Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A13O0098

HARD LANDING AND TAIL STRIKE

PORTER AIRLINES INC.
BOMBARDIER DHC-8-402 C-GLQO
SAULT STE. MARIE AIRPORT
SAULT STE. MARIE, ONTARIO
26 MAY 2013

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report A13O0098

Hard landing and tail strike

Porter Airlines Inc.
Bombardier DHC-8-402 C-GLQO
Sault Ste. Marie Airport
Sault Ste. Marie, Ontario
26 May 2013

Summary

The Porter Airlines Inc. Bombardier DHC-8-402 (registration C-GLQO, serial number 4270) was operating as POE689 on a scheduled flight from Billy Bishop Toronto City Airport, Ontario, to Sault Ste. Marie Airport, Ontario. During touchdown on Runway 30 at 2216 Eastern Daylight Time, the tail struck the runway. After landing, the aircraft taxied to the gate, where the passengers were deplaned. There were no injuries to passengers or to the crew; however, there was substantial damage to the aircraft. The occurrence took place during the hours of darkness. The emergency locator transmitter was not activated.

Le présent rapport est également disponible en français.

Factual information

History of the flight

This was the first flight of the day for the flight crew. The planned routing consisted of a flight between Billy Bishop Toronto City Airport (CYTZ), Ontario, and Sault Ste. Marie Airport (CYAM), Ontario, followed by a return flight to CYTZ.

The flight consisted of 4 crew members—the captain, who performed the role of pilot monitoring (PM), the first officer (F/O), who performed the role of pilot flying (PF), and 2 cabin crew members—and 59 passengers.

On arrival at CYAM, the flight crew was given clearance for a visual approach to Runway 30.

Based on the aircraft weight, the landing reference speed (VREF)[1] used by the flight crew for this approach was 121 knots.

An approach briefing was given prior to descent, and all appropriate checklists were completed throughout the approach as required by the company's standard operating procedures (SOP).[2] The PF had limited experience on the aircraft and was reminded by the PM that the DHC-8-400 is a heavy aircraft and that there is a need to slow the aircraft down and get it stabilized on the approach.

Flight data recorder information for the vertical profile of the aircraft, at 4.75 nautical miles (nm) and 1.5 nm from the threshold, is located in appendices A and B.

The aircraft was cleared to land at 2213:32,[3] 5 nm from the airport and descending through 2500 feet above sea level (ASL). At this point (3 minutes prior to touchdown), the autopilot was disengaged by the PF and the remainder of the approach was flown manually.

At 2214:31, as the aircraft descended through 1640 feet ASL, the indicated airspeed was decreasing through 133 knots (VREF +12), and the aircraft was on the appropriate 3° precision approach path indicator (PAPI) glide path. There were minor variances both above and below the glide path as the PF hand-flew the aircraft; these variances were corrected with a combination of slight pitch and power changes. As the approach continued, the PM divided his attention between monitoring the aircraft instruments and the visual approach.

At 2215:22, as the aircraft passed through 500 feet above the touchdown zone (HAT), the indicated airspeed was stable at 127 knots (VREF +6). The PM made the required stabilized call-out and indicated that the runway was at the 12 o'clock position; this was acknowledged by the PF. The aircraft started to drift above the glide path, but the PM said nothing as the PF was

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1 Bombardier DASH 8 Q400 *Aeroplane Operating Manual*, Volume 1, revision 25, Definitions - VREF refers to the approach speed at a height of 50 feet above the runway in the landing configuration.

2 Porter Airlines Inc., *Standard Operating Procedures*, Revision 9, 01 January 2012.

3 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

taking corrective action. The PF applied slight nose-down pitch, and the indicated airspeed began to increase, but the aircraft continued to drift above the glide path.

At 2215:47, as the aircraft was passing through 250 feet HAT, the indicated airspeed had increased to 131 knots (VREF +10), and the aircraft was drifting up toward the 3.5° PAPI glide path. The PF reduced the engine torque (power) from 13% to 5% (flight idle) and pitched the nose down slightly. From this point on, the aircraft speed began to decrease rapidly, and the descent rate increased. The PM was monitoring the visual approach at the time and did not notice the power reduction, the rapid airspeed reduction, or the increasing descent rate.

