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Australian Transport Safety Bureau

Collision of passenger train T842 with station platform

Cleveland, Queensland | 31 January 2013



Investigation

ATSB Transport Safety Report

Rail Occurrence Investigation

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Addendum

Page	Change	Date
54	Figure 24: Row 5 - Track section location amended	7 Jan 2014
76	Buffer stop design criterion – QR response 255 t	5 March 2014

Safety summary

What happened

At about 0940 on 31 January 2013, a Queensland Rail passenger train (T842) failed to stop at the Cleveland station platform and collided with the end-of-line buffer stop, the platform and the station building at a speed of about 31 km/h. There were 19 people on board the train (including the driver and a guard); three people were on the platform and five were in the station building. A number of people were treated for minor injuries and transported to hospital for further examination.

At the request of the Queensland Government, the ATSB initiated an investigation into the accident.

Train T842 at Cleveland station



Source: Dept of Transport and Main Roads, Queensland

What the ATSB found

The ATSB's investigation found that local environmental conditions had resulted in the formation of a contaminant substance on the rail running surface. This caused poor adhesion at the contact point between the train's wheels and the rail head. The braking effectiveness of train T842 was reduced as a result of reduced adhesion and the train was unable to stop before hitting the end-of-line buffer stop.

The ATSB concluded that Queensland Rail's risk management processes prior to the accident had not adequately assessed, recorded, managed and communicated the risks associated with operating trains on their network under low adhesion conditions.

In addition, Queensland Rail had not undertaken exercises to test the preparedness and effectiveness of their emergency management system. Shortfalls were identified in the response to the accident with respect to internal communications within train control and between staff at Cleveland station which resulted in incomplete information being provided to key personnel.

What's been done as a result

Queensland Rail initiated a risk mitigation strategy in response to the collision of train T842 at Cleveland station on 31 January 2013. The strategy included the formation of a Wheel Rail Interface Working Group that identified the wheel/rail interface risks, particularly for Queensland Rail's fleet of IMU160/SMU260 class trains being operated under certain conditions.

Queensland Rail have also implemented a series of risk controls including identifying localised black spot locations and applying vegetation control measures, treating rail-head contaminants, reviewing and updating driver training with enhanced train handling advice about wheel slide and the trialling of sanding equipment on IMU160/SMU260 class trains. Queensland Rail have now undertaken emergency exercises to test the effectiveness of their emergency response arrangements and are implementing new communication protocols for emergency incident response.

Safety message

Rail operators should recognise that train braking performance may be significantly impaired when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion. Rail operators should put appropriate measures in place to assess and mitigate the risk to the safe operation of trains under these conditions.

Contents

The occurrence	1
Events prior to collision	1
Service T842	1
The collision	2
Post collision	5
Emergency response coordination	5
Vehicle recovery	6
Infrastructure repairs	7
Context	8
Location	8
Organisation	8
Infrastructure	8
Track	8
Overhead traction system	9
Buffer stop	9
Slippery track conditions	10
Track adhesion and friction	11
Rail head and train wheel contaminants	11
Rail head and train wheel profiles	14
Train driver	16
Driver's actions	16
Train information	16
Braking system	17
Brake inspection and tests	19
Pre-service brake conformance testing (IMU160 class)	21
Brake software changes	21
Test train SMU292	21
Wheel tread dressing	22
Train crashworthiness	23
Station overruns	27
Frequency by train class	27
Locations where trains have higher incidence of overrun	28
Previous Queensland Rail train wheel slide occurrences	33
Beerwah 9 January 2009	33
Beerwah 9 March 2009	36
Narangba and Morayfield 28 January 2013	36
Caboolture - test train	37
Train testing and data irregularities	38
BCU	38
VCU	39
Brake test methodology	39
Investigations of slide occurrences by other organisations	40
Siemens Nexus train overruns - Melbourne	40
Derailment of CityRail train 312A - Thirroul, NSW 11 September 2006	41
Rail slide occurrences - United Kingdom	42
Reference documents for the management of wheel slide	42

Train driver training	43
Training and qualifications	43
Emergency response management	44
Documented emergency management procedures	44
Emergency management training of involved Queensland Rail staff	45
Exercising emergency management procedures	45
Roles and responsibilities of train control personnel	46
Procedures for the assurance of Overhead Line Equipment (OHLE) safety	47
Actions of Queensland Rail staff at the emergency site	48
Communications between network control and Cleveland station	49
Train operations internal emergency debrief	49
Management of safety risks	50
Regulatory oversight of Queensland Rail	51
Confidential reporting system	55
Safety analysis.....	56
Organisational risk management	56
Beerwah	57
Other occurrences	58
Buffer stop collision risk	58
Regulatory oversight	59
Beerwah	60
Investigation report reviews	61
DTMR spot and compliance safety audits	62
National Rail Safety Regulator (NRSR)	62
Driver training for braking under conditions of low adhesion	62
Effectiveness of emergency management response	64
Design and accessibility of the Emergency Management Specification:	64
Preparedness and role of customer service staff in emergency response	65
Exercising simulated emergencies	66
Actions and interactions of train control personnel	66
Managing and communicating OHLE status	68
Criticality of efficient and standard communication protocols	68
Opportunities for organisational learning about emergency management	69
Findings.....	70
Contributing factors	70
Other factors that increased risk	70
Other findings	71
Safety issues and actions	72
Management of risk associated with poor adhesion	72
Safety issue description:	72
Current status of the safety issue:	73
Assessment and recording of rail safety risks	73
Safety issue description:	73
Cross divisional recognition of rail safety risks	74
Safety issue description:	74
Current status of the safety issue:	74
Application of safety actions from internal investigations	75
Safety issue description:	75
Awareness of rail safety occurrences in other jurisdictions affecting rail fleet type	76
Safety issue description:	76
Current status of the safety issue:	76
Buffer stop design criterion	76

Safety issue description:	76
Driver's manual explanation of effects and control of low adhesion	77
Safety issue description:	77
Effective coordination of emergency communications	78
Safety issue description:	78
Emergency management exercises	78
Safety issue description:	78
Post emergency debrief and findings	79
Safety issue description:	79
Occurrence notification standard and guideline	80
Safety issue description:	80
General details	81
Occurrence details	81
Train: T842	81
Sources and submissions	82
Sources of information	82
References	82
Submissions	83
Appendices	84
Appendix A - Safety issues update	84
Queensland Rail's response to the ATSB's preliminary report published on 13 March 2013	84
Appendix B – Other investigations	86
RAIB - Esher, United Kingdom	86
RAIB - Lewes, United Kingdom	86
RAIB - Review of adhesion-related incidents during autumn 2005	87
Australian Transport Safety Bureau	89
Purpose of safety investigations	89
Developing safety action	89
Glossary.....	90

The occurrence

Events prior to collision

In the days prior to train T842 colliding with the buffer stop at Cleveland station, a tropical low formed in the Gulf of Carpentaria before tracking in an easterly direction toward the west coast of Cape York Peninsula. Just prior to its making landfall near Kowanyama, the Bureau of Meteorology identified this system as a Category 1 Tropical Cyclone, Oswald. After landfall, Oswald rapidly weakened into a low pressure system, tracking southward and inland from the Queensland coast and into northern New South Wales. The low pressure system brought damaging winds, heavy rainfall and flooding to areas of south-eastern Queensland.¹

These weather conditions resulted in the closure of several sections of the Brisbane suburban rail network, including the Cleveland line, where a tree and other debris had fallen on the railway damaging the overhead power infrastructure.

The Cleveland rail line was closed to rail traffic between Wellington Point and Cleveland station at 1442 on 27 January 2013. Rail services to Cleveland station remained suspended until the night of 30 January when an inspection of the overhead wiring was made by maintenance staff. On 31 January 2013, services on the Cleveland line recommenced with the first train arriving at Cleveland station at 0440 and later departing at 0451. A further 11 services arrived and departed Cleveland before service T842.

Service T842

The crew of the accident train consisted of a driver and guard who commenced duty at 0615 on 31 January 2013. The crew were initially tasked to operate service 1E29 from Beenleigh station to Bowen Hills. This service departed at 0643 and arrived at Bowen Hills station at 0753, where the crew was relieved by another driver and guard².

The crew then had a short break before commencing their next task of operating service T842, a 6-car Doomben to Cleveland train, departing Doomben at 0755. The service was scheduled to arrive at the Bowen Hills station at 0811 but arrived at 0816 due to operational delays.

The crew were orally briefed by the train crew they were relieving on the train's performance, commonly referred to as a train handover report. There was nothing in this report to indicate that there were any issues with the operation of the train.

The train departed Bowen Hills station and was scheduled to stop at all stations to its final destination of Cleveland. The train arrived at Roma Street at 0822 having stopped at the previous two stations.

The train then departed Roma Street at 0823 continuing to stop at all stations without incident until the section between Cannon Hill and Murarrie, where it was held at a red signal near the Queensport Road South crossing. Here the train was held for about 16 minutes due to an overhead electrical supply failure which resulted in train operations being reduced to single line running. Service T842 was required to wait for an opposing inbound service heading to Brisbane Central.

Once cleared, train T842 continued its journey and arrived at Murarrie station at 0903. The train departed Murarrie at 0904, continuing towards Cleveland.

¹ Bureau of Meteorology Special Climate Statement 44 – extreme rainfall and flooding in coastal Queensland and New South Wales 5 February 2013.

² Bowen Hills station is a common Queensland Rail train crew change point.

The collision

As train T842 was approaching Wellington Point station (two stations before Cleveland), the driver heard a train control radio report of a platform over-run of another train at the next station, Ormiston. The driver was contacted by his guard to confirm that he had heard the report of the platform over-run.

Having been alerted to another train's (1A29) issue in stopping on approach to Ormiston station, the driver approached the platform at reduced speed and experienced little difficulty in stopping the train at the platform. The driver noticed that, towards the end of the stopping sequence, his console indicated some wheel slide but he did not consider this unusual and it was barely noticeable.

At 0936 train T842 departed Ormiston station, accelerating to the posted line speed of 70 km/h. There was no indication of any wheel slip on departure from the station and it appeared to the driver that the rails were dry.

The train continued towards Cleveland and was rounding the left-hand curve in the 70 km/h section when the driver observed that signal CD12P located between the Wellington Street overpass and the Gordon Street overpass was showing a green aspect. The green aspect of CD12P indicated to the driver that the train would have a proceed aspect at the next signal (CD12), allowing the train to enter Cleveland station.

Figure 1: Location of Ormiston and Cleveland stations



Source: Google Earth

The train was on a straight section of the track with a posted speed of 80 km/h but, as the section was short, the driver elected not to increase the speed of the train in anticipation of the left-hand curve and 70 km/h track speed just past the Gordon Street overpass.

When the train was in the vicinity of the Gordon Street overpass the driver applied the brakes to maintain the train's speed on this downhill section of track at 70 km/h. After 3 seconds the driver released the brakes and then reapplied them 10 seconds later. This action was usual driving

practice and done in anticipation of slowing the train to 25 km/h for the track turnout³ located 84 m before Cleveland station.

Shortly after the train exited the Gordon Street overpass and about the time that the driver started to brake for his approach to Cleveland station, light rain started to fall.

The driver noticed that the train was not slowing as expected. A minimum brake application followed by a half-way brake application at this location was usually sufficient to slow the train to the required speed. The driver had no recollection of the wheel slip-slide alarm activating and continued to be concerned that the train was not slowing.

The driver then moved the brake controller to the half way position and then further into the full service brake⁴ position. He observed that there was still no appreciable reduction in the train's speed. He then saw that the Cleveland home signal (CD12) was showing a yellow proceed aspect and the associated junction indicator was illuminated, indicating the train was to pass through the turnout into the southern platform. While the driver's focus remained on trying to slow the train, the train was now about 100 m from passing CD12 and about 270 m from the turnout.

The driver was becoming increasingly concerned as the train rapidly approached the turnout, so he moved the train brake to the emergency position and also applied the park brake before entering the points. The train proceeded through the points at a speed of close to 56 km/h and into the down platform located on the southern side of the station. The speed as the train entered the platform remained close to 56 km/h.

As the train approached the platform the driver removed his foot from the driver safety control.⁵ At this point, the driver had exhausted all available avenues at his disposal to stop the train.

The train continued along the platform towards the buffer stop⁶ at the end of the line, slowing gradually as it moved along the platform.

At 0940 the train collided with the buffer stop at a speed close to 31 km/h, shearing the buffer stop from its foundation and rotating it onto its side. The train then rode up and over the buffer stop and collided with an overhead power line mast located immediately behind. The impact flattened the mast and brought down the overhead high voltage wiring onto the train and platform. The train continued into the station building where it came to rest (Figure 2).

³ A combination of a set of points, V crossing and guard rails which permits traffic to turnout from one track to another. Source: National Guideline Glossary of Railway Terminology Version 1.0, 3 December 2010.

⁴ The maximum braking position for normal service operations.

⁵ A vigilance system which reacts by making a penalty brake application if a continuous control input required of the driver is interrupted or not detected, commonly called the "dead man's pedal".

⁶ A structure erected at the end of a track at main line terminals or dead end sidings which is intended to stop rolling stock.

Figure 2: View of lead passenger car bridging the buffer stop and the overhead catenary mast.



Source: Queensland Police Service

When the train had come to a stop, the driver placed an emergency call alerting train control to the collision and seeking urgent assistance.

The guard

The guard was located in the front driver cab of the fourth car. At Ormiston station, the guard observed a 'shudder' as the train stopped, but was not concerned as the train did not overshoot the platform. The guard observed that the train departed Ormiston station normally.

On approach to Cleveland station, the guard was standing and preparing to change cabs for the train's subsequent departure. As the train traversed the points at the turnout, the guard noted that he was rocked from side to side. He attributed this to higher than normal speed. Shortly thereafter, realising that the train might not stop before the end of the platform and anticipating an impact, the guard braced himself against the dashboard.

Both the driver and guard sustained superficial injuries.

Passengers

There were 17 passengers on the train at the time of the collision. The majority of the passengers were seated in the front three cars of the train, with nine located in the first car.

Some passengers travelling on the service had observed unusual braking at Ormiston station, which they variously described as 'jolting', or 'grip and release'. Passengers observed no further anomalies on the journey between Ormiston and Cleveland until the train traversed the points, when some passengers observed that the train was approaching the end of the line at speed.

With no warning or announcement and little time to assess the situation and prepare, some passengers were able to brace for the impact while others were not. Two passengers were standing in preparation to exit the train at the time of collision.

Passengers sustained varying degrees of injury associated with the impact, including bruising, muscle strain and soreness. One passenger sustained a superficial head wound when their head struck a framed poster. No passengers were admitted to hospital.

A number of passengers reported an enduring psychological reaction to the event following the collision.

The station

There were four members of the public and four Queensland Rail employees on the Cleveland station platform or within the station vestibule and buildings at the time of the collision. One person located in the station amenities block sustained minor injuries after being trapped amongst building debris. This person was rescued by a member of the public after a short period of time.

Train station staff

Two of the three station staff were in the station office at the time of collision and did not observe the train on its approach. One staff member was located at the station end of the platform, and a spare driver was located at the door to the staff meal room. Both of these staff members observed the train approach the station at a higher than normal speed and both noted the absence of any sounds normally associated with train braking.

Post collision

Emergency response coordination⁷

At 0938 the train control operator received an emergency call from the driver of train T842 advising that his train had collided with the buffer stop.

The train control supervisor received a call on the emergency line from a Cleveland station staff member at 0940. The staff member informed the train control supervisor that the train cabin had gone through the toilet block and that the person in the toilet had been rescued. The station phone was then passed to the spare driver and the train control supervisor informed him that the power lines had been de-energised, but had not been isolated and earthed and that it was therefore not deemed safe for anyone to exit the train or to be on the platform. He also directed the spare driver to have the station master call an ambulance.

At 0941 a passenger activated the emergency door release in the second car and the spare driver on the station platform directed them to remain on the train due to the overhead train power lines being pulled down during the collision. However, one passenger exited the train, and was followed by another three passengers. These passengers then left the station. One of the four returned at a later time and received medical assistance. The remaining passengers and the train crew complied with the spare driver's direction and waited for advice on when it was safe to leave.

Meanwhile, Cleveland station customer service staff were busy attempting to secure the station and providing assistance to the passengers and members of the public in the station.

At 0944 the guard contacted the train control operator to ascertain the status of the power lines and whether or not the passengers could leave the train. The train control operator said that the overhead power had been 'switched off.' The guard then replied that he would start letting passengers off. Soon after, at 0947, the guard activated the emergency door release in the fifth car and the two passengers in the rear of the train departed.

⁷ Multiple time sources have been used to reconstruct the sequence of events in the post collision response, including train control voice recordings, on-train CCTV footage, station platform CCTV footage, the electrical control officer log book, and the Queensland Rail train operations internal debrief document. Best efforts have been made to establish correct time sequence by corroborating multiple sources of evidence.

At 0947 the train control operator contacted the driver advising him that passengers should not be permitted to leave the train due to the power lines being down on the platform.

At 0951 Queensland Fire and Rescue Service contacted the train control supervisor to advise that they were on site at Cleveland station. The train control supervisor advised that the overhead power was de-energised, but not yet isolated and earthed, and was therefore to be treated as live.

At 0951, the remaining passengers and crew were escorted from the train under the supervision of Emergency Services personnel, and were then provided with medical assistance.

At 1021, the Queensland Rail incident commander arrived to manage the site.

At 1034, the Queensland Rail electrical control operator confirmed that the overhead power had been earthed and it was now safe for passengers and crew to disembark the train. However this had occurred some 30 minutes beforehand.

At 1128, the Queensland Rail incident commander confirmed that 13 passengers and the driver had been transported to Redlands Hospital for examination and medical treatment and at 1135 the Queensland Fire and Rescue completed an under-train inspection.

Vehicle recovery

Vehicle recovery operations were planned and commenced at 1142 on the day of the collision. The four trailing cars of train T842 were inspected on site and found to be in a condition suitable for travel by rail.

Diesel service train L822 was despatched from Mayne Yard situated near Bowen Hills and was on standby at Wellington Point by 1252. The service was then despatched to Cleveland where it was used to recover the last three undamaged cars in the train. This phase of the operation was completed at 1950.

At 2035 service LF73 departed Bowen Hills and travelled to Cleveland and subsequently recovered the trailing car in the remaining portion of the train. This phase of the operation was completed at around 2330 when the car had been successfully separated from the two damaged leading cars.

The two leading cars of train T842 had sustained significant damage and had to be lifted by crane from the site onto low bed loaders to be transported by road (Figure 3).

Figure 3: Recovery of car 5173



Source: The Courier Mail

Extraction of the damaged cars from the site commenced at around 0200 on 1 February 2013 and was finally completed at 0430 when the lead car of the train was secured to a low loader trailer.

The four trailing cars in train T842 were transported by rail to Mayne Yard in Brisbane and the remaining two cars were transported by road to Redbank for storage.

Infrastructure repairs

Repairs to the infrastructure commenced at 0500 on 1 February 2013 once the rolling stock had been cleared from the site.

At 0600 operations had begun to release the overhead power mast structure and the damaged buffer stop from the debris at Cleveland station with the removal of the damaged buffer stop completed at 1305.

The positioning of a temporary buffer stop, replacement of the overhead power mast foundation, the replacement of the mast and overhead wiring, together with repairs to the signals, were tasks conducted over the following days. These repairs were completed by 0113 on 3 February 2013. Temporary repairs were also made to the Cleveland station building over this time.

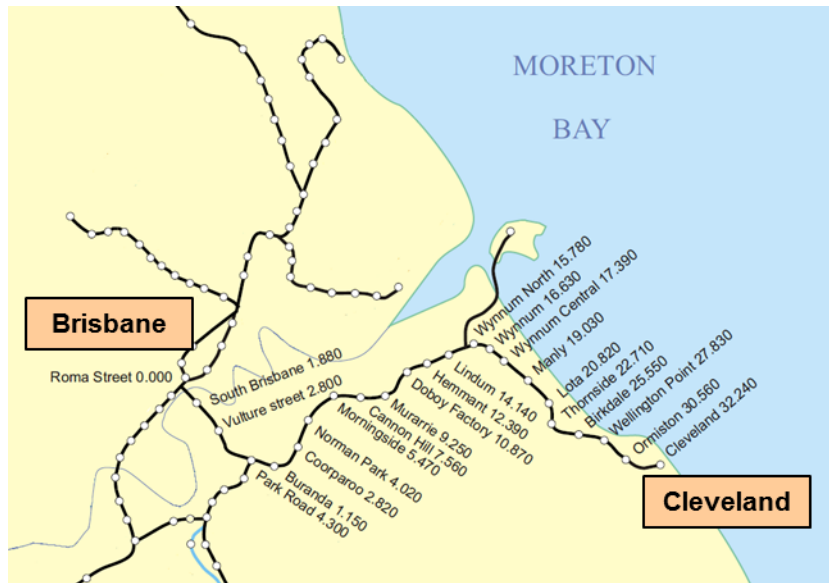
At 0310 on 3 February 2013 test train HF74 departed Mayne Yard for Cleveland to test the infrastructure repairs. At 0434 this service then departed Cleveland on the return journey and at 0500 the emergency response was declared to be over and normal services to Cleveland were resumed.

