Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A20Q0015

CONTROLLED FLIGHT INTO TERRAIN

Service aérien gouvernemental of Quebec
Bell 206L-4 (helicopter), C-GSQA
Lac Saint-Jean, Quebec
22 January 2020

Canada

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Transportation Safety Board of Canada
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741; 1-800-387-3557
www.tsb.gc.ca
communications@tsb.gc.ca

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Summary

On the morning of 22 January 2020, 2 helicopters operated by Quebec's Service aérien gouvernemental took off from the Montréal/St-Hubert Airport (CYHU), Quebec, at 0750 Eastern Standard Time, bound for Saint-Henri-de-Taillon, Quebec, to provide air support to a search for snowmobilers who had been reported missing the day before.

Early in the afternoon, one of the 2 helicopters, the Bell 206L-4 (registration C-GSQA, serial number 52060), was released from this assignment, and the pilot, alone on board, took off from Saint-Henri-de-Taillon at 1402, bound for the La Tuque Aerodrome (CYLQ), Quebec. Approximately 7 minutes after takeoff, the helicopter struck the frozen, snow-covered surface of Lac Saint-Jean. The aircraft was destroyed but there was no post-impact fire. Despite serious injuries, the pilot was able to egress from the aircraft and call the Service aérien gouvernemental dispatcher to report the accident.

The dispatcher notified the pilot of the 2nd helicopter involved in the search. That pilot went to the scene of the accident accompanied by 2 first responders. The helicopter landed at approximately 1445, then took off again to evacuate the injured pilot to the hospital in Roberval, Quebec.

The emergency locator transmitter in the occurrence helicopter activated. The signal was detected by the Canadian Mission Control Centre in Trenton, Ontario, at 1410:34.

1.0 FACTUAL INFORMATION

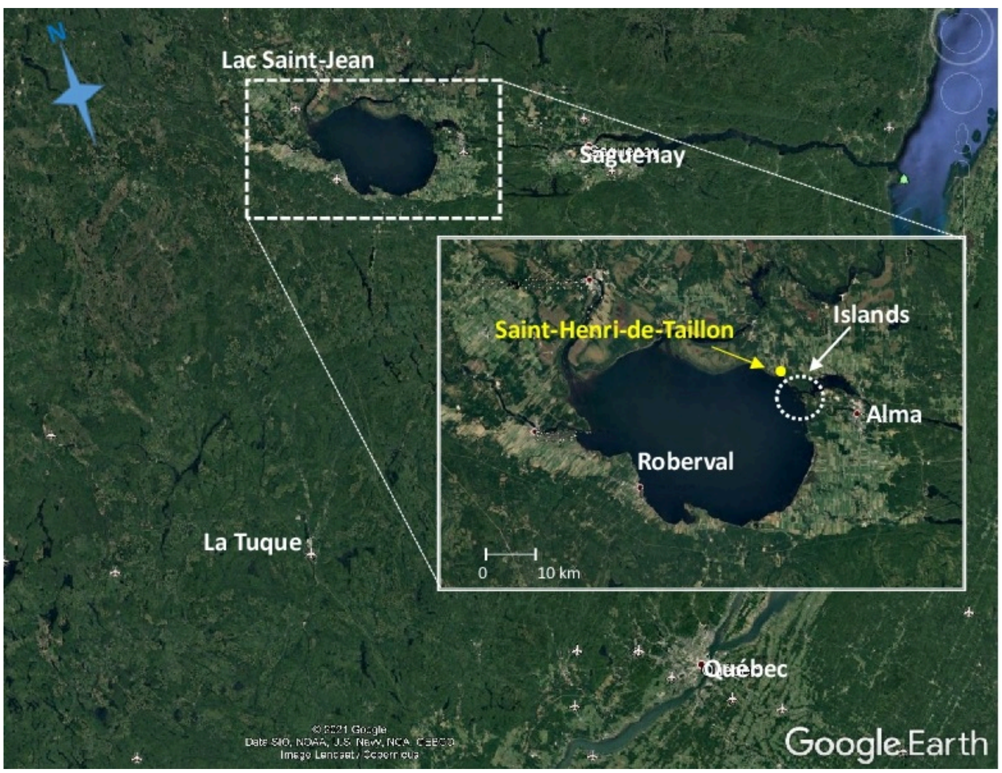
1.1 History of the flight

At approximately 0600[1] on the morning of 22 January 2020, Quebec's Service aérien gouvernemental (SAG) dispatcher contacted the occurrence helicopter pilot to tell him that he needed to fly to Saint-Henri-de-Taillon, Quebec, with another helicopter to provide air support to a search for snowmobilers who had been reported missing the day before. The pilot completed the pre-flight planning and loaded the necessary rescue equipment into the Bell 206L-4 helicopter (registration C-GSQA, serial number 52060).

The 2 SAG helicopters took off from the Montréal/St-Hubert Airport (CYHU), Quebec, at 0750, each with the pilot and 1 passenger on board. They stopped at the La Tuque Aerodrome (CYLQ), Quebec, to refuel, and arrived at their destination at 1025.

From 1130 until 1219, the occurrence pilot conducted searches at very low altitude, less than 100 feet above the frozen surface of Lac Saint-Jean, in the vicinity of the islands near La Grande Décharge Lake (Figure 1).

Figure 1. Map of the general area of the occurrence, with magnification in box (Source: Google Earth, with TSB annotations)



Once the searches were done, the pilot went to refuel at the Alma Airport (CYTF), Quebec, where he landed at 1230, before returning to Saint-Henri-de-Taillon and touching down at 1325.

1 All times are Eastern Standard Time (Coordinated Universal Time minus 5 hours).

Early in the afternoon, given that only one aircraft was required to continue the search, and given that the rear sliding door of the occurrence helicopter was difficult to close, it was decided to send the aircraft back to CYHU.

The pilot, the sole occupant of the aircraft, took off at 1402 bound for CYLQ, intentionally keeping a low speed to stay under the maximum speed allowed for an open sliding door (90 knots) in case the door accidentally opened in flight. Approximately 7 minutes after takeoff, the helicopter struck the frozen, snow-covered surface of the lake and came to rest on its left side. The aircraft was destroyed but there was no post-impact fire.

At the time of the impact, the pilot believed that he was in cruise flight at approximately 500 feet above ground level (AGL) when he suddenly felt a rapid longitudinal deceleration, heard the engines surge, and became disoriented by a perceived rotation to the left.

Although he was seriously injured, the pilot was able to egress from the aircraft and call the dispatcher to report the accident. At 1412, the dispatcher called the pilot of the 2nd helicopter, who had remained at Saint-Henri-de-Taillon, and asked him to rescue the injured pilot. Two Sûreté du Québec (SQ) first responders were notified and accompanied the rescue pilot. The aircraft touched down at the accident site at 1445. It then took off again at 1500 with the injured pilot on board and headed to the Roberval Airport (CYRJ), Quebec, where an ambulance was waiting to take the injured pilot to the city's hospital.

The Canadian Mission Control Centre in Trenton, Ontario, received a distress signal from the emergency locator transmitter (ELT) at 1410:34 and notified the Joint Rescue Coordination Centre (also in Trenton), which sent a Griffon helicopter to the accident site. The helicopter landed at 1504 and waited for police to arrive.

1.2 Injuries to persons

The pilot was the sole occupant of the helicopter.

Table 1. Injuries to persons

Degree of injury	Crew	Passengers	Persons not on board the aircraft	Total by severity of injury
Fatal	0	–	–	0
Serious	1	–	–	1
Minor	0	–	–	0
Total injured	1	–	–	1

1.3 Damage to aircraft

The aircraft was destroyed by the impact with the frozen surface of Lac Saint-Jean.

1.4 Other damage

Not applicable.

1.5 Personnel information

Table 2. Personnel information

	Pilot-in-command
Pilot licence	Airline transport pilot licence — helicopter (ATPL)
Medical expiry date	01 March 2020
Total flying hours	7291
Flight hours on BH06 (BH06T)*	1050 (158.3)
Flight hours in the 7 days before the occurrence	0
Hours on duty before the occurrence	8.3
Hours off duty before the work period	17

*A BH06 rating applies to all Bell 206 single-engine models, while the BH06T rating applies to the Bell 206 twin-engine models.

The pilot held an airline transport pilot licence — helicopter, endorsed with night flying and Group 4 instrument ratings, for which he had received initial training and renewal training in 2019. He had been working for the SAG since 2005. He had received flight training on the occurrence aircraft on 25 September 2019 as part of the annual pilot training given by the SAG. The pilot held the licence and qualifications required for the flight in accordance with existing regulations.

1.6 Aircraft information

Table 3. Aircraft information

Manufacturer	Bell Textron Canada Ltd.
Type, model and registration	Bell 206L-4 (twin-engine conversion), C-GSQA
Year of manufacture	1994
Serial number	52060
Certificate of airworthiness issue date	25 April 1994
Total airframe time	5883.25
Engine type (number of engines)	Turbine Rolls-Royce 250-C20R (2)
Rotor type (number of blades)	Semi-rigid rotor (2)
Maximum allowable take-off weight	4550 lbs (2064 kg)
Recommended fuel type(s)	Jet A, A-1, B
Fuel type used	Jet A-1

The SAG had purchased this aircraft in 1994. It was new and had been modified in accordance with Supplemental Type Certificate (STC) SH01-30 approved by Transport Canada (TC). This STC includes the installation of 2 Rolls-Royce 250-C20R engines and a combining gearbox.

Technical records indicate that in December 2019, the main transmission gearbox and the combining gearbox were removed as part of a scheduled overhaul at an approved workshop. The SAG took advantage of this overhaul to inspect the main rotor mast, the

2 engines, and several other components. At the time of the accident, the aircraft had completed 8.5 flight hours since being returned to service on 20 December 2019, with no deficiencies having been identified.

Technical records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations.

1.6.1 Altimeters

The aircraft was equipped with a radio altimeter and a conventional altimeter.

