Report 01-104

express freight Train 547 and express freight Train 531

collision

Mokoia

7 March 2001

Abstract

On Wednesday 7 March 2001 at about 2233 Train 531, a southbound express freight train collided with the rear of Train 547, another southbound express freight service which had stalled on the Mokoia Bank between Whareroa and Mokoia on the Marton to New Plymouth Line. Train 531 had entered the section and was going to assist Train 547 when the collision occurred. The locomotive engineer of Train 547 had not protected the rear of his disabled train to warn the locomotive engineer of Train 531 as he approached.

Safety issues identified included:

- the effectiveness of the process for identifying and confirming the location of a disabled train
- the effectiveness of the track warrant theory recertification process in identifying any shortcomings in rules knowledge of operating staff
- control of locomotive engineers' hours of duty.

Three safety recommendations were made to the operator covering these issues.

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Abbreviations

CRM	crew resource management
k	kilometre(s)
km/h	kilometres per hour
LE1	locomotive engineer Train 547
LE2	locomotive engineer Train 531
m	metre(s)
MNPL	Marton - New Plymouth line
t	tonne(s)
TC	train controller
Tranz Rail	Tranz Rail Limited
TWACS	Track Warrant Assisted Computer System
WIC	work in conjunction

Data Summary

Train type and number:	express freight Train 547 and express freight Train 531		
Date and time:	7 March 2001 at about 2233		
Location:	124.05 km, Mokoia (MNPL)		
Type of occurrence:	collision		
Persons on board:	crew:	Train 547	1
		Train 531	1
Injuries:	crew:	Train 547	1 serious
		Train 531	1 minor
Damage:	The locomotive and 5 wagons on Train 531 were damaged and derailed		
Operator:	Tranz Rail Limited (Tranz Rail)		
Investigator-in-charge:	D L Bevin		

1. Factual Information

1.1 Narrative

1.1.1 On Wednesday 7 March 2001 Train 547 was a Whareroa to Longburn down express freight service and consisted of locomotives DFT7092 and DFT7051 coupled and 34 wagons. The train had a gross weight of 1114 t with a length of 561 m and was crewed by a locomotive engineer (LE1).

1.1.2 LE1 had commenced duty at his book-on depot of Whareroa at his rostered time of 2015 on Wednesday 7 March 2001 to meet an inbound shunting service from Stratford, which consisted of the 2 locomotives and tonnage for Train 547. When the shunt service arrived at Whareroa LE1 spoke briefly with the incoming LE who advised him that "the locomotives were performing well" and he had not experienced any problems with the train.

1.1.3 Train 547 left Whareroa at 2130. About 12 minutes later LE1 applied more power as it started to climb the grade towards Mokoia but the locomotive began slipping and the train lost speed, finally coming to a halt at about 2145. LE1 immediately advised the train controller (TC) by radio that he had "run into a problem on the Mokoia Bank. A bit overload. Come to a stop. Doesn't want to pick up again." LE1 did not specify the stations between which his train was disabled, nor was there a requirement for him to do so.

1.1.4 The TC asked LE1 for the metrage where Train 547 had stalled. LE1 did not know and said "I'm at a half k peg at the moment, I'll give you a call up the hill when I get to the other one."

1.1.5 At about 2150 LE1 left his cab and went to find an identifiable metrage point. Because of known radio reception difficulties in the area he took his mobile telephone in preference to his portable radio and walked south against the metrage and up the grade towards Mokoia. He said that in the dark he missed the next kilometrage peg (at the 123.00 km) which would have helped him determine his exact location.

1.1.6 While LE1 walked up the gradient he called the TC by mobile telephone and the following conversation took place:

TC So where abouts are you roughly then?

LE1 Mokoia

TC You're at Mokoia?

LE1 Yeah. Not quite round, up the top here.

TC Oh, okay.

LE1 About three quarters of the way up.

TC Oh, right.

LE1 I stopped at half peg so its got no metrage written on it.

TC Fair enough.

LE1 I'm just going up here trying to find the next one.

TC Well, give us a ring back.

1.1.7 The following conversation took place once LE1 saw the Mokoia track warrant intermediate board (see Figure 1) in the distance:

TC [name] here. Control.

LE1 Yeah [name], what's the Mokoia intermediate board?

TC Ah, the 122.90

LE1 122.90. I've just come around the corner and that's the next one.

TC Okay.

LE1 So on the back of the half...

TV So that will be 122.500, there somewhere.

LE1 Yeah.

TC Okay. Plan of attack, we'll just push you through to Wanganui. Check in at Patea on the way through and at the moment 522 is in Wanganui so I might actually get him through to Waitotara, meet you and see how it goes.

LE1 Okay, I'll give you a call when I get in the engine.

TC Not a problem.

LE1 He'll be able to take the monitor[1] off and look after that, wont he? *

TC Yeah, should be able to. We'll need to reissue you a warrant when you get back there.

LE1 Okay.

*LE1's comment referred to LE2 when he arrived with Train 531 at the rear of Train 547.

1.1.8 The TC said he thought the Mokoia Bank was south of Mokoia and that Train 547 was therefore south of Mokoia. He assumed that LE1 had walked in a northerly or metrage increasing direction towards Mokoia and that if he could see the Mokoia Intermediate Board which was located at the 122.9 km the train must be stalled "at 122.500, somewhere there".

1.1.9 LE1 contacted the TC by radio when he got back to his locomotive cab at about 2215. At 2218 track warrant number 45 (refer Figure 5) was issued to him on Train 547 which contained a clause 12 stating that his train was disabled at the 122.50 km "between Manutahi and Mokoia". LE1 knew his train was not between Manutahi and Mokoia but did not challenge this because he "thought it was worded this way to enable the train to be pushed into the next section." LE1's acceptance of track warrant 45 confirmed to the TC that the location of Train 547 at 122.50 km was correct.

1.1.10 Train 531 was a New Plymouth to Wellington express freight service and consisted of locomotives DFT7282 and DC4156 coupled and operating in multiple with 22 wagons and was crewed by a locomotive engineer (LE2). The gross weight was 835 t with a length of 380 m.

[1] Train end monitor - a device attached to the coupling and air hose at the rear of the last wagon to monitor brake pressure, last vehicle movement and activate the tail light. All of this information was transmitted from the train end monitor to the LE by radio.

1.1.11 Train 531 had arrived at Whareroa at 2130 and while waiting for Train 547 to clear the section ahead LE2 heard on his radio that it had stalled. He suggested to the TC that his train proceed in to the section and assist Train 547 to Patea where a tonnage reduction could be carried out to enable Train 547 to continue. After further discussion the TC and LE2 decided that Train 531 would push Train 547 all the way to Wanganui.

1.1.12 At 2222 the TC issued track warrant number 46 (see Figure 6) to LE2 at Whareroa. This advised LE2 that Train 547 was disabled "at 122.50 KM MPL" and instructed Train 531 to proceed to Train 547 and provide assistance. Track warrant number 46 did not specify where the 122.50 km was but LE2 had heard over his radio while track warrant 45 was being issued to LE1 by the TC that it was between Manutahi and Mokoia. Train 531 departed from Whareroa at 2223.

1.1.13 LE2 slowed Train 531 to about 45 km/h as he approached the 125.00 km peg and rechecked the location of the disabled train on his track warrant. He calculated that he was still 2.5 km from the disabled train at that point. He also checked his speed restriction advice and saw that a 25 km/h restriction commenced at the 123.80 km. Because he had not yet reached that metrage this confirmed to him his position in relation to 122.50 km where he expected Train 547 to be.

1.1.14 Train 531 had slowed as it started to climb towards Mokoia. LE2 had just put his speed restriction advice aside when his train rounded a 45 km/h left-hand curve and he saw "a container right in front of my train". He said that it had only become visible when the locomotive headlight straightened up after rounding the curve and he estimated that the rear of Train 547 was then only "about half a wagon length away."

1.1.15 LE2 immediately shut off power and applied the independent brake, but he did not have time to apply the emergency brake. He estimated the speed at the time of impact as about 25 - 30 km/h as he had been slowing for the approaching 25 km/h speed restriction at the 123.85 km.

1.1.16 After the impact LE2 advised the TC what had happened and queried him as to the supposed location of Train 547 as he had been led to believe it was between Mokoia and Manutahi. He then left his cab to assess the damage and noticed the 124.00 km peg "about 3 wagon lengths to south of my locomotive". This put the point of impact at about 124.05 km.

1.1.17 LE2 contacted LE1 by radio and asked where he was and "he confirmed he was at the 122.50 km peg. I was surprised by this. I expected the train would be at least 1.5 kilometres further south. He said that he had expected detonators to be in place on the track at the rear of Train 547 and a radio call from LE1 as he got closer. He had planned to bring the speed of his train down further and to attempt to make radio contact with LE1 as he approached the 122.50 km. LE2 said that there had been no radio communication with LE1 prior to impact.