At 2216:00, as the aircraft passed through 90 feet HAT, the airspeed was decreasing below VREF. The PF reacted by starting to pitch the nose up, and the engine torques were increased to 7%.

At 2216:04, the enhanced ground proximity warning system (EGPWS) started announcing the height from 50 feet HAT as the aircraft rapidly descended. As the aircraft crossed the threshold at 40 feet, the speed was decreasing through 116 knots (VREF -5), and the aircraft was below the 2.5° PAPI glide path. The PM noticed that the power had been reduced to near flight idle and that the aircraft was descending rapidly (approximately 900 feet per minute). The PM called for the addition of engine power seconds before the aircraft touched down. The PF rapidly pitched the nose up then added power as the aircraft touched down at 2216:07.

The underside of the aircraft tail section struck the surface of the runway during touchdown.

The maximum recorded pitch attitude during the landing was 7.3°. The peak value may not have been captured due to the interval of data sampling, so the pitch may have been higher than 7.3°. The recorded pitch value was consistent with the landing gear being at or near fully compressed at the time of the tail contact. The *g*-load[4] on landing was 3.05.

Damage to aircraft

The examination of the aircraft revealed impact and scuff marks on the skin, structural stiffeners and longerons of the lower part of the aft portion of the fuselage (Photo 1). Repairs to the aircraft included replacing the damaged fuselage skin along with the damaged structural stiffeners and longerons.

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4 Measurement of acceleration force; one *g* equals the normal force that gravity exerts on a body.

Photo 1. Damage to aircraft (Source: Altech Adjusters and TSB)

Flight crew

The flight crew members were certified and qualified for the flight in accordance with existing regulations. This was the first pairing of this crew, each of whom had more than 15 hours off-duty the night prior to the occurrence.

The captain was hired by Porter Airlines Inc. on 26 March 2007. At the time of the occurrence, the captain had approximately 8410 hours total time, including 3835 hours on the DHC-8-400 with Porter Airlines Inc. The captain completed the initial DHC-8-400 type rating in April 2007. On 07 February 2013, the captain had completed recurrent pitch awareness training. In addition to normal flying duties, the captain has also held the position of training captain since August 2011. This was not a training flight, and the captain was acting only as a captain and not a training captain.

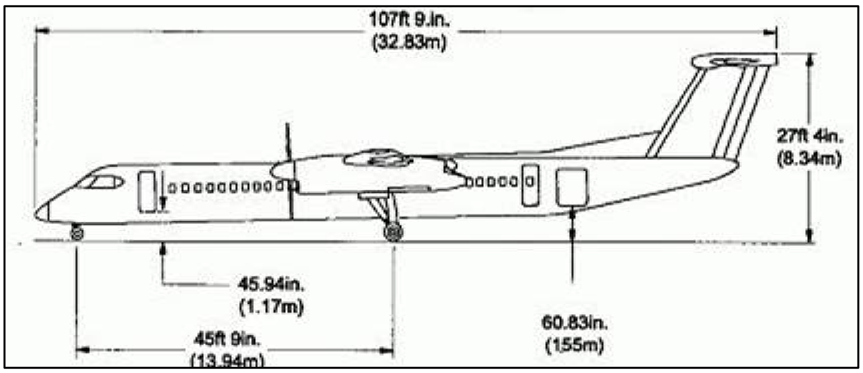
The F/O was hired by Porter Airlines Inc. on 14 January 2013. At the time of the occurrence, the F/O had approximately 2484 hours total time, including 134 hours on the DHC-8-400 with Porter Airlines Inc. The F/O completed the initial DHC-8-400 type rating on 24 February 2013, and as part of this curriculum completed the pitch awareness training. During the F/O's DHC-8-400 initial line indoctrination, training captains identified areas requiring improvement. These included appropriate management of approach power/pitch and the elimination of large power changes to chase speed in descent. Line indoctrination was completed on 06 April 2013.

The F/O flew a total of 5 days in May, with flights on 01, 02, 23 and 24 May. The F/O last flew at night on 02 May 2013. The occurrence flight on 26 May was the first and only flight of the day. Prior to working for Porter Airlines, the F/O was employed for a number of years as a flight instructor on small aircraft. Following this, the F/O took a position in 2011 as a F/O flying the Piper Navajo and King Air 350 for a small company.

