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

RAIL TRANSPORTATION SAFETY INVESTIGATION REPORT R20W0102

MAIN-TRACK TRAIN DERAILMENT

Canadian Pacific Railway Company
Freight train 320-227
Mile 12.8, Ignace Subdivision
Near Ignace, Ontario
25 May 2020

Canada

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Summary

On 25 May 2020, at approximately 1443 Eastern Daylight Time, Canadian Pacific Railway Company train 320-227 was travelling eastward at 46 mph on the Ignace Subdivision when 53 hopper cars loaded with grain derailed at Mile 12.8 near Ignace, Ontario. As a result, grain was released from several cars. There were no dangerous goods involved, and no fire was reported. No one was injured.

1.0 FACTUAL INFORMATION

On 25 May 2020, Canadian Pacific Railway Company (Canadian Pacific or CP) train 320-227 departed Winnipeg, Manitoba, destined for Thunder Bay, Ontario. Before departure, the train underwent a successful No. 1 brake test[1] and a safety and maintenance inspection.[2]

The distributed power (DP) unit train[3] consisted of 2 head-end locomotives, 1 mid-train remote locomotive, located after the 112th car, and 222 hopper cars loaded with grain. It weighed 30 307 tons and was 12 896 feet long. The train's composition met CP's train marshalling requirements.

1 The No. 1 brake test, conducted by certified car inspectors, verifies brake pipe integrity and continuity, brake rigging condition, air brake application and release, and piston travel on each car.

2 The safety and maintenance inspection is an inspection of major freight car and locomotive components. Transport Canada requires that this inspection be performed on every train departing from a designated safety inspection location; the railway files these locations with Transport Canada.

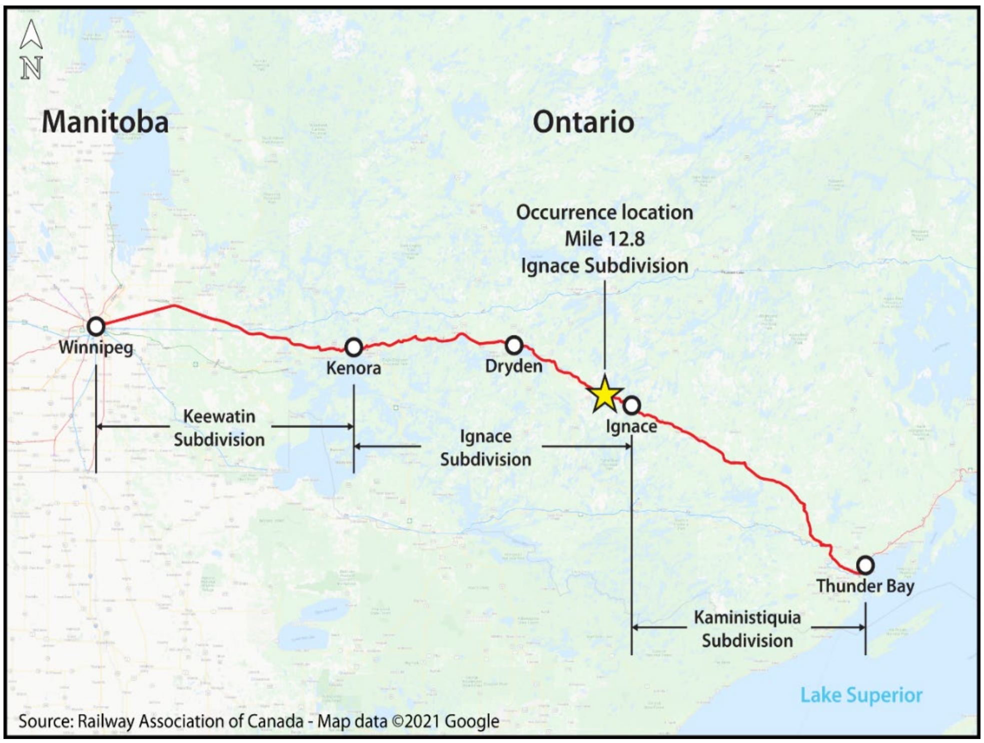
3 A unit train is a train carrying a single commodity in cars of similar type, length, and weight.

The operating crew consisted of a locomotive engineer and conductor; both crew members met established rest and fitness requirements and were qualified for their respective positions.

1.1 The occurrence

At approximately 1443,[4] while the train was travelling at 46 mph eastward on the Ignace Subdivision, a train-initiated emergency brake application occurred near Ignace, Ontario. Once the train had stopped, the crew performed an inspection and determined that 53 cars had derailed at Mile 12.8 (Figure 1). Several of the derailed cars had breached, releasing their load of grain (wheat and flax). No one was injured.

Figure 1. Occurrence location (Source: Railway Association of Canada, Canadian Rail Atlas, with TSB annotations)



Before the emergency brake application, the crew had not noticed any track or train handling anomalies. At the time of the occurrence, the weather was clear with a temperature of 20 °C.

1.2 Site examination

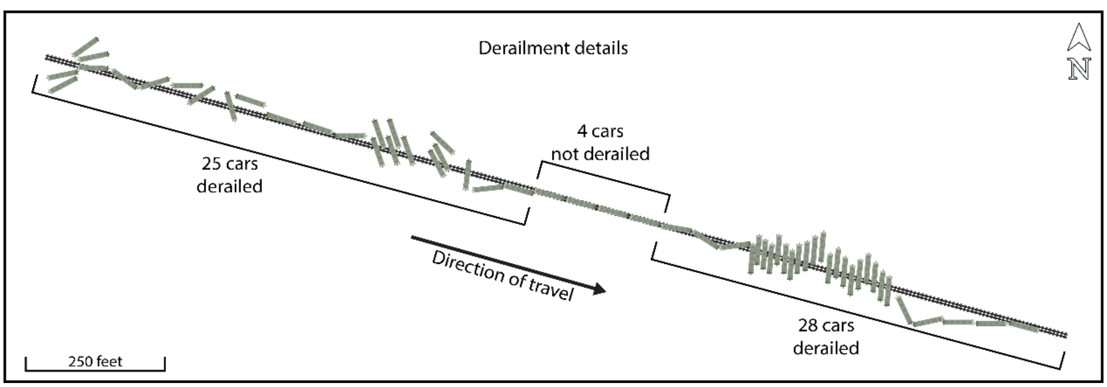
The 53 cars had derailed in a jackknife position in 2 separate pile-ups (Figure 2).

4 All times are Eastern Daylight Time.

Figure 2. Occurrence site showing the 2 pile-ups of derailed cars (Source: Canadian Pacific, with TSB annotations)

The train had separated after the 26th car, and there was a gap of about 30 car lengths between this car and the 2 pile-ups of derailed cars. The first pile-up consisted of 28 cars (positions 27 to 54), and the second pile-up consisted of 25 cars (positions 59 to 83). Between these, 4 cars had remained on the track and had not derailed (Figure 3).

Figure 3. Site diagram showing the position of the derailed cars (Source: TSB)



About 1600 feet of track was damaged or destroyed in the occurrence area.

Due to excessive rainfall in May 2020, there was standing water on the north (left) side of the track in the immediate vicinity of the 2 pile-ups (Figure 4). An equalization culvert, which was located in the area, was in good condition.

Figure 4. Water accumulation beside the north track (Source: Canadian Pacific)

After the derailment, a temporary 10 mph speed restriction was put in place from Mile 12.2 to Mile 13.5. This was later updated to a temporary 25 mph speed restriction from Mile 12.5 to Mile 13.2.