1.1.18 LE1 had been back in his locomotive cab about 20 minutes at the time of the collision. He suffered a back injury and LE2 suffered whiplash as a result of the impact.

1.1.19 The second locomotive on Train 547 was subsequently found to be not on-line[2] when Train 547 stalled. LE1 said that he had not been advised that the second locomotive was not operating when he took over the train at Whareroa and he had not checked the locomotives before Train 547 had departed. He also did not check the second locomotive after his train had stalled.

1.1.20 LE1 said that although the locomotive dynamic brake[3] could be used on the descending grade from Whareroa he usually found that the train brake was adequate to control the speed of the train and in line with his usual driving practice had not used the dynamic brake on this occasion.

[2] When locomotives are on-line it means that they operate in multiple from the cab in which the LE is positioned.
[3] The dynamic brake is a fully electrical retarding brake which is used to control the speed of a train.

1.2 Site details

1.2.1 Metrages on the MNPL commenced at Marton and increased in a northerly direction. Trains 547 and 531 were down trains travelling south so were moving in a metrage decreasing direction.

1.2.2 Mokoia was located in track warrant territory between Whareroa and Manutahi on the Marton to New Plymouth Line (refer Figure 1) and was identified by a track warrant intermediate board (refer Figure 2).

1.2.3 The Mokoia intermediate board showed the same details on both sides and was used to divide the Manutahi to Whareroa track warrant section for trains running in either direction. Tranz Rail's Track Warrant Control Regulations defined an Intermediate Board as:

A notice board provided between stations or sidings to identify a location which may be used to designate a limit for a track warrant.

1.2.4 After leaving Whareroa, southbound trains descended a 1 in 60 grade for 4 km before the track levelled out for about 1 km. and then ascended a 1 in 50 gradient known as the Mokoia Bank (refer Figure 3) for about 2 km.

1.2.5 Tranz Rail advised that the gradient referred to as the Mokoia Bank commenced at the 124.80 km between Whareroa and Mokoia and finished about 10 m beyond the Mokoia intermediate board in the Mokoia to Manutahi section. The grade included 3 x 300 m curves, 3 x 240 m curves, 1 x 220 m curve and 2 x 200 m curves. The 300 m curves were restricted to a maximum speed of 60 km/h, the 240 m and 220 m curves were restricted to 55 km/h and the 200 m curves were restricted to 50 km/h.

1.2.6 The track through Mokoia for southbound trains was flat for about 500 m but then descended a 1 in 70 grade for about 1.5 km. It then levelled out for about 1.5 km before it again climbed a 1 in 50 grade for about 2 km (the Manutahi Bank) until it reached Manutahi where it levelled out again.

1.2.7 Tranz Rail advised that gradient diagram books were available in a central location within the train control centre for reference by TCs. While these books showed details of track gradients including kilometrages, they did not identify specific grades by name.

1.2.8 About 30 m north of the Mokoia intermediate board and in the direction in which LE1 was walking was the Mokoia Road level crossing. Beside the level crossing was a small hut with a sign attached which displayed the name of the level crossing and the metrage it was located at (refer Figure 4). LE1 had not walked as far as the level crossing but instead had stopped once he had seen the Mokoia intermediate board at the top of the grade in the distance.

1.2.9 A 25 km/h temporary speed restriction was in place between 123.85 km and 123.00 km at the time. Within this restriction there was a 300 m curve (usual maximum authorised track speed 60 km/h) and 2 x 240 m curves (usual maximum authorised track speed 55 km/h). Tranz Rail advised that this speed restriction had been in effect since December 2000 and although the speed restriction was over reasonably steep terrain no other stallings had been reported since it was implemented.

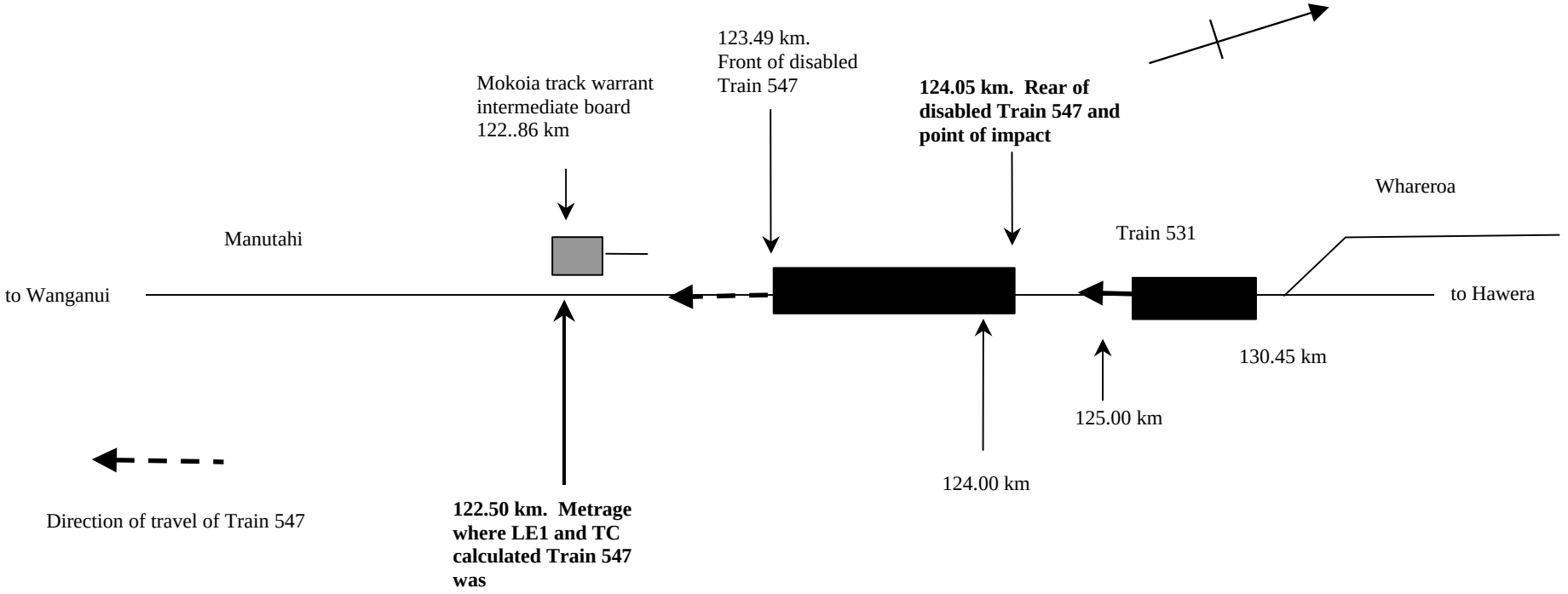

Figure 1
Track plan from Whareroa to Manutahi
(not to scale)

Figure 2
The intermediate board at Mokoia

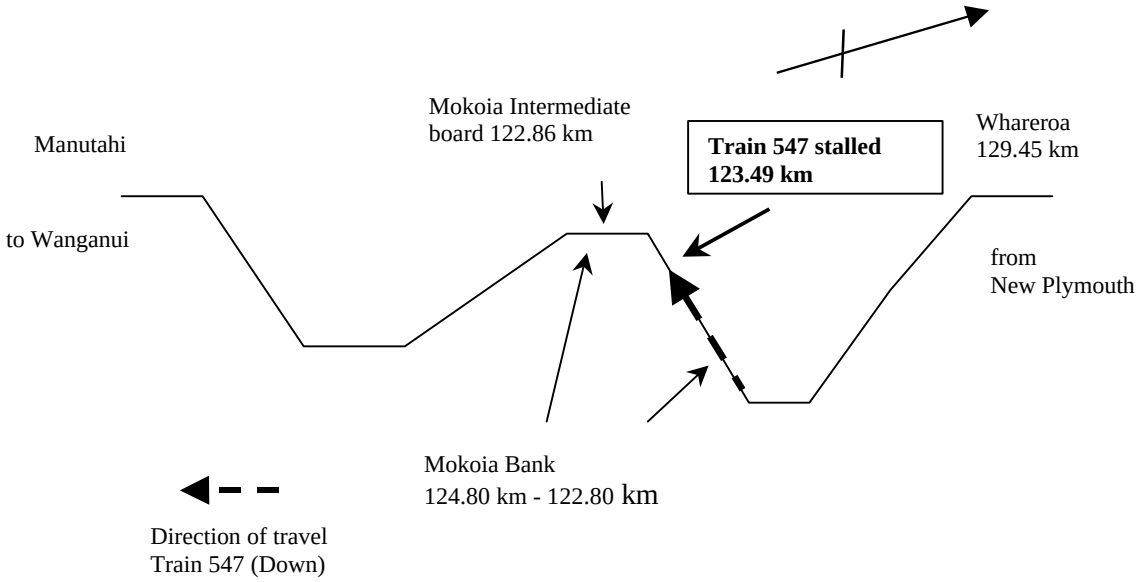

Figure 3
Gradient diagram Whareroa to Manutahi
(not to scale)

