Transportation Safety Board
of Canada

Bureau de la sécurité des transports
du Canada

RAILWAY INVESTIGATION REPORT
R03V0083

MAIN-TRACK DERAILMENT

CANADIAN NATIONAL
TRAIN NO. 356-51-14
MILE 7.9, FRASER SUBDIVISION
MCBRIDE, BRITISH COLUMBIA
14 MAY 2003

Canada

Railway Investigation Report

Main-Track Derailment

Canadian National
Train No. 356-51-14
Mile 7.9, Fraser Subdivision
McBride, British Columbia
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Synopsis

On 14 May 2003, at approximately 1210 Pacific daylight time, Canadian National freight train No. 356-51-14, travelling eastward from Prince George, British Columbia, to Edmonton, Alberta, derailed two locomotives and five cars loaded with lumber on a bridge at Mile 7.9 of the Fraser Subdivision near McBride, British Columbia. A fire ensued and the bridge, the two locomotives, and the five cars and their contents were destroyed. The two crew members were fatally injured.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 The Accident

On 14 May 2003, at approximately 0625 Pacific daylight time,[1] Canadian National (CN) freight train No. 356-51-14 (the train) departed Prince George, British Columbia, travelling eastward on the Fraser Subdivision destined for Edmonton, Alberta.

An outgoing train crew at McBride, British Columbia, at Mile 0.0 of the Fraser Subdivision, who were called for duty at 1140, were anticipating the arrival of the train at approximately 1230. In prior communication with the rail traffic controller (RTC), they had determined that the train was operating approximately one hour late due to engine problems en route. Shortly after 1300, the conductor attempted to contact the train, but there was no response. He then called the RTC to determine what the further delay might be. The RTC had not heard from the crew since approximately 1140 when the train was near Loos, British Columbia. He attempted to contact the train 12 times between 1323 and 1335, but received no response. The last confirmed location of the train was identified by the wayside inspection system at Mile 12.27 at 1201:08. At 1339, the RTC called the Assistant Track Supervisor (ATS) on the Tete Jaune Subdivision and, at 1344, he called the Track Supervisor (TS) at Mile 56 of the Fraser Subdivision to request their assistance in locating the train. At 1354, the outgoing conductor at McBride and a track maintenance employee were dispatched in a taxi to locate the train. The location of the train at the bridge at Mile 7.9 (see Figure 1) was apparent because of the black smoke.

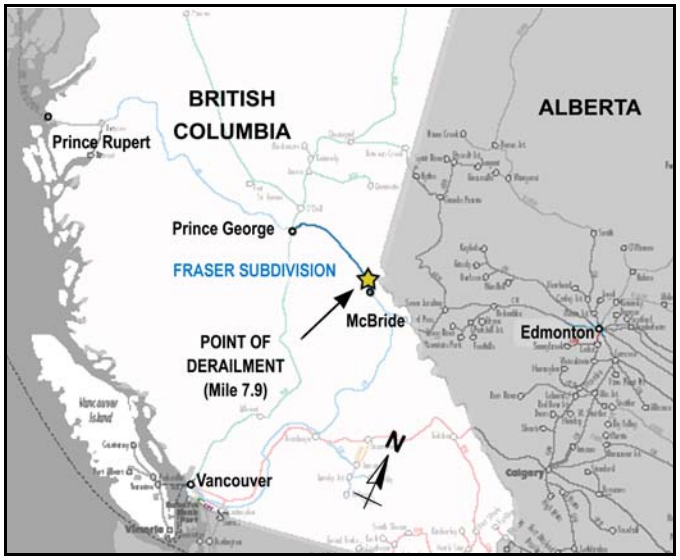

Figure 1. Location of the derailment

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[1] All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

Road access to the bridge was not available; however, they were able to get within approximately 1 km. Considering the possibility of exposure to toxic vapours from dangerous goods and the obvious severity of the situation, the conductor instructed the track maintenance employee to return and notify emergency services. The conductor continued westward to the east end of the bridge. He observed that the locomotives and a number of the cars were in the gully and on fire. He was unable to locate the crew members. The heat from the fire was so intense that access to the locomotives was impossible. The RTC was advised that two locomotives and several cars of lumber had derailed at the bridge at Mile 7.9 and were engulfed in flames at the bottom of the gully.

The closest hi-rail vehicle access to the derailment site was a public crossing at Mile 5.7, which was used by CN to transport emergency response personnel and other responders to the accident site. Later, a trail was opened and responders were able to access the bridge by vehicle. The Royal Canadian Mounted Police were advised of the accident at 1408 and arrived at the scene at 1430. The British Columbia Ambulance Service and fire rescue from McBride were notified at 1415 and arrived at the scene at approximately 1530.

Local residents recalled first sighting smoke in the vicinity of the bridge at about 1215. The initial report of the fire was made to the Provincial Forest Fire Reporting Centre at 1335, which dispatched a ground assistance crew at 1444 and a helicopter at 1455. The helicopter arrived on site at 1550 and commenced dumping water over the last derailed car to prevent the fire from spreading through the rest of the train.

1.2 *Injuries*

The locomotive engineer and the conductor were fatally injured in the accident.

1.3 *Damage*

The fire was contained within the immediate bridge area. The entire bridge, two locomotives, and five cars loaded with lumber were destroyed by fire. Several acres of the surrounding terrain were damaged by the fire and by the ensuing clean-up operation. The derailment site was subsequently restored to the satisfaction of environmental regulatory authorities.

1.4 *Train Information*

The train was approximately 5730 feet in length, weighed about 8800 tons, and was powered by two locomotives. The train consisted of 85 freight cars: 68 loads, 4 empties, and 13 residue tank cars.

Both locomotives were manufactured by General Motors. The lead locomotive, CN 5512, was a six-axle SD 60F class locomotive. It weighed 193.5 tons and was 71 feet 2 inches in length. The trailing locomotive, CN 5448, was a six-axle SD 50 class locomotive. It weighed 195 tons and was 71 feet 2 inches in length.

1.5 *Personnel Information*

The crew consisted of a locomotive engineer and a conductor. Both were familiar with the territory, were qualified for their positions, and met fitness and rest standards.

1.6 *Train Operations*

The Fraser Subdivision consists of a single main track that extends from McBride, Mile 0.0, to Prince George, Mile 146.1. Train movements on the Fraser Subdivision are governed by the Occupancy Control System of the *Canadian Rail Operating Rules* and supervised by an RTC located in Edmonton.

The daily traffic over the Fraser Subdivision consisted of six freight trains and one passenger train. The total tonnage carried in 2002 was approximately 17 million gross tons. The distribution of gross weight per vehicle, in pounds, is given in Figure 2.

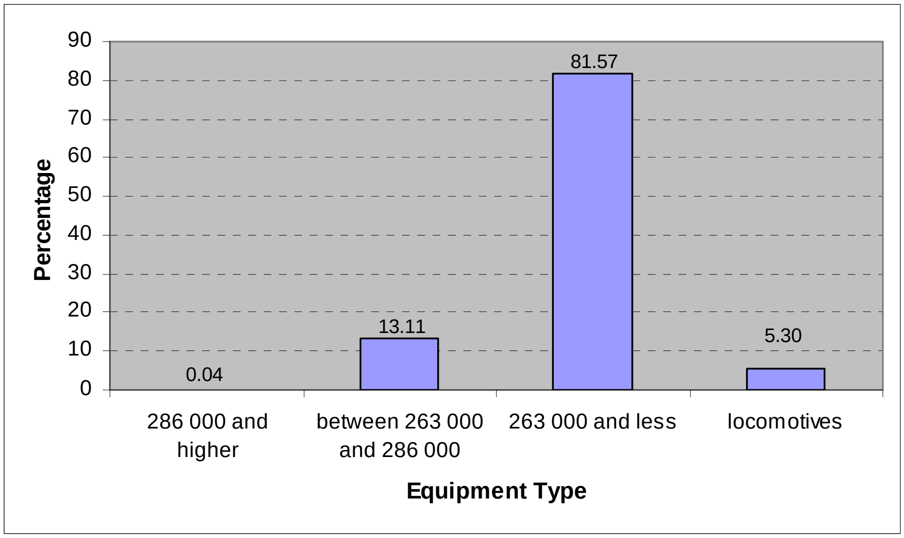

Figure 2. Equipment distribution by type

1.7 *Weather*

The weather at the time of the derailment was overcast with moderate wind. There were storms in the area. The visibility was good and the reported temperature was about 15°C.

1.8 Locomotive Event Recorders

The two locomotive event recorders (LERs) were sent to the TSB Engineering Laboratory for analysis. The data could not be recovered because the LERs had been severely damaged by fire and heat. The memory chips in the LER from the lead locomotive were damaged, but remained in fair condition; however, the support battery, inside the protection box where the chips were located, had exploded under the high temperature in the fire, thereby eliminating the data (TSB Engineering Laboratory report LP 044/03). The electronic cards and the cabling in the LER of the trailing locomotive were completely destroyed.

In previous investigations of occurrences in which LERs were heavily damaged or destroyed, the Board emphasized the importance of the survivability of LER data.

- In August 1996, near Edson, Alberta, a CN train collided head on with a cut of 20 runaway cars. The three people in the cab of the lead locomotive of the freight train were fatally injured. The LER from the lead locomotive was destroyed in the collision and the ensuing fire. The LERs from the second and third locomotives were recovered, and the data were downloaded (TSB report R96C0172).

- In March 1997, as a result of a large roadbed depression at Mile 106.15 of the Ashcroft Subdivision near Conrad, British Columbia, a CN train travelling towards Kamloops, British Columbia, derailed. Both crew members were fatally injured. The data from the LER could not be recovered because the locomotives were destroyed by fire (TSB report R97V0063).

- In December 1999, near Mont-Saint-Hilaire, Quebec, cars from CN train 783 travelling on the north track of the Saint-Hyacinthe Subdivision derailed, fouling the south track at Mile 50.84. CN train 306, travelling eastward on the south track, collided with the cars of train 783 as they derailed. The two crew members on train 783 were fatally injured in the accident. The LER data from the two locomotives were unrecoverable (TSB report R99H0010). As a result, the Board issued the following recommendation:

  > Transport Canada ensure that the design specifications for locomotive event recorders include provisions regarding the survivability of data. (R02-04, issued September 2002)

- In January 1999, a VIA Rail Canada Inc. train passed signal 2328S at Mile 232.8 of the CN Kingston Subdivision at Trenton Junction, Ontario. The train subsequently passed through a main-track switch that was in the reversed position in a trailing-point direction (TSB report R99T0017). The investigation resulted in the following recommendation:

  > The Department of Transport, in conjunction with the railway industry, establish comprehensive national standards for locomotive data recorders that include a requirement for an on-board cab voice recording interfaced with on-board communications systems. (R03-02, issued July 2003)

Transport Canada (TC) accepted both of the Board's recommendations and is closely following the progress of a rule being developed by the Federal Railroad Administration (FRA) in the United States on data survivability and crashworthiness of LERs. Transport Canada will initiate a similar rule-making process in Canada. The Railroad Safety Advisory Committee, which is chaired by the FRA with representation from TC, North American railways, unions, and other stakeholders, has initiated a working group to address broader issues associated with the LERs including parameters to be recorded.

As of July 2004, TC has developed terms of reference for creating a project team on the development of national standards for addressing the survivability of LERs. The team will consist of representatives from TC, the Canadian railway industry, and the FRA.

The scope of the project is to identify options and provide advice on establishing comprehensive national standards and may include:

- identification of present regulatory requirements for LERs, including survivability and specifications for the type of data recorded both in Canada and in the United States;

- identification of present and future regulatory requirements for event recorders, including audio capabilities both in Canada and in the United States;

- identification of present and future LER technologies available to the industry, including survivability, type of data that can be recorded, audio capabilities, and interface with on-board communication systems;

- drafting of a final report identifying options and providing advice to TC and the rail industry on the potential establishment of comprehensive national standards for LERs; and

- development by the industry of national safety standards on LERs.

The project began in the fall of 2004. A draft report will be prepared by April 2005 by the project team with an anticipated completion date of December 2005.

1.9 *Particulars of the Track*

The track passes through primarily heavily forested and mountainous terrain along the Fraser River. In the area of the occurrence, the maximum permissible speed was 25 mph for freight trains and 35 mph for passenger trains. The track structure consisted of 136-pound continuous welded rail laid on 14-inch double-shouldered tie plates, secured with four spikes per tie, and anchored every second tie. There were approximately 3120 ties per mile. The ballast consisted of crushed rock. The ties and ballast were in good condition.