Aircraft

C-GLQO is a series 400 Dash 8 aircraft (DHC-8-402) manufactured by Bombardier Inc. in 2009. The aircraft is a modern twin-engine turboprop that measures 107 feet, 9 inches in length (Figure 1), with propellers that are 13.5 feet in diameter, and that has a maximum take-off weight of 63 930 pounds. The aircraft can carry a maximum of 78 passengers.

Figure 1. Aircraft dimensions (Source: Bombardier Aerospace)



Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The weight and centre of gravity were within the prescribed limits. The aircraft was equipped with an emergency locator transmitter, but forces were insufficient to activate it.

Enhanced ground proximity warning system

The aircraft was equipped with an EGPWS. The system warns of potentially unsafe terrain closure rates. During approach with the flaps set for landing, the system provides aural call-outs at 2500, 100, 50, 40, 30, 20 and 10 feet above ground level based on the radio altimeter.

DHC-8-402 aircraft geometry

The normal pitch attitude of the DHC-8-402 in landing configuration with the flaps at 15° is 3.5° nose-up on a 3° final approach path at VREF.[5]

The manufacturer has determined that the pitch attitude required for the aircraft tail to make contact with the runway is dependent on main gear strut extension as follows:

- With struts fully extended, the pitch angle is approximately 10.2°, assuming zero runway crown;[6]

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5 Bombardier, pilot eye/wheel height chart.

6 The runway crown is the highest point of the runway, laterally.

- With struts fully compressed, the pitch angle is approximately 6.9°, assuming zero runway crown; and
- A runway crown may reduce the pitch angle by up to 0.5°.[7]

Operations

Porter Airlines Inc.'s mandatory pitch awareness training emphasizes the requirement for flight crews to arrest higher-than-normal descent rates below 100 feet HAT on approach with the application of power, rather than with an increase in pitch attitude.

Section 2.6.1. of the DHC-8-400 *Aeroplane Operating Manual* (AOM) indicates that the normal approach speed is 170 knots until approximately 5 nm from the airport, at which point a gradual reduction in airspeed is initiated. The airspeed is to be stabilized at VREF no later than 500 feet HAT.

Regarding stabilized approaches, Porter Airlines SOP, revision 9.1, section 2.15.2 - Stabilized Approach, states the following:

> A stabilized approach is characterized by a constant-angle, constant-rate of descent approach profile ending near the touchdown point, where the landing maneuver begins. All appropriate briefings and checklists should be accomplished before 1000' height above touchdown (HAT) in IMC and before 500' HAT in VMC. Crews shall adhere to the stabilized approach criteria at all times while on approach.
>
> An approach is stabilized when all of the following criteria are maintained from 1000' HAT to touchdown:
>
> 1. The airplane is on the correct track
> 2. The airplane is in the proper landing configuration
> 3. After GS intercept or after the FAF:
>   - GS deviation of < 1 dot
>   - Loc deviation of < 1 dot
> 4. Rate of descent is no greater than 1000 fpm
> 5. If expected rate of descent is >1000 fpm, special approach brief required
>
> At 500' HAT the PM will call "STABILIZED" if the following conditions are met:
>
> - Speed is V_{REF} + 10 kts and – 0 kts
>
> **Note:** Speed additives for gusty conditions must remain within the stabilized criteria (i.e. VREF +10 and -0 kts, including gust).
>
> **Note:** Speed additives when landing with INCR REF switch ON exceed the above criteria so no additional speed tolerance is permitted (i.e., INCR REF switch ON: V_{REF} + 20 kts / 15kts maximum).

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7 Bombardier document number SPAL-02-00558.

> **Note:** Approach configuration and the landing configuration are planned to be the same. Therefore, V_{REF} and V_{APP} will be the same speed and the approach and landing speeds will be based on a single reference speed i.e. V_{REF}.
>
> The PF will respond "CHECK"
>
> If any of the above conditions are not met between 1000' HAT and 500' HAT, the PM will call "NOT STABILIZED" and the PF will call "CORRECTING" or "GO-AROUND, CHECK POWER"
>
> If any of the above conditions are not met at or below 500' HAT, the PM will call "GO-AROUND" and the PF will call "GO-AROUND, CHECK POWER".