Figure 4
The identification sign at Mokoia Road level crossing

1.2.10 Tranz Rail advised that the following criteria were used to determine the appropriate speed when speed restrictions were placed in difficult geographic conditions:

> T:200 Infrastructure Engineering Handbook
> 885 There is a need to constantly monitor and review speed restrictions to avoid:
>
> Unnecessary speed restrictions
> Speed restriction value being too low/high or too long in length
> Being placed in a difficult operational area e.g.: on an uphill grade
>
> This should primarily be done by Track and Structures Managers, however Gangers also need to keep a close watch on the need, placing and speed value of speed restrictions.
>
> However, if a Temporary Speed Restriction is required, it will be applied irrespective of location. Where location would cause an operating problem, the track should be repaired so that the TSR value can be raised or removed.

1.2.11 The maximum authorised track speed for express freight trains between Whareroa and Mokoia was 70 km/h.

1.3 Locomotive load schedules

1.3.1 The maximum permissible tonnage for an express freight train between Whareroa and Waitotara with 2 DFT locomotives operating in multiple was 1400 t, while that for a single DFT locomotive was 950 t.

1.3.2 The additional weight of the non-operating locomotive meant that the gross tonnage of Train 547 increased from 1114 t to 1201 t which was 251 t over the maximum load for a single DFT locomotive.

1.3.3 Tranz Rail advised it was the LE's responsibility to ensure he had sufficient locomotive power engaged to haul trains from starting and intermediate locations.

1.4 Protection of disabled trains

1.4.1 LE1 said that it had been many years since a train he had been driving had become disabled and required assistance from the rear. As a result he had forgotten the requirement to provide protection in such situations.

1.4.2 The TC said "my understanding is that the driver is to put out protection" and "I would have expected the drivers, they were talking to each other anyhow, to know exactly where the disabled train was." When asked what channel he would have expected the LEs to be using he said "I would have expected them to use the local channel[4]. But in saying that later on in the evening there was cross-talk between the drivers on my channel, but I wasn't listening to them, I was actually talking to the NCM [network control manager] at the time and I just left it to them because I just assumed that they were talking to each other about location."

[4] The local channel (Channel 1) was a VHF point-to-point radio communication system which did not use repeaters and was not monitored by train control. Under normal circumstances its coverage 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.

1.4.3 Tranz Rail's Track Warrant Control Regulation 22(b) stated in part:

> (b) Train Disabled -
>
> When a train becomes disabled the Locomotive Engineer must immediately advise particulars to Train Control who in turn will arrange for a relief locomotive to assist the disabled train from the section. A new track warrant must be issued instructing the disabled train to remain where it is disabled until arrival of the relief locomotive. A member of the crew of the disabled train must then proceed in the direction from which the relief locomotive is to approach and at 200 m from the disabled train place 2 detonators on each rail 10 metres apart; . . . From this point the crew member of the disabled train can pilot the relief locomotive to the disabled train

1.4.4 The TC advised that his understanding of the requirement for advice of the metrage of a disabled train was the kilometrage at which the locomotive was standing.

1.4.5 Tranz Rail advised that:

> There is a requirement to specify the metrage of the location of the train. However, TWC Regulation 22 (b) does not specifically say what this metrage should be in regard to the starting location of the relief locomotive/train and the disabled train.
>
> Section 6 of the Rail Operating Code is more specific, when specifying what must be included in a track warrant that is issued to the relief locomotive, it says "Advise the location of the disabled train. (Make sure the location given is at the end nearest to the relief locomotive).
>
> Section 6 is available for Train Controllers only.

1.5 Track warrant procedures for assisting disabled trains

1.5.1 Tranz Rail's track warrant procedures for assisting disabled trains are included as Appendix A to this report.

1.5.2 The TC said that the TWACS software automatically entered the information "122.50 km MPL is between Manutahi and Mokoia" on track warrant 45 (refer Figure 5) but prevented him from repeating it on track warrant 46 (refer Figure 6).

