Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A06W0104

LOSS OF CONTROL AND COLLISION WITH TERRAIN

PRECISION HELICOPTERS INC.
BELL 206B C-GPGX (HELICOPTER)
NOSE MOUNTAIN TOWER, ALBERTA
03 JULY 2006

Canada

Aviation Investigation Report

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Summary

The Precision Helicopters Inc. Bell 206B Jet Ranger helicopter (registration C-GPGX, serial number 1362) was departing from a prepared helicopter landing area adjacent to the Nose Mountain, Alberta, fire observation tower at approximately 1815 mountain daylight time. A pilot and three initial attack firefighters were on board. The landing area was located in a clearing, on a mountain plateau, situated at the north edge of a steep escarpment. After lifting off, the pilot hover-taxied around a pile of brush on the west side of the clearing and departed in a westerly direction, toward the escarpment. When the helicopter overflew the rim of the escarpment, it began to yaw to the right. The pilot was unable to control the yaw with the application of full left pedal. As the helicopter rotated through 180°, the pilot lowered the collective to regain directional control. The helicopter descended onto the escarpment, rolled over, and came to rest on its left side. One firefighter sustained fatal injuries and another firefighter sustained serious injuries. The pilot and the third firefighter sustained minor injuries. The impact forces activated the onboard emergency locator transmitter. The helicopter was substantially damaged, but there was no post-impact fire.

Ce rapport est également disponible en français.

Other Factual Information

Precision Helicopters Inc. operates two Eurocopter AS 350 helicopters and one Bell 206B helicopter under the sections 702 and 703 of the *Canadian Aviation Regulations* (CARs).

The helicopter had been chartered by the Alberta Ministry of Sustainable Resource Development Forest Protection Branch (ASRD-FPB). It had been dispatched with the pilot and the three-member initial attack firefighting crew from the Graham Fire Base at 1614 mountain daylight time.[1] There had been widespread thunderstorm and lightning activity in the area, and the crew was tasked to investigate reports of forest fires burning to the south of Nose Mountain.

After encountering thunder cells and strong downdrafts en route to the fires, the pilot diverted to Nose Mountain to take on fuel. Another thunderstorm moving through the Nose Mountain area forced the pilot to land six miles south of Nose Mountain to allow time for the weather to pass. The helicopter arrived at the Nose Mountain landing area at 1803 where it was shut down and the firefighters deplaned. Approximately 22 US gallons of Jet A fuel was added, bringing the indicated total fuel on board to 45 US gallons. Following refuelling, the pilot and the same three firefighters boarded the helicopter and departed on the accident flight.

Weather

Visual meteorological conditions prevailed at Nose Mountain at the time of the accident. However, there was widespread thunderstorm and lightning activity in the area. Hourly winds and temperatures are not formally recorded at the site. Temperature estimates from personnel at the site ranged from 15°C to 28°C. Using a figure of 22°C, the density altitude would have been approximately 7000 feet. The winds were shifting from the northeast to the southeast at speeds estimated up to 10 knots.

Landing Area

The landing area measured about 200 by 150 feet and was on the northeast side of a clearing, surrounded on three sides by trees up to 25 feet tall. Second growth brush had recently been removed from the clearing to improve aircraft operations and facilitate multiple helicopter landings and departures. A mound of brush about 6 feet high and 20 feet in diameter had been piled in the clearing, to the west of the landing area. The distance from the landing area to the escarpment was about 200 feet, and the distance from the take-off position to the rim of the escarpment was about 125 feet (see Appendix A). The elevation of the landing area is 4879 feet above sea level (asl).

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1 All times are mountain daylight time (Coordinated Universal Time minus six hours).

The prevailing winds were normally from the west, and pilots usually departed from the landing area to the west and over the escarpment. A departure directly to the east would have required an initial climb of 25 to 30 feet to clear the tree-line. The pilot had departed directly from the landing area toward the escarpment many times in the past, often at high gross weight.

