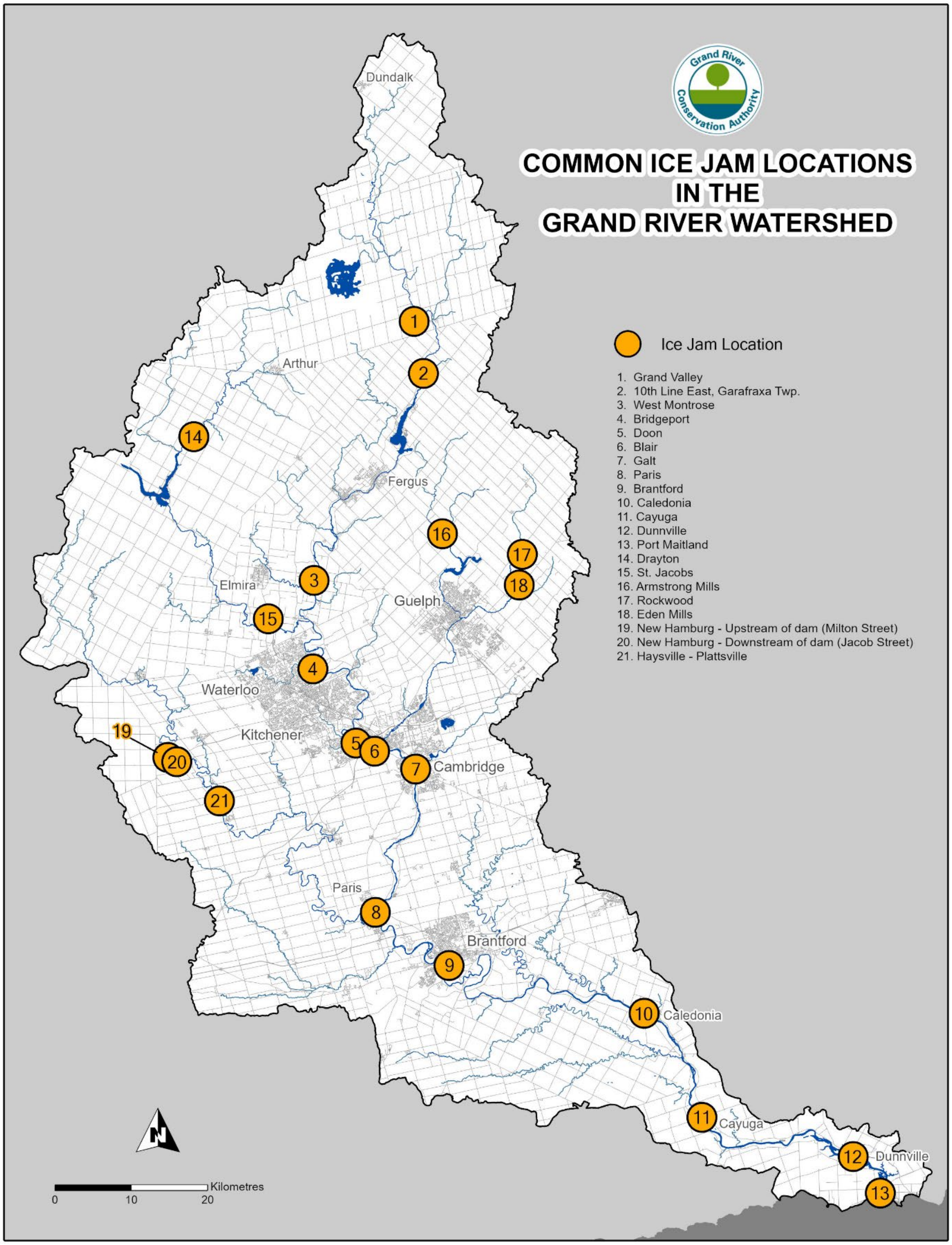
Site#	Location	Frequency	Impacts	Mitigation Works or Factors	Ability to Monitor or Detect Ice Jam
1	Grand Valley	Semi frequent	Roads and Buildings	Luther Dam Historic Dredging	(Potential for Gauge)
2	10th Line East Grafraxa Twp.	Frequent	Road		Historically
3	West Montrose	Frequent	Roads and Buildings	Shand Dam/Historic Dredging	Camera and Gauge
4	Bridgeport	Infrequent	-	Dike	Gauge
5	Freeport	Infrequent	Roads and Buildings		
6	Doon	Frequent	Trailer Park and STP*	Mannheim/Hidden Valley Dam	
7	Blair	Frequent	Buildings	Mannheim/Hidden Valley Dam	(Potential for Gauge)
8	Galt U/S of Parkhill Dam	Frequent	Municipal Rowing Club	Dike	(Potential for Gauge)
9	Galt D/S of Parkhill Dam	Infrequent	Road and Gas Station	Dike/ Parkhill Dam	Gauge

Site#	**Location**	**Frequency**	**Impacts**	**Mitigation Works or Factors**	**Ability to Monitor or Detect Ice Jam**
10	Paris	Infrequent	Road and Buildings	Dike/Paris Dam	Municipal Level Gauge
11	Brantford	Frequent	Road and Buildings	Dike/Wilkes Dam	Camera and Gauge
12	Six Nations of the Grand River 4th Line and Bateman Line	Frequent	Road and Access to Buildings		
13	Caledonia Upstream of Dam	Frequent	Roads and Buildings	Partial Dike	**(Potential for Gauge)**
14	Caledonia Downstream of Dam	Infrequent		Partial Dike	
15	Cayuga	Frequent	Roads and Buildings		**(Potential for Gauge)**
16	Dunnville Upstream of Dam	Frequent	Roads and Buildings		**Gauge**
17	Dunnville Downstream of Dam		Roads and Buildings, STP*, Arena		**Gauge**
18	Port Maitland	Frequent	Roads and Buildings		**Gauge**
19	Irvine River Salem				
20	Drayton				

Site#	Location	Frequency	Impacts	Mitigation Works or Factors	Ability to Monitor or Detect Ice Jam
21	St. Jacobs	In frequent 1958	STP*, Buildings	St. Jacobs Dam	
22	Armstrong Mills	Semi frequent	Buildings Driveways		**Gauge**
23	Rockwood	Semi frequent	Roads, Driveways, Buildings		
24	Eden Mills	Semi frequent			
25	Nith Above New Hamburg	Infrequent			
25	New Hamburg	Semi frequent		Partial Dike/New Hamburg Dam	**Gauge**
26	Haysville	Semi frequent			
27	Plattsville - Oxford Twp	Semi frequent			
28	Drumbo	Semi frequent			

***STP-Sewage Treatment Plant**

Figure 1: Communities Vulnerable to Ice Jam Flooding Grand River Watershed



3.0 General History of Ice Jam Floods

A qualitative summary of major ice jams is included in Table 2. The information in Table 2 is specific to major ice jams. Several minor ice jams may have occurred over the years but information presented in Table 2 is intended to summarize major events referenced in the 1982 basin management study with observations added since that time. The original information compiled in the 1982 basin management study was referenced from newspaper articles and conservation reports including the 1954 and 1962 Grand River Hydraulic reports.

Of particular note are the February 2018 ice jam that caused overtopping of the Brantford dikes and ice jam damage in the City of Cambridge, the February 2009 ice jam that caused severe flooding in the communities of Cayuga and Dunnville, the February 1996 ice jam that caused near overtopping of the Brantford dikes, the 1981 ice jam in the community of West Montrose is the highest on record in that community and threatened damage to the West Montrose covered bridge, and a 1979 ice jam caused severe flooding in the community of Paris.

Table 2 Chronology of Major Ice Jams Grand River Watershed

Year	Locations
1852	Galt, Brantford (March 14)
1857	Galt, Cayuga (February 14)
1860	Galt, Brantford (March 4)
1861	Brantford (March 2)
1865	Galt (March 21)
1866	Galt
1867	Galt
1870	Bridgeport (April 7)
1893	Brantford (March 6)
1898	Blair, Bridgeport (March 12)
1899	Brantford (March 16); Salem (April 11)
1900	Galt (February 8); Brantford (April 1)
1902	Elora, Fergus
1903	Elora, Fergus

Year	Locations
1904	Galt, Brantford (March 26)
1905	Fergus (March 24); Hespeler (March 25)
1913	Galt, Brantford, Freeport (March 13); Dunnville (March 15)
1918	Galt, Brantford (February 20)
1922	Galt (March 7)
1928	Blair (March 25)
1929	Salem, Freeport, Cayuga (March 15)
1930	Dunnville
1934	Bridgeport, Galt, Brantford, Cayuga (March 3)
1939	Grand Valley (March 29)
1942	New Hamburg (March 10)
1948	Grand Valley, Caledonia (March 10); Dunnville (March 17)
1950	Caledonia
1951	Caledonia
1952	Freeport
1954	Caledonia
1965	Caledonia
1971	West Montrose
1972	Grand Valley (April 14)
1974	Grand Valley (March 5); West Montrose
1975	West Montrose
1976	West Montrose

Year	Locations
1977	Caledonia, Dunnville, West Montrose
1979	Paris (March 5)
1980	West Montrose
1981	Paris (February 19); Dunnville (February 22); West Montrose (February 23)
1986	Brantford, Drayton (March 13); West Montrose, Ayr, New Hamburg
1987	Grand Valley (April 4)
1988	New Hamburg, Brantford (February 1)
1989	10th Line Bridge (February 1); Bloomingdale, Moorefield, Drayton (March 15); Rockwood (March 16)
1990	Sims Locks (January 18); 10th Line Bridge evacuation (March 12); Wellesley (December 29); New Hamburg (December 30)
1991	New Hamburg (March 2)
1992	Grand Valley (March 9)
1996	Brantford in February
2004	Ice jam in Paris
2009	Cayuga and Dunnville in February
2018	Cambridge and Brantford in February
2019	West Montrose

4.0 Ice Processes in the Grand River Watershed

4.1 Ice Formation Process

Communities vulnerable to ice jams in the Grand River Watershed are summarized in Table 1. A qualitative assessment is included in this table of frequency and potential severity of ice jam flooding. There is nuisance ice jam flooding that occurs naturally in the rivers’ floodplain and if it does not affect structures or roads, it often goes unnoticed as simply a natural process. In other areas, structures and roads are impacted by ice jams and this document focuses more on those areas where there is a risk or structural flooding or infrastructure flooding is a potential impact from ice jams. This document strives to explain the ice jam processes in those communities.

The frequency of ice jams varies depending on many factors, including how cold the weather is during the winter, how the freeze-up occurred over the winter, whether there were midwinter breakups that caused ice jams that froze in place, and whether rapid melt occurred not allowing time for ice to erode or loosen up before river flows increased. Whether ice jams occur and the severity of these jams is affected by these factors.

There are mitigating circumstances for ice in the watershed. A classic example is the large reservoirs. The large reservoirs act as ice storage areas so for the drainage area above Shand, Conestogo, Guelph, and Woolwich dams, ice is stored in these reservoirs and doesn't affect downstream areas often. An overlooked value of these large reservoirs is their ice mitigation properties. Further mitigating factors that help reduce the potential of ice jams will be discussed later in this document.

4.2 Types of Ice and Processes Leading to Ice Formation

It is first useful to discuss and classify the different types of ice. While there are many types or descriptions for types of ice, this document will simplify the descriptions into three categories. These include sheet ice, frazil ice, and conglomerate ice which can be a combination of sheet ice frazil and frazil ice.

4.2.1 Sheet Ice

Sheet ice typically forms on slow-moving water surfaces upstream of dams, riffles, and rapids in a river system, in areas where water ponds. Sheet ice forms a smooth surface and depending on the severity of the winter may continue to build over the winter to a significant thickness of ice, varying between 0.1 meters to a metre thick. In very severe winters if flows are very low in the river, sheet ice may actually freeze to the bottom of the river and anchor to the bottom of the river.

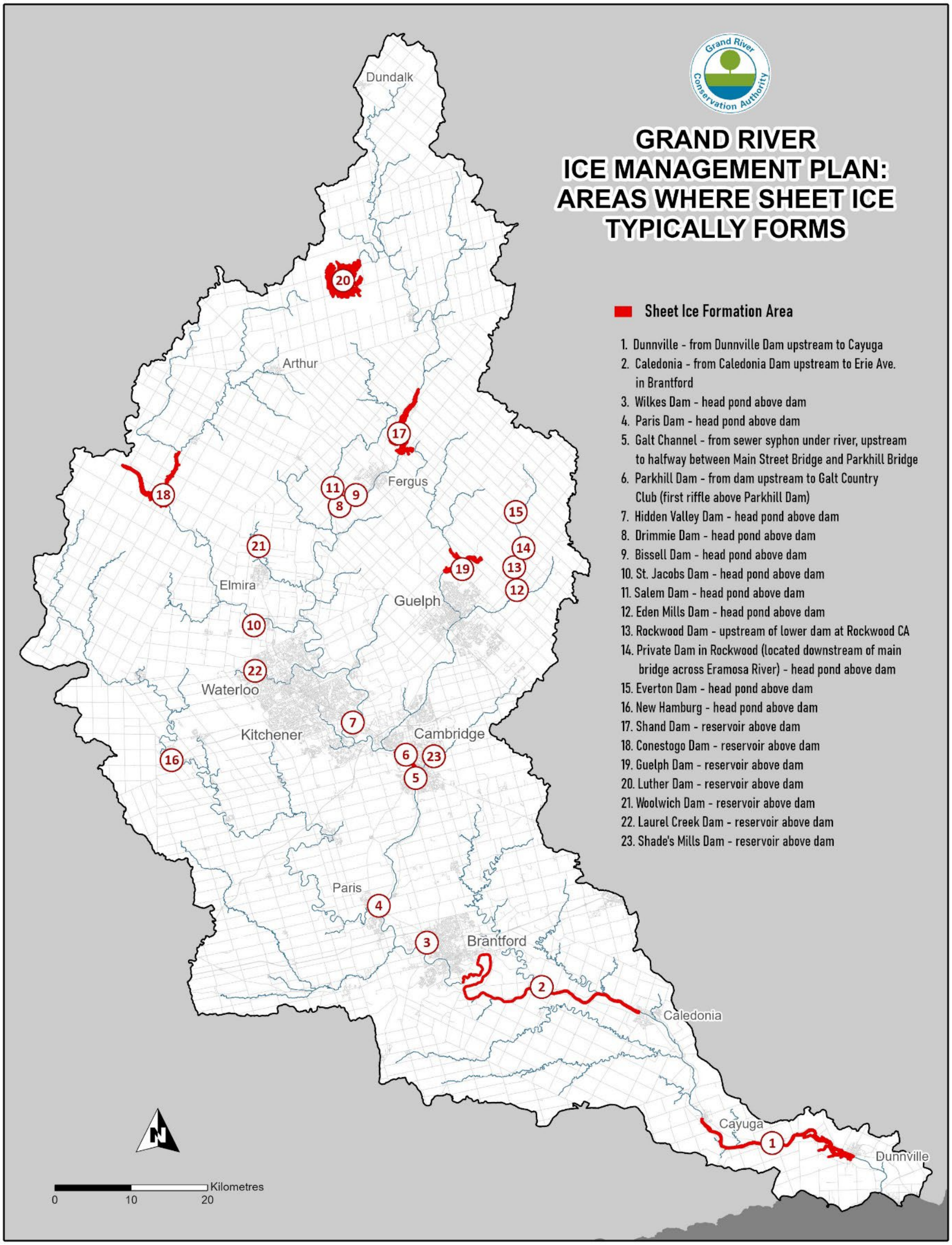
Examples of sheet ice areas in the Grand River are upstream of the seven large dams and upstream of low-head dams, Dunnville, Caledonia, Wilkes, Paris, Parkhill, Hidden Valley, Bissell, St. Jacobs, Salem, Rockwood, Eden Mills, and New Hamburg low-head dams. Sheet ice also forms in flat reaches. Examples of flat reaches are downstream of Conestogo Dam and through the Kitchener-Waterloo Reach, downstream of the confluence of the Conestogo River to the Hidden Valley Dam. In the Grand River, the river slope downstream of Brantford changes to a very flat slope downstream of Erie Avenue. Sheet ice forms from the Caledonia Dam upstream through the oxbow to upstream of Erie Avenue in the City of Branford. This sheet ice area is located immediately downstream of the City of Branford dikes and influences the potential for ice jams through the dike reach. The Brantford dike reach will be discussed in more detail in this document. Figure 2 illustrates the location of low-head dams and river reaches where sheet ice typically forms. Sheet ice can form some of the strongest ice in the river. Strong sheet ice forms in extremely cold conditions such as double-digit below freezing temperatures persistent for an extended period of time. The winter of 2018 was a good example of a winter with strong persistent cold conditions that produced strong sheet ice and a large volume of ice.

