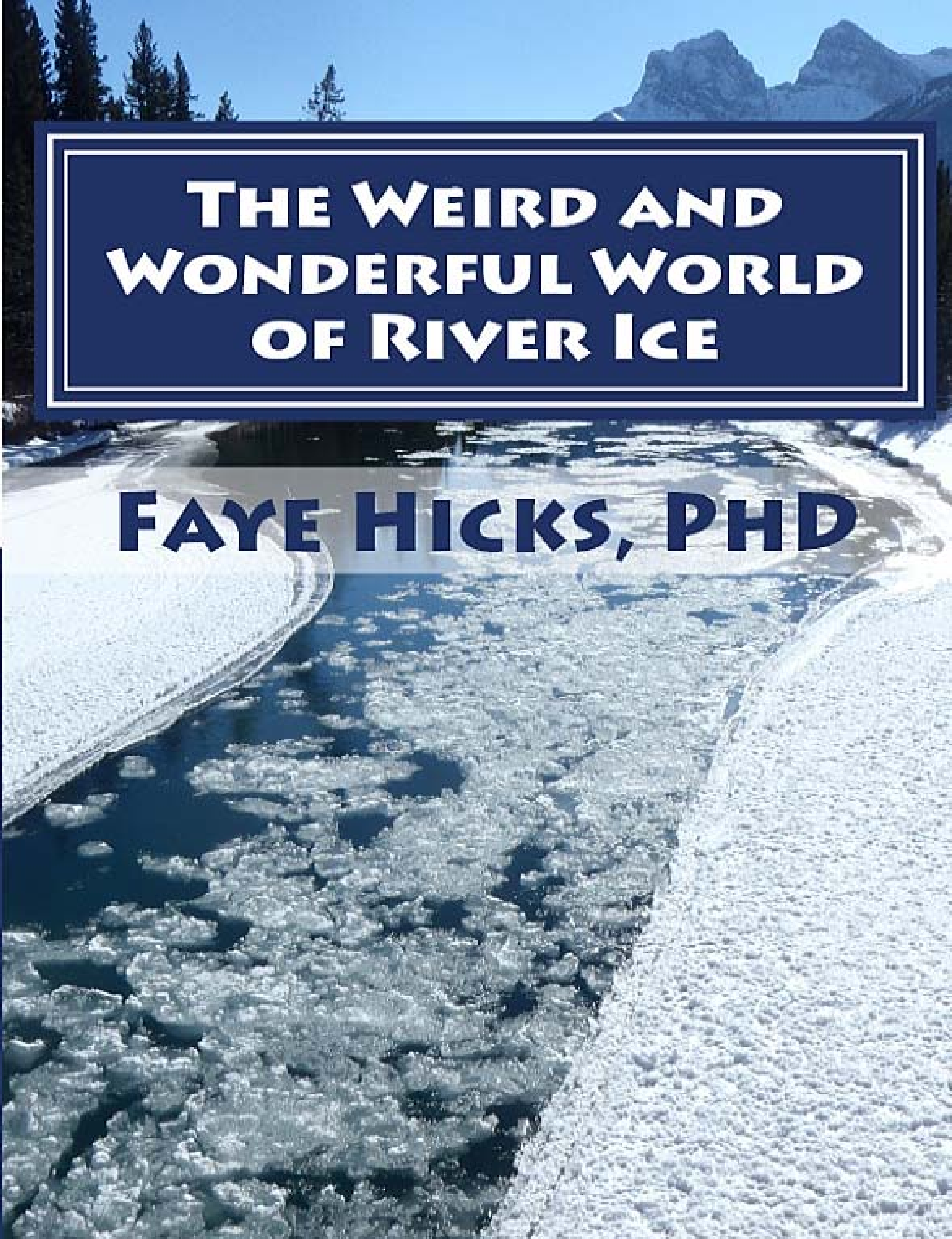
The Weird and Wonderful World of River Ice

Faye Hicks, PhD



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River Ice

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Cover photo by Dr. Mark Loewen:
Freeze-up on the Bow River at Canmore, Alberta.

Author's Notes

River ice affects most streams in the northern hemisphere for many months each winter and is often responsible for severe floods. Not only that, river ice forms in many very strange and wonderful ways, thanks to the complex interactions of cold weather and stream currents. Personally I knew absolutely nothing about river ice until I began working as a river engineer more than 30 years ago, even though I had just completed a degree in civil engineering! So I am not surprised that most people who live in cold climates know very little about how river ice forms, evolves, or decays. For anyone who has ever wondered about this fascinating topic – this book offers an introduction to river ice processes, complete with dozens of beautiful photos. I hope that in reading it, you will come to share my fascination with, and enjoyment of, the weird and wonderful world of river ice.

I'd like to extend my sincere gratitude to the many friends, students, and colleagues who kindly provided pictures for this book. Thank-you for being so generous in sharing your wonderful photos. Most were taken on rivers in Canada, but there are a couple from Alaska, as well. I'd also like to thank my dear friends Sylvia Morice, Julia Blackburn, and Selma Guigard, for kindly agreeing to review and edit this book. Your time and efforts are greatly appreciated.

Thanks for reading and I hope you enjoy learning about river ice!

Faye Hicks
Edmonton, December 2013

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Introduction

You may have noticed that ice covers on rivers and streams form, evolve, and decay quite differently compared to what you typically see on lakes. This difference is mainly because river currents and weather conditions both play significant roles in river ice cover formation and deterioration. The result is a beautiful, complex, and fascinating variety of ice processes. If you've never noticed the interesting ice processes occurring on the rivers near you – read on and find out about the many different ways in which ice comes and goes on our northern rivers. Then start watching your own nearby streams from a safe vantage point – such as from a bridge – and see if you can recognize some of these same ice phenomena.

Water Cooling

Before ice can form in a stream, the river water must first cool to the freezing point (Photo 1). Typical water temperatures in late fall will vary, depending upon the location of the stream, its shape and size, its exposure, and whether flows are controlled by a dam or other engineering structure. Of course it will also depend upon the weather. An interesting fact that most people don't realize is that river water actually *supercools* to just below 0°C during freeze-up.