1.5.3 Tranz Rail advised that the preparing of track warrants under the "work in conjunction" process required very little input from the TC. After the TC had entered the kilometrage at which Train 547 was disabled into the computer while preparing track warrant number 45, the software then identified the points between which the kilometrage was and generated the respective clause 12 instructions for both track warrants 45 and 46. However, the TC could include additional information (free text) on the track warrant prior to issuing, if desired.

```
Track Warrant No.            45               WEDNESDAY        7 MARCH
To LOCO ENGR 547
At 122.50 km MPL
   1.X  Track Warrant No.           44      is cancelled.
   4.X  Work between WHAREROA                   and 7FI     WAITOTARA
   6.X  Main line reported clear 1819      (except for 531)
  10.X  Call Train Control at PATEA
  12.X  Other instructions 547 must not move from 122.50 KM MPL until
        arrival of 531 as relief locomotive from
        WHAREROA.
        122.50km MPL is between
        MANUTAHI and MOKOIA.
                                                        Train Controller

Repeat correct at 2218 hrs.
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Figure 5
Copy of track warrant number 45 which was issued to LE1

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Track Warrant No.            46               WEDNESDAY        7 MARCH
To LOCO ENGR 531
At WHAREROA
   4.X  Work between WHAREROA                   and 7FI    WAITOTARA
   6.X  Main line reported clear 2218      (except for 547)
  12.X  Other instructions 547 is disabled at 122.50 KM MPL.  Assist 547
        to 7FI WAITOTARA in accordance with
        regulations

                                                        Train Controller

Repeat correct at 2222 hrs.
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Figure 6
Copy of track warrant number 46 which was issued to LE2

1.6 Personnel

The LE of Train 547 (LE1)

1.6.1 LE1 was a certified Grade 1 LE who had 32 years experience, of which 30 had been spent in Stratford.

1.6.2 LE1's last theory certification had been in September 2000. His last safety observation had been in November 2000. His theory re-certification had included a 10 questions, multi-choice answer examination on track warrant control, which he had passed with maximum marks.

1.6.3 He was in good health and did not consider he was suffering from any home or work-related stress or fatigue.

1.6.4 LE1 said that he had finished his previous shift at 0715 on the morning of the collision. He had travelled home to Stratford and went to bed about 0815, rising at about 1300. He stayed up until 1800 when he went back to bed for an hour's sleep before waking at 1900 and getting up to go to work.

1.6.5 LE1's previous work pattern is discussed in section 1.9

The LE of Train 531 (LE2)

1.6.6 LE2 was a certified Grade 1 LE who had 20 years experience, all of which had been spent in New Plymouth. He had transferred to Stratford about 3 months earlier when the locomotive depot at New Plymouth was downsized. His most recent theory certification and safety observation had both been in June 2000.

1.6.7 He was in good health and did not consider he was suffering from any home or work-related stress.

1.6.8 LE2 had worked 10.5 hours the previous day (rostered 10.5) and 11 hours the day before that (rostered 9.5 hours). The 3 days prior to these he had been off duty.

The train controller (TC)

1.6.9 The TC had about 4 years train control experience and at the time of the incident was responsible for the movement of trains between Otaki and Marton, Marton and New Plymouth, and Palmerston North and Woodville. He had also been employed by Tranz Rail as a TC from 1984 to 1987.

1.6.10 The TC's last theory certification had been in September 2000, his last desk assessment in January 2001 and his last tape playback audit in March 2001. Tranz Rail advised that for his track warrant theory recertification the TC was required to undertake the same computer-based theory assessment as LE1.

1.6.11 The TC had worked 8.25 hours on each of the 2 days prior to the accident. The third day prior he had been rostered off duty.

1.7 Plans to assist Train 547

1.7.1 Tranz Rail advised it was the TC's responsibility to make suitable recovery arrangements in connection with all train failures. Various publications such as rulebooks, operating codes and gradient diagram books were available to assist TCs in this regard.

1.7.2 The following plans to assist Train 547 were discussed at different times between the TC, the LEs and the network control manager:

- Train 547 to set back to Whareroa and reduce tonnage
- Train 531 to push Train 547 through to Patea where tonnage would be reduced and attached to Train 531
- Train 531 to push Train 547 right through to Wanganui
- the locomotives of Train 531 to proceed to where Train 547 was disabled, remove tonnage from the rear and return it to Whareroa.

1.7.3 LE2 and the TC decided between them that in the interests of timekeeping and to remove the need to call out staff to assist with shunting the best option was for Train 531 to push Train 547 right through to Wanganui.

1.7.4 When LE1 had been advised that his train was going to be pushed through to Wanganui by Train 531 he had initially expressed concerns based on the size of the combined trains and the gradients that would be encountered enroute. He suggested to the TC that it might be a better option for the locomotives of Train 531 to come and take some tonnage off the rear of his train and take it back to Whareroa.

1.7.5 The TC then discussed this option with LE2 who felt that it was just as easy to push Train 547 through to Wanganui. LE2 had checked the available locomotive power with the combined tonnages with his working timetable and was confident that the push through could be accomplished. The TC then agreed to this plan as did LE1.

1.7.6 There was no discussion at any time between LE1, LE2 and the TC about the possibility that the second locomotive on Train 547 might not be operating and should be checked.

1.8 Locomotive event recorder data

1.8.1 Data from the event recorder from DFT7282, the lead locomotive of Train 531 was downloaded and supplied for analysis.

1.8.2 Tranz Rail advised that the event recorder data from DFT7092, the lead locomotive of Train 547, was not extracted.

1.9 Rostering

1.9.1 Tranz Rail had procedures in place for controlling base hours of work, including maximum shift lengths, shift rotation and time between shifts. Section 3, Clause 1.0 of the Tranz Rail "Rail Operating Manual" specified that rosters were to be constructed at or about 80 hours each fortnight – within 76 to 83 hours being considered acceptable. There was a process in place for monitoring the maximum hours worked during A week and B week of each fortnight, but not overlapping fortnights made up of the second week (B week) of a rostered fortnight and the first week (A week) of the next rostered fortnight. A process was also in place which allowed for the monitoring of the number of consecutive shifts of LEs, both within rostered fortnights (A and B weeks) and overlapping (B and A weeks) fortnights. The fortnight ending 10 March in which the accident occurred was an overlapping fortnight.

1.9.2 In the 10 days before the accident LE1's rostered hours on his master roster were 65 hours and his mini-rostered hours were 82 hours. These hours and the actual hours worked by LE1 over this period are shown in the following table.

	Mini-Rostered shifts	**Mini-Rostered hours**	**Actual hours worked**	**Master Rostered hours**
Day 1	0100 - 1030	9.50 hours	9.50 hours	Rostered off duty
Day 2	2015 - 0530	9.25 hours	10 hours	9.25 hours
Day 3	2015 - 0530	9.25 hours	9.25 hours	9.25 hours
Day 4	2015 - 0530	9.25 hours	10.50 hours	9.25 hours
Day 5	2015 - 0530	9.25 hours	11 hours	9.25 hours
Day 6	2015 - 0530	9.25 hours	10 hours	9.25 hours
Day 7	1915 - 0300	7.75 hours	9.75 hours	Rostered off duty
Day 8	Rostered off duty	Rostered off duty	Off duty	Rostered off duty
Day 9	2015 - 0530	9.25 hours	10.50 hours	9.25 hours
Day 10	2015 - 0530	9.25 hours	11 hours	9.25 hours
Total		**82 hours**	**91.5 hours**	**74 hours**
Day 11	2015 - 0530	9.25 hours	2.25 hours	9.25 hours
Day 12	2015 - 0530	9.25 hours		9.25 hours
Day 13	2015 - 0530	9.25 hours		9.25 hours
Day 14	Rostered off duty	Rostered off duty	off duty	Rostered off duty

The collision occurred on day 11.

Days 1 and 7 were shown on the master roster as rostered days off duty but LE1 said he had worked these in response to requests from the roster centre to fill vacant jobs because of a shortage of LEs. LE1 said that shortly before commencing duty at 2015 on day 6 the roster centre had contacted him and asked if he would start work at 1915 on day 7, to which he agreed. This was his seventh consecutive nightshift.

The incident happened about 2.25 hours into the shift on Wednesday 7 March (day 11).

1.9.3 LE1's shift on day 11, the day of the incident, was his third consecutive night shift, and he was rostered for night shifts on days 12 and 13. The week before he had worked 7 consecutive night shifts (days 1-7) before having 1 day rostered off duty (day 8) and had started night shift again on day 9.

1.9.4 Assuming LE1 had worked his fortnight without incident, he would have worked 12 night shifts, with 1 day off duty after the first 7 days, for a total of about 119.25 hours. He had already worked about 94.75 hours for the fortnight at the time of the collision. His rostered hours for the overlapping fortnight from his master roster were 92.5 hours and from his mini-roster were 110 hours.

1.10 Previous occurrences involving attention loss

1.10.1 The Commission has investigated 3 occurrences involving attention loss linked to fatigue (which led to microsleeps). Reports on these are:

- Railway Occurrence Report 00-115, Westmere, a derailment on 22 September 2000, following a high speed entry into a restricted speed curve (published August 2001).
- Railway Occurrence Report 00-117, Kai Iwi, a derailment on 26 November 2000, also following a high speed entry into a restricted speed curve (published August 2001).
- Rail Occurrence Report 00-121, Middleton, a collision on 8 December 2000, when a northbound train overran a signal and collided with a southbound train (published August 2001).

In addition Rail Occurrence Report 00-111, Tapuata, involving a track warrant overrun on 14 June 2000, concluded a short-term loss of attention may have been a factor in the events that occurred, although sleep loss and fatigue were not considered to be factors (published April 2001).

1.10.2 Associate Professor Philippa Gander PhD, an internationally recognised sleep and fatigue management expert was engaged by the Commission to assist in the area of fatigue considerations associated with Rail Occurrence Reports 00-115, 00-117 and 00-121. Particular parts of her expert opinion which are relevant to this investigation have been included in Appendix B to this report.

1.11 Human factors

1.11.1 The Commission engaged a human factors consultant, to assist in assessing human factor behaviour associated with this incident.

2 Analysis

2.1 General

2.1.1 Train stalling can and does occur for a number of reasons and Tranz Rail's rules and procedures allow for this. The significance of this incident is not that the train stalled, but having stalled, the standard operating procedure to respond to such an event was not followed. Factors related to the stalling are included in the report because without the stalling the incident would not have occurred.