A timber trestle (see Appendix A for timber trestle characteristics and nomenclature) was located across a dry gully at Mile 7.9. The track alignment on the bridge was tangent with a 0.33 per cent ascending grade in the eastward direction. Sight-lines approaching the bridge from the west were approximately 2100 feet.

A track geometry car tested the track on 10 May 2003. There were no deficiencies detected at the bridge location. A rail flaw detection car tested the rail for internal defects on 29 October 2002; no defects were found in the vicinity of the bridge.

The track was last inspected on 12 May 2003 by an ATS riding in a hi-rail vehicle. No deficiencies were noted at the bridge. Several days prior to the accident, a train experienced a pull apart just west of the bridge at Mile 7.9. The crew had to make several switching movements across the bridge. During these movements, the conductor was in a position to observe the bridge while riding the side of a rail car at slow speed. No anomalies were noted on the bridge. The investigation also determined that train crews and track maintenance personnel traversing the bridge in the days prior to the accident observed no unusual conditions.

1.10 *Particulars of the Bridge*

The bridge was an open deck timber pile trestle comprised of 26 spans with a total length of 293 feet. The maximum height of the bridge was 26 feet.

The bridge was rebuilt in 1969 in accordance with CN plan R-1198-1, approved by the Canadian Transport Commission in January 1969. The properties of the timber used for the superstructure of the bridge followed the CN timber material specification for Douglas fir (larch).

The substructure of the bridge consisted of 27 pile bents. The central bents (bents 8 to 20) had 6 piles and the remaining bents had 5 piles. The diameters of the piles ranged from 12 inches to 16 inches.

The original caps on this bridge were 12 inches by 14 inches by 14 feet. The replaced caps were 14 inches by 14 inches by 14 feet.

The spans were constructed with eight stringers per span, which were bundled in two chords of four stringers each, centred under each rail. The stringer cross-section measured 8 inches by 16 inches.

The deck ties were 8 inches by 8 inches by 12 feet, spaced 4 inches apart. The running rails were 136-pound continuous welded rail manufactured in 1984 and 1985. The rail was laid on 14-inch double-shouldered bridge tie plates fastened to the ties with two spikes per plate. Consistent with standard practice, rail was not anchored on the bridge. The guard rails were 100-pound rail, jointed with four-hole splice bars and spiked every second tie. They were installed 17 inches from the gauge side of the running rail. This distance does not conform to the standard distance of 9 inches specified in CN Standard Plan TS-1108 for open deck bridges.

The bridge was built over a gully through an unstable ground area. There was no record of any bridge movement in recent years.

1.11 Occurrence Site Information

The locomotives toppled off the bridge, dropping approximately 25 feet into the gully below (see Photo 1). The following three cars were piled perpendicular to the centre line of the bridge. The first car behind the trailing locomotive came to rest across the cab portion of the trailing locomotive. The top portion of this locomotive's cab was torn off. The fourth car stopped in an upright position toward the west dump wall of the bridge. The fifth car was derailed, but remained upright on the west approach of the bridge.

Photo 1. Occurrence site

The west end of the bridge (spans 7 to 26) was destroyed during the derailment and the fire that followed. Approximately 65 feet of the east end of the bridge (spans 1 to 6) remained standing, but were damaged by the fire (see Figures 3 and 4).

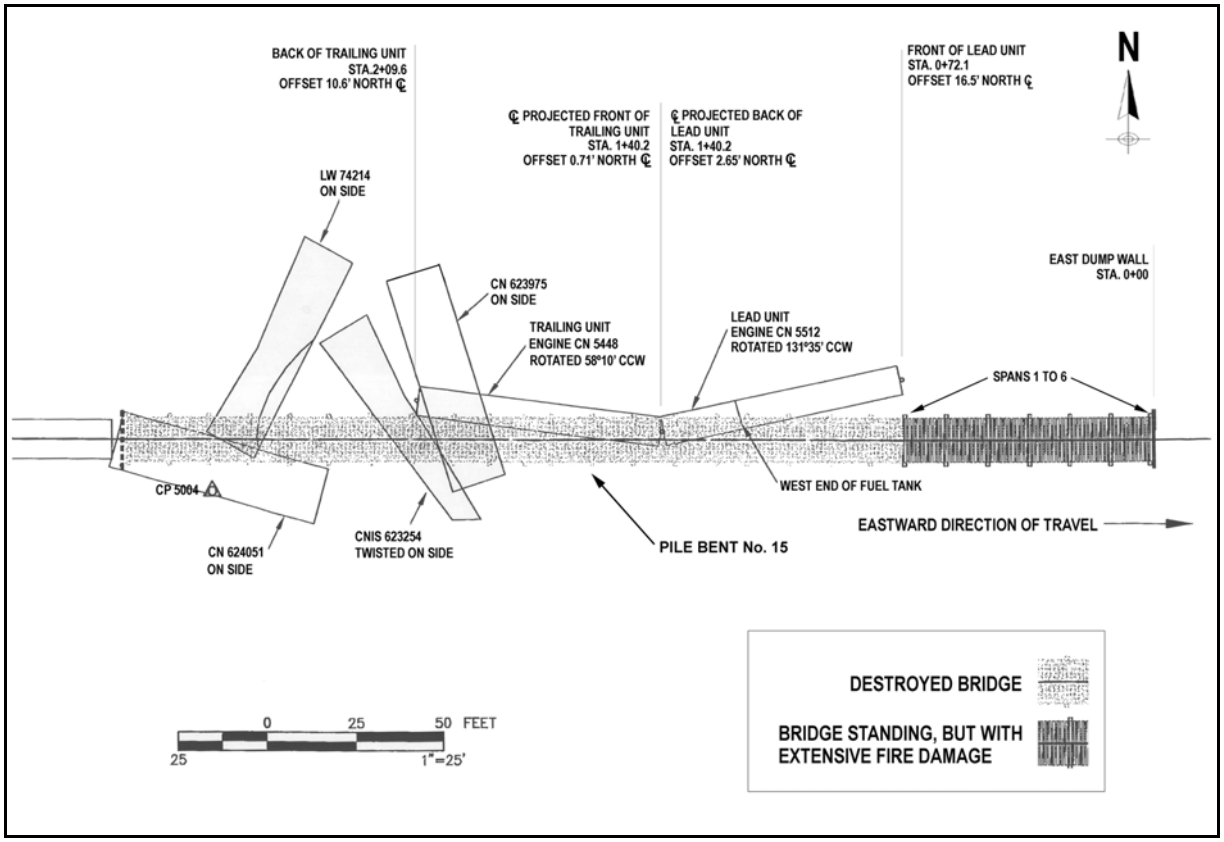

Figure 3. Derailment site plan

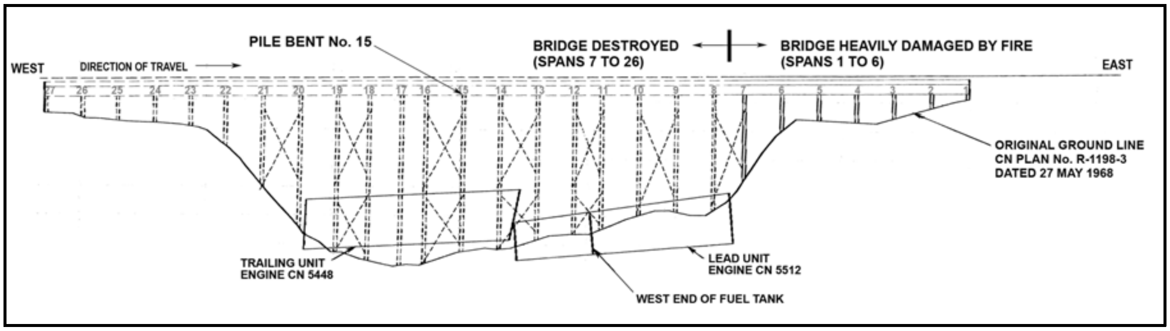

Figure 4. Side elevation of bridge

The two locomotives came to rest between bents 7 and 20 near the centre line of the bridge. They were coupled rear to rear. Measurements of their final resting positions were taken relative to the centre line of the bridge and are shown on the diagram (see Figure 5). The front end of the lead locomotive was 72 feet from the east dump wall and the end of the trailing locomotive was 210 feet from the east dump wall. The lead locomotive had rotated through 131 degrees from the upright position, coming to rest on the bank of the gully. The trailing locomotive rotated through 58 degrees.

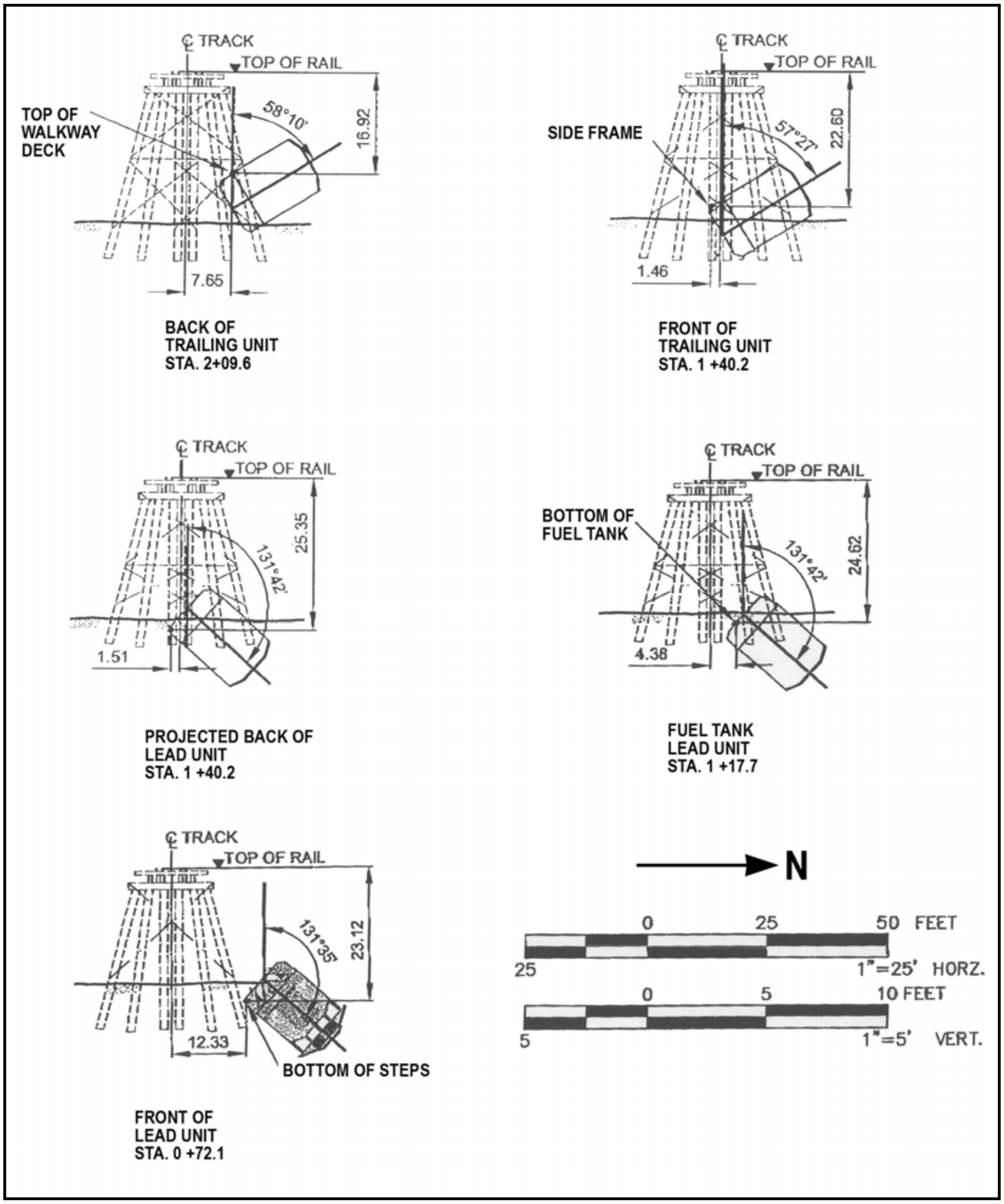

Figure 5. Resting positions of locomotives

Marks on the left side of the lead truck of the lead locomotive showed the imprint of a rail head. There were marks on the bottom of the locomotive's pilot (snow plough) possibly caused by contact with the base of the north running rail. There were also rail head marks on the front end and on the front baffle plates on the underside of the fuel tank (see Photo 2). Abrasion marks were found on three traction motor gear casings on the leading truck. There were minor marks on the trailing traction motor gear case cover on the south side of the trailing truck of the lead locomotive. The minimum clearance between the top of the rail and the underside of the locomotive fuel tanks and traction motor gear casings for this type of locomotive is 6.25 inches.

