Final report RO-2017-101: Signal Passed at Danger ‘A’ at compulsory stop boards protected worksite, Pongakawa, Bay of Plenty, 7 February 2017

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Final Report

Rail inquiry RO-2017-101
Signal Passed at Danger 'A' at
compulsory stop boards protected worksite
Pongakawa, Bay of Plenty
7 February 2017

Approved for publication: August 2018

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1982 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

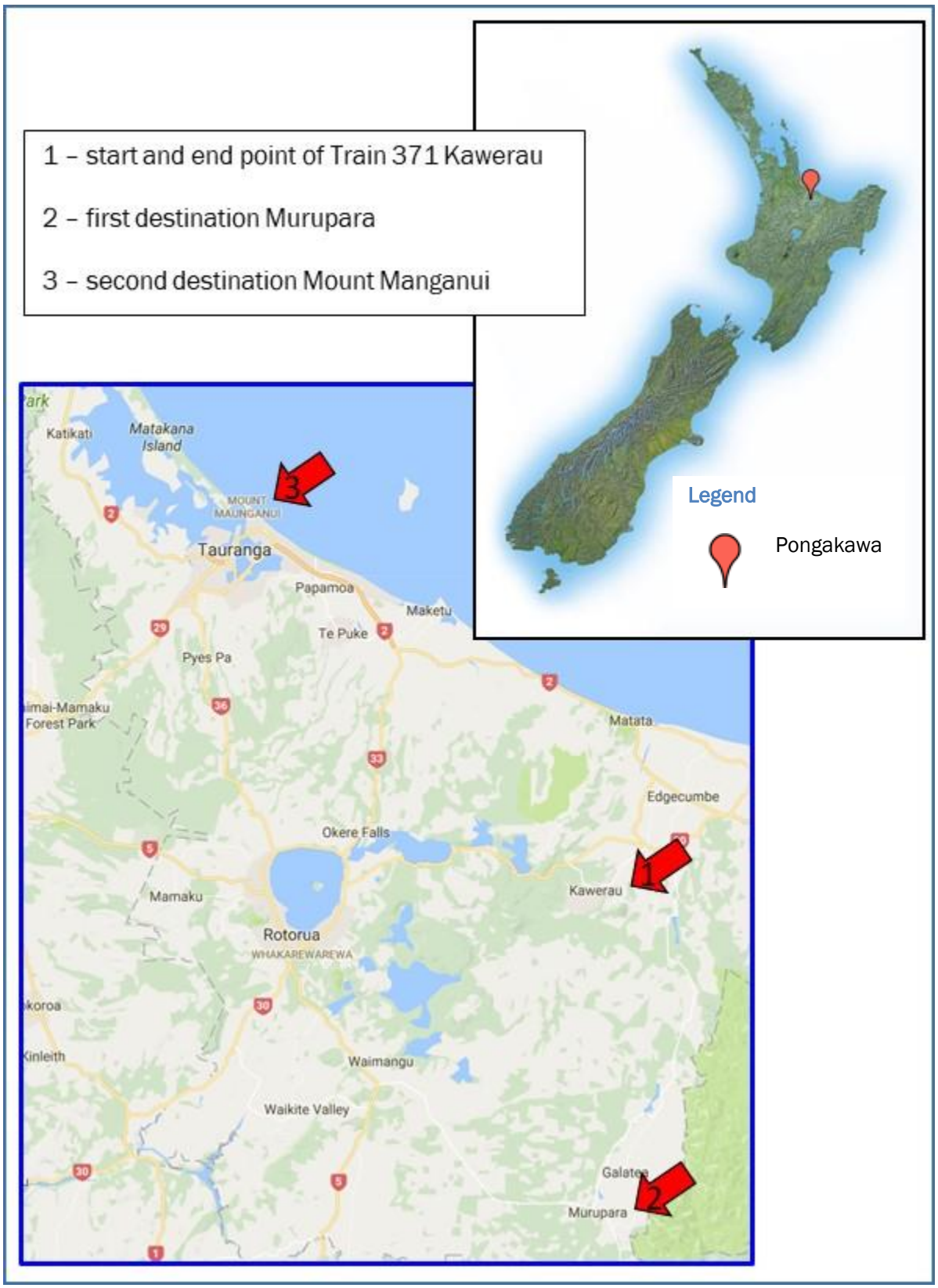
Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this report are provided by, and owned by, the Commission.

Verbal probability expressions

The expressions listed in the following table are used in this report to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis.

Terminology (Adopted from the Intergovernmental Panel on Climate Change)	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33% to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	< 1% probability	



Location of incident

Contents

Figures

Abbreviations

Commission	Transport Accident Investigation Commission
ESS	Epworth Sleepiness Scale
GPS	global positioning system
km/h	kilometre(s) per hour
KMC	Kupe Mobile Controller
m	metre(s)
RMO	Rail Medical Officer

Glossary

eProtect	a system that detects whether a locomotive has failed to stop before reaching a compulsory stop board. If this occurs it automatically activates the emergency brakes on the locomotive, bringing the train to a forced stop, thereby providing an independent backup to the driver
compulsory stop boards	a set of boards protecting a worksite, at which all trains must stop and obtain permission from the worksite rail protection officer to pass
hi-rail vehicle	a road vehicle fitted with retractable rail wheels such that it can be driven along rail track and on/off track at level crossings and other suitable places
KMC module	an electronic module on each locomotive of a train that monitors the current location of the train against the locations of worksites across New Zealand, which it receives over the mobile phone network. It is part of the eProtect system
Rail Medical Officer	a qualified GP engaged by KiwiRail to complete medical assessments of employees and prospective employees in a specific locale.
rail protection officer	the person in a work group who is responsible for all those working at the worksite. They authorise worker access to the track and trains to pass through the worksite once the track is confirmed clear as required
speed restriction	a temporary reduction in line speed. The details of the speed, location of the restriction and reason are provided to drivers in a daily speed restriction bulletin
Train Control	the National Train Control Centre in Wellington railway station, where the movements of trains and maintenance track occupancies are authorised by train controllers
Tranzlog	an on-board data recorder that logs details of a train's speed, location, control settings, etc
warning boards	sometimes referred to as 'outer warning boards', a series of boards placed ahead of compulsory stop boards to indicate to a train driver that the train is approaching a worksite and it will need to be stopped at the compulsory stop boards (see Figure 8 for the standard positions of warning boards)
work group	a group of infrastructure workers who repair and upgrade track and infrastructure

Data summary

Vehicle particulars

Train type and number:	DL9262 – Train 371 from Mount Maunganui to Kawerau
Classification:	diesel-electric freight locomotive
Manufacturer:	Dalian, China
Year of manufacture:	2010+
Operator:	KiwiRail
Consist:	single DL locomotive with 30 mostly empty wood wagons
	470 metres, 447 tonnes
Date and time	7 February 2017 at 1015[1]
Location	Pongakawa, Bay of Plenty
Persons involved	train driver and bridge work group of three persons
Injuries	none
Damage	none
Weather	clear and sunny

Figure 1
Diesel electric locomotive DL9262

[1] Times in this report are New Zealand Daylight Saving Time (Co-ordinated Universal Time +13 hours) and are expressed in the 24-hour mode.

1. Executive summary

1.1. On 7 February 2017 work had begun on replacing a support pile under a rail bridge on a single-line section of track between Mount Maunganui and Kawerau on the East Coast Main Trunk line. Two sets of warning boards had been placed either side of the worksite to alert train drivers to the worksite ahead. A set of compulsory stop boards had been placed 500 metres from either side of the worksite, where train drivers were required to stop and request permission to enter the worksite from the rail protection officer of the maintenance team.

1.2. At about 1000 a freight train was en route from Mount Maunganui to Kawerau. The driver was nearing the end of a 10½-hour night shift. Later, the driver did not recall seeing any of the warning or compulsory stop boards and only noticed the presence of a hi-rail maintenance vehicle beside the track as the train was approaching the bridge. The driver reduced the train speed to 25 kilometres per hour shortly before crossing the bridge without authorisation.

1.3. The rail maintenance workers were working under the bridge at the time, about to remove one of the support piles. Nobody was injured and there was no damage to the train or bridge.

1.4. The Transport Accident Investigation Commission (Commission) **found** it likely that the driver was experiencing 'microsleeps' at the time the train passed the warning and stop boards. The driver was later diagnosed as suffering from a sleep disorder that affects the quality of sleep. Additionally, the driver had had difficulty sleeping the evening prior to the incident due to the hot ambient temperature. The fact that the driver had been awake for more than 10 hours through the night and was nearing the end of the shift was also a factor.

