Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

RAILWAY INVESTIGATION REPORT
R15V0003

MAIN-TRACK TRAIN DERAILMENT
CANADIAN PACIFIC RAILWAY
FREIGHT TRAIN 199-10
MILE 76.7, MOUNTAIN SUBDIVISION
STONEY CREEK, BRITISH COLUMBIA
13 JANUARY 2015

Canada

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Cat. No. TU3-6/15-0003E-PDF
ISBN 978-0-660-05749-1

This report is available on the website of the
Transportation Safety Board of Canada at www.tsb.gc.ca

Le présent rapport est également disponible en français.

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 R15V0003

Main-track train derailment
Canadian Pacific Railway
Freight Train 199-10
Mile 76.7, Mountain Subdivision
Stoney Creek, British Columbia
13 January 2015

Summary

On 13 January 2015, at approximately 0530 Pacific Standard Time, Canadian Pacific Railway freight train 199-10, travelling westward on the north main track of the Mountain Subdivision, derailed 6 empty platforms (a single platform intermodal flat car and all platforms from a 5-platform intermodal flat car) near Stoney Creek, British Columbia. The derailment occurred on the Stoney Creek Bridge (Mile 76.7). There were no injuries, and no dangerous goods were involved.

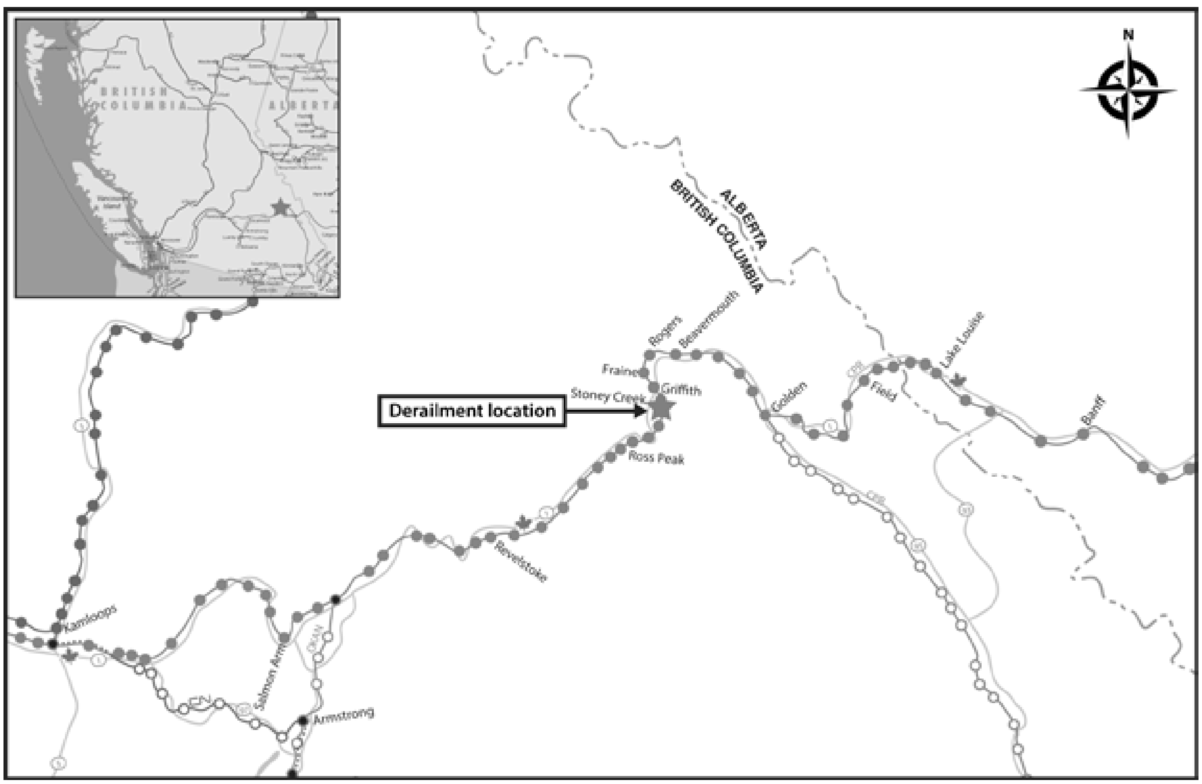
Le présent rapport est également disponible en français.

Factual information

On 13 January 2015, Canadian Pacific Railway (CP) Train 199-10 (train 199), originating in Field, British Columbia, was travelling westward on the Mountain Subdivision, destined for Vancouver, British Columbia. The train consisted of 3 head-end locomotives and 43 cars (20 loaded cars and 23 empty cars, totalling 111 platforms[1]). The train weighed about 4775 tons and was 6812 feet long.

The crew comprised a locomotive engineer and a conductor. The crew members were familiar with the subdivision, met fitness and rest standards, and were qualified for their respective positions.

Figure 1. Map of derailment location (Source: Railway Association of Canada, *Canadian Railway Atlas*, with TSB annotations)



The accident

The train departed Field at approximately 0005.[2] The crew was scheduled to operate the train from Field to Revelstoke, British Columbia (Figure 1). The train refuelled in Golden, British Columbia, and departed at 0140.