Strong sheet ice is often referred to as blue ice, the ice has a bluish tinge to it and it's extremely strong. Strong sheet ice formed in the winter of 2018. Sheet ice can be anywhere from a few centimeters up to meters thick, the strong ice is resistant to break up and can obstruct ice movement from upstream areas backing up water and forming ice jams and in some cases ice dams. In the winter of 2018, an ice jam and later an ice dam formed upstream of the Parkhill Dam, which later released and sent a wave of water down the river. The wave of water and ice is termed a "jave".

The release of ice and water during the February 2018 ice dam that released a jave which had a similar effect to a dam break; water and ice were stored behind the ice jam, which formed a barrier similar to a dam that subsequently released a wave of water and ice similar to a dam break. The resultant jave sent sheet ice on to highway 24 immediately downstream of Cambridge, sheet ice blocks were several metres deep over highway 24. The release of the Cambridge ice jam contributed to the overtopping of the Brantford dikes. Figure 3 illustrated sheet ice blocks on Highway 24 through the City of Cambridge downstream of the diked reach in that community.

This event also provides an illustrative example of strong sheet ice blocks. The movement of strong sheet ice can also cause extreme damage. The strong sheet ice blocks can be pushed under the floodplain and if structures are present those structures may be moved off their foundation and severely damaged. Sheet ice blocks can push onto on roads and crush or damage vehicles when the ice sheet moves on to the roads. It was fortunate that the ice jam release in February 2018 occurred at approximately 1:00 a.m. when vehicle traffic was greatly reduced on Highway 24 south of Cambridge. One vehicle was affected on Highway 24 that morning and emergency crews had to rescue the occupant. Sheet ice blocks can shear off trees along the banks of the river as they move downstream and reform and shape riverbanks as they transit a river.

Figure 2: Locations of Dam and Reaches Where Sheet Ice Typically Forms



Figures 3a and 3b: Examples of Sheet Ice Blocks Highway 24 City Of Cambridge 2018 Ice Jam

4.2.2 Frazil Ice

Another type of ice that forms in the river is frazil ice, which is composed of fine ice crystals that form in the water. When the water surface is super cooled, ice crystals form on the surface during cold conditions where turbulent water is present. Turbulent flow is present in river rapids, water falls and steep sections of the river. A significant amount of ice crystals form in a specific steeper reaches of the river where turbulent flow and rapids exist. Reaches like the river through the Elora Gorge, downstream of the City of Cambridge to Brantford, downstream of Caledonia to Cayuga, the southern Nith River downstream of Ayr, and the Conestogo River downstream of the Conestogo Dam. These are reaches of river that can generate large volumes of frazil ice. Figure 4 illustrates a map that depicts reaches of river that can generate frazil ice given specific flow and temperature conditions.

Conditions that are conducive to generating frazil ice are cold double digit below freezing conditions, windy conditions, and snowy conditions. If flows are low, fewer reaches or a lesser extent of the river will generate frazil ice and if little or no flow exists frazil ice may not be generated. This is important to note when referring to figure 4. Figure 4 indicates the reaches that have high potential to generate frazil ice, however if flows are very low when cold windy conditions develop, some of the reaches indicated in Figure 4 may not generate frazil ice. A good example is the upper Conestogo, if moderate to high flows are present that reach can generate frazil ice, but if flow is very low, limited amounts of frazil ice are generated. Very cold conditions, windy conditions, snowy conditions, and moderate to high flow conditions together influence frazil ice production.

The largest amount of frazil ice typically forms when higher flows are present coupled with double digit below freezing cold air temperatures. Windy conditions can further super cool turbulent reaches of the river and the river can become a frazil generating machine capable of generating large volumes of frazil ice.

Frazil ice travels downstream until it encounters sheet ice upstream of low-head dams for example and then that frazil ice will become stationary and start to accumulate. As frazil ice accumulates, it can fill the main channel of the river between the banks, choking off flow and forcing water into the floodplain adjacent to the river. As frazil ice continues to fill the channel, the frazil ice blockage or jam will progress upstream, more frazil flows down, gets blocked, fills the river channel and the process continues. If frazil ice generation continues, it will continue to accumulate and work back upstream until it reaches areas of turbulent water and will begin to drown out the reaches generating frazil ice.

Alternately, weather conditions may change and warmer temperatures will reduce the amount of frazil ice being generated. River flow may decline and reduce the amount of turbulent water in reaches. This can also reduce frazil ice generation. It’s important to realize the river has almost a limitless ability to generate frazil ice if high and cold conditions persist. The process continues until either the turbulent reaches are drowned out, the temperatures warm, or the flows subside. To put in perspective the immense capacity of the river to generate frazil ice, the winter of 2004 provides a good example.

In 2004 there was a mid-winter melt which increased river flow; extreme cold conditions followed the melt. As a result of subsequent snowy conditions, frazil ice began to form and accumulate at the leading edge of sheet ice downstream of Brantford in the oxbow portion of the river. Frazil ice continued to accumulate and fill the river channel all the way upstream to the town of Paris. Frazil ice filled the river from bank to bank through the entire river reach from Brantford to the Paris Dam, eventually filling the river to the height of the Paris dam which is 3 metres high. Figure 5 illustrates a picture of the Paris Dam from downstream of the dam, the dam is hardly visible as a result of the river channel downstream of the dam being filled with frazil ice.

Frazil ice is different than sheet ice; it is weaker and more prone to erosion by water. However, if a sudden melt occurs, frazil ice obstructs the channel’s capacity to convey flow, and as a result flow is forced onto the floodplain. Frazil ice degrades faster than sheet ice, however what often happens is if the sheet ice starts to break up and frazil ice is in the channel, the sheet ice and frazil ice form an ice jam together, blocking channel flow and forcing flow on to the floodplain and potentially consolidating. If frazil and sheet ice consolidate and freeze into place, an ice jam can form that is very resistant to ablating or releasing.

Figure 4: Map Illustrating Typical Reaches of River Where Frazil Ice is Generated

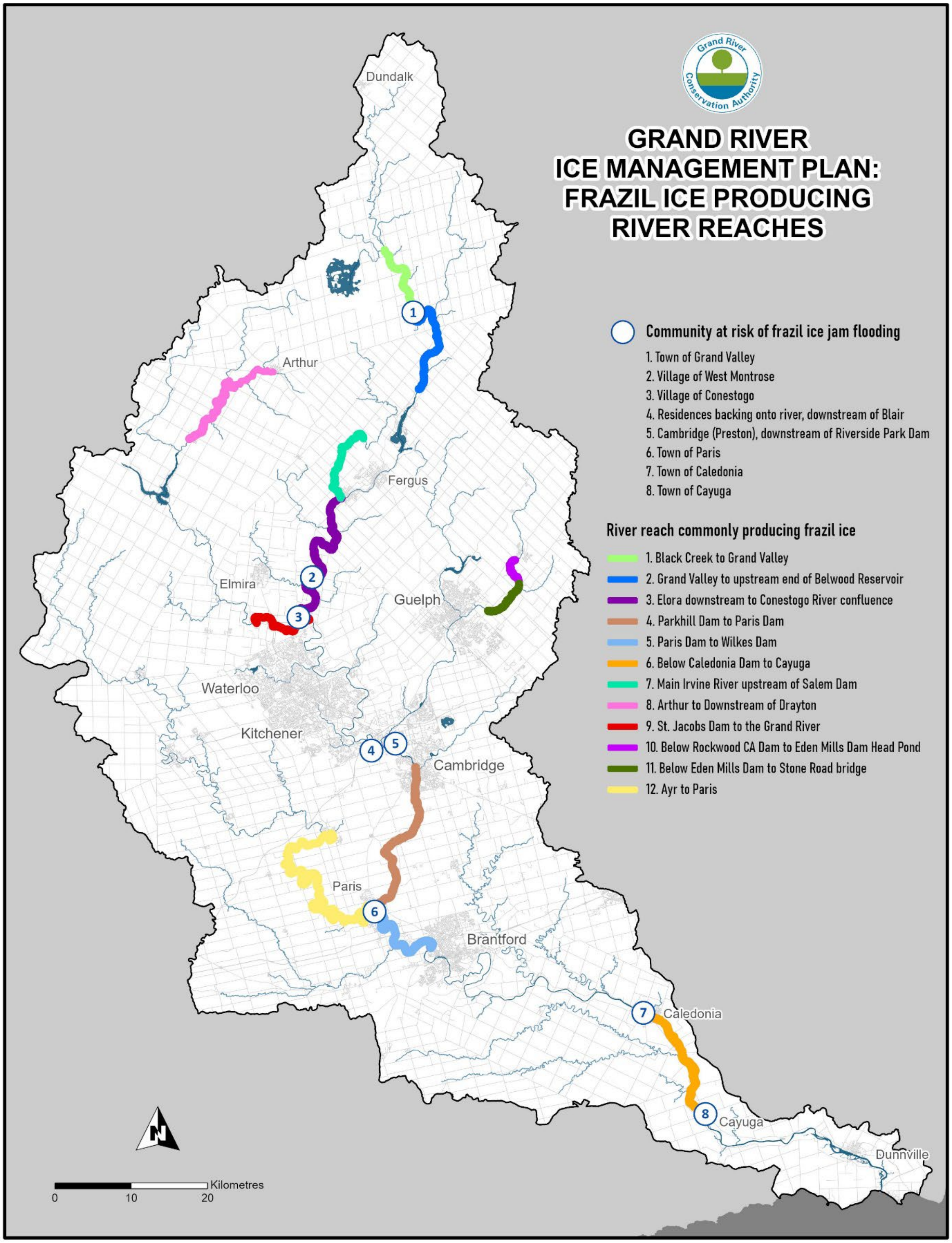
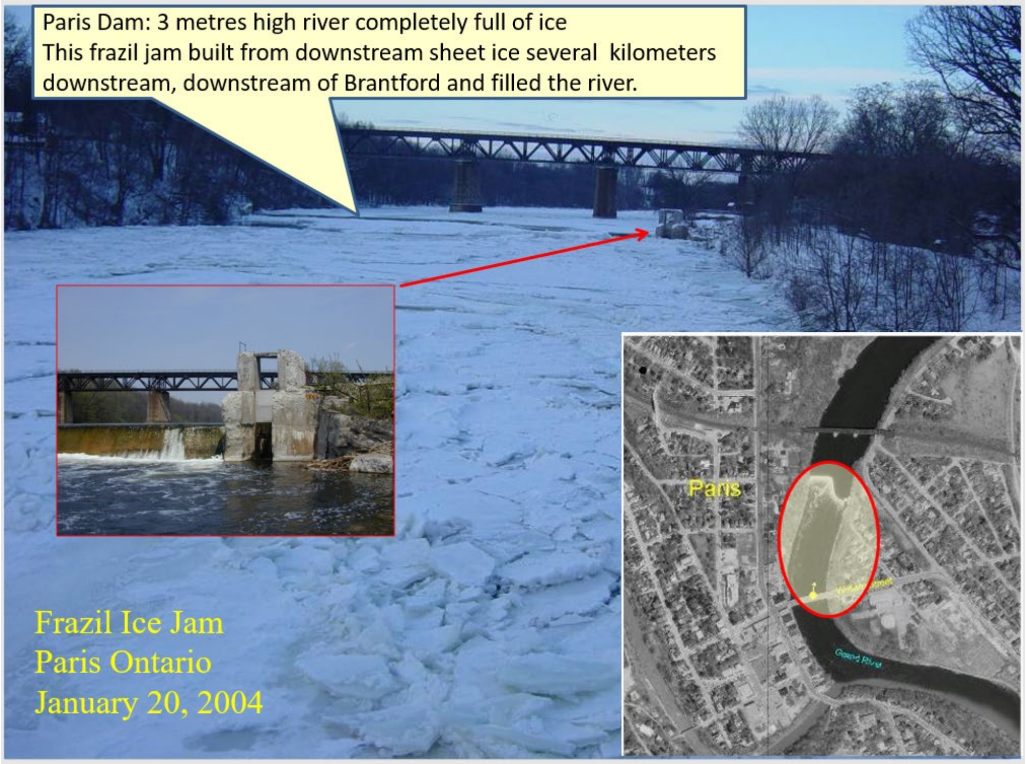


Figure 5: Picture of Paris Dam January 2004 River Channel Filled with Frazil Ice



Paris Dam: 3 metres high river completely full of ice
This frazil jam built from downstream sheet ice several kilometers downstream, downstream of Brantford and filled the river.

Frazil Ice Jam
Paris Ontario
January 20, 2004

Figure 6: Frazil Ice January 2004 Downstream of the City of Brantford

4.2.3 Conglomerate Ice

The third type of ice is conglomerate ice. Conglomerate ice is a mix of broken-up sheet and frazil ice. Conglomerate ice jams often form during early winter melts. Early winter or mid winter melts are often rapid short-lived melts. Theses melts tend to generate flow into the river, start to move ice sheets, and are often followed by a flash freeze. Often weather conditions during these mid winter melts can change from double digit warm temperatures with rain to below freezing double digit temperatures with high flows in the river as a result of melting snow and rain. These mid winter melt conditions create the ideal conditions for moving sheet ice and generating frazil ice, which is a very undesirable combination from an ice jam perspective.

Conglomerate ice jams often occur at the upstream end of the sheet ice reaches identified in Figure 2. The length of time of the mild temperatures and the magnitude of flows in the river are often not sufficient to lift or move the sheet out of the reaches identified in Figure 2, however flows can be sufficient to move the thinner sheet ice in other reaches of the river and send it downstream until it encounters the leading edge of strong sheet ice. This was the case during an early winter melt in January 2018. Sheet ice upstream of Cambridge travelled down the Grand River and jammed at the leading edge of the sheet ice upstream of Parkhill Dam. Sheet ice south of Cambridge and in the Nith River travelled down to Brantford and jammed at the leading edge of sheet ice downstream of the Brantford dikes.

After the mild conditions, extreme cold conditions returned, causing large amounts of frazil ice to form and flow downstream and collect in the location where the sheet ice jammed. The sheet ice jam and frazil ice fused to create a conglomerate ice jam. The frazil ice filled the voids between the jammed and jumbled ice sheets. The cold conditions also caused new sheet ice to form in upstream reaches above the ice jams in Cambridge and Brantford.

Conglomerate ice jams can be quite thick, up to several metres thick, they can choke off capacity of the main channel to convey flow and ice and can be very resistant to break-up. It takes a longer period of flow and mild temperatures to degrade a conglomerate ice jam. The major ice jam that occurred in 2018 in Cambridge and Brantford resulted from conglomerate ice jams being in place downstream of Brantford and upstream of Parkhill Dam in the City of Cambridge combined with a rapid February melt and the highest daily rainfall ever observed in the month of February. The rapid melt and increase in flow did not allow time for the conglomerate ice jams to degrade before new ice and debris travelled down the river and backed up behind these ice jams. The situation was further complicated when the ice jam in Cambridge formed a temporary ice dam that released and sent a wave of ice and debris down the river, a Jave. The Jave slammed into the ice jam in place in Brantford and caused overtopping of the Brantford dikes.

The picture in Figure 7 illustrates an ice block that was deposited in the floodplain downstream of the Brantford dikes. This picture helps illustrate the composition and size of conglomerate ice that was in the river channel downstream of the Brantford dikes impeding flow. It also illustrates the jumbled mix of sheet ice, frazil ice and in some cases debris in conglomerate ice and the immense thickness of conglomerate ice.

Figure 5: Example of Conglomerate Ice February 2018 Ice Jam Grand River at Brantford

4.4 Moderating Factors Affecting Ice and Ice Jams

There are several factors that can moderate or influence ice formation and ice jams in the Grand River watershed. This section discusses some of the factors or considerations that moderate ice and risk of ice jams.