2.1.2 The maximum load for an express freight train with 2 DFT locomotives between Whareroa and Mokoia was 1400 t. Train 547 was within this limit provided that both of the DFT locomotives were operating. However, this was not the case and the weight of the non-operating locomotive added another 87 gross tonnes to the weight of the train, making a total of 1201 gross tonnes. This was 251 t over the maximum tonnage for a single DFT locomotive through this section.

2.1.3 The speed restriction from the 123.85 km to the 123.00 km had been in effect since December 2000 but as no other stallings had been reported since that time it is considered that it did not contribute to this incident. The 25 km/h speed restriction meant that the train was travelling slower than the normal maximum authorised line speed as it approached and began to climb the gradient but if both locomotives had been on-line this would not have prevented Train 547 from successfully negotiating the climb to the top. Because the second locomotive was not on-line the slower speed, together with the overload meant that it was inevitable that the train would not reach the top.

2.1.4 Analysis of the locomotive event recorder output showed that Train 531 was travelling at 20 km/h at the time of impact.

2.1.5 In general the rules and procedures covering trains disabled in track warrant territory were suitable but there was a weakness in the method of determining the exact metrage of a disabled train and a safety recommendation covering this issue has been included in Section 5 of this report.

2.1.6 The major contributing factor to this incident was that the rules applicable to disabled trains were not followed. It is considered that a check list between the TC and LE1 would have been an effective way of reinforcing that correct procedures were followed and a safety recommendation covering this issue has been included in Section 5 of this report.

2.1.7 A recent investigation by the Commission into a subsequent occurrence involving the incorrect advice to the TC of the metrage of a disabled train was closed without the publication of a report after it was found that the error was noticed by the locomotive engineer and corrected with the TC before the arrival of the relief locomotive at the site. Even if the error had not been discovered there was no possibility of a collision between the relief locomotive and the disabled train because of the correct actions and protection measures taken by all staff concerned.

2.2 The actions of operating staff involved

LE1

2.2.1 Had LE1 used the dynamic brake while descending the grade after leaving Whareroa he might have become aware that the second locomotive was off-line however, there was no requirement for him to do so, and his handling of the train on this downhill grade and the climb towards Mokoia did not contribute to the train stalling.

2.2.2 If LE1 had checked the second locomotive after his train had stalled he should have found that it was not on-line. Had he then returned it to power he should have been able to lift his train and continue without assistance. Why LE1 did not check his locomotives before seeking assistance for his disabled train is not known. Logically LE1 should have checked the locomotives before departing from Whareroa. However, given that the 2 locomotives appeared to be on-line, and the information supplied by the incoming LE on Train 547 at Wareroa did not contradict this, LE 1 assumed that this was the case.

2.2.3 Although it was difficult for LE1 to find the next metrage peg in the dark, his local knowledge should have reminded him that the Mokoia Road level crossing was almost at the top of the grade he was walking up. Had he continued walking he would have been able to accurately determine his location from the signage at the level crossing. LE1 should have identified his exact location and not relied on an assumption by the TC as to his whereabouts.

2.2.4 The suggestion by LE1 to the TC that LE2 could "look after" the train end monitor on the rear of Train 547 suggested that LE1 was hoping to avoid going to the rear of his train to assist LE2 with the coupling of the 2 trains (he had forgotten his need to go to the rear and protect his train). The agreement of the TC to this suggestion indicated that he was unfamiliar with the protection requirements as this was the opportunity to challenge LE1 on the need to go to the rear of the train for that purpose. How an agreement could be reached between LE1 and the TC on a plan which required LE2 to drive his un-piloted train up to an unprotected and disabled train, stop and then remove the train end monitor from the rear of the disabled train, get back on to his locomotive and move his train forward to couple up to the rear of it, is difficult to comprehend. LE2 was expected to do all this in the dark and without assistance, or prior consultation, while LE1 sat in his locomotive cab. The safety implications for a single person undertaking such a task were significant and were made worse by the dark and the underfoot conditions. This should have highlighted the need for LE1 to assist, even though the protection requirement had been overlooked. This plan had not been discussed with LE2 but had it been it is highly likely LE2 would have challenged LE1 and the TC regarding the requirement for protection at the rear of the disabled train.

2.2.5 Track warrant 45 was addressed to LE1 at the 122.50 km which in itself may not have caused him to question his location but clause 12, which stated that the 122.50 km was between Manutahi and Mokoia, should have alerted him and caused him to challenge the TC. This was the first defence against the incorrect location of Train 547. LE1 knew his train had not passed through Mokoia because he had just returned from walking forward and uphill and had seen the Mokoia intermediate board in the distance. There was no possibility his train was disabled at a point between the Mokoia intermediate board and Manutahi as specified in track warrant 45.

LE2

2.2.6 LE2 had expected protection to be provided and LE1 to meet his train and pilot it on to the rear of Train 547 in accordance with his knowledge of the rules and regulations. He had not been advised by the TC that he was to "look after" the train end monitor at the end of Train 547

2.2.7 LE2 had taken all reasonable precautions after departing Whareroa, based on his knowledge that Train 547 was disabled at the 122.50 km, and his actions had no bearing on the collision. The locomotive event recorder confirmed that Train 531 was already reducing speed for the speed restriction ahead when LE2 made his brake application immediately before impact.

2.2.8 The last wagon of Train 547 was at 124.05 km, 1550 m closer to Whareroa than the metrage contained in track warrant 46 and to where LE2 expected it to be. Even though the kilometrage of Train 547 was incorrect, application of the protection provisions in accordance with Tranz Rail's track warrant regulations would have prevented the collision. Therefore, it is considered that the notification of the incorrect metrage was not the prime causal factor of the accident, it was a contributing factor and a safety recommendation covering this issue has been included but in Section 5 of this report.

The train controller

2.2.9 While LE1 was attempting to determine the exact location of his train he had made several references to walking uphill while talking to the TC. During his first conversation after leaving the locomotive cab he said "I'll give you a call up the hill", in the second he said "about three-quarters of the way up" and again "I'm just going up here trying to find the next one." Although LE1 was unable at that stage to give the TC his exact metrage these comments clearly reflected his intentions to walk uphill as he attempted to locate an identifying metrage, despite the fact that he was moving in the "down" traffic direction.

2.2.10 LE1 did not take any action or make any statement which could have led to the TC contending that LE1 was walking in the northerly or metrage increasing "up" direction. For Train 547 to have stalled south of Mokoia it would have had to have been on an uphill gradient, which fitted the TC's understanding that the Mokoia Bank was south of Mokoia. However, if this had been so, LE1's references to "climbing the hill" would have meant that he was walking away from Mokoia towards Manutahi. If LE1 had walked uphill and in a metrage increasing direction from a location south of Mokoia and seen the Mokoia intermediate board in the distance it would have meant that his train was stalled on a downhill grade. The TC obviously missed the relevance of LE1's references to walking uphill and the chance to question his location.

2.2.11 If the TC had referred to the gradient diagram book available in the train control centre he would have seen immediately that there was no uphill gradient until nearly 3 km south of Mokoia when the gradient towards Manutahi (the Manutahi Bank) commenced. If Train 547 was at the 122.50 km, as he believed, it would have been stalled on nearly level track and this would have been evident from the book.

2.2.12 The TC understood that the metrage where a train was disabled related to where the locomotive was standing. LE1 had advised that he had stalled close to a half-kilometre peg and the TC assumed, with LE1's concurrence, that the locomotive had come to a stop at the 122.50 km. Tranz Rail's procedures required that when the TC advised the location of the disabled train in a track warrant, such location should be given as the end nearest to the relief locomotive. The relief locomotive was coming from Whareroa and if the locomotive had been standing at the 122.50 km, the last wagon of the train would have been at the 123.06 km, 200 m north of the Mokoia intermediate board and still in the Whareroa to Mokoia section. However, because LE1 accepted without question track warrant 45, which had been addressed to him at the 122.50 km, the TC probably accepted this as confirmation of the trains position.

2.2.13 The TC did not provide effective incident management during the situation in that he:

- did not require LE1 to provide an accurate metrage for the disabled train, satisfied instead to do calculations on a "somewhere there" basis
- did not refer to his grade diagram book to get an understanding of the terrain where Train 547 had stalled
- did not refer to his working timetable when discussing tonnage and locomotive combination options with LE2, instead leaving LE2 to do all the calculations from his locomotive cab at Whareroa
- relied on the LEs to provide an effective plan to move Train 547 from the section
- did not challenge LE1 about the need to protect the rear of his train and remain there to pilot the relief train on to the rear.
- did not refer to his rule book to ensure procedures were being adhered to
- agreed to a plan involving LE2 without consulting with him.

2.2.14 Although the TC understood that "the driver was to put out protection" he agreed to a plan which saw LE1 stay in his locomotive cab instead of going to the rear of his train. At the time this was discussed the TC did not ask LE1 for confirmation that protection had been provided. It would have been reasonable for the TC to assume that protection had not been provided because it would be most unlikely LE1 would have provided protection at the rear of his train and then returned to his locomotive cab without waiting for the arrival of Train 531. LE1 had only been out of his locomotive cab for about 20 minutes so there would not have been enough time for him to have done so.