Photo 2. Rail head marks on the baffle plate on the underside of the fuel tank

An outside bridge pile in bent 15 penetrated the side of the trailing locomotive's cooling air inlet shutters. The pile had moved approximately eight feet forward from its original vertical position. No marks were found on the underside of the trailing locomotive, nor were there any impact marks on the wheels of either locomotive.

The running rail and guard rail were found hanging from the remaining portion of the bridge, twisted and tangled within the wreckage. The rails were broken in several pieces at the west end of the bridge. Scrapes and impact marks (see Photo 3) on the side of the south guard rail and on the head on the north guard rail indicate that the lead locomotive had contacted the guard rails approximately 145 feet from the east dump wall.

Photo 3. Impact mark on the guard rail splice bar bolt

Although the rail and fastenings were affected by heat from the fire, they were in good condition. Approximately 5.5 feet of the south rail and 13.7 feet of the north rail were not recovered despite extensive search efforts. It was determined that the unrecovered segment of the south rail was from a location on the bridge 19.7 feet east of the west dump wall (span 25) and the unrecovered segment of the north rail was from a location on the bridge 59 feet east of the west dump wall (span 21).

1.12 Examination of Rolling Stock

No sand or skid marks were found on the track approaching the bridge to indicate that an emergency brake application had been made before the locomotives arrived at the bridge. Inspection of the standing portion of the train indicated that the train brakes were in emergency, consistent with the separation of the brake pipe that would have occurred when the train derailed. Examination of the locomotive controls in the lead locomotive and TSB Engineering Laboratory analysis of control components (report LP 047/03)[2] indicated that the reverser was in the forward position and the throttle was in notch 7 when the train derailed. The extent of damage to the locomotives and LER systems precluded further verification of the exact position of all locomotive controls. The locomotive running gear on both locomotives showed no indication of defective wheels or axles.

There were no exceptions detected on the train as it passed the Mile 12.27 wayside inspection system at approximately 1201, nor was there any indication that there had been dragging equipment in the vicinity of the bridge. The wreckage of the train was examined; there were no pre-derailment defects that may have contributed to the accident.

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[2] This report and report LP 046/03 are available upon request from the TSB.

1.13 Examination of Broken Rail

Several samples of broken and sheared rail pieces found at the west end of the bridge were examined at the TSB Engineering Laboratory (report LP 046/03). The results indicated that the rail pieces broke as a result of instantaneous excessive stresses sustained during the derailment. No rail defects or signs of a progressive failure mechanism were found.

1.14 Bridge Inspection and Maintenance

1.14.1 Job Transitions

In the early 1990s, the Bridges and Structures (B & S) Supervisor in Prince George was responsible for inspecting and maintaining timber bridges on the CN north line. In the mid-1990s, responsibility for timber bridge inspections was transferred from the B & S Supervisor to the Planning and Inspection (P & I) Engineer in Edmonton. Inspection reports were no longer submitted to the B & S Supervisor directly, but instead to the P & I Engineer for assessing and scheduling maintenance work. In addition, in 1999, a new B & S Manager was appointed for CN's Pacific Region (Alberta and British Columbia) with overall responsibility for bridges and structures.

As a result of a reorganization and workforce adjustment in July 1999, the responsibility for bridges and structures on the CN north line was transferred to the B & S Supervisor in Kamloops. During the transition period, in addition to performing the duties of a B & S Supervisor, the incumbent B & S Supervisor took on new duties as a Track Supervisor in January 2000, and carried both responsibilities until March 2000. The incumbent B & S Supervisor provided an outstanding list of work to be performed, which included the bridge at Mile 7.9, to the incoming B & S Supervisor. No priority was assigned to the activities on this list.

Furthermore, there were personnel changes involving both the P & I Engineer and the B & S Supervisor positions. During the reorganization and workforce adjustment of July 1999, the incumbent P & I Engineer was to be replaced. However, he remained on the job until March 2000 and continued to review inspection reports. During this transition period, the incoming P & I Engineer was performing other duties.

In addition to the supervisory changes listed above, between the time that the 1999 detailed inspection was carried out on the bridge at Mile 7.9, and the time that bridge repairs were effected between 2001 and 2002, as many as five different foremen worked on the bridge at Mile 7.9.

1.14.2 *Inspection and Maintenance Guidelines*

Bridge inspection requirements are detailed in CN Standard Practice Circular (SPC) 4000, *Inspection of Steel, Timber and Concrete Bridges*, dated 15 December 1997 (see excerpts in Appendix B). These requirements were further detailed in commentary, dated 19 October 1998, used in training sessions. Maintenance requirements for timber bridges and decks are outlined in SPC 4001, *Standards of Maintenance for Timber Bridge Decks*, and SPC 4300, *Standards of Maintenance for Timber Bridges* (see excerpts in Appendix C).

The frequency of bridge inspections is, in general, governed by the tonnage handled and the importance of the line where the bridges are located. The frequency of inspections outlined in the SPC may be increased, based on local conditions. As the Fraser Subdivision carries over 10 million gross ton-miles annually, the SPC requires that all bridges on the subdivision be inspected in detail at least once in five years and that each bridge shall receive a full visual inspection at least once every year.

A detailed inspection of a structure is conducted to ensure the integrity of the structure and to obtain accurate information for determining the carrying capacity and for determining required repair or replacement needs. A detailed inspection includes measurements and documentation of the defects and deterioration of all the components of the structure and includes an observation of the surrounding terrain.

A full visual inspection is a periodic inspection conducted between detailed inspections to ensure the integrity of a structure and to note any condition or change that requires investigation or attention. This type of inspection includes looking at all the critical components of the structure and comparing them with the previous detailed inspection. The inspector must get close enough to each component and connection of the structure to view it clearly.

Both detailed and visual inspections of timber bridges include hammer sounding the bridge components and drilling areas where decay is suspected. Bridge inspectors carry out detailed and visual inspections of bridges in accordance with CN SPCs and prepare reports of the condition of the bridges. Bridge inspectors need to have a good understanding of the structure and need to be aware of any changes or modifications made to the structure. At the time of the accident, there were three inspection teams covering CN's Pacific Region; historically, there had been five.

For safety purposes, each inspection report, whether detailed or visual, must contain sufficient information about the condition of the bridge to achieve the following:

- determine the safety of the structure;
- establish future maintenance and replacement programs;
- gather and maintain the history of the structure; and
- provide information for executing repairs.

According to CN SPC 4000, and its training guidelines, the inspector is required to include in the report a qualitative assessment of the condition of the structure's components based on the applicable maintenance standards. The components are rated according to a condition-priority rating system. For the condition, the qualifiers Good (G), Fair (F), Poor (P), and Bad (B) are used (see section 4 of Appendix B). Priority ranges from priority 1 to priority 9. Priority 1 indicates that the work is urgent and should be done as soon as possible (within six months) while priority 9 indicates that no work is required at that time. Priority is assigned by considering all factors including class of track, traffic levels (gross ton-miles), and status of subdivision.

The SPCs and the CN *Bridge Inspection Workshop Manual* provide instructions on how to perform inspections, including details on the most critical areas to inspect and the criteria to assess the safety of the various components of a timber bridge. Components that have deteriorated beyond acceptable maintenance standards and are no longer capable of carrying their required load are deemed reject.

A reject stringer is one that meets any of the following criteria:

- it is broken;
- it is horizontally split at or near the horizontal centre line;
- there is bulging of the sides or crushing at the cap bearing area;
- it has internal rot with voids of three inches or more;
- there is surface rot on top of stringer in excess of one-inch deep;
- there is less than three inches of stringer bearing on the cap.

A reject cap is one that meets any of the following criteria:

- it has a horizontal split extending through the width of the cap that is over two feet in length;
- there are vertical splits extending the height of the cap that are over two feet in length;
- there is crushing into the cap by piles, posts, or stringers, or bulging of the sides of caps;

- internal rot has developed that leaves a shell of less than four inches of sound timber; or
- it is broken.

The inspection results are recorded on forms Timvis1A and Timvis2A. When timber components are drilled, this is recorded on the component inspection reports. The SPC requires that old and new inspection reports, as well as copies of any photographs, are forwarded to the office of the P & I Engineer. In addition, if an inspector recognizes the existence of hazardous conditions during the course of an inspection, he must notify the P & I Engineer and take the necessary steps to ensure safety.

The P & I Engineer reviews the inspection reports, assesses the condition of bridges, culverts, and other structures, and develops and prepares the short- and long-term maintenance and replacement programs. At the time of the occurrence, the P & I Engineer in the Pacific Region was responsible for inspecting and planning required maintenance work for approximately 600 steel and concrete bridges, 550 timber bridges, and over 10 000 culverts.

1.14.3 Inspection Training

A bridge inspector needs a good understanding of bridge structures and their potential modes of failure. This requires a thorough practical knowledge of structural engineering principles, of acceptable maintenance and inspections practices, and of approved testing techniques. The inspector must also be conversant with operating and safety rules, and railway operations. Consequently, CN SPC 4000 requires occasional audits of the quality of work of inspectors and their immediate supervisors.

At the time of the occurrence, inspectors were generally promoted from within the ranks of the B & S Department of the railway and were primarily trained through on-the-job training and workshops. No formal certification was required for timber bridge inspectors.

The last workshop prior to the occurrence was conducted in March 1999. This four-day workshop entitled "Inspection Procedures and Quality Practices" was aimed at further enhancing the knowledge of all inspectors across the CN system and ensuring cross-system uniformity of the inspection and reporting process. The workshop was designed to provide inspectors with a better understanding of a structure's behaviour, critical inspection locations for each type of structure (knowing where, how, and what to look for to find bridge deficiencies), and uniform report documentation. The information presented in the workshop was prepared using the latest SPC 4000, and its associated training commentary, as well as past inspection courses, and the personal experience and knowledge of B & S staff.

The workshop was provided to CN inspectors and P & I engineers and was attended by employees from the Pacific Region. At least one member of each of the inspection teams that carried out inspections on the bridge at Mile 7.9 of the Fraser Subdivision between 1998 and 2002 had attended the 1999 workshop.

1.14.4 *Inspection of the Bridge*

Inspection reports for the five years prior to the occurrence revealed that the bridge at Mile 7.9 was visually inspected in 1998, 1999, 2000, and 2002. There was no visual inspection performed in 2001. Cursory inspections were also performed by the B & S Supervisor, but these were not documented. Following the 1999 (July 23) visual inspection, a detailed inspection was recommended and was carried out between 31 July and 02 August 1999.

The following is a summary of the results of annual inspections performed on the bridge between 1999 and 2002. Additional details are provided in Appendix D.

1.14.4.1 *1998 Visual Inspection (21 October)*

The inspection information was reported on forms Timbvis1 and Timbvis2. These forms are similar to forms Timbvis1A and Timbvis2A; however, the condition-rating of individual components is based on a three-point scale (Good, Not Hazardous, Put on Repair Program) while the overall condition rating of the structures was based on the condition-priority rating system as specified in the SPC 4000 training guide.

The superstructure, substructure, and the deck of the bridge were rated as F5 (fair condition with a priority 5). The individual components of the bridge were rated as either Good or Not Hazardous. The guard rail was noted as non-standard. The visual inspection form was initialled on 10 November 1998 as reviewed by the P & I Engineer.

1.14.4.2 *1999 Visual Inspection (23 July)*

In June 1999, the B & S Supervisor identified a bulging cap and a cracked stringer. As a result, on 22 June 1999, a capacity rating[3] of the stringers was carried out, and a 10 mph slow order was placed on the bridge. The slow order was removed shortly after, when three caps were replaced, and a helper stringer was installed. The B & S Supervisor also requested that the bridge undergo additional inspections.