4.4.1 Influence of Large Reservoirs on Ice

The large reservoirs in the Grand River watershed can influence and moderate ice in many different ways.

First of all, the large reservoirs act as ice storage areas as they store the ice from the drainage areas upstream of the reservoirs. Large reservoirs providing significant ice storage include Shand, Conestogo, Guelph, and Woolwich dams. Their ability to store ice and moderate flows from upstream areas helps reduce flood risk to downstream communities.

The large reservoirs also provide flow regulation both during freeze-up when the ice sheet initially forms and during breakup periods whether they be mid-winter melts or the spring breakup and melt. During the freeze-up period, reservoirs can be used to reduce downstream flows as much as possible to initiate ice sheet formation at flows as low as possible. A rule of thumb is that it takes as much flow in the river to break up the ice as was there when the ice initially formed. There are other modifying factors to that rule of thumb but ideally, for ice management purposes, it is best to initiate ice cover at as low flow as possible.

During breakup, the reservoirs can moderate downstream flows to reduce pressure on existing ice jams and provide time for existing downstream ice jams to degrade and break up. The reservoirs delay flood peaks from upstream areas above the reservoirs to give the downstream areas where ice jams may be in place time for ice to degrade. This is an important ice management strategy that can be achieved with these large reservoirs. This approach was important during the February 2018 event when the ice jam was intact in the Brantford dike reach.

A final often unrecognized benefit of the large reservoirs is winter flow augmentation. Winter flow augmentation helps avoid the ice sheet freezing to the bottom of the river. The constant flow discharged by the reservoirs over the winter creates a separation between the ice sheet and the bottom of the river. If the ice sheet freezes to the bottom of the river it is more resistant to break up during the spring breakup and melt creating a higher potential for ice jams.

The reservoirs can also be used to try to moderate flows during mid-winter melts or periods when extreme cold conditions exist that cause frazil ice to be generated in the river. A challenge with mid-winter melts in recent years is the mild conditions that cause the melt are often followed by flash freezes of extreme cold conditions. The extreme cold conditions generate frazil ice. The large reservoirs can be used to help reduce downstream flows which subsequently reduces the potential for frazil ice creation.

Mid-winter melts create challenging times for reservoir operations, but they can be used to help moderate downstream frazil ice creation. Stored water in the reservoirs often has to be released to recover flood management storage in these reservoirs. There is often a narrow window to discharge stored water before the downstream ice sheet starts to form. These competing objectives of limited downstream frazil ice creation and recovering reservoir flood management storage have to be weighed and balanced in the periods following a mid-winter melt.

4.4.2 Impacts of low-head dams on Ice

Low-head dams can influence ice in both positive and negative ways. Low-head dams initiate sheet ice formation in the backwater area upstream of the low-head dam. The sheet ice that forms upstream of low-head dams may be very strong and may be resistant to breaking up when there is a melt event. This can cause upstream ice jams to occur at the leading upstream edge of the sheet ice above these dams. One example of this is the sheet ice upstream of Dunnville Dam which extends up to the community of Cayuga, contributing to the ice jam risk in that community.

Low-head dams can create a finite amount of ice storage, providing some benefit to downstream areas. Caledonia dam creates a large upstream ice storage area, providing benefits to downstream communities of Cayuga and Dunnville.

Generally, a benefit provided by low-head dams is that as the ice sheets go over the low-head dams, then it is broken into smaller blocks or chunks of sheet ice. This is important for downstream areas as smaller ice blocks and chunks can more easily transit to the river. A good example of this ice management benefit is the Cambridge-Galt reach of the Grand River downstream of Parkhill Dam. The Parkhill Dam causes the ice sheet to break into smaller chunks that then can transit to the downstream flood channel between the Cambridge dikes more easily avoiding ice jams in the flood channel itself.

The influence of low-head dams from an ice management perspective needs to be carefully assessed when low-head dams are being evaluated for potential removal. Figure 2 identifies the low-head dams that influence ice in the larger rivers in the Grand River watershed.

4.4.3 Influence of Wastewater Discharge to the River

There are several wastewater plants in the Grand River watershed that discharge treated effluent to the river system. The treated effluent is warmer in temperature compared to regular river water. This warmer water can moderate ice for finite reach downstream of the wastewater discharge. This is most notable on the Speed River; the Guelph sewage treatment plant discharge is a large percentage of the Speed River low flow discharge downstream of the City of Guelph. The warm effluent combined with groundwater discharge in the river valley downstream of Guelph moderates ice in the Speed River downstream of Guelph to the Grand River.

The other benefit of wastewater discharge from an ice management perspective is, like winter flow augmentation from the large dams, the flow from these plants helps avoid the ice sheet freezing to the bottom of the river.

4.4.4 Groundwater Discharge

Groundwater discharge is a significant component of flow in the Grand River south of Cambridge, the Nith River downstream of New Hamburg, the Speed River downstream of Guelph, and the Eramosa River system. The temperature of groundwater discharge is approximately equal to the mean annual temperature, so in the Grand River watershed it would be approximately around 8 degrees Celsius. The warmth of groundwater during winter months and the flow volume provided by groundwater can help moderate ice. The warmth of the groundwater can help melt and degrade ice and the groundwater flow helps prevent the ice sheet freezing to the bottom of the river. Groundwater discharge can also help moderate the ice sheet freezing to the shore in some reaches. The groundwater discharges at the shore valley interface, which are often open sections of the ice sheet that can be observed along the shore.

It is hard to quantify the benefits of groundwater discharge and its influence on ice and ice jam risk. However, from a qualitative perspective, if conditions have been dry or if extended drought conditions have existed, the volume of groundwater discharge to the river system will be diminished and it may be inferred that there is a higher potential for ice formation and ice jams in the river.

Information from the groundwater monitoring network and flow gauges can assist in assessing the state of the groundwater system and groundwater discharge present in the river system.

5.0 Ice Jam Forecasting

Many factors affect whether ice jams actually occur. These can include the amount and strength of ice in the river, the existence of frozen ice jams from previous melt events, and how spring breakup occurs. A gentle spring breakup and melt over an extended period of time can degrade and ablate the ice and ice jams may not occur. Ideal conditions for spring breakup are moderately warm daytime temperatures followed by cool above freezing nighttime temperatures over several days. These types of conditions create a slow release of melt water to the river which allows the ice to degrade, weaken, and dissipate without forming jams. A sudden melt coupled with warm temperatures and rain causes river flows to increase rapidly with little or no time for the ice to erode, weaken, and dissipate. If there is a lot of ice in the river and the ice is strong, sudden melt conditions are likely to result in ice jams.

The severity of the ice jam will depend on the volume of ice, strength of ice, and magnitude of flow. All these factors conspire to affect the severity of an ice jam. Based on the above, it is important to understand that it is not possible to accurately quantify or forecast ice jams. It is possible to anticipate conditions that are conducive to ice jams, or to anticipate the potential for ice jams but where, when, and how severe the ice jams will occur cannot be forecasted.

Ice jam potential and the type of ice jam can be grouped into three categories. These categories include freeze-up ice jams, mid winter breakup ice jams, and spring break ice jams.

5.1 Freeze-up Ice Jams

Freeze-up ice jams occur at the start of winter when temperatures start to cool and there is an absence of sheet ice in the river. Sheet ice will start to form first, and if flows are low, sheet ice formation may proceed without incident. Ice conditions for sheet ice formation are low flows and moderately cold conditions. If flows are high in the river heading into winter freeze-up and severely cold temperatures exist, frazil ice will be generated during the freeze-up process. Frazil ice will accumulate at the upstream leading edge of the sheet ice and continue to fill the space between the channel banks with frazil ice.

The severity of the frazil ice accumulation is very dependent on flow and temperature. If flows are low to moderate, less frazil ice will be generated. Lower volumes of frazil ice will reduce the potential for severe flooding. The main channel between the banks of the river may fill with ice and water levels and ice will rise to the point when flow can find relief on adjacent floodplains. If flows are higher, more frazil ice is generated, water and ice levels will rise and find relief on the adjacent floodplain to the point where the river flow has found sufficient relief on the floodplain to bypass the ice-filled channel and lower portion of the floodplain. Flows and ice will find an equilibrium. Communities susceptible to frazil ice jam flooding include the Village of West Montrose and Town of Paris.

5.2 Mid Winter Ice Jams

Mid winter breakup ice jams have different characteristics than freeze-up ice jams. During mid-winter break up, sheet ice and frazil are present in the river system. Mid-winter breakup flows are often not sufficient to break up and flush ice out of the whole river. Sheet ice movement may occur in some reaches which will flow down the river and typically accumulate at the leading edge of sheet ice above the low-head dams. If river flows are high enough, sheet ice above the low-head dam may release and flow downstream to the next low-head dam and accumulate.

Depending on the magnitude of flow, some of the sheet ice may be deposited in the adjacent floodplain. Two points of potential large volumes of sheet ice accumulation and ice jams are downstream of the City of Brantford at the leading edge of the sheet ice through the oxbow and upstream of Parkhill Dam at the leading edge of the sheet ice upstream of Parkhill Dam. If flows are sufficient, sheet ice upstream of Parkhill Dam will release and flow downstream accumulating downstream of the City of Brantford. Its important to note that downstream of the

City of Brantford there are typically kilometres of sheet ice through the oxbow reach all the way down to the Caledonia Dam. For sheet ice to move out of the areas downstream of the City of Brantford, high sustained flows and persistent mild conditions would be required to degrade the ice sheet downstream of the City of Brantford to the point that it would release. The sheet ice downstream of the City of Brantford is typically very resistant to releasing. A caveat to the previous statement is that an ice sheet's resistance to movement is dependent on the strength of the ice and volume of the ice in the river. The strength and volume of ice in the river is dependent on the amount of cold weather during the portion of winter preceding the mid-winter melt. Following a mid-winter melt, frazil ice generation can be a concern and further complicate ice jams that form.

5.3 Spring Breakup Ice Jams

Spring break-up ice jams are similar to mid-winter melts. Ice sheet movement follows the same progress as described above. The severity of spring break-up jams can be much greater as the river flows will typically be higher and pre-existing ice jams may be in place. The severity of the spring break-up ice jams will depend on if there are existing ice jams in place, the strength and volume of ice in the river at the time of breakup, how rapid the melt occurs, and the magnitude of the resultant flows in the river. Typically, spring break-up ice jams have more potential to push ice blocks onto the floodplain and create more potential for damage.

As previously noted, it is not possible to forecast whether or not ice jams will occur or how severe the ice jam might be. It is possible to anticipate the potential for the risk ice jams but its not possible to accurately predict ice jams.

The Province of Ontario published the Provincial Ice Management Manual in 1984. This document provides an overview of ice management including conditions causing ice jams, break-up factors, and predictive techniques along with preventative and assessment measures. Some of the predictive techniques from this manual are used in the Grand River watershed and discussed in the next section of this document.

6.0 Monitoring or Awareness of Ice Jam Potential

Given that its not possible to forecast ice jams, monitoring and awareness are important components of ice jam management that are achievable. This section discusses approaches used to monitoring ice conditions and anticipate potential for ice jams.

6.1 Freezing Degree Day Monitoring and Freeze-up Ice Cover Forecasting

The key major factor influencing ice in the river is cold weather. Monitoring and analyzing air temperature is one of the approaches used to anticipate ice conditions in the river. Historically, only daily minimum and maximum air temperature data was available. There are many procedures focused on degree day approaches to anticipate ice conditions. Hourly air temperature is now available which has created the opportunity to update historical degree day approaches to cooling or warming degree hour approaches.

During the initial freeze-up when ice initially forms on the river, a freezing degree day calculation is used to anticipate ice cover formation. Daily maximum and minimum temperatures are added together. If the sum of the maximum and minimum daily temperature is negative, this constitutes a negative freezing degree day and is the starting point for the freezing degree day model. Subsequent sums of daily maximum and minimum daily temperatures are added to the previous negative degree day sum. The accumulation of negative days continues until a threshold of negative 70 freezing degree days has accumulated. Based on previous observations, between -70 and -125 average negative degree days, ice sheet formation generally occurs.

A secondary calculation uses only the daily minimum temperature and cumulates the daily minimum temperature once it begins to go negative. This is referred to as absolute maximum freezing degree days. Once a threshold of -225 absolute maximum freezing degree days is reached, ice sheet formation can be anticipated.

An example of the West Montrose ice cover forecasting spreadsheet is illustrated in Table 3. This forecasting spreadsheet will be improved in the future by converting it to use hourly data, the ice sheet formation thresholds would have to be revised and updated based on hourly data. It is however important to keep in mind ice sheet formation forecasting is not an exact science, many factors affect the formation of the ice sheet. The spreadsheet forecast model is more meant to inform water managers when conditions are approaching or favourable for ice sheet formation to focus staff attention during that period.

Table 3 Example of West Montrose Ice Cover Forecasting Spreadsheet

ICE COVER FORECAST FOR WEST MONTROSE									
Date	Flow at West Montrose (cm)	SHAND Discharge (cm)	Maximum Daily Temp.	Minimum Daily Temp.	Average Negative Degree Days	**(-225 C.)** Absolute Maximum Negative Temp.	**(-70 to -125 C.)** Cumulative Negative Degree Day	Snow Forecast cm	Wind Forecast (km/hr)
Sun. Dec. 27, 2015	15.2	11.9	2	-2.5	-0.3	-2.5	-0.3	0	25 NW
Mon. Dec. 28, 2015	15.3	11.9	1	-9	-4.0	-11.5	-4.3	0	25 E
Tues. Dec. 29, 2015	16.5	11.9	0.5	-9	-4.3	-20.5	-8.5	5	35 SW
Wed. Dec. 30, 2015	24.8	20.2	5.5	-0.5	2.5	-21.0	-6.0	0	40 W
Thurs. Dec. 31, 2015	27.4	20.2	2	-1.5	0.3	-22.5	-5.8	0	35 W
Fri. Jan. 1, 2016	25.1	18.1	1	-4.5	-1.8	-27.0	-7.5	1	30 W
Sat. Jan. 2, 2016	23.6	20.8	-4	-6	-5.0	-33.0	-12.5	4	30 W
Sun. Jan. 3, 2016	22.5	20.6	-0.5	-4.5	-2.5	-37.5	-15.0	0	5 N
Mon. Jan. 4, 2016	7.0	4.1	-0.5	-18	-9.3	-55.5	-24.3	2	20 SW
Tues. Jan. 5, 2016	6.7	4.1	-12.5	-19	-15.8	-74.5	-40.0	0	20 SW
Wed. Jan 6, 2016	7.9	4.2	-4.5	-18	-11.3	-92.5	-51.3	0	20 SW
Thurs. Jan. 7, 2016	7.6	4.3	-0.5	-9	-4.8	-101.5	-56.0	0	6 S
Fri. Jan. 8, 2016	7.2	4.2	1.3	-3	-0.9	-104.5	-56.9	0	15 SE
Sat. Jan 9, 2016			3	-2	0.5	-106.5	-56.4	0	25 SW
Sun. Jan. 10, 2016			5	2	3.5	-104.5	-52.9	0	45 NW
Mon. Jan. 11, 2016			3	-1	1.0	-105.5	-51.9	1	35 W
Tues. Jan. 12, 2016			-8	-11	-9.5	-116.5	-61.4	4	30 SE
Wed. Jan. 13, 2016			-6	-13	-9.5	-129.5	-70.9	1	35 W
Thurs. Jan. 14, 2016			-8	-11	-9.5	-140.5	-80.4	1	25 W
Fri. Jan. 15, 2016			-5	-10	-7.5	-150.5	-87.9	0	35 W
Sat. Jan. 16, 2016									
Sun. Jan. 17, 2016									
Mon. Jan. 18, 2016									
Tues. Jan. 19, 2016									

ICE COVER FORECAST FOR WEST MONTROSE									
Date	Flow at West Montrose (cm)	SHAND Discharge (cm)	Maximum Daily Temp.	Minimum Daily Temp.	Average Negative Degree Days	**(-225 C.)** Absolute Maximum Negative Temp.	**(-70 to -125 C.)** Cumulative Negative Degree Day	Snow Forecast cm	Wind Forecast (km/hr)
Wed. Jan. 20, 2016									
Thurs. Jan. 21, 2016									
Fri. Jan. 22, 2016									
Sat. Jan. 23, 2016									
Sun. Jan. 24, 2016									

Start populating the sheet once the sum of the daily maximum temperature and an overnight temperature is less than or equal to zero.