Photo 1 Before ice can form, the river water must first supercool to just below 0°C.
(North Saskatchewan River, Alberta - photo source: Faye Hicks.)

Border Ice Formation

Skim ice is typically the first ice seen on northern rivers each winter (Photo 2). It forms on the surface of the relatively calm, slow-moving, shallow water along the river banks and around the edges of islands. Skim ice can also form around the edges of sand and gravel bars.

Photo 2 Skim ice observed on the on the Kananaskis River in Alberta.
(Photo courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)

Skim ice coverage increases in extent, growing out from the banks to form *border ice* (Photo 3). Border ice also thickens over time and, as a result, the ice closest to the bank will freeze right to the river bottom. Further out, where the flow is moving faster, border ice can be very thin and fragile. For this reason, it is very dangerous to walk out on border ice.

Photo 3 Border ice observed on the North Saskatchewan River, Alberta.
(Photo courtesy of Tadros Ghobrial.)

Frazil Formation, Flocculation and Floatation

In the turbulent, faster moving portions of the stream, ice is created in the form of *frazil ice* particles. These are very tiny discs of ice that typically range in size from less than 0.1 mm up to about 5 mm in diameter. If you scoop up a bit of frazil ice out of a river (Photo 4), it will look something like ice shavings. Photo 5 shows a close up view of some individual frazil particles photographed under polarized light.

Frazil particles are very 'sticky' in supercooled water, so they tend to group into clusters (Photos 6 and 7). Frazil ice in this state is termed *active frazil* and it also sticks to bed sediments and underwater plants.

Photo 4 Examples of frazil ice particles grown in a lab. *(Photo courtesy of Robyn Andrishak.)*

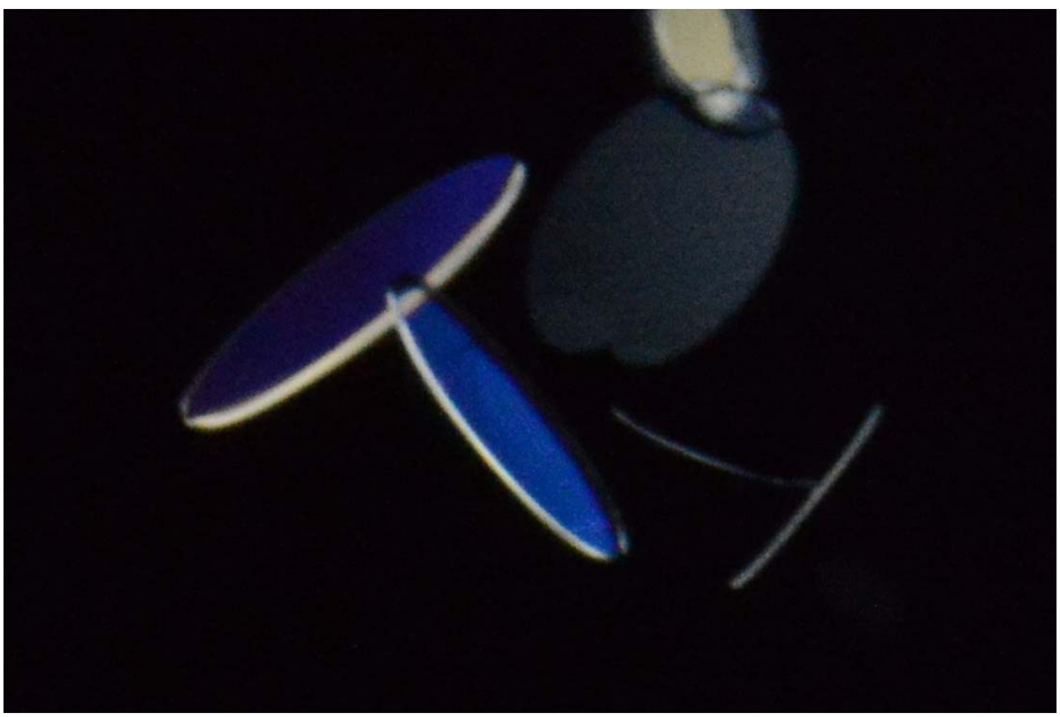


Photo 5 Frazil ice particles photographed in the lab under polarized light. The field of view shown is approximately 4 mm high. *(Photo courtesy of Vincent McFarlane.)*

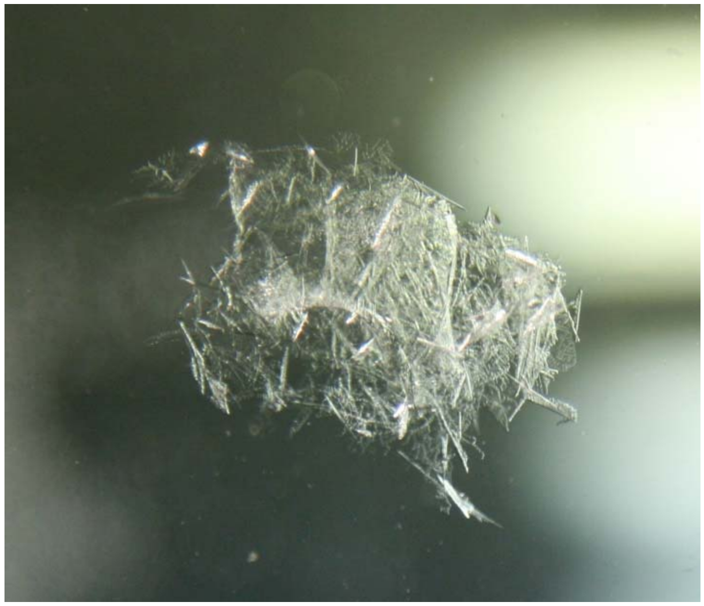


Photo 6 Frazil floc observed in the laboratory. *(Photo courtesy of Tadros Ghobrial.)*

