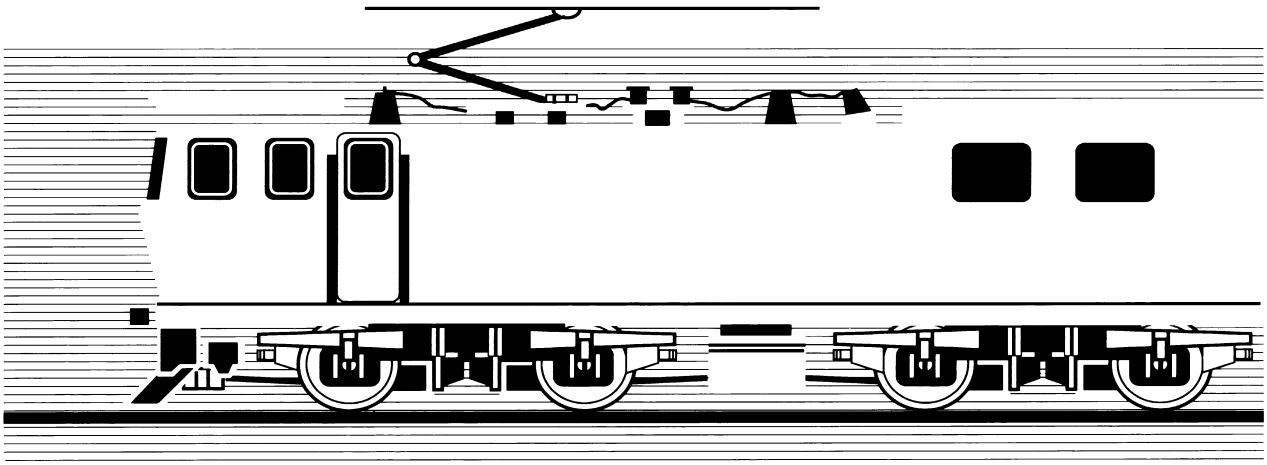
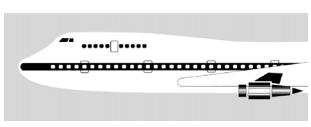
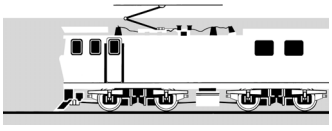


RAILWAY OCCURRENCE REPORT

05-102 **track warrant control irregularities, Woodville and Otane** **18 January 2005**


TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

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.

Report 05-102

track warrant control irregularities

Woodville and Otane

18 January 2005

Abstract

On Tuesday 18 January 2005, a track warrant control irregularity occurred at Woodville when a track warrant was issued to a locomotive engineer authorising his train to berth on the main line at Makotuku to cross an opposing train. The locomotive engineer of the opposing train was already in possession of a track warrant authorising his train to berth on the main line at Makotuku.

On the same day a second track warrant irregularity occurred when a track warrant was issued to a locomotive engineer authorising his train to proceed from Otane to Takapau to cross an opposing train. The locomotive engineer of the opposing train was already in possession of a track warrant authorising his train to travel to Waipukurau for the same crossing. He brought this to the attention of the train controller and a potential head-on collision between the trains was averted.

There were no injuries.

Safety issues identified included:

- fatigue arising from rostering procedures for train controllers
- the use of rostered off duty train controllers to meet short-term staff shortages in the train control office
- the inability of the locomotive engineer to check the detail of issued track warrants against the preparation details.

Because of the similarities arising from each incident they have been combined into one report.

Five safety recommendations have been made to the Chief Executive of ONTRACK.

Contents

Figures

Abbreviations

m	metre(s)
PNGL	Palmerston North – Gisborne Line
t	tonnes
Toll Rail	Toll NZ Consolidated Limited
TWACS	track warrant computer system
TWC	track warrant control
UTC	coordinated universal time
VDU	visual display unit
VHF	very high frequency

Data Summary

Rail Occurrence Number	Train Number	Train Type	Date	Time[1]	Location
05-102	Train 627	express freight	18 January 2005	1757	Otane
05-101	Train 624	express freight	18 January 2005	0454	Woodville

Type of occurrences: track warrant control irregularities

Damage: nil

Injuries nil

Infrastructure provider New Zealand Railways Corporation (ONTRACK)

Operator: Toll NZ Consolidated Limited (Toll Rail)

Investigator-in-charge: D L Bevin

[1] Times in this report are New Zealand Daylight Standard Times (UTC + 13 hours) and are expressed in the 24-hour mode.

1 Introduction

1.1 On Tuesday 18 January 2005, there were 2 track warrant control irregularities on the Palmerston North - Gisborne Line (PNGL).

1.2 Because of the similarities of the incidents they have been combined into one report although the factual information and analysis applicable to each incident is dealt with separately.

2 General Information

2.1 Operating system

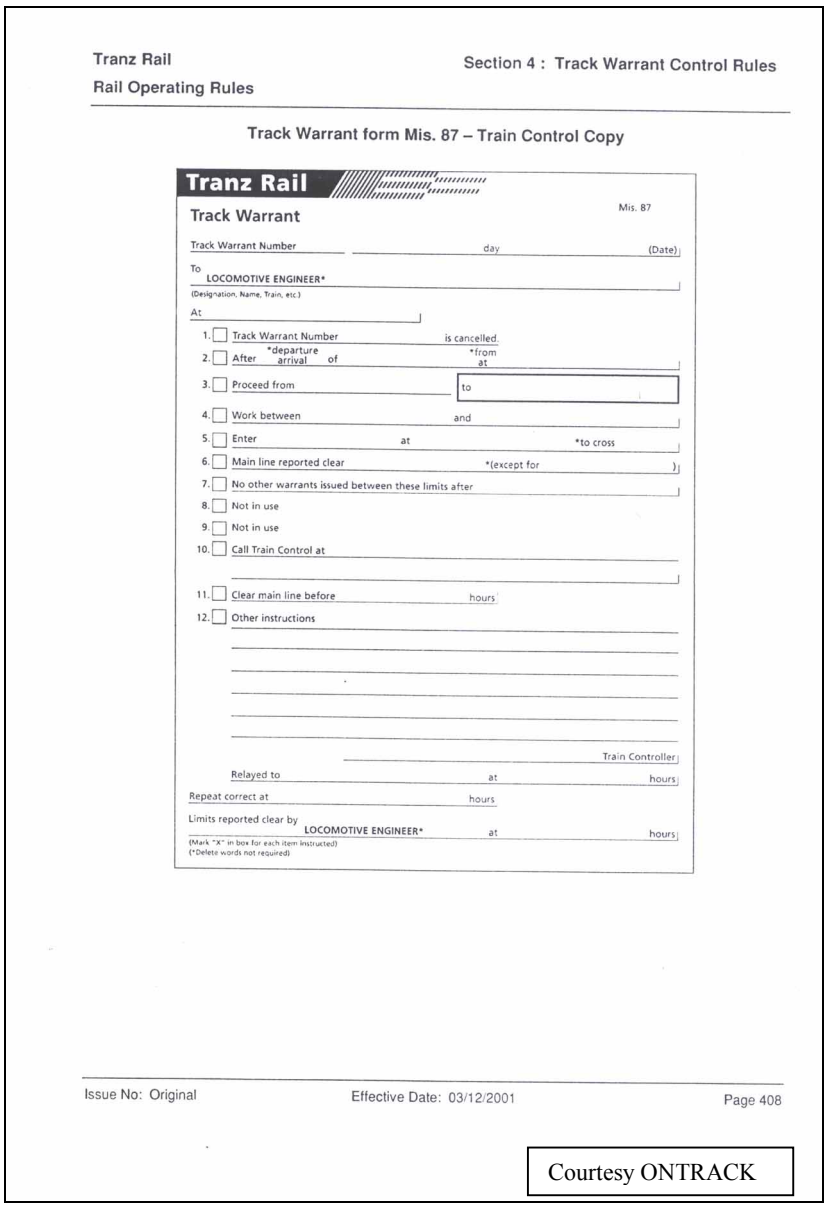
2.1.1 Track Warrant Control (TWC) was introduced into New Zealand Railways in 1988 as an alternative to a signalling system for train operation on lower traffic density lines. TWC was a method for ensuring that only one train had authority to occupy a section of track at any time.

2.1.2 Following its implementation, the TWC process was enhanced by the introduction of a track warrant computer system (TWACS) in train control for the preparation of track warrants. The train controller used a computer, which was programmed to prevent the preparation of a track warrant for an opposing train if another had already been prepared or issued for the same section.

2.1.3 When issuing a track warrant to a locomotive engineer, the train controller relayed the details by radio or telephone. The locomotive engineer transcribed the details on to a prepared form, and then read them back to the train controller as a check. There was no facility in the locomotive cab for the locomotive engineer to check the details of the track warrant against those in TWACS.

2.1.4 The readout / readback procedures required the train controller to check the details of the track warrant as it was issued by scrolling down the TWACS visual display unit (VDU), highlighting each detail as he read it out to the locomotive engineer, and then again as it was repeated back.

2.1.5 The ‘location to’ limit of the track warrant appeared twice in the prepared track warrant, firstly in clause 3, the ‘proceed from / to’ information, and secondly clause 5, where berthing instructions could be defined. Figure 1 shows the manual track warrant form (Mis 87) prepared by the train controller; the more common electronic version prepared in TWACS had the same layout.



Tranz Rail
Rail Operating Rules

Section 4 : Track Warrant Control Rules

Track Warrant form Mis. 87 – Train Control Copy

Tranz Rail

Track Warrant

Mis. 87

Track Warrant Number _____ day _____ (Date)

To LOCOMOTIVE ENGINEER*
(Designation, Name, Train, etc.)

At

1. ☐ Track Warrant Number _____ is cancelled.
2. ☐ After *departure / arrival of _____ *from / at _____
3. ☐ Proceed from _____ to _____
4. ☐ Work between _____ and _____
5. ☐ Enter _____ at _____ *to cross _____
6. ☐ Main line reported clear _____ *(except for _____)
7. ☐ No other warrants issued between these limits after _____
8. ☐ Not in use
9. ☐ Not in use
10. ☐ Call Train Control at _____
11. ☐ Clear main line before _____ hours
12. ☐ Other instructions

Train Controller

Relayed to _____ at _____ hours

Repeat correct at _____ hours

Limits reported clear by LOCOMOTIVE ENGINEER* _____ at _____ hours

(Mark "X" in box for each item instructed)
(*Delete words not required)

Issue No: Original Effective Date: 03/12/2001 Page 408

Courtesy ONTRACK

Figure 1
The train controller's copy of the track warrant (manual version)

2.1.6 Between Woodville and Hastings the PNGL was single track so, to enable opposing trains to cross, sections of double line, or crossing loops, were provided at Oringi, Dannevirke, Makotuku, Takapau, Waipukurau and Otane. To control such crossings, train controllers stipulated berthing instructions on the track warrant.