Use daily temperatures and snow fall from Shand Dam daily reservoir report. Forecast daily maximum temperatures from the Weather Network Fergus location. http://www.theweathernetwork.com/ca/weather/ontario/fergus

This spreadsheet forecasts freeze-up/establishment of the ice sheet at West Montrose. Potential for frazil ice is affected by river flow, severity of cold conditions, snow and strong winds or winds following the alignment of the river. Snow with cold conditions can enhance frazil ice production. Wind and cold temperatures can enhance frazil ice production. The combination of cold conditions with snow and wind is one of the worst combinations and will enhance frazil ice production and potential for frazil ice jams. A warm spell may require the accumulated negative degree days to be reset, that's a judgement call.

Information from this spreadsheet in combination for the history of freeze in ice jams at West Montrose can be used to identify potential flow and weather conditions that could cause a freeze in ice jam. Monitor flow and levels conditions at the West Montrose Gauge Station to maintain awareness of ice conditions. Use the camera at the West Montrose gauge station to monitor ice conditions Ask River Watch staff to visit the site to assess and report on ice sheet formation as needed.

Many factors can affect ice sheet formation, including wind, snow, flow, and the presence of frazil ice. Frazil ice can complicate freeze-up and initial ice sheet formation. If conditions are extremely cold and windy at the time of freeze-up, frazil ice can be anticipated. The amount of frazil that is produced by the river will be influenced and amplified by the amount of flow in the river, extreme cold freezing air, wind, and snow. Increased flow increases the number and length of turbulent flow reaches/areas in the river, extreme cold and wind increases supercooling of the water surface, and snow falling on the river creates slush. All these factors conspire to affect frazil ice creation and the potential for frazil ice jams. The freezing degree day accumulation model/spreadsheet is also used to anticipate frazil ice conditions and the potential for frazil ice jams during the initial freeze-up period.

River flow gauges are used to monitor river level and flow. When the ice sheet forms, it backs up river levels causing them to rise. Monitoring gauge levels can inform water managers if the ice sheet has formed through the gauge reach. River cameras have been added at West Montrose and Brantford gauge stations. River camera photos and video can be used to monitor ice sheet formation. Field staff can be requested as needed to visit specific sites to monitor conditions during the initial freeze-up of the ice sheet. Reservoir discharges can be reduced in some reaches to aid in the initial smooth formation of the ice sheet. The reach downstream of Shand Dam through West Montrose is an example of a reach where reservoir discharge can be adjusted in some situations to assist with ice sheet formation, reducing the potential for freeze-up ice jams.

6.2 Winter Freezing Degree Day Accumulation Monitoring

Another technique used to monitor the potential for ice accumulation and potential for the creation of strong ice is the accumulation of freezing degree days over the course of the winter.

Freezing degree day accumulation over the course of the winter is a measure of how cold the winter has been. If the winter has been extremely cold there is more potential to create ice, potentially creating a larger volume of ice in the river system. However, it is only one indicator and other factors can affect the volume and strength of ice that develops in a given winter.

The degree day accumulation is started on December 1st and continues until April 30th, although ice typically breaks up in March and by mid April at the latest. The average of the maximum and minimum daily temperature is accumulated starting December 1st and continuing through the winter as the winter progress. The Shand Dam climate station is used as an indicator for the watershed. Daily climate records are available from Shand Dam dating back to 1939.

A chart of the annual maximum cumulative freezing degree day for the period 1940 to 2024 is presented by Figure 8. The years with damaging ice jams are also shown on the chart in Figure 8 to illustrate that the coldest winters don't necessarily result in damaging ice jams. Whether ice jams occur is very dependent on how the spring break-up occurs. If the spring break-up is gradual, there is time for ice to dissipate and move out of the river system without incident.

The winter of 2014 is a good example of a long cold winter however the spring breakup was gradual and no major ice jams occurred. A large number of cumulative freezing degree days can also indicate a long persistent winter as was the case in 2014, spring breakup didn't occur until mid April.

A chart of annual cumulative freezing degree days to March 12th is presented by Figure 9, it illustrates how this technique can be used to quickly put in context the history of cumulative freezing degree days for a given date during the winter. If for example a melt event was expected for March 12th, this technique can quickly present the history of cumulative freezing degree days for the period of record to March 12th each year. This context can assist with putting any given winter into context with previous winters. The moving five-year average trend line presented on the chart in Figure 9 indicates a trend to warmer winters. While there is a trend to warmer winters, natural variability can still result in very cold winters like 2014 and 2015 amid a period of warmer winters.

Figure 6: Maximum Annual Freezing Degree Day Chart Shand Dam 1940 to 2024

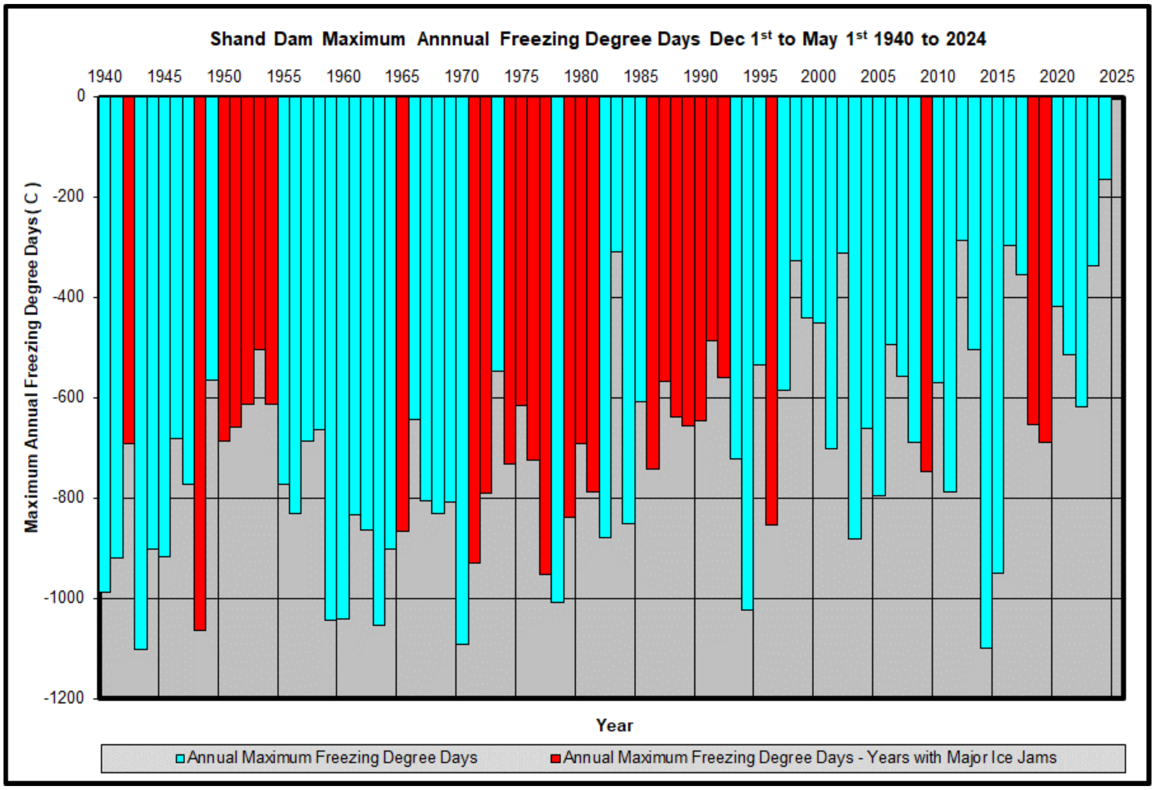
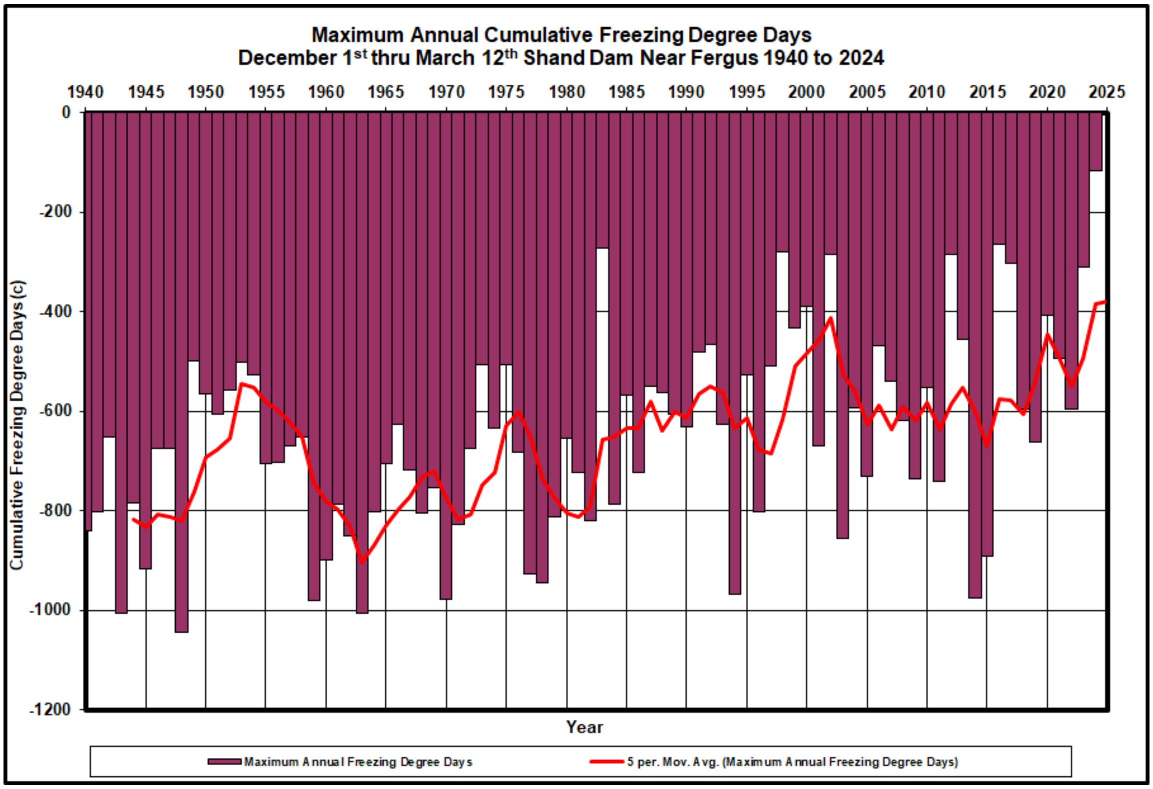
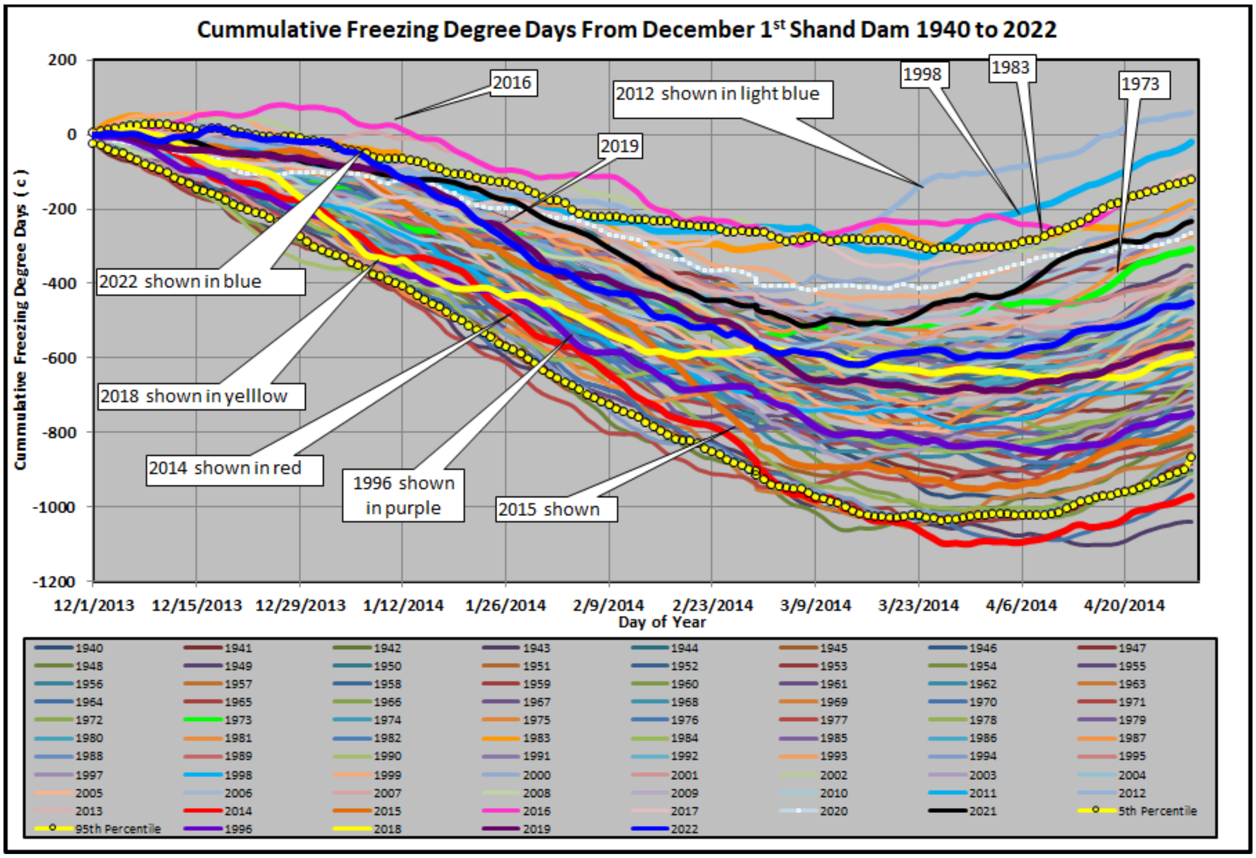


Figure 7: Annual Freezing Degree Day Chart Shand Dam for March 12th 1940 to 2024



One final way to use cumulative freezing degree days for various winters to evaluate the potential for ice jams is to present cumulative freezing degree days, day by day starting from December 1st for all years in the period of record and highlight specific years. The chart presented by Figure 10 illustrates daily cumulative freezing degree days for Shand Dam from December 1st for each year for the period 1940 to 2022. Specific years are highlighted in the record for reference; some of the referenced years had major ice jams. The advantage of Figure 10 is that it illustrates the variability in the accumulation of freezing degree days in one chart. It illustrates how persistently cold some winters were and how rapid the freezing degree day accumulation occurs some winters, the 2018 winter highlighted in yellow is a good example. The rapid accumulation of freezing degree days during that winter built strong blue ice, the amount of ice and strength of ice in the 2018 winter resulted in major ice jams. The chart presented in Figure 10 allows for quick comparison of a current winter accumulated freezing degree days to the previous history of winters providing context when assessing potential for severe ice jams.

