RAILWAY OCCURRENCE REPORT
R97V0063

DERAILMENT

CANADIAN NATIONAL
TRAIN NO. Q-102-51-26
MILE 106.15, ASHCROFT SUBDIVISION
CONRAD, BRITISH COLUMBIA
26 MARCH 1997

Transportation Safety Board of Canada

Bureau de la scurit des transports du Canada

Railway Occurrence Report

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Synopsis

At 0606 Pacific standard time on 26 March 1997, Canadian National train No. Q-102-51-26 (train 102), travelling from Boston Bar, British Columbia, to Kamloops, British Columbia, on the Ashcroft Subdivision encountered a large roadbed depression and derailed at Mile 106.15, near Conrad, British Columbia. Both crew members were fatally injured.

The Board determined that an extraordinary volume of surface water run-off from melting heavy snow cover and high seasonal precipitation was not captured and carried away as intended by the drainage system above the adjacent Trans-Canada Highway. The water soaked into the ground, migrated through the highway fills, and infiltrated and destabilized the railway subgrade. The railway subgrade could not sustain the resultant high pore pressure and collapsed. Contributing factors included the presence of moisture-sensitive alluvial deposits in the bottom area of the railway subgrade and the overlapping nature of the highway fills which created a contiguous groundwater flow path into the railway fills.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 The Accident

On 26 March 1997, Canadian National (CN) train 102 departed Boston Bar, Mile 125.5 of the Ashcroft Subdivision, at approximately 0530[1], travelling eastward in early daylight, destined for Kamloops, Mile 0.0. The rail traffic controller (RTC) supervising train movements on the Ashcroft Subdivision from the RTC Centre in Edmonton, Alberta, noted train 102's normal eastward progress on the Centralized Traffic Control System (CTC) panel and observed the indication when it occupied the block at West Conrad, Mile 106.4. Within seconds of train 102's occupying the block, the CTC between Boston Bar and Lasha, Mile 96.5, malfunctioned. To determine the location and well-being of train 102, the RTC made several attempts to contact the train by radio. He met with no response, although the crew members of a westward train holding the siding at Cisco, Mile 101.0, advised that train 102 had not yet passed their location. The RTC then radioed CN employees working in the Conrad area asking them to determine the whereabouts of train 102.

At approximately 0645, a maintenance-of-way employee discovered the two locomotives and numerous double-stacked container cars from train 102 at the bottom of a large depression in the railway subgrade at Mile 106.15. Loaded, open hopper sulphur cars from westward unit sulphur train R-711-51-22 (train 711), stored on the adjacent siding, were also observed derailed, in and around the depression. Some of the derailed sulphur cars had overturned and spilled their contents. Fuel had leaked from the derailed locomotives and ignited. The resulting fire had engulfed the derailed equipment and scattered container contents, but the spilt sulphur was unaffected. As the two crew members were not located following a search of the area, it was assumed, and subsequently confirmed, that they had not been able to exit the locomotive cab and jump from the train before it reached the depression.

Fill from the subgrade of the Trans-Canada Highway, parallelling the railway above the tracks, had slipped away, and cracks were noted in the pavement directly above the wreckage. To prevent further slippage of the highway roadbed and to ensure the safety of motorists and first responders working below, road traffic was restricted to the lane next to the hillside. The concrete barrier at the outside edge of the roadway was removed. A pit and drainage system was also constructed above the highway to carry draining surface water away from the accident area. The size of the cracks was monitored, and an immediate evacuation of the accident area was to be initiated if these cracks became wider than 5 mm.

The mountainous terrain made fire-fighting difficult, and helicopters water-bombed the burn area. The fire proved troublesome but was finally extinguished at about 1700 on 28 March 1997. After the fire was put out, the remains of the locomotive engineer and the conductor were located and recovered from the cab of the lead locomotive.

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1 All times are Pacific standard time (Coordinated Universal Time (UTC) minus eight hours) unless otherwise stated.

Fire again erupted around the locomotives at 0500, 29 March 1997, and took several hours to extinguish. At 0530, 30 March 1997, the clean-up operation was terminated, and employees were evacuated from the site when the highway cracks were noted to be widening. When the size of the cracks remained unchanged for a period of 5 ½ hours, work resumed. The rest of the clean-up and restoration was uneventful.

The derailed cars and cargo were removed. The locomotives were drained of any remaining diesel fuel and oil, filled with concrete and buried in the subgrade. The track was restored and opened for operation at 0200, 06 April 1997.

At this time, reconstruction of the highway slope began, as monitoring and testing had established that no further slippage of highway fills was occurring and water saturation levels had decreased. Highway repairs were completed on 10 April 1997.

1.2 Injuries

The locomotive engineer and the conductor were fatally injured.

1.3 Damage to Equipment

Fourteen freight cars and two locomotives were damaged beyond repair.

1.4 Other Damage

Approximately 1,200 feet of main track and siding was destroyed.

1.5 Personnel Information

The train crew consisted of a conductor and a locomotive engineer, both of whom were in the lead locomotive. They were qualified for their respective positions and met fitness and rest standards established to ensure the safe operation of trains.

1.6 Train Information

The train included 2 locomotives, 72 loaded cars and 5 empty cars. It weighed approximately 4,850 tons and was about 5,580 feet in length.

1.7 Particulars of the Track

The Ashcroft Subdivision extends from Kamloops (Mile 0.0) to Boston Bar (Mile 125.5) and was opened for traffic in 1915.

The main track consisted of 136-pound continuous welded rail (CWR) laid in 1994. The rail was laid on concrete ties installed about 2,640 per mile (the Conrad Siding was laid on timber ties). Ballast was crushed rock, and the track was last resurfaced in 1995. The track condition in the derailment area was good. Between Mile 106.2 and Mile 106.0, the maximum authorized speed was 30 mph for freight trains and, between Mile 113.2 and Mile 106.2, it was 35 mph.

1.8 Occurrence Site Information

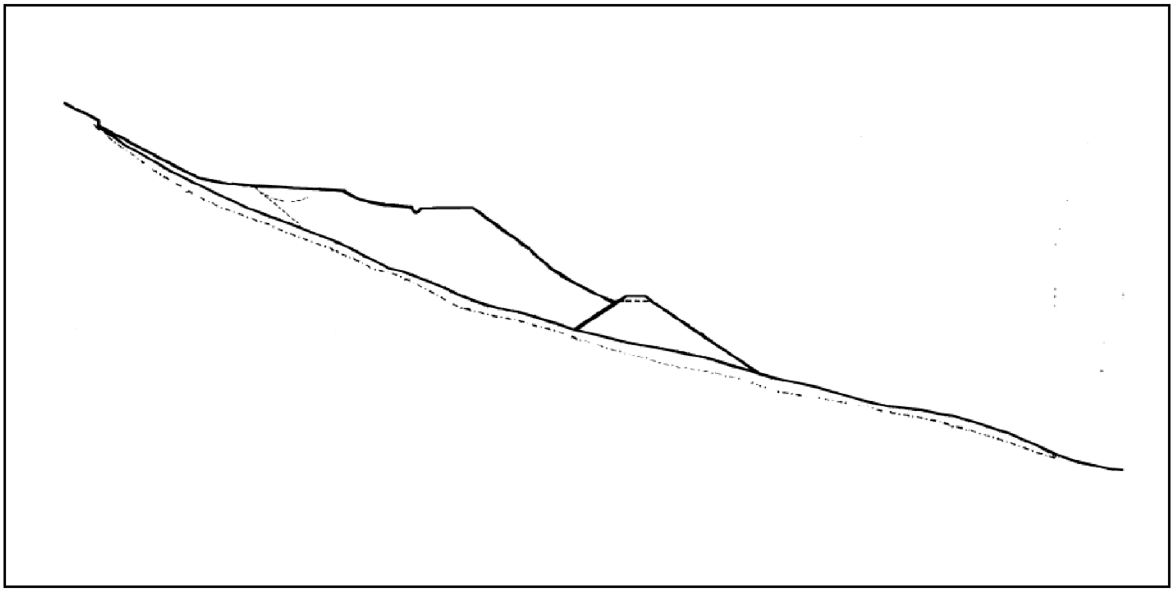
1.8.1 General

In the area of the derailment, the single main track and siding (west of the main track) run between the Trans-Canada Highway, approximately 60 m (197 feet) to the east and 34 m (112 feet) above, and the Fraser River, approximately 150 m (492 feet) to the west, and 50 m (164 feet) below. The railway embankment and toe of the highway fills had slipped away, leaving a void approximately 60 m (197 feet) long and 12 m (40 feet) deep, stretching up into the highway fills. The mud-like fill had flowed west, trailing into the Fraser River. The locomotive consist and first three cars of train 711 were standing upright and railed on the siding south of the depression. The fourth car was derailed and leaning, the fifth and sixth cars had rolled onto their sides and spilled their lading, while the seventh car was lying partially down the embankment. The eighth, ninth and tenth cars were near the bottom of the embankment on the westerly edge of the pile-up of equipment at the bottom of the depression, while the eleventh car was derailed and upright north of the slide area. The tenth car had come to rest approximately 46 m (150 feet) west of the siding track. The pile of equipment included the locomotive consist and the first six cars from train 102. The seventh and eighth cars were upright, but derailed, on the south edge of the depression (See Figure 1).