1.3 Subdivision information

The Ignace Subdivision extends between Ignace (Mile 0.0) and Kenora, Ontario (Mile 146.12). It is the middle of 3 subdivisions on the CP line between Winnipeg and Thunder Bay, with the Keewatin Subdivision to the west and the Kaministiquia Subdivision to the east. Construction began on this route in 1875, more than a century ago. It crosses a challenging variety of topography across the Canadian Shield, including hundreds of miles of rugged terrain, swamps, and peatlands.

Before 1990, CP had double track between Winnipeg and Thunder Bay. Eastbound heavy bulk train traffic used the north track, and westbound intermodal and empty bulk train traffic ran on the south track. In approximately 1990, the railway removed the south track, leaving some portions for passing tracks and sidings. As a result, most of the territory is single track.

Train movements on the subdivision are governed by the centralized traffic control system, as authorized by the *Canadian Rail Operating Rules* and dispatched by a CP rail traffic controller located in Calgary, Alberta.

Ignace Subdivision freight traffic volumes for 2018 to 2020 are shown in Table 1.

Table 1. Freight traffic volumes on the Ignace Subdivision from 2018 to 2020 (Source: Canadian Pacific)

Year	Volume (million gross ton-miles per mile)
2018	34.17
2019	35.85
2020	37.88

1.4 Particulars of the track

The track on the Ignace Subdivision is classified as class 4, according to the Transport Canada–approved *Rules Respecting Track Safety*, also known as the Track Safety Rules (TSR).[5]

In the area of the derailment, the track runs through wet, soft, and swampy low-lying terrain. The track is tangent and level, changing to a 0.2% descending grade at Mile 12.8 eastward. There is also a 0.3° right-hand curve from Mile 12.95 to Mile 13.14. A road is located on the south side.

The track structure consisted of 136-pound RE[6] continuous welded rail manufactured by IAT International, Inc. in the Czech Republic, rolled in 2015, and installed in 2016. It lay on hardwood ties, secured on 14-inch double-shouldered tie plates and fastened with 3 spikes per plate. The rail in the area of the derailment was generally box-anchored[7] every other tie, with little rail movement observed. A tie replacement program had been conducted in 2017.

The ballast was CP grade 4.5[8] from the Dyment Quarry, with full cribs and 12-inch shoulders.

In 2020, prior to and at the time of the derailment, no slow orders due to track conditions were in effect.

5 *Rules Respecting Track Safety* (Track Safety Rules) (approved by Transport Canada 25 November 2011, effective 25 May 2012).

6 RE is an abbreviation that refers to the specific rail section, with dimensions established by the American Railway Engineering Association (AREA). It is stamped on rail manufactured in accordance with this AREA specification. AREA merged with the American Railway Engineering and Maintenance-of-Way Association in 1997.

7 Rail anchors are used to restrain longitudinal movement of the rail due to thermal expansion and contraction or the passage of trains. They are applied perpendicular to the base of the rail on either side of the tie at the location of the tie plate, using a wrench, a sledgehammer, or a machine.

8 For CP, grade 4.5 ballast must have 3 to 4 fracture faces; 100% pass through 2½-inch sieve, 90 to 100% pass 2-inch sieve, 60 to 80% pass 1½-inch sieve, 15 to 35% pass 1-inch sieve, and 0 to 5% pass ¾-inch sieve. The ballast is predominantly between 2½ inches and 1½ inches in size.

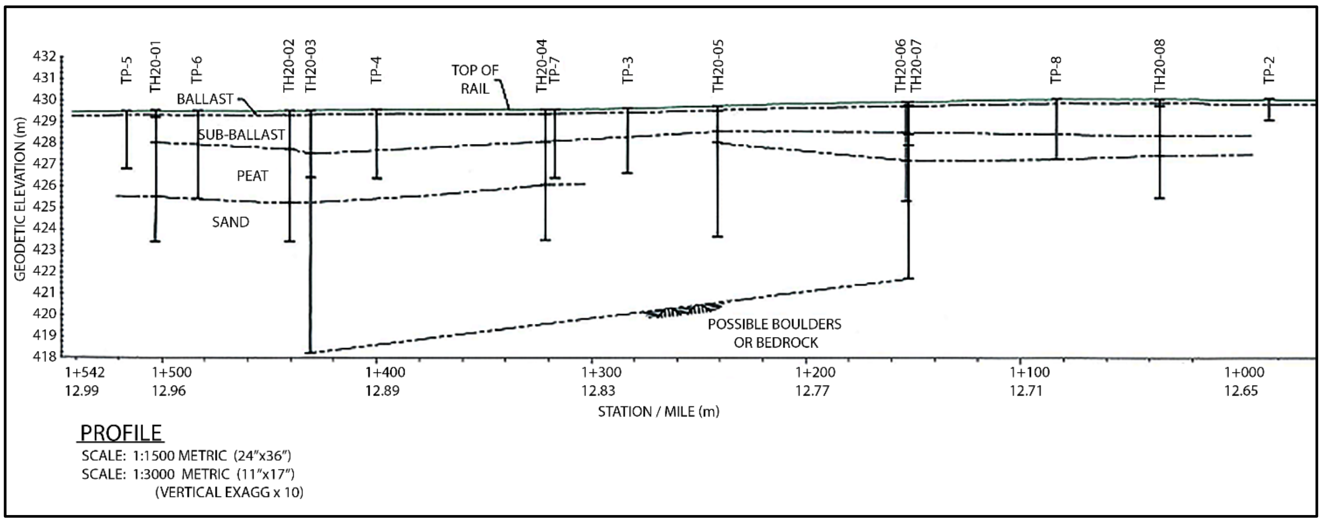
1.5 Composition of the subgrade

CP retained a geotechnical consultant to perform an investigation to determine the subgrade composition and whether an underlying problem with the subgrade may have played a role in the occurrence.

To determine the nature and quality of the subgrade below the track, geotechnical samples were taken in the area of the derailment.

Figure 5 shows the location where 8 test holes were drilled and where test pits were dug between Mile 12.67 and Mile 12.99, as well as the soil profile at those locations.

Figure 5. Schematic showing the location of test holes and test pits, and the soil profile at these locations (Source: Canadian Pacific)



Note: In this figure, the test holes are indicated by the prefix "TH" followed by the hole number. TP stands for "test pit."

An examination of the 8 samples (1 at each test hole) determined the following:

- The ballast layer was 0.3 m deep and made of a mixture of fine-grained and coarse-grained gravel. The gravel was grey, dry, and compact.
- The sub-ballast layer was 1.2 to 1.5 m deep and consisted of poorly graded sand (rated SP-SM according to the Unified Soil Classification System), which was black and brown, wet, loose, and fine-grained. It also contained traces of silt (16% in the second test hole) as well as a mixture of fine-grained and coarse-grained gravel. Starting at a depth of 0.5 to 0.8 m, there was some free water, indicating that the water table was very high in the area of the derailment.
- Beneath the ballast and sub-ballast layers, peat was encountered at a depth of 1.5 to 2.0 m. It was generally brown to dark brown, saturated, and loose. The thickness of the peat ranged from 0.5 to 1.7 m from Mile 12.67 to Mile 12.80, and from 1.1 to 2.6 m from Mile 12.80 to Mile 12.90. Different types of peat were found in the samples, depending on the location of the test holes:

- In the upper portion of some of the samples, there was coarse-fibrous peat crisscrossing fine-fibrous peat. The plant structure was recognizable. This peat was predominantly fibrous, with slight-to-moderate decomposition.
- In the upper to mid-portion of some of the samples, at a depth ranging from 1.3 to 3.0 m, the peat contained recognizable woody particles held within predominantly non-woody, fine-fibrous peat. The woody particles were pieces of the corduroy road[9] originally laid on the peat during the construction of the railway.
- In the bottom portion of some of the samples, at a depth of about 1.3 to 3.0 m, the peat was amorphous, with very high to nearly complete decomposition. Nearly no plant structures were recognizable.
- Moisture content was determined to be 102% to 145% in fibrous peat and 381% in amorphous peat.

