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

AIR TRANSPORTATION SAFETY ISSUE INVESTIGATION REPORT A18Q0140

OCCURRENCES IN QUEBEC AND NUNAVUT ON RUNWAYS UNDERGOING CONSTRUCTION THAT ARE REDUCED IN WIDTH

Canada

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Table of contents

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EXECUTIVE SUMMARY

This safety issue investigation examines a series of 18 occurrences that took place at certain airports undergoing construction in Quebec and Nunavut between 2013 and 2018.

Further to the investigation of an occurrence that took place in June 2018 when runway rehabilitation work was being carried out at the Baie-Comeau Airport, Quebec, it was discovered that another 14 similar occurrences had taken place at other airports in Quebec and at an airport in Nunavut since 2013. A summary review of these occurrences revealed a particularity in the method used to carry out the construction: the width of the runway was reduced rather than the length. In all but 2 cases, aircraft had manoeuvred on the closed portion of the runway during takeoff or landing.

Considering this a matter of concern, the TSB issued Aviation Safety Advisory A18Q0094-D1-A1, addressed to Transport Canada Civil Aviation (TCCA), on 12 July 2018. However, when 2 more similar occurrences took place shortly after the advisory was released, the TSB launched this investigation to highlight any systemic underlying causes or contributing factors, and assess the risk they pose. Information obtained during this investigation determined that an additional occurrence had taken place in Quebec, at the Schefferville Airport in August 2015, but had not been reported.

The construction method most frequently used for runway rehabilitation in Canada and abroad consists of reducing the runway length rather than the width. A review of international standards and recommended practices and of Canada's regulatory framework for construction revealed the absence of information on which method should be used for runway rehabilitation, and the absence of Canadian standards for airport construction. Neither International Civil Aviation Organization (ICAO) documents nor the *Canadian Aviation Regulations* (CARs) and related standards authorize or prohibit either method. The decision lies entirely with the airport operator.

Given that reducing the width of a runway does not require the runway to be closed completely, this method provides a decisive advantage for operators of airports that have operational requirements or specific economic pressures, which was the case for the

4 airports reviewed in this investigation. However, this uncommon method requires that appropriate precautions be taken to ensure the safety of flight operations.

This method of runway rehabilitation requires a new configuration for runway markings. Without specific construction-related standards at their disposal, airport operators complied with regulations relating to airports. It was clear from reviewing these regulations that the various requirements and cases are complex and some concepts not detailed enough. If the wording used in airport standards and regulations is complex and lends itself to several interpretations, these standards and regulations could lead to different measures and solutions that all appear to comply with the requirements, but in reality, may not reflect the regulator's intention with respect to safety.

Furthermore, given the absence of standards related to the safety of operations during airport construction, including standards related to required visual aids, the visual aids used on the reduced-width runways reviewed in this investigation were insufficient for pilots to be able to clearly distinguish the closed portions. The runway markings used for construction at the airports under review were not clear, convincing, and consistent; consequently, the pilots were not able to distinguish the open portion of each runway and manoeuvred the aircraft on the closed portion, which, in some cases, resulted in damage to the aircraft.

If an airport operator plans to carry out construction activities at their airport, they must communicate the necessary information to pilots by having a NOTAM issued by NAV CANADA. However, information pertaining to airport construction, which is temporary and may be complex, can be difficult to communicate clearly and effectively in a NOTAM. Over the years, the way these notices are presented and how they are provided to flight crews have not only been called into question several times, but have also been considered to be contributing factors in a number of aviation occurrences.

The investigations into those occurrences highlighted certain deficiencies that make these notices inadequate and could hinder the communication of the information. In addition to being written entirely in capital letters and consisting primarily of abbreviations and acronyms, these notices are published in a text format only, which limits how clearly a pilot can visualize areas that are closed due to construction. Currently, NOTAMs in Canada cannot include graphics and only include text, the format and style of which can hinder the effective communication of information. Consequently, even though the pilots involved in the occurrences under review had all read the available NOTAMs related to the partial runway closures, their mental models were inaccurate and they were not able to identify which portions were closed.

Consequently, the TSB recommends that

NAV CANADA make available, in a timely manner, graphic depictions of closures and other significant changes related to aerodrome or runway operations to accompany the associated NOTAMs so that the information communicated on these hazards is more easily understood.

TSB Recommendation A21-01

Any airport operator planning to carry out construction activities at their airport without interrupting operations must also prepare a plan of construction operations (PCO) and have it approved by TCCA. The purpose of the plan is to demonstrate that the airport will comply with established operating standards for the duration of the construction period. The investigation revealed that PCOs were difficult to prepare given the absence of standards, recommended practices, guidelines, and any other type of information on the subject. The absence of standards for the preparation of PCOs is in addition to the absence of general standards on airport construction and to the complexity of regulations regarding runway markings to be used.

The evaluation of a PCO by TCCA staff is vital to the safety of operations at an airport during construction. However, TCCA inspectors do not have standards or recommended practices at their disposal to complete the task. Consequently, in the absence of standards, guidelines, and recommended practices, PCOs were approved using informal procedures, without assessing the risk that pilots might not be able to recognize or distinguish the closed portions of the runways, and without including control measures to mitigate this risk.

The implementation of standards, recommended practices, and guidelines pertaining to the safety of operations during airport construction could improve the quality of PCOs, as well as the management of the risks associated with these temporary conditions and the safety of flight operations in these conditions. Consequently, the TSB issued Aviation Safety Advisory A18Q0140-D1-A1 to TCCA to make the organization aware of the absence of such standards, recommended practices, and guidelines pertaining to the safety of operations at airports undergoing construction, and to encourage the implementation of corrective measures as soon as possible.

Although safety measures are an integral part of airport operations and flight operations, they did not prevent the occurrences under review. Yet, these safety measures are part of a regulatory framework that promotes a systemic culture of safety and risk management for both airport operators and TCCA. The introduction of safety management systems (SMS) changed how safety is managed, by establishing a systemic risk management framework that includes a safety oversight component that should allow for proactive and reactive risk management. The 4 airports under review each had an SMS, but these SMSs did not comply with regulatory requirements and were not effective, given that they did not prevent the occurrences from happening in the first place or prevent repeated similar occurrences from happening. These SMSs were not assessed by TCCA when they were put in place, and the airport operators did not benefit from TCCA feedback and follow-up.

TCCA adopted its own internal SMS, the Integrated Management System (IMS), to implement and manage the Transport Canada (TC) Aviation Safety Program. With respect to

the occurrences under review, TCCA was required to take action, including evaluating and approving the PCOs for the planned construction. However, the investigation determined that the TCCA inspectors had not followed IMS processes. For instance, they had not conducted risk assessments.

Safety management and regulatory surveillance are TSB Watchlist 2020 issues. The TSB has repeatedly emphasized the benefits of an SMS that allows companies to manage risk effectively and make operations safer. Yet, implementing an effective SMS is only part of the issue. Proper regulatory surveillance is also needed.

However, TC is not always able to identify ineffective operator processes and take action in a timely manner. For that reason, safety management will remain on the TSB Watchlist until operators in the air transportation sector that do have an SMS demonstrate to TC that it is working—that hazards are being identified and effective risk-mitigation measures are being implemented.

Likewise, regulatory surveillance will remain on the TSB Watchlist until TC demonstrates, through assessments of surveillance activities in the air transportation sector, that the new surveillance procedures are identifying and rectifying non-compliances, and that TC is ensuring that an operator returns to compliance in a timely fashion and is able to manage the safety of its operations.

This investigation has highlighted these deficiencies regarding airport surveillance. Although the occurrences under review took place primarily in Quebec and Nunavut, the investigation determined that these deficiencies all resulted from systemic underlying causes or contributing factors that a national safety program should have identified. Inevitably, it begs the question as to whether the situation is the same in other TCCA regions. In light of this, the Board is concerned that if TCCA does not provide adequate surveillance of airports in Canada, the risk of an accident related to flight operations at airports increases, particularly when the airports are undergoing construction.

1.0 INTRODUCTION

1.1 What is a safety issue investigation?

The Transportation Safety Board of Canada's (TSB) mandate is to advance safety in transportation. It conducts investigations into occurrences in order to determine their causes and contributing factors, identify safety deficiencies, and make recommendations designed to mitigate or eliminate such safety deficiencies.

When several occurrences take place presenting commonalities and happening under similar circumstances, this could be an indication of systemic underlying causes or contributing factors.

When that happens, if the TSB determines that a significant safety issue exists, it launches a safety issue investigation. According to the TSB Policy on Occurrence Classification,[1] this type of investigation, which corresponds to a class 1 occurrence, consists of a comprehensive study into a series of occurrences with common characteristics and which, over time, have formed a pattern linked to one or more risks.

1.2 Context

Every runway will need to be rehabilitated at some point. The construction method used most often in Canada and abroad consists of temporarily reducing the length of the runway by closing the ends and performing the work on one end at a time or on both ends at the same time.

Another method, which is not as common, consists of reducing the runway width, dividing the entire length of the runway and closing one side of the runway at a time. However, this method, which is used in Canada in particular, has led to a number of occurrences during landings and takeoffs on reduced-width runways in Quebec and Nunavut.

On 24 June 2018, a Bombardier DHC-8-300 aircraft operated by Jazz Aviation LP was conducting scheduled flight JZA8964 under instrument flight rules (IFR) from Mont-Joli Airport (CYYY), Quebec, to Baie-Comeau Airport (CYBC), Quebec, with 18 passengers and 3 crew members on board. Because of ongoing rehabilitation work being carried out on Runway 10/28 at the destination airport, the runway width had been reduced by half, to 75 feet, over the entire length of the runway, and only the northern lateral half was usable. As it was landing on Runway 10, the aircraft was lined up with the usual runway centreline—that is, the middle of the unreduced runway width—instead of the middle of the open lateral half of the runway. When the aircraft landed, the right main landing gear touched the ground on the closed lateral half of the runway. The gear's inner wheel then struck a temporary runway edge light, causing a flat tire as the aircraft continued its landing

[1] Transportation Safety Board of Canada, TSB Policy on Occurrence Classification (effective 1 May 2018, last revised 24 February 2021), at https://www.tsb.gc.ca/eng/lois-acts/evenements-occurrences.html (last accessed on 30 November 2021).

roll toward the open lateral half of the runway. There were no injuries. Other than the flat tire, the aircraft was not damaged. The investigation determined that there were no closed markings on the closed southern lateral half of the runway.

This incident was reported to the TSB, which launched investigation A18Q0094. From the start of the investigation, a review of data from the TSB's Aviation Safety Information System (ASIS),[2] Transport Canada Civil Aviation's (TCCA) Civil Aviation Daily Occurrence Reporting System (CADORS)[3,4] and NAV CANADA's aviation occurrence report (AOR) system[5] drew the TSB's attention to the fact that this aviation occurrence was not unique. In fact, the compilation of the data available in these databases identified 15 occurrences that had taken place since 2013 involving a reduced-width runway at 2 airports in Quebec (Montréal/St-Hubert [CYHU] and Baie-Comeau) and at 1 airport in Nunavut (Iqaluit [CYFB]).

Given the high likelihood that more similar incidents could occur, and knowing that a landing or takeoff conducted beyond the established limits of a runway could cause serious injuries to occupants and significant damage to aircraft, the TSB issued Aviation Safety Advisory A18Q0094-D1-A1[6] to TCCA on 12 July 2018. The advisory stated that although a NOTAM[7] had been issued in each occurrence to indicate the closure of portions of the runway, the pilots were not able to quickly distinguish the open portion of the runway from the closed portion of the runway. It was therefore reasonable to conclude that the runway markings used during the rehabilitation work had not been effective, to the point where flight crews mistakenly believed that the entire width of the runway was available.

This aviation safety advisory immediately drew the attention of the Regional Community Airports Coalition of Canada (RCAC),[8] which then invited the TSB to give a presentation on

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2 TSB Aviation Safety Information System, at https://www.tsb.gc.ca/eng/stats/aviation/data-5.html (last accessed on 23 November 2021).

3 TCCA Civil Aviation Daily Occurrence Reporting System, at https://wwwapps.tc.gc.ca/Saf-Sec-Sur/2/cadors-screaq/m.aspx (last accessed on 23 November 2020).

4 All occurrences in ASIS also appear in CADORS.

5 Given that the NAV CANADA aviation occurrence report (AOR) system is internal to NAV CANADA, it is not accessible to the public. However, the information entered in the system is sent to TC and the TSB.

6 Transportation Safety Board of Canada, Aviation Safety Advisory A18Q0094-D1-A1: Aircraft landing on the closed portion of reduced-width runways at airports where repair and maintenance work is being conducted (12 July 2018), at https://www.tsb.gc.ca/eng/securite-safety/aviation/2018/a18q0094/a18q0094-d1-a1.html (last accessed on 23 November 2021).

7 A NOTAM is "[a] notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations." (Source: NAV CANADA, TERMINAV bilingual terminology database).

8 The Regional Community Airports Coalition of Canada (RCAC) is an organization of airports and associations representing airports across Canada. It is dedicated to promoting the viability of regional and community airports across Canada. Direct membership consists of over 62 airports Canada wide, as well as reciprocal membership agreements with the British Columbia Aviation Council (BCAC), Saskatchewan Aviation Council

the subject to its members. The TSB gave this presentation on 20 November 2018, at which time it learned that the method of reducing the runway width for construction work had previously been used elsewhere in Canada and that airport operators had a wide range of knowledge about and mixed views on the matter. A request to TCCA confirmed that this method had only been used at the Peace River Airport (CYPE), Alberta. It should be noted that no occurrences were reported during construction work at that airport.

The TSB's concerns were heightened when 2 new similar occurrences[9] took place in Quebec in 2018, after the release of Aviation Safety Advisory A18Q0094-D1-A1.

Given the number of similar occurrences taking place and their repetition at all of the airports in Quebec and Nunavut where the width of the runway had been reduced for construction purposes, the TSB launched this safety issue investigation. Using the methodology described in Appendix A, the TSB sought to determine the factors that led to these occurrences, analyze the existing lines of defence, and identify what could have prevented these types of occurrence or what could prevent them in the future.

It should be noted that information obtained during the investigation revealed that an 18th occurrence had taken place in Quebec, at the Schefferville Airport (CYKL), and had not been reported.

1.3 Scope

This report is meant for the aviation sector in general, and for airport operators and Transport Canada (TC) in particular.

The focus of this investigation is occurrences reported to the TSB that took place between 2013 and 2018 at airports in Quebec and Nunavut[10] on runways whose width was reduced for construction activities. The year 2013 marked the first time an occurrence was reported involving a runway that was reduced in width during construction work. The year 2018 was when this investigation began.

This investigation first examines the various relevant aspects and existing lines of defence for Canadian airport operations, followed by those for flight operations in Canada. The investigation then focuses on safety management and airport surveillance in Canada. This investigation also draws a parallel with the situation in Alaska, another place where runways have been reduced in width to carry out construction activities. Finally, the investigation analyzes the various factors that led up to the occurrences under review despite the existing lines of defence, to identify deficiencies.

(SAC), Airport Management Council of Ontario (AMCO) and the Réseau québécois des aéroports (RQA). (Source: Regional Community Airports Coalition of Canada, at http://www.rcacc.ca [last accessed on 23 November 2021]).

9 TC CADORS reports 2018Q1937 and 2018Q2366, at https://wwwapps.tc.gc.ca/Saf-Sec-Sur/2/CADORS-SCREAQ/q.aspx?lang=eng (last accessed on 23 November 2021).

10 Aviation occurrences in the eastern part of Nunavut are reported to the TSB's regional office in Quebec.

2.0 OCCURRENCES UNDER REVIEW

After obtaining the dates of all construction work performed on runways at airports within the TSB's Quebec Region since the beginning of 2006,[11] a search was performed in the TSB's Aviation Safety Information System (ASIS) database. This search did not reveal any occurrences related to a reduced-length runway, but did identify 15 occurrences related to a reduced-width runway. A review of NAV CANADA's aviation occurrence reports (AORs) identified 2 other occurrences related to a reduced-width runway. These 17 occurrences took place between 2013 and 2018 at 3 airports: Montréal/St-Hubert (CYHU) and Baie-Comeau (CYBC) in Quebec and Iqaluit (CYFB) in Nunavut. The investigation also discovered an 18th occurrence that had taken place at Schefferville (CYKL), Quebec, in 2015, but had never been reported. This safety issue investigation will focus on these 18 occurrences (Appendix B).

2.1 Occurrences to be reported to the TSB

The *Transportation Safety Board Regulations*[12] state when it is mandatory to report an occurrence to the TSB. Furthermore, the TSB Policy on Occurrence Classification defines the various classes of occurrences to be reported on a mandatory or voluntary basis.

The 18 aviation occurrences reviewed in this investigation can be broken down as follows:

- 1 class 3 occurrence that needed to be reported;
- 11 class 5 occurrences that needed to be reported;
- 3 class 5 occurrences that did not need to be reported, but were considered significant enough to be entered voluntarily as class 5 occurrences in the TSB's database;
- 2 occurrences that did not need to be reported and were not considered significant enough to be entered voluntarily in the TSB's database;[13]
- 1 unreported occurrence, discovered during the investigation, which was not classified because not enough information was available.

2.2 Data available and common characteristics

The amount of information available for the majority of the 18 occurrences under review was limited given that most of them had been classified as class 5 occurrences and a few of

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11 The year 2006 was chosen to allow a sampling of occurrence data recorded before and after the implementation of safety management systems (SMSs) at airports. It should be noted that although SMS became mandatory for airports in 2008, 2 exemptions were issued granting them an implementation delay.

12 Transportation Safety Board of Canada, SOR/2014-37, *Transportation Safety Board Regulations*, subsection 2(1).

13 These occurrences are recorded in NAV CANADA's AOR system under report numbers AOR-234116 – 1 and AOR-237394 – 1. Their descriptions are available in TC's Civil Aviation Daily Occurrence Reporting System at https://wwwapps.tc.gc.ca/Saf-Sec-Sur/2/CADORS-SCREAQ/q.aspx?lang=eng, under report numbers 2018Q1654 and 2018Q2366 (last accessed on 23 November 2021).

them were not recorded in the TSB database. Only the information for the class 3 occurrence was detailed. An analysis of the data available, as limited as it was, highlighted some common characteristics (Table 1) among the various occurrences.

Table 1. Data available and common characteristics in the occurrences under review

Category	Characteristic	Number of occurrences with the characteristic
Occurrence reporting	Recorded in the TSB database	15
	Recorded in NAV CANADA's AOR system only	2
	Unreported/unrecorded	1
Airport size	Small airport that offered a local, regional, or remote service	15
	Large airport that served a national, provincial, or territorial capital	3
Safety management system (SMS) and plan of construction operations (PCO)	Airport where an SMS was required and put in place	18
	Airport with an approved PCO	18
Notification to pilots	NOTAM	18
	AIP Canada (ICAO) supplement	2
Time of occurrence	Day	15
	Night	2
	Unknown	1
Phase of flight	Approach or landing	15
	Takeoff	2
	Unknown	1
Occurrence type	Runway excursion	16
	Aircraft struck temporary runway edge lights	9
	Aircraft landed on a taxiway	1
Aircraft damage and injuries to occupants	Aircraft damage	6
	Injuries to occupants	0
	Unknown	1
Aircraft registration	Canadian	11
	U.S.	6
	Unknown	1
Aircraft category	Small aircraft*	5
	Medium private and business aircraft**	6
	Medium-lift jet	3
	Medium-lift turbo-prop aircraft (commercial aviation – transport category)	2
	Jumbo jet (commercial aviation – transport category)	1
	Unknown	1
Operation/operator type	Canadian general aviation	2
	Canadian private operator	1

	Foreign private operator	3
	Canadian commercial air services – aerial work	2
	Canadian commercial air services – airline operations	6
	Foreign commercial air services	3
	Unknown	1

* Airplane that has a maximum permissible take-off weight of 5700 kg (12 566 pounds) or less.

** For the purposes of this investigation, medium private and business aircraft means a turbo-jet airplane that has a maximum weight of more than 5700 kg (12 566 pounds) and for which a Canadian type certificate has been issued authorizing the transport of not more than 19 passengers.

3.0 AIRPORT OPERATIONS IN CANADA

3.1 Context

This investigation focuses on occurrences that took place at airports. The *Aeronautics Act*[14] provides the following definitions:

> ***aerodrome*** means any area of land, water (including the frozen surface thereof) or other supporting surface used, designed, prepared, equipped or set apart for use either in whole or in part for the arrival, departure, movement or servicing of aircraft and includes any buildings, installations and equipment situated thereon or associated therewith.
>
> ***airport*** means an aerodrome in respect of which a Canadian aviation document[15] is in force.[16]

3.1.1 Background

Canadian airports and their operations have evolved over time. Transport Canada (TC) gives the following context in its *Aviation Safety Program Manual for the Civil Aviation Directorate*:

> 4. Until the 1990s, airports in Canada were owned, operated, or subsidized by the federal government through the Department of Transport. Beginning in 1992, control of many Canadian airports was devolved to local airport authorities. This governmental initiative would later become known as the National Airports Policy (NAP).
>
> 5. After conducting extensive studies in the early 1990's, the Government of Canada made the decision to commercialize a number of its major activities, including the operation of most airports and the provision of air navigation services. The transfer of airport operations began in 1992.[17]

Today, TC still owns 41 airports:

- 18 small airports[18] that offer local, regional or remote service and are operated by either TC (14) or a third party (4). Eleven of those 18 airports are in Quebec, 7 of

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14 Government of Canada, *Aeronautics Act*, R.S.C. (1985, ch. A-2).

15 Canadian Aviation Document means "any licence, permit, accreditation, certificate or other document issued by the Minister under Part I [of the *Aeronautics Act*] to or with respect to any person or in respect of any aeronautical product, aerodrome, facility or service." (Source: Government of Canada, *Aeronautics Act*, R.S.C. [1985, ch. A-2])

16 Government of Canada, *Aeronautics Act*, R.S.C. (1985, ch. A-2), subsection 3(1).

17 Transport Canada, *Aviation Safety Program Manual for the Civil Aviation Directorate*, Issue no. 04 (31 December 2015).

18 The list of small airports owned by Transport Canada can be found at https://tc.canada.ca/en/aviation/operating-airports-aerodromes/list-airports-owned-transport-canada#_Small_airports_owned (last accessed on 24 November 2021).

which are operated by TC, specifically the Air, Marine, and Environmental Programs Directorate.

- 23 large airports that serve a national, provincial, or territorial capital, and are operated by third parties. These airports are part of the National Airports System,[19] which has a total of 26 airports. Three of these 23 large airports are in Quebec.

The occurrences under review in this investigation took place at 4 airports. The Schefferville Airport is one of the small airports owned by TC. It has a single runway and is critical to serving the community. It is operated by the Société aéroportuaire de Schefferville. The Montréal/St-Hubert and Baie-Comeau airports are privately owned and operated. The Montréal/St-Hubert Airport has 3 runways, 2 of which are parallel. The Baie-Comeau Airport has a single runway and is a hub for emergency medical evacuation flights. The Iqaluit Airport in Nunavut is part of the National Airports System. Like the Schefferville Airport, it has a single runway and is critical to serving the community. It is owned and operated by the territorial government.[20]

3.1.2 Airport operator and airport manager

An airport operator is the holder of the airport certificate and may be a corporation (a company, a provincial, territorial, or municipal government, etc.) or a person.

If the operator is a corporation, airport management is delegated to a person: the airport manager.

The *Canadian Aviation Regulations* (CARs) use the term *principal* to refer to this person, and defines it as follows:

> a ***principal*** means:...
>
> **(h)** in respect of an airport:
>
> **(i)** any person who is employed or contracted by its operator on a full- or part-time basis as the airport manager, or any person who occupies an equivalent position,
>
> **(ii)** any person who exercises control over the airport as an owner, and
>
> **(iii)** the accountable executive appointed by its operator [...][21]

The terms *manager* and *director* are both used. Regardless of the title used, this person occupies an important position as the holder of the Canadian aviation document or on behalf of the holder. Contrary to similar positions with air operators and approved

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19 The list of airports that make up the National Airports System can be found on TC's website at https://tc.canada.ca/en/aviation/operating-airports-aerodromes/list-airports-owned-transport-canada#National_Airports_System (last accessed on 24 November 2021).

20 TC does not own any airports in Nunavut.

21 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 103.12(h).

maintenance organizations, the airport manager position does not have any minimum requirements in terms of relevant experience or qualifications.

3.1.3 Airports Capital Assistance Program

Operating an airport requires significant resources that are at times beyond the means of the airport certificate holder. This is often the case for regional airports, which "can struggle to raise enough revenue for operations"[22] and their maintenance. However, these airports "play an essential role in Canada's air transportation sector"[23] and they are essential to the communities they serve as they are often the only existing transportation link. That is why, in 1995, the federal government introduced the Airports Capital Assistance Program (ACAP), which provides support to eligible airports that "are not owned or operated by the Government of Canada."[24] This program, administered by the Air, Marine, and Environmental Programs Directorate, provides funding for "airside safety-related capital projects"[25] that:

- improve regional airport safety;
- protect airport assets (such as equipment and runways);
- reduce operating costs.[26]

In order to be eligible for ACAP, an airport must meet specific criteria,[27] such as demonstrating on its application that it offers year-round scheduled commercial passenger service.

Among the airports where the occurrences under review took place, the Montréal/St-Hubert and Baie-Comeau airports were eligible for ACAP and had obtained funding for the planned runway rehabilitation.

3.2 Standards and regulatory framework

Airport operations in Canada are governed by a variety of texts: act, regulations, policies, standards and recommended practices. Consequently, construction activities carried out at

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22 Transport Canada, Airports Capital Assistance Program, at https://tc.canada.ca/en/programs/airports-capital-assistance-program (last accessed on 24 November 2021).

23 Ibid.

24 Transport Canada, Apply for ACAP funding, at https://tc.canada.ca/en/aviation/operating-airports-aerodromes/apply-acap-funding (last accessed on 24 November 2021).