2.1.7 The signalling at Takapau was remotely controlled from ONTRACK's[2] national train control centre in Wellington. When shunting the sidings at Takapau, it was usual for northbound trains to require the train controller to clear 8RB Up Starting Signal from Loop to proceed to allow room for the shunting manoeuvre to be undertaken (see Figure 2).

[2] ONTRACK is the trading name of New Zealand Railways Corporation.

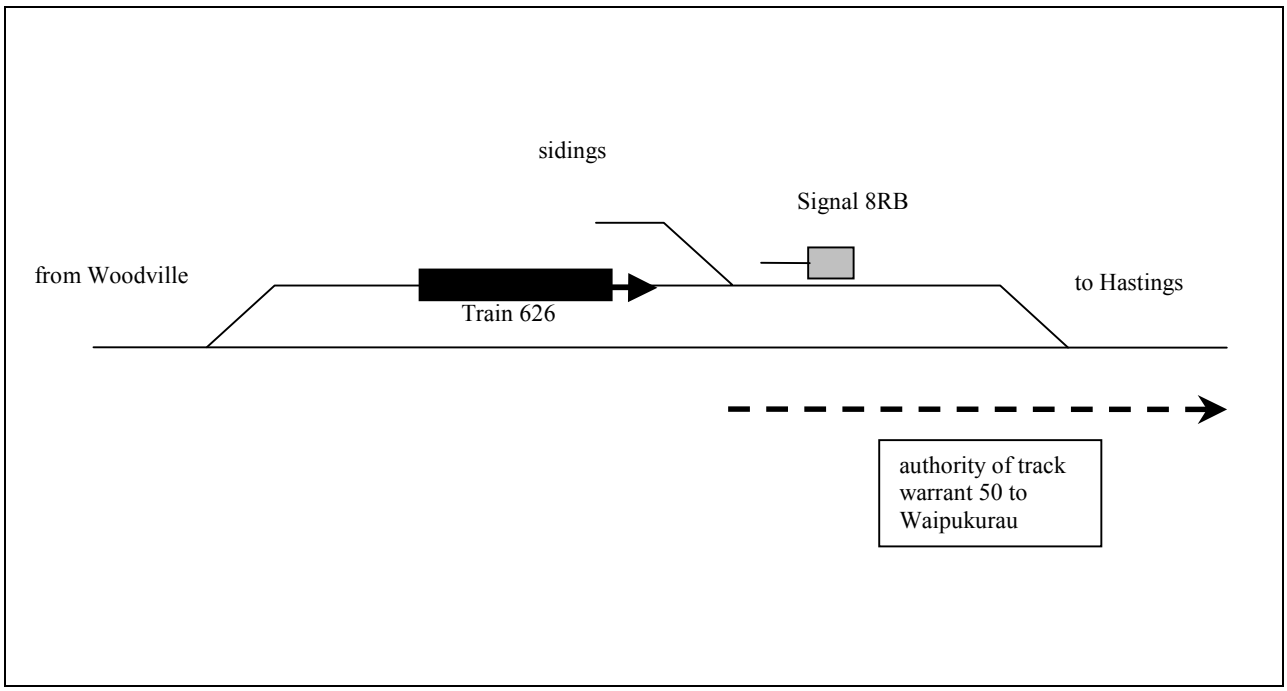


Figure 2
Shunting arrangements at Takapau (not to scale)

2.2 Radio systems

Train control radio system

2.2.1 An automatic selective calling (Selcall) system was used on very high frequency (VHF) radio to send the locomotive identification number and a status or alarm indication to train control.

2.2.2 When required, the system sent the following status indications to train control:

- vigilance alarm activated by an emergency brake application
- portable radio removed from holder
- portable radio replaced in holder
- transmission from train on the portable radio
- transmission from train on locomotive radio
- base call to train control
- emergency alarm from locomotive

2.2.3 Train control to train radio coverage on the PNGL was provided as follows:

- Palmerston North to Woodville – channel 4 (except Manawatu Gorge channel 2)
- Woodville to Waipukurau – channel 3
- Waipukurau to Gisborne – channel 2

2.2.4 Radio signals were channelled through various repeaters along the route; as a train progressed along the route, the locomotive engineer manually selected the appropriate channels when he passed the area boundaries. Alternatively, he could leave the radio scanner on and the radio would lock on to any channel on which it detected voice traffic.

2.2.5 Messages between train control and trains were displayed on the train control radio VDU. The display included the locomotive or train number. The train controller was required to input this information in the radio computer prior to the commencement of each trains' journey.

Local radio channel

2.2.6 Channel 1, a VHF point-to-point radio communication system that did not use repeaters, was provided for communication between locomotive engineers and local staff such as roving shunters.

2.2.7 The range for channel 1 transmission in particular localities was not normally documented, but under normal circumstances was expected to be in the order of 5 km, depending on the power output of the radio in use, the terrain and other sources of interference.

2.2.8 When approaching a station at which communication was required with local staff, the locomotive engineer would manually select channel 1 on his locomotive cab radio. This would allow communication to be established with station staff, but at the same time would stop the radio scanning the train control channels.

2.3 Train control diagram

2.3.1 Train control diagrams showed the timetables of all scheduled trains, printed in green. Information such as time allowed for shunts en route and crossings with opposing trains was also shown.

2.3.2 Based on the actual time of departure, train controllers drew plot lines on the diagram using a black pencil to show the anticipated progress of trains. The pencil plot line was overwritten with a blue line when the track warrant was issued. The blue line corresponded to, and replaced, the pencil plot line and showed the anticipated progress of the train, including intermediate stopovers for operational requirements en route and the limits of the track warrant issued.

2.3.3 The track warrant number issued to each train, as well as the berthing arrangements for crossing purposes, was also endorsed on the train control diagram.

2.4 Rostering of train controllers

2.4.1 There was no definition for 'rostered day off' in ONTRACK's policy and procedure for rostering. Rostering was set around 'work periods' and 'minimum time off'. Where 'rostered days off' were shown on the roster, these were provided for the purpose of completing the fortnightly timesheets.

2.4.2 A review of rosters covering this period showed that the rostering of train controllers for 5 consecutive night shifts was common practice throughout the train control centre. The number of consecutive night, or at-risk, shifts worked by locomotive engineers had been the subject of a separate internal review by Tranz Rail Ltd (now Toll Rail), following a series of derailments and collisions arising from fatigue and sleep issues during 2000.

2.4.3 On 7 June 2005 Toll Rail advised in part:

> At-Risk shifts are all shifts that start between 2000 hours and 0300 hours. If three at-risk shifts are worked in a row then a mandatory off duty time of 54 hours minimum is required.
>
> This arrangement was implemented in early 2001. These principles have not been formally documented, however a rostering standard document has been drafted and it is hoped that this will be published formally in the near future.

This recovery period following a sequence of at-risk shifts recognised the need to restore sleep debt accumulated during those shifts.

2.4.4 ONTRACK's Rail Operating Manual outlined the following rules for the initial construction of Train Control master rosters:

- a maximum of 10 shifts per fortnight
- each shift is to be of generally 8 hours 10 minutes duration. This may be relaxed at weekends to satisfy the social needs of the persons operating the roster
- each fortnight to be generally made up of a maximum 80 – 85 hours actual
- mandatory minimum 11 hours 30 minutes continuous time off between shifts.

2.4.5 The Rail Operating Manual included the following rules for medium and short notice changes to the master roster:

Mandatory maximum shift length / number of consecutive shifts:

	Up to 8 hrs 10 mins	10 hrs 10 mins	12hrs 10 mins
Day	12	10	3
Late	12	10	3
Night	7	6	3

Mandatory rest time off

- total actual hours not to generally exceed 110 per fortnight
- mandatory 11 hours 30 minutes minimum time off between shifts[3]
- mandatory 12 shift maximum consecutive shift pattern regardless of length of shifts

2.4.6 The Collective Employment Agreement between ONTRACK and the train controllers provided for:

- an absolute maximum work period of 14 hours
- a minimum rest period between shifts of 10 hours
- a maximum number of 12 consecutive shifts before an off-duty day

2.4.7 Train control rosters did not provide for scheduled breaks away from the desk for rest periods or personal needs breaks while on duty. However, refreshment and toilet facilities were near by, and breaks were often available from the train control desk, depending on the workload, although these were not at consistent or regular times.

2.4.8 On 25 November 2005,Toll Rail advised that in 2003 its predecessor, Tranz Rail, had initiated discussion with Rail, Maritime and Transport Union delegates regarding the consecutive number of at-risk shifts and mandatory rest periods. However, the proposal was not supported by the delegates, in part because the concept might have been unworkable given the turnover of train controllers at the time.

[3] The Collective Employment Agreement between ONTRACK and the train controllers provided for a mandatory minimum rest time of 10 hours.

2.4.9 Toll Rail said that at that time the train control environment was seen as unstable because of a planned relocation to Auckland and this seemed likely to result in more staff turnover and some resistance to the implementation new track occupancy procedures. Because of this it had been decided to defer further discussion on the issue until some stability had been restored. However, a new management report had been introduced to monitor hours of work on an ongoing basis to identify and manage instances where train controllers worked excessive hours or regular shift extensions.

2.4.10 On 2 December 2005, ONTRACK advised that the key issues that needed to be overcome were:

- the variability of qualifications and experience amongst staff
- the actual number of staff available through shortage or having not yet reached Level 3 qualification[4], and
- the fact that while the staff compliment was set at 34, some roster rotations consisted of 5 staff due to the skills required to control multi areas

To implement a roster with fewer night shifts and minimum hours off over a 24/7 roster required additional staff qualified at Level 3 for which the training period was a minimum of 18 months.

In December 2004 some shift rotations within train control master rosters started to include three consecutive night shifts followed by rostered time off duty. However, the extent to which this could be trialled was severely limited by the mix of qualifications. Since less qualified staff can only work certain shifts and to maintain shift coverage there was still a need to exceed the 3 consecutive night shift goal. This trial continues along with ongoing recruitment and training to increase the staff establishment and mix of competencies.

2.5 Sleep and fatigue

2.5.1 Fatigue can be defined as a progressive loss of mental and physical alertness that can end in sleep. Lack of sleep, sleeping at different times of the day, mental stress or high mental workload will quickly result in mental fatigue. One becomes increasingly inattentive while trying to concentrate on tasks. As fatigue increases, short-term memory becomes less effective and one may forget vital information[5].

2.5.2 Fatigue is used as a catch-all term for a variety of different experiences, such as physical discomfort from overworking a group of muscles, difficulty concentrating, difficulty appreciating potentially important signals, and problems staying awake. In the context of an investigation, fatigue is important if it potentially reduces efficiency, erodes the safety margin, or otherwise impairs cognitive or physical performance.[6]

2.5.3 Every aspect of human performance can be degraded by sleep loss and sleepiness, including physical and mental performance. Once sleep debt or fatigue builds, only sleep can maintain or restore performance levels.