Context

Location

Cleveland is a coastal suburb located approximately 25 km east-southeast of Brisbane CBD. By rail, Cleveland is a terminating station about 37 track kilometres from Roma Street station (Brisbane).

Figure 4: Location of Cleveland



Source: Queensland Rail. (Extract from System Maps, modified for clarity)

Organisation

Queensland Rail provides suburban commuter rail services on the City network, covering Brisbane, Ipswich and the Sunshine and Gold Coasts. Queensland Rail also provides long distance passenger services to other major centres in Queensland. The Cleveland rail line is part of the Queensland Rail city network with passenger services at about 30 minute intervals during week days shortening to about 15 minute intervals during the peak period.

Infrastructure

Track

The track structure between Ormiston and Cleveland stations consisted of 50 kg/m rail fastened to concrete sleepers laid on a bed of hard rock ballast. The track approaching Cleveland station had a falling grade⁸ of 1:130 from about the Wellington Street overbridge to just before the turnout, where the track grade transitioned to level into the station platform.

Inspections following the collision showed no evidence of obvious track defects or misalignments. The track geometry measurement car run carried out in September 2012 found the track to be within tolerances and of sound alignment.

The rail along this section was in good condition with some side wear on the high leg of the curve on the approach into Cleveland station. Rail lubricant residue was obvious on the bottom of the

⁸ A measure of the rate at which the railway is inclined (rising or falling). Gradients are signed +ve (rising) or -ve (falling) in respect of the direction of travel. Source: National Guideline Glossary of Railway Terminology.

gauge face of this rail indicating the rail lubrication of this length of track⁹ was being maintained. There was no evidence of rail lubricant on the head (top) of the rail. The rail wear was within limits.

The rail on curves is generally ground every two years and this track section was last ground in June 2012. The rail on the tangent (or straight) track had not been included in the rail grinding cycles. This track carries around 8 million tonnes of traffic per year consisting of light axle load vehicles and there was no evidence of distress or damage on the rail head. The rail wheel contact patch was narrow and centred, indicating that rail grinding was not necessary.

There were two turnouts on the approach to Cleveland station, 650A and 650B. Turnout 650A divided the single track approaching the station into the two platforms and was a 1 in 12, 60 kg, fixed heel switch, with a rail bound manganese (RBM) crossing. This turnout was fixed to concrete bearers and had resilient clips fastening the rail to the sleepers. The turnout was observed to be in very good condition. Turnout 650B was on the approach to Cleveland station platform 2 and provided access to a storage road. Turnout 650B was identical to 650A and was found to be in a similar condition.

Overhead traction system

The overhead traction power equipment is the structures and overhead equipment necessary for the supply of traction power to electric trains. Queensland Rail trains operate on a 25 kV AC traction system. Trains collect power through a pantograph when in contact with the single overhead contact wire that is supported by catenary wires cantilevered from trackside masts.

During the collision, car 5173 rode up and over the buffer stop and then collided with the end of line overhead power catenary pole located behind the buffer stop. The force of the impact collapsed the pole, dislodging the catenary wires and tensioning equipment as the train continued to travel towards the platform end and station buildings.

Buffer stop

A buffer stop is a structure located at the end of a railway track section and is designed to prevent a train travelling beyond defined limits, such as railway station terminals. The buffer stop should include features to limit injuries to train drivers, passengers and the public and to minimise damage to rolling stock, buildings and other infrastructure. Energy absorbing and rigid buffer stops are the two most common types used by railways in Australia.

The purpose of an energy absorbing buffer stop is to progressively transform a train's residual kinetic energy into heat through friction elements that move together with the buffer stop frame along the track or through the displacement of hydraulic rams or springs.

The rigid buffer stop was the first type to be used on railway systems and generally consists of a frame or block rigidly fixed to the rails or in the ground. A rigid buffer stop has a limited ability to dissipate a train's kinetic energy and is generally only effective in low speed collisions, nominally 5 km/h or less. Rigid buffer stops were installed at the Cleveland station.

Buffer stop design

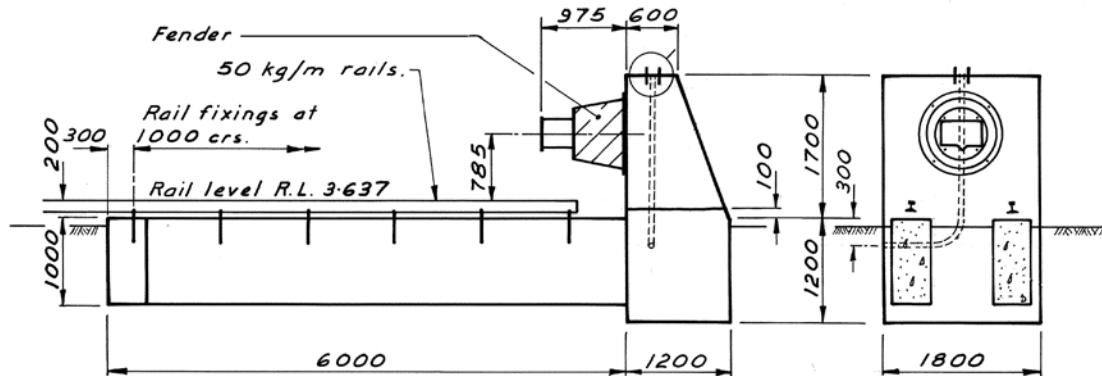
A buffer stop's capacity to stop a train is determined according to the train's maximum weight and speed. When designing buffer stops a standard method is to base calculations on a passenger train travelling between 10 km/h and 15 km/h. For example, for the design of buffer stops on terminal tracks, German passenger train operator Deutsche Bahn uses a collision speed of 10 km/h in their calculations.

The Queensland Rail's South East Queensland Network (SEQN) has a total of seven buffer stops located on running lines at Cleveland, Domestic Airport, Varsity Lakes and Nambour railway stations.

⁹ Lubrication applied to the rail gauge face is used to minimise rail wear.

The buffer stops located at the end of the island platform tracks at Cleveland station are rigid reinforced concrete structures with rubber fenders (Figure 5). The buffer stop was constructed of a 2.9 m high concrete block protruding vertically 1.7 m from the ground and attached to a pair of horizontally reinforced concrete beams extending about 5.5 m under each rail.

Figure 5: Design of buffer stops installed at Cleveland station



Source: Queensland Rail Limited – Chief Civil Engineers Branch

A rubber fender is attached to the concrete block that also has a contact plate matching the profile of the City Train coupler. Design drawing notes showed the buffer stops at Cleveland station were calculated to arrest a train with a maximum mass of 200 t at a maximum impact speed of 5 km/h. The leading edge of each buffer stop was located about 15 m beyond the train stopping point and the end of the station platform. There was no track laid behind the buffer stop and there was a further 5 m between the buffer stop and the Cleveland station building foundation and pavement that arose about 800 mm above ground level (Figure 2).

Train T842 weighed about 256 t and was travelling at about 31 km/h when it collided with the buffer stop. The impact force significantly exceeded the design capability of the concrete buffer stop which was unable to dissipate the train's energy and so failed. This allowed the train to continue into the Cleveland station building.

Slippery track conditions

In the morning preceding the collision at Cleveland, Queensland Rail train control received three reports of trains that had overshot the platform at Ormiston, the station before Cleveland.

- At 0542, the first revenue service to Cleveland (service number 1802) overshot the station platform by six cars. The driver reported a very slippery track.
- At 0834, the driver of service number 1A25 (from Cleveland) reported that the train had overshot the platform by five cars due to a slippery, wet track.
- At 0927, the driver of service number 1A29 (from Cleveland and the train immediately prior to the incident train, T842) reported that the train had overshot the platform by three cars. The driver advised there were gum leaves on the track that may have contributed to the slide.

The driver of T842 overheard the conversation over the train control radio about the slippery conditions at Ormiston station and reduced the speed of the train to about 40 km/h. In addition, the train control operator advised the driver of train T842 to exercise caution through Ormiston station.

While slippery conditions were not specifically reported at Cleveland station, reports of slippery conditions at Ormiston (about 2 km away) along with leaf litter on the track suggests that conditions of reduced track adhesion existed in the area near Cleveland immediately before the collision of train T842.

Track adhesion and friction

In relatively simple terms, friction is the force which resists the movement of one object against another object. The coefficient of friction is the ratio of the friction force between the two objects to the force pressing them together. A slippery surface will have a low coefficient of friction. Static friction force is the force required to initiate sliding whereas kinetic friction force is the force required to maintain sliding. Kinetic friction is generally lower than static friction. That is, less force is required to maintain sliding once an object is already sliding. In a rail context, adhesion is used to define the friction that is available to transfer the driving (or braking) force between the wheel and the rail¹⁰. As the coefficient of friction decreases, the friction available for adhesion also decreases.

The steel-steel (wheel-rail) contact patch is relatively small (about 1 cm²). Under braking, the contact area can be divided into a stick area (adhesion) and a slip area. As the braking effort increases, the stick area decreases until a saturation point at which point the stick area disappears completely. When this occurs, the contact patch is in a state of pure sliding with no rotation of the wheel and, due to the static-kinetic friction relationship, less braking effort is required to maintain sliding. Consequently, the best braking performance is available when a level of adhesion is maintained at the wheel-rail contact patch, which in turn is dependent on the coefficient of friction.

The coefficient of friction is strongly influenced by the introduction of other materials at the interface between the two objects, either to increase friction or decrease friction. In this case, a visual inspection of the track leading into Cleveland Station (undertaken by Queensland Rail staff following the collision) found evidence of a film of black scale type material deposited on the rail head adjacent to the running surface.

Rail head and train wheel contaminants

Samples of contaminants were collected by Queensland Rail staff from the heads of both rails and were preserved for further analysis. Five samples were taken from the rail head (and one sample was taken from below the rail gauge) on the section of line leading into No 2 platform at Cleveland Station (the train braking region). These samples were sent to the University of Queensland and were analysed for substances such as woody or leaf material, oils, grease, soaps, corrosion products, soil, rock, metals and other particles.

Staff from the University of Queensland also took fifteen samples from various wheels on the two leading vehicles (cars 5173 and 7173) of train T842 after they had been transported to the Redbank maintenance facility and re-railed. It was noticed by ATSB investigators and University staff that some fresh vegetable matter had been deposited on the wheels during the re-railing and subsequent shunting process. These areas were avoided when collecting the samples for testing. The samples taken for analysis were flaky, dark grey in colour and were generally free of greases and fresh vegetable matter.

Rail wheel samples

Testing of the samples from the rail wheels revealed traces of iron oxide, plant debris and sand. Some samples showed traces of oxidised oils from grease suggesting that this was due to heating at the wheel/rail contact region. This heating probably occurred as a result of a brief wheel lock when the train was under emergency braking.

The greases were present in very small quantities and were unlikely to have affected the level of adhesion during the braking of the train.

The University of Queensland report observed that various batches of samples 'produced evidence of value in assisting the investigation of this accident' but also that some samples 'ended up providing less scientific information than they might have had proper sampling been

¹⁰ Sometimes the term 'traction' is used for driving and the term 'adhesion' used for braking.

undertaken'. The report commented that had detailed notes been taken by the sampler at the accident site, these notes would have been 'of great value to the laboratory analyst in the deconvolution of complex observations and results'. The University of Queensland report recommended that forensic scientific officers should attend accident sites to collect samples before an accident scene is disturbed.

Rail head samples

Six rail reference samples of lubricants containing hydrocarbon oils and solid lubricant additive (used for rail friction modification, gauge face lubrication) and heavily compressed eucalyptus leaf materials were taken at various locations more than 1.5 km from Cleveland station. These reference samples were analysed to determine if lubricative elements were present in samples taken from the rail head and rail gauge faces within the train braking region on approach to Cleveland station and to find if these elements were present at levels that could affect adhesion at the wheel-rail interface.

The University of Queensland report confirmed the five samples taken from the rails within the train braking region showed various vegetative materials including leaf tissue, woody particles, and iron oxide. The analysis of these samples did not reveal any of the lubricant compounds (found in the reference samples taken near Ormiston) that that would have further reduced levels of friction.

The report discussed the impact of leaf litter on rail contact surfaces and the concentration of eucalyptus trees bordering the rail corridor. It noted that oil glands located between the outer layers of eucalyptus leaves contain significant quantities of oils that have a lubricating effect.

The report stated that:

The sugars and starches present in the leaves will be water sensitive yielding rather slimy gels of good lubricity. Furthermore, they will feed bacteria and fungi, both of which are known to develop as slime layers on organic substrates. Leaves which have been present in water for a while do develop such a slimy feel, but as such microbiological growth takes several days to develop, such a situation could not develop on fresh leaf litter upon a frequently used line. However, sugars and starches from squashed leaf litter would be present as a gel fairly quickly upon wetting.

There were strong winds and rain, described by the Bureau of Meteorology as very much above average, which led to train services to Cleveland being suspended for about 3.5 days prior to the collision of train T842. At this time leaves dislodged from trees and other plant matter from within and adjacent to the rail corridor were deposited on the track and rail heads. This organic matter was also subjected to rain which would have promoted microbiological growth over the time of the track closure.

When train services resumed on 31 January 2012, the 12 train services before T842 would have crushed and distributed any organic matter on the rail head and also disturbed the leaf litter lying between the rails and beside the track (Figure 6).

Figure 6: View from Cleveland station platform showing leaf litter about the track and (insert) crushed on the rail head.



Source: Queensland Police Service


While the Bureau of Meteorology weather station¹¹ located at Brisbane Airport (approximately 20 km north-west of Cleveland station) did not record any rainfall at the time of the occurrence, there was evidence of light rain falling at Cleveland as train T842 approached the station. The forward facing video on train T842 showed the driver had intermittently used the windscreen wiper while travelling through a very light shower of rain shortly after departing Ormiston station. The video showed there was probably insufficient rain to wash and clean the heads of the rails before the passage of train service T842.

A number of studies have examined the relationship between wheel-rail friction and adhesion¹². The studies found that that the levels of friction and adhesion were reduced depending on the type of contamination. Table 1 provides a comparative indication of the friction/adhesion levels relevant to the type of contamination present at the wheel-rail contact patch. The studies indicated that a damp leaf film produced significantly reduced levels of friction and adhesion.

¹¹ The BoM site recorded (at 0930) cloudy conditions with a temperature of 25.7 °C, relative humidity of 72 per cent and wind from the north-northeast at 13 km/h.

¹² Wheel-rail interface handbook, edited by R. Lewis and U Olofsson (2009)

Table 1: Scale of friction/adhesion

Condition of rail surface	Scale of friction/adhesion
Dry, clean rail	Good
Wet, clean rail	
Greasy rail	
Moist rail	
Damp leaf film on rail	

For the track leading into Cleveland station, the water droplets from the light rain settling on the rail head mixed with the decaying organic matter/iron oxide compound would have created an emulsion that coated both the rail head and the train wheels. These compounds would have adversely affected the level of adhesion at the wheel/rail interface and likely reduced the effective braking performance of train T842.

Rail head and train wheel profiles

The contact between the wheels of a rail vehicle and the rail is a key element of railway operation and effective management of this interface is critical to safe railway operations.

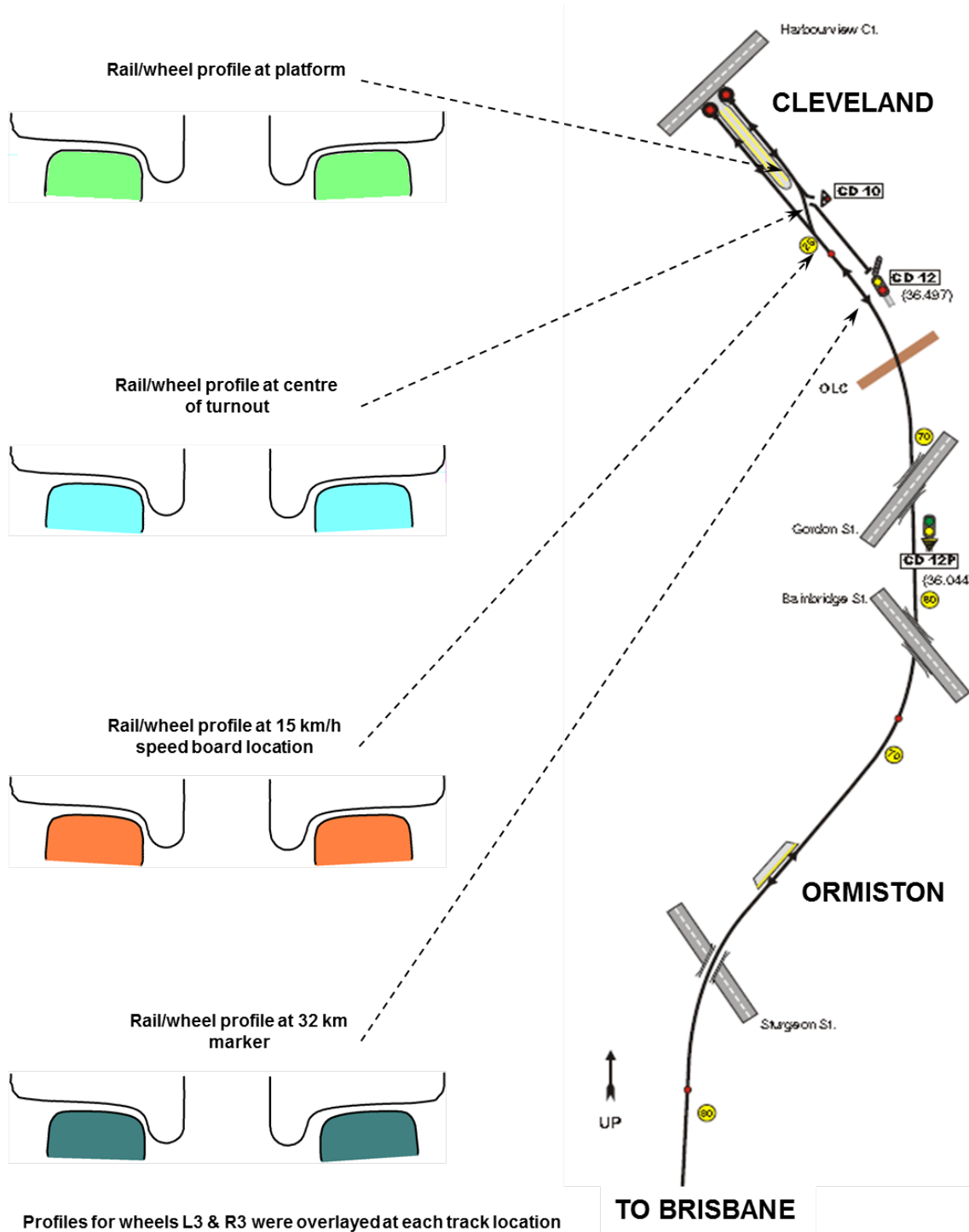
Regular inspection and maintenance of rolling stock wheel and rail head profiles are critical in ensuring that profile geometries are correctly matched to ensure wear is minimised and vehicle dynamics and performance are optimal.

Profile measurements of all wheels on accident train T842 and both rails at 10 locations over a section of about 1 km of track between Ormiston and Cleveland stations were conducted using 'MiniProf' wheel and rail profile measuring instruments¹³. The rail profiles were taken at specific points on the track leading into and through the region where the driver made applications of the brake to slow train T842 immediately before the Cleveland station (Figure 7).

These measurements were taken to determine if the wheel and rail profiles, and the positioning of the contact patch between the wheels and rails, was compliant with rolling stock and network engineering standards and specifications. With the assistance of Computer Aided Design (CAD) software, MiniProf profiles of the wheels were overlayed onto the MiniProf rail profiles and aligned at the contact patch regions.

¹³ A MiniProf instrument is a tool for measuring cross sectional profiles of rolling stock wheels and rail.

Figure 7: Leading passenger car 5173 wheel profiles and rail profiles at specific locations on approach to Cleveland station



The investigation found that although the rolling stock wheel and rail head profiles showed a very small amount of wear, both were compliant with Queensland Rail engineering standards and specifications. It was concluded that the profile condition of these components and the tracking of the wheels/bogies were unlikely have contributed to the wheel slide experienced by train T842 near Cleveland on 31 January 2013.

Train driver

The driver of train T842 had been employed as a train driver for 20 years with current training and route knowledge competencies to operate trains on the Brisbane Suburban Area Network. The driver had been assessed as fit for duty in accordance with the requirements of the National Standard for Health Assessment of Rail Safety Workers.

Following the collision the train driver was tested for blood alcohol content. This test returned a negative result. There was no indication that the driver's performance was affected by physical, medical or cognitive factors.