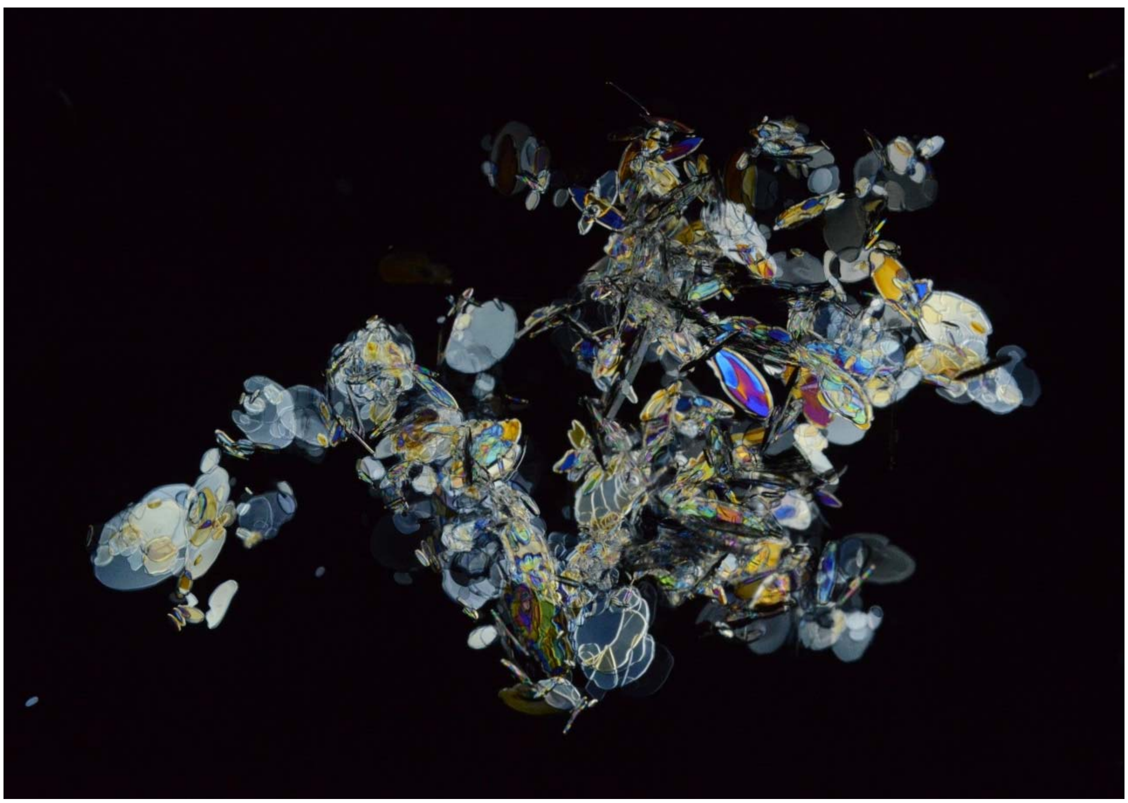


Photo 7 Frazil floc photographed under polarized light, exposing the individual frazil particles. The field of view in this photo is about 2.3 cm high. *(Photo courtesy of Vincent McFarlane.)*

The clusters of frazil increase in size, eventually forming into balls of slush (Photo 8). The frazil slush floats to the water surface where the exposed portion freezes to form *frazil pans* (Photo 9). Frazil pans are also known as *pancake ice* or *pan ice*.

Photo 8 Frazil slush observed on the North Saskatchewan River in Alberta. *(Photo courtesy of Tadros Ghobrial.)*

Photo 9 Frazil pans observed on the North Saskatchewan River in Alberta. *(Photo source: Faye Hicks.)*

As frazil pans drift downstream with the river's currents, they tend to collide with one another along the way, particularly as their numbers increase. These collisions create the rough (bright white) upturned edges seen in Photo 9. Frazil pans may also freeze together edge to edge or when they slide under and over each other. These groupings of frazil pans are called *frazil rafts* (Photo 10). Some of the frazil particles or pans may also collect along the border ice (Photo 11).

Photo 10 Frazil pans and rafts observed on the North Saskatchewan River in Alberta. *(Photo source: Faye Hicks.)*

Photo 11 Frazil pans frozen to the border ice on the North Saskatchewan River in Alberta. *(Photo courtesy of Tadros Ghobrial and Mark Loewen.)*

Anchor Ice

In some cases, ice crystals may develop directly onto sands and gravels on the river bottom. In other cases, active frazil particles may come into contact with the river bottom and become attached to these bed sediments. In gravel bed rivers, where the rocks are sufficiently large to resist the ice buoyancy, the ice will be held (or anchored) on the bed, forming *anchor ice* (Photos 12 to 14).

Photo 12 Anchor ice observed on the Kananaskis River in Alberta.
(Photo courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)

Anchor ice deposits can increase in size as additional frazil ice accumulates, or as ice particles already frozen to the river bottom grow. In small streams, this can result in the formation of anchor *ice dams* that can back up the river's flow (Photos 15 to 17).

Photos 13 and **14** Underwater views of anchor ice observed on the Kananaskis River in Alberta. *(Photos courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)*

Photo 15 Ice dam observed on a small unnamed stream in Nunavut. *(Photo courtesy of Jaime Hogan, Brent Topp, and Sara Gauthier.)*

Photo 16 Ice dam observed on a small tributary of the Kananaskis River in Alberta.
(Photo courtesy of Vincent McFarlane, Jennifer Nafziger, and Stefan Emmer.)

Photo 17 Ice dam observed on the Kananaskis River in Alberta.
(Photo courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)

Anchor ice can accumulate in sufficient quantities to lift sediment particles right off the stream bed and float them up to the surface (Photo 18). This process is called *sediment rafting*, and the ice carrying these particles of sand and gravel eventually forms part of the river's ice cover. Sediment rafting explains why particles of sand and gravel are often found embedded in river ice covers (Photo 19). Vegetation can also be incorporated into the ice cover in this same way (Photo 20). Anchor ice and anchor ice dams can also separate from the rocks on the river bed and float downstream. This sometimes happens on bright winter mornings, when the sun's energy heats the rocks very slightly and the freezing bond is broken. Sudden flow changes can also cause anchor ice to release.

