

Transportation Safety Board
of Canada



Bureau de la sécurité des transports
du Canada

**RAILWAY INVESTIGATION REPORT
R13W0124**



SUBGRADE COLLAPSE AND DERAILMENT

**VIA RAIL CANADA INC.
TRAIN P69341-28
MILE 83.55 TOGO SUBDIVISION
TOGO, SASKATCHEWAN
28 APRIL 2013**

Canada

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

Railway Investigation Report R13W0124

Subgrade collapse and derailment

VIA Rail Canada Inc.
Train P69341-28
Mile 83.55 Togo Subdivision
Togo, Saskatchewan

28 April 2013

Summary

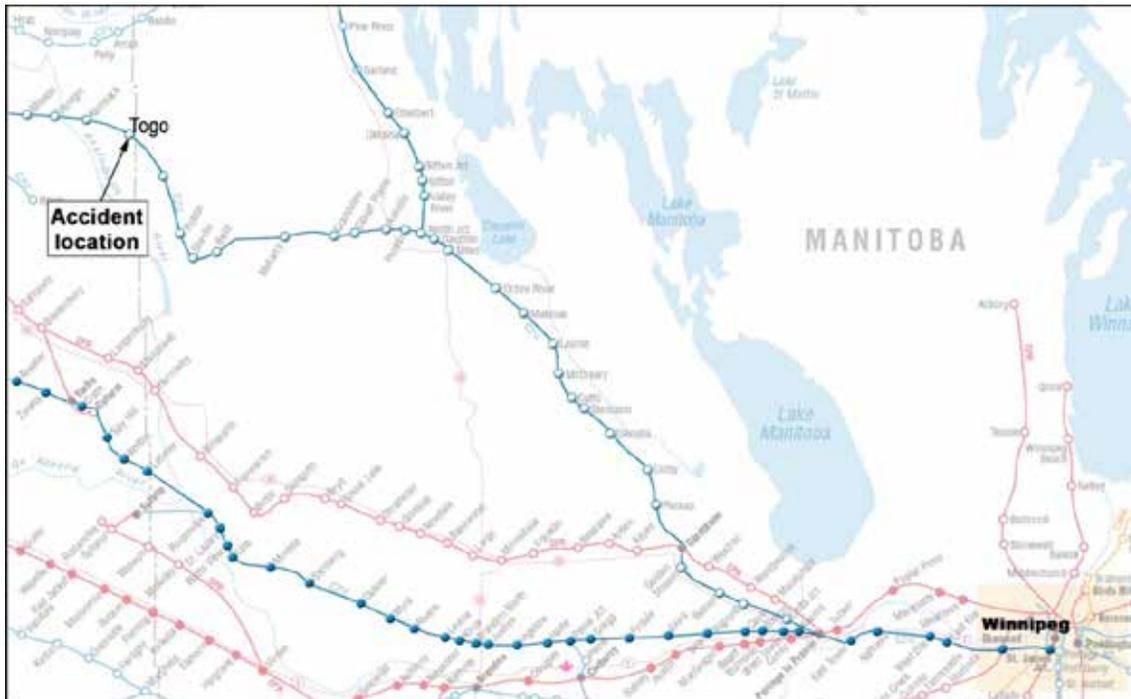
On 28 April 2013, at approximately 1840 Central Standard Time, VIA Rail northward passenger train No. P69341-28 encountered a roadbed slump at Mile 83.55 of the Canadian National Railway Togo Subdivision, near Togo, Saskatchewan. The two locomotives and the two leading cars derailed. The fuel tanks on both locomotives ruptured, leaking diesel fuel that ignited and burned until it dissipated into the subgrade material. There were no injuries.

Ce rapport est également disponible en français.

Factual information

On 28 April 2013, VIA Rail Canada Inc. (VIA) passenger train No. 69341-28 (the train) was proceeding northward from Winnipeg to Churchill, Manitoba, on Canadian National Railway's (CN's) Togo Subdivision (Figure 1). The train consisted of two locomotives (VIA 6405 and VIA 6458), one baggage car and four passenger coaches. The train was operated by two locomotive engineers (the crew) and was transporting two on-board VIA service personnel, one VIA mechanic, and seven passengers. The crew members were qualified for their positions, were familiar with the territory, and met regulatory rest requirements.