To depart toward the escarpment on the accident flight, it was necessary to manoeuvre the helicopter to avoid the brush pile. The pilot performed a clearing hover turn to the right, then hover-taxied southward, while maintaining a westerly heading, along the southeast edge of the clearing. This positioned the helicopter for an unobstructed take-off run to the west, across flat ground and toward the escarpment. The helicopter did not attain sufficient speed for translation lift[2] before reaching the rim of the escarpment. The accident site is at latitude 54º34′ N, longitude 119º38′ W.

Pilot

The pilot was certified and qualified for the flight in accordance with existing regulations. He held a valid Canadian commercial helicopter pilot licence and a valid aircraft maintenance engineer (AME) licence. He had accumulated about 5250 hours of total flying experience, of which about 3750 hours were on Bell 206 helicopters. He had worked for Precision Helicopters Inc. since 1981 and had performed flying duties since 1986. At the time of the accident, he was the company Chief Pilot and the Operations Manager.

He met all company recurrent ground and flight training requirements and was knowledgeable of the conditions that can contribute to insufficient power situations and unanticipated right yaw in Bell helicopters. The pilot had used the Nose Mountain landing area several hundred times during the 20 years he had been flying in the area and five or six times in 2006. The pilot was well rested before commencing his duty day at 1030 in the morning, and there was no indication that physiological factors had affected his performance. He was characterized by clients and peers as being an extremely competent and cautious pilot.

Helicopter

There was no indication of any pre-existing flight control or tail rotor drive system malfunction that would have contributed to the accident. The engine (Rolls-Royce 250 C20) had been modified with the installation of a Rolls-Royce 250-C20B compressor and turbine, under the provisions of an approved Allison Commercial Engine Bulletin. The effect of this modification was to provide improved high-altitude performance. The helicopter was fitted with a particle separator.

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2 Translation lift is the additional lift obtained through airspeed because of increased efficiency of the rotor system when transitioning from a hover to horizontal flight.

Helicopter Weight and Balance

The pilot had estimated the weight of the firefighters and their gear before departing the Graham fire base. This practice was the norm for the helicopter pilots engaged in firefighting activities. On the weight and balance report provided to TSB investigators by the pilot, the firefighter weights were recorded as 200, 150, and 130 pounds, and the baggage weight was recorded as 100 pounds. As a result, the gross weight at take-off was calculated as 3104 pounds. The maximum take-off weight for a Bell 206B helicopter with an internal load is 3200 pounds.

All of the gear and equipment on the helicopter was subsequently recovered and weighed on a calibrated scale. The total weight of the gear and equipment was 239 pounds. It was estimated that each passenger was wearing an additional 14 to 17 pounds of personal firefighting gear and safety equipment that was not included in the original passenger weight estimates.

Post-accident weight and balance calculations using the revised gear and passenger weights indicated that the weight at take-off was approximately 3245 pounds.

Passenger Weighing Practices

Section 703.37 of the CARs requires air operators to have a weight and balance system that meets the *Commercial Air Service Standards* (CASS). CASS Section 723.37 describes three methods to determine the weight of passengers: by actual weight, by using approved standard weights, or by using approved survey weights. Cargo weight must be actual weight.

The Precision Helicopters Inc. operations manual required actual weights to be used for computing the load when the pilot-in-command estimates the passenger weights to be more or less than the published standard weights. As indicated above, the pilot had estimated the weight of passengers and gear on board the helicopter.

ASRD-FPB provides *The Pilot's Handbook* to pilots working on fire management programs in Alberta. The handbook imparts basic information on ASRD-FPB policy and procedures. Appendix B of the handbook outlines the pilot and government representative responsibilities for rotary-wing load calculations. It states that the pilot is responsible for computing the allowable payload on a helicopter; however, a government representative is responsible for providing an accurate passenger/cargo manifest and weights.