The Canadian Pacific Railway (CPR) Thompson Subdivision traverses the opposite side of the Fraser River Canyon, clearly visible from the derailment site.

1.8.2 Geotechnical

The terrain is mountainous and heavily forested. The highway, originally built in 1948, had been realigned in 1952 and 1960. Each realignment resulted in the highway being moved closer to the railway right-of-way (See Figure 2). The highway subgrade and embankment consist of local fill materials laid over original ground. The highway embankment is at an approximate 1 to 1.5 slope. A service road, 3 m (10 feet) wide, runs between the railway subgrade and the toe of the highway fill.



The railway subgrade was built in 1915 using local fill materials laid on *in situ* ground material. In 1979, the railway built a parallel siding track west of the main track. The additional fill for the siding embankment, composed of granular material, was also placed on the original ground surface material.

The railway embankment is at an approximate 1 to 1.5 slope.

Water run-off from the mountain slopes and surrounding watershed flowed toward the Trans-Canada Highway through a natural drainage path at an estimated flow rate of two cubic metres a minute[2], soaking into the ground about 36 m (118 feet) from the highway. The water run-off was intended to flow under the road and railway subgrade to the Fraser River through a series of culverts. A catch basin on the east side of the highway held no water. The vertical corrugated-metal culvert servicing the catch basin extended approximately 1 m (3 feet) above ground level, with holes randomly punched in the side to allow water entry. There was no culvert or flue connecting the stream with the vertical drain in the catch basin.

1.8.3 The Spilled Sulphur

Although solid sulphur, shipped in pellet form in this instance, is not subject to the Transportation of Dangerous Goods Regulations, it nevertheless produces a poisonous gas (sulphur dioxide) when burned and is, therefore, a safety risk at locations where ignition is possible. Most of the spilled product was recovered but an unquantifiable amount mixed with the displaced fill, some of which flowed into the Fraser River. Since it is practically insoluble in water, it will settle into the river sediments and remain in the soils in the slide area. It does not present a health risk in either location.

1.9 Method of Train Control

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2 Measurement made by geotechnical consultants at 1500 on 26 March 1997.

Train movements on the Ashcroft Subdivision are governed by the CTC authorized by the Canadian Rail Operating Rules (CROR) and supervised by an RTC in Edmonton.

1.10 Weather

Snow is recorded to have first fallen in Conrad on 16 November 1996. There was steady accumulation through December until 01 January 1997, when the precipitation turned to rain. January 1997 was recorded as the wettest month on record, with 240.7 mm of rainfall at the Vancouver International Airport which, according to Environment Canada, has climatic conditions similar to the Conrad area. The month of February did not produce any abnormal levels of precipitation.

The snow pack began to thaw in the Conrad area in the middle of February (based on the Lytton 2 weather station which is approximately 13 km north of Conrad). The week of 11 March to 18 March was sightly cooler and significant snowfalls occurred on 15 March and 16 March (based on the Lytton 2 weather station and the Lytton Botanie weather station, which is located 24 km north of Conrad). During the three following days, precipitation changed from snow to rain. Based on the two Lytton weather stations, 20 mm to 25 mm of rain fell, producing a rain on snow event which caused high run-off. In two days, 25 cm of new snow melted at Lytton 2 and in three days, 22 cm of new snow melted at Lytton Botanie. The winter snow pack (of approximately 55 cm) began to melt at a rate of 1.3 cm per day and, on 25 March (warmest day of the year to that point at Lytton 2), the rate of melting at Lytton Botanie went to approximately 5 cm per day.

The second heaviest one-day rainfall in 59 years at the Vancouver International Airport occurred on 01 March 1997 with 47.2 mm of rain. This record was exceeded when 48.4 mm of rain fell on 18 March 1997. More than 20 mm of rain fell each day on 17 March 1997 and 19 March 1997.

Similar conditions were noted at the Lytton 2 weather station.

The recorded precipitation between October 1996 and March 1997 was 1,327.0 mm of precipitation, the wettest six months in 59 years. Record rainfalls and snowfalls were recorded across most of southern British Columbia.

On 26 March 1997, it was approximately the 41st day of run-off caused from melting snow. The rate of melting had increased suddenly between 17 March and 19 March with an event of rain on snow.

At the time of the accident, the temperature was approximately eight degrees Celsius, with light south winds and no precipitation.

1.11 Recorded Information

1.11.1 Train 102

The event recorder data could not be recovered from the fire-damaged locomotives of train 102.

1.11.2 Train 711

The event recorder data from standing train 711 revealed that it experienced an emergency brake application, signifying train separation, at a recorded time of 0437:04.

1.11.3 Signal Activity Report

Electronic signal activity data indicate that eastward CPR train 902, operating on CN track by arrangement, travelled over CTC Signal 1064 (Conrad West, Mile 106.4) at a recorded time of 0353:05.

Train 102 travelled from CTC Signal 1160 (Inkitsaph, Mile 116.0) at a recorded time of 0548:36 to CTC Signal 1064 at a recorded time of 0605:49. At a recorded time of 0606:22, the CTC signal system at Conrad became inoperative.

1.12 Other Information

1.12.1 The Subgrade Failure

1.12.1.1 Geotechnical Engineering Report Findings

A geotechnical engineering report prepared by Dr. Stephen G. Evans (Geotechnical Engineer and Engineering Geologist for Geological Survey of Canada), adviser to the Transportation Safety Board of Canada, and Dr. K. Wayne Savigny, P.Eng., P.Geol. (Geotechnical Engineer and Engineering Geologist for Bruce Geotechnical Consultants Inc., Vancouver), consultant to CN, concluded that the day of the derailment followed a lengthy period, possibly as long as 41 days, of steadily increasing seasonal run-off from melting of an unusually heavy snow pack. Site observations from 26 March 1997 indicated that run-off from the stream gully directly above the landslide area had infiltrated the old and existing highway fills before reaching the culvert at the edge of the present Trans-Canada Highway. This sustained infiltration created a water table through the highway fills. Development of the highway facility in the Conrad area had involved encroachment of successive Trans-Canada Highway embankments onto the CN right-of-way. It culminated in 1960, when the Trans-Canada Highway embankment was placed against the pre-existing CN embankment, creating for the first time the physical possibility of a contiguous groundwater flow path through the fills and sustained elevation of pore pressures in the pre-existing CN embankment. The event of 26 March 1997 consisted of two landslides. A smaller, first event, centred north of the prominent landslide scar, involved a failure of the west side of the siding fill and caused the derailment of the sulphur train (train 711). The second, much larger, event was initiated by the first but retrogressed into the thick gully fill rather than into the full backscarp from the first event. Both landslides were caused by the elevated water pressures. The extent to which the slides retrogressed was related to the level of the water table and the loose compaction of the original railway embankment fill.

A slope stability analysis indicated that the railway fill was stable when the water table was limited to buried alluvial deposits beneath the sequence of fills. At steady-state flow conditions, the fill overlaying the centre of the gully was marginally stable. The centre portion of the fill benefited from the draw down effect of the alluvial deposits, but the margins of the gully experienced high water pressure (pore pressure) because of the absence of this drain effect. Under the elevated water pressure, native low to non-plastic silts in the foundation of the subgrade initiated the first failure event.