Driver's actions

On the morning of the collision, the driver of train T842 approached Ormiston station at a reduced speed following advice that previous trains had encountered difficulty in stopping. He did not encounter difficulty in stopping the train at Ormiston although there was some indication of a minor wheel slide near the end of the stopping sequence. Following the departure from Ormiston station there was no indication of any wheel slip, indicating to the driver that there was sufficient adhesion. The track in this locality was dry and while overcast, there was no sign of rain.

The train departed for Cleveland station on the final section and was operated in accordance with the conditions that were known to the driver when departing Ormiston station. On the downhill section of track prior to Cleveland station the driver encountered localised light rainfall. This event coincided with the driver applying the train brakes on the initial setting, following the standard procedure and his training, to commence reducing the train speed for the 25 km/h points located immediately prior to the Cleveland station platform.

The subsequent excessive wheel slide that occurred saw the driver faced with the decision of reducing the brake application to control the wheel slide in an effort to enhance the braking effort, knowing that the speed of the train was not reducing as expected. The act of reducing the amount of brake application may have controlled the wheel slide but there was nothing to support the assumption that better braking was going to be achieved. The action of reducing braking effort was also counter intuitive, with the driver tasked to slow and stop the train on the Cleveland station platform before colliding with the buffer stop. In accordance with the recommendations provided in his training in relation to prolonged wheel slide events, when all other actions to slow the train had proved futile, the driver then made an emergency brake application.

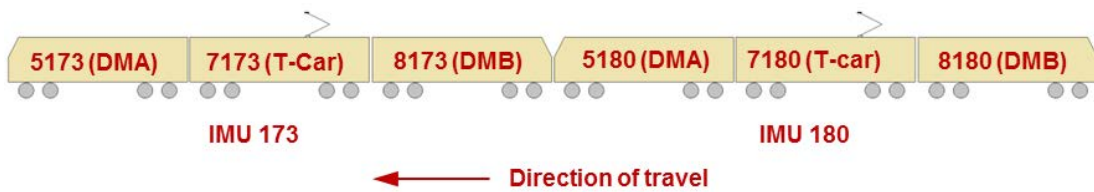
Review of the train driver's actions on approach to Cleveland station with respect to speed and braking indicates that they were consistent with sound driving practice and did not contribute to the accident.

Train information

Queensland Rail currently operates 28 Interurban Multiple Unit (IMU) 160 class electric trains, numbered 161 to 188 and 36 Suburban Multiple Unit (SMU) 260 class electric trains, numbered 261 to 296. Each IMU160 and SMU260 unit consists of two driving motor cars (DM car) coupled to either end of a non-powered trailer car (T-car), to form the typical set configuration of DMA – T car - DMB. The IMU160 and SMU260 class trains are similar in construction and operation, with the addition of a passenger toilet facility in the IMU160. The IMU160 and SMU260 class electric trains were constructed by a Downer EDI Rail/Bombardier Transportation Australia joint venture and progressively delivered to Queensland Rail between 2004 and 2011.

In service, the IMU160 or SMU260 configuration typically operate either as a single 3-car set or coupled with another set to form a 6-car train. The tare weight for each configuration is 128.2 t and 256.4 t respectively. At the time of the occurrence two 3-car sets (IMU173 and IMU180) were coupled to form train T842 (Figure 8). IMU 173 and IMU180 were delivered to Queensland Rail on 5 February 2008 and 17 June 2010 respectively.

Figure 8: Train T842 configuration



Braking system

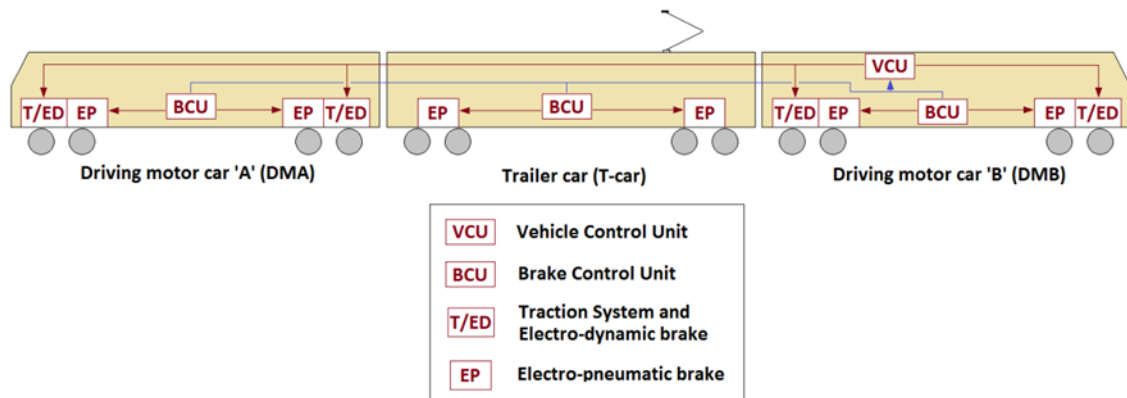
The IMU160 (and SMU260) trains are equipped with both electro-dynamic (ED) and electro-pneumatic (EP) braking systems. These braking systems have been used since the introduction of the suburban electric train fleet in 1976.

The ED system uses the electric traction motors fitted to the axles of each bogie of the DM car to provide regenerative braking.¹⁴ The electric energy generated during regenerative braking is fed back into the overhead power supply system.

The EP system provides a friction brake¹⁴, through the application of air pressure from the brake reservoir to the disc brake units fitted to each axle of the train. As the T-car is non-powered, braking effort for it, when required, is provided by the EP system only.

The application of the ED and EP braking systems of the IMU160 class is managed by interconnected microprocessor-based Vehicle Control and Brake Control Units (VCU and BCU respectively). Each 3-car set is fitted with a VCU that controls the electric motors via a traction converter in each DM car, providing either power or regenerative braking as required. BCUs are fitted to each car (DM and T-car) of the 3-car set to control the application of EP braking for each car and to interface with the VCU in providing ED braking (Figure 9).

Figure 9: IMU160 braking system configuration



The braking system is designed to preference ED braking to maximise the effect of the retardation provided by regenerative braking and to reduce wear on friction brake components. EP braking will supplement ED braking as required to provide the required brake demand.

Operation of the brake control lever by the driver causes a brake demand signal to be transmitted to the VCU and BCU, initiating the braking system. The braking effort provided by the ED and the EP systems is then blended by the BCU depending on vehicle speed and loading to ensure the braking effort satisfies required brake demand. The blending of the braking systems during a

¹⁴ Refer to Glossary section of this report for definitions.

normal service brake application provides the maximum braking rate during stopping, while maintaining passenger comfort.

Typically the primary braking effort for the train is provided by the ED system of each DM car. The braking is blended by the BCU so that each DM car provides the required brake effort for its mass plus half the mass of the T-car, due to the T-car being fitted with the EP system only.

In situations where low adhesion between the wheel and rail head may occur the VCU and BCU control systems incorporate a Wheel Slip Protection (WSP) feature that provides wheel slip-slide control in the event of an axle losing adhesion with the surface of the rail head. WSP for each of the ED (VCU controlled) and EP (BCU controlled) systems work independently although the BCU in the T-car transmits speed reference signals to the VCU.

The WSP systems of each DM car integrate the application of ED and EP braking to ensure the preference for ED braking is maintained (where possible) in controlling a slide while controlling any EP application on the T-car to improve stopping distances, wheel life and reduce brake pad wear in the wet.

If a wheel slide has been detected in the preceding two stops, the control system of the 3-car set modifies the blending of the braking effort provided by each of the DM cars. In this situation the braking effort is now evenly distributed across all three cars of the train with the T-car providing friction braking through its EP system. In this mode when a DM car reduces its ED braking effort the T-car will automatically blend additional braking effort to compensate. Under wheel slide conditions the BCU in the T-car will manage slide control of its axles using the EP system while the DM cars will continue to manage slide through the ED system.

Train T842 experienced slippery conditions when stopping at Ormiston station prior to the collision at Cleveland. This initiated the WSP and modified the blending of braking effort provided by the DM cars to then integrate the application of ED and EP braking for each of the two 3-car sets.

In conditions where poor adhesion is encountered or when a specified variance between the brake demand signal and ED brake effort achieved is detected for a time period, the traction system is inhibited. Control of the wheel slide is then passed to the BCUs of each car and EP braking is used to bring the slide under control through the action of anti-skid valves acting on the brake cylinders of each axle.

Emergency brake

A fail-safe emergency brake system is provided on each 3-car set. The emergency brake operates on the EP system and applies full brake cylinder pressure on each car. The WSP function continues to operate during emergency braking, however, the ED braking system is disabled to avoid wheel slip from over-braking.

Park brake

A driver operated park brake is fitted to three of the axles on each DM car. The park brake, when selected, is applied through the release of air pressure enabling the spring-actuated mechanism to apply pressure to the disc brake of the corresponding axle.

The disc brake mechanism is common to the park brake and EP braking systems. The park brake unit is fitted with an anti-compound valve¹⁵. Under normal conditions the anti-compound valve prevents approximately 80% of the additional force from the parking brake should they both be applied simultaneously to avoid wheel locking resulting in a wheel skid.

Under low adhesion conditions the application of the park brake has the potential to affect the normal operation of the WSP system. Queensland Rail analysis of data extracted from other incident trains has shown a minor reduction in brake pipe pressure when the park brake has been

¹⁵ Refer to Glossary section of this report for definitions.

applied but, as the WSP remains active, there were no reports of the train wheels locking and creating flat spots.

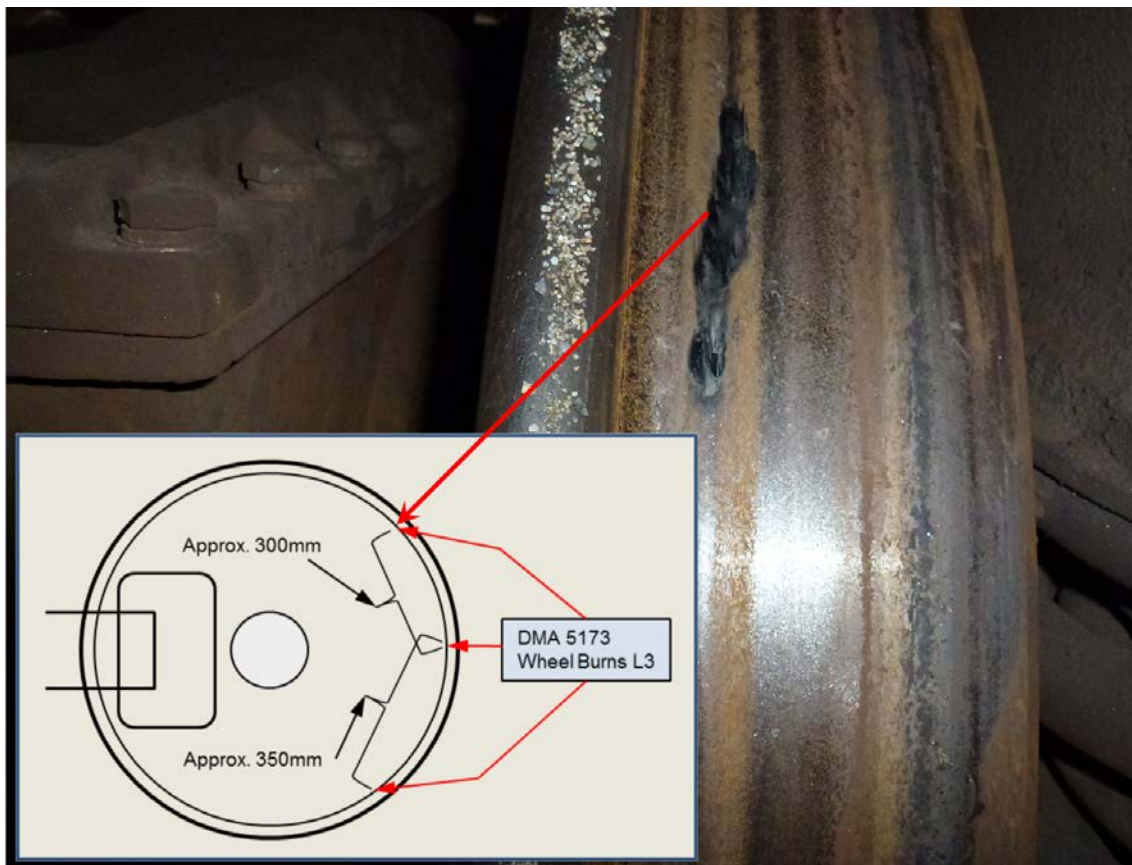
Queensland Rail issued an instruction to drivers advising that the use of the park brake in emergency situations should be avoided. Investigations undertaken by Queensland Rail of train drivers applying the park brake in an emergency found that this did not affect the typical operation of the train braking/WSP system.

From the available evidence it is unlikely that the operation of the park brake of train T842 contributed to the collision and the driving and braking actions taken by the train driver in an attempt to stop the train were consistent with the driver’s training and normal driving practice.

Brake inspection and tests

Inspections of the wheels for all cars after the collision revealed minor flats¹⁶ at three near equally spaced positions about the tread circumference of an axle on the leading car (5173) and one wheel flat of an axle on the last car (8180). It is possible that the multiple tread flats on one axle of car 5173 indicate that WSP may have briefly been compromised. The equal spacing around the wheel circumference is indicative of the brake activation and release function while WSP was attempting to control the slide (Figure 10).

Figure 10: One of three wheel slide burns on car 5173, trailing bogie, wheel L3

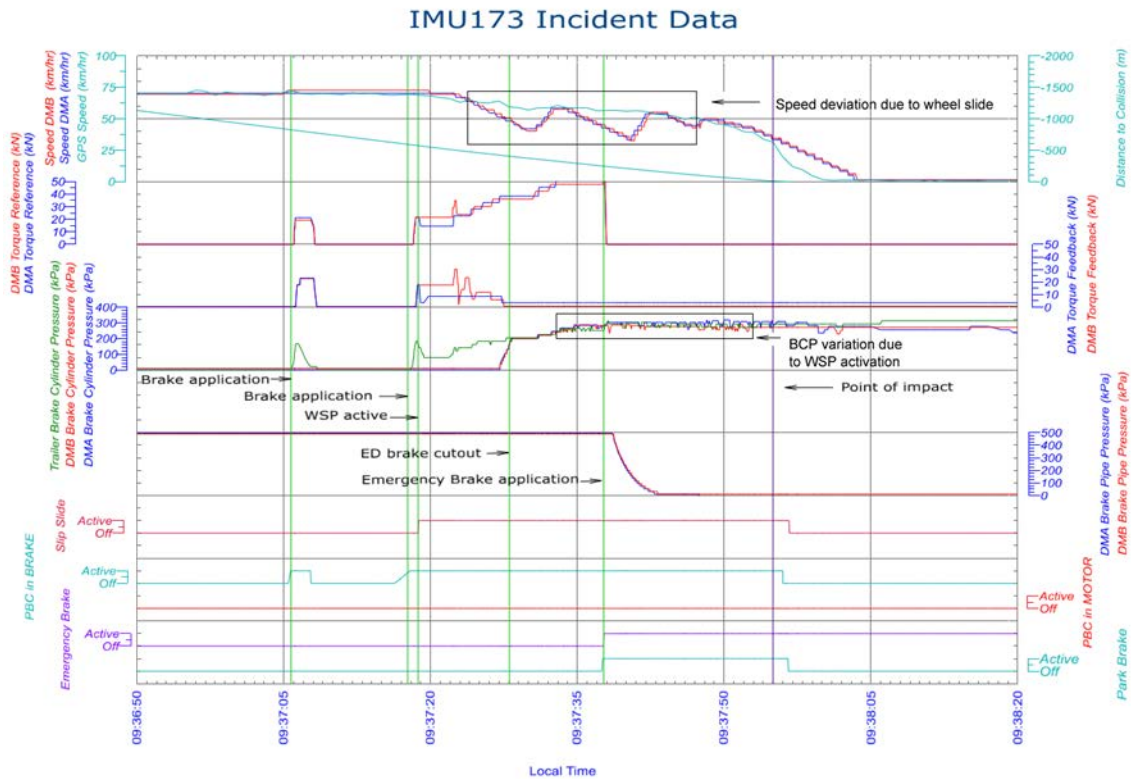


Source: ATSB

¹⁶ Loss of roundness of the tread of a wheel usually caused by wheel slip or wheel slide. Source: National Guideline Glossary of Railway Terminology Version 1.0, 3 December 2010.

Analysis of information extracted from car 5173's data logger (Figure 11) shows the train was travelling about 69 km/h (0937.18) when the driver made the service brake application to slow the train about 590 m from the Cleveland station. Less than one second later, the WSP system detected slide. Brake cylinder pressures, particularly after the application of the emergency brake at 56 km/h, display numerous fluctuations as the WSP system intervened to apply and release the brakes in attempting to control the slide. Fluctuations in speed were also recorded where the WSP system remained active throughout the service brake and emergency brake applications until the point of impact.

Figure 11: Extract of data log from IMU5173



Brake force tests

A series of brake force tests were carried out on the two leading cars, 5713 and 7173, at the Redbank maintenance facility. These tests were to determine whether the brake pad clamping force on each disc rotor on each wheel of both cars was in accordance with Queensland Rail's and the brake manufacturer's specifications.

With ATSB investigators present, Queensland Rail technical staff carried out three individual tests on each brake caliper/rotor using specified air pressures for service and emergency brake applications. Before commencing the tests, the brake pads were removed from each axle set and inspected for wear. All brake pads were found to have adequate friction material remaining with minimal wear evenly distributed across the pad surface. Some pads displayed small areas of glazing. Disc rotor wear was also minimal. Pressure transducers placed between the brake caliper actuating pistons and the disc rotors were used to measure clamping forces on each axle set. A calibrated 'Smart Shoe' testing instrument was used to measure and record these forces when the specified air pressures were applied.

All tests revealed that there were no significant variations of the clamping forces for the service and emergency brake applications and the brake clamping forces on each disc rotor were within specified limits.

The brake force tests on cars 5713 and 7173 indicated there was sufficient brake caliper force applied to the disc rotors to decelerate train T842 had there been sufficient adhesion at the wheel/rail interface.

Pre-service brake conformance testing (IMU160 class)

Before the introduction of the IMU160 fleet to operational service, tests were conducted to validate the operation of the brake system in normal, electro-pneumatic and emergency modes. Tests were also conducted to confirm the correct operation of the WSP system on rails that had been lubricated with a water/detergent mixture on a near level track gradient. The train (IMU161, a three-car set) was tested in the various brake modes and adhesion conditions at five speeds; 40, 60, 80, 100 and 130 km/h in tare and loaded mass conditions. The WSP system was set so that no skidding of the wheels could occur.

The tests were repeated for a 6-car set which found that the tare and loaded deceleration rates were not significantly different.

Brake software changes

Since the introduction of the IMU160 and SMU260 class trains there have been several brake software changes. Knorr Bremse, the designer and manufacturer of the brake equipment fitted to these trains, carries out all modifications to the brake software in Germany to effectively manage quality control over its products. All changes to brake software are verified through a comprehensive set of tests to ensure that brake system performance is optimised with parameters set for local conditions including WSP. Every software change for the IMU and SMU trains was tested locally in accordance with Downer EDI Rail Engineering Specification CES01183 Rev A (2007) to achieve a nominal deceleration rate of 1.2 m/s² with the application of full service brake on tangent level track.

Queensland Rail records show the first WSP software change occurred in the IMU160 fleet in February 2009. This change was made in response to an undesirable power operation fault. Further brake software changes were trialled in November 2009 (v1.1) however these were not implemented due to an anomaly encountered during testing. Knorr Bremse, in consultation with Queensland Rail's contractors, Downer EDI Rail and Bombardier Transportation, then designed another series of changes to correct the anomaly. Results of tests carried out in February 2010 indicated the tests were successful and plans were made to implement revised software version (v1.2) before the end on May 2010. However in July 2010 software v1.2 was tested in SMU275, SMU279 and SMU283 and problems were encountered in relation to the retention of wheel diameter parameters and associated speed reference faults were recorded.

Further changes were made to the software to rectify these faults which resulted in software version v1.30. Acceptance testing of software v1.30 was carried out using SMU283, SMU284 and SMU288 and these tests were again validated through bench and static testing by Knorr Bremse, and dynamic testing on track by Queensland Rail. Between December 2010 and January 2011 software v1.30 was also upgraded and tested on IMU161 and SMU289.

The revised software configuration (v1.30) was approved for release and implementation on the whole IMU160 and SMU260 fleet through an engineering instruction that was issued on 7 April 2011. Records show brake software changes for these fleets were completed on 7 May 2011. At the time of the collision at Cleveland station, software v1.30 was installed on IMU173 and IMU180.

Test train SMU292

Overnight on Wednesday 13 and Thursday 14 February 2013, a series of tests were conducted to measure the stopping distance of a train similar to the train involved in the Cleveland collision under a range of wheel/rail adhesion conditions.