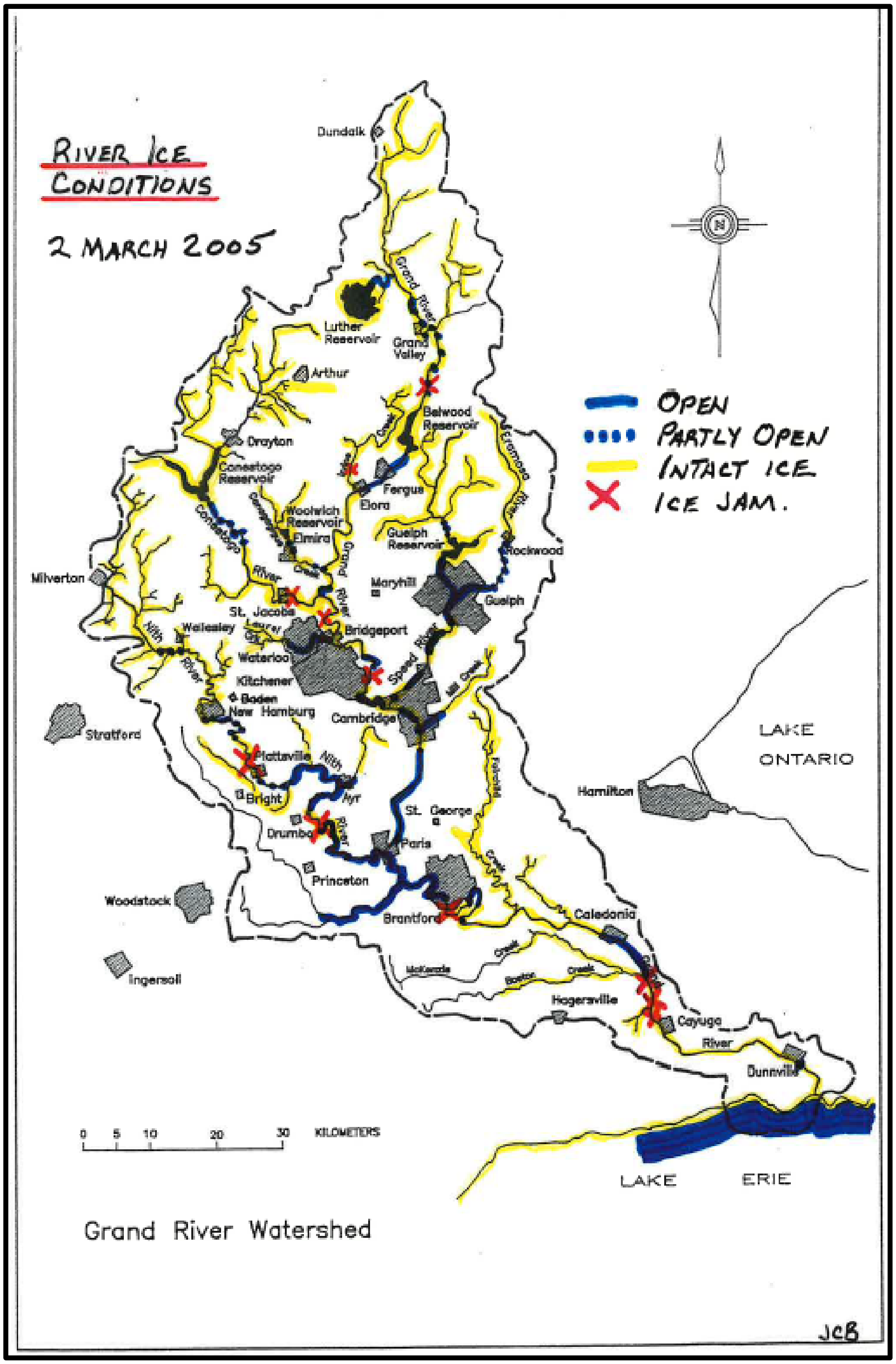
Figure 8: Cumulative Freezing Degree Days by Day of Year Shand Dam 1940 to 2022



6.3 River Watch Ice Condition Maps

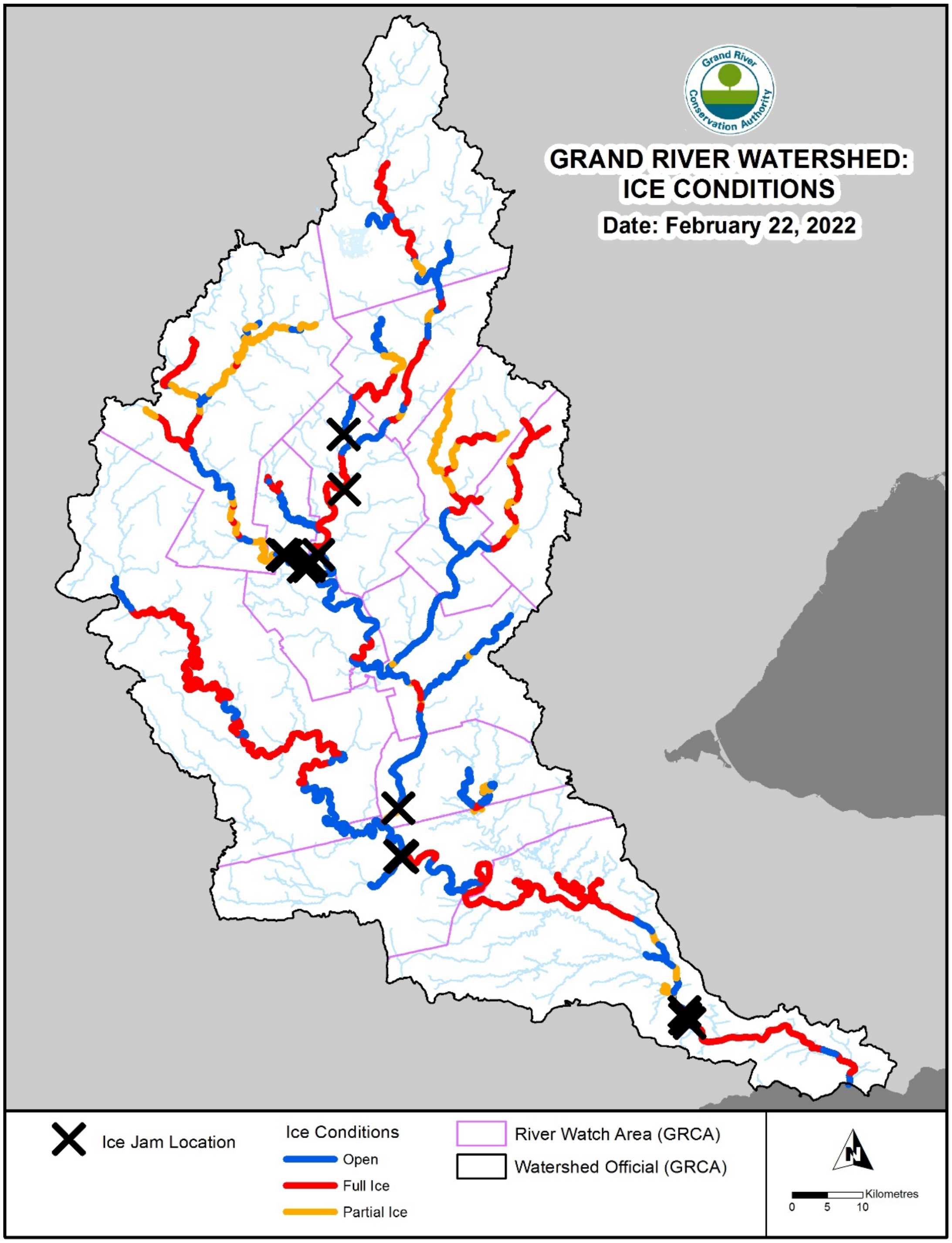
Another component of ice monitoring is the River Watch program. Field staff from GRCA Conservation Areas are assigned to specific reaches of river. They provide eyes in the field to monitor floods including ice jams events. These field staff are called upon to complete reconnaissance and report on conditions prior to spring break-up or incoming flood events. These field observations provide valuable information that provides a picture of conditions prior to spring breakup. One of the products produced from their field observations is an ice conditions map of the watershed. Field staff report on the presence or absence of ice, and general observations about the quality of the ice along with location where ice jams are present. The field reports from individual staff are summarized onto one map of the watershed to provide a watershed summary of ice conditions. Figures 11 and 12 provide examples of these maps, originally these maps were hand drawn, in recent years digital maps have been produced.

Figure 9: Example of Hand Drawn Ice Conditions Map March 2nd 2005



The digital maps provide the same content as the hand-drawn map but in a digital format. Having this information organized in a digital format, keeps it well-organized, accessible, and presents the opportunity to complete further analysis and prepare additional digital products. A history of ice conditions maps is available from 1997 forward; this history of maps is included in Appendix A of this report.

Figure 10: Example of Digital Ice Conditions Map February 22nd 2022



The history of ice jam locations captured in the ice conditions maps is very valuable. It captures knowledge of recurring ice jam locations digitally so that the information won't be lost and can be used to create useful maps for GRCA staff and municipal partners. Ice jam-prone areas can be identified and information captured in an overall summary map so that as staff change, knowledge continues to be passed on.

6.4 Remotely-Piloted Aerial Systems Surveillance of Ice Conditions

In recent years, many municipal emergency management and police departments have acquired aerial Remotely-Piloted Aircraft Systems (RAPS, otherwise known as drones). RAPS devices can be very effective at providing an aerial view of river ice and ice jams. The following photo is an aerial photograph from social media on January 29, 2018 following the ice jam event that month. The picture presented by Figure 13 is of the Grand River in the vicinity of the Colborne Street bridge in the City of Brantford.

RAPS surveillance offers the opportunity to gather good records regarding ice conditions and ice jams in a safe manner. Working around ice can be dangerous and remote observations with RAPS reduces the health and safety issues of getting close to and working around ice.

Some devices are capable of delivering thermal imagery which can provide insights to the strength and thickness of ice and how ice may be degrading as a result of water erosion.

Working with municipal emergency management staff, critical ice reaches, and typical ice jam locations can be identified to focus reconnaissance efforts leading up to and during ice jam events. The reconnaissance information collected by RAPS supports better long-term understanding of ice and ice jams and provided critical status reporting during ice jam events.

Figure 11: RAPS Photo Example Ice in Grand River Colborne Street Bridge

Photo credit: Maro Dabek

7.0 Weather Forecasting Tools and Information

Weather forecast information is critical to flood forecasting, dam safety, and ice management. Weather forecast information allows for the early awareness of potential weather systems that could result in floods, dam or dike safety issues, and potential for ice jams and ice movement.

Beyond the publicly available forecast information, the GRCA also subscribed to two additional weather forecasting services from Meteoblue and Kisters.

The Meteoblue weather forecasting service provides hourly forecasts seven days into the future. Weather forecast parameters include air temperature, precipitation of both snow and rain, wind speed, and wind direction. The Meteoblue service provides forecasts from an ensemble of sixteen weather forecast models. Hourly digital forecast data is provided for three locations in the Grand River Watershed, including the Town of Grand Valley, City of Cambridge, and City of Branford. Updated hourly forecasts are provided every 6 hours throughout the day. Digital forecasts for the three locations noted is the most probable forecast based on analysis of the ensemble of forecasts model. The hourly forecast data from Meteoblue provide weather forecast inputs for the GRCA's flood forecasting model and ice management awareness techniques as discussed later in this report.

The second forecasting service used by the GRCA is the Kisters HydroMaster weather forecasting application. The HydroMaster weather forecasting application provide digital spatial precipitation both forecast and observed. It can provide near term nowcast projected weather radar information 3 hours into the future and weather forecast 7 days into the future. The HydroMaster product provides a range of flexibility to report precipitation forecast and accumulation based on spatial boundaries such as watersheds, areas upstream of reservoirs, and urban catchment. It is an advance weather forecasting environment with alarm notification and complex analysis capabilities. It does not currently include forecast air temperature information.

The combination of HydroMaster and Meteoblue provide the combination of forecast weather information to support GRCA operational needs for flood forecasting, dam safety, and ice management. Forecast weather information support weather assessment tools used to anticipate ice jam or ice management concerns.

7.1 Weather Forecast Assessments

Near-term weather assessments with respect to ice focus on three main considerations including ice sheet formation during initial freeze-up, frazil ice generation, and ice sheet break-up or movement.

Ice sheet formation was previously discussed in this section and the example of the ice cover forecasting spreadsheet is present by Table 3. Currently the ice cover forecasting spreadsheet uses daily information, a future improvement would be to adapt the forecasting spreadsheet to use hourly information and consider creating forecasting spreadsheets for Grand Valley, West Montrose and Brantford. This would be anticipated ice sheet formation over a broader area of the watershed. Formation of the ice sheet through the West Montrose reach is over primary interest which why it has been the focus to this date.

Weather assessments ensure an awareness of frazil ice conditions throughout the winter season. Frazil ice can complicate existing ice jams that may be in place or cause new ice jams to form, therefore maintaining a level of awareness throughout the winter season is important. Double digit below freezing temperatures coupled with windy conditions and turbulent flow conditions are the main concern for frazil ice generation. Given the right conditions, the river has an almost limitless ability to generate frazil ice.

The third weather assessment considered through the winter season are weather conditions that could cause ice sheet movement. This includes mid-winter melts or spring break-up. Ice sheet movement is an important consideration for ice jam risk potential. If ice sheets start to move, the potential risk for ice jams is increased. Assessing potential for ice sheet movement includes assessing both the forecast air temperatures that will influence snowmelt and associated snowmelt runoff and rainfall that influence snowmelt and runoff. The issue to be assessed is if a forecast event will generate enough runoff to trigger ice sheet movement. A warming degree hour technique is used and is discussed in the next section.

7.2 Warming Degree Hour Technique Used to make inferences of Ice Sheet Movement

The provincial ice management manual includes information about degree day thresholds to estimate ice breakup. Historically degree day techniques were used since maximum and minimum daily air temperatures were readily available and hourly air temperature data was rarely available. Hourly air temperature data is now readily available. Cumulating the observed and forecast hourly air temperatures provides a better representation of the energy associated with an event and whether there is sufficient energy and rainfall in an event to trigger ice sheet movement or breakup.

An approximate threshold for ice sheet movement has been developed for the Grand River based on analyzing historical events. The general threshold used in the Grand River watershed is 160 warming degree hours over a 1 to 2 day period of time. If this threshold is expected to be exceeded or met, it indicates the incoming event is a weather event that needs to be monitored closely as it could cause bank full flow conditions which could initiate the movement of ice. The more the threshold is exceeded, the more extreme the melt event. More energy results in more melt and a more rapid melt. The magnitude of the melt is also influenced by the amount of water stored in the snow pack and the amount of rain associated with an incoming weather event.

Figure 12: Warming Degree Hour Chart Example February 18th 2018 Weather Forecast

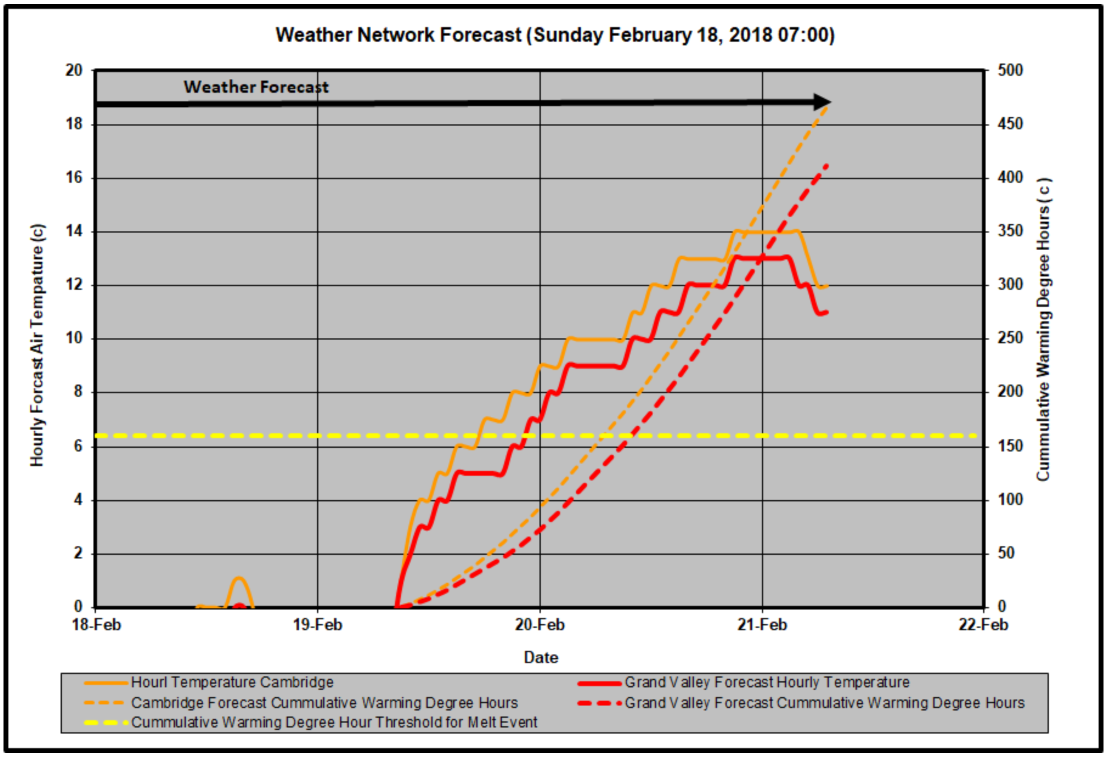


Figure 14 presents an example of a warming degree hour cumulative chart from a February 18th 2018 event that relied on the Weather Network forecast hourly temperature information. The cumulative warming degree hour technique can anticipate when ice sheet move might occur several days ahead based on the weather forecast. In the example provided by Figure 14, ice movement was anticipated two and a half days prior. While ice movement can be anticipated when ice jams might form and break-up is not possible to forecast.