The first failure event exposed the original CN fill which was loose and, at the lower portion, water-saturated. This fill then slipped away in retrogressing shallow slumps until the loose, water-saturated original fill was eliminated.

1.12.1.2 British Columbia Ministry of Transportation and Highways Report

A geotechnical report prepared by B.C. Beattie, P. Eng. (Geotechnical Engineer), and J.A. Valentinuzzi, P. Eng. (Regional Geotechnical and Materials Engineer), for the British Columbia Ministry of Transportation and Highways (MoTH) stated that the large breach in the railway embankment was a result of earth flow that regressed up the slope from the toe of the railway embankment and removed a section of the embankment under the railway track, as well as part of the fill-slope toe of the Trans-Canada Highway. Initial investigation of the surface run-off coming down a gully immediately east of the highway embankment indicated that a significant amount of water was running down the gully and almost immediately infiltrating the ground at the mouth of the gully. To prevent further infiltration, the water was diverted north along a plastic-lined trench into a MoTH culvert. A slope indicator/piezometer was installed to monitor highway grade movement and water depth. As a result of the investigation and monitoring, MoTH is reasonably sure that the Trans-Canada Highway embankment is currently stable following CN remediation of the embankment slope. MoTH is presently working on a drainage design that will prevent the surface run-off at the mouth of the gully from infiltrating the ground by directing any future surface run-off into the existing culvert under the highway and into the recently constructed CN drainage system.

1.12.2 Geotechnical Inspection Programs

1.12.2.1 CN Geotechnical Program

The CN Geotechnical Engineering Branch functions as a support group to the local district engineering staff. Western region resources are located at regional headquarters in Edmonton. The region has one senior geotechnical engineer, supported by technical engineering services, who relies on consulting engineers who are experts in their field and familiar with the Fraser Canyon territory. The inspection program included three components: an annual reconnaissance, site-specific inspections and emergent-condition inspections.

The annual reconnaissance component is undertaken through a site inspection with the objective of reviewing the long-term stabilization program in light of current conditions, establishing priorities for remedial work and confirming work programs for the ensuing year. The annual visit is performed by the senior geotechnical engineer for the area who is accompanied by the district engineer and a track supervisor who is familiar with the territory. Problem areas are identified by local engineering staff. Historical records, if available, are used. Those areas identified as in need of remedial work are advanced to the senior engineering officials.

Site-specific inspections are conducted by the senior geotechnical engineer and contracted to external consultants. They are undertaken to assess conditions, develop remedial strategies, collect field information required for engineering design and review the status of remedial work in progress. These inspections centre on technical issues and are directed by the senior geotechnical engineer.

Emergent-condition inspections are undertaken as required by the senior geotechnical engineer, external consultants, or both, in response to emergency situations or concerns raised in the field. The geotechnical inspections focus on rockslides and unstable back slopes as well as drainage conditions, the stability of shoulders and embankments, roadbed subsidence and the activities of nuisance beavers.

There had been 34 CN Engineering Branch field inspections (annual and site-specific) of the Ashcroft Subdivision from 1993 to the accident date. Most inspections focussed on rockslide threats; however, geotechnical problems and drainage issues were identified. The stability and drainage of the highway embankment at Mile 113.7 (approximately 1 ½ mile away from the occurrence site) were identified as problematic and, after the railway informed the MoTH, corrective measures were undertaken (including a revision of the highway alignment).

1.12.2.2 CN Landslide Prevention Program

In 1995, CN had engaged a consultant to develop a hazard and risk management methodology for rock slopes and review CN's practice vis-à-vis the management of natural hazards (including landslides, washouts, rockfalls and debris torrents). This review evaluated CN's practice and benchmarked against other railway, transportation and utility firms. It included recommendations for developing a format to inspect potential rockslides, avalanches, grade stabilization, mud slides, drainage systems and sub-soil conditions.

As a result of the first project, a Rockfall Hazard and Risk Assessment system for the quantitative assessment of rockfall risks and prioritization of mitigative work was developed. This system was piloted in the Fraser corridor in 1996 and subsequently implemented across the balance of CN's Pacific District in 1997.

1.12.2.3 The MoTH Highways Geotechnical Program

MoTH did not have a proactive geotechnical program. The highway contractor engaged by MoTH carried out routine inspections and maintenance of the roadway and related structures, and reported any unusual conditions to the district MoTH office. The district office would then request the MoTH Geotechnical Engineering Branch to investigate.

Geotechnical Engineering Branch representatives stated that it was not probable that a lay person could detect subsurface geotechnical problems. They also said that no formal relationship between the MoTH geotechnical engineers and their counterparts within either CN or CPR existed. Their direct involvement with the local highway district is typically in response to an emerging situation, and there were no proactive geotechnical surveillance programs in place, due to limited resources.

The highway contractor had not reported any significant geotechnical concerns in the area since 1992. Therefore, the Geotechnical Engineering Branch had not carried out any geotechnical inspections in the area. MoTH records do not indicate that a landslide area had previously been brought to the attention of the Geotechnical Engineering Branch.

1.12.3 *Inspection Programs*

1.12.3.1 *Transport Canada Track Inspector Activity*

The Transport Canada (TC) infrastructure inspection program uses safety inspectors to monitor randomly selected sections of track for compliance with Track Safety Rules. The inspections include observations to ensure that drainage facilities adjacent to the track are free from obstructions. In addition, cursory visual inspections are made with respect to grade and rock-slope stability. If drainage or stability problems are evident, then detailed assessments would be performed by either a dedicated railway infrastructure officer or a railway works engineer.

TC's Pacific Region included two specialized inspector positions: railway infrastructure officer and railway works engineer. The railway infrastructure officer monitored the railway industry's compliance with regulations and standards related to the construction and maintenance of railway trackage, drainage systems and rights-of-way. Such inspections also included a cursory examination of bridges. It was not, however, within the scope of the railway infrastructure officer's duties to consider subsurface conditions, nor did the position involve specific training in soil or rock mechanics, and the officer was not expected to have expertise in this area. The railway works engineer planned and organized regional programs to monitor the railway industry's compliance with the construction and maintenance standards for bridges, structures and other works on the railway rights-of-way, and was responsible for TC's crossing and trespassing programs. Although the incumbent railway works engineer had a working knowledge of geotechnical matters, this was not a requirement for the position.

1.12.3.2 *CN Track Inspection Program*

1.12.3.2.1 *CN Track Inspector Duties*

Railway track inspections are carried out in compliance with both TC Track Safety Rules and the CN Maintenance-of-Way Standard Practice Circulars (SPC). Track inspection personnel may include the track supervisor, assistant track supervisor or a qualified person as defined in the Track Safety Rules. The Track Safety Rules stipulate that a track be inspected at such a frequency and method as to ensure safe operation at the authorized speed. The applicable SPC outlines that the track at Conrad be inspected twice weekly, with at least two days between inspections. The track supervisor last inspected the subdivision from train CN 103-25-10 on 25 March 1997. Two low spots were identified for remedial work (Mile 77.3 and Mile 107.2). The assistant track supervisor had inspected the track at Mile 106.15 by Hi-rail on 22 March 1997. No irregularities were noted.

CN's SPC list those items to be inspected, the mode of travel for inspections, and when and by whom the inspections are to be performed. The modes of travel are either walking, track motor car, Hi-rail vehicle or train. In addition, the SPC list the following specific items to observe for anomalies: rail, track fastening components, ballast, line, surface, cross-level, gauge, turnouts, railway crossings, drainage, slides, right-of-way conditions, clearances, road crossings and track signs.

Two employees were tasked with special track inspection duties from November 1996 to April 1997, between Mile 74.8 (Spences Bridge) and Mile 125.3 (Boston Bar). The patrols were performed as directed by the track supervisor and as permitted by the RTC who authorizes track occupancy. There was no CN requirement that detailed the minimum number of times a special track patrol was to be performed over a given subdivision.

The special track patrol is required to detect slides, rocks on the track and other anomalies that would affect the safe operation of trains. The employee charged with the responsibility of patrolling track on the Ashcroft Subdivision between Boston Bar and Spences Bridge was required to report any problems with the track to the RTC and, from there, the RTC would take any action as deemed necessary to protect trains.