1.5. The train locomotive was fitted with a global-positioning-based safety system (eProtect) that should have automatically applied the train brakes when the train failed to stop at the compulsory stop boards. The Commission **found** that this safety defence failed due to an unnoticed error within the device on board this particular locomotive that was preventing it utilising the global positioning system's location of the worksite.

1.6. The Commission identified three **safety issues:**

- the KiwiRail medical assessment process did not ensure that the employee being assessed completed the online medical questionnaire themselves. There is some evidence that the system could potentially allow managers or others to complete the questionnaire on employees' behalf
- KiwiRail did not have a mature fatigue risk management system to ensure that relevant personnel performed at adequate levels of alertness
- the eProtect KMC module on this locomotive had been transmitting error messages for three weeks before the incident, but the activity database was not being monitored for this type of error.

1.7. KiwiRail took a **safety action** to address the issue with the eProtect system, and the Commission made two **recommendations** to KiwiRail to address issues with its medical assessment programme and its fatigue risk management system.

1.8. **Key lessons** arising from the inquiry were:

- train drivers and other shift workers need to ensure that they are medically fit and make appropriate lifestyle choices that will enhance the amount and quality of their sleep, in order to avoid being fatigued or tired while at work
- transport operators must ensure that their staff are fully educated on the factors that can cause or contribute to their becoming tired or fatigued while performing safety-critical roles
- technological systems need to be fully tested and have undergone full failure mode analysis if they are going to be relied on as safety defences for preventing accidents and incidents.

2. Conduct of the inquiry

2.1. The incident occurred at 1015 on Tuesday 7 February 2017. The NZ Transport Agency notified the Transport Accident Investigation Commission (Commission) soon after the incident occurred. The Commission opened an inquiry under section 13(1) of the Transport Accident Investigation Commission Act 1990 to determine the circumstances and causes of the incident and appointed an investigator in charge.

2.2. Commission investigators travelled to KiwiRail's Mount Maunganui terminal and the Pongakawa incident site on Wednesday 8 February to conduct the site investigation.

2.3. Commission investigators interviewed:

- the locomotive engineer (train driver)
- the bridge work group[2]
- the manufacturer of the eProtect[3] system
- KiwiRail's eProtect database system administrator.

2.4. The investigators obtained documents and records for analysis, including:

- Tranzlog[4] data from the train
- a copy of the eProtect activity database
- documentation related to the specification, development, testing and introduction of, training in and rollout of the eProtect system
- records of the train driver's post-incident sleep study.

2.5. The KMC (Kupe Mobile Controller) module[5] from on board the locomotive was seized by the Commission for forensic software and hardware analysis.

2.6. On 19 April 2018 the Commissioners considered a draft report and approved it to be sent to 12 interested persons for consultation.

2.7. The Commission received three submissions. The Commission considered the submissions, and changes as a result of those submissions have been included in the final report.

2.8. On 23 August 2018 the Commission approved the final report for publication.

[2] A group of infrastructure workers who repair and upgrade track and infrastructure.
[3] A system that detects whether a locomotive has failed to stop before reaching a compulsory stop board. If this occurs it automatically activates the emergency brakes on the locomotive, bringing the train to a forced stop, thereby providing an independent backup to the driver.
[4] An on-board data recorder that logs details of a train's speed, location, control settings, etc.
[5] An electronic module on each locomotive of a train that monitors the current location of the train against the locations of worksites across New Zealand, which it receives over the mobile phone network. It is part of the eProtect system.

3. Factual information

3.1. Background

3.1.1. Tuesday 7 February 2017, the day of the incident, was the first of three planned days of repair work on Bridge 107, which involved replacing a section of wooden support pile under the bridge.

3.1.2. The work involved dismantling a wooden support from the bridge and replacing the lower section with a metal sleeve filled with concrete (see Figure 2). With the lower section of the support removed, the bridge would have been deemed unusable until the replacement pile was in place. There would have been a risk of damage to the repair had a train traversed over the bridge before the concrete used in the repair had set, a window of between 45 minutes and one hour.

Figure 2
The repaired section of bridge support

3.1.3. On the same day the train driver involved in the incident started a shift in Kawerau at 0115. The driver took an empty freight train from Kawerau to Murupara and then took a loaded log train from Murupara to Mount Maunganui, which involved crossing Bridge 107 before the worksite had been established. The driver then departed Mount Maunganui on Train 371 (the train) bound for Kawerau, which was scheduled to pass over Bridge 107 after the worksite had been established (see Figure 3).

3.1.4. The worksite was protected using KiwiRail Rule 905. Compulsory stop boards were erected either side of the worksite, at which the train had to stop and gain permission to pass and enter the worksite. Outer caution boards and whistle boards were erected before the compulsory stop boards. The purpose of the outer caution boards was to alert the driver to the compulsory stop boards ahead. The whistle boards were a prompt for the driver to sound the train whistle to warn the work group of the train's approach (see section 3.3 for more detail).

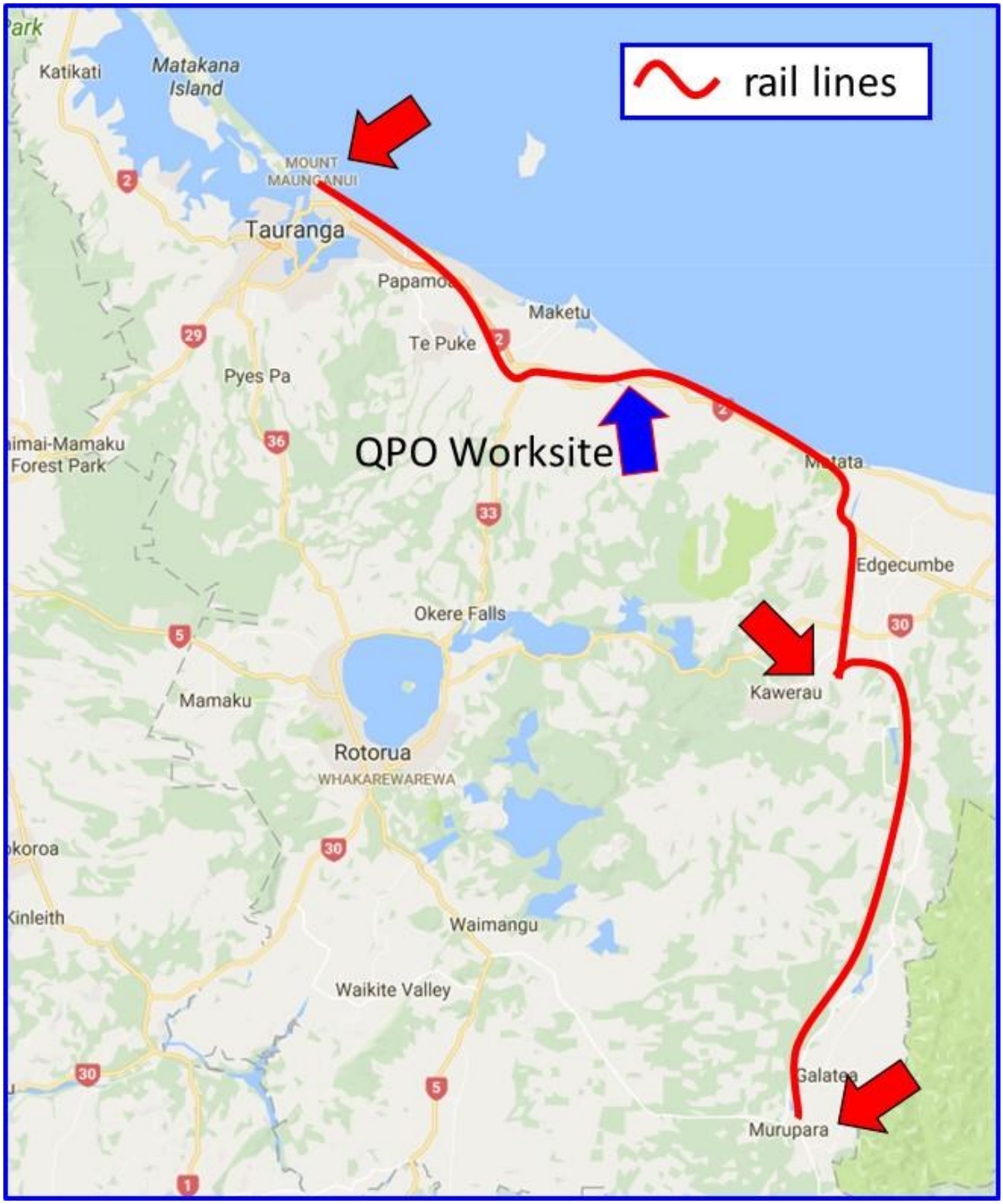


Figure 3
Map of key journey locations (*Image source – Google Maps*)

3.2. Narrative

3.2.1. A three-person work group had been assigned to the Bridge 107 worksite. They had placed the caution boards, the whistle boards and the compulsory stop boards either side of their worksite. The compulsory stop boards were placed 500 metres (m) out from the worksite (see Figure 4). They then called Train Control[6] at 0830 to confirm the worksite had been established.