1.6 Peat foundations

Peat is a naturally occurring substance formed when organic matter (usually plant) is preserved in anoxic conditions below a high water table in areas of poor drainage, such as swamps or wetlands. Peat is characterized by high organic content, high water content, poor drainage, large void ratio, high compressibility, and low bearing capacity.

In geotechnical engineering, the common view of peat is that it should be avoided as a foundation material whenever possible. However, avoidance is not always an option, particularly when building linear, continuous structures such as railways, pipelines, and roads.[10]

Canada has more peatland than any other country in the world. Muskeg and other peatlands cover up to 1.2 million km^2, about 18% of Canada’s land area.[11] Peat is found primarily on the Canadian Shield and northern areas of the country.

Considering the extent of peatlands in Canada, construction of some of the railway routes, such as the CP route from Thunder Bay to Winnipeg, had no alternative but to cross through this type of terrain.

1.6.1 Engineering properties of peat

The hydraulic conductivity of peat depends highly on the depth and degree of decomposition. Peat is highly permeable near the surface and less so in lower layers. When

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9 A corduroy road is a type of log road made by placing logs (or timber) perpendicular to the direction of the track.

10 M. T. Hendry, “The geomechanical behaviour of peat foundations below rail-track structures,” doctoral thesis (University of Saskatchewan December 2011), at central.bac-lac.gc.ca/.item?id=TC-SSU-201112237&op=pdf&app=Library&oclc_number=1032940749 (last accessed 06 February 2023).

11 Ibid.

fibrous peat is consolidated,[12] the channels through which water flows collapse and water is forced out. During consolidation, peat undergoes very large decreases in hydraulic conductivity, commensurate with a large decrease in void ratio (or water content).

The stiffness and strength of peat are strongly related to the reinforcing effect of the interlocking plant fibres in the peat: the higher the organic fibre content, the stronger the peat. The strength of peat can be increased when water content is reduced through consolidation. The primary consolidation of peat is rapid due to peat's initial high hydraulic conductivity, and can be measured in weeks and months. In comparison, the secondary compression of peat is measured in years. The magnitude of secondary compression is high and may account for more than 60% of the total settlement. Secondary compression is often the dominant consolidation process, during which ongoing track maintenance, such as shimming and surfacing, is required.

1.6.2 Railway embankments built on peat foundations

When the CP section linking Winnipeg to Thunder Bay was built more than a century ago, the embankment was constructed on the original peat surface using a corduroy road, which was then loaded with local borrow materials. This technique reinforced the base of the embankment and spread the load over the peat foundation. However, logs buried in wet, acidic, anaerobic soils, such as peat or muskeg, decay very slowly. Therefore, these embankments continued to settle for many years, up to today.

Most existing railway structures in Canada have been in service for more than a century. Train loads have been increasing steadily since the original construction of the Canadian railway network; newer rail cars are currently rated at a gross rail load of 286 000 pounds or 125.5 tons. Train lengths have also steadily increased, leading to increasingly longer periods of cyclic loading. Higher loads have put greater demands on the existing infrastructure, particularly the structures built on weak foundations, such as peat. Soft track, frost heaves, bearing capacity issues, slope failures, and sinkholes are common problems of railway embankments and track built on peat.

1.6.3 TSB Railway Investigation Report R04Q0040

On 17 August 2004, 18 tank cars of Canadian National Railway Company train U-781-21-17, a petroleum product unit train, derailed in the marshy area of the Grande Plée Bleue, near Saint-Henri-de-Lévis, Quebec.[13] The TSB investigation focused on roadbed stability and the effects of cyclic axle loading on peat foundations.

Train loading generates pore water pressure that can cause excessive cyclic deformation, settlement of the embankment, or rapid shear failure of embankments and peat foundations. When a soil is saturated, water fills the pore spaces between soil particles. As a result, hydraulic water pressure in the soil voids exerts pressure on the soil particles. The

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[12] Consolidation refers to a reduction in volume as a response to increased pressure and lower water content.

[13] TSB Railway Investigation Report R04Q0040.

water will initially take some of the load, so it is not all transmitted to the soil. However, because water has no shear strength, the effective contact stress between the soil particles controls the strength of the soil.

As part of the investigation of the derailment near Saint-Henri-de-Lévis, several boreholes were drilled to establish the stratigraphic profile along the centre of the track and to install instrumentation to measure variations in pore water pressure and vertical deformation in the soil under train load. The measurements indicated that average values for vertical movement and pore pressure tend to increase with the number of cars passing, thereby creating an accumulation at the end of a train's passage. Once the last car passes, the excess pressures dissipate gradually; however, there continues to be residual settling. The measurements also indicated that residual settlement is cumulative: it builds up as a result of repeated passages, especially those of heavily loaded trains. Real-time measurements of vertical movement under the railway confirmed that these permanent settlements can amount to several centimetres per year.

The investigation, which included geotechnical studies commissioned by the TSB, also showed how the subgrade can gradually fail. It established that the repeated passage of loaded trains results in maximum pore pressure at the centre of the peat layer, and that the intensity of pore pressure depends on the axle load and train speed. This excess pressure reduces the shear strength of the peat, resulting in fibre distortion and gradual realignment of the peat fibres into 2 shear planes as the permanent settlement under the railway track increases. The fibres are gradually broken from the centre of the peat layer. Once the shear strength of the peat is reached, the subgrade can suddenly fail due to punching, causing sudden significant settlements and collapse of the railway track.

The investigation determined that the derailment near Saint-Henri-de-Lévis likely occurred when the cars were unable to negotiate a sudden collapse of the track resulting from the failure of the subgrade, most likely caused by punching through the underlying peat layer. Axle weight, tonnage, and train speed and frequency can contribute to punching.

Given that additional research efforts were required to enhance the understanding of these phenomena and reduce risk, the Board recommended that

> the Department of Transport and the railway industry conduct in-depth studies on the behaviour of saturated organic materials under cyclic loading.
>
> **TSB Recommendation R07-03**

Based on an in-depth study of the behaviour of saturated organic materials under cyclic loading, conducted by the Transportation Development Centre's[14] Railway Ground Hazard Research Program team in September 2012, the Board reassessed the response to the recommendation as Fully Satisfactory.

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14 The Transportation Development Centre is Transport Canada's central research and development branch. It manages a multimodal research and development program aimed at improving the safety, security, energy efficiency, and accessibility of the Canadian transportation system and protecting the environment.

1.7 Track inspections

1.7.1 Inspections by hi–rail vehicle

The track in the area of the derailment was inspected by a hi–rail vehicle on 3 occasions the week before the derailment (Table 2), exceeding the twice-weekly requirement in the TSR for class 4 track. No defects were observed.

Table 2. Track inspections conducted by hi–rail vehicle in the area of the derailment from 19 May to 25 May 2020

Date	Mile	Method
2020-05-19	5.0 to 34.15	T-Vehicle*
2020-05-21	5.0 to 28.0	T-Vehicle
2020-05-25	5.0 to 12.0	T-Vehicle
2020-05-25	12.0 to 19.0	Observation**

* A T-Vehicle is a hi–rail vehicle equipped with a geometry testing system that augments rail safety inspections performed using an autonomous track geometry measurement system or a track evaluation car by measuring a variety of crucial aspects of track geometry, including superelevation, curvature, and gauge.

** This method consists of a visual inspection that can be performed by hi–rail vehicle or by foot.

1.7.2 Rail flaw inspections

Rail flaw inspection is non-destructive testing conducted for the early detection of internal rail defects, so that remedial action can be taken before rail failure.

In the 12 months before the derailment, rail flaw inspections were conducted 4 times in 2019 (27 June, 30 August, 08 November, and 31 December) and twice in 2020 (25 February and 01 May).