Between 25 February 1997 and 24 March 1997, 21 special track patrols were carried out between Mile 75.0 and Mile 125.0. On 16 of these patrols, rocks were discovered on the track and removed.

On the night of 25 March 1997, the special track patrol employee between Boston Bar and Spences Bridge began the shift at 2200 and was scheduled to work until the following morning at 0600. The track patrol employee stated that, at the start of the shift at Spences Bridge, he requested access to the track twice and, each time, was refused by the RTC because of the heavy volume of train traffic. At approximately 0200, the track patrol employee again attempted to get on the track but was told by the RTC that access was possible from Spences Bridge to Seddall, Mile 82.8, but not out again because of train traffic. There are no set-off locations or access to the highway at Seddall. The special track patroller opted not to accept this opportunity to enter the track and, therefore, did not patrol the track on the shift before the occurrence. The special track patroller had similarly been denied access on 23 March 1997.

Although the special track patrol was not performed on the night of 25 March 1997, a signal maintainer and six trains travelled over the area (between the hours of 1900, 25 March 1997, and 0400, 26 March 1997) where the slide later occurred. Neither the signal maintainer nor any of the train crews reported having detected any anomaly with the track at that location.

1.12.3.2.2 CN Track Inspection and Special Track Patroller Training

CN track inspection and special track patrol employee qualification entails 90 days of field training, and two days of classroom study followed by written examinations. The track inspection and special track patrol employees had taken the qualification course in 1995.

In addition to gaining basic knowledge of track construction and maintenance, the track inspector and special track patrol employees are taught to identify potential problems such as sink holes, pumping or churning ballast, swamps or bogs, soft track, varying water levels and plugged culverts. Beaver dam locations that pose a water build-up threat also require constant attention. They are not, however, instructed to be concerned with adjacent highway works and drainage systems.

During special track patrol duties, employees are required to be aware of all track-related abnormalities such as slides, washouts and any irregularities in water flow into culverts. In addition, all rock and debris on the right-of-way within clearance points of equipment are to be removed, if possible, or arrangements made to afford protection to trains and track maintenance-of-way equipment.

Track maintainer/special track patrol employees did not receive any formal training about the origins of landslides or subsurface geotechnical problems. The track and geography at Mile 106.15 had not been identified as a problem area.

1.12.3.2.3 Track Inspector/Special Track Patrol Track Occupancy

The authority under which the special track patrols and track inspectors gain access to the track is governed by CROR Rule 49, Track Occupancy Permit (TOP), which specifies the manner in which the TOP is to be issued. The RTC is responsible for issuing a TOP on request, train traffic permitting, and is further responsible for ensuring that it is conducted in accordance with the applicable CROR rules. A TOP is in effect until cancelled. Any anomalies detected by a special track patrol are immediately reported to the RTC.

The RTC Centre personnel received no specific information from the engineering department regarding the intent of the special track patrols or prioritization of the conduct of these patrols. Training on engineering activities is limited to the specific guidelines of the process by which track patrols are granted access to the track in relation to the movement of trains on a given subdivision.

1.12.3.2.4 *The Track Geometry Car*

The Ashcroft Subdivision is surveyed by a track geometry inspection car three times per year. The car last covered the Conrad area on 14 November 1996; no deficiencies were noted at Mile 106.15.

1.12.4 *MoTH Inspection Program*

1.12.4.1 *General*

MoTH management of provincial highway maintenance and drainage works ensures that roadways throughout the province are safe for motor vehicle travel. MoTH has contracted the majority of its maintenance and inspection requirements to private contractors since 1987. The contractor must adhere to all applicable inspection and maintenance criteria as defined by MoTH and as contained in the Maintenance Services Manual.[3] Work is organized by routine maintenance, preventative maintenance and annual maintenance. The frequency of inspections varies from winter to spring. In the winter, all roads under MoTH jurisdiction were to be inspected every 8 hours, whereas in the spring, the frequency was reduced to once every 48 hours. The winter season usually ends on 15 March but the 8-hour inspection schedule was in effect on 26 March due to the extremely wet weather conditions.

1.12.4.2 *MoTH Relationship with the Private Contractor*

The highway contractor involved had been performing contract work for the MoTH since June 1996. The last reported detailed inspection of the ditching and culverts in the area of the accident occurred on 26 February 1997. Sequential records of culvert inspections are not maintained by the contractor.

The contractor was not responsible for the configuration of the drainage scheme at the accident location. The territory stretched for 1,500 lane-km. The work force is reduced from 115 persons during the winter to 85 persons in the spring.

1.12.4.3 *Road Inspector Duties*

The contractor will inspect to schedule, perform work and report to the province any conditions which are not specifically identified by the maintenance standard immediately on detection or notification. A report of the inspections completed during the previous month is provided to the province within seven days of the end of the month. The basic criteria for inspections include visual signs of unstable slopes and obstructed drainage so as to ensure that the road surface is clear and safe to be used by the public.

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[3] The *Maintenance Services Manual: Standards for Road and Bridge Maintenance Services* outlines the agreed-upon duties, established by the MoTH for British Columbia, that are to be followed by the contracted company. It also includes the frequency with which the various duties are to be completed.

The road inspector will look for the following highway conditions relevant to water drainage: ditches for blockages or lack of capacity to carry anticipated flow volumes, particularly for expected winter and spring run-off and again during the spring thaw period; blocked or damaged drains; back slopes, fill slopes and embankments for settlement, erosion or instability; and curb and gutters for damage or drainage obstructions. The roadway above Mile 106.15 had not been noted as requiring attention.

1.12.4.4 Road Inspector Training

The road inspectors consisted of employees with extensive knowledge of the area, through their work experience with present and previous employers who had contracted the maintenance work. The most senior inspector had 30 years' service. The road inspectors receive no formal training about the origins of landslides, such as soil conditions and subsurface water conditions.

Highway patrols for the area are deployed in 10-hour shifts (0600 to 1600 and 1830 to 0430). Each shift covers the assigned area with two vehicles containing one driver each. On 25 March 1997, a patroller drove the Conrad area near the end of his shift and did not notice anything unusual in the accident area.

1.12.5 Communications

1.12.5.1 CPR Train 998-25

On 26 March 1997 at approximately 0532, as eastward CPR freight train 998-25 (train 998) departed Kanaka, Mile 103.9 of the CPR Thompson Subdivision, the crew members observed derailed freight cars of a CN freight train across the Fraser River at Conrad. They saw one derailed sulphur car lying on its side, its contents spilled down the slope and at least one car on either side derailed, but upright. The crew members stated that it did not appear to them to be more than a minor derailment and they assumed that CN officials were aware of the situation, so did not report it to their RTC. At approximately 0610, as train 998 approached Lytton, Mile 94.9, they advised the crew of westbound train 991-21 of the CN accident. As the westbound train approached Kanaka, the crew members observed a major derailment with fire and smoke at Conrad. They did not take action and assumed, as had the preceding crew, that CN was aware of the situation.

1.12.5.2 *Motorist Observations*

At approximately 0550, 26 March 1997, a Kamloops linen-supply-company employee driving south on the Trans-Canada Highway past Lytton (opposite Mile 100.00 on the CN Ashcroft Subdivision) in light traffic, en route to the CN bunkhouse at Boston Bar, noticed derailed cars and spilled sulphur on the railway right-of-way just below the roadway. He did not notice a landslide and, being unaware of the respective locations of the two major railway companies in the Fraser Valley, did not know if the derailment was on CN or CPR track. He arrived at the bunkhouse at approximately 0615 and advised the CN Transportation Clerk on duty of his observations. At this time, the Transportation Clerk had just spoken to the Ashcroft RTC on the telephone and was aware that the RTC was not experiencing problems on the subdivision. The Transportation Clerk consulted with two train crew members in the bunkhouse and, collectively, they concluded that the derailment had occurred on CPR property.

At approximately 0625, the Transportation Clerk in Boston Bar, having received a telephone call from the Edmonton crew dispatcher, mentioned the reported derailment. The Edmonton crew dispatcher consulted with his supervisor who, not having heard of a derailment, also concluded that the derailment must be on CPR property. No further action was taken by the CN employees concerned.