Figure 4
The warning boards and compulsory stop boards for the worksite

3.2.2. Train Control advised the work group that the first train through the worksite would arrive at approximately 0935, heading south.

3.2.3. At approximately 1000 the train comprising a single locomotive hauling 30 empty wagons approached Bridge 105 on the East Coast Main Trunk line (see Figure 5).

3.2.4. The driver slowed the train for the longstanding 40-kilometre-per-hour (km/h) speed restriction[7] over Bridge 105.

[6] The National Train Control Centre in Wellington railway station, where the movements of trains and maintenance track occupancies are authorised by train controllers.
[7] A temporary reduction in line speed. The details of the speed, location of the restriction and reason are provided to drivers in a daily speed restriction bulletin.

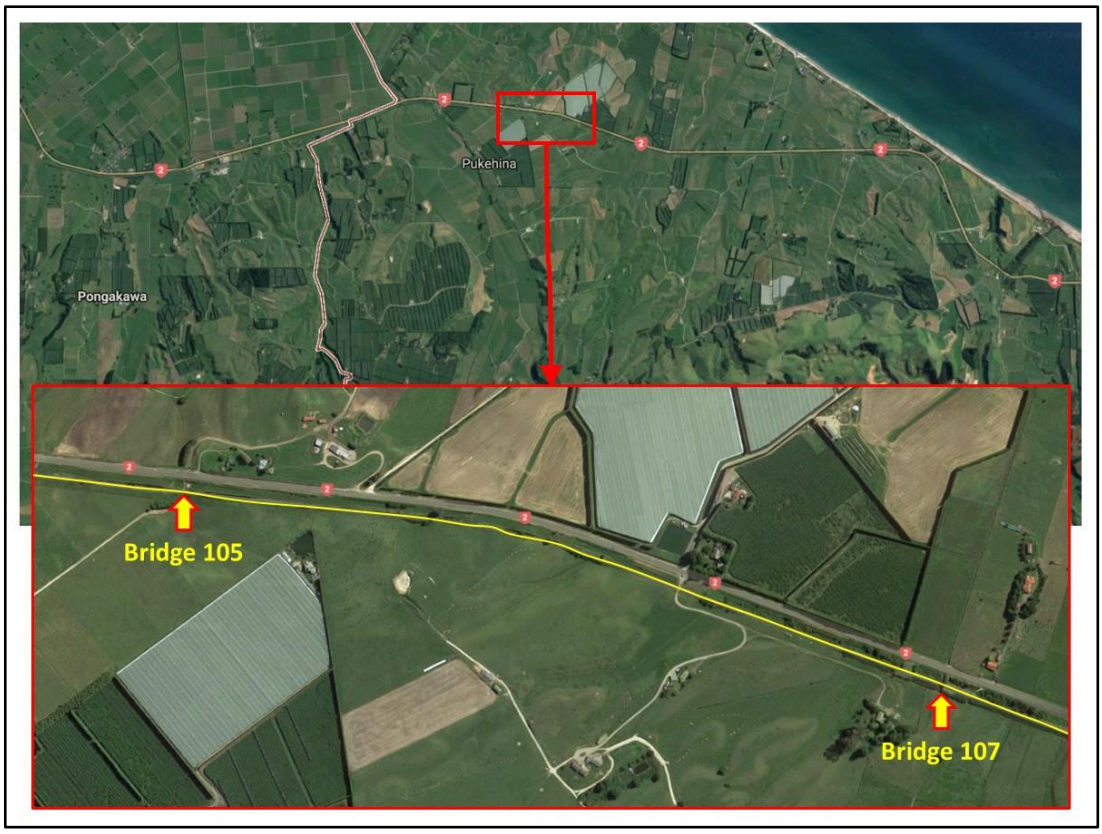


Figure 5
Location of Bridges 105 and 107
(*Image source – Google Maps*)

3.2.5. After crossing Bridge 105 the train was allowed to gather speed before the driver started to slow again for another longstanding 40 km/h speed restriction over Bridge 107.

3.2.6. The driver did not notice either the outer caution boards or the whistle boards, and did not sound the train horn.

3.2.7. As the train approached Bridge 107 the driver noticed a hi-rail vehicle[8] on the far side of the bridge. This prompted the driver to check the daily speed restriction bulletin[9] to ensure that the speed limit over Bridge 107 had not been lowered below 40 km/h due to work on the bridge. The driver slowed to 25 km/h to be on the safe side.

3.2.8. As the train crossed the bridge the driver noticed one of the site workers walking towards the hi-rail vehicle.

3.2.9. After the train had crossed the bridge, the driver received a radio call asking why the train had not stopped at the compulsory stop boards.

3.2.10. The bridge support that the work group was replacing had been dismantled but had yet to be cut when the train passed over the bridge.

3.2.11. The driver stopped the train, with the rear of the train approximately 600 m beyond Bridge 107.

3.2.12. Two of the three-person bridge work group members were working under the bridge when the train passed directly over their heads (see Figure 6).

[8] A road vehicle fitted with retractable rail wheels such that it can be driven along rail track and on/off track at level crossings and other suitable places.
[9] A sheet separate from the daily information bulletin detailing the permanent and temporary speed restrictions around the network, and their locations.

Figure 6
Location of bridge work group members when the train crossed Bridge 107

3.2.13. The train had passed the compulsory stop boards by 1.6 kilometres; it passed through the worksite and nearly reached the far side of the protected area when it stopped. Passing compulsory stop boards without permission is classed as a Signal Passed at Danger 'A'[10].

3.2.14. The locomotive was fitted with an automatic system called eProtect, which was supposed to have alerted the driver when the train was approaching the worksite. The same system was designed to automatically apply the brakes on the train if it did not stop at the compulsory stop boards. The system did not provide any alert to the driver, and did not automatically apply the train brakes.

3.3. Compulsory stop board worksite protection system (Rule 905)

3.3.1. Worksites are normally planned and authorised in advance for planned work and maintenance.

3.3.2. Every day a daily information bulletin (see Figure 7) is promulgated by KiwiRail by geographical area. It is available at each depot and provided to all train drivers before they start their shifts. Drivers often highlight sections pertinent to their trains and routes, as seen in Figure 7. The daily information bulletin contains details of:

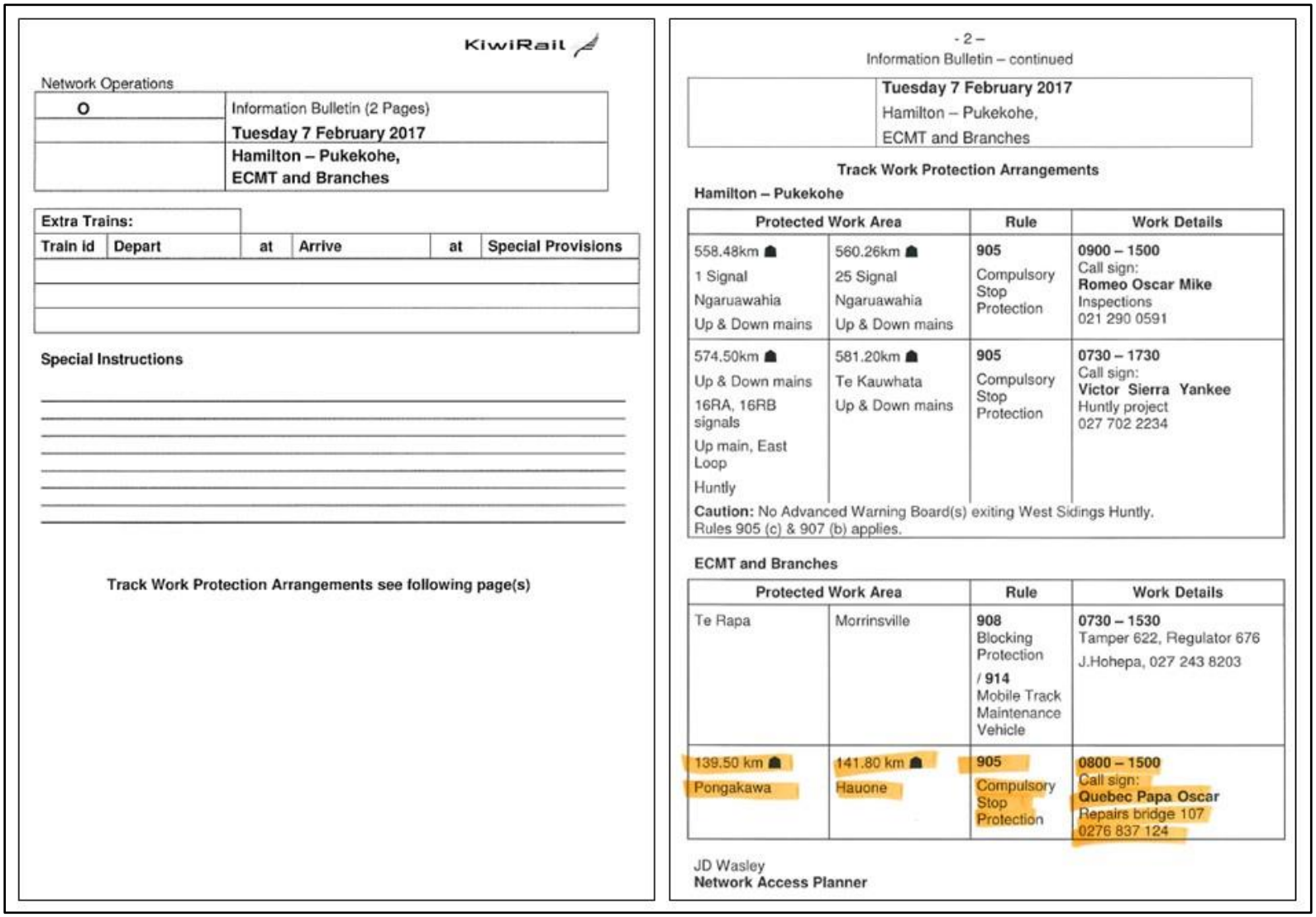
i. additional trains running in the area