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1 An intermodal flat car can consist of a single platform (that is, one car body) or multiple platforms connected with articulating couplings. Each car is considered as a single car regardless of the number of connected platforms.

2 All times are Pacific Standard Time.

During discussions with the rail traffic controller (RTC) in Calgary, Alberta, it was decided that train 867 would proceed ahead of train 199 through the Mount Macdonald Tunnel, given that the crew of train 867 were running over their permissible hours of work. Train 199 would then have to wait another 3 hours before entering the Mount Macdonald Tunnel. Because of the length of the Mount Macdonald Tunnel, approximately 50 minutes is required for each train to traverse the tunnel and for the tunnel to be purged of exhaust before the next train can proceed through it.

At approximately 0300, recognizing the extent of the delays, the RTC contacted train 199 to discuss a possible routing change due to train congestion. During these discussions, the crew indicated that they were “close to the tonnage” limit, but that they were agreeable to a routing change. The RTC then obtained permission from the director of rail traffic control (the director) to operate train 199 over the Connaught Main Track, rather than the originally scheduled Macdonald Main Track.

After receiving confirmation from the director, the RTC rerouted train 199 through the Connaught Tunnel. Upon receiving the rerouting details, the train crew advised the RTC that, because of the steep grade between Fraine and Stoney Creek, they would need to run from Rogers through to the siding at Stoney Creek without stopping to ensure that the train would not lose momentum.

Upon reaching Beavermouth, British Columbia (Mile 62.0), train 199 was stopped for approximately 30 minutes for a meet with train 402. When train 199 departed Beavermouth at 0330, there was a clear signal ahead. As indicated in CP’s General Operating Instructions (GOI) and highlighted in the Train Area Marshalling (TrAM[3]) messages for TrAM Area 5 on the crew’s train consist, the crew reduced the equivalent driving axles[4] from 24 to 23 by cutting out a traction motor on 1 of the operating locomotives.

While operating past Fraine towards Stoney Creek, train 199 continued to lose speed as it climbed the grade. At 0505, the train crew advised the RTC that they were at Mile 76.6 and that train speed was now at 1 mph owing to the steep grade. Shortly thereafter, the train came to a stop on a 8.75-degree right-hand curve, with the head end of the train at the west-end bridge abutment of the Stoney Creek Bridge. To continue up the grade, it was decided to cut in the 24th driving axle. After an unsuccessful attempt to pull the train up the hill, the RTC issued train 199 a Rule 577.[5] Train 199 was therefore authorized to back up (that is, down the hill) until it was on a tangent track where the grade was not as steep. The train would then make another attempt at cresting the grade.

As the train was backing up, an undesired emergency brake application occurred. Once the train came to a full stop, the conductor exited the locomotive to inspect the train. It was

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3 TrAM is CP’s computerized tool to determine area-specific train marshalling rules.

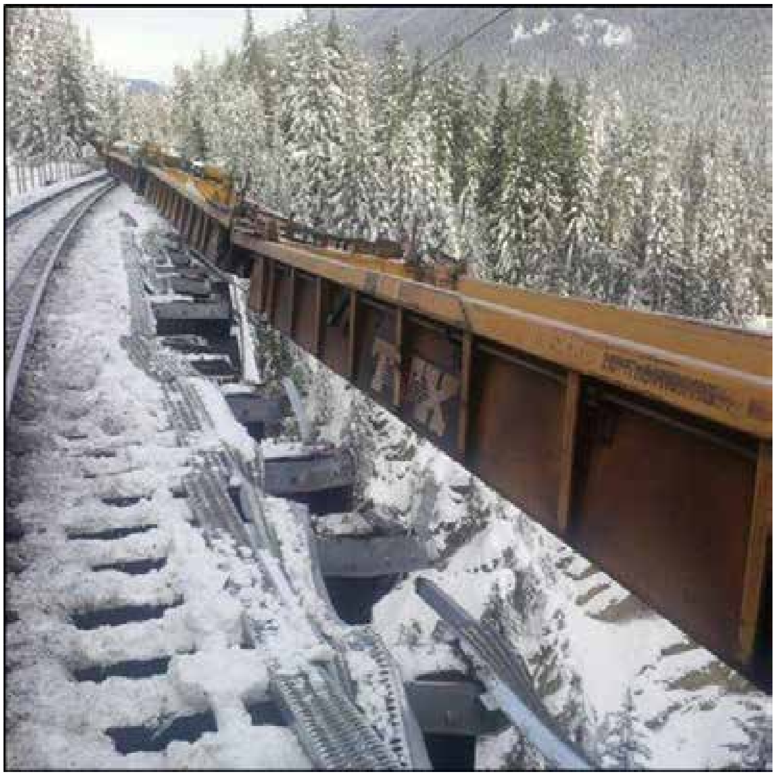
4 CP General Operating Instructions (GOI) Section 7 Appendix 2: Locomotive haulage ratings and equivalent axle counts determine the number of equivalent driving axles per type of locomotive.

5 *Canadian Rail Operating Rules* (CROR) Rule 577 is a work authority provided by the RTC (in writing) to the train crew, which permits the crew to move the train in either direction within specified limits.

determined that 6 platforms from 2 empty intermodal flat cars had derailed on the Stoney Creek Bridge. The crew advised the RTC of the situation. There were no injuries, and no dangerous goods were involved.