The 31 December 2019 inspection found a cracked bolt hole at a joint at Mile 14.079, and the 01 May 2020 inspection found a cracked bolt hole at a joint at Mile 26.046.

1.7.3 Inspections using the autonomous track geometry measurement system

The autonomous track geometry measurement system (ATGMS) uses a non-contact, laser-based optical measuring system attached beneath a box car for near-real-time defect detection. It can operate on any train at the permitted track speed, up to 80 mph, providing notification of critical defects with a link to geographic information system (GIS) mapping. “The system’s ability to consolidate defect information allows it to predict track deterioration, thus improving service, reducing derailments and unplanned work outages, and allowing for increased planning around track maintenance.”[15] The box car can be placed anywhere in the train and does not require special marshalling. Generally, the car is sent repeatedly over long routes to obtain repeated measurements and ensure that all parallel

[15] Canadian Pacific Railway Company, *Corporate Sustainability Report 2016,* p. 19, at cpr.ca/en/about-cp-site/Documents/cp-csr-2016.pdf (last accessed 06 February 2023).

main lines and sidings are surveyed. CP is currently operating 3 ATGMS box cars in revenue freight trains.

In 2020, before this occurrence, an ATGMS box car was run in the area of the derailment on 21 and 31 March, 15 and 23 April, and 01 and 15 May. The test brush charts identified the following conditions between Mile 12 and Mile 13:

- S22 – Vertical displacement of a 22-foot chord along the surface of the rail.
- R31 – Measurement, in inches, of the elevation runoff in a 31-foot section of track; when a dip is found in the rail surface, it is compared with the reading taken for the previous 31 feet of rail.
- RC55 – Rate of change of cross-level in a 55-foot section of track.
- D ELV T – Design elevation tangent defects that indicate excess superelevation in tangent track.

Because the conditions recorded by the ATGMS box car runs did not meet the thresholds[16] specified in CP's *Track Evaluation Cars: Guidelines for Defects & Reports*, they were monitored, but not otherwise actionable.

1.7.4 Inspections by track evaluation car

Inspections using a track evaluation car (TEC) are conducted periodically on the Ignace Subdivision. These inspections mainly measure and evaluate track alignment, surface variations, cross-level variations, gauge conditions, curvature, and other geometrical properties of the track using a loaded, rail-bound vehicle.

Defects identified during a TEC inspection are categorized as priority, near-urgent, or urgent.[17]

- A priority defect has not yet reached condemnable limits per the TSR, but is trending close. Priority defects must be corrected as soon as possible to ensure that they do not deteriorate, becoming urgent defects.
- A near-urgent defect is a priority defect that is within ⅛ inch of becoming urgent.
- An urgent defect exceeds the TSR limits and requires immediate correction, with a mandatory slow order (unless corrected before the passage of the next train).

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16 On class 4 track, S22 measurements above ⅝ inch are considered priority defects. R31 measurements above 1 inch and up to 1½ inches are considered priority defects; R31 measurements above 1½ inches are considered urgent defects. RC55 measurements above 1¼ inches and up to 1¾ inches are considered priority defects; RC55 measurements above 1¾ inches are considered urgent defects. D ELV T measurements above 1 inch and up to 1¼ inches are considered priority defects; D ELV T measurements above 1¼ inches are considered urgent defects.

17 Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 28 October 2019), and *Track Evaluation Cars: Guidelines for Defects & Reports* (2014).

Tests were conducted by a TEC on the Ignace Subdivision on 16 September 2019, 24 October 2019, and 07 April 2020. The following defects were noted and addressed in the area of the derailment before the occurrence:

- On 16 September 2019, 4 urgent and 10 near-urgent D ELV T defects were detected in Mile 12. Non-actionable RC55 conditions were also found.
- On 24 October 2019, 1 priority D ELV T defect was detected.
- On 07 April 2020, 8 R31 defects, measuring between ¾ and 1¼ inches, were detected on the north and south rails between Mile 11.7 and Mile 13.5. In addition, the test identified 3 S22 priority defects at Mile 13.5. These defects were consistent with frost heaves and were corrected by shimming and surfacing. In 2 instances, the R31 defects were found at the same location on both rails, indicating a dip in the track.

1.8 Track maintenance

In the occurrence area, some undulations in the track profile and variations in track alignment were present. Frost heaves were also common in the winter between freeze-up and thaw, which lasted into June after some winters. Frost heaves are caused by the freezing of excess moisture in the subgrade soil. As subgrade standing water freezes, it forms ice lenses that cause the soil and the track above it to heave. Frost heaving leads to track surface, profile, and alignment defects that can be difficult to correct because of the frozen condition of the track. Lowering a track once it has heaved is a very difficult procedure; heaving can be compensated for only by salting the area and shimming the track in the uneven and undulating sections.[18]

Installing shims is very labour-intensive, and shimmed areas require spot surfacing. Shimming requires removing anchors and lifting the rail and tie plates off the ties. Shims are installed between the tie plate and tie. The rail and tie plates are then re-installed, and anchors are reapplied when the track settles back into the ballast.

In the area of the derailment, in the winter of 2019–20, 5600 shims were installed by district gangs that work across subdivisions. The challenges related to shimming activities in the winter before the occurrence were compounded by equipment issues.[19]

In addition to shimming activities, CP's track maintenance records show that, at Mile 12.8, in the area of the derailment, track maintenance personnel conducted joint elimination by flash butt welding on 23 and 24 May 2019, and on 20 May 2020, as well as surfacing on 17 September and on 22 and 24 October 2019.

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[18] S. Wilk and B. Bakkum, "Potential frost heave detection and remediation methods," *Railway Track & Structures* (September 2020).

[19] Only one Mark IV tamper and regulator was available. It was shared with the Keewatin Subdivision, and it reportedly had frequent mechanical breakdowns and parts shortages.

1.9 Inspection technologies for ground hazards

The Transportation Development Centre's Railway Ground Hazard Research Program is a collaborative effort of Canadian railways, federal agencies, universities, and other stakeholders to develop and evaluate scientific and technical solutions to help railways manage the risks associated with ground hazards.[20]

Railway inspection technologies and procedures are based mainly on evaluations of track conditions at surface level. They are effective for observing track settlements; however, the distortion of peat fibres, or rather the level of compression in the peat layer, cannot be seen by the naked eye or during surface inspections. As a result, an impending collapse is very difficult to detect. Ground-penetrating radar can measure cumulative settlement over peat and help assess the risk of sudden subgrade collapse. Railways have studied the use of ground-penetrating radar technology to confirm underlying subgrade conditions, map the extent of the problem, and develop remediation programs.[21] CP has not used this technology on the Ignace Subdivision.

1.10 Post-occurrence track repairs, maintenance, and inspections

To repair the track after the derailment, the damaged rail from Mile 12.5 to Mile 12.8 was replaced with 1600 feet of new 136-pound continuous welded rail, with every tie anchored.

A toe berm was constructed on the north side, from Mile 12.5 to Mile 12.8, to stabilize the area. The existing embankment on the south side was also extended to Mile 12.8. Toe berms are used to widen the base of an embankment, which distributes the embankment load over a greater surface area and increases the factor of safety of the embankment against slip circle failure.[22]

CP track maintenance records show that surfacing was conducted in the area in the days after the derailment, from 26 to 28 May 2020. Inspections conducted after this work, however, indicate that cross-level issues persisted.

Inspections by TEC conducted on 27 May, 19 June, and 05 July indicated that the RC55 conditions persisted. An inspection conducted on 16 September recorded 4 urgent D ELV T defects, measuring between 1¼ and 1⅜ inches, from Mile 12.8 to Mile 12.9.

