Report 08-110, train control operating irregularity, leading to potential low-speed, head-on collision, Amokura, 23 September 2008

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Report 08-110

train control operating irregularity

leading to potential low-speed, head-on collision

Amokura

23 September 2008

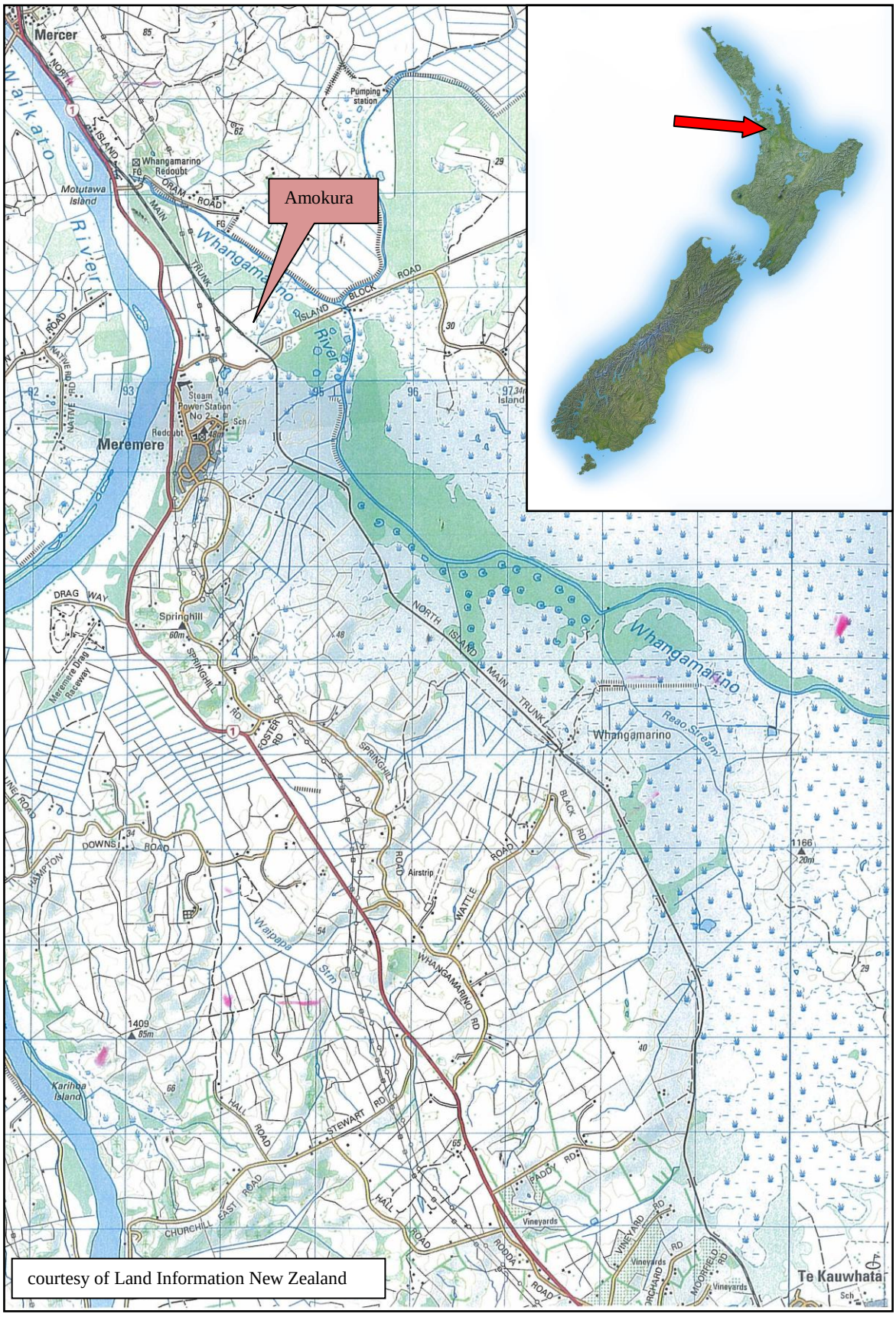

Figure 1
Location of incident

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Abbreviations

CF	communication failure
DLAS	double line automatic signalling
KiwiRail	KiwiRail Limited
km	kilometre(s)
NIMT	North Island Main Trunk
NTCC	national train control centre (in Wellington)
UTC	universal co-ordinated time

Data Summary

Date and time:	23 September 2008 at 0700[1]
Location:	Amokura, North Island Main Trunk
Access Provider:	Ontrack
Persons in train control:	night shift: 2
	day shift: one
Train operator:	KiwiRail Limited
Persons on board Train 225:	one
Persons on board Train MP1:	one
Persons on board Train 210:	one
Injuries:	nil
Damage:	nil
Investigator-in-charge:	Vernon Hoey

[1] Times in this report are New Zealand Daylight Time (UTC + 12) and are expressed in the 24-hour mode.

Executive Summary

A train controller starting his morning shift on 23 September 2008 unknowingly planned to direct a freight train along a line that was occupied by another freight train, which was standing awaiting routing through an area where a signalling fault was under repair. He was not aware the second train was stationary on the line. A potential low-speed, head-on collision was avoided when the first train was subsequently routed along the adjacent line after the signal failure had been partially corrected.

The existence of the second train was not known to the train controller because the senior controller in charge of the previous shift had omitted to record the movement of the train on the train control diagram, and it was not showing on the mimic screen in the national train control centre owing to the signal failure. Neither the current train controller, nor the previous controller and a trainee controller he was mentoring had noticed that the second train, which was a scheduled service, was not displayed on the train control system.

The train controller who omitted to record the second train on the train control diagram was suffering from fatigue caused by an excessive planned and unplanned work roster that offered limited opportunity to sleep, in spite of his working hours closely conforming to the minimum requirements of the network service provider.

Investigations into previous train control incidents have led to recommendations about the potential use of existing onboard train technology to give train control live tracking of train locations, which could have helped avoid this incident by showing the existence of the second train in spite of the signalling failure.

KiwiRail management has introduced a new fatigue policy since the incident, and it has previously responded to fatigue related recommendations resulting from investigations into previous incidents. Since this incident the Transport Accident Investigation Commission has made 3 new recommendations to the rail regulator concerning train controller rostering, shift handover procedures and the retraining of train controllers after extended breaks from operating critical systems.

(Note this executive summary condenses content to highlight key points to readers and does so in simpler language and with less technical precision than the remainder of the report for the benefit of a non-expert reader. Expert readers should refer to and rely on the body of the full report.)

1 Factual Information

1.1 Narrative

1.1.1 At about 0700 on 23 September 2008, a train controller in charge of the Waikato desk in Ontrack's[2] national train control centre (NTCC) in Wellington initiated arrangements to issue an authority for northbound (Up) Train 210 to travel "wrong-line-running" along the Down main line from Amokura to Mercer, to minimise delaying the train during a signalling system failure at Amokura. Amokura was a junction station located at 604.62 kilometres (km) on the North Island Main Trunk (NIMT).

1.1.2 The train controller had just started his shift and was not aware that a Down train (MP1) was standing stationary on the Down main line at Amokura just ahead of Train 210 (see Figure 2). A signal maintainer working on the failure of the local signalling system at Amokura contacted the train controller and told him that he had partially resolved the signalling problem. The train controller abandoned the wrong-line-running arrangements he had initiated and routed Train 210 along the normal Up main line instead.

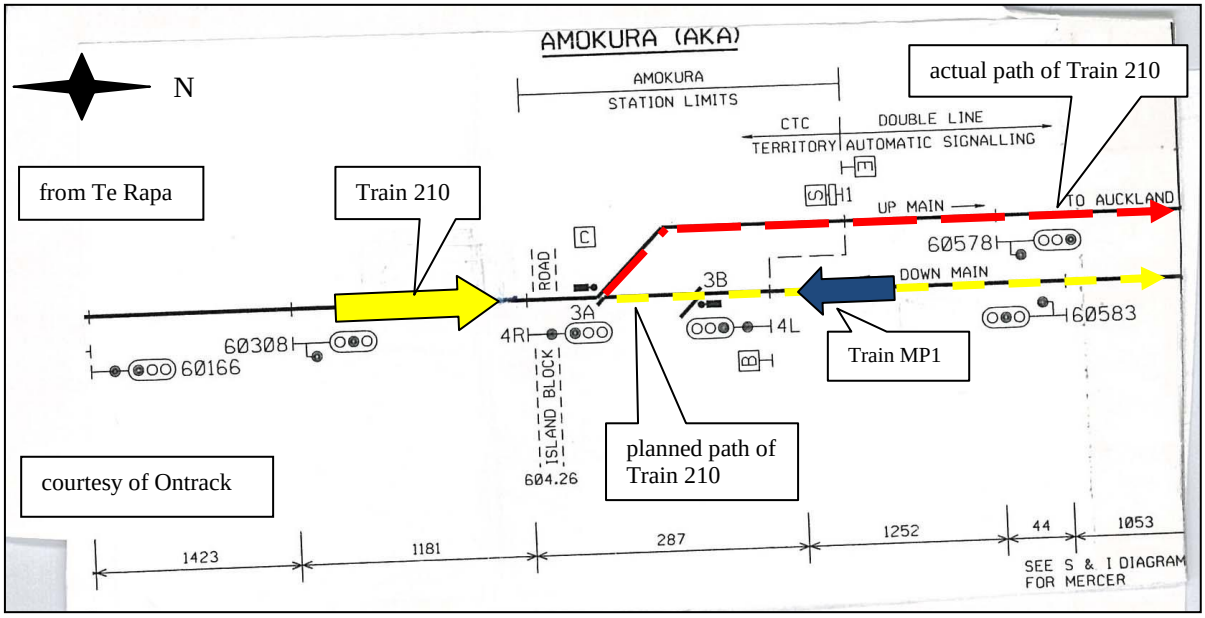

Figure 2
Track/Signalling layout at Amokura (not to scale)

1.1.3 The locomotive engineer of Train 210 rounded a curve between Island Block Road level crossing and No.3A motor points and saw Train MP1 standing stationary on the Down main line beyond Signal 4L, the line on which his train would have been routed if the wrong-line-running process had been followed through.

1.2 Track features and operating systems

1.2.1 The section of the NIMT between Te Rapa and Auckland covered a distance of 136.5 km and was mostly double-tracked. This allowed trains travelling in opposite directions to run on segregated Up and Down main lines (see Figure 3). There were sections of single-line within that section, the first being a short section over the Waikato River at Ngaruawahia (between Te Rapa and Te Kauwhata) and the second being between Te Kauwhata and Amokura, a distance of 13 km. Double line automatic signalling (DLAS) was the operating system in use on the double-line sections and centralised traffic control was the operating system in use on the single-line section between Te Kauwhata and Amokura.

[2] Brand name of the rail infrastructure owner, maintainer and access provider at the time.