ii. special instructions that could be required for any additional trains

iii. track work protection arrangements in the area covered by the bulletin, which include:

- the area covered by the protected worksite, including meterage where appropriate
- which specific type of protection rule will be in force for each worksite
- the times that the worksite and protection will be in place
- the radio call sign of the worksite
- a brief description of the work being undertaken
- a contact mobile number for the worksite, to be used if the worksite rail protection officer[11] cannot be reached by radio
- an indication that the worksite is protected by the eProtect system.

[10] When a train passes a perfectly displayed stop signal or sign without authorisation.
[11] The person in a work group who is responsible for all those working at the worksite. They authorise worker access to the track and trains to pass through the worksite once the track is confirmed clear as required.



KiwiRail

Network Operations

O	Information Bulletin (2 Pages)
	Tuesday 7 February 2017
	Hamilton – Pukekohe, ECMT and Branches

Extra Trains:

Train id	Depart	at	Arrive	at	Special Provisions

Special Instructions

Track Work Protection Arrangements see following page(s)

- 2 –

Information Bulletin – continued

	Tuesday 7 February 2017
	Hamilton – Pukekohe,
	ECMT and Branches

Track Work Protection Arrangements

Hamilton – Pukekohe

Protected Work Area		Rule	Work Details
558.48km 1 Signal Ngaruawahia Up & Down mains	560.26km 25 Signal Ngaruawahia Up & Down mains	**905** Compulsory Stop Protection	**0900 – 1500** Call sign: **Romeo Oscar Mike** Inspections 021 290 0591
574.50km Up & Down mains 16RA, 16RB signals Up main, East Loop Huntly	581.20km Te Kauwhata Up & Down mains	**905** Compulsory Stop Protection	**0730 – 1730** Call sign: **Victor Sierra Yankee** Huntly project 027 702 2234
Caution: No Advanced Warning Board(s) exiting West Sidings Huntly. Rules 905 (c) & 907 (b) applies.			

ECMT and Branches

Protected Work Area		Rule	Work Details
Te Rapa	Morrinsville	**908** Blocking Protection / **914** Mobile Track Maintenance Vehicle	**0730 – 1530** Tamper 622, Regulator 676 J.Hohepa, 027 243 8203
139.50 km Pongakawa	141.80 km Hauone	**905** Compulsory Stop Protection	**0800 – 1500** Call sign: **Quebec Papa Oscar** Repairs bridge 107 0276 837 124

JD Wasley
Network Access Planner

Figure 7
Daily information bulletin for 7 February 2017
Highlights made by driver involved in the incident

3.3.3. On the day of the incident the worksite was protected using KiwiRail Rule 905 – Compulsory Stop Protection. The rule required two sets of warning boards to be erected alongside the track to warn all train drivers that they are approaching a set of compulsory stop boards. The train is required to stop at the compulsory stop boards (see Figure 8). The worksite was also protected by the eProtect system, as indicated by the ☗ icon on the daily information bulletin (see Figure 9).

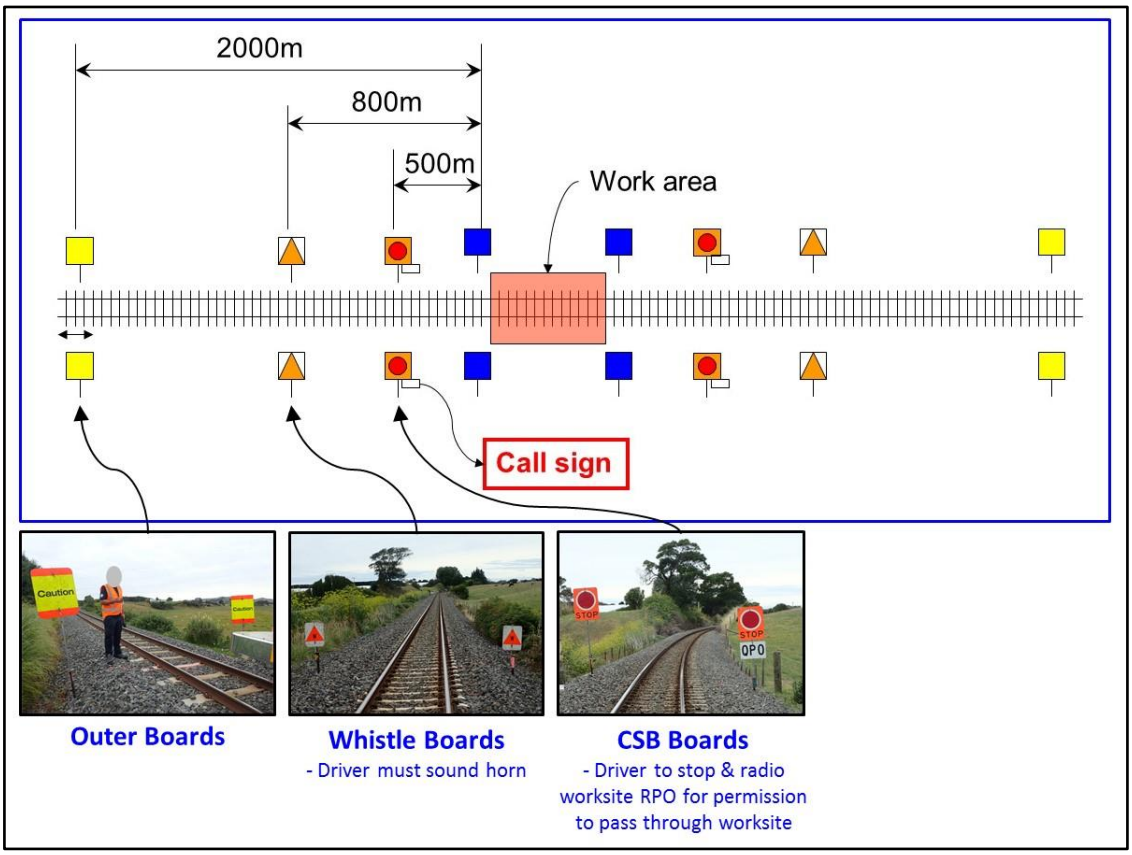


Figure 8
Relative position of Rule 905 boards to actual worksite

3.3.4. Once stationary at the compulsory stop boards the train driver had to radio the rail protection officer to request permission to access the worksite. This communication would give the rail protection officer the opportunity to confirm that the worksite was clear and safe for the train to pass through, and impose any special conditions on the train, such as further reduced speed through the site.