1.12.5.3 *Inter-Company and Inter-Modal Practices*

Although the CN, CPR and MoTH systems operate in proximity to one other in the Fraser Valley between Kamloops and Hope and, occasionally, come together, e.g., at overpasses and adjacent and touching fills, there was no communications protocol in place. In addition, there is no formal requirement or section in MoTH procedures to direct first responders to communicate with either CN or CPR should a highway/railway situation occur that could affect the safe movement of railway or highway traffic.

The railways are governed by the CROR with regards to communications. General Rule A (iv) requires, in part, that every railway employee connected with the movement of trains communicate conditions that may affect the safe movement of a train or engine, by the quickest available means, to the proper authority.

CROR Rule 102(a) requires the crew members of a train or engine that stops as a result of an emergency brake application or abnormal conditions to provide protection on adjacent tracks and the tracks of other railways that may be obstructed. General Rule A is in effect at all times, whereas Rule 102(a) is applied when the respective transportation organizations operate rail traffic adjacent to each other.

The CN and CPR RTC centres have dedicated telephone links to each other and other railway company RTC centres to provide information on emergency situations that might develop in areas of adjacent trackage.

1.12.5.4 *Other Inter-Company Emergency Communication Practices*

The CPR Network Management Centre (NMC) also has an emergency phone to which the RTC responds immediately; however, this phone applies only to those RTCs that are controlling trains operating on CROR

Rule 102 territory. Should a report be received from non-railway personnel about an emergency situation concerning another railway, the RTC would communicate with the CPR police, by recorded message, who would then contact the CN police, via recorded message, to advise them of the emergency situation.

1.12.6 The Emergency Response

A unit of the Provincial Emergency Program (PEP), a provincially based volunteer organization that consists of local citizens who coordinate available resources and assist in implementing local emergency plans, was based in Lytton. The local emergency program coordinator for the PEP was notified of the landslide by the Royal Canadian Mounted Police (RCMP) Search and Rescue Division at 0715, and a group of eight volunteers responded to the emergency call. They arrived at Conrad at 0730. Under RCMP direction, the emergency rescue team was dispatched to search the immediate derailment area for the crew members, whose whereabouts were not immediately known, in the event that they had evacuated the locomotive cab before the derailment. The emergency rescue team was relieved of its duties at 1100 on 26 March 1997.

As part of the PEP, the British Columbia Ministry of Environment personnel were deployed to the site to provide professional and technical advice and direction in the event that dangerous goods were involved. The proximity of the site to the Fraser River was the focus of the initial attention to ensure pollutants were not entering the waterway and endangering the fish habitat. Although some sulphur may have reached the river, it was not considered an environmental threat. Other potential pollutants, such as diesel fuel, were contained and removed.

The accident location was approximately 1.5 km upwind of the Siska First Nations Community. At approximately 0730 on 26 March 1997, the Siska Band leaders opted voluntarily to evacuate the 100 residents of their community due to the potential for contamination from the burning train. At approximately 1400, the residents returned to their dwellings when government experts found no threat to their well-being.

1.12.7 *Previous TSB Investigations*

1.12.7.1 *Nakina*

In July 1992, a CN freight train encountered a collapsed subgrade at Mile 135.0 of CN's Caramat Subdivision near Nakina, Ontario. The train travelled onto the suspended portion of track and plummeted into a pond. Two crew members were killed and a third sustained serious injuries. In this occurrence, the roadbed failure was caused by a sudden draw down of the water in a pond from a breached beaver dam. The roadbed had been built on a base of glacial lacustrine silt and peat at the turn of the century, and the water-saturated silt had become unstable as a result of the rapid draw down of water. The track remained intact and suspended over the depression and had not affected the CTC signal system. Pole-mounted code and communication wires were thought to have been damaged by the derailing train (TSB report No. R92T0183).

The TSB issued four safety recommendations as a result of the Nakina accident:

> The Department of Transport, in collaboration with the Department of Energy, Mines and Resources and the railways, institute a program to identify other potential locations of incipient failure where main track has been laid over weak sediments or where waters adjacent to main track may be subject to rapid draw down;
>
> (R93-04, issued June 1993)

> The Department of Transport impose restricted speeds for trains traversing those sites identified as most vulnerable to failure caused by draw down of adjacent waters;
>
> (R93-05, issued June 1993)

> The Department of Transport, in consultation with the railway industry, identify and implement corrective measures to increase soil stability with an acceptable factor of safety at those locations identified as being vulnerable to terrain slump; and
>
> (R93-06, issued June 1993)

> The Department of Transport review the adequacy of current roadbed design criteria for laying roadbed over peat, silt, or other weak sediments.
>
> (R93-07, issued June 1993)

The TC response to these recommendations focussed on the draw down event that resulted in the subgrade collapse. TC's safety action included meeting with senior officials of CN and CPR to review the details of the accident and determine if certain CN actions, i.e. strategic beaver population control, aerial surveys of beaver dams and verification of track inspection processes, were satisfactory. CN was requested to stabilize embankments where there was the possibility of a similar accident.

TC also advised that it should be recognized that the subject line was constructed over 80 years ago and that construction standards have undergone radical changes since that time. TC indicated that, should any new railway lines be constructed, the design and construction would be carried out in accordance with the applicable engineering standards.

1.12.7.2 Orient Bay

In April 1994, a CN freight train encountered a washout depression at Mile 91.0 of the Kinghorn Subdivision, near Orient Bay, Ontario. Two crew members were seriously injured and one sustained minor injuries. The roadbed failure was attributable to water infiltration and weakening of the glacial lacustrine silts and clays. The track had remained intact and suspended over the depression and did not affect the Occupancy Control System (OCS) method of train control being employed (TSB report No. R94W0101).

1.12.8 Recent Investigations

Subsequent to the Conrad landslide, there have been two other subgrade failures leading to derailments.

1.12.8.1 Pointe au Baril

On 07 April 1997, a CPR train plunged into a depression in the track at Mile 44.8, Parry Sound Subdivision, near Pointe au Baril, Ontario, resulting in the derailment of 4 locomotives and 14 cars. The subgrade failure was attributable to hydrostatic stresses from changes in water levels as a result of a beaver dam. One crew member sustained serious injury and two had minor injuries. The loose state of the sand fill was viewed as a contributing factor in the subgrade failure. The track remained intact and suspended over the depression, allowing the Automatic Block Signal System (ABS) to continue to function as the train approached the area of failure (TSB report No. R97T0097).

1.12.8.2 Coteau

On 06 May 1997, at 0045 eastern daylight time, the roadbed collapsed under a moving CN train, derailing 2 locomotives and the first 12 of 20 cars at Mile 34.55, Kingston Subdivision, near Coteau, Quebec. Two crew members received minor injuries. The collapse was attributable to the presence of weak clays under the subgrade and water saturation from several sources including surface water migration through the railway embankment (TSB report No. R97D0113).

1.12.9 Coroner's Inquest

On 22 August 1997, after hearing four days of testimony from 14 witnesses, a coroner's jury classified the cause of death for the train crew as accidental. The jury made 10 recommendations (see Appendix A). The first recommendation refers to the CN Root Cause Committee Report (see Appendix B). Root Cause Committees are established by the railway on a case-by-case basis, are tasked with one accident and are composed of management and union members. The general purpose of such committees is to review accidents, assess potential causes and make recommendations to prevent the accident from recurring.

2.0 Analysis

2.1 Introduction

Based on the recorded data and the geotechnical analysis, an initial small landslide event occurred at 0437, undermining the siding and derailing cars from standing train 711. The first landslide was followed by another larger event at an undetermined time, which created a large depression under the main track. The main track and wayside fibre-optic CTC cable remained intact and suspended over the depression, allowing the CTC to continue to function as designed. With train 711 standing on the siding to the inside of the curve obstructing forward visibility, crew members of train 102 would have had no opportunity to observe the landslide in time to stop their train or jump from the locomotive.

The recorded data indicate that train 102 averaged 27 mph in the 35 mph and 30 mph zones between Signal 1064 and Mile 106.15, and approached the depression on a clear signal indication. Neither the train crew nor supervising RTC had any indication of the danger at Mile 106.15. The manner of train operation and RTC supervision, therefore, played no role in the accident.