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[3] A capacity rating is carried out to assess the load-carrying capability of the bridge to determine if it can safely carry the traffic.

The P & I Engineer carried out a visual inspection on 23 July 1999. The inspection information was recorded on forms Timbvis1A and Timbvis2A. The condition of the individual components was shown as Good or Fair. The guard rail was noted as non-standard. There was no overall condition rating shown on this report. After the training course held in 1999, bridge inspectors were under the understanding that the overall condition-priority rating was no longer required. The visual inspection form was initialled as reviewed by the outgoing P & I Engineer on 10 September 1999.

1.14.4.3 1999 Detailed Inspection (31 July–02 August)

A detailed inspection, including drill testing of the main components of the bridge (deck, stringers, caps, and piles) was performed between 31 July and 02 August 1999. The drilling details were reported on separate forms as specified in the SPC 4000 training guide.

The inspectors prepared a summary report with these indications:

> Deck—The overall deck condition was rated as P5. This condition rating could be improved to G5 if 20 ties were installed and the deck was double-spiked.
>
> Stringers—The following stringers were assessed to be reject:

Span Number	**Stringer Number**	**Amount of internal rot (inches)**
1	5	10
6	6	12
11	3	14
14	6	14
15	2	11
15	4	11
15	5	12
26	5	12
26	8	11

> Overall Condition—The overall condition rating of the superstructure was P3. This condition rating could be improved to F5 with the addition of helper stringers.[4]
>
> Bents—The caps at bents 2 and 3 (caps 2 and 3) were determined to be reject: they had internal rot, horizontal splits, and signs of crushing. Cap 15 was assessed as "possibly reject" due to nine inches of internal rot on its north side. There was one reject pile at bent 10. The overall condition rating of the substructure was P5. This condition rating could be improved to F5 if two or three of the caps under consideration were replaced.

The inspectors submitted the complete drilling report and the inspection report summary to the P & I Engineer on 19 August 1999. On 23 August, the P & I Engineer forwarded the inspection findings to the rest of the B & S management team, which comprised the B & S Manager, the Structural Engineer, the P & I Engineer, and the B & S Supervisors.

The following stringers, which were reject according to the SPC criteria, were not included in the summary prepared by the inspectors:

Span Number	**Stringer Number**	**Amount of internal rot (inches)**
1	2	6
3	2	3
5	2	5
6	5	7
8	8	3
12	6	6
26	4	11

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[4] Helper stringers are generally added as a temporary measure to the outside of a chord to provide additional strength when it has been determined that a stringer in a chord has materially deteriorated to the extent that its ability to carry the required load has been diminished.

The inspectors identified cap 15 as possible reject rather than reject, even though it did not meet the SPC requirements, as it had an internal void of nine inches on its north portion. The internal void was located between piles 4 and 5, and under stringers 5 and 6. Based on the drilling pattern, the exact extent of the internal rot is not known, but it could have extended, at maximum, from pile 3 to pile 5, a distance of almost 3½ feet.

There was no bridge capacity rating made at this time, nor was any corrective action undertaken.

1.14.4.4 2000 Visual Inspection (01 August)

Photocopies of the completed 1998 inspection forms (Timbvis1 and Timbvis2) were used to record the 2000 inspection results rather than blank revised inspection forms Timbvis1A and Timbvis2A. The inspection showed that the condition of all major components was rated as Good or Not Hazardous. The guard rail was noted as non-standard. The condition rating of the bridge remained as F5. The condition of the deteriorated components identified in the 1999 detailed inspection was not reflected in this report.

In addition to the visual inspection, the bridge deck was drill tested on 01 August 2000, even though the deck had been drilled as part of the detailed inspection in 1999: 35 per cent of the ties were in good condition; 33 per cent had checks; 24 per cent showed some rot, crushing or split; and 8 per cent were reject.

These inspection forms were not initialled as reviewed.

1.14.4.5 2001 Inspection

There were no records indicating that a full visual inspection was performed in 2001. On 31 October 2001, an inspection team was asked to check timber not yet replaced. The inspection team recorded their observations on 03 November 2001 indicating that it appeared that nothing had been changed, and scaffolding remained in place.

1.14.4.6 2002 Visual Inspection (25 September)

Photocopies of the completed 1998 inspection forms (Timbvis1 and Timbvis2) were again used to record the inspection results rather than blank revised inspection forms Timbvis1A and Timbvis2A. The condition rating of all major components was not modified and was identical to the ratings of 1998 and 2000.

A broken stringer in span 2 was identified on 26 September 2002. On 27 September, a timber bridge capacity rating for span 2, with 7 stringers, determined that the bridge capacity was sufficient to carry 286 000 pounds loading at the authorized speed of 25 mph.

The condition rating of the bridge remained as F5. The deteriorated condition of the components identified in the 1999 detailed inspection was not reflected in this inspection report. The inspection forms were not initialled as reviewed.

1.15 Bridge Maintenance

The annual bridge maintenance and replacement program is finalized with the B & S management team. For each steel structure in the program, the Structural Engineer prepares specific drawings outlining the work to be performed and materials to be acquired. These drawings are forwarded to the B & S Supervisors and those who execute the work. Once the work is completed, the drawings are returned to the office with all the work performed, including any modifications or additions, clearly indicated on the drawings. The drawings are filed as an update to the bridge records.

For timber bridges, drawings are not prepared because the bridges are based on a standard design. The program is communicated to the B & S Supervisors either verbally, or by sending an inspection report, or via e-mail. The B & S Supervisor then orders the required materials and allocates the appropriate human resources to carry out the work. The maintenance work to be carried out is communicated directly to the crews. There is no exchange of drawings to show the details of the required work, and there is no formal recording system in place to indicate, to the regional or head office, the nature and extent of the completed work. The only information available on the work carried out on timber bridges are the updates noted by inspectors during their annual inspections.

Inspection reports and repair crew information show that the following maintenance work was carried out on the bridge at Mile 7.9 of the Fraser Subdivision:

- Prior to the detailed inspection performed in 1999, caps 6, 10, 19, 20, 21, and 26, and one short and one long stringer in the south chord of span 26 were replaced. Helper stringers were installed between spans 18 and 19.

- The proposed 2000 Capital Program included replacing deteriorated piles, caps, and stringers at four bridge locations on the Fraser Subdivision, including the bridge at Mile 7.9; however, there were no specific details recorded as to what work had to be performed. There was no indication that any work was undertaken at Mile 7.9 in 2000.

- The proposed 2001 Capital Program consisted of adding helper stringers to spans 1, 6, 11, 14, 15, and 26; replacing caps 2, 3, 5, 11, 15, 17, 23, and 24; and renewing 20 ties. A maintenance crew commenced repair work in June 2001. The crew replaced caps 2, 3, and 5. The work stopped when their crane was damaged. The crew was subsequently diverted to other locations because of fire and other emergencies. The maintenance crew returned in September 2001 and installed new caps at bents 11, 17, 23, and 24.

On 31 October 2001, the P & I Engineer requested that bridge inspectors check on any timber that had not been replaced. He was advised that it appeared the work had not been completed, and the scaffolding was still in place. There is no indication that helper stringers were installed in 2001.

- The proposed 2002 Capital Program did not include work at Mile 7.9, other than subdivision general maintenance. However, in April 2002, a maintenance crew installed helper stringers between bents 14 and 16, on the outside of both stringer chords, and removed the scaffolding.

- There was no record or other indication that cap 15, which was identified in the 1999 drilling summary as being a possible reject, was replaced.

1.16 Capacity Rating of the Bridge and the Equipment

A capacity rating is carried out to assess the load-carrying capability of a bridge to determine if it can safely carry the traffic. The capacity rating of a bridge is determined by the capacity of its weakest component. It is derived from the computation of stresses based on the bridge's design, the materials with which the bridge was built, and the actual physical condition of the bridge as identified through the latest inspection. In general, for timber bridges, the capacity rating is governed by the shear capacity of the stringers. The condition of the piles and caps can also be a limiting factor for the carrying capacity of the structure, but the capacity rating is seldom computed for these components.

Capacity rating is expressed as a Cooper E loading. The Cooper E loading was introduced by Theodore E. Cooper in 1894 for the design of railway bridges. It was calculated using the axle loading and spacing based on the configuration and weight of a steam locomotive of that era followed by a tender. The original configuration is still used to design modern bridges; however the axle loading has been increased to reflect actual equipment weight. Currently, Cooper E80 loading is used to design new bridges. This loading represents axle loads of 80 000 pounds each, spaced in the same configuration as Cooper's steam locomotive (see Appendix E).

Because the configuration of railway equipment varies, and the spacing between axles is not five feet as in the Cooper E loading, each locomotive and rail car is given an equivalent Cooper E rating to assess its effects (essentially bending and shear forces) on a bridge. The equipment rating represents a Cooper E loading that would produce effects of the same magnitude on the bridge as the railway equipment under consideration.

1.16.1 *Capacity Rating of the Stringers*

The allowable horizontal shear stress used for capacity rating is stipulated in the AREMA (American Railway Engineering and Maintenance of Way Association) standards for the design of timber bridges. It is obtained by increasing the unit shear stress by 10 per cent for regular equipment and can be increased by 30 per cent for equipment not regularly assigned. The allowable stresses can be further increased by 15 per cent if the speed over the bridge is reduced to not more than 10 mph.

In 1969, the unit shear stress for Douglas fir (larch) was 90 psi (pounds per square inch) and the allowable horizontal shear stress was 100 psi. In 1983, the unit shear stress was decreased to 75 psi to reflect the reduced strength of second-growth timber. Accordingly, the allowable horizontal shear stress was reduced to 83 psi.

According to AREMA standards, if the anticipated stresses exceed those permissible under these rules, the loading is to be restricted until the indicated remedial work has been done so that the permissible stresses will not be exceeded. The remedial work will typically consist of replacing defective parts or placing additional stringers. When the permissible stresses are closely approached, or when the physical condition of the main members is degraded, the bridge shall be kept under frequent inspection as long as it continues in service.

After the occurrence, CN carried out a capacity rating of span 15, which had two deteriorated stringers in the south chord and one in the north chord. The rating calculation was performed for the "as built condition" (four sound stringers per chord) and for the "actual condition" (two sound interior stringers and a helper stringer per chord). The axle load was distributed equally among the two sound interior stringers and the helper stringers; the contribution of the deteriorated stringers was not included in the calculation. Because the bridge was built in 1969, the allowable horizontal shear stress used was 100 psi. The capacity rating was governed by the shear capacity of the stringers and is presented in Table 1.

	Number of sound stringers (8" x 16" x 11'9" each)	**Cooper E Rating (at zone speed)**
As Built Condition	4	E80.2
Actual Condition	3	E59.4

Table 1. Capacity rating of span 15, south chord

Using CN criteria, the TSB determined that the capacity rating for span 15 prior to the installation of helper stringers would have been Cooper E38.

The capacity rating for span 26, which had two deteriorated stringers and no helper stringer in the north chord, is listed in Table 2.

	Number of sound stringers (8" x 16" x 11"9" each)	Cooper E Rating (at zone speed)
As Built Condition	4	E87.0
Actual Condition	2	E42.0

Table 2. Capacity rating of span 26, north chord

The following list presents the equivalent Cooper E ratings for the locomotives (CN 5448 and CN 5512) involved in the derailment, and for regular cars (263 000 pounds), as well as for the heaviest cars (286 000 pounds) that travel over the Fraser Subdivision.

Equipment	Equivalent Cooper E Rating
Heaviest car (286 000 pounds)	E61.3
Regular car (263 000 pounds)	E56.4
Locomotives (CN 5448 and CN 5512)	E53.1

1.16.1.1 Independent Engineering Analysis

An independent engineering analysis was conducted to assess the distribution of wheel loads between stringers. A three-dimensional model was used to determine the rail-to-ties and the ties-to-stringers load distribution for various wheel load positions. As an example, Table 3 presents the distribution obtained for span 15.