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20 Research projects conducted under this program include ground hazard risk identification and analysis; landslide investigation; ground hazard event triggers; technology for evaluating, monitoring and predicting ground hazards; seismic rock fall detection; heavy axle loading on soft subgrades; risk mapping of sensitive clays; ballast fouling; and risk estimation for railways and landslides. (Source: Transport Canada. "Railway Ground Hazard Research Program," at tc.canada.ca/en/rail-transportation/rail-safety/railway-ground-hazard-research-program (last accessed 06 February 2023).

21 A. Roghani, M. Hendry, M. Ruel, T. Edwards, P. Sharpe, and J. Hyslip, "A case study of the assessment of an existing rail line for increased traffic and axle loads," presented at the International Heavy Haul Association 2015 Conference (Perth, Australia, 21–24 June 2015).

22 A slip circle failure is a rotational failure (settlement) of a block of subgrade embankment constructed over relatively deep deposits of soft soils. The failure surface is in the form of an arc.

An ATGMS box car was run on 08 July and 07 August. In the 08 July test, 2 near-urgent D ELV T defects were detected in Mile 12. In the 07 August test, 1 urgent and 5 near-urgent D ELV T defects were detected in the same section of track.

The superelevation defects, found during the 27 May inspection by a TEC and the 07 August inspection using the ATGMS box car, were not in a curve location, indicating that 1 rail was higher than the other on tangent track. Rails in tangent track should have the same elevation. If they do not, rail cars can rock and possibly derail when passing through such a section of track. Car loading, suspension, and truck condition may also increase the risk of derailment.

1.11 Other occurrence in the area of the derailment

On 17 June 2020, 22 days after this occurrence, CP train 3850-003, proceeding eastbound on the Ignace Subdivision, derailed the mid-train locomotive and 17 cars near Mile 12.9. The train was powered by 2 DP locomotives—1 at the head end and 1 in a mid-train position. It was hauling 157 loaded coal cars, measured 8364 feet, and weighed 21 394 tons. The TSB did not investigate this occurrence.

A track buckle was witnessed, and CP attributed this derailment to irregular track alignment. At the time of the derailment, a 25 mph temporary slow order was in effect between Mile 12.5 and Mile 13.2 following the occurrence derailment on 25 May, and a heat slow order was also in effect, as the temperature at the time of the occurrence was 32 °C.

On the Ignace Subdivision, loaded unit trains travel eastbound, which contributes to eastbound rail movement. Following the occurrence derailment on 25 May, the damaged track had been repaired using new track panels laid with every tie anchored; the undamaged track to the west of the repair was still anchored every other tie. This made the repaired section of track more secure than the undamaged section to the west, resulting in the rails of the undamaged section being pushed up against the rails of the repaired section, likely contributing to the track buckling.

1.12 Locomotive event recorder data

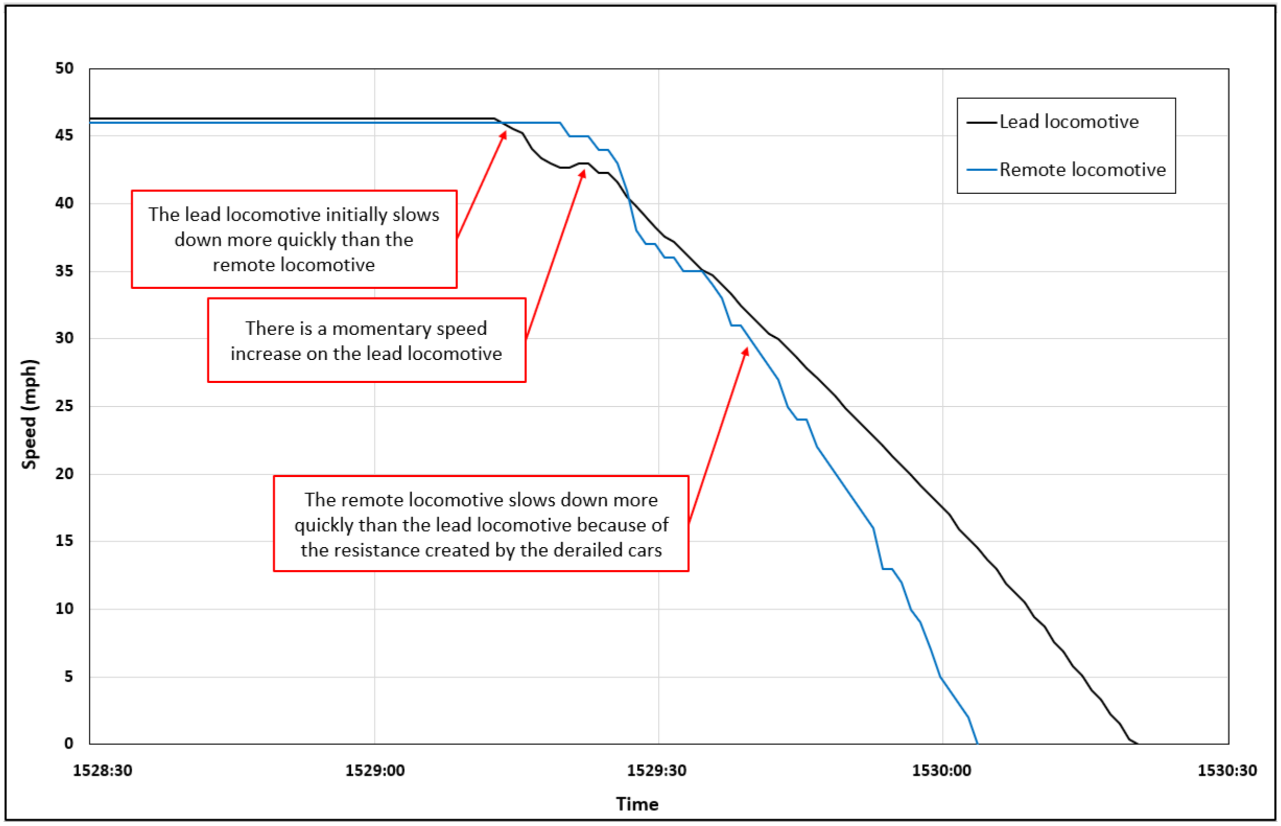
The locomotives were equipped with locomotive event recorders (LERs). A review of the data from the lead locomotive confirmed that a train-initiated emergency brake application had occurred just before the derailment. The LER data also indicated that, before the emergency brake application, there were no significant train handling issues such as erratic throttle modulations or sudden accelerations or decelerations. At the time of the emergency brake application, the train had been travelling at 46 mph in throttle position 8 for 1 hour and 19 minutes.

The LER timestamps for the lead and remote locomotives were synchronized.[23] The data from both locomotives were also analyzed to compare speed profiles of the 2 consists (lead and remote) from the time the train went into emergency until it stopped in the derailed position. Before the derailment, the speed profiles matched to within 0.5 mph, indicating that the DP system worked as intended, even during the train-initiated emergency brake application.

A review of the speed profile information determined that, in the early stage of the derailment, the lead locomotive's deceleration rate became more pronounced than that of the remote locomotive (Figure 6). The head-end portion separated behind the 26th car (closer to the lead locomotive) and continued travelling in emergency until it stopped. The cars immediately behind this separation (positions 27 to 54) stopped quickly because of the emergency brake application, but the remote locomotive kept pushing for another second (causing a momentary increase in speed) until it sensed the emergency brake command and idled down. During this short period, a second group of cars (positions 59 to 83) derailed, leaving 4 cars on the track between the 2 pile-ups of derailed cars. The difference in speed profiles between the lead and remote locomotives (Figure 6) explains why there were 2 separate pile-ups of derailed cars.