River Cameras

Use of remote digital cameras has become more common in recent years as camera and high-speed cellular communications technology have evolved. Two digital cameras are installed and are used to monitor river ice conditions by the GRCA at the West Montrose and Brantford stream gauge sites. These cameras were installed in 2014 prior to the spring break-up in 2014 which had the potential to be a flood of record.

The West Montrose and Brantford sites were selected as these sites have a history of ice jams and ice jams pose a risk to residents at these locations. While these cameras can be used to monitor river conditions, their primary purpose and reason for installation was to enhance ice monitoring. Figure 15 illustrates pictures capture at each of these sites in January 2024.

Figure: 13a and 15b: (15 a above) River Camera Photos West Montrose and 15b (below) Brantford River Cameras

Photos from river cameras are available in real-time on the GRCA website and are updated on a five-minute basis. Information from the cameras provides real time status updating of ice conditions complimenting information from the river flow and level gauges. Information from the cameras is stored and can assist the post-analysis of ice conditions throughout the winter season including during periods of ice formation, break-up, and jamming.

7.3 Stream Gauges (Voice Alert System)

Stream gauges monitor in-river observed conditions of water levels and open water flows. If ice is present at a stream gauge, flow estimates aren’t available as the relationship between gauge level and stream flow is based on open water conditions. The presence of ice backs up water and invalidates the relationship between gauge level and gauge flow.

Regardless, if flow information is unavailable from a stream gauge due to ice conditions, river level at stream gauges is still very useful to monitor ice and ice jam conditions. Not all communities that are subject to the risk of ice jam flooding have stream gauges, however many do. Stream gauges are located in the following communities that are at risk from ice jams: Port Maitland, Dunnville, Brantford, Cambridge, Doon/Freeport, Bridgeport, West Montrose, Drayton, St. Jacobs, and New Hamburg. These stream gauges help monitor the status of ice conditions in these communities. Recently, the County of Brant has added river gauge monitoring stations in the community of Paris.

Stream gauges can assist with status reporting of ice jam conditions and detection of unexpected ice jams. Ice jams at times are unpredictable, and stream gauges can alert water management staff to unexpected ices jams. The GRCA monitoring system monitors selected river level gauges for potential ice jams. The river level rate of rise is monitored to detect a potential ice jam condition. If potential ice jam conditions is detected by the monitoring system, a voice alert message and email is sent to the duty office on call. Upon receipt of the potential ice jam condition, the duty officer reviews the stream gauge information, discusses the information with the senior operator, and the senior operator decides on the appropriate action which may include contacting the municipal flood coordinator and issuance of a flood warning message.

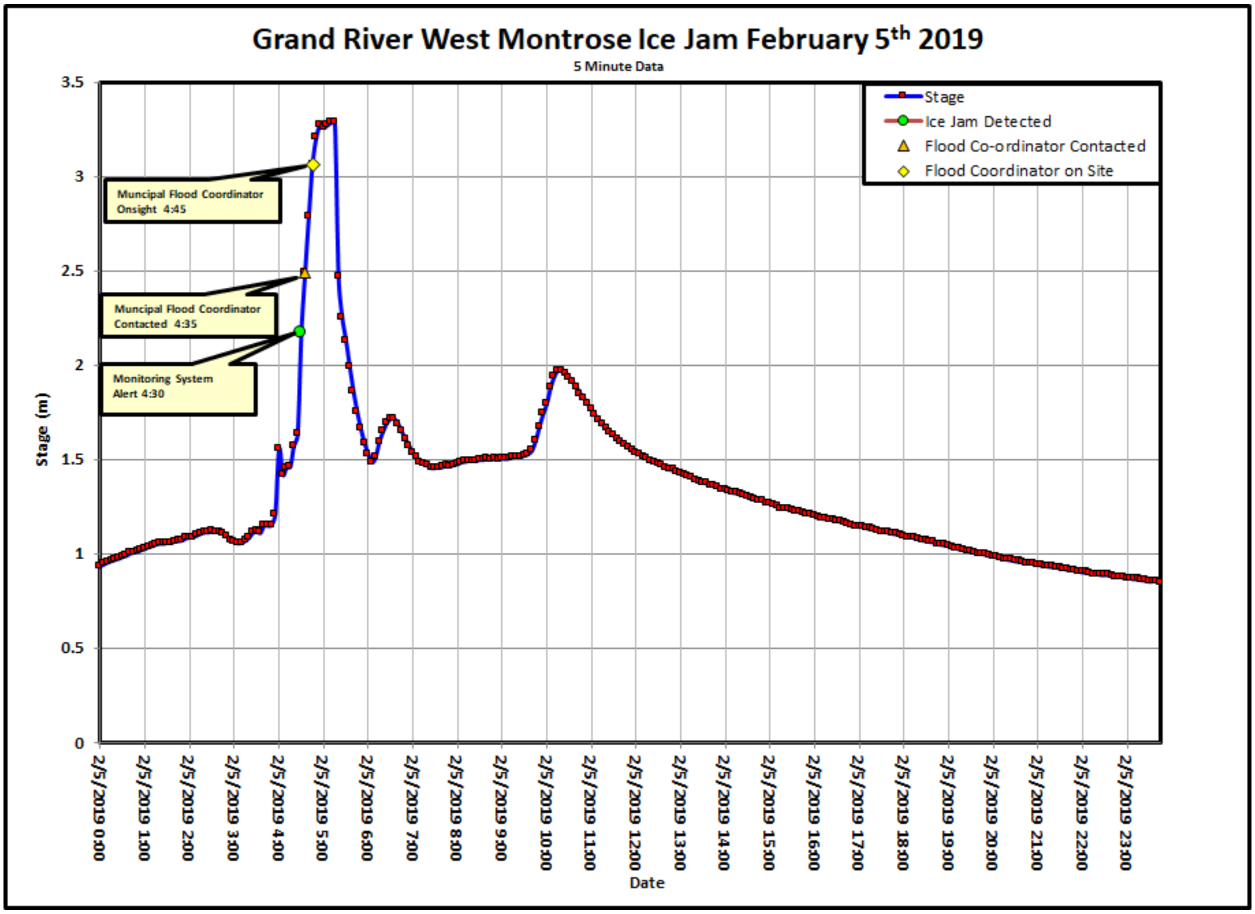
Figure 16 illustrates an example of the real-time monitoring system detecting an unexpected ice jam at the West Montrose gauge station and alerting staff. The monitoring system detected the ice jam initial river rise at 4:30 am, the duty officer received the call, and the municipal flood coordinate was contacted at 4:35 am, the municipal flood coordinator arrived at the site by 4:45 am. The example illustrated by Figure 16 is an example of an ideal response, not all responses can happen with that sort of efficiency. A watershed conditions statement was issued the prior afternoon advising flood coordinators in specific communities of a heightened risk of ice jams. The detection of the ice jam by the monitoring system coupled with the public awareness through the watershed conditions statement demonstrated an efficient and timely response.

Figure 16 illustrated how quickly an ice jam can form, rise, and release. The ice jam in West Montrose on February 5th of 2019 started to rise at 3:55 am, it peaked at 4:55 am and receded back down to normal levels by 6:05 am. The ice jam lasted a total of 2 hours in this example. Ice jams don't always release so quickly, if the downstream ice is strong and resistant to movement, ice jams can last for hours, days, or weeks depending on conditions.

A similar monitoring detection system is in place for ice jams in the City of Brantford. River levels are monitored downstream of the Colborne Street Bridge through the Brantford dike reach. In the case of the City of Brantford, both the GRCA and the City of Brantford operate monitoring systems that monitor the river level and issue alerts to staff when ice jams are detected. This system was put in place following the February 1996 ice jam in the City of Brantford.

River level gauges can be used to track the progression of an ice jam down a river system. Examples are provided in the next section.

Figure 14: Example of West Montrose Ice Jam and Monitoring System Detection



7.4 Ice Flow and Ice Jave Monitoring and Forecasting

As ice jams or the wave associated with ice jams, javes, move down the river, stream gauges can be used to track the status of movement and estimate/forecast the arrival times at downstream locations. There are several gauge stations along the large rivers in the Grand River watershed that can be used to monitor the movement of a jave down the river. However, the arrival times of the jave at downstream locations have an associated uncertainty.

While the travel time between gauge stations is known based on analysis of previous floods, what is uncertain is whether the ice jams at a location may stop or interrupt the downstream progression of the jave. If an ice jam occurs, the downstream progression of ice and potentially flood waters are halted, and an ice dam can form forcing ice and water on the floodplain adjacent to the river. The accumulation of water and ice can result in a much higher and larger jave when the ice jam releases.

During the February 2018 ice jam event, an ice dam formed at a pre-existing ice jam upstream of the Parkhill Dam. When the ice dam broke, it sent a large jave of ice, water, and debris (tree length logs in some cases) down the river. Reviewing the gauge levels from the 2018 event, the ice dam was difficult to anticipate or discern from the existing gauge network. The combination of the high flows in the river, with the added flow of ice and debris from the jave, and a pre-existing ice jam in place downstream of the Brantford dike reach, all conspired with the rapid melt to result in overtopping of the Brantford dikes.

The breakup in 2019 also resulted in an ice wave moving down the river however it was not as severe as the 2018 ice jam. The ice jave progressed down the river downstream with little interruption and the expected arrival times could be forecast using typical travel times between gauge stations. Figures 17 and 18 illustrate the flood wave and jave travel down the river system.

Figure 17 Ice Jam Jave Grand River February 2018

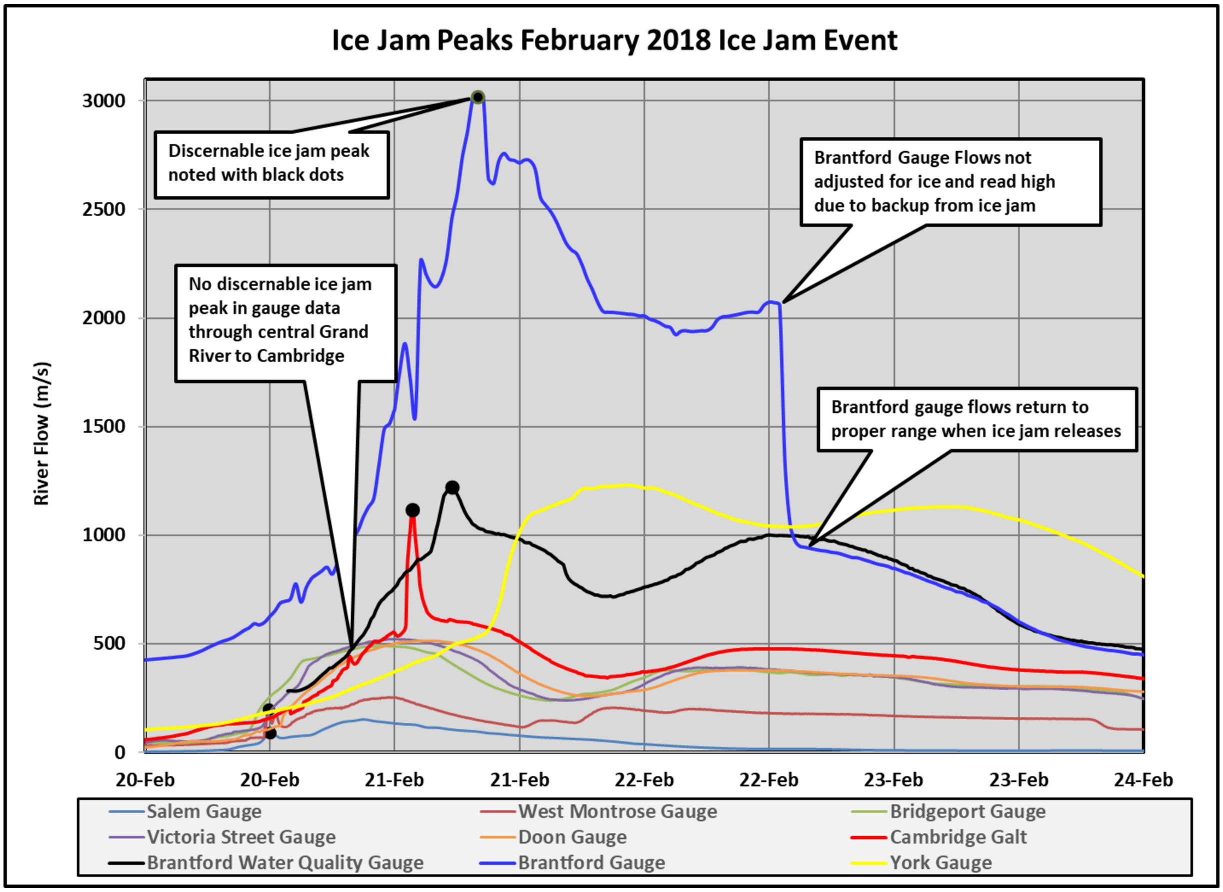
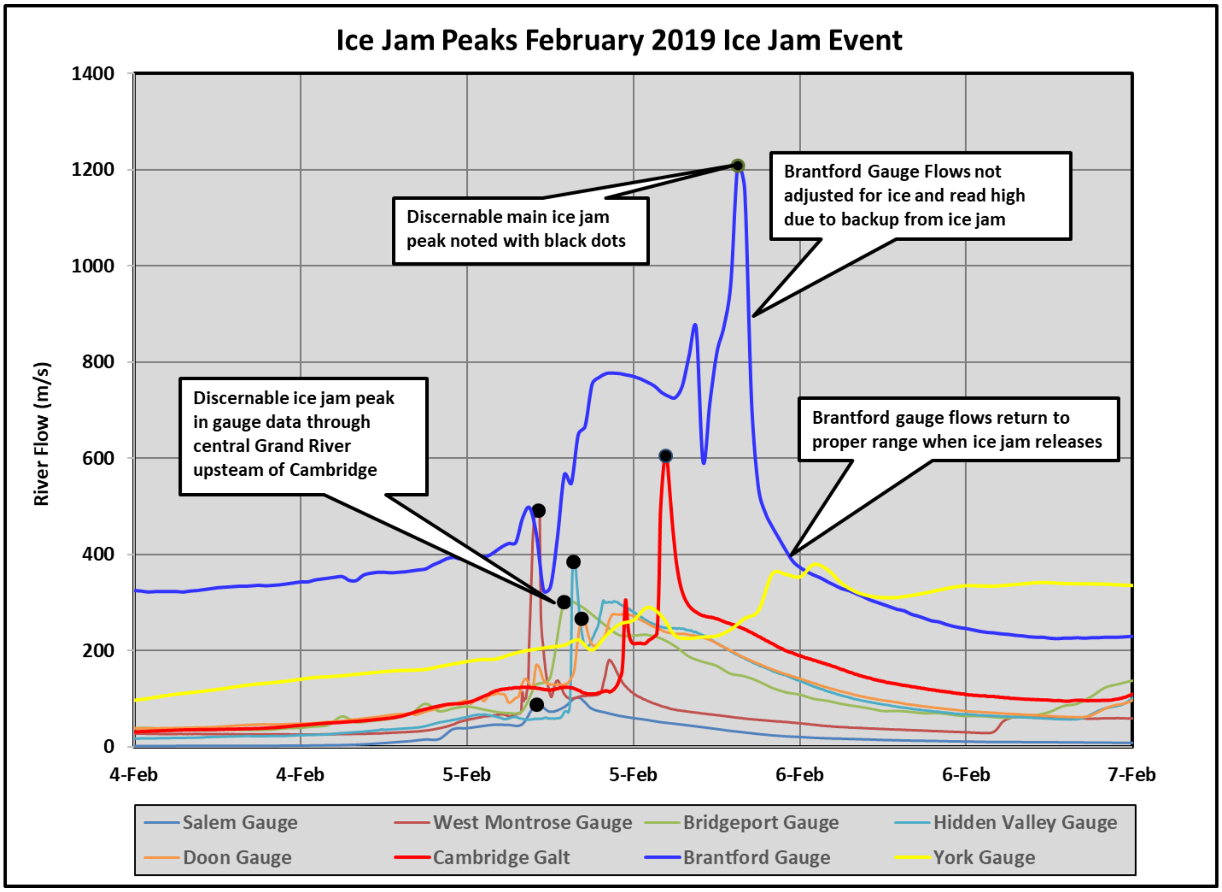


Figure 18: Ice Jam Jave Grand River February 2019



7.5 Ice out thresholds for Dams

Predicting when ice will breakup and the ice sheet above the low-head dams on the river will break-up and move downstream is difficult to predict. When the ice sheet will break up above a low-head dam is very dependent upon the strength of the ice sheet. The strength of the ice sheet varies depending on the length of the winter, the persistence of cold conditions to build strong ice during the winter, the presence of snow on the ice sheet to insulate it, and how rapidly the break-up occurs.