The weather at the time of the occurrence was cloudy, with a temperature of −10 °C.

Photo 1. Derailed cars on the Stoney Creek Bridge (view looking west) (Source: Canadian Pacific Railway)



Track–train dynamics

At the wheel–rail interface, there is a combination of lateral (L) forces and vertical (V) forces. The ratio of lateral to vertical (L/V) forces determines the likelihood of the wheel staying on the rail head. During train operations, the tendency for a wheel to derail increases as the L/V ratio increases. When there are high lateral forces combined with low vertical forces, the wheel flanges will tend to push up and over the gauge face of the rail. Under these circumstances, especially when empty cars are travelling through a curve, the cars can stringline to the inside of the curve. In addition, if there are sufficiently high lateral forces, the rail can also cant outward and roll over.

Track–train dynamics differ between tangent track and curved track:

- When a train is being pulled on tangent track, the train is in draft, which means that the longitudinal forces are tensile and act along the centerline of the track. When a train is being pushed on tangent track, the train is in buff, which means that the longitudinal forces are compressive and act along the centerline of the track. These forces are transmitted serially through the train between the coupler pivot points.

- When a train is being pushed on curved track, the longitudinal forces are compressive. When a train is being pulled on curved track, the longitudinal forces are tensile. In either circumstance (pushing or pulling), the couplers are angled, resulting in lateral forces being transmitted by the wheels to the rails. The magnitude of the lateral forces at the rail is determined by several factors, including the longitudinal force, the coupler angle, the grade, and the degree of curvature.

Steep gradients and sharp curves add rolling resistance, increasing the required longitudinal forces, whether in draft or buff. High lateral forces will typically result in a high L/V ratio. Limiting the longitudinal forces can help ensure that L/V ratios are kept below critical levels.

Mountain Subdivision

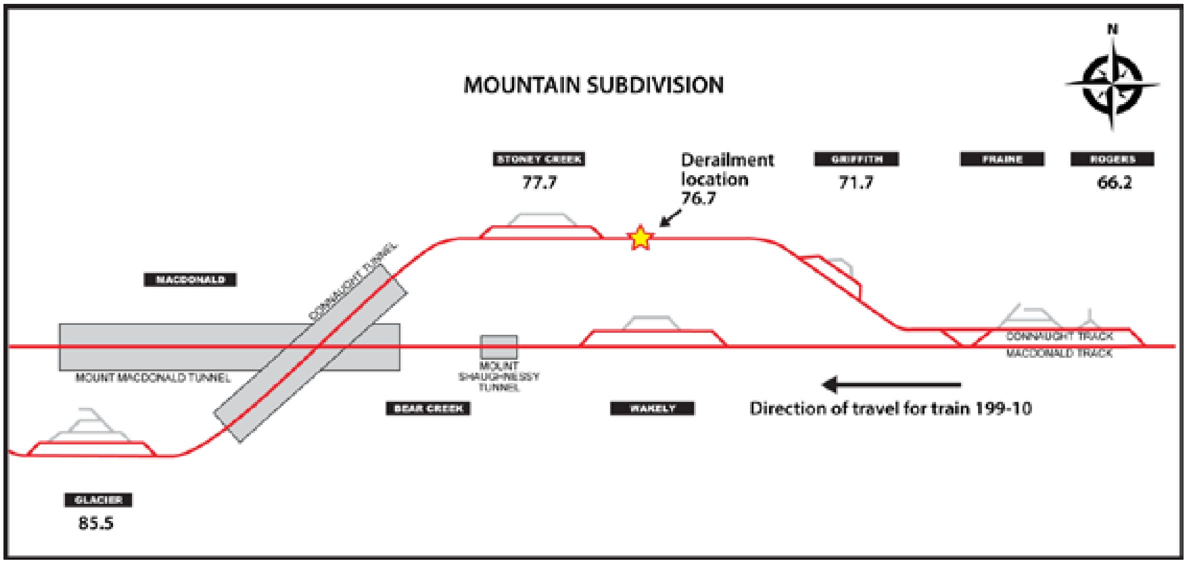
Train movements on the Mountain Subdivision are governed by the centralized traffic control system, as authorized by the *Canadian Rail Operating Rules* (CROR) and supervised by an RTC located in Calgary, Alberta. Train traffic on this subdivision consisted of about 25 freight trains per day. The maximum authorized timetable speed for freight trains in the vicinity of the derailment was 30 mph.

The Mountain Subdivision begins in Field (Mile 0.0) and continues westward to Revelstoke, British Columbia (Mile 125.70). At Rogers (Mile 66.2), the Mountain Subdivision changes from single main track to double main track that ends at Flat Creek, British Columbia (Mile 94.2).

Within the double-track section (Figure 2),

- the Connaught Main Track, which includes the Connaught Tunnel (Mile 79.6 to Mile 85.1.), runs from Mile 66.2 to Mile 94.2; and
- the Macdonald Main Track, which includes the Mount Macdonald Tunnel (Mile 79.3 to Mile 88.6), runs from Mile 66.2 to Mile 94.2.

Figure 2. Double-track section of the Mountain Subdivision



The Mount Macdonald Tunnel is normally used for westbound trains. The Connaught Tunnel is normally used for eastbound trains. However, about once per week, westbound trains were being rerouted to the Connaught Tunnel, when permitted, to ease traffic congestion. The maximum ascending grade for westbound trains using the Connaught route is 2.4%. In comparison, the maximum ascending grade for westbound trains using the Macdonald route is 1.25%.