25 Transport Canada, *Departmental Plan 2017-2018 – Supporting Information on Lower-Level Programs*, section 1.3.1.3: Small Aerodrome Support, at https://tc.canada.ca/en/supporting-information-lower-level-programs#program-1-3-transportation-infrastructure (last accessed on 24 November 2021).

26 Transport Canada, Airports Capital Assistance Program, at https://tc.canada.ca/en/programs/airports-capital-assistance-program (last accessed on 24 November 2021).

27 The ACAP eligibility criteria are described on TC's website, at https://tc.canada.ca/en/aviation/operating-airports-aerodromes/apply-acap-funding (last accessed on 24 November 2021).

airports are subject to regulatory requirements and standards that airport managers must follow.

3.2.1 International standards and recommended practices

The International Civil Aviation Organization (ICAO), a specialized agency of the United Nations, was created in 1944 to establish safety and security standards for civil aviation operations throughout the world. It publishes standards and recommended practices in 19 annexes to the *Convention on International Civil Aviation*.

> *Standard:* Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.
>
> *Recommended practice:* Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.[28]

When a Contracting State does not comply, in whole or in part, with a standard contained in an annex, it must give notification to ICAO of all national differences.[29] Furthermore, the State is invited to extend such notification to any differences from the recommended practices contained in an annex when the notification of such differences is important for the safety of air navigation.[30]

As an ICAO Contracting State, Canada agrees to comply, where possible, with the Organization's standards and recommended practices.

ICAO's Annex 14 discusses aerodromes in general and Volume I pertains to aerodrome design and operations. However, it makes no mention of any methods to be used for runway rehabilitation. Chapter 10 covers aerodrome maintenance, but it provides technical information and very little on airport operations during construction activities. At the time of this investigation, Canada had reported 113 differences from ICAO's standards and recommended practices described in Annex 14, Volume 1. Of these 113 differences,

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28 International Civil Aviation Organization, Annex 14 to the *Convention on International Civil Aviation* — Volume 1, *Aerodrome Design and Operations*, Eighth Edition (July 2018), Foreword, Status of Annex Components, pp. xiii and xiv.

29 Requirement imposed by Article 38 of the *Convention on International Civil Aviation*.

30 International Civil Aviation Organization, Annex 14 to the *Convention on International Civil Aviation* — Volume 1, *Aerodrome Design and Operations*, Eighth Edition (July 2018), Foreword, Action by Contracting States, p. xiii.

7 related to Chapter 10, but none of them concerned runway rehabilitation. All of the differences notified by Canada are published in NAV CANADA's *AIP Canada (ICAO).*[31]

In addition to its annexes, ICAO publishes a number of other documents, some of which clarify how to apply the standards and recommended practices found in the annexes.

Such is the case for the *Aerodrome Design Manual*, particularly Part 1, which discusses runways and is closely linked to the specifications stated in Annex 14, Volume I. This manual "fulfills the requirement for guidance material on the geometric design of runways and associated aerodrome elements."[32] It states the physical characteristics of runways, including minimum widths and factors to be taken into consideration to ensure the safety of operations under normal circumstances.[33] However, it does not discuss these characteristics during construction work or directly address runway maintenance or rehabilitation.

3.2.2 *Canadian Aviation Regulations*

Aerodrome operations in Canada are governed by CARs Part III. Subparts 301 and 302 contain the requirements that are of interest to this investigation.

Subpart 301 applies to aerodromes, but excludes airports, heliports and military aerodromes. Section 301.04 states requirements regarding the runway markers and markings to be used when a runway is partially or fully closed for more than 24 hours: regardless of the runway length, a closed marking shall be displayed at each end of the runway or part thereof. This section also states that the markings do not apply when the closure is "for 24 hours or less."[34]

CARs Subpart 302 applies to airports and is therefore directly relevant to this investigation. It covers requirements for the issuance of an airport certificate and the obligations of airport operators, including the contents of an airport operations manual (AOM). According to certification requirements, the standards and recommended practices published for airports in Canada must be followed. The AOM is somewhat of a written contract between the airport operator and Transport Canada Civil Aviation (TCCA). It contains policies and procedures regarding airport operations. Airport operators must comply with their AOM if they wish to retain their operating certificate. Unlike CARs Subpart 301, Subpart 302 does not provide specific requirements regarding the runway markers and markings to be used when a runway is closed. Instead, it states that airport operators must comply with "standards set out in the aerodrome standards and recommended practices publications."[35]

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31 NAV CANADA, *AIP Canada (ICAO)*, Part 1 – General (GEN), section 1.7, Table 1.7: Differences from ICAO Standards.

32 International Civil Aviation Organization, document no. 9157, *Aerodrome Design Manual*, Part 1: Runways, Third Edition (2006), Foreword.

33 Ibid., Chapter 5, section 5.1: Runways.

34 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section 301.04.

35 Ibid., section 302.07.

(See sections 3.2.3.1 *Procedures for the certification of aerodromes* and 3.2.3.2 *Aerodrome standards and recommended practices* of this report.)

CARs Subpart 302 also includes the airport operators' obligations to provide information when certain situations exist at airports, such as when construction work is being performed:

> **(2)** Subject to subsection (3), the operator of an airport shall give to the Minister, and cause to be received at the appropriate air traffic control unit or flight service station, immediate notice of any of the following circumstances of which the operator has knowledge:
>
> **(a)** any projection by an object through an obstacle limitation surface relating to the airport;
>
> **(b)** the existence of any obstruction or hazardous condition affecting aviation safety at or in the vicinity of the airport;
>
> **(c)** any reduction in the level of services at the airport that are set out in an aeronautical information publication;
>
> **(d)** the closure of any part of the manoeuvring area of the airport; and
>
> **(e)** any other conditions that could be hazardous to aviation safety at the airport and against which precautions are warranted.
>
> **(3)** Where it is not feasible for an operator to cause notice of a circumstance referred to in subsection (2) to be received at the appropriate air traffic control unit or flight service station, the operator shall give immediate notice directly to the pilots who may be affected by that circumstance.[36]

Finally, also within CARs Subpart 302, sections 302.500, 302.501 and 302.502 discuss safety management systems (SMS) that airport operators must establish and maintain pursuant to section 107.02 (see section 3.3 *Safety management system* of this report).

3.2.2.1 Exemptions from regulatory requirements

Subsection 5.9(2) of the *Aeronautics Act* allows the Minister of Transport or a designated representative to grant an exemption "if the exemption [...] is in the public interest and is not likely to adversely affect aviation safety."[37] Furthermore, according to Staff Instruction (SI) REG-004, published by TCCA:

> When considering a request for a ministerial exemption from the CARs, TCCA Headquarters and Regional personnel shall demonstrate due diligence and document the decision-making process. [...] Assessments shall be conducted for the consideration of all ministerial exemptions. An assessment is a comprehensive, documented process used in decision-making to determine a course of action. [...]
>
> The decision to issue, deny or cancel a ministerial exemption pursuant to subsection 5.9(2) of the *Aeronautics Act* shall be made further to an assessment(s) of the two following criteria:

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36 Ibid., subsections 302.07(2) and (3).

37 Government of Canada, *Aeronautics Act* (R.S.C., 1985, c. A-2), subsection 5.9(2).

> (a) Aviation safety;
>
> (b) Public interest.[38]

3.2.3 Canadian procedures, standards and recommended practices

In addition to the CARs, there are standards and recommended practices that provide guidance for airport operations in Canada. These include *Procedures for the Certification of Aerodromes as Airports* (TP 7775) and *Aerodrome Standards and Recommended Practices* (TP 312),[39] which are incorporated by reference[40] into the CARs and have the force of law.

3.2.3.1 Procedures for the certification of aerodromes

3.2.3.1.1 Applicability

The most recent edition of TP 7775 dates back to 1991. At that time, the *Air Regulations* and *Air Navigation Orders* were in effect, and under the leadership of the Director General, Air Navigation System, TCCA Civil Aviation Aerodrome Standards[41] inspectors were using TP 7775 for their oversight activities. Since then, the CARs have replaced the former regulations and orders, but the 1991 version of TP 7775 has remained in effect and is still used by both airport operators and aerodrome inspectors.

3.2.3.1.2 Contents relevant to this investigation

As its name indicates, this publication describes procedures for the certification of aerodromes as airports, including the obligations of the airport certificate holder. With respect to construction at an airport, it states that if construction activities are planned at an airport, the holder of the airport certificate shall:

> submit a Plan of Construction Operations to the Regional Manager, Air Navigation System Requirements, to obtain approval prior to carrying out any construction activities while continuing the operational use of runways, taxiways or other manoeuvring surfaces at the airport. All details of the construction activities, precautions, signage to be used, etc. are to be included in the plan.[42]

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38 Transport Canada, Staff Instruction (SI) REG-004: Process for the Assessment of Exemptions from the *Canadian Aviation Regulations*, Issue 01 (effective 14 April 2008).

39 The latest edition of this publication (5th Edition), published in 2015, is available on TC's website at https://tc.canada.ca/en/aviation/publications/aerodromes-standards-recommended-practices-tp-312 (last accessed on 24 November 2021).

40 Incorporation by reference is a mechanism which allows documents that are not in the text of the regulations to be made part of the regulations and to have the force of law.

41 Section and position names used by TCCA at the time.

42 Transport Canada, TP 7775, *Procedures for the Certification of Aerodromes as Airports*, Second Edition (March 1991), subsection 2.2.1(g), p. 2-2.

However, no specifics are given regarding the method, nature, or extent of the activities; how the operator is to prepare the plan; or what process TCCA uses to evaluate and approve the plan.

With respect to the communication of information about construction activities, TP 7775 states that the airport operator must arrange for NOTAMs to be issued at least 10 days before the proposed restrictions come into effect.

3.2.3.2 Aerodrome standards and recommended practices

3.2.3.2.1 Applicability

The 5th and most recent edition of TP 312[43] came into effect on 15 September 2015. It should be noted that the 4 previous editions remain in effect, so the 5th edition does not supersede the 4th edition,[44] which dates back to 1993. Therefore, airport operators are not obliged to comply with the standards in the most recent edition. Section 302.07 of the CARs, commonly referred to as the "grandfather clause", states that:

> [t]he operator of an airport shall
>
> **(a)** comply:
>
> **(i)** subject to subparagraph (ii), with the standards set out in the aerodrome standards and recommended practices publications, as they read on the date on which the airport certificate was issued,
>
> **(ii)** in respect of any part or facility of the airport that has been replaced or improved, with the standards set out in the aerodrome standards and recommended practices publications, as they read on the date on which the part or facility was returned to service, […][45]

In its Advisory Circular (AC) 302-18,[46] TCCA explains the CARs grandfather clause that allows an airport operator to continue complying with an edition of TP 312 other than the most recent one.

As a result, airport operators must keep a record of their facilities, indicating which edition(s) of TP 312 apply to each facility. For example, it is possible for an airport lighting system to have been certified in compliance with the 3rd or 4th edition, then further to an upgrade, the lighting system now complies with the 5th edition.

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43 Transport Canada, TP 312, *Aerodrome Standards and Recommended Practices*, 5th Edition (effective 15 September 2015).

44 Ibid., 4th Edition (March 1993).

45 Transport Canada, SOR/96-433, *Canadian Aviation Regulations,* subsection 302.07(1).

46 Transport Canada, Advisory Circular (AC) 302-18: Grandfathering at Airports Pursuant to *Canadian Aviation Regulation* (CAR) 302.07, Issue 01 (11 November 2014).

The occurrences under review in this investigation all took place on runways that needed to comply with the 4th edition of TP 312.[47] However, all information published with respect to level of service certification needed to comply with the 5th edition of TP 312.

3.2.3.2.2 Contents relevant to this investigation

TP 312 states the standards and recommended practices for airports in Canada. It establishes requirements such as the physical characteristics, obstacle limitation surfaces, visual aids, and technical services that operators of certified land aerodromes (i.e. airports) must satisfy in support of flight operations, with no mention of construction activities. The most recent edition presents an entirely new approach, and from now provides standards based on operations rather design. In AC 302-021,[48] TCCA explains that:

> (1) The introduction of TP312 5th edition is a change in the application concept of the "standards" affecting airport certification. This shift from the design based concept under the previous editions of TP312 to an operational concept in TP312 5th aligns the certification standards to the actual (or planned) operation at site by linking the standards to specific aircraft characteristics, aerodrome operating visibility condition, and level of service (Precision, Non-Precision, Non-Instrument)[...].
>
> (2) This change to an operational concept requires airport operators to be more knowledgeable of the aircraft operations occurring (or planned for) at the airport whereas previous editions of TP312 were of a design based concept using primarily the runway length in a Code number system to link the standards applicable to the facility.
>
> (3) The operational based concept under TP312 5th edition uses specific characteristics of the critical aircraft (current or planned) to link the respective standards. Each standard in TP312 5th directs the reader as to which of these aircraft characteristics is being called upon by the standard. These characteristics include:
>
> (a) Wingspan (with consideration of the aircraft approach speed category);
>
> (b) Outer main gear span; and
>
> (c) Tail height.
>
> (4) With the introduction of TP 312 5th, all certified airport operators will be required to:
>
> (a) amend their Airport Operations Manual (AOM) to include additional information; and
>
> (b) submit an update to the aeronautical publications regarding the certification level of the various parts of the certified aerodrome (airport).

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47 Transport Canada, TP 312, *Aerodrome Standards and Recommended Practices*, 5th Edition (effective 15 September 2015), Foreword, p. 12.

48 Transport Canada, Advisory Circular (AC) 302-021: Introduction of TP312 5th Edition, Issue 03 (3 August 2017).

> This is required so that aircrews may assess the aerodrome as being "...*suitable for the intended operation*" as currently required under 602.96 (2)(b) of the CAR. At this time, there is nothing in the *Integrated Aeronautical Information Publications* that informs the Aircraft Operator as to the certification level of the infrastructure provided at the airport. Only a general statement is provided as to whether or not the facility is "Certified" or "Registered". This general statement does not provide the Aircraft Operator adequate detail as to the suitability of each facility offered at an airport.[49]

The 4th and 5th editions of TP 312 both discuss the visual aids to be used to indicate closed or unserviceable portions of a runway.[50] Although the wording is different, both editions require closed markings[51] at each end of a runway, or portion thereof, declared permanently closed or unserviceable. For temporary closures, the 4th edition recommends using these closed markings, but does not require them when the closure is for a "short duration" as long as sufficient notice is provided by air traffic services. The 5th edition also does not require closed markings when the closure is for a short duration if there are other means to advise pilots and vehicle operators of the closure. Neither the 4th nor 5th edition provides a definition for "short duration." However, both editions provide the possibility of utilizing means or materials other than paint to indicate these short-duration closures when airport operators choose to display markings. The operators of the airports where the occurrences under review took place considered that a closure for a few weeks was a "short-duration closure," which relieved them of the strict duty to display closed markings while the work was being performed.

In terms of other runway markings (runway edge markings, runway centreline markings, etc.), the 4th and 5th editions of TP 312 differ. The 4th edition states that these markings must be obliterated on the closed portion of the runway only when the closure is permanent. It should be noted that the French version of the 5th edition requires removal of these markings regardless of the duration of the closure, while the English version only requires removal of the markings in the event of permanent closure.[52]

Finally, all runway markings applicable to normally open portions of runways, as described in TP 312, must be properly displayed on the open side of a reduced-width runway, in compliance with CARs Subpart 302,[53] the requirements of which are applicable at all times while a certificate is valid.

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49 Ibid., section 3.0: Background.

50 Section 7.1.1 of the 4th edition and section 5.2.24.2 of the 5th edition.

51 White X displayed on the runway (see Figure 2 in section 3.4.3 *Runway markings during construction* of this report).

52 Transport Canada, TP 312, *Aerodrome Standards and Recommended Practices*, 5th Edition (effective 15 September 2015), section 5.2.24.1.

53 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subparagraph 302.07(1)(a)(i).

3.3 Safety management system

Historically, the safety of flight operations was strictly related to regulatory compliance and was based on reactive risk management in response to incidents and accidents. However, it became evident that regulatory requirements alone could not foresee all of the risks associated with a particular activity. It was then that the concept of SMS was introduced. An SMS consists of

> [a] systematic approach to managing safety, including the necessary organizational structures, accountability, responsibilities, policies and procedures.[54]

The SMS concept was quickly endorsed and recommended by ICAO. In 2005, TCCA required the implementation of SMS within civil aviation, initially for airlines and approved maintenance organizations.

In early 2008, SMSs became mandatory for airports pursuant to sections 107.01 and 107.02 of the CARs.

However, TCCA published 2 exemptions granting a delay in implementing SMS

> to enable holders of airport certificates to introduce a safety management system in an orderly manner and without disruption of their normal operations, by following the SMS implementation program published by the Minister in the Advisory Circular 300-002 titled *Safety Management System Implementation Procedures for Airport Operators.*[55]

According to these 2 exemptions, the Iqaluit Airport, as a member of the National Airports System, had until 31 March 2011 to implement its SMS and the Baie-Comeau, Montréal/St-Hubert, and Schefferville airports had until 31 March 2012.

According to the CARs, the holder of an airport certificate issued pursuant to section 302.03 of the CARs "shall establish, maintain and adhere to a safety management system."[56] This system "shall be adapted to the size, nature and complexity of the operations, activities, hazards and risks associated with the operations of the holder"[57] and shall include:

> **(a)** a safety policy on which the system is based;
>
> **(b)** a process for setting goals for the improvement of aviation safety and for measuring the attainment of those goals;
>
> **(c)** a process for identifying hazards to aviation safety and for evaluating and managing the associated risks;

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54 International Civil Aviation Organization, Annex 19 to the *Convention on International Civil Aviation — Safety Management*, Second Edition (July 2016), Chapter 1: Definitions.

55 Transport Canada, Exemptions from certain *Canadian Aviation Regulations* to facilitate the implementation of safety management systems by holders of airport certificates effective 1 January 2009, Purpose section.

56 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section 107.02.

57 Ibid., section 107.04.

> **(d)** a process for ensuring that personnel are trained and competent to perform their duties;
>
> **(e)** a process for the internal reporting and analyzing of hazards, incidents and accidents and for taking corrective actions to prevent their recurrence.[58]

Furthermore, Subpart 302 of CARs stipulates that an airport's SMS must include the following components:

> **(c)** procedures for the collection of data relating to hazards, incidents and accidents;
>
> **(d)** procedures for the exchange of information in respect of hazards, incidents and accidents among the operators of aircraft and the provider of air traffic services at the airport and the airport operator;
>
> **(e)** procedures for analysing data obtained [...][59]

Subpart 302 of CARs further states that

> [t]he person managing the safety management system shall:
>
> **(a)** establish and maintain a reporting system to ensure the timely collection of information related to hazards, incidents and accidents that may adversely affect safety;
>
> **(b)** identify hazards and carry out risk management analyses of those hazards;
>
> **(c)** investigate, analyze and identify the cause or probable cause of all hazards, incidents and accidents identified under the safety management system;
>
> **(d)** establish and maintain a safety data system, by either electronic or other means, to monitor and analyze trends in hazards, incidents and accidents;
>
> **(e)** monitor and evaluate the results of corrective actions with respect to hazards, incidents and accidents;
>
> **(f)** monitor the concerns of the civil aviation industry in respect of safety and their perceived effect on the holder of the airport certificate.[60]

To help airport operators implement their SMS and meet CARs requirements, TCCA published *Guidance on Safety Management Systems (SMS) Development,*[61] in which SMS components are described in detail.

According to this guide, the safety oversight component of the SMS

> is fundamental to the safety management process. Safety oversight provides the information required to make an informed judgment on the management of risk in your organization. Additionally, it provides a mechanism for an organization to critically review its existing operations, proposed operational changes and additions

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58 Ibid., section 107.03.

59 Ibid., section 302.502.

60 Ibid., section 302.505.

61 Transport Canada, Advisory Circular (AC) 107-001: Guidance on Safety Management Systems (SMS) Development, Issue 01 (1 January 2008).

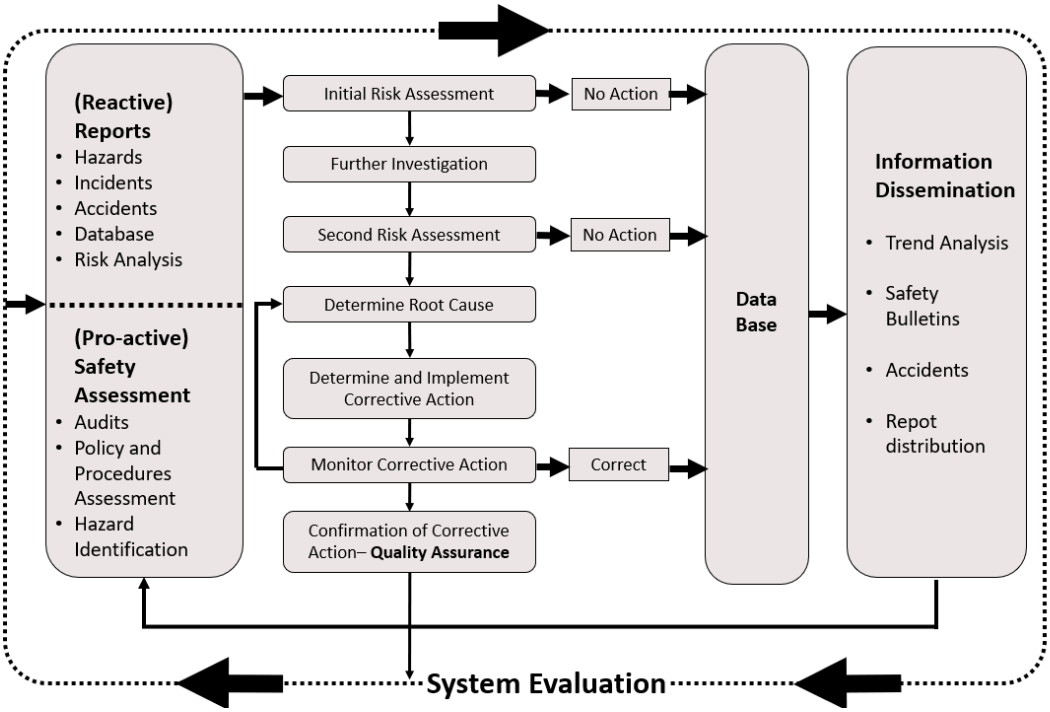
or replacements, for their safety significance. Safety oversight is achieved through two principal means:

(a) Reactive processes for managing occurrences, including event investigation and analysis;

(b) Proactive processes for managing hazards, including procedures for hazard identification, active monitoring techniques and safety risk profiling.[62]

Figure 1 illustrates the safety oversight component of an SMS and highlights the 2 key aspects of safety management: the reactive aspect and the proactive aspect.

Figure 1. Flowchart showing the safety management system process (Source: Transport Canada, Advisory Circular [AC] 107-001: Guidance on Safety Management Systems (SMS) Development, Issue 01 [1 January 2008])



A proactive SMS "must actively seek out potential safety hazards and evaluate the associated risks."[63] The airport operator must therefore consider the potential hazards of each activity. Risk assessments may be used to identify potential hazards and apply risk management techniques. These risk assessments should be undertaken "during the implementation of [the] SMS and at regular intervals thereafter" and "when major operational changes are planned."[64] Therefore, a risk assessment should be carried out for runway rehabilitation that involves the partial closure of a runway given that this construction work is a major operational change.

62 Ibid., section 6.0.

63 Ibid., section 6.3.1: Safety Assessment.

64 Ibid., section 6.3.2: Assessment Frequency.

If events occur despite proactive risk management, the SMS must allow the operator to react so that the events do not reoccur.

> Every event is an opportunity to learn valuable safety lessons. The lessons will only be understood, however, if the occurrence is analyzed so that all employees, including management, understand not only what happened, but also why it happened. This involves looking beyond the event and investigating the contributing factors, the organizational and human factors within the organization, that played a role in the event.[65]

The investigation revealed that only the Montréal/St-Hubert Airport had followed the proactive safety management process by conducting and documenting a risk assessment as part of its construction plan, and none of the airports had followed the reactive process required by CARs after the occurrences.

To prevent a potential issue in an SMS component from going undetected, and to ensure continuous improvement of the SMS, a quality assurance component was included.

According to the *Guidance on Safety Management Systems (SMS) Development*,

> [a] quality assurance program (QAP) defines and establishes an organization's quality policy and objectives. It also allows an organization to document and implement the procedures needed to attain these goals. A properly implemented QAP ensures that procedures are carried out consistently, that problems can be identified and resolved, and that the organization can continuously review and improve its procedures, products and services.[66]

Furthermore, TCCA explains in the guide that quality assurance is based on the principle of continuous improvement which, in most modern management systems, is achieved through the following steps: Plan, Do, Check, and Act (PDCA). A QAP corresponds to the Check step of the PDCA process and ensures that the Act portion achieves the desired results.

TCCA then stresses once again the importance of the process:

> It has been said that "the emphasis with assuring quality must focus first on process because a stable, repeatable process is one in which quality can be an emergent property." This emphasizes the importance of focusing on process and on the need to ensure that processes are documented. The reason we need to do this is that in order to verify the effectiveness of a process, <u>it must be used</u>; in order to improve a process, we must be assured that the process we are improving was in fact the process that was originally being used. Remember, you cannot improve a process unless that process has been documented. So, what is meant by process?
> Process is the sequence of steps taken to arrive at a given output, and in the context used here, is the output from planning (Plan), it is the way that management expects work to be done.[67]

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65 Ibid., section 6.2.1: Event and Hazard Reporting.

66 Ibid., subsection 9.0(1).

67 Ibid., section 9.3: Focus on Process.

The airport managers of some of the airports under review admitted to not properly understanding SMS requirements and not knowing whether or not the SMS they had implemented complied with regulatory requirements.

3.4 Runway rehabilitation

3.4.1 Plan of construction operations

Airport construction planning generally extends over several years. In Canada, from a regulatory standpoint, an airport operator cannot begin maintenance or improvement activities that will have an impact on certification without first submitting a plan to TCCA.

In accordance with TP 7775, if an airport operator plans to carry out runway rehabilitation without interrupting operations, the operator must prepare a plan of construction operations (PCO).[68] Given that the validity of an airport certificate depends on the AOM, once approved by TCCA, the PCO is like a temporary amendment to the AOM, describing the measures that will be put in place during construction to meet relevant standards and mitigate risks. Furthermore, because the operator has an SMS, it must follow the SMS's principles and, if major changes are involved, perform a risk assessment.