A near-level section of track was used and all brake activations were commenced at a speed of 70 km/h. The heads of the rails were lubricated for each test with water, undiluted truck wash and a mixture of water and truck wash respectively. Test car set SMU292 was also fitted with piping to direct the truck wash and water onto the contact patch between the head of the rail and the wheels. Transducers were connected to the train's brake cylinders and valves to convey data to temporary on-board recording equipment in order to assess the operation of the train's braking system.

Initial tests were made in accordance with the operators procedure and brake performance criteria on dry track to determine the time and deceleration rate of SMU292 under EP brake/no regenerative brake, EP brake/regenerative brake and emergency brake.

Following the application of the brake and once the desired braking conditions for each test had stabilised (at a speed less than 70 km/h), the time to attain a defined reduction in speed over a range of 50 km/h was used to derive the respective deceleration rate.

Results showed when under an emergency brake application the test train decelerated at a rate of 1.329 m/s² over 10.4 seconds.

Queensland Rail brake performance criteria for this test allow an acceptable time range of between 9.9 –13.2 seconds and deceleration rates of between 1.05 –1.4 m/s².

A total of 12 tests were carried out. In two of the tests when truck wash was applied to the rail head the train took 28.5 seconds (0.487 m/s²) and 31.4 seconds (0.442 m/s²) respectively to stop using a full service brake application (EP brake/no regenerative brake).

Following the test, data was extracted from the test train's Vehicle Control Units, Brake Control Units, data loggers and forward-facing video. A video camera was also mounted on the driver's vestibule to record the activation of slip-slide warnings and other functions on the driver's console.

The data from the accident train and test train SMU292 were separately analysed and compared. Analysis of data from both trains indicates that the braking system on the Cleveland-bound accident train (T842) was working as designed when operating under low adhesion conditions.

Wheel tread dressing

Various brake system configurations are used across the Queensland Rail passenger train fleet. The current fleet was introduced to service between 1979 and 2011 and is fitted with electro-pneumatic brake combinations of tread only, tread and disc and disc only. The whole fleet is fitted with WSP and all new trains introduced to service after 1994 are fitted with regenerative braking. The EMU class introduced to service between 1979 and 1987, ICE (1996-1997) and SMU200 (1994-1995) are fitted with tread brake systems only. The SMU220 class, introduced between 1999 and 2001, have a combination braking system with tread brakes fitted to both power cars and the trailer car is fitted with axle mounted disc brakes alone.

Where tread brakes are fitted to a train, wheel tread surface cleanliness is maintained each time the brake block contacts the wheel tread through brake applications made by the train driver. The cleaning of the wheel tread assists in the detection of a train for track signalling purposes and, importantly, improves braking efficiency.

Trains that are fitted solely with disc brakes do not benefit from regularly having the wheels cleaned during application of the brake, although some disc-braked trains are fitted with wheel tread dressers to perform this function. The primary function of a wheel tread dresser is to remove any compacted or embedded materials such as leaf litter or grease that can form an insulating and/or friction modifying coating on the wheel surface. Wheel tread dresser units are mounted on the train's bogies and have a friction pad facing the wheel tread surfaces. When activated, the friction pad makes contact with the wheel tread thereby skimming free any contaminants that have been collected.

In 1996 the IMU100 fleet was the first to be introduced exclusively with disc brakes. Four train sets of this class (101-104) were fitted with wheel tread dresser units with Bombardier Transportation extensively involved in assisting Queensland Rail with the performance testing of these units. Queensland Rail operated and serviced these four trains with wheel tread dressers for about 15 years. It was found after their introduction that signalling detection was acceptable for these trains with or without wheel tread dressers fitted. With respect to braking, Queensland Rail engineers found there was no noticeable difference in the braking performance on trains fitted with tread dressers. In addition, regular maintenance was required on the wheel tread dressers and further, that they 'proved to be unreliable'.

As a result of this experience the wheel tread dressers were removed from these train sets in 2011. New contracts issued for the manufacture of the later classes of trains (IMU's 120,160 and SMU's 220, 260) did not specify the fitment of wheel tread dressing equipment.

Train crashworthiness

The IMU160 and SMU260 class trains were designed to include developments that had been made in the previous manufacture of vehicles built for the TransPerth (Western Australia) and Queensland Rail fleets. These vehicles incorporated a European style flat roof with raft under-slung equipment that enabled improved production and assembly methodologies.

To ensure these vehicles met the design specifications and were able to reach a minimum service life of 30 years, tests of the car body were carried out. To test the structural integrity and crashworthiness of the car body, 24 separate load cases were carried out using finite element analysis¹⁷ (FEA) modelling that included proof of design, ultimate (collision), fatigue, normal and buckling loads.

The most severe non-conforming regions that were identified during the FEA tests were monitored at the car body by strain gauge testing. The car body design included features to enhance crashworthiness through the inclusion of collision posts at each end of the vehicle, extending from the underframe to the roof structure. The structural resistance to roll-over was also evaluated.

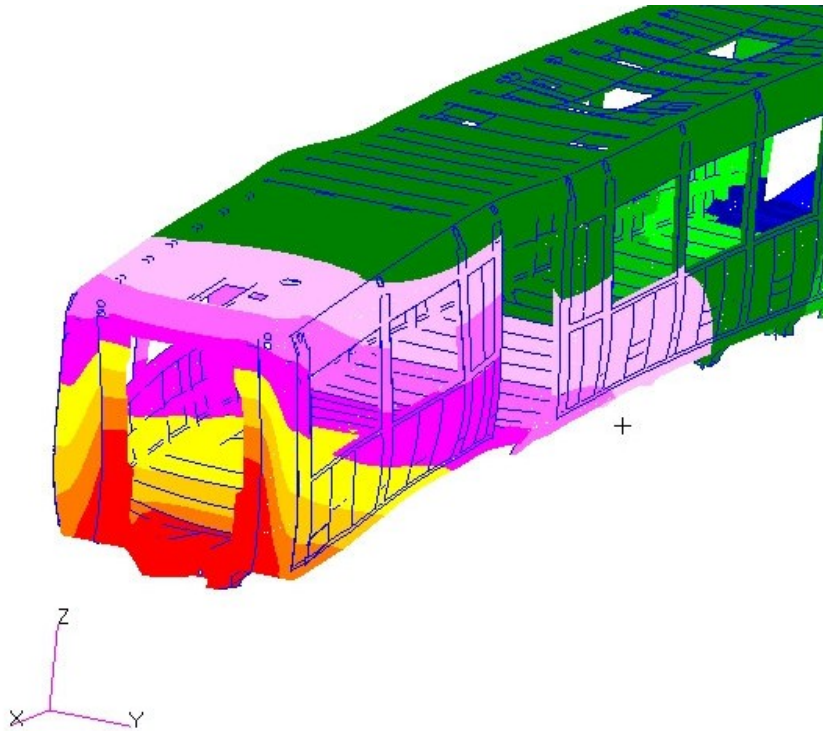
Three dimensional wire frame diagrams produced during FEA modelling show regions where the most stress and plastic deformation was likely to occur by the use of colour rendering. Regions of the model displaying warm to hot colours indicate higher stress concentrations for each load applied at predetermined points on the model surface. Cool colours depict areas of low stress.

During the collision at Cleveland, the leading car's coupler impacted the buffer stop which transferred the longitudinal load through the headstock¹⁸ primarily at the floor level of the train. The maximum ultimate loads tested during the FEA modelling were set at 260 MPa where all regions of stress would exceed the critical design threshold. This stress level is the minimum allowable for all car body structural materials under ultimate loads. The following examples of FEA models show the concentrations of stress at collision loads of 2600 kN at the leading portion of the car body (Figure 12), the driver cab frame (Figure 13)and headstock (Figure 14).

¹⁷ Finite element analysis is a mathematical computer model of a material or a design that is put under stress to verify that the proposed design is able to perform to engineering specifications before the product is constructed.

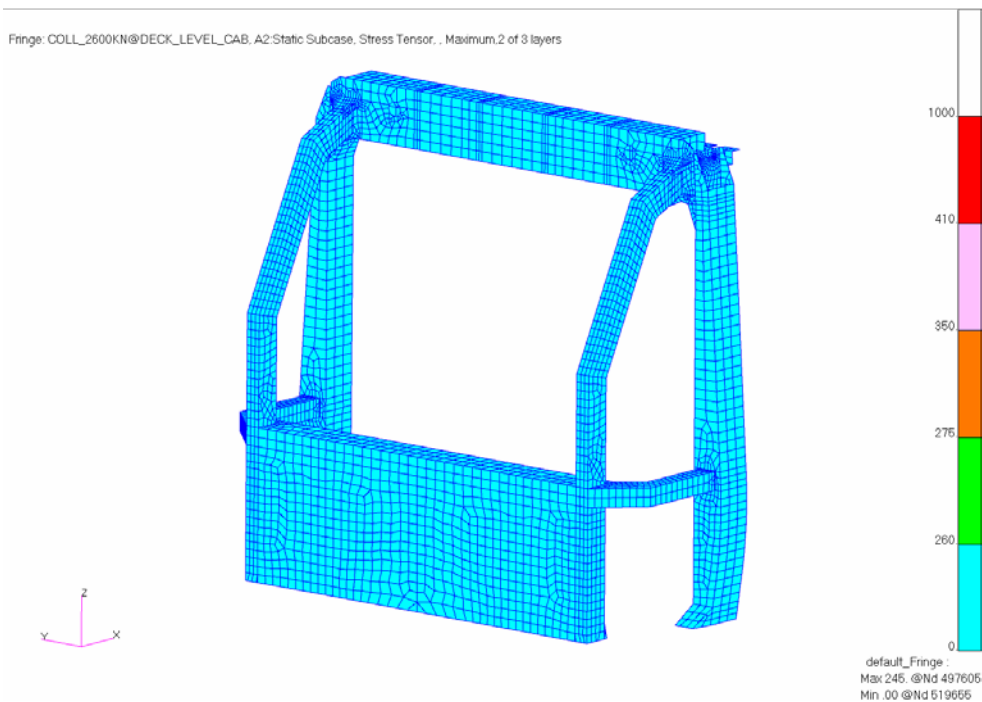
¹⁸ The transverse structural member located at the extreme end of the vehicle's under frame that supports the coupler.

Figure 12: Finite element analysis of IMU160 and SMU260 class showing stress concentration levels of the car body resulting from a frontal collision load of 2600 kN at floor level. (Maximum longitudinal car body deflection = 21.9 mm at end wall)



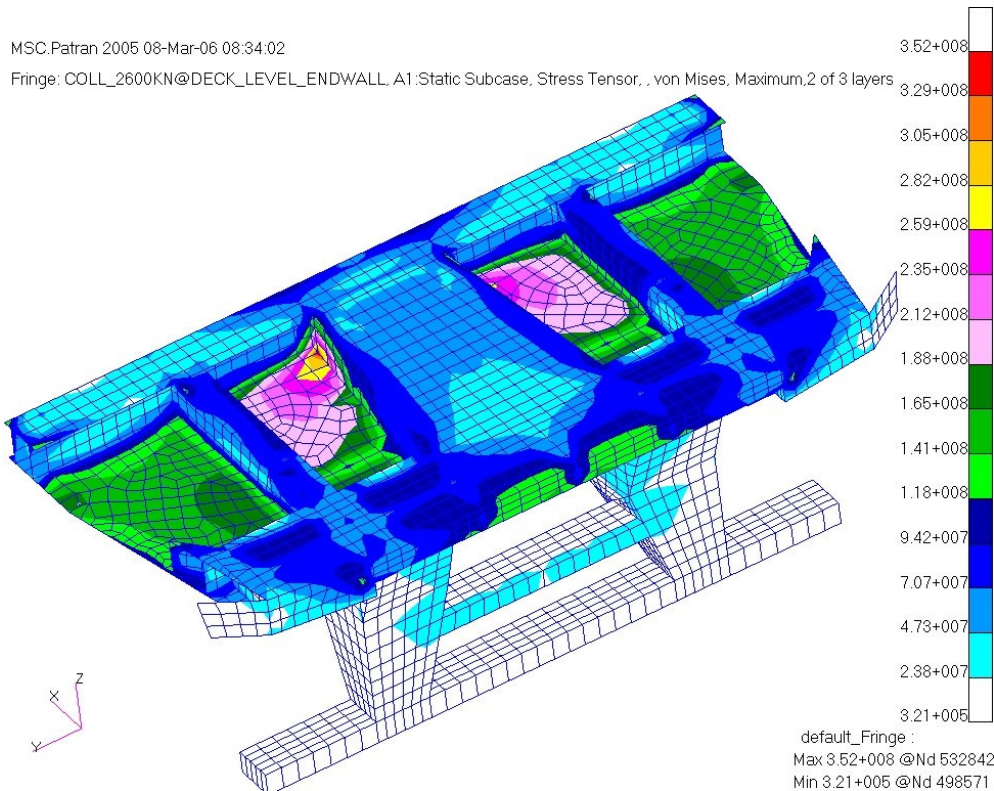
Source: Bombardier Transportation

Figure 13: Finite element analysis of IMU160 and SMU260 class showing stress concentration levels of the drivers cabin frame under a frontal collision load of 2600 kN at floor level.



Source: Bombardier Transportation

Figure 14: Finite element analysis of IMU160 and SMU260 class showing stress concentration levels of the headstock under a frontal collision load of 2600 kN at floor level.



Source: Bombardier Transportation

The leading vehicle on train T842, car 5173, was travelling at about 31 km/h when it struck the Cleveland station buffer stop, fracturing it from its foundation before colliding with and collapsing the overhead catenary mast and demolishing part of the station building (Figure 2). The average deceleration force applied to train T842 during the collision sequence (between initial impact and vehicles stationary) was calculated at about 700 kN, about 27% of the force applied during crashworthiness analysis (2600 kN). Post-accident inspections of car 5173 showed the vehicle structure had resisted the impacts and external debris from the collision had not intruded into the driver’s cabin and workspace. Small fragments of glass from the single-piece laminated windscreen had separated from the inside layer and lodged on the forward section of the driver’s console and fractures of the fibre reinforced plastic driver’s desk were visible on the right-hand lower corner adjacent to the train radio and intercom handsets. There was minimal deformation across the headstock section of the train and minor damage to the windscreen and driver’s cabin roof that resulted from the collision with the overhead catenary mast. (Figure 15)

The structural integrity of other body elements of car 5173 remained intact however there were noticeable distortions in the stainless steel lower exterior side-walls located between the driver’s cabin door and the first passenger entry/exit doorway on the ‘A’ end. Extensive distortion of the underfloor structural members and sheeting occurred when the lead bogie was forced upward as car 5173 rode over the broken buffer stop before impacting the station building. An inspection of the passenger saloon floor centrally above the lead bogie displayed a visible hump that had risen about 25 mm over an area of about two square metres. There were no protrusions of metal or visible tears in the floor covering. There were two passengers in this region who were seated near the windows against the bulkhead behind the train driver’s cabin and electrical compartments but no passengers were standing on or near the impacted floor section at the time of the collision.

Figure 15: Resultant damage to the front of car 5173 after colliding with buffer stop, overhead electrical catenary mast and station building.



Source: ATSB

The investigation found that the IMU160 class of vehicles that made up train T842 had resisted and absorbed the significant forces resulting from the frontal collision with the end of line buffer stop, overhead power line catenary pole and station building structures with minimal intrusion into the driver's cabin and passenger saloon areas. It was also considered that the rising intrusion of the interior floor into the passenger saloon would have had a negligible effect on passengers that could have been standing in this region at the time of the collision.

Interior crashworthiness is the ability of a vehicle interior to reduce injuries not associated with deformation of the vehicle structure or ejection from the vehicle in an accident. There is currently no Australian standard for interior crashworthiness of rail vehicles. In the absence of Australian standards or guidelines, standards developed in the United Kingdom (UK) by the Rail Safety and Standards Board (RSSB) were referenced.

Railway Group Standard GM/RT2100 *Requirements for Rail Vehicle Structures* defines the requirements for the design and integrity of rail vehicle structures, including interior crashworthiness. For passenger vehicles, GM/RT2100 refers to British/European standard BS EN 15227:2008 which states that mean longitudinal deceleration in the survival spaces shall be limited to 5 g for rail vehicles.

In this case, the deceleration of train T842 was about -2.7 m/s^2 (about 0.28 g), significantly less than the criteria defined in the British/European standard.

The interior of the IMU160 and SMU260 class is devoid of sharp fittings and seating furniture to minimise passenger injury. The passenger cabin is open-plan near doorways. The seats and stanchions are fitted with grab handles to assist passenger restraint while the train accelerates and stops. The passengers on train T842 that were standing and seated in forward and rearward

facing seats sustained various minor injuries during the deceleration and collision sequence. The injuries ranged from muscle strain to a shoulder/arm while holding onto the hand rails and bracing for impact, bruising from impact with seat frames and a minor cut when a passenger’s head struck a poster frame near the driver’s cabin.

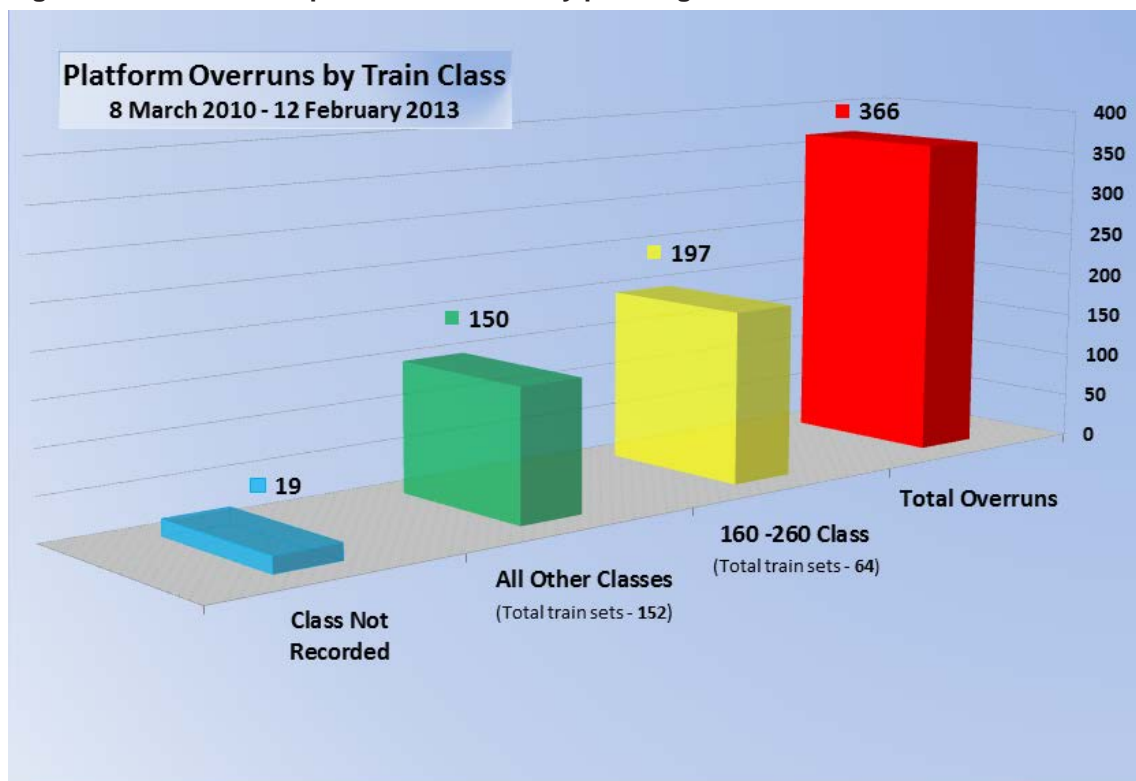
Station overruns

Frequency by train class

Queensland Rail’s Citytrain Information Reporting System (CIRS) occurrence data for the period 8 March 2010 to 12 February 2013 was reviewed to assess the volume and frequency of trains that had been reported by drivers for overrunning station platforms. The data was filtered to separate IMU160 and SMU260 class trains and this information was compared to all remaining train classes operating on the Citytrain network (Figure 16). A small quantity of data (about 5 per cent) did not contain sufficient information to determine the train class and these trains were shown as ‘Class not recorded’. The data shows that a disproportionately higher number of the IMU160 and SMU260 class trains were involved in overrun occurrences, particularly considering that these trains only comprise 30 per cent of the fleet.

The remaining 70 per cent of the Citytrain fleet, mostly comprising tread braked and a combination of tread and disc braked train sets, were found to be involved in significantly less overruns.

Figure 16: Train station platform overruns by passenger train class



The review found many of the overrun occurrence descriptions had recorded the climatic and/or track conditions as wet or slippery track. Other occurrences provided no explanation as to why the overrun had occurred. Analysis revealed that 98 per cent of the overrun reports in the CIRS had been categorised as Train Crewing - Past Signal/Platform events. The remaining 2 per cent of overruns were categorised as Rolling stock – Braking System Faults with the incident summaries showing that these events included evidence of the train’s WSP equipment being active while the train was braking. The CIRS did not provide a category for overruns attributed to low adhesion.