Track information

In the vicinity of the derailment, the track was Class 2, as defined in the Transport Canada–approved *Track Safety Rules*. The track was in good condition.

The high rail in the vicinity of the derailment was 136-pound Nippon Steel manufactured in 2006. The low rail was 136-pound Nippon Steel manufactured in 2007. The tie plates were rolled plates with a 2/2 spiking pattern and elastic fastenings. There were no rail anchors. The ballast was 4.5-inch crushed rock in good condition with 18-inch–wide shoulders.

Equipment information

The 3 locomotives on train 199 were GE 4400 horsepower 6-axle units. The locomotives were in serviceable condition, with the third unit isolated.[6] Maintenance records for the locomotives indicated that there were no outstanding issues.

The mechanical records for the derailed cars were reviewed. No defects had been reported for these cars.

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6 The term “isolated” describes a locomotive that is operational but not used for power in train.

Data from the 3 wayside hot box detectors (HBDs) at Mile 44.9, Mile 54.5, and Mile 74.8 of the Mountain Subdivision showed that no HBD alarms had been activated for this train. In addition, there had been no alarms at the wheel impact load detector at Mile 47.9 of the Mountain Subdivision.

Documentation provided to the train crew

The train crew was provided with paperwork that included the TrAM information, consist details, dangerous goods information, and other pertinent information for the subdivision. The conductor received the paperwork that was specific to his job function, and the locomotive engineer received the paperwork that was specific to his job function.

Train area marshalling

Train marshalling instructions are provided within CP's GOI Section 7, TrAM. These instructions specify (in part):

> Through a supported computer program, marshalling rules are utilized to enable the operation of heavier trains, and distributed power trains with a mix of different car types, both loaded and empty.
>
> TrAM restrictions are noted on the train consist with regards to trailing tonnages limits for specific types of equipment depending on type, length and adjacent car, weight of car, and curvature/grade of track to operate on.
>
> Placement of cars with cushioned drawbars [angled couplers], remote locomotive consists, restrictions on dynamic brake use and placement of light cars on certain ascending grades are provided.

TrAM area designations (1 to 6) are defined by their combination of grade, curvature, and other operational factors. On some subdivisions, the TrAM area designation differs depending on the direction of travel and/or the track. The TrAM areas are indicated in the CP timetables. The Connaught track is designated as TrAM Area 5. Train 199's documents identified two TrAM Area 5 violations:

- Maximum trailing car tonnage[7] was exceeded on 4 cars.
- There was insufficient weight for Ascending Grade Weight Zone[8] if there were 24 equivalent driving axles on 4 listed cars.

Specific train marshalling instructions can also apply to each TrAM area. For example, the restrictive marshalling instructions that apply to trains operating on mountain grades do not apply to trains operating in areas of gentler grades and curvatures.

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7 The maximum trailing car tonnage usually varies by TrAM area and also depends on the type and weight of the car.

8 Ascending Grade Weight Zone restricts car or platform weight on the extreme head end of the train. These restrictions apply to mixed, light bulk and light uniform trains.

Checking the train consist for Train Area Marshalling violations

Section 7 (part 3) of CP's GOI specifies (in part):

> Specific messages are listed for TrAM Areas 1 to 6 on all train consists regardless of the TrAM areas in which the train actually operates. Train crews must ensure that there are no marshalling violations applicable to the TrAM Area(s) in which they will operate.

The following example is provided in the GOI:

> This train is marshalled correctly to operate in TrAM Areas 1, 2 and 3, because there are no violations that apply to all areas, and no area specific violations in TrAM Areas 1, 2 and 3. However, this train has specific violations that apply to Areas 4, 5 and 6. These marshalling violations would need to be corrected before the train operates in Area 4, 5 or 6.

Time Table 41, which was applicable for the occurrence train, includes a footnote that references Section 11.17 of the Time Table. The footnote indicates (in part):

> When travelling westward via the MacDonald track, the TrAM Area is 3.
> When travelling westward via the Connaught track, the TrAM Area is 5.

Before departure from Field, the train crew had reviewed the train consist for TrAM restrictions for its routing over the Mountain Subdivision. As the routing was planned to be through the Mount Macdonald Tunnel, the train crew determined that there were no restrictions along this route. However, the Connaught track was designated as TrAM Area 5. With the routing change to the Connaught track, there were now TrAM violations for train 199 that did not exist for the Macdonald track. The train crew did not, however, completely recheck the consist for TrAM Area 5 restrictions, as required by CP's GOI.

Section 7 (part 4.1) of CP's GOI specifies (in part):

> If there are any marshalling violations applicable to the TrAM area(s) in which you will operate the train, notify the RTC and request instructions. If marshalling information is incomplete or missing, and you are unable to determine whether marshalling is correct for the TrAM area(s) in which you will operate the train, then notify the RTC and request a TrAM check.

Section 7 (part 4.4) of CP's GOI specifies (in part):

> En route Train Area Marshalling Violations
>
> In the event a TrAM marshalling violation is discovered while a train is en route, the train must be stopped and NMC [Network Management Centre] contacted. The NMC will provide instructions to the crew on how to remarshall the train to remove the marshalling violation, and, if the train is able to be moved before the marshalling violation is corrected, what restrictions will apply to movement of the train.

