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

AVIATION INVESTIGATION REPORT A12C0005

LOSS OF CONTROL AND COLLISION WITH TERRAIN

KEYSTONE AIR SERVICE LIMITED
PIPER PA31-350 NAVAJO CHIEFTAIN, C-GOSU
NORTH SPIRIT LAKE, ONTARIO
10 JANUARY 2012

Aviation Investigation Report

Loss of Control and Collision with Terrain

Keystone Air Service Limited
Piper PA31-350 Navajo Chieftain, C-GOSU
North Spirit Lake, Ontario
10 January 2012

Report Number A12C0005

Summary

The Piper PA31-350 Navajo Chieftain (registration C-GOSU, serial number 31-7752148), operating as Keystone Air Service Limited Flight 213, departed Winnipeg/James Armstrong Richardson International Airport, Manitoba, enroute to North Spirit Lake, Ontario, with 1 pilot and 4 passengers on board. At 0957 Central Standard Time, on approach to Runway 13 at North Spirit Lake, the aircraft struck the frozen lake surface 1.1 nautical miles from the threshold of Runway 13. The pilot and 3 passengers sustained fatal injuries. One passenger sustained serious injuries. The aircraft was destroyed by impact forces and a post-impact fire. After a short period of operation, the emergency locator transmitter stopped transmitting when the antenna wire was consumed by the fire.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The pilot arrived at Winnipeg/James Armstrong Richardson International Airport (CYWG), Manitoba, at approximately 0530 [1] to prepare for a 0730 departure. The flight departed CYWG for North Spirit Lake (CKQ3), Ontario, at 0751 on an instrument flight rules (IFR) flight plan. The planned routing was from CYWG to Deer Lake (CYVZ), Ontario, with an enroute stop in CKQ3 to drop off a passenger. The remaining 3 passengers were then to be flown onward to CYVZ for meetings. Enroute, the aircraft flew just above the cloud tops at an altitude of 9000 feet above sea level (asl).

The flight arrived in the CKQ3 area at about 0930, and the pilot broadcast a traffic advisory on the CKQ3 aerodrome traffic frequency (ATF). The airport foreman, who was plowing the runway, advised the pilot that snow clearing was underway and would be completed in about 10 minutes. The pilot replied indicating intention to delay the landing until snow clearing was completed. The aircraft was heard flying overhead CKQ3 for several minutes, and sounded near and low, but could not be seen due to heavy snow and cloud cover.

Ice was accumulating on the aircraft's windshield during the delay. The pilot called again several minutes later to ask whether snow clearing was completed. The airport foreman advised the pilot that approximately 60% of the runway had been cleared and that the equipment was in the process of exiting the runway. The pilot commenced the approach. During the approach, the aircraft banked to the left and then steeply to the right, and then struck the ice at about 0957 (Figure 1).

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1 All times are Central Standard Time (Coordinated Universal Time minus 6 hours).

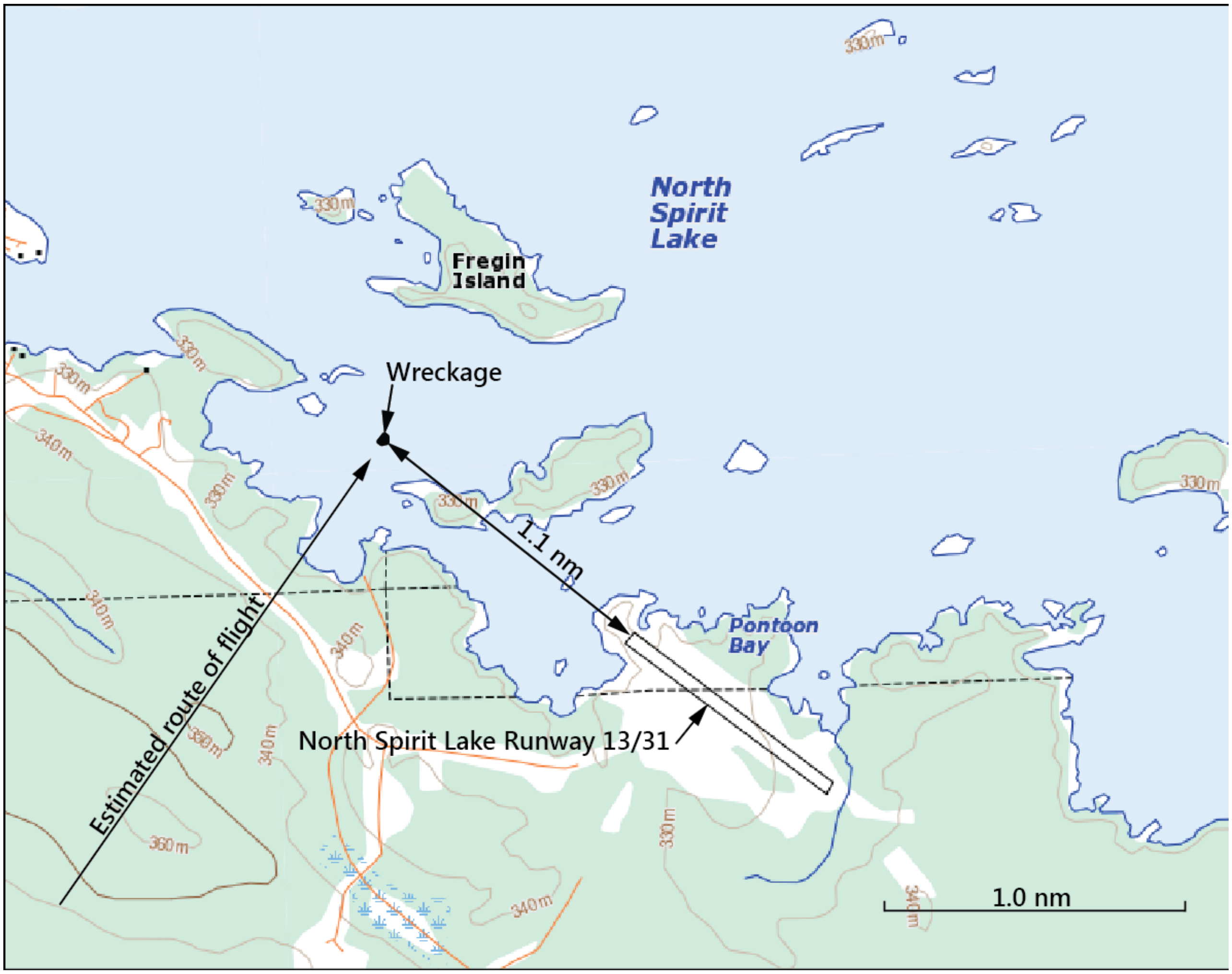

Figure 1. Wreckage location

1.2 *Injuries to Persons*

Table 1. Injuries to persons

	Crew	Passengers	Total
Fatal	1	3	4
Serious	–	1	1
Minor/None	–	–	–
Total	1	4	5

1.3 *Damage to Aircraft*

The aircraft was destroyed by impact forces when the aircraft struck the frozen surface of the lake. Most of the aircraft was consumed by a post-impact fire.