Figure 1. Accident location (Source: *Canadian Rail Atlas*, Railway Association of Canada)



The accident

At approximately 1840,¹ the train was proceeding westward at 38 mph on a raised portion of track near Mile 83.55 when the crew observed a 10-foot portion of track just ahead where ballast was missing. The crew placed the train into emergency, but could not stop before traversing the roadbed slump. The embankment further collapsed beneath the train as the train passed over this location, and the two locomotives, a baggage car and the first passenger car derailed upright.

The passenger car came to rest straddling the gap that had opened up under the train (Photo 1). The fuel tanks on both locomotives ruptured in the area of the trailing end plates, due to contact with the rails, and the leaking fuel ignited. Both locomotives caught fire and sustained

¹ All times are Central Standard Time.

significant damage (Photos 2 and Photo 3). All VIA personnel and passengers on board were safely evacuated, and there were no injuries.

Photo 1. A passenger car straddles an embankment after the train encountered a roadbed slump that subsequently collapsed.



Photo 2. Locomotive VIA 6405, showing damage from the accident fire



Photo 3. Locomotive VIA 6458, showing damage from the accident fire



Weather

At the time of the accident, the temperature was about 5°C, and there was a 30-km/h wind from the northwest. In the five days prior to the accident, rapid snowmelt had depleted much of the 50 cm of snowpack in the vicinity of the accident.

As recorded by Environment Canada, the maximum daily temperatures for nearby Roblin, Manitoba, were the following:

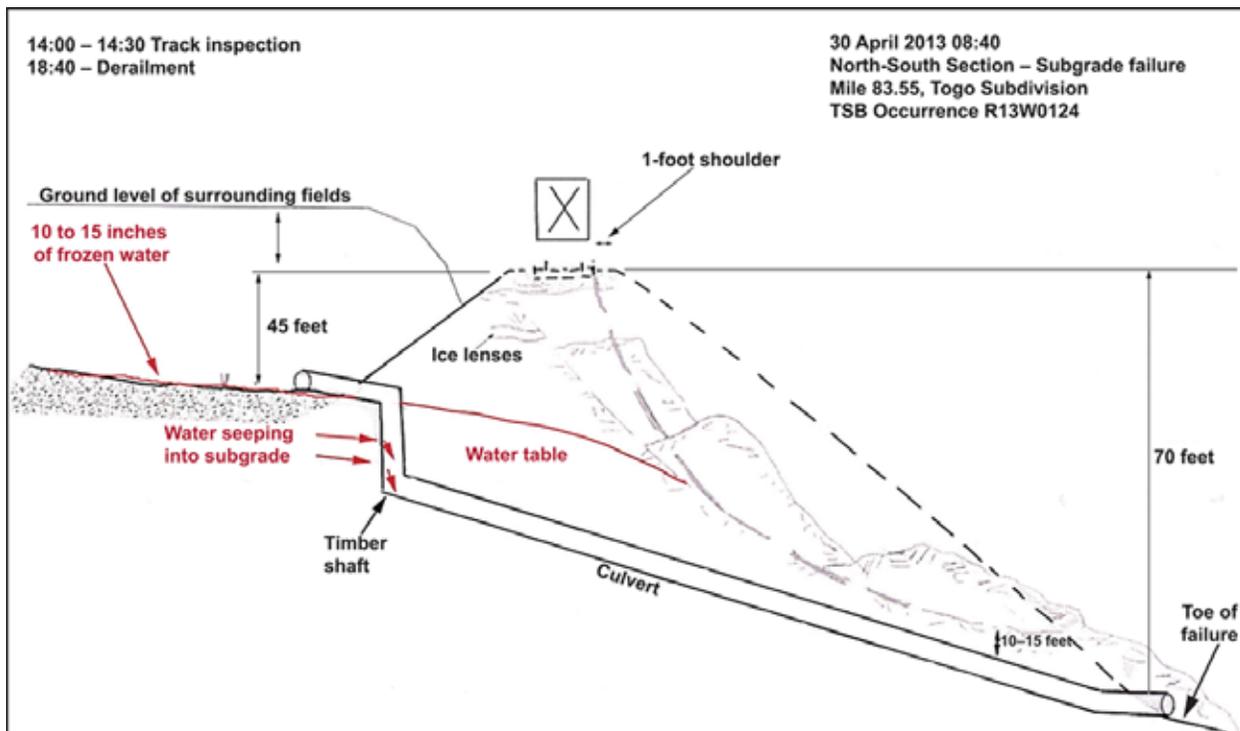
Date	Temperature
24 April 2013	0.1°C
25 April 2013	2.3°C
26 April 2013	7.9°C
27 April 2013	13.1°C
28 April 2013	6.1°C