	Stringer Number	All stringers in sound condition	Moment of inertia of stringers 2, 4, and 5 reduced by 25 per cent	Moment of inertia of stringers 2, 4, and 5 reduced to 0 per cent
South Chord	Helper 1	10.7	11.6	26.2
	1	22.6	24.5	33
	2	18	14.2	0
	3	30.4	34.7	40.8
	4	18.4	15	0
North Chord	5	18.4	14.9	0
	6	30.4	34.5	35
	7	18	14.7	22.6
	8	22.5	24.4	27.1
	Helper 2	10.7	11.5	15.3

Table 3. Percentage of wheel load distributed by stringer, span 15
Note: minor variance in per cent totals is due to software

For the south chord, the analysis determined that the helper stringer would carry approximately 12 per cent of the wheel load, assuming that the deteriorated stringers 2 and 4 sustain their shared load without crushing, while stringer 3 carries approximately 35 per cent of the load. If stringers 2 and 4 are unable to sustain any load, the helper stringer's share increases to 26.2 per cent of the load, while stringer 3 carries 40.8 per cent of the load. A similar distribution is observed on the north chord, where the share of stringer 6 increases to 35 per cent.

When the above wheel load distribution and CN's criteria for capacity rating are applied to the "actual condition" of span 15, the capacity rating decreases from Cooper E59.4 to Cooper E49 for the south chord (two sound interior stringers and a helper stringer) and to Cooper E57 for the north chord (three sound interior stringers and a helper stringer).

1.16.1.2 Allowable Horizontal Shear Stress

Several studies indicate that, if a stringer does not have any horizontal splits or checks, which often occur during the seasoning of the timber members, the allowable horizontal shear stress can be multiplied by a factor of 2. If there is a horizontal split that is up to four inches for an eight-inch deep stringer, the factor is 1.67.

1.16.2 Capacity Rating of Cap 15

The capacity rating of cap 15 was not carried out. In practice, assessing the condition of caps is based on the extent of crushing, bulging, internal rot, and horizontal splits as outlined in the SPCs. Generally, a failing cap will provide external warning signs; however, caps that have internal rot surrounded by a strong shell can fail suddenly.

1.17 Regulatory Overview

Transport Canada (TC) is responsible for administering and enforcing the provisions of the *Railway Safety Act*.

The roles and responsibilities of TC's headquarters and regional offices with respect to bridge inspection are based on the Rail Safety Functional Model outlined in the Rail Safety Organizational Change Proposal of March 2000. Headquarters designs and maintains national audit, inspection, and enforcement programs. This includes developing and maintaining national systems, including data requirements, collection, analysis, and communication of the results.

The regions participate in the development and in the design and modification of the national audit, inspection, and enforcement programs. The regions also develop and conduct monitoring and enforcement activities (e.g., audits and inspections) and manage the regional complaint process.

1.17.1 Bridge Monitoring Program

Bridge Monitoring Program (1994) instructions are currently included in the TC Engineering Manual. Draft guidelines for monitoring bridges were updated in 1996 and 1997.

This approach to monitoring the safety of bridges consists of cursory inspections, specific inspections, and a review and audit of the records of the railway's own compliance monitoring programs.

- A *cursory inspection* is a quick check for damage or obvious signs of deterioration or distress and is usually carried out by the railway infrastructure officer while performing track inspection.

- A *specific inspection* consists of a systematic visual examination of the structure; it involves walking across and around the structure, observing the different features, and looking for signs of deterioration or distress. It is supplemented by a "Bridge Condition Report."

- An *audit of railway inspection records* is a review and audit carried out after any questionable field findings are noted or when deemed necessary.

The current engineering functional program is focused primarily toward cursory inspection. An infrastructure officer conducts cursory bridge inspections while performing track inspections. There is no examination of procedures, practices, or associated documentation as part of this inspection. Any non-compliance is noted on a form entitled "Track Inspection Defect Report" that is then issued to the railways for corrective action.

FRA staff provided training on bridge inspection to TC regional infrastructure officers in 2001. However, at the time of the occurrence, there was no TC Headquarters Bridge Engineer to provide assistance to the regions as is the case for other railway activities.

The cursory inspections were carried out consistently across Canada. However, the specific inspections and the audits of railway inspection records were not performed in all regions. In several regions, specific inspections were prompted only by complaints or when there were issues related to roadways passing underneath bridge structures. There was no audit of the working procedures and practices.

The Pacific Region had a program for specific bridge inspections; between 1999 and 2003, 38 specific bridge inspections were carried out on Canadian Pacific Railway lines. Eight of these inspections were documented on Bridge Condition Reports. Many of these specific inspections also involved an audit of railway inspection records. There were no specific inspections nor were there audits of records performed on any CN subdivision over the same period.

The Pacific Region infrastructure officer carried out regular track infrastructure inspections on the Fraser Subdivision in 2000 and 2002, performing cursory inspections of structures at that time. During a cursory inspection of the bridge at Mile 7.9 performed in June 2000, the infrastructure officer noted a surface and line defect at the bridge approaches and requested that a bridge safety assessment be carried out. The surface and line deficiency was corrected. In November 2000, CN responded indicating the following:

- The bridge received a detailed inspection including drilling of the main components in August 1999.
- A full visual inspection of the bridge was conducted in August 2000.
- Following the 1999 inspection, some timber work was performed and additional work was scheduled for 2001.

This response was considered satisfactory and TC did not do any additional follow-up.

1.18 Safety Management System

In 2000, TC and the railway industry adopted a Safety Management System (SMS) framework. The intent was to provide a more directed and focused approach to safety. The SMS framework is "a formal framework for integrating safety into day-to-day railway operations and includes safety goals and performance targets, risk assessments, responsibilities and authorities, rules and procedures, and monitoring and evaluation processes." The objectives of the SMS are to ensure that safety is given management time and corporate resources, and that it is subject to performance measurement and monitoring on par with financial and production goals. The stated outcome of the SMS is to reduce public and employee fatalities and injuries, reduce property damage resulting from railway accidents, and reduce the impact of accidents on the environment.

As part of the requirement under the *Railway Safety Management System Regulations* that came into force on 31 March 2001, CN developed an SMS that was submitted to TC. This SMS was audited by TC in 2003. The audit consisted of an examination of the submission and its associated reference material. From this examination, interview questions were prepared and administered to six levels within the company (senior management, managers, line supervisors, employees, and management and employee health and safety committee members). Supporting documents were also reviewed to verify compliance with the SMS regulations. The audit covered a broad cross-section of CN operations from both headquarters and the regions.

The SMS function at TC is handled by the SMS group, which is an entity separate from the functional groups (engineering, equipment, and operations). The SMS audit team is complemented by functional inspectors selected from various regional offices. When conducting an audit, the SMS group petitions the functional groups to determine if there are any issues that should be addressed. This may lead to questions on specific issues. For example, in engineering, TC's audit of CN included a number of questions about drainage and culverts, as this issue was a concern following a number of derailments due to subgrade failures. For other areas that have not been specifically identified as areas of high risk, such as bridges, few or no questions may be asked. For example, the audit only examined the availability of SPC 4000 to the field supervisor, whereas the compliance with the SPC was not raised, nor was the adequacy of the existing procedures and practices.

1.19 Other Information

1.19.1 Radar Module Malfunction

The lead locomotive, CN 5512, had been experiencing problems en route. It was determined that a component referred to as a "radar module" had been functioning intermittently. When the radar module is not functioning properly, it limits the locomotive's capacity to generate power and the locomotive is limited to a maximum speed of about 25 mph. The RTC and Mechanical

Department were aware of the problems that the crew were experiencing with the lead locomotive. Prior to the occurrence, the crew was instructed to bypass this module so they could resume track speed. They lost approximately two hours traversing the Fraser Subdivision as a result of this problem.

1.19.2 Communications

Train crews on the Fraser Subdivision were provided with hand-held portable radios, which transmit and receive messages reliably within a range of two to three miles. There was no means for crews at the bunkhouse to communicate directly with train crews beyond the two- to three-mile range of the hand-held portable radios; however, there was a telephone for communicating with the RTC in Edmonton.

Unlike the Centralized Traffic Control System, which continuously provides the approximate train location to the RTC, in Occupancy Control System territory, a train's location is not communicated automatically to a central location. Therefore, the RTC must obtain a train location report and physically enter this information into the system. A train crew is only required to provide train location information to the RTC if their train is delayed en route and/or having passed specific locations previously identified by the railway.

1.19.3 Post-Accident Site Information

The railway elected not to reconstruct the bridge at Mile 7.9. A permanent bypass (shoofly) was constructed around the bridge location. Due to unstable soils in the area, CN installed a slide detection system to monitor the grade for stabilization. The detection system is solar-powered and is equipped with a radio talker system that provides a vocal message within a 10-mile radius if the subgrade should fail. The message is transmitted at two-minute intervals.

2.0 Analysis

2.1 The Derailment

Train operation was not considered to be a causal factor in this occurrence. The examination of the controls indicated that the reverser was in forward position and the throttle was in notch 7 when the train derailed. The position of the automatic brake handle could not be determined. As there were no sand marks approaching the bridge to indicate that an emergency brake application had been made prior to the locomotives' arrival at the bridge, it is unlikely that the crew had noticed any abnormality on the bridge. Since the view of the bridge was clear for a distance of approximately 2100 feet, had there been any indication of a fire or track misalignment on the bridge, the crew would have had sufficient time to reduce the throttle and make a brake application, or place the train into emergency. However, in the absence of event recorder data, and due to the extensive damage to the locomotive controls, it was not possible to determine if the emergency brake application that occurred was operator-initiated from the locomotive while on the bridge, or was due to the derailment.

The wreckage of the train was examined and there was no evidence that a mechanical failure contributed to the accident. There were no exceptions detected on the train as it passed the last wayside inspection system nor was there any indication of dragging equipment in the vicinity of the bridge.

2.1.1 Possible Accident Scenarios

The TSB examined all the available physical evidence in the context of two possible derailment scenarios. The first scenario is a rail failure leading to the train derailment and subsequent bridge collapse; the second scenario is a bridge component failure, leading to the train derailment.

2.1.1.1 First Scenario

This scenario involves the possibility of a rail failure west of bent 15. In the vicinity of bent 15, where the locomotives toppled off the bridge, there were no track defects identified during the last track inspection and no abnormal conditions were reported by previous trains. The running rails and the guard rails were not fractured at that location. Therefore, it can be concluded that the condition of the rail and the track surface in the vicinity of bent 15 did not cause the locomotive to be diverted off the bridge. Also, the results of the TSB Engineering Laboratory analysis indicated that the rail pieces recovered during the investigation broke as a result of instantaneous excessive stresses sustained during the derailment.

A segment of the north rail in span 21 and a segment of the south rail in span 25 were not recovered. It is unlikely that the locomotives derailed over the unrecovered segment of the south rail in span 25 because they toppled off the north side of the bridge. The Board considered whether they could have derailed over the unrecovered segment of the north rail on span 21. Had the locomotives derailed over the north rail, the guard rails would have prevented them from diverging from the bridge until they reached span 15. As the capacity of the stringers of span 15 and cap 15 was reduced due to internal deterioration, they would not have been able to sustain the weight of the locomotives and the hammering impact of the wheels.

However, these physical findings must be considered:

- The first marks on the running rails and guard rails, and the impact mark on the splice bar bolt of the guard rail were located east of bent 15, which indicates that the lead locomotive was not in a derailed position west of bent 15.

- The absence of marks on the underside of the trailing locomotive indicates that it was not in a derailed condition when it rolled off the bridge.

- There were no impact marks on the wheels of the trailing truck of the lead locomotive and none on any of the wheels of the trailing locomotive, all of which would have had to pass over the rail break.

- The rail was in good condition, with minimal wear, and there were no rail defects reported by the track inspector or previous trains.

- The conditions conducive to brittle fracture were not present because the cumulative traffic that went over the rail since its installation was low, and the warm temperature would minimize the thermal stresses and the susceptibility of the rail to fracture.

- The rail breaks at the west dump wall occurred under a rapid overstress, suggesting that the continuous welded rail was still continuous and was put under tension and fractured while supporting the weight of the train.

These physical findings, when considered as a whole, lead to a conclusion that the first scenario is highly unlikely.

2.1.1.2 Second Scenario

The second scenario is the failure of bridge components leading to the train derailment. The outside pile of bent 15 penetrated the north side of the trailing (second) locomotive cooling air inlet shutters and had moved approximately eight feet forward from its original vertical position, which would indicate that there was little forward movement at the time the locomotive rolled over. Furthermore, the trailing locomotive came to rest on its side close to the centre line of the bridge, which indicates that it did not drop from the side of the bridge, but rather it dropped down after the bridge caved in.