1.2.2 In double-line areas, trains ran on the left-hand track in the direction of travel. The running order of trains was directed by the train controllers. This was achieved with mimic screen signalling systems installed in the NTCC and by issuing instructions to signal box controllers who operated controlled signals and points systems at other locations.

1.2.3 Train controllers manually operated the signalling systems at Te Kauwhata, Whangamarino, Amokura and Mercer. Train movements on the single line sections between Te Kauwhata, Whangamarino and Amokura and on the double line section between Amokura and Mercer (an overall distance of 17.5 km between Te Kauwhata and Mercer) were displayed on a mimic screen at the Waikato desk in the NTCC.

1.2.4 Separation between following trains on either the Up or Down main lines was governed by (any number of) intermediate signals located between controlled signalled locations, such as between Amokura and Mercer, to maintain separation between trains travelling in the same direction. Intermediate signals were non-operator controlled and proceed aspects (green for clear-proceed for 2 sections, or yellow for caution-proceed for one section) would only be displayed when the track circuits in the section(s) beyond the next signal(s) in advance were unoccupied.

1.3 Sequence of events

1.3.1 At 2300 on 22 September 2008, a train controller in training (trainee) took charge of the Waikato desk in the NTCC. The trainee was under on-job-training guidance from a senior train controller and he remained at the desk until 0300 the following day (23 September 2008), at which time he handed back charge to the senior train controller. This was done to allow the trainee to continue with theory training on a signalling system that was new to him.

1.3.2 At 0441, the senior train controller was alerted by an adjacent Auckland desk train controller when Signal 8L[3] at Paerata had not been cleared to proceed for the pending movement of Train 225 (a southbound Auckland-Wellington express freight service).

1.3.3 At 0442, recorded data events in the NTCC signalling system showed Signal 8L at Paerata was manually cleared and Train 225 travelled past it at 0444. The senior train controller later said that he "couldn't recollect" drawing a plot line recording the train movement on the train control diagram. During this time, the voice recording system showed that he was performing some peripheral duties, which included folding the diagram in readiness to hand back charge of the desk so the trainee could resume his practical training.

1.3.4 Between 0451 and 0454, the senior train controller handed back charge of the Waikato desk to the trainee. During the handover process, there was no comment made about the running of Train 225 even though it had passed Paerata about 7 minutes earlier, nor was there any comment on Train MP1, scheduled through Paerata 18 minutes later.

1.3.5 At 0506, Train 225 passed through Mercer (the next station past Paerata monitored by train control) under clear proceed signals, but its passage was not observed on the mimic screen by the trainee and was not recorded on the train control diagram because he was not aware of its existence. At the time, both train controllers were dealing with a signalling failure at Te Awamutu (south of Te Rapa) that had been affecting train movements in that area from 0400.

1.3.6 At about 0510, the locomotive engineer of Train 225 slowed and stopped his train at Amokura (the next station past Mercer monitored by train control). However, at an undetermined time prior to this event, a communication failure (CF) had resulted in the disconnection of the signalling system at Amokura from the signalling system in the NTCC. This meant that the train's arrival and stationary presence on the Down main line at Amokura was not displayed on the mimic screen at the Waikato desk, and as previously mentioned its existence was not recorded on the train control diagram.

[3] Signal 8L at Paerata was the boundary on the Down main line between the Auckland and Waikato train control desks.

1.3.7 At 0514, Signal 8L at Paerata was cleared to proceed by the trainee after he was questioned by the senior train controller on the preparations he was intending to make for the first of a series of morning peak-hour suburban passenger services scheduled to travel to Pukekohe (just south of Paerata). At this time the trainee brought the matter of the CF alarm at Amokura to the attention of the senior train controller. On advice, the trainee called out a signal maintainer to address the problem, noting that Train 225 would be the next train in the Paerata area. Neither train controller was aware at that time that Train 225 was already standing at Amokura, 28 km further south.

1.3.8 At 0520, a Down train approached Paerata. The senior train controller commented that it was a suburban service to Pukekohe, but the trainee, who had previously cleared Signal 8L, said that he thought it was Train 225 and recorded its passage at 0524 with that identity. This movement was actually Train MP1 (a southbound Auckland-Tauranga express freight service). The senior train controller was heard to say on the voice recording system that he had recalled hearing about Train 225 earlier and not drawing it down on the train control diagram (see Figure 3).

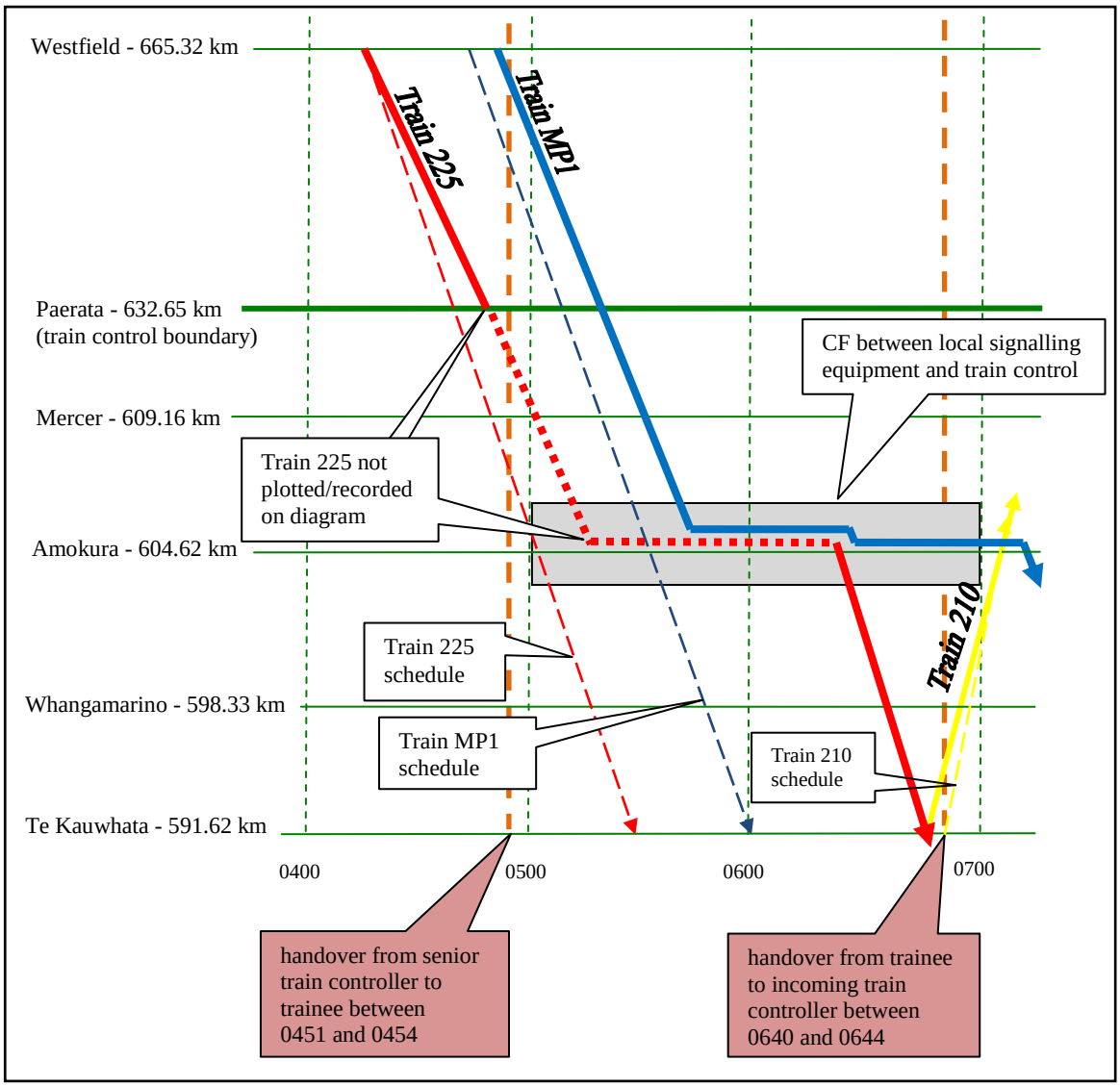

Figure 3
Recorded train journeys between Westfield and Te Kauwhata (not to scale)

1.3.9 A download of the train control signalling system data showed that between 0535 and 0543, the trainee entered several indication recheck commands via the mimic screen in an attempt to restore the Amokura signalling system, but without success.

1.3.10 At 0546, Train MP1 passed through Mercer under clear proceed signals, but its passage was not observed by the trainee on the mimic screen and not recorded on the train control diagram.

1.3.11 At about 0550, the locomotive engineer of Train MP1 slowed and stopped his train at a signal protecting Train 225 at Amokura. He saw the rear of the train ahead in the darkness and decided to take a nap based on an assumption that both trains were probably waiting for an Up train travelling across the single line from Te Kauwhata to Amokura.

1.3.12 At 0601, the locomotive engineer of Train 225, after waiting for about 45 minutes (his estimation of the running time for an Up train to travel from Te Kauwhata), telephoned the trainee train controller from his mobile phone. The trainee instructed the locomotive engineer to leave his cab and hand operate both sets of No.3 motor points (refer Figure 2 on page 1) to the reverse position, which was the setting for Down trains to travel from the Down main line to the single-line at Amokura.

1.3.13 While hand operating the points, the locomotive engineer of Train 225 spoke to the signal maintainer who had arrived on the scene. The signal maintainer mentioned that repairs to the failed signalling system would take a while.

1.3.14 At 0626, Train 225 left Amokura on a Mis.59[4] authority. The locomotive engineer of Train MP1 had been aroused when he heard the trainee issue the Mis.59 over the radio system and moved his train towards Signal 4L protecting No.3 points after Train 225 had moved off. He also saw the signal maintainer working in the vicinity of a nearby building that housed the local signalling equipment. The locomotive engineer did not contact train control to advise that his train was stopped at Amokura, as he was required to do.

1.3.15 KiwiRail's operating rule 109 (f) said that when a train had been stopped at a signal, the locomotive engineer must ascertain the reason for the delay.

1.3.16 Between 0640 and 0644, a rostered changeover occurred in train control between the trainee and an incoming train controller. During the changeover the trainee said that Train 225 was travelling from Amokura to Whangamarino on a Mis.59 and he explained that a signal maintainer was on site at Amokura searching for the fault in the signalling system. During this time no mention was made of Train MP1.

1.3.17 At 0649, northbound Train 210 left Te Kauwhata after Train 225 had passed by. Shortly afterwards, and knowing that No.3 points at Amokura were isolated and secured in the reverse position, the incoming train controller saw an opportunity to minimise delaying Train 210 by running it wrong-line the short distance to Mercer. At about 0700 and after Train 210 had just passed Whangamarino, the incoming train controller informed the locomotive engineer on Train 210 of his plan. The process would have required Train 210 to stop at Signal 4R at Amokura to be issued with a Mis.60 wrong-line-running authority.