1.4 Other Damage

A small amount of residual contaminants might have remained after the wreckage was removed. The fact that the accident site was on the frozen surface of the lake limited damage to the aircraft itself.

1.5 Personnel Information

Records indicate that the pilot was certified and qualified for the flight in accordance with existing regulations. The pilot held a commercial pilot licence with a group 1 multi-engine instrument rating and a category 1 medical certificate. The pilot's logbooks were reviewed. They contained records of the pilot's flying activity until 14 November 2011, and indicate that the pilot had approximately 2400 hours of total flight time, 2300 hours of which had been accumulated on small single-engine aircraft as a student and then as an instructor. In addition, the pilot had approximately 125 flight hours on multi-engine aircraft, of which approximately 95 hours were on type. During the pilot's multi-engine instrument training, and Keystone's line indoctrination training, the pilot accumulated 55.2 hours of instrument flight, of which approximately 2.5 hours was in actual instrument meteorological conditions (IMC).

The pilot began employment with Keystone Air Service Limited (Keystone) in October 2011. The pilot received initial company indoctrination training in a variety of areas: aircraft proficiency, icing, and dangerous goods, as required by Keystone's company operations manual (COM) and the *Canadian Aviation Regulations* (CARs). Included in this training was material on human factors. The human factors training contained Transport Canada (TC) document TP 14175E − *Human Performance Factors for Elementary Work and Servicing*. Other recommended human factors documents, such as TP 12863 − *Basic Handbook*, TP 12864 – *Advanced Handbook*, and TP 12865 – *Instructor's Guide*, were not used in the indoctrination training.

The pilot received icing training in the form of ground school instruction during initial pilot training for private and commercial pilot licences. At the beginning of the pilot's employment with Keystone, the pilot received training and instruction in icing issues from a senior training pilot, and watched a training video (National Aeronautics and Space Administration [NASA] In-flight Icing Training for Pilots). Keystone's COM also contains directives requiring instruction relative to the aircraft manual, Flight in Icing Condition Equipment, Flight in Icing Condition Equipment – Night, Operations of Aircraft in Icing Conditions, and Aerodynamic Effects of Airborne Icing. After the training, the pilot successfully completed a 3-part icing exam, as required by Keystone's COM. Although the operator did not conduct annual winter operations briefings, the pilots were required to complete annual recurrent icing training.

The human factors training did not include any material pertaining to pilot decision-making (PDM) or to threat and error management (TEM), nor was such material a requirement. Training in PDM and in TEM aids pilots in making sound operational decisions, especially in a self-dispatch environment based on available information and experience.

After completing initial training with Keystone, the pilot successfully completed a pilot proficiency check (PPC). The pilot then completed approximately 55 hours of line indoctrination training on the Piper PA31-350. Line indoctrination training consisted of a series of flights accompanied by a supervisory pilot. These flights were conducted primarily in visual meteorological conditions (VMC), and to a lesser extent, in IMC. Only a small amount of aircraft icing was encountered during these flights. The flights were flown fully or partially in uncontrolled airspace outside of air traffic control (ATC) radar coverage, and the aircraft altitudes flown were not recorded.

The occurrence flight was the pilot's third flight into CKQ3. The pilot had completed 19 flights in VMC during the 7 days of flying as a single pilot following completion of line indoctrination.

The pilot was described as ambitious, eager to prove competent, and cautious.

1.6 Aircraft Information

The Piper PA31-350 Navajo Chieftain is a twin-engine aircraft with retractable landing gear and constant speed propellers, with a maximum take-off weight of 7368 pounds. The aircraft was configured to carry a pilot and up to 9 passengers. The aircraft was certified for day or night flights, under visual flight rules (VFR) or IFR.

Records indicate that the aircraft was maintained in accordance with the Keystone approved maintenance control system. A review of the technical records indicates that there were no deferred or outstanding defects on the aircraft. The pilot did not report any technical difficulties with the aircraft before the occurrence.

A review of the empty and operational weight and balance revealed that the aircraft was within the specified limitations for the occurrence flight. At the time of the occurrence, the aircraft had approximately 765 pounds of fuel on board.

The *Pilot's Operating Handbook* (POH) and the *Approved Airplane Flight Manual* (Report 2046) for the PA31-350 indicated that the occurrence aircraft was certified for flight in light and moderate icing conditions. The aircraft was equipped with the following de-ice equipment:

- Wing and tail de-icing system,
- Heated windshield,
- Heated pitot tube,
- Propeller de-ice, and
- Elevator horn de-icing boot.

Light and moderate icing are terms used to describe the intensity of the ice. Although the POH does not have a definition for light or moderate icing, TC [2] defines these terms as follows:

> - Light – The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour).
> - Moderate – The rate of accumulation is such that even short encounters become potentially hazardous, and use of de-icing or anti-icing equipment or diversion is necessary.

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2 Transport Canada (TC), TP 14371E (02/2012), *Aeronautical Information Manual* (TC AIM), MET – Meteorology 2.4 – Airframe Icing, page 119, available at http://www.tc.gc.ca/publications/en/tp14371/pdf/hr/tp14371e.pdf (last accessed on 01 November 2013)

As equipped, the occurrence aircraft was certified to depart on a flight when light to moderate icing was forecast for the intended route. The United States Federal Aviation Administration (FAA) defines the term "forecast icing" as "environmental conditions expected by a national weather service or an FAA-approved weather provider to be conducive to the formation of in-flight icing on aircraft." [3] However, the manufacturer indicated that once the occurrence aircraft encountered known icing conditions, the de-icing system was to be used to help divert the flight clear of ice, and was not to be used for continued flight in known icing conditions. The FAA defines the term "known icing conditions" as "atmospheric conditions in which the formation of ice is observed or detected in flight." [4] The reference relating to this point is in FAA Advisory Circular 135-9. [5] However, advisory circulars are not routinely used in a pilot's indoctrination and training curriculum. Keystone's COM does not make any reference to this advisory circular.

In 1980, a modification kit (Piper Service Spares Letter 361) was made available that would have certified this PA31-350 aircraft to be flown into known icing conditions. The modification to the aircraft included the installation of the following additional equipment:

- Inboard wing de-ice boots;
- Heated stall warning vane; and
- NACA [6]-style non-icing air intake scoops for the combustion heater.

The manufacturer indicated that aircraft that are certified for flight into known icing conditions may continue flight in light or moderate icing conditions.

This modification was not installed on the occurrence aircraft.

Discussions with past and present Keystone pilots who flew the PA31-350 aircraft type revealed that they were uncertain as to the aircraft's operational limitations given its icing certification.

1.7 Meteorological Information

Before departure, the pilot gathered weather and notices to airmen (NOTAM) information from the NAV CANADA website, which is standard practice for Keystone.