The train crew was aware that the director had been involved in the discussions for rerouting the train. No specific concerns had been expressed regarding train operations for the

Connaught route by the director. At CP, when trains are rerouted, there would typically be a discussion between the RTC and the director. However, there were no formal policies or instructions specifically requiring the train crew or the RTC to check for TrAM violations when a train is rerouted. In addition, there were also no specific policies requiring the director to review a train consist for TrAM area violations before authorizing a train to reroute onto an alternate track. Although directors of rail traffic control were expected to do so, there was no specific training material relating to their responsibility to check for TrAM restrictions before rerouting.

In this occurrence, the director believed that the train crew would recheck the train consist for TrAM violations. As the train crew members believed that the revised routing was operationally acceptable for their train and that it had been considered by the RTC and the director, the train consist was not further checked for TrAM area violations relevant to the Connaught track.

Automatic equipment identification

All North American rail cars are equipped with automatic equipment identification (AEI) tags that provide information to railways when the cars pass an active trackside AEI reader. Some AEI readers had also been programmed to alert the RTC office if a train marshalling violation existed. This information could then be communicated to the train crew. At the time of the occurrence, not all of the AEI readers had been set up to provide this information.

In this occurrence, train 199 passed a trackside AEI reader at Golden. No train marshalling violations were identified by this scanner, given that train 199 was scheduled to operate over the Macdonald Track (TrAM Area 3).

Destination marshalling

Destination marshalling groups cars destined for the same location together in blocks. This marshalling approach tends to ease the workload related to enroute switching activities. By minimizing the handling of cars, destination marshalling has operational advantages, including reduced crew workload, reduced train delays, and cost savings. This train marshalling approach is commonly used in the railway industry.

However, depending on the specific customer requirements, destination marshalling can lead to a disproportional distribution of loaded cars at the tail end of the train and empty cars at the head end. Under these circumstances, train dynamics would be affected and would not likely be optimal.

Director of rail traffic control position at Canadian Pacific Railway

The director of rail traffic control provides supervision and oversight of the work of the RTC Centre.[9] At CP, directors normally work 4 shifts of 12 hours on consecutive days followed by

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9 The *Canadian Rail Operating Rules* contain the following definition: Proper Authority —The rail traffic controller or the appropriate railway supervisor.

3 days off, and they typically rotate between day shifts (0500 to 1700) and night shifts (1700 to 0500) every 2 weeks (2 weeks on day shifts, followed by 2 weeks on night shifts).

The shift schedule can, however, change to accommodate unforeseen circumstances, such as unavailability of directors due to illness. During the shift, breaks are normally taken at irregular times based on the operational activity at any given time.

Work–rest history for the director of rail traffic control

The director had been promoted to the position in 2001 after 4 years as an RTC. The TSB obtained a 9 day sleep/wake history for the director for the days leading up to the occurrence and analyzed the data. The analysis established that the director had worked an 8 hour shift on 06 January before completing 4 consecutive night shifts and had begun his scheduled 3 days off at 0500 on 11 January. The days off were to be 11, 12, and 13 January. He was scheduled to return to work on 14 January at 0500.

When working the night shift, the director would normally have 7 to 8 hours of sleep during the day. This sleep period was either in one block after completing the shift, or in two blocks, with a sleep period of about 5 hours after finishing the shift followed by a 2 hour nap before reporting for the next night shift.

On the Sunday morning following the last night shift, the director began his transition from daytime sleep back to nighttime sleep. He had a short sleep of about 4 hours on Sunday morning. He then had a full night's sleep of about 8 hours on Sunday night, waking at about 0500 on Monday, 12 January.

At 1700 on Monday, he was requested to return to work to cover the shift of another director who was not available owing to a family emergency. Reporting to work at 1800, the director was scheduled to work until 0500 on 13 January. Because he had had little notice of the shift, there was no opportunity for him to obtain additional sleep in preparation for the night shift. The director had been awake for approximately 13 hours when he started his shift.

Regulatory requirements with respect to scheduling employees

Transport Canada's (TC's) amended *Railway Safety Management System Regulations, 2015*[10] had been under development for at least 2 years. There had been ongoing discussions between TC and the railway industry regarding the necessary amendments to the regulations. The proposed regulations were published in *Canada Gazette,* Part I, on 05 July 2014. Interested persons were given the opportunity to make representations concerning the proposed regulations within 90 days.

Section 28 of the regulations states (in part):

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10 Government of Canada, *Canada Gazette,* Part II, Volume 149, no. 4 (25 February 2015), *Railway Safety Management System Regulations, 2015,* available at http://laws.justice.gc.ca/eng/regulations/SOR-2015-26/page-1.html (last accessed on 27 June 2016); the regulations were effective as of 01 April 2015.