[23] There was a 1-second transmission delay between the lead and remote locomotives. This is expected, as it takes at least 1 second for the DP system on the lead locomotive to transmit an action by radio to the remote locomotive; for the DP system on the remote locomotive to receive, decode, and execute the command; and for the LER to register the change.

Figure 6. Graph showing speed profiles for the lead and remote locomotives during the derailment (Source: TSB, based on data from the locomotive event recorders)



1.13 Train dynamics simulations

In January 2021, the TSB conducted a train dynamics simulation of the occurrence train around Mile 12 of the Ignace Subdivision to verify the in-train forces and determine if they could be causal to the derailment. The following results were obtained:

- The maximum in-train forces before the emergency brake application were 84 kips as the train was travelling at 46 mph in throttle 8 position. The train travelling at this speed over tangent track would not have generated high draft forces.
- A simulation of the emergency brake application initiated at around Mile 12.8 showed a maximum in-train buff force of 216 kips, which would not have resulted in a significant run-in force.[24] This is consistent with the data recorded by the LERs, which did not indicate a sudden change in speed.

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24 A well-maintained track should tolerate in-train buff forces of 325 kips. (Source: W. Egan, TUV Rheinland, "Controlling Train Forces of Larger Trains and the Potential Effects on Track Structure," presented at the International Association of Railway Operating Officers Technical Conference at the Railway Interchange 2011, Minneapolis, Minnesota, United States, 20 September 2011.)

The data collected and reviewed by the TSB as part of its investigation also indicated the following:

- Coupler knuckles on the occurrence cars were rated at more than 300 kips in new condition, if no flaws or defects were present. The maximum in-train forces determined from the simulation were below this value.
- On several previous ascending grades, from Mile 67 to Mile 61, from Mile 44 to Mile 40, and at Mile 19, the 2 head-end locomotives were generating draft forces between 115 and 155 kips. As a result of the 50% higher draft forces on the cars near the head end of the train, if there had been a flawed knuckle, it most likely would have failed on those ascending grades rather than at the derailment location.

The TSB also conducted train dynamics simulations to determine the difference in generated in-train forces when using a tail-end remote locomotive rather than a sense and braking unit (SBU) when initiating or propagating an emergency brake application. The results indicated that, had the occurrence train been equipped with a tail-end remote locomotive (a 2-1-1 configuration instead of a 2-1-0[25]), the maximum in-train forces during the emergency brake application would have been reduced to 196 kips.

1.14 Management of in-train forces

Train operations have changed significantly in recent years. Newer locomotives have improved dynamic braking capability and energy management systems; these locomotives, when distributed in the middle and/or at the end of trains, along with improved train marshalling and handling, have allowed railways to operate longer and heavier trains. Long, heavy trains can generate significant buff and draft forces due to the slack action of the train resulting in increased in-train forces. To minimize these forces, and prevent derailments and/or reduce their severity, the following elements must be considered:

- Train marshalling
- Placement of DP locomotives within a train
- Train handling
- The topography of the territory a train is operating on and the associated track grade and curvature

1.14.1 Distributed power train operations

DP systems provide synchronous or independent control of up to 4 remote locomotives distributed throughout a train. Train handling commands used on the lead locomotive are transmitted by DP radio to each of the remote locomotives. When the remote locomotives receive the radio message, they respond by executing the train handling commands. When

25 In a 2-1-0 configuration, there are 2 locomotives on the head-end, 1 locomotive mid-train, and none at the end of the train.

the train is operating in DP synchronous mode, the signals sent by the lead locomotive ensure synchronous operation with the remote locomotives.

DP systems reduce drawbar forces, making it possible to safely operate heavier trains. They also ensure faster brake applications and shorter brake distances.

DP trains can be configured with a remote locomotive on the tail end or with an SBU instead. An SBU is an electronic device mounted on the rear coupler of the last car and connected to the brake pipe. The SBU senses train movement, monitors brake pipe pressure at the tail end, and sends the information by radio to the controlling locomotive, where it is displayed in the cab. SBUs enable locomotive engineers to initiate emergency brake applications simultaneously from both ends of the train. When equipped with an SBU, a train can apply all of its brakes in emergency in half of the time that it would take a similar train configured with only head-end locomotives.

However, compared with tail-end remote locomotives, SBUs have some limitations. They have a shorter communication range with the lead locomotive (1½ to 1¾ mile, as opposed to 3 to 4 miles), although their range can be extended when they are used with repeaters.[26] Even with repeaters, SBUs transmit only emergency brake application commands, unlike tail-end remote locomotives, which also transmit service brake applications and other information, including throttle and dynamic brake settings. SBUs also have a smaller depletion choke size for the brake pipe. Consequently, they require more time to propagate the emergency braking signals, could generate higher in-train forces,[27] and require longer stopping distances.

1.14.2 Train area marshalling

TrAM (train area marshalling) is CP's proprietary computer-based train marshalling program, introduced in December 2003 and updated several times since then. TrAM determines the strategic placement of cars and DP remote locomotives in a train for optimal distribution of weight and motive power. TrAM helps maintain in-train forces at acceptable levels (below 200 kips[28] of steady-state buff or draft force) under a normal range of train handling and operating conditions.

TrAM is based on normal train operations and includes a comprehensive set of train marshalling rules designed to apply marshalling restrictions based on the topography of a train's operating territory. CP has characterized the topography of its subdivisions as TrAM areas 1 to 5, which differ by their ascending and descending grades, track curvatures, and

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26 A repeater is a device that receives and retransmits a radio signal to extend the range of 2-way radio transmissions.

27 In-train forces are dynamic buff and draft forces. Buff forces are applied as the train compresses and draft forces are applied as the train stretches. These longitudinal forces put stress on rail cars and their components.

28 1 kip is equivalent to 1000 pounds of force.

undulated track profile. Based on the train route, TrAM area 1 has the least train marshalling restrictions and TrAM area 5 has the most restrictions.

About 85% of CP's entire track network is considered TrAM area 1, including the Ignace Subdivision on the route from Winnipeg to Thunder Bay.

The train was marshalled in a 2-1-0 configuration, which was compliant with TrAM requirements for loaded unit grain trains operating in area 1. It also met CP's instructions for DP trains.[29]

1.15 Increased size of unit grain trains

On 04 December 2018, CP unveiled a new high-efficiency product (HEP) train model that is 8500 feet long.[30] It can carry more than 40% more grain than the 7000-foot train model, when combined with the additional capacity of CP's new high-efficiency hopper cars. The new cars can carry 10% more grain by weight and 15% more by volume than the older Government of Canada cars they are replacing.[31] Many of the cars involved in the derailment were new high-capacity hopper cars. All were rated for 286 000 pounds or less gross rail load, depending on age and design, and had been maintained in accordance with industry standards.

Following the introduction of the HEP trains, CP further increased the length of unit grain trains; those operating from Bowden, Alberta, to Vancouver, British Columbia, were composed of 168 new high-capacity hopper cars loaded with 18 480 tons of grain and were 9700 feet long.

On 13 March 2020, CP started to operate even longer unit grain trains on the route from Winnipeg to Thunder Bay. Between 13 March 2020 and the occurrence, 32 such trains were operated on this route, with the following frequency:

- March: 4 trains
- April: 16 trains
- May: 12 trains

The 32 trains, on average, carried 224 cars, weighed 30 937 tons, and measured 13 083 feet (54% longer than the 8500-foot HEP trains). The longest carried 243 loaded grain cars, weighed 33 320 tons, and measured 14 219 feet.

From the time of the derailment until 31 December 2020, CP operated 34 similar long and heavy trains on this route.

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29 Canadian Pacific Railway Company, *Authorized Distributed Power Placement for Trains*, Version 2 (April 2020).