There are no routine weather observations available for CKQ3. The 0900 aviation routine weather report (METAR) for Red Lake (CYRL), Ontario, 97 nautical miles (nm) south of CKQ3, was: wind 170° True (T) at 6 knots, visibility 15 statute miles (sm) in light snow, overcast cloud

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3 Federal Aviation Administration (FAA), *Aeronautical Information Manual* (AIM) (22 August 2013), available at http://www.faa.gov/air_traffic/publications/ATPubs/AIM/aim.pdf (last accessed on 31 October 2013)

4 Ibid

5 FAA Advisory Circular (AC) 135-9 – Federal Aviation Regulations (FARs) Part 135: Icing Limitations (issued 30 May 1981), available at http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%20135-9/$FILE/AC135-9.pdf (last accessed on 31 October 2013)

6 National Advisory Committee for Aeronautics

based at 1000 feet above ground level (agl), temperature minus 1°C, dew point minus 3°C, and altimeter setting 29.53 inches of mercury.

The aerodrome forecast (TAF) for CYRL, issued at 0738 and valid from 0900 to 1200, was predicting winds 270°T at 8 knots, visibility of 5 sm, with light snow, light freezing drizzle, and broken cloud at 1000 feet agl and overcast at 2500 feet agl.

The graphical area forecast (GFA) for the CKQ3 area was predicting visibility of 1 to 4 sm in light snow, with patchy ceilings of 800 feet agl in snow showers and moderate mixed icing from 3000 feet asl to the surface, associated with freezing drizzle and mist (Appendix B and Appendix C).

Weather conditions observed in the area of CKQ3 at the time of the accident were ceilings of approximately 150 to 200 feet agl, with a visibility of approximately ¼ sm in snow and freezing drizzle. A pilot who had been flying in the CKQ3 area just before the accident reported severe icing at approximately 3000 feet asl, and had to divert the aircraft. That pilot subsequently filed a pilot report (PIREP) with NAV CANADA.

1.7.1 Previous Flights by Occurrence Pilot

A number of previous flights conducted by the occurrence pilot were examined**.**

The investigation reviewed the relevant METARs for departure and destination stations, and the GFAs for enroute areas to assess whether the flights on those days would have been conducted in IMC or VMC. The information from these METARs and GFAs was as follows:

- 20 December 2011 (Winnipeg to Saint Andrews, Manitoba, to Berens River, Manitoba, to Saint Andrews to Winnipeg) − departure: broken cloud at 9600 feet and visibility 15 sm; enroute: forecast of cloud bases at 8000 feet and cloud tops at 14000 feet; Berens River: broken cloud at 7500 feet and visibility 15 sm. Moderate icing was forecast in the cloud, and freezing level was at the surface. Total airtime was 2.0 hours.

- 21 December 2011 (Winnipeg to Saint Andrews to Berens River to Saint Andrews to Winnipeg) − departure: scattered cloud at 2500 feet, scattered cloud at 4500 feet, and visibility 15 sm; enroute: forecast of cloud bases at 4000 to 5000 feet and cloud tops at 16000 feet; arrival at Berens River: overcast cloud at 1800 feet and visibility 15 sm; departure from Berens River: overcast cloud at 1200 feet and visibility 4 sm in light snow; arrival at Saint Andrews and Winnipeg: overcast cloud at 8900 feet and visibility 15 sm. No icing was forecast en route. Total air time was 1.8 hours.

- 22 December 2011 (Saint Andrews to Winnipeg to North Spirit Lake to Saint Andrews) − departure: overcast cloud at 1700 feet and visibility 15 sm; enroute: forecast of overcast cloud at 3000 to 4000 feet, cloud tops at 8000 feet, occasional ceilings at 3000 feet scattered and tops at 6000 feet; arrival at CKQ3: no METAR available; the METAR for Red Lake, 97 nm south of CKQ3: overcast cloud at 2500 feet and visibility 12 sm in light snow; departure from CKQ3: conditions as at arrival. En route, scattered cloud at 3000 feet, cloud tops at 6000 feet, becoming broken cloud at 3000 to 4000 feet and tops at 8000 feet. No icing in cloud was forecast. Total air time was 2.8 hours.

- 29 December 2011 (Winnipeg to Little Grand Rapids, Manitoba) − departure: overcast cloud at 500 feet and visibility 10 sm; enroute: forecast of overcast cloud at 500 to 800 feet and cloud tops at 14000 feet; arrival and subsequent departure at Little Grand Rapids: overcast cloud at 1000 feet and visibility 15 sm; arrival at Saint Andrews: overcast cloud at 1100 feet and visibility 15 sm. Local moderate mixed icing was forecast in cloud from 3000 feet to the surface. Total air time was 1.8 hours.

- 02 January 2012 (Saint Andrews to Winnipeg to Cross Lake, Manitoba, to Winnipeg) − departure: scattered cloud at 1100 feet and visibility 15 sm; enroute: broken cloud at 3000 feet, tops at 6000 feet and localized broken cloud ceilings at 800 feet; arrival and departure at Cross Lake (Norway House was used): broken cloud at 2500 feet and visibility 9 sm in snow; on arrival at Saint Andrews: scattered cloud at 2000 feet and visibility 15 sm. No icing was forecast. Total air time was 3.6 hours.

- 08 January 2012 (Winnipeg to Berens River to Poplar River, Manitoba, to Winnipeg) − departure: scattered cloud at 9500 feet and 23000 feet, and visibility 15 sm; enroute: broken cloud at 6000 feet, cloud tops at 10000 feet and local broken cloud at 2000 to 3000 feet; arrival and departure at Berens River: no reports available; arrival at Winnipeg: scattered cloud at 5000 feet and 10000 feet, and visibility 15 sm. No icing was forecast. Total air time was 2.3 hours.

These flights were completed by the occurrence pilot as single pilot. The flights were flown fully or partially in uncontrolled airspace outside of ATC radar overage, and the enroute aircraft altitudes flown were not recorded.

1.8 Aids to Navigation

CKQ3 is not serviced by any ground-based navigational aids. Navigation to CKQ3 was accomplished by Keystone pilots using their global positioning system (GPS).

The low-level airspace in the vicinity of CKQ3 is uncontrolled. The area minimum altitude (AMA) in the vicinity of CKQ3 is 2700 feet asl. This altitude is designated to provide terrain clearance for aircraft operating in uncontrolled airspace. Under normal circumstances, pilots operating under IFR are not authorized to descend below the AMA, except in accordance with an approved instrument approach procedure or when operating in VMC. At an airport with no instrument approach procedure and the ceiling below AMA, the pilot has the option of diverting the aircraft to an airport that does have an instrument approach, or the pilot can divert to an area where VFR flight rules exist.

CKQ3 did not have an approved instrument approach procedure; however, there was an approved instrument approach for CYVZ. There was no indication that either the pilot or the operator had developed an improvised instrument approach to CKQ3.

1.9 Communications

Equipment operators at CKQ3 use fixed very high frequency (VHF) radios tuned to the ATF, so that they can communicate with inbound aircraft.

After the pilot broadcast a traffic advisory on the ATF, the airport foreman established communication with the pilot, with all of the relevant and requested information. There was no indication from the pilot of any urgency or problems with the flight. These communications were not and are not required to be recorded.