The radio altimeter transmits a radio signal to the ground and receives the return from the same signal after it is reflected off the ground. It measures the time elapsed between the transmission and reception of the radio signal to calculate the aircraft's height AGL,[2] which is then indicated on the dial.

A decision height selector bug allows the pilot to choose a minimum height (Figure 2). If the aircraft descends below the selected minimum height, a light illuminates and an alarm sounds to notify the pilot. The decision height selector bug on the radio altimeter found at the accident site was set to 0 feet.

Figure 2. Radio altimeter on the occurrence aircraft (Sources: TSB [main image] and manufacturer's brochure [inset image])

Unlike the radio altimeter, the conventional altimeter uses the current atmospheric pressure to obtain an altitude indication above sea level (ASL) rather than AGL. Given that atmospheric pressure constantly changes, for the altitude indication to be accurate, the altimeter must be manually calibrated on a regular basis using the current local atmospheric pressure. If the atmospheric pressure value used to set the altimeter (altimeter setting) is higher than the actual atmospheric pressure, the indicated altitude will be overestimated,[3] and vice versa.

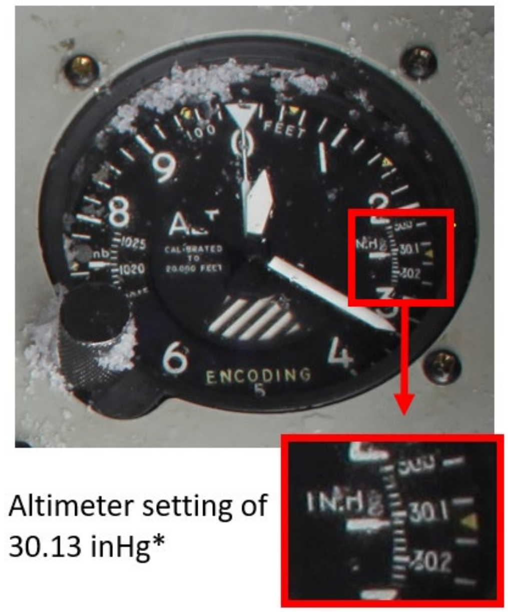
[2] Precision is ±5 feet from 50 to 100 feet and ±5% from 100 to 500 feet.

[3] A value of 0.01 inches of mercury (inHg) corresponds to 10 feet.

The altimeter setting on the occurrence aircraft's conventional altimeter read 30.13 inches of mercury (inHg) (Figure 3). The atmospheric pressure at CYTF at the time of the accident was 30.08 inHg, which represents a 50-foot overestimation of the indicated altitude.

Tests performed on the conventional altimeter at the TSB Engineering Laboratory in Ottawa, Ontario, showed that the margin of error for the altitude indication was 20 feet or less for simulated altitudes below 500 feet, which is within the allowable margin of error for the instrument according to *Canadian Aviation Regulations* (CARs) Standard 571.[4]

Figure 3. Conventional altimeter on the occurrence aircraft (Source: TSB)



*corrected for parallax error

1.7 Meteorological information

The "Clouds and Weather" graphic area forecast issued at 1231 was valid as of 1300 and forecast the following weather conditions for Lac Saint-Jean:

- visibility greater than 6 statute miles (SM);
- broken clouds at 3000 feet, with tops at 5000 feet ASL; and
- surface winds from the southwest at 15 knots, gusting to 25 knots.

The "Icing, Turbulence and Freezing level" graphic area forecast for the same period was forecasting a 60-knot low-level jet stream causing moderate turbulence, and the possibility of moderate mixed icing due to local freezing drizzle from the surface to 3000 feet ASL.

The aerodrome routine meteorological reports (METARs) from the weather stations at CYRJ and Bagotville Airport (CYBG), Quebec, were the available reports closest to the accident site, 16 nautical miles (NM) to the west and 36 NM to the east, respectively. The weather conditions reported at these 2 stations at 1400 are listed in Table 4.

[4] Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Part V, Standard 571, Appendix B – Altimeter System Test and Inspection.

Table 1. Weather conditions reported at the Roberval (CYRJ) and Bagotville (CYBG) airports at 1400

Airport	Weather conditions
CYRJ	• visibility 25 SM • overcast ceiling at 1700 feet AGL • surface winds from 170° true (T) at 11 knots, gusting to 18 knots, direction variable between 160°T and 220°T • temperature −3 °C, dew point −7 °C • altimeter setting 30.00 inHg
CYBG	• visibility 25 SM • broken ceiling at 3000 feet AGL, with an additional layer of broken clouds at 22 000 feet AGL • surface winds from 110°T at 6 knots • temperature −6° C, dew point −9° C • altimeter setting 30.09 inHg

No snowfall was reported by these 2 stations after 0900 and, based on information gathered, the investigation determined that there was no precipitation or icing during the occurrence flight. Weather conditions were suitable for a visual flight rules (VFR) flight.

The CYTF automated weather observation system (AWOS), located approximately 8 NM east of the accident site, did not record any data. However, based on information gathered at the airport, it was determined that the altimeter setting indicated by the AWOS at 1419 on the day of the accident was 30.08 inHg.

1.7.1 Lighting conditions

The diffused light on the day of the accident reduced shadows and contrast on the lake's snow-covered surface (Figure 4). In addition, given that the accident occurred at around 1400, a little more than 2 hours before sunset,[5] the light had already begun to fade, making it more difficult to perceive details.

5 On the day of the accident, the sun set at 1629 in Alma. (Source: National Research Council sunrise/sunset calculator, at https://cnrc.canada.ca/en/research-development/products-services/software-applications/sun-calculator/ [last accessed on 08 November 2021]).

Figure 4. Photos of the accident site taken on the day of the accident and the next day (Sources: Sûreté du Québec [22 January] and TSB [23 January])

22 January 2020 | 23 January 2020

1.7.1.1 Flat light and whiteout

Flat light can be defined as

> the condition in which diffused lighting occurs due to cloudy skies, especially when there is snow covered ground below, reducing or eliminating contrast and shadows.[6]

The U.S. Federal Aviation Administration's (FAA's) *Aeronautical Information Manual* (AIM) defines *flat light* as

> an optical illusion, also known as "**sector or partial white out.**"[emphasis in original] It is not as severe as "white out" but the condition causes pilots to lose their depth-of-field and contrast in vision. Flat light conditions are usually accompanied by overcast skies inhibiting any visual clues. […] Flat light can completely obscure features of the terrain, creating an inability to distinguish distances and closure rates.[7]

Also in the AIM, the FAA provides a definition for a related phenomenon, *white out*, for which it distinguishes 2 types:

> **White Out.** As defined in meteorological terms, white out occurs when a person becomes engulfed in a uniformly white glow. The glow is a result of being

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6 Computer Training Systems, Arctic Flying: Part 2, at https://www.ctsys.com/arctic-flying-part-2/ (last accessed on 08 November 2021).

7 Federal Aviation Administration, *Aeronautical Information Manual* (31 December 2020), paragraph 7-6-13.

> surrounded by blowing snow, dust, sand, mud or water. There are no shadows, no horizon or clouds and all depth-of-field and orientation are lost. A white out situation is severe in that there are no visual references. […]
>
> **Self Induced** [*sic*] **White Out.** This effect typically occurs when a helicopter takes off or lands on a snow-covered area. The rotor down wash picks up particles and re-circulates them through the rotor down wash. The effect can vary in intensity depending upon the amount of light on the surface. This can happen on the sunniest, brightest day with good contrast everywhere. However, when it happens, there can be a complete loss of visual clues.[8]

In material designed to supplement pilot training on flying in flat light and whiteout conditions, the FAA notes that the definitions it provides for *flat light* and *white out* are not "intended to be official scientific explanations, but merely to serve as operational definitions suitable to the aviation community for the purpose of this training." It also states that "[t]hese terms should not be used interchangeably."[9]

Furthermore, the FAA warns pilots that even when visual references are good, it does not mean that it is safe to continue the flight:

> When flying alongside lakeshores, use them as a reference point. Even if you can see the other side, realize that your depth perception may be poor and it is easy to fly into the surface. If you must cross the lake, check the altimeter frequently and maintain a safe altitude while you still have a good reference. Don't descend below that altitude.[10]

In Canada, the *Transport Canada Aeronautical Information Manual* (TC AIM) makes no mention of the term *flat light*, referring only to the term *whiteout*. The TC AIM describes the term *whiteout* as follows in the section on flight operations in winter:

> Whiteout (also called milky weather) is defined in the *Glossary of Meteorology* (published by the American Meteorological Society) as:
>
> > *"An atmospheric optical phenomenon of the polar regions in which the observer appears to be engulfed in a uniformly white glow. Neither shadows, horizon, nor clouds are discernible; sense of depth and orientation is lost; only very dark, nearby objects can be seen. Whiteout occurs over an unbroken snow cover and beneath a uniformly overcast sky, when with the aid of the snowblink effect, the light from the sky is about equal to that from the snow surface. Blowing snow may be an additional cause."*
>
> Light carries depth perception messages to the brain in the form of colour, glare, shadows, and so on. These elements have one thing in common, namely, they are all modified by the direction of the light and changes in light intensity. For example, when shadows occur on one side of objects, we subconsciously become aware that the light is coming from the other. Thus, nature provides many visual clues to assist us in discerning objects and judging distances. What happens if these clues are

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8 Ibid.

9 Federal Aviation Administration, Flying in Flat Light and White Out Conditions (2001), at https://www.faasafety.gov/gslac/alc/libview_normal.aspx?id=6844 (last accessed on 08 November 2021).

10 Ibid.

removed? Let's suppose that these objects on the ground and the ground itself are all white. Add to that, a diffused light source through an overcast layer which is reflected back in all directions by the white surface so that shadows disappear. The terrain is now virtually devoid of visual clues and the eye no longer discerns the surface or terrain features.

Since the light is so diffused, it is likely that the sky and terrain will blend imperceptibly into each other, obliterating the horizon. The real hazard in whiteout is the pilot not suspecting the phenomenon because the pilot is in clear air. In numerous whiteout accidents, pilots have flown into snow-covered surfaces unaware that they have been descending and confident that they could "see" the ground.