At the time of the accident, ASRD-FPB had no formal system in place to provide helicopter pilots with actual individual firefighter weights, including personal gear. As well, there was no information available to firefighters to indicate that excess weight was a critical issue on the smaller helicopters used by ASRD-FPB.

Firefighters employed by ASRD-FPB undergo fitness testing annually in the spring. At that time, they weigh themselves and record their own weight. This self-weighing procedure forms part of the ASRD-FPB weight-monitoring system. Not included in that recorded weight is the extra gear firefighters are required to wear or have on them while flying in a helicopter: boots; hard hat; coveralls; gloves; a safety belt containing a first-aid kit and water bottle; and in the case of a team leader, one or two hand-held radios.

In recent years, ASRD-FPB had preferred to transport initial attack crews in helicopters capable of carrying larger loads, such as the Eurocopter AS 350. ASRD-FPB continued to use Bell 206B helicopters during periods when helicopters were in high demand, such as when firefighting activities were being carried out. The initial attack crews were familiar with the higher load carrying capacity of the AS 350 helicopter.

Engine Power Available

For helicopters, engine power available is a term commonly used to refer to the differential between the power being used and the limits of the engine performance, namely, power turbine speed, temperature, and torque. Increases to density altitude or aircraft weight and hover flight in tailwind conditions all result in an increase in the power required to hover. In turn, this reduces the margin of engine power available and affects the overall take-off performance. In a light helicopter, such as the Bell 206, seemingly insignificant weight additions can affect the power required to hover.

The maximum permitted take-off torque for the engine installed on the accident helicopter is 100 per cent for five minutes, with a transient over-torque of 110 per cent permitted for five seconds. Before the commencement of forward flight from the departure point in the clearing, the torque required to hover in ground effect was 96 per cent; it is probable that this value increased slightly during the initial transition out of the stationary hover. The usual torque indications for Bell 206B helicopters hovering in ground effect and in similar load and conditions are reported to be in the order of 85 to 90 per cent. The helicopter did not attain the benefits from translational lift before reaching the rim of the escarpment, where the performance benefit of ground effect was lost. Considering the helicopter weight and the density altitude, an increase in power above 96 per cent would have been required to maintain level flight once the helicopter cleared the rim of the escarpment.

Unanticipated Right Yaw

The adverse phenomenon of unanticipated right yaw (URY) is highly publicized in training and other aviation literature.[3, 4, 5, 6] The information contained in these documents is reproduced in a Federal Aviation Administration (FAA) publication titled *The Rotorcraft Flying Handbook,* which states the following:

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3 Bell Helicopter Textron Operations Safety Notice OSN 206-83-10, *Supplemental Operating & Emergency Procedures*, 31 October 1983.

4 Bell Helicopter Information Letter 206-84-41, *Low Speed Flight Characteristics Which Can Result in Unanticipated Right Yaw*, 06 July 1984.

5 Bell Helicopter Textron Inc. Special RotorBreeze Insert, *Low Speed Flight Characteristics Which Can Result in Unanticipated Right Yaw*, July/August 1984.

6 Federal Aviation Administration Advisory Circular 90-95, *Unanticipated Right Yaw in Helicopters*, 26 December 1995.

> Unanticipated yaw is the occurrence of an uncommanded yaw rate that does not subside of its own accord and, which, if not corrected, can result in the loss of helicopter control. This uncommanded yaw rate is referred to as loss of tail rotor effectiveness (LTE) and occurs to the right in helicopters with a counter-clockwise rotating main rotor. . . .
>
> LTE is not related to an equipment or maintenance malfunction and may occur in all single-rotor helicopters at airspeeds less than 30 knots. It is the result of the tail rotor not providing adequate thrust to maintain directional control, and is usually caused by either certain wind azimuths (directions) while hovering, or by an insufficient tail rotor thrust for a given power setting at higher altitudes.