Before preparing a PCO, airport operators must determine the nature of the construction activities required, the associated operational constraints, and in accordance with their SMS, they must identify potential hazards. According to airport operators, the elements that are generally considered and assessed are:

- the importance of the airport to the community it serves;
- the various flight operations that take place at the airport;
- the types of aircraft that use the airport;
- the number of runways;
- constraints related to the air operators that use the airport;
- seasonal conditions that dictate when the construction is carried out.

Given that there are no official standards or recommended practices for the preparation of PCOs, airport operators often ask consultants to draft their PCO. In general, the airport operator will authorize the consultant to prepare the PCO, a process that involves meetings and discussions with various stakeholders. If an applicable airport standard cannot be met during construction, the airport operator may request an exemption from TCCA. Once the PCO is ready, it is submitted to TCCA for evaluation and approval.

The TSB obtained a copy of the 39 PCOs approved by TCCA between 2006 and 2018 for the airports in Quebec and the Iqaluit Airport in Nunavut. Of the 39 PCOs, 4 were for the airports that had reduced the runway width and where the occurrences under review had

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[68] Transport Canada, Advisory Circular (AC) 302-021: Introduction of TP312 5th Edition, Issue 03 (03 August 2017), section 4.4: Airport Improvements Following the Introduction of TP 312 5th Edition.

taken place. A review of all the plans revealed that there was, indeed, no standard format for PCOs, and that they generally contained the following elements:

- description of the work to be performed;
- filing of plans;
- construction procedures;
- communications plan;
- closed portions of runways and temporary markings;
- on-site safety;
- appendices.

The review of the 39 PCOs also highlighted the fact that they included civil engineering information (paving techniques, logistics information on how to perform the work, plans, specifications, etc.). This information is neither reviewed nor validated by the inspectors tasked with approving PCOs. Although it is not related to any regulatory requirements, the possibility of obtaining financial assistance is also considered when a PCO is being prepared. In interviews conducted for the purposes of this investigation, airport operators explained that the civil engineering elements in the PCOs were related to funding requests submitted to the Air, Marine, and Environmental Programs Directorate under ACAP. In addition, the operators were under the impression that the least expensive option would be favoured by ACAP officers. For example, painting X on the surface of a freshly paved runway was not acceptable for ACAP given that the removal of these markers at the end of the construction work could damage the surface and lead to additional costs.

The addition of civil engineering information in the PCOs allowed airport operators to prepare a single document to demonstrate to the 2 TC entities—TCCA for approval of the work, and the Air, Marine, and Environmental Programs Directorate for funding—that their respective requirements were met, in addition to a common requirement where "applicants must show that their project is needed to meet the required level of safety."[69]

With regard to risk management in the PCOs reviewed, of the 4 airports where the occurrences under review took place, only 1 PCO included a risk assessment. The PCOs for the other 3 airports simply provided a reminder that airport operations were subject to the airport's SMS and stated that SMS briefings or training would be given to stakeholders.[70]

3.4.2 Construction methods

With construction work on a runway come traffic disruptions. Therefore, the goal of an airport operator that is planning construction is always to minimize these disruptions, and to minimize the time that the runway is closed completely.

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69 Transport Canada, Apply for ACAP funding, at https://tc.canada.ca/en/aviation/operating-airports-aerodromes/apply-acap-funding (last accessed on 24 November 2021).

70 The period covered by this report began in January 2006, before the implementation of SMS at airports; however, all of the occurrences examined in this report took place after the implementation of SMS.

3.4.2.1 Reduced-length runway

The construction method most often used in Canada and abroad consists of temporarily reducing the length of the runway by closing the ends and performing the work on one end at a time or on both ends at the same time. This way, the remaining portion of the runway can be kept open. Other benefits of this method are limiting the time that the runway is closed completely while work is performed on the middle part of the runway, and being able to keep the runway markings and lighting used in the normal runway configuration. This method is appropriate for small aircraft and certain types of larger aircraft that can operate on a reduced-length runway.

3.4.2.2 Reduced-width runway

Another method of runway rehabilitation consists of reducing the runway width—dividing the entire length of the runway in 2 and closing one side at a time while keeping the other side of the runway open. A benefit of this method is that it does not require complete closure of the runway; however, it does require a new configuration for runway markings and lighting. A reduced-width runway may be appropriate for small aircraft and for large aircraft, provided that they are approved for operations on narrow runways (see section 4.2.2 *Narrow runway operations* of this report). This is the method that was used in all of the occurrences under review.

Reducing the width of a runway for rehabilitation purposes does not seem to be common practice. The investigation determined that this method was rarely used in Canada and the United States (see section 6.0 *Cases in the United States, and in Alaska in particular* of this report).

3.4.2.3 Considerations when choosing a method

When choosing a method for runway rehabilitation, the airport operator must take several factors into consideration, including the role that the airport plays in the communities it serves. The airport operator must consult the affected communities to determine how to limit the disruptions caused by the construction work and the duration of the work. Small airports located in remote areas or far from large urban centres, and which often have only one runway, are indispensable to the communities they serve in terms of supplying essential products and emergency medical services. Because closing the one and only runway is not a viable option, regardless of the length of the construction period, the airport operator will choose to close a portion of the runway width.

The airport operator must also take economic factors into consideration when choosing the construction method. Even if an airport is relatively close to a large urban centre and has more than one runway, the airport operator cannot ignore the needs and requirements of air operators, who prefer that the runway be kept open, and therefore favour the runway rehabilitation method that involves closing a portion of the runway width.

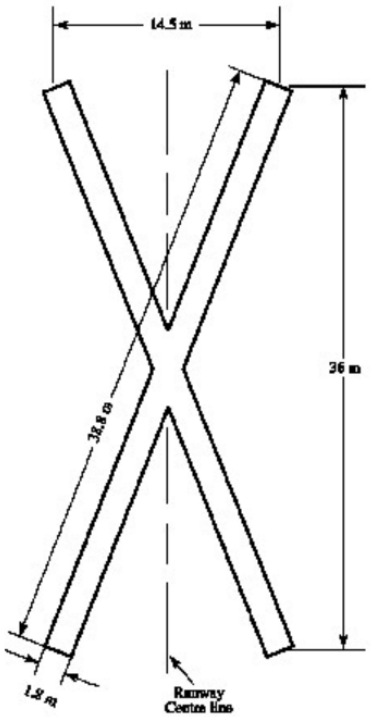
Therefore, the operator of an airport that has passenger service provided by a single commercial air operator will choose the option that avoids closing the runway in order to have the least impact possible on the air operator's operations.

3.4.3 Runway markings during construction

At aerodromes, visual aids are crucial to the proper use of taxiways, runways, and other movement areas, as well as to airside safety. Runways have various markings that enable pilots to properly identify the runway boundaries and centreline. When construction activities are carried out on a runway, some of the markings must be added, moved, or removed. When a runway or portion thereof is closed or unserviceable, closed markings (Figure 2) may or may not be required depending on the aerodrome's status (certified or not), the duration of the closure, and in the case of airports (certified aerodromes), the edition of the standards and recommended practices (TP 312) that applies.

The occurrences under review in this investigation all took place on runways that needed to comply with the 4th Edition of TP 312.

Figure 2. Drawing of a closed marking (Source: Transport Canada, TP 312, Aerodrome Standards and Recommended Practices, 4th Edition [March 1993])



Therefore, closed markings were mandatory for permanent closures, but only recommended for temporary closures; they could be omitted for short-duration closures. Furthermore, other runway markings (runway edge markings, centreline, etc.) did not need to be obscured in the closed area given that the closures were not permanent. Finally, the markings on the open side of the runway needed to comply with the standards stated in TP 312. The operators of the airports at which the occurrences under review took place had considered that a closure for a few weeks constituted a "short-duration closure," which meant that they were not systematically required to display closed markings during the construction work.

An examination of the PCOs for the 4 airports under review revealed that the temporary runway markings varied greatly, not only between airports, but also between different phases of work at the same airport. Furthermore, the investigation determined that the markings that were actually in place at a given point in time did not always reflect what was planned and described in the PCO approved by TCCA. Owing to the temporary nature of the work and the scarcity of documentation available regarding the status of work while it was being completed, it was impossible to compile a list of all of the markings used that did not

match the PCOs, whether or not they had been approved by TCCA after the initial approval of the PCO. The following sections provide examples of some of the differences in markings identified during the investigation at the airports under review for which photos were available, namely Iqaluit, Montréal/Saint-Hubert, and Baie-Comeau.

3.4.3.1 Iqaluit Airport

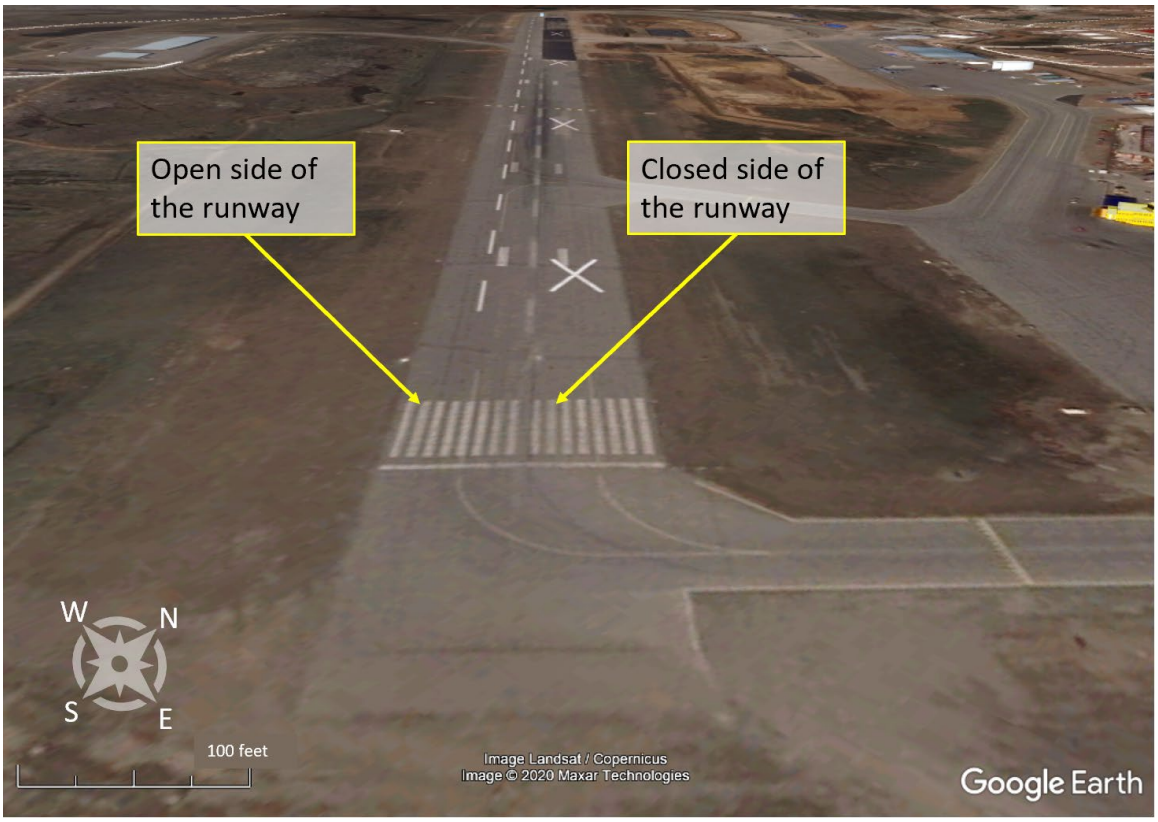
Construction at the Iqaluit Airport was to be completed over several phases, from May 2014 to December 2017, and was described in a single PCO. For the runway[71] rehabilitation phases, a length reduction (displaced threshold) and a width reduction were planned. The PCO stated that the "runway closures" would be indicated by a temporary closed marking, without specifying whether the closures would affect the width, the length, or both. However, on the technical drawings that accompanied the description, closed markings were placed at regular intervals along the entire length of the closed side of the runway. The PCO did not specify whether the runway markings that no longer applied would be removed.

A Google Earth image[72] of the Iqaluit Airport taken during construction (Figure 3) shows closed markings placed at regular intervals along the entire length of the closed side of the runway, and a new centreline was marked on the open side of the runway. However, the original threshold and centreline markings had not been removed and were still visible.

71 The Iqaluit Airport has a single runway.

72 Google Earth image dated 21 July 2015.

Figure 3. Aerial view of the runway markings used at the Iqaluit Airport during construction (Source: Google Earth, with TSB annotations)



3.4.3.2 Montréal/St-Hubert Airport

Construction at the Montréal/St-Hubert Airport, which involved Runway 06L/24R,[73] was scheduled to take place over a period of 2 years and broken down into 6 phases: the 1st phase, which would take place in 2016, was described in one PCO, while phases 2 to 6, which would take place in 2017, were described in another PCO. Like the Iqaluit Airport, the construction work at this airport involved not only a reduction in the width of the runway, but also a reduction in the length (displaced threshold). During the 1st phase, the width of the runway would be reduced to 100 feet and the length would be reduced to 5000 feet. The temporary runway markings that were planned complied with TP 312. The PCO stated that, in order to clearly define the open portion of the runway, temporary runway edge markings would be placed on each side of the open portion of the runway. The PCO also indicated that closed markings (colour not specified) would be displayed at intervals of a maximum of 300 m over the full width of the closed runway (i.e. at both ends). It was also stated that illuminated X's would be placed at both runway thresholds at night while the runway was closed completely.

The runway configuration for phases 2 to 6 also involved a reduction in the runway width (reduced to 75 feet) and length (displaced threshold), with the same arrangement of closed markings as that used in the 1st phase.

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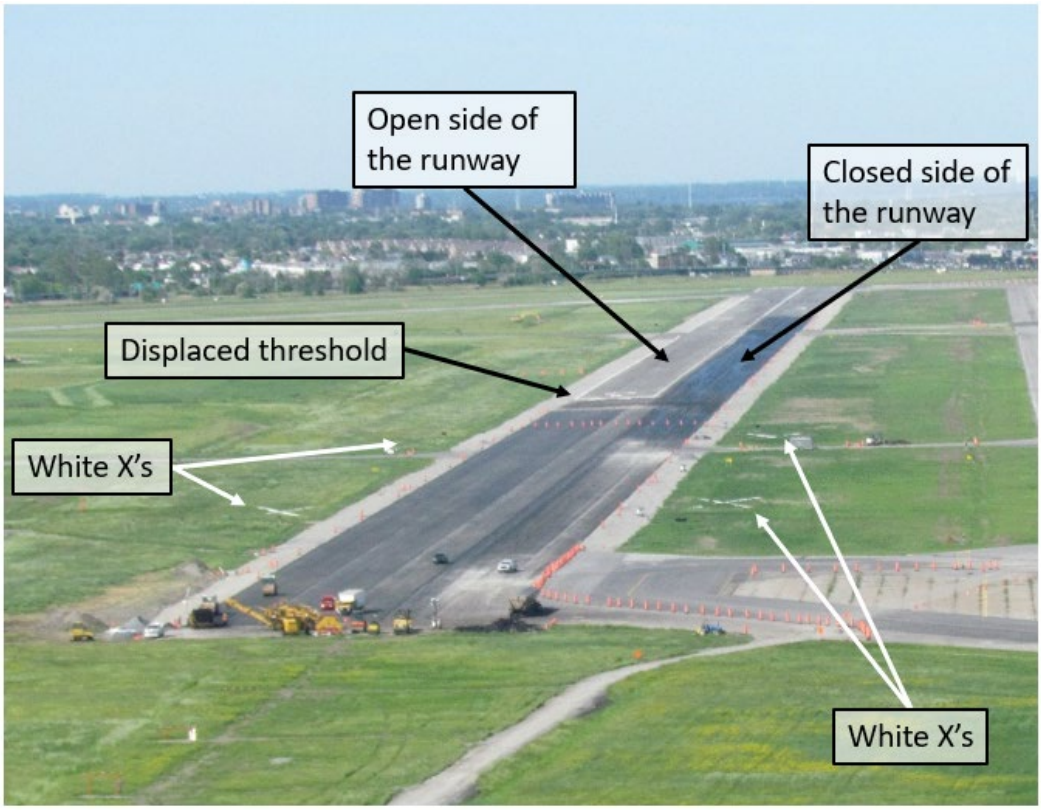
73 The Montréal/St-Hubert Airport has 3 runways: 06L/24R, 06R/24L and 10/28.

In reality, as shown in a photo taken by the TSB in 2016 during the 1st phase of construction (Figure 4), white closed markings with little contrast were installed in the grass on each side of the runway where it was closed along the entire width (displaced threshold).

Figure 4. Aerial photo of the runway markings used for Runway 24R at the Montréal/St-Hubert Airport during the 1st phase of construction (Source: TSB)



3.4.3.3 Baie-Comeau Airport

Construction at the Baie-Comeau Airport was scheduled for June to August 2018 and was broken down into 7 phases, described in a single PCO. This PCO did not include a plan to display closed markings on the closed side of the runway,[74] but it did include a plan to place them in the grass for phase 5. The threshold markings and runway identification number would be removed from the closed side of the runway and the runway number would be displayed at the centreline of the open side. Finally, the PCO included a plan to replace the former runway centreline markings with runway edge markings and place runway centreline markings on the open side.

The planned runway edge markings were actually used; however, the centreline markings and closed markings were not (Figure 5). In light of the repeated incidents that were occurring during the rehabilitation of the south side of the runway, the airport operator decided to display a closed marking in the grass, on the closed side of the runway in line

74 The Baie-Comeau Airport has a single runway.

with each runway threshold, for the rehabilitation of the north side of the runway. These 2 markings were white, and larger than what was recommended in TP 312.

Figure 5. Aerial photo of Runway 10 at the Baie-Comeau Airport during the rehabilitation work on the south side of the runway in June 2018 (Source: Baie-Comeau Airport, with TSB annotations)

3.4.3.4 Peace River Airport

Construction at the Peace River Airport was scheduled to be completed in several phases during the summer of 2015, and was described in a single PCO. For the phases involving runway rehabilitation,[75] a reduction in the width of the runway was planned. The PCO stated that temporary centreline and threshold markings would be displayed on the open portion of the runway and would be removed before the final markings were put in place. Furthermore, technical drawings that accompanied the description showed closed markings at regular intervals on the runway strip, along the entire length of the closed side of the runway.

The investigation was unable to determine whether the proposed markings were applied as proposed.

75 The Peace River Airport has a single runway.

3.5 Communication of construction information by the airport operator

Pursuant to paragraph 302.07(1)(d) of the CARs, an airport operator shall "notify the Minister in writing at least 14 days before any change to the airport, the airport facilities or the level of service at the airport that has been planned in advance and that is likely to affect the accuracy of the information contained in an aeronautical information publication."[76] Furthermore, pursuant to subsections 302.07(2) and (3) of the CARs, an airport operator shall "give to the Minister, and cause to be received at the appropriate air traffic control (ATC) unit or flight service station, immediate notice"[77] of specific situations, including the closure of any part of the manoeuvring area at the airport.

To do this, the airport operator must communicate the required information to NAV CANADA, Canada's exclusive provider of aeronautical information services. As part of its Integrated Aeronautical Information Package, NAV CANADA publishes the following aeronautical information products:[78] *AIP Canada (ICAO)*, *AIP Canada (ICAO)* supplements, aeronautical information circulars (AIC), and NOTAMs. The nature and validity period of the information to be published determines the choice of product. In the case of temporary information, such as that pertaining to runway rehabilitation, 2 products are available: *AIP Canada (ICAO)* supplements and NOTAMs.

3.5.1 NOTAMs

Pursuant to TC's TP 7775, an airport operator planning to carry out construction activities at its airport must issue a NOTAM before the work begins.

According to the *Canadian NOTAM Procedures Manual*,[79]

> [a] NOTAM is a notice distributed by means of telecommunications containing information concerning the establishment, conditions or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations. [...]
>
> The basic purpose of a NOTAM is the distribution of information that may affect safety and operations in advance of the event to which it relates, except in the case of unserviceable facilities or unavailability of services and activities that cannot be foreseen. Thus, to realize its purpose the addressee must receive a NOTAM in sufficient time to take any required action. The value of a NOTAM lies in its "news content" and its residual historical value is therefore minimal.[80]

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76 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 302.07(1)(d).

77 Ibid., subsections 302.07(2) and 302.07(3).

78 In Annex 15, ICAO defines an aeronautical information product as "[a]eronautical data and aeronautical information provided either as digital data sets or as a standardized presentation in paper or electronic media." (Source: International Civil Aviation Organization, Annex 15 to the *Convention on International Civil Aviation — Aeronautical Information Services*, Sixteenth Edition [July 2018], Chapter 1: General, p. 1-6).

79 This manual is now titled *Canadian NOTAM Operating Procedures*. *Canadian NOTAM Procedures Manual* was the title of the manual versions in effect when the occurrences under review took place.

80 NAV CANADA, *Canadian NOTAM Procedures Manual*, version 16.4 (31 March 2016), p. 11.

The process to request that a NOTAM be issued is quick and well known by airport operators, as they are regularly required to issue NOTAMs and have at their disposal the *Canadian NOTAM Procedures Manual*, which describes precisely how to prepare this type of message. When requesting that a NOTAM be issued, airport operators must provide the necessary information to the appropriate NAV CANADA flight information centre or flight service station.

NAV CANADA's *Canadian NOTAM Procedures Manual* is based on ICAO standards in Annex 15,[81] in the *Aeronautical Information Services Manual*[82] and in the *Procedures for Air Navigation Services – ICAO Abbreviations and Codes*.[83]

According to the *Canadian NOTAM Procedures Manual*, NOTAMs shall be

> as brief as possible, stating only the essential facts,[4] and so compiled that its meaning is clear and unambiguous. Clarity shall take precedence over conciseness.
>
> [4] NOTAMs are not issued after the fact just for the records to show that NOTAMs were issued. For example, if no NOTAMs were issued during the actual outage or closure, it is not permitted to promulgate the information after the fact.[84]

The text is written entirely in capital letters and consists primarily of abbreviations and acronyms.[85] Also, NOTAMs do not contain graphics.

The versions of the manual in effect when the various occurrences under review took place indicated the following:

> 5 5.2.3.4 Runway Width Reduction
>
> A NOTAM may be issued when a runway is closed along its length, thus reducing its width. If provided, the reason for the partial closure, such as resurfacing, and the restrictions if applicable, to aircraft size, shall be included.[86]

Furthermore, the examples presented in the manual for a reduced-width runway included information on the affected runway, the closed portion along with its orientation (compass point), the width of the available portion and the wingspan of authorized aircraft. The

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81 International Civil Aviation Organization, Annex 15 to the *Convention on International Civil Aviation — Aeronautical Information Services*, Sixteenth Edition (July 2018).

82 International Civil Aviation Organization, document no. 8126 AN/872, *Aeronautical Information Services Manual*, Sixth Edition (2003).

83 International Civil Aviation Organization, document no. 8400, *Procedures for Air Navigation Services – ICAO Abbreviations and Codes*, Ninth Edition (2016).

84 NAV CANADA, *Canadian NOTAM Procedures Manual*, version 16.4 (31 March 2016), p. 21.

85 According to Appendix C of the *Canadian NOTAM Procedures Manual*, there are 336 abbreviations and acronyms.

86 NAV CANADA, *Canadian NOTAM Procedures Manual*, version 11 (27 June 2013), version 14.4 (3 April 2014), version 14.10 (18 September 2014), version 16.4 (31 March 2016), version 17.6 (12 October 2017).

various examples did not contain specific standard terms or acronyms to designate a reduction in runway width.

> Example: 120001 NOTAMN CYUY ST-BRUNO-DE-GUIGUES
>
> CTA4 SOUTH 50 FT RWY 10/28 FULL LEN CLSD DUE RESURFACING. ACFT WITH A WING SPAN GREATER THAN 50 FT NOT AUTH NORTH SIDE 50 FT
>
> YYMMDDHHMM TIL YYMMDDHHMM[87]

At the same time, the NOTAM examples given in the manual to illustrate a reduction in runway length contained acronyms pertaining to the distance available on takeoff or landing.[88] These acronyms are known by pilots since they are used in calculating aircraft performances.

> Example: 170001 NOTAMN CYUL MONTREAL/PIERRE ELLIOTT TRUDEAU INTL
>
> CYUL FIRST 1700 FT RWY 06R CLSD. THR 06R IS RELOCATED 1700 FT. DECLARED DIST:
>
> RWY 06R TORA 7900 TODA 8884 ASDA 7900 LDA 7900
>
> RWY 24L TORA 7900 TODA 7900 ASDA 7900 LDA 7900
>
> YYMMDDHHMM TIL YYMMDDHHMM[89]

At all of the airports under review, the NOTAMs issued for the various construction periods (Appendix C) followed the examples given in the various versions of the *Canadian NOTAM Procedures Manual* in effect when the occurrences under review took place.

3.5.2 *AIP Canada (ICAO)* supplements

Every ICAO Contracting State is required to publish an aeronautical information publication (AIP), which contains "aeronautical information of a lasting character essential to air navigation."[90] Canada publishes the *AIP Canada (ICAO)*, the main source for Canadian aeronautical information. It is updated regularly, and amendments are published every 56 days.

"[T]emporary operational changes of long duration (three months or longer), as well as information of short duration that contains extensive text and/or graphics, are published in

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87 Ibid.

88 For example, TODA for take-off distance available, ASDA for accelerate-stop distance available, LDA for landing distance available.

89 NAV CANADA, *Canadian NOTAM Procedures Manual*, version 11 (27 June 2013), version 14.4 (3 April 2014), version 14.10 (18 September 2014), version 16.4 (31 March 2016), version 17.6 (12 October 2017).