Consequently, whenever a pilot encounters the whiteout conditions described above, or even a suspicion of them, the pilot should immediately climb if at low level, or level off and turn towards an area where sharp terrain features exist. The flight should not proceed unless the pilot is prepared and competent to traverse the whiteout area on instruments.

In addition, the following phenomena are known to cause whiteout and should be avoided if at all possible:

a) water-fog whiteout resulting from thin clouds of super-cooled water droplets in contact with the cold snow surface. Depending on the size and distribution of the water droplets, visibility may be minimal or nil in such conditions.

b) blowing snow whiteout resulting from fine snow being plucked from the surface by winds of 20 kt or more. Sunlight is reflected and diffused resulting in a nil visibility whiteout condition.

c) precipitation whiteout resulting from small wind-driven snow crystals falling from low clouds above which the sun is shining. Light reflection complicated by spectral reflection from the snow flakes and obscuration of land marks by falling snow can reduce visibility and depth perception to nil in such conditions.

If at all possible, pilots should avoid such conditions unless they have the suitable instruments in the aircraft and are sufficiently experienced to use a low-speed and minima rate of descent technique to land the aircraft safely.[11]

TC AIM's description of a whiteout includes the flat light phenomenon, making it difficult to distinguish between the 2 phenomena.[12] Both flat light and whiteout can occur when visibility is good; however, the conditions under which each of these phenomena can occur and the risk that they represent differ.

For clarity and precision, the term *flat light*, as defined by the FAA, will be used in this report to describe the lighting conditions that prevailed on the day of the occurrence.

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11 Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), AIR – Airmanship (08 October 2020), section 2.12.7: Whiteout.

12 TC has informed the TSB that it recognizes the benefit of improving its documentation and will work with appropriate experts to update the TC AIM to clarify the definitions and explanations of these 2 phenomena.

1.8 Aids to navigation

The aircraft was equipped with a GPS (global positioning system) built into the instrument panel for navigation. No flight data could be retrieved because the type of GPS in question does not allow data to be saved.

1.8.1 Visual flight rules navigation charts

In general, the main navigation tool used by pilots conducting VFR flights is the VFR navigation chart (VNC). It is available in paper format or digitally (with the ForeFlight application, for example) and includes a topographical representation of the surface, with the terrain elevation indicated. However, the elevation is not indicated for larger lakes such as Lac Saint-Jean. The elevation of Lac Saint-Jean is approximately 322 feet, not 0 feet, as is the case with other large bodies of water, such as oceans and seas.

The terrain elevation indicated on VNCs is mainly used for pre-flight planning and is not used to determine a pilot's altitude AGL during flight. However, a pilot in flight may unconsciously associate an elevation of 0 feet with any large body of water and interpret the altitude indicated on a conventional altimeter as an altitude AGL when the aircraft is flying over water.

In contrast, helicopter pilots flying at altitudes of 500 AGL or less estimate and maintain their altitude visually by following the terrain rather than maintaining a specific altitude indicated on a conventional altimeter.

In this occurrence, the pilot had the relevant VNCs for the flights, as required by the SAG,[13] but he did not use them on the return flight. Throughout the day, the pilot estimated his altitude AGL visually, without using the altitude indicator on the radio altimeter.

1.9 Communications

Not applicable.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), and neither was required by regulation. Without an FDR, it was impossible

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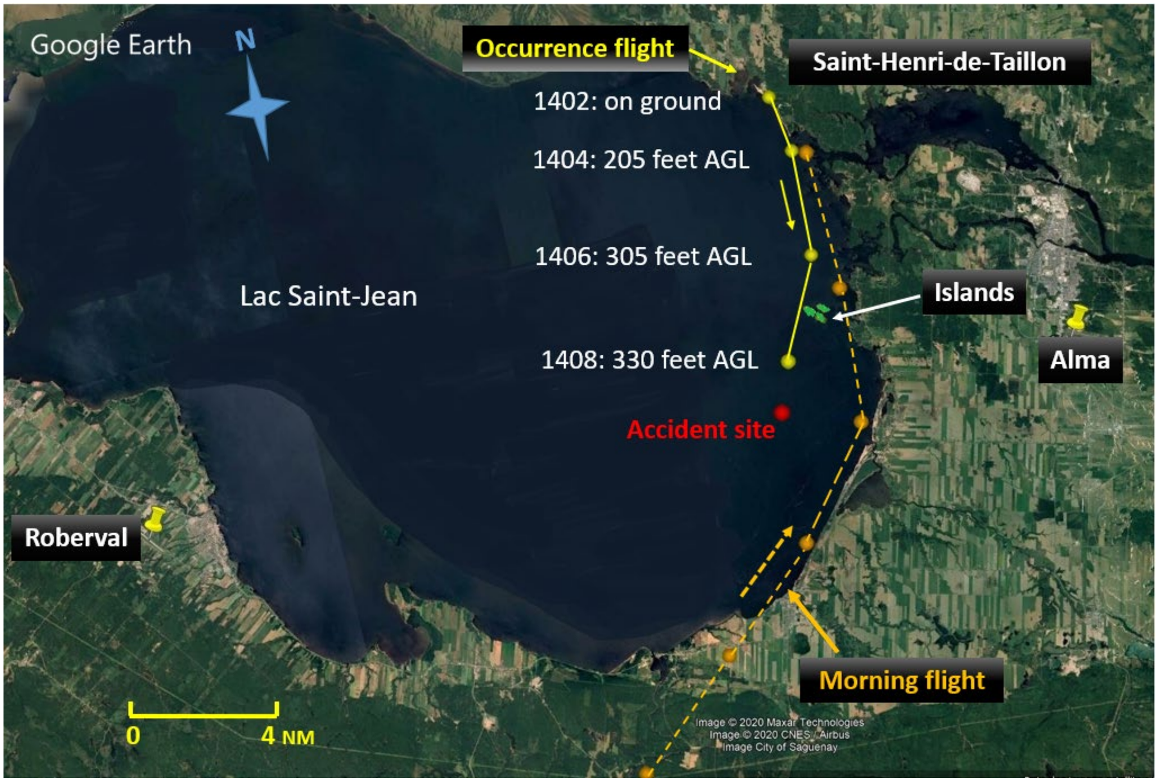
[13] Ministère des Transports du Québec, Service aérien gouvernemental, *Manuel d'exploitation*, Modification no. 1 (01 September 2016), Chapter 2: Exploitation, section 2.10.1: Documents minimums requis à bord, p. 2-5.

to accurately determine exactly when the descent began, or what the aircraft's descent profile was as it struck the surface of the lake.

However, the aircraft was equipped with a satellite flight tracking system, and data were retrieved from the SAG's aircraft tracking and management website. This system recorded the aircraft's GPS position, altitude, and ground speed every 2 minutes (Figure 5).

Figure 5. Representation of the morning flight (dashed line) and occurrence flight (solid line) (Source: Google Earth, with TSB annotations based on data from the flight tracking system)



For the flight out in the morning, the pilots of the 2 helicopters, including the occurrence one, decided to fly along the eastern shore of Lac Saint-Jean as they headed to Saint-Henri-de-Taillon because of the low contrast over the lake.

For the return flight in the afternoon, the occurrence pilot had planned to fly at a low altitude (approximately 500 feet AGL) because there was a headwind. The aircraft took off from Saint-Henri-de-Taillon at 1402 and flew a track that was almost parallel to the eastern shore of the lake. At 1406, at an altitude of 305 feet AGL and 1 NM laterally from the shore, the aircraft was approaching a group of islands 1.3 NM ahead. The pilot veered right, flying west of the islands. At 1408, the aircraft was 2.4 NM laterally from the shore at an altitude of 330 feet AGL. The aircraft struck the surface of the lake about 1 minute later, approximately 1.34 NM further. The angle between the height of the last recorded position at 1408 and the point of impact was approximately 2.3°.

1.12 Wreckage and impact information

1.12.1 General

The wreckage was examined at the accident site, and again at the TSB Engineering Laboratory, with representatives of the aircraft manufacturer, the engine manufacturer, and the aircraft's owner in attendance.

1.12.2 Accident site

The main debris at the accident site was scattered over a distance of approximately 260 feet, along a straight line that matched the direction of flight indicated in the flight tracking system, i.e., south-southwest. The extent of the debris indicates that the horizontal speed at the time of impact was likely high, and that the angle at which the aircraft hit the frozen surface of the lake must have been shallow, which is characteristic of a controlled-flight-into-terrain (CFIT) accident rather than a loss-of-control accident (which is generally associated with a lower horizontal speed due to a steeper vertical descent).[14]

Only the tip of the tail and its rotor, along with the mast and main rotor, were found far from the wreckage trail (Figure 6). On impact, a helicopter's main rotor blades may be projected over a great distance in all directions[15] due, in part, to the kinetic energy and gyroscopic inertia produced by the rotation of the blades.