Site examination

The roadbed slump and subsequent embankment collapse occurred in a 2.17° left-hand curve on a 0.5% descending grade. An approximately 60-foot-wide section of the embankment that spanned a small ravine had failed. The toe of the failure was near the outlet of a 48-inch culvert that was designed to provide drainage from the north side of the track to the south side.

The culvert through the grade at Mile 83.55 was a compound² design. On the north side, a 48-inch corrugated steel inlet pipe connected with a square, metal-lined timber vertical shaft about 45 feet deep that acted as a manhole and connected to the outlet pipe below (Figure 2).

Figure 2. Cross-section detailing culvert, raised track, and slope failure (Source: Canadian National Railway [CN], amended and annotated by TSB)



² Compound culverts use a combination of culvert sections, which may include a vertical portion, in order to accommodate a significant drop in elevation while still controlling water flow velocity at each end of the culvert.

Photo 4. Ice blocking culvert outlet



Site examination shortly after the accident determined the following:

- The culvert was not displaced by the landslide.
- The culvert outlet was plugged with ice (Photo 4), which prevented drainage, allowing water to accumulate in the upslope ditch.
- The crown of the timber cribbing had partially collapsed, and the metal sides were bulged inward, exposing saturated, sandy soil above the drop structure.
- The north face of the embankment was covered with phreatophyte vegetation,³ which thrives in areas where the soil is saturated or in groundwater discharge areas.
- The embankment was saturated, and water was leaking into the timber vertical shaft structure due to excess pore water pressure⁴ in the outside soil.
- Water was spurting out from rivet holes in the culvert due to excess pressure in the barrel of the pipe.
- Ice lenses were present in the exposed face of the landslide.
- Slump blocks due to a retrogressive landslide⁵ were present throughout the landslide. The minimal back-tilting of the slump blocks indicated mainly translational downward movement.

³ Phreatophyte vegetation refers to plants that grow where the water table is shallow and near the surface.

⁴ Pore water pressure refers to the pressure of groundwater held within a soil in gaps between the particles.

⁵ The failure surface extends or propagates in the direction opposite to the movement of the displaced material.

- The toe of the slide was located above the culvert, at the top of a weak clay layer that formed a natural barrier to water penetration. Failed material spilled out and ran beyond the toe of the embankment and over the culvert, which was not displaced by the slide.
- Additional water seepage was observed at various locations within the landslide along the toe of the embankment and on the west side of the culvert outlet.

Subdivision and track information

The train operates twice weekly to Churchill, Manitoba, departing Winnipeg on Tuesdays and Sundays.

Rail traffic on the Togo Subdivision is operated under the Occupancy Control System, as authorized by the Canadian Rail Operating Rules (CROR), and supervised by a rail traffic controller in Edmonton, Alberta. In the vicinity of the accident, the maximum speed for freight trains and passenger trains is 35 mph and 40 mph respectively. According to the Transport Canada-approved *Track Safety Rules*, the track is designated as Class 3.

The rail was 115-pound continuous welded rail (CWR) laid on 14-inch double-shoulder tie plates secured to softwood ties with five spikes per plate. The ballast was a mixture of gravel and rock, about 12 inches deep with one-foot-wide shoulders. The track was generally in good condition.

Track inspections were being conducted in advance of each train during the spring thaw period. On the day of the accident, the track was inspected by hi-rail between 1400 and 1430, with no anomalies observed. A track geometry test had been conducted on 11 April 2013, and rail flaw ultrasonic testing had been performed on 26 March 2013 and 26 April 2013. In all cases, no defects were detected.

The most recent track maintenance work performed in the area was the replacement of a broken compromise rail joint on 07 March 2013.