Photo 18 Result of sediment rafting seen on the Kananaskis River in Alberta. This rock had come to rest on top of some anchor ice further downstream.
(Photo courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)

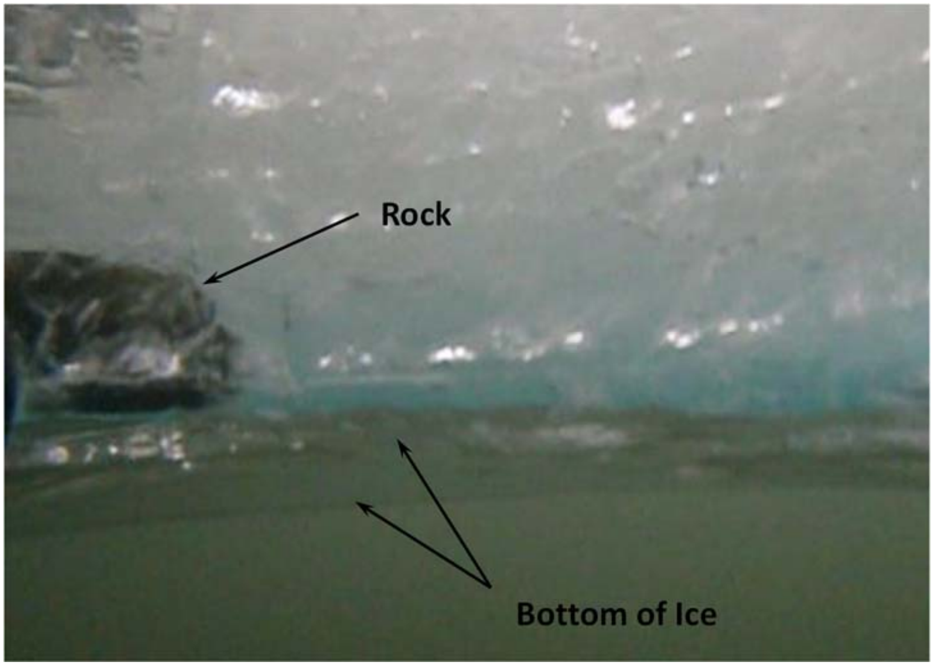


Photo 19 Example of a rock embedded in a river ice cover.
(North Saskatchewan River photo source: Faye Hicks.)

Photo 20 Example of a layer of vegetation embedded in a river ice cover.
(Mackenzie River photo source: Faye Hicks.)

Bridging of Frazil Pans

As freeze-up progresses, more and more frazil pans and rafts form. At the same time the extent of border ice increases, extending further and further out into the channel (Photo 21).

Photo 21 Freeze-up on the Bow River in Alberta. *(Photo courtesy of Mark Loewen.)*

As the surface concentrations of frazil pans increase beyond about 80 to 90%, surface ice *congestion* and *bridging* become likely. As the frazil pans and rafts pack in tightly, they stop moving downstream. Typical bridging locations are at tight bends and at locations where the channel narrows, such as between bridge piers or at natural constrictions. Border ice growth can enhance or create constrictions that may also serve as bridging points. Photo 22 illustrates such a site.

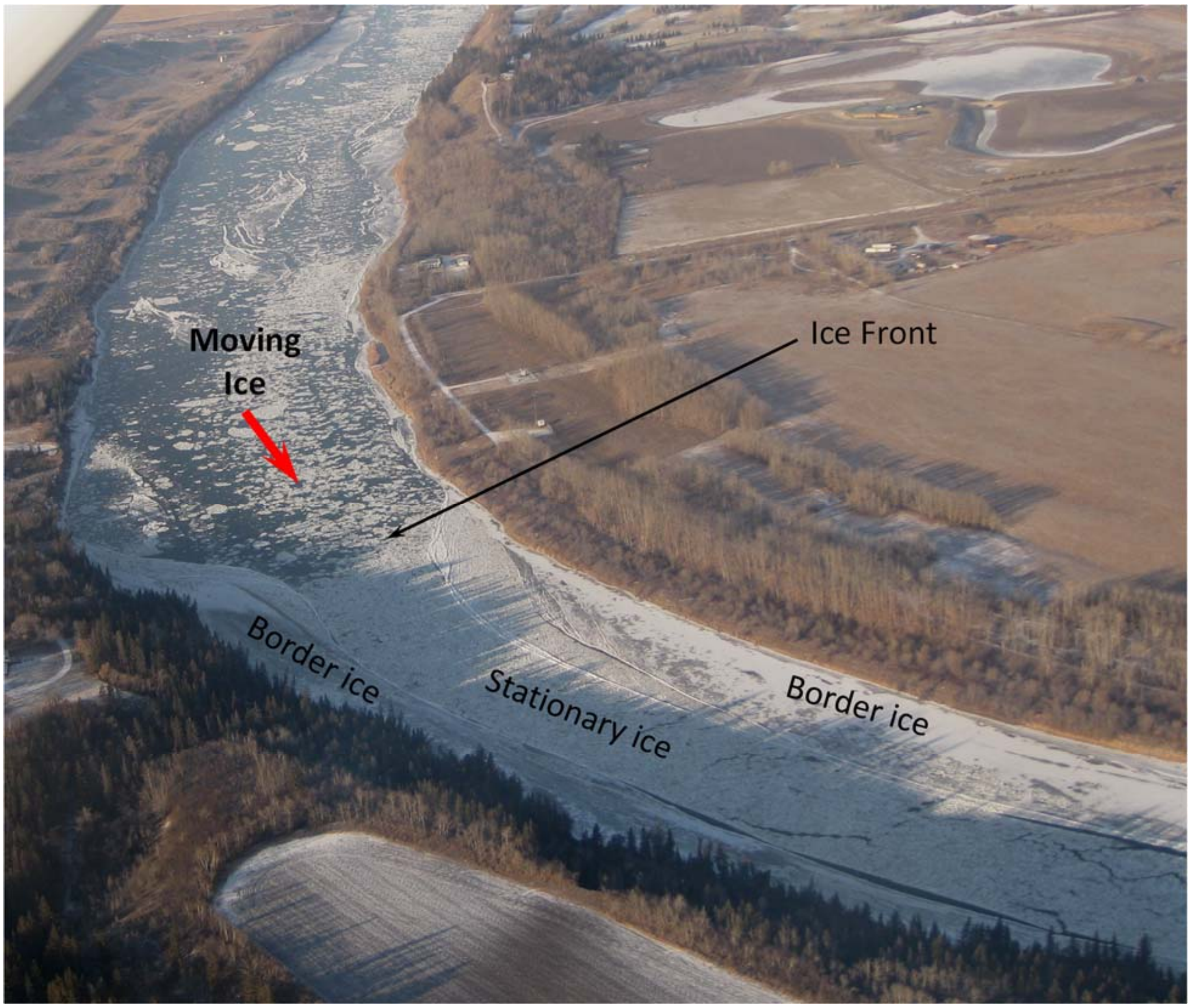


Photo 22 Natural constrictions, and those enhanced by border ice encroachment, present likely spots for bridging to occur.
(North Saskatchewan River, Alberta - photo courtesy of Tadros Ghobrial and Mark Loewen.)