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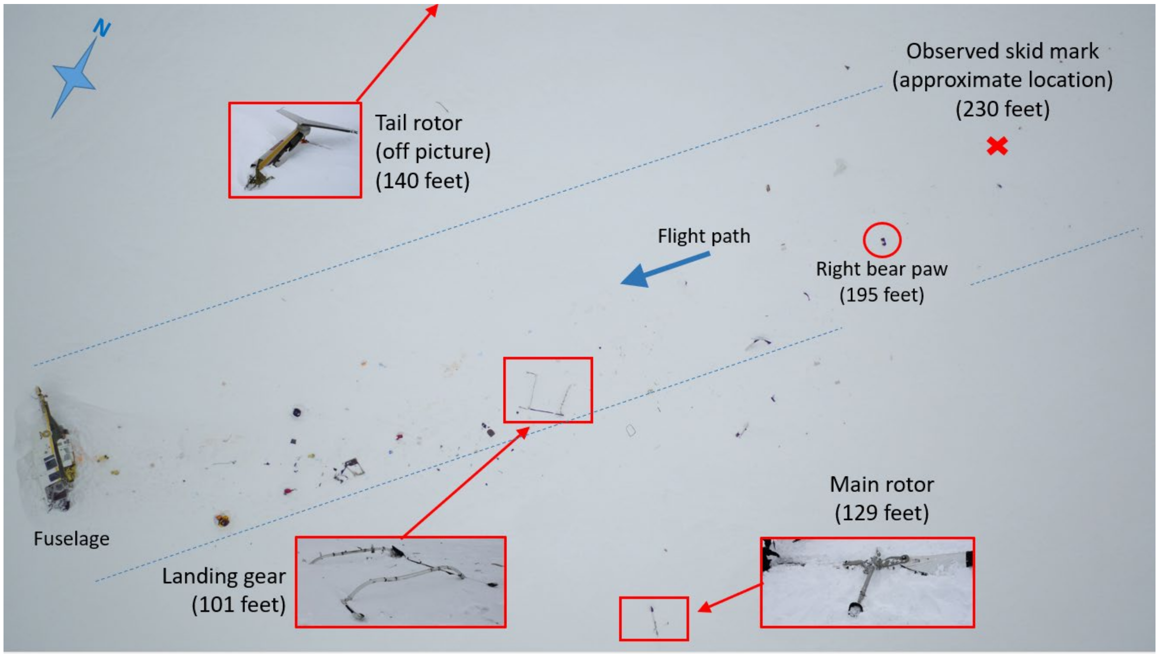
[14] This steep vertical component associated with a loss of control in flight is related to the fact that helicopters are dynamically unstable on the pitch and roll axes and react quite quickly to the slightest movement of the flight controls. (Source: Australian Government Civil Aviation Safety Authority, "Every which way but loose", in *Flight Safety Australia*, at https://www.flightsafetyaustralia.com/2020/05/every-which-way-but-loose/ [last accessed on 09 November 2021]).

[15] R. H. Wood and R. W. Sweginnis, *AAI Aircraft Accident Investigation*, Part II: Investigation Techniques, Chapter 25: Helicopter Accident Investigation (2003).

Figure 6. Aerial view of the accident site showing the distribution of debris and distance from the fuselage (Source: Sûreté du Québec, with TSB annotations)



No trace of the impact on the ground was visible when investigators arrived at the site the next day, the wind having swept the snow-covered surface. However, information gathered indicated that a clear skid mark had been observed along the wreckage trail, approximately 230 feet from the fuselage, when the first responders arrived. The observed orientation of the skid mark indicated that the nose of the aircraft was pointing left in relation to the wreckage trail. However, because the skid mark was no longer visible when investigators arrived at the site, measurements could not be taken to confirm its exact orientation or to check if there were any other skid marks in the snow. The right skid's bear paw[16] was found 195 feet from the fuselage, near debris from one of the main rotor blades and the tail boom's left horizontal stabilizer.

The aircraft was lying on its left side and the front part was substantially damaged. The nose and instrument panel were almost completely detached from the fuselage at the cockpit floor. The cockpit doors and roof were torn off. The pilot seat attachments had failed. The rear sliding door was still solidly attached to its track and the integrity of the rear cabin was not compromised. The fuselage showed several signs of buckling and, on the ceiling, structural deformation. The upper part of the fuselage, where the hydraulic components and flight control systems were located, was crushed. There was no indication of a fuel leak.

1.12.3 Laboratory examination of the wreckage

The wreckage was transported to the TSB Engineering Laboratory for a more detailed examination.

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16 The term "bear paw" refers to an attachment to the rear of the skid designed to increase the surface area for landings on soft terrain.

There was no damage to the right side of the fuselage, indicating that it did not come into contact with the frozen surface of the lake during the accident sequence. The flight controls showed signs of multiple overload failures related to the impact; however, continuity of the power plant components[17] and flight controls could be confirmed. There were no signs of pre-existing deficiencies in any of the components. The examination of the warning panel lights did not reveal any significant information. The 2 engines were sent for testing at a Rolls-Royce authorized maintenance repair and overhaul center in the United States. The tests did not find any mechanical or other deficiencies that could have contributed to the accident.

The damage and deformations observed on the fuselage and landing gear were analyzed. From a structural standpoint, this analysis found that the damage and deformations had occurred when the aircraft struck the frozen surface of the lake hard and that it had been upright, the left skid hitting the surface before the right skid. The scratches, dents and crack found on the lower part of the fuselage indicate that the aircraft was moving laterally to the left when it struck the surface of the lake. There was no indication of a yawing motion at the time of impact. The fittings that attach the cross tubes to the fuselage broke and the landing gear detached from the fuselage.

One of the main rotor blades severed the tail boom at the horizontal stabilizer at an angle of approximately 7.5°, which indicates that the rotor disc was likely angled to the left at the time. This contact caused the rotor mast to separate at the main transmission gearbox.

The examination determined that the damage and deformations were caused by the impact when the aircraft struck the frozen surface of the lake during the initial phase of the accident. However, it is possible that another impact occurred shortly before the main impact, but did not cause any damage.

1.13 Medical and pathological information

There was no indication that the pilot's performance was affected by medical, pathological, or physiological factors.

1.14 Fire

There was no post-impact fire.

1.15 Survival aspects

The aircraft had an ELT that was working properly, transmitting the distress signal and the aircraft's last recorded GPS position.

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[17] Engines, combining gearbox, power shaft, and main transmission gearbox.

The pilot was wearing a flight helmet even though the SAG does not require pilots to wear one when conducting flights on a Bell 206. Some SAG pilots choose instead to wear a flight headset when they are flying a Bell 206 given the low headroom when wearing a helmet and the tight space in the cockpit.

Figure 7. Impact marks on top of the pilot's helmet (Source: SAG, with TSB annotations)

Marks found on the top of the helmet shell indicate that a major shock occurred in that area (Figure 7). The TSB has previously highlighted the importance of wearing a helmet to prevent fatal injuries or to reduce the effects of non-fatal head injuries received in an accident.[18] These effects may vary from confusion to complete loss of consciousness.

In addition to wearing a helmet, the pilot had fastened the 4-point shoulder harness. During the lateral impact, the pilot's seat attachments failed. One of the most critical factors in being able to physically withstand impact forces is the way in which occupants are restrained and supported by their seat and restraint system. A more even distribution of the forces of deceleration over the body surface increases the chances of survival.[19]

Finding: Other

Wearing a flight helmet and fastening the 4-point shoulder harness helped to reduce the severity of the injuries to the pilot, who was able to egress from the aircraft and contact the dispatcher to get help quickly.

1.16 Tests and research

1.16.1 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP019/2020 – Engine Data Recovery
- LP020/2020 – Engine Analysis
- LP022/2020 – Warning Panel Lamps Analysis
- LP023/2020 – Instruments Analysis
- LP036/2020 – Impact Analysis

18 TSB air transportation safety investigation reports A18W0025, A16W0126, A16P0161, A16P0069, A14Q0060, A13H0001, A12C0084, A11W0070, A09A0016, A05P0103, and A02P0320.

19 North Atlantic Treaty Organization (NATO), "Human Tolerance and Crash Survivability" in *Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation*, RTO-EN-HFM-113, (August 2005), p. 6-5.

1.17 Organizational and management information

Through the SAG, the Ministère des Transports of Quebec operates a fleet of airplanes and helicopters and works with its partners to ensure an appropriate response to emergency situations or situations requiring a specialty air service.[20] The SQ is the operating partner for the fleet of helicopters, which at the time of the occurrence included a medium-lift helicopter (a Bell 412) and 2 light helicopters (a Bell 206B and the occurrence Bell 206L-4).

Unlike its fleet of airplanes, which it operates pursuant to a private operator registration document and an air operator certificate, at the time of the occurrence, the SAG operated its fleet of helicopters under the general rules of Part VI of the CARs. Therefore, even though pilots were required to keep their knowledge up to date pursuant to section 401.05 of the CARs, the SAG was not required to provide any specific training to its helicopter pilots or to establish operating procedures. However, the SAG did produce a company operations manual (COM) and a training program based on CARs requirements.

1.17.1 Service aérien gouvernemental of Quebec company operations manual

In its COM, the SAG states the procedures to be followed for helicopter operations to ensure the safety of flights and missions.[21]

Missions flown on the Bell 412 with 2 pilots may be conducted under either VFR or instrument flight rules (IFR), while missions on the Bell 206B and 206L-4 (helicopters always flown by a single pilot) are conducted under day VFR only. Given the operational differences, some of the procedures in the COM may apply only to the Bell 412 or only to the Bell 206.

1.17.1.1 Radio altimeter procedures

The very nature of single-pilot VFR operations in light helicopters like the Bell 206 is such that manoeuvres are regularly conducted at low altitude or close to the ground. Consequently, depending on the circumstances, it is not always advisable for pilots to divert their attention from their primary task (which is to visually fly the helicopter close to the ground and obstacles) and focus inside the cockpit to monitor the height AGL indicated on the radio altimeter. Therefore, in general, air operators do not recommend the use of a radio altimeter for these types of operations and do not equip their fleet of helicopters with the instrument.

The SAG uses its Bell 206 helicopters primarily for low-altitude search and rescue flights in which a trained observer is seated in the front passenger seat.

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[20] Ministère des Transports of Quebec, Service aérien gouvernemental, at https://www.transports.gouv.qc.ca/fr/services/sag/pages/service-aerien-gouvernemental.aspx (last accessed on 09 November 2021).

[21] Ministère des Transports of Quebec, Service aérien gouvernemental, *Manuel d'exploitation*, Modification no. 1 (01 September 2016), Préambule.