Section 2.16.2 of the SOP, which provides details on pitch awareness and call-outs, states that the PM is required to call out the pitch attitude below 100 feet HAT on approach when the pitch is greater than or equal to 5°. If the pitch attitude reaches 6°, the PF must respond "correcting" and either decrease the pitch angle, or execute a go-around. The SOP further states, "To decrease the landing descent rate and not exceed a pitch attitude of 6 degrees, at anytime the landing descent rate is higher than desired; power will be required in the landing flare through touchdown."

In addition, the AOM indicates, "DO NOT exceed 6° nose up during landing flare to avoid the fuselage contacting the runway."

The SOP defines the call-outs for the PF and PM, but it does not outline PM duties or what the PM should be monitoring throughout the different stages of flight.

Stabilized approach and energy management

Following the recommendations of the Approach and Landing Accident Reduction (ALAR) Task Force,[8] the Flight Safety Foundation (FSF) created and distributed an ALAR toolkit intended to reduce the number of approach and landing accidents.

The FSF toolkit defines a stabilized approach, including the minimum altitude at which an approach should be stabilized, as well as all the elements of a stabilized approach.[9] One of the recognized elements is that speed should be between VREF and VREF +20 knots. Specific limits of excessive deviation for approach elements, along with a stabilization altitude limit, provide pilots (PF and PM) with a shared reference point, thereby reducing the possibility of ambiguity. In such a context, deviations are detected more quickly and calls are faster and more accurate.

In 2012, there were 24.4 million departures for a worldwide fleet of civil-operated, commercial, western-built jet airplanes heavier than 60 000 pounds maximum gross weight.[10] An article in

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8 Approach and Landing Accident Reduction (ALAR) Task Force of the Flight Safety Foundation (FSF).

9 ALAR toolkit, FSF ALAR Briefing Note 7.1: Stabilized Approach.

10 *Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959–2012*, Boeing Commercial Airplanes (August 2013).

AeroSafety World[11] stated that, while only 3.5% to 4% of approaches are unstable, 97% of unstable approaches are continued to a landing, with only 3% resulting in a go-around.

The TSB identified the need to reduce the incidence of unstable approaches that are continued to a landing in its investigation into the accident involving FAB6560 in Resolute Bay, Nunavut (A11H0002). Following this investigation, the Board recommended that:

> Transport Canada require CARs Subpart 705 operators to monitor and reduce the incidence of unstable approaches that continue to a landing.
>
> **TSB Recommendation A14-01**

In its response to A14-01, Transport Canada (TC) issued a Civil Aviation Safety Alert (CASA) on 27 June 2014 (CASA 2014-03). The CASA had been developed to encourage Subpart 705 operators to use their safety management systems (SMS) to identify the incidence of unstable approaches and to develop mitigation measures for the risk they pose. It also encouraged the voluntary participation of Subpart 703 and 704 operators to mitigate the risk posed by unstable approaches. Additionally, the CASA emphasized the value of voluntary flight data monitoring (FDM) programs to better understand what factors are influencing the occurrence of unstable approaches.

One year after publication of the CASA, TC intends to use the existing surveillance system to review operator effectiveness at identifying the incidence of and mitigation measures for unstable approaches. Air operators who indicate that they do not have a problem with unstable approaches in their operation will be asked to demonstrate how they have reached this conclusion. Additionally, TC plans to follow up with the pilot community to verify that unstable approaches are being reported and monitored through the SMS.

TC’s response relies on the existing defence of SMS to mitigate the risk, and indicates that FDM will remain a voluntary program. SMS have been in place for several years for Subpart 705 operators, yet the incidence of unstable approaches has not been effectively addressed. Although the proposed use of SMS to specifically identify the incidence of unstable approaches and to implement mitigation strategies is a positive step, it will be some time before the effectiveness of this action can be validated. Additionally, without the requirement for an FDM program, operators may not have the data to assess the risk to their operation posed by unstable approaches.

Therefore, the response to Recommendation A14-01 was assessed as Satisfactory in Part.

Approach-and-landing accidents are a 2014 Watchlist issue

The Watchlist is a list of issues posing the greatest risk to Canada’s transportation system; the TSB publishes it to focus the attention of industry and regulators on the problems that need addressing today.

As this occurrence demonstrates, landing accidents continue to occur at Canadian airports.