Juxtaposed Ice Covers and Frontal Progression

Incoming ice floes will tend to accumulate upstream of the bridging point, causing an ice front to progress upstream in a manner similar to cars backing up in a traffic jam. This process is known as *frontal progression*. The frazil pans and rafts may accumulate edge to edge on the water surface, creating a *juxtaposed ice cover* (Photo 23) or, if the current is sufficiently strong, the surface ice may be swept under the ice front and then deposited on the underside of the cover in a process known as *hydraulic thickening*. The increased thickness obstructs the flow and slows the river current. Once the current slows sufficiently, ice floes will no longer be swept under the ice cover and the ice front can continue its upstream progression. In extreme cases, velocities may be high enough that the entire ice cover formed at the bridging site may be swept downstream, after which bridging must reoccur before frontal progression of the ice cover can resume.

Photo 23 Example of a juxtaposed ice cover observed on the Athabasca River, Alberta. *(Photo source: Faye Hicks.)*

Hummocky Ice Covers and Freeze-up Ice Jams

A river ice cover is relatively fragile in these initial formation stages and so it is very prone to collapsing into a jumbled mass known as a *hummocky ice cover* (Photo 24). A collapse of the ice cover is especially likely in cases where the river current is strong or when the ice front is progressing quickly upstream. This collapse (or *consolidation*) of the ice creates a very thick and rough ice cover that can severely block the river's flow. Consequently, ice levels can get very high and flooding can result. If this happens, the hummocky ice cover is called a *freeze-up ice jam*.

Photo 24 A hummocky ice cover formed during freeze-up on the Bow River in Alberta. *(Photo courtesy of Julia Blackburn and Twyla Hutchison.)*

After an ice cover has been in place for a while, the water between the ice floes freezes. This freezing strengthens the ice accumulation, making it less likely to collapse. Freezing of the water in the pores of the frazil slush lying underneath the ice cover also adds strength. However, a spell of unusually warm weather or rapid changes in water levels can destabilize it again.

Ice Cover Growth and Snow Ice

The change in phase from water to ice actually releases heat, which in turn warms the water slightly. This warming means that further supercooling cannot occur unless there is some heat loss from the water surface. Heat loss cannot occur if an ice cover forms on the water surface and therefore, once the ice has covered the entire water surface, local frazil production stops. At this point, cold weather will cause the ice cover to thicken by *thermal growth*, in a manner similar to what happens as the ice cover thickens on a lake. Snow insulates the ice cover from the cold air above. Therefore, thermal growth slows down as the snow on the ice cover gets deeper.

Snow on the ice cover can also create a thicker ice cover. When the snow cover is heavy enough, it can weigh down the ice cover so that the top of the ice pushes below the water. Water then seeps up through cracks in the ice and saturates the lower layers of the snow. This wet snow then freezes to form a very milky-colored ice called *snow ice* (Photo 25).

Photo 25 Snow ice layers exposed in broken sheet ice on the Peace River, Alberta. (*Photo source: Faye Hicks.*)

Photo 26 shows a typical ice core taken out of a river – it illustrates all of the resulting ice layers. In the center of the sample is the frazil ice which formed first. Frazil ice can be distinguished by the fact that it contains particles of sediment, picked up from the bed before the frazil flocculated sufficiently to float to the surface. To the left, which is the top of the ice core sample, is the snow ice with its characteristic milky white appearance. To the right, which is the bottom of the ice, is the extremely transparent thermal ice.

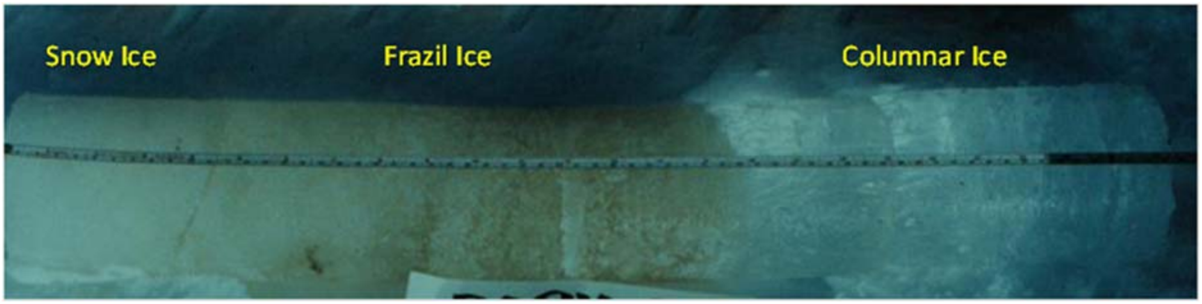


Photo 26 Ice core sample from the Mackenzie River, illustrating the various ice layers typically found within a river ice cover. *(Photo source: Faye Hicks.)*

Thin slices of river ice, called *thin sections*, can be examined under polarized light to reveal the unique crystal structures that correspond to these various ice types (Photo 27). Snow ice and frazil ice are seen to have very small, roughly circular crystals. In contrast, thermal ice grows in long columnar grains.