2.5.4 Lack of sleep and/or a reduction in sleep quality are the main factors affecting levels of fatigue, mood, health, and ultimately, performance. We lose sleep either by reducing a single sleep period by a large amount (acute sleep loss) or by building up a sleep debt over time by reducing sleep on consecutive sleep periods (accumulated sleep loss). Attempting to sleep at times when the body is less inclined to do so will disrupt sleep. The duration of the sleep period will be shorter, and the structure will be altered, resulting in further lost sleep[7].

[4] A train controller qualified to operate 3 train control desks within the train control centre.
[5] Source - Fatigue Management Guide for Canadian Pilots, Transport Canada, 2003.
[6] Source - A Guide for Investigating for Fatigue, Transportation Safety Board of Canada, 1997.
[7] Source - Fatigue Management for Canadian Pilots, Transport Canada, 2003.

2.5.5 A paper entitled "Fatigue Management in the New Millenium"[8] stated that:

- Night work – as the amount of night work increases, so does the amount of sleep that must be attempted at biologically inappropriate times. Sleeping 'out of synch' with the body's biological clock results in reduced duration and quality of sleep. This in turn reduces the restorative value of sleep obtained.
- Research data indicates that shift workers obtain significantly less sleep than those who are not shift workers. Moreover, the quality of that sleep is also significantly reduced. Sleep loss during night work is typically 1 – 3 hours per day. Furthermore, sleep deprivation can accumulate across a block of shifts, which leads to higher fatigue.
- Taken together, both employers and employees have clear responsibilities with respect to managing fatigue. The basic responsibilities of both parties relate to ensuring that adequate sleep can be obtained between shifts so that fatigue does not reach dangerous levels during shifts. Thus, lack of sleep causes fatigue and sleep allows recovery from fatigue.
- Research by the Centre for Sleep Research at the University of SA [South Australia] has clearly demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. That is, significantly delayed response and reaction times, impaired reasoning, reduced vigilance [and] hand-eye co-ordination.

2.5.6 Most people who are fatigued do not realise how tired and impaired they are and disregard the warning signs of fatigue. Major indicators of severe fatigue include:

- incorrect reading of equipment
- missing a reference point
- not remembering the last command given
- giving wrong commands
- degraded mental abilities (including memory, decision making and perception)[9].

Occurrence 05-102, Train 627, Otane, 18 January 2005

3 Factual Information

3.1 Narrative

3.1.1 On Tuesday 18 January 2005, Train 627 was a southbound express freight train travelling from Napier to Palmerston North. The train consisted of a DX class locomotive and 31 wagons for a total gross weight of 509 t and a total length of 465 m and was crewed by a locomotive engineer.

3.1.2 On the same day, Train 626 was a northbound express freight train travelling from Palmerston North to Napier. The train consisted of a DX class locomotive and 19 wagons for a total gross weight of 394 t and a total length of 285 m and was crewed by a locomotive engineer.

3.1.3 On arrival at Hastings at about 1700, the locomotive engineer of Train 627 received a track warrant to proceed to Otane, where he was to berth on the main line and receive another track warrant to continue his journey.

[8] Author Professor Drew Dawson, University of South Australia Centre for Sleep Research.
[9] Source - Fatigue Management Guide for Canadian Pilots, Transport Canada, 2003.

3.1.4 While at Dannevirke at about 1705, the locomotive engineer of Train 626 was issued with track warrant 50 authorising his train to travel to Waipukurau and berth on the loop to cross Train 627.

3.1.5 Train 627 arrived at Otane at about 1757 and the locomotive engineer contacted the train controller for another track warrant. The train controller issued track warrant 51 authorising Train 627 to proceed from Otane to Takapau and berth on the main line to cross Train 626. The locomotive engineer of Train 627 read the track warrant back to the train controller, who confirmed the readback correct.

3.1.6 Train 626 was scheduled to shunt at Takapau and, while he was berthed on the loop and waiting to commence the shunt, the locomotive engineer heard the train controller issue track warrant 51 to the locomotive engineer of Train 627 at Otane. He realised that as he was already in possession of a track warrant to travel to Waipukurau, a conflicting track warrant had been issued and he immediately advised the train controller of the irregularity.

3.1.7 The train controller then called the locomotive engineer of Train 627, who confirmed that he had just been issued with a track warrant to proceed to the main line at Takapau to cross Train 626. The train controller told the locomotive engineer of Train 627 to stop his train, but he had already done so.

3.1.8 The trains were about 30 km apart and both were stationary when the irregularity was confirmed.

3.2 Site and track warrant information

3.2.1 Operations on the PNGL south of Hastings on the day included a planned crossing of northbound express freight Train 626 with southbound express freight Train 627 at Waipukurau. Such planned crossings were standard procedure on the single line track operated under the TWC system. Figure 3 shows the relationship of localities to the planned crossing.

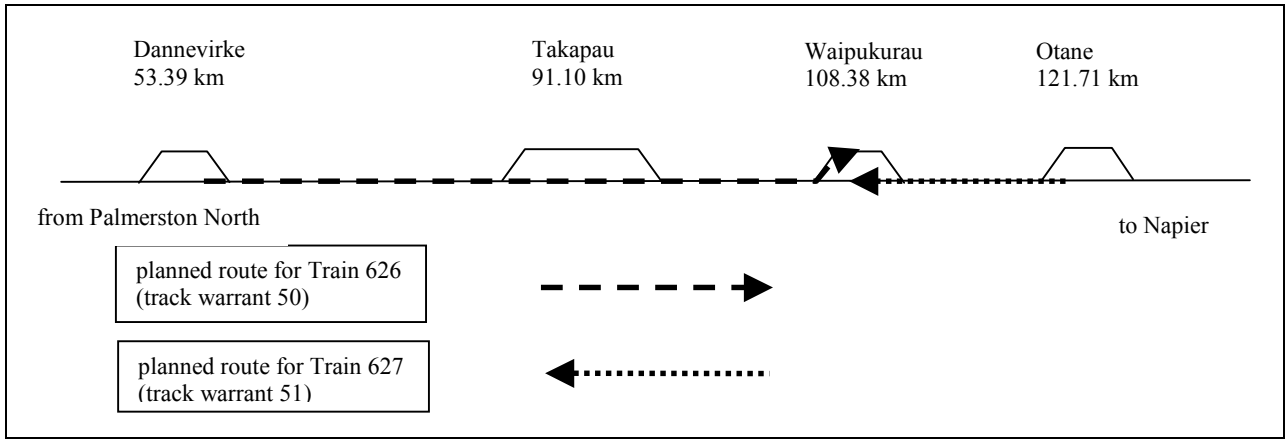


Figure 3
Relationship of localities to the planned crossing (not to scale)

3.2.2 Comparisons between the 2 track warrants as prepared in TWACS and as read out by the train controller are as follows:

- track warrant 50, as prepared, authorised Train 626 to proceed from Dannevirke to the loop at Waipukurau to cross Train 627 (see Figure 3)
- track warrant 50, as read out at 1705, authorised Train 626 to proceed from Dannevirke to the loop at Waipukurau to cross Train 627 (see Figure 4)
- track warrant 51, as prepared, authorised Train 627 to proceed from Otane to the main line at Waipukurau to cross Train 626 (see Figure 3)
- track warrant 51, as read out at 1757, authorised Train 627 to proceed from Otane to the main line at Takapau to cross Train 626 (see Figure 4).

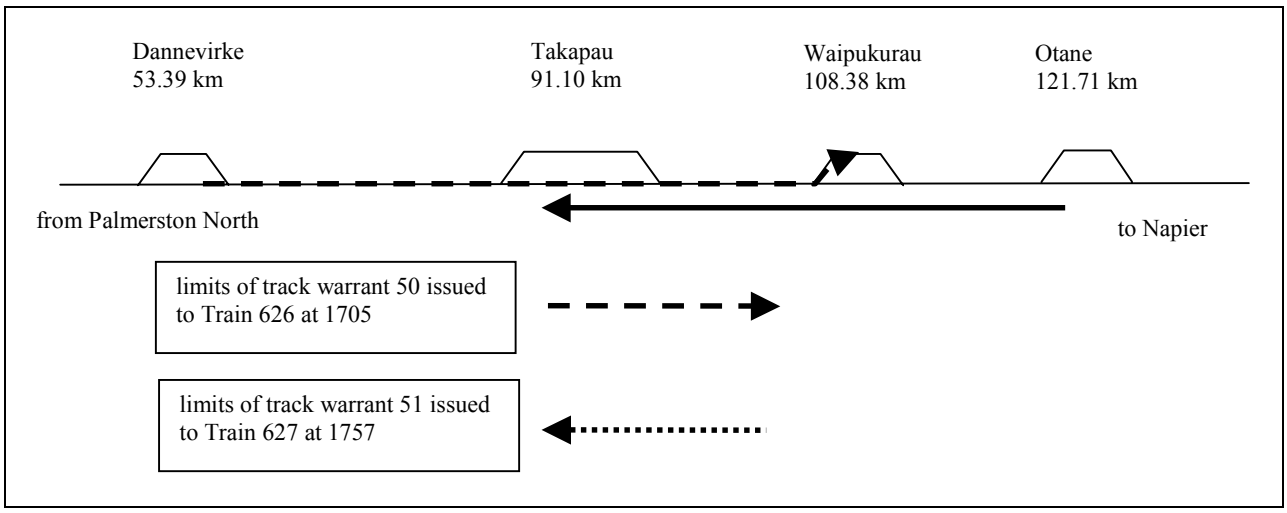


Figure 4
The limits of track warrants 50 and 51 as issued (not to scale)

3.3 Train control voice tape

3.3.1 A copy of the train control voice tape was supplied for analysis.

3.3.2 At about 1713 the train controller advised the roving shunter[10] that Train 626 would be arriving at Takapau at about 1750 to shunt. On completion of the shunt, Train 626 was to continue on to Waipukurau to cross Train 627. Both trains were required to shunt at Waipukurau.

3.3.3 Although only the train controller's side of the conversation could be heard, it was evident that the roving shunter had suggested that Takapau was a better crossing place than Waipukurau because of the convenience provided by the automatic signalling arrangements. The train controller was aware of that but said he needed the locomotives off Train 626 in Napier for a return service and was therefore prioritising that train.

3.3.4 At about 1747, the train controller made the comment to himself that he would be glad to get home.

3.3.5 Immediately after issuing track warrant 51 to Train 627, the train controller responded to a base call from Train 626 by asking the locomotive engineer if he required a signal to commence the shunt. It was then that the locomotive engineer of Train 626 challenged the train controller about track warrant 51.

3.4 Personnel

Locomotive engineer Train 626

3.4.1 The locomotive engineer held current certification for Grade 1 locomotive engineer's duties. He had about 30 years experience in locomotive running duties, all of which time he had been based in Napier. His rostered shift on this day included driving express freight Train 625 south from Napier to change over with Train 626 and return. He changed on to Train 626 at Dannevirke and called the train controller by radio for a track warrant to travel north.