30 Canadian Pacific Railway Company, "CP showcases new high capacity hopper cars, High Efficiency Product train" (04 December 2018), at https://www.cpr.ca/en/media/cp-showcases-new-high-capacity-hopper-cars (last accessed 06 February 2023).

31 Canadian Pacific Railway Company, "CP completes biggest-ever Canadian crop-year haul, stands ready for 2020-2021 harvest" (05 August 2020), at cpr.ca/en/media/cp-completes-biggest-ever-canadian-crop-year-haul-stands-ready-for-2020-2021-harvest (last accessed 06 February 2023).

1.16 Railway safety management systems

The *Railway Safety Management System Regulations, 2015* (SMS Regulations), which came into force in 2015, require railway companies to develop and implement a safety management system (SMS). Although the SMS Regulations specify the processes to be included in a company SMS, they provide railway companies with flexibility in determining the most appropriate way to implement these processes, based on company-specific factors.

One such process required by the SMS Regulations[32] is a risk assessment process, where railway companies must conduct assessments to identify risks and required remedial action.

Subsection 15(1) of the SMS Regulations states, in part:

> A railway company must conduct a risk assessment in the following circumstances
>
> […]
>
> (c) when a proposed change to its railway operations, […] may affect the safety of the public or personnel or the protection of property or the environment:
>
> […]

1.16.1 Canadian Pacific's safety management system

In accordance with the SMS Regulations, CP has developed and implemented an SMS. CP's SMS includes a risk assessment policy and procedure, and is routinely updated and refined to support continuous improvement.

CP's risk assessment procedure lists the conditions under which a risk assessment must be performed. One such condition includes any proposed change to CP operations that could "create or increase a direct safety risk to employees, railway property, property transported by the railway, the public or property adjacent to the railway."[33] The procedure outlines how to assess each change to operations using the CP risk assessment tool. The process involves identifying the potential undesired events and their likely consequences that could occur as a result of a change to operations, and identifying their risks and any required mitigation measures.

1.16.2 Canadian Pacific's evaluation of changes to train operations

CP conducted a simulation to assess and validate its instructions for DP trains before the new HEP trains were introduced in December 2018. The simulation considered track structure conditions based on regulatory requirements and CP's track standards. The simulation was conducted for loaded unit grain trains that had been increased in length to 168 cars (from 112 cars) on the route west from Bowden to Vancouver over TrAM area 3.

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[32] Transport Canada, SOR/2015-26, *Railway Safety Management System Regulations, 2015* (as amended 01 April 2015), subsection 15(1).

[33] Canadian Pacific Railway Company, *Risk Assessment Procedure*, version 2.0 (last revised 30 June 2017), section 2.1.1, p. 2.

The Ignace Subdivision, which is in the less-restrictive TrAM area 1, was not part of the simulation performed.

CP did not consider the introduction of the new HEP trains as a change to operation requiring a risk assessment, based on its interpretation of the SMS Regulations and its own internal process. Therefore, no risk assessment was performed.

1.16.3 Previous TSB investigations related to changes in operations at Canadian Pacific

Since the new SMS Regulations came into effect in 2015, the TSB has investigated 6 other occurrences in which CP did not consider its operational changes to be significant enough to require a risk assessment.[34]

Following the TSB's investigation into the Yoho accident in February 2019,[35] which resulted in the derailment of a freight train and the fatal injuries of 3 crew members, the Board determined that the railway companies' SMSs are not yet effectively identifying hazards and mitigating risks in rail transportation. When hazards are not identified, either through reporting, data trend analysis, or by evaluating the impact of operational changes, and when the risks that they present are not rigorously assessed, gaps in the safety defences can remain unmitigated, increasing the risk of accidents. The Board also determined that, until CP's overall corporate safety culture and SMS framework incorporate a means to comprehensively identify hazards, including the review of safety reports and data trend analysis, and assess risks before making operational changes, the effectiveness of CP's SMS will not be fully realized. Therefore, in March 2022, the Board recommended that

> the Department of Transport require Canadian Pacific Railway Company to demonstrate that its safety management system can effectively identify hazards arising from operations using all available information, including employee hazard reports and data trends; assess the associated risks; and implement mitigation measures and validate that they are effective.
>
> **TSB Recommendation R22-03**

1.17 TSB Safety Issues Investigation Report SII R05-01

In 2005, the TSB conducted a safety issues investigation involving an extensive analysis of train derailments and their relationship to bulk tonnage traffic.[36] Loaded high-capacity rail cars in unit trains pose special problems to main lines where weak track conditions (ties, ballast, and subgrade) may be common. A unit train consist is usually uniform; that is, all cars are of the same design and loading, with the car trucks and car bodies responding more or less as one unit. Therefore, each rail car on the train responds to track irregularities in

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34 TSB rail transportation safety investigation reports R19C0015, R19C0002, R18H0039, R17D0123, R16C0065 and R16W0074.

35 TSB Rail Transportation Safety Investigation Report R19C0015.

36 TSB Safety Issues Investigation Report SII R05-01.

the same manner as the previous car, leading to cumulative impacts at irregularities that the train encounters in the track structure. Trains with numerous rail cars of the same design and with high load capacity provide the track little or no opportunity for elastic recovery[37] during their passage. As a result, high-capacity unit trains can hasten permanent and usually non-uniform track deformation.

1.18 TSB Watchlist

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

Safety management is a Watchlist 2022 issue. As this occurrence demonstrates, when changes to railway operations are proposed, all potential hazards need to be identified and risk assessments must be conducted in order to mitigate safety hazards.

ACTION REQUIRED

Safety management will remain on the Watchlist for the **rail** transportation sector until operators demonstrate to TC that their SMS is effective.

[37] Elastic recovery refers to the track's ability to return to its original shape after being loaded and unloaded.

2.0 ANALYSIS

The train was operated in a manner that was consistent with company and regulatory requirements. A review of the recorded information did not reveal track anomalies on Canadian Pacific Railway Company's (CP) Ignace Subdivision, equipment defects or train handling issues that could be considered causal to the derailment.

The investigation was unable to conclusively determine the cause of the accident. The analysis will focus on the stability of the track, including the condition of the subgrade in the area of the derailment, the effects of cyclic loading on peat foundations, as well as the management of changes to train operations.

2.1 Nature and quality of the track subgrade

In the vicinity of the occurrence, there were indications of some roadbed movement such as undulations in the track profile and variations in track alignment.

An examination of 8 geotechnical core samples taken in the area of the derailment (about Mile 12.8) indicated that the sub-ballast layer was made of poorly graded sand, which was black and brown, wet, loose, and fine-grained, with up to 16% silt. Material with more than 10% silt and clay is not considered free-draining and may have low bearing capacity, especially if saturated by a high water table. In the area of the derailment, starting at a depth of 0.5 to 0.8 m, there was some free water, indicating that the water table was very high. Peat was encountered beneath the sub-ballast layer. Peat, a naturally occurring organic soil, is characterized by high water content, poor drainage, and high compressibility, which result in reduced strength of the peat fibres.

Soft subgrade in areas of poor drainage creates issues with track stability and failure of bearing capacity. Because the track between Winnipeg, Manitoba, and Thunder Bay, Ontario, was built more than a century ago when material and construction techniques were different, some locations on the track continuously experience poor water drainage, soft subgrade, and recurring geometry conditions. Proper drainage is key to track stability, but draining a large, flat peatland area is impossible. In addition, replacing long sections of soft subgrade is not practical, and ongoing ballast maintenance does not typically address the underlying poor drainage problems.

The poor drainage conditions at the derailment location caused water to accumulate adjacent to and under the track. The accumulated water resulted in frost heaving during winter freezing of the roadbed, differential track cross-level measurements, and the need for frequent shimming and surfacing to maintain track alignment, surface, and profile.