7.6 Ice Thickness Monitoring

Limited ice thickness information is available or collected. Working on ice poses health and safety risks to employees, for this reason ice thickness information is not actively collected.

There are some ice thickness measurements from GRCA reservoirs that permit ice fishing activities, this sort of ice thickness information is more collected for ice safety of patrons and not for ice management purposes.

There is periodic ice thickness information available from Water Survey of Canada stream gauge stations. When technicians visit the stream gauge stations to complete under ice flow measurements, they will note the ice thickness. This information is sporadic and has not been formally analyzed.

8.0 Ice Jam Risk Mitigation

There have been some historical projects focused specifically on reducing the potential for ice jams and other projects or activities that have helped reduced the risk of ice jams although that was not their primary objective.

8.1 Removal of Sediment Downstream of Grand Valley Boyne Creek Delta

In 1982, the GRCA completed a project to remove a delta of sediment that formed in the Grand River at the confluence of Boyne Creek and the Grand River downstream of Grand Valley. The delta of sediment was removed to improve ice passage downstream of the community of Grand Valley. Ice jam flooding was a persistent flooding issue in the community of Grand Valley through the late 1970s and early 1980s. Ice jams form downstream of Grand Valley in the vicinity of the Byone Creek confluence and cause a backup of the ice jam into Grand Valley resulting in flooding in the community.

It doesn’t appear this project was a formally adopted project of the GRCA and appears to have been completed as a special one-time project.

8.1.1 West Montrose Island Removal

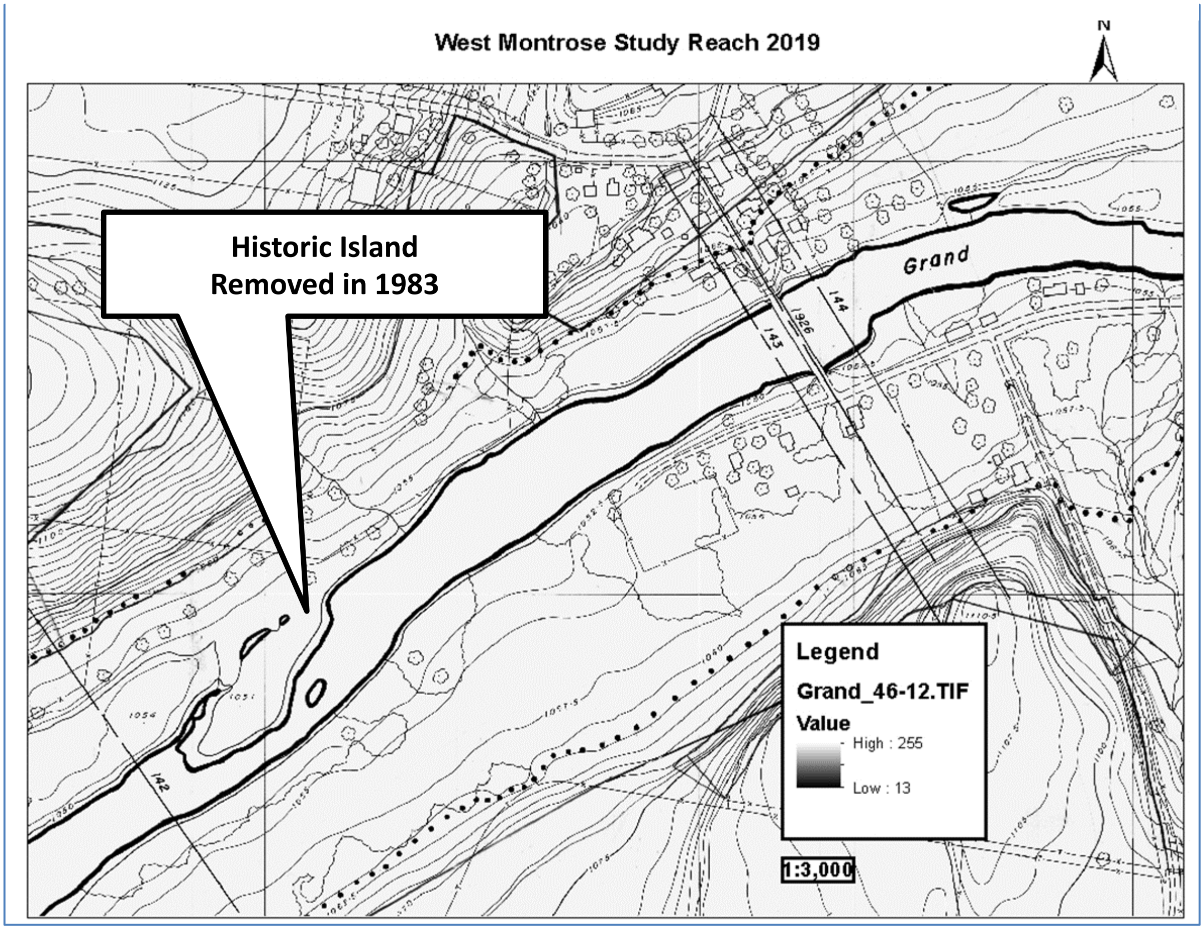
In 1983, the GRCA completed a project downstream of West Montrose to remove an island that occupied two-thirds of the river width downstream of the West Montrose Bridge. Removal of the island was intended to improve ice passage and reduce the risk of ice jam flooding through the community of West Montrose. Ice jam flooding had been a persistent problem through West Montrose in the late 1970s culminating with a major ice jam on February 22nd 1981. The 1981 ice jam is the highest on record. Following the 1981 ice jam, investigations were completed to assess alternatives to reduce the risk of ice jam flooding in West Montrose. A project was carried out in 1983 to remove the island in the river downstream of West Montrose. It does not appear this was a formally adopted GRCA project and appears to have been completed as a special one-time project.

8.1.2 Channelization Through Community of Drayton

Channelization and diking of the Conestogo River through the community of Drayton was completed in the late 1980s. The combination of increased channel capacity and diking reduced the potential flooding from natural flow events and reduced the risk of ice jam related flooding. The channelization improved the movement of ice through this reach of river.

The over banks of the channel through Drayton above the low water level were cleared of vegetation and accumulated sediment in 2016. This work was completed to restore some of the channel capacity lost over the years due to sedimentation and vegetation growth.

Figure 19: Island Downstream of West Montrose Removed to Reduce Ice Jam Risk



8.1.3 Diking Grand River Kitchener-Bridgeport

A dike was completed in the late 1970's to reduce the risk of flooding to the community of Kitchener-Bridgeport. Completion of this dike also reduced the risk of ice jam-related flooding in this community.

8.1.4 Channelization and Diking Cambridge-Galt (late 1970s and early 1980s)

Channelization and diking was completed through the Cambridge-Galt reach of the Grand River through the late 1970s through to the mid-1990s. This work was designed to reduce flood risk through this reach. The increased channel capacity improved ice movement which, in combination with diking, reduced the potential of ice jam flooding through this reach. It is important to also recognize the benefits of Parkhill dam to force break-up of the ice sheet as it falls over the dam resulting in smaller ice blocks that more easily move through the downstream flood channel. The area upstream of Parkhill Dam can provide as storage area for ice however, as seen in February 2018, it can also be the site for ice jams and ice dams to form.

8.1.5 Channelization and Diking City of Brantford (1980s)

Channelization and diking was completed through the Brantford reach of the Grand River through the late 1970s through to the mid-1990s. This also included the removal of Lorne dam. This work was designed to reduce flood risk through this reach. The increased channel capacity improved ice movement which, in combination with diking, reduced the potential of ice jam flooding.

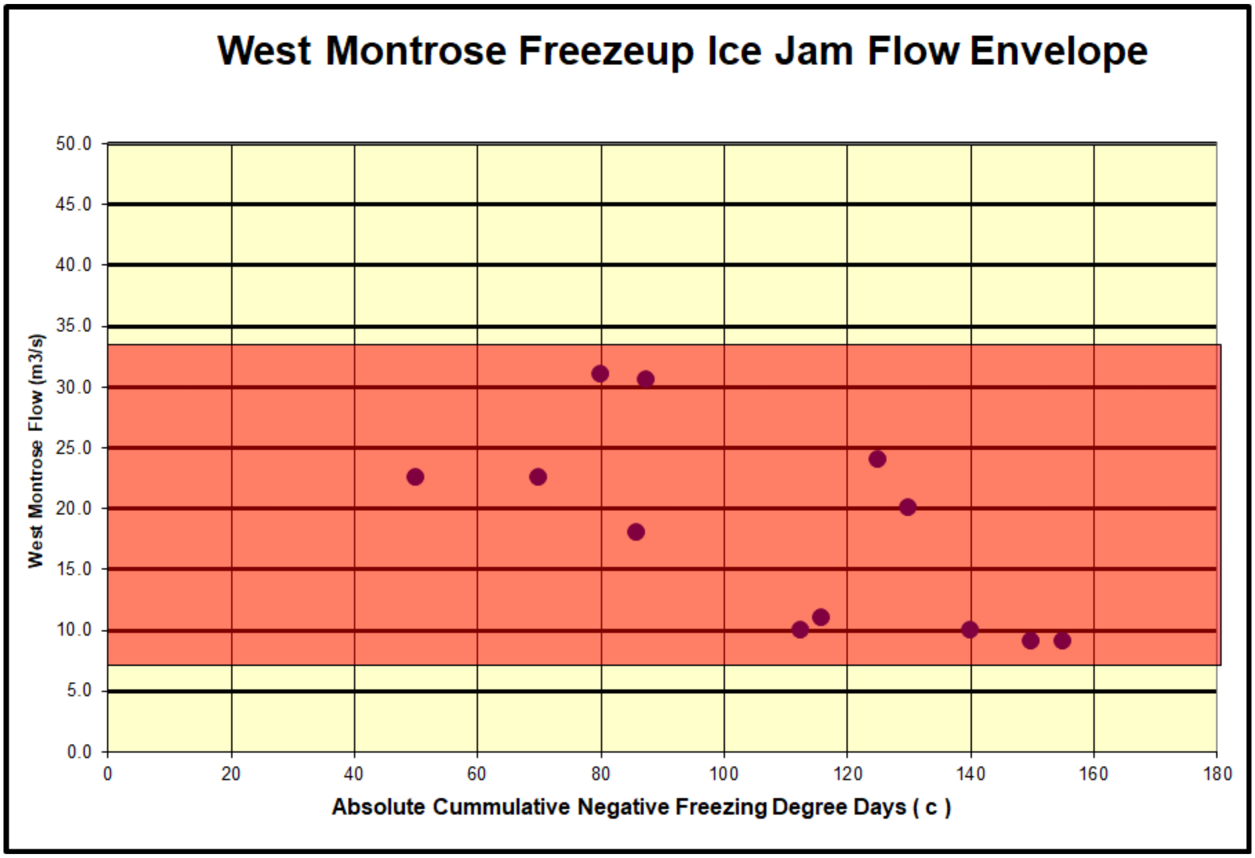
However, the Grand River is prone to ice jams forming at the downstream end of the dike reach due to strong sheet ice through the oxbow and at Fish Island downstream of the main dike reach. Overtopping of the Brantford dikes occurred in February 2018 as a result of an ice jam in the vicinity of Fish Island, a sudden melt, and the release of an ice dam upstream of the Parkhill Dam through the Cambridge reach of the Grand River.

8.2 Reservoir Operations

Reservoir operations can assist with reducing the risk of ice jams to some extent but aren't able to prevent ice jams from occurring.

Shand Dam can be used to influence ice sheet formation through the West Montrose reach of the Grand River. Flows from Shand dam can be adjusted to either facilitate a smooth ice formation at a low flow through the West Montrose reach or operated to flush frazil ice through the reach if river flows are high. Analysis of previous freeze up ice jams was analyzed for the West Montrose reach and compared to river flow through the reach at the time of ice sheet formation. The results of the analysis are presented in Figure 20. If flows at the time of ice sheet formation can be regulated to 7 m^3/s or less, there is reduced potential for frazil ice jams at the time of freeze up and the ice sheet formation is smooth at a low flow. Forming the ice sheet at a flow preserves channel capacity and reduces the flow required to later breakup the ice sheet. Typically, it takes as much flow in the river to move the ice sheet as was there when it formed.

Figure 20: West Montrose Freeze-up Ice Jam Flow Envelope



If flows through the West Montrose reach are high, regulating flows to maintain flow above 32 m^3/s flushes frazil through the West Montrose reach. It must be kept in mind that flushing frazil ice through West Montrose pushes the frazil ice further downstream where it is likely to accumulate either upstream of Hidden Valley Dam, Parkhill Dam, or downstream of the Brantford dikes. As flows through the West Montrose reach recede, reducing Shand Dam discharge to regulate flow below 7 m3/s to facilitate a smooth ice sheet during freeze-up is the objective. There is a large tributary of the Grand River, the Irvine River, that joins the Grand River upstream of the West Montrose reach and downstream of Shand Dam. It is not always possible to regulate flows below 7 m^3/s through the West Montrose reach by reducing the Shand Dam discharge as the local inflow downstream of Shand Dam to the West Montrose reach is higher than 7 m^3/s. Being aware of the flow range through the West Montrose reach that has a higher risk of ice jams is useful information, however flow conditions may preclude the ability to regulate flows to the desired range to reduce the risk of ice jam.

Winter flow augmentation and the ability to increase discharge prior to an anticipated ice break-up are additional approaches that may help reduce the risk of ice jam. Winter flow augmentation helps prevent the ice sheet from freezing to the bottom of the river. If the ice sheet freezes to the bottom of the river, it is more resistant to break-up or to moving out when flows increase, which increases the risk of ice jams. The ice sheet will attach to the bottom of the river if flows are very low or non-existent. Flow augmentation during the winter maintains flow in the river helping to avoid the ice sheet freezing to the bottom of the river. Increasing river flow by increasing reservoir discharge before break-up can help erode, degrade, and weaken the ice sheet before breakup. This can be an effective means of using the reservoir to reduce the risk of flooding. This approach proved effective in the spring of 2014, an ice sheet was present in the river through the community of Grand Valley, thus there were concerns for potential ice jams at the time of break-up. The discharge from Luther Dam was increased to help erode the ice through the community of Grand Valley. The combination of using the Luther Dam flow to erode ice and the gentle melt at the time of break-up helped avoid ice jams through Grand Valley

The final way large reservoirs can be used to help reduce the risk of ice jam flooding is to regulate and reduce downstream flood flows at the time of break-up particularly when ice jams are in place. Delaying reservoir discharge provides additional time for the ice and ice jams to degrade and weaken. This was the strategy used in 2018 when a large ice jam was in place downstream of the Brantford dikes. Reservoir discharge increases were delayed to reduce downstream flooding and reduce pressure on the ice jam in place through the Brantford reach. Reservoir discharge increases were delayed until after the ice jam had released.

8.3 Ice Jam Mitigation Studies

When warranted, ice jam studies are completed to investigate ice jam mitigation options. An ice jam study was carried out following the February 2018 ice jam through the Brantford reach which resulted in the overtopping of the Brantford dikes.