3.4.2 Train 626 was required to shunt at Takapau en route to Waipukurau. The locomotive engineer said this made no difference to the track warrant authority as the points and signals at Takapau were controlled by the train controller so a separate authority was not required to enter the loop or sidings.

[10] A person who travels between stations to shunt trains as required.

3.4.3 The locomotive engineer said that when he was about to start the shunt at Takapau, he had with his radio on scan mode, expecting the roving shunter at Takapau to call with instructions regarding the forthcoming shunt, so he only heard the track warrant being issued in the background.

3.4.4 He realised that something was wrong because he already held a track warrant authorising him to proceed to the loop at Waipukurau to cross Train 627, and the track warrant he heard being issued conflicted with his authority. He immediately called the train controller and told him that he thought a track warrant had just been issued for Train 627 to proceed to the main line at Takapau.

3.4.5 He did not hear again from the train controller, but assumed he had checked with the locomotive engineer of Train 627 who had probably confirmed the error.

Locomotive engineer Train 627

3.4.6 The locomotive engineer held current certification for Grade 1 locomotive engineers' duties. He had about 30 years experience in locomotive running duties, the last 3 years operating over the PNGL. On this day he was rostered to take Train 627 to Palmerston North and return to Napier by road.

3.4.7 At Hastings he had received a track warrant from the train controller authorising his train to proceed to the main line at Otane. On arrival at Otane he berthed his train on the main line and called the train controller, who then issued track warrant 51 for Train 627 to continue to Takapau and berth on the main line.

3.4.8 The locomotive engineer wrote down the details of track warrant 51 as the train controller read it out, and he then confirmed it by reading the details back to the train controller. Once he had completed the readback, the train controller confirmed that the details were correct and completed the time of issue.

3.4.9 He had just started his train moving when he heard the locomotive engineer of Train 626 question the train controller about the limits of the track warrant issued to Train 627. He clearly heard that locomotive engineer ask the train controller if Train 627 had been authorised to the main line at Takapau as he (the locomotive engineer of Train 626) was currently at Takapau and in possession of a track warrant authorising him to continue on to Waipukurau. As soon as the locomotive engineer of Train 627 heard that, he brought his train to a stop.

3.4.10 He then received a call from the train controller, asking if he had been issued with a track warrant to proceed to the main line at Takapau. The locomotive engineer confirmed that this was the case and the train controller asked him to stop his train, which he had already done.

3.4.11 The locomotive engineer said that because he was in a different radio channel area he would not have expected to hear the issuing track of warrant 50 to Train 626 at Dannevirke. However, occasionally he had heard radio transmissions from trains in Dannevirke (on channel 3) while he was in Hastings (on channel 2).

The train controller

3.4.12 The train controller had 24 years experience in train control duties. His rostered shift on 18 January was from 0650 to 1500 on the Manawatu train control desk[11], after which, because of a staff shortage, he transferred to the Provincial train control desk[12] until 1900, an actual rostered shift of 12 hours and 10 minutes. This shift extension was because of a general staff shortage and was planned in advance to cover the shortage of train controllers in the roster and to allow for the training of a new recruit during that period.

[11] The Manawatu train control desk directed train movements from Otaki to Marton and New Plymouth and from Palmerston North to Woodville.
[12] The Provincial train control desk directed train movements from Masterton to Gisborne (PNGL) and from Waitakere to Otiria (North Auckland Line).

3.4.13 The train controller said that after the crew change between Trains 625 and 626 at Dannevirke, the incoming locomotive engineer for Train 626 had called him for a track warrant to proceed. The train controller issued track warrant 50 to the locomotive engineer, which authorised Train 626 to proceed to Waipukurau and berth on the loop.

3.4.14 At about 1755 the locomotive engineer of Train 627 had called him from Otane and requested a track warrant to continue his journey, so the train controller recovered track warrant 51 on the TWACS VDU and issued it by reading it out to the locomotive engineer. The train controller said that in the readout, for some reason, he had transposed Takapau for Waipukurau and did not detect his error when the locomotive engineer read back the track warrant[13].

3.4.15 As soon as the train controller had confirmed the track warrant readback as correct, the locomotive engineer of Train 626 queried him saying that he had a conflicting track warrant which authorised him to proceed to Waipukurau. The train controller questioned him but the locomotive engineer was adamant that was what he had heard, so the train controller immediately contacted the locomotive engineer of Train 627 who confirmed that he did have authority to proceed to the main line at Takapau.

3.4.16 Once the train controller realised the situation he instructed the locomotive engineer of Train 627 to stop his train. He ensured the signal authorising Train 626 to enter the Takapau to Waipukurau section was at stop then advised the network control manager of the circumstances.

3.4.17 The train controller said he had prepared a track warrant on TWACS for Train 627 to cross at Waipukurau, with Train 627 to berth on the main line because it was the longer train[14]. Both Train 626 and Train 627 were scheduled to shunt at Waipukurau and this berthing arrangement assisted that process. He had then filed the track warrant in TWACS until he needed to issue it to the locomotive engineer of Train 627.

3.4.18 He said that when the locomotive engineer of Train 627 called from Otane he had brought the prepared track warrant up on the TWACS VDU, confirmed it was correctly prepared for Otane to Waipukurau, then drew a corresponding blue plot line on the train control diagram before commencing the readout issue process. He did not know why he had transposed Takapau for Waipukurau during the read out of track warrant 51. He said he had earlier been talking to the roving shunter, when confirming that the shunter was to go to Takapau to shunt Train 626, then go on to Waipukurau to cross and shunt both Train 626 and Train 627, and he felt that may have been why Takapau had stuck in his mind. He said he had scrolled down the TWACS monitor as he read out the track warrant to the locomotive engineer and again as the track warrant was read back to him but that he had missed the transposing of Takapau for Waipukurau 4 times during the issue and read back process.

3.4.19 The train controller said he had felt a little tired when he had started his shift on the day of the incident. He also had a slight headache but said he had not considered that a problem at the time, although in hindsight it might have been. His shift on the Provincial train control desk had not been particularly busy, so he had spent time preparing train control diagrams and other paperwork for the following day.

3.4.20 The train controller said that he had gone to bed between 2100 and 2200 the previous evening but had not had a good night's sleep. He had woken at least twice during the night and he had risen at 0530 to ready himself for his shift, which commenced at 0650.

3.4.21 He said he did not usually go to bed on completion of his last rostered night shift, preferring instead to stay awake and relax around the house until it was time to go to bed that night. He had tried sleeping on the mornings he came off his last night shift but had then experienced difficulty getting to sleep that night.

[13] The train control tape confirmed that TW 51 was issued to the locomotive engineer of Train 627, and authorised his train to proceed from Otane to Takapua to cross Train 626.
[14] The train control diagram confirmed the crossing of the trains had been plotted for Waipukurau.

3.5 Rostering

Locomotive engineer Train 626

3.5.1 In the fortnight leading up to the incident the locomotive engineer had been rostered on duty for 54 hours 5 minutes and had actually worked for 68 hours and 45 minutes.

3.5.2 The incident happened about 5 hours 30 minutes into his shift, which had commenced at 1130 on Tuesday 18 January. He was on his first shift after 2 days off duty.

Locomotive engineer Train 627

3.5.3 In the fortnight leading up to the incident the locomotive engineer had been rostered on duty for 79 hours 10 minutes, the same hours as he actually worked.

3.5.4 The incident happened about 2 hours 50 minutes into his shift, which had commenced at 1410 on Tuesday 18 January. He was on his second consecutive shift after 2 days off duty.

The train controller

3.5.5 In the fortnight ending 18 December 2004 the train controller's posted roster[15] showed he had been rostered for, and worked, 99 hours. This included him working 2 extra work periods on what had originally been rostered as days off. As a result he worked 12 of the 14 days, 10 of those days consecutively.

3.5.6 In the fortnight ending 1 January 2005 his posted roster showed that he had been rostered for shifts totalling 83 hours 20 minutes and although his timesheet showed he had worked for 84 hours 20 minutes, this time included 6 days off work as rostered days off and statutory holidays.

3.5.7 The posted rostered and corresponding actual hours for the period 2 January to 17 January, the 16 days before the incident, are shown in the following table.

Date	Hours worked	Rostered hours	Actual hours
2 January (day 1)	1450 – 2300	8 hours 10 minutes	8 hours 10 minutes
3 January (day 2)	1450 – 2300	8 hours 10 minutes	8 hours 10 minutes
4 January (day 3)	1450 – 2300	8 hours 10 minutes	8 hours 10 minutes
5 January (day 4)		Rostered Day Off	Nil
6 January (day 5)	1350 - 2100	7 hours 10 minutes	7 hours 10 minutes
7 January (day 6)	2250 – 0700	8 hours 10 minutes	8 hours 10 minutes
8 January (day 7)	2250 – 0700	8 hours 10 minutes	8 hours 10 minutes
9 January (day 8)	2250 – 0700	8 hours 10 minutes	8 hours 10 minutes
10 January (day 9)	2250 – 0700	Rostered Day Off	8 hours 10 minutes
11 January (day 10)	2250 – 0700	Rostered Day Off	8 hours 10 minutes
12 January (day 11)		Rostered Day Off[16]	Nil
13 January (day 12)	0650 – 1500	8 hours 10 minutes	8 hours 10 minutes
14 January (day 13)	0650 – 1500	8 hours 10 minutes	12 hours 10 minutes
15 January (day 14)	0650 – 1500	8 hours 10 minutes	8 hours 10 minutes
Fortnight totals			**101 hours**
16 January (day 15)	0650 - 1500	8 hours 10 minutes	8 hours 10 minutes
17 January (day 16)	0530 - 1400	8 hours 30 minutes	8 hours 30 minutes
18 January (day 17)	0650 - 1900	12 hours 10 minutes	11 hours
Total			**126 hours 40 minutes**

[15] The posted roster was the actual roster the train controller was required to work, compiled from the agreed base roster but amended as necessary to allow for staff unavailability.
[16] Although the roster showed 12 January as RDO the train controller had already worked until 0700 that morning.

3.5.8 The incident happened at 1757 on day 17, when the train controller was about 11 hours into a 12 hours 10 minutes shift. The shift had originally been rostered for 8 hours 10 minutes but had been extended by 4 hours to cover staff shortages.

3.5.9 Days 4, 9, 10 and 11 were days he was rostered off duty. The use of days 9, 10 and 11 for this purpose allowed for a break of 3 days for him to recover after completing his third and last night shift at 0700 on day 8 and before starting his next shift at 0650 on day 12. When the train controller was called back to work on days 9 and 10 to fill vacancies on the roster caused by illness among train controllers, that recovery break was reduced to a single day.

3.5.10 The shifts worked by the train controller on days 9 and 10 were an extension of his previous 3 consecutive night shifts and meant that he had worked 6 consecutive shifts made up of one late shift and 5 night shifts. He had a break of about 26 hours between finishing the late shift on day 5 and starting his first night shift on day 6.