1.10 Aerodrome Information

1.10.1 North Spirit Lake / CKQ3 Airport

North Spirit Lake is a small remote community located in Northwestern Ontario, 230 nm northeast of Winnipeg, and has a population of approximately 260 people. The only mode of transportation in and out of North Spirit Lake is by air, and by winter ice roads to some of the neighbouring communities.

CKQ3 is at an elevation of 1082 feet asl. The runway is a gravel strip that is 3518 feet in length and 100 feet wide. The runway is numbered in relation to its magnetic direction, which in this case is 130° and 310°, and is referred to as Runway 13/31. CKQ3 is operated by the Ministry of Transportation of Ontario (MTO).

1.10.2 Airport Operations

Runway condition reporting (RCR) for this and other MTO northern airports, including CYVZ, is listed in the *Canada Flight Supplement* (CFS) as being available from 0800 to 1700.

On a weekday, the airport foreman arrives at 0800, checks the runway condition, and then sends the runway information to the Winnipeg Flight Information Centre (FIC), which then distributes the RCR via a NOTAMJ. NOTAMJ are special-series NOTAM that contain information related to the condition and braking action of runway surfaces in accordance with published reporting requirements. [7] MTO procedures require that the foreman check the runway and issue an RCR before finishing the shift (usually around 1630). On days when runway conditions vary, such as during periods of continuous snowfall, the airport foreman may issue as many as 4 RCRs during the day.

There is no monitoring of runway conditions at CKQ3 outside of the published hours, nor on weekends or holidays. MTO does not maintain a communication network that monitors runway conditions or airport status at its airports. Outside of the published RCR reporting hours, there is no means by which pilots or air operators can obtain runway information for MTO-operated airports.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was either required by regulation.

Given the combined accident statistics for CARs Subparts 702, 703, and 704 operations, the Transportation Safety Board (TSB) has previously stated that there is a compelling case for industry and the regulator to proactively identify hazards and manage the risks inherent in these operations. In order to manage risk effectively, industry and regulators need to know why incidents happen and what the contributing safety deficiencies may be. Moreover, routine monitoring of normal operations can help these operators both improve the efficiency of their

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[7] NAV CANADA, *Canadian NOTAM Procedures Manual* (Version 8, 20 October 2011)

operations and identify safety deficiencies before they result in an accident. In the event that an accident does occur, recordings from lightweight flight-recording systems will provide useful information in the investigation to enhance the identification of safety deficiencies. Based on this conclusion, the TSB recommended in Aviation Safety Recommendation A13-01 that:

> [t]he Department of Transport work with industry to remove obstacles and develop recommended practices for the implementation of flight data monitoring and the installation of lightweight flight recording systems for commercial operators not required to carry these systems.

1.12 Wreckage and Impact Information

TSB investigators arrived on scene approximately 26 hours after the accident. The aircraft struck the frozen surface of the lake in a right-wing-low attitude at both a high rate of descent and forward speed. Contents of the aircraft, such as baggage and cargo, were found strewn halfway up the wreckage trail, indicating an early breakup of the cockpit and cabin area. The wreckage trail was generally aligned with the extended centreline of the runway. It was approximately 380 feet long, and the aircraft had come to a rest in an upright position, facing a southeasterly direction (Photo 1). Damage to the propellers suggests that the engines were producing power at the time of the impact. A post-impact fire consumed a majority of the aircraft.

An approximate 4-foot section of the right-wing leading edge containing the stall warning vane was torn off and found approximately halfway down the wreckage trail. This section of leading edge was not affected by the fire, and exhibited some clear and mixed ice that was approximately 3/8 inch thick (Photo 2). The stall warning vane was not heated, and exhibited hard packed ice inside the stall warning housing, trapping the vane in a downward position (Photo 3). The left horizontal-stabilizer leading edge was also not affected by the fire, and exhibited ice accumulation (Photo 4).

Inspection of the wreckage revealed that the main landing-gear actuator pistons were retracted and the nose-gear actuator piston was extended, indicating that the landing gear was extended. The left-wing flap position was found partially extended in the approach position. An inspection of the fuel selector pedestal face revealed that the left fuel selector knob was in the inboard position. The right knob was consumed by the fire. The fuel crossfeed knob was in the off position.

The aircraft de-ice system included a series of inflatable, fabric-reinforced rubber boots that are cemented span-wise across the leading edges of the wings, horizontal stabilizer, and vertical fin. Within the rubber boots are inflatable tubes that expand using air pressure provided by the engine-driven vacuum pumps, and are designed to break off accumulated surface ice on a timed cycle when activated by the pilot.

Many of the aircraft de-ice system components were consumed by the post-impact fire. Other components that were recovered had suffered burn damage to the point that examination and bench testing was inconclusive. The vacuum pumps were recovered along with the engines, and no anomalies were found. An examination of the remaining de-ice boots and plumbing that was not damaged did not reveal any anomalies. Due to the extent of fire damage, it could not be determined whether the aircraft de-ice system had been functioning normally.

Investigators secured some instrumentation and flight control cables for further analysis at the TSB Laboratory in Ottawa. Analysis of the flight control cables revealed that the failures were of an overload nature, and likely resulted from the impact. Analysis of the instrumentation was inconclusive due to the extent of fire damage.

An inspection of the remaining aircraft wreckage did not reveal any pre-impact anomalies.

No altimeter settings could be extracted from any of the altimeters due to fire damage.

Photo 1. Wreckage on site

Photo 2. Leading edge ice

Photo 3. Stall warning vane

Photo 4. Ice on the horizontal stabilizer leading edge

1.13 Medical Information

There was nothing found to indicate that the pilot's performance was degraded by physiological factors. The pilot's work/rest schedule was such that fatigue was not considered a factor in this occurrence.

1.14 Fire

1.14.1 General

Impact forces caused deformation of the aircraft structure, which compromised the fuel system. Fuel was released from the right wing in the vicinity of the aircraft's exhaust system. The hot exhaust components ignited the fuel, and a fire resulted almost immediately. The fire was fed by fuel from the right-wing fuel tank and the slightly elevated left-wing fuel tank. Fuel from the elevated left wing migrated and moved the fire to the fuselage and right wing area, within a short time, limiting the survivable time inside the cabin after the accident.

Post-impact fires (PIFs) have been documented in previous TSB investigations as a risk to aviation safety. As well, following TSB Safety Study SII A05-01, completed in 2006, the TSB concluded that the defences against PIFs in impact-survivable accidents involving small aircraft are, and will remain, inadequate unless countermeasures are introduced to reduce the risk. The most effective ways to prevent PIFs in accidents involving existing small aircraft are to eliminate potential ignition sources, such as hot items and high-temperature electrical arcing and friction sparking, and to prevent fuel spillage by preserving fuel system integrity in survivable crash conditions. Technology that is known to reduce the incidence of PIFs by preventing ignition and containing fuel in crash conditions may be selectively retrofitted to existing small aircraft. Therefore, the Board recommended, in TSB Recommendation A06-10, [8] that:

> [t]o reduce the number of post-impact fires in impact-survivable accidents involving existing production aircraft weighing less than 5700 kg, TC, the FAA, and other foreign regulators conduct risk assessments to determine the feasibility of retrofitting aircraft with the following:
>
> - Selected technology to eliminate hot items as a potential ignition source;
> - Technology designed to inert the battery and electrical systems at impact to eliminate high-temperature electrical arcing as a potential ignition source;
> - Protective or sacrificial insulating materials in locations that are vulnerable to friction heating and sparking during accidents to eliminate friction sparking as a potential ignition source; and
> - Selected fuel system crashworthiness components that retain fuel.