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11 Flight Safety Foundation, “Failure to Mitigate,” *AeroSafety World* (February 2013).

The TSB calls on Transport Canada and operators to do more to reduce the number of unstable approaches that are continued to a landing.

Transport Canada also must complete its risk-based analysis and move forward with regulatory changes.

Airports must develop tailored solutions to lengthen runway end safety areas or install other engineered systems and structures to safely stop planes that overrun runways.

See more information about this Watchlist issue.

Weather

The 2200 aviation routine weather report (METAR) for CYAM reported the weather as: wind 280° True at 4 knots, visibility 15 statute miles, few clouds at 21 000 feet ASL, temperature 8°C, dew point 2°C, altimeter 30.25 inches of mercury.

Airport information

CYAM has 2 asphalt runway surfaces: Runway 04/22, which is 5990 feet long and 200 feet wide, and runway 12/30, which is 5991 feet long and 200 feet wide. Runway 30 is equipped with an omnidirectional approach lighting system, threshold and runway end lighting, and high-intensity runway edge lights (5 variable-intensity settings). The Runway 30 PAPI at CYAM is installed 1100 feet from the threshold and is adjusted to indicate a slope of 3° for an aircraft with an eye-to-wheel height of up to 10 feet.

Approach slope indicator systems

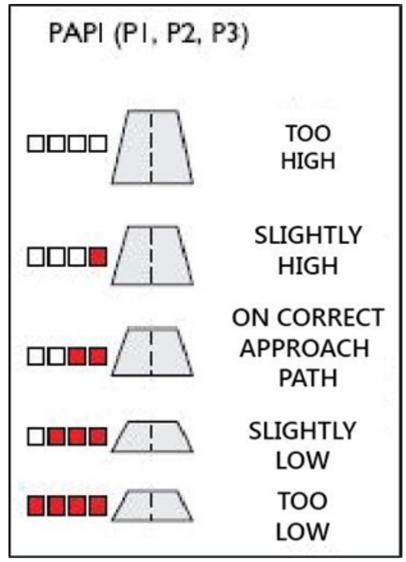
The following information is taken from the Transport Canada *Aeronautical Information Manual*, section AGA 7.6.1 (effective 18 October 2012 to 04 April 2013):

> An approach slope indicator consists of a series of lights visible from at least 4 NM (2.5 NM for abbreviated installations) designed to provide visual indications of the desired approach slope to a runway (usually 3°). At a certified airport, aircraft following the on-slope signal are provided with safe obstruction clearance to a minimum of 6° on either side of the extended runway centreline out to 4 NM from the runway threshold.

The approach slope indicators or visual glide slope indicators comprise different types of systems, including the PAPI. The PAPI consists of 4 lights located on the left-hand side of the runway in the form of a wing bar. When the 2 units nearest the runway edge appear red and the remaining two appear white, the aircraft is on the nominal 3° approach slope. At an approach slope of 3.5° or above, all 4 light units will appear white (Too High), whereas at an approach slope of 2.5° or below, all 4 light units will appear red (Too Low) (Figure 2).

When viewed in perspective, these limits are similar to a cone with the small end near the touchdown point. The nominal 3° approach slope is the centre axis of the cone with the 3.5° and 2.5° slopes extending above and below the nominal path. Therefore, the farther the aircraft is from the threshold, the more room there is for deviation above or below the glide path. The closer the aircraft gets, the less room there is for deviation as the cone shrinks.

Figure 2. PAPI (Source: Transport Canada *Aeronautical Information Manual*, TP 14371 [18 October 2012], AGA – Aerodromes, section 7.6.2.3)



Previous occurrences

This was Porter Airlines Inc.'s second aft fuselage strike on landing; the previous event occurred on 21 April 2009 in Ottawa, Ontario (TSB aviation investigation report A09O0073) and involved very similar circumstances. Porter Airlines Inc. has an approved SMS in place to monitor, investigate and take corrective action for occurrences that happen within the company. Following the 2009 occurrence, Porter Airlines Inc. conducted an SMS investigation and issued a flight operations bulletin entitled *Pitch Awareness Training* (17 August 2009). Outlined in the bulletin is a clarification of the pitch awareness call-out SOP and a reiteration of the requirement for arresting abnormal descent rates with engine power.