3.5.11 The train controller had worked 15 of the 17 days up to and including the day of the incident and 12 of the last 13 days.

3.5.12 In the 6 weeks preceeding the incident the train controller had worked 5 of his 10 rostered days off.

3.6 Sleep / wake information

3.6.1 The train controller's apparent loss of situational awareness prompted a close look at the possible role of fatigue in this incident. The Commission engaged Ms Leigh Signal, PhD, Associate Director of the Sleep/Wake Research Centre at Massey University in Wellington to assist in analysing the likelihood that sleep loss and fatigue were causal factors. Her input is included in Section 4, paragraphs 4.16 – 4.20.

4 Analysis

4.1 The train controller was an experienced shift worker who had developed a pattern of sleep for coping with night shifts. However, his pattern on completion of his last night shift was not to go to bed, but rather relax around home then go to bed that night, sleeping through until he awoke. In doing so he effectively lost a night's sleep, which added to the sleep debt he had accumulated as a matter of course during his 5 consecutive night shifts. The disrupted sleep he had on the night prior to the incident would have further added to his accumulated sleep debt. A safety recommendation covering fatigue management training has been made to the Chief Executive of ONTRACK.

4.2 In the 4 weeks preceeding the incident the train controller had worked on 4 of his rostered 7 days off, which contributed to his total fortnight hours for that period of 99 hours and 101 hours respectively. There can be numerous reasons why train controllers agree to work extra shifts over and above those for which they are originally rostered. They are:

- remunerative incentives
- loyalty to fellow train controllers, who may be unwell, less rested or have important commitments away from work
- concern about possible effects of refusal on relationships with other train controllers professional motivation to ensure that the system runs smoothly
- loyalty to the business
- ability to do so by qualification

4.3 The relatively small group within the total numbers of train controllers who were Level 3 qualified made those train controllers more often suitable for covering staff shortages. However, working additional shifts reduces the time available for all other activities away from

work, including opportunities for recovery sleep. More limited off-duty time may further increase the pressure to sacrifice sleep to meet other time demands such as household and family roles, or recreational activities.

4.4 The use of staff on rostered days off to fill vacancies to meet operational requirements was historical and not uncommon and was not unique to the train control office. However, the inclusion of rostered days off in the train control roster should have been primarily to ensure that train controllers had sufficient time off duty to recover from shifts worked, to rest for future shifts and for recreational purposes. These days should have been used as a counter to fatigue, but the regular practice of calling train controllers back to work negated the value of the rostered day off. A safety recommendation covering this issue has been made to the Chief Executive of ONTRACK.

4.5 Working additional shifts reduces the time available for all other activities away from work, including opportunities for rest and relaxation. Limiting off-duty time may further increase the pressure on individuals to sacrifice sleep, rest or relaxation to meet other demands such as household and family roles.

4.6 The extension of the train controller's night shift from 3 consecutive nights to 5 nights meant a reduction in his rest, recovery and recreational period from 3 days to one day before commencing his next shift rotation. This was clearly inadequate. By the end of this night shift rotation the train controller's performance would have deteriorated and, given his practice of not going to bed after completing his last night shift, he would have carried some residual tiredness and fatigue forward into his next shift rotation.

4.7 The train controller had 24 hours off duty after completing the last night shift before he started the day shift rotation. On the day preceding the incident, his shift had commenced at 0530 and finished at 1400. The early starts from home, required to commence his day shifts at 0650 (and 0530 the previous day), would have further added to any tiredness and fatigue arising from accumulated sleep debt from his previous extended night shift rotation.

4.8 For locomotive engineers, Tranz Rail[17] had addressed the practice of working excessive consecutive at-risk shifts with the introduction of a maximum number of such shifts that could be worked before a mandatory rest period. However, attempts to introduce similar rostering protocols for train controllers have been unsuccessful because of the mix of train controller competencies and a general shortage of resources. A safety recommendation covering these issues is made to the Chief Executive of ONTRACK.

4.9 The risk for locomotive engineers suffering from fatigue while working at-risk shifts is to fall asleep at the controls of the locomotive. That for train controllers in the same situation is more likely to be that of deterioration in performance caused by accumulated fatigue, which in turn could lead to a decline in operational proficiency and cognitive impairment, as was probably the case in this incident. Such a situation is an unacceptable risk in an operating environment and to reduce the possibility of this happening the train control roster procedures should have included both restrictions on the number of consecutive at-risk shifts which could be rostered as well as a requirement for a mandatory rest period following such a shift rotation. A safety recommendation covering this issue has been made to the Chief Executive of ONTRACK.

4.10 Following its establishment on 1 September 2004, ONTRACK inherited the issues relating to rostering and actual hours worked by train controllers from Toll Rail. From that time the train control function was separated from the operator's responsibility. However, Toll Rail had inherited the train control function from Tranz Rail Limited following its purchase of that company in May 2004, at which time the function still rested with the operator.

[17] Predecessor to Toll Rail

4.11 The rules applying to medium and short notice changes to the master roster enabled fortnightly shifts to be increased from 10 to 12, maximum actual hours to be increased from 85 hours to 110 hours and the maximum length of a shift to be extended from 8 hours 10 minutes to 12 hours 10 minutes. The mandatory minimum time off of 11 hours 30 minutes remained the same but was reduced to 10 hours by the Collective Employment Agreement. Although the train controller's posted hours, number of shifts and hours worked regularly exceeded the parameters determined in the master roster compilation process, they did remain within those parameters applying to medium and short notice changes and those conditions included in the Collective Employment Agreement. However, given present-day knowledge of sleep and fatigue effect on shift workers the hours of work permitted beyond the master roster compilation conditions were excessive and overdue for review with a view to better reflecting advances made in this field.

4.12 Some time earlier, the train controller had discussed with the roving shunter the requirement to shunt Train 626 at Takapau and the crossing and shunting of both trains at Waipukurau. The shunter had a preference for the crossing to take place at Takapau, but the train controller had reiterated that Waipukurau was his preference. It would therefore seem more likely that Waipukurau, rather than Takapau, would have been on his mind. Certainly his planning and plotting, and the preparation of track warrant 51, reinforced by the blue line plot immediately before issuing track warrant 51, confirmed that he had always intended the 2 trains would cross at Waipukurau.

4.13 When Train 627 arrived at Otane, the train controller recovered track warrant 51 on the TWACS VDU. He issued the track warrant to the locomotive engineer who read it back correctly. Unfortunately, in the locomotive cab there was no record of the track warrant as prepared in TWACS, so the locomotive engineer could only repeat back to the train controller what had been read out to him. Under the track warrant readout / readback procedure, the acknowledgement from the train controller therefore confirmed that the track warrant had been read back correctly, but could not confirm that the details of the track warrant corresponded to that prepared in TWACS. The readout / readback process was therefore not a defence against a slip[18] by the train controller either when reading out the details from the TWACS VDU or against missing any errors when scrolling through the TWACS version on the VDU during the read back. Had the locomotive engineer been able to verify the details against those of the original track warrant as prepared in TWACS, this would have provided an additional defence and it was likely that the error would have been identified at that time.

4.14 The track warrant readout / readback procedure provided 4 opportunities for the train controller to have identified the transposing of "Waipukurau" to "Takapau". However, he twice missed the opportunity while reading the track warrant out to the locomotive engineer, and twice more when it was read back to him. A safety recommendation covering the introduction of a cross-checking procedure for station names when preparing and issuing track warrants has been made to the Chief Executive of ONTRACK.

4.15 The train controller may possibly have been distracted and he may have neglected to follow the scroll-down procedure during both stages of the issue process. However, the shift had been very quiet so it was unlikely that other duties would have distracted him at this time, and this possibility has been discounted.

4.16 Cognitive skills are thought to be reliant on the functioning of the prefrontal region of the cerebral cortex, recent evidence has shown that this area of the brain is affected by as little as one night of sleep loss (References 1 - 4). In a recent publication, Harrison and Horne (5) discuss evidence that suggests a raft of cognitive skills are adversely affected by sleep loss. The skills that are affected include: attending to complex information while filtering out distractions, following a situation and recognising the need to apply new strategies, lateral thinking and innovation, risk assessment, maintaining interest, controlling mood and behaviour, the ability to self-monitor performance and the ability to communicate effectively.

[18] A slip is an unintentional action where the failure involves inattention. These are errors in execution.

4.17 The inability to adequately self-monitor performance is recognised as a fatigue-related change in performance. Transposing the correct place name in the track warrant with the name of a location that was recently used, and not detecting this error, was consistent with fatigue-related decrements to performance.

4.18 Time-on-task fatigue refers to reduced performance as a consequence of continuously performing mental or physical tasks (6). Complex tasks and tasks involving vigilance are particularly susceptible to this type of decrement (7). Time-on-task fatigue is exacerbated by both acute sleep loss and a cumulative sleep debt (8, 9). Time-on-task fatigue can be minimised with the provision of adequate rest breaks within a shift and limiting the duration of a shift. The length of a work period before a rest break occurs, and the duration of the rest break, are somewhat dependent on the type of task being performed. Early work done in this area demonstrated that performance declined consistently over time and that breaks of as little as 5 minutes could improve performance (10).

4.19 The length of time on duty prior to the incident is of some concern. There is no information available on the frequency or duration of rest breaks taken by the train controller during the 11 hours preceding the incident. However, it is understood that there is no system in place for ensuring that scheduled breaks away from the desk occur, although toilet and refreshment facilities are close by. It would be expected that the train controller's ability to remain vigilant would decline across the course of the shift if insufficient rest breaks were taken.

4.20 The train controller had changed over to a less busy desk and as a result had time off task as he completed other duties not directly involving active train control duties. This reduced workload probably also offered him an opportunity to partake of a break but it is doubtful that either of these factors would have adequately compensated him for the extended shift he was rostered to work. Recommendations from an expert advisory group in the trucking industry suggest that at a minimum, breaks should be at least 15 minutes duration and after every 5 hours of work (11).

4.21 Acute sleep loss results from both total sleep loss and also a single night of sleep restriction. It has been shown that curtailing sleep for one night by as little as 2 hours produces measurable increases in sleepiness (12) while decrements in performance are most apparent once sleep is restricted to 5 hours or less in a single night (13). It is not only the amount of sleep obtained but also the quality of sleep that is important. Disturbed sleep is clearly related to increased sleepiness and decreased performance and mood (14).

4.22 Train 626 had arrived at Takapau at about 1754 but the locomotive engineer had not immediately switched his radio to channel 1 to talk with the shunter. As a result, at 1757, he heard the train controller read out track warrant 51 to the locomotive engineer of Train 627 when his scanner locked on to channel 2, followed by the readback, and was therefore able to challenge the train controller once he thought an error had been made. Had he changed his radio to channel 1 immediately before, or on arrival at Takapau, he would not have overheard the issuing of track warrant 51 and therefore would not have been in a position to challenge the train controller. Instead Train 627 would have departed Otane with the locomotive engineer in possession of a track warrant to cross Train 626 at a station beyond that to which Train 626 was already authorised to advance for the same crossing.