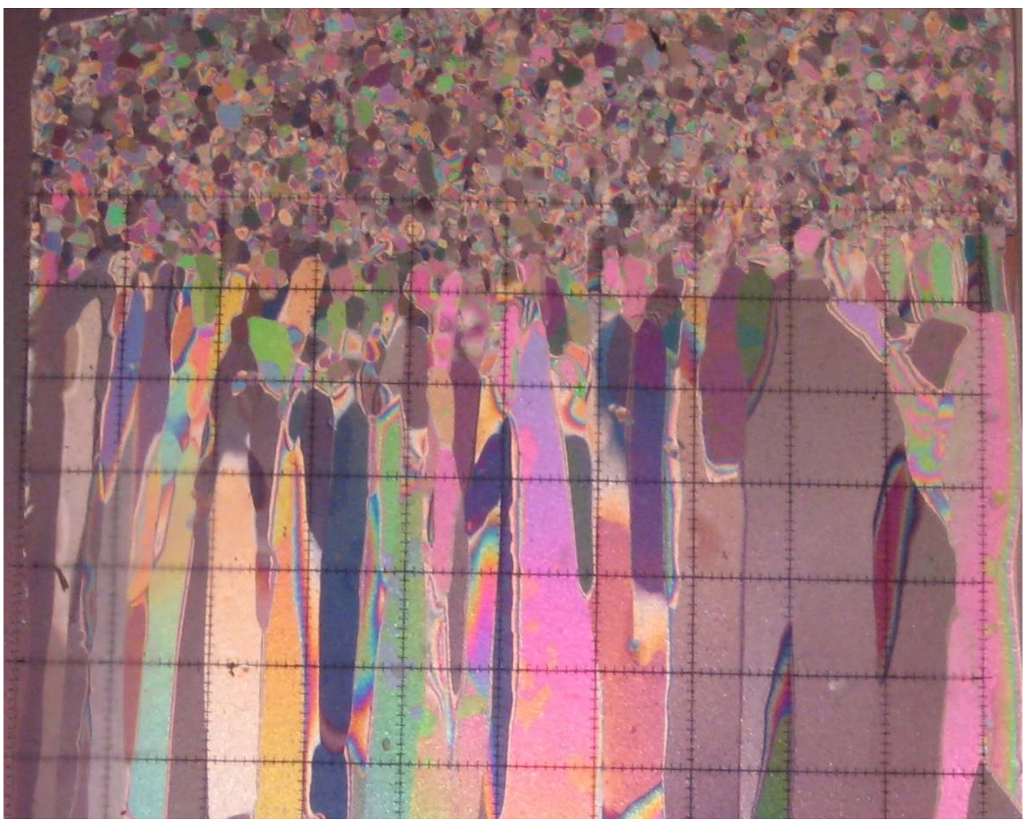


Photo 27 A *thin section* sample of ice from the North Saskatchewan River, Alberta, observed under polarized light to expose the crystal structure. The grid squares are 1 cm x 1cm. *(Photo source: Faye Hicks.)*

Other Ice Formation Processes

Aufeis

In some streams, winter flows are extremely low and the flow is sufficiently shallow for the river to freeze right to the bed. Subsequent flow can push through cracks in the ice up onto the surface (Photo 28), freezing in successive layers each superimposed upon the previous. The resulting ice formation is termed *aufeis* which is German for ‘ice on top’. This type of ice is also well known by its Russian name, *naled*, and is sometimes referred to as an *icing*.

Photo 28 Water flooding the ice surface and freezing to form aufeis on Jarvis Creek, Alaska. *(Photo courtesy of Steven Daly.)*

Over the course of the winter, the extent and thickness of aufeis can be substantial, and can cause flooding (and aufeis formation) onto the floodplain (Photo 29). Small tributaries and springs can also be a source of aufeis deposits on river ice covers (Photo 30).

Photo 29 Aufeis observed in the floodplain along Jarvis Creek, Alaska.
(Photo courtesy of Steven Daly.)

Photo 30 Groundwater from springs can spread onto the ice cover to form aufeis.
(Athabasca River, Alberta, photo source: Faye Hicks.)

Aufeis can also form inside highway culverts, creating *culvert icing*s (Photo 31). These ice blockages often occur on streams with very small winter flows. This culvert icing happens because the steel pipe is very effective at conducting away heat, and so the water cools and freezes to the inside of the pipe. Subsequent flows have to push up on top of that ice and this water freezes, too. Over the winter, the ice builds up, layer by layer, and can eventually fill the entire pipe. Culvert icings are a common cause of culvert washout in northern Canada. These washouts typically occur during the spring snowmelt when flows are relatively high. The water backs up behind the blocked culvert until it eventually overtops, and washes out, the road.

Photo 31 Example of culvert icing on small unnamed creek in northern Alberta. *(Photo source: Faye Hicks.)*

Granular Ice or Marble Ice

Another interesting ice formation process occurs when frazil pans pass through river rapids. The delicate ice pans break up into pieces that can then be transported over dozens of kilometers under the downstream ice cover. As the pieces of ice tumble along the underside of the ice cover, they become rounded through abrasion against other similar ice particles, just as gravel on a riverbed is rounded during transport by abrasion against other rocks. Photo 32 illustrates the resulting *granular ice* formed by this process. Some river ice specialists call this *marble ice*, because of its size and appearance.

Photo 32 Granular ice observed on the Athabasca River in Alberta. *(Photo courtesy of Kristel Unterschultz.)*

Ice Circles

Another interesting freeze-up phenomenon is the occurrence of *ice circles* or *ice discs* (Photos 33 and 34). These typically occur where the stream currents have to curve around a river bend, especially in places where large surface eddies result. Curved or swirling flow paths create a curved drag force on the underside of the developing border ice. If the ice is really thin and frail, then the ice cover will break up and be washed away with the flow. If the ice cover is thick and strong, then it will withstand this rotational force and nothing will happen. However, if the ice is weak enough to be fractured but not weak enough to break up completely, then an ice disc may form (Figure 35). The rotating ice grinds against the remaining (shorefast) ice – rounding the edges and making the disk almost perfectly round. Some river ice specialists refer to these ice discs as *pizza ice*.

Ice discs can also form when frazil pans and rafts get caught in a river eddy. As more and more pans are trapped, they freeze together and eventually form one very large rotating raft, grinding against the stationary ice to create the disc shape.