The COM states that [translation]:

> To reduce the risk of inadvertent collision with terrain, follow these procedures:
>
> Set the highest value on the EFIS [electronic flight instrument system] altimeter and the lowest value on the instrument panel altimeter.
>
> **Note**: only the higher value will activate the audible alarm.
>
> - VFR en route: one radio altimeter at 400 feet and the other at 100 feet;
> - VFR over water: one radio altimeter at 400 feet and the other at 50 feet;
> - IFR at takeoff: two radio altimeters at 400 feet;
> - IFR en route: one radio altimeter at 1000 feet or 1500 feet in designated mountainous areas and the other at 100 feet;
> - IFR on approach: one radio altimeter at the DA [decision altitude] or MDA [minimum descent altitude] and the other at 100 feet.
>
> The radio altimeter altitude warning must be set to the same altitude on both pilots' indicators.
>
> This procedure can be deviated from in a particular situation or to comply with a standard operating procedure. However, before any deviation, the other crew member must be notified.[22]

The Bell 412 is the SAG's only aircraft with 2 radio altimeters. The Bell 206L-4 had only one and the Bell 206B has none. However, no other procedures are given to reduce the risk of inadvertent collision with terrain if the aircraft is not equipped with 2 radio altimeters.

The investigation determined that it was not common practice for SAG pilots to use the radio altimeter decision height selector bug in the occurrence aircraft, and that use of this selector bug was left to the pilots' discretion. The radio altimeter triggers an audible alarm when the pilot intentionally flies below the minimum altitude setting on the decision height selector bug. This alarm was considered a possible distraction that could negatively impact flight safety.

1.17.1.2 Unsafe conditions

The whiteout phenomenon is discussed in the "Vol dans des conditions dangereuses" [flight operations in unsafe conditions] section of the COM, which states [translation]:

> **When whiteout conditions are known or expected during takeoff or landing, the PIC [pilot-in-command] must:** [emphasis in original]
>
> Ensure that there is enough reserve power to hover out of ground effect before landing or takeoff.
>
> Before landing, stabilize the hover at an altitude that allows the snow to disperse.[23]

However, the COM does not address the specific phenomenon of flat light.

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22 Ibid., Chapter 2: Exploitation, section 2.48: Procédures relatives au radioaltimètre, p. 2-38.

23 Ibid., Chapter 2: Exploitation, section 2.61.6: Condition de voile blanc, p. 2-47.

1.17.2 Training

Pilot training is intended to enhance the knowledge and skills needed to effectively manage various flight-related risks. To that end, the SAG has developed a training program based on CARs requirements, even though the regulations do not require this training for the SAG's type of helicopter operations.

The program takes into account the types of aircraft it uses and its area of operation. Annual training on the occurrence aircraft included a minimum of 3 hours of theory and 1 hour of practice in flight.

According to the training program, whiteout is addressed during landing and takeoff flight exercises only. The SAG's training program does not specifically cover the phenomenon of flat light.

1.17.2.1 Flight tests

Over the course of their career, commercial pilots must undergo various flight tests or annual in-flight assessments to check their knowledge and skills in executing various manoeuvres.

For that purpose, TC has published a flight test guide for helicopters, which contains "guidelines on the conduct of Pilot Proficiency Checks (PPCs)."[24] It describes in detail the practical exercises assessed by approved check pilots and the elements they must take into account during their exercise assessment.

According to this guide, whiteout is one of the execution criteria that must be taken into account by the check pilot in assessing the candidate during the landing exercise only.[25] However, flat light is not a criterion that is specifically addressed in the guide. The occurrence pilot had regularly put into practice his knowledge of whiteout risks during takeoffs and landings as part of flight tests before the occurrence.

1.18 Additional information

1.18.1 Spatial awareness

Spatial awareness is a person's ability to be aware of the relationship between them and the environment around them. When a person moves on the ground, their brain uses and processes the information provided by their senses, e.g., vision, the musculoskeletal system (proprioception) and the inner ear (vestibular apparatus), to establish an accurate spatial awareness.

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[24] Transport Canada, TP 14728, *Proficiency Checks and Aircraft Type Ratings – Flight Test Guide (Helicopters)*, Second Edition (December 2019).

[25] Ibid., p. 31.

During a flight, interpretation of information received by the senses other than vision can mislead pilots if they cannot orient themselves visually. For example, acceleration may be perceived as a nose-up pitch. In the context of a flight, vision becomes the main source of reliable information to maintain good spatial awareness. The more visual information the brain receives to process, the more accurate the representation of movement in space.

Insufficient visual information, such as reference points outside the aircraft, may lead to illusions that affect spatial awareness. For example, during a night flight, which normally provides less visual information than a day flight, lights look closer than they actually are. A complete loss of visual information leads to spatial disorientation. In that case, the pilot will maintain control of the aircraft only by referring to the appropriate flight instruments, provided that the pilot has the skill level needed for IFR flight.

From 2010 to 2019, the TSB investigated 48 occurrences which involved conditions that were known to affect a pilot's spatial awareness (Appendix A).

1.18.2 Visibility, visual references, and visual cues

During a VFR flight, pilots must ensure that they maintain visual contact with the surface at all times.[26] To do so, visibility and visual references are needed. Daytime visibility refers to the distance at which unlit prominent features, such as terrain or buildings, can be identified.

Visual references are one or more elements that are visible on the terrain (or to the terrain itself). These elements help pilots to determine their position and their movement in space, as well as to identify the horizon. In the occurrence flight, there was a sharp contrast between the shoreline and the overcast sky and snow-covered lake surface, making the horizon clearly visible.

Visual cues are all elements that provide visual information (shadows, textural gradient[27] and the size of familiar objects[28]), which is processed by the brain unconsciously to determine both position and movement in space. Visual cues are essential for depth perception, which is characteristic of 3-dimensional (3D) vision. During the occurrence flight, several fishing huts were on the lake; however, the investigation was unable to determine how many there were, where they were located, or their proximity to the flight path.

For VFR flights, it is important that visibility allows the pilot to see visual references which, in turn, must provide enough visual cues to maintain proper spatial awareness. The quality and number of visual cues provided by the visual references may be insufficient to maintain 3D vision, as is the case when flying over a surface with no contrast in flat light. When visual

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26 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 602.115(a).

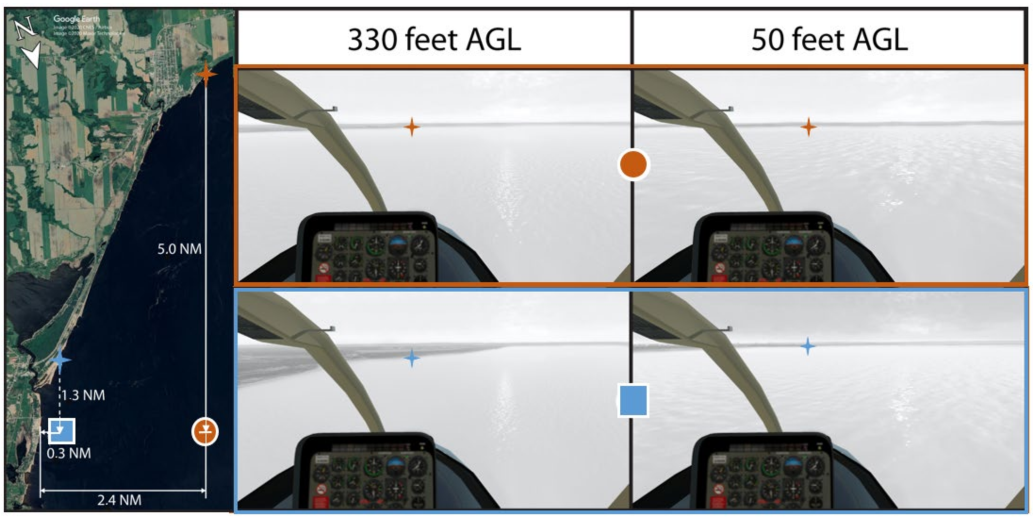
27 Details of the texture of an object, such as the leaves or branches of a tree, disappear as altitude increases.

28 An object, such as a house, will appear smaller as altitude increases, but the object may also provide an indication of height through its surroundings (people, cars, etc.).

cues are insufficient, 3D vision deteriorates and becomes 2 dimensional (2D). This deterioration may, however, go unnoticed, which makes flat light an insidious risk and dangerous to pilots. In general, pilots see well because visibility is good, but they may not notice when their depth perception is reduced, or gone completely.

Figure 8 illustrates a simulated view of the shoreline from the cockpit at 2 different altitudes—330 feet AGL and 50 feet AGL—when there is no contrast at the surface. The top 2 images represent the view from the accident location (2.4 NM from the shoreline), and the bottom 2 images represent the view from a distance closer to the shoreline (0.3 NM), for comparison purposes.

Figure 8. Simulated view of the shoreline from the cockpit at 330 feet above ground level and 50 feet above ground level when the aircraft is 2.4 nautical miles and 0.3 nautical miles from the shoreline (Source: TSB)



When the aircraft is 2.4 NM from the shoreline, the shoreline has the same profile at both altitudes, which shows that, at these 2 altitudes, a lateral distance of 2.4 NM is too great to be able to notice a loss of altitude if the shoreline is the sole visual reference being used. However, when the aircraft is at a lateral distance of 0.3 NM, the amount of shoreline that can be seen decreases with a loss of altitude.

1.18.3 Risk management

In aviation, a risk can be described as the possible consequence of a hazard that is not controlled or eliminated. To make safe decisions, pilots must first identify hazards in order to assess their risk level and then determine the appropriate actions to take. To this end, pilots use the experience and knowledge they have gained, mainly through various types of training, to identify hazards and ensure that they establish and maintain accurate situational awareness before and during a flight.

For the return flight, the occurrence pilot had noted that winds were from the south-southwest, and that the headwinds would slow his speed and increase the flight time needed to arrive at his destination. Given that the aircraft's twin engines reduced the risks associated with losing power at low altitude by helping to maintain altitude or by reducing the descent rate, the pilot had planned to conduct the flight at approximately 500 feet AGL, which would enable him to fly safely at an altitude where the strength of the wind is generally weaker.

The flight had to be conducted during daylight. However, civil twilight at CYHU was expected to end at 1718. The overcast sky at the time of takeoff meant that light was low and was fading faster than if the sky had been partially overcast. The aircraft's twin engines made it possible to plan a more direct flight path to gain time, which enabled the pilot to fly further from the shoreline than the glide distance,[29] with no additional risk if one of the engines lost power. The pilot took these operational constraints into consideration when making decisions before and during the flight.