1.3.18 In the meantime, the incoming train controller pre-prepared his copy of the Mis.60. However, the signal maintainer contacted him moments later and said that No.3 points were now restored to working order. At about 0703 and when Train 210 was approaching Signal 60308 (midway between Whangamarino and Amokura), the train controller instructed the locomotive engineer that the Mis.60 would not be issued and his train would travel on the Up main line as normal.

[4] A train control issued written authority for a train to pass a departure signal at stop and travel through a single section to the next station in advance.

1.3.19 At 0708, Train 210 passed Signal 4R at Amokura and the locomotive engineer said that he "got a hell of a shock" when he saw Train MP1 standing on the Down main line where, if the Mis.60 had been issued and executed, he would have driven his train (see Figure 4).

Figure 4
The approach to Amokura from the south

1.3.20 The incoming train controller said that he too was quite shocked to be told of a train standing on the Down main line at Amokura and reported details of the situation to the Network Control Manager. He added that after the No.3 points were restored, the indication display of Train MP1 standing on the Down main line "did not come back [on the mimic screen] until some time later".

1.3.21 The locomotive engineer of Train MP1 said that he was surprised when he heard the incoming train controller initiate arrangements to issue the Mis.60, but did not question the train controller's plan. He said that "moments" (later calculated to be 8 minutes) after he heard the incoming train controller initially inform the locomotive engineer of Train 210 of the plan, Train 210 appeared into view and travelled past on the Up main line.

1.3.22 The locomotive engineer of Train MP1 said that he thought his train would be "getting away in a few seconds" to allow his train to pass through Amokura before the Mis.60 would be issued to Train 210. He added that he didn't normally "pester" train control because the train controller was busy doing his thing, and didn't on this occasion because he had overheard some of the radio transmissions relating to the disruption at Te Awamutu.

1.3.23 In addition to informing the train controller, the locomotive engineer of Train 210 reported details of the incident to his supervisor in Te Rapa.

1.4 The signalling system failure

1.4.1 A 50-year-old copper cable system stretched from Te Kauwhata to Mercer. This copper cable was connected at Te Kauwhata to a fibre-optic link from the NTCC. The copper cable carried signalling commands and train occupation information for the area between Te Kauwhata, Whangamarino, Amokura, Mercer and the NTCC.

1.4.2 There was a cable link between the copper cable and the signalling system at Amokura. The copper cable was ageing and was considered by Ontrack to be less reliable than desired. The copper cable was laid though swampy and rocky geology, and these environmental conditions had resulted in a higher failure rate when compared to other similar cabling arrangements across the national signalling system network.

1.4.3 During Saturday 20 and Sunday 21 September 2008, the weekend prior to the incident, Ontrack had installed a replacement wireless system between a modem at Te Kauwhata (where it was linked to the NTCC fibre-optic network) and Amokura. This meant that control of the signals at Amokura was separated from the copper cable system that retained control of the signals at Mercer, Whangamarino and Te Kauwhata. Ontrack said that the CF that occurred on the morning of Tuesday 23 September had probably been in the new wireless link. There had been no history of any other failures in either the old or the new signalling system at Amokura in the 2 months leading up to and during the 16 months following the incident.

1.4.4 Even though a route through Amokura had not been cleared for Train 225, the CF had the effect of restoring any previously cleared operator-controlled signals to stop. Train detection was also lost during such a failure. On the other hand, intermediate signals were not affected and they continued to operate as normal.

1.5 Event summary diagrammatic

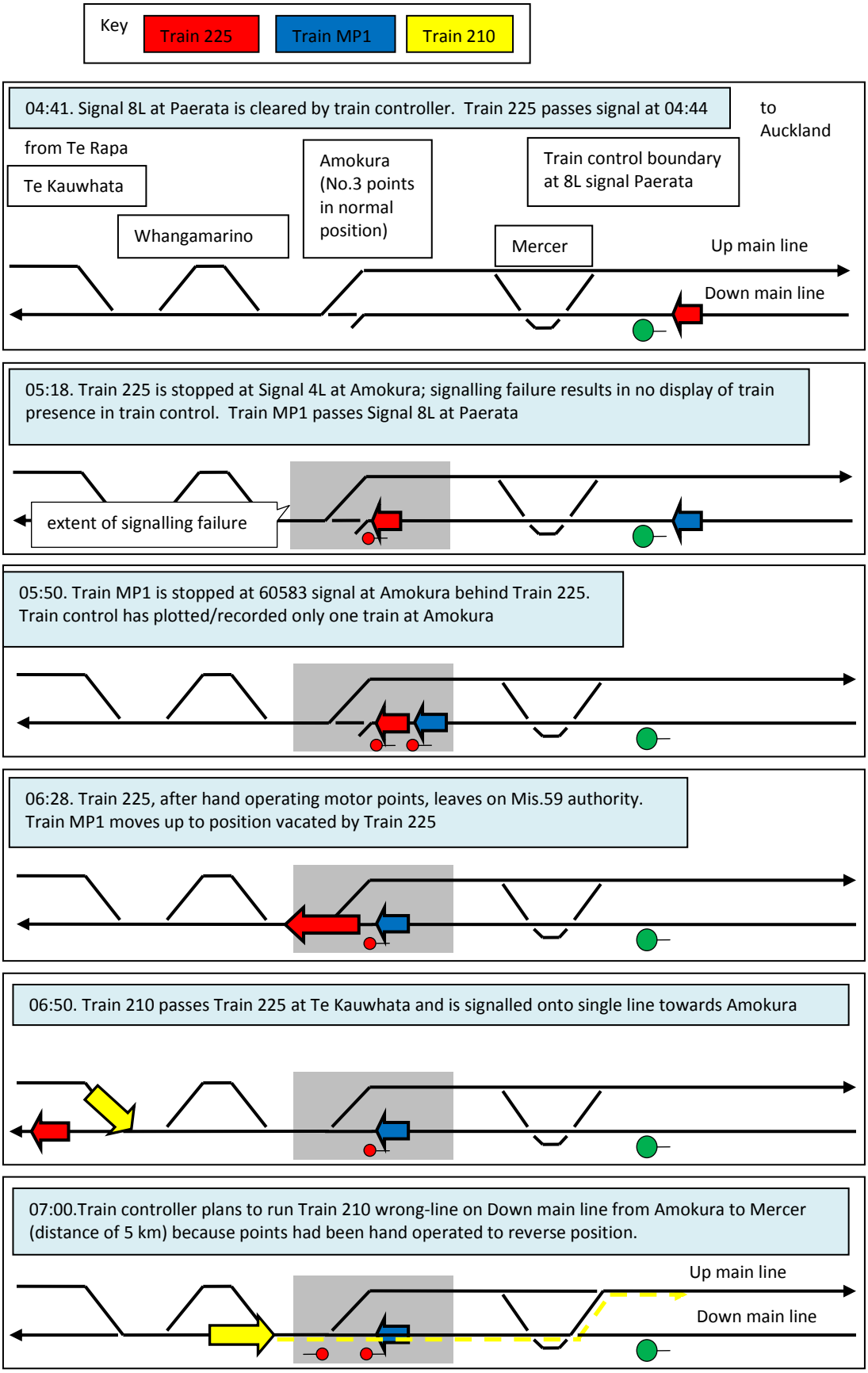

Figure 5
Summary of train movements from the narrative (not to scale)

1.6 Personnel

Senior train controller

1.6.1 The senior train controller had more than 25 years' experience in the role. He was suitably qualified and held a current licence to operate across the areas covered on the 3 northern group desks, those being Auckland, Taumarunui/Waikato and East Coast Main Trunk. Additionally, the senior train controller performed a rostering coordinator's role for himself and other train controllers working across the northern train control group.

1.6.2 During the weeks preceding the incident, the train controller worked the following hours.

Day and date 2008	Actual hours worked	Comments	Duration of breaks
Sunday 24 August	1000-1800	extra work period*	
Monday 25 August	0640-1450		
Tuesday 26 August	0640-1450		
Wednesday 27 August	1440-2250		
Thursday 28 August	1440-2250		
Friday 29 August	1440-2250		
Saturday 30 August	1150-1800	extra work period*	
Sunday 31 August	off		**45 hours**
Monday 1 September	1440-2250		
Tuesday 2 September	1440-2250 2240-0300#	cover for sickness	
Wednesday 3 September	1440-2250		
Thursday 4 September	1440-2250		
Friday 5 September	1440-2250		
Saturday 6 September	rostered day off		
Total hours worked for fortnight: 100.00			**56 hours**
Sunday 7 September	off		
Monday 8 September	0640-1450		
Tuesday 9 September	0640-1450		
Wednesday 10 September	0640-1450		
Thursday 11 September	0640-1450		
Friday 12 September	0800-1600		
Saturday 13 September	0650-1800	extra work period*	
Sunday 14 September	rostered day off		**53 hours**
Monday 15 September	2240-0730#	cover for signalling outage*	
Tuesday 16 September	2240-0650#		
Wednesday 17 September	2240-0650#		
Thursday 18 September	2240-0650#		
Friday 19 September	2240-0650#		
Saturday 20 September	off		**24 hours**
Total hours worked for fortnight: 93.20			
Sunday 21 September	0650-1500	extra work period*	
Monday 22 September	0640-1240 +2240-0650#	extra work period*	
Tuesday 23 September	Train 225 not recorded at Paerata at 0443		

next day
* days worked on weekend breaks that impeded sleep recovery
+ 10 hours off between shifts instead of the mandatory 11.5 hours.

1.6.3 The train controller explained that he had reluctantly decided to work the extra work periods on 21 and 22 September to cover for sickness and because there was "no one else to cover the shift at all; no one else available on the roster to operate the second desk". He said that he made the decision as a last resort and after briefing the Network Control Manager on the situation. He added that the day shift on 21 September had been extra-busy because he was covering 2 desks instead of the normal one desk. Because his fellow train controllers had been consistently working weekends, he said that he had noticed a trend whereby they had begun to make themselves unavailable to work on their weekends off.

1.6.4 The train controller said that he probably had a good sleep after finishing his week of night shifts at 0650 on Saturday 20 September. He said that his sleep on the Saturday night/Sunday morning would probably have been disjointed (waking at 0200 and not getting back to sleep until 30 to 90 minutes later) because his body would have still been adjusting between daytime and night-time sleeping. He would have had a similar sleep pattern on the Sunday night/Monday morning. He said that during the 10-hour break between the shifts on the afternoon of Monday 22 September he would have slept between 1800 and 2100 before commencing his night shift at 2240. The train controller said that these sleep arrangements added to his fatigue.

1.6.5 The train controller explained that he was about to begin a second consecutive week of night shifts in order to resume the training of the trainee on his return from an area familiarisation trip. The train controller said that it had been his decision to accept this roster rotation even though he "had trouble sleeping the first night shift", but "normally you wouldn't do it [roster himself or accept such a roster change]".