Train 102 plunged into the depression, severing the fibre-optic CTC cable and breaking the suspended track as recorded by the CTC breakdown at 0606:22. The severity of the crash and the crushing effect of the cars derailing into the depression and onto the locomotive consist, as well as the ensuing fire, made survival impossible.

The analysis will discuss the factors leading to the subgrade failure, drainage design and track inspection considerations, railway operation and communications issues, and the railway–MoTH interface.

2.2 Consideration of the Facts

2.2.1 The Subgrade Collapse

2.2.1.1 General

The subgrade collapse is attributable to water saturation and build-up of pore pressure in moisture-sensitive fills as a result of record-high precipitation and water-drainage failings. Identified geotechnical shortcomings included:

1) railway fills laid over local glacial materials, creating an unnoticed subsurface drainage conduit;

2) local glacial deposits of varying qualities and suitabilities exploited as construction materials to fill gullies and build both the highway and railway subgrades which proved to be unstable when water-saturated;

3) loose compaction of the railway subgrade, reflective of the technology at the time of construction (1911 to 1914), exacerbating the rapidity of the failure once initiated and the degree to which it retrogressed;

4) the 1960 placement of highway fills against the upslope of the railway embankment, creating a contiguous fill section and allowing subsurface water to flow to the railway subgrade with resultant elevated pore pressure; and

5) surface water not being drained away by the culvert system installed for such a purpose.

In the recent past, this area had not displayed any track or roadbed anomalies to indicate that water saturation of the subgrade had occurred or that roadbed stability was in any way affected. Regular track and highway inspections and patrols offered no observable indication of the ongoing water saturation and the pending landslide.

2.2.1.2 Meteorological Considerations

The recorded fall, winter and spring precipitation in southern British Columbia exceeded that of previous years by a wide margin. These data, as well as the rate of snow-melt, did not apparently trigger concern among the stakeholders in the transportation system. Although it is appreciated that the local population views these months as "wet", there is no guideline with commensurate warnings and heightened alertness to indicate when the extent of rainfall and accumulated snow pack becomes a safety risk. It is noteworthy that the sophisticated meteorological recording systems and extensive record keeping are not applied to such a practical and useful purpose.

2.2.1.3 Drainage Issues

There was an apparent awareness of the need to drain run-off from the natural collection area, above both the highway and railway, to the river below. The culvert system would have been adequate for the task had the water not soaked into the ground before reaching the culvert opening. In all likelihood, the system was never monitored during actual run-off conditions to ensure that water from above the highway was drained away, while road authority employees mistakenly concluded that, since roadside snow-melt and precipitation disappeared, the system was functioning as expected. There is a need to ensure that the responsible authority is aware of the full design requirements of any such system and that, following construction and periodically thereafter, such systems be monitored under actual field conditions to ensure that their intended purpose is fulfilled. It would also seem that, when drainage features of a highway affect railway infrastructure, the railway practices include periodic inspections of the highway system.

2.2.2 Railway Operating Considerations

2.2.2.1 Track Circuit Integrity

As this and other accidents of this type have demonstrated (R92T0183 and R97T0097), washouts of the subgrade may result in the track- and wayside-signal communications lines remaining intact. In CTC territory, not only are train crews and supervising RTCs not given any indication of a roadbed failure, but the still-functioning signal system continues to display favourable signal indications reinforcing the erroneous notion that the soon-to-be-occupied track ahead is safe. Such favourable signal indications could tend to lessen the vigilance of train crews even if environmental conditions warrant heightened caution. It is believed that systems could be developed to identify subgrade collapse and cause an immediate “stop” indication on both wayside signal systems and the RTC panel in CTC territory. It would also seem that an alarm in the locomotive cab would enhance the effectiveness of any such system and provide protection in OCS areas not equipped with ABS.

2.2.2.2 Routine Track Inspections

The weekly CN track inspection regimen and TC regulatory overview were not geared to landslide issues. Although water-flow concerns were a component of the inspection process, considerations of general geographic stability were not. Neither the railway inspectors nor the TC safety officers were sensitized to proactively identify emerging landslide issues through training and/or corporate/departmental philosophy. It is apparent that track inspection forces require a heightened geotechnical awareness.

Routine track inspection processes were also conducted with no concern for the drainage systems on the adjacent highway, although at Mile 106.15 and other places, the respective subgrades overlapped and drainage systems were shared. A comprehensive approach to track safety would see enhanced awareness and inspection of any drainage system affecting the railway.

2.2.2.3 Special Track Patrols

The special track patrollers, trained to the same standards and working with similar instructions as the routine track inspectors, did not consider the geotechnical aspects of track and roadbed safety during the routine conduct of their duties unless they noted a disturbance of the track they were patrolling (misalignment and/or subsidence of track). Indeed, as their inspections were carried out at night and in the early morning, they had limited opportunity to observe emerging conditions other than that of the immediate track and roadbed illuminated by their vehicles. Trained personnel operating in daylight conditions would improve safety.

The uneventful movement of a train through a given area is thought by many railway employees to be an indication that the track is safe and, as a consequence, lessens the need for, and utility of, special track patrols. It is noted that heavy train traffic pre-empted special track patrol access to the main track on two occasions in March. The special track patrol records, however, demonstrated that over 75 per cent of these patrols in March on the area between Mile 75.0 and Mile 125.0 led to the discovery and removal of rocks on the track. While trains are not often damaged by such rocks, the potential for larger and dangerous rockslides seemingly existed on a continuing basis.

While it cannot be conclusively stated that the special track patroller who was denied access in the early morning before the accident would have patrolled the vicinity of Mile 106.15 after the first slide, and thus sounded the alarm and halted train traffic, such a possibility existed.

It would seem, therefore, that special track patrols play a key safety role. Every effort must be made to ensure that they are afforded access to the main track when such access is requested.

2.2.3 Communications

2.2.3.1 Inter-Company

It is probable that the crew members of CPR train 998, having noticed derailed train 711 approximately ½ hour before the arrival of train 102, could have prevented the accident by
informing their RTC of their observations. The CPR crew incorrectly reasoned that CN would be aware of the derailment, as a train was involved and trains are normally manned.

Clearly, the CROR requirement respecting the reporting of unsafe conditions (General Rule A (iv)) refers to the conditions of one's own company, and not those of another railway. It cannot, therefore, be said that there is a CROR requirement to report such an observation. However, in all likelihood, a rule requirement for such reporting would have prompted the CPR crew to report the first derailment.

No doubt the dedicated link between the CPR and CN RTC centres could have facilitated the relay of information on the sulphur train derailment. However, the rationale for such a communication link is narrow (i.e., a dangerous situation in areas of adjacent track), and a wider mandate encompassing any reported unsafe condition on an observed portion of the other company's right-of-way with a protocol for verification that the involved company was aware of the reported condition would improve safety. Such a procedure would require that crews operating in the Fraser Canyon have knowledge of the communication link and awareness of the need for such a system.

2.2.3.2 General Public

The linen-supply-company employee travelling on the Trans-Canada Highway also noticed the derailed sulphur train before the arrival of train 102. There can be no doubt that other motorists noticed the derailment as well. While the time available to the linen-company employee to alert the railway was extremely limited, it would seem that many others would have had a much longer time, since daylight conditions were reported at 0530. While it would not be expected that non-railway employees would understand the serious nature of the situation, two notions are evident:

1) The nature of the Fraser River Canyon in times of heavy precipitation or seasonal run-off is such that heightened alertness to risk of landslides among all highway users is warranted. Such alertness would involve being aware of whom to contact to report observed dangerous conditions. This information could be displayed on signs along the roadway.

2) Many motorists travel with cellular telephones and other means of communication, such as two-way radios, making quick notification of dangerous conditions possible.

2.2.3.3 CN Employees

Although CN employees at the Boston Bar bunkhouse were informed of the derailed sulphur train after train 102 had already derailed and could not have prevented the accident, their reaction was not one of extreme concern. Even when the discussion involved the Edmonton crew dispatch centre, the employees concerned did not grasp the potentially dangerous nature of the situation or exhibit a heightened interest. It would seem that, considering the weather, the springtime conditions and the geography of the area concerned, railway employees would be sensitive and reactive to any report of a derailment. While it is appreciated that it was concluded by all that the derailment was on CPR track, this conclusion should have evoked concern for the safety and well-being of CPR employees.