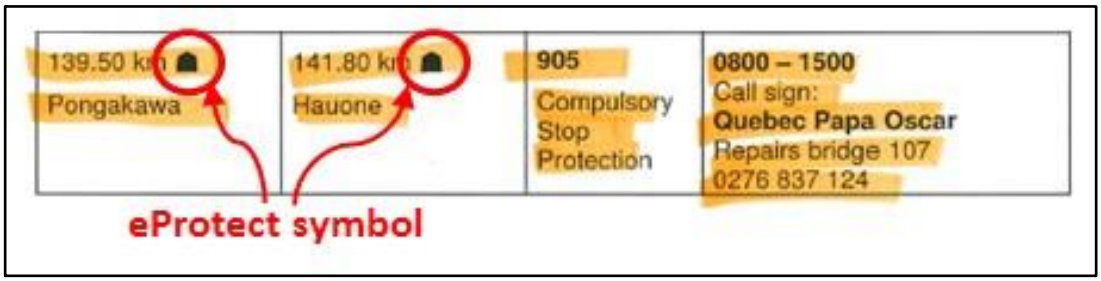


Figure 9
Extract from daily information bulletin, 7 February 2017

3.4. eProtect system

3.4.1. eProtect is a safety defence that utilises the real-time GPS (global positioning system) position of a train alongside technology on board the locomotive to warn the driver that the train is approaching a worksite. It automatically applies the train's brakes if it approaches too fast or fails to stop at a set of compulsory stop boards.

3.4.2. On 21 July 2016 KiwiRail issued Semi Permanent Bulletin No. 489, which stated:

> eProtect is a system on locomotives that uses GPS technology to monitor the speed of trains approaching Compulsory Stop Boards, and penalty brakes the train if it does not stop at the Compulsory Stop Boards.

The bulletin stated that the eProtect system would be going live on all lines as the training of "affected drivers and applicable Rail Protection Officers was completed".

3.4.3. The eProtect system utilises existing technology on board KiwiRail's locomotives, taking the trains' real-time GPS positions and comparing them with the latest information on worksite locations around New Zealand. The locations of the worksites are sent to all locomotives over the mobile phone network (see Figure 10).

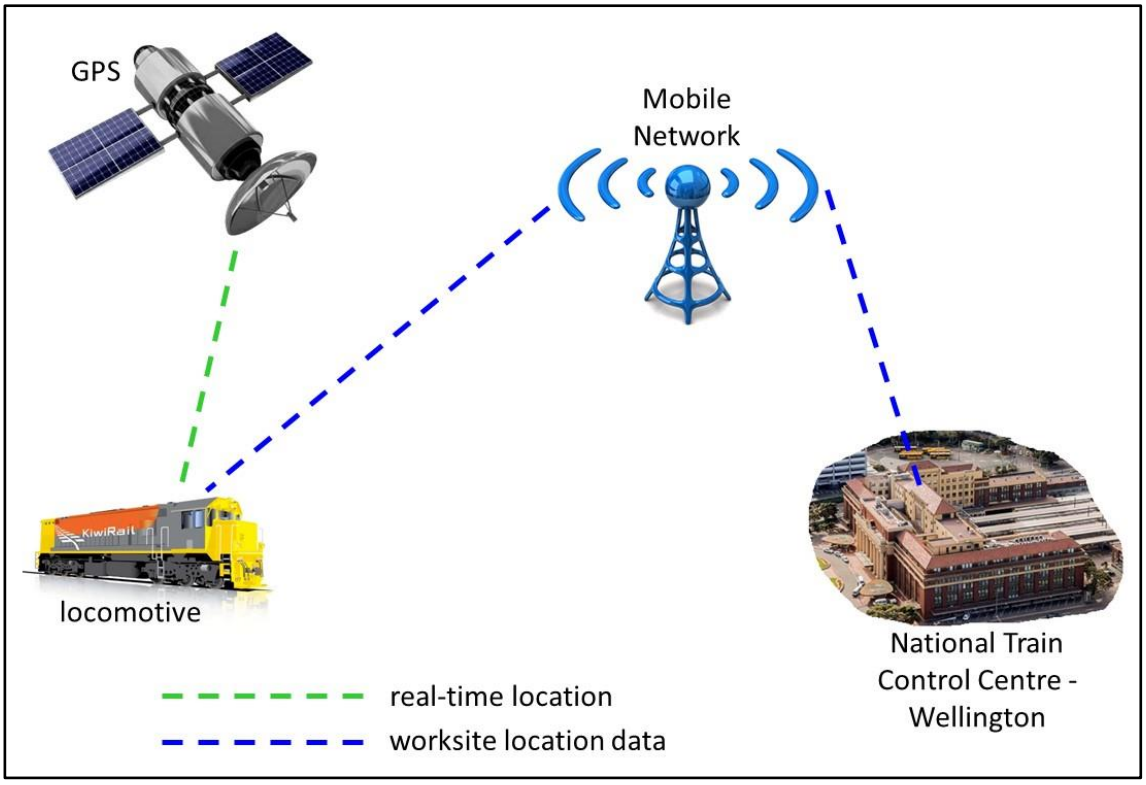


Figure 10
eProtect system data diagram

3.4.4. There are three interconnected systems on each locomotive that work together to provide the eProtect system (see Figure 11). These are:

i. a GPS unit, which receives the real-time GPS position of the locomotive

ii. a KMC module, which was initially installed to monitor train locations and send train GPS positions back to Train Control. The KMC module was modified to receive and store locations of worksites around New Zealand via the mobile network, and monitor the position of the locomotive in relation to the locations of the worksites

iii. a Tranzlog event recorder, which monitors and records the details of the locomotive's control settings. The Tranzlog can automatically apply the brakes if it receives a signal from the KMC module to do so.

Figure 11
eProtect system component parts on board locomotives

3.4.5. When a locomotive arrives at the outer caution boards of a worksite, the eProtect system is configured to sound a signal alert alarm[12] to notify the driver. At 500 m and 300 m from the compulsory stop boards the system checks that the speed of the locomotive is below 40 km/h and 35 km/h respectively. If not, the system activates the locomotive brakes automatically. At the compulsory stop boards, eProtect checks that the locomotive remains stationary for at least 10 seconds. If not, it applies the locomotive brakes automatically (see Figure 12).

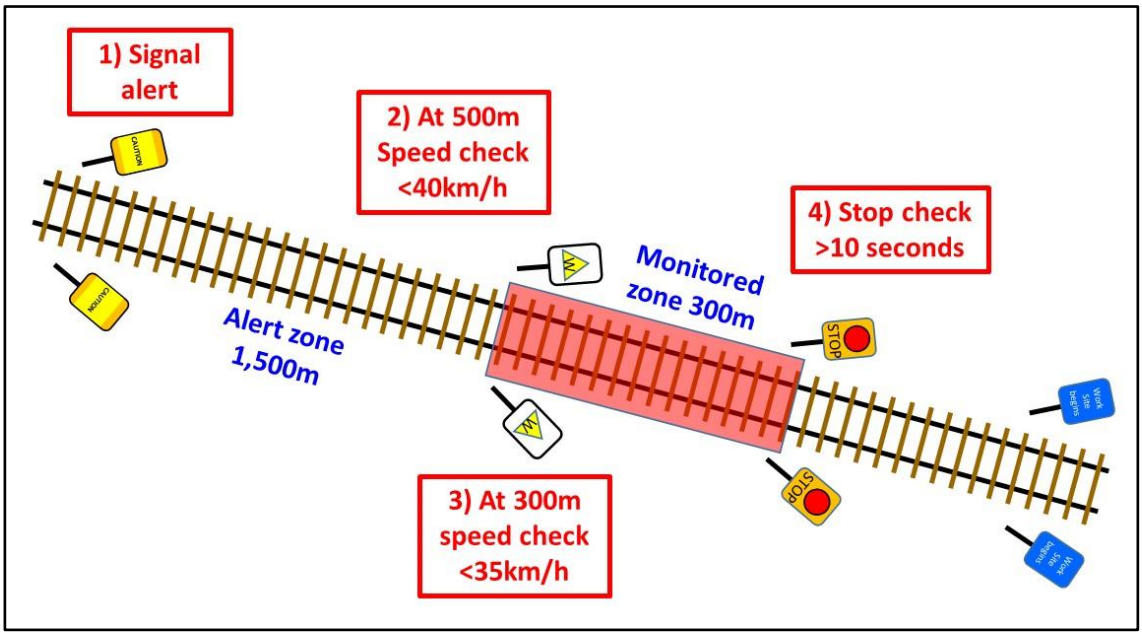


Figure 12
Stages of eProtect system checks

3.4.6. An eProtect system brake activation will not necessarily prevent a locomotive passing compulsory stop boards. It is intended to minimise the distance that a locomotive can move past the boards and prevent it entering an area where work is being undertaken.

3.4.7. The eProtect system utilises both GPS and mobile phone signals, which can be affected by local terrain and tunnels. KiwiRail considers that the eProtect system was designed and implemented as a supplementary overlay system, thereby providing another safety defence to the primary defence achieved by Rule 905. The primary protection for workers at a worksite is the train driver observing and stopping at the compulsory stop boards.

[12] A visual light and an audible alarm that can be set by the driver when passing a caution (Yellow) signal as a reminder that the next signal is likely to be a stop signal. It can also be activated by the eProtect system when approaching a compulsory-stop-board-protected worksite.