90 International Civil Aviation Organization, Annex 15 to the *Convention on International Civil Aviation — Aeronautical Information Services*, Sixteenth Edition (July 2018).

an *AIP Canada (ICAO)* Supplement in accordance with the International Civil Aviation Organization's (ICAO's) Annex 15."[91]

AIP Canada (ICAO) supplements are published every 28 days. Airport operators who want to have an *AIP Canada (ICAO)* supplement published to disseminate information regarding airport construction must provide the information to NAV CANADA at least 49 days in advance. The investigation discovered that airport operators were often unaware of the process for requesting to have a supplement published for 2 main reasons: unlike NOTAMs, supplements are not documents that airport operators have published regularly, and the request process is not easy to find. It can be found in the *Transport Canada Aeronautical Information Manual* (TC AIM),[92] but it is not mentioned anywhere else, in any TCCA or NAV CANADA document or on any of their websites. The investigation determined that in order to have an *AIP Canada (ICAO)* supplement published, an airport operator had to submit a request by email or by telephone. Contact information is provided in the TC AIM.[93]

Of the 4 airports where the occurrences under review took place, the Montréal/St-Hubert and Baie-Comeau airports had had an *AIP Canada (ICAO)* supplement published.

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91 Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual*, effective from 26 March 2020 to 8 October 2020, MAP – Aeronautical Charts and Publications, section 2.2: AIP Canada (ICAO) Supplements.

92 Ibid.

93 Contact information can be found in section 2.1 of the MAP chapter.

4.0 FLIGHT OPERATIONS IN CANADA

4.1 Types of flight operations

The occurrences under review fell under different categories of flight operations: general aviation (2 occurrences), private operators (4 occurrences) and commercial air services (11 occurrences). The category of one of the occurrences under review (Schefferville) is unknown.

General aviation primarily includes recreational pilots who use small single- or twin-engine aircraft for their personal needs. The pilots usually hold a pilot permit – recreational or a private pilot licence. They typically conduct relatively simple flights.

Private operators mainly include commercial pilots and turbo-prop or turbo-jet aircraft used for business or private needs. These pilots hold a private or commercial pilot licence and various additional ratings, as necessary. The aircraft used for this type of flight operations are higher performance and more complex than those used for general aviation. They often require 2 pilots. Pursuant to section 604.03 of the *Canadian Aviation Regulations* (CARs), their operation requires a private operator registration document, which is issued by Transport Canada Civil Aviation (TCCA) once the required criteria have been met.[94]

Finally, commercial air services cover several categories of operations: aerial work, air taxi operations, commuter operations, and airline operations. The aircraft used for commercial operations in the occurrences under review fell into the aerial work and airline operations categories. Commercial air services pilots hold a commercial pilot licence or an airline transport pilot licence and various additional ratings, as necessary. The aircraft used vary depending on the category of operations: small aircraft are generally used for aerial work and air taxi operations, while larger, higher performing, and more complex aircraft requiring 2 pilots are used for commuter and airline operations. Regardless of the type of operations, operators must obtain a commercial operator's certificate from TCCA and meet specific conditions pursuant to CARs Part VII, including establishing un operational control system approved by TCCA.

Private and commercial operations by U.S. aircraft are governed by U.S. regulations in a manner similar to those in Canada.

4.2 Flight planning

Regardless of the type of flight operations, flight planning is a step that is critical to flight safety. It is when all of the elements necessary for the flight must be gathered and reviewed.

CAR 602.71 states that "[t]he pilot-in-command of an aircraft shall, before commencing a flight, be familiar with the available information that is appropriate to the intended flight."[95]

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94 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section 604.04.

95 Ibid., section 602.71.

For general aviation aircraft, flight planning is done by the pilot and is often limited to using aviation information available in NAV CANADA's aeronautical information publications and on various websites.

In the case of commercial air service operators and some private operators, pilots have more resources at their disposal, such as the company operations manual and standard operating procedures (SOPs). Some also have the assistance of a company dispatch service for planning and conducting the flight.

4.2.1 Flight information

One of the fundamental steps of flight planning is obtaining and reviewing current information relevant to the planned flight. In Canada, the Minister of Transport has delegated to NAV CANADA the "responsibility for the collection, evaluation and dissemination of aeronautical information"[96] and also the "responsibility for the provision of aviation weather services in Canadian airspace."[97] NAV CANADA is therefore the main source of information available for flight planning purposes and has a website dedicated to flight planning.[98]

4.2.1.1 Aeronautical information

NAV CANADA publishes various aeronautical information products based on the nature and validity period of the information being published: *AIP Canada (ICAO)*[99] for information of a lasting nature; *AIP Canada (ICAO)* supplements for "temporary operational changes of long duration (three months or longer), as well as information of short duration that contains extensive text and/or graphics;"[100] aeronautical information circulars for "information of general interest and information on administration matters;"[101] and finally, NOTAMs for temporary information of a short duration and operationally significant temporary changes of long duration made on short notice. Information on runway rehabilitation is therefore published in *AIP Canada (ICAO)* supplements and in NOTAMs.

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96 Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual*, effective from 26 March 2020 to 8 October 2020, MAP – Aeronautical Charts and Publications, section 1.0: General Information.

97 Ibid., MET – Meteorology, section 1.1: General.

98 NAV CANADA, Flight Planning, at https://www.navcanada.ca/en/flight-planning/flight-planning-and-reporting.aspx (last accessed on 25 November 2021).

99 Additional information pertaining to *AIP Canada (ICAO)* is published in the *Canada Flight Supplement*, *Canada Water Aerodrome Supplement*, *Canada Air Pilot*, various aeronautical charts and the *Designated Airspace Handbook*. (Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual*, effective from 26 March 2020 to 8 October 2020, MAP – Aeronautical Charts and Publications, section 2.1: AIP Canada (ICAO)).

100 Ibid., section 2.2: AIP Canada (ICAO) Supplements.

101 NAV CANADA, *AIP Canada (ICAO)*, Part 1 – General (GEN), section 3.1.3.3: Aeronautical information circulars.

The *AIP Canada (ICAO)* supplements and NOTAMs in effect are made available to pilots on NAV CANADA's Aviation Weather website.[102] The supplements are also posted on the *AIP Canada (ICAO)* website.[103]

4.2.1.1.1 NOTAMs

In accordance with paragraph 302.07(2)(d) of the CARs, the 4 airports had NOTAMs issued to notify pilots of the partial closure of their runway due to construction, and all of the pilots involved in the occurrences under review had read the NOTAMs applicable to their respective flights. The NOTAMs complied with the format indicated in NAV CANADA's *Canadian NOTAM Procedures Manual* in effect at the time of the occurrences. They were written in capital letters, consisted primarily of abbreviations and acronyms, and did not contain any graphics.

These construction-related NOTAMs were part of a long series of NOTAMs reviewed by the pilots before their flight. TSB Aviation Investigation Report A17Q0059,[104] released on 03 July 2018 for one of the occurrences under review, highlighted the issue of conciseness and clarity in NOTAMs. It also emphasized the risk of pilots forgetting the information in the NOTAMs, and the risk of construction-related information getting lost in the multitude of NOTAMs to be reviewed. In that occurrence, the flight crew had obtained a copy of the NOTAMs applicable to its flight before departure. The copy attached to the flight plan included a list of 121 NOTAMs, 37 of which pertained to the Montréal/St-Hubert Airport. Of those 37 NOTAMs, 9 related to Runway 06L, including 1 relating to the displacement of the Runway 06L threshold, 1 relating to the length of runway available for landing, and 1 relating to the reduction in the width of Runway 06L. The NOTAM pertaining to the reduction in the width of the runway was 16th on the list. It stated that aircraft with a wingspan of over 78 feet needed to give airport authorities 48 hours notice. The aircraft used for this flight had a wingspan of over 78 feet, so the NOTAM applied; however, there was no indication that such a notice was given to the airport authorities. The information gathered during this investigation indicates that despite the NOTAMs, the information from the automatic terminal information service (ATIS),[105] and communications with the controller, the flight crew incorrectly believed that only the runway length had been reduced. The temporary markings were not convincing enough for the crew to correct its erroneous situational awareness (see section 4.4.2.1 *Situational awareness* of this report).

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102 NAV CANADA, Aviation Weather website, at https://flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Langue=anglais&NoSession=NS_Inconnu&Page=forecast-observation&TypeDoc=html (last accessed on 25 November 2021).

103 NAV CANADA, *AIP Canada (ICAO)*, at https://www.navcanada.ca/en/aeronautical-information/aip-canada.aspx (last accessed on 25 November 2021).

104 See brief description in Appendix B – Occurrences under review, in this report.

105 Automatic terminal information service is "[t]he provision, throughout the day or a specified portion of the day, of current, routine information to arriving and departing aircraft by means of continuous and repetitive recorded broadcasts." (Source: NAV CANADA, TERMINAV terminology database).

The TSB report concluded that the use of the words "reduced width," in a NOTAM for a runway width reduction, would clearly identify the condition and reduce the risk of ambiguity.

In 2012, the U.S. Federal Aviation Administration's (FAA's) Airport Construction Advisory Council (ACAC)[106] published the results of research conducted to mitigate the hazards associated with airport construction. The results indicated that the significant number of NOTAMs and their format were contributing factors to the accidents under review:

> **NOTAMs**: Large airports frequently have a significant number of NOTAMs in place, especially during times of airport construction. This can lead to information being overlooked by the people who really need it: pilots, dispatchers and air traffic controllers. Also, the information contained in NOTAMs sometimes elude an operator's memory just when it is most needed — during the takeoff or landing phases of flight when information saturation and risk tends [*sic*] to reach a peak. Also, the NOTAM format (all capital letters and infrequently used abbreviations) is often awkward to interpret or subject to misunderstanding.[107]

The ACAC proposed a solution to this problem, based on the principle that a picture is worth a thousand words: it suggested the introduction of graphic NOTAMs to present information more clearly and gave the example shown below in Figure 6.

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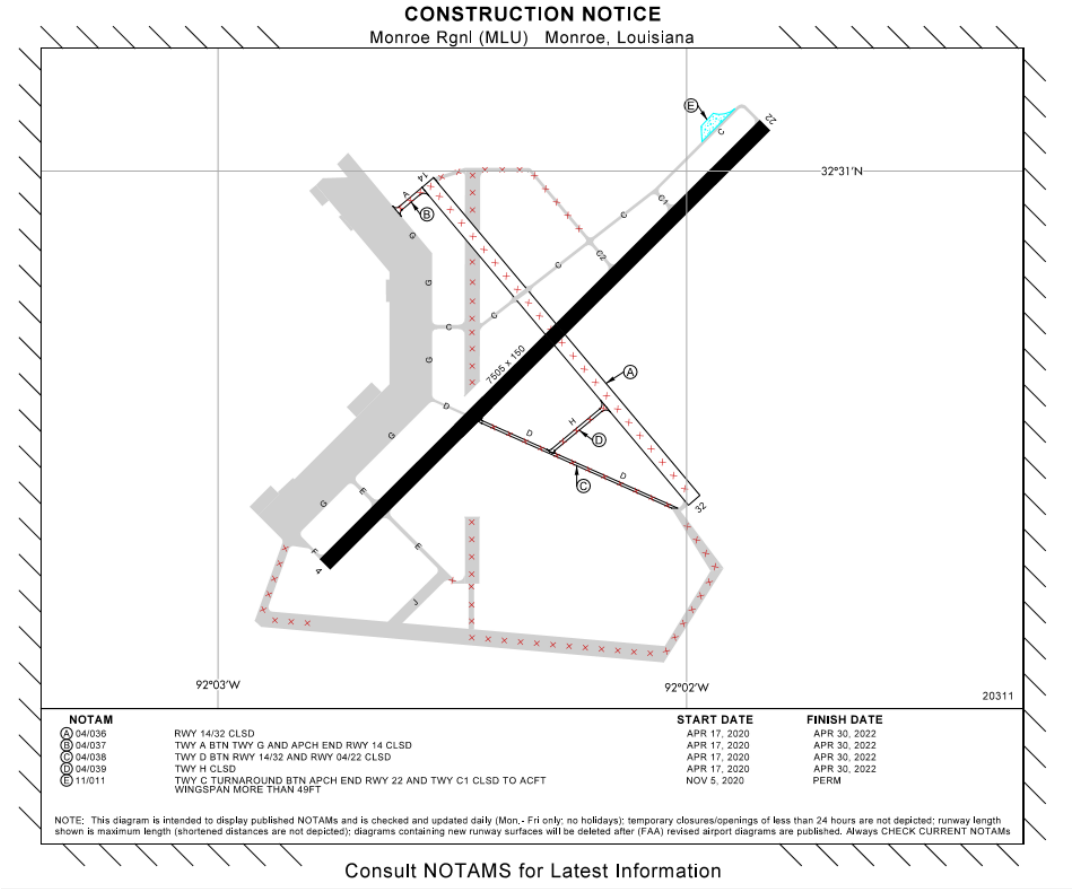
106 The U.S. Federal Aviation Administration's Airport Construction Advisory Council is a working group made up of the Federal Aviation Administration, the Air Traffic Organization, the National Air Traffic Controllers Association, the Airports Council International – North America, the Air Line Pilots Association, the Aircraft Owners and Pilots Association, airlines, the International Air Transport Association, the International Civil Aviation Organization and the National Business Aviation Association, which identifies potentially hazardous situations during airport construction. It works with airports, the aviation industry, and international organizations to implement means of significantly mitigating the associated risks. (Source: Federal Aviation Administration, Runway and Taxiway Construction, https://www.faa.gov/airports/runway_safety/runway_construction [last accessed on 25 November 2021].)

107 Federal Aviation Administration, Air Traffic Organization, What's on your runway? Airport Construction Advisory Council – Mitigating Hazards Associated with Airport Construction (2012), "Common Causal Factors", p. 4.

Figure 6. Example of a graphic NOTAM (Source: Federal Aviation Administration, "Airport Construction Notices", at https://www.faa.gov/air_traffic/flight_info/aeronav/aero_data/Apt_Constr_Notices/ [last accessed on 16 November 2021])



More recently, in 2018, further to the investigation of an occurrence that took place at the San Francisco Airport (KSFO), California, United States, the U.S. National Transportation Safety Board (NTSB) released incident report NTSB/AIR-18/01[108] in which it identified the poor readability of NOTAMs as a factor negatively impacting the effectiveness of communications. The NTSB made particular reference to the format and presentation of NOTAMs, which are written entirely in capital letters, making it difficult to read, interpret, and retain the messages. The U.S. report also pointed out that the many NOTAMs issued and provided to pilots before a flight are not organized in order of importance; they are simply presented chronologically by publication date. Consequently, pilots must review all of the information and determine what is relevant.

In addition, while investigating occurrence A18A0085,[109] the TSB determined that the presentation style of NOTAMs and the order in which they are published (chronological order) led the aircraft flight crew and dispatch to misinterpret the information being

108 National Transportation Safety Board, Aircraft Incident Report NTSB/AIR-18/01 (25 September 2018).

109 TSB Air Transportation Safety Investigation Report A18A0085, at https://www.bst.gc.ca/eng/enquetes-investigations/aviation/2018/a18a0085/a18a0085.html (last accessed on 25 November 2021).

communicated. The crew, who had to review a large number of NOTAMs, all written in capital letters and appearing in an order that required extraction of the relevant information, established an inaccurate mental image of the situation and thought that Runway 23 was closed when it was active. The crew therefore landed on the only other runway, Runway 14, which at the time of landing was no longer the designated arrival runway due to weather conditions. The aircraft overran the runway.

Finally, in Annex 15, the International Civil Aviation Organization (ICAO) addresses the issue of the effectiveness of communicating aeronautical data and information in relation to human factors, and states that:

> [t]he organization of an AIS [aeronautical information service] as well as the design, contents, processing and distribution of aeronautical data and aeronautical information shall take into consideration human factors principles which facilitate their optimum utilization.[110]

4.2.1.1.2 Automatic terminal information service

According to the *Transport Canada Aeronautical Information Manual* (TC AIM):

> ATIS is the continuous broadcasting of recorded information for arriving and departing aircraft on a discrete VHF [very high frequency]/UHF [ultra-high frequency] frequency. Its purpose is to improve controller [...] effectiveness and to relieve frequency congestion by automating the repetitive transmission of essential but routine information.[111]

Of the airports reviewed in this investigation, only the Montréal/St-Hubert Airport had ATIS. The message pertaining to the airport construction under review reminded pilots of elements already found in the NOTAM in effect and did not add any new information or clarification. Given that this message was simply a reminder of the NOTAM, it was not investigated further.

4.2.1.1.3 *AIP Canada (ICAO)* supplements

As far as supplements are concerned, in the cases under review, the Baie-Comeau and Montréal/St-Hubert airports had an *AIP Canada (ICAO)* supplement published for the scheduled airport construction. Those supplements indicated the reduction in the runway width, and the Baie-Comeau supplement included a diagram to illustrate the changes to the runway during the construction period. The supplement for the Montréal/ St-Hubert Airport did not include a diagram, and instructed pilots to check the applicable NOTAMs before landing and taking off. However, the Montréal/St-Hubert Airport had posted a

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110 International Civil Aviation Organization, Annex 15 to the *Convention on International Civil Aviation — Aeronautical Information Services*, Sixteenth Edition (July 2018), section 3.7: Human factors considerations.

111 Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual*, in effect from 26 March 2020 to 8 October 2020, RAC – Rules of the Air and Air Traffic Services, section 1.3: Automatic Terminal Information Service.

graphic representation of the construction plan and a copy of the relevant NOTAMs on its website, along with a link to the NOTAM web page. The investigation was unable to determine whether the pilots had consulted those supplements.

4.2.1.2 Weather information

NAV CANADA offers a range of aviation weather services, some of which are "provided to it under a contractual agreement with Environment and Climate Change Canada."[112] Various forecasts and weather observations are published by NAV CANADA in the form of messages and maps at regular and varied intervals. This information is available from NAV CANADA's flight information centres, on NAV CANADA's Aviation Weather website, and in part on NAV CANADA's Collaborative Flight Planning Services website. While in flight, pilots also take part in communicating current information by reporting the conditions they encounter. All relevant weather information is reviewed at the flight planning stage. An examination of the weather information for the flights under review concluded that weather conditions were not a factor in the occurrences. All of the occurrences took place when visibility was 7 statute miles or more, and only one took place during rain showers.

4.2.1.3 Flight dispatching

Pursuant to section 705.20 of the CARs, air operators in the airline category must have a dispatching service as part of an operational control system. Although this requirement does not apply to other operators, they often use an internal or external dispatching service.

Flight dispatchers "are assigned the responsibility of exercising safe and efficient operational control over […] flights in conjunction with the Pilot-in-Command […]."[113] To achieve this, dispatchers help pilots with flight planning and provide them with the necessary information. They also perform flight following[114] and flight watch.[115] Flight dispatching helps to alleviate pilots' workload before and during the flight. However, not all pilots have access to such a service for planning and conducting their flights.

4.2.2 Narrow runway operations

Pursuant to the CARs, commercial air service operators and private operators must have an operational control system. As part of this system, they must verify whether the

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112 Ibid., MET – Meteorology, section 1.1: General.

113 Transport Canada, Flight dispatcher and check dispatcher training and operation manuals, at https://tc.canada.ca/en/aviation/commercial-air-services/flight-dispatcher-check-dispatcher-training-operation-manuals (last accessed on 25 November 2021).

114 Flight following is "the monitoring of a flight's progress, the provision of any operational information that might be requested by the pilot-in-command, and the notification of the flight training unit and search and rescue authorities if the flight is overdue or missing." (Source: Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section 101.01).

115 Flight watch means "maintaining current information on the progress of a flight and monitoring all factors and conditions that might affect the flight." (Source: Ibid.).

aerodromes and routes being used are suitable for their aircraft.[116] With regard to aerodromes, the main question is whether the runways are long enough for the types of aircraft being used. The runway length required is dictated by the take-off and landing performances of each aircraft, which are validated during aircraft certification and stipulated in the aircraft flight manual (AFM). Another question is whether the runway width is suitable for the scheduled operations, particularly when a runway width is reduced due to airport construction. Indeed,

> [t]he minimum runway width is that which is sufficient to allow the aeroplane to be safely controlled during take-off and landing using procedures, which can be consistently executed in service by crews of average skill. The width shall be sufficient to prevent any landing gear wheel from leaving the runway during take-off and landing in expected operating conditions, including engine failure.[117,118]

Although there are aerodrome design standards that associate the required runway width with the aircraft that will use the runways,[119] there is no aircraft certification standard that defines a minimum runway width. However, some aircraft manufacturers indicate a minimum in the approved AFM and publish the related procedures in an AFM supplement. When the width of the runway being used is less than the minimum indicated in the AFM, if any, then the runway is considered to be a narrow runway from an operational standpoint. Therefore,

> [a]ir operators need to be aware that their aeroplanes may not be meeting the criteria for their type certification, unless they operate in accordance with the appropriate approved data.[120]

Consequently, in accordance with Commercial and Business Aviation Advisory Circular (CBAAC) No. 0248, air operators who plan to operate on narrow runways "should check whether the manufacturer has published procedures for doing so in an AFM Supplement."[121] If no procedures exist, air operators should contact the aircraft manufacturer and request that the manufacturer seek TCCA Aircraft Certification approval for the desired minimum runway width.

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116 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 604.142(2), and subparagraphs 722.07(2)(b)(ii), 723.07(2)(b)(ii), 724.07(2)(b)(ii) and 725.07(2)(b)(ii) of the *Commercial Air Service Standards*.

117 Transport Canada, Commercial and Business Aviation Advisory Circular (CBAAC) 0248: Narrow Runway Operations (19 December 2005).

118 This circular was cancelled 23 December 2020, when the 4th edition of the *Air Operator Certification Manual* (TP 4711) was published.

119 These standards, which can be found in TC's *Aerodrome Standards and Recommended Practices* (TP 312), are directly from ICAO Annex 14, Volume 1, Chapter 1.

120 Transport Canada, Commercial and Business Aviation Advisory Circular (CBAAC) No. 0248: Narrow Runway Operations (19 December 2005).

121 Ibid.

An AFM supplement does not necessarily constitute "approval to conduct operations from narrow runways."[122] Therefore, it is recommended that air operators detail in their company operations manual their procedures for operating into and out of an airport with narrow runways.

In the cases under review, some of the air operators had done the necessary checks and had sent a notice to pilots advising them of the reduced runway width and the supplemental procedures for narrow runway operations.

4.3 Standard operating procedures

SOPs, including standard calls and checklists, are vital sources of information that provide pilots with guidelines for the general operation of the aircraft. They help pilots with decision making and coordination between crew members, if applicable. They provide pilots with appropriate solutions for various situations under normal or abnormal operations, and for emergency situations. SOPs are not only guidelines for the general operation of aircraft; they are universally recognized as the basis for aviation safety.

SOPs may or may not be mandatory depending on the type of flight operations being conducted. According to the CARs, SOPs are mandatory for commercial air services (aerial work, air taxi operations, commuter operations, and airline operations) when the aircraft being used requires at least 2 pilots:

> Every air operator shall, for each of its aircraft that is required to be operated by two or more pilots, establish and maintain standard operating procedures that enable the crew members to operate the aircraft within the limitations specified in the aircraft flight manual and that meet the *Commercial Air Service Standards*.[123]

For private operators, this requirement applies when they have decided to establish an aircraft operating manual, which must contain these SOPs:

> An aircraft operating manual shall
>
> **(a)** contain aircraft operating procedures that are consistent with those contained in the aircraft flight manual;
>
> **(b)** contain, if the aircraft flight manual is not carried on board the aircraft, the aircraft performance data and limitations specified in that manual, and clearly identify them as aircraft flight manual requirements;
>
> **(c)** contain the private operator's standard operating procedures, if any; […][124]

Finally, SOPs are not used by general aviation pilots, i.e. recreational pilots who conduct flights with single-pilot aircraft.

Many air operators use SOPs to ensure that tasks are performed properly on board the aircraft, that the aircraft are operated in accordance with the manufacturer's instructions,

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122 Ibid.

123 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsections 702.84(1), 703.107(1), 704.124(1) and 705.138(1).

124 Ibid., subsection 604.37(2).

that communications between pilots and air traffic control (ATC) comply with established standards, and that the company's policies and procedures are followed. In addition, SOPs enable 2 pilots who have never flown together to perform their respective flight crew member duties, knowing exactly what each of them has to do for the entire flight. Even if SOPs are presented as a checklist or a quick reference guide, pilots must be able to perform the most critical actions from memory and then refer to written procedures to confirm.

Among the occurrences under review, a large number of them involved commercial operations, which require SOPs. However, because not all Canadian private operators are required to have SOPs, the investigation was unable to determine how many of them had such procedures. The investigation did not examine the cases involving U.S. operators.

4.3.1 Preparation for takeoff

Preparation for takeoff is a step that is critical to safety, regardless of the flight planned. It includes checking aircraft performance and the standard instrument departure (SID) procedure, if applicable. When flight operations are conducted in accordance with SOPs, this step is an integral part of the procedures. When the flight crew consists of 2 or more pilots, applying best practices during the preparation for takeoff should guide the crew to conduct a pre-takeoff briefing. Briefings are essential to crew members for maintaining a shared situational awareness (see section 4.4.2.1 *Situational awareness* of this report). They also help to assimilate relevant operational information and anticipate its impact on the operation of the aircraft. During a pre-takeoff briefing, the pilot-in-command establishes priorities and divides the tasks between the pilots, thus establishing a common mental model for the upcoming flight. This briefing allows pilots to review the expectations during takeoff one last time, and to ensure that they have the same perception of the elements in their environment and the same understanding of their meaning and impact on the flight.

Among the occurrences under review, 2 took place during takeoff, both on aircraft requiring 2 pilots.

4.3.2 Preparation for approach and landing

Similar to the preparation for takeoff, the preparation for approach and landing is essential to safety, and is also an integral part of SOPs, if applicable. Preparation for approach and landing is generally done in cruising flight, before beginning descent and after the crew has received the latest weather conditions and determined which of the runways in use it will land on. This preparation may include checking ATIS, programming a flight management system for the approach, and completing a pre-descent checklist. The preparation may also include an approach briefing with a review of the approach chart, if necessary, the weather conditions, and NOTAMs. In the occurrences under review that took place during landing, 13 involved aircraft requiring at least 2 pilots and, therefore, required an approach-and-landing briefing.