> Process with Respect to Scheduling
>
> 28. (1) A railway company must apply the principles of fatigue science when scheduling the work of the employees referred to in subsection (2), including the principles
>
> (a) that human fatigue is governed by physiology;
>
> (b) that human alertness is affected by circadian rhythms;
>
> (c) that human performance degrades in relation to hours of wakefulness and accumulated sleep debt; and
>
> (d) that humans have baseline minimum physiological sleep needs.
>
> 28. (2) The railway company must include, in its safety management system, a method for applying the principles of fatigue science when scheduling the work of an employee who is required to work according to a schedule that
>
> (a) is not communicated to the employee at least 72 hours in advance;
>
> (b) requires the employee to work beyond his or her normal work schedule; or
>
> (c) requires the employee to work between midnight and 6:00 a.m.
>
> 28. (3) The railway company must communicate, to any employees who are required by the railway company to work according to a schedule referred to in subsection (2), how the principles of fatigue science have been taken into account when requiring them to work according to that schedule.

Fatigue management

TC recognizes the potential impact of fatigue on human performance and considers fatigue to be one of the most important safety issues facing the rail industry.[11] The principal regulatory requirement to address fatigue is the *Work/Rest Rules for Railway Operating Employees.*[12] These rules specify the maximum duty periods for operating employees and for individuals serving in the capacity of operating employees.

Recognizing that flexible, multi-faceted solutions are required to address the issue of fatigue, the rules require railway companies to submit to TC a fatigue-management plan that considers (at a minimum):

- education and training,
- scheduling practices,
- dealing with emergencies,
- alertness strategies,
- rest environments,

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[11] Transport Canada, Rail Safety (2010). Fatigue Management Plans: Requirements and Assessment Guidelines, September 1, 2010, Revised March 1, 2011, p. 4, available at https://www.tc.gc.ca/eng/railsafety/guideline-618.htm (last accessed on 27 June 2016).

[12] Transport Canada, *Work/Rest Rules for Operating Employees*, TC O 0-140, February 2011, available at: https://www.tc.gc.ca/eng/railsafety/rules-tco140-364.htm (last accessed on 27 June 2016).

- implementation policies, and
- evaluation of fatigue-management plans and crew-management effectiveness.[13]

Guidelines for the assessment of fatigue-management plans, developed by the regulator and industry, recognize that continuous wakefulness of more than 19 hours and working between the hours of midnight and 0600 are among the key fatigue risk factors.[14] Mitigation strategies for these risk factors include education, adequate time for sleep, diet, and exercise. In addition, the importance of napping as a countermeasure when required to work during a period of circadian low is highlighted in the guidelines:

> For persons working this shift, it is also important to acknowledge the need for time to nap during the midnight hours. Use of break time for short naps should be an acceptable part of the work situation. However, the risks of sleep inertia are more pronounced during this time period and may need to be planned for and anticipated for naps taken between 0000 and 0600. Fatigue Management Plans should address the need for, and the guidelines surrounding, napping for employees required to work between 0000 and 0600.[15]

The work/rest rules and the associated fatigue-management plans developed by railway companies applied only to operating employees.[16] There were no such rules or requirements for RTC staff and other railway employees.

Within the RTC work environment, fatigue countermeasures normally consist of breaks (workload permitting) and caffeinated beverages. However, napping is not considered acceptable at the RTC Centre.

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13 Transport Canada, Rail Safety (2010). Fatigue Management Plans: Requirements and Assessment Guidelines, September 1, 2010, Revised March 1, 2011, p. 7, available at https://www.tc.gc.ca/eng/railsafety/guideline-618.htm (last accessed on 27 June 2016).

14 Ibid., p. 13.

15 Ibid., p. 20.

16 As defined in the *Work/Rest Rules for Railway Operating Employees*: " 'Operating Employee' means a locomotive engineer, conductor, trainman, yardman, pilot, operator of remote control locomotives and operator of light rail passenger equipment, as well as any person whose preponderance of time is spent in such classifications, working in any class of service who is physically involved in the operation or switching of trains, engines and equipment. Any other person who performs the duties of an operating employee is deemed to be an operating employee while those duties are being performed."

Analysis

The analysis will focus on the rerouting of trains, on train area marshalling, and on sleep-related fatigue.

The accident

The derailment occurred when 6 empty platforms from 2 intermodal flat cars stringlined while the train was proceeding under high tractive effort in a 8.75-degree curve on a 2.2% grade. The train had been losing speed as it ascended the grade, until it stalled. Believing that the train had stopped because of the steep grade, the train crew attempted a number of actions, including adding back the 24th driving axle. In addition, the train was authorized to back up onto tangent track in order to make another attempt at cresting the grade. During the reverse movement, the undesired emergency brake application occurred, as the cars had already derailed before the train came to the initial stop.

As the train ascended the grade and travelled through the curve, the angled couplers produced increased lateral forces at the wheel–rail interface of the low rail. The low vertical force of the empty intermodal flat cars, combined with the high lateral forces, resulted in a high lateral-to-vertical (L/V) ratio, eventually reaching the point where wheel climb over the low rail occurred, resulting in the derailment of the 2 cars.

The suitability of the train to operate over the Macdonald track had been verified at Field before departure. The train was rerouted to the Connaught track because of impending train delays and congestion on the Macdonald track. However, the train had a number of Train Area Marshalling (TrAM) violations, as it was not marshalled in a manner that was suitable for the Connaught track.