The pilot had considered the low contrast over the surface of the lake as a potential risk to the search operations being conducted near the ground and during takeoffs and landings throughout the day. Based on his knowledge, he associated low contrast due to whiteout primarily with a risk to low-level flights, including landings and takeoffs, while he associated the loss of visual references and/or horizon with poor visibility that could occur at any phase of flight. Given that visibility was good and the shoreline and several fishing huts were clearly visible, the pilot did not consider flying over the lake during the return flight to CYHU to be risky at the planned altitude.

Knowledge of the distinct and insidious nature of flat light is an important element of situational awareness and a pilot's decision-making process. Therefore, the main defence to mitigate the risk of CFIT in a situation similar to that of the occurrence flight is to be aware of the effects of flat light in order to be aware of the associated flight-related risks, regardless of the phase of flight.

1.18.4 TSB investigation reports

In 1990, the TSB published Aviation Safety Study 90-SP002: Report of a Safety Study on VFR Flight into Adverse Weather.[30] This report found that 27 of the 33 helicopter accidents from 1976 to 1986[31] had occurred in whiteout conditions, and many accidents had occurred as a result of an inadvertent descent that was not detected by the pilot.

In 2019, the TSB published Air Transportation Safety Issue Investigation (SII) A15H0001.[32] The objective was to improve safety by reducing the risks in air-taxi operations across Canada. The air-taxi sector continues to experience more accidents that any other in the commercial aviation industry. An operator that conducts aerial work or air-taxi operations (transporting passengers) must hold an air operator certificate issued by TC. Because the

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29 Glide distance is the distance that can be travelled in the event of engine failure.

30 Available at http://www.tsb.gc.ca/eng/rapports-reports/aviation/etudes-studies/90SP002/90SP002.html.

31 Accidents involving Canadian-registered aircraft in Canadian territory, over the period from 1976 to 1985.

32 Available at http://www.tsb.gc.ca/eng/rapports-reports/aviation/etudes-studies/a15h0001/a15h0001.html.

SAG is a State operator, it is not required to hold an operator certificate issued in accordance with Part VII of the CARs. The procedures described in its operations manual are based on the requirements stipulated in CARs Subpart 703, which applies to air-taxi operations. Given that the operating context of SAG Bell 206 helicopters is similar to helicopter air-taxi operations, it is worthwhile to consider the discussions and conclusions of that investigation.

Phase 1 of the SII, which included an examination of the TSB investigation reports for 167 occurrences, revealed that most fatalities resulting from accidents involved flights that had begun in visual meteorological conditions, continued through the loss of visual references, and ended in either CFIT or a loss of control. An analysis of accident data found that contributing factors fell into 2 broad areas:

- acceptance of unsafe practices; and
- inadequate management of operational hazards.

In phase 2, investigators conducted interviews with industry stakeholders to better understand the pressures faced by the industry, as well as the issues encountered in daily activities. The information gathered was organized into 19 safety themes which, after further analysis using additional data, yielded various conclusions. Of the 19 themes, the following 2 and their respective conclusions are relevant to this report:

- *On-board technology*,[33] if incorporated into an operation, has significant potential to enhance safety in air-taxi operations.
- *Training of pilots and other flight operations personnel* is essential for them to develop the skills and knowledge they need to effectively manage the diverse risks associated with air-taxi operations.

The varied and complex nature of the air-taxi sector and the extent of the competing pressures introduce hazards and risk factors that are different from those in other aviation sectors, including those faced by airlines. The way in which operators manage hazards or risks determines the level of safety of their operations. The fewer or weaker the defences in place, the thinner the safety margin.

Many operators are taking a proactive approach to safety, identifying and mitigating risks associated with their activities, and a number of them are taking measures that exceed regulatory requirements.

Risks affecting the air-taxi sector have persisted for decades and are resistant to more traditional safety mitigations.

The traditional approach to safety management is based on compliance with regulations and a reactive response to incidents and accidents. Modern safety management principles

[33] On-board technology, also known as growth technology, refers to terrain avoidance instrumentation, ground proximity warning systems, GPSs, etc.

promote a proactive search for hazards, identifying risks, and instituting better defences to reduce risk to an acceptable level.

Further analysis of the accident data identified weak or missing defences that, if improved or added, have the potential to enhance safety. Many operators use on-board technology and training to enhance the safety of their operations. They may go above and beyond existing regulations and implement active TSB recommendations, without waiting for regulatory amendments by TC to enhance safety. Although compliance with safety regulations is fundamental, operators that simply comply with the standards set by the regulations are not well situated to identify emerging safety problems.

1.19 Useful or effective investigation techniques

Not applicable.

2.0 ANALYSIS

The pilot held the licence and qualifications required for the flight. There was no indication that the pilot's performance was affected by medical, pathological or physiological factors. Weather conditions at the time of the occurrence were suitable for a visual flight rules (VFR) flight.

Given the fact that no pre-existing mechanical deficiencies were found during the thorough examination of the wreckage (which included examining the flight controls, engine controls, hydraulic system, combining gearbox, main rotor and tail rotor with their respective transmissions) and given the results of the tests performed on the 2 engines, it is unlikely that a mechanical issue or failure in flight contributed to the accident.

Consequently, the analysis will focus on the following points:

- flat light
- training
- management of operational hazards
- flight progression

2.1 Flat light

There was no precipitation during the occurrence flight and visibility was approximately 25 statute miles (SM). The shoreline was visible from a distance and the sky was overcast, producing diffused light. The less-pronounced shadows and lower contrast on the snow-covered surface of the lake created flat light conditions (Figure 4). Given the time of day, the light was fading, further decreasing the perception of details. The absence of textural details at the surface of the lake caused a significant reduction in visual cues over the lake. These cues were essential for depth perception and 3-dimensional (3D) vision.

Finding as to causes and contributing factors

Even though visibility was 25 SM, flat light was obscuring the shadows and contrast at the snow-covered surface of the lake, reducing the visual cues needed for depth perception and 3D vision.

The hazard of flat light is its insidious nature. Even when visibility is good and the horizon is visible, a loss of depth perception may go undetected by the pilot. Given that flat light is an optical illusion, neither flight experience nor an instrument rating can help to better identify the loss of 3D vision. This illusion adversely affects spatial awareness and increases the risk of controlled flight into terrain (CFIT) if it is not recognized.

2.2 Training

Training is recognized as a means of providing pilots with the knowledge and skills they need to effectively manage the various risks associated with their operations. Although it was not required by regulations, the Service aérien gouvernemental (SAG) of Quebec had implemented a training program based on requirements for air operators.

Through various training courses and flight tests taken over the course of his career, the occurrence pilot had had an opportunity to put into practice, during takeoffs and landings, the knowledge he had gained about the risks associated with whiteout, i.e., loss of visual references and low contrast. Practising these techniques close to the ground tends to reinforce the notion that low contrast is only a risk during takeoff and landing. This notion is further reinforced by the fact that the *Transport Canada Aeronautical Information Manual* (TC AIM) does not distinguish flat light from whiteout, for which the risks of flying in reduced visibility conditions are well known. The terms *flat light* and *whiteout* should not be used interchangeably because, even if the 2 phenomena can occur in reduced visibility conditions at takeoff, landing, and in cruise flight, flat light can also occur in cruise flight when visibility is good and visual references allow the pilot to identify the horizon, making it particularly insidious.

Finding as to risk

If the reference documents provided by TC do not make a clear distinction between the phenomenon of flat light and that of whiteout, there is a risk that pilots will not differentiate between the specific risks associated with each hazard.

During the occurrence flight, the pilot recognized the low contrast, but did not associate it with flat light or recognize it as a potential risk to his flight.

Finding as to causes and contributing factors

The pilot's knowledge and training did not provide him with the skills to recognize the risks associated with low contrast resulting from flat light during cruise flight and when good visibility made it possible to see the shoreline in the distance.

2.3 Management of operational hazards

The SAG took the initiative to implement measures to mitigate the risks associated with its operations, even though the regulations in effect did not require it to do so. It included procedures for using a radio altimeter in its company operations manual to reduce the risk of CFIT. However, these procedures only applied to operations on the Bell 412 when it was flown by 2 pilots, and required the use of 2 radio altimeters. Furthermore, the radio altimeter was rarely used by SAG pilots when they were flying the occurrence aircraft and it was not installed on the other Bell 206 because the nature of SAG operations did not always lend itself to its use.

In addition, the company operations manual did not include any CFIT risk mitigation measures for operations on a Bell 206 in flat light or whiteout conditions.

TSB Aviation Safety Study 90-SP002, published in 1990, found that the majority of the helicopter accidents analyzed had occurred in whiteout conditions, and that many of the accidents had occurred as a result of an inadvertent descent that was not detected by the pilot. In addition, TSB Air Transportation Safety Issue Investigation A15H0001, published in

2019, revealed that most fatalities resulting from airplane and helicopter accidents involved flights that had begun in visual meteorological conditions, continued in conditions leading to the loss of visual references, and ended in either CFIT or a loss of control.

That investigation also revealed that weak or missing defences had contributed to those accidents. For several years, the inadequacy of the defences identified in many accident investigations confirms the persistence of these hazards and risk factors. Given the similar context of SAG Bell 206 operations and those of helicopter air-taxi operations, it is worthwhile to consider the discussions and conclusions of that investigation, which pointed to the varied and complex nature of the air-taxi sector. According to the investigation, the factors contributing to air-taxi accidents from 2000 to 2014 fell into 2 broad areas, one of which was *inadequate management of operational hazards*.

In the context of managing operational hazards, the traditional approach to safety management is based on regulatory compliance and a reactive response to incidents and accidents. Modern safety management principles promote a proactive search for hazards, identifying risks, and instituting better defences to reduce risks to an acceptable level. Many operators are taking a proactive approach to safety management to identify hazards and mitigate the risks associated with their activities. They are using on-board technology and training to enhance the safety of their operations. Consequently, the way operators manage hazards and risks determines the level of safety of their operations.