Drainage

Surface drainage is controlled by topography and is directed via valley tributaries toward the meltwater channel. Surface drainage is concentrated in these tributaries, and the water flow is conducted across the railway right-of-way through culverts installed in these low areas.

In the vicinity of the accident, the track traverses a number of cut and fill sections near the rim of the valley wall. This valley was a glacial meltwater channel that had formed during the last glacial retreat approximately 12 000 years ago. The fill sections span natural drainage courses that extend from the plain to the north to the valley below track level.

The railway subgrade across the ravine was originally built using local fill materials (i.e., mostly permeable sand and gravel) laid on top of the natural ground material. The area between Mile 84 and Mile 88 has a history of instability, which includes upper and lower slope failure,

subsidence and sinkholes.⁶ However, there was no record of slope instability at the accident location (Mile 83.55) prior to the accident.

Culvert inspection system at Canadian National Railway

CN's Bridge Condition System (BCS) is used to manage inspection information for bridges, culverts and other structures (e.g., tunnels, sheds, retaining walls, etc.). The BCS resides in two separate databases (SAP⁷ and Lotus Notes), which share information to generate BCS inspection forms.

The SAP system maintains inspection information on the Engineering Plant Inventory (EPI). EPI information is used in BCS to determine which inspection forms are to be used in the inspection of a particular bridge, culvert, or other structure. Lotus Notes generates the appropriate inspection form, which is filled in by the inspector and reviewed by the planning and inspection engineer.

The BCS culvert inspection form is used to verify inventory information and to report on the current condition. For each culvert component or feature, such as culvert portals (headwall, wing wall), rip rap, erosion, scour, debris/blockage, embankment, vegetation, roof, walls, floor, circumferential joints, and longitudinal joints, a score or ranking is assigned during the inspection (Appendix A).

At CN, culverts undergo detailed inspections every five years. During the 2003 inspection, the occurrence culvert was rated as being in good condition. A review of the 2008 inspection form for this culvert revealed that:

- the inspection did not mention the compound design; and
- the pipe, erosion, scour, roof, walls, circumferential and longitudinal joints, and embankment were rated as "7", meaning that no repairs were required in the foreseeable future.

The accident occurred before the 2013 culvert inspection was to be performed.

Ground hazard training

CN and Canadian Pacific Railway have developed a ground hazard training program for maintenance-of-way and operating personnel to identify warning signs for natural ground hazards, such as rock falls, slides, and washouts. The training focuses on geotechnical issues, such as rockslides and unstable backslopes, as well as drainage conditions, stability of shoulders and embankments, and roadbed subsidence.

⁶ A sinkhole is a depression in the ground due to undermining of the surface, usually by water.

⁷ SAP AG is a German multinational software corporation that makes enterprise SAP software to manage business operations and customer relations.

The CN track inspectors responsible for this location had not received any significant training in ground hazards. Training that focused on geotechnical issues, including drainage conditions, had not been given to all employees tasked with carrying out inspections.

Geotechnical examination

CN retained a geotechnical consultant to conduct an examination into the subgrade failure. This field examination was undertaken approximately two months after the accident, to characterize the site stratigraphy and groundwater conditions. Six boreholes, each instrumented with piezometers⁸ were drilled to examine how the soil layers of the uplands area related to the fill. In particular, an assessment was conducted to determine whether the upland groundwater was flowing into the railway embankment at Mile 83.55 and, for comparison purposes, at Mile 83.40. Data from the boreholes were also used to characterize the fill and the foundation under the railway embankment.

The following was determined:

- The embankment at Mile 83.40 had high shear strength and was not prone to failure if adequate drainage was maintained.
- Boreholes in the valley wall at Mile 83.55 identified that mixed sands, silts, and clays extended to a depth of 30.5 meters.
- Piezometer readings, measured water levels and spring elevations, along with seepage analyses, indicated that the water table was mounded and estimated to be elevated to about half the embankment height.
- At Mile 83.55, a “ballast pocket”⁹ was likely present, creating a perched water table within the track embankment leading to saturation of the fill and formation of the observed ice lenses.
- The frozen culvert was blocking surface drainage, resulting in ponding in the upslope ditch, as well as excess hydraulic head in the culvert barrel and the timber vertical shaft structure.
- The excess head on the leaking drop structure and culvert rivet holes resulted in an elevated piezometric surface in the embankment.
- A rapid melt of the snowpack beginning approximately one week before the derailment resulted in a rapid increase in groundwater levels.
- A weak clay base layer rising to an elevation approximately equal to the pipe crown elevation, and upward into the embankment, formed the base of the landslide.