Photo 33 Rotating ice disc observed on the Exploits River in Newfoundland. *(Photo courtesy of Rod Baird.)*

Photo 34 Closer view of the Exploits River ice disc in Newfoundland. Note the blue barrel on the bank to get an idea of the scale. *(Photo courtesy of Rod Baird.)*

Photo 35 Ice disc seen on the Ram River in Alberta. *(Photo courtesy of Rich Brown.)*

Ice Balls, Flowers, and Trumpets

On streams where water levels vary frequently and substantially – for example downstream of hydro-dams and in some tidal estuaries – additional, unique ice formations are sometime observed. For example, ice can be left stranded in shelves suspended over the water (Photo 36) and, if a brief warm spell happens, some pretty strange ice formations result. Photos 37 to 41 show some of my favorite examples from the Kananaskis River in Alberta. This river is regulated for hydropower production and so it experiences very dramatic water level variations every day. Many bizarre and beautiful ice formations develop as a result.

Photo 36 Ice shelf stranded at low flow on the Kananaskis River in Alberta. Notice the bark missing from the tree, indicating that this is a common occurrence.
(Photo courtesy of Stefan Emmer, Jennifer Nafziger, and Vincent McFarlane.)

Photo 37 Anchor ice exposed at low flow on the Kananaskis River in Alberta.
(Photo courtesy of Vincent McFarlane, Jennifer Nafziger, and Stefan Emmer.)

Photo 38 Ice balls seen on the Kananaskis River in Alberta.
(Photo courtesy of Vincent McFarlane, Jennifer Nafziger, and Stefan Emmer.)

Photo 39 Ice trumpets seen on the Kananaskis River in Alberta.
(Photo courtesy of Vincent McFarlane, Jennifer Nafziger, and Stefan Emmer.)

Photo 40 Ice stalactite on the underside of an ice shelf in the Kananaskis River in Alberta. *(Photo courtesy of Jennifer Nafziger, Stefan Emmer, and Vincent McFarlane.)*

Photo 41 Ice flower and ice leaf seen on the Kananaskis River in Alberta. *(Photo courtesy of Jennifer Nafziger and Stefan Emmer.)*

Winter Ice

The winter ice cover can sometimes be stark and featureless; however, just as often it can be incredibly beautiful. Waterfalls are especially stunning in winter. The one shown in Photo 42 is about 30 m high (~100 feet). It is awe-inspiring to see such a powerful natural force stopped entirely.

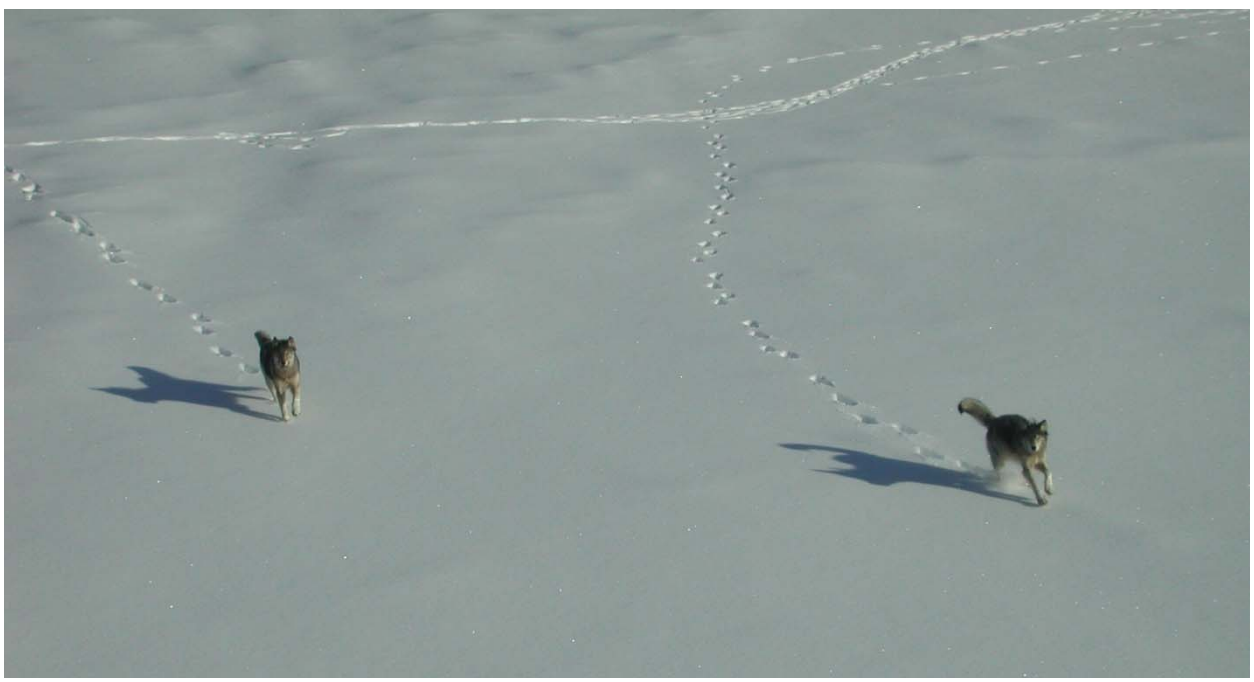
Photo 42 Winter view of Alexandra Falls on the Hay River in the Northwest Territories. *(Photo source: Faye Hicks.)*

Even the flatter stretches of a river can be beautiful in the quiet stillness of winter. All other sensory distractions are muted, allowing you to focus entirely on the visual experience (Photo 43). Hummocky ice covers, smoothed by wind and blowing snow, look like a sea of frozen waves or a moonscape (Photo 44).

Both humans and animals use the ice cover as a transportation corridor in winter. Upstream of Fort McMurray in Alberta – wolves are often seen hunting on the ice cover (Photos 45 and 46).

Photo 43 The Athabasca River in Alberta. Note the surface texture of the ice cover. *(Photo source: Faye Hicks.)*

Photo 44 Ground view of hummocky ice cover in winter, Athabasca River, Alberta. *(Photo source: Faye Hicks.)*



Photos 45 and **46** Wolves are often seen on the Athabasca River ice cover in winter.
(Photo source: Faye Hicks.)