Finding as to causes and contributing factors

While the train was travelling along CP's Ignace Subdivision, on a section of tangent track with differential cross-level measurements, the bearing capacity of the soft, saturated peat subgrade was likely exceeded, resulting in a sudden subgrade failure that led to the derailment.

2.2 Track inspections

The track between Mile 12 and Mile 13 underwent frequent geometry inspections, which revealed surface and cross-level conditions, as well as geometry defects (S22 – vertical displacement, R31 – elevation runoff, RC55 – rate of change of cross-level, and D ELV T – design elevation tangent defects). Such track geometry defects can be exacerbated by tie, ballast, subgrade, and drainage conditions.

During an inspection by track evaluation car on 07 April 2020, a priority R31 rail surface defect of 1⅛ inches was detected at the same location on both the north and south rail, which is unusual as this defect normally occurs on only 1 rail. R31 defects create a dip in the rail; the passage of heavily loaded cars would make this dip more pronounced over time, increasing tie damage.

The D ELV T conditions were ½ inch or less, but they indicated superelevation in tangent track, which should not have superelevation. When superelevation occurs in tangent track away from a curve, as in this occurrence, it is due to differential settlement between the rails. In this occurrence, the south rail was superelevated, indicating that the north rail had settled relative to the south rail. This condition would have caused a load transfer to the north rail (the low rail). Although the double track had been removed from the south side, the embankment remained and acted as a stabilization berm for the south rail.

Finding: Other

Surface and cross-level conditions, as well as geometry defects detected by frequent geometry testing conducted before the derailment, provided signs of possible unstable subgrade in Mile 12.

Railway inspection technologies and procedures are based mainly on evaluations of track conditions at surface level. They are effective for observing track settlements; however, the distortion of peat fibres or, rather, the level of compression, cannot be seen by the naked eye or during surface inspections. Although railway inspection procedures and technologies cannot directly detect the risk of impending subgrade collapse, they can provide signs of unstable subgrade.

Finding as to risk

Railway inspection procedures and technologies that are based on surface observations cannot measure underlying subgrade conditions, increasing the risk that impending subgrade failure will go undetected.

2.3 Cyclic loading on peat foundations

Geotechnical studies have found that, when a train passes over peat foundation, vertical rail movement occurs and pore water pressure increases, reducing shear strength of the soil and the underlying peat. Average vertical movement and pore pressure values tend to increase with the number of cars passing, thereby creating an accumulation at the end of the train's passage. Once the last car passes, the excess pressure dissipates gradually. However, there continues to be residual settling, which is cumulative; it builds up as a result of repeated passages, especially under long, heavily loaded unit trains.

Settlement of the embankment under the passage of trains results in underlying peat fibre distortion, realignment of the fibres, and loss of strength. The distortion increases as axle load and speed increase, and the peat fibres eventually exceed their elastic limit; under these conditions, the overextended fibres can shear, resulting in punching through the underlying peat layer or a sudden failure of bearing capacity.

Train lengths and loads have been increasing steadily since the original construction of the Canadian railway network, putting greater demands on the existing infrastructure. Between 13 March and 24 May 2020, the average length of the 32 loaded unit grain trains that operated on the Ignace Subdivision was 13 083 feet, and the average weight was 30 937 tons. The scheduling of the long, heavy grain trains caused cyclic loading, and the pore water pressure was unable to dissipate. The cyclic loading exacerbated existing track geometry anomalies, contributing to the subsequent failure of the subgrade.

Finding as to causes and contributing factors

The operation of loaded high-capacity rail cars in unit train consists created longer periods of cyclic loading and provided little opportunity for the elastic recovery of this track with geometry anomalies, accelerating the deterioration of the inherently unstable track subgrade.

2.4 Management of in-train forces

The effective management of in-train forces requires a systematic approach that includes proper train marshalling and strategic placement of distributed power (DP) locomotives within a train, taking into account the topography of the territory a train is operating on and the associated track grade and curvature.

DP locomotives can be added in multiple configurations throughout a train. In this occurrence, the train met CP's instructions for DP trains and was marshalled in a 2-1-0 configuration, which was compliant with CP's train area marshalling software (TrAM) requirements for loaded unit grain trains operating in TrAM area 1.

DP locomotives contribute to the reduction of drawbar forces and improve air brake signal propagation throughout a train's air line. This improves train handling, reduces in-train forces, and reduces braking distances.

A sense and braking unit (SBU) has a smaller depletion choke size for the brake pipe compared to locomotive automatic brake and vent valves, and more time is required to propagate an emergency braking signal. The simulation showed that, had the occurrence train been equipped with a tail-end remote locomotive instead of an SBU, the propagation of the emergency brake signal to the tail-end cars would have been quicker and the in-train forces generated by the tail-end on the cars ahead during the emergency brake application would have been reduced.

Finding: Other

A train equipped with a tail-end remote locomotive reduces the in-train forces generated during emergency brake applications more effectively than one equipped with an SBU.

2.5 Change in train operations on the Ignace Subdivision

In December 2018, CP introduced a new longer and heavier high-efficiency product (HEP) train to expedite the movement of the 2019–20 grain crop to port. CP later further increased the size of these trains. The 32 loaded unit grain trains that operated on the Ignace Subdivision between 13 March and 24 May 2020 were significantly longer and heavier, on average, than the original HEP trains. The occurrence train weighed 30 307 tons and measured 12 896 feet.

Risk assessments must be conducted before implementing operational changes that have the potential to introduce new hazards or increase the level of severity of existing hazards. CP had determined that it was not necessary to perform a risk assessment before the introduction of the HEP trains on the Ignace Subdivision. Therefore, there was no opportunity to identify cyclic loading on the subgrade on the Ignace Subdivision as a potential hazard and ensuing mitigation measures were not considered.

Finding as to risk

If no evaluation of the limitations of track subgrade is performed, the effects of increased cyclic loading will be undetermined, increasing the risk of subgrade collapse leading to a derailment.

3.0 FINDINGS

3.1 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. While the train was travelling along Canadian Pacific Railway Company's Ignace Subdivision, on a section of tangent track with differential cross-level measurements, the bearing capacity of the soft, saturated peat subgrade was likely exceeded, resulting in a sudden subgrade failure that led to the derailment.

2. The operation of loaded high-capacity rail cars in unit train consists created longer periods of cyclic loading and provided little opportunity for the elastic recovery of this track with geometry anomalies, accelerating the deterioration of the inherently unstable track subgrade.

3.2 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. Railway inspection procedures and technologies that are based on surface observations cannot measure underlying subgrade conditions, increasing the risk that impending subgrade failure will go undetected.

2. If no evaluation of the limitations of track subgrade is performed, the effects of increased cyclic loading will be undetermined, increasing the risk of subgrade collapse leading to a derailment.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. Surface and cross-level conditions, as well as geometry defects detected by frequent geometry testing conducted before the derailment, provided signs of possible unstable subgrade in Mile 12.

2. A train equipped with a tail-end remote locomotive reduces the in-train forces generated during emergency brake applications more effectively than one equipped with a sense and braking unit.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Canadian Pacific Railway Company

Canadian Pacific Railway Company (CP) constructed a toe berm on the north side of the track to balance the existing former track embankment on the south side, and completed rehabilitation and stabilization work on the south side of the track after the derailment. The toe berm helps to evenly distribute loading of the subgrade and to counter differential settlement through the derailment area.

CP conducted simulations and modified the distributed power configuration for grain trains of 224 cars. Such trains are now operated with a tail-end remote locomotive (distributed power train configuration 2-1-1) instead of a sense and braking unit (distributed power train configuration 2-1-0, the configuration of the occurrence train). Trains with 112 or 168 cars are still permitted to operate with a sense and braking unit instead of a tail-end remote locomotive.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 22 February 2023. It was officially released on 21 March 2023.