TC responded to these recommendations in November 2006 and January 2007, but because these responses contained no action or proposed action that will reduce or eliminate the risks associated with this deficiency, TC's overall response to Recommendation A06-10 was assessed as Unsatisfactory. The Board has determined that the residual risk associated with the deficiency identified in Recommendation A06-10 remains significant, and consequently, the TSB will renew efforts to encourage adoption of the recommendation.

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[8] Transportation Safety Board (TSB) Recommendation A06-10 (29 August 2006), available at http://www.bst-tsb.gc.ca/eng/recommandations-recommendations/aviation/2006/rec_a0610.asp (last accessed on 31 October 2013)

1.15 Survival Aspects

The surviving passenger evacuated the aircraft through the rear cabin door, and pulled the deceased pilot out of the cockpit through the cockpit window. As the fire began to intensify, the survivor attempted to put out the fire on the right wing. The local residents noted the cessation of the aircraft engine sound, and the smoke on the lake. The residents responded to the accident site, and then notified the local authorities (Nishnawbe-Aski Police Service). Due to the location of the accident, the only way to access the site was by snowmobile. When the local authorities and community members arrived at the site, the aircraft was engulfed in flames. The surviving passenger was transported to Winnipeg for medical attention.

CKQ3 has an Airport Emergency Response Plan that describes protocol and procedures in the event of an aircraft accident. There is no aircraft firefighting capability on the airport. The community has a volunteer fire department, but it is staffed on an irregular basis. It is not equipped to fight an aircraft fire, and did not attend. The nursing station has an emergency response vehicle, but it was not used to respond due to the accident location.

The aircraft was equipped with an emergency locator transmitter (ELT). The ELT transmitted for a period of time, but the Joint Rescue Coordination Center stopped receiving a signal shortly after the time of the accident. The ELT antenna wiring was consumed by the post-impact fire.

1.16 Tests and Research

No special tests were conducted for this occurrence.

1.17 Organizational and Management Information

1.17.1 Keystone Air Service

Keystone operates a commercial air service under Subparts 702, 703, and 704 of the CARs, and provides charter services to various destinations in North America. The accident flight was conducted under CARs Subpart 703.

Keystone's main base of operation is located at the Saint Andrews Airport in Saint Andrews. Keystone also has a base at CYWG, which operates on a Type C operational control system. Air operations conducted under Subparts 702, 703, and 704 of the CARs require a minimum Type C operational control system. The Type C operational control system is generally used by smaller air operators that conduct short flights over an area close to the base of operations.

When operating under a Type C operational control system, the operations manager delegates operational control of the flight (i.e., decision to dispatch) to the pilot-in-command, but retains responsibility for all flight operations. Under this system, pilots are not normally required to consult with company supervisory personnel before dispatching from a base of operations. However, should the need have arisen, the pilot did have the option of consulting the chief pilot or a senior, more experienced pilot to help assess the feasability of the flight.

There were no formal procedures in place, such as a pre-flight risk-assessment checklist. Such checklists can be used to help pilots evaluate the actual risk of the flight. The checklist makes provision for the cumulative effects of minor risks, which can raise the overall risk significantly, suggesting that the flight not be carried out unless some of the risk is mitigated. Such procedures are used by some operators and flight schools, but are not required under the CARs.

The CARs require that, before conducting single-pilot flight on multi-engine aeroplanes into IMC, pilots flying under CARs Subpart 703 shall have accumulated 1000 total flight hours, which includes a minimum of 100 flight hours on multi-engine aeroplanes. In addition, the pilot shall have 50 hours of simulated or actual flight in IMC, and a total of 50 hours of flight time on the aeroplane type.

Although not required by the CARs, Keystone's *Company Operations Manual* requires pilots to undergo line indoctrination for each type of aircraft the company operates. The pilot will fly with a training pilot and be assessed for competency on many phases of flight using a line-indoctrination training record check sheet. The pilot must accumulate a minimum of 50 hours of line-indoctrination flight time and be successfully assessed on completion of the training, using the prescribed check sheet.

Under Subpart 602.71 of the CARs, pilots shall familiarize themselves with all of the available information for the intended flight, including runway conditions. Other than a visual inspection by the pilot before landing, neither Keystone nor the pilot had a method for obtaining runway surface conditions outside of the airport operating hours published in the CFS. Although no runway condition reports were available at the time, the pilot completed the flight planning; the pilot's weather briefing included information from the TAFs of surrounding communities, CYRL, Pickle Lake (CYPL) and Island Lake (CYIV), all of which forecast light snow.

Operations conducted under Subpart 703 of the CARs require an operational control system to determine and record calculated fuel requirements for the flight, and the aircraft's weight and centre of gravity (C of G). The pilot departed with 1100 pounds of fuel. The pilot filed a round-trip IFR flight plan with the Winnipeg FIC indicating an itinerary of CYWG−CKQ3−CYVZ−CKQ3−CYWG, with Brandon (CYBR) as the arrival alternate. The total specified flight time en route, including the alternate plus a 30-minute reserve, was 4.75 hours, and would have consumed 950 pounds of fuel.

Neither the pilot's operational flight plan nor the C of G calculations was recovered, and no record of these items was found at CYWG or at the operator's base at Saint Andrews.

1.17.2 Dispatch in Marginal Weather

In small and medium-sized air operations. it is common practice for owners and senior management to be involved in the day-to-day operation. On several occasions, senior management of Keystone had become involved in the dispatch process by challenging a pilot's decision not to depart, suggesting that the pilot could always turn around or divert. Keystone pilots would sometimes leave the decision to depart with the customer, who would be advised of the forecast and of the possibility that the flight might not be completed, and that the cost of the flight would rest with the customer. This practice, along with management involvement in the dispatch process, may have resulted in some pilots feeling pressure to undertake flights at times when the pilots' judgement made them think that they should not do so.

Management pressure to complete flights into adverse weather conditions was common knowledge among the pilot group. The investigation revealed that the occurrence pilot was never personally challenged by senior management. During a line indoctrination flight, the occurrence pilot conducted a missed approach at the destination airport due to low cloud. The pilot was advised by the supervising pilot that senior management would not be pleased with the decision to conduct a missed approach.

1.18 Additional Information

1.18.1 Pilot Decision-Making

PDM (pilot decision-making) can be described as making the right choice at the right time, and avoiding circumstances that can lead to difficult choices. Many decisions are made on the ground, and a well informed pre-flight choice avoids the need for a much more difficult in-flight decision.