4.4 Crew resource management

Crew resource management (CRM) is the effective use of all available resources — human, hardware and information — to conduct flights safely and efficiently.[125] CRM includes skills, abilities, attitudes, communication, situational awareness, problem solving, and teamwork. CRM is related to the cognitive abilities and interpersonal skills required to manage a flight. These cognitive abilities include the mental processes needed to establish and maintain accurate situational awareness, solve problems, and make decisions. The interpersonal skills are related to communications and behaviours associated with teamwork.

4.4.1 Threat and error management

Modern CRM incorporates threat and error management (TEM). The 3 core elements of TEM are threats, errors, and undesired aircraft states. Every flight has hazards that the crew must manage. These hazards, referred to as threats, increase flight risks and may include environmental threats (adverse weather conditions, runway contamination, etc.) or operational threats (short runways, etc.). TEM emphasizes the principles of anticipation, recognition and recovery[126] and is based on the proactive recognition of threats that could reduce safety margins. Crews can establish counter measures during the planning stage or during flight, modifying the plan according to circumstances.

Effective error management is associated with specific behaviours by the flight crew, the most common being vigilance, an invitation to ask questions or provide feedback, and assertiveness.[127,128,129,130,131,132,133] Although threats exist and errors occur during most flight segments, they are rarely accompanied by serious consequences, because the crew is

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125 Transport Canada, *Development and Implementation of an Advanced Qualification Program (AQP),* at https://tc.canada.ca/en/aviation/commercial-air-services/approved-check-pilot-acp-advanced-qualification-program-aqp/development-implementation-advanced-qualification-program-aqp (last accessed on 25 November 2021).

126 A. Merritt and J. Klinect, "Defensive Flying for Pilots: An Introduction to Threat and Error Management", *The University of Texas Human Factors Research Project: The LOSA Collaborative* (Austin, Texas: 2006).

127 Ibid.

128 Dan Maurino, "Threat And Error Management (TEM)", *Flight Safety and Human Factor Programme – ICAO*, Canadian Aviation Safety Seminar (Vancouver, British Columbia, 18 to 20 April 2005).

129 Flight Safety Foundation, "Crew Resource Management", *Approach-and-Landing Accident Reduction Tool Kit – Briefing Note 2.2* (2009).

130 Transport Canada, Advisory Circular (AC) No. 700-042: Crew Resource Management (CRM), Issue 02 (14 March 2020), Appendices A and E.

131 Civil Aviation Safety Authority, Australian Government, *Safety Behaviours: Human Factors for Pilots Resource Guide*, Chapter 10: Threat and error management (2009), p. 151.

132 Federal Aviation Administration, Advisory Circular (AC) 120-51E: Crew Resource Management Training, (22 January 2004).

133 European Aviation Safety Agency, European Helicopter Safety Team, "The Principle of Threat And Error Management (TEM) for Helicopter Pilots, Instructors and Training Organisations" (December 2014).

managing them effectively. Effective risk management in the cockpit is intrinsically linked to effective CRM.

Finally, an aircraft is in an undesired state when it is in a high-risk situation, most often due to the mismanagement of a threat or an error.

The occurrences under review all had a specific threat: the temporary runway configuration. Errors made in taking action or not taking action resulted in the pilots operating on closed portions of runways, which is an undesired aircraft state.

4.4.2 Situational awareness and mental models

4.4.2.1 Situational awareness

Situational awareness is the perception of the elements in the environment, the comprehension of their meaning and the projection of their status in the future.[134] In a dynamic environment, situational awareness requires extracting information from the environment, integrating this information with relevant internal knowledge to create a coherent mental picture of the current situation, and using this picture to anticipate future events.[135]

Problems can occur during these 3 steps and result in situations where critical elements are not detected, their importance is not perceived, or their consequences are not anticipated.

For pilots, situational awareness translates into a mental model of the existing relationship between location, flight conditions, configuration and energy state of the aircraft, as well as any other factors that could affect safety, such as obstructions, airport conditions, weather conditions, etc.[136]

Situational awareness is developed and maintained through a process of continually reassessing the situation: in the cockpit, the flight crew members' situational awareness is influenced by their goals and expectations, their respective experience, and many other factors that influence what draws the attention of each of the members and how they perceive and interpret the elements in the environment.[137]

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134 M.R. Endsley, "Design and Evaluation for Situation Awareness Enhancement" in the *Proceedings of the Human Factors Society: 32nd Annual Meeting* (Santa Monica, California: 1988), pp. 97 to 101.

135 SKYbrary, "Situational Awareness", at https://www.skybrary.aero/index.php/Situational_Awareness (last accessed on 26 November 2021).

136 Ibid.

137 M. R. Endsley, "Situation Awareness in Aviation Systems", in J. A. Wise, V. D. Hopkin and D. J. Garland, *Handbook of Aviation Human Factors*, 2nd Edition (Boca Raton, Florida: CRC Press, 2010), Part II: Human Capabilities and Performance, Chapter 12, p. 12-3.

4.4.2.2 Mental models

A mental model is an internal structure that enables a person to describe, explain, and predict events and situations in their environment.[138] When a mental model is adopted, it is resistant to change. New convincing information must be assimilated in order to change the mental model. An inaccurate mental model will interfere with the perception of critical elements or the comprehension of their importance.[139]

Pilots create core mental models during training, when they gain the knowledge that will be needed for all phases of flight. For example, the mental model of an approach and landing is one of the core models acquired during training. This model includes approach procedures, as well as the markings and lighting usually found on a runway. Therefore, the core mental model that pilots acquire for construction at an airport includes the temporary visual aids, the closed markings, and the dissemination of information pertaining to the airport construction.

Mental models are essential for reacting effectively in dynamic environments where every second counts, because they reduce the need for time-consuming assessments and enable pilots to act quickly. However, they can also lead to errors in the perception of information.

In operational situations, pilots use their prior experience and knowledge to quickly categorize a situation and choose the most appropriate course of action.[140] Therefore, in frequently recurring situations, pilots often base their attention and expectations on their mental model of the situation, given that their prior experience determines which information is important and how the situation will unfold.

However, a person's attention span and ability to process information are limited. Although people can quickly shift their attention from one source of information to another, they can only be fully attentive to one source of information at a time. These limitations on attention force pilots to adjust according to the situation.

When pilots are attentive to the visual cues from their operational environment, their respective mental model of the situation and their expectations of the environment have a strong influence on their selective attention.[141] In other words, pilots will anticipate which elements of information will be important, in their opinion, and where the visual cues would normally be located.

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138 E. Salas, F. Jentsch and D. Maurino, *Human Factors in Aviation*, 2nd Edition (Academic Press, 2010), p. 66.

139 M. R. Endsley, "Situation Awareness in Aviation Systems", in J. A. Wise, V. D. Hopkin and D. J. Garland, *Handbook of Aviation Human Factors*, 2nd Edition (Boca Raton, Florida: CRC Press, 2010), Part II: Human Capabilities and Performance, Chapter 12, p. 12-12.

140 G. Klein, "Naturalistic decision making", *Human Factors,* Volume 50, No. 3 (June 2008), p. 456-460.

141 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, 3rd Edition (2000, Prentice Hall: Upper Saddle River New Jersey), pp. 70 to 74.

4.4.2.3 Confirmation bias

Once their mental model of a situation has been established, people tend to seek out elements that support or confirm their interpretation and minimize or ignore the importance of information that seems to contradict the model. This is referred to as confirmation bias.

This bias may lead a person to not question their first interpretation and to not change it when new information is received. It may also lead the person to pick out the information that supports their current state of awareness and reject information that contradicts their expectations.[142,143] We often hear what we expect to hear and see what we expect to see.

Pilots work in a complex environment that requires monitoring of multiple sources and types of information. When pilots receive information about the environment that reflects what they are expecting, they tend to react quickly and accurately. However, when they receive information that is contrary to their expectations, their reaction is slower and may be inappropriate.[144]

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142 A. Tversky and D. Kahneman, "Judgment under uncertainty: Heuristics and biases", in: D. Kahneman, P. Slovic and A. Tversky (Ed.), *Judgment under uncertainty: Heuristics and biases* (New York, NY: Press Syndicate of the University of Cambridge, 1982).

143 A. Tversky and D. Kahneman, "Causal schemas in judgments under uncertainty", in: D. Kahneman, P. Slovic and A. Tversky (Ed.), *Judgment under uncertainty: Heuristics and biases* (New York, NY: Press Syndicate of the University of Cambridge, 1982).

144 M.R. Endsley, "Situation Awareness in Aviation Systems", in J. A. Wise, V. D. Hopkin and D. J. Garland, *Handbook of Aviation Human Factors*, 2nd Edition (Boca Raton, Florida: CRC Press, 2010), Part II: Human Capabilities and Performance, Chapter 12, pp. 12-1 to 12-22.

5.0 SAFETY MANAGEMENT AND AIRPORT SURVEILLANCE BY TRANSPORT CANADA CIVIL AVIATION

5.1 Safety management

Transport Canada Civil Aviation (TCCA) implements and manages Transport Canada's (TC's) Aviation Safety Program across Canada, which includes the Aviation Safety Regulatory Framework and the Aviation Safety Oversight program.[145]

TCCA's mission is to:

> develop and administer policies and regulations for the safest civil aviation system for Canada and Canadians using a systems approach to managing risks.[146]

In Annex 19, the International Civil Aviation Organization (ICAO) stipulates that "States shall establish and maintain an SSP [State Safety Programme] that is commensurate with the size and complexity of the State's civil aviation system."[147] Furthermore, in its *Safety Management Manual*, ICAO states that "the State may also apply the principles of safety risk management to its own regulatory and SSP activities."[148] As a result, TCCA adopted a national safety program, the Civil Aviation Integrated Management System (IMS), to implement a nationally consistent program that integrates all of its activities, both at Headquarters and in the regions.

5.1.1 Civil Aviation Integrated Management System

In its *Aviation Safety Program Manual for the Civil Aviation Directorate*, TCCA explains that:

> 1. Safety Management System contributes to improve systems and procedures to maximize the safety of aviation operations. As SMS [safety management system] is directed towards external stakeholders, Civil Aviation imposes a similar model to reach management excellence and continuous improvement. This is the Integrated Management System (IMS) which can be considered as an internal SMS.
> 2. Safety management is based on the premise that hazards, risks, and threats will always exist. Systemic and proactive management is therefore required to identify and control these hazards, risks, and threats before they lead to mishaps. A proactive safety culture involves Civil Aviation and industry working together to reduce the likelihood of accidents.

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145 Transport Canada, *Aviation Safety Program Manual for the Civil Aviation Directorate*, Issue 04 (31 December 2015).

146 Ibid., section 4.2: Civil Aviation's Vision and Mission.

147 International Civil Aviation Organization, Annex 19 to the *Convention on International Civil Aviation — Safety Management*, Second Edition (July 2016), section 3.1: State safety programme (SSP).

148 International Civil Aviation Organization, document no. 9859, *Safety Management Manual (SMM)*, Third Edition (2013), Chapter 4, section 4.2.17.

3. Safety is defined as "The condition to which risks are managed to acceptable levels." SMS aims to reduce risks in aviation and seeks to steer the accident rate downward.[149]

TCCA defines IMS-related roles and responsibilities in the *Civil Aviation Integrated Management System (IMS) Standard,*[150] which applies to all Civil Aviation staff.

TCCA also presents Civil Aviation's business model (Figure 7) that is "based on risk management and applies to all activities and processes in the delivery and management of its regulatory program."[151] Risk management is normally initiated by collecting and integrating proactive and reactive data from various sources. These data are then analyzed to determine the scope of the issue and measure the impact. Next is the phase that lies at the heart of the model, estimating and evaluating risks, where it is determined whether risks are acceptable or whether risk control measures need to be put in place. Finally, during the measure impact and communication phase, risk-mitigation strategies are verified to determine if the desired results are achieved. If the desired results are not achieved, a diagnostic exercise must be conducted on the design and execution of the process used.[152]

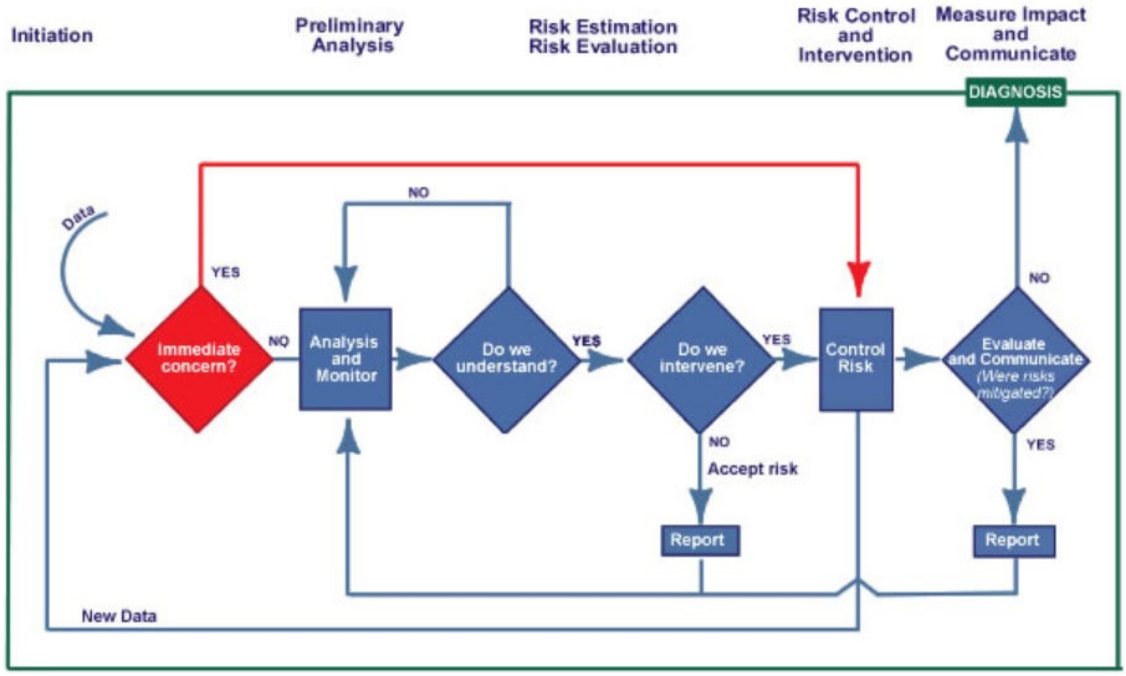
149 Transport Canada, *Aviation Safety Program Manual for the Civil Aviation Directorate*, Issue 04 (31 December 2015), section 4.3: Safety Management System (SMS) at a glance.

150 Transport Canada, TP 14693, *Civil Aviation Integrated Management System Standard* (May 2007).

151 Transport Canada, *Aviation Safety Program Manual for the Civil Aviation Directorate*, Issue 04 (31 December 2015), section 5.1: Risk Management.

152 Ibid.

Figure 7. Flowchart showing Civil Aviation's business model (Source: Transport Canada, Staff Instruction [SI] QUA-008: Risk Management Process for Aviation Safety Activities, Issue 03 [14 June 2013])



In Civil Aviation Directive (CAD) QUA-007 on the integrated risk management framework, TCCA defines the principles that guide its risk management approach, and explains that:

> TCCA takes effective measures to align all activities on a Risk-Based approach. The following five questions provide a general overview leading to a deeper process to optimally manage risk:
>
> (a) What has changed?
>
> (b) What can happen?
>
> (c) What is the effect?
>
> (d) What are the options?
>
> (e) What are the next steps?[153]

Finally, in support of the IMS, TCCA created the Risk Management Committee (RMC), whose mandate is to act as a team of experts to develop the risk management methodology, make continuous improvements, and implement the activities required to ensure the integrated risk management framework within TCCA's program is effective. After establishing a risk management methodology that includes guidance, instructions, processes, tools, and other reference documents, the RMC reviewed Staff Instruction (SI) QUA-008, *Risk Management Process for Aviation Safety Activities.*

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153 Transport Canada, Civil Aviation Directive (CAD) QUA-007: Transport Canada Civil Aviation Integrated Risk Management Framework, Issue 02 (13 December 2010), section 4.0: Principles.

The main change made to the SI after this review was in section 6.0, in which TC introduced the risk management toolbox, explaining that:

> [t]he issues/situations/problems that require Risk Analysis are various and can be presented on a spectrum where the degree of complexity and the severity of the impact are estimated to determine the level of the risks. Thus, various issues/situations/problems necessitate adapted tools. That is why TCCA through RMC has developed a set of tools to adequately address these considerations […][154]

CAD QUA-007 and SI QUA-008 were reviewed for the purposes of this investigation and revealed that the questions that needed to be asked to determine whether risk management was necessary were properly stated and the risk management process was described in detail, including how it was to be documented. However, there was no guidance indicating who should ask these questions and when.

Like civil aviation stakeholders' SMS, TCCA's IMS must include a quality assurance component, which is "the means by which Civil Aviation monitors and continually improves the management of the Civil Aviation Program."[155] To do this, TCCA performs assessments, which are "any process comprised of a review of the organization in order to determine if the IMS is documented, in place and effective."[156] The *Civil Aviation Integrated Management System (IMS) Standard* describes the continuous improvement cycle Plan, Do, Check, and Act (PDCA) and refers to the same principles as those that apply to SMS. Section 9.1 states:

> 1. The organization shall plan and conduct quality assurance on its activities to ensure that their management systems conform to the requirements of this Standard.
> 2. Management shall analyze process [*sic*] and systemic data to measure performance, effectiveness and efficiency as a means to continuously improve.
> 3. Internal assessments shall be planned, conducted, documented and reviewed to verify compliance, effectiveness and opportunities for improvement to all management system and aviation program processes, including all referenced processes and management system manual documentation.
> 4. Corrective action shall be taken to ensure conformity of an activity area where planned results or service standards have not been met.[157]

The investigation discovered that TCCA inspectors only knew about the IMS portion relating to risk assessment. However, it is not being used systematically when change happens.

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154 Transport Canada, Staff Instruction (SI) QUA-008: Risk Management Process for Aviation Safety Activities, Issue 03 (effective 14 June 2013).

155 Transport Canada, Civil Aviation Directive (CAD) QUA-011: Civil Aviation Internal Quality Assurance, Issue 01 (10 April 2008), subsection 3.0(3).

156 Ibid., paragraph 2.3(1)(a).

157 Transport Canada, TP 14693, *Civil Aviation Integrated Management System Standard* (May 2007), section 9.1: Quality Assurance.

5.1.2 Evaluation and approval of plans of construction operations

There is no official standard or recommended practice for the evaluation of plans of construction operations (PCOs). The investigation determined that without such standards at their disposal, TCCA inspectors responsible for evaluating PCOs in TC's Quebec and Prairie and Northern regions[158] had designed their own guides.

The purpose of a PCO review is, first, to check for compliance with the *Canadian Aviation Regulations* (CARs) and standards and recommended practices applicable to Canadian aerodromes during construction. Thus, the TCCA inspector must determine which standards apply to the various parts of the airport and, based on that, which editions of *Aerodrome Standards and Recommended Practices* (TP 312) will apply to the airport construction. Second, a PCO review assesses the risks associated with the work and the control measures proposed by the airport operator. If necessary, the inspector may ask the airport operator for further details or recommend/require different or additional control measures. Once the inspector has verified compliance with regulations, standards, and recommended practices, and has verified that the planned risk control measures for safe operations are appropriate, the inspector can approve the PCO.

TCCA's IMS describes the risk assessment process and how to document it. However, this process was not used by TCCA inspectors when they reviewed the 4 PCOs involving a reduction of the runway width. Inspectors in TCCA's Quebec Region considered that the risk assessment required by the airport operators as part of the preparation of their PCO was sufficient to justify approval of control measures without conducting a further risk assessment. Nevertheless, of the 4 airports where a reduction of the runway width was planned, only 1 airport (Montréal/St-Hubert) had documented a risk assessment in its PCOs.

5.2 Oversight

Regulatory oversight has always been TCCA's basic tool for verifying whether a Canadian aviation document holder is complying with regulatory requirements. The introduction of SMS for the aviation industry has fundamentally changed "the way TC approaches its oversight responsibilities."[159]

Before the introduction of SMS,

> [t]raditional oversight methods focused solely on determining regulatory compliance using a system of direct inspection of an organization's aircraft, personnel, records and other systems.[160]

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158 The Iqaluit Airport, Nunavut, is part of TC's Prairie and Northern Region.

159 Transport Canada, Staff Instruction (SI) SUR-001: Safety Management System Assessment and Program Validation Inspection Procedures, Issue 02 (6 February 2009), section 3.0: Background.

160 Ibid.

This method was based on the principle that simply complying with the CARs would guarantee safe flight operations and on reactive risk management of incidents and accidents.

Since the introduction of SMS, TCCA oversight has changed. In addition to traditional regulatory oversight, it now includes a series of activities designed to verify "that enterprises are complying with regulatory requirements and that they have effective systems in place to ensure they comply with regulatory requirements on an on-going basis."[161] Therefore, TCCA's role is to "ensure that organizations have effective policies, processes and procedures in place"[162] to proactively manage risks. To fulfill this role, TCCA performs "assessments, program validation inspections (PVIs) and process inspections (PIs)."[163]

When the CARs require that an organization have an SMS, as is the case for airports in Canada, TCCA is responsible for assessing and validating the SMS. Furthermore, surveillance activities, particularly assessments, will always start with the SMS. Assessment are used to verify that an SMS will enable an organization to comply with regulatory requirements over time, and to validate the implementation of the SMS. PVIs provide for system-level surveillance and a global review of the organization using sampling methods to verify whether the organization can comply with regulatory requirements on an on-going basis. PIs are inspections that focus on one or more specific processes. They help verify whether the processes comply with regulatory requirements and work properly.

The frequency of these various periodic inspections depends on the type of operation, turnover of the organization's key personnel, its compliance history, and the nature of findings from previous surveillance activities. The various factors are translated into risk indicators, which TCCA uses to establish inspection frequency. The frequency of the inspections also depends on the resources available within TCCA to perform the work.

Information gathered during this investigation revealed that the Quebec Region is the only region that has inspectors assigned specifically to airports. In the other regions, the inspectors tasked to airports are also responsible for air operators and are not airport specialists. At the time of the occurrences, the Quebec Region had 6 inspectors tasked to 55 airports. However, only 3 of them were available full time for airport surveillance and services. The Technical Team Leader could not conduct inspections on a full-time basis given his other responsibilities, and 2 other inspectors were assigned to aerial obstacles and heliports. Given the large number of airports in this region in relation to the number of inspectors available, it was difficult for the inspectors to perform the initial SMS

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161 Transport Canada, Advisory Circular (AC) SUR-004: Civil Aviation Surveillance Program, Issue 01 (19 November 2015), section 3.0: Background.

162 Transport Canada, Staff Instruction (SI) SUR-001: Safety Management System Assessment and Program Validation Inspection Procedures, Issue 02 (6 February 2009), section 3.0: Background.

163 Transport Canada, Advisory Circular (AC) SUR-004: Civil Aviation Surveillance Program, Issue 01 (19 November 2015), section 3.0: Background.

assessments in a timely manner. Furthermore, the inspectors believed that it would be impossible to conduct periodic SMS inspections of all airport operators.

Finally, the frequency of airport inspections depends on seasonal constraints, which significantly restrict the period during which inspections can be conducted, and on the logistics involved in inspecting remote airports spread out over a large area.

If TCCA inspectors identify deficiencies or non-compliances with regulatory requirements in the course of their various surveillance activities, they issue findings, which are factual reports of evidence of non-compliance with CARs requirements. Findings of non-compliance may be classified as minor, moderate, or major,[164] but they all require corrective action by the organization, which must submit a corrective action plan to TCCA within a set timeframe. Once the corrective action plan has been accepted by TCCA, the inspectors conduct an administrative or on-site follow-up to ensure that the plan has indeed been implemented. If there were major or systemic findings, a 2nd follow-up may be necessary at a later date to verify whether the measures put in place are effective. The need for a 2nd follow-up will be indicated in the original assessment report. If necessary, TCCA may then take enforcement action, increase surveillance, and take action with respect to the operator's certificate.[165]

The 4 airports under review in this investigation had to implement their SMS by the deadlines stated in the 2 exemptions issued by TCCA in January 2008 and 2009. These 2 exemptions expired on the scheduled dates (March 2011 and 2012, respectively) and were not renewed. TCCA was unable to validate the 4 SMSs by the deadlines, and it took up to 3 years after the exemptions had expired for the validations to be completed. When the validations were performed, non-compliances were identified in most of the SMS components, resulting in major findings, which placed the operators at risk of enforcement action. These findings required the operator to take corrective action, and TCCA to conduct a 2nd follow-up. Not only was this follow-up not done, but the assessments and periodic inspections that should have taken place did not. SMS evaluations were not conducted for the Iqaluit Airport, which falls under the responsibility of the Prairie and Northern Region.

5.3 TSB Watchlist

The TSB Watchlist identifies key safety issues that need to be addressed to make Canada's transportation system even safer.

Safety management and regulatory surveillance have been on the TSB Watchlist since 2010, and are still on Watchlist 2020.

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164 TCCA discontinued the classification of non-compliances with the releases of Edition 02 of Staff Instruction (SI) SUR-029 in October 2019, and Edition 09 of Staff Instruction (SI) SUR-001 in June 2019.

165 Transport Canada, Advisory Circular (AC) SUR-004: Civil Aviation Surveillance Program, Issue 01 (19 November 2015).

As the occurrences under review have demonstrated, some companies consider safety to be adequate as long as they comply with regulatory requirements, but regulations alone cannot predict all risks unique to a particular operation. That is why the TSB has repeatedly emphasized the benefits of SMS, an internationally recognized framework that allows companies to manage risk effectively and make operations safer.

Implementing an effective SMS is only part of the issue. Proper regulatory surveillance is also needed. A number of TSB investigation reports[166] have established that TC is not always able to identify ineffective operator processes and take action in a timely manner.

ACTIONS REQUIRED

Safety management will remain on the Watchlist for the air transportation sector until:

- Transport Canada implements regulations requiring *all* commercial operators to have formal safety management processes; and
- Transportation operators that do have an SMS demonstrate to TC that it is working—that hazards are being identified and effective risk-mitigation measures are being implemented.