⁸ A device used to measure static groundwater pressure. A pressure gauge (transducer) can be vibrating-wire, pneumatic, or strain-gauge in operation, converting pressure into an electrical signal.

⁹ A ballast pocket is a lens of free-draining granular material within the track embankment.

Locomotive fuel-tank crashworthiness requirements

In 1997, Transport Canada (TC) approved the initial *Railway Locomotive Inspection and Safety Rules* (called also the *Locomotive Safety Rules*). These rules outlined the minimum criteria for locomotive design and crashworthiness, including improved construction standards for fuel tanks on *new* locomotives. Part II, Section 19.1 of the rules stated (in part):

Fuel tanks, on new locomotives purchased subsequent to the approval of this rule, are to be of high impact resistant design which meet or exceed current Association of American Railroads (AAR) Manual of Standards and Recommended Practices (MSRP) Recommended Practice-506 (RP-506).¹⁰

RP-506 was later implemented as AAR MSRP Standard S-5506, entitled Performance Requirements For Diesel Electric Locomotive Fuel Tanks (S-5506). S-5506 details the crashworthiness performance requirements for locomotive fuel tanks and states (in part):

- The minimum thickness of the sides, bottom sheet, and end plates of the fuel tank shall be equivalent to 5/16-in. steel plate at 25,000 psi yield strength (where the thickness varies inversely with the square root of yield strength).
- The lower 1/3 of the end plates shall have the equivalent penetration resistance by the above method of 3/4-in. steel plate at 25,000 psi yield strength. This may be accomplished by any combination of materials or other mechanical protection.¹¹

In January 2006, the *Locomotive Safety Rules* were modified to include the requirements for S-5506 for *new* locomotives. This inclusion remained unchanged in the version of the rules dated February 2010.

Locomotives VIA 6405 and VIA 6458

Both VIA 6405 and VIA 6458 were 4-axle, 3000-horsepower diesel-electric locomotives built for passenger service in 1989, as part of a fleet of 53 General Motors (GM) F40PH-2D locomotives manufactured for VIA between 1986 and 1990. These VIA locomotives were originally built in accordance with the standard in place during the 1980s, which had no specific requirements for the crashworthiness performance of locomotive fuel tanks.

In 2007, VIA contracted CAD Industries in Montreal, Quebec, and commenced a rebuild program for the GM F40PH-2D fleet, during which each locomotive was stripped down to its frame and rebuilt from top to bottom. The locomotives were rebuilt with technical upgrades for improved operating efficiencies, and a new crashworthy locomotive event recorder (LER) was installed. However, similar to the findings of a previous TSB investigation (R12T0038), in which

¹⁰ Transport Canada, TC O 0-112: *Railway Locomotive Inspection and Safety Rules* (revised 04 February 2010), Part II, Section 19.1

¹¹ Association of American Railroads (AAR) *Manual of Standards and Recommended Practices* (MSRP), Standard S-5506: Performance Requirements For Diesel Electric Locomotive Fuel Tanks (S-5506), Subsection 4.1: Design Considerations

the fuel tank of rebuilt VIA locomotive 6444 was ruptured and released diesel fuel, no upgrade was made to include new crashworthy fuel tanks that met the S-5506 criteria.

Samples of the ruptured fuel tanks for VIA 6405 and VIA 6458 were sent to the TSB Laboratory for examination. The examination determined the following:

- The thickness of the bottom sheet of the fuel tanks was about 3/16 inches (in steel), while the lower third of the end plates measured about 5/16 inches thick—below the S-5506 requirements of 5/16 inches and 3/4 inches, respectively.
- The measured thickness and estimated yield strength results were significantly lower than the minimum S-5506 requirements.