The TSB also investigated a tail strike on a DHC-8-300 series aircraft (TSB aviation investigation report A12Q0161). This occurrence was also due to a hard landing and excessive pitch on touchdown.

Bombardier statistics as of 2013 indicate there have been 20 DHC-8-400 tail strike / runway contact events worldwide.[12] Bombardier has developed a training video entitled "Pitch Awareness" and recommends that operators develop pitch awareness SOP. The video highlights the importance of controlling the nose-up attitude when landing the DHC-8-300 and the DHC-8-400 series aircraft.

While the DHC-8-400 is 23 feet longer than the DHC-8-300, when the landing gear strut is compressed during a hard landing, both aircraft sustain impact of the fuselage at an attitude of approximately 7° nose-up. The video also highlights the importance of controlling an excessive rate of descent by increasing power rather than increasing the nose-up attitude near the ground. An increase in power will increase airflow over the wings directly behind the propellers and, therefore, increase lift even if forward velocity does not change.

TSB Laboratory reports

The following TSB Laboratory report was completed:

- LP 098/2013 – Flight Data Recorder Download and Analysis

12 Bombardier Inc.: Tailstrikes Totals Q400, 2000 to 2013.

Analysis

The flight crew was qualified in accordance with regulations. The aircraft was certified, equipped and maintained in accordance with regulations. The weather is not considered to be a causal factor in this occurrence. The flight from the time the autopilot was disconnected until 500 feet above the touchdown zone (HAT) was uneventful and in accordance with standard operating procedures (SOP). The analysis will therefore examine the approach profile from the time the autopilot was disconnected 3 minutes before touchdown and the final 43 seconds from 500 feet HAT to touchdown.

From the point the autopilot was disconnected and the pilot flying (PF) started hand-flying the aircraft, there were minor deviations both above and below the ideal 3° glide path. These deviations could be considered normal as the PF adjusted to hand-flying the aircraft. The deviations were corrected by small changes in aircraft pitch attitude and engine power. When the aircraft was above the ideal glide path, pitch attitude and engine power were reduced slightly. When the aircraft was slightly below the ideal glide path, pitch attitude and engine power were increased slightly.

At 500 feet HAT, the aircraft was on track and configured for landing, the rate of descent was approximately 400 feet per minute (fpm), and the speed was 127 knots indicated (landing reference speed [VREF] +6). At this time, the aircraft met all company-defined requirements for a stabilized approach, and the appropriate “Stabilized” call was made by the pilot monitoring (PM).

The flight data recorder (FDR) data show that, seconds before crossing 500 feet HAT, the aircraft had drifted slightly below the glide path and that a correction had been applied back to the glide path. As the approach continued, the aircraft continued to drift above the glide path. The PF attempted to correct with slight nose-down pitch and minor engine power reduction. When the aircraft passed through 300 feet HAT, the indicated airspeed had increased to 131 knots; this was still within VREF +10. The aircraft, however, continued to drift above the ideal 3° precision approach path indicator (PAPI) glide path. Seconds later, as the aircraft passed through 250 feet HAT, the PF reduced the engine power from 13% to approximately 5% flight idle and pitched the nose down slightly. This power reduction would have significantly decreased the airflow and lift over the wings. As well, the fact that the profile drag from the propellers would have been in fine pitch at flight idle would have slowed the aircraft. The indicated airspeed began to decrease immediately. However, the aircraft continued to drift above the glide path and, at 0.4 nautical miles and 200 feet HAT, reached the 3.5° PAPI glide path, at which point the vertical descent rate began to increase.

As the aircraft passed through approximately 90 feet HAT, the airspeed dropped below VREF and continued to decrease. At the same time, the vertical speed was increasing above -800 fpm and the aircraft was drifting below the ideal 3° PAPI glide path. The PM did not notice the increased rate of descent, most likely because he was monitoring the visual approach out the window at this point and not the aircraft instruments. As a result, no call-out for a go-around, as required by the company SOP, was made by the PM when the airspeed dropped below VREF. Continuing the approach when an aircraft does not meet the criteria for a stabilized approach is cited by the Flight Safety Foundation as being a contributing factor in 66% of approach and landing accidents and serious incidents. Neither crew member identified that the airspeed had dropped below VREF; the flight no longer met the requirements of a stabilized approach, and an overshoot was required.