In general, URY may occur when a helicopter is operating at low speed and high power in a tailwind, especially at higher altitudes, where the air is thinner and tail rotor thrust and efficiency are reduced. The initial pilot response to correct this condition is to lower the collective lever. This reduces the torque produced by the main rotor, reduces the anti-torque thrust requirement of the tail rotor, and increases its efficiency.

Even though helicopter pilots are aware of the URY phenomenon, several occurrences in the past have shown that pilots did not recognize the potential for URY before experiencing the loss of control. It was not determined if the occurrence pilot had recognized that the existing wind, density altitude, and terrain conditions created the potential for URY to occur during the accident take-off and departure.

Hover Performance

The hover out-of-ground effect (HOGE) charts in the Bell 206B Flight Manual provide hover performance (that is, maximum allowable gross weight) for conditions of pressure altitude and temperature. The charts are divided into Area A and Area B. Area A indicates hover performance for which satisfactory stability and control has been demonstrated in relative winds of 17 knots sideward and rearward for all loading conditions. Area B indicates hover performance that can be realized in calm winds or in winds outside the critical relative wind azimuth area. Tail rotor control may not be possible for operations in Area B of the hover ceiling charts when the relative wind is in the critical wind azimuth area. For the Bell 206B, the critical relative wind azimuth area extends clockwise 50° from the nose of the helicopter to 210° from the nose of the helicopter (see Appendix B).

The Bell 206B HOGE chart indicates that, for the conditions at the occurrence site, 2925 pounds would be the maximum weight to HOGE and remain in Area A (see Appendix C). At 3245 pounds, the helicopter was about 320 pounds above that maximum weight, and now in Area B of the HOGE chart.

Crashworthiness/Survivability

The firefighter in the left cockpit seat was seriously injured by the main rotor when the main rotor penetrated the cabin following impact with the terrain. The firefighter in the left cabin seat was fatally injured, likely due to a combination of the same main rotor strike and ground impact forces. Rescue and medical information indicated that this firefighter was likely wearing only the lap-belt and not wearing the available shoulder harness portion of the seat restraint. Two-bladed teetering rotor systems are inherently unstable at low rpm compared to multi-bladed rigid rotor systems, and information from similar accidents indicates that helicopters with two-bladed main rotor blade systems demonstrate a higher rate of injury caused by the rotor blades penetrating the cabin than do helicopters with multiple main rotor blade systems.

The fire tower attendant initiated rescue efforts via the forestry radio network, and two helicopters were diverted to the accident site. The pilot, fire-tower attendant, and arriving forestry personnel performed emergency first aid at the site. The occupants of the occurrence helicopter were transported by helicopter to Grande Prairie, Alberta.

Analysis

There was no information of any pre-existing flight control or tail rotor drive system malfunction that would have contributed to a loss of tail rotor function. The analysis will focus on the pilot's experience and familiarity with the site, environmental factors, performance that was available from the helicopter, helicopter take-off weight, and survivability factors.

Pilot Experience and Familiarity with the Site

The pilot was experienced on Bell 206B helicopters, knowledgeable on the conditions that contribute to unanticipated right yaw, and familiar with the Nose Mountain landing area. He had departed the landing area in a westerly direction many times in the past. He was aware that the winds were gusting and variable in direction, and was able to maintain directional control of the helicopter downwind as he hover-taxied to avoid the brush pile. This may have provided reassurance that a westerly take-off could be safely accomplished in the existing wind conditions. Despite the pilot's high level of knowledge and experience, there was no information that he had recognized or considered the possibility of URY before commencing the take-off.

Avoidance of rotorcraft phenomena, such as URY, requires recognition of the conditions that contribute to an event and initiation of corrective action before experiencing the event. Repositioning the helicopter to avoid the brush pile may have increased the risk associated with the take-off. This reduced the take-off distance available and made it less likely that the helicopter would achieve translational lift speed in downwind conditions before reaching the escarpment.