Most reports stated how far the train had overrun the platform and this was measured using the number of car lengths or parts thereof, ranging from half of one car up to six cars where nominally each passenger car is about 24 m long.

Some of the overrun events were selected for investigation by Queensland Rail Train Management Improvement Officers (TMIO) and the train drivers were interviewed to assess the events and conditions that contributed to the train overrunning the station platform.

The records of these investigations showed that where wheel slide was experienced, it was usually reported that the track was wet or slippery. Most investigations provided more information about the operational consequences of the overrun including the effect on train service delivery times.

A few overrun investigations found the train driver had misjudged the stopping distance or not remembered the service type that they were driving (express or stop all stations) and after regaining their situational awareness, finding that they were unable to stop their train at the station stopping mark. These types of events were excluded from the ATSB's analysis of the overrun data.

Locations where trains have higher incidence of overrun

Between 8 March 2010 to 1 January 2013, 366 platform overrun reports were recorded throughout the Queensland Rail Citytrain network (Figure 17). These reports included all suburban passenger multiple unit types and 197 of these occurrences involved IMU160 and SMU260 class vehicles fitted with wheel slip-slide control systems.

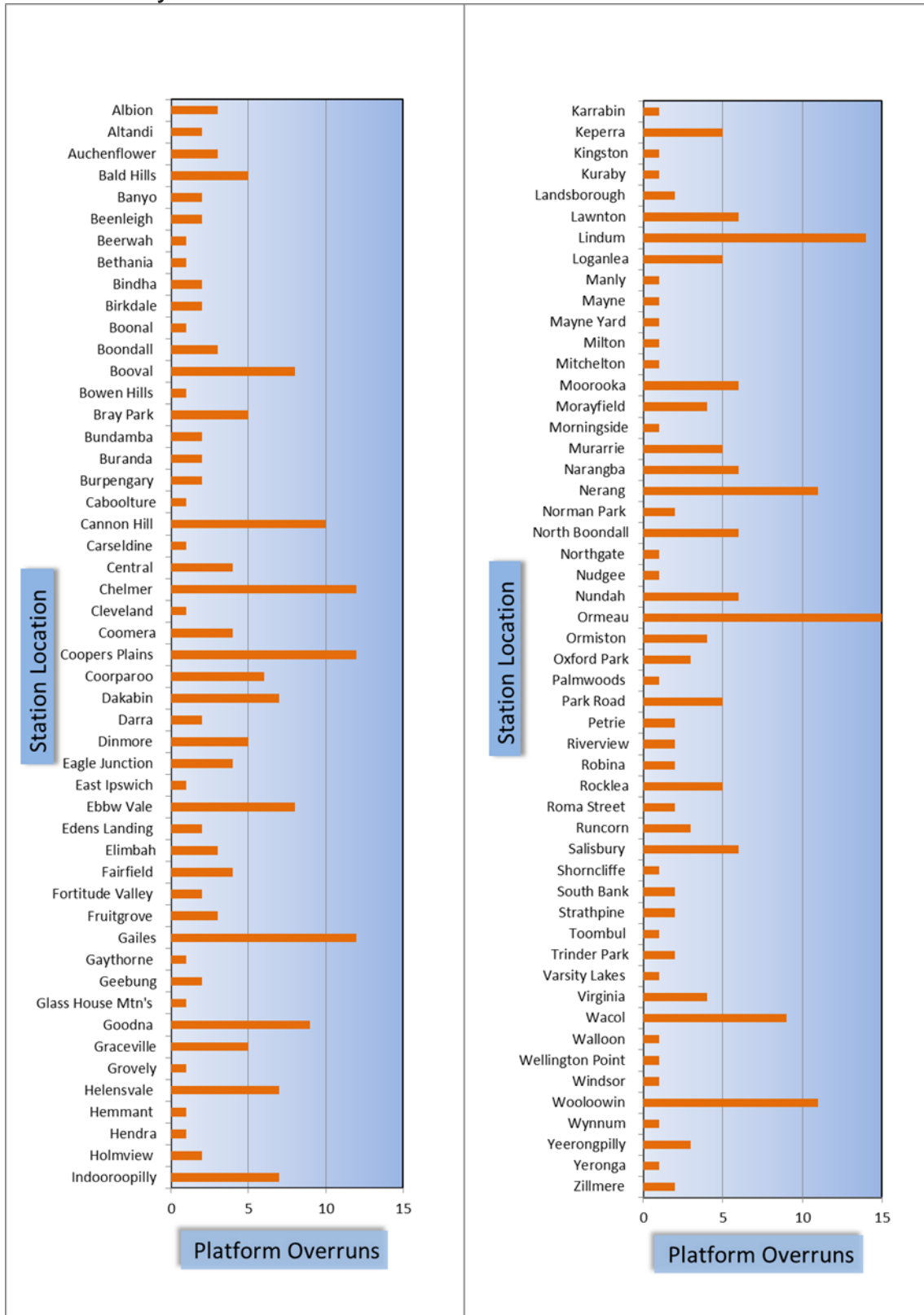
Many of these records of events contained evidence of poor track adhesion due to wet weather or track contamination. For the period January 2010 to January 2013, investigation records for IMU and SMU class trains found the event causes were 'Human Contributed' (59%), 'Low Adhesion' (33%) and 'Rolling stock Contributed' (8%).

For the month of January 2013, immediately before the collision at Cleveland, there were 25 investigated occurrences where low adhesion was cited as the event cause. There were 19 occurrences where 'human contributed' was listed as the cause and five of these had observed that wet track was a contributing factor.

These investigations were conducted by supervisory or investigation staff who would interview the train driver and occasionally the guard and other involved persons. In most instances the investigator was a TMIO who interviewed the train driver. For the majority of these investigations the TMIO would only provide advice to the driver on how to adjust and improve their driving and braking technique to reduce the likelihood of train slides when stopping at station platforms and signals. A review of the TMIO notes and findings found where the track was contaminated with leaves and moisture, the TMIO did not offer an explanation or provide training to the driver on why contamination to the rails may have adversely affected the driver's ability to slow or stop the train while braking under these conditions.

Where drivers were unable to stop their train before overrunning the platform by less than six car lengths, approval was sought from the network controller to set back onto the platform to allow passengers to board and alight. Where a train was set back onto the platform a Special Proceed Authority (SW10) was issued to the driver to complete the move. Where SW10's were issued, delay times to the service were recorded, usually ranging between 1 and 6 minutes. Occasionally, where a train had exceeded the platform stopping point by more than six car length's the network controller would recommend the train driver continue to the next station.

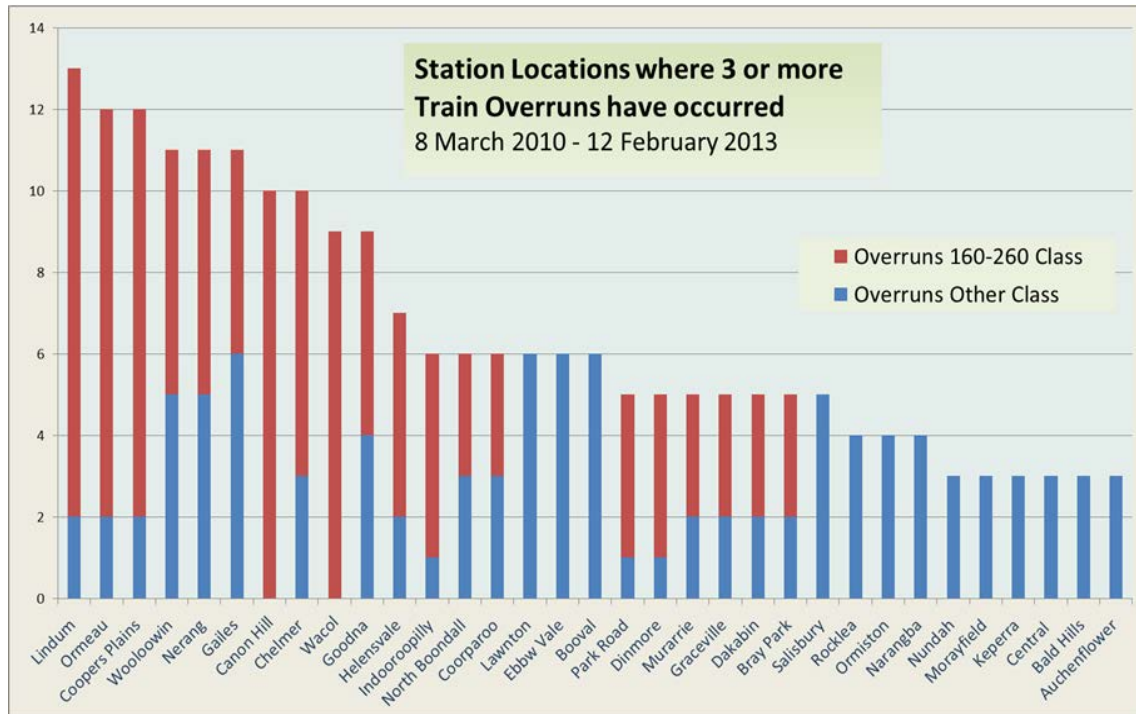
Figure 17: All passenger train overruns at station platforms (alphabetical order) March 2010 to January 2013



An assessment of overrun data was made to discover if particular train types had a higher incidence of slide occurrences when stopping at railway stations and whether individual locations showed a higher number of occurrences (Figure 18) for trains that were predominantly fitted with disc or tread brakes. The overrun occurrences involving the IMU160 and SMU260 classes were compared with the other train classes in the Queensland Rail Citytrain fleet for the period 8 March 2010 to 12 February 2013.

The findings exclude station locations where there were less than three train overrun occurrences and trains where the class type was not identified.

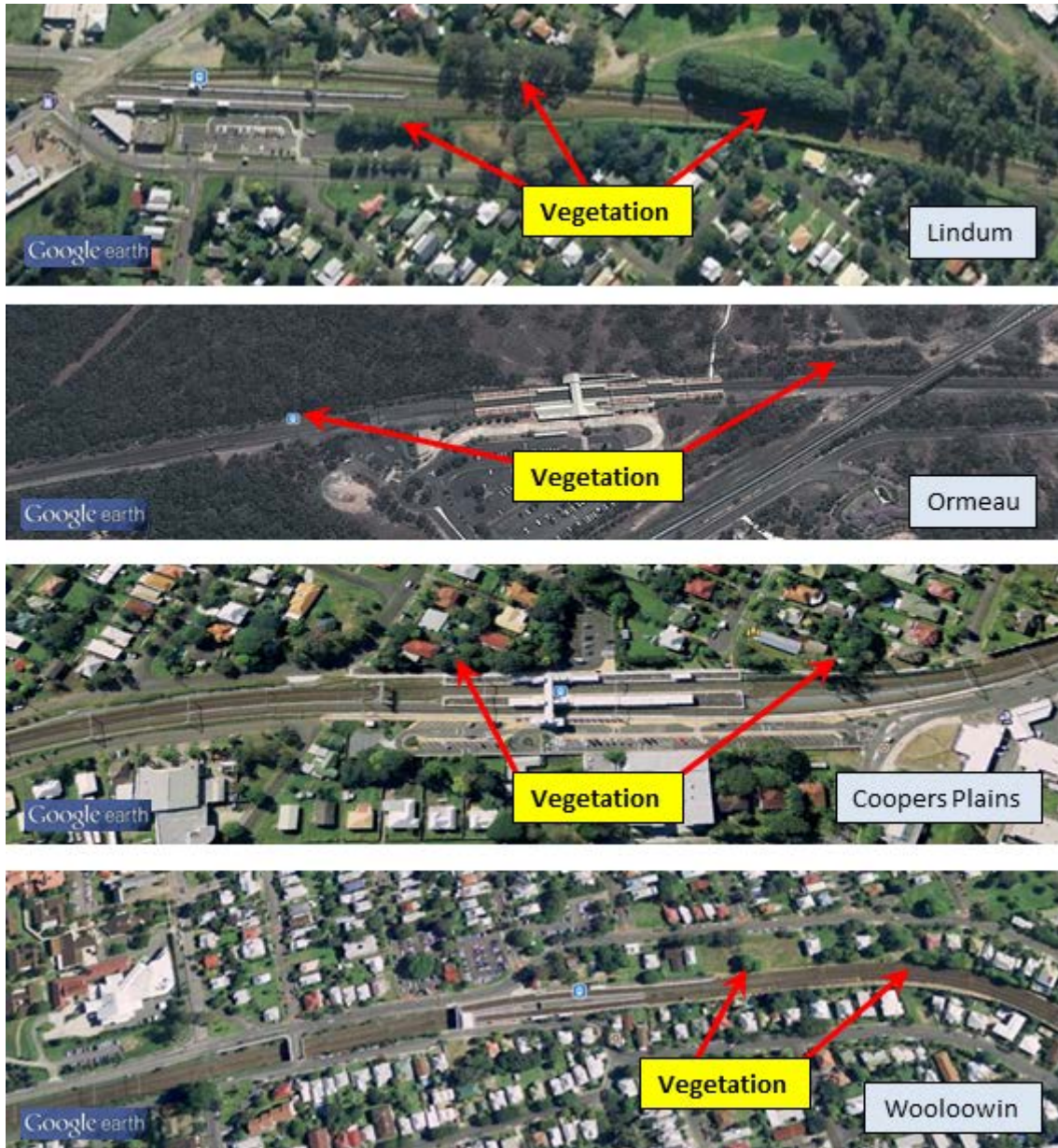
Figure 18: Incidence of passenger train overruns by station location



The assessment included a review of aerial photographs showing vegetation growing along the railway corridor on the approaches to each of the station platforms to discover if leaf fall may have contributed to overrun occurrences.

Typically, the top 10 locations where trains had overrun station platforms were found to have vegetation growing next to, or overhanging the railway corridor, and were within the train braking zones on the approach to these stations. Figure 19 shows the topography either side of railway stations recording the greatest number of overruns for the period.

Figure 19: Railway station locations recording a high incidence of train overruns where trackside vegetation on the approaches was identified.



The results showed the IMU160 and SMU260 class trains had higher incidence of station overruns at Lindum, Ormeau, Coopers Plains, Canon Hill and Wacol. Most locations included overruns by the other classes of trains except Canon Hill and Wacol where the IMU160 and SMU260 classes were solely represented. The remaining 23 station locations that recorded a lower number of overrun events with other classes included 13 stations that did not have the IMU160 and SMU260 class represented. Where there were three or more overrun occurrences recorded at these railway stations for this period, 163 involved the IMU160 and SMU260 class and 101 were by the other train classes.

Figure 20: Railway station locations recording a high incidence of train overruns where trackside vegetation on the approaches was identified.



Previous Queensland Rail train wheel slide occurrences

Beerwah 9 January 2009

Occurrence background

On 9 January 2009, Queensland Rail passenger train 1L13, consisting of train units SMU262 and SMU267, departed Roma Street station, arriving at Caboolture at 1855.

On approach to Beerwah station at about 1924, signal BH27 displayed a yellow flashing aspect, indicating that train 1L13 was to enter the crossing loop from the main line before arriving at the station. At the same time, opposing train passenger train 1990 was departing Landsborough station and was travelling south towards Beerwah station on the main line.

After departing Beerwah station at 1926 the driver of train 1L13 accelerated to a speed of 43.9 km/h. About 270 m from signal BH23, that was displaying a red (stop) aspect, the driver made an initial brake application. Shortly after, while travelling at 34.5 km/h, the driver increased the braking effort and the train began to slide. The driver progressively applied more brake until reaching the full service brake position; however, the train speed had only reduced to 22 km/h and continued to slide.

When the driver realised that train 1L13 was probably going to pass signal BH23 at stop, he engaged the train park brake in a final bid to stop his train and immediately radioed the network controller¹⁹ calling an emergency and requesting all other trains be stopped.

The train stopped about 12 m past signal BH23 before it became foul of the mainline. (The train event recorder showed train 1L13 had registered a slide condition for a total of 43 s from when the brakes were initially applied.)

The network controller contacted the driver of opposing train 1990 and it stopped on the mainline shortly after passing signal BH29(2) that had subsequently restored to stop as result of signal BH23 being passed by train 1L13. This SPAD occurrence was assessed by Queensland Rail as a serious event that warranted further investigation.

Queensland Rail investigations

Following the SPAD occurrence at Beerwah, SMU262 and SMU267 were transferred to the Mayne maintenance facility and quarantined. An investigation was commenced by the Queensland Rail Passenger Services Rolling stock Assets division and a site inspection at the incident location near Beerwah station was carried out. In parallel to the Passenger Services Rolling stock Assets investigation, investigations were also conducted by Queensland Rail Network and the Queensland Rail Passenger Safety Investigation Unit.

At the conclusion of the Queensland Rail Network investigation, the report recommended that the General Manager Passenger Services Rolling stock Assets conduct an engineering investigation of train sets SMU262 and SMU267 and report the findings to back to Network. The Passenger Safety Investigation Unit initiated an investigation to compile a risk profile to re-evaluate what controls could be implemented to reduce exposure to the risks associated with this SPAD event.

The Passenger Services and Rolling stock Assets division subsequently extracted train event and brake control unit data and video imagery before carrying out inspections and static tests in the workshop. A series of still images were captured from the leading camera on train 1L13 and analysed. These images provided the sequence of events for train 1L13, as it approached and then passed signal BH23, view of the headlights of opposing and approaching train 1990 and when both trains had come to a stop about 35 m from the point of conflict (Figure 21).

¹⁹ The titles of network controller and Network Control are also referred to as train control operator and Train Control in Queensland Rail documentation.

Figure 21: Video image from the leading camera on train 1L13 showing opposing train 1990 on the adjacent track, 30 seconds after both trains stopped.

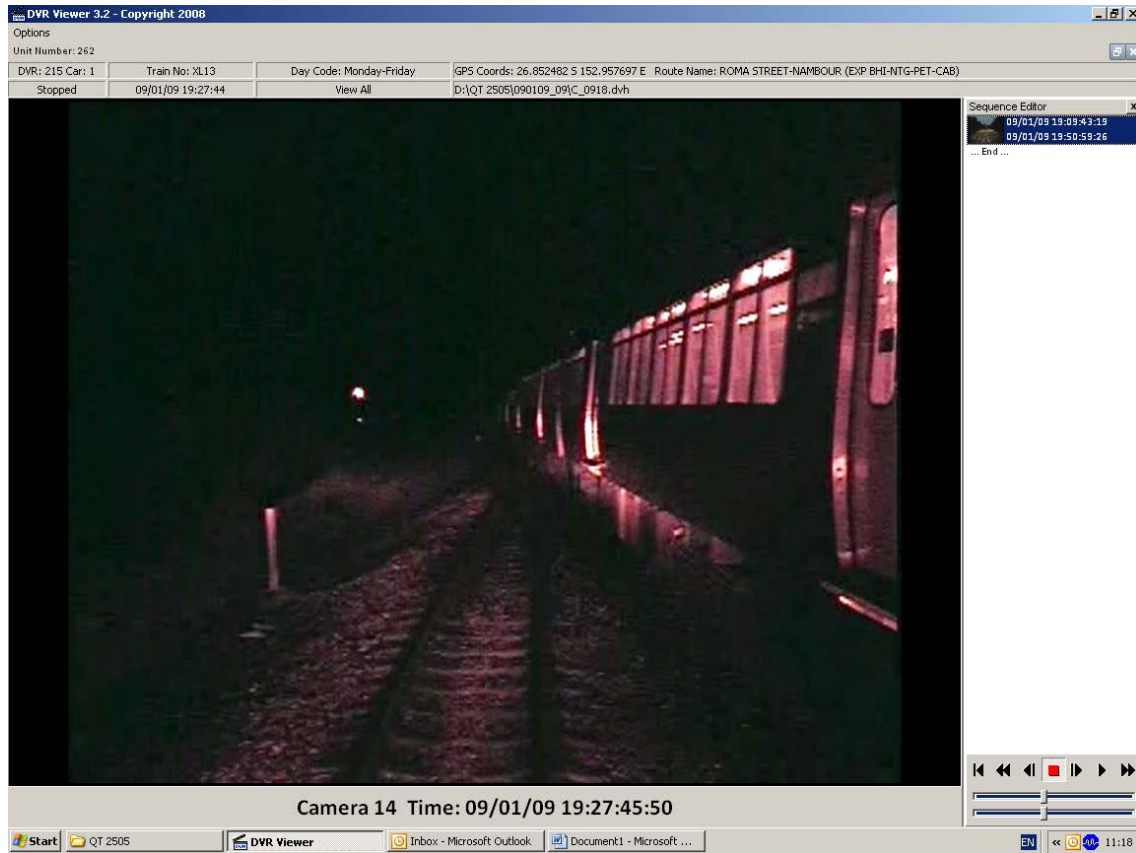


Image Source: Queensland Rail

The rolling stock inspections included checking of underframe components to ensure brake gear was intact, that there was no sticking of the brake calipers and the actuators were operating normally, there was even wear of the brake pads, wheel profiles were correct and that there was no damage to the WSP equipment. Inspections found no damage to this equipment, and tests found the brakes were applying and releasing correctly with the dump valve operation. The WSP self-test on SMU262 and SMU267 had operated as designed.