Regulatory surveillance will remain on the Watchlist for the air transportation sector until TC demonstrates, through surveillance activity assessments, that the new surveillance procedures are identifying and rectifying non-compliances, and that TC is ensuring that a company returns to compliance in a timely fashion and is able to manage the safety of its operations.

5.4 TSB recommendations involving safety management systems and regulatory oversight

TSB Aviation Investigation Report A13H0001,[167] which examined the 2013 accident involving an Ornge air ambulance at Moosonee, Ontario, highlighted that companies with an SMS do not all have the same ability or commitment to effectively manage risk. As a result, the regulator must be able to choose the type, frequency, and focus of its surveillance activities to provide effective oversight of operators that are unwilling or unable to meet regulatory requirements or effectively manage risk. The regulator must also be able to take appropriate enforcement action in these cases.

As part of investigation A13H0001, the TSB found that TC's approach to surveillance activities did not lead to the timely rectification of non-conformance.

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166 TSB aviation investigation reports A17Q0050, A16P0186, A16P0092, A15P0217, A15P0081, A15Q0120, A14A0067, A13H0001, and A13W0120.

167 TSB Air Transportation Safety Investigation Report A13H0001, at https://www.bst.gc.ca/eng/enquetes-investigations/aviation/2013/a13h0001/a13h0001.html (last accessed on 26 November 2021).

Therefore, the Board recommended that

> [t]he Department of Transport conduct regular SMS assessments to evaluate the capability of operators to effectively manage safety.
>
> **TSB Recommendation A16-13**

In addition, investigations have highlighted the fact that, when faced with an operator that is unable or unwilling to address identified safety deficiencies, TC has had difficulty adapting its approach to ensure that deficiencies are effectively identified and addressed in a timely manner.

Therefore, to ensure that companies use their SMS effectively, and to ensure that companies continue operating in compliance with regulations, the Board also recommended that

> [t]he Department of Transport enhance its oversight policies, procedures and training to ensure the frequency and focus of surveillance, as well as post-surveillance oversight activities, including enforcement, are commensurate with the capability of the operator to effectively manage risk.
>
> **TSB Recommendation A16-14**

Since that time, the TSB has followed up with TC on action being taken to address these recommendations. TC has provided responses to each recommendation indicating what action has been or will be taken, and the TSB has assessed those responses. When the present report was published, TC's last responses had been received in September 2020. The TSB's assessment of these responses, as well as previous responses and assessments, are available on the TSB website.[168]

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[168] Air transportation safety recommendations, at http://bst-tsb.gc.ca/eng/recommandations-recommendations/aviation/index.html (last accessed on 26 November 2021).

6.0 CASES IN THE UNITED STATES, AND IN ALASKA IN PARTICULAR

Information gathered during the investigation drew the TSB's attention to the United States, and Alaska in particular, because runway rehabilitation had been carried out there using the method of reducing the runway width. Furthermore, after searching in the U.S. Federal Aviation Administration (FAA)[169] and U.S. National Transportation Safety Board (NTSB)[170] databases, the TSB discovered that no incidents had been reported for the airports and construction periods involved. Curious to know why identical airport construction had led to occurrences in Canada, but not in the United States, the TSB further studied the situation in the United States to try to identify what might account for this difference in results. After contacting the FAA, the TSB obtained the construction safety and phasing plans (CSPPs) for the King Salmon (AKN) and Coldfoot (CXF) airports, both of which are located in Alaska and had reduced the width of the runway undergoing construction.

6.1 Airport construction standards and recommended practices

A review of the 2 U.S. CSPPs showed that there were several standards and recommended practices for airport construction in general, and for runway rehabilitation with a reduced-width runway in particular.

6.1.1 Advisory Circular (AC) 150/5370-2G

The first significant document, Advisory Circular (AC) 150/5370-2G, published by the FAA and titled *Operational Safety on Airports During Construction,*[171] is intended for U.S. airport operators. It describes the procedures to be followed to ensure operational safety at airports during construction. In complying with this circular, airport operators certified under Part 139 of Title 14 of the *Code of Federal Regulations* know that they are complying with the regulations during construction. The following 2 important points should be noted:

- This circular makes no reference to a reduction in runway width.
- The procedures contained in this advisory circular are considered recommendations, except for airports at which the construction project is wholly or partially funded under the Airport Improvement Program,[172] in which case, the airport is required to comply with the procedures and measures specified in the circular.

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169 Federal Aviation Administration, Accident & Incident Data, at https://www.faa.gov/data_research/accident_incident/ (last accessed on 26 November 2021).

170 National Transportation Safety Board, Aviation Accident Database & Synopses, at https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx (last accessed on 26 November 2021).

171 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017).

172 For further information on this program, see the FAA's Overview: What is AIP web page, at https://www.faa.gov/airports/aip/overview/ (last accessed on 26 November 2021).

This circular is divided into 3 chapters that cover planning a construction project at an airport, the content of CSPPs, and the organization and presentation of information in a CSPP, respectively.

6.1.1.1 Construction planning

Chapter 1 describes in detail the aspects that must be taken into consideration when planning airport construction. The circular states that "[s]afety, maintaining aircraft operations, and construction costs are all interrelated. Since safety must not be compromised, the airport operator must strike a balance between maintaining aircraft operations and construction costs."[173] This chapter also addresses safety management, explaining that pursuant to FAA Order 5200.11, *FAA Airports (ARP) Safety Management System (SMS),*[174] the FAA must conduct a risk assessment in certain cases; the circular also provides the procedure to be followed, if applicable. Finally, this chapter clearly defines the roles and responsibilities of everyone involved in the project.

6.1.1.2 Construction plan contents

Chapter 2 of the circular gives a complete and detailed description of the elements that need to be included in a CSPP. It explains that a CSPP must "identify all aspects of the construction project that pose a potential safety hazard to airport operations and outline respective mitigation procedures for each hazard."[175]

6.1.1.2.1 Visual aids

Section 2.18, which covers runway and taxiway visual aids, states that the CSPP "must ensure that areas where aircraft will be operating are clearly and visibly separated from construction areas, including closed runways."[176] Furthermore, daily inspections by the airport operator are required for the duration of the construction to ensure that visual aids are properly displayed and are serving their intended function. The section also states that these visual aids "must be clearly visible to pilots and must not be misleading, confusing, or deceptive."[177]

6.1.1.2.2 Temporary runway markings

Section 2.18.2 explains that temporary runway markings are often required during construction, and that the markings must comply with the standards stated in

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173 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017), Chapter 1.

174 Federal Aviation Administration, Order 5200.11: FAA Airports (ARP) Safety Management System (30 August 2010).

175 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017), Chapter 2.

176 Ibid., section 2.18.

177 Ibid.

AC 150/5340-1, *Standards for Airport Markings.*[178] In addition the section states that "[r]unways and runway exit taxiways closed to aircraft operations are marked with a yellow X."[179] For runways, it is preferable for these X signals to be lighted[180] and "placed on or near the runway designation numbers."[181]

6.1.1.2.3 Partially closed runways and displaced thresholds

Section 2.18.2.1.3 states that "[w]hen threshold markings are needed to identify the temporary beginning of the runway [...], the markings must comply with AC 150/5340-1[, *Standards for Airport Markings*]."[182] Furthermore, "[a]n X is not used on a partially closed runway or a runway with a displaced threshold."[183]

6.1.1.3 Organization and presentation of information

Chapter 3 of the circular provides guidelines for writing a CSPP: the contents of the CSPP are to be presented in the same order as Chapter 2 of the circular, with the same section titles. The circular provides details on what each subsection should contain and how the information should be presented.

6.1.1.4 Appendices

Of the 6 appendices to AC 150/5370-2G, 3 in particular are relevant to this investigation. First, Appendix A lists FAA publications that could prove useful in writing a CSPP. From this list of publications, AC 150/5300-13A, *Airport Design,*[184] and AC 150/5340-1, *Standards for Airport Markings*,[185] were reviewed.

Next, Appendix B provides definitions for the terms and acronyms used in the circular, including the adjective "temporary", which is relevant to this investigation and is defined as "[a]ny condition that is not intended to be permanent."[186]

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178 Federal Aviation Administration, Advisory Circular (AC) 150/5340-1: Standards for Airport Markings (27 September 2013).

179 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017), section 2.18.2.

180 A lighted X is an X mounted on a structure on an incline so that it is as visible as possible during approach.

181 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017), section 2.18.2.

182 Ibid., section 2.18.2.1.3.

183 Ibid.

184 Federal Aviation Administration, Advisory Circular (AC) 150/5300-13A: Airport Design (28 September 2012).

185 Federal Aviation Administration, Advisory Circular (AC) 150/5340-1: Standards for Airport Markings (27 September 2013).

186 Federal Aviation Administration, Advisory Circular (AC) 150/5370-2G: Operational Safety on Airports During Construction (13 December 2017), Appendix B,

Finally, Appendix C is a complete checklist with references to Chapter 2 for each element covered in the plan. It is an effective method of ensuring that nothing has been left out when preparing the CSPP.

6.1.2 Federal Aviation Administration memorandum to Alaska

The review of the 2 CSPPs for the airports in Alaska (King Salmon and Coldfoot) also uncovered the existence of a document that is very relevant to this investigation: an FAA memorandum, dated 05 April 2012, which specifically discusses reduced-width (or half-width) runway operations during construction. Because this construction method was deemed necessary for certain airports in Alaska where full closure of the runway is not an option, the FAA used this memorandum to fill the gap in guidance on the subject in AC 150/5370-2G, *Operational Safety on Airports During Construction*.

It presents runway half-width operation as a particular method that is only authorized if the following 3 criteria are satisfied:

- The airport does not have a second runway with sufficient capability.
- The airport does not have a taxiway of sufficient length and configuration to be used as a temporary runway.
- There are no other viable transportation modes available to serve the community.

The memorandum also describes in detail the visual aids to be used when the runway width is reduced. It states that "horizontal X's"[187] must be placed on the ground on the closed side of the runway in the direction of the length of the runway, and that the former markings must be obliterated on the closed side of the runway. Finally, it indicates that markings used on the open side of the runway must comply with regulatory requirements (Figure 8).

[187] "Horizontal X" means any marking in the shape of an X displayed on the ground.

Figure 8. Aerial view of the runway markings used at Edward G. Pitka Sr. Airport (PAGA), Galena, Alaska (Source: Google Earth, with TSB annotations)

6.1.3 Standard operating procedure

A 3rd significant document stood out during the review of the 2 CSPPs: the FAA's standard operating procedure for evaluating CSPPs presented for construction projects wholly or partially funded by the Airport Improvement Program.[188]

This standard operating procedure is divided into 3 sections, the first 2 of which are relevant to this investigation, because they describe the roles and responsibilities of those involved and the procedure for evaluating CSPPs. Subsection 1.1.2 explains that Part 139 of Title 14 of the *Code of Federal Regulations* does not fully prescribe how inspectors oversee the compliance of certified airports (Part 139) during construction. Therefore, reviewing CSPPs is an effective method of validating on-going compliance in such a situation. Section 2, which provides a complete and detailed procedure to be followed when evaluating a CSPP, states that a review of CSPPs is a systematic process with the ultimate goal of ensuring that the CSPP complies with the standards and recommended practices described in AC 150/5370-2G. It further states, in subsection 2.7 of the procedure, who must determine whether a risk assessment is required under FAA Order 5200.11, and when it must be conducted.

6.2 Safety management

The review of the CSPPs also drew our attention to safety management by the FAA, given that one of the plans reviewed (King Salmon) referred to the FAA's internal SMS and included details of the risk assessment that it had conducted when evaluating the plan. The reference document on the subject, Order 8000-369B, *Safety Management System,*[189] is the SMS implementation policy, in accordance with the International Civil Aviation Organization's (ICAO's) Annex 19. For U.S. airports, the details of this internal SMS and its implementation can be found in FAA Order 5200.11.

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188 Federal Aviation Administration, Standard Operating Procedure ARP SOP 1.00, FAA Evaluation of Sponsor's Construction Safety and Phasing Plans Funded by the AIP or PFC Programs (effective 1 October 2013).

189 Federal Aviation Administration, Order 8000-369B: Safety Management System (18 March 2016).

6.3 Communication of airport construction information

Similar to Canada, the United States complies with ICAO's recommended practices regarding the dissemination of aeronautical information in general, and information pertaining to airport construction in particular, and issues NOTAMs and supplements. However, further to the study carried out by the Airport Construction Advisory Council (ACAC), the FAA began to publish airport construction notices, which are diagrams highlighting construction areas and restricted runways and taxiways. A review of a large number of airport construction notices revealed that each notice included an airport diagram clearly indicating the closed portions of the runway or taxiway with a red X. Furthermore, each notice included a note to remind pilots to consult the NOTAMs for the latest information.

According to information provided by the FAA for the purposes of this investigation,[190] the graphical representation of the NOTAM published in the airport construction notice for the reduction in the width of Runway 12/30 at the King Salmon Airport for construction work carried out in 2018 and 2019 depicted the runway being rehabilitated as one half black (open side) and the other half white with red X's (closed side), describing the width closure in a note below the diagram.

All airport construction notices in effect can be found on a dedicated FAA web page.[191] The site where NOTAMs are posted can be accessed from that page. This web page will likely disappear soon because the diagrams are now available on the FAA NOTAM search page.[192] In addition, to make more pilots aware of the vital information published in these NOTAMs, and to make it easier to incorporate this information in the flight planning process, these airport construction notices are now included in cockpit electronic flight bag applications, such as ForeFlight.

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190 The NOTAM in question could not be obtained, given that NOTAMs are only kept for a brief period.

191 Federal Aviation Administration, "Airport Construction Notices", at https://www.faa.gov/air_traffic/flight_info/aeronav/Aero_Data/Apt_Constr_Notices/ (last accessed on 26 November 2021).

192 Federal Aviation Administration, "FNS NOTAM Search", https://notams.aim.faa.gov/notamSearch/nsapp.html (last accessed on 26 November 2021).

7.0 ANALYSIS

Each time the width of a runway was reduced during rehabilitation work at in Quebec and Nunavut between 2013 and 2018, it resulted in incidents during landing and takeoff. Following a series of similar occurrences, the TSB launched this safety issue investigation to highlight any systemic underlying causes or contributing factors. The occurrences under review in this investigation took place in favourable weather conditions, and nearly all of them took place during the day. They involved a variety of aircraft, flight operations, and pilots with various ratings, who were not able to quickly distinguish the open portion of the runway from the closed portion. The information gathered during this investigation led the TSB to ask the following 2 questions:

1. Why, despite the preventive measures available, were pilots not able to identify the open portion of the runway during takeoffs and landings on runways that were reduced in width during rehabilitation work?

2. Why, despite the risk management culture prescribed by the *Canadian Aviation Regulations* (CARs) for airport operators and the culture developed internally at Transport Canada Civil Aviation (TCCA), did incidents and accidents repeatedly occur during takeoffs and landings on runways that were reduced in width during rehabilitation work?

To answer these 2 questions, this analysis will focus on the various contributing factors, beginning with direct, concrete, or obvious factors. Then, gradually drilling down to the source, the analysis will focus on the less obvious underlying factors, causes or deficiencies. The analysis will begin by examining the method chosen to carry out the construction work and the runway markings used during construction. It will then examine how information pertaining to the airport construction is communicated to pilots, followed by a closer look at the plan of construction operations (PCO) that airport operators must prepare, and will conclude with safety management and airport surveillance.

7.1 Construction method and runway markings

7.1.1 Construction method

The occurrences under review took place on runways undergoing construction that had been reduced in width. However, the construction method most frequently used for runway rehabilitation in Canada and abroad consists of reducing the runway length rather than the width. A review of international standards and Canada's regulatory framework for construction revealed the absence of information on which method should be used for runway rehabilitation, and the absence of Canadian standards for airport construction. Neither International Civil Aviation Organization (ICAO) documents nor the CARs and related standards authorize or prohibit either method. The decision lies entirely with the airport operator. Given that this method of reducing the width of the runway is rare, the reason for choosing it was examined.

7.1.1.1 Determining factors in the choice of method

Unlike reducing the length of the runway, which is done in 3 phases and requires complete closure of the runway while the middle portion is being rehabilitated,[193] reducing the width of a runway does not require complete closure of the runway while the work is being carried out, making this a critical factor when choosing a construction method. There are situations where a runway closure, regardless of how brief, is simply not possible for various reasons. This is the case for small airports that have a single runway, and are located relatively far from large urban centres or in a remote area. These airports are indispensable to the communities they serve, both for supplying essential goods and for emergency medical services. In these cases, airport operators must consult the affected communities to determine how to limit the impact and duration of disruptions caused by the airport construction, but closing the one and only runway is generally not an option. Three[194] of the 4 airports under review in this investigation had a single runway; 2 were critical to serving the community,[195] and 1 was a hub for emergency medical evacuation flights.[196]

Economic reasons may also drive the choice of construction method. Reducing the length of the runway may be ruled out to avoid completely closing the runway, even when the airport is relatively close to a large urban centre and has more than 1 runway, as is the case for the Montréal/St-Hubert Airport. Given that operations at this type of airport are economic- and business-oriented, the airport operator cannot ignore the needs and requirements of the air operators. The main air operator serving an airport may also put pressure on the airport operator to choose the method that will limit or eliminate the need to close the runway.

In addition, at airports where only one commercial air operator offers passenger service, the airport operator cannot afford to "lose" the air operator and will be more likely to give in to pressures and choose the solution favoured by the air operator.

Finding as to risk

If the airport construction planning process places too much emphasis on external economic pressures to avoid closing the runway, there is an increased risk that not enough emphasis will be placed on safety.

Regardless of the reason(s) behind the decision to reduce the width of the runway, this decision must be made in an informed manner, which means being aware that this is not the usual method and taking the steps necessary to ensure the safety of flight operations.

The U.S. Federal Aviation Administration (FAA) officially recognizes this method, particularly for Alaska. However, it recognizes it as an exception to the rule and has

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193 When the length of the runway is reduced for runway rehabilitation, the construction is generally carried out in 3 phases. The first 2 phases on the ends, and the 3rd phase on the middle portion of the runway.

194 Baie-Comeau, Schefferville, and Iqaluit.

195 Schefferville and Iqaluit.

196 Baie-Comeau.

established strict criteria that airport operators must meet in order to obtain authorization to reduce the width of the runway during rehabilitation.

For example, using these criteria in Canada as a risk mitigation strategy could prevent airports such as Montréal/St-Hubert (which has 3 runways) and Baie-Comeau (where the community served is accessible by road) from closing the width of the runway.

7.1.1.2 Impact of the chosen method on air operators

The decision to reduce the width of a runway may have specific repercussions on air operators' operations on that runway. Affected air operators must therefore be made aware of this reduction so that they can check whether the runway width available during construction will be sufficient and so that they can meet the specifications stipulated by the manufacturers of the various aircraft they operate. In the occurrences under review, air operators had only 3 ways of being made aware: NOTAMs, *AIP Canada (ICAO)* supplements and, if applicable, consultations carried out by airport operators during construction planning as required by the airport operators' safety management system (SMS).

If the runway width is insufficient, air operators must take appropriate action, and communicate that action to flight crew members and dispatchers, as applicable. If necessary, they must also ensure that a supplement is included in the affected aircraft's flight manuals to allow narrow runway operations. The investigation determined that, in some cases, air operators had performed the checks necessary and had sent a notice to pilots informing them of the reduced runway width and of the additional procedures for narrow runway operations. However, the investigation was unable to determine whether all of the air operators involved in the occurrences had followed the manufacturer's procedures for narrow runways and whether this was a contributing factor for some of the occurrences.

Finding as to risk

If air operators are not aware of a reduction in the width of a runway, there is a risk that they will not ensure that the width of the runway falls within the limits specified in the aircraft flight manuals.

7.1.2 Runway markings during construction

Although reducing the width of the runway during construction has the advantage of keeping the runway open, it requires a new configuration for runway lighting and markings. According to the CARs, the temporary markings used vary depending on the aerodrome (certified or not), the duration of the construction work, and the applicable edition of *Aerodrome Standards and Recommended Practices* (TP 312). All of the runways on which the occurrences under review took place were at airports (certified aerodromes) that had to comply with the 4th Edition of TP 312. However, a review of the PCOs for the 4 airports revealed that the planned temporary markings varied greatly both between airports and between different phases of construction at the same airport. It is therefore appropriate to examine this difference in markings.

7.1.2.1 Factors influencing runway markings

7.1.2.1.1 Complexity of regulations

It was clear from reviewing these regulations that the various requirements and cases are complex and some concepts not detailed enough. First, the fact that all 5 editions of TP 312 are in effect and may or may not apply depending on when the aerodrome was certified and/or when each facility was replaced or upgraded does not make it easy for the airport operator. The airport operator must determine which edition applies to which facility and adhere to the corresponding standards. In reading the different editions, it is difficult to know which standard applies to the closed markings to be displayed for permanent, temporary, or short-duration closures.

Closed markings are mandatory for permanent closures, but only recommended for temporary or short-duration closures. However, nowhere is it stated what is meant by "short duration." Nevertheless, the investigation revealed that the regulator's intention was to allow airport operators to not display closed marking for short-duration construction, provided that sufficient notice is given through air traffic services (4th Edition of TP 312) or through some other means (5th Edition). The airport operators involved in the occurrences under review had considered a closure for a few weeks to be a "short-duration closure," which meant they were not strictly required to display closed markings during construction.

If we then compare TP 312 with the regulatory requirements stated in CARs Subpart 301 (which applies to aerodromes other than airports and heliports), we see that the CARs are more specific regarding closed markings and stipulate the exact configuration to be used for the markings depending on the runway length. Furthermore, the CARs do not require markings for construction that lasts "24 hours or less" (regardless of the runway length). The CARs expression "24 hours or less" seems to match the expression "short duration" used in TP 312. However, given that Subpart 301 does not apply to airports, there was nothing requiring the operators of the airports under review in this investigation to display the markings in this manner.

The regulations are just as complex regarding the other runway markings (runway centreline, runway edge, etc.) in the closed area. According to the 4th Edition of TP 312, these markings are only to be obliterated when the closure is permanent. It should be noted that the French version of the 5th Edition requires the markings to be removed regardless of the duration of the closure, while the English version requires them to be removed for a permanent closure.

The inconsistency and ambiguity regarding runway markings used at various aerodromes, stemming from regulations that are complex and not detailed enough, result in different runway marking configurations (e.g. X's displayed in the grass, no closed markings, or former runway markings still visible in the closed area), which all theoretically comply with the regulations.

Finding as to risk

If the wording used in airport standards and regulations is complex and lends itself to several interpretations, these standards and regulations could lead to different measures and solutions that all appear to comply with the requirements, but in reality, may not reflect the regulator's intention with respect to safety.

Among the airports under review, the Schefferville Airport was the only one that displayed closed markings along the entire length of the closed side of the runway and removed the other runway markings in the closed area even though it was not required to do so by regulations.

Finding as to causes and contributing factors

Given the absence of standards related to the safety of operations during airport construction, including standards related to required visual aids, the visual aids used on the reduced-width runways reviewed in this investigation were insufficient for pilots to be able to clearly distinguish the closed portions.

It is interesting to note that the United States has chosen a straightforward solution, simply referring to permanent or temporary closures, with no reference to the duration of the temporary closures. Furthermore, in Alaska, the FAA requires that closed markings be used for all closures when the runway is reduced in width. Similar to Canada, these markings are large X's, but unlike Canada, where these markings are white, Alaska uses yellow markings, which contrast with normal white runway markings. In Alaska, the FAA also requires that the former markings on the closed side of the runway be removed, and like Canada, that the markings on the open side of the runway comply with regulatory requirements.

7.1.2.1.2 Pressures related to construction funding

In addition to the regulations being complex and not detailed enough, the investigation revealed another factor that may have had an impact on the runway markings used: applications for construction funding under the Airports Capital Assistance Program (ACAP). In some cases, airport operators who had applied for ACAP funding decided not to display closed markings to increase their chances of receiving the funding, because they were under the impression that program officers would favour the least expensive option. Information gathered during the investigation revealed that in at least 1 case, painting an X on a newly-paved surface was unacceptable to ACAP given that removal of these markings after construction could damage the surface and lead to additional costs. As a result, airport operators in this situation, knowing that the markings are not required but simply recommended by regulations, may choose the least expensive option and ignore the possible impacts on safety. It appears, therefore, that contradictions within TC influence decisions made by airport operators, who may not apply the safety measures recommended by TCCA.

Finding as to risk

If using safety measures that are not mandatory—such as displaying closed markings—compromises an airport operator's ability to obtain funding from ACAP, the airport operator may decide not to take these safety measures.

The FAA, which also has a funding program for airports making improvements, imposes specific conditions and procedures for airports receiving funding in its Advisory Circular (AC) 150/5370-2G. This circular states that safety, maintaining aircraft operations, and construction costs are all interrelated, but safety must not be compromised. Therefore, the airport operator must strike a balance between maintaining aircraft operations and construction costs.

7.1.3 Visual identification of the open portion of the runway

Flight operations rely on a number of safety measures at all levels to manage the many risks and threats. For example, thorough flight planning by the pilot or flight crew is required before any flight begins in order to identify potential threats, assess their impact on flight safety, and form a mental image of the flight. When an aircraft is flown by a crew, the crew also conducts a pre-departure briefing and an approach briefing before landing in accordance with the company's standard operating procedures (SOPs). The purpose of these briefings is to reinforce the pilots' mental model of the upcoming phases of flight and the actions to be taken.

When a pilot has properly understood the information in a NOTAM regarding the open portion of a runway during construction, the temporary markings are simply a confirmation or visual reminder of the mental model that was invariably created while reading the NOTAM. However, if the pilot has not properly understood or retained the information concerning the open portion of the runway, the markings become an essential visual defence to correct an inaccurate mental model. It is therefore important for the markings to be clear, convincing, and consistent with pilots' expectations and mental models, especially because pilot workload is very high during approaches, landings, and takeoffs.