Outstanding recommendation on locomotive crashworthiness

As outlined in TSB's investigation into the Burlington derailment (R12T0038), VIA's GM F40PH-2D locomotives were originally built prior to the establishment of crashworthiness standards and the *Locomotive Safety Rules*. Because the *Locomotive Safety Rules* only apply to new locomotives, there was no regulatory requirement for VIA to rebuild the locomotives in accordance with current crashworthiness standards. Despite opportunities to upgrade the cab structure, fuel tank, and truck securement during the rebuild program, the locomotives were rebuilt in accordance with the minimum requirements of the *Locomotive Safety Rules*.

The absence of a regulatory requirement to upgrade locomotive crashworthiness during a major rebuild increased the risk that the rebuilt locomotives would be susceptible to cab structural failure, fuel-tank failure, and truck securement failure during derailments, each of which occurred during the Burlington accident. Therefore, the Board recommended that

The Department of Transport require that crashworthiness standards for new locomotives also apply to rebuilt passenger and freight locomotives.

TSB Recommendation R13-03

In September 2013, TC responded that it accepts the recommendation and that it is planning to initiate a rule-making process to mitigate this deficiency. In April 2014, the Board reassessed TC's response to Recommendation R13-03 as having Satisfactory Intent.

Analysis

The train was operated in accordance with company and regulatory requirements. The mechanical condition of the rolling stock did not contribute to the accident. The analysis will focus on track and culvert inspection, drainage, and slope instability in the vicinity of the accident, and on the crashworthiness of locomotive fuel tanks.

The accident

The crew observed a 10-foot portion of ballast missing under the track, just ahead of the train near Mile 83.55, and placed the train into emergency. Although immediate action was initiated, the range of vision available to the crew did not allow sufficient time to stop the train before reaching the affected area. As the train traversed the unsupported portion of track, the embankment collapsed further beneath the weight of the train, leading to the derailment.

Geotechnical examination

Groundwater was an important factor leading to the landslide. Understanding the prevailing groundwater conditions at the time of the landslide is key to analyzing the subgrade collapse. Moreover, examination of the materials used to construct the embankment at Mile 83.40 revealed that the embankment had high shear strength and was not prone to failure if adequate drainage was maintained.

The embankment collapse occurred due to water saturation and the build-up of pore pressure in moisture-sensitive fills, which resulted from a rapid snowmelt and inadequate water drainage due to the ice plug at the culvert outlet. The frozen culvert had blocked surface drainage and had caused ponding in the upslope ditch. This ponding in turn resulted in excess hydraulic head forming in the culvert barrel and drop structure. The excess head on the leaking drop structure and culvert rivet holes resulted in an elevated piezometric surface condition in the embankment, making it more susceptible to failure. The combination of all factors listed in the geotechnical study caused the landslide.

Track and culvert inspections

At Canadian National Railway (CN), culverts normally undergo detailed inspections every five years. The most recent (2008) inspection did not mention the compound design, and it indicated that no repairs were required in the foreseeable future. The accident occurred before the 2013 culvert inspection was performed.

The track had been inspected about four and a one half before the landslide. At that time, there were no obvious indications of the impending embankment failure. The initial roadbed slump likely occurred sometime between the inspection and the arrival of the train.

The culvert/vertical shaft drainage system was of unique design. Most of the culvert system was underground and not visible from track level during routine track inspections. However, there were other indications of underlying problems. The rapid warm-up and snowmelt in the previous five days had resulted in ponding in the upslope ditch. The ice-blocked culvert outlet

was another indicator, but it was only visible if track inspectors stopped and climbed down the bank to the outlet. In this occurrence, the routine track inspections did not identify the blocked drainage system.

The CN track inspectors had not received any significant training in identifying precursor ground conditions. Training that focused on geotechnical issues, including drainage, had not been given to all employees tasked with carrying out inspections. Without regular training in identifying precursor ground hazards, such as inadequate drainage, track inspectors may not detect unstable ground conditions in a timely manner, increasing the risk of a derailment.

Locomotive fuel-tank crashworthiness

The fuel tanks on both VIA Rail locomotives ruptured when they came into contact with the rail during the derailment and supported the weight of the locomotives. This event resulted in a diesel fuel-fed fire that damaged both locomotives. The fuel tanks' ruptures occurred in areas that would have required reinforcement to meet S-5506 fuel-tank crashworthiness criteria. These locomotives had been rebuilt as part of VIA's locomotive rebuild program initiated in 2007. However, upgraded locomotive fuel tanks were not part of this program.