2.2.4 Geotechnical Expertise

Although both CN and MoTH had geotechnical expertise on their respective staffs and the orientation of some aspects of their geotechnical programs was generally proactive, corrective measures for identified problems were mostly reactive in nature. It is possible, however, to apply geotechnical expertise in a more proactive manner. It is highly desirable that MoTH and the railway companies share their resources and expertise to identify and monitor both areas prone to slumps and landslides, and water drainage concerns.

2.2.5 Continuing Subgrade Slumps

Many miles of Canadian railway subgrade are susceptible to failure. As indicated in sections 1.12.7 and 1.12.8, serious accidents involving loss of life or significant injury can, and do, occur. TC has chosen to deal with safety issues and TSB recommendations arising from these accidents on an individual basis. Remedies such as beaver control and culvert inspections are the professed remedy, while it is indicated that new railways will be built to modern standards.

The presence of moisture-sensitive alluvial deposits in the heart of railway subgrades is the consequence of both the limitations of construction capabilities and the understanding of soil characteristics at the time of their initial construction (circa 1900). The ability to compact the subgrade and the importance of such activity suffered from similar shortcomings. The five cited TSB investigations into roadbed collapse have these two weaknesses as common and causative features. It can only be concluded, therefore, that many sections of Canadian railways built on fills in locations that can be exposed to unusual water events, whether high levels of precipitation, rapid melt of heavy snow pack, natural drain water collection or drainage disruption and associated build-up, such as beaver dams or blocked culverts, are a safety risk. Steps are required to identify, monitor and, where possible, modify the fills or create drainage systems to prevent water degradation.

3.0 Conclusions

3.1 Findings

1. The manner of train 102's operation and RTC supervision played no role in the accident.

2. The subgrade collapse consisted of two slump events, a smaller first event at 0437, followed by a second, larger event at an unknown time but before the arrival of train 102 at 0606.

3. The subgrade collapse is attributable to water saturation and built-up pore pressure in railway fills.

4. Subgrade slump events may leave wayside signal and communication systems intact, allowing a permissive indication which is interpreted by most crews to convey the message that the track is safe.

5. The drainage system did not meet its intended design, which was to collect and divert water run-off under the highway and railway.

6. The railway did not inspect or monitor drainage systems on the adjacent highway.

7. In all probability, the highway drainage system at this location was never monitored during run-off conditions to ensure that water was captured and drained away as intended.

8. CN and MoTH geotechnical expertise was not always used in a proactive manner.

9. The record rainfall and accumulated snow pack did not trigger concern among the stakeholders in the Fraser River Canyon transportation system nor was the meteorological monitoring system used to generate a warning.

10. The unstable fill condition was attributable to moisture-sensitive alluvial deposits located in the heart of the railway subgrade as a consequence of the limitations of construction capabilities and a lack of understanding of soil characteristics at the time of construction (circa 1900).

11. Routine track inspections, special track patrols and regulatory overview were not geared to geotechnical issues.
12. Special track patrols play a key safety role but cannot contribute to the detection of geotechnical concerns beyond the immediate right-of-way when conducted at night.

13. There is no CROR requirement to report observed unsafe conditions on other railways, although such a requirement would likely have led to CPR's reporting of the landslide before the derailment of train 102.

14. Although derailed train 711 was in the range of vision of motorists for a considerable time, no reports of the derailment were made to either railway company or to public authorities, with one exception.

15. The communication protocol between CN and CPR was not aimed at reporting safety concerns for opposing companies in areas where the respective rights-of-way were not contacting or proximate.

16. The extreme climatic conditions during the weeks preceding the occurrence did not evoke an increased awareness to the reported derailment in the Fraser River Canyon among some CN employees.

17. The presence of moisture-sensitive alluvial deposits make many miles of Canadian railways roadbed susceptible to slumping when water-saturated.

3.2 Cause

An extraordinary volume of surface water run-off from melting heavy snow cover and high seasonal precipitation was not captured and carried away as intended by the drainage system above the adjacent Trans-Canada Highway. The water soaked into the ground, migrated through the highway fills, and infiltrated and destabilized the railway subgrade. The railway subgrade could not sustain the resultant high pore pressure and collapsed. Contributing factors included the presence of moisture-sensitive alluvial deposits in the bottom area of the railway subgrade and the overlapping nature of the highway fills which created a contiguous groundwater flow path into the railway fills.

4.0 Safety Action

4.1 Action Taken

4.1.1 TSB Interim Recommendations

As a result of this investigation, whereas the Board determined that the extraordinary volume of surface water run-off had destabilized the railway subgrade, and a concern that the continuing spring run-off may create further problems, the Board issued the following Interim Railway Safety Recommendations:

> The Department of Transport, in collaboration with Canadian National, Canadian Pacific Limited, and the British Columbia highway authority:
>
> a) identify locations where railway or adjacent highway roadbeds were constructed of fill laid on silts or other similar soil material;
>
> b) for those locations identified as per above, assess the adequacy of existing drainage for the spring run-off and determine if the roadbed foundations are susceptible to water saturation; and
>
> c) where applicable, implement a monitoring program to detect roadbed subgrade instability as a result of water saturation.
>
> (R97-01, issued April 1997)
>
> The Department of Transport, in collaboration with the Railway Association of Canada:
>
> a) evaluate the effectiveness of current track continuity warning systems vis-à-vis roadbed failures;
>
> b) evaluate alternative methods for confirming the integrity of the roadbed during high risk periods; and
>
> c) sponsor research to develop more reliable technologies for monitoring the integrity of both the track and the roadbed.
>
> (R97-02, issued April 1997)

Following the recommendations, the railway industry, the provincial Ministry of Transportation and Highways (MoTH), and Transport Canada undertook several initiatives to address the safety issues.

4.1.2 Industry Cooperation

Shortly after the TSB's Interim Recommendations were issued, meetings were held between CN, CPR, MoTH, Transport Canada and the Geological Survey of Canada (GSC) to address the issues raised in the recommendations. Joint meetings are now being held twice annually and annual meetings have been initiated to discuss topics of mutual concern between the three main railways in the province and the MoTH.

4.1.3 Remedial Action at the Occurrence Site

Additional surface drainage works were constructed at the occurrence site. A prototype "washout detector" was developed and immediately installed at Mile 106.15 of the Ashcroft Subdivision. Three other sites were subsequently protected in a similar fashion. On 07 April 1997, a slope indicator (SI) was installed, to a depth of 35 m, in a test hole drilled in the road shoulder above the rail embankment failure. The SI measures horizontal soil movement and will alert a technical staff person to any ground/slope shifts in the immediate vicinity. In addition to monitoring the SI installation, geotechnical personnel perform a visual inspection of the site and the roadway cracks every one to two weeks. All data are analyzed by a geotechnical engineer, and then copied to the district highways manager responsible for the Conrad area, with recommendations for action to be taken if deemed necessary. Regular track inspections were temporarily augmented with special track patrols. CN instructed RTCs that priority must be given to special track patrols and that they must be given sufficient track time to cover their territory at least once per night.

4.1.4 Identification of Roadbed Instability

Phase 1 of a study undertaken by the GSC and the University of British Columbia in partnership with the railway industry and the MoTH has been completed by the GSC. The report, entitled *Magnitude-frequency Analysis of Landslide Hazards along the Main Transportation Corridors of Southwestern British Columbia*, contains objectives and describes the results of the rock slope research to date. A second phase of the report, having nation-wide application, will focus on the development of methodologies to characterize landslide hazards as they affect transportation networks.

Recent aerial photographs of the Thompson/Fraser corridor have been interpreted to identify sites geologically similar to Conrad. Potential sites identified were subsequently inspected and drainage improvements have been completed.

Geotechnical subsurface investigations were undertaken at selected locations and pneumatic piezometers were installed to measure groundwater pressures.

CN initiated a series of extraordinary field inspections including aerial surveillance of the Jasper-to-Hope corridor, jet boat inspections along the North Thompson River, and ground level inspections by foot and Hi-rail vehicle of culverts and surface drainage patterns to ascertain whether emerging spring conditions posed a threat to the integrity of the railway.