4.23 The alertness of the locomotive engineer of Train 626 prevented a possible head-on collision situation between the 2 trains. Although the defences inherent in the TWACS track warrant preparation process would have prevented the train controller from preparing a track warrant to advance Train 627 to Takapau, there was no defence in the audio / visual track warrant issue process to prevent the inadvertent transposing of track warrant limit station names. The plotting on the train control diagram confirmed that the train controller had planned for, and intended the crossing to take place at Waipukurau. However, once Train 627 had departed from Otane, there would have been no further opportunity to avoid a potential head-on collision with Train 626.

4.24 After completing the shunt at Takapau, the locomotive engineer required permission from the train controller to enter the Takapau to Waipukurau section. This permission was a clear proceed indication on Signal 8RB and the train controller could only give this authority when the locomotive engineer was in possession of the necessary track warrant to continue which, in this case, he was. Before clearing the signal the train controller was required to check his plotting on the train control diagram. However, such a check in this instance would have shown that the crossing of Trains 626 and 627 was plotted for Waipukurau and, as the diagram would have also confirmed that both Trains 626 and 627 had been issued with the relevant track warrants to proceed to Waipukurau, there would have been nothing that would have alerted him to the mistake in his earlier issuing of track warrant 51 to Train 627 at Otane and he would probably have cleared the signal.

4.25 Only seconds after issuing track warrant 51 to the locomotive engineer of Train 627, the train controller received a base call from Train 626. He had responded by asking the locomotive engineer if he required a light to do the shunt. The light referred to was a proceed indication on Signal 8RB to provide extra room for Train 626 to shunt. This same signal authorised a departure from Takapau and the train controller's offer, coming as it did only seconds after he had issued track warrant 51, showed that at that time he believed the trains were going to cross at Waipukurau as planned. It was not until the locomotive engineer of Train 626 challenged him that he became aware of the irregularity, and without that fortuitous alert it was unlikely that he would have realised his error.

Occurrence 05-101, Train 624, Woodville, 18 January 2005

5 Factual Information

5.1 Narrative

5.1.1 On Tuesday 18 January 2005, Train 624 was a northbound express freight train travelling from Palmerston North to Napier. The train consisted of 2 DX class locomotives in multiple and 19 wagons for a total gross weight of 471 t and a total length of 315 m and was crewed by a locomotive engineer.

5.1.2 On the same day Train 629 was a southbound express freight train travelling from Napier to Palmerston North. The train consisted of a DX class locomotive and 28 wagons for a total gross weight of 625 t and a total length of 435 m and was crewed by a locomotive engineer.

5.1.3 At about 0410, the locomotive engineer of Train 629 had received a track warrant at Hastings for his train to proceed to Makotuku and berth on the main line to cross Train 624.

5.1.4 At about 0452, the locomotive engineer of Train 624 received a track warrant at Woodville authorising his train to proceed to Makotuku and berth on the main line to cross Train 629. The track warrant also contained an instruction for the locomotive engineer to call train control at Dannevirke.

5.1.5 When he had passed through Dannevirke, the locomotive engineer of Train 624 called train control and confirmed that he held a track warrant to proceed to Makotuku and berth on the main line to cross Train 629. The train controller responded that the track warrant should read to berth on the loop, at which point both the locomotive engineer and the train controller realised that the track warrants issued to the locomotive engineers of Trains 624 and 629 instructed them both to berth on the main line at Makotuku.

5.1.6 The train controller instructed the locomotive engineer of Train 624 to continue on to Makotuku but to stop before entering the station and he would be issued with a new track warrant to alter the berthing arrangements.

5.1.7 Train 629 was required to shunt at Takapau, and before departing after the shunt the locomotive engineer called the train controller who confirmed that Train 624 was berthed on the loop at Makotuku to cross Train 629.

5.2 Site and track warrant information

5.2.1 Operations on the PNGL south of Hastings on the day included a planned crossing of northbound express freight Train 624 with southbound express freight Train 629 at Makotuku. Such planned crossings were standard procedure on the single line track operated under the TWC system. Figure 4 shows the relationship of localities to the planned crossing.

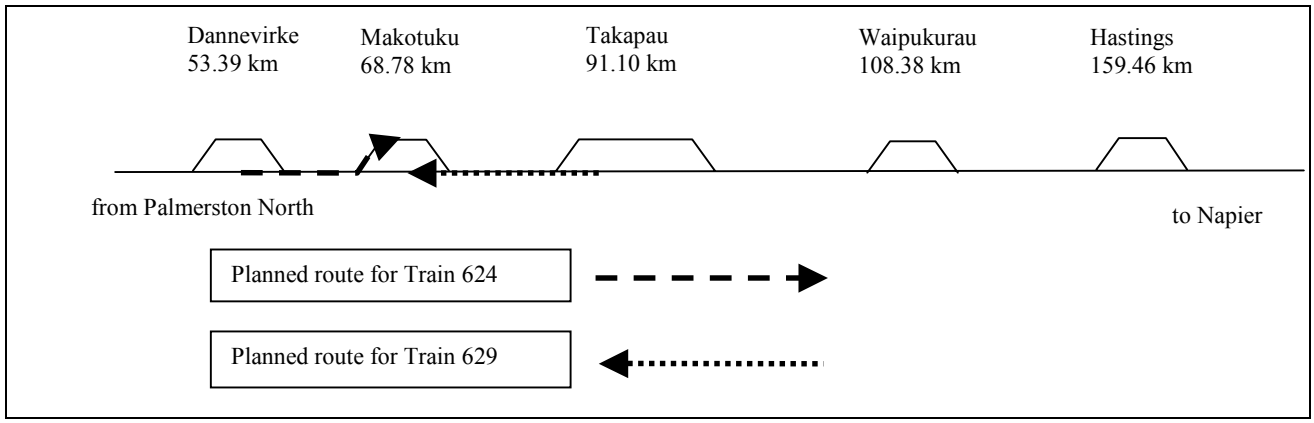


Figure 5
Relationship of localities to the planned crossing (not to scale)

5.2.2 Comparisons between the 2 track warrants as prepared in TWACS and as read out by the train controller:

- track warrant 5, as prepared, authorised Train 629 to proceed from Hastings to the main line at Makotuku to cross Train 624 (see Figure 5)
- track warrant 5, as read out at 0413, authorised Train 629 to proceed from Hastings to the main line at Makotuku to cross Train 624 (see Figure 6)
- track warrant 6, as prepared, authorised Train 624 to proceed from Woodville to the loop at Makotuku to cross Train 624 (see Figure 5)
- track warrant 6, as read out at 0454, authorised Train 624 to proceed from Woodville to the main line at Makotuku to cross Train 624 (see Figure 6).

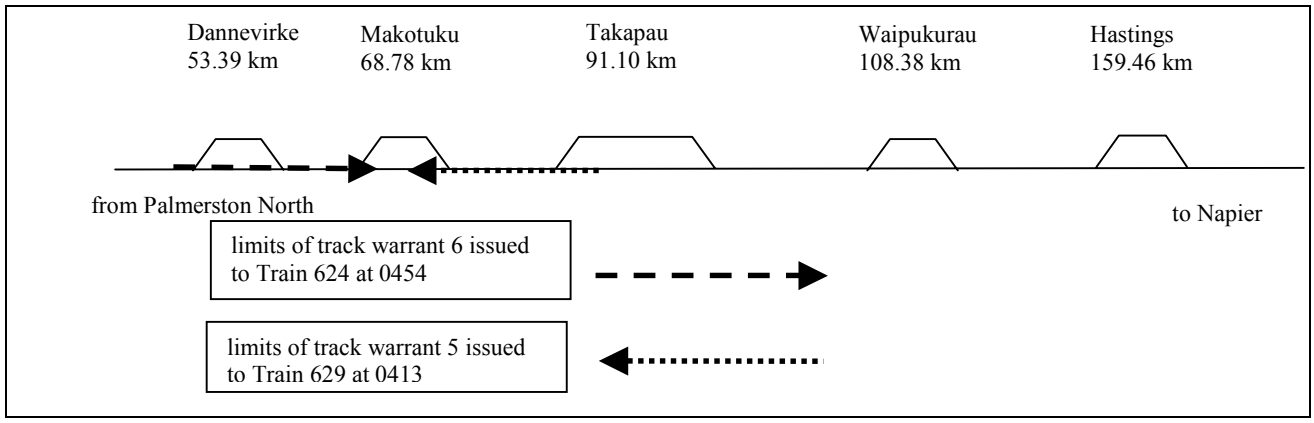


Figure 6
The limits of track warrants 5 and 6 as issued (not to scale)

5.3 Personnel

Locomotive engineer Train 629

5.3.1 The locomotive engineer held current certification for Grade 1 locomotive engineers' duties. He had about 25 years experience in locomotive running duties, for all of which he had been based in Palmerston North. His original rostered shift for the day had been as depot duties driver but his duties had been changed and instead he drove Train 622 from Palmerston North towards Napier to change over with Train 629, which was running about 6 hours late, and return to Palmerston North.

5.3.2 He changed from Train 622 on to Train 629 at Hastings then radioed the train controller for a track warrant to commence his return journey. He was issued with track warrant 5, which authorised his train to proceed from Hastings to Makotuku and berth on the main line to cross Train 624.

5.3.3 As he approached Makotuku the locomotive engineer radioed the locomotive engineer of Train 624 on channel 1 to ascertain his whereabouts[19]. The locomotive engineer of Train 624 confirmed that his train was berthed on the loop at Makotuku and that Train 629 was clear to enter the main line.

5.3.4 The locomotive engineer said that at the time he arrived at Makotuku he was unaware that a track warrant irregularity had earlier occurred.

Locomotive engineer Train 624

5.3.5 The locomotive engineer held current certification for Grade 1 locomotive engineers' duties. He had about 25 years experience in locomotive running duties, for all of which he had been based in Palmerston North. His rostered shift for the day was to drive Train 624 to Napier and return to Palmerston North by road.

5.3.6 On arrival at Woodville, the locomotive engineer had called train control and received a track warrant for his train to proceed to the main line at Makotuku to cross Train 629. The track warrant included an instruction for him to call train control when he passed through Dannevirke. The locomotive engineer wrote down the details of the track warrant as the train controller read it out, and he then read it back to the train controller. Once he had completed the read back the train controller confirmed that the details were correct and timed the track warrant.

5.3.7 The locomotive engineer had been aware that Train 629 was running very late and that he would cross it somewhere, and there had been nothing unusual in the read out or read back of the track warrant at Woodville.

5.3.8 He radioed train control as his train cleared Dannevirke and advised the train controller that he was in possession of a track warrant to Makotuku, where his train was to berth on the main line to cross Train 629. The train controller challenged him and said the track warrant should read Train 624 to take the loop but the locomotive engineer confirmed his copy read to take the main line.