During a locomotive rebuild program, nothing precludes a company from upgrading fuel tanks to reduce risk of rupture during accidents. Despite opportunities to make these improvements, the VIA locomotive rebuild was carried out in accordance with the minimum requirements of the *Locomotive Safety Rules*. Since the locomotives were built prior to the establishment of locomotive fuel-tank crashworthiness standards, and since the *Locomotive Safety Rules* only apply to new locomotives, there was no regulatory requirement to upgrade the locomotive fuel tanks during the VIA Rail locomotive rebuild program. If locomotives are not required to be rebuilt in accordance with the latest crashworthiness standards, there is an increased risk of fuel-tank failure during derailments.

Findings

Findings as to causes and contributing factors

1. As the train passed over the unsupported portion of track, the embankment collapsed further beneath the weight of the train, leading to the derailment.
2. The embankment collapse occurred due to water saturation and build-up of pore pressure in moisture-sensitive fills, which resulted from a rapid snowmelt and inadequate water drainage due to the formation of an ice plug at the culvert outlet.
3. The frozen culvert had blocked surface drainage and had caused ponding in the upslope ditch, which resulted in excess hydraulic head in the culvert barrel and drop structure.
4. The excess head on the leaking drop structure and culvert rivet holes resulted in an elevated piezometric surface condition in the embankment, making it more susceptible to failure.
5. The routine track inspections did not identify the blocked drainage system.

Findings as to risk

1. Without regular training in identifying precursor ground hazards, such as inadequate drainage, track inspectors may not detect unstable ground conditions in a timely manner, increasing the risk of a derailment.
2. If locomotives are not required to be rebuilt in accordance with the latest crashworthiness standards, there is an increased risk of fuel-tank failure during derailments.

Other findings

1. The embankment at Mile 83.40 had high shear strength and was not prone to failure if adequate drainage was maintained.

Safety action

Safety action taken

Transportation Safety Board of Canada

On 22 July 2013, the Transportation Safety Board issued Rail Safety Advisory letter (RSA) 10/13 to Transport Canada (TC). The RSA outlined the risk of fuel-tank rupture/puncture and of release of diesel fuel during collisions and derailments, and it suggested that TC may wish to review the *Locomotive Safety Rules* to ensure that there are clear, consistent fuel-tank crashworthiness criteria for both new and rebuilt locomotives.

Transport Canada

On 21 August 2013, TC responded that TC Rail Safety was following up with the Railway Association of Canada (RAC) and its member railway companies to request them to file revised rules by March 2014. This action is intended to ensure that the Association of American Railways (AAR) fuel-tank standards apply not only to new locomotives, but also to remanufactured passenger and freight locomotives.

Canadian National Railway

Canadian National Railway (CN) produced a video on spring readiness inspections. Two supporting documents were produced, providing additional information specific to signs of potential track embankment instability as it pertains to differential water head, seepage under tracks, and rapid drawdown conditions. The material was provided to all track inspectors and supervisors as a refresher.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 21 May 2014. It was officially released on 11 June 2014.

Visit the Transportation Safety Board's website (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

Appendices

Appendix A: Culvert inspection ranking

Ranking		Commentary
9	Very good	New condition. No repairs in the foreseeable future.
8		Almost new condition. No repairs in the foreseeable future.
7	Good	Could be upgraded to new condition with very little effort.
6		Generally good condition. Functioning as designed with no signs of distress or deterioration.
5	Adequate	Acceptable condition and functioning as intended. No repairs necessary at this time.
4		Below minimum accepted condition. Low priority for repairs.
3	Poor	Presence of distress or deterioration. Not functioning as intended. Medium priority for replacement, repair or restriction.
2		May require continued observation until work is completed. High priority for replacement, repair or restriction.
1	Immediate action	Danger of collapse and/or danger to users. Track closure, replacement, repair and/or restriction required as soon as possible.
N	Not accessible	Not accessible for inspection or not seen during the current inspection.
X	Not applicable	

Source: Canadian National Railway (CN)