1.6.6 After starting the night shift on Monday 22 September, the train controller spent the first 3 to 4 hours observing the trainee working at the desk. The change-over between 0451 and 0454 occurred because of a need to give the trainee time to continue DLAS rules theory revision away from the desk. He added that throughout the on-job-training period, he had taught the trainee to place Signal 8L at Paerata on manual control. By doing this, the trainee was compelled to clear the signal physically for every Down train.

1.6.7 The train controller said that he generally coped well with most of the shifts, but the day shift was the one with which he struggled. He suggested that the day shift week between 7 and 13 September "could have contributed to quite a bit of fatigue". He said that he was able to get sleep whenever he wanted to when he was working late shifts. His normal pattern for night shifts was to sleep "in the morning and then again I have a small rest period before starting work" in the evening. He found that kept him quite refreshed, particularly "having that little extra rest period" before starting work at 2300.

1.6.8 The train controller added that he had been diagnosed some years earlier with sleep apnoea (a sleep-related airways disorder) and he used a device that helped to keep his airways open while sleeping. The train controller had made his own appointment arrangements to see the rail industry sleep specialist for the diagnosis and treatment. The device was successful in treating his sleep apnoea. He said that he was physically fit and used to be a marathon runner, but after a recent hip operation he had taken up cycling to maintain physical fitness and wellbeing.

Trainee train controller

1.6.9 The trainee train controller had 11 months' experience in train control. His first desk certification had been attained on the East Coast Main Trunk desk on 17 October 2007. This desk was operated with a day shift only. After gaining about 6 months' experience on that desk, he was moved to the Taumarunui desk during April 2008 and started training on the area between Marton and Te Rapa.

1.6.10 The trainee gained certification for the Taumarunui desk in June 2008. A boundary change was planned for train control whereby the newly named Waikato area/desk was going to gain the section of double-line territory between Te Rapa and Paerata. Previously, the Taumarunui desk had not had any double-line territory. The trainee was concerned that he was only going to have about 4 weeks operating the area by himself before the boundary change was to occur. He mentioned his concerns to other people and his manager. He said that "he was told to take it easy through this and [we will] gradually get you up to speed".

1.6.11 Initially the Waikato desk was extended from Te Rapa to Paerata together with the North Auckland Line, and it wasn't until sometime later that the section between Marton and Taumarunui was transferred to the Manawatu desk. The trainee said that "during this period he was having some trouble with the new area between Te Rapa and Paerata but was told to take my time and [you will get] time to learn it thoroughly". Additionally, he was being tutored on the rules that applied to DLAS.

1.6.12 During the week before the incident, the trainee travelled to the Te Rapa-Paerata area on a familiarisation trip, but the planned 3-day trip was curtailed by half a day because of an aircraft breakdown. He worked a day shift on Friday 19 September and had the weekend off before being rostered on at 2300 on Monday 22 September. He reported that he was well rested and on the Monday had had an easy day, including an afternoon nap prior to starting work.

Incoming train controller

1.6.13 The incoming train controller had 5 years' experience in the role. In 2006, he accepted a transfer from the Central train control area to the Northern area because of staff shortages and had subsequently gained certification on the East Coast Main Trunk, Taumarunui and the newly formed Waikato desk. He was suitably qualified and held a current licence to operate as a train controller.

1.6.14 The incoming train controller said that he was well rested before reporting for duty at 0640 on the day of the incident.

Manager network operations

1.6.15 The Manager Network Operations (manager) had overall authority for the running of train control and other support functions. He had a train control background and was familiar with the working of the NTCC and policy requirements for rostering and shift and fatigue management.

1.6.16 The manager said that roster management was achieved through the work done by 3 roster coordinators (of which the senior train controller was one) in accordance with contractual and policy guidelines. Limitations in the payroll system meant there was no system available to report on hours worked by train controllers.

1.6.17 The manager said that it was only after consultation and deliberation that the decision was made to create the new train control boundary at Paerata. Compelling reasons, such as the increase in services in the Auckland suburban rail operation, constraints in the radio system and creating a workload balance across the 3 desks in the northern train control area meant that Paerata was the best choice for the new boundary station. The workload assessment was achieved by reviewing completed train control diagrams and making judgements from that information.

1.6.18 The manager submitted that the issues surrounding the trainee train controller were unique and there were no other options available but to treat him as a trainee and therefore provide him with all the training needed to enable him to become comfortable and gain certification in the newly extended area.

1.6.19 The manager explained that on-job-training provided an opportunity for a trainee to get to know the new desk area. The trainee, like all new recruits, had been trained in DLAS together with other signalling systems during the train control school. This meant that it had been about 10 months from when the trainee had graduated from the school until he commenced his on-job-training in the new area that incorporated DLAS for the first time.

Locomotive engineers

1.6.20 The locomotive engineers on Trains 225, MP1 and 210 were all employed by KiwiRail and had an average of 30 years' train-driving experience between them on the Auckland-Te Rapa section of the NIMT. They were all suitably qualified and held current licences to operate as grade one locomotive engineers.

1.6.21 All 3 locomotive engineers said that they were well rested and all reported that their respective train journeys up to the time that they arrived at or neared Amokura on the morning of the incident were uneventful.

1.7 The national train control centre (NTCC)

Its function

1.7.1 The NTCC controlled the main line (controlled network) of about 4000 km and was split into 15 geographic areas controlled from 10 desks. A single train controller controlled the movement of trains running on the controlled network within each of the variously combined areas. A suitably equipped cubicle was provided for each of the 10 desks. Flexibility of signalling, radio and auxiliary systems meant that the 10 desks could be merged into a lesser number of active desks during off-peak shifts and at weekends. The minimal number to which the desks could be merged was 3. When merged, the 3 desks covered the northern and southern halves of the North Island and the whole South Island.

1.7.2 A principal and long standing feature of the NTCC operation was the paper-based train control diagram (see Figure 6). The diagram showed the timetable linear (in green) of all scheduled Up and Down trains with their running numbers that were scheduled to run within a 24-hour (midnight to midnight) period. Before accepting a train into their area, the train controller was responsible for creating a safe path. There were procedures in place to notify train controllers of additional trains and train cancellations.

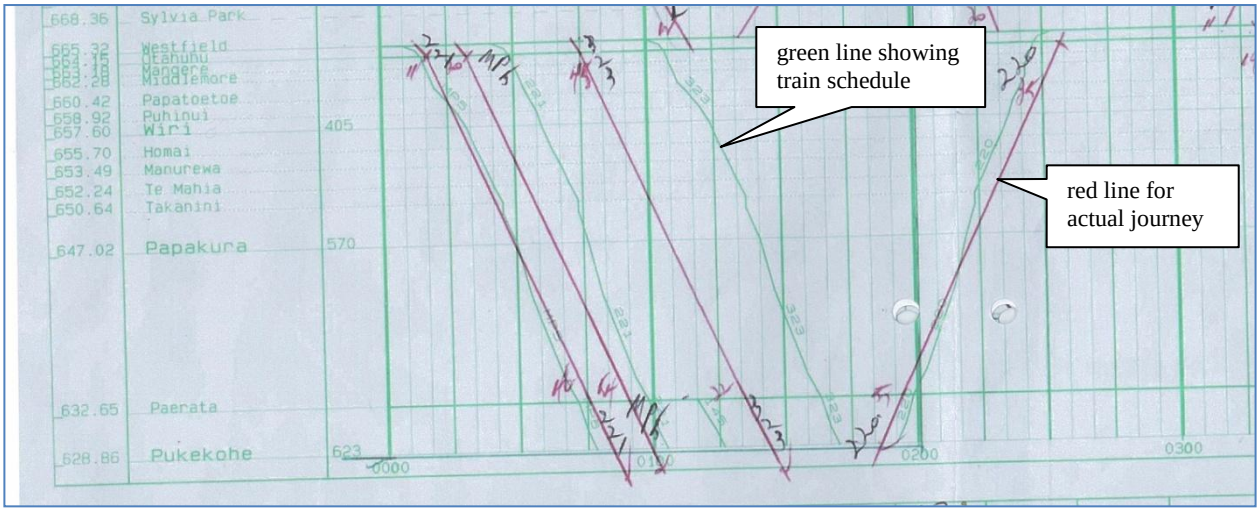

Figure 6
Train control diagram

1.7.3 Train control centres throughout Australia also relied on the paper-based train control diagram practice of plotting and recording train movements. The diagram was referred to as the train control graph in Australia.

1.7.4 Train controllers drew plot lines in pencil on the diagram to show an anticipated path of a train based on actual movement information, rate of progress and other influencing factors of which they were aware. This enabled train controllers to calculate times at en-route stations where train crossings could be optimised. This same plotted information was replaced in red ink to record the actual journeys as trains passed through stations visible on the mimic screen and from times provided by signal box controllers.

1.7.5 Because diagrams were laterally wide on a "landscape" format, there were folding conventions that train controllers were required to follow to ensure that active portions of somewhere between 4 and 6 hours into the future remained visible at all times.

1.7.6 Trains travelling towards Auckland were classified as Up trains and were identified with even reporting numbers such as 210. Trains travelling away from Auckland were classified as Down trains and were identified with odd running numbers such as 225. The prefix MP was used for dedicated services that ran between Auckland and Tauranga with containerised import/export freight. Train 210 was classified as a priority freight service.

Boundary change

1.7.7 A timetable change that introduced an expanded Auckland suburban rail operation on 13 July 2008 necessitated alterations to geographic boundaries in 3 desks in the NTCC in order to spread work load balances (see Figure 7). On that date, the following changes occurred:

Group	Old area name	Boundary changes that occurred on 13 July 2008		New area name
		Old area	New area	
Northern	Auckland	Waitakere-Te Rapa	Waitakere-Paerata	Auckland
Northern	Taumarunui	Te Rapa-Marton	Paerata-Taumarunui*	Waikato
Central	Manawatu	Marton-Otaki	Taumarunui-Otaki	Manawatu

*During the night shift (2300-0700) the new desk area was Paerata-Marton.

1.7.8 Prior to the introduction of the changes, Ontrack had conducted a risk assessment of a train being dispatched without authority between the Auckland and Waikato desks at the new boundary of Paerata. On the network, Te Rapa was a principal station equipped with a signal box operated by a signal box controller, but Paerata was equipped with a signalling system operated from train control. Using the risk assessment protocols contained in the National Rail System Standards, the assessment rated the likelihood and consequence of such an event as "low". This meant that the risk could be monitored and accepted.

1.7.9 Ontrack issued train control instruction N008 dated 13 July 2008, which said in part that:

> **DISPATCH OF TRAINS PAERATA**
>
> Paerata is the boundary between Waikato and Auckland Train Control.