The train crew believed that the only additional restriction for the Connaught track was to reduce the driving axles from 24 to 23. The train crew members did not completely reverify the train consist for all TrAM conditions, as they believed that the revised routing was operationally acceptable. While CP's General Operating Instructions establish that train crews must ensure there are no TrAM violations applicable to the territory they will operate over, there were no specific instructions for the train crew to reverify the TrAM criteria when trains are rerouted.

Before authorizing the rerouting arrangements, the director of rail traffic control (the director) did not reverify the train for TrAM violations, and there were no formal policies or instructions to do so. Although directors were expected to do so, there was no specific training material relating to their responsibility to check for TrAM restrictions before rerouting.

Reverifying a train consist following a routing change

When involved in the discussions to reroute the train, the train crew considered only the tonnage and the power of the train with regard to operational suitability for the Connaught track. However, the Connaught track had TrAM Area 5 restrictions, indicating that the train was not suitable for this route.

For the rail traffic controller (RTC), there were no formal instructions relating to reverifying a train consist for TrAM violations when a train is rerouted. The common practice at CP when trains are rerouted typically includes a discussion between the RTC and the director. If a train consist is not reverified for potential TrAM violations after a routing change, it could be operated on a route that is not operationally suitable, increasing the risk of a derailment.

Placement of empty rail cars within a train during marshalling

There are many operational advantages to destination marshalling, which groups cars destined for the same location together in blocks. For example, this marshalling approach tends to decrease the workload related to enroute switching activities.

Although destination marshalling can be much more efficient for train operations, it can lead to a disproportional distribution of loaded cars at the tail end of the train and empty cars at the head end. Under these circumstances, train dynamics would be affected and would not likely be optimal. CP's TrAM rules, when followed, prevent this kind of condition from occurring. However, if a train is marshalled with a significant number of empty rail cars placed in front of loaded cars (that is, TrAM rules are not followed), the in-train forces tend to be elevated, especially when operating in mountain-grade territory, increasing the risk of a derailment.

Work–rest history of the director of rail traffic control

In this occurrence, the director had obtained a reasonable amount of good-quality sleep during his most recent block of night shifts. However, he was in the process of transitioning back to a nighttime sleep schedule when he was called in for work on the evening of Monday, 12 January. Because of the short notice of the overtime shift, the director was not able to obtain additional sleep before starting work. As a result, the director had been awake continuously for 13 hours at the beginning of his shift and for 24 hours at the planned completion of his shift.

Many aspects of human performance decrease after 17 hours of wakefulness. In fact, 19 hours of continual wakefulness is recognized as a key risk factor in rail safety.[17] Furthermore, 22 hours of wakefulness is considered the upper limit at which almost all aspects of human performance decline owing to fatigue, as sleepiness will increase to the point that the individual may have difficulty staying awake.[18]

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17 Transport Canada, Rail Safety (2010). Fatigue Management Plans: Requirements and Assessment Guidelines, September 1, 2010, Revised March 1, 2011, p. 13, available at https://www.tc.gc.ca/eng/railsafety/guideline-618.htm (last accessed on 27 June 2016).

18 M. Beaumont, D. Batejat, C. Pierard, O. Coste, P. Doireau, P. Van Beers, F. Chauffard, D. Chassard, M. Enslen, J. Denis, and D. Lagarde. "Slow release caffeine and prolonged (64-h) continuous wakefulness: Effects on vigilance and cognitive performance," *Journal of Sleep Research*, Vol. 10, No. 4 (2001), pp. 265-276.

At approximately 0300 (after being awake for about 22 hours), the director was consulted with respect to the possibility of rerouting train 199. This discussion took place during a period of circadian low for the director, during which the propensity to sleep was greater and the effect of sustained wakefulness on performance was more pronounced. The director was in a fatigued state at the time the decision was made to reroute the train. It could not be determined whether fatigue played a role in the director not verifying with the RTC that train 199 was compliant with TrAM for the Connaught track.

Fatigue-management practices for employees involved in routing trains

Sleep-related fatigue can have a negative impact on all aspects of human performance. Risk factors that increase the likelihood of fatigue include acute or chronic sleep disruption, continuous wakefulness, circadian rhythm effects, sleep disorders, and medical conditions that can impair the ability to sleep. In this occurrence, there were no indications that sleep disorders or medical conditions affecting the ability to sleep were present for the director. However, the other 4 risk factors for fatigue were present to a degree that human performance would likely have been affected.

For certain groups of railway employees, fatigue is recognized as a significant threat to railway safety. As a result, the importance of a proactive, multi-faceted approach to managing the risks associated with fatigue is well understood. However, the application of the work/rest rules and the requirement for railway companies to develop fatigue-management plans are limited to operating employees.

In this occurrence, the director was called upon to work through a period of circadian low. Also, because of the short notice for his work shift, he had been awake for over 22 hours when he was consulted regarding the routing change for train 199. Certain fatigue countermeasures, such as strategic napping, are not typically used within the RTC work environment. If fatigue-management principles and best practices are not considered, are not permitted by company policy, and are not used by all employees involved in operating or routing trains, including personnel at the Rail Traffic Control Centre, employees can be in a fatigued state when making critical safety decisions, increasing the risk of non-optimal decisions leading to accidents.

Findings

Findings as to causes and contributing factors

1. The derailment occurred when 6 empty platforms from 2 intermodal flat cars stringlined while the train was proceeding under high tractive effort in a 8.75-degree curve on a 2.2% grade.