Commencing on 22 January 2009, the first of three dynamic tests were carried out on the Beenleigh/Ormeau railway line to assess train set SMU262 and SMU267's WSP braking performance by simulating the actions of the train driver on 9 January 2009, the day of the SPAD. Thirteen brake tests were carried out over a 700 m section of track where both rails on a 90 m section were friction modified using combinations of water, water and liquid detergent solution and undiluted liquid detergent. The tests found the train's braking system operated as designed under the modified adhesion conditions, stopping within normal expected distances and deceleration rates. It was concluded that these tests 'could not truly replicate the driver's actions in the very low adhesion conditions experienced at Beerwah'.

The second round of tests on 22 February 2009, were carried out on Gold Coast railway using undiluted truck wash liquid detergent manually applied to both rail surfaces for a distance of 292 m (126 m before and 166 m after the point brake application). Four test runs were made and it was found that similar adhesion levels and extended stopping distances were achievable and these distances were similar to those experienced by the driver of train 1L13 near Beerwah. These tests also confirmed the operation of the suspension and that brake cylinder pressures were operating at the specified levels under tare and loaded mass conditions.

The third series of tests on 22 April 2009 compared the braking performance of the similarly designed IMU120 class fleet with results of the two previous tests carried out on SMU262 and

SMU267. Four test runs were carried out on the same section of track as those for test number two using train sets IMU123 and IMU124. Truck wash was applied to the surface of the rails for each test however the tests found that after the second test run the truck wash was dispersed and the rail surfaces were cleansed providing higher levels of adhesion. The third test was not able to closely replicate the low adhesion conditions produced in test number two, resulting in a shorter train stopping distance.

Three separate reports were produced following the investigations. Common sources of information were used to generate these reports including train data event recorders, train videos and network control systems. The findings from these investigations reported:

<ul style="list-style-type: none"> the distance between signal BH23 and the track points joining the main line was 35 m where a vehicle going beyond this point would be within the collision path of an oncoming train
<ul style="list-style-type: none"> from the location of signal BH23, visibility of high speed trains approaching from the north is very limited, 'giving the driver no time to respond should there be an unexpected emergency situation'
<ul style="list-style-type: none"> there was no overlap on the departure side of signal BH23 that provided 'a safety zone against a rail vehicle overrunning the signal'
<ul style="list-style-type: none"> the track gradient on approach to signal BH23 is steep at 1 in 81
<ul style="list-style-type: none"> the speed of train 1L13 was recorded at 43.9 km/h where the limit on the Beerwah crossing loop was 25 km/h
<ul style="list-style-type: none"> the crossing loop track at the northern end of Beerwah station was fringed with large eucalyptus trees and there were large quantities of leaves and other vegetative materials skirting both rails
<ul style="list-style-type: none"> drizzling rain was falling at the time of the SPAD event
<ul style="list-style-type: none"> the WSP systems fitted to IMU120 and SMU260 class trains 'will endeavour to make the best use of adhesion available' however where poor adhesion conditions are encountered there are no actions the driver can take to reduce the stopping distance of the train
<ul style="list-style-type: none"> under poor adhesion conditions, similar to those at Beerwah on 9 January 2009, the braking performance of IMU120 and SMU260 class trains would be the same
<ul style="list-style-type: none"> three separate dynamic tests carried out on train sets SMU262 and SMU267 and IMU123 and IMU124 found the trains had operated in accordance with design and performance specifications.

Recommendations from the reports included:

<ul style="list-style-type: none"> 'the circumstances of this SPAD event be utilised as a training tool by QR Passenger to ensure all drivers are aware of the requirement to adhere to speed boards, specifically after turnouts and crossovers where no other speed board is present'
<ul style="list-style-type: none"> QR Passenger to consult with QR Network to establish the 'feasibility of relocating the position of signal BH23 to the Landsborough end of the Beerwah station platform' to increase the overlap (safety zone)
<ul style="list-style-type: none"> QR Passenger consult with QR Network to identify locations similar to Beerwah where the placement of signals poses extreme risk/s.
<ul style="list-style-type: none"> QR Passenger review the method of braking and reinforce that method with QR Passenger train drivers

Beerwah 9 March 2009

Before third train braking performance test had taken place (discussed above), a second SPAD occurrence occurred at Beerwah on 9 March 2009 where train H401 passed signal BH25 by about 5 m.

This train was a non-revenue tuition train that was operating for driver training purposes. At the time of the occurrence light rain was falling. Both the trainee and tutor drivers were aware of the signal at stop ahead, the downhill gradient on approach to signal BH25 and that the weather conditions were not conducive to good adhesion. The trainee driver applied the brakes earlier than normal.

Soon after applying the brakes the train started to slide and the drivers expected the WSP system would effectively manage and control the slide. When the train was about 35 m from signal BH25 the drivers realised their train was not going to stop before passing the signal, however they were confident the train would stop clear of the track points ahead.

Train H401 was travelling at about 2 km/h when it passed signal BH25. As the train had stopped beyond signal BH25, a SPAD alarm was generated at the network control centre. This alarm prompted the network controller to make an emergency call to the driver to stop the train.

The investigation determined that the cause of the SPAD was a lack adhesion between the train wheels and the rails during braking and the rail was probably 'contaminated by eucalyptus oil' although this was not visible to the drivers. The driver was found to have applied the brakes sufficiently early to stop the train, even in light rain, however the drivers were not aware of the lubricating effect of a contaminant on the surface of the rails.

Recommendations from this occurrence were for:

- QR Network to conduct a tribological²⁰ investigation of the approaches to signals BH23 and BH25 at Beerwah
- QR Network to consult with QR Passenger to investigate the feasibility of developing and implementing procedures to ensure that under light rain conditions, passenger trains only approach signals BH23 and BH25 displaying a proceed aspect at a reduced speed, to reduce the risk of a collision caused by continuous wheel slide on the downhill approach to those signals.

Following two slide events and SPADs involving SMU262 and SMU267 near Beerwah in 2009, Downer EDI and Bombardier Transportation assisted Queensland Rail in the testing and validation of braking of these incident trains. A Downer EDI and Bombardier Transportation report supplement, appended to the Queensland Rail investigation report, found low adhesion conditions were experienced by these trains. The examination of data and the practical track tests verified that both trains had operated as designed and in accordance with braking performance specifications.

The findings and recommendations arising from numerous workshop tests, field tests and subsequent internal investigations were carried out to learn from and inform Queensland Rail managers and directors of the contributing safety factors and risks that had been identified and reported.

Narangba and Morayfield 28 January 2013

At about 1623 on 28 January 2013, three days before the collision at Cleveland station, the driver of train 1141 (SMU292 and SMU269) reported that his train had overshot the Narangba station platform by about 400 m due to excessive wheel slide after applying the emergency brakes. On

²⁰ Tribology is the branch of science and engineering dealing with friction, wear and the lubrication of interacting surfaces in relative motion.

the return service at Morayfield station, the train experienced another slide and reportedly it took an excessive amount of time to stop. Neither occurrence resulted in a SPAD nor was Queensland Rail obliged to report these events to the rail safety regulator.

The Queensland Rail investigation noted that a severe weather system had contributed to these occurrences and the combination of moisture, decaying vegetative matter and rust had contaminated rail surfaces thereby reducing the levels of adhesion at the wheel/rail interface.

Following analysis of the event recorders on train units SMU292 and SMU269 the investigation concluded that although the train had experienced a severe slide, the braking system had operated as designed. The investigation recommended ‘that a technical investigation be undertaken to determine the disparity in braking distance when the train units encounter a state of severe slide.’

The technical investigation and tests to validate the correct operation of the IMU and SMU braking systems fitted with WSP were carried out following the Cleveland station collision. These elements are discussed within the brake inspection and test section of this report.

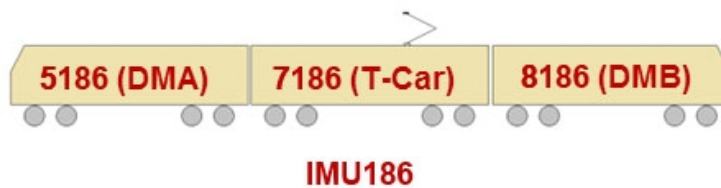
Caboolture - test train

On 19 February 2013 tests were conducted by Queensland Rail on the Caboolture line using single unit train IMU186 (Figure 22) to measure and determine the train stopping distance under natural conditions. No friction modifiers, such as truck wash, were applied to the head of the rails before the tests and any contaminants present on the surface of the rail were unknown.

The ATSB were not present when these tests were carried out but were subsequently advised that the train had been in condition of slide for an extensive period of time after the brakes had been applied. All electronic data and video files that had been extracted from the train were requested for further examination and analysis.

Two tests were conducted near the Shire of Caboolture at night, where light showers of rain had been recorded during the day and evening. Evidence of rain was recorded by the train video and on replay showed a few water droplets on the train windscreen and wet station platform paving. An aerial view of the track corridor where the tests were carried out, about 4 km north of the Caboolture railway station shows an extensive section of trackside vegetation that may have contaminated the rail surfaces affecting adhesion levels at the wheel/rail interface during the braking tests.

Figure 22: IMU186 consist.

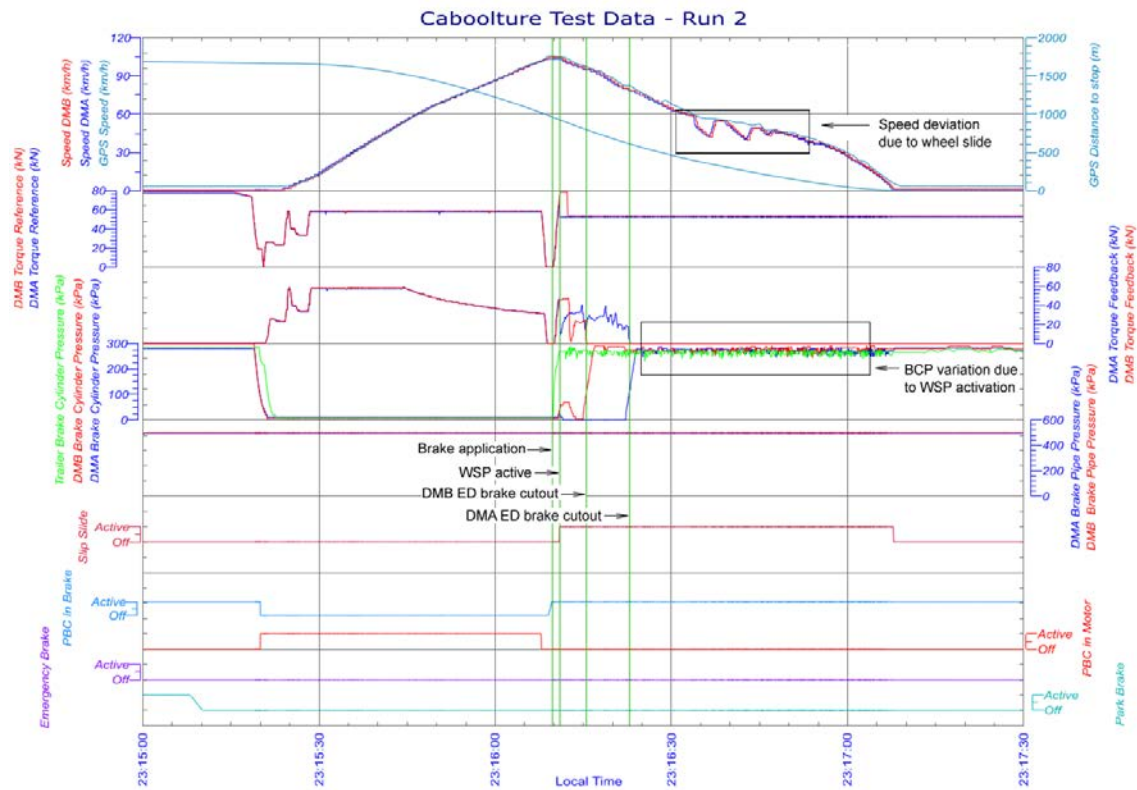


While under acceleration in test 1, the train had two periods of WSP activation to correct wheel slip. When the train reached a maximum of speed of 103 km/h, a full service brake application was initiated. As there had been a slide event recorded on a braking stop before Test 1 the train immediately began to slide and friction braking was subsequently applied. The data showed a rise in brake cylinder pressures (BCP) producing an increase in friction braking, first on the T-Car followed by the DMA and DMB cars at intervals of about 6.2 s and 2.6 s respectively. The deceleration rate, calculated between the nominal speeds of 90 km/h to 10 km/h, was 0.659 m/s². The train was in a slide condition for a total period of just over 45 s, and failed to meet the specified deceleration rate between 1.01 and 1.23 m/s² in accordance with Downer EDI Rail Engineering Specification CES01183 Rev A (2007)

The second test was carried out about 20 minutes later where the train accelerated to a maximum speed of 106 km/h before the brake was applied. Two seconds after braking had been initiated the

T-Car BCP increased as the friction brakes progressively applied. About 1 s after the initial brake application, the slide parameter (WSP) activated and remained in this condition for 56.8 s until the train had slowed to 2 km/h. When assessed with identical nominal speeds used in Test 1, the deceleration rate was calculated to be 0.476 m/s² (Figure 23) again failing to meet the Downer EDI CES01183 specification.

Figure 23: IMU186 brake test 2 - Caboolture - 19 February 2013



Train testing and data irregularities

The analysis of data extracted from the accident train T842 and the test trains of 13-14 February 2013 (Gold Coast line – SMU292) and 19 February 2013 (Caboolture line – IMU186) revealed irregularities between the data files provided for each train set. This prevented a complete comparison of information from both series of tests. Although some pertinent data parameters on the event recorder were not recording correctly, and a complete set of time correlated BCU data was not available, information from other sources (e.g. on train video) was used to verify responses and timing of individual train systems.

Following the collection of data from the accident train event recorders, VCU and BCU's, and the data extracted from the same items of equipment on subsequent test trains it was found that irregularities existed between the data sets provided. The data extracted from these items was used to verify the functionality of braking systems.

BCU

Data files provided by Queensland Rail found a time adjustment was required to correct the recorded time to GPS time for the files related to accident train T842. Analysis showed these time corrections to be inaccurate but some information from the event data recorder was able to be used to determine the braking configuration. Additionally, a real time clock failure on the accident train (car 7180) prevented the investigation team from obtaining any data from this unit.

The BCU's fitted to SMU292 and used in conducting the brake tests on 13 and 14 February 2013 on the Gold Coast line, had not been reset to reflect the current dates and times. The time settings

on some BCUs varied between minutes and years from the correct time, where some failures could be attributed to internal battery issues. Consequently, investigators were unable to discriminate between historical data and new data associated with the test brake runs and were unable to compare the incident train recordings with the test train recordings.

Each BCU entry is accompanied with either 'Entry was marked as cleared' or 'Entry was not cleared.' While events may be logged on the BCU event history log, and can be time-correlated to the event recorders, it is not known what clears these events, or what causes the cleared events to remain indefinitely in the event history log. The BCU event history log does not record when the event was marked as cleared. No document was provided to state how the event is cleared, or once cleared, what removes the event from the event history log.

Data extracted from the BCU event and fault logs for the DMA and DMB cars on accident train T842 were found to be recording 'just for commissioning' text entries. These entries were also recorded on the Caboolture test train, again specific to the DMA and DMB cars. Considering the IMU160 and SMU260 class trains were commissioned in 2004, these fault log entries probably should have been removed or updated before these classes of trains were assessed fit for operational service.

VCU

The brake test runs for the Caboolture line tests, SMU292 Gold Coast line tests and accident train T842 had different types of VCU files provided and therefore no comparative analysis on the operation of the VCU on train T842, SMU292 or IMU186 could be conducted.

In addition, as the VCU fault log only records faults when they occur and do not record when a fault is cleared, the duration of each fault cannot be determined.

Brake test methodology

A review of the brake testing methodology found some elements of the train deceleration and stopping tests on 13 – 14 February 2013 (train SMU292) were not carried out in accordance with the DEDI Rail Engineering Specification CES01183 Rev A (2007) or to generate measurement results that were consistent and accurate.

- When reporting the deceleration rates and assessing each test as a pass or fail, Queensland Rail applied the full service braking rating criteria across the whole period of brake application when the full service brake was not continually in an active position.
- To measure stopping distances, engineering specification CES01183 requires that an average of three test runs are to be performed for each braking mode. Only one run was performed for each braking sequence.
- The measurements of stopping distances using wayside track infrastructure and dye-marked track increments are prone to a number of errors. This method relies on the driver using visual references to determine when to make a brake application at a predetermined point on the track – at speeds of 70 km/h a one second delay adds an error of approximately 20 m.
- A Queensland Rail work instruction developed for tests on train SMU292 stated that the lineal deceleration rates were to be calculated within the speed band of 60 km/h and 20 km/h. The actual brake tests calculated the deceleration rate at speeds between 60 km/h and 10 km/h.
- The use of axle rotation data recorded by the train event recorder is inaccurate for creating pass or fail results where a test train experiences extended periods of wheel slide.
- For the tests carried out on 13 – 14 February 2013, the track section over where the tests were conducted was dye-marked in 10 m increments. Queensland Rail staff used these increments to record the train stopping distance. For the tests carried out near

Caboolture, only data extracted from the on-board equipment was provided to the ATSB for analysis and supporting information to determine how Queensland Rail staff had measured stopping distance was not provided. For both test trains, ATSB investigators used GPS time extracted from the train video cameras to measure train stopping distances.

Investigations of slide occurrences by other organisations

Siemens Nexas train overruns - Melbourne

Following a spate of platform overrun events involving Siemens-manufactured Nexas trains operating on the Melbourne passenger network, the Office of the Chief Investigator, Transport Safety (OCI) commenced an investigation.

Six overruns had occurred between 8 February 2009 and 3 March 2009. The most prominent event occurred on 25 February 2009 when a train travelling from Melbourne to Frankston was braking on moist rails on a 1:52 downgrade while approaching Ormond Railway station. The driver made a service brake application to slow the train and when the train was about 165 m from the platform and not slowing as expected, the driver applied the emergency brake. The train continued to slide past a signal at stop and through the North Road level crossing, after the flashing lights had commenced operating but before the barrier gates had lowered. The train had overrun the southern end of the station platform by about 250 m and was 850 m from the point where the brakes had initially been applied.

The OCI examined the Ormond station event and the broader history of overruns on the Melbourne network. The investigation explored five related areas that were seen as potential contributors to these occurrences in the environment, track infrastructure, the train, train handling and network risk management.

The investigation found that the majority of overruns had occurred while the track was moist with light rain or dew and included contaminants of iron oxides and mineral clays. The environmental conditions and contaminants had encouraged a pre-condition that was found to have substantially lowered the levels of adhesion between the rail and train wheel contact surfaces.

An examination of the track reviewed track geometry and rail head profile and concluded that in general the track was within specified tolerances and 'was unlikely to have been highly contributory to the frequency of overrun events'. The investigation reported that maintaining track in an ideal condition would contribute to optimising braking performance.

The investigation found that the Nexas trains were more prone to overrun events than the X'Trapolis class trains also operating on the Melbourne network. The significant differentiating factor between these train types was the Nexas trains were fitted only with disc brakes; whereas the X'Trapolis trains were equipped with a combination of tread brakes on all wheels and axle mounted disc brakes on the motor car axles. Both classes of trains were fitted with WSP to manage braking performance and respond to the wheel slide events in low adhesion conditions. Tests showed the X'Trapolis train brakes were able to condition the wheel and remove contamination collected from the rails while braking, thereby improving adhesion at the wheel/rail interface.

After testing of both train types, the investigation found the WSP with EP friction braking offered comparable performance with similar (bogie-controlled) brake systems. It was found that the bogie-controlled WSP system fitted to the Nexas trains was less capable and 'there can be a lag in braking effort during and after the transition from ED to EP braking' when attempting to control severe wheel slide events.

Additionally, the good braking performance of Nexas trains in dry conditions may have established a high driver expectation of the train's braking effectiveness and driving techniques may have

contributed to some overrun events through early transition to WSP braking when operating under low adhesion conditions.

Prior to the Ormond station overrun, the network manager had implemented control measures to manage risk associated with these events that included issuing safety advisory notices to drivers, the placement of speed restrictions on approach to level crossings and signals at stop, additional train driver training in 'brake handling and defensive driving techniques' and the monitoring of trains speeds with random compliance checks.

Safety actions taken following the event at Ormond station were:

- The train operators 'introduced new operating procedures and reinforced a number of others. The mitigating strategies have included speed restrictions for Nexus trains at several locations and the roll-out of defensive driving training to existing drivers was also completed in 2009'
- Based on international experience where the application of sand to the rail head in low adhesion conditions usually eliminates train overruns, the Nexus fleet were fitted with sanding devices. This work was completed on 18 June 2011.