Below 500 feet HAT, the SOP is very specific: if the aircraft is no longer stabilized, then a call for a go-around is required. The PM knew the PF had reduced power at 250 feet HAT to correct for the increased airspeed and high approach, but did not realize how much the power had been reduced. Everything still appeared to be relatively normal at this point and within the company-defined parameters of a stabilized approach. When the airspeed dropped below VREF, the approach was no longer stabilized as per the SOP. By the time the PM realized there was something wrong, there was no time left to react or take corrective action. If SOP do not clearly define the duties of the PM, there is an increased risk that unsafe flight conditions could develop.

At 40 feet HAT, the PM realized that the aircraft had slowed too much and was descending too rapidly, and told the PF to add power just before impact. The PF reacted by applying aggressive nose-up control followed by an increase in the engine power. However, the airspeed was decreasing through 113 knots (VREF -8), and the vertical speed had increased to over -900 fpm and was still increasing. When a higher rate of descent occurs near the ground, the manufacturer recommends that pilots use power versus nose-up pitch to reduce the rate of descent and limit the nose-up attitude to 6°. Both flight crew members had received pitch awareness training and were aware of the need to limit pitch on touchdown and use power to control the descent rate.

The PF had limited experience on an aircraft the size of the DHC-8-400 and had only just completed line indoctrination 2 months prior to the occurrence. During the PF's training on the DHC-8-400, the appropriate management of approach power / pitch and the elimination of large power changes in descent to chase speed were areas identified that needed improvement. Initially during this approach, the PF was correcting the glide path and airspeed with small power and pitch changes. During the approach, the aircraft's deviations above and below the glide path were relatively constant; however, after the aircraft passed 500 feet HAT, these minor changes were no longer as effective because there was less tolerance and time for the changes to take effect. With the aircraft drifting farther above the glide path and the airspeed increasing, the PF overcorrected by reducing the engine power to flight idle. As the aircraft rapidly approached the ground, the PM called for more power to reduce the descent rate and the PF instinctively reacted by pulling back on the control column increasing the pitch attitude. The PF pitched the nose up beyond the limits stated in the SOP and the manufacturer's pitch awareness training. This action did not achieve the desired result of slowing the rate of descent. The high rate of descent with power coupled with the high nose-up attitude of the aircraft resulted in the hard landing that compressed the struts and allowed the tail to strike the runway.

The company SOP defines the criteria for a stabilized approach; however, one item that is not mentioned is glide path when using visual glide scope indicators such as the PAPI. There are indications for instrument landing system (ILS) glide slope deviation, which would be applicable during an ILS approach, but no limits for the visual approach. The FDR data clearly indicate that the aircraft was constantly deviating above and below the glide path after the autopilot was disconnected, yet by company SOP the aircraft met all the criteria for a stabilized approach while passing through 500 feet HAT. The only defined parameter that made the approach unstable was when the indicated airspeed dropped below VREF at 90 feet HAT. If

SOP do not clearly define the requirements for a stabilized visual approach, there is an increased risk that continued flight could result in a landing accident.

Findings

Findings as to causes and contributing factors

1. Neither crew member identified that the airspeed had dropped below landing reference speed; the flight no longer met the requirements of a stabilized approach, and an overshoot was required.

2. The pilot monitoring did not identify the decreasing airspeed and increasing descent rate in time to notify the pilot flying or intervene.

3. In response to the pilot monitoring's warning to add power, the pilot flying pitched the nose up beyond the limits stated in the standard operating procedures and the manufacturer's pitch awareness training.

4. The high rate of descent coupled with the high nose-up attitude of the aircraft resulted in the hard landing that compressed the struts and allowed the tail to strike the runway.

Findings as to risk

1. If standard operating procedures do not clearly define the requirements for a stabilized visual approach, there is an increased risk that continued flight could result in a landing accident.

2. If standard operating procedures do not clearly define the duties of the pilot monitoring, there is an increased risk that unsafe flight conditions could develop.

Safety action

Safety action taken

Porter Airlines Inc.

Immediately following this occurrence, Porter Airlines Inc. initiated a safety management system investigation. Part of the immediate corrective action involved a revision of the *Pitch Awareness Training* document (Rev 6.0 / 29 May 2013) to highlight previous occurrences and the need to arrest high descent rates with power and not pitch.