1.7.10 The instruction specified procedures for the transfer of Up trains from the Waikato desk train controller to the Auckland desk train controller because of the design of the signalling system at Paerata. On the other hand, Signal 8L provided for a simpler transfer arrangement for Down trains. The Waikato desk signalling system provided train controllers with 2 options to operate Signal 8L at Paerata. They could either operate the signal manually for each Down train (such as was done for Trains 225 and MP1 in this instance) or allow the signalling system to clear the signal automatically. The automatic function was widely available and used at other signalling locations in the NTCC. The optional choice allowed train controllers to select either method to manage workload.

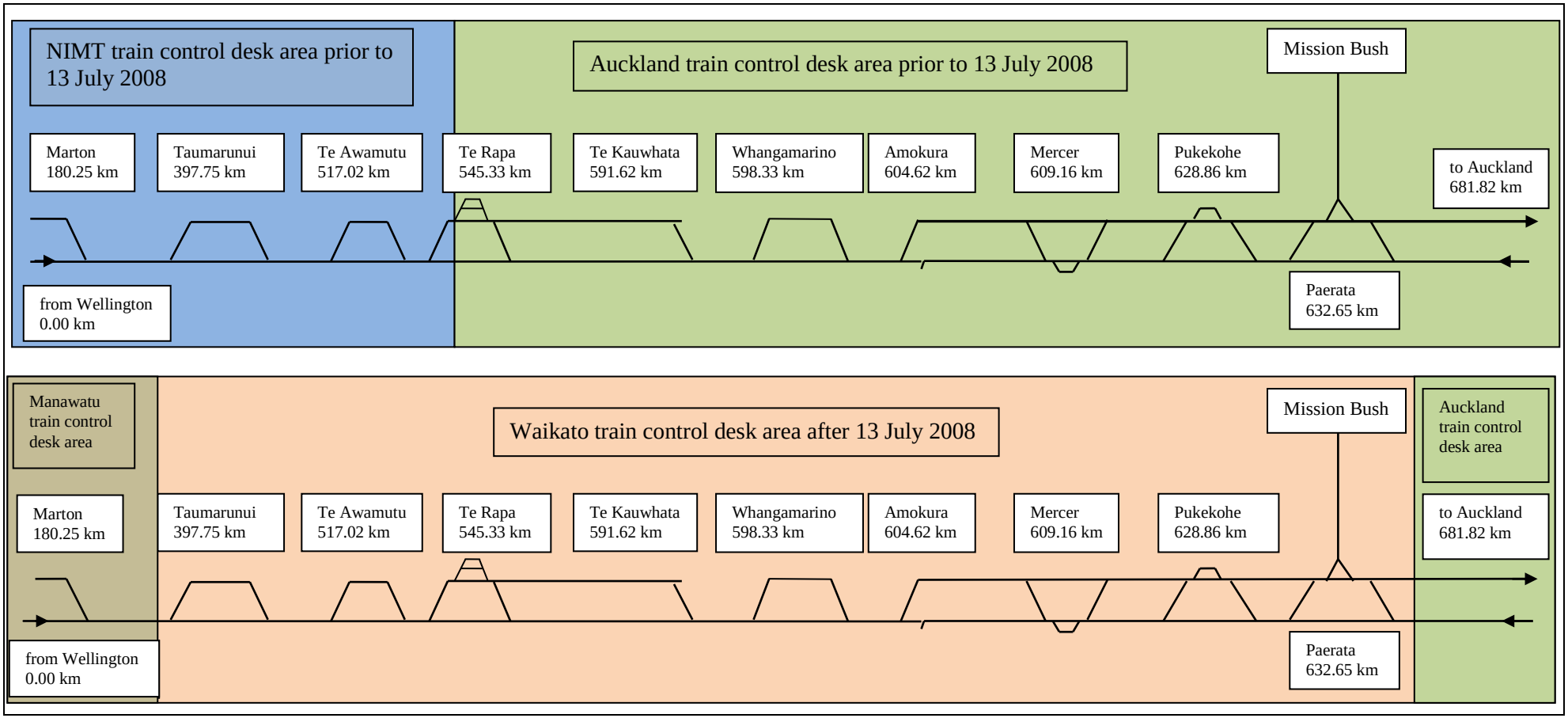

Figure 7
Train control boundaries and track layout on the NIMT between Auckland and Marton including Amokura (not to scale)

Wrong-line running

1.7.11 Wrong-line running was a situation whereby trains could be authorised to travel on the main line that was not configured for running in that direction. In other words, an Up or Down train could be authorised to run on the right-hand track in the direction of travel. This type of train running practice was used world-wide. In New Zealand, the authority was given on a Mis.60 form, which specified the signalled locations, such as Amokura and Mercer, between which the train would be routed wrong-line. The distances over which trains were run wrong-line were kept to a minimum.

1.7.12 Wrong-line running generally occurred for 2 reasons:

- planned infrastructure activity on one of the main lines
- emergency situations.

1.7.13 KiwiRail's rail operating procedures (an internal controlled document) dated 3 October 2005, supplement 10.1, instruction 5.2 track and time permit (Mis.60) summary of procedures, stated in part that:

> The sequence of issuing the track and time permit (Mis.60) is:
>
> - Carry out the checks as detailed herein to establish that it is safe to issue the Mis.60.
> - Ensure the appropriate protection is applied.

The check instructions in the rail operating code required that matters such as the authority and number, addressees, location, reason for issue, hours of operation, special conditions, last train information, encroaching trains, plotting, issuing and handover portions of the Mis.60 be addressed sequentially to ensure that other trains did not enter the affected area while the authority was in operation.

1.7.14 Planned infrastructure activity was organised by the Authorities group located within the wider NTCC, and wrong-line running to circumvent planned track activity on one line of a double-line section was formally notified on a daily information bulletin or a special bulletin. In emergency situations, train controllers had the authority to run trains on wrong-lines without recourse to a special bulletin.

Train control desk handover

1.7.15 KiwiRail's rail operating procedures (an internal controlled document) dated 3 October 2005, supplement 10.1, instruction 3.9 train control desk handover stated in part that:

> Effective and comprehensive handover between train controllers is a critical safety element of the role. A train controller must be prepared to hand over the areas being controlled or a portion of these at any time during their shift, without warning. To achieve this objective the train controller must practise self-auditing to ensure the diagram and associated electronic/paper records are continuously updated and movements plotted to ensure an accurate plan is maintained.
>
> **Outgoing train controller – preparation for hand over**
>
> - Ensure the diagram is up to date with all movements, both completed and planned. Movements must be plotted to the boundary of the diagram or destination if terminating within the area
> - All handovers MUST be "face to face" and not "rushed".
>
> **Outgoing train controller**
>
> - Progress of each individual movement is described.

Incoming train controller

- Signs each graph as hand over is accepted. This indicates that the handover has been completed releasing the outgoing train controller from their responsibilities for the area concerned.

CAUTION: The outgoing train controller must not leave the desk until this task has been fully completed.

1.8 Train controllers

Rosters and hours of work

1.8.1 At the time of the incident, the NTCC had a team of 34 but was operating with 33 train controllers. The northern group had 11 train controllers, with one certified member working in an area alongside train control who could be called upon for planned relief.

1.8.2 KiwiRail's rail operating manual (an internal controlled document) dated February 1998, section No.5, rostering train controllers, pages 2 and 3, 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 is to be generally made up of a maximum 80-85 hours actual
- mandatory minimum 11 hours 30 minutes continuous time off between shifts.

Policy guidelines for medium- and short-term changes to operating rosters were under consultation.

The manual included the following rules for medium- and short-notice changes to the master roster:

Mandatory maximum shift length / number of consecutive shifts:

Shift	**Hours**	**Shift duration**		
		up to 8 hours 10 minutes	up to 10 hours 10 minutes	up to 12 hours 10 minutes
day	0700-1500	12	10	3
late	1500-2300	12	10	3
night	2300-0700* *next day	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
- mandatory 12 shift maximum consecutive shift pattern regardless of length of shifts.

1.8.3 On 20 November 2009, the National Operational Safety Co-ordinator in Ontrack further advised the following:

> At the time of the incident, Ontrack had an automated exception reporting system that generated an email advice for hours exceeding 14 in any work period, and for hours exceeding 110 in each fortnight. These systems were reactive to provide management investigation into breach of maximum limits. This was the only system in place to provide overview. Train control roster coordinators worked to a general directive to take practicable steps to keep train control fortnightly hours to below 98 per fortnight and to not roster staff to rotate from a night shift to a day shift with 24 hours off duty in between whenever practicable.
>
> Ontrack had developed a draft fatigue management policy that proposed updated guidelines for train control (and wider business). This policy was and is under construction and had/has not yet been adopted into practice.

Previous recommendations about rosters and hours of work

1.8.4 In 2002 and 2005, three incidents occurred when the train controllers had worked consecutive shifts without adequate breaks, leading to errors of judgement being made. It was found that there were insufficient measures in place to manage proactively shift rotations and actual hours being worked. Safety recommendations were made as a result of the investigations.

1.8.5 On 15 July 2003, the Transport Accident Investigation Commission (the Commission) recommended to the Managing Director of Tranz Rail that he critically review policy for train control rosters with respect to the allowable numbers of consecutive shifts and hours worked to ensure:

- mini rosters are controlled within defined criteria compatible with the principles used in compiling base rosters
- defined criteria are met before offering additional shifts to train controllers
- actual hours are monitored and immediate corrective action taken when factors increase rostered shifts beyond acceptable limits (008/03).

1.8.6 On 9 July 2003, the Managing Director of Tranz Rail replied in part that:

> Tranz Rail accepted the preliminary safety recommendation, which was subsequently adopted unchanged as the Commission's final safety recommendation.

1.8.7 On 6 December 2005, the Commission recommended to the Chief Operating Officer 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)
- 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, time off duty on rostered days off (098/05)
- 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).

1.8.8 On 19 December 2005, the Chief Operating Officer of Ontrack replied in part:

> Ontrack accepts and will implement recommendations 097/05, 098/05 and 100/05. The timeframe 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.

1.8.9 On 25 January 2008, the Safety Specialist in Ontrack submitted a request to close safety recommendation 100/05, saying that it had produced a presentation document covering historical and contemporary thinking from Occupational Safety and Health in relation to shift work. Ontrack also advised that a fatigue awareness programme for families would be prepared and completed by the middle of 2008. On 21 February 2008, the Commission approved the change of status of recommendation 100/05 to closed acceptable.

1.8.10 Safety recommendations 008/03, 097/05, 098/05 and 099/05 remained open at the time of the incident at Amokura on 23 September 2008.

1.8.11 On 20 November 2009, the National Operational Safety Co-ordinator in Ontrack advised of the following actions in regard to open recommendations:

> Recommendations 097/05 and 008/03: Ontrack has been working to obtain and implement a computer assisted rostering programme for train control and signal box staff. Training and a trial of the CMS [crew management system] used for locomotive engineers was implemented in October 2009 in train control. This system displays a dynamic calculation of hours worked and recommends staff work availability according to criteria that gives preference to the most rested staff. The definition of policy enhancing existing contractual and procedure rules has yet to be finalised and consulted on in conjunction with an Ontrack fatigue management policy.
>
> Recommendation 098/05: The approved establishment for train control is currently 35 for 27.5 FTE [full time employee] shifts.