The specific threat in the occurrences under review was the fact that the runways involved were undergoing construction and had a temporary configuration. The pilots had consulted the NOTAMs issued for the airports involved and were aware that the runways were undergoing construction and that their width had been reduced. Furthermore, the flight crews had conducted pre-departure briefings and approach briefings before landing, as appropriate. Even so, the occurrences under review resulted in 16 runway excursions, as well as 2 go-arounds during which the crew successfully managed the undesired aircraft state in a timely manner. Some of the pilots stated that they were expecting to be able to easily identify the open portion of the runway, which was not the case. It is therefore worthwhile to examine the human factors and their influence on the occurrences under review.

Situational awareness lies at the core of a pilot's decisions, and this situational awareness, which enables pilots to form a mental image of the situation, is based on mental models that

the pilot has assimilated up to that point through training and experience. Depending on the elements that pilots perceive and their own personal mental models, they interpret the meaning and importance of the perceived elements, with a natural tendency to give more weight to information that matches their mental model (confirmation bias), and to discard information that does not match. From there, pilots anticipate the future state of the perceived elements and make decisions accordingly.

In the occurrences under review, the width of the runways had been reduced, which is not common practice for airport construction. Based on the mental model of a runway undergoing construction that the pilots had acquired during training, they most likely expected the runway to be reduced in length, which would mean that although the runway was shorter, the configuration of the lighting and markings would remain the same. They expected the open portion of the runway to be clearly defined. It is reasonable to conclude that when pilots create a mental model of a reduced-width runway, they will use the same logic as that used for markings on a reduced-length runway, and will visualize a clearly defined open portion. In reality, X markings were displayed, but some of them were not very visible (low contrast) and at times they were placed in the grass beside the runway (Montréal/St-Hubert) or displayed on the runway strip without the original markings (centreline and threshold) having been removed (Iqaluit).

Although the pilots had consulted the NOTAMs informing them of the construction and the reduced runway width, without runway markings that were clear, convincing, and consistent with their expectations and mental models, the pilots found themselves approaching a runway that appeared to be open across the entire width. Using their interpretation of the situation, and influenced by confirmation bias, they dismissed other visual cues indicating otherwise, including temporary centreline lights, different markings, and even X's beside the runway. Given that a person's attention span and ability to process information are limited and that the pilots were at a critical point of the flight, they focused their attention primarily on takeoff and landing and proceeded with their actions based on their interpretation of the situation. Unable to distinguish the closed area, they believed that the entire width of the runway was open and manoeuvred on the closed side of the runway.

The runway markings used during construction at the 4 airports likely did not match the pilots' core mental model to allow them to distinguish the open portion of the runway from the rehabilitation area of each runway. Given the inconsistent and unclear visual cues, the pilots proceeded with their landing or takeoff as if the entire width of the runway was open.

Finding as to causes and contributing factors

The runway markings used for construction at the airports under review were not clear, convincing, and consistent; consequently, the pilots were not able to distinguish the open portion of each runway and manoeuvred the aircraft on the closed portion, which, in some cases, resulted in damage to the aircraft.

It is interesting to note that among the occurrences under review, 6 involved aircraft registered in the United States, where manoeuvring areas that are still open are clearly and visibly separated from construction areas, including closed runways. In such a case, it is

reasonable to believe that, given their training and experience, pilots of U.S. aircraft expected to see a clear and visible separation between construction areas and open manoeuvring areas, which might explain why ⅓ of the occurrences involved pilots of U.S. aircraft.

It should also be noted that in the United States, in the state of Alaska, the distinction between visual aids for reduced-length runways and those for reduced-width runways (X displayed along the entire length of the closed side of the runway) is generally more visually obvious and can therefore potentially reduce the risk of incorrect visual identification of the open runway.

7.2 Communication of construction information by the airport operator

If an airport operator plans to carry out construction activities at their airport, they must communicate the necessary information to pilots by having a NOTAM issued and possibly having an *AIP Canada (ICAO)* supplement published.

7.2.1 NOTAMs

Information pertaining to airport construction, which is temporary and may be complex, can be difficult to communicate clearly and effectively in a NOTAM. Over the years, the way these notices are presented and how they are provided to flight crews have not only been called into question several times, but have also been considered to be contributing factors in a number of aviation occurrences. The investigations into those occurrences highlighted certain deficiencies that make these notices inadequate and could hinder the communication of the information. The fact that the text is written entirely in capital letters and contains a significant number of abbreviations of all kinds (some of which are not well known), the large number of NOTAMs generally related to a flight, and the order in which the NOTAMs are provided to pilots are all elements that detracted from the readability and the effectiveness of the communication.

In the occurrences under review in this investigation, the NOTAMs consisted primarily of abbreviations and acronyms. TSB Aviation Investigation Report A17Q0059 noted that the use of the words “reduced in width” in a NOTAM intended to indicate a reduction in runway width would clearly indicate the condition while reducing the risk of ambiguity, given that a reduction in runway width is less frequent than a reduction in length.

Furthermore, the occurrences under review in this investigation highlighted another deficiency with NOTAMs, that is, the fact that they are limited to text and do not include graphics. The pilots involved in the occurrences under review had consulted the NOTAMs issued for the construction activities and were aware of the reduced runway width. However, when they read the NOTAMs, they were unable to form an accurate mental image of the situation or visualize what the runway undergoing construction would look like. As a result, the mental models and expectations they had regarding airport construction prevailed over the reality, and the pilots were not able to distinguish the closed portion from the open portion of the runway.

All of these elements that detract from the readability and effectiveness of NOTAMs are directly related to human factors. According to ICAO, aeronautical information services should take these factors into consideration, particularly in the design and distribution of aeronautical data and information.

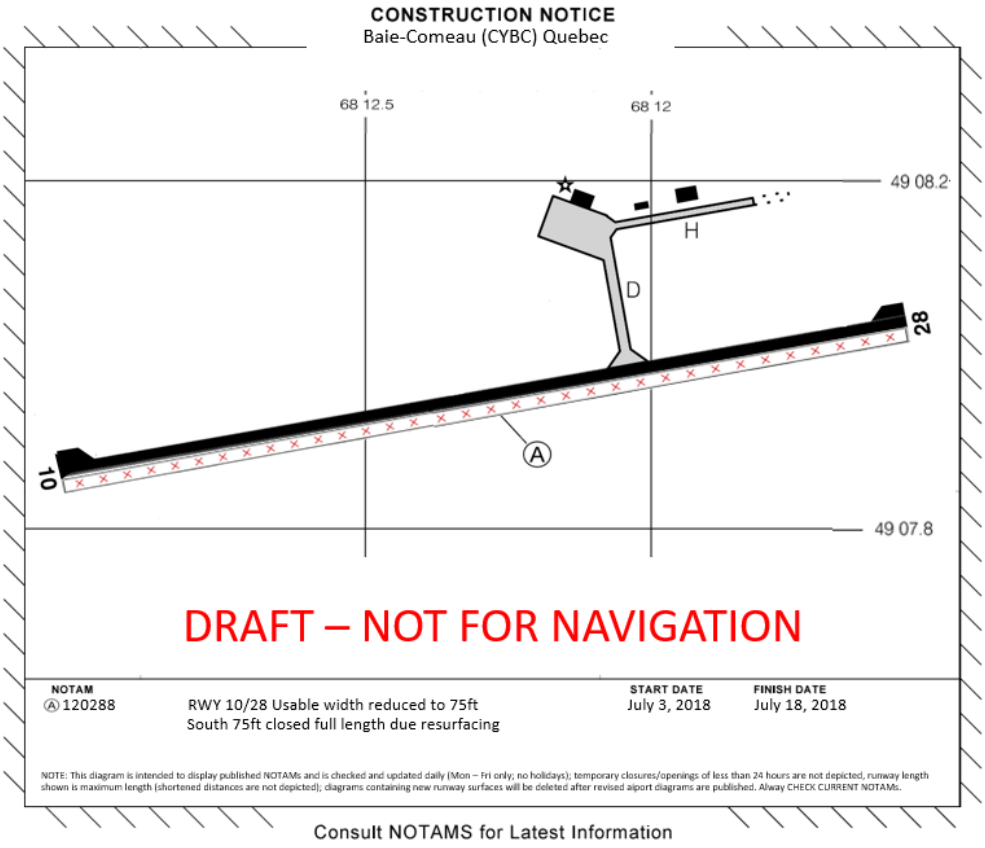
It should be noted that the United States also publishes information regarding airport construction through NOTAMs. However, it also publishes an airport construction notice, which is a graphic version of a NOTAM clearly illustrating the affected runways and taxiways on the airport diagram. Pilots can then easily and clearly visualize the construction and the related changes and know exactly what to expect.

All airport construction notices in effect are posted on a dedicated FAA web page, where they are listed alphabetically by aerodrome name, making them easy to access. This web page will likely disappear soon since the diagrams are now available on the FAA NOTAM search page.

Based on the method used by the FAA for its airport construction notices, the TSB created a graphical representation (Figure 9) from the NOTAM below for the Baie-Comeau Airport:

> 180288 CYBC SOUTH 75 FT RWY 10/28 FULL LEN CLSD DUE RESURFACING. NORTH 75 FT AVBL ACFT MAX WINGSPAN 78 FT AND REF LDG SPEED BLW 123 KT. NORTH 75 FT AVBL 48 HR PN TEL 418-445-0566 FOR ACFT WINGSPAN BTN 79 FT AND 118 FT AND OUTER MAIN GEAR SPAN BTN 20 FT AND 30 FT. FOR ACFT WINGSPAN LESS THAN 79 FT AND OUTER GEAR SPAN LESS THAN 20 FT, 2 HR PN 1807031609 TIL APRX 1807182300

Figure 9. Example of a graphical representation of the NOTAM for the Baie-Comeau Airport created according to the U.S. Federal Aviation Administration's model for Airport Construction Notices (Source: TSB)



Finding as to causes and contributing factors

Currently, NOTAMs in Canada cannot include graphics and only contain text, the format and style of which can hinder the effective communication of information. Consequently, even though the pilots involved in the occurrences under review had all read the available NOTAMs related to the partial runway closures, their mental models were inaccurate and they were not able to identify which portions were closed.

7.2.2 *AIP Canada (ICAO)* supplements

NOTAMs are not the only communication products available to Canadian airport operators to disseminate information about airport construction. Airport operators can also request the publication of an *AIP Canada (ICAO)* supplement. Indeed, information about airport construction fits perfectly with the type of information published in a supplement: these supplements are used to communicate temporary operational changes of long duration (3 months or longer) as well as information of short duration that contains extensive text and/or graphics.

However, the investigation revealed that airport operators are often unaware of the process for requesting publication of a supplement for 2 main reasons: unlike NOTAMs, airport operators do not have supplements published regularly, and the request process is not easy to find. It can be found in the *Transport Canada Aeronautical Information Manual*, but it is

not mentioned anywhere else, in any TCCA or NAV CANADA document or on any of their websites. The investigation also determined that, for many airport operators, the deadlines for publishing supplements are not compatible with the unforeseen circumstances that may arise while planning runway rehabilitation.

Although *AIP Canada (ICAO)* supplements are published every 28 days, airport operators must provide the information to be published to NAV CANADA at least 49 days in advance. This may explain why only 2 of the 4 airports under review had a supplement published. However, it is worth noting that only 1 of the 2 supplements contained a graphic image of the airport construction.

Finding as to risk

Although *AIP Canada (ICAO)* supplements may contain graphic images that help the reader understand what a partial closure of the runway looks like at an airport, if the process for publishing these supplements is not well known and takes too long, airport operators may not use this method of publication, which could hinder the communication of important safety information.

7.3 Plan of construction operations

7.3.1 Preparation

Any airport operator planning to carry out construction activities at their airport without interrupting operations must prepare a PCO and have it approved by TCCA. The purpose of this plan is to demonstrate that the airport will comply with TP 312 standards for the duration of the construction period. The investigation revealed that PCOs were difficult to prepare given the absence of standards, recommended practices, guidelines, and any other type of information on the subject. Airport operators are therefore left to their own devices to determine what information to include in the plan and which format to use. They most often use consultants, but the consultants do not have any additional reference documents to help prepare the PCO.

The absence of standards for the preparation of PCOs is in addition to the absence of general standards on aerodrome construction and to the complexity of regulations regarding runway markings to be used. A review of a number of PCOs for the purposes of this investigation revealed inconsistency between the various documents, and the inclusion of information that was not always relevant, including technical civil engineering information. This was the case for the PCOs at the airports where the occurrences under review took place. Furthermore, those PCOs contained very little information on the SMS and only indicated how the stakeholders would be informed of the SMS practices. Finally, only 1 airport had PCOs that included a risk assessment.

Finding as to causes and contributing factors

There are no standards, recommended practices, or guidelines for the preparation of PCOs. As a result, the plans prepared by the airport operators did not cover the risk that pilots might not be

able to recognize or distinguish the closed portions of the runways and did not include control measures to mitigate this risk.

It should be noted that unlike their Canadian counterparts, U.S. airport operators have access to a complete document, AC 150/5370-2G, *Operational Safety on Airports During Construction,* published by the FAA, which helps them plan their construction in accordance with specific standards and recommended practices, and prepare their construction plan for approval. As a result, U.S. airport operators know that if they follow the circular, they will comply with aerodrome standards, including those that apply during airport construction.

7.3.2 Evaluation and approval

The evaluation of a PCO by TCCA staff is vital to the safety of operations at an airport during construction. The investigation showed that this activity is complex for several reasons.

First, TCCA inspectors do not have standards or recommended practices on the subject at their disposal to complete the task. As a result, TCCA inspectors in the Quebec and Prairie and Northern regions wrote their own guides. However, given that these guides have not been approved by TCCA Headquarters and are not updated, they do not guarantee an effective evaluation of PCOs or consistency at the national level.

Finding as to risk

If inspectors who evaluate PCOs do not have a nationally standardized evaluation guide at their disposal, some risk factors may go undetected due to inconsistencies between regions.

Next, like airport operators, TCCA inspectors must work with airport regulations that are complex and not entirely up to date. First of all, TC's *Procedures for the Certification of Aerodromes as Airports* (TP 7775), which is incorporated by reference into CARs and describes procedures for certifying aerodromes as airports, requires that airport operators planning construction prepare a PCO. By approving this PCO, a document which is similar to a temporary amendment of the airport operations manual (AOM) and describes the measures that will be put in place during construction to comply with standards, the inspector validates the retention of the airport's operating certificate. The problem is that, on the one hand, TP 7775 does not provide specifics regarding the plan, and on the other hand, it dates back to 1991, that is, a time when the CARs did not yet exist.

Finding as to risk

If TCCA standards are not updated periodically, the standards may not adequately meet the regulatory requirements.

Next, TP 312, which is also incorporated by reference into the CARs, does not make the inspectors' job easy because all editions are in effect and apply based on when the various facilities were certified. As a result, inspectors must begin by determining which editions of TP 312 apply to the facilities affected by the construction. Furthermore, TP 312 does not include a section that specifically addresses airport construction; it refers to closed markings only. A review of the PCOs approved by TCCA for the airports covered by this investigation revealed that not all airports had planned to display closed markings on the

closed side of the runway. According to 4th and 5th editions of TP 312, these markings could be omitted for temporary closures of a short duration. Given that the concept of short-duration is not defined, TCCA inspectors evaluating PCOs are not able to assess this PCO element, even though these markings are critical in distinguishing the closed portion from the open portion of the runway.

Finding as to causes and contributing factors

In the absence of standards, guidelines, and recommended practices, PCOs were approved using informal procedures, without assessing the risk that pilots might not be able to recognize or distinguish the closed portions of the runways, and without including control measures to mitigate this risk.

Finally, another element that complicates TCCA inspectors' evaluation of PCOs is the inclusion of technical civil engineering information. The investigation showed that the airport operators who had submitted a funding application to ACAP for the airport construction had voluntarily included this information in their PCO so that they could prepare a single document intended for both TCCA and the Air, Marine, and Environmental Programs Directorate. However, these civil engineering elements make it more difficult for TCCA inspectors to evaluate a PCO. Some inspectors add a note to the PCOs they approve, indicating that the approval does not cover the civil engineering elements.

If we compare the situation to the United States, the inspectors there who evaluate and approve airport construction plans wholly or partially funded under the Airport Improvement Program have very detailed SOPs. This allows them to verify with certainty whether the construction plans comply with the standards set forth in AC 150/5370-2G, to assess the risks and proposed control measures for the construction and, for airports governed by Part 139 of Title 14 of the *Code of Federal Regulations*, to ensure compliance with those regulations. Although these SOPs were originally intended for evaluating construction plans receiving funding from the Airport Improvement Program, they can also be used as a reference for evaluating construction projects that are not funded by this program.

7.4 Safety management and airport surveillance

The safety measures that are an integral part of airport operations and flight operations did not prevent the occurrences under review for a number of concrete reasons and factors. However, these safety measures are not isolated; they are part of a regulatory framework that promotes a systemic culture of safety and risk management, for both airport operators and TCCA. Therefore, this investigation examined safety management and airport surveillance to try to understand why, in such a context, the occurrences under review took place and have continued to take place over the years.

7.4.1 Safety management by airport operators

Safety has always been vital to airports, but the introduction of SMS has changed how it is managed. SMS establishes a systemic risk management framework which includes a safety oversight component that should allow for proactive and reactive risk management.

Although SMS became mandatory for airports in early 2008, airports had until 31 March 2011 or 2012 (depending on the airport type) to implement their system, pursuant to exemptions issued by TCCA.

Implementation was predicated on TCCA evaluation of these systems within the same timeframe. However, in the case of the 4 airports under review, because SMS evaluation was done much later, the airports did not benefit from TCCA feedback and follow-up for the implementation. This follow-up was all the more important because airport managers, who are appointed by airport operators (i.e. holders of the airport certificate), occupy a position that does not require a minimum amount of experience or relevant qualifications. Some airport managers have even admitted that they do not fully understand the SMS requirements. Consequently, they did not know whether the SMS they had implemented complied with regulatory requirements.

A review of the documents prepared by the inspectors after their evaluations showed that, indeed, the systems did not comply. The absence of follow-up by TCCA adversely affected the quality of the SMSs put in place, which proved to be ineffective and, in turn, adversely affected the quality of construction planning. When planning construction, the airport operators were required to follow the proactive risk management process in their SMS to identify any hazards and implement appropriate control measures while still complying with the regulations. Moreover, the risk management process that had to be completed before beginning construction was only carried out and documented by the Montréal/St-Hubert Airport. If the other 3 airports also conducted a risk assessment, it was not documented.

The safety oversight component of the SMSs at the 4 airports under review was not effective, given that the SMSs did not proactively manage the risks associated with the construction and the reduction in the runway width and prevent the occurrences from taking place. These SMSs also did not reactively manage the risks and prevent a repetition of similar occurrences. In fact, 3 incidents occurred at the Iqaluit Airport, 8 at the Montréal/St-Hubert Airport, and 4 at the Baie-Comeau Airport. The SMS investigation process should have been initiated after each occurrence to identify the root causes and the corrective action that needed to be taken to avoid a repeat of similar occurrences. However, the information obtained during the investigation revealed that no reactive management action had been documented for any of the occurrences. In the case of the Baie-Comeau Airport, given the repetition of occurrences during phase 1 of construction, the airport operator took corrective action and displayed closed markings during phase 2 of construction, but this corrective action was not documented. However, adding these markings did not prove sufficient to prevent other occurrences during phase 2.

Finding as to risk

If, contrary to the requirements of their SMS, airport operators do not conduct risk assessments or post-occurrence investigations, the likelihood that effective risk control measures will be put in place is greatly reduced.

7.4.2 Safety management and airport surveillance by Transport Canada Civil Aviation

In accordance with ICAO's Annex 19, which stipulates that "States shall establish and maintain an SSP [State Safety Programme] that is commensurate with the size and complexity of the State's civil aviation system,"[197] TCCA adopted its own internal SMS, the Integrated Management System (IMS), to implement and manage TC's Aviation Safety Program. This IMS applies to all of its staff and its activities. With respect to the occurrences under review involving runway rehabilitation, TCCA was required to take action, including evaluating and approving the PCOs for the planned construction. In doing so, TCCA inspectors were supposed to follow the IMS safety management process to approve the PCOs and determine whether the plans met the risk management criteria for aviation safety before approving them.

The investigation determined that TCCA inspectors had not followed the IMS process and did not fully understand the system. However, they did have a good understanding of the core IMS step of risk assessment, without knowing that it was part of the IMS, and occasionally performed these assessments outside of the IMS framework. Of the PCOs for the 4 airports under review, only 1 (Montréal/St-Hubert) contained a risk assessment conducted by the airport operator. In that case, the inspector believed that the assessment was sufficient and he did not need to conduct one himself, which was not true. In the other 3 cases, the inspectors did not realize that the PCOs did not contain a risk assessment and did not conduct one themselves, either as part of the IMS framework or not. Civil Aviation Directive (CAD) QUA-007, *Transport Canada Civil Aviation Integrated Risk Management Framework*, and Staff Instruction (SI) QUA-008, *Risk Management Process for Aviation Safety Activities*, present the risk management process in detail, including the questions to be asked to determine whether risk management is necessary. Therefore, if an initial PCO proposed a reduction in the width of the runway, the answer to the question "What has changed?" should have triggered a risk assessment, given that this construction method is different from the usual method of reducing the runway length. However, neither the CAD nor the SI state who should ask these questions and when they should be asked. It is therefore possible that the insufficient details on this point in the reference documents could account for this omission.

[197] International Civil Aviation Organization, Annex 19 to the *Convention on International Civil Aviation — Safety Management*, Second Edition (July 2016), section 3.1: State safety programme (SSP).

Finding as to risk

If the implementation of TC's oversight policies and procedures is inconsistent, there is a risk that the resulting oversight will be ineffective at ensuring that operators are able to effectively manage the safety of their operations.

In contrast, in the United States, the FAA's SOPs for evaluating construction plans submitted for work that is wholly or partially funded by the Airport Improvement Program stipulates who must determine whether and when a risk assessment is needed. In Alaska, the fact that the FAA risk management process was used when it needed to be (King Salmon) likely contributed to the implementation of appropriate risk control measures and to the fact that no occurrences took place.

By following this critical step in the IMS—the risk assessment—as part of the evaluation and approval of the PCOs related to the occurrences under review, TCCA inspectors had an opportunity to identify the existing and potential risks and issues and to officially report them within the IMS framework. Indeed, the evaluation of the first PCO that included a reduced-width runway for the occurrences under review was an opportunity to highlight the fact that there were no standards for PCOs, both in terms of their evaluation and in terms of their preparation.

Furthermore, risk assessment provided an opportunity to point out the fact that certain reference documents, such as TP 7775, were out of date. This document, which dates back to 1991—before the introduction of the CARs—is incorporated by reference into the CARs and is still used by inspectors to justify the requirement for airport operators to present a plan before beginning construction. However, the document does not contain information on how to evaluate these plans and only gives a brief description of what needs to be presented to TCCA.

Also, when examining the actual construction work described in the PCO and the related measures planned to ensure the safety of flight operations, such as visual aids, inspectors following the IMS risk assessment principles had an opportunity to highlight the complexity of and deficiencies in the regulations on the subject. In particular, they could point out the difficulties arising from the fact that all editions of TP 312 are in effect and apply based on when the various facilities were certified, as well as the ambiguity of certain concepts that are key in interpreting the texts, such as "short-duration closure", which determines whether or not closed markings need to be used.

Risk assessments gave inspectors the opportunity to highlight the fact that CARs Subpart 301 refers to a similar concept when it mentions being "closed for 24 hours or less," but that this subpart does not apply to airports. Inspectors had a chance to point out that the insufficient details in the regulations could lead to various measures and solutions being taken, all in compliance with the regulations, but not necessarily in keeping with the regulator's original intention.

Within the IMS framework, all of these points that could be brought up during the evaluation of an initial PCO were to be documented as data to be included in the system itself and analyzed, so that risks could be assessed and actions taken accordingly.

A follow-up then needed to be conducted during construction to check whether the control measures put in place were working properly. In our case, this follow-up was not done, and no one noticed that occurrences had taken place. The data pertaining to these incidents was therefore not incorporated into the system and could not be taken into consideration in the risk management of future operations, thereby negating the effectiveness sought by the reactive risk management process.

In addition, the TCCA inspectors should have gathered this data as part of the PCO evaluation, during the control measures follow-up that is conducted once the PCOs are approved, and as part of their traditional regulatory oversight of airports.

None of that took place. Neither the airports' SMS nor TCCA's IMS were able to ensure that this critical data was included in the IMS, making the system ineffective. This absence of data only served to hinder the evaluation of subsequent PCOs proposing a reduced-width runway, in other words, the proactive management of risk. These PCOs continued to be approved without control measures being re-assessed, and occurrences continued to take place.

Adding the data to the IMS as the occurrences under review took place could have enabled the inspectors to initiate a reactive investigation to identify issues in the previously approved PCOs, along with any new hazards. Then, TCCA could have noted that, even within TC itself, there are competing pressures and that the Air, Marine, and Environmental Programs Directorate, which is in charge of ACAP, could influence airport operators, who could then decide not to apply safety measures recommended by TCCA. The investigation also could have led inspectors to question why pilots were unable to distinguish the open portion from the closed portion of the runway. Given that the risk control measures initially put in place were not effective, according to the Civil Aviation business model (Figure 7), a diagnostic of the PCO approval process would have been necessary to determine whether there were deficiencies in its application.

The issues that could have been noted by the inspectors in their post-occurrence investigations were indicators that the inspectors could have taken into consideration to move up the dates of the evaluations and periodic inspections of the relevant SMSs. None of the occurrences led to a re-evaluation of the SMSs.

The effectiveness of airport SMSs is directly related to TCCA oversight. When SMS became mandatory for airports, TCCA issued exemptions to allow these systems to be put in place gradually, which delayed their implementation by several years. Furthermore, questions can be raised about the workload of TCCA inspectors assigned specifically to airports in the Quebec Region, given the limited staff available to perform airport surveillance. This situation may have contributed to the fact that airport operators did not benefit from a follow-up by TCCA during this implementation period, resulting in partial and ineffective SMSs. When the exemptions expired, TCCA staff members in the Quebec Region were still not able to complete all of the SMS implementation evaluations, which is why the SMSs at the airports under review in this region were evaluated up to 3 years later. Questions can also be raised about the workload and knowledge of inspectors in the Prairie and Northern

Region and other regions, given that they are not airport specialists and are also assigned to other types of operations. In the Prairie and Northern Region, SMS evaluations were not conducted.