Ice jam studies focus on the root cause of ice jams in a given reach of a river. Once the root cause of the ice jams is understood, potential mitigation options are considered. In the case of ice through the Brantford reach, this area is very much influenced by the strong sheet ice that forms through the oxbow reach downstream of Brantford where the river slope changes and is much flatter. Ice jams also seem to be affected by Fish Island downstream of the main Brantford dike reach. When ice jams form in the vicinity of Fish Island, flow capacity is reduced through the narrowest portion of the Brantford dike reach near Gilkison Street. The reduced flow capacity can result in overtopping of the dikes.

Results of the ice jam mitigation study identified floodplain relief and raising a portion of the Brantford dike floodwall along River Road. Increasing the ability of flow and ice to gain relief to the floodplain between Gilkison Street and the river is one floodplain relief area. Creating relief to the floodplain by clearing vegetation and possibly contouring the floodplain will provide more flood capacity and space for ice, allowing ice to spread out rather than build up. The second floodplain relief area is between the downstream portion of River Road and the River at Birkett’s Lane. Creating floodplain relief in this area will allow ice and flow to by pass ice jams at Fish Island and spread out and gain relief to the broad floodplain downstream of Birkett’s Lane and River Road. Complementing additional floodplain relief is raising a portion of the floodwall along River Road. The consultant’s investigation report about the Brantford ice jam recommended these mitigation options. The next step is to refine these options and consult with the public through the Environmental Assessment process.

8.3.1 Canadian Coast Guard Icebreaking Port Maitland

The Canadian Coast Guard operates a fleet of icebreakers on the Great Lakes and through the St. Lawrence seaway. These icebreakers are capable of breaking up ice for ship passage through the seaway and for breaking up ice in ports to allow ship access.

The Coast Guard, when called upon and if available, will deploy an icebreaker to Port Maitland to break up ice at the mouth of the Grand River to Port Maitland. A protocol is available through Emergency Management Ontario (EMO) to request Coast Guard assistance. The Community Emergency Management Coordinator (CEMC) for Haldimand County has to make the request to EMO based on advice or a request from the GRCA.

Breaking up ice at the mouth of the Grand River has been effective in the past. The Canadian Coast Guard has responded to requests in a timely manner and is willing to help provided the appropriate Coast Guard equipment (ship) is available to clear ice from Port Maitland. The Canadian Government has a shared services agreement with the US Coast Guard. In the event thata Canadian Ice Breaker is not available to break ice at Port Maitland, the Canadian Coast Guard can request the US Coast Guard to dispatch an icebreaker to Port Maitland. This has happened once in the past, In 2002, a US Coast Guard icebreaker broke ice in Port Maitland. A picture of the US Coast Guard icebreaker deployed to Port Maitland in 2002 is illustrated by figure.

Figure: 21 US Coast Guard Icebreaker Breaking Ice Port Maitland 2002

8.4 Blasting

Historically, blasting of ice jams with explosives was sometimes used to break up ice jams. Blasting has not been used to break up ice jams in the Grand River since the early 1980’s.

Blasting of ice jams is not currently used for a couple of reasons. Blasting an ice jam simply transfers the problem downstream. The ice needs some place to go and if ice is present downstream it has no place to go and blasting ice won't improve this situation. There is also consideration of the liability if an upstream municipality blasts ice and an ice jam forms in a downstream municipality. There are major health and safety considerations regarding how and if blasting experts can safely access the ice to place the explosives. Finally, there is consideration of the potential environmental damage and environmental approvals required which may not be available or available in a timely manner.

While the above considerations all resulted in blasting not being used as an option anymore, it is also possible that winter flow augmentation has also contributed to avoiding the need for blasting. Blasting is often used when the ice sheet is anchored and frozen to the bottom of the river. The intact frozen-in ice sheet is often blasted to loosen it up and fracture it so it will move out. Winter flow augmentation has helped reduce ice sheets in the main Grand River and its tributaries below large reservoirs from having ice sheets freeze to the bottom of the river.

9.0 Climate Change Considerations

There are four trends associated with climate change that have implications for ice jams. These four trends include:

1. More mid-winter melts are occurring in January and February typically followed by flash freezes
2. March and April rainfall patterns are occurring earlier in the year in the months of January and February.
3. More rapid swings in temperature from extreme double digit cold temperatures to mild double digit warm temperatures accompanied with rainfall.
4. A more unstable polar vortex that swings further south that can bring sustained periods of double-digit cold temperatures.

There has been a tendency since the early 1990s for more frequent mid-winter melts in the months of January and February followed by flash freezes. The challenge with mid-winter melts is they are often not of sufficient magnitude or duration to clear ice completely out of the river and can result in ice jams downstream of Brantford or upstream of Cambridge as observed in January 2018. The flash freezes following these melts during periods of higher flows in the river can cause large volumes of frazil ice to be generated that can further complicate ice jams making them more resistant during the normal spring melt.

There has been a trend in recent years of rainfall events and volumes occurring in January and February that would typically only be experienced in March and April. January 2020 saw the largest one-day rainfall in January on record. February 2018 saw the largest one-day rainfall in February on record. The challenge with rainfall events of this magnitude, coupled with double digit mild temperatures is this combination causes rapid increases in river flows with little time for river ice to degrade. These conditions can lead to severe ice jams particularly if pre-existing ice jams are in place.

A third trend of concern is rapid swings in temperature from sustained extreme cold conditions to extreme mild conditions over a very short period of time, in some cases less than a day. This rapid transition from extreme cold to extreme mild conditions doesn't allow time for river ice to degrade and loosen up. Increased flows to the river can start ice sheet movement but where strong sheet ice exists, ice jam can be expected and typically result.

The final trend observed in recent years that has been attributed to climate change is an unstable polar vortex. The polar vortex can shift south and bring severe cold double digit freezing temperatures to the Grand River watershed. These sustained periods of cold weather can build large volumes of strong sheet ice. The strength and volume of this ice increases the risk of ice jams when the spring breakup occurs.

10.0 Ice Research in the Grand River Watershed

Ice research has been completed in the past, notably by Environment Canada Dr. Spyros Beltaos. Research papers by Dr. Beltaos are included in the reference section of this management plan.

10.1 Characterization of Major Ice Flood Damage Centre Reaches

Identifying the ice jam characteristics for specific river ice jam reaches is an important step toward understanding ice jam risk and the factors affecting risk in different reaches. A characterization example is included below for the Grand River Port Maitland to Dunnville Reach. The following example provides a template that could be used to document information and knowledge in other reaches. These reach characterizations can provide useful technical information and knowledge when dealing with an ice jam in a specific reach.

Grand River - Port Maitland Dunnville Reach Example Template

- **Mechanisms Contributing to Risk of Ice Jams**

Ice jams in the reach of the Grand River from Port Maitland to downstream of Dunnville Dam are influenced by the ice sheet in Lake Erie and by the bend in the River upstream of the community of Port Maitland.

Ice jams through this reach are influenced by the sheet ice in Lake Erie and by the sheer volume of ice moving down the river from the upstream watershed. If the Lake Erie sheet ice states intact, it obstructs the ice moving down the river and will form an ice jam typically at the bend in the river upstream of the community of Port Maitland. The sheet ice from Lake Erie typically extents up to the noted bend in the river, it obstructs ice moving down the river, an ice jam builds until the ice and flow in the river can find sufficient relief in the floodplain beyond the banks of the river.

- **Affected Area**

The areas typically affected are the portion of the town of Dunnville downstream of Dunnville Dam, portion of Dunnville along Sulphur Creek and portion of Port Maitland West of the River.

There are several marinas in this reach of the river however it is presumed the marinas would not be significantly impacts as it is their off season.

- **Last Major Ice Jam**

Last major ice occurred in this reach in February 2009. Major flooding was experienced in the community of Dunnville downstream of Dunnville Dam and in the community of Port Maitland. Flooding in areas downstream of the Dunnville Dam approached the Regulatory Flood Elevation for this reach of river.

- **Factors Aggravating the Risk of Ice Jams**

Intact sheet ice in Lake Erie at the mouth of the Grand River through Port Maitland is the largest contributing factor to ice jams through this reach. The size of the upstream watershed and the potential of that upstream watershed to produce large volumes of ice is also a large contributing factor. Other factors aggravating ice jams through this reach are the volume of ice and strength of ice moving down the river from the upstream watershed. If the winter has been particularly cold, large volumes of ice can be generated from the upstream watershed. The severity of cold conditions can also build strong blue ice which resists breaking up as it has travels down the river and flows over low-head dams in Caledonia and Dunnville.

- **Factors Mitigating the Risk of Ice Jams**

The Caledonia and Dunnville Dams act as ice storage areas and provide a level of mitigation by causing ice chunks/blocks to break up as the ice flows over these dams.

- **Monitoring In Place To Anticipate and Detect Ice Jams**

There is river level monitoring in place at Port Maitland, at Sulphur Creek downstream of Weir 3 on Dunnville Dam and above Dunnville Dam at Weir 3. These gauges provide real-time water level information with the ability for real-time alarming if specified level thresholds are exceeded. The Port Maitland and Sulphur Creek gauges play an important role to detect ice jams and report on water level conditions during ice jams.

The level gauge upstream of Dunnville Dam plays an important role, reporting levels upstream of Dunnville dam and provides useful information regarding movement of ice or backup of ice upstream of Dunnville Dam.

Improved monitoring by the addition of river level gauges and river cameras at Cayuga and at Caledonia Dam would provide additional early detection of ice movement upstream of the Town of Dunnville offering additional advance warning of the potential for ice jams.

- **Mitigation Options to Reduce the Risk or Impacts of Ice Jam Flooding**

The primary mitigation option for ice jams in the community of Dunnville is the ability to call in the Canadian Coast Guard ice breaker when needed to break up ice at the mouth of the Grand River to allow passage of ice out into Lake Erie.

- **Recommendations to Enhance Monitoring and Response**

Addition of threshold monitoring for ice jams at the Port Maitland, Sulphur Creek and Dunnville Dam gauge stations by the addition of rating of change alarm notifications.

Additional of level monitoring at the highway 3 bridge over the Grand River in the community of Cayuga and at the Caledonia Dam in the community of Caledonia. The addition of river cameras is also recommended at these locations.

11.0 Summary

Ice jams are a naturally occurring phenomena in rivers in cold climates. Many factors affect ice formation, ice accumulation and ice break, all these factors influence the risk of ice jams along with the weather conditions at the time ice breaks up. While the risk of ice jams can be anticipated, they cannot be predicted or forecast. The main focus if ice management in the Grand River watershed is awareness of the potential for ice jams, anticipating when break-up may occur, and monitoring conditions during ice break-up.

Recommendations

1. It is recommended the history of ice monitoring maps and associated reports from 1997 to present be analyzed and the geographic location where ice jams have occurred be organized in the GRCA's GIS system. The creation of this GIS layer would be accomplished with internal staff resources in 2025.
2. Once the coordinates of ice jam locations have been organized, it is recommended that the Municipality-wide flood emergency maps be updated to include known locations of historical ice jams and that updated flood emergency maps be prepared and distributed to municipal Community Emergency Management Coordinators.
3. It is recommended that Table 2 in this report "Chronology of Major Ice Jams Grand River Watershed" be maintained annually to document occurrences of major ice jams and have available for quick reference.
4. It is recommended that a GIS layer of key reaches where RAPS surveillance information would be beneficial be created. The identified reaches would be beneficial to ice management, ice jam documentation and ice jam status reporting. Once created, this GIS layer should be shared with local municipal emergency management staff who coordinate RAPS surveillance. Pre-identifying reaches of interest is intended to assist with optimizing use of RAPS to safely capture ice and ice jam information. The creation of this GIS layer would be accomplished with internal staff resources in 2025.It is recommended that investigation and documentation during and after major ice jams continue as an effort to build ice jam knowledge and understanding in the Grand River Watershed.
5. It is recommended that watershed wide ice conditions maps continue to be created to document ice conditions throughout the winter and ideally immediately prior to anticipated ice breakup.
6. It is recommended that the template used to document ice processes completed for the Port Maitland Dunnville reach in this report be completed for the other high risk ice jam reaches in the Grand River Watershed, including:
    a. Grand River – Dunnville Dam to Cayuga Reach
    b. Grand River – Caledonia Reach
    c. Grand River – Paris Reach
    d. Grand River – Cambridge Blair Reach
    e. Grand River – Cambridge Freeport Reach
    f. Grand River – Conestogo-West Montrose Reach
    g. Grand River –10th Line Reach

    h. Grand River – Grand Valley Reach
    i. Conestogo River – Drayton Reach
    j. Conestogo River – St. Jacob Reach
    k. Speed River – Armstrong Mills–Damby Mills Dam Reach
    l. Eramosa River – Rockwood Reach
    m. Eramosa River – Eden Mills-Cooks Mills Reach
    n. Nith River – New Hamburg Reach
    o. Nith River – Haysville Reach
    p. Nith River – Oxford County-Drumbo Reach

7. The completion of templates for other high risk ice jam locations will be completed over the coming year as time permits. t is recommended that additional river level monitoring be implemented at the following locations to monitor ice movement, and to detect and monitor ice jams:

    a. Grand River at Cayuga
    b. Grand River at Caledonia Dam
    c. Grand River at Brantford Erie Avenue
    d. Grand River at Above Parkhill Dam
    e. Grand River at the East Garafraxa 10th Line Bridge
    f. Grand River at Grand Valley at the Main Street Bridge.

    The anticipated budgetary cost for the above recommendation is an initial cost $12,000 which could be funded from the gauge reserve. It is recommended the purchase and installation of this equipment be completed with internal staff resources in 2025.

8. It is recommended that river level monitoring sensors be implemented at the following existing water quality gauge sites to monitor ice movement, detecting ice jams, and monitoring ice jams:

    a. Grand River at the Blair Water Quality Gauge
    b. Grand River at the Glen Morris Water Quality Gauge

    The anticipated budgetary cost for the above recommendation is an initial cost of $3,000 which could be funded from the gauge reserve. It is recommended the purchased and installation of this equipment be completed with internal staff resources in 2025.

9. It is recommended that additional river camera monitors be considered at the following locations to monitor ice movement and ice jams:

    a. Grand River at Cayuga
    b. Grand River at Caledonia

    The anticipated budgetary cost for the above recommendation is an initial cost of $3,000 which could be funded from the gauge reserve. It is recommended the purchase and installation of this equipment be completed with internal staff resources in the 2025 to 2026 time frame.

10. It is recommended that the aging infrastructure of the current tipping bucket rain gauges be replaced with modern heated tipping bucket rain gauges capable of monitoring both liquid

and frozen precipitation. This recommendation in response to changing climate conditions and trends towards more mid-winter melts. Modern heated tipping bucket rain gauge technology is better equipped to operate through winter and spring conditions. Precipitation observations are a primary input to flood forecasting models and operational decisions. Currently, the GRCA operates 28 rain gauges throughout the watershed.

The anticipated budgetary cost for the above recommendation is an initial cost of $120,000 for the new equipment which could be funded from land sales reserve. It is recommended the purchase and installation of this equipment be completed with internal staff resources over the next three years, during the 2025 to 2027 time frame.

References

Beltaos, S. 1983. River Ice Jams: Theory, Case Studies and Applications. Journal of Hydraulic Engineering, ASCE, Vol. 109(10), pp. 1228-1359

Beltaos, S. 1984a. Study of River Ice Breakup using Hydrometric Station Records, Proceedings of Workshop on the Hydraulics of River Ice, Fredericton, N.B. Canada, pp. 41-59

Beltaos, S. 1987. Ice Jams, IHAS Workshop on River Ice, Vancouver

Frigon, 1981 Ice Jams in the Grand River Basin Unpublished Report

Maclaren Plansearch Lavalin, 1984, Ice Jam Flood Frequency Study, Canada-Ontario Flood Damage Reduction Program

Ministry of Natural Resources and Forestry, November 1984. Ice Management Manual

KGS Group, 2019, Brantford Ice Jam Study

Ecosystem Recovery, 2021, Brantford Ice Jam Mitigation Feasibility Study

Appendix A – Available_Ice_Condition_Maps_1997-2023

3 Supporting Spreadsheets and Informatoin for Ice Management Plan\Appendix A - Available_Ice_Condition_Maps_1997-2023.pdf

Appendix B – Characterization Ice Jam Locations in the Grand River Watershed

3 Supporting Spreadsheets and Informatoin for Ice Management Plan\Appendix B – Characterization Ice Jam Locations in the Grand River Watershed.pdf