1.8.12 On 20 November 2009, the National Operational Safety Co-ordinator in Ontrack further advised the following:

> The approved train control establishment is currently 35. With the committed re-signalling of the Auckland network and the subsequent replacement of signal boxes, Ontrack is considering options to staff the new train control system for Auckland. These options will change the ratio of staff available for multi-skilling and therefore improve the range of options for rostering staff to cover shifts.

1.9 Fatigue

Fatigue in transport

1.9.1 The following comment was sourced from a training manual titled "Human Factors for Transport Safety Investigators". The manual was compiled for a course facilitated by the Australian Transport Safety Bureau (Australian Transport Safety Bureau, November 2004):

> A former chairperson of the National Transportation Safety Board in the United States of America said in 2002 that fatigue is recognised as a primary cause of serious transportation accidents across all modes in that country. A similar view had been expressed in the Australian House of Representatives during 2000 when they said that human fatigue is now recognised around the world as being the main cause of accidents in the transport industry.

Four identified elements that induce fatigue were:

- inadequate rest
- symptoms associated with disturbed or displaced biological rhythms
- excessive muscular or physical activity
- excessive cognitive work being undertaken.

The defined fatigue elements that affect human beings were:

- short term memory
- the timing of tasks and attention
- communication
- physical strength.

Major indicators of fatigue include:

- incorrect reading of equipment
- missing a reference point
- not remembering the last command given
- giving wrong commands.

People can be fatigued without feeling tired and fatigue can effect work performance more dramatically than just yawning at work. Fatigue can be detrimental to performance at work and at home. Human beings have a hard-wired genetically determined biological need for sleep and a circadian pacemaker that programs us to sleep at night and be awake during the day. Twenty-four hour operations challenge these basic physiological principles.

Previous references about fatigue issues

1.9.2 Since 2000, the Commission has reported on a number of operating occurrences in the rail industry where the underlying theme was the loss of awareness and attention by locomotive engineers succumbing to the effects of fatigue. During the same period there were a lesser number of occurrences where fatigue affected the performance of train controllers. On 16 December 2005, the Commission published parallel rail occurrence reports (05-102 and 05-105) covering 3 train-control-related incidents in which the following safety issues were identified:

- fatigue arising from rostering procedures for train controllers
- train controllers being pulled back from rostered time off to meet short-term staff shortages in train control.

1.9.3 As part of the 2005 investigation, the Commission engaged Ms Leigh Signal, PhD, Associate Director of the Sleep/Wake Research Centre at Massey University in Wellington to assist in analysing whether sleep loss and fatigue were causal factors. Because the circumstances around this investigation have similarities with those in 2005, some of her previous discussion has been included again:

> 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. 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. However, performance and alertness can be affected throughout the 0001 to 0800 window.

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. Thus for a shift worker, consecutive night shifts are likely to result in the rapid accumulation of a sleep debt.

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

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.

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.

2 Analysis

The incident

2.1 The DLAS track circuitry and signalling arrangements were designed for trains running in the normal direction on 2 segregated main lines. This meant that when a train was wrong-line-running there were no signals to guide the locomotive engineer and no track circuit arrangements to protect the movement. Beyond Signal 4R at Amokura for instance, the next facing signal that Train 210 would have come across was at Mercer, about 5 km away. Within that same section, there were 3 signals erected to maintain separation for Down train movements.

2.2 On the other hand, single-track main lines, such as between Amokura and Te Kauwhata, were set up for bi-directional running with specialised single-line signalling and track circuit systems. Wrong-line-running did therefore carry additional risks and it was for this reason that Ontrack procedures required that its extent of operation be kept to the minimum necessary to circumnavigate unusual situations.

2.3 There was a check system to be followed by train controllers (only persons authorised) before a wrong-line-running authority was issued. It was clear from the instructions that the preparation, issue and execution of a wrong-line-running authority relied heavily on the accurate recording of train movements on the train control diagram. Another principal tool available that could be used to verify train locations was the signalling system mimic screen. It was ironic that under normal circumstances train movements on the double-line section between Mercer and Amokura would be displayed on the mimic screen (and therefore be visible to train controllers), unlike most other double-line sections throughout the network that were not displayed in train control or anywhere else. However, on this occasion the signalling failure at Amokura had prevented that function occurring.

2.4 Under these circumstances, with the signalling system failure and the presence of trains not displaying on the mimic screen, the prime tool for train controllers to remain aware of all trains in their areas was by referencing the plotted and recorded train journeys on the train control diagram. It was from viewing the recorded train information on the diagram that the incoming train controller elected to route Train 210 on the wrong line, a decision that was logical and within his authority. The fact that Train MP1 was not recorded on the diagram was a significant omission by the previous train controller that could have led to a low-speed head-on collision.

2.5 If the decision to send Train 210 wrong-line-running along the Down main line where Train MP1 was standing had been followed through, the only remaining defence that could have prevented a low-speed head-on collision was the reaction of the locomotive engineer and the braking capability of Train 210, unless the locomotive engineer of Train MP1 had contacted the train controller.

Figure 8
Amokura looking north

2.6 The locomotive engineer of Train MP1 had 2 opportunities to influence the sequence of events that contributed to his train being un-noticed by the 3 train controllers. The first was when he moved his train up to Signal 4L after Train 225 had left. He was required to call train control at that point and alert it to his train standing at Signal 4L, but instead he made a judgement call to not disturb the train controller. This was a breach of operating rules and was a clear opportunity to make the presence of his train known to the train controller for the first time.

2.7 The second opportunity was when the locomotive engineer of Train MP1 overheard the controller making plans to authorise Train 210 to travel wrong-line, putting it on a collision course with his train. An analysis of the data available showed there was a 3-minute period before the plan was changed back to normal running after partial resolution of the signal fault. Either the locomotive engineer did not fully comprehend the significance of the train controller's plan, or it was an example of inadequate crew resource management technique.

2.8 The Commission reported on crew resource management issues in 6 rail occurrence reports between 2003 and 2007, which included train control operating practices on 3 occasions. Those reports were:

- 03-104, express freight Train 380, derailment, near Taumarunui, 16 February 2003
- 05-102, track warrant irregularities, Woodville and Otane, 18 January 2005
- 06-106, express freight Train 826, signalling irregularity, Cora Lynn, 31 July 2006
- 07-108, express freight Train 720, track warrant overrun at Seddon, 12 May 2007
- 07-110, collision, express freight Train MP2 and work train 22, Ohinewai, 19 June 2007
- 07-113, express freight Train 239, wagons left in the section at 514.94 km, between Te Awamutu and Te Kawa, 22 September 2007.

2.9 On 18 December 2008 in report 07-113, the Commission recommended that because effective crew resource management is a critical component of every rail participant's operational safety system, and is particularly critical to safe outcomes where rail operational systems integrate, the Chief Executive of the NZ Transport Agency is to ensure that a review is undertaken of current crew resource management training by all participants in the rail industry, including how the principles of crew resource management are being implemented. The outcome of the review and any corrective action should ensure that staff are equipped with the skills necessary to use crew resource management techniques effectively to reduce operational occurrences.

2.10 The recommendation remained open at the time of the incident at Amokura, and therefore the Commission has not made a new safety recommendation.

2.11 Train 210 would have been required to stop at Signal 4R at Amokura then approach the level crossing just beyond the signal at 10 km per hour because of the wrong-line-running. The 287-metre distance between Signal 4R and Signal 4L (about where Train MP1 was standing) meant that there would have been about 250 metres between the trains. If Train 210 had collided with Train MP1, it would therefore have likely been at slow speed. Fortuitously, the signalling failure was partially resolved just before this point and Train 210 was routed along its correct route, thus avoiding the potential for collision.

2.12 Train controllers essentially operate alone at their desks and under the circumstances of this incident the integrity of the system relied primarily on their correctly recording the trains' progress and whereabouts on the train control diagram. The Commission has already commented in previous report 07-108, track warrant overrun at Seddon, about the benefits of having some other system capable of monitoring the locations of trains on the rail network as part of leading up to positive train control in future, and has an open safety recommendation dealing with that safety issue.

2.13 Systems incorporated into the Tranzlog event recorders now installed on all main line locomotives and multiple units are currently available for development into an integrated system that would have made Train MP1 visible to the train controller in spite of the signal failure and in spite of the senior controller's omission to record it on the train control diagram. This report instead examines how some hours earlier a highly experienced train controller missed the passage of Train 225 through Paerata, and why that omission was not detected by the later involvement of the trainee and the incoming train controller.

2.14 What occurred in the NTCC that morning amounted to what is described in human factor terms as slips and lapses on the part of the senior train controller and missed opportunities by the trainee and later the incoming train controller. The types of error made by the senior train controller were symptomatic of fatigue. The Commission has determined that the senior train controller would have been suffering from fatigue before starting his shift the night before the incident. This report examines the issue of fatigue, and defences that should have been in place to prevent, or detect the risk of a train controller working excessive hours and abnormal shift rotations that led to his becoming fatigued.

Rostering and effect on fatigue

2.15 The use of train control staff on rostered days off to fill vacancies to meet operational requirements was historical and not uncommon within KiwiRail and its predecessors. Rostered days off primarily ensured that safety critical staff such as train controllers had sufficient off-duty time to recover from shifts worked and to rest for future shifts. The opportunity for rest and recreation and, most importantly, sleep is lost each time a train controller is called back for extra work periods.

2.16 It was 0440 when the senior train controller omitted to register and follow through with the verbal and physical cues regarding Train 225 approaching and passing through Paerata. He was on his first shift of a second consecutive week of night shifts. He had just come off a week of night shifts and had to adjust to sleeping at night again during a 3-day period while working 2 additional shifts during those days. He resumed a night shift pattern at 2300 on Monday 22 September, having already worked a 6-hour shift on that same day.

2.17 Research by sleep/wake experts (La Sapienza University and the Aeroporto Pratica di Mare of Rome) shows that the period between 0300 and 0500, and particularly 0430, is the time at which a person's body clock reaches its lowest body temperature, leading to reduced cognitive performance. This performance reduction could happen to anyone working a night shift, even if that person were well rested. On this occasion the senior train controller had not had the opportunity to recover because of the shift rotations, hours worked and the working of extra work periods in the weeks leading up to the incident. It is highly likely that the train controller was suffering from a cumulative sleep debt and was fatigued before starting the night shift when the incident occurred. His omission occurred towards the end of that shift and at the worst possible time for good cognitive performance.

2.18 The disturbing aspect of this incident is that the train controller became fatigued while still largely working within Ontrack's minimum rest/maximum hours policy. There was no evidence of other factors contributing to his fatigue, such as quality of sleep or lifestyle balance issues. He maintained a good level of fitness and had successfully undergone treatment for a previously diagnosed condition affecting quality of sleep.