3.5. The train driver

3.5.1. The train driver was based at Kawerau, and at the time of the incident had seven years' experience driving freight trains for KiwiRail. The driver held current certification and had a good driving record at the time of the incident.

3.5.2. The driver had returned to work following two rostered days off. In preparation for the night shift the driver had gone to bed at approximately 1900 and woken at about 0000 on Tuesday 7 February. The driver had a one-hour commute from Rotorua to Kawerau before starting the shift at 0115. The driver later reported having had difficulty sleeping the night before the shift because of the high ambient temperature.

3.5.3. Following the incident the driver was relieved of duty and underwent a post-incident drug and alcohol test. The result of the test was negative.

4. Analysis

4.1. Introduction

4.1.1. The unauthorised entry of a train to a worksite is a serious incident that in this case had the potential to cause harm to the persons maintaining the bridge. Had the bridge support pile that was being replaced been removed, the bridge may have moved such as to cause the train to derail.

4.1.2. The primary defence against a train making an unauthorised entry to a worksite was Rule 905, which required the driver to stop the train and request permission from the work group to cross the bridge. The eProtect system was another safety defence that had been put in place in case the first failed. That system too failed to prevent the train entering the worksite.

4.1.3. The following analysis discusses how and why these systems failed.

4.1.4. Rule 905 relies on the driver being aware of the location of the worksite, and seeing and complying with the warning and compulsory stop boards. This analysis discusses the various factors that likely contributed to the driver not seeing the warning and compulsory stop boards.

4.1.5. Three safety issues are discussed:

- the KiwiRail medical assessment process did not ensure that the employee being assessed completed the online medical questionnaire themselves. There is some evidence that the system could potentially allow managers or others to complete the questionnaire on employees' behalf
- KiwiRail did not have a mature fatigue risk management system to ensure that relevant personnel performed at adequate levels of alertness
- the eProtect KMC module on board the locomotive had been transmitting error messages for three weeks before the incident, but the activity database was not being monitored for this type of error.

4.2. What happened

4.2.1. At the start of the shift the driver collected a copy of the daily information bulletin from the Kawerau depot. The driver noted the planned worksite at Bridge 107 and highlighted the entry because it would affect the route for the train's return journey that day (see Figures 6 and 7). This was almost nine hours before the train entered the worksite without authorisation.

4.2.2. In that nine hours the driver took trains from Kawerau to Murupara, then from Murupara to Mount Maunganui, which involved crossing Bridge 107 at night before the worksite was established for the day.

4.2.3. The driver was returning from Mount Maunganui to Kawerau, nearing the end of a 10½-hour shift. Meanwhile the worksite had been established at Bridge 107. It was daylight and all of the appropriate warning and compulsory stop boards had been erected in the correct locations, but the driver later did not remember seeing any of the warning and compulsory stop boards.

4.2.4. The Commission considered possible reasons for the driver not seeing the warning boards. Distraction from some source might cause drivers to miss one set of warning boards. However, it would be unlikely to cause them to miss three. A review of mobile phone records showed no activity leading up to the incident.

4.2.5. The driver's description of events suggested that the driver was very likely experiencing microsleeps when the train was passing the warning and compulsory stop boards. Microsleeps are described as brief interruptions of consciousness that last from a few seconds up to a few minutes when the brain ceases to process visual or audio inputs until the person is reawakened. The person is effectively disengaged from their environment. Microsleeps are a manifestation of extreme physiological sleepiness. The individual is often unaware that they

are experiencing microsleeps and can still perform basic tasks autonomously, but do not register additional audio or visual signs or alarms (Morgenstern, 2015).

4.2.6. The reasons for the driver experiencing microsleeps are discussed in the following sections. The driver recalled that the first indication of a worksite was seeing a hi-rail vehicle parked beside the track near Bridge 107. There had been a longstanding speed restriction of 40 km/h over both Bridges 105 and 107 that the driver was well aware of. The train event recorder confirmed that the driver had reduced the speed of the train to 40 km/h before passing over Bridge 105.

4.2.7. The driver's first reaction on seeing the hi-rail vehicle at Bridge 107 was to refer briefly to the 'speed restrictions'[13] sheet whilst slowing the train to 25 km/h as a precaution. By then the train was so close to the bridge that this was all the driver had time to do.

4.2.8. The incident showed that Rule 905 relies heavily on human performance to be effective. The introduction of the eProtect system was a good initiative for providing a further technical defence against trains entering worksites without authorisation.

4.2.9. However, in this case the eProtect system did not work due to a technical fault. The eProtect system should have automatically applied the train brakes when the train did not stop at the compulsory stop boards. The reason for the eProtect system not working is analysed further in the following sections.

4.2.10. There is no indication inside locomotives to inform drivers that the eProtect system is, or is not, functioning correctly. Drivers do not rely on the system as it does not prevent a driver passing compulsory stop boards; instead it minimises the distance that a train can pass them and therefore the potential consequences.

4.3. Human factors

Safety issue – the KiwiRail medical assessment process did not ensure that the employee being assessed completed the online medical questionnaire themselves. There is some evidence that the system could potentially allow managers or others to complete the questionnaire on the employees' behalf.

4.3.1. The Commission considered whether fatigue could have been a factor contributing to the driver missing the warning and compulsory stop boards.

4.3.2. Fatigue is described as a complex state characterised by a lack of alertness and reduced mental and physical performance, often accompanied by drowsiness (Sirois, 2018). Fatigue is more than sleepiness and its effects are more than falling asleep. Symptoms and consequences include:

- measurable changes in performance
- lapses in attention and vigilance
- delayed reactions
- impaired logical reasoning and decision-making
- reduced situational awareness
- low motivation for optional activities
- poor assessment of risk or failure to appreciate consequences of action
- operator inefficiencies.

4.3.3. The Commission used a Fatigue and Risk Analysis model (Health and Safety Executive UK, 2013) to analyse the driver's work roster for the period leading up to the incident. The model

[13] A separate daily information sheet that lists the various permanent and temporary speed restrictions for that line.

revealed that the driver's roster was unlikely to have, on its own, caused the driver to be fatigued. The pattern of the roster afforded ample time for rest and restorative sleep.

4.3.4. Having just completed two days off duty, the driver had ample opportunity to sleep before commencing the shift. However, opportunity for sleep is not a guarantee that adequate sleep is obtained. Lifestyle choices and the quality of sleep are important factors as well.

4.3.5. The driver reported having had a poor-quality sleep before starting the shift due to it being a hot and humid night.

4.3.6. Subsequent to the incident the driver was examined by a doctor and referred to Waikato Hospital to undergo a controlled sleep study. The hospital's Respiratory Services Sleep Laboratory's sleep specialists completed a Level III sleep study. They diagnosed the driver as suffering from mild obstructive sleep apnoea.

4.3.7. Obstructive sleep apnoea is the most common type of sleep apnoea and is caused by the complete or partial blocking of the upper airway during sleep. This reduction in airflow and blood oxygen triggers a sudden interruption of sleep. One consequence of sleep apnoea is sleep deprivation due to the repetitive disruption of sleep activity.

4.3.8. Adults with sleep apnoea commonly suffer from excessive awake-time sleepiness. This can result in an individual falling asleep for brief periods during the course of their normal activities.

4.3.9. There were three factors that very likely contributed to the risk of the driver having sleepiness episodes leading up to the incident:

- the accumulative effects of sleep apnoea
- the stated poor quality of sleep prior to the driver's shift
- the 10-plus hours that the driver had been 'time awake' and driving trains during the early hours of the morning.

4.3.10. It is difficult to weight these factors in order of effect, but collectively they meant it was likely that the driver was experiencing microsleeps when the train passed the warning and compulsory stop boards leading up to the worksite.

4.3.11. There is evidence that the driver was alert enough to reduce the speed of the train to 40 km/h for the permanent speed restriction over both bridges. However, the evidence suggests that the driver then lapsed into one or more microsleeps, which ended or were interrupted when the hi-rail vehicle trackside was sighted.

4.3.12. Currently, KiwiRail's periodic medical screening programme requires health assessments of staff in safety-critical roles every five years up to the age of 50, every two years up to the age of 60, and annually thereafter. The programme consists of an online health questionnaire, to be completed by an employee before a visit to a KiwiRail-approved medical officer for a physical examination.

4.3.13. The Australian National Transport Commission's national standard for health assessment of rail safety workers has been adopted by the New Zealand National Rail Safety Standards Executive, and is therefore utilised by KiwiRail. The standard has been developed from roading standards in Australia, and is formally reviewed every four years.

www.ntc.gov.au/Media/Reports/(7B079897-1863-CA93-474F-AD96AD9C6C3F).pdf

4.3.14. Section 18.6 of the standard deals with sleeping disorders and contains a flowchart for the assessment of safety-critical workers (see Figure 13). Following this flowchart, the driver in this case scored low both on the Epworth Sleepiness Scale[14] and for their clinical markers such as

[14] A scale that measures awake-time sleepiness through the use of a very short questionnaire. This can be helpful in diagnosing sleep disorders. It was introduced in 1991 by Dr Murray Johns of Epworth Hospital in Melbourne, Australia.