5.3.9 The locomotive engineer said the train controller then realised that both trains had instructions to berth on the main line at Makotuku; he was then instructed to continue on but to stop before entering Makotuku, where the train controller would reissue the track warrant to correct the berthing arrangements.

[19] When trains were crossing at a TWC station the locomotive engineers were required to establish the whereabouts of each other by calling on radio channel 1as they approached.

The train controller

5.3.10 The train controller had about 5 years experience in train control duties. His shift had started at 2250 the previous day and was due to finish at 0700. He was operating the Wellington[20] and Hawkes Bay train control desks.

5.3.11 The train controller said it had been a quiet shift, with Trains 624 and 629 the only trains moving at the time. He said that when he received the radio call from Train 624 at Woodville he had issued track warrant 6 to the locomotive engineer, but in doing so he read out the wrong berthing instructions and instructed Train 624 to berth on the main line, instead of the loop, to cross Train 629.

5.3.12 He realised his error only when the locomotive engineer of Train 624 called him clear of Dannevirke. Train 629 still had to shunt at Takapau and could not leave there without the train controller clearing a signal so, as he was satisfied the trains would not conflict, he instructed the locomotive engineer of Train 624 to continue on to Makotuku but stop before entering the station, at which time the train controller would reissue the track warrant to regularise the berthing arrangements.

5.3.13 He recalled there had been some radio interference at the time the locomotive engineer had read back track warrant 6, but a replay of the train control audio tape had not identified anything unusual. However, the playback had confirmed to him that he had incorrectly read out the berthing instructions and, when the locomotive engineer repeated the track warrant containing the error, the train controller had confirmed it as correct.

5.3.14 The train controller said he had not been sleeping well prior to the incident. The weather had been hot and, although he had made arrangements to cool the room, he was still having difficulty sleeping. He had also being doing several night shifts as well as being rotated on different shifts, and had found it difficult keeping up with his change of shifts and when he should be sleeping and when not to.

5.3.15 The train controller said that his last extended break from work had been a two-week period of annual leave about 4 months earlier.

5.4 Rostering

Locomotive engineer Train 629

5.4.1 In the fortnight leading up to the incident the locomotive engineer had been rostered on duty for 45 hours 20 minutes and had actually worked for 45 hours and 30 minutes.

5.4.2 The incident happened about 7 hours 50 minutes into his shift, which had commenced at 2200 the previous night. He was on his fifth consecutive shift, his first night shift, after a day off duty.

Locomotive engineer Train 624

5.4.3 In the fortnight leading up to the incident the locomotive engineer had been rostered on duty for 82 hours 45 minutes and had actually worked for 78 hours 25 minutes.

5.4.4 The incident happened about 2 hours 20 minutes into his shift, which had commenced at 0330. He was on his first shift after 3 days off duty.

[20] The Wellington train control desk controlled train movements from Wellington to Otaki.

The train controller

5.4.5 In the fortnight ended 18 December 2004 the train controller's posted roster showed he had been rostered for, and worked, 93 hours 50 minutes. He had worked 11 shifts during the fortnight.

5.4.6 In the fortnight ended 1 January 2005 the train controller's posted roster showed he had been rostered for, and worked, 89 hours 50 minutes. He had worked 11 shifts during the fortnight.

5.4.7 In the fortnight ended 15 January 2005 the train controller's posted roster showed he had been rostered for 90 hours 50 minutes and had worked 95 hours 10 minutes. He had worked 11 shifts during the fortnight.

5.4.8 The posted rostered and corresponding actual hours for the train controller for the 7 days before the incident are shown in the following table:

Date	Hours worked	Rostered hours	Actual hours
11 January (day 1)	2150 - 0700	9 hours 10 minutes	9 hours 10 minutes
12 January (day 2)	2250 - 0700	8 hours 10 minutes	8 hours 10 minutes
13 January (day 3)	2250 - 0700	8 hours 10 minutes	8 hours 10 minutes
14 January (day 4)	2250 - 0700	8 hours 10 minutes	8 hours 10 minutes
15 January (day 5)	2250 - 0700	8 hours 10 minutes	8 hours 10 minutes
16 January (day 6)		RDO[21]	Nil
17 January (day 7)	2250 - 0700	8 hours 10 minutes	8 hours 10 minutes
18 January (day 8)	2250 - 0700	8 hours 10 minutes	6 hours

5.4.9 The incident happened at 0450 on day 8, when the train controller was about 6 hours into an 8 hour 10 minutes shift.

5.4.10 The train controller had been rostered off duty on 22 December following a shift rotation of 6 consecutive shifts comprising 3-day shifts (0650 - 1500) and 3 late shifts (1450 - 2300). However he had been called back to work 1850 - 2300 on that day to cover absences in the train control office.

5.4.11 His next shift rotation started at 1850 on 23 December when he commenced a shift rotation of 4 night shifts (2250 - 0700) by working a shift of 12 hours and 10 minutes, again to cover a shortage of train controllers.

5.4.12 On Saturday 1 January, the train controller had finished his third consecutive late shift at 2300 and had commenced duty again at 0650 on Sunday 2 January at the start of a shift rotation of 6 consecutive shifts comprising 3 day shifts and 3 late shifts.

5.4.13 The train controller had worked a shift rotation of 6 consecutive day shifts from Monday 6 December up to and including Saturday 11 December. From Sunday 12 December up to and including Monday 17 January he worked 3 consecutive day shifts (2 January to 4 January inclusive), the rest of the work period being taken up with a mix of 12 late shifts and 14 night shifts.

5.4.14 From 5 December 2004 to 17 January 2005, the train controller had 10 rostered days off duty. Of these he had worked until 0700 on the morning on 3 occasions and had been called back to work on another.

5.4.15 On Monday 10 January, the train controller commenced a shift rotation of 5 consecutive night shifts, finishing at 0700 on Saturday 15 January, which was also a rostered day off. At 2250 on Sunday 16 January he started another shift rotation of 5 consecutive night shifts to finish at 0700 on Thursday 20 January. The incident happened on the second of these shifts.

[21] Although the roster showed 16 January as RDO the train controller had already worked until 0700 that morning.

5.4.16 The posted roster showed that on Monday 24 January the train controller was rostered to commence a shift rotation of 6 consecutive shifts comprising 2 day shifts, 1 late shift and 3 night shifts.

5.5 Sleep / wake information

5.5.1 The train controller's apparent disrupted circadian body clock arising from frequent roster changes over a significant time prompted a close look at the possible role of fatigue in this incident. The Commission engaged Ms Leigh Signal, PhD, Associate Director of the Sleep/Wake Research Centre at Massey University in Wellington to assist in analysing the likelihood that sleep loss and fatigue were causal factors**.** Her input is included in Section 6, paragraphs 6.1 – 6.5.

6 Analysis

6.1 Humans have peaks and troughs in daily functioning across a range of physiological and behavioural variables, including temperature, hormone levels, the sleep-wake cycle, mood and performance (Reference 15). These daily variations are controlled by a group of cells located in the brain referred to as the circadian biological clock. The circadian clock effectively "programmes" us for wakefulness during the day and sleep at night. Due to the circadian biological clock, sleepiness is maximal in the early hours of the morning (0300 - 0500) with another, smaller peak in the middle of the afternoon (16). However, performance and alertness can be affected throughout the 12 am to 8 am window (17).

6.2 The circadian system also helps maintain wakefulness during the day, making it difficult for individuals who are working at night and sleeping during the day to obtain sufficient sleep. In fact, some workers get approximately 2 – 4 hours less sleep per 24 hours than day workers (18). Thus for a shift worker, consecutive night shifts are likely to result in the rapid accumulation of a sleep debt.

6.3 The circadian clock keeps in time with the 24-hour day-night cycle by environmental cues, particularly exposure to light (19). The pattern of work and rest, physical activity (20) and social interaction (21) are additional, weaker cues that help keep the clock in time with the day-night cycle.

6.4 When a shift worker changes to a new shift schedule, such as working at night and sleeping during the day, many of the cues that keep the circadian clock in time with the day-night cycle encourage the circadian pacemaker to shift to the new pattern of work and rest. As a consequence, the body's systems get out of step with the day-night cycle and each other, like after travel to a new time zone.

6.5 For a shift worker there is a further complication. The change in the pattern of work and rest creates conflicting cues for the circadian clock, which attempts to adapt to the new pattern of activity and sleep, but is constantly drawn back to its diurnal orientation by exposure to daylight. The result is incomplete adaptation to the new work pattern (22).

6.6 The incident occurred at 0450, a time at which performance is most impaired in the 24-hour cycle for someone who is diurnally orientated. Despite his best efforts, the train controller had experienced difficulty sleeping during the day, suggesting he was obtaining less sleep than he required. His work pattern had included frequent changes between shifts, which were likely to have caused constant disruption to his circadian rhythms and his sleep.

6.7 Between finishing duty at 2300 on Tuesday 21 December and starting again at 2250 on Thursday 23 December the train controller originally had a rostered break off duty of nearly 48 hours (including a rostered day off on Wednesday 22 December). However, he was called back to work 1900 – 2350 (nearly 5 hours) on Wednesday. This change reduced his previously rostered off duty time from a continuous break of about 48 hours to two separate breaks of

20 hours and 24 hours respectively. However, another roster change brought his starting time on Thursday forward to 1850 and consequently reduced his second break to 20 hours before commencing what was then a shift of 12 hours 10 minutes duration.

6.8 The calling back to work of train controllers on their rostered days off was discussed in Rail Occurrence Report 05-102, which covered the earlier track warrant incident at Otane, and a safety recommendation covering this issue has been made to the Chief Executive of ONTRACK.

6.9 The train controller's rostered day off on Day 6 came after he had completed a night shift rotation at 0700 that morning, which meant that the rostered day off was already reduced to 17 hours. This had also happened on 2 previous occasions.

6.10 Rostered days off should have been provided to ensure that train controllers had adequate off duty time to recover from shifts worked, to rest for future shifts and for recreational purposes. During his break of 40 hours, which included only one normal sleep period on the night of Day 6, the train controller was expected to recover from the fatigue effects of sleep debt accumulated during the previous night shift rotation, enjoy some recreational time and attend to any family or personal matters before preparing himself again for another rotation of night shifts. The time off between the rotations was clearly inadequate for him to have sufficiently recovered from the first night shift rotation, much less prepare for the second night shift rotation and attend to any of his other responsibilities.

6.11 The lack of recovery and preparation time between the train controller's rostered rotations would have contributed to his difficulty keeping up with his changes of shifts and his confusion as to when he should be sleeping and when he should not be. He had a rostered break of only 40 hours, which included only one normal night's sleep, between completing the first roster rotation of 5 consecutive night shifts and starting the second consecutive night shift rotation. It was therefore likely that he approached the second night shift rotation without adequate sleep recovery and preparation, which resulted in him carrying forward a residual sleep debt accumulated during the previous rotation.