2.19 In the 4 weeks preceding the incident, the senior train controller had worked 7 extra work periods. Four of those extra work periods were worked during rostered long weekend breaks designed to provide rest and recreation away from the workplace. There were 4 breaks away from work during the 4-week period. There was only one break that included 2 complete 24-hour periods (midnight to midnight), but even then the train controller had finished at 2300 on the eve of that 2-day break. On the weekend prior to the incident, a rostered 65-hour break was reduced to only 24 hours after the train controller reluctantly had to roster himself to work 2 extra work periods. One of those extra work periods involved working a combined desk because of staff issues. There are a number of reasons for train controllers agreeing to work 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 the 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.

2.20 Because of his longevity in the role, the senior train controller was a member of a group within the whole NTCC who had agreed to undertake on-job-training of new recruits throughout his train control career because of his multi-desk qualifications. Additionally he had agreed to undertake daily rostering for the northern train control group. Working additional shifts reduces the time available for all other activities away from work, including opportunities for sleep recovery. Reduced off-duty time may further increase the pressure to sacrifice sleep to meet other time demands, such as household and family responsibilities or recreational activities.

2.21 The senior train controller had several critical rostering decisions to make in the weeks leading up to the incident. In some cases there may have been little or no option, so through loyalty to the business he decided to work the extra shifts himself. Regardless of what prompted him to accept the additional shifts, there was no control mechanism to intervene and prevent him working the extra work periods. In any event he was still working within KiwiRail Network's maximum allowable working hours with the exception of one reduced-time-off period between shifts on Monday 22 September, so any system of automatically preventing staff working outside allowable limits would therefore not have been activated, suggesting that the criteria for setting maximum working hours might need to be reviewed.

2.22 Following the occurrence, KiwiRail revised its instruction on train control roster policy and fatigue management. An overall comparison of the old instructions applicable at the time of the incident (refer paragraph 1.8.2) and the new instructions (refer paragraph 4.2) shows that a new condition has been applied to the maximum hours that can be worked and, the number of consecutive night shifts that can be worked followed by a 50-hour rest period. Additionally there is now a more detailed level of medium and short notice roster management than was not present at the time of the incident. However, in the area of maximum shift length and consecutive shifts table, and mandatory rest time, the rules remain unaltered. The Commission considers that the new policy is an improvement is some areas of fatigue management but does not provide adequate solutions to the critical areas as described. A recommendation has been made to the Chief Executive of NZ Transport Agency to address this safety issue.

2.23 The train controller did not realise that by working the extra shifts he was becoming increasingly fatigued. Reasons for this could have been that physiologically he had become normalised to the physical demands posed by roster changes and extra days worked, or more possibly he did not realise how fatigued he had become because he had been a shift worker for most of his career and was used to such state of mind.

2.24 If the train controller had declined to work these extra shifts during the weekend prior to the incident, management would have been required to act and provide a solution to the problem. In agreeing to the increased workload, the senior train controller involuntarily either masked the extent of the roster problem from management or allowed management to ignore it.

2.25 While some work has been done on rosters within KiwiRail, most of this has primarily been for locomotive engineers. The roster that has train controllers working through the lowest point of cognitive functioning while nearing the end of their shifts should be reviewed. Another factor to consider is the quality of sleep that an off-going controller can obtain when trying to fall asleep during daylight hours. The body naturally wants to sleep during the hours of darkness. A change-over of shifts earlier in the morning that allows a train controller finishing his shift the opportunity to at least start sleeping while still dark could be beneficial. A recommendation has been made to the Chief Executive of NZ Transport Agency to address this safety issue.

2.26 Another consideration is the level of activity that is generally occurring at the time the shift changes. On the Waikato desk, the northern part of the section is starting to be affected by the early commuter trains and planned/unplanned track activity starting for the day, whose occupation needs to be managed by the train controller.

2.27 There is also an issue over the speed at which train controller changeovers occur when they are dealing with unusual circumstances. Once the incoming train controller had arrived for the start of his shift, the trainee and senior controller gave a short handover then promptly left. The incoming train controller was then left to deal with an unusual situation of the signalling system failure while the number of trains he had to control was increasing. The senior train controller had omitted to record Train 225 on the train control diagram, which ultimately resulted in him and later the trainee losing awareness of where Trains 225 and MP1 were located. There was, however, an opportunity to correct the misunderstanding. Train MP1 was scheduled on the train control diagram and would have been visible to all the train controllers, and in the absence of any formal or late notice of its cancellation, they should have been expecting it. This should have been identified during both handovers, the first being between the senior train controller and the trainee, and the second being between the trainee and the incoming train controller, about 2 hours later.

2.28 The trainee was still under training and struggling to cope with the new area and the DLAS system, and the senior controller was fatigued, both of which could be reasons for their not noticing that Train MP1 was missing. The task of overseeing the trainee would have been demanding, but with the added distraction of the disruption at Te Awamutu and the signalling failure at Amokura, the senior train controller was handling several critical tasks at once. "Load shedding" is a term used when a person becomes overloaded and begins ignoring information received when it is not relevant to the task that they are performing. Fatigue reduces the human ability to process large volumes of information, so load shedding begins sooner. This could be an explanation for the senior train controller not realising the significance of Train 225 in his area and not plotting it on the train control diagram, thus losing awareness of what was occurring with the movements of Trains 225 and MP1 between Paerata and Amokura.

2.29 The incoming controller also had the opportunity to question the whereabouts of Train MP1 because at 0640 its schedule had the train nearing Te Rapa, and even if it had been running up to 90 minutes late, the train would then have been still travelling in the Paerata-Te Rapa area. An analysis of the train control voice recording system showed that the handover was completed in less than 4 minutes, was conducted without the senior train controller being present and did not include a systematic identification of where each train was located in relation to its schedule. The incoming train controller was then left to absorb the complexities of what was happening in his area.

2.30 While there are detailed instructions to be followed during handovers to ensure details of all known events are transferred between train controllers, on this occasion vital information was not covered during the 2 handovers. There would be some benefit in having the instruction expanded to provide that when unusual circumstances exist, train controllers maintain control of the desk either until the situation is resolved sufficiently or until the incoming train controller has had time to fully understand the situation, in other words acquire situational awareness. Such a policy promotes effective communication and good crew resource management, and should result in a seamless handover of a critical function. A recommendation has been made to the Chief Executive of the NZ Transport Agency to address this safety issue.

2.31 The Commission has reported on a number of previous occurrences where fatigue was found to have affected the performance of rail industry staff working in safety-critical operational areas. The 2 principal operational areas that have featured in published reports involve locomotive engineers and, to a lesser extent, train controllers. While locomotive cabs are equipped with vigilance devices to monitor locomotive engineer performance (including the effects of fatigue), there is currently no way of measuring train controller vigilance.

2.32 Train control is a critical function in the rail system, and train controllers are safety-critical staff who need to be operating efficiently with a high degree of alertness, because their decisions and actions can result in hazardous situations similar to those that occurred during this incident.

2.33 There is anecdotal evidence that the roster rotation as currently practised is long standing and coincidentally suited the availability of public transport for train controllers to get to and from work, specifically transport by train, rather than focusing on optimising human performance and well-being.

2.34 The train control discipline has been a 24-hour and (mostly) a 7-day-a-week operation since its inception in New Zealand, whether undertaken in satellite locations around the country or, as technology has advanced, centralised during the 1990s into one centre. While advances in rostering techniques in response to research have been picked up by the train crew and ferry crew divisions of KiwiRail and its predecessors, the same advances have not been applied to train control rosters to mitigate the effects of fatigue, in spite of earlier trials to introduce minimum rest periods and altered rotations.

2.35 The importance of alertness in train control operations was recently noted in the United Kingdom, where in November 2009, a rail accident report was published following the derailment of 2 locomotives in East Somerset, United Kingdom on 10 November 2008 (Rail Accident Investigation Branch, November 2009). It found that the signaller (equivalent of a signal box controller and a position similar to a train controller in New Zealand) was suffering from fatigue owing to the nature of the shifts and long hours worked during a 4-week period leading up to the incident. There was also a signalling failure at the time of the incident.

2.36 The conclusions made in the investigation were similar to those of other United Kingdom investigations, which concluded that signaller fatigue was a factor in 6 other incidents between 2002 and 2003. Among the recommendations made in the report was one that required the access provider (equivalent to KiwiRail Network) to address fatigue with its safety-critical staff.

Training

2.37 The circumstances around the boundary change meant that the train controller had to re-familiarise himself with the DLAS system during his on-job-training 10 months after his initial training, with no following consolidation period working with DLAS. It was clear from the trainee train controller's comments that he harboured personal concerns about the looming boundary changes on the newly created Waikato desk area, 4 weeks after he had gained certification on the NIMT desk area. This situation of the changed area so soon after certification to the old area created a level of personal stress. The responses he received from his colleagues and management did not seem to provide the solution or confidence that he was looking for. Additionally, the trainee's situation probably had some effect on the senior train controller because he had to roster himself on with the trainee for longer than he would have the boundary change not intervened.

2.38 During his discussion with the Commission, the trainee explained that he was having some difficulties with some of the complexities of the new area, which included stations where trains arrived and left from different sidings associated with the stations. Ontrack had told the trainee that he had as much time as possible to learn the new area, which while addressing his concerns then added to the workloads of other train controllers who had to monitor the trainee as part of his on-job-training.

2.39 The desk certification timeline the trainee followed meant there was a 10-month gap between his initial training on DLAS rules (which he was required to pass before commencing on-job-training on his first desk) and starting practical working with DLAS in the newly formed Waikato desk. The circumstances that led to the trainee having 10 months was out of the ordinary because of the area change, but if that had not occurred, the period of time would most likely have been longer. The lack of consolidation with DLAS following his initial training, and the potential lag in time that could occur before having to work with the system without further training was a safety issue that the Commission has recommended that the Chief Executive of the NZ Transport Agency address.

3 Findings

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

3.1 The incoming train controller's plan to route Train 210 wrong-line-running up the Down main line could have resulted in a low-speed head-on collision with stationary Train MP1.

3.2 The incoming train controller had no knowledge that Train MP1 was standing stationary on the Down main line at Amokura; without that knowledge his plan to route Train 210 wrong-line-running up the Down main line would have seemed logical and authorised under train control procedures.

3.3 The location of Train MP1 not being known to 3 successive train controllers was the result of 3 successive failures within the system: the senior train controller's omission to plot the train on the train control diagram, the signalling system failure, and all 3 train controllers missing the cue that the train did not feature near its timetabled slot on the diagram.

3.4 In the event of a signalling failure similar to that which occurred at Amokura, controlling trains on the network was largely reliant on the actions of one person, the train controller. An independent system that showed the location of trains across the network would significantly reduce the risk of train collisions due to system or human failure.