Environmental Factors

Three environmental factors presented a greater than usual challenge on this take-off:

- the winds were easterly and shifting, with gusts, due to the recent passage of a thunderstorm through the area;
- a take-off to the east was hampered by the presence of trees; and
- a brush pile within the clearing prevented a take-off directly from the landing area toward the escarpment.

The wind direction was particularly significant, in that a departure to the west placed the tail of the helicopter within the critical relative wind azimuth area. This increased the risk of URY. As well, departing in a tailwind required significantly more distance to accelerate through transitional lift. Departing in the tailwind also increased the likelihood of the helicopter encountering down-flowing air over the rim of the escarpment.

Helicopter Performance

The helicopter left ground effect before achieving translational lift speed. This meant that more blade pitch (higher power demand) was required on both the main rotor and the tail rotor to maintain height and directional control. Furthermore, the pilot likely increased collective pitch initially as the helicopter crossed the rim of the escarpment. This rapidly degenerating condition placed the helicopter in a situation where the power required to fly exceeded the power available from the engine transmission system. As a result, rotor performance and engine power limits were exceeded.

The high engine power demand, the low airspeed, the high density altitude, and the tailwind conditions contributed synergistically to a loss of tail rotor efficiency and thrust. The helicopter began an unanticipated turn to the right, as there was insufficient tail rotor thrust to counter the torque from the main rotor.

The only option available to the pilot was to lower the collective lever in an attempt to prevent the helicopter from turning. This action stopped the turn, but initiated a descent onto treed and sloping terrain. There was insufficient height above ground to effect a recovery before the helicopter touched down and rolled over.

Weight at Take-off

Although ASRD-FPB had implemented a firefighter weight monitoring program, it was ineffective. There was no mechanism to provide helicopter pilots with actual individual firefighter weights, and no instruction had been given to the firefighters that extra weight was critical in small helicopters such as the Bell 206.

The pilot had estimated the weight of the load on the helicopter because there was no system in place to provide helicopter pilots with actual firefighter crew and gear weights. As a result, the take-off weight of the helicopter was underestimated by approximately 140 pounds and the helicopter was approximately 320 pounds over the HOGE chart limit of 2925 pounds. These factors contributed to the helicopter being operated outside its performance capabilities.

Multiple small weight increments of personal items and equipment can cause a progressive and remarkable degradation to the specification hover and take-off performance in smaller helicopters. Assiduous monitoring by pilots of passengers and equipment loads is the sole solution to prevent overloading the helicopter, particularly in challenging environmental conditions of high density altitude and unfavourable winds.

Survivability Factors

It is probable that the passenger in the rear left seat was not wearing the available shoulder harness. This likely increased the severity of his injuries. One blade of the two-bladed main rotor struck and penetrated the left cockpit and cabin during the accident sequence, which significantly increased the occupant injuries.

Findings as to Causes and Contributing Factors

1. The conditions of a shifting tailwind, over-gross weight, and high density altitude collectively exceeded the rotor and engine performance limits of the helicopter, and the helicopter was unable to take-off in the distance available.

2. Rotor performance was further lost when the helicopter flew out-of-ground effect over the rim of the escarpment, precipitating a degenerating situation of insufficient power available, and the helicopter could not sustain flight.

3. In the conditions encountered during the take-off, the helicopter entered a vulnerable regime where unanticipated right yaw occurs. There was insufficient tail rotor thrust to counter the torque from the main rotor, and the helicopter turned right.

4. Although the pilot’s recovery actions arrested the right turn, there was insufficient height to prevent the helicopter from striking the terrain.

5. The inhospitable characteristics of the terrain immediately below the helicopter prevented the pilot from carrying out an uneventful landing and the helicopter rolled over on touchdown.

6. The weight of the helicopter at take-off was incorrect because of inaccurate estimates of the weights of the firefighters, their gear, and the equipment. For the existing conditions, the take-off weight exceeded both the maximum gross weight limit and the hover out-of-ground effect (HOGE) ceiling limit.