2.3 LE1 fatigue

2.3.1 The changes Tranz Rail made to the Crew Management System to monitor the hours worked by an LE did not provide any effective management of LE1's rostered hours. This was supported by the fact that under this new process LE1 exceeded the 98 hours limit, albeit by one hour. The highlighting in red of an LEs hours once they exceed 84 hours could be a useful alert to the operator but to effectively manage these hours the process needs to include an enhancement that absolutely prohibits an LE from being rostered beyond the maximum 98 hours and needs to be expanded to also cover overlapping fortnights. Had this been the case it would not have been possible for LE1 to have been rostered for 110 hours in one fortnight.

2.3.2 The enhancement to the Crew Management System to allow for the monitoring of the number of consecutive shifts of LEs was also ineffective as a management process. While the process allowed for shifts exceeding 10 in succession to be highlighted it did not differentiate between day and night shifts and left the opportunity for an LE to work 10 consecutive night shifts without being brought to the roster persons attention. Although LE1's consecutive night shifts did not total 10, he did work 7 such shifts before having one day off and this was considered by the Commission to be excessive.

2.3.3 Given LE1's mini-roster for the preceding period it is highly likely that sleep debt induced cumulative fatigue, which in turn lowered the LE's arousal levels, attentional resources and mental and physical performance.

2.3.4 The following safety recommendation was previously made to the managing director of Tranz Rail, which related to biological sleepiness leading to microsleeps. This safety recommendation, included in Rail Occurrence Report 00-117 regarding a derailment near Kai Iwi on 26 November 2000, was that he:

> research information available on factors contributing to biological sleepiness in LEs, with particular regard to the possible adverse effect of continuous night shifts, and take steps to:
>
> minimise the probability of biological sleepiness leading to microsleeps
>
> provide an effective defence against any microsleep which may occur leading to an unacceptable risk exposure (025/01)

Tranz Rails response is included in Section 4.3 of this report.

Sleep pattern

2.3.5 On the day of the collision LE1 had a maximum of 6 hours sleep and probably less depending on the time he went to bed and how well he slept. Assuming that he had obtained between 5 and 6 hours of sleep it is probable that this would in itself have reduced his performance capacity. If the pattern on this day was typical of his usual pattern when coming off late-running shifts, then it is highly likely he would have been in chronic sleep debt on the day of the collision. Chronic sleep debt means that he was unable to return to normal mental and physical functioning after sleep, which is a definition of fatigue. Therefore, sleep debt was probably instrumental in inducing fatigue, which led to performance impairment.

Sleep disorder

2.3.6 The LE said that he was not suffering from any sleep disorders.

2.4 Rostering issues

Forward rotation and short breaks between shifts

2.4.1 The overall pattern of LE1's rostered shifts indicated that rotation was primarily forward, that is consecutive shifts occurred progressively later. This is generally considered to be preferable to backwards rotation, because the circadian body clock has a tendency to run slightly slow, and it is easier to fall asleep later, rather than earlier [9,18,19]. Forward rotations also reduced the likelihood of very short breaks between shifts, which can restrict the time available for sleep, because each new shift starts later than the preceding one.

2.4.2 Breaks between shifts must also contain all the other activities of life, including commuting to work, eating, interactions with family and friends, exercise and other recreation. Where there is insufficient time available for these activities there could be pressure on LEs to cut back their sleep time.

2.4.3 The amount of sleep that a person can obtain during a break is highly dependent on the time of day at which the break occurs [18]. Short breaks between shifts, particularly during the day, limit the time available for sleep and can accelerate the accumulation of sleep debt across consecutive shifts.

2.4.4 In the 10 days preceding the collision LE1 had only one rostered break of 41 hours 15 minutes free from work, from 0300 on Sunday 4 March until 2015 on Monday 5 March. Because of the late running of his last train this break was reduced to 39 hours 15 minutes.

2.4.5 On 19 June 2001 the following safety recommendations which related to control of hours of work and alertness management training were made to the managing director of Tranz Rail. The safety recommendations, included in Report 00-115 regarding a derailment at Westmere on 22 September 2000, were that he:

2.4.5.1 Put in place control measures to ensure:

Mini Rosters are controlled within defined criteria compatible with the principles used in compiling base rosters

defined criteria are met before offering extra shifts to LEs

actual hours are monitored and immediate corrective action taken when late running or other factors increase rostered shifts to defined unacceptable levels (017/01)

2.4.6 The Commission is of the opinion that the actions taken by Tranz Rail have not yet fully met the intent of the safety recommendation and accordingly the status of the safety recommendation is "open".

Late running

2.4.7 Late running, particularly after night shifts, reduces the time available for sleep during the biologically preferred time and can contribute to the accumulation of sleep debt across consecutive shifts. On the 2 nights preceding the collision LE1's shifts had run 1 hour 15 minutes late and 1 hour 45 minutes late respectively.

Of the preceding 9 night shifts worked by LE1 prior to the collision the following late running had been incurred:

2 hrs 30 min late	1
1 hr 45 min late	2
1 hr 15 min late	2
45 min late	2

2.4.8 Late running also reduces the amount of time available for all activities away from work, and may increase the pressures on an LE to restrict his sleep in order to participate in other areas of life.

Working on rostered days off

2.4.9 In the 10 days preceding the collision LE1 had worked on 2 of his 3 rostered days off. This resulted in his having worked 7 consecutive shifts (5 of them night shifts) before having one rostered day of duty and then working another 2 consecutive night shifts, before the incident shift.

2.4.10 There can be numerous reasons why LEs agree to work extra shifts over and above those for which they are originally rostered. These include:

- remunerative incentives
- loyalty to fellow LEs at the depot, who may be less well rested or have important commitments away from work
- concern about possible effects of refusal on relationships with other LEs, or with the company
- professional motivation to ensure that the system runs smoothly
- loyalty to the company.

2.4.11 Callouts at the Stratford locomotive depot were common for filling vacant slots on the roster or to relieve crews of late-running trains, and it seems reasonable that LE1's willingness to work additional shifts was primarily in response to the company's needs rather than personal factors.

2.4.12 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.

2.4.13 Working additional shifts prior to a block of night shifts prevents an LE from being well rested going into the night shifts.

2.4.14 Based on the hours of duty of LE1 during the 10 days leading up to the collision it is probable that at the time his train stalled he suffered a loss of attention due to chronic fatigue, which would offer an explanation for the following lapses on his part:

- he did not check that the second locomotive was operating correctly before departure and after his train stalled
- he did not positively establish the correct location of his disabled train
- when the TC issued track warrant number 45 which stated that Train 547 was disabled at the 122.5 km between Manutahi and Mokoia, LE1 did not challenge it even though he knew his train was not between Manutahi and Mokoia
- he did not give any thought to protection requirements for his train

2.5 Comparison of the Mokoia collision with 3 other incidents involving attention loss

2.5.1 The following table compares this incident with 3 other recent incidents where loss of attention through fatigue (in those 3 cases causing microsleeps) was suspected:

	Westmere Derailment (00-115) 22/9/2000	Kai Iwi Derailment (00-118) 26/11/2000	Middleton Collision (00-121) 8/12/2000	Mokoia Collision
Time of day	2338	0105	0400	2233
Time on shift	4 hrs	3 hrs 25 min	6 hrs	2 hr 18 min
Completed shifts since last 2- night break	5th	5th	6th	9th
Late running on prior night shifts	4/4 (average 1 hr 36 min)*	4/4 (average 55 min)*	4/5 (average 38 min)*	7/9 (average 1 hr 20 min)*

* averages represent the total hours of late running divided by the number of services running late

2.5.2 These incidents have the following in common with Mokoia:

- they occurred on a night shift that was between the 5th and 9th in a sequence of night shifts
- the preceding night shift had also run late.
- they all occurred at or near the daily peak in biological sleepiness.
- none of the LEs perceived that the events leading up to the respective incidents (either at home or at work) were in any way unusual.

2.6 The effectiveness of the recertification processes

2.6.1 LE1 had undergone his latest theory certification and safety observation in September 2000 and November 2000 respectively. However, his actions highlighted shortcomings, probably compounded by sleep deprivation, in his track warrant knowledge in that he appeared to have forgotten the mandatory requirement to protect his disabled train in the direction from which assistance was to be provided, and to wait at a point beyond his train from which to pilot the assisting locomotive to his disabled train. As a result of this the principal defence against a collision in this situation was not put in place. The agreement with the TC that LE2 would look after the train end monitor showed that both the TC and LE1 knew of no other reason why he should proceed to the rear of his train. A safety recommendation covering this issue is included in Section 5 of this report.

2.6.2 The TC said he understood "that the driver is to put out protection" but he did not seem to realise that protection was mandatory under track warrant regulations. His comment that he would have expected the drivers to know exactly where the disabled train was "because they were talking to each other anyhow" suggested that the TC considered such communication to be adequate protection and highlighted a lack of knowledge of the track warrant regulations on his part. There was no evidence on the train control audio tape of any cross talk between LE1 and LE2 via the train control radio channel immediately prior to the impact. The discussions the TC heard were probably those taking place between the LEs after the collision. These conversations were difficult to decipher from the train control audio tapes, but references to metrages could be heard.