As we have seen above, flat light is particularly insidious and may also occur in cruise flight when visibility is good. Although regulations require that training and flight tests cover the phenomenon of whiteout, they do not specifically address flat light, which should not be confused with whiteout. Therefore, even though compliance with safety regulations is fundamental, operators that simply comply with the regulations are not well situated to identify all safety issues associated with their operations and to adequately manage operational hazards.

Finding as to risk

If air operators that operate aircraft in accordance with visual flight rules do not take proactive measures to provide specific training on flat light or the use of on-board technology to enhance situational awareness, pilots could find themselves in flat light conditions without being aware of it, increasing the risk of CFIT.

2.4 Flight progression

2.4.1 Pre-flight preparation

Early in the afternoon, only 1 aircraft was needed to continue the search, and given that the rear sliding door of the occurrence aircraft was difficult to close, it was decided to send the aircraft back to Montréal/Saint-Hubert Airport (CYHU), Quebec.

For the return flight, the pilot intentionally kept his cruise speed at 90 knots to stay under the maximum speed allowed for an open sliding door, in case the door accidentally opened during the flight.

Refuelling was planned at the La Tuque Aerodrome (CYLQ), Quebec. The pilot had noted that winds were from the south-southwest and that these headwinds would slow his speed and increase the flight time needed to arrive at his destination. The flight had to be conducted during daylight, which meant landing at CYHU by 1718, knowing that the light would be fading rapidly as sunset approached due to the overcast sky. The pilot therefore planned to conduct the return flight at approximately 500 feet above ground level (AGL), given that the aircraft's twin engines reduced the risks associated with losing power at low altitude. This allowed him to fly safely at an altitude where the strength of the wind is generally weaker.

2.4.2 The flight

At 1402, the aircraft took off from Saint-Henri-de-Taillon, Quebec, and flew a path that was almost parallel to the lake's shoreline. He stayed on this flight path for the first 4 minutes of flight, as he continued to climb. The pilot assessed his height visually using the shoreline and some islands ahead of him.

At 1406, the aircraft was at an altitude of 305 feet AGL and was approaching the group of islands. A pilot flying an aircraft with 2 engines does not need to be as concerned about the glide distance from the shoreline. If an engine loses power, the second engine enables the pilot to maintain altitude or reduce the descent rate. Given that the visibility enabled the pilot to see the shoreline to his left and ahead of him, he believed that there was no additional risk in flying further from the shore than the glide distance.

Finding as to causes and contributing factors

Given the operational constraints related to speed and remaining daylight, and the fact that the aircraft had twin engines, the pilot, who was able to distinguish the shoreline in the distance, veered to the right to fly a more direct path to his destination, moving laterally away from the shoreline.

The flat light was obscuring the shadows and contrast at the snow-covered surface of the lake, reducing the visual cues needed for the pilot to perceive depth, which is characteristic of 3D vision. Seeing the visual references, and based on his knowledge and training on whiteout, the pilot felt confident that he could maintain his height visually over the snow-covered surface of the lake without the need for flight instruments such as a radio altimeter.

As long as he kept a close lateral distance to the shoreline and could see the islands ahead of him, the pilot had enough visual cues, including the size of familiar objects, to maintain his 3D vision. However, once he had passed the islands, he did not notice that as he moved away from the shoreline, there were fewer cues.

Finding as to causes and contributing factors

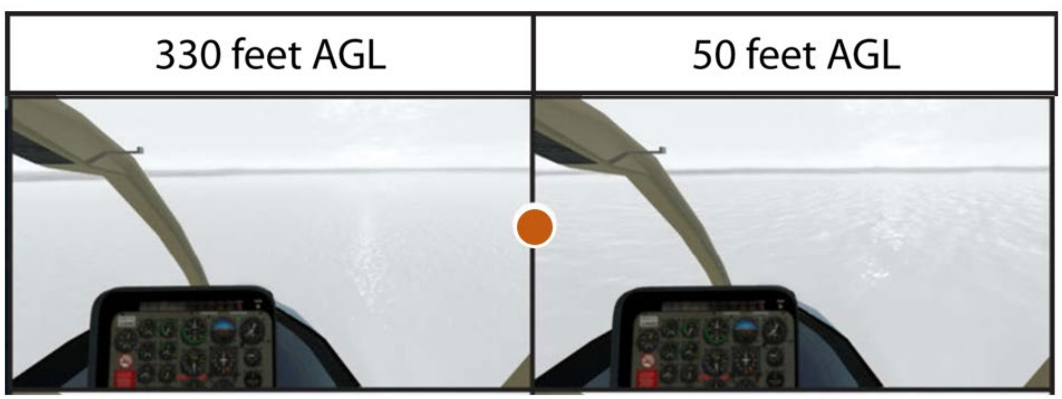
Even though the shoreline was visible in the distance, once the pilot moved laterally away from the shoreline and passed the islands, there was a significant reduction in reliable visual cues on the ground to help the pilot establish and maintain his height visually over the snow-covered surface of a lake; this situation went unnoticed by the pilot.

2.4.3 Collision with the surface of the lake

At 1408, approximately 1 minute after passing the islands, the helicopter was at an altitude of 330 feet AGL. Approximately 1 minute later and 1.34 NM further, the aircraft struck the snow-covered surface of the lake. The angle between the height of the last recorded position at 1408 and the point of impact was approximately 2.3°. For comparison purposes, an approach at this angle would be considered a shallow rate of descent. However, without a flight data recorder, it was impossible to determine exactly when the descent began, or what the aircraft's descent profile was when it struck the surface of the lake. The pilot did not feel any change in flight profile between the time the aircraft was at 330 feet and when it struck the frozen surface of the lake. It is therefore reasonable to conclude that the transition was gradual.

According to the simulated view of the shoreline from the cockpit at 330 and 50 feet AGL (Figure 9), without any contrast at the frozen surface of the lake, and once the islands had been passed, the appearance of the shoreline would change very little because the lateral distance would be too great to notice a loss of altitude at these heights if the shoreline was the only visual reference used.

Figure 9. Simulated view of the shoreline from the cockpit at 330 feet above ground level and 50 feet above ground level when the aircraft is 2.4 nautical miles from the shoreline (Source: TSB)



The insidious nature of flat light could explain why the pilot held onto the strong impression that he was in cruise flight at approximately 500 feet AGL when he suddenly felt a sharp longitudinal deceleration, heard the engines surge, and became disoriented by a perceived rotation to the left. This disorientation continued until the aircraft came to rest on its left side.

The main debris at the accident site was scattered over a distance of approximately 260 feet, along a straight line that matched the direction of flight indicated by the flight tracking system. Only the rotors had been projected away from the line of debris, after a main rotor blade severed the tail boom and caused the main rotor mast to separate from the transmission. This scattering of debris is consistent with that which would have resulted from the effect of kinetic energy and gyroscopic inertia of the rotors at the time of an accident. The separation of the 2 rotors would have caused the engines to surge when they became free of their constraints. This engine surge matches the noise heard by the pilot. The linear scattering of the debris appears to indicate a high speed and horizontal component at the time of impact.

A clear skid mark observed approximately 230 feet from the wreckage when the first responders arrived corresponds to the point of impact near the first debris on the ground. However, this skid mark was no longer visible when TSB investigators arrived, and precise measurements could not be taken to confirm the orientation of the skid mark, which was reported to be further to the left than the orientation of the line of debris.

According to the TSB Engineering Laboratory impact analysis report, from a structural standpoint, the severing of the tail boom by a main rotor blade at the horizontal stabilizer, and the deformations of the fuselage and landing gear had occurred when the aircraft struck the frozen surface of the lake hard in an upright attitude, with the left skid striking the surface before the right skid in the crash sequence. Furthermore, the failure of the landing gear attachments and the scratches, dents, and the crack found on the lower part of the fuselage indicate that the aircraft was moving laterally to the left when it struck the surface of the lake. There was no indication of a strong spin at the time of impact.

Although the impact analysis concluded that the damage occurred during lateral movement, it is possible that another impact had already occurred, without causing any damage.

The pilot initially felt a strong longitudinal deceleration, which did not match what he would have felt when the helicopter struck the frozen surface of the lake forcefully as it was moving laterally to the left. It is therefore possible that a lighter impact occurred before the one that caused the damage. However, because there was no visible trace of a collision with terrain when the TSB investigators examined the site, it was impossible to determine precisely when the helicopter struck the frozen surface of the lake.

Looking at the occurrence as a whole, many pieces of information gathered have a high degree of certainty, such as the presence of flat light, the extent and linear scattering of the debris, and the pilot's strong impression that he was in cruise flight when a strong longitudinal deceleration occurred. Furthermore, there was no indication of a pre-existing mechanical deficiency. Consequently, it was determined that the most likely scenario was that an unexpected descent occurred, without the pilot noticing it, as the helicopter flew over the lake, and that this unexpected descent ended in a CFIT accident.

Finding as to causes and contributing factors

Given the significant decrease in reliable visual cues on the ground, an unexpected descent went unnoticed by the pilot and the helicopter struck the frozen surface of the lake. It is highly likely that the helicopter was under control at that point.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. Even though visibility was 25 statute miles, flat light was obscuring the shadows and contrast at the snow-covered surface of the lake, reducing the visual cues needed for depth perception and 3-dimensional vision.

2. The pilot's knowledge and training did not provide him with the skills to recognize the risks associated with low contrast resulting from flat light during cruise flight and when good visibility made it possible to see the shoreline in the distance.

3. Given the operational constraints related to speed and remaining daylight, and the fact that the aircraft had twin engines, the pilot, who was able to distinguish the shoreline in the distance, veered to the right to fly a more direct path to his destination, moving laterally away from the shoreline.

4. Even though the shoreline was visible in the distance, once the pilot moved laterally away from the shoreline and passed the islands, there was a significant reduction in reliable visual cues on the ground to help the pilot establish and maintain his height visually over the snow-covered surface of a lake; this situation went unnoticed by the pilot.