Abrasion marks, which were located on the bottom of the front end and front baffle plates of the fuel tank and on the traction motor gear casings on the leading truck of the lead locomotive, indicate that the trailing truck never derailed. Rather, this indicates that the bridge caved in under the lead locomotive and the locomotive came briefly into contact with the north running rail and the guard rail while it was dropping into the gully.

It is more likely that some bridge members failed in the vicinity of bent 15, either under the load of the locomotive or that of a previous train. Due to internal rot present in the stringers of span 15 and in cap 15, this portion of the bridge was weakened. Even though the south chord of span 15 had a low capacity rating, it is unlikely that it failed under the weight of the lead locomotive because the units dropped on the north side of the bridge. However, stringer 6 was overloaded, and cap 15 had an internal void on its north portion, which may have extended to a point directly under stringers 5 and 6. As the load shared by these stringers was increased due to the internal rot of the adjacent stringers, the reaction load transferred to cap 15 was concentrated over a smaller surface, thus exerting stresses over the existing void that would have exceeded the cap's bearing capacity.

Generally, caps fail through progressive crushing, bulging, or horizontal splits and are replaced when these characteristics are present; however, cap 15 had an internal void with a surrounding solid shell that would have appeared to be sound externally. Given that the interior void had been detected almost four years prior to the occurrence, it is very likely that the internal deterioration had progressed significantly, further reducing the shell thickness and increasing the risk of a sudden failure.

Because some rail sections were missing, and all bridge components were burnt, it is not possible to entirely eliminate the possibility of a broken rail at span 21 nor to conclusively confirm that a bridge component failed. However, given the information collected on the rail, the dynamics of the derailment, and the condition of the stringers in span 15 and the condition of cap 15 as reported in 1999, it is most likely that cap 15 failed under traffic as its capacity was exceeded.

2.2 Bridge Inspection and Maintenance

In 1999, the detailed inspection report was submitted to the P & I Engineer 17 days after the drilling and was disseminated to the B & S Supervisors. Stringers 2, 4, and 5 on span 15, and stringers 4, 5, and 8 on span 26 had internal rot exceeding the SPC limits and were identified as reject. The depth of the internal rot on some of these stringers reached three-quarters of the depth of the member, suggesting that the capacity of those reject members was significantly reduced and, correspondingly, the capacity of the bridge. The deterioration in caps 2, 3, and 15, which included crushing, horizontal splitting, or rot, also warranted immediate attention.

It appears that there were inconsistencies in the methods and criteria used to assess the safety of timber bridge components that exceed the CN SPC limits and are declared as reject, depending on whether there were external signs or hidden internal rot. For instance, on two other occasions when a single stringer on this bridge was identified as cracked or broken, a capacity rating was immediately performed and preventive action was taken. It appears that a broken stringer or a bulging cap will elicit an immediate response because it is evident that it has lost all its carrying capacity. However, a stringer or cap with internal rot does not appear to trigger any immediate action, perhaps because the degradation is progressive, leading to a belief that there is residual capacity. Consequently, the residual capacity of members may be overestimated, and the severity of the condition, not fully recognized.

Caps are critical members for which there is no redundancy, that is, if one fails, there is no other element available as a backup. Therefore, they are replaced when they no longer meet the SPC criteria and are identified as reject. Generally, their load capacity is not calculated because of the complexity of modelling the behaviour and the stress distribution, and quantifying the residual strength of the deteriorated timber.

With regard to the stringers on spans 15 and 26, their carrying capacity was affected by the internal deterioration of the timber. According to calculations carried out by CN after the occurrence, the capacity rating was Cooper E59.4, slightly below the equivalent rating for 286 000-pound cars. However, prior to the installation of the helper stringers between 1999 and 2002, the capacity rating of span 15 would have been Cooper E38, which is well below the rating for the locomotives, for the regular cars, and for the heaviest cars travelling over the subdivision. The capacity of span 26 was estimated as reduced to Cooper E42.

Even though the calculated capacity rating of the structure was lower than the equivalent rating of the equipment, no failure occurred between 1999 and the time of the occurrence because there was a high safety margin associated with the timber unit shear stress. The shear capacity of rectangular members such as stringers is controlled by their ability to resist horizontal shear. The mode of failure associated with horizontal shear results in a horizontal split that runs longitudinally down the centre of the member and splits it into two pieces. Because wood is not an engineered material and is not homogeneous, there is a high variability in the shear stress value and, therefore, high safety margins are used.

The general standard used by railways in North America for the capacity rating of stringers normally uses 100 psi as the design shear stress level. This value is an allowable limit that is well below the ultimate resistance of the timber. In fact, some studies have shown that this value can safely be multiplied by a factor of two when a thorough examination of the members is carried out and there is no indication of visible horizontal splits. Therefore, the exact capacity rating of the stringers can only be determined when the actual condition of the stringers is known; otherwise, their capacity is conservatively estimated for the worst scenario, which assumes the presence of horizontal splits.

According to industry standards, under normal circumstances, when defects such as those identified by the 1999 detailed inspection were known to exist, the loading or the speed should have been restricted so that the permissible stresses would not be exceeded until the remedial work was completed, and the bridge should have been frequently inspected. However, after the detailed inspection, neither the urgency nor the severity of the bridge condition was fully recognized. Consequently, no capacity rating was carried out nor was any immediate remedial action taken, and the maintenance work on the bridge was not given a high priority.

The following list, which was developed from information laid out in section 1.14.4.3, indicates that there were discrepancies between what was identified for repair in the drilling report, what repairs were planned, and what was actually carried out.

1999 Drilling Report	**Planned Maintenance**	**Actual Repairs Completed**
Span 1, stringers 2 and 5	Add helper stringers	Nil
Span 3, stringer 2	Nil	Nil
Span 5, stringer 2	Nil	Nil
Span 6, stringers 5 and 6	Add helper stringers	Nil
Span 8, stringer 8	Nil	Nil
Span 11, stringer 3	Add helper stringers	Nil
Span 12, stringer 6	Nil	Nil
Span 14, stringer 6	Add helper stringers	Helper stringers added (2002)
Span 15, stringers 2, 4, and 5	Add helper stringers	Helper stringers added (2002)
Span 26, stringers 4, 5, and 8	Add helper stringers	Nil
Caps 2, 3, and 15	Replace caps 2, 3, 5, 11, 15, 17, 23, and 24	Replaced caps 2, 3, 5, 11, 17, 23, and 24 (2001)

The following factors further suggest that the urgency and severity of the defects was never fully recognized after the detailed inspection, and that the maintenance work on the bridge was not given a high priority:

- The planning undertaken in 2000 and 2001 did not accurately reflect the defects identified in the 1999 drilling report.
- In 2000, the planned work was not performed nor were any precautionary measures taken to ensure the safety of the bridge.
- The work planned in 2001 was partially completed.
- No measures were taken to ensure that the work not completed was rescheduled.

- Cap 15, which was planned for replacement in 2001, was not replaced in that year nor when the repair crew returned in 2002.

The failure to identify the urgency and the severity of the condition of the bridge was not recognized, despite subsequent inspections, because of shortcomings in the inspection, assessment, planning, and maintenance process. This process relies on the adequacy of, and compliance with, safety standards and procedures. When the defences built into this process are breached, unsafe conditions can develop. Several shortcomings associated with the conduct of inspections and quality assurance, and pressures created by workload and job transitions have been identified.

2.2.1 Inspections

2.2.1.1 Visual Inspections

Inspectors not only need to be made aware when there is a defective component identified on a structure, but they need to recognize when there is a change to the condition of a component. They must have a basic understanding of the significance of the observed change, so that it can be appropriately reported and acted upon when this change becomes critical. Therefore, they must be aware of previously reported defects.

The visual inspections subsequent to the detailed inspection performed in 1999 were not full visual inspections as prescribed by CN SPC 4000. A full visual inspection should have included looking at all the critical components of the structure and comparing them with the previous detailed inspection. However, these visual inspections did not refer to the 1999 detailed inspection, but instead were based on photocopies of inspection forms from visual inspections dating back to 1998. As a result, the condition of the critical components of the structure identified as reject in the 1999 detailed report was not reported in subsequent inspections; therefore, the condition of these components could not be monitored adequately nor acted upon accordingly.

The use of photocopies of previous inspection reports has the advantage of ensuring that information from previous inspections is readily available to the inspectors. The accepted general practice was to use the previous year's inspection form and to note changes by crossing out the information on work that was completed and adding new inspection information. In 1999, a visual inspection report was filled out on an individual form, whereas a photocopied, crossed-out 1998 form was used for the 2000 and 2002 inspections.

The SPC 4000 states that each inspection report should contain sufficient information to achieve purposes such as determining the load that the structure can safely support and establishing future maintenance programs. When the condition of defective components is not updated on each inspection report, these purposes cannot be met.

2.2.1.2 *Condition Rating of Bridge Components*

The qualitative assessment of a bridge's condition (condition rating) made by inspectors in the field reflects the overall condition of the bridge's components, but not the condition of individual components. This contrasts with generally accepted practices of safety systems and with CN SPC 4000, which states that the condition-priority rating system qualifiers refer not only to the condition of the overall structure, but also to the condition of individual components. Reliance on an overall assessment of a system may be appropriate when the system has built-in redundancy, as stringers or piles have, which means that if one fails, there are others that can accommodate the resulting load transfer. However, when the system's safety relies upon single components, such as a cap, an overall assessment will not flag an unsafe condition and will give a false indication that the system is safer than it actually is.

For example, in the summary of the detailed inspection reports, the superstructure was rated as P3 (poor, priority 3) and the substructure as P5 (poor, priority 5), despite the fact that the deterioration of several caps and stringers exceeded the SPC limits, and they were declared as reject. According to the CN guidelines, that condition should have been shown as B1 (bad, priority 1), because those components had deteriorated beyond acceptable maintenance standards, and work was required to bring them up to acceptable standards.

Subsequent to the detailed inspection and prior to any repair work being carried out, the visual inspection reports indicated that some caps were showing signs of crushing, yet the overall condition of the caps was rated as F (fair), a condition for which work is required to arrest deterioration or to restore to "as built" condition, but where the deterioration level is well within the limits permitted within the maintenance standard.

2.2.1.3 *Frequency of Inspections*

There is no record that a full visual inspection was carried out on the bridge at Mile 7.9 in 2001. When inspections are not carried out regularly, the progression of deterioration is not monitored in a timely fashion, and emerging unsafe conditions can go undetected, putting railway employees and the general public at risk.

2.2.2 *Quality Assurance*

The adequacy of, and compliance with, existing standards and procedures, sign-off of inspection reports, and documentation of activities are key components of quality assurance or audit programs. These programs, when they are robust, help ensure that the specific process has been undertaken and applied in a consistent manner.

Even though CN's SPCs acknowledge the use of occasional audits to ensure the quality of work of inspectors and their immediate supervisors, the audits that were carried out were not effective. As a result, non-compliance with safety-critical procedures was not identified and rectified. In an environment where workload is high and reliance is placed on the capabilities of inspectors and the quality of their reports, the effectiveness of audits is essential to assess the adequacy of practices and their variance with company procedures.

Although inspection reports were reviewed, after 1999, they were not signed-off by those responsible for the inspection, assessment, and planning functions. Without sign-off, there is no means to ensure that potentially unsafe conditions on a bridge have been thoroughly reviewed and assessed.

Although in the past there had been a work inventory system that tracked work completed, at the time of the occurrence, there was no recording system in place to indicate the nature and extent of the completed work. As a result, there was confusion regarding the outstanding work to be performed on the bridge. In 2001, work on the bridge was interrupted, and when work resumed in 2002, defective components, such as cap 15, were overlooked.

2.2.3 Training

The observed variance between company procedures (SPCs) and actual field practices in conducting inspections, using the condition rating, and underestimating the severity of the condition of components with internal rot, indicates that the employees' knowledge of the SPCs was inadequate. It also indicates that the training on bridge inspection provided to employees both on-the-job and through workshops did not meet its aim of enhancing the knowledge of all inspectors across the CN system and ensuring cross-system uniformity of the inspection and reporting process.

2.2.4 Impact of Job Transitions and Workload

Other factors contributed to the failure to take the required corrective action until 2002, namely workload and overlapping responsibilities during job transitions.