3.5 Fatigue resulting from a burdensome planned and unplanned roster was the prime reason for the senior train controller omitting to plot the progress of Train 225 on the train control diagram.

3.6 The trainee train controller's performance was commensurate with the level of training he had received, and his lack of experience together with workload on the desk at the time contributed to his not identifying that the whereabouts of Train MP1 was unknown.

3.7 Distraction with other tasks, which included the disruption at Te Awamutu and the signalling failure at Amokura, is likely to have contributed to both train controllers missing the passages of the trains through Paerata and Mercer.

3.8 The incident could have been averted had the locomotive engineer of Train MP1 alerted train control to his train's location standing at Signal 4L at Amokura as he was required to do.

3.9 The incident could also have been averted had the locomotive engineer of Train MP1 challenged the train controller on his intended plan when he learned of his intention to route Train 210 on the same line on which his train was standing, as would be expected under effective crew resource management.

3.10 The trainee train controller refreshing his knowledge in DLAS rules at the same time as undergoing on the job training complicated the desk training process, requiring more handovers during a shift and, possibly contributing to the train controllers collectively losing situational awareness of where all trains in their area.

3.11 There would be some safety benefits in KiwiRail's training system for train controllers specifying a maximum period for which new and returning train controllers can be away from using critical systems such as DLAS before requiring retraining.

3.12 The lack of meaningful handovers between the senior train controller and the trainee train controller, then between the trainee train controller and the incoming controller at change of shift, at a time of heavy work-load, contributed to the incoming controller not identifying that the whereabouts of Train MP1 was unknown.

3.13 KiwiRail's standards for maximum working hours and minimum rest periods on the train control roster could have resulted in a train controller being fatigued at the start of a shift even in the absence of any other fatigue-inducing factors.

3.14 KiwiRail's system for ensuring that train controllers did not exceed maximum working hours and minimum rest periods was reactive and did not prevent the senior train controller exceeding shift rotation practices.

4 Safety Actions

4.1 On 5 March 2009, KiwiRail's Operational Risk and Compliance Manager advised by email that the following safety action had been taken in regard to crew resource management practices:

> The key issue identified in respect of KiwiRail Freight's locomotive engineers' involvement in the incident was the lack of application of Crew Resource Management principles by the locomotive engineer of MP1 when he overheard the conversation between the Train Controller and Train 210 regarding a proposed wrong line running movement. The MP1 locomotive engineer should have challenged this immediately.
>
> Operations Manager, Linehaul counselled the MP1 locomotive engineer on the application of Crew Resource Management principles in this and similar situations.
>
> The incident has also been tagged "CRM opportunity" in KiwiRail Freight's incident database. This identifies this incident as a potential Case Study for re-validation courses.

4.2 On 10 December 2009, Ontrack's Manager Network Operations advised by letter that the following safety actions had been taken with the issue of an instructional document A011.

ONTRACK
New Zealand Railways Corporation Rere Totika

Train Control Instruction A011

ROSTER POLICY FOR FATIGUE MANAGEMENT

10 December 2009

This instruction applies to rosters for Train Controllers, and is to be read in conjunction with Employment Agreements and the Rail Operating Manual. The provisions of any Employment Agreement/s or the Rail Operating Manual shall take precedence.

Master Roster Design:

- A maximum of 10 shifts per fortnight.
- Each shift is to be generally of 8 hours and 10 minutes duration. This may be relaxed at weekends to satisfy the social needs of the persons operating the roster.
- Each fortnight is to be generally made up of a maximum 80-85 hours actual
- Mandatory minimum 11 hours and 30 minutes continuous time off between shifts
- The maximum number of planned consecutive nights shifts in a Master Roster shall not generally exceed 5 after which 50 hours off duty shall be provided

Medium and Short Notice Changes to Master Roster:

- Fortnightly planned hours are not to exceed 99 unless permission is given to exceed this by the Manager Network Operations.
- In any event where three shifts of 12 hours length are worked in a row, a rest period of 24 hours must be provided immediately following unless permission is given to reduce this by the Manager Network Operations.
- A greater fatigue risk exists when changing rotations from a night shift. Upon ending any sequence of night shifts, staff must have a minimum of 32 hours off duty unless permission is given to reduce this by the Manager Network Operations.
- The Network Control Manager must be advised when any shift is extended at short notice and monitoring must be arranged for any risk periods of those shifts.
- No night shift that started before 00:00 may be extended beyond 07:30 without approval of the Manager Network Operations.

Mandatory Maximum Shift Length and Consecutive shifts:

Shift	Up to 8hrs 10 min	Up to 10 hrs 10 min	Up to 12 hrs 10 Min
Day	12	10	3
Late	12	10	3
Night	7	6	3

Mandatory Rest Time:

- Total actual hours not to generally exceed 110 per fortnight

- Mandatory 11 hours and 30 minutes time off between shifts
- Mandatory 12 shift maximum consecutive shift pattern regardless of length of shifts

Authorisation of Exceptions:

Before giving any approval to reduce any Medium/Short notice rest time, the employee working the affected shift must be consulted about their rest activity using the question guide in the appendix below, and the approving manager and employee must be satisfied that the risk of fatigue error is low.

When an employee works a shift with a reduced Medium/Short notice rest period, the Network Control Manager must be advised and arrange for casual monitoring of the employee's alertness by the NCM/other on duty staff within the risk hours of 13:00 to 16:00, and 03:00 to 07:00. Risk hour monitoring periods must be entered into the NCM Calendar and the appointment printed and filed on the Daily Report file.

Monitoring Fatigue Signs:

Employees on extended shifts and monitoring staff will watch for and report to the NCM:

- Uncontrollable desire to sleep
- Lack of concentration
- Impaired recollection of timing or events
- Irritability
- Poor judgment or decision making
- Reduced capacity for effective interpersonal communication
- Reduced hand-eye coordination
- Reduced perception
- Reduced vigilance
- Slower reaction times

Note: It is important to note that individuals who are fatigued are commonly unable to evaluate their own level of impairment and as a consequence it is the supervisor or colleagues that are more likely to notice the affects of fatigue.

Appendix: Questions for assessing fatigue risk

- How many hours were worked in the 14 days immediately preceding the proposed additional hours?
- What was the pattern of hours worked in the last 14 days? – Consider night shifts, 12 hr shifts as higher risk
- Is the individual likely to be suffering from sleep debt or had sleep loss?
- How long and what quality have the previous sleep periods been?
- Are there any personal factors that could create a higher fatigue risk? Consider health, family, work stress factors
- How well has the individual coped in the past with the demands of additional duty hours?

Manager Network Operations

5 Relevant Safety Recommendation from previous report

5.1 On 19 February 2009, the following safety recommendation was made to the Chief Executive of the NZ Transport Agency in published report 07-108, track warrant overrun at Seddon on 12 May 2007, and is repeated in this report for completeness:

> The terms of reference for Project Kupe 9 (reference name for a new train control to locomotive cab radio system) do not currently include further development into full positive train control capability. The Commission recommends the NZ Transport Agency takes action to ensure that any project to enhance train control functionality results in a progressive move to achieving positive train control (005/09).

5.2 On 9 March 2009, the Chief Executive of the NZ Transport Agency replied to this safety recommendation, and others, as follows:

> Thank you for your letter dated 19 February 2009 containing the above final safety recommendations.
>
> We intend to work closely with the relevant rail industry participants with an aim to implementing and closing these recommendations as soon as practicable. We are unable to give you an exact timeframe, as this will depend on the outcome of discussions we have with these participants.
>
> When these discussions are concluded and the appropriate evidence has been gathered we will be in touch with TAIC with a view to closing these recommendations.

6 Safety Recommendations

6.1 The Transport Accident Investigation Commission Act 1990 requires the Commission to issue its safety recommendations to the appropriate regulator even though another person or organisation may appear to be the more appropriate recipient. This is because the regulator will, in many cases, be better placed to facilitate the implementation of the safety recommendations through its statutory, legal or other arrangements with the persons or organisations concerned.

6.2 Note that, unless otherwise expressly stated in this report, the mere fact of issuing the following safety recommendations to the Chief Executive of the NZ Transport Agency does not mean that the Chief Executive contributed in any way to the incident referred to in this report.

6.3 The following safety recommendations are not listed in any order of priority:

6.4 On 21 July 2010 it was recommended that the Chief Executive of the NZ Transport Agency addresses the following safety issues:

> Standards for maximum working hours and minimum rest periods on the train control roster could result in a train controller being fatigued at the start of a shift even in the absence of any other fatigue-inducing factors. The train control roster policy including, but not limited to, standards for maximum working hours and minimum rest periods should be reviewed to ensure it is designed to mitigate fatigue and promote wellness. (017/10).
>
> During this incident, 2 successive train control handovers were conducted in a fashion that did not detect the presence of all train movements, and on each occasion the trainee, then the incoming controller, assumed the responsibility for the desk before they had acquired full situational awareness of the status of all movements within their area. The area of train control would benefit from some form of external review of processes to identify if these practices were confined to this one event or symptomatic of a wider systemic issue. (018/10).

> The trainee controller having to refresh his knowledge in double-line automatic signalling rules at the same time as undergoing desk certification complicated the desk certification process, requiring more handovers during a shift. There would be some safety benefits in KiwiRail's training system for train controllers in specifying a maximum period for which new and returning train controllers can be away from using critical systems such as double-line automatic signalling before requiring refreshing in these systems. Trainee train controllers not being fully current in critical systems, or potentially experienced train controllers returning to using a critical system that they have not used for some time, is a safety issue. (019/10).

6.5 On 29 July 2010 the Chief Executive of NZ Transport Agency replied as follows:

> We intend to work closely with KiwiRail with an aim to implementing and closing these recommendations as soon as practicable.
>
> Discussion on them will commence on the publication of the report and will be ongoing. Any outstanding Transport Accident Investigation Commission (TAIC) recommendations also form an integral part of our annual safety assessments of the rail industry.
>
> When these discussions are concluded and the appropriate evidence has been gathered, we will be liaising with TAIC with a view to closing these safety recommendations.

7 Works Cited

- Australian Transport Safety Bureau. (November 2004). *Human Factors for Transport Safety Investigators.* Canberra: Australian Transport Safety Bureau, Australian Government.
- Rail Accident Investigation Branch. (November 2009). *Derailment of two locomotives at East Somerset Junction.* Woking: Rail Accident Investigation Branch, Department of Transport.
- M Casagrande, D Matella and E Di Pace from the "La Sapienza" University and M Casagrande, F Pirri and F Guadalupi from the Centro Sperimentale di Volo, Reparto Medicina Aeronautica e Spaziale, Aeroporto Pratica di Mare, both entities based in Rome, Italy (published online on 25 November 2005), *Orienting and alerting: effect of 24 hour of prolong wakefulness*.

Approved on 21 July 2010 for Publication

Mr John Marshall QC
Chief Commissioner

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