2.6.3 The TC seemed to have been completely unaware of the requirement contained in Section 6 of the Rail Operating Code, which required the advising of the location of a disabled train on a track warrant as the position of the end of the train nearest to the section from which assistance was to be obtained. In all his discussions with LE1 the metrage given was 122.50 km, which corresponded with his understanding that the locomotive had stopped near a half-kilometre peg. The distance of 560 m between the locomotive and the last wagon of Train 547 was significant in the context of assistance being provided from the rear.

2.6.4 The track warrant theory re-certification examination undertaken by the TC was based only on the rules and regulations pertaining to track warrant control within the rule book. The examination did not contain questions on information contained in other specific publications available for the guidance of TCs such as Section 6 of the Rail Operating Code. Therefore, it is considered that the current track warrant theory recertification examination does not adequately test a TC's knowledge of pertinent information contained in all the reference manuals and documents available to them. A recommendation covering this issue is included in Section 5 of this report.

2.6.5 The protection of a disabled train under all signalling systems within Tranz Rail is a basic operational safety requirement and is not restricted to just track warrant control. All operating staff should be familiar with the protection requirements. LE1 and the TC were conversant with the relevant track warrant regulations relating to the protecting of a disabled train and it is surprising that 2 experienced and appropriately certified staff members could have overlooked this vital safety requirement, especially as they could have referred to their rulebooks at the time to ensure that they were correctly following procedures. Such action would probably have brought the protection requirements to their attention and implementation would have prevented the collision.

2.6.6 These shortcomings question the effectiveness of the recertification process to test the track warrant knowledge of operating staff. It is questionable whether the current track warrant theory recertification examination, based as it is on 10 multi-choice questions, is comprehensive enough, given that LEs and TCs only undertake the examination every 2 years.

2.7 Crew resource management

2.7.1 Crew Resource Management (CRM) is a general term covering crew management in highly operational situations: for example, on ships, in control rooms of power plants, in aircraft and in medical operating theatres.

2.7.2 The way human beings interact, communicate and make decisions in such situations is quite similar. Equally, errors in such circumstances are also similar. Training in this area was developed in the airline industry as a result of research showing that most aircraft incidents occurred as a result of management errors rather than technical malfunction. The concept has since been adopted and formally adapted to suit the maritime industry.

2.7.3 Examples of common CRM failings are preoccupation with minor technical problems, failure to delegate the tasks and assign responsibilities, failure to communicate intent and plans, and failure to detect and challenge deviations from standard operating procedures.

2.7.4 Failure to detect and challenge deviations from standard operating procedures was a contributing factor to this collision. There were opportunities for both LE1 and the TC to challenge each other's concepts but this was not done. These included:

- LE1 omitting to establish his exact location and the TC not ensuring that the exact location was established.
- The omission of the TC to challenge LE1 about the requirement for protection when LE1 suggested that LE2 could "look after" the train end monitor at the back of his train
- The omission of LE1 to challenge the TC when he realised that track warrant 45 showed his train to be at an incorrect metrage

2.7.5 The following safety recommendation was previously made to the to the managing director of Tranz Rail, which related to CRM training. This safety recommendation, included in Rail Occurrence Report 98-107 regarding Train 411, wrong line running, Ngaruawahia, was that he:

> introduce formalised crew resource management training for Train Control Operators, Signalmen and LE's based in the training available in the aviation and marine industries. (001/99)

Tranz Rail's response is included in Section 4.4 of this report.

2.7.6 The following safety recommendation was previously made to the managing director of Tranz Rail, which related to crew resource management procedures. This safety recommendation, included in Rail Occurrence Report 00-106 regarding a track warrant overrun at Mataura, was that he:

> introduce the formalised crew resource management procedures recommended in safety recommendation number 001/99 and ensure that such procedures include remote control operators operating main line shunts. (006/01)

Tranz Rail's response is included in Section 4.4 of this report.

3. Findings

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

3.1 Train 547 stalled because there was insufficient locomotive power on-line to enable the train to climb the Mokoia Bank.

3.2 Train 531 collided with disabled Train 547 because the rear of Train 547 had not been protected in accordance with Tranz Rail's procedures.

3.3 Despite their current certification neither the TC nor LE1 recalled the mandatory requirements for the provision of protection for disabled trains under track warrant operations.

3.4 The twelve night shifts with one night off as rostered in the mini-roster for LE1 for the fortnight Sunday 25 February to Saturday 10 March were excessive and the nine night shifts already worked by him leading up to the incident undoubtedly contributed to his fatigue.

3.5 The mini-rostered hours for LE1 for the fortnight Sunday 25 February to Saturday 10 March (overlapping) (about 110) were excessive.

3.6 The actual fortnight hours that LE1 would have worked had the incident not occurred (about 117) were excessive.

3.7 Tranz Rail's newly introduced changes to the Crew Management System did not prevent LE1 from being rostered in excess of 98 hours for a fortnight nor against working excessive consecutive night shifts. The system also did not monitor total fortnightly hours for overlapping fortnights.

3.8 LE1 was probably suffering from a loss of attention and physiological arousal caused by fatigue through the effect of accumulated sleep debt during his shift on Wednesday 7 March.

3.9 Tranz Rail's track warrant theory recertification examination paper was ineffective in detecting shortcomings in LE1's and the TC's knowledge of track warrant operation.

3.10 Tranz Rail's track warrant theory recertification examination did not adequately test the TCs knowledge of all relevant track warrant reference book.

3.11 The stalling was not effectively "incident managed" by the TC.

4. Safety Actions

4.1 Alterations to procedures for disabled trains

4.1.1 On 27 June 2001 Tranz Rail advised that:

> Tranz Rails internal investigation identified the clarity and availability of instructions for relief of disabled trains as a key issue. A briefing has been issued to Locomotive Engineers and Train Controllers clarifying what information is needed when dealing with a disabled train, in particular focusing on including the length of a train, considering the direction relief is coming from and the use of detonator protection.
>
> New rules are presently being drafted significantly changing the presentation of the existing rules for disabled trains in all signalling categories. These will cover the above and be organised into more concise steps, rather than the rather wordy style presently used.

4.1.2 On 17 October 2001 Tranz Rail advised that:

> Tranz Rail has issued revised procedures for disabled trains in TWC, SLAS, CTC and DLAS territory on Bulletin number 742 effective at 1200 on Friday 19 October 2001. A copy of this bulletin is attached.
>
> In addition to the above, the Track Warrant Rules have been revised and will be implemented on 3 December 2001. This revision includes concise steps relevant to TWC for disabled train recovery and includes the generic steps outlined in Bulletin 742.
>
> All other signalling regulations are being revised and will include a format similar to the new Track Warrant Rules as each section is added to the Rail Operating Rules.

A copy of Bulletin 742 is attached to this report as Appendix C.

4.2 Locomotive engineer fatigue

4.2.1 Tranz Rail advised that they intend to commission Associate Professor Philippa Gander, PhD, Director, Sleep / Wake Research Centre in Wellington, to update the present training package for LEs before the end of 2001. This will be followed by any further revision, and when complete, training of trainers. In the interim, information from the existing package has been highlighted in weekly safety information sent to operating staff, including LEs. As an interim step, a number of LEs who have shown signs of lapses of concentration have been taken through the existing package.

4.2.2 On 27 November 2001 Tranz Rail advised that they:

> have completed the revised Alertness Management training package and have commenced training. It is planned to have all Locomotive Engineers trained by end of June 2002.

4.3 Roster management

4.3.1 On 16 July 2001 the managing director of Tranz Rail advised that they:

> completed a review of recent literature relating to factors contributing to biological sleepiness in Locomotive Engineers during April 2001.
>
> This review identified consistent opinion regarding sequences of night shifts. More specifically, there is now a view that the number of night shifts in rotating rosters should be confined to three, and in the case of permanent night shift, six. Tranz Rail Locomotive Engineers work to rotating rosters.
>
> The literature also recognised the importance of a recovery period following a sequence of night shifts to restore "sleep debt" accumulated during these shifts.
>
> The information was first reviewed by the Locomotive Engineers' Council (a joint Tranz Rail/Rail Maritime and Transport Workers Union forum) at their 10/11 May meeting. It has subsequently been decided to prepare rosters with sequences of night shifts confined to three followed by mandatory time off. These rosters will be piloted in four depots.
>
> Towards the end of the pilot period (likely to be several months) Locomotive Engineers working these rosters will be surveyed to identify if they have found the revised rostering principles more beneficial.
>
> It is expected the pilot period will commence during August 2001 and the review will take place in late October / early November 2001.
>
> A final decision regarding a permanent change to these rostering principles will be made following an analysis of the results of the pilot and further discussion within the Locomotive Engineer's Council.

4.3.2 On 27 November 2001, Tranz Rail advised that:

> The pilot period has been extended until early 2002 to allow completion of an independent survey of Locomotive Engineers at the depots involved.

4.3.3 On 27 November 2001 Tranz Rail advised that it had commenced monitoring Locomotive Engineers hours and had introduced a maximum of 98 hours maximum rostered hours each fortnight on 15 January 2001. The company had also introduced a modification to the Crew Management System monitoring the number of consecutive shifts both within and between fortnightly roster periods. This was introduced on 18 February 2001.