An important component of PDM is good situational awareness, which requires a pilot to align the reality of a situation with his or her expectations. Inadequate or ineffective PDM can result in operating beyond an aircraft's capability or exceeding the pilot's abilities.

When conditions are either particularly good or bad, the decision to depart is an easy one. However, the decision can become complicated when conditions become marginal. Complicating factors, such as economics, customer commitments, and professional obligations, compounded by conditions that do not clearly argue against departing, can interfere with even the most safety-conscious pilot's decision making.

Klein's [9] expectation-primed decision making is a mature model that describes how skilled professionals make rapid decisions in complex environments. Less experienced crews have fewer prior experiences to draw upon, and will have fewer linkages between the current context and their prior experience. Consequently, documented procedures and decision criteria become even more valuable to less experienced crews.

1.18.2 Threat and Error Management

To better understand the role of the crew in managing risk during normal operations, the NASA University of Texas, Human Factors Crew Resource Project has developed a model called the "threat and error management" (TEM) model.

The model is based on the premise that, in every flight, hazards that must be handled by the crew will be present. These hazards increase the risks during a flight and are termed "threats" in the TEM model. Threats include such things as weather conditions, traffic, aircraft serviceability issues, unfamiliar airports, etc. Provided that the crew members have an opportunity to handle the threat, effective management of the hazard leads to a positive outcome with no adverse consequences. However, mismanagement of the threat can lead to crew error, which the crew must also manage. Mismanagement of crew error may lead to an undesired aircraft state, which can lead to an accident. At any point, effective management of the situation by the crew can mitigate the risk, and the situation may be inconsequential.

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9 G.A. Klein, The Recognition-Primed Decision (RPD) model: Looking back, looking forward, in C.E. Zsambok and G. Klein (eds), *Naturalistic Decision Making* (1997), pages 285−292

The TEM model has been widely adopted as the foundation for modern crew resource management (CRM) training courses. CRM courses are intended to provide flight crews with practical tools to help them avoid, trap, or mitigate threats and errors that are typical in commercial aviation operations. A typical CRM course also includes the core elements of PDM training, and expands on those concepts to include a broader understanding of decision making.

At present time, CRM training is required only for the larger CARs Subpart 705 commercial carriers. It is not required for CARs Subpart 703 and 704 operators. In 2009, the TSB issued Recommendation A09-02:

> The Department of Transport require commercial air operators to provide contemporary crew resource management (CRM) training for *Canadian Aviation Regulations* (CARs) subpart 703 air taxi and CARs subpart 704 commuter pilots.

In January 2012, a TC-led focus group met to develop a proposal that would address Recommendation A09-02. On 24 April 2012, the Civil Aviation Regulatory Committee (CARC) determined that contemporary CRM training standard would be developed for CARs Subparts 702, 703, 704, and 705 operations to include the TEM model, to enhance flight crews' ability to assess conditions and make appropriate decisions in critical situations. This course of action, if implemented, would substantially reduce or eliminate the deficiency identified in Board Recommendation A09-02. However, at present, no new training standards have been developed, and this proposed change has yet to become regulation. As a result, the Board's assessment of TC's response to this Recommendation A09-02 remains assessed as Satisfactory Intent.

1.18.3 Aircraft Icing

Under certain atmospheric conditions, critical surfaces of an aircraft such as the wings, horizontal stabilizer, vertical fin, control surfaces, and propellers can start to accumulate ice. The ice accumulation will result in a degradation of the aerodynamic properties of the flight surface, and increase the aerodynamic drag and the stall speed of the aircraft. Reconfiguring the aircraft, such as with the application of flaps and/or gear extension, will further increase the aircraft's aerodynamic drag and its stall speed.

Stall speed is the minimum airspeed required by an aircraft's airfoil to produce sufficient lift to sustain flight. When the aerodynamic shape or properties of an airfoil/wing are sufficiently compromised, the wings will no longer support the weight of the aircraft, and the aircraft will no longer be able to sustain controlled flight.

TC and FAA have published advisory circulars, civil aviation safety alerts, and aeronautical information manuals that offer guidance with regard to the risk associated with aircraft flight in icing conditions. Although the guidance material does define terms associated with icing, there exists a lack of clarity between the terms "known icing conditions"and "light to moderate icing conditions." When a pilot encounters or observes light to moderate ice accumulate on the aircraft, the pilot is in actual known icing conditions. Terms such as "flight in"and "flight into"are confusing and can result in those terms being understood to be interchangeable. The POH for the occurrence aircraft indicates that the aircraft may be flown in light to moderate icing conditions, suggesting that the aircraft may continue flight in icing conditions.

The FAA was in the process of updating its interpretation of commonly used icing terms, but the work was temporarily discontinued in early 2012.

1.18.4 Safety Management System

The TSB has recognized that, implemented properly, safety management systems (SMSs) allow aviation companies on their own to identify hazards, manage risks, and develop and follow effective safety processes. Canada's large commercial carriers have been required to have a SMS since 2005. However, for smaller operators, such as those which do aerial work or provide air taxi or commuter services, implementation has been delayed to provide additional time to refine procedures, guidance material, and training.

Keystone Air Service does not have, nor is there a regulatory requirement to have, a SMS in place. In 2005, Keystone Air Service voluntarily began transition to a SMA, but it discontinued its transition for various reasons in 2009.

2.0 Analysis

2.1 Aircraft

No aircraft technical defects were found that could have contributed to the occurrence. The analysis will concentrate on operational factors and pilot decision-making.

2.2 Pilot

The majority of the pilot's flying experience was in a training environment, either as a student or an instructor, in visual flight rules (VFR) weather conditions, with less complex aircraft.

At Keystone, the pilot successfully completed the required training, pilot proficiency check (PPC), and line indoctrination training in excess of that required by the company operations manual (COM). However, transition to a job as a pilot with Keystone, a *Canadian Aviation Regulations* (CARs) Subpart 703 air taxi operator, put the pilot in new and more challenging flying environments while operating a more sophisticated aircraft type. Operating single-pilot instrument flight rules (IFR) would have increased the workload, and would have made it more difficult to formulate effective solutions to problems as they arose.

The pilot's multi-engine and instrument flight times on arrival at Keystone, together with the times accumulated during line indoctrination training, satisfied both the company and CARs experience requirements for single-pilot, multi-engine flight into instrument meteorological conditions (IMC). An analysis of the applicable weather information for the pilot's flights after completion of line indoctrination training was completed. But because the aircraft's enroute altitudes were not recorded, the investigation could not determine an accurate profile of the pilot's flight time in IMC, or of the pilot's experience in icing conditions while employed at Keystone.

The flights from 20 December 2011 to 08 January 2012 were conducted to a large extent in uncontrolled airspace and outside of air traffic control (ATC) radar coverage. The weather conditions for most of the flights were such that flight into IMC would not have been required. On some flights, ceilings would likely have required flight into IMC, and some exposure to icing conditions was likely as well. Overall, the pilot had accumulated flight experience in clouds and icing conditions, but would not have encountered icing conditions as severe as those on the accident flight.