6.12 In the 5 weeks preceding the incident, the train controller had worked 26 late or night shifts, interspersed with only one shift rotation of 3 consecutive day shifts 2 weeks prior to the incident. It was therefore not surprising that his sleep patterns and routine were disrupted, and he was undoubtedly suffering from fatigue caused by accumulated sleep debt as a result.

6.13 Had the incident had not happened, the train controller would probably have been available for all his rostered work periods up until Saturday 29 January. He would then have worked 5 day shifts, 13 late shifts and 20 night shifts since 12 December.

6.14 The train controller's planning and plotting, reinforced by the blue line plot immediately before issuing track warrant 6, confirmed that he had intended for Train 624 to berth in the loop at Makotuku. When he became aware of the irregularity regarding the berthing arrangements at Makotuku he immediately satisfied himself that there was no likelihood of a collision between the trains and then instituted procedures that allowed both trains to advance without creating a potential head-on collision situation. His recovery actions were safe and appropriate and in accordance with documented TWC procedures.

6.15 As previously highlighted the locomotive engineer was not able to access the TWACS prepared track warrant. As a result he was totally dependent on the information being verbally transmitted by the train controller, and the readback to, and confirmation by, the train controller was not an effective defence against incorrect information being transmitted and being confirmed as correct. Again, the confirmation from the train controller to the locomotive engineer was that the readback had been correct, not that the information it contained was necessarily correct. If the locomotive engineer had been able to verify the readout details against those of the original track warrant as prepared in TWACS, this would have provided an additional defence, and it is likely that the error would have been identified at that time.

7 Findings

Findings and safety recommendations are listed in order of development and not in order of priority.

05-102 Otane 18 January 2005

7.1 Train 626 and Train 627 were being correctly operated at the time and the actions of the respective locomotive engineers did not contribute to the incident.

7.2 Neither rostered hours, nor the hours actually worked by the locomotive engineers of Trains 626 and 627 were excessive and did not contribute to the incident.

7.3 The track warrant irregularity was identified because of the locomotive engineer's alertness, with a large element of good luck and not from any safety defences within the track warrant issue procedure.

7.4 The challenge by the locomotive engineer of Train 626 to the train controller prevented a potential head-on collision between the trains.

7.5 Although the posted rostered hours for the train controller for the fortnight 5 December 2004 to 18 December 2004 met the guidelines for medium and short notice changes, they were excessive.

7.6 Although the posted rostered hours for the train controller for fortnight 2 January 2005 to 15 January 2005 met the guidelines for medium and short notice changes, they were excessive.

7.7 The train controller's multi desk qualification made him one of the few train controllers available to fill vacancies and ultimately contributed to the excessive hours he worked.

7.8 The performance of the train controller was probably impaired due to a cumulative sleep debt.

7.9 Any time-on-task fatigue caused by a lack of insufficient breaks during the extended shift would have been further compounded by the effect of the sleep loss.

05-101 Woodville 18 January 2005

7.10 Train 624 and Train 629 were being correctly operated at the time and the actions of the respective locomotive engineers did not contribute to the incident.

7.11 Neither rostered hours, nor the hours actually worked by the locomotive engineers of Trains 624 and 629 were excessive and did not contribute to the incident.

7.12 There was no likelihood of a collision between Train 624 and 629 as a result of the inadvertent transposing of the berthing arrangements by the train controller.

7.13 The recovery actions of the train controller when he became aware of the irregularity regarding the berthing instructions for Makotuku were safe and appropriate.

7.14 The train controller was probably suffering the effects of fatigue arising from accumulated sleep debt as a result of the excessive number of late and night shifts he had worked in the 6 weeks leading up to the incident.

7.15 Disrupted circadian biological rhythms as a result of the number of shift changes he had experienced over a significant length of time would also have contributed to his fatigue.

Common

7.16 The use of staff on rostered days off to cover staff shortages within train control reduced their recovery time, preparation time and recreation time between shift rotations to an inadequate level.

7.17 Although ONTRACK had a system for monitoring total posted roster hours and actual hours worked each fortnight by train controllers, the system was reactive and did not restrict or control shifts or total hours worked..

7.18 The readout / readback process for issuing track warrants did not provide a defence against the inadvertent transposing of track warrant limit station names by the train controller.

7.19 The confirmation following the read back of a track warrant could be for the correctness of the read back but could not imply that the information corresponded with that stored in TWACS and visible to the train controller on the VDU before him.

7.20 There was no facility in the locomotive cab to enable the locomotive engineer to compare track warrant information received verbally from the train controller with that contained in TWACS.

8 Safety Recommendations

8.1 On 2 March 2005, the Commission recommended to the Chief Executive of ONTRACK that he:

> initiate changes to the Track Warrant Computer System to introduce a cross check function in the Clause 3 "to location" field when train controllers are issuing previously prepared track warrants (024/05).

8.2 On 14 April 2005 the Chief Operating Officer of ONTRACK replied in part:

> New Zealand Railways Corporation (NZRC) intend to implement this recommendation.
>
> A fixed date cannot be supplied for full implementation of this recommendation, however we are currently working through a timeframe for this to occur.

8.3 On 8 August 2005, ONTRACK advised:

> During readout of Track Warrants the Train Controller will be required to confirm the clause 3 'to location' from a selection menu in TWACS. The selected location must match the location selected when the track warrant was prepared. The readout process cannot continue until this action has been successfully completed.
>
> ONTRACK plan to implement this change by the end of September 2005.

8.4 On 15 July 2003, the Commission made the following safety recommendation to the Managing Director of Tranz Rail relating to train control rostering procedures and was included in Railway Occurrence Report 02-118 regarding a near collision between an express freight train and a hi-rail vehicle at Tauranga on 7 August 2002:

> put in place control measures to ensure:
>
> - posted rosters are controlled within defined criteria compatible with the principles used in compiling base rosters
> - defined criteria are met before offering extra shifts to train controllers
> - actual hours are monitored and immediate corrective action is taken when operating or other factors increase rostered shifts beyond defined acceptable levels (008/03)

8.5 On 9 July 2003, the Managing Director of Tranz Rail accepted the Preliminary Safety Recommendation, which was subsequently adopted unchanged as the Commission's Final Safety Recommendation.

8.6 The Commission redirected this safety recommendation to the Chief Executive of ONTRACK on 15 March 2005. The safety recommendation is equally applicable to these incidents.

8.7 On 6 December 2005 the Commission recommended to the Chief Executive of ONTRACK that he:

> introduce into existing train control rostering procedures a defined maximum number of consecutive at-risk (night) shifts that may be worked together with provision for a mandatory rest period before commencing the next shift rotation (097/05)
>
> and
>
> ensure that adequate appropriately trained staff are available to enable relief for vacancies amongst train controllers as a result of sickness etc to be undertaken without calling on staff rostered for or already on mandatory rest periods between shifts (098/05)
>
> and
>
> ensure that where a train control shift is extended beyond 8 hours a mandatory break of at least 15 minutes is available to the train controller as close as practicable to the start of the shift extension (099/05)
>
> and
>
> ensure that existing fatigue management training programmes include, but are not limited to, issues such as sleep practices, lifestyle, family commitments and the use of drugs including alcohol and stimulants etc (100/05).

8.8 On 19 December 2005 the Chief Operating Officer of ONTRACK replied in part:

> ONTRACK accept and will implement recommendations 097/05, 098/05 and 100/05. The time frame for implementation of these recommendations is yet to be determined.
>
> In regard to recommendation 099/05, a further review is required to be carried out before ONTRACK can decide whether this recommendation can be implemented.

Approved on 16 December 2005 for Publication

Hon W P Jeffries
Chief Commissioner

References

1. Petiau, C, Harrison, Y, Delfiore, G, et al., *Modification of fronto-temporal connectivity during a verb generation task after a 30 hour total sleep deprivation: a PET study.* Journal of Sleep Research, 1998. **2**(Supplement 2): p. 208.

2. Drummond, SPA, Brown, GA, Stricker, JL, et al., *Sleep deprivation-induced reduction in cortical functioning response to serial subtraction.* NeuroReport, 1999. **10**: p. 3745-3748.

3. Drummond, SPA, Brown, GA, Gillin, JC, et al., *Altered brain response to verbal learning following sleep deprivation.* Nature, 2000. **403**: p. 655-657.

4. Thomas, M, Sing, H, Belenkey, G, et al., *Neural basis os alertness and cognitive performance impairments during sleepiness. I. Effects of sleep deprivation on waking human regional brain activity.* Journal of Sleep Research, 2000. **9**: p. 335-352.

5. Harrison, Y and Horne, JA, *The impact of sleep deprivation on decision making: A review.* Journal of Experimental Psychology: Applied, 2000. **6**(3): p. 236-249.

6. Sanders, MS and McCormick, EJ, *Human Factors in Engineering and Design*. 7th ed ed. 1993, Singapore: McGraw-Hill.

7. Holding, DH, *Fatigue*, in *Stress and Fatigue in Human Performance*, G.R.J. Hockey, Editor. 1983, Wiley: New York. p. 145-167

8. Dorrian, J, Rogers, NL, and Dinges, DF, *Behavioral alertness as measured by psychomotor vigilance performance: a neurocognitive assay sensitive to the effects of sleep loss*, in *Sleep Deprivation: Clinical Issues, Pharmacology and Sleep Loss Effects.*, C.A. Kushida, Editor. 2005, Marcel Dekker: New York. p. 39-70.

9. Van Dongen, HPA, *Time-on-task fatigue with increasing chronic sleep loss*, T.L. Signal, Editor. 2005.

10. Mackworth, JF, *Vigilance and Attention: A Signal Detection Approach*. 1970, Middlesex: England: Penguin Books Inc.

11. Fatigue Expert Group, *Options for regulatory apporach to fatigue in drivers of heavy vehicles in Australia and New Zealand*: Australian Transport Safety Bureau, Land Transport Safety Authority, National Road Transport Commission; 2001.

12. Rosenthal, L, Roehrs, TA, Rosen, A, et al., *Level of sleepiness and total sleep time following various time in bed conditions.* Sleep, 1993. **16**(3): p. 226-32.

13. Taub, JM and Berger, RJ, *Performance and mood following variations in the length and timing of sleep.* Psychophysiology, 1973. **10**: p. 559-570.

14. Bonnet, MH, *Acute Sleep Deprivation*, in *Principles and Practice of Sleep Medicine*, M.H. Kryger, T. Roth, and W.C. Dement, Editors. 2005, Elsevier Saunders: Philadelphia. p. 51-66.

15. Dijk, D-J, *Light, circadian rhythms, and the homeostatic regulation of human sleep.*, in *Physiology, Stress, and Malnutrition: Functional Correlates, Nutritional Intervention*, J.M. Kinney and H.N. Tucker, Editors. 1997, Lipponcott-Raven. p. 55-78.

16. Czeisler, CA and Khalsa, SBS, *The human circadian timing system and sleep-wake regulation*, in *Principles and Practice of Sleep Medicine*, M.H. Kryger, T. Roth, and W.C. Dement, Editors. 2000, WB Saunders Company: Philadelphia. p. 353-375.

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