4.4 Crew resource management

4.4.1 Tranz Rail advised:

> 001/99
> Service Delivery will review the crew resource management training available within New Zealand for the aviation and marine industry to assess its suitability to meet the requirements of our operation. If accepted such training would be linked into our current training requirements for Locomotive Engineers, Signalbox and Train Control staff.
>
> 006/01
> Tranz Rail accept this recommendation. This is presently being evaluated to determine the best way to facilitate these principles to staff. Tranz Rail expect to complete this evaluation by end of June 2001.

4.4.2 On 27 November 2001 Tranz Rail advised that:

> Crew Resource Management training is presently being provided in conjunction with Alertness Management training

5. Safety Recommendations

5.1 On 17 December 2001 the Commission recommended to the managing director of Tranz Rail that he:

5.1.1 develop and introduce a checksheet for use by train controllers when dealing with disabled trains, to include such detail as:

- the exact metrage of the disabled train and how it was established
- the length of the disabled train
- the recognised points between which it was disabled
- the end from which relief is to come
- the actions taken to protect the disabled train
- confirmation that the intended recovery action was discussed with the locomotive engineers of the disabled train and the relief train (067/01)

5.1.2 replace the current multi-choice track warrant theory recertification examination for locomotive engineers with a more comprehensive examination which incorporates all track warrant control rules and regulations contained in the rulebook (068/01)

5.1.3 develop a separate track warrant theory recertification examination for train controllers, which covers all relevant track warrant rules and regulations and other instructions included in reference manuals and books. (069/01)

5.2 On 9 January 2002 the Managing Director, Health, Safety & Environment, Tranz Rail replied:

5.2.1 **Final Safety Recommendation 067/01**
Tranz Rail accept this recommendation. The check sheet will be a computer generated pro forma which the Train Controller will complete as each step is actioned. This will be printed on completion and attached to the train control diagram.

It is expected that this process will be implemented by the end of February 2002.

5.2.2 **Final Safety Recommendation 068/01**
Tranz Rail accept this recommendation in part. It is agreed that the content of the bi-annual track warrant theory assessment should be more comprehensive and the number of questions will be increased to provide a wider coverage of track warrant rules and regulations. However, it is still proposed to retain the existing computer based multi-choice assessment method.

It is expected that the revised papers will be implemented by the end of February 2002.

5.2.3 **Final Safety Recommendation 069/01**
Tranz Rail accept this recommendation. It is intended that Train Controllers will complete the more comprehensive assessment outlined in 068/01 together with a separate assessment covering Rail Operating Code procedures specific to Train Control.

It is expected that the latter assessment will be implemented by the end of February 2002.

Approved for publication 13 December 2001

Hon. W P Jeffries
Chief Commissioner

Appendix A

Track Warrant procedures for assisting disabled trains

A1 Tranz Rail's Rail Operating Code Section 6 Clause 12.8.32 stated as follows:

> Regulation 22(b) - Mis 39's[5] will not be used in Track Warrant territory. The disabled train must be instructed by track warrant to remain stationary at a specified point until the relief locomotive removes it.
>
> The track warrant issued to the disabled train must:-
>
> Cancel the original track warrant.
>
> Authorise the train to "work between" the station to which the relief locomotive will assist and the nearest metrage peg on the other side of the train.
>
> Advise the train which direction assistance will come from.
>
> Instruct the train to remain where it is until the arrival of the relief locomotive
>
> The track warrant issued to the relief locomotive must:-
>
> Authorise the relief locomotive to "work between" limits which must encompass the location of the disabled train.
>
> Advise the location of the disabled train. (Make sure the location given is at the end nearest to the relief locomotive).
>
> Instruct where to assist the train to.

A2 Tranz Rail's Track Warrant Assisted Computer System (TWACS) User Manual Clause 2.1.7 Work in Conjunction stated, in part:

> If the warrant has Clause 4 limits, the option of entering a "Work in Conjunction" (WIC) paragraph into Clause 12 will be given. A WIC is the only way TWACS will permit entering data into Clause 12 to conform with TWC Regulation 4(a)[6]. A selection list will give a brief outline of each WIC. When selected, further selections or input boxes will be provided to complete the variable information in the selected WIC. The "Work in Conjunction area" must be wholly within the clause 4 limits.
>
> "Work in Conjunction" options (WICs) are those entries that are used in Clause 12 to permit the limits of two or more issued warrants to overlap in accordance with TWC Regulation 4(a). . .
>
> Some of the information contained in a WIC is selected by the Controller and the remainder is entered by the system. The identities and limits entered by the system are determined by either the information selected , or by what is in the overlapping warrants . . .
>
> Information shown in "text" enclosed in [ ] will be selected by the Controller. Information shown in "text" enclosed in < > will be entered by TWACS . . .

[5] A Mis 39 is a form completed by the locomotive engineer of a disabled train to the train controller and locomotive engineer of a relief train or locomotive undertaking that he will not move his train until relief arrives.

[6] Track Warrant Regulation 4(a) stated: That portion of the line which is common to both track warrants is within the "work between" limits of each warrant. The respective track warrants must advise the addressees of each other's presence on the same part of the line, and contain any instructions necessary to ensure safe working.

DETAILS OF EACH WIC

1(a) Disabled Train

This WIC is used in the warrant issued to a disabled train waiting for assistance.

TEXT = <train ID> must not move from <Mis 87 at> until arrival of [ID of relief locomotive] as relief locomotive from [location assistance is coming from]...

1(b) Relief Locomotive

This WIC is used in the track warrant issued to a locomotive or train which is going to assist a disabled train.

TEXT = <train ID> is disabled at <Mis 87 “at” of disabled train>. Assist <ID of disabled train> to [location which disabled train is to be taken] in accordance with Regulations...

Appendix B

Method for assessing fatigue

Fatigue assessment was based on a method developed by the United States National Transportation Safety Board and the NASA Fatigue Countermeasures Program (1). Bracketed number references used in the assessment are included at Appendix C.

The method seeks information on the following factors known to produce fatigue-related performance impairment:

- extended wakefulness
- acute sleep loss and cumulative sleep debt
- presence of a sleep disorder
- critical times in the daily cycle of the circadian body clock.

Prior sleep loss / sleep debt

Insufficient prior sleep increases biological sleepiness at all times in the circadian body clock cycle. To be alert and to function well, each person requires a specific amount of nightly sleep. If individual "sleep need" is not met, the consequences are increased biological sleepiness, reduced alertness and impaired physical and mental performance [3,5,10].

For most people, getting 2 hours' less sleep than they need on one night (an acute sleep loss of 2 hours) is enough to consistently impair their performance and alertness the next day. The reduction in performance is particularly marked if less than about 5 hours' sleep is obtained [11,12]. The effects of several nights of reduced sleep accumulate into a "sleep debt", with sleepiness and performance becoming progressively worse [10,13]. Typically it takes 2 full nights for sleep and daytime functioning to return to normal after sleep loss [11,13,14].

In general, night workers find it difficult to obtain extended sleep during the day [2,6-9]. Typically, daytime sleep periods are about a third shorter than night-time sleep periods [2,9]. The more rapid accumulation of sleep debt on night shift is recognised in regulations in other transportation sectors that limit the number of night shifts in a row. For example, air traffic controllers are generally limited to 2 night shifts in a row [16].

Night workers are seldom able to sleep beyond the early afternoon, when the circadian body clock moves the brain and body into "awake mode" and sleep becomes difficult, if not impossible. Thus, late-running night shifts further restricted the opportunities for LE1 to sleep during the biologically preferred time, and probably contributed to his sleep debt at the time of the accident.

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Appendix C

Train Operations
WELLINGTON

BULLETIN NO. 742 Tranz Rail
(Semi-permanent) 17 October, 2001

C A N C E L L A T I O N

Bulletin No.735 (Semi permanent) dated 16 October 2001 re alterations to Rules and Regulations is cancelled.

NOTE: Where a paragraph is marked with a vertical line and the print is italic this indicates either it is a new instruction or if it was a previous change, a further change has been made.

Commencing at 1200 hours on Friday 19 October 2001 and continuing until further advised the following instructions will operate. The relative Rules are modified accordingly.

Rules and Regulations, General Rules

2. Definitions (new definition)

Addressee: The person to whom the operating authority is addressed and who is responsible for ensuring the provisions of the authority are carried out.

Regulations, TWC & SLAS 22, CTC 17, DLAS 13

Existing emergency procedures are enhanced with the following additional requirements:-

Metrage of the disabled train:

- *This must be the nearest metrage peg that is **clear** of the end of the train in the direction the relief train will arrive from,*
- *This is to include a 200 metre safety buffer.*

Confirmation of Protection

- *Train Control must confirm protection arrangements **before** authorising any relief train.*

If detonator protection cannot be provided due to a bridge without walkways or a constrictive tunnel:

- *The Locomotive Engineer must advise Train Control,*
- *Train Control must advise the relief train of the situation and direct that, while in the obstructed section, speed must be reduced to enable the relief train to stop in **half** the clear distance that can be seen ahead.*

These changes to train disabled procedures:

For Locomotive Engineers:

- *clarify the metrage to be given when disabled,*
- *include a new requirement to add a 200m safety buffer, and*
- *advise what to do when detonators cannot be used due to a bridge with no walkway or a constrictive tunnel.*

For Train Controllers:

- *introduce a new requirement for Train Control to confirm the protection is in place*
- *introduce a new requirement to advise the relief train to reduce speed when protection cannot be provided.*

Code and Audit Manager