2.3 Pilot Decision-making and Threat- and Error-management Training

Keystone's initial pilot training did not include any pilot decision-making (PDM), crew resource management (CRM) or threat- and error-management (TEM) training. Without such training applied to relevant examples of Keystone's flight operations, the company's initial training left inexperienced pilots not always prepared for self-dispatch. While new regulations for CRM training have been accepted by the Civil Aviation Regulatory Committee (CARC), under the current regulations, CARs 703 and 704 operators are not required to provide CRM training. As a result, there is an increased risk that crews operating under CARs 703 or 704 will experience breakdowns in CRM.

Keystone PA31-350 pilots were uncertain as to the aircraft's certification or capability to fly into icing conditions, and as a result, likely did not pass on an understanding of these issues to the occurrence pilot.

2.4 Self-dispatch

The flight departed from Keystone's base in Winnipeg/James Armstrong Richardson International Airport (CYWG), where the operator relied on the pilot for operational decisions and self-dispatch. Keystone does not have any company procedures or tools in place to aid the pilot in deciding whether or not to depart, or to support the pilot by providing information regarding runway conditions. The nature of a self-dispatch system leaves the pilot with the decision as to whether the flight should depart, based on the pilot's training, experience, and operational pressures. The pilot was relatively new to the Piper PA31-350 aircraft type, passenger flights to remote airports, and winter operations in icing conditions. This lack of familiarity and experience increased the risk that the flight would depart into conditions beyond the capabilities of the aircraft and the pilot.

2.5 Dispatch in Marginal Weather

Management involvement in the dispatch process may have resulted in some pilots feeling pressure to undertake flights at times when the pilots' judgement made them think that they should not do so.

2.6 Pilot's Decision to Depart

The occurrence flight was the pilot's seventh trip as pilot-in-command; that is, without another pilot for supervision. The weather in CYWG and enroute was VFR, and the area forecast for North Spirit Lake (CKQ3) was predicting moderate icing associated with freezing drizzle and light snow. It could not be determined whether the pilot consulted with the passengers regarding the weather at CKQ3 and the possibility of not completing the flight. VFR weather conditions in CYWG and a forecast of only light snow may have influenced the pilot's decision to depart.

2.7 Pilot's Decision to Descend

The pilot was ambitious, with a desire to get the job done and not disappoint. Although not personally challenged by management, the pilot was also aware of the pressure from management to complete flights, as pointed out during the pilot's training. It is possible that these factors may have influenced the pilot's decision-making process or made it more likely that the pilot would continue the approach when adverse conditions were encountered.

There was no runway condition reported at the time the occurrence flight departed CYWG. As a result, the pilot had no prior knowledge of the snow clearing operations, and likely did not consider that the runway would not be available for landing on arrival. Consequently, the reality of the arrival differed significantly from the pilot's expectations. This difference would likely have resulted in decreased situational awareness, and increased the pilot's workload and the pressure under which the pilot was working. Combined with limited experience flying in icing conditions, these factors likely impaired the pilot's decision-making abilities to the point where the effects of icing on the continued viability of the flight may not have been considered. The pilot's decision to continue the flight below area minimum altitude (AMA) to complete the approach and landing, with no published approach procedure, increased the risk of collision with terrain.

2.8 Instrument Approach Procedure

There was no published approach procedure for CKQ3, and no other pre-existing approach procedure was found, so it is likely that the pilot improvised the approach procedure for the global positioning system (GPS). This process likely increased workload and adversely affected the pilot's ability to maintain situational awareness.

2.9 Aircraft Icing

Given the pilot's limited experience in IMC, it is likely that the pilot was not fully aware to what extent the aircraft was certified for icing. Inconsistent use of icing terms and a lack of their definitions can decrease awareness and lead to confusion as to the aircraft's certification and capability in icing conditions.

After beginning the descent into CKQ3, the pilot made a call on the aerodrome traffic frequency (ATF), and was advised that the runway was being plowed. With the descent into cloud and the temperature below freezing, conditions were conducive to icing and at some point, ice began to build up on the aircraft's critical surfaces. Despite having the option of diverting the aircraft to Red Lake (CYRL) or Deer Lake (CYVZ), both of which had IFR approaches, the pilot held in cloud for approximately 25 minutes. The time spent in cloud on descent and in the holding pattern resulted in the aircraft accumulating ice on its critical surfaces.

The remaining ice found on the 4-foot section of the right-wing leading edge and on the left horizontal-stabilizer leading edge indicates that a significant amount of ice accumulated on the aircraft's critical surfaces in flight. The investigation was not able to assess the serviceablility of the de-ice system because of extensive impact and fire damage.

If the system was not serviceable, the pilot's options were to either avoid icing conditions or divert the flight as soon as icing was apparent or the de-ice system unserviceability was noted. Neither of those options was taken, so it is most likely that the system was serviceable.

If the de-ice system was serviceable, the system was not effective in removing ice from those areas affected, due to either insufficient de-ice system activation, or in-flight icing that accumulated at a rate that exceeded the system's capacity.

It is likely that once the runway was cleared, the pilot extended the landing gear and set approach flaps before turning onto final approach. With the stall warning vane trapped in a downward position, the stall warning system would have been inoperative and would have provided no warning to the pilot of a stall condition. The accumulation of ice and the change in aircraft configuration resulted in an increased stall speed and an increase in drag.

2.10 Accident Scenario

Much of the information related to the accident flight occurred outside of controlled airspace and ATC radar coverage, and was not recorded; therefore, the exact accident sequence cannot be determined.

The available information indicates that the aircraft was certified and equipped for dispatch and that the pilot met the minimum requirements for dispatch on the accident flight. However, the runway at CKQ3 had not been cleared, and the weather conditions in the area presented significant challenges for single-pilot flight with an aircraft not equipped for continuous flight in icing conditions. Moreover, these challenging conditions arose at or near the destination, making a diversion back to Winnipeg seem a less feasible option once the aircraft had started its descent and had started to accumulate ice.

The most likely scenario is that the flight proceeded normally until the aircraft started its descent into the North Spirit Lake area. During the descent, the pilot learned that the flight would have to hold until the runway was cleared of snow. The aircraft began to accumulate ice, and its ability to climb back on top of cloud would have diminished.

The pilot, anxious to complete the flight successfully, likely did not appreciate the extent of the aircraft's limitations in icing conditions, and believed that the best option was to continue to CKQ3 and hold, then land once the runway was clear.

As the descent continued below the AMA, the aircraft would have continued to accumulate ice, especially on areas such as the wing root sections that did not have the benefit of de-ice capability. The pilot, occupied with the hold and approach, likely no longer had the situational awareness to fully consider the other options of diverting the flight to either CYRL or CYVZ, and continued in a gradually deterioriating flight situation.

By the time the runway was clear, the aircraft would have accumulated a significant amount of ice. As the aircraft manoeuvred onto final approach, the turns and changes in the aircraft configuration likely added enough drag to cause the aircraft to stall at an altitude from which recovery by the pilot was not possible.