The fact that TCCA issued exemptions implied that the risk assessments relevant to these exemptions had taken place and that a follow-up was needed. A follow-up could have enabled TCCA to realize that its initial evaluations of the airport SMSs had not been completed within the expected timeframe. Also, when the evaluations were eventually done, the purpose was to determine whether the operators were complying with the CARs rather than verifying whether the SMS in place was being used and proving effective. TCCA staff members in the Quebec Region were also under the impression that it would then be impossible to conduct the periodic inspections of all the airport operator SMSs, given the large number of airports in this region in relation to the number of inspectors available.

The investigation revealed that the workload of inspectors in the Quebec Region exceeds staff capacity, which has a direct adverse effect on airport surveillance and the safety of airport operations.

In the occurrences under review, even traditional regulatory oversight was not effective: the Civil Aviation Daily Occurrence Reporting System did not enable TCCA to notice the repetition of similar occurrences even though all of the occurrences under review were entered in the system. Finally, the last safety net, the IMS quality assurance program (QAP), also let the IMS's systemic issues fall through the cracks.

IMS and SMS, which form the SSP or State Safety Programme recommended by ICAO, were introduced to add a level of safety to safety management and oversight of the aviation industry and to proactively manage risks. IMS and SMS are part of an official regulatory framework; they are described in detail in a number of reference documents; the processes are explained in detail; roles and responsibilities are defined; and a risk management committee was even established to manage the methodology of the risk management process. These systems were intended to identify the factors and risks that had contributed to the occurrences under review, but they did not meet this goal.

Finding as to risk

If TCCA's IMS procedures, such as risk assessments and post-occurrence investigations, are not fully understood and followed as intended, potentially repetitive or widespread hazards may not be identified, preventing risk control measures from being put in place.

7.5 Conclusion

This investigation sought to answer 2 questions:

1. Why, despite the preventive measures available, were pilots not able to identify the open portion of the runway during takeoffs and landings on runways that were reduced in width during rehabilitation work?

2. Why, despite the risk management culture prescribed by the CARs for airport operators and the culture developed internally at TCCA, did incidents and accidents repeatedly occur during takeoffs and landings on runways that were reduced in width during rehabilitation work?

The investigation identified specific issues with airport operations and flight operations. First of all, the construction method chosen, the visual aids used during construction, and the way that airport construction information is communicated to pilots are all hazards which, when combined with several human factors, translate into concrete and direct risks to flight operations and result in pilots not being able to identify the open portion of the runway. The investigation determined that some of these hazards and risks result from other hazards, such as the complexity of the regulations and the absence of clear standards for airport construction in general, and for runway rehabilitation involving a reduced-width runway in particular. They also result from the absence of standards for preparing and approving construction plans, as well as, in some cases, pressure being put on airport operators, which influences their decisions about the construction method and markings. All of these hazards and risks were contributing factors in the occurrences under review.

The investigation then demonstrated that these hazards and risks existed, persisted, and continued to cause occurrences because the risk management that needed to be done by airport operators was not effective. This ineffectiveness resulted from 2 main issues: inconsistent implementation of TCCA oversight policies and procedures, and inadequate SMS oversight by TCCA. The limited resources dedicated to airport surveillance very likely hindered this oversight. The investigation raises questions about the effectiveness of the risk management process within TCCA itself. For the occurrences under review, we can only conclude that the implementation of SMS designed to add a level of safety to flight operations did not prevent the occurrences from taking place or continuing to take place.

8.0 FINDINGS

8.1 Findings as to causes and contributing factors

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

1. Given the absence of standards related to the safety of operations during airport construction, including standards related to required visual aids, the visual aids used on the reduced-width runways reviewed in this investigation were insufficient for pilots to be able to clearly distinguish the closed portions.

2. The runway markings used for construction at the airports under review were not clear, convincing, and consistent; consequently, the pilots were not able to distinguish the open portion of each runway and manoeuvred the aircraft on the closed portion, which, in some cases, resulted in damage to the aircraft.

3. Currently, NOTAMs in Canada cannot include graphics and only contain text, the format and style of which can hinder the effective communication of information. Consequently, even though the pilots involved in the occurrences under review had all read the available NOTAMs related to the partial runway closures, their mental models were inaccurate and they were not able to identify which portions were closed.

4. There are no standards, recommended practices, or guidelines for the preparation of plans of construction operations. As a result, the plans prepared by airport operators did not cover the risk that pilots might not be able to recognize or distinguish the closed portions of the runways and did not include control measures to mitigate this risk.

5. In the absence of standards, guidelines, and recommended practices, plans of construction operations were approved using informal procedures, without assessing the risk that pilots might not be able to recognize or distinguish the closed portions of the runways, and without including control measures to mitigate this risk.

8.2 Findings as to risk

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

1. If the airport construction planning process places too much emphasis on external economic pressures to avoid closing the runway, there is an increased risk that not enough emphasis will be placed on safety.

2. If air operators are not aware of a reduction in the width of a runway, there is a risk that they will not ensure that the width of the runway falls within the limits specified in the aircraft flight manuals.

3. If the wording used in airport standards and regulations is complex and lends itself to several interpretations, these standards and regulations could lead to different measures and solutions that all appear to comply with the requirements, but in reality, may not reflect the regulator's intention with respect to safety.

4. If using safety measures that are not mandatory—such as displaying closed markings—compromises an airport operator's ability to obtain funding from the Airports Capital Assistance Program, the airport operator may decide not to take these safety measures.

5. Although *AIP Canada (ICAO)* supplements may contain graphic images that help the reader understand what a partial closure of the runway looks like at an airport, if the process for publishing these supplements is not well known and takes too long, airport operators may not use this method of publication, which could hinder the communication of important safety information.

6. If inspectors who evaluate plans of construction operations do not have a nationally standardized evaluation guide at their disposal, some risk factors may go undetected due to inconsistencies between regions.

7. If Transport Canada Civil Aviation Directorate standards are not updated periodically, the standards may not adequately meet the regulatory requirements.

8. If, contrary to the requirements of their safety management system, airport operators do not conduct risk assessments or post-occurrence investigations, the likelihood that effective risk control measures will be put in place is greatly reduced.

9. If the implementation of Transport Canada's oversight policies and procedures is inconsistent, there is a risk that the resulting oversight will be ineffective at ensuring that operators are able to effectively manage the safety of their operations.

10. If the Transport Canada Civil Aviation Directorate's Integrated Management System procedures, such as risk assessments and post-occurrence investigations, are not fully understood and followed as intended, potentially repetitive or widespread hazards may not be identified, preventing risk control measures from being put in place.

9.0 SAFETY ACTION

9.1 Safety action taken

9.1.1 NAV CANADA

After TSB Aviation Investigation Report A17Q0059, which highlighted the issue of clarity and conciseness of NOTAMs, was published on 03 July 2018, NAV CANADA updated its *Canadian NOTAM Procedures Manual*. The new version, published on 31 January 2019, included wording to be used for NOTAMs relating to a runway width reduction. The NOTAM must include the phrase USABLE WIDTH REDUCED TO XXX FT and the word WIDTH can no longer be abbreviated.

In addition, on 10 October 2019, NAV CANADA published another version of the manual, which reflected the transition to the International Civil Aviation Organization (ICAO) NOTAM format. As explained in a frequently asked questions document about the transition to the ICAO NOTAM format,

> [t]he adoption of the ICAO NOTAM format – already used by most countries – will ensure compliance with international standards and will eliminate the need for pilots who fly international routes to be familiar with more than one NOTAM format. It will also pave the way for more advanced filtering functionality, reducing NOTAM clutter by help[ing] pilots access just the NOTAMs pertinent to their flight.[198]

9.1.2 Transportation Safety Board of Canada

On 12 July 2018, the TSB issued Aviation Safety Advisory A18Q0094-D1-A1,[199] addressed to Transport Canada Civil Aviation (TCCA). In this advisory, the TSB alerted TCCA to landings on the closed portion of reduced-width runways at airports where repair and maintenance work was being conducted. The runway markings used during this work did not appear to be convincing, leading flight crews to mistakenly believe that the entire width of the respective runways was available.

In addition, on 05 August 2021, the TSB issued Aviation Safety Advisory A18Q0140-D1-A1,[200] also addressed to TCCA. In this advisory, the TSB made TCCA aware of the absence of

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198 NAV CANADA, NOTAM Transition FAQ [frequently asked questions] document, "Why is NAV CANADA transitioning to the ICAO NOTAM format?", available at https://www.navcanada.ca/en/icao%20notam%20-%20faq_en.pdf (last accessed on 30 November 2021).

199 Transportation Safety Board of Canada, Aviation Safety Advisory A18Q0094-D1-A1: Aircraft landing on the closed portion of reduced-width runways at airports where repair and maintenance work is being conducted (12 July 2018), at https://www.tsb.gc.ca/eng/securite-safety/aviation/2018/a18q0094/a18q0094-d1-a1.html (last accessed on 30 November 2021).

200 Transportation Safety Board of Canada, Aviation Safety Advisory A18Q0140-D1-A1: Absence of standards, recommended practices and guidelines pertaining to the safety of operations at airports under construction (05 August 2021), at https://www.tsb.gc.ca/eng/securite-safety/aviation/2018/a18q0140/a18q0140-d1-a1.html (last accessed on 30 November 2021).

standards, recommended practices, and guidelines for safe operations at airports undergoing construction. As a result, when construction work is being planned and carried out, elements for complying with the applicable regulatory provisions and for implementing effective measures to mitigate the risks related to operations during the construction work are missing.

9.1.3 Transport Canada Civil Aviation

On 30 September 2019, TCCA published Advisory Circular (AC) 302-030,[201] *Adherence to Standard during periods of construction,* in response to the TSB's Aviation Safety Advisory A18Q0094-D1-A1. In this circular, TCCA reminded airport operators to comply with the applicable aerodrome standards and recommended practices and to issue detailed NOTAMs. TCCA also reminded airport operators to ensure that NOTAMs issued for construction work are very clear.

On 16 September 2021, TCCA responded to Aviation Safety Advisory A18Q0140-D1-A1, indicating that regulations and standards in effect, as well as actions already taken in response to Aviation Safety Advisory A18Q0094-D1-A1, were sufficient.

9.2 Safety action required

9.2.1 NOTAM publishing procedures

Further to the investigation of an occurrence that took place in June 2018 when runway rehabilitation work was being carried out at the Baie-Comeau Airport, Quebec, it was discovered that another 14 similar occurrences had taken place at other airports in Quebec and at an airport in Nunavut since 2013. A summary review of these occurrences revealed a particularity in the method used to carry out the construction: the width of the runway was reduced rather than the length.

Considering this a matter of concern, the TSB issued Aviation Safety Advisory A18Q0094-D1-A1, addressed to TCCA, on 12 July 2018. However, when 2 more similar occurrences took place shortly after the advisory was released, the TSB launched this investigation to highlight any systemic underlying causes or contributing factors, and assess the risk they pose.

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201 Transport Canada, Advisory Circular (AC) 302-030: Adherence to Standard during periods of construction, Issue 01 (30 September 2019).

If an airport operator plans to carry out construction activities at their airport, they must communicate the necessary information to pilots, by having a NOTAM[202] issued and possibly having an *AIP Canada (ICAO)* supplement[203] published.

The process to request that a NOTAM be issued is quick and well known by airport operators, as they are regularly required to have NOTAMs issued and have at their disposal the *Canadian NOTAM Operating Procedures Manual*, which describes precisely how to prepare this type of message. Once a NOTAM is written, the airport operator must provide the necessary information to the appropriate NAV CANADA flight information centre or flight service station, which will issue the NOTAM.

Airport operators may also have an *AIP Canada (ICAO)* supplement published. Unlike NOTAMs, supplements may contain graphic images. However, although the *AIP Canada (ICAO)* supplements are published every 28 days, airport operators must provide the information to be published to NAV CANADA at least 49 days in advance. For many airport operators, the deadlines for publishing supplements are not compatible with the unforeseen circumstances that may arise while planning runway rehabilitation.

In the occurrences under review in this investigation, the NOTAMs complied with established procedures, consisting primarily of abbreviations and acronyms, and indicating the condition without, however, clearly stating that the width of the runway was reduced. TSB Aviation Investigation Report A17Q0059 noted that the use of the words "reduced in width" in a NOTAM intended to indicate a reduction in runway width would clearly indicate the condition while reducing the risk of ambiguity, given that a reduction in width is less frequent than a reduction in length. This deficiency has since been corrected in the *Canadian NOTAM Procedures Manual*.

Furthermore, the occurrences under review in this investigation highlighted another deficiency with NOTAMs, that is, the fact that they are limited to text and do not include graphics. The pilots involved in the occurrences under review had consulted the NOTAMs issued for the construction activities and were aware of the reduced runway width. However, when they read the NOTAMs, they were unable to form an accurate mental image of the situation or visualize what the runway undergoing construction would look like. As a result, the mental models and expectations they had regarding airport construction prevailed over the reality, and the pilots were not able to distinguish the closed portion from the open portion of the runway.

All of these elements that detract from the readability and effectiveness of NOTAMs are directly related to human factors. According to ICAO, aeronautical information services

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202 A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations. (Source: NAV CANADA, TERMINAV terminology database).

203 Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual*, effective from 25 March 2021 to 7 October 2021, MAP – Aeronautical Charts and Publications, section 2.2: AIP Canada (ICAO).

should take these factors into consideration, particularly in the design and distribution of aeronautical data and information. Currently, NOTAMs in Canada are only issued in a text format, which limits how clearly a pilot can visualize areas that are closed due to construction.

Consequently, the Board recommends that

> NAV CANADA make available, in a timely manner, graphic depictions of closures and other significant changes related to aerodrome or runway operations to accompany the associated NOTAMs so that the information communicated on these hazards is more easily understood.
>
> **TSB Recommendation A21-01**

9.3 Safety concern

9.3.1 Regulatory surveillance of airports by Transport Canada

Historically, the safety of flight operations was strictly related to regulatory compliance and was based on reactive risk management in response to incidents and accidents. However, it became evident that regulatory requirements alone could not foresee all of the risks associated with a particular activity. It was then that the concept of a safety management system (SMS) was introduced, which was endorsed and recommended by ICAO in 2000.

TCCA then required the implementation of SMS within civil aviation: in 2005 for airlines and approved maintenance organizations, and in 2008 for airports.

TCCA also decided to apply the principles of safety risk management to its own activities by adopting a national safety program, which includes the Integrated Management System (IMS). The purpose of the IMS was to enable TCCA to implement a nationally consistent program that integrates all of its activities, both at Headquarters and in the regions.

Together, aviation industry stakeholders' SMSs and TCCA's internal SMS — the IMS — form the SSP, or State Safety Programme, recommended by ICAO. They were introduced to add a level of safety to safety management and oversight of the aviation industry and to proactively manage risks. IMS and SMS are part of an official regulatory framework: they are described in detail in a number of reference documents; the processes are explained in detail; roles and responsibilities are defined; and a risk management committee was even established to manage the methodology of the risk management process.

These systems were intended to identify the factors and risks that had contributed to the occurrences under review, but they did not meet this goal. The implementation of SMS at airports implied that TCCA would evaluate the systems within a set timeframe. However, TCCA was not able to complete all of the SMS evaluations or follow-ups required to assess the effectiveness of safety management at the airports under review within the required timeframe.

This investigation revealed that TCCA inspectors, who are tasked with traditional regulatory oversight as well as surveillance of airport SMSs, did not have a nationally standardized and up-to-date guide at their disposal to evaluate construction plans, which could hinder the detection of certain risk factors. Furthermore, information gathered during the investigation showed that TCCA's oversight policies and procedures were not being followed consistently, and that some of the key procedures in TCCA's IMS were not fully understood by the inspectors. Consequently, potentially repetitive or widespread hazards may not be identified, preventing risk control measures from being put in place.

Although, given the scope of the investigation, the occurrences reviewed were primarily limited to those identified in Quebec, it is concerning to note that they all resulted from systemic underlying causes or contributing factors that a national safety program should have identified. Inevitably, it begs the question as to whether the situation is the same in other TCCA regions.

The Board is concerned that if TCCA does not provide adequate surveillance of airports in Canada, the risk of an accident related to flight operations at airports increases, particularly when the airports are undergoing construction.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 17 November 2021. It was first released on 15 December 2021.

Correction

The last part of the first sentence of the 5th paragraph and the first sentence of the 6th paragraph of the Executive Summary had been inadvertently deleted in the report first published, and have been restored.

The corrected version of the report was released on 20 January 2022.

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

APPENDICES

Appendix A – Investigation methodology

The investigation was carried out in 4 main stages.

The 1st stage consisted of gathering general information on aerodromes and airports, identifying stakeholders, and reviewing national and international regulations, standards and recommended practices applicable to airports. The regulatory framework and requirements for airport safety management systems (SMS) were reviewed, along with Transport Canada Civil Aviation's (TCCA) integrated risk management framework.

The 2nd stage was dedicated to examining all of the plans of construction operations (PCOs) pertaining to runway rehabilitation (reductions in either length or width) submitted by airport operators in Quebec and Nunavut since 2006. The year 2006 was chosen to cover the periods before and after the mandatory implementation of airport SMSs, and to cover runway rehabilitations with and without a reduced width. For each PCO examined, the following elements were gathered and analyzed:

- the steps taken and procedures followed by the airport operators when preparing PCOs;
- the PCO evaluation and approval process used by TCCA;
- safety surveillance carried out by the airport operator during construction;
- TCCA oversight during construction;
- compliance with national and international standards and recommended practices;
- compliance with the *Canadian Aviation Regulations* (CARs);
- TCCA's use of risk management principles;
- the strength of the SMSs airport certificate holders used when preparing the PCOs;
- incidents/accidents reported to the TSB during runway rehabilitation.

During the 3rd stage, the incidents/accidents reported to the TSB during runway rehabilitation projects involving a reduction in length or width since 2006 were gathered and analyzed, highlighting the following elements:

- risk control measures put in place for the construction;
- SMS reports filed after the incidents/accidents;
- analysis of the incidents/accidents carried out by the airport operator as part of its SMS;
- corrective action taken by the airport operator as part of its SMS;
- follow-up carried out by the airport operator as part of its SMS.

In addition, in cases where the runway width was reduced, the following elements were gathered and analyzed:

- actions required by a pilot when planning for and conducting a flight, and the impact of these actions on the safety of a flight to an airport where the landing runway is reduced in width;
- pilots' expectations when planning to land on a reduced-width runway;
- human performance as a contributing factor to an incident/accident.

Given that information gathered during this stage revealed that this construction method had been used in the United States, a search was conducted in the U.S. National Transportation Safety Board (NTSB) report database to determine whether any incidents/accidents had occurred on runways that had been reduced in width during construction and had been the subject of an investigation. The fact that no incidents were found in this search drew the attention of the TSB, which then further studied the situation in the United States to try to identify what might account for this difference in results.

The 4th and final stage consisted of analyzing all the information gathered during the previous 3 stages to identify the various factors that had contributed to the occurrences, along with any safety deficiencies, and to propose solutions and make recommendations.

Appendix B – Occurrences under review

Occurrence no.	Class	Date	Description of the occurrence	Visibility/ Precipitation	Day or night
A13Q0160	5	2013-09-14	• Iqaluit (CYFB), Boeing 767-200, commercial air service – airline operations • Aircraft landed and taxied on closed portion of runway • Aircraft hit 6 temporary runway lights • Slight cuts to 2 tires	10 SM/None	Day
A15Q0103	5	2015-07-08	• Iqaluit (CYFB), Boeing 737-200, commercial air service – airline operations • Lateral deviation during landing • Aircraft hit a few temporary runway lights • Minor damage to 1 tire	30 SM/None	Day
A15Q0097	5	2015-07-11	• Iqaluit (CYFB), Boeing 737-200, commercial air service – airline operations • Aircraft landed and taxied on closed portion of runway • Aircraft hit a few temporary runway edge lights • Damage to fairing at intake to air cycle installation	15 SM/None	Day
N/A	N/A	2015-08-11	• Schefferville (CYKL) • No information (occurrence not reported) • Tire traces in the gravel on the closed portion of the runway	Unknown/ Unknown	Unknown
A16Q0121	5	2016-09-27	• Montréal/St-Hubert (CYHU), Hawker 900XP, U.S. private operator • Landing excursion • No damage	7 SM/None	Night
A16Q0130	5	2016-10-17	• Montréal/St-Hubert (CYHU), Hawker 800XP, U.S. private operator • Alignment on temporary runway edge lights and take-off roll began on the edge of the runway • Takeoff aborted • Aircraft hit 5 temporary runway edge lights • Flat tire	9 SM/None	Night
A16Q0132	5	2016-10-19	• Montréal/St-Hubert (CYHU), Piaggio P180 Avanti II, private operator • Problem with propeller, feathered in flight • Emergency declared and emergency landing • Runway overrun • No damage	9 SM/None	Day
A16Q0143	5	2016-11-08	• Montréal/St-Hubert (CYHU), Hawker 800XP, U.S. commercial air service • Aircraft hit a temporary runway edge light on takeoff • Damage to aircraft unknown	9 SM/None	Day
A17Q0127	5	2017-05-04	• Montréal/St-Hubert (CYHU), Piper PA31, commercial air service – aerial work • Aircraft hit temporary runway edge lights during landing • No damage	9 SM/None	Day

A17Q0059	3	2017-05-15	• Montréal/St-Hubert (CYHU), Bombardier Global Express, U.S. commercial air service • Aircraft hit temporary runway edge lights during landing • Major damage to the landing flap and engine fairing and blown tire	9 SM/None	Day
A17Q0079	5	2017-06-07	• Montréal/St-Hubert (CYHU), Cessna C650, U.S. private operator • Landing on Taxiway Charlie • No damage	9 SM/None	Day
A17Q0153	5	2017-10-01	• Montréal/St-Hubert (CYHU), Cessna 172R, general aviation • Landing on closed side of runway • No damage	9 SM/None	Day
A18Q0093	5	2018-06-21	• Baie-Comeau (CYBC), Cessna R182, commercial air service – aerial work • Aircraft landed on closed side of Runway 28 • No damage	9 SM/None	Day
AOR-234116-1	N/A	2018-06-21	• Baie-Comeau (CYBC), Bombardier DHC8-3, commercial air service – airline operations • Difficulty identifying open portion of runway • Go-around • No damage	9 SM/None	Day
A18Q0094	5	2018-06-24	• Baie-Comeau (CYBC), Bombardier DHC8-3, commercial air service – airline operations • Aircraft hit temporary runway edge lights during landing • No damage	9 SM/None	Day
A18Q0108	5	2018-07-09	• Baie-Comeau (CYBC), Cessna Citation 680A, U.S. commercial air service • Aircraft hit temporary runway edge lights during landing • Flat tire	7 SM/Rain	Day
A18Q0116	5	2018-07-22	• Baie-Comeau (CYBC), Cessna 182, general aviation • Aircraft landed on closed side of runway • No damage	9 SM/None	Day
AOR-237394	N/A	2018-08-19	• Baie-Comeau (CYBC), Bombardier DHC8A, commercial air service – airline operations • Difficulty identifying open portion of runway • Go-around • No damage	9 SM/None	Day

Source: TSB Aviation Safety Information System

Appendix C – Examples of NOTAMs issued to inform pilots of a reduced-width runway during construction at the 4 airports under review

Examples of NOTAMs used at the Iqaluit Airport (CYFB)

150145 CYFB EAST 100 FT RWY 16/34 FULL LEN CLSD DUE RESURFACING
1507080045 TIL 1507211115

150153 CYFB FIRST 3605 FT RWY 34 CLSD. AVBL WID 100 FT.
THR 34 IS RELOCATED 3605 FT.
DECLARED DIST:
RWY 16: TORA 5000 TODA 5000 ASDA 5000 LDA 5000
RWY 34: TORA 5000 TODA 5984 ASDA 5000 LDA 5000
TUE 0130-1115
WED 0045-1130
THU 0030-1115
FRI 0045-1145
SAT 0015-1245
SUN MON 0005-1145
1507080045 TIL 1507141115

Examples of NOTAMs used at the Montréal/St-Hubert Airport (CYHU)

160466 CYHU RWY 06L/24R WID REDUCED TO 100 FT
AVBL FOR ACFT WITH WINGSPAN GREATER THAN 78 FT 72 HR PN
1611031854 TIL APRX 1612071900

170483 CYHU 75 FT SOUTH SIDE RWY 06L/24R FULL LEN CLSD.
AVBL AS TWY BTN TWY M, R AND J.
NORTH SIDE AVBL ACFT WINGSPAN GREATER 78 FT WITH 48 HR PN.
AUG 24 1912-2230
AUG 25-OCT 24:
MON-SAT 1000-0100
SUN 1000-0000
1708241912 TIL 1710240100

Example of the NOTAM used at the Baie-Comeau Airport (CYBC)

180288 CYBC SOUTH 75 FT RWY 10/28 FULL LEN CLSD DUE RESURFACING.
NORTH 75 FT AVBL ACFT MAX WINGSPAN 78 FT AND REF LDG SPEED BLW 123 KT.
NORTH 75 FT AVBL 48 HR PN TEL 418-445-0566 FOR ACFT WINGSPAN BTN 79 FT AND 118 FT AND OUTER MAIN GEAR SPAN BTN 20 FT AND 30 FT.
FOR ACFT WINGSPAN LESS THAN 79 FT AND OUTER GEAR SPAN LESS THAN 20 FT, 2 HR PN
1807031609 TIL APRX 1807182300

Example of the NOTAM used at the Schefferville Airport (CYKL)

150042 CYKL EAST 75 FT RWY 18/36 CLSD DUE CONST.
NON-STANDARD MARKING, NON-STANDARD LIGHTING.
1230-1930 DLY
1507251230 TIL APRX 1508091930