The Breakup Period

Eventually spring comes and our northern rivers and streams are released from their winter bonds. On some rivers, the breakup period is relatively innocuous – the ice just sits and melts in place (Photo 47). This is called a *thermal breakup*.

Photo 47 Thermal breakup on the Athabasca River, Alberta.
(Photo source: Faye Hicks.)

Candle ice is a common feature seen along the river banks as the river ice melts. Because ice melts first at its crystal boundaries – the columnar ice is separated into long slender ice crystals that look like candles (Photo 48). Columnar ice can melt into some pretty weird shapes as the candles form (Photo 49). Sometimes the candle ice is carried downstream with the flow as the river opens up. When this happens – you can hear a magical, tinkling sound as the ice candles clink against each other. For many people who live in northern countries, this musical sound is a welcome harbinger of spring.

Photo 48 Candle ice seen on the Mackenzie River, Northwest Territories.
(Photo source: Faye Hicks.)

Photo 49 Candle ice seen in the Mackenzie Delta, Northwest Territories.
(Photo source: Faye Hicks.)

Spring is also when the snow melts and, if the snowpack is deep, a pretty big wave of snowmelt water can occur in the streams and rivers receiving this runoff. This *spring freshet* typically causes faster currents under the ice and open leads develop in the ice cover (Photo 50). Water may also be forced up onto the ice cover through these open leads if water levels are rising quickly (Photos 50 and 51).

Photo 50 Open leads developing in the Mackenzie River during breakup. The green areas on the ice cover are water, pushing up through the open leads and overflowing onto the downstream ice cover. *(Photo source: Faye Hicks.)*

Photo 51 View of overflow from ground level – Athabasca River, Alberta.
(Photo source: Faye Hicks.)

As rising water levels put pressure on the ice cover to float upwards, *hinge cracks* will form along the river banks and the main ice sheet will then be free to float upwards with the rising water. The ice still attached along the river banks will become submerged by the rising water, and will melt away quickly. Shortly after, *transverse cracks* will start forming in the ice cover (Photo 52). At this point, the remaining ice is in discrete sheets that are free to be carried along with the river flow.

At first, the movement of these ice sheets will be constrained by the river's shape, since they will be too big to maneuver around the bends (Photo 52). Therefore, much of the ice movement consists of the ice sheets pushing against each other and ridging (Photo 53). During this ridging process, the ice sheets may break into smaller pieces. Eventually, as the sheets break up and the water levels continue to rise, *ice clearing* begins (Photo 54). Ice clearing signals the onset of a *dynamic breakup*, one in which ice is carried on the snowmelt wave. In a dynamic breakup, ice jam formation and release events are likely to occur (Photos 55 to 57).

Photo 52 Here in the Mackenzie Delta, the ice along the river banks has melted away and transverse cracks have formed. However, most ice sheets are still too big to maneuver around the river bends. *(Photo source: Faye Hicks.)*

Photo 53 Ice sheet ridging on the Athabasca River in Alberta. *(Photo source: Faye Hicks.)*

Photo 54 Ice clearing on the Athabasca River in Alberta.
(Photo source: Faye Hicks.)

Photo 55 Ice jam on the Hay River, Northwest Territories.
(Photo courtesy of Robyn Andrishak.)

Photo 56 Ice jam on the Hay River, Northwest Territories.
(Photo source: Faye Hicks.)

Photo 57 Aerial view of ice jams around Vale Island at Hay River, Northwest Territories.
(Photo source: Faye Hicks.)

Ice jam events are particularly dangerous as they can cause very high water levels and severe flooding with little advance warning (Photo 58). Buildings can be swept right off their foundations as ice pushes up onto the banks (Photo 59).

Photo 58 Ice jam flooding along the Hay River, Northwest Territories. The arrow indicates the location of the damaged building shown in the next photo. *(Photo source: Faye Hicks.)*

Photo 59 Closer view of the building damaged when sheets of ice were pushed ashore. *(Photo source: Faye Hicks.)*

Eventually, ice jams either melt out or release. If they release, then a violent *ice run* results, with the wave of ice and water rushing downstream at terrifying speeds (Photo 60).

Photo 60 Ice run following ice jam release event on the Athabasca River in Alberta . Flow is from left to right – notice the ice jam reforming further downstream.
(Photo source: Faye Hicks.)

When an ice jam releases, the ice out in the middle of the channel is carried away quickly because of the faster currents there. In contrast, the ice closer to the river banks is usually grounded and cannot move easily. This difference sets up a shearing interface between the moving ice and the grounded ice (Photo 61). Once the moving ice leaves, *remnant ice* is left behind in strips along the river banks (Photo 62). This remnant ice has a near vertical inner face which is called a *shear wall* (Photo 63). Remnant ice typically takes several weeks to melt (Photo 64).

Photo 61 Shearing interface seen on the Hay River in the Northwest Territories. *(Photo source: Faye Hicks.)*

Photo 62 Remnant ice left behind after ice jam release on the Hay River in the Northwest Territories. *(Photo source: Faye Hicks.)*

Photo 63 The steep inner face on the remnant ice is called a shear wall.
(Hay River, Northwest Territories - photo source: Faye Hicks.)

Photo 64 After breakup, the remnant ice along the river banks must still melt before the river is completely ice free. *(Hay River, Northwest Territories - photo source: Faye Hicks.)*

Eventually the remnant ice does melt away and the stream is once again completely free of ice (Photo 65). However, evidence of the ice can still be seen, since the tree line – which is set well back from the water's edge – clearly marks the edge of the active ice zone.

Photo 65 The effects of river ice are still visible along the river banks in summer, as only grass has time to get established in the active ice zone.
(Hay River, Northwest Territories - photo courtesy of Jennifer Nafziger.)

Summary

I hope you've enjoyed learning about the weird and wonderful world of river ice, and that you're now inspired to go out and witness these many amazing phenomena for yourself. Please remember to do it safety and never venture onto an ice cover. River ice is extremely dangerous and even in the coldest winters there can be spots where strong currents prevent a safe ice cover from forming. So enjoy the river ice from safe vantage points on the banks or from a bridge; always go with a friend; and always be sure to tell someone at home where you are going and when you'll be back. And if you do happen to capture something really amazing or beautiful with your camera – I'd love to hear about it!

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