3.0 Findings

3.1 Findings as to Causes and Contributing Factors

1. The pilot's decision to conduct an approach to an aerodrome not serviced by an instrument flight rules approach in adverse weather conditions was likely the result of the pilot's inexperience, and may have been influenced by the pilot's desire to successfully complete the flight.

2. The pilot's decision to descend into cloud and continue in icing conditions was likely the result of inadequate awareness of the Piper PA31-350 aircraft's performance in icing conditions and of its de-icing capabilities.

3. While waiting for the runway to be cleared of snow, the aircraft held near North Spirit Lake (CKQ3) in icing conditions. The resulting ice accumulation on the aircraft's critical surfaces would have led to an increase in the aircraft's aerodynamic drag and stall speed, causing the aircraft to stall during final approach at an altitude from which recovery was not possible.

3.2 Findings as to Risk

1. Terminology contained in aircraft flight manuals and regulatory material regarding "known icing conditions," "light to moderate icing conditions," "flight in," and "flight into" is inconsistent, and this inconsistency increases the risk of confusion as to the aircraft's certification and capability in icing conditions.

2. If confusion and uncertainty exist as to the aircraft's certification and capability in icing conditions, then there is increased risk that flights will dispatch into icing conditions that exceed the capability of the aircraft.

3. The lack of procedures and tools to assist pilots in the decision to self-dispatch leaves them at increased risk of dispatching into conditions beyond the capability of the aircraft.

4. When management involvement in the dispatch process results in pilots feeling pressure to complete flights in challenging conditions, there is increased risk that pilots may attempt flights beyond their competence.

5. Under current regulations, *Canadian Aviation Regulations* (CARs) 703 and 704 operators are not required to provide training in crew resource management / pilot decision-making or threat- and error-management. A breakdown in crew resource management / pilot decision-making may result in an increased risk when pilots are faced with adverse weather conditions.

6. Descending below the area minimum altitude while in instrument meteorological conditions without a published approach procedure increases the risk of collision with terrain.

7. If onboard flight recorders are not available to an investigation, this unavailability may preclude the identification and communication of safety deficiencies to advance transportation safety.

4.0 Safety Action

4.1 Action Taken

4.1.1 NAV CANADA

1. NAV CANADA has published an approved instrument approach procedure for the North Spirit Lake aerodrome in the April 2012 revision of the *Canada Air Pilot*.

4.1.2 Keystone Air Service

1. The operator has revised its operations manual and implemented a multi-crew policy that applies to all instrument flight rules flights.

2. The operator has amended its flight-training record-keeping procedures by changing the training forms to make it easier and more efficient to prove that all required training has been completed.

3. The operator has updated the captain's trip report form to include provisions for progressive fuel-state monitoring.

4. The operator has revised its operational flight plan form to include the calculated landing weight and landing centre of gravity.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 19 September 2013. It was officially released on 21 November 2013.

Visit the Transportation Safety Board's website (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. 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 – Transportation Safety Board Laboratory Reports

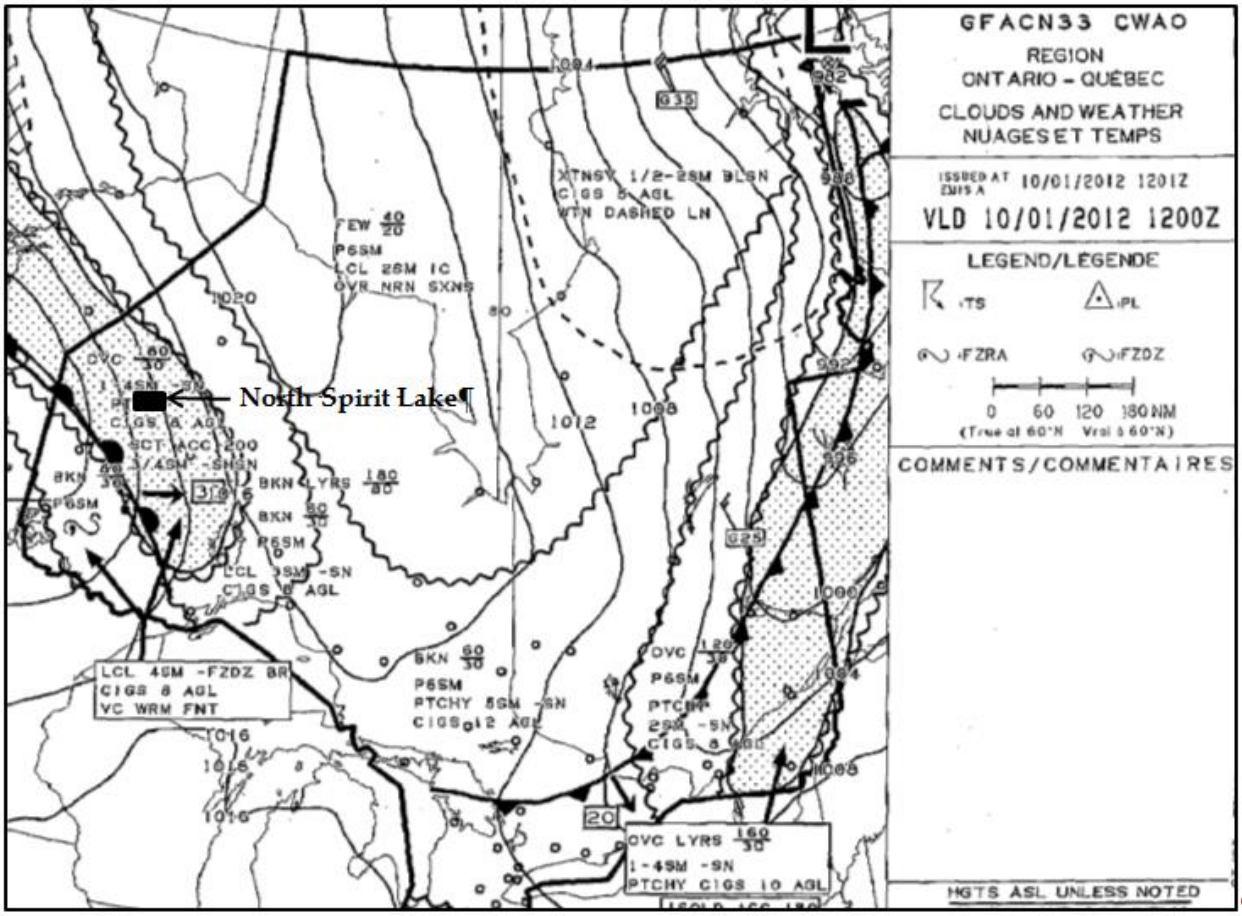
The following Transportation Safety Board (TSB) Laboratory reports were completed:

LP028/2012 – Examination of aircraft flight control cables.

LP016/2012 – Examination of aircraft instruments and Garmin GNS 530.

These reports are available from the Transportation Safety Board of Canada upon request.

Appendix B – Graphical Area Forecast: Clouds and Weather



Appendix C – Graphical Area Forecast: Icing, Turbulence, and Freezing Level