7. The main rotor penetrated the left-side cockpit and cabin, contributing to the severity of the injuries to the passengers.

8. It is probable that the passenger in the rear left seat was not wearing the available shoulder harness; this likely increased the severity of his injuries.

9. There was no system in place for the Alberta Ministry of Sustainable Resource Development Forest Protection Branch (ASRD-FPB) to provide helicopter pilots with actual individual weights of fire crew and their personal gear.

Safety Action Taken

On 11 December 2006, the TSB issued Safety Information Letter A060041, Passenger and Equipment Weights in Helicopter Fire-Fighting Operations, to the Director, Wildfire Operations, Alberta Ministry of Sustainable Resource Development. The Safety Information Letter identified that assiduous monitoring of passenger and equipment loads is the sole solution to prevent overloading of helicopters, and that a process to provide pilots with accurate firefighter crew and gear weights may help to ensure that helicopters involved in firefighting activities in Alberta are flown within prescribed weight and balance limits.

In response to Safety Information Letter A060041, the Alberta Ministry of Sustainable Resource Development Forest Protection Branch (ASRD-FPB) advised that it was taking the following actions:

- The "Equipment List and Weights" in the ASRD-FPB *The Pilot's Handbook* will be reviewed.

- The elevation of the tower and fuel cache sites will be added to the ASRD-FPB publications and air operations 2007 maps.

- High-quality weigh scales will be purchased for use by crews at the primary fire bases and warehouses.

- A copy of the Safety Information Letter has been distributed to all ASRD-FPB area offices.

- The Pilot Responsibility and ASRD Representative Responsibility have been clarified in sections 6.10 and 6.11 of the ASRD-FPB standard operating procedures, as follows:

    - The pilot is responsible for completing the load calculation correctly, using the proper performance chart information, as per the company's operations manual, *Canadian Aviation Regulations* (CARs) and the *Commercial Air Service Standards*.

    - The pilot is responsible for computing the allowable payload.

    - The pilot shall check, or be informed of, any subsequent passenger/cargo manifested weights completed under the initial load calculation to ensure that allowable payloads are not exceeded.