BMI and blood pressure; therefore they did not exceed the threshold for referral for a follow-up sleep study. As part of the continuous improvement cycle of the standard there are already discussion documents out for consultation with regards to potential changes to tighten the standard. Many of these proposed changes would likely have indicated that this driver required a follow-up sleep study.

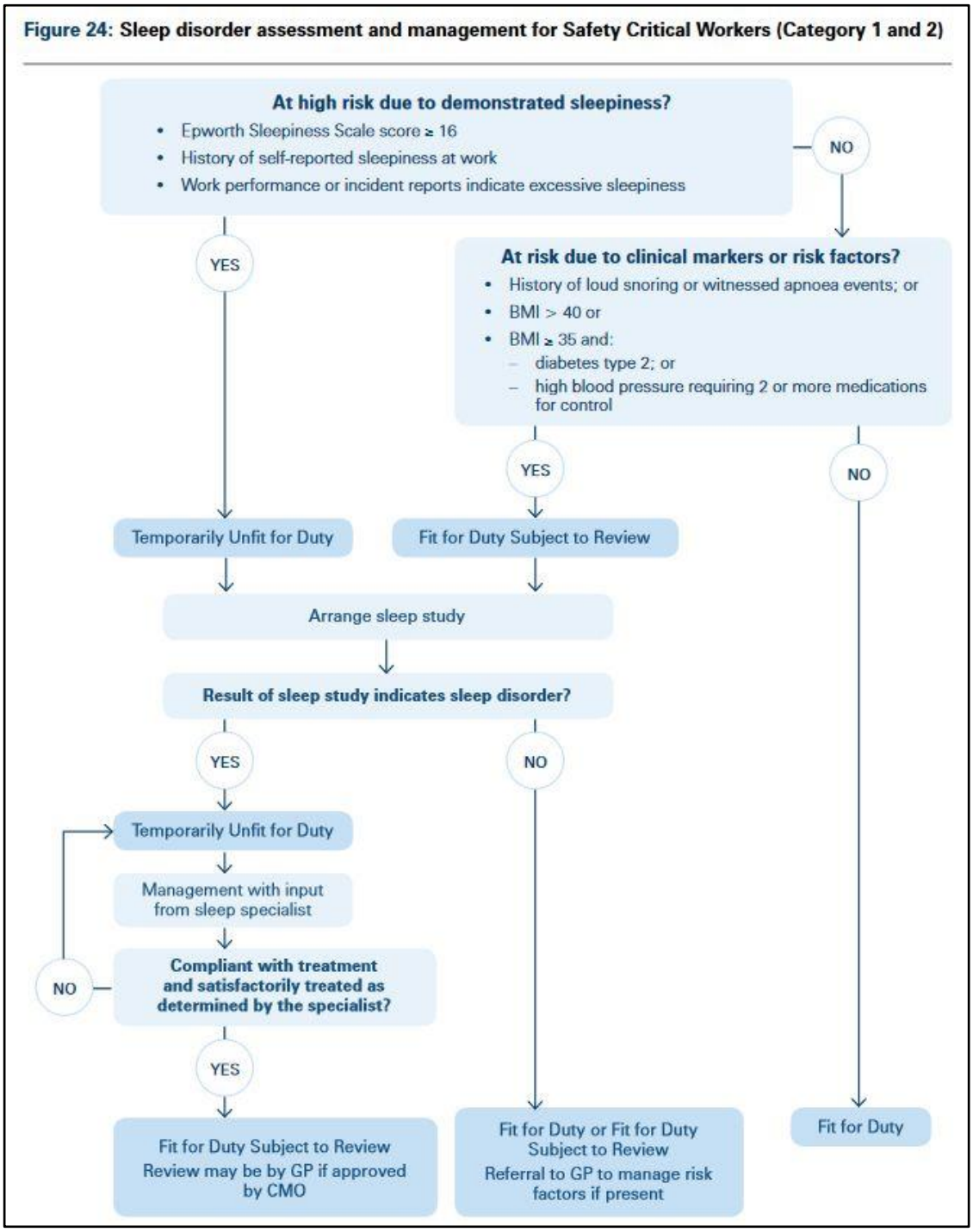


Figure 13
Australian National Transport Commission standard for sleep disorder assessment of rail safety critical workers

4.3.15. In this case the driver reported that someone else had completed the online medical questionnaire part of the medical assessment for the driver, before the health assessment. It is not clear as to why that happened, but it was a clear departure from the KiwiRail procedure, and of concern. It is an indication that the importance and safety benefits of the medical assessment programme were not fully realised by those involved.

4.3.16. Currently, part of the KiwiRail pre-medical online questionnaire completed by each individual utilises the Epworth Sleepiness Scale set of questions to assess the sleepiness of the individual as an initial screening test for sleeping disorders. Respondents are asked to rate their usual chances of dozing off or falling asleep whilst engaging in eight different activities.

4.3.17. KiwiRail acknowledged that the screening tests for sleeping disorders have relatively low validity in clinical trials (Satya Krishna Ramachandran MD, 2009). Consequently, KiwiRail's rail medical officers[15] put more weight on the clinical indications of sleeping disorders, such as BMI and high blood pressure referred to above.

4.3.18. Notwithstanding the fact that the driver did not personally complete the pre-medical questionnaire, when the driver did complete it after the incident, the score was not high enough on the sleepiness scale to warrant any follow-up under the sleeping disorder medical assessment procedure alone.

4.3.19. Subsequent to the incident and the diagnosis of sleep apnoea, the driver has been provided with aids to reduce the effects of sleep apnoea and made a number of other lifestyle changes to improve quality of sleep, with reported good results. This shows the importance of early detection of sleep disorders and the importance of education on lifestyles for shift workers. The Commission makes a recommendation to KiwiRail to ensure that the periodic medical check system captures data directly from the intended subjects.

4.4. Fatigue management

Safety issue – KiwiRail did not have a mature fatigue risk management system to ensure that relevant personnel performed at adequate levels of alertness.

4.4.1. In section 1 of the New Zealand Rail Operating Rules and Procedures, rail personnel are deemed unfit for duty if they:

i. are under the influence of alcohol or drugs

ii. have any illness or condition, mental or physical, which affects alertness, coordination, reaction or safety

iii. have not sufficiently rested to remain alert during their work.

4.4.2. As with most operators of transport vehicles, train drivers are required to self-certify whether they are 'fit for duty' before attending their allocated shifts. Due to issues on a national scale associated with earthquakes that KiwiRail was dealing with at the time, the driver felt self-pressured to attend work, despite having had a poor night's sleep. The driver was also concerned that calling in unfit for work would leave little time to arrange a replacement driver to cover the shift.

4.4.3. Currently KiwiRail uses a FAID software system to assess its master rosters for potential fatigue issues and also for post-incident analysis. This type of software aims to ensure that each roster position gives the individual ample opportunity to sleep between shifts, and that the roster is compiled according to current good roster design principles, which include providing cover drivers[16]. The driver's roster was considered normal and was not a factor in this incident.

4.4.4. A number of other safety-critical transport sectors have introduced simple checklists or prompts (CAA, 2018) as part of their fatigue awareness training and education, to assist individuals in determining if they are fit for duty (see Figure 14).

[15] A rail medical officer is a qualified general practitioner engaged by KiwiRail to complete medical assessments of employees and prospective employees in a specific locale.
[16] A spare driver planned into a roster who steps in if a rostered driver is unable to complete a particular shift.

Figure 14
Example fitness-for-work prompt sheet

4.4.5. On the day of the incident the cover driver planned for the KiwiRail Kawerau roster had already been assigned to cover another driver. Other drivers who were not rostered to work on this day may have been able to cover the shift, but may not have been adjusted to a night-shift work pattern.

4.4.6. In November 2016 KiwiRail held fatigue management workshops with the Rail and Maritime Transport Union and Professor Philippa Gander from the Sleep/Wake Research Centre at Massey University Wellington. As part of these workshops a new regulatory approach in the form of a fatigue risk management system (Medicine, 2012) was identified as the next step in fatigue management at KiwiRail. This is a data-driven safety management system that is based on combined scientific and operational expertise and includes processes for monitoring safety performance and continuous improvement. A fatigue risk management system is made up of four parts:

i. organisational components
   - fatigue risk management policy and documentation
   - fatigue risk management promotional processes – education and training

ii. operational components
   - fatigue risk management processes
   - fatigue risk management safety assurance processes.