Because the incoming P & I Engineer continued to work on other assignments for nine months, he may have thought that repairs were under way or completed. As there were no formal records confirming what remedial work had been undertaken between the 1999 detailed inspection and 2001, there was no mechanism in place to ensure that all necessary repairs were carried out. Although it would have been possible to compare the actual work completed against the maintenance program, the P & I Engineer relied on annual visual inspections to identify the work that was done to the bridge.

Subsequent to the detailed inspection, the B & S Supervisor was made aware of the deficiencies on the bridge, but there was no immediate action taken. In the past, the B & S Supervisor had taken immediate action to ensure that unsafe conditions were addressed. It is likely that, because he was in transition between two jobs and was performing both jobs for part of the time, the urgency of the action was overlooked. Nevertheless, he did provide a list of outstanding work to be performed to the incoming B & S Supervisor. However, the list did not depict either the urgency or the priority of the work required at Mile 7.9. Although these job transitions were part of a planned reorganization, it appears that the new supervisors were not informed of the urgency of the work required at Mile 7.9.

Because of the large number of structures under his purview, the workload required to sustain the inspection, assessment, and planning functions, and the disturbance due to job transitions, the P & I Engineer relied on the inspectors' overall assessments and most recent visual reports to establish priorities for maintenance programs. These reports did not indicate any deficiencies on the bridge; therefore, the severity and urgency of the condition that was identified in 1999 was neither recognized nor corrected.

2.3 *Adequacy of the Repairs*

It is an industry practice to add helper stringers to temporarily strengthen a span or to maintain a span's carrying capacity before the structure can be rehabilitated. Because the helper stringers are not bound to the existing chord and are located outside the chord towards the end of the ties, the flexibility of the ties does not ensure an equal distribution of the axle load, as demonstrated by the three-dimensional model used in the independent assessment of the load distribution between stringers. Therefore, helper stringers are not as effective as internal stringers and do not completely compensate for a loss of capacity due to the deterioration of internal stringers. When helper stringers are considered to carry the same load as internal stringers, the actual capacity rating of a span is less than the capacity rating calculated.

This practice, which overestimates the contribution of the helper stringers, can lead to overestimating the carrying capacity of the bridge and, thus, increasing the risk of overloading and failure of the internal stringers. For instance, the capacity rating calculated by CN for span 15 is Cooper E59.4, while the capacity rating calculated using the load distribution from the three-dimensional model is Cooper E49.

2.4 *Transport Canada Bridge Monitoring Program*

Although TC had developed a program for monitoring bridges that called for field inspections and audits of railway records, the program was not consistently carried out by all regions. Cursory inspections of bridges were conducted consistently by railway infrastructure officers, but not all regions carried out specific bridge inspections or audits of railway records. Even in the regions where audits of records were undertaken, there was no audit of the working procedures and practices to ensure that the requirements of the SPCs were being complied with. Consequently, procedural-based issues could not be detected by the functional groups.

In this occurrence, the deficiencies associated with bridge inspection and maintenance might have been identified by TC had the engineering functional program carried out an audit of working procedures and practices. The SMS audit has the potential to identify procedural-based deficiencies in the areas that are sampled; however, the probability that specific issues or areas will be included in an audit is low because of the broad pool of potential issues from which the audit team must sample. Therefore, it is important to ensure that the functional groups can identify procedural-based deficiencies and bring them to the attention of the SMS group for auditing.

2.5 Communications

The RTC was not aware of the train's location because communication between the RTC and the train crew was limited. Had the territory been equipped with a system that communicates the location of the train at frequent intervals, or had there been frequent calls between the train and the RTC, the train's location and status could have been recognized earlier, prompting a quicker reaction. The quicker the determination of an occurrence, the quicker emergency responders can get to a site to provide assistance, and the more likely evidence will be preserved.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The two crew members on train 356-51-14 were fatally injured when the lead locomotive toppled off the bridge and was destroyed by fire.

2. It is most likely that cap 15 crushed under the weight of the lead locomotive when its bearing capacity was exceeded, leading to the bridge caving in and the subsequent derailment.

3. As the load shared by stringers 5 and 6 of span 15 was increased due to the internal rot of the adjacent stringers, the reaction load transferred to cap 15 was concentrated over a smaller area, thus exerting increased stresses over the existing void in cap 15.

4. The condition of cap 15, identified as reject in the 1999 detailed report, was not reflected in subsequent inspection reports. Therefore, its continuing deterioration was not reassessed.

5. The failure to identify the urgency and the severity of the condition of the bridge was not recognized, despite subsequent inspections, because of shortcomings in the inspection, assessment, planning, and maintenance process.

6. As a result of heavy workload, and overlapping duties during job transitions, the Planning and Inspection (P & I) Engineer relied on the inspectors' overall assessments and most recent visual inspection reports, which did not indicate any deficiencies on the bridge. Therefore, the severity and urgency of the condition that was identified in 1999 was not recognized.

7. Even though Canadian National (CN) Standard Practice Circulars (SPCs) acknowledge the use of occasional audits to ensure the quality of work of inspectors and their immediate supervisors, the audits that were carried out were not effective.

8. Because there was no Transport Canada (TC) audit of work procedures, there was no opportunity to identify the deficiencies associated with such bridge inspection and maintenance procedures.

3.2 Findings as to Risk

1. Reliance on an overall assessment of a system may be appropriate when the system has built-in redundancy, as in the case of stringers or piles. However, when the system's safety relies upon single components, such as a cap, an overall assessment will not identify an unsafe condition and will give a false indication that the system is safer than it actually is.

2. When the condition of defective components is not updated on each inspection report, the report no longer accurately reflects the actual condition of the structure, which can lead to miscalculating the load-carrying capacity of a bridge.

3. The practice of assigning equal loads to all stringers, including helper stringers, can lead to overestimating the carrying capacity of a bridge, thus increasing the risk of overloading and failure of the internal stringers.

4. Unless careful analysis of detailed inspection reports is carried out as a matter of course, and capacity ratings are performed using the remaining sound timber sections, the severity of bridge conditions may not be fully appreciated.

5. In an environment where workload is high and reliance is placed on the capabilities of inspectors and the quality of their reports, the effectiveness of audits is essential to assess the adequacy of practices and their variance from company procedures.

6. Had the territory been equipped with a system that communicates the location of the train at frequent intervals, such as the Global Positioning System, or frequent calls been made between the train and the rail traffic controller, the train's location and status could have been recognized earlier, prompting a quicker response.

3.3 Other Findings

1. Based on the available evidence and subsequent analysis, neither train operations nor a mechanical failure contributed to this occurrence, nor is it likely that track failure was a factor.

2. The complete destruction of the bridge and all its related components, the loss of the locomotive event recorder data, and lack of complete and comprehensive bridge maintenance and inspection records impeded the investigation efforts.

3. Even though the calculated capacity rating of the structure was lower than the equivalent rating of some of the equipment handled over the bridge, no failure occurred between 1999 and the time of the accident because there was an adequate safety margin associated with the timber unit shear stress.

4. The observed variance between company procedures (SPCs) and actual field practices in conducting inspections, using the condition rating, and underestimating the severity of the condition of components with internal rot, suggests that the training on bridge inspection (both on-the-job and workshops) provided to employees did not meet its aim of enhancing the knowledge of all inspectors across the CN system and ensuring cross-system uniformity of the inspection and reporting process.

4.0 Safety Action

4.1 Action Taken

4.1.1 Inspection and Maintenance of Timber Bridges

A number of bridge components were identified as defective and were not repaired by Canadian National (CN) because of shortcomings in inspection and maintenance practices. Deficiencies associated with the inspection and maintenance of timber bridges were identified during the TSB investigation.

As a result, concerned that CN's inspection and maintenance practices were not providing a primary line of defence for timber bridges on the CN network, the Board recommended that:

> Canadian National verify the condition of its timber bridges and ensure their continued safety with effective inspection and maintenance programs. (R03-04, issued December 2003)

Subsequently, CN responded, indicating that it had completed a review of its timber bridge inspection practices and the condition of its timber bridges. CN further indicated that, as of April 2004, all timber bridges had been inspected in full compliance with CN Standard Practice Circular 4000, *Inspection of Steel, Timber and Concrete Bridges*, and that Bridge Summary Reports (five-year plans), identifying required repair and maintenance activities, were current.

CN advised that, as of June 2004, it has put into place a comprehensive, computerized Bridge and Culvert Condition System (BCS) to capture bridge and culvert condition information electronically from the field and to store the data in a centralized database. Bridge components are ranked from 1 (poor) to 9 (new), which is intended to facilitate improved identification and prioritization of required repairs. CN advised that the inspection process is automated, from inspection planning and scheduling to inspector and Planning and Inspection (P & I) Engineer sign-off. Both inspector and P & I Engineer sign-off activities are stored in the database. CN reports that, with the new BCS system, all rankings and comments noted from previous inspections will be brought forward when the next inspections are generated.

CN also advised that, as of July 2004, all inspectors have been trained in how to use the BCS. CN had all inspectors undergo a one-week bridge and culvert inspection refresher training in January 2005. CN intends to provide a four-day comprehensive refresher training program every four years.

CN advised that the BCS is part of CN's overall Bridge Management System (BMS), which is still under development. CN also indicated that the compilation of bridge and culvert inventory was completed in 2002, and the BCS was implemented in 2004. CN expects to complete the planning module in 2005. It will assist in automating the prioritizing and scheduling of bridge maintenance and repair, and the tracking of completed work activities. CN advised that, until the BMS is completed, the regions will continue to use their Bridge Summary Reports. CN advised that, as of December 2003, the completion of all timber bridge maintenance and repair work is reported by e-mail by the Regional Bridge Supervisors to Bridges and Structures (B & S) Engineers.

In July 2003, Transport Canada's (TC) Pacific Region met with CN officials to discuss the bridge program. Following the meeting, TC conducted a review of CN's inspection and maintenance records to ensure that CN had verified the condition of its bridges.

4.1.2 Transport Canada's Monitoring Program

Because it was concerned that all available bridge inspection information was not being used by TC's compliance review program, the Board recommended that:

> Transport Canada incorporate in its compliance reviews a comparison of railway working procedures and practices with railway inspection and maintenance records. (R03-05, issued December 2003)

TC indicated that it is revising its existing inspection and monitoring programs to integrate monitoring and inspection activities of railway infrastructure, equipment, and operations into the Safety Management System (SMS).

TC advised that the SMS approach will require that TC examine each railway company's standards and practices with respect to the safety management of its infrastructure, as well as audit company inspection and maintenance records.

TC advised that, by incorporating compliance reviews with the comparison of working procedures and practices and by examining railway records, TC will have a better opportunity to discover gaps in railway management of bridge condition assessment and repair. TC indicated that it is aggressively developing an audit program that focuses on all railway structures.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 09 November 2004.

Appendix A – Timber Trestle Characteristics

Timber trestles consist of a substructure of wooden bents that support a superstructure composed of stringers (horizontal beams) and a deck. The portion between two bents is a span. Train axle loads are transferred to the ground through the rails, the deck, stringers, caps, and bents.

A bent is a braced framework of timbers or piles. The bents are designated as pile bents when the wood piles, which are driven into the ground, extend up to the superstructure. Frame bents, made with sawn timber, can be used over driven piles, which have been cut at ground level, to accommodate higher bridges or to repair deteriorated piles.

The bent is topped with a cap, which is a horizontal timber that secures the members of the bent, provides a seat to the stringers, and distributes the superstructure loads to the piles.

Stringers are longitudinal timbers spanning between bents. They transfer the axle loads from the deck to the bents. Stringers are centred below each rail. They can be spaced or bundled together as a chord.

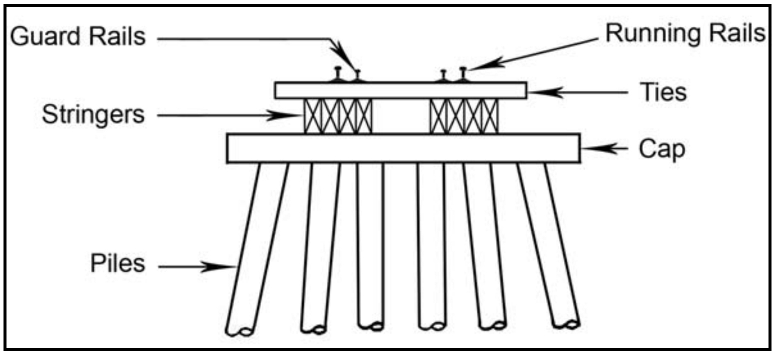


Figure 6. Typical cross-section of an open deck pile trestle

The deck consists of the ties, tie plates, running rails, and guard rails. On open decks, such as the deck on the bridge at Mile 7.9, the ties are placed directly on the stringers, whereas on ballasted decks, a ballast trough is installed over the stringers and a standard track structure is used.