The investigation also recommended that train operators review operations and procedures for track condition monitoring, train performance monitoring and driver training. A further recommendation was directed to the Victorian Department of Transport and train operators to ensure train braking performance and acceptance criteria for operations in low adhesion conditions were adequately assessed in future rolling stock procurements.

Derailment of CityRail train 312A - Thirroul, NSW 11 September 2006

At 0532 on 11 September 2006, the leading car on passenger service 312A, derailed at catch-points in the vicinity of No.3 platform at Thirroul, NSW after failing to stop at signal WG 568D. The occurrence was investigated by the Office of Transport Safety Investigations in NSW.

On approach to the signal the train did not respond to normal braking techniques, forcing the driver to apply his emergency brakes approximately 20 m prior to the signal. The train consisted of an eight-car Tangara²¹ set and was carrying approximately 30 passengers who were safely disembarked under the direction of the guard. There were no injuries and only minor damage to the train and track. The prevailing weather conditions were wet and blustery.

Train speed, signalling anomalies, driver fatigue and wheel and rail defects were excluded as contributory factors. Brake failure was eliminated at the beginning of the investigation as a result of on-site testing undertaken by engineers. The investigation then focussed on track conditions and the braking process.

Severe weather conditions prevailing at the time were found to be responsible for the formation of an emulsion consisting of rust, moisture and salt building up on the rail which had not been used for about 58 hours. This resulted in a particularly slippery rail surface that reduced braking effectiveness. Historically, there had been a number of similar instances of Tangara trains encountering stopping difficulties in wet and inclement conditions at Thirroul and in the wider south coast region. Fitted with disc brakes, the Tangara contributes less to rail head conditioning during normal operation than trains with brake shoes that assist in removing contamination from the wheel tread.

In this instance, braking effectiveness was reduced to such a degree that significantly greater stopping distances were needed than was usual. This should have been apparent to the driver from an experience of minor wheel slip under similar conditions earlier in the trip. However, insufficient allowance was made by the driver for a reduction in braking effectiveness.

²¹ A Tangara passenger train consists of four double-deck cars.

Despite a memo issued by the operator to all its drivers in 2003, there was still a lack of understanding of the operation of the WSP system fitted to Tangara trains. Lengthy periods of dry weather deny drivers the opportunity of maintaining their skills in handling adverse weather conditions. The dry periods also reduced the opportunities during initial training and periodic re-assessment of drivers to practice and be tested in these skills. However, there is no evidence that a better understanding of the WSP system would have prevented this particular derailment.

Key recommendations from the investigation sought to have the operator review the adequacy of current training, assessment and instructions to ensure drivers had a thorough understanding of the effect of adverse environmental conditions on braking efficiency, and the need to adjust train handling accordingly. It was also recommended that the operator investigate better use of simulation so that weather does not remain the sole determinant of the extent of training and currency of experience of its drivers.

Rail slide occurrences - United Kingdom

The Rail Accident Investigation Branch (RAIB) is the independent investigation body responsible for investigating accidents and incidents occurring on the railways of Great Britain and Northern Ireland and tramways in England and Wales.

Following two serious Signal Passed at Danger (SPAD) incidents at Esher on 25 November 2005 and Lewes on 30 November 2005, the RAIB carried out investigations that found the primary cause of both events was poor adhesion between the train wheels and the rail.

The RAIB investigations examined the contributing factors and provided recommendations to minimise the risk of further events. Concise overviews of the RAIB investigations are located within the appendices of this report.

Reference documents for the management of wheel slide

The Rail Safety & Standards Board (RSSB) in the United Kingdom is owned by the rail industry and facilitates the work of the industry by improving the health and safety performance of the United Kingdom's railways. The organisation also develops and publishes technical standards and guidelines for its members.

The Rail Industry Safety and Standards Board (RISSB) is the Australian equivalent of RSSB. With reference to the management of rolling stock wheel slide, a review of the RISSB Guideline Risk Register shows 'brakes being inadequate when moving' and 'inadequate adhesion' as risks; however, at the time of this investigation there was no Australian standard or guideline for the management of rolling stock wheel slide when rail vehicles are braking under conditions of low adhesion. In the absence of Australian standards or guidelines, the RSSB standards and guidelines were used in this investigation for reference in the management and control of rolling stock wheel slide and rail contamination.

The RSSB documents referred to in this investigation are:

'Guidance on Low Adhesion between the Wheel and Rail – Managing the Risk - GM/GN 8540 (current issue one - February 2009)'

This document notes that infrastructure managers and railway operators shall jointly implement measures to reduce the risks generated by low adhesion between the wheel and the rail that cannot be eliminated by local treatment at specific sites.

'Guidance on testing Wheel Slide Protection Systems fitted on Rail Vehicles GM/GN 2695 (current issue one - December 2010)'

This document is intended to assist railway organisations, equipment suppliers, train manufacturers and procurement organisations involved in specifying WSP equipment for rail vehicles intended for mainline network operation in Great Britain.

'Braking System Requirements & Performance for Multiple Units - GMRT2044 (Issue one, May 1994 - current issue four - December 2010)'

This document defines the performance requirements and principles of operation for the braking systems of multiple units to ensure system safety and safe interoperability.

The braking performance that shall be achieved by all trains composed of multiple units that are operating at speeds not exceeding 200 km/h on level track with normal levels of adhesion available. Another guideline has been produced for trains operating above speeds of 200 km/h.

Train driver training

Training and qualifications

Prior to operating electric passenger trains on the Brisbane metropolitan network train drivers and guards are trained by Queensland Rail, which is a registered training organisation. Train drivers and train guards are trained to the level of Certificate III in Transport and Logistics (Rail Operations).

The facilities used by Queensland Rail to conduct this training are located within the Mayne Rail Complex in Brisbane City. The facility includes classrooms, a train simulator and a separate rail facility on which there is sufficient room to stow a suburban multiple unit. The trainees are then able to inspect and examine the units and relate this information to the classroom instruction provided during the course.

The initial training for accreditation is approximately 15 weeks in duration and involves classroom instruction, simulator training and operation of a train on track. The nominated period of training varies between 1197 hours and 1077 hours depending on the previous experience of the trainee.

The practical aspect of the train management involves train unit operation using non-revenue services referred to as HF trains. Towards the end of the classroom based training, trainees practice their driving skills under tuition on the core route, the Ferny Grove line, for about one and a half weeks.

On completion of the initial classroom training phase, the trainee driver is assessed on their competency to progress to the next phase of training and is referred to as a driver that is available to be placed with a route tutor. When the trainee has completed the driving school phase they are qualified to drive on the Ferny Grove line, primarily based on their experience, training and assessments conducted during the classroom based program. In practice the trainee will be in the company of a tutor until such time as all route tuition is completed.

The training with a route tutor places the trainee driver one on one with a tutor driver. The trainee and tutor are rostered to conduct services throughout the Brisbane metropolitan network during which time the trainee has the opportunity to learn and practice on all the routes, providing both a fare paying service and preparing for a future assessment. Before any assessment is undertaken the trainee is required to know the routes intimately including signal numbers and location, track layout and track profile, speed boards and speed limits and associated infrastructure relevant to the safe operation of the trains. The trainee driver also needs to be familiar with train handling over the sections of track including the speeds and driver actions that are required on approach to the all train stations within the network.

Each trainee's training progress is monitored and reviewed under the direction of the Manager Train Service Delivery Development. Trainee drivers who have completed the full training then undergo a formative assessment by the training unit. This is carried out to ensure that the trainee is ready for final assessment and any gaps in training are identified and where appropriate additional tuition is provided. This assessment takes approximately 3 days.

Following the assessment, if the training unit is satisfied that the trainee is ready for the final summative assessment, arrangements are made for the trainee to be assessed by train

operations inspectors responsible to the Compliance Manager. Occasionally, if there are insufficient resources and a train operations inspector is unavailable, a tutor driver may be delegated to conduct the assessment. However, the assessment is not conducted by the tutor driver who was directly involved in the trainee driver's tuition. The assessment takes approximately 5 to 6 days to complete. If the trainee driver is then assessed as competent, the training for accreditation is complete and the trainee driver is then considered fully qualified for train driver duties.

For the train driver's qualifications to remain current, the driver must be reassessed and re-accredited every 18 months. This aspect of the ongoing training is referred to as the maintenance of competency (MOC). The process involves theory and practical observations of the train driver's competence. A route is selected for the assessment at which time it is expected that the driver would be able to demonstrate an intimate knowledge of the features associated with it. The MOC theory covers all aspects of the safe working system, testing of trains, train operations, train handling and driving emergencies. Any driver who does not complete the required MOC and whose qualification has expired is withdrawn from the operational roster until such time as the driver is reassessed and the qualification is restored.

Emergency response management

Queensland's *Transport (Rail Safety) Act 2010*²² and Regulations²³ require rail transport operators to develop an emergency management plan which covers aspects of an emergency including:

- the consequences of the emergency event
- the risks to the safety of persons arising from the emergency
- measures to mitigate the effect of the emergency
- procedures for restoring railway operations and assisting people affected by the emergency
- procedures for effective communication and cooperation throughout the implementation of the appropriate response measures.

Further, key personnel (including external emergency services agencies - Queensland Ambulance Service, Queensland Fire and Rescue Service and the Queensland Police Service) shall be provided with information about the relevant elements of the plan and be able to do anything that may be required of them under the plan.

Documented emergency management procedures

At the time of the Cleveland accident, Queensland Rail had in place a comprehensive suite of emergency management guidance documents, including a Standard²⁴, Plan²⁵, Procedures and a Specification²⁶.

The Specification was the key document used by train control and train crew personnel and it identified the central coordination point for emergency management as train control. The document specified the roles and responsibilities for the train control operator, electrical control operator, train control supervisor, and train control manager in the case of a rail safety related emergency. There were also clearly specified tasks and responsibilities allocated to the train crew and to the 'first Queensland Rail worker' at the scene.

²² *Transport (Rail Safety) Act 2010*, s82. <https://www.legislation.qld.gov.au/LEGISLTN/ACTS/2010/10AC006.pdf>

²³ *Transport (Rail Safety) Regulations 2010*, s14.

<https://www.legislation.qld.gov.au/LEGISLTN/CURRENT/T/TrantRailR10.pdf>

²⁴ Queensland Rail (2012). MD-12-208. *Emergency Management Standard. (Version 2.0)*

²⁵ Queensland Rail (2012). MD-12-279 *Emergency Management Plan (Version 1.0)*.

²⁶ Queensland Rail (2011). Specification SAF/SPC/0022/EMG *Rail Emergency Response Plan. Version 1.1*

The Specification detailed procedures for foreseeable emergency response situations affecting rail traffic, including:

- emergencies including; at level crossings, persons hit by train, overhead line equipment, passenger door, dangerous goods and environmental
- derailments, collisions, fires, threats, evacuations, defective rolling stock and unsafe loads, track obstructions, Signals Passed at Danger, wrong side signal failures, serious injury or illness on trains, Standstill Orders and lost communications.

Emergency management training of involved Queensland Rail staff

Train control staff

The train control operator involved in the Cleveland accident had been provided with formal training in the Emergency Management Specification whilst undertaking his initial training for the position, some four years earlier. Further, as part of annual competency checks, train control staff undertook refresher training in the standards and procedures applicable to their role, including content on emergency response, every 12 months. This refresher training was typically provided via one-on-one tuition regarding the content of the Specification (including scenario discussion), followed by a written examination. The train control supervisor and the train control operator had each completed their maintenance of competency within the previous 12 months and were therefore considered current in the training.

Train crew

Queensland Rail's train crew are provided with formal training in emergency response procedures as part of their maintenance of competency checks every 18 months. The training typically involves classroom discussion as well as simulator-based scenario training, and is formally assessed by a written examination. The driver, guard and spare driver (at Cleveland station at the time of the accident) had all completed their maintenance of competency checks within the last 18 months and were therefore considered to be current in emergency response management training.

Station customer service staff

Queensland Rail customer service staff were not employed as rail safety workers²⁷, and were not expected to fulfil a key role in emergency response for rail transport events beyond the initial notification to train control. Consequently, customer service staff were provided with limited training in emergency procedures for rail transport emergencies, with the expectation that their role was one of notifying train control and thereafter following direction provided.

Exercising emergency management procedures

The Australian Emergency Management Institute²⁸ recommends the conduct of emergency response exercises, wherein simulated events substitute for real events, as an essential component of preparedness. Such exercises can assist in evaluating plans, promoting awareness, developing or assessing competence, practicing interoperability, validating training, identifying gaps and evaluating equipment, techniques or processes.²⁹

Further, it is a statutory requirement that a rail transport operator's emergency management plan provides for 'the evaluation, testing, and if necessary, revision of the measures and procedures

²⁷ A worker conducting 'rail safety work' as defined in the *Transport (Rail Safety) Act 2010*, s10.

²⁸ Attorney General's Department, see www.em.gov.au

²⁹ Australian Emergency Management Institute. (2012). *Managing Exercises. Handbook 3: Australian Emergency Management Handbook Series*. Attorney General's Department. www.em.gov.au/Publications/Australianemergencymanualseries/Pages/ManagingExercises.aspx

mentioned in the plan.³⁰ The legislation does not prescribe the frequency or nature of the testing, other than to require that ‘in-house exercises’ be conducted, that testing be conducted in accordance with the intervals stated in the plan, and after each significant change is made to the plan. The regulations also require the operator to arrange for each emergency service to participate in the testing of the operator’s emergency management plan for railway operations.³¹

Queensland Rail’s emergency management guidance documentation referred to the exercising of emergency management procedures. Based on guidance documentation produced by Australian Emergency Management³², Queensland Rail had determined three levels of exercising, those being discussion exercises, desktop exercises and field exercises. The Emergency Management Plan specified that these exercises would occur at a frequency of 1-2 times per annum for discussion exercises, 3-4 times per annum for desktop exercises and usually not less than 2 yearly for field exercises. Field exercises were defined as the deployment of personnel to a simulated emergency, which may involve elements of functional exercises³³ and often test control arrangements as well as ‘on the ground’ skills.³⁴

Queensland Rail’s Emergency Management Plan was reviewed by the Department of Transport and Main Roads (DTMR) via periodic audits of their safety management system and by attending some planned emergency exercises. A DTMR audit of the Gulflander railway³⁵ on 20 September 2011 found Queensland Rail had not liaised with the local emergency services as required by s82 of the *Transport (Rail Safety) Act 2010* and issued Queensland Rail with a notice of non-compliance to rectify this infringement of legislation. In general, the DTMR reported that Queensland Rail was meeting the requirements of the *Transport (Rail Safety) Act 2010* for exercising its Emergency Management Plan.

Roles and responsibilities of train control personnel

Key personnel at train control with specified roles in relation to emergency response at Cleveland station on 31 January 2013 included the train control operator, the train control supervisor, the electrical control operator, and the train control manager.

The Specification detailed the lines of communication to be adopted during an emergency. Specifically, the first Queensland Rail worker on the scene was to notify the train control operator. The Specification detailed a number of tasks allocated to the train control operator, including communicating with the train control supervisor and the electrical control operator, confirming the train driver or another Queensland Rail worker as the on-site coordinator, notifying emergency services, and introducing emergency working, among other tasks. The Specification nominated the train control operator as the ‘primary contact point for on-site management’³⁶, clearly stating ‘To promote rail command and control, information about the emergency is to be directed through the train control operator by all parties involved, until the Queensland Rail commander has arrived at the scene.’^{37 38}

³⁰ *Transport (Rail Safety) Act 2010*, s82.

³¹ *Transport (Rail Safety) Regulations 2010*, s14.

³² Australian Emergency Management Institute (2012).

³³ The term ‘Functional Exercise’ is interchangeable with ‘Desktop Exercise.’

³⁴ Queensland Rail (2012). MD-12-279 *Emergency Management Plan. Version 1.0*, p19.

³⁵ A Queensland Rail tourist railway service that operates between Croydon and Normanton in North Queensland.

³⁶ Queensland Rail (2011). Specification SAF.SPC/0022/EMG *Module EP1-01 Rail Emergency Response Plan. Version 1.1*. p10

³⁷ Queensland Rail (2011). Specification SAF.SPC/0022/EMG. *Module EP1-04 Overhead Line Equipment Emergency, Version 1.0*. p6.

³⁸ Queensland Rail (2011). Specification SAF.SPC/0022/EMG. *Module EP1-07 Collision, Version 1.0*. p6.

The role of the train control supervisor was similarly clearly articulated, as 'support(ing) the response at the site by coordinating other related requests, enquiries and reports.'³⁹ The train control supervisor's role included tasks such as checking safe working and track protection, communicating with incident response coordinators, arranging for a Queensland Rail commander and investigation team to be appointed and deployed, communicating with corporate affairs, and arranging for CCTV downloads, amongst other duties. The responsibilities of the train control supervisor comprised higher level and associated tasks, freeing the train control operator to coordinate communications and direct the workers on site.^{40 41}

Procedures for the assurance of Overhead Line Equipment (OHLE) safety

Queensland Rail has a specified emergency procedure to be adhered to in the case of an Overhead Line Equipment (OHLE) Emergency.⁴² The procedure details three standard definitions regarding the condition of OHLE, as follows:

De-energised: disconnected from any live electrical equipment, usually by the opening of a circuit breaker, this means the power has been turned off but the area is electrically not safe

Isolated: disconnected from any possible source of electrical supply by means of visible breaks

Earthed: A circuit is earthed when it is connected to the earth by a conductor.

When the OHLE is isolated and earthed, it means the overhead line equipment has been turned off and made electrically safe at the emergency site.

De-energising the OHLE can be performed remotely from the Network Control Centre by the electrical control operator. However, in order to isolate and earth the OHLE at the emergency site, a linesman must be deployed to the appropriate switch control box. Because linesmen may be working throughout the network at any given time, the time required to deploy a linesman to perform the emergency response is variable, depending on where the closest qualified staff member is located at the time of the event.

After observing a trip on the OHLE between Lindum and Cleveland, and shortly thereafter becoming aware of the collision, the electrical control operator de-energised the OHLE between Lindum and Cleveland. He then communicated the status of the OHLE as de-energised, but not isolated or earthed clearly to the train control supervisor. He also explained this to the spare driver at Cleveland station via phone, using the standard terminology, but also explaining its implications for the movement of passengers from the train. The spare driver then passed this information to others including passengers and the driver.

The electrical control operator then, at 09:43, commenced communications to deploy a linesman. However, the travel required meant that the linesman did not perform the isolation until 10:29. The OHLE was not confirmed as earthed, and therefore the emergency site as electrically safe, until 10:34. By this time, the passengers had been evacuated from the train by emergency services personnel some 30 minutes previously.

³⁹ Queensland Rail (2011). Specification SAF SPC/0022/EMG Module EP1-01 Rail Emergency Response Plan. Version 1.1. p10

⁴⁰ Queensland Rail (2011). Specification SAF SPC/0022/EMG Module EP1-01 Rail Emergency Response Plan. Version 1.1. p10

⁴¹ Queensland Rail (2011). Specification SAF.SPC/0022/EMG. Module EP1-04 Overhead Line Equipment Emergency, Version 1.0. p12.

⁴² Queensland Rail (2011). Specification SAF.SPC/0022/EMG. Module EP1-04 Overhead Line Equipment Emergency, Version 1.0

Actions of Queensland Rail staff at the emergency site

Queensland Rail's emergency management procedures require the train control operator to appoint an on-site coordinator, normally the most senior Queensland Rail employee at the scene. The on-site coordinator is to assume command of the site, to communicate that assumption to others at the site, and to be the central point of communication with the train control operator.

Due to the nature of this event, the staff on site at the time of the collision included the train crew, customer service staff, including the station master, and a spare driver. Whilst the driver and guard were in communication with the train control operator, the station master did not communicate directly with train control. The train control supervisor initially communicated with the spare driver, to whom a phone had been passed from a customer service attendant. At no point during the initial response did the personnel at the site or at train control clearly identify a single on-site coordinator to whom all information would be passed. Consequently, the train crew, customer service staff, and the spare driver were all in possession of varying information and direction from train control, and their actions in the initial response to the emergency reflected these communication gaps.

Train crew

After reporting the collision to the train control operator, the driver took a few moments to collect himself. He then went back through the passenger car to assess the situation and to provide assistance to the passengers.

The guard, being situated in the driver cab of the fourth car, could initially access only the rear passenger cars. The guard did exit the train onto the platform and enter the front car set in his desire to provide assistance to passengers therein and later repeated this action, returning to the rear car set. This action, while well intentioned, was not in accordance with procedures for managing an overhead line equipment emergency, and placed the guard at risk of electrical injury.

Customer service staff

The customer service staff focussed their efforts on securing the station from onlookers and assisting passengers and other customers on the platform and in the station building. The spare driver assumed some level of authority on the platform itself, directing passengers to remain inside the train until the collapsed power line had been confirmed safe, and assisting customers on the platform to safety. It was unusual for a spare driver to be at the station. Had this not been the case, it is unclear whether station customer service staff, with limited training in emergency response procedures, would have been equipped to provide this direction to passengers. Some passengers complied with the direction to remain inside the train; others did not and disembarked the train. In the absence of an authoritative on-site coordinator, these passengers proceeded out of the station unchallenged by Queensland Rail staff, and without any post incident medical assessment being undertaken.