2. Believing that the train had stopped because of the steep grade, the train crew attempted a number of actions, including a reverse movement that resulted in the emergency brake application.

3. As the train ascended the grade and travelled through the curve, the angled couplers produced increased lateral forces at the wheel–rail interface of the low rail.

4. The low vertical force of the empty intermodal flat cars, combined with the high lateral forces, resulted in a high lateral-to-vertical ratio, eventually reaching the point where wheel climb over the low rail occurred, resulting in the derailment of the 2 cars.

5. The train had a number of Train Area Marshalling violations, as it was not marshalled in a manner that was suitable for the Connaught track.

6. The train was rerouted to the Connaught track because of impending train delays and congestion on the Macdonald track.

7. Believing that the revised routing was operationally acceptable, the train crew did not completely reverify the train consist for all Train Area Marshalling conditions.

8. Before authorizing the rerouting arrangements, the director of rail traffic control did not reverify the train consist for Train Area Marshalling violations.

9. While Canadian Pacific Railway’s General Operating Instructions establish that train crews must ensure there are no Train Area Marshalling (TrAM) violations applicable to the territory they will operate over, there were no specific instructions to reverify the train consist for TrAM violations before rerouting.

Findings as to risk

1. If a train consist is not reverified for potential Train Area Marshalling violations after a routing change, it could be operated on a route that is not operationally suitable, increasing the risk of a derailment.

2. If a train is marshalled with a significant number of empty rail cars placed in front of loaded cars (that is, Train Area Marshalling rules are not followed), the in-train forces tend to be elevated, especially when operating in mountain-grade territory, increasing the risk of a derailment.

3. If fatigue-management principles and best practices are not considered, are not permitted by company policy, and are not used by all employees involved in operating or routing trains, including personnel at the Rail Traffic Control Centre, employees can be in a fatigued state when making critical safety decisions, increasing the risk of non-optimal decisions leading to accidents.

Other findings

1. The director of rail traffic control was in a fatigued state at the time the decision was made to reroute the train.

2. It could not be determined whether fatigue played a role in the director of rail traffic control not verifying that train 199 was compliant with Train Area Marshalling for the Connaught track.

Safety action

Safety action taken

Canadian Pacific Railway

Following this occurrence, Canadian Pacific Railway (CP) made changes to its automatic equipment identification (AEI) scanner system to provide Train Area Marshalling (TrAM) violation alerts when a train marshalling restriction is identified after a train passes the scanner.

In addition, CP made changes to the role of the rail traffic controller (RTC) with respect to TrAM. The RTCs are now responsible for knowing and understanding the TrAM area zones of the territories under their control and for applying the required train movement restrictions. The following guidance is included in the revised process:

> When a controller questions a train crew, to clarify and confirm the ability to run on 'non-traditional' routing, a clear concise query must be made by the responsible controller, and the response relayed to the duty RTC director for final permissions.
>
> "CP1234 East, is your train consist permitted to travel on Xxxxx track per General Operating Instructions and/or Time Table instructions?"
>
> If there are any marshalling violations applicable to the TrAM area(s) in which the crew will operate the train, they must notify the RTC and request instructions.
>
> If marshalling information is incomplete or missing, and the crew is unable to determine whether marshalling is correct for the TrAM area(s) in which they will operate the train, then they must notify RTC and request a TrAM check. When this occurs RTC must obtain a TRAM check (computer verification of marshalling violations and corrective action to be taken) from the RTC director before allowing the train to continue.

Following the accident, CP's General Operating Instructions (GOI) were updated to state explicitly that cutting out traction motors to reduce equivalent driving axles below 24 does not meet the requirement in the instruction for operating trains in an ascending grade weight zone (Figure 3).

Figure 3. Canadian Pacific Railway's General Operating Instructions, showing updates

8.2 Certain train types operating in Ascending Grade Weight Zones must comply with the following additional marshalling restrictions. Heavy Bulk trains are not affected by the Ascending Grade Weight Zone Rules.

Conventional Trains			
Train Type	**Less Than 24 Equivalent Driving Axles² - Any Tonnage**	**24 or More Equivalent Driving Axles²/³**	
		Not more than Threshold Tonnage (item 6.4)	**Greater than Threshold Tonnage (item 6.4)**
• Light Bulk	Ascending Grade Weight Zone restrictions do not apply		Prohibited
• Mixed • Heavy Uniform¹			Cars or platforms on extreme head end must pass minimum weight requirement shown in item 8.3
Distributed Power Trains			
If maximum Buff and Draft forces are not exceeded anywhere on the train, the train complies with AGWZ Rules. Excessive Buff and Draft forces, if applicable, are shown in Part 3 of TrAM Messages.			

Note 1: Crews are responsible to ensure that Heavy Uniform Conventional trains do not operate in an AGWZ in violation of these requirements.
There will NOT be any TrAM message concerning AGWZ for these types of trains.

Note 2: See GOI Section 1, Appendix 4 for equivalent driving axle counts.

Note 3: Cutting out Traction Motors on Locomotives to reduce Equivalent Driving Axles below 24 does not meet the requirement of this instruction, train must be remarshalled or Distr Power used.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 8 June 2016. It was officially released on 30 June 2016.

Visit the Transportation Safety Board'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 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.