Guard rails are installed on bridges longer than 100 feet (30 m) and run parallel to and are situated between the running rails. Their purpose is to guide derailed rolling stock and to prevent it from falling off the bridge.

At each end of the bridge, a timber wall (a dump wall or a back wall) perpendicular to the centre line of the bridge retains the track embankment and ballast.

Spans are numbered in the direction of increasing mileage, with span 1 being at the east end of the bridge. Piles and stringers are numbered from left to right when facing increasing mileage.

Appendix B – Excerpts from Canadian National Standard Practice Circular 4000

The following are excerpts from Canadian National (CN) Standard Practice Circular (SPC) 4000 that may be applicable to the occurrence of 14 May 2003 at the bridge at Mile 7.9 of the Fraser Subdivision near McBride, British Columbia.

1.0 GOAL

The goal is to provide, within the economic frame work and with available tools and techniques, an accurate condition report of all the CN owned and operated bridges to ensure the safety of all the rolling stock within the authorized load limit and the public who are authorized to use these structures.

Inspectors (Officer or Engineer authorized to inspect the bridges) shall inspect the bridges in accordance with this SPC and other best practices approved by the appropriate regulatory agency and shall record the physical condition of the structure and its surroundings that may affect the safety of operations and the public.

The main purposes of the inspections are:

- to determine the safe load the structure can support,
- to establish future maintenance and capital programs,
- to determine future cash flow and capital requirements,
- to gather and maintain the history of the structure,
- to provide information for the execution of repairs,
- to provide database information for the plant inventory system,
- to verify the accuracy of the information provided in the Plant Inventory System (PINS).

Each inspection report should contain sufficient information to achieve the purposes described above.

2.0 TYPES OF INSPECTIONS

2.1 Detailed Inspections

A Detailed inspection of a structure is conducted to ensure the integrity of the structure and to obtain accurate information for determining the carrying capacity and/or required repair or replacement needs. A detailed inspection includes measurements and documentation of the defects and deterioration of all the components of the structure and includes an observation of the surroundings.

2.2 Visual inspection

2.2.1 Full Visual Inspection

A Full Visual inspection is a periodic inspection between detailed inspections to ensure the integrity of a structure and to note any condition or change that requires investigation or attention. Visual inspection includes looking at all the critical components of the structure and comparing with the previous detailed inspection. The Inspector must get close enough to each component and connection of the structure to view it clearly.

2.2.2 Cursory Visual Inspection

A Cursory Visual Inspection or “Bridge Visit” is the occasional check by an Engineer or an officer assigned by the Bridge Engineer to ensure the integrity of the bridge and that there is no visible damage to the deck, superstructure or substructure.

2.3 Emergency Inspection

An Emergency inspection is a visual inspection to ensure the integrity of the structure as a result of an emergency situation such as derailment, accident, or local failure and entails a detailed inspection of the components damaged by the incident. This is to assess any damage and the need for emergency repairs and/or replacement to ensure the safety and serviceability of the structure.

2.4 Special Inspection

A Special inspection is conducted under special circumstances. This may include inspections to allow dimensional loads, to verify existing information in the field or to work out a detailed work plan. Special inspections may be required after a reported earthquake or other such circumstances.

2.5 Follow-up Inspection

A Follow-up inspection is carried out at intervals as warranted by the situation (as directed by the Engineer) to note the changes in the development of defects which have already been detected.

3.0 INSPECTION FREQUENCIES

Inspection frequencies, in general, are governed by the tonnage and importance of the line, but may be increased at the discretion of the Engineer.

3.1 Core Line - Traffic above 50 MGTM

Each bridge shall be inspected in detail at least once in two years or more frequently as the situation warrants.

Each bridge shall be fully visually inspected at least once every year.

3.2 Core Line - Traffic> 30 MGTM + Minimum Rating < 110 % of Authorized Load

Each bridge shall be inspected in detail at least once in two years or more frequently as the situation warrants.

Each bridge shall be fully visually inspected at least once every year.

3.3 All Remaining Core Lines

Bridges with a Minimum Rating in their current condition less than or equal to 100 % of their authorized load level shall be inspected in detail at least once in two years or more frequently as the situation warrants.

All other core line bridges shall be inspected in detail at least once in five years or more frequently as the situation warrants.

Each bridge shall be fully visually inspected at least once every year.

3.4 Non-Core Line

If the line carries greater than 10 MGTM, then treat as a core line for inspection purposes.

The following are excerpts from CN's SPC 4000 training guide.

4.0 INSPECTION REPORTS

The inspector will include, in the report, his evaluation of each structure. This will be based on his judgement of the structure condition and with reference to the applicable maintenance standards. Condition identification words: GOOD, FAIR, POOR, or BAD, will be used as described below.

GOOD: The structure and/or component parts are not deteriorated from the "as-built" condition. No maintenance work is required on account of condition, however, in some cases, work may be done to prevent deterioration or to improve appearance or image as necessitated by circumstances.

FAIR:	The structure and/or some of its component parts are starting to deteriorate. Work is required to arrest deterioration and/or to restore to "as built" condition. Condition is well within those permitted by the maintenance standard.
POOR:	The structure and/or some of its component parts have deteriorated and are approaching the limits outlined by the maintenance standards. Work is required to maintain (i.e. to stay within) the acceptable standards.
BAD:	The structure and/or some of its component parts have deteriorated beyond the acceptable maintenance standards. Work is required to regain the acceptable standards.

7.0 TIMBER BRIDGES

Stringers

Examine all stringers for soundness and surface defects. Note the size and number of stringers in each span when different stringer sizes occur or reinforcing stringers have been added. Check if the bearing length of stringers on the caps is adequate, and if all of the stringers are bearing on the caps, are properly chorded and securely anchored. Note the size and condition of shims (if any) between the stringers and caps.

Check for decay, crushing or bulging of the sides over the caps. Check also for horizontal splits or checks, particularly when sloping grain or knots are present.

Caps

Inspect caps and sills for soundness, especially over the piles or posts.

Check for crushing, bulging of the sides and for splits or checks. Also, note the condition and the size of shims (if any) between the caps and piles/posts and between posts and sills.

Appendix C – Excerpts from Canadian National Standard Practice Circular 4300

The following are excerpts from Canadian National Standard Practice Circular 4300 that may be applicable to the occurrence of 14 may 2003 at the bridge at Mile 7.9 of the Fraser Subdivision near McBride, British Columbia.

6. Limits for Caps and Sills

Caps and Sills shall be rejected if they show:

(a) Horizontal splits extending through the width of the cap or sill and over 2 feet in length.
(b) Vertical splits extending the height of the cap or sill and over 2 feet in length.
(c) Crushing into the cap or sill by piles, posts or stringers or bulging of the sides of caps or sills.
(d) Internal rot has developed which leaves a shell of less than 4 inches of sound timber.

7. Limits for Stringers

Stringers shall be rejected if they show:

(a) Horizontal splits at or near the horizontal centre line.
(b) Bulging of the sides or crushing at the cap bearing area.
(c) Internal rot with voids of 3 inches or more.
(d) Surface rot on top of stringer is in excess of 1 inch.
(e) Less than 3 inches of stringer bearing on the cap.

Appendix D – Additional Inspection Details

These are additional details from Canadian National inspections of the bridge at Mile 7.9 of the Fraser Subdivision near McBride, British Columbia.

1998 Visual Inspection (21 October)

The following additional information regarding the condition of major components was noted on form Timbvis2:

Track: East approach ties low 2¼" from base of rail

Stringers: Span 24–stringer 4, horizontal split
Stringers have uneven bearing on caps

Caps: Cap on bent 6 has minor crushing.
Cap at bent 10 has vertical split ½" x 8' at centre
Cap at bent 26–new 14" x 14"

1999 Visual Inspection (23 July)

The following additional information regarding the condition of major components was noted on form Timbvis2A:

Track: East approach ties low 2", west approach ties low 1"

Stringers: Fair condition
Helper stringer between spans 18 and 19

Caps: Caps 6, 10, 19, 20, 21, and 26 are new 14" x 14" x 14'
All other caps are 12" x 14" x 14'

2000 Visual Inspection (01 August)

The following additional observations regarding the condition of major components were noted on form Timbvis2:

Track: East approach ties low 2¼" from base of rail
East approach still very low 2" to 3" and bridge in hole
West approach low and rail hanging ¼" at 4 ties

Stringers: Span 24–stringer 4 has horizontal split
Stringers have uneven bearing on caps
Bent 7–stringers 1 to 4 require shims ⅛" to ¼"
Bent 11 shimmed 1½"
Helper stringer at spans 18 and 19

Caps: Cap at bent 6 has minor crushing
Cap at bent 10 has vertical split ½" x 8' centre
Cap at bent 26–new 14" x 14"
Last 5 caps at west end showing signs of crushing
New timber on site assume replacement

2002 Visual Inspection (25 September)

The following additional observations regarding the condition of major components were noted on form Timbvis2:

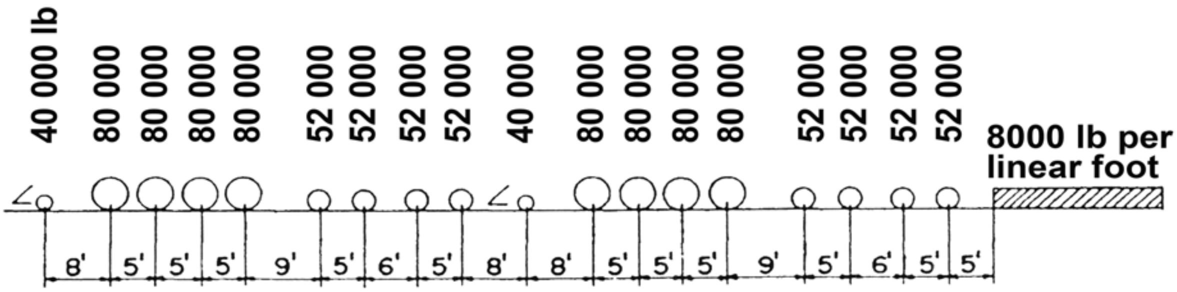
Track: East approach ties low 2¼" from base of rail
East approach still very low 2" to 3" and bridge in hole
West approach low and rail hanging ¼" at 4 ties (same)

Stringers: Stringers have uneven bearing on caps
Bent 7–stringers 1 to 4 require shims ⅛" to ¼"
Some pumping ½" under load
Bent 11 shimmed 1½"
Bent 12 shimmed ½"
Bent 13 shimmed ½"
Helper stringer at spans 18, 19, right side
Helper stringer at bents 14, 15, 16, both sides
Span 2–stringer 2 diagonal split 44" long from cap–Broken

Caps: Cap 10–vertical split ½" x 8' centre
Cap at bent 26 new 14" x 14"
New cap bents 2, 3, 5, 6, 10, 11, 17, 19, 20, 21, 23, 24, 26 (14" x 14")

Appendix E – Cooper E Loading Schematic

This Cooper E loading schematic shows the axle distribution as originally presented by Theodore E. Cooper in 1894 using the wheel spacing of a steam locomotive of that era. The weights per axle shown on this schematic are those specified by the actual AREMA (American Railway Engineering and Maintenance of Way Association) standards.



Appendix F – Glossary

AREMA	American Railway Engineering and Maintenance of Way Association
ATS	Assistant Track Supervisor
B	bad (rail condition)
B & S	Bridges and Structures
C	Celsius
CN	Canadian National
F	fair (rail condition)
FRA	Federal Railroad Administration
G	good (rail condition)
km	kilometre(s)
LER	locomotive event recorder
m	metre(s)
MGTM	million gross ton-miles
mph	mile(s) per hour
P	poor (rail condition)
P & I	Planning and Inspection
psi	pound(s) per square inch
RTC	rail traffic controller
SMS	Safety Management System
SPC	Standard Practice Circular
TC	Transport Canada
TS	Track Supervisor
TSB	Transportation Safety Board of Canada
°	degree(s)
‘	feet
“	inches
℄	centre line