5. Given the significant decrease in reliable visual cues on the ground, an unexpected descent went unnoticed by the pilot and the helicopter struck the frozen surface of the lake. It is highly likely that the helicopter was under control at that point.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If the reference documents provided by Transport Canada do not make a clear distinction between the phenomenon of flat light and that of whiteout, there is a risk that pilots will not differentiate between the specific threats associated with each hazard.

2. If air operators that operate aircraft in accordance with visual flight rules do not take proactive measures to provide specific training on flat light or the use of on-board technology to enhance situational awareness, pilots could find themselves in flat light conditions without being aware of it, increasing the risk of controlled flight into terrain.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. Wearing a flight helmet and fastening the 4-point shoulder harness helped to reduce the severity of the injuries to the pilot, who was able to egress from the aircraft and contact the dispatcher to get help quickly.

4.0 SAFETY ACTION

4.1 Safety action taken

The Board is not aware of any safety action taken following this occurrence.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 17 November 2021. It was officially released on 01 December 2021.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

APPENDICES

Appendix A – TSB investigations in which conditions known to affect pilot spatial awareness were identified

Occurrence number	Date	Factual information about the occurrence	Location
A19P0176	2019-12-10	**Loss of control and collision with terrain** Piper Aerostar PA-60-602P, C-FQYW	Gabriola Island, British Columbia
A19O0178	2019-11-27	**Loss of control and collision with terrain** Piper PA-32-260, N50DK	Kingston Airport, Ontario, 3.5 NM N
A19Q0153	2019-09-04	**Loss of control and collision with terrain at night** Cargair Ltd. Cessna 172M, C-GSEN	Racine, Quebec
A19W0105	2019-08-06	**Controlled flight into terrain** Alkan Air Ltd. Cessna 208B Grand Caravan, C-FSKF	Mayo, Yukon, 25 NM ENE
A19Q0128	2019-07-29	**Loss of control and collision with terrain** Beechcraft Bonanza V35B, N3804X	Senneterre, Quebec, 7 NM NE
A19P0112	2019-07-26	**Controlled flight into terrain** Seair Seaplanes Cessna 208 Caravan, C-GURL	Addenbroke Island, British Columbia
A19Q0091	2019-06-18	**Loss of control on takeoff and collision with ground** Cargair Ltd. Piper PA-23-250 Aztec, C-GDUL	Trois-Rivières Airport, Quebec
A19A0025	2019-05-01	**Controlled flight into terrain** Piper PA-46-350P, N757NY	Makkovik Airport, Newfoundland and Labrador, 35 NM SE
A19O0026	2019-03-04	**Collision with terrain** Robinson Helicopter Company R66 (helicopter), C-GAUA	Timmins (Victor M. Power) Airport, Ontario, 18 NM WNW
A19C0016	2019-03-04	**Controlled flight into terrain** Amik Aviation Ltd. Cessna 208B Caravan, C-FAFV	Little Grand Rapids Airport, Manitoba, 0.75 NM S
A18Q0186	2018-11-19	**Collision with terrain** Eurocopter EC120B (helicopter), C-FSII	Sainte-Agathe-des-Monts, Quebec, 5 NM W
A18O0134	2018-09-25	**Controlled flight into terrain** Essential Helicopters Robinson R44 Raven II (helicopter), C-GMCT	Toronto/Buttonville Municipal Airport, Ontario, 9 NM N
A18P0090	2018-06-28	**Visual flight rules flight into deteriorating weather and collision with terrain** Cessna 182P, C-GKKU	Hope, British Columbia, 19 NM NE

A18Q0016	2018-02-02	**Collision with terrain at night** Robinson R44 Raven I (helicopter), C-GYMG	Saint-Joachim-de-Courval, Quebec
A17C0147	2017-12-16	**Collision with terrain** Piper PA-23-250 Aztec, C-FIPK	Baldur, Manitoba, 5 NM E
A17P0170	2017-11-26	**Visual flight rules flight into deteriorating weather and collision with terrain** Mooney M20D, C-FESN	Revelstoke, British Columbia, 26 NM NE
A17O0209	2017-09-21	**Collision with water** Cessna 150J, C-FHPU	Goderich, Ontario
A16P0186	2016-10-13	**Loss of control and collision with terrain** Norjet Inc. Cessna Citation 500, C-GTNG	Kelowna Airport, British Columbia, 4.5 NM NE
A16P0180	2016-10-10	**Loss of control and collision with terrain** de Havilland DHC-2 (Beaver), C-GEWG	Laidman Lake, British Columbia, 11 NM E
A15O0188	2015-11-09	**Collision with terrain** Cessna 182H, C-GKNZ	Parry Sound Area Municipal Airport, Ontario
A15C0130	2015-09-08	**Collision with terrain** Apex Helicopters Inc. Robinson R44, C-GZFX	Foleyet, Ontario, 17 NM S
A14O0217	2014-11-11	**Collision with terrain** Flyblocktime Incorporated Cessna 150M, C-GJAO	Whitney, Ontario, 8 NM S
A14A0067	2014-08-16	**Collision with terrain** Manan Air Services (dba Atlantic Charters) Piper PA-31 Navajo, C-GKWE	Grand Manan, New Brunswick
A13H0002	2013-09-09	**Collision with water** Government of Canada, Department of Transport MBB BO 105 S CDN-BS-4 (helicopter), C-GCFU	M'Clure Strait, Northwest Territories
A13P0166	2013-08-16	**Controlled flight into terrain** Air Nootka Ltd. de Havilland DHC-2 (floatplane), C-GPVB	Hesquiat Lake, British Columbia, 3NM W
A13C0073	2013-07-01	**Collision with water** Custom Helicopters Ltd. Bell 206B (helicopter), C GQQT	Gull Lake, Manitoba
A13H0001	2013-05-31	**Controlled flight into terrain** 7506406 Canada Inc. Sikorsky S-76A (helicopter), C-GIMY	Moosonee, Ontario
A13C0014	2013-02-10	**Continued visual flight into instrument meteorological conditions - Collision with terrain** Cessna 210C, C-FWUX	Waskada, Manitoba, 3 NM N
A13F0011	2013-01-23	**Controlled flight into terrain** Kenn Borek Air Ltd. de Havilland DHC-6-300 Twin Otter, C-GKBC	Mount Elizabeth, Antarctica

A12C0141	2012-10-16	**Collision with terrain** Aerofab Inc. Lake 250, C-GZLC	Pickle Lake, Ontario
A12C0084	2012-07-04	**Controlled flight into terrain** Sunrise Helicopters Incorporated Bell 206B (helicopter), C-GUIK	Angusville, Manitoba, 6 NM SW
A12P0079	2012-06-01	**Loss of visual reference and collision with terrain** Bailey Helicopters Limited Eurocopter AS350-B2 (helicopter), C-FBHN	Terrace, British Columbia, 14 NM W
A12P0070	2012-05-13	**Controlled flight into terrain** de Havilland DHC-2 MK 1 (Beaver) (floatplane), C-GCZA	Peachland, British Columbia, 10 NM W
A12W0031	2012-03-30	**Loss of control and collision with terrain** Kananaskis Mountain Helicopters Ltd. Bell 206B JetRanger (helicopter), C-GLQI	Loder Peak, Alberta, 0.4 NM NW
A11W0180	2011-11-30	**Controlled flight into terrain** Trek Aerial Surveys Cessna 185E, C–FXJN	Fort St. John, British Columbia, 12 NM E
A11W0152	2011-10-05	**Continued visual flight into instrument meteorological conditions - Collision with terrain** Rotorworks Inc. Bell 206B (helicopter), C-FHTT	Drayton Valley Industrial Airport, Alberta, 1 NM S
A11W0151	2011-10-04	**Controlled flight into terrain** Air Tindi Ltd. Cessna 208B Caravan, C-GATV	Lutsel K'e, Northwest Territories, 26 NM W
A11Q0168	2011-08-27	**Collision with terrain following night-time takeoff** Robinson R44 Raven II (helicopter), C-GEBY	Saint-Ferdinand, Quebec
A11C0100	2011-06-30	**Collision with terrain** Lawrence Bay Airways Ltd. de Havilland DHC-2, C-GUJX	Buss Lakes, Saskatchewan, 2 NM SE
A11W0070	2011-05-20	**Loss of control – Collision with water** Campbell Helicopters Ltd. Bell 212 (helicopter), C–FJUR	Slave Lake, Alberta, 12 NM W
A10A0122	2010-12-14	**Controlled flight into terrain** Aero Peninsule Ltee (doing business as Air Optima) Cessna 310R, C-GABL	Pokemouche, New Brunswick, 5.5 NM WNW
A10Q0148	2010-09-01	**Loss of visual reference - Collision with trees** Canadian Helicopters Limited Eurocopter AS350 B-2 (helicopter), C-GHVD	Chibougamau, Quebec, 12 NM NW
A10Q0132	2010-08-17	**Loss of visual reference with the ground, loss of control, collision with terrain**	Sept-Îles, Quebec, 22 NM N

		Héli-Excel Inc. Eurocopter AS350-BA (helicopter), C-GIYR	
A10Q0133	2010-08-16	**Collision with sea** Universal Helicopters Newfoundland Limited Bell 206L (helicopter), C-GVYM	Clyde River, Nunavut, 40 NM NW
A10A0085	2010-08-05	**Collision with water** Cessna 414A, C-GENG	Sydney, Nova Scotia, 13 NM ENE
A10P0244	2010-07-31	**Collision with terrain** Conair Group Inc. Convair 580, C–FKFY	Lytton, British Columbia, 9 NM SE
A10Q0111	2010-07-16	**Controlled flight into terrain at cruising altitude** Air Saguenay (1980) Inc. de Havilland DHC-2, C-GAXL	Lake Péribonka, Quebec, 12 NM WSW
A10A0056	2010-05-26	**Controlled flight into terrain** North Wind Aviation Ltd. Piper Navajo PA31-350, C-FZSD	Cartwright, Newfoundland and Labrador, 60 NM W