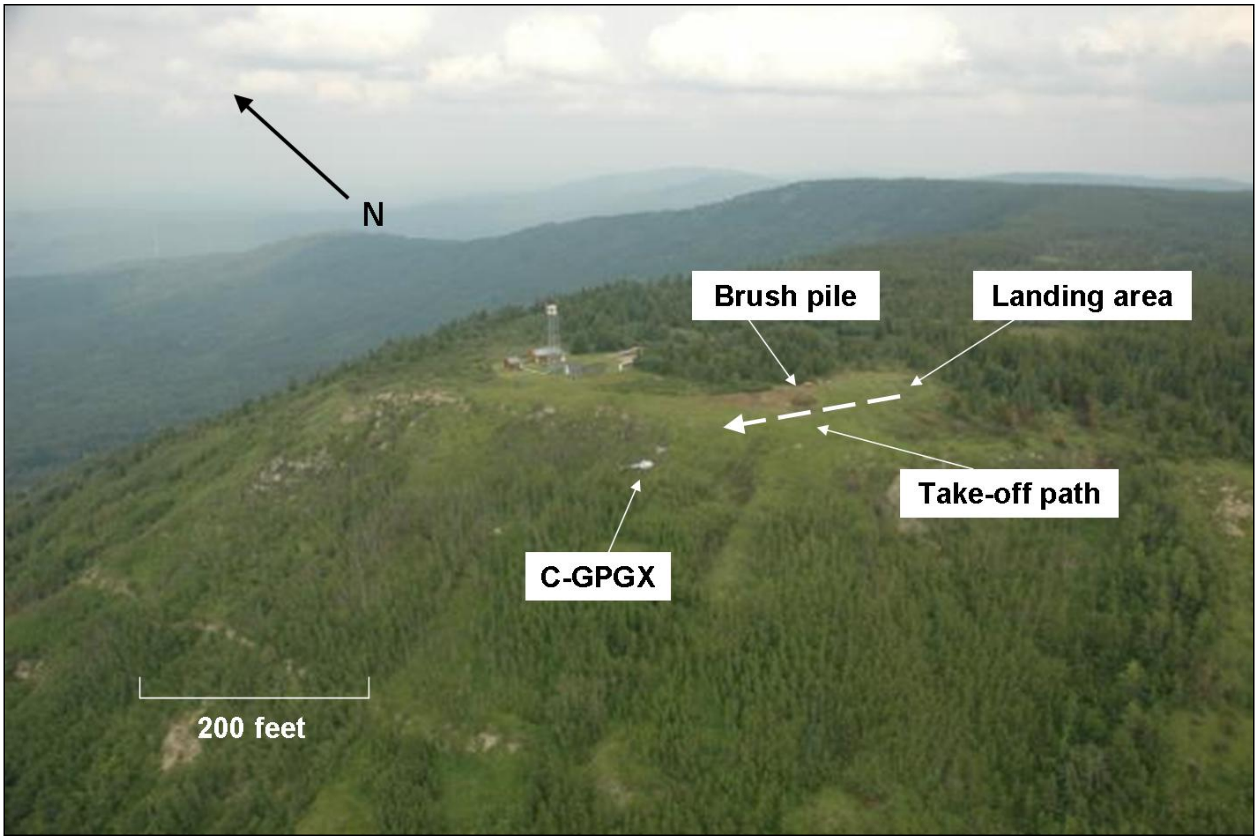
- The ASRD representative responsible for a flight (for example, crew leader, loadmaster, Wildfire Ranger, Forest Officer) is responsible for providing the pilot with a complete passenger/cargo manifest including accurate weights, and advising the pilot of all dangerous goods being carried.

- The passenger/cargo manifest/weights form can be used to record the information given to the pilot.

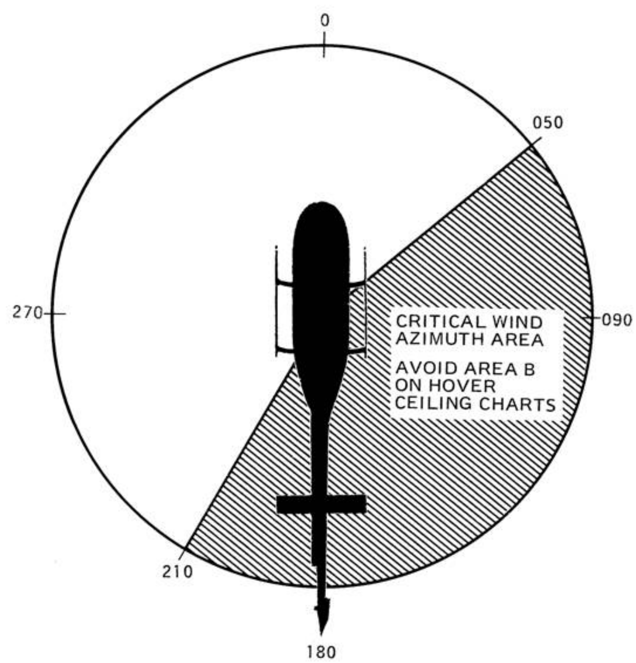
On 14 May 2007, the Forest Protection Branch advised that all the proposed remedial actions had been implemented. As well, aviation audits were conducted at three of the four major Mountain Pine Beetle controls within Alberta, and the issue of providing accurate weights was reviewed and stressed at a recent training course for Type 1 and Type 1F initial attack leaders.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 12 July 2007.

Appendix A – Landing Area and Accident Site



Appendix B – Critical Relative Wind Azimuth Area for Bell 206B



CRITICAL RELATIVE WIND AZIMUTH AREA

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Appendix C – Hover Out-of-Ground Effect Chart for Bell 206B