CN developed a slope-monitoring assessment form, which was distributed with instructions to engineering and running trades, to report all incidents relating to rockslides and landslides to the geotechnical department for action or historical data to assess long-term stability of soil slopes.

Transport Canada has modified its track monitoring program to include culvert and drainage conditions, on specific territories (such as the areas indicated in the report), as an integral component of the sampling program.

In addition to the annual rock slope inspections carried out since the 1970s, CPR started making formal geotechnical inspections in 1997 to assess subgrade and drainage conditions along much of the main track, including the Calgary-to-Vancouver, Winnipeg-to-Toronto and the British Columbia coal route from Sparwood to Golden. Following annual inspections, numerous detailed site-specific inspections are made by the Geotechnical Group staff or consultants to assess areas where stability concerns are noted.

4.1.5 Monitoring Technology

Transport Canada met with railway industry representatives to discuss the track continuity warning systems and the evaluation of alternative measures for confirming the integrity of the roadbed. The railway industry subsequently considered the following systems:

- level beam detectors using electro-level beam sensors to detect movement;
- time domain reflectometry using existing buried fibre-optic cable sheathing to sense washout or ground-slip conditions;
- a guided radar system using coaxial cables and radio frequency to detect disturbance;
- seismic trigger (accelerometer) used to detect ground movement;
- a slump/washout detector used in conjunction with existing track circuits to initiate stop signals, RTC notification, and a broadcast message; and
- digital comparison of images from interferometric radar scans.

The guided radar system is considered to be the best option for detecting discontinuity in rail. A pilot project, referred to as the “Field Disturbance System” project , has been established to test aspects of system performance. Transport Canada, through its Transportation Development

Centre, has a direct involvement and is also contributing to the project as part of the Railway Safety research and development program. The finalization of the production version is expected by 01 March 1999, and is to be followed by a verification period of 12 weeks.

CN subscribes to World Weather Watch (WWW) to give supervisors advance warning of severe weather conditions and facilitate the early planning and implementation of response strategies. CPR is evaluating a similar system.

4.1.6 Training

CN and CPR have jointly developed a subgrade hazard training program for maintenance-of-way employees entitled *Geotechnology for Railroaders*. This course, which lasts one and a half days, has been delivered to CN and CPR personnel across the country. Transport Canada infrastructure officers have also attended an abbreviated version of the course.

4.1.7 Public Assistance

CN is installing highly visible decals on the back of signage at all public crossings to assist public reporting of potentially hazardous conditions. The decals identify the exact crossing location and give a "1-800" emergency number linked to the CN Police.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 22 December 1998.

Appendix A - Findings and Recommendations as a Result of Inquest - B.C. Coroner's Court

1. We endorse the Root Cause General Recommendations as proposed by CN Management and Union Personnel. We recommend that this report is completed as soon as possible and these recommendations are implemented. This should include any further alternatives and recommendations in the final report.

   This report should be shared with CP, Ministry of Highways and other Provincial, Federal or private agencies having a vested interest in the Thompson/Fraser Canyon Corridor.

2. We recommend that CN/CP and Ministry of Highways continue to develop a working relationship of sharing information related to works and issues of mutual benefit in the Thompson/Fraser Canyon Corridor. This process should also include other Provincial and Federal agencies and other private utilities operating within this corridor.

3. Environment Canada should review the adequacy of the present precipitation collection recorders in the Thompson and Fraser Canyons. Existing facilities should be maintained in a working condition. The requirement for additional recording stations so that an accurate representation of weather conditions in this area can be realized should be evaluated.

4. CN and CP should evaluate the feasibility of and implement low tech precipitation reading systems in sections of the canyon known to experience sudden and severe rainfall events. The information from these recorders should form part of the regular log inspection reports. Incidents of unusually severe weather conditions should be conveyed to track superintendents and geotechnical personnel.

5. We recommend that a safety committee be struck involving CN and various unions to examine the issue of safety, track patrols, communication and education at all levels.

6. We recommend that CN/CP and B.C. Ministry of Highways establish a comprehensive engineering data base regarding maintenance, construction and remedial works undertaken in the Thompson/Fraser Canyon corridor. We recommend that these parties meet a minimum of once a year to exchange, review and communicate information as to their activities in the corridor.
7. We recommend that CN and CP and B.C. Ministry of Highways install readable signage, similar to that relating to forest fire alerts, on the highways adjacent to the railway rights of way indicating 1-800 numbers available to the public who wish to report any unusual events. The installation of emergency call boxes along the Fraser/Thompson corridor should also be considered.

8. We recommend that CN examine technology that would allow train crews to maintain contact with the RTC while outside the engine. Measures should be examined and implemented so that the RTC in event of equipment failure or loss of communication with rail crews can be notified as soon as possible to minimize emergency response times.

9. All transportation users of the Thompson/Fraser Canyon corridor should be encouraged to observe and report any abnormal incidents in the corridor.

10. We recommend that technology be investigated so that in the event of the failure of the air brakes on a parked and unattended train that the RTC is immediately alerted so that an appropriate response can be implemented.

11. We recommend that in areas similar to Conrad, in the Fraser Canyon, the Ministry of Highways should become aware of the potential of increasing unfavourable geotechnical conditions by the random dispersal of snow from the highway.

12. We recommend that the results of this Inquest be communicated to B.C. Rail for it's [sic] information.

Appendix B - CN Root Cause Committee Report

Section 3.0 General Recommendations

The following are not directed at the specific causal factors of the three incidents that were identified during this RCI. Rather, they are general recommendations directed at reducing the level of risk that is inherent in the operation of trains over mountainous terrain:

1. It is recommended that CN continue research, on an accelerated basis, on systems and devices that will provide a warning through CTC circuitry, when track bed integrity has been compromised. Warnings should be as site specific as possible.

2. When the need for additional risk specific track patrols for an area has been identified by the track supervisor, these patrols should receive priority handling by the RTC to ensure that the risk area is adequately monitored.

3. When additional risk specific patrols are set up, this information should be communicated to train crews by notice. These notices should specify both the nature of the risk and the anticipated length of time in which the patrols will be in place.

4. It is recommended that the current fibre optic monitoring system be modified to trigger an audible alarm in the Montreal NMC and at Walker S&C whenever a cable break occurs. Additionally, a remote alarm (i.e. pager) should trigger whenever the regular monitoring station is not physically attended.

5. It is recommended that the OMC 800 number be communicated to all employees with instructions to call immediately when they note or are made aware of an incident involving a train or a threat to safe train movement. This communication to employees could include the use of phone stickers, safety flashes, wallet cards and/or posters. These should include a reference to CROR General Rule A(iv).

6. It is recommended that CN undertake hazard mapping of the Jasper to Vancouver corridor. This should include a systematic identification of potential problem areas based on a review of aerial photos, characterization of slope angles, soil types, etc. and the development of a data base containing this information. Having this information available would lead to situations where an incident at a particular location would trigger an assessment of other locations with similar physical characteristics or attributes.

7. It is recommended that the CN emergency phone numbers currently published in BC telephone directories be evaluated by the senior manager of the RTCC to ensure that they are routed correctly.

8. A CN emergency phone number should be published in the telephone directory of every town along our right of way.

9. It is recommended that a geo-hazard information package be developed for train crew that tells them what to look for and report.

10. It is recommended that the current 800 number labeling program for railway crossings be accelerated.

11. It is recommended that all contractors who work for CN be provided with emergency procedures information that includes telephone numbers.

Appendix C - Glossary

ABS	Automatic Block Signal System
B.C.	British Columbia
CN	Canadian National
CPR	Canadian Pacific Railway
CROR	Canadian Rail Operating Rules
CTC	Centralized Traffic Control System
CWR	continuous welded rail
GSC	Geological Survey of Canada
m	metre(s)
MoTH	Ministry of Transportation and Highways
mph	mile(s) per hour
NMC	Network Management Centre
OCS	Occupancy Control System
PEP	Provincial Emergency Program
RCMP	Royal Canadian Mounted Police
RTC	rail traffic controller
SI	slope indicator
SPC	Standard Practice Circular(s)
TC	Transport Canada
TOP	Track Occupancy Permit
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
WWW	World Weather Watch