As well, the company initiated the following actions:

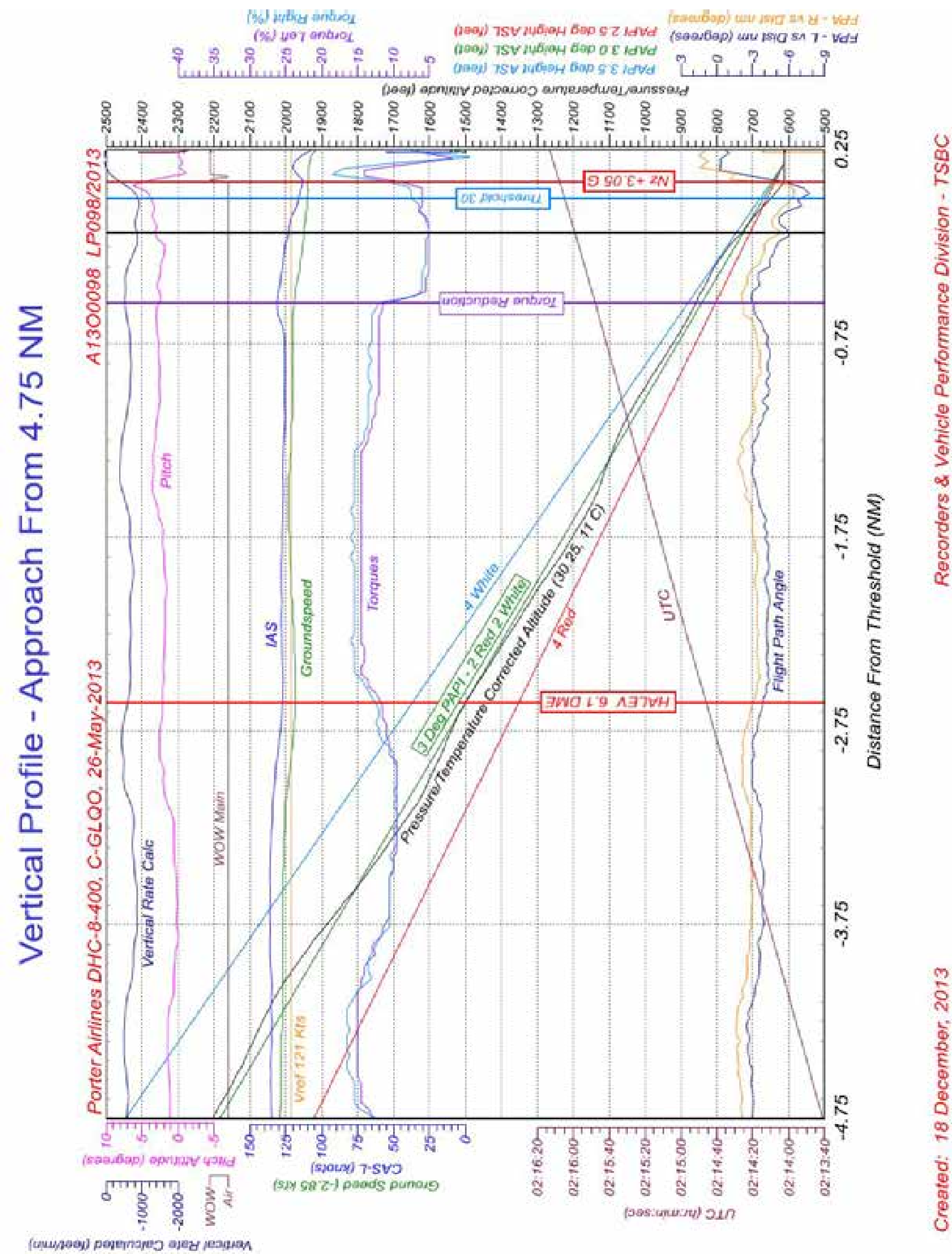
- Conducted a review of training for training captains and line pilots;
- Reviewed the use of flap settings on approach;
- Provided further clarification on the stabilized approach procedure; and
- Re-emphasized hazards associated with nighttime operations.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 28 January 2015. It was officially released on 12 February 2015.

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 – Vertical profile from 4.75 nautical miles



Appendix B – Vertical profile from 1.5 nautical miles