4.4.7. KiwiRail currently has a draft fatigue risk management system policy for locomotive engineers and train controllers, plus a number of existing processes and systems that fit within a fatigue risk management system. KiwiRail has used gap analysis to identify missing parts from its existing fatigue management systems and assigned actions to address these shortfalls. While some of these missing parts have been addressed, others are still works in progress.

4.4.8. Driving trains is a safety-critical role. Additional guidance and training may have helped the driver to evaluate their condition better before attending the shift.

4.4.9. The Commission makes a recommendation to KiwiRail to ensure that a comprehensive fatigue risk management system continues to be developed and fully implemented within the organisation.

4.5. Technical factors

Safety issue – The eProtect KMC module on the locomotive had been transmitting error messages for three weeks before the incident, but the activity database was not being monitored for this type of error.

4.5.1. An interrogation of the eProtect activity database logs from KiwiRail showed that the KMC module on board the incident locomotive had started to send self-generated error messages

from 16 January 2017, three weeks before the incident. The error messages indicated that the KMC module was capable of receiving worksite positions from Train Control, but it was unable to write them to memory. This meant the KMC module had no worksite details with which to compare the train's current GPS position and could not take action when the train passed the compulsory stop boards.

4.5.2. The Commission obtained the eProtect KMC module from the locomotive involved in the incident. The module was forensically examined with assistance provided by the KMC module manufacturer. The module was the processor of the eProtect system on board the locomotive. It received details of rail worksite locations around New Zealand using the mobile phone network, and compared them to the real-time GPS positions of the locomotive. As mentioned previously, the KMC module was designed to alert drivers when their locomotives were approaching known worksite locations, and if necessary take action should the trains approach the worksites too fast or fail to stop at compulsory stop boards.

4.5.3. The examination of the KMC module identified a hardware fault, which was traced to a failed integrated circuit chip. The integrated circuit chip was used by the KMC module to switch its memory power source from the external 12-volt supply to an internal battery backup whenever the locomotive was powered down.

4.5.4. It was not possible to determine why the chip failed. The design and manufacturing specifications did not indicate a lifecycle for this type of integrated circuit chip. However, irrespective of why the chip and subsequently the KMC module failed, the issue is that the module had reported the error to the eProtect activity log database, but the monitoring process had not picked up the error message.

4.5.5. Without the ability to write the location of the worksite at Bridge 107 to its memory, the KMC module was not aware of its existence. Thus the data for the location of the compulsory stop boards was missing, and that is why the eProtect system failed to apply the train brakes when the train did not stop at the boards.

4.5.6. During the development of the eProtect system, the KMC module was programmed to send messages back to the eProtect activity log database, which in turn notified four different addressees at KiwiRail by email when certain conditions occurred. These conditions included a variety of faults and errors, including GPS faults and communication errors. However, the particular mode of failure that occurred in this instance had not been envisaged, so the system was not programmed to generate an email alert to KiwiRail staff.

4.5.7. The lack of an email or other warning message being generated by the eProtect system meant the KMC module was sending error messages to the eProtect activity log database, alerting that it could not write the worksite GPS details into its on-board memory. However, these error messages were not identified or acted on because the eProtect activity database was not actively monitored by KiwiRail for this type of occurrence.

4.5.8. The specification, development, trialling and rollout of the eProtect system by KiwiRail and its contractors were comprehensive. From the records detailing the system requirements, development and testing that were provided to the Commission, it is apparent that not all the modes of failure of the KMC module or the eProtect system were fully understood and planned for before the system was put into service. No failure mode analysis had been undertaken on the system, and this specific mode of failure was not being monitored. The Commission has made a recommendation on this issue in report RO2017-102.

4.5.9. When the eProtect system works correctly it greatly enhances safety around protected worksites. Although the eProtect system is considered an additional safety defence against trains inadvertently entering worksites without authorisation, its function is important, particularly when the primary defence is reliant on human factors.

4.5.10. KiwiRail has made technical changes to the eProtect system to address this safety issue; see section 6.

5. Findings

5.1. The safety of the people at the worksite and on the train was compromised when the driver did not see the outer warning and compulsory stop boards and made an unauthorised entry to the worksite.

5.2. The reason for the driver not seeing the outer warning and compulsory stop boards was that the driver was likely experiencing microsleeps at the time.

5.3. The driver was very likely susceptible to experiencing microsleeps due to a combination of the following factors:

- the driver suffered from mild obstructive sleep apnoea, which was affecting the quality of sleep
- the driver had experienced a poor night's sleep before beginning the night shift, due to the hot ambient temperature
- the driver had been awake for more than 10 hours and was nearing the end of a 10½-hour night shift.

5.4. The safety benefits derived from the KiwiRail safety-critical worker health assessment were not fully realised by those involved, and as a result the driver's sleep apnoea had gone undetected.

5.5. KiwiRail has a draft fatigue risk management system policy that is still under development. Had the current system been able to provide additional guidance to drivers, it may have helped them to evaluate their condition better before attending shifts.

5.6. The eProtect system was a safety defence for preventing trains inadvertently entering worksites without authorisation. The system did not work on this occasion because a technical error in the processing unit on board the locomotive had not been detected and rectified by KiwiRail staff.

5.7. The error in the processing unit on board the locomotive had not been detected because the eProtect system had not been subjected to a full failure mode analysis before being put into service.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressing safety issues identified during an inquiry

6.2. In response to the incident KiwiRail has introduced a proactive 'polling' system that interrogates the event log on each locomotive every two hours and highlights any locomotives that have logged more than 10 error events in that two-hour period. An email is then generated for any such locomotives, which are then flagged as 'Not To Run' until the fault has been investigated and resolved at a maintenance facility.

6.3. Since 2016 KiwiRail has had a Fatigue Safety Action Group to establish and run a fatigue risk management system and its integration with the other parts of the organisation.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case recommendations have been issued to KiwiRail with notice of these recommendations given to the NZ Transport Agency.

7.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations made to KiwiRail

7.3. The KiwiRail medical assessment process did not ensure that the employee being assessed completed the online medical questionnaire themselves. There is some evidence that the system could potentially allow managers or others to complete the questionnaire on the employees' behalf.

On 23 August 2018 the Commission recommended that the Chief Executive of KiwiRail improve the health assessment system to ensure that the periodic medical check system captures data directly from the subject. (018/18)

On 26 September 2018, KiwiRail replied:

> Medical Assessment Process
>
> KiwiRail accepts that there exists the possibility that someone could complete the periodic health assessment online medical questionnaire on behalf of the intended subject, and will now work towards implementing changes which will eliminate this possibility.

7.4. Currently KiwiRail does not have a fully developed, comprehensive fatigue risk management system to ensure that all relevant personnel perform at adequate levels of awareness.

On 23 August 2018 the Commission recommended that the Chief Executive of KiwiRail ensure that a comprehensive fatigue risk management system is fully developed and implemented within the organisation. (019/18)

On 26 September 2018, KiwiRail replied:

> Fatigue Risk Management System
>
> KiwiRail presently has two streams of work in progress which are addressing fatigue risk management. There is a review of the enterprise wide fatigue policy that includes a wider organisational focus on occupational health and wellbeing related fatigue. This includes physical fatigue, mental fatigue and sleep fatigue risk. Secondly and concurrently with this, the respective business units are addressing specific fatigue risk management initiatives and providing educational information on how to best manage risks occurring from fatigue.
>
> The fatigue risk management strategy program is a joint KiwiRail and Rail & Maritime Transport Union project delivered through the High Performance High Engagement program. A fatigue risk management strategy is currently under development for train drivers/train controllers, and eventually will be introduced across the business.

Notice given to Regulator

7.5. On 23 August 2018 the Commission **gave notice** to the Chief Executive of the NZ Transport Agency that the Commission had recommended that:

The Chief Executive of KiwiRail improve the health assessment system to ensure that the periodic medical check system captures data directly from the subject.

7.6. On 23 August 2018 the Commission **gave notice** to the Chief Executive of the NZ Transport Agency that the Commission had recommended that:

The Chief Executive of KiwiRail ensure that a comprehensive fatigue risk management system is fully developed and implemented within the organisation.

8. Key lessons

8.1. Train drivers and other shift workers need to ensure that they are medically fit and make appropriate lifestyle choices that will enhance the amount and quality of their sleep, in order to avoid being fatigued or tired while at work.

8.2. Transport operators must ensure that their staff are fully educated on the factors that can cause or contribute to their becoming tired or fatigued while performing safety-critical roles.

8.3. Technological systems need to be fully tested and have undergone full failure mode analysis if they are going to be relied on as a safety defence for preventing accidents and incidents.

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