The situation of the customer in the amenities block, who became trapped by debris as a result of the collision, was an issue which customer service staff were unable to resolve. Interview evidence indicated that customer service staff were unable to determine a safe way to assist, or prioritised securing the station over assisting the individual. After some discussion, a member of the public (a minor) provided assistance by forcing open the door, and clearing a pathway through the debris so the affected customer could safely exit.

Overwhelmed by the task of securing the station from an increasing crowd of onlookers, the station customer service staff were not in a position to identify and provide a safe and controlled waiting area for customers from the platform and station building, and those passengers who disembarked the train of their own accord, some of whom left the station without being medically assessed.

Passenger impressions

Interviews with passengers and customers at the station indicated overall satisfaction with the manner in which the emergency was managed by Queensland Rail and emergency services staff. Concerns raised were related to a perception of confusion and panic by the customer service staff, particularly regarding the provision of assistance to the customer trapped in the amenities block, as well as a perceived lack of coordination of a controlled area to await medical assistance. Passengers on the train were generally satisfied with the manner in which their evacuation was managed, and with the provision of information and guidance from the train crew. Impressions of Queensland Rail's provision of post-incident support in the weeks following the collision were also largely positive.

Communications between network control and Cleveland station

The importance of effective and efficient communications during the response to an emergency event is broadly acknowledged. As Leadbeater (2010) points out, 'Access to information that is timely, accurate and consistent is a critical element in any disaster or major incident.'⁴³ The Transport (Rail Safety) Regulations 2010 specifically identify communication as a key component of a rail operator's emergency response system, requiring 'procedures for effective communication and cooperation throughout the implementation of the appropriate response measures.'⁴⁴

The nature of managing an emergency response to an event at a geographically removed location means that train control staff are almost completely dependent on accurate and timely communications from those at the site. However, early communications from an emergency site are frequently unreliable. As Falkenrath (2005) highlights, 'first reports are usually inaccurate'; and 'accurate reports are typically embedded within significant uncertainty'⁴⁵. Whilst the voice communications from the spare driver and from customer service staff at Cleveland station were supplemented by information gleaned from the station CCTV footage, the availability of this footage to the train control staff was unreliable, and indeed was the subject of a number of additional voice communications from the train control supervisor trying to regain the vision.

Train operations internal emergency debrief

In accordance with its emergency management procedures, Queensland Rail conducted an internal emergency debrief.⁴⁶ The debrief document largely consisted of a sequence of events commencing from the receipt of the emergency broadcast from the train driver, through to the resumption of normal passenger services from Cleveland station on Sunday 3 February 2013. The debrief found that the safety incidents were managed and reported in accordance with internal organisational guidelines. The sole area for improvement identified was that 'the Cleveland Area Queensland Fire and Rescue Service staff (had) limited awareness of hazards presented by Queensland Rail's fallen overhead line equipment', and determined that improvement was needed in the application of the existing provisions in the Specification for OHLE emergencies for the maintenance of communications with emergency response agencies to manage the electrical hazard prior to the arrival of Queensland Rail staff on site.

⁴³ Leadbeater, A. (2010). Speaking as one: The joint provision of public information in emergencies. *The Australian Journal of Emergency Management*, 25 (3). p22. www.em.gov.au/Documents/Leadbeater.PDF

⁴⁴ Transport (Rail Safety) Regulations 2010, s14.

⁴⁵ Falkenrath, R. (2005.) Homeland Security and Consequence Management. The Challenge of Proliferation: *A Report of the Aspen Strategy Group*: The Brookings Institution. www.brookings.edu/~media/research/files/articles/2005/6/summer%20terrorism%20falkenrath/2005_aspen.pdf

⁴⁶ Queensland Rail (2013). *Cleveland Derailment – Train Operations Internal Emergency Debrief* QT.A 4697.

Management of safety risks

Risk management is a process that includes the identification, analysis, evaluation, treatment, communication and ongoing monitoring of risks and is recognised as an integral component of good management practice.⁴⁷ The management of rail safety risks associated with operations of a railway demands a sound management system that aims to ensure railway organisations develop and maintain standards, procedures and rules to provide safe operational and engineering processes and systems. The objective is to manage these risks to a level that 'so far as is reasonably practicable' (SFAIRP) will avoid injury to people and damage to property.

ATSB investigators reviewed multiple risk registers that were in place before and after the division of Queensland Rail's passenger and freight businesses into separate entities. The division of the business formed the independent organisations of Queensland Rail Ltd passenger services (Queensland Rail) and the public company (part-owned by the Queensland government) QR National freight entities (now known as Aurizon Operations Ltd).

Prior to the division of the Queensland Rail business on 1 July 2010, the passenger services business compiled a 'Business as Usual' risk register to ensure that rail safety risks would be adequately controlled throughout the business change process.

To satisfy legislative requirements, Queensland Rail also applied for rail safety accreditation with the intention of commencing operations as a new entity on 1 July 2010. The 'Business as Usual' risk register was used to demonstrate to the DTMR Rail Safety Regulation Branch that through the business change process there would not be an increase in the level of rail safety risk and all identified risks would be adequately controlled.

The 'Business as Usual' risk register structure consisted of a Rail Safety Strategic Risk Register, which identified governance risks at a high level, and three subordinate Rail Safety Tactical Risk Registers in the functional divisions of Network, Customer and Operations. The tactical risk registers listed rail safety risks, controls for each of those risks and included managers responsible for developing and implementing tactical risk controls. The tactical registers assigned responsibilities to the Safety General Managers and Group General Managers that were aligned to each functional division. The custodian of the rail safety risk structure was the Executive General Manager, Safety and Environment. The frameworks of the tactical registers were structured and aligned to the (ON-S1) standard and OC-G1 guideline.

Following a review of Queensland Rail's application for accreditation, the DTMR applied a condition to Queensland Rail's rail safety accreditation notice stating that the 'Business as Usual' risk register must be reviewed within six months and a status report be provided to the Director (Rail Safety Regulation) by 31 December 2010. In compliance with the condition of accreditation, Queensland Rail provided a status report to the DTMR by 31 December 2010 that identified processes to implement and maintain the Rail Safety Risk Registers on a continuing and business as usual basis with reviews of rail safety risks for all registers occurring at least every 3 months.

The DTMR reviewed the 'Business as Usual' risk register status report and following minor amendments the condition that was applied to Queensland Rail's rail safety accreditation was removed on 28 February 2011. No additional conditions affecting the management and control of risks were applied to Queensland Rail's rail safety accreditation before the collision at Cleveland on 31 January 2013.

⁴⁷ AS/NZS ISO 31000:2009 Risk management - Principles and guidelines

Regulatory oversight of Queensland Rail

Legislation and accreditation

The Department of Transport and Main Roads (DTMR) is the statutory authority regulating rail safety in Queensland. On 1 September 2008 the DTMR issued Queensland Rail with a notice of accreditation in accordance with section 128 of the then *Transport Infrastructure Act 1994*. The accreditation notice included the requirement to comply with the National Rail Safety Accreditation Package (NRSAP - Version 2- December 2005). The NRSAP was developed by the Rail Safety Regulators Panel to provide a nationally consistent approach to rail safety accreditation. The package provides guidance to accredited rail organisations and for applicants seeking rail safety accreditation and was endorsed by the Australian Transport Council.

With respect to role of the rail safety regulator the NRSAP states:

The Rail Safety Regulator:

- sets the minimum requirements for the scope and content of SMSs in accordance with the legislative framework;
- makes recommendations for draft Acts and Regulations for consideration by governments and parliaments;
- exercises discretion in the recognition or mandating of standards to promote appropriate levels of safety management and performance;
- assesses whether the SMS submitted by the applicant demonstrates that the applicant has the systems, skills and capacity to run **railway operations** safely and whether the SMS complies with the minimum requirements set by the regulator.

In particular, the regulator assesses whether the applicant has developed and implemented a safety management system based on risk management and continuous improvement, and that there is a clear linkage between hazards identified, the assessment of risks arising from the hazards, and the control measures applied;

- monitors compliance with the **railway organisation's** terms of accreditation through compliance auditing, compliance inspection and **compliance investigation**;
- undertakes industry safety promotion and education to facilitate compliance and promote improved safety outcomes;
- undertakes enforcement action where necessary with consideration to a publicly available compliance and enforcement policy;
- monitors safety performance through **occurrence** reports, trend analysis and, where applicable, the Annual Safety Report submitted by **railway organisations**;
- may report on safety performance through an annual industry safety report.

The *Transport Infrastructure Act 1994* also provided for an audit regime where the DTMR was to prepare an annual audit program for inspecting the activities of accredited railway operators and where the DTMR reasonably believed that there are safety concerns with a railway operator or there was non-compliance with a railway provision, further inspections may have been carried out. Provisions also existed where disciplinary action could be taken against an accredited railway following an inspection under an audit program.

On 1 September 2010 the *Transport (Rail Safety) Act 2010* and Transport (Rail Safety) Regulation came into force in Queensland. The Act and Regulation superseded the *Transport Infrastructure Act 1994* and are based on the National Transport Commission's national model Rail Safety Bill 2006 (and amendments) and national model Rail Safety Regulations. The model Regulations draw significantly on the content of the National Rail Safety Accreditation Package and the Australian Rail Safety Standard - 4292.1 (2006).

The *Transport (Rail Safety) Act 2010* and Regulation has resulted in significant changes to DTMR's rail safety regulatory regime. In submission DTMR stated:

The *Transport (Rail Safety) Act 2010* (TRSA) enacted in September 2010 is dedicated rail safety legislation, with its objectives focused on the requirement to ensure the safety of railway operations. TRSA is based upon model law that was adopted by all jurisdictions. It no longer referred to the Australian Standard AS4292 and provided a risk based approach to rail safety.

The objectives of TRSA placed an emphasis on ensuring safety on both the rail transport operator and the regulator. There are substantial differences in the objectives of TIA compared with TRSA, with TRSA directed towards safety and controlling risks associated with rail operations.

TRSA also provided the Rail Safety Regulator with additional powers to conduct inspections and compliance investigations. These compliance activities are in addition to retaining a no blame investigation option. TRSA introduced rail safety duties and offences for rail transport operators, and provided the regulator and rail safety officers with more powers to enforce safety measures. The legislation also introduced enforcement powers such as improvement and prohibition notices.

With the introduction of TRSA, the Rail Regulation Unit (RRU) reviewed its processes and procedures to align them with the added powers and enforcement provisions of the new legislation. The RRU also reviewed its compliance and enforcement policy in line with the national focus of a single regulatory regime. The policy enabled and empowered the rail safety officers with the ability to enforce the provisions of the legislation in a more effective manner.

The reporting regime for category A and category B incidents has been reviewed and tightened to enable the RRU to monitor incidents in a timelier manner. A revised process for reviewing investigation reports and incident trending has been implemented. The introduction of TRSA has enabled a more effective way for the RRU to conduct regulatory activities through compliance inspections and compliance investigations.

The RRU is provided, by the data group within the Land Transport Safety Branch, with a monthly report of category A incidents and sometimes requests specific trending analysis of particular incidents.

The RRU has also redefined the risk modelling for each of the accredited rail transport operators enabling a broader spread and effective use of regulatory resources in its compliance activities.

Training of rail safety officers has been undertaken giving them skills, knowledge and competence empowering them to confidently act in accordance with their responsibilities under TRSA. The training has consisted of Certificate IV (Investigations), and the Diploma of Government (Rail Safety Regulation). Other specific training on the legislation, and changes made to the processes and procedures of the RRU has also been conducted. The introduction of TRSA, the training, and the evolution towards a national regulatory regime has resulted in a cultural change within the RRU in Queensland.

Co-regulation

Rail safety regulation in Australia is achieved through a consultative approach and mutual co-operation between the accreditation authorities (safety regulators) and rail transport operators (RTOs). Rail transport operators may set their own standards. Operators regularly reference Australian Standards that are jointly formed with consultation of the broader rail industry in a process facilitated by the RISSB. When an RTO is granted rail safety accreditation, the RTO is responsible for the assessment and management of risks in accordance with their safety management system to ensure that identified risks are controlled to acceptable levels of safety for their type of railway.

In such a co-regulatory rail safety environment, accreditation authorities set minimum requirements for the content of safety management systems and are accountable under legislation for monitoring the safety performance of RTOs. This is achieved through the application of compliance audits of an RTO's safety management system rather than setting prescriptive standards and monitoring compliance with them.

The accreditation authority also monitors an RTO's safety performance through the mandatory reporting of notifiable safety occurrences and their assessment and/or investigation.

Notification of occurrences

In June 2008, State and Territory rail safety regulators agreed on a standard set of 21 notifiable occurrence types, each containing sub-categories with supporting definitions. The notifiable occurrences are documented in standard (ON-S1) and guideline (OC-G1). The occurrence types are divided into two reporting categories. Category A occurrences must be reported to the regulatory authority by the rail operator within 2 hours. These reports contain a high level of detail and are individually reviewed by the DTMR.

Category B occurrence reports contain less detail about the event and are forwarded to the regulatory authority within 72 hours. The purpose of these documents is to provide a classification for each occurrence type and to provide detailed descriptions (including examples of events) to achieve consistency in categorising occurrences by RTOs and the reporting of these to the relevant regulatory authority.

Notifiable occurrences listed in OC-G1 are specific to the top or final event in an occurrence sequence and do not provide for the reporting of preceding or contributing events. Where preceding event information is available, this information may also be categorised. Inherent in a top event only notification system, contributing factor information may be embedded within the occurrence description text which may disguise lead indicators for the event and potentially others. The reporting of occurrences in this format can conceal underlying safety issues which may not be readily apparent unless a detailed analysis is performed.

Queensland Rail provides the DTMR with occurrence data in accordance with OC-G1 on a regular basis, and although the occurrence descriptions generally provide a high level of detail about each event, the underlying cause(s) leading to an occurrence may not always be readily apparent.

DTMR review of occurrences

In July 2004 the DTMR and Queensland Rail discussed the safety implications of SPAD and trains exceeding their limits of authority events. It was agreed (in an MoU) that from July 2004, conditional SPAD and train exceeding limits of authority events would be considered as Category A occurrences, rather than Category B, and a 2 hour notification would be provided to the DTMR by Queensland Rail. The SPAD notification agreement is unique to the rail network in Queensland and remains in force.

As slip-slide events are not specifically defined as a notifiable occurrence in the OC-G1 there was no requirement for Queensland Rail to provide this information under the existing reporting regime unless the safety occurrence impinged upon another occurrence type, for example an authority exceedance or SPAD.

The ATSB extracted 1259 Category A and B occurrence reports from the DTMR occurrence notification database for the period between January 2009 and January 2013. Field searches were made for slip-slide and adhesion information within the OC-G1 categories: SPAD, proceed authority exceeded, track and civil infrastructure irregularity, rolling stock irregularity and train warning and enforcement.

An examination of these notification reports revealed limited evidence of slip-slide or adhesion being identified as contributing factors. In all cases any slip-slide or adhesion information was contained within description fields of the occurrence report. In all only seven notifications were found which referenced train slip-slide or adhesion information (Figure 24).

Following the collision at Cleveland, the DTMR wrote to Queensland Rail on 5 March 2013 requiring Queensland Rail to report any future wheel slide/slip events under OC-G1 12.5 – Braking System Irregularity.

Figure 24: OC-G1 occurrence categories where slip-slide information was embedded

OC-G1 category	Date	Track section	Description (abbreviated)
Signal Passed at Danger (SPAD) Notified as Cat 'A'	9 January 2009	Beerwah – Landsborough	Train 1L13 passed Beerwah signal BH23 at stop. The driver called network control advising the train was not going to stop before passing signal and was experiencing slip-slide while braking. The driver continued to slide, used a full service brake application and later applied the hand brake in an attempt to stop the train before the signal. Conditions at the time were described as light rain falling with the tracks becoming very slippery – immediate cause identified as lack of adhesion.....
Signal Passed at Danger (SPAD) Notified as Cat 'B'	27 January 2009	North Coast Line - Exhibition Loop	Train 1718 passed signal ME24 onto the same signal section as 19R0. Train 1718 contacted control and advised train had passed by 1 car length due to slippery conditions on the track.
Signal Passed at Danger (SPAD) Notified as Cat 'A'	9 March 2009	Beerwah - Landsborough	Train H401 passed Beerwah signal BH25 at danger by 4 metres while #7 points were set at reverse. Train JLS3 in advance of H401 was still in the section ahead. Driver was aware signal BH25 was red but experienced wheel slide when attempting to stop his train.
Signal Passed at Danger (SPAD) Notified as Cat 'A'	9 October 2010	Caboolture – Nambour	Train TLS5 passed signal BH25 at danger by 15 metres. Emergency radio call made to TLS5 to stop. Driver stated that he was braking to stop at signal BH25 and the train slipped past the signal.
Signal Passed at Danger (SPAD) Notified as Cat 'B'	16 April 2011	Clapham – Acacia Ridge	2F12 routed to Rocklea siding. Driver reported excessive wheel slip in Rocklea siding due to long grass which requires cutting. Signal SY33 at Salisbury restored in face of 2F12 stopped 5m past signal. Signal fault coordinator advised signal SY33 at Salisbury restored due to momentary loss of detection (possibly caused due to grass on track).
Rolling stock irregularity Notified as Cat 'B'	13 January 2013	Caboolture – Nambour	Driver of U106 (IMU177) approaching Landsborough made an emergency radio call to advise the train was going to slip past signal LH14 at a red. Driver further advised he had applied the brakes but they had failed to function due to the wet weather. Signal LH14 cleared as the train approached and driver advised he travelled through Landsborough 7 points at 19km/h. Train Monitoring Improvement Officer arranged to speak with the driver at Caboolture.
Track and Civil Infrastructure Notified as Cat 'B'	31 January 2013	Corinda - Bundamba	Driver 1524 (SMU 280/291) advised track into Gailes platform on the up western main line was very slippery. Absolute signal block applied to the up track Gailes and started warning all trains. All trains warned and recorded on a "condition affecting the network" form. At 12:30 hours track occupancy authority issued to protection officer to sand tracks. At 12:35 hours driver 1530 reported slippery coming into station. At 15:32 hours driver 1532 advised he approached at 20 km/h under road speed and found it slippery but could stop by the marker.

Confidential reporting system

The DTMR established a confidential rail safety reporting system in September 2010 for rail safety workers and the broader community to report rail safety issues and behaviours that may compromise safe railway operations. The reporting of safety matters through the confidential reporting system was intended to be utilised when employees and members of the public were not able to report these issues through the usual employer or public transport reporting systems. This service was extensively communicated to employees within the Queensland rail industry.

DTMR advised that no reports had been received for train braking irregularities or slip-slide occurrences since the reporting system's inception.

Safety analysis

On the morning of 31 January 2013 as train T842 approached Cleveland station on a downhill grade there was a film of leaf tissue and oils on the rail head and light rain falling. The rail running surface almost certainly exhibited poor adhesion at the contact between the train's wheels and the rail head which resulted in wheel slide when the train's brakes were applied. The driver's operation of the train was in accordance with normal practice and the train's brake system worked as designed. The primary factor which led to the collision of train T842 with the end-of-line buffer stop and station building at Cleveland was poor wheel/rail adhesion.

There is clear evidence that the newer, fully disc-braked and WSP-equipped trains in the Queensland Rail fleet are particularly susceptible to wheel slide in conditions of low adhesion. There had been many reports of slip-slide events and several significant incidents involving these trains in the years between their entry into service and the accident at Cleveland. Analysis of slip-slide events at stations for the Queensland Rail fleet for the three years before the collision at Cleveland shows a clear link between train type, weather conditions and location. The IMU160 and SMU260 class trains have had proportionally many more slip-slide events, often in wet conditions (when this information was recorded), than other trains in the fleet and more often in areas where there is vegetation growing adjacent to the railway line on station approaches.

Many railways around the world have risk control systems to actively monitor and control levels of adhesion around their networks. These include both the forecasting of where and when low adhesion may occur (based largely on environmental conditions) and also systems for improving wheel/rail adhesion that are fitted to the train or applied to the track. In the United Kingdom, where conditions of low adhesion are a prevalent and well understood problem (particularly in autumn with leaf contamination of the rails), rail operators are required to have systems to identify and treat low adhesion 'black spots' in their networks.

At the time of the collision at Cleveland, Queensland Rail did not have a system in place to actively identify, monitor and treat the risks associated with conditions of low adhesion around their network.

Organisational risk management

Like many organisations, Queensland Rail manages its business and operational risks through a cascading system of risk registers. High level risks are identified in the Rail Safety Strategic Risk Register which is then promulgated through to the three subordinate Rail Safety Tactical Risk Registers relevant to the functional divisions of network, customer and operations. The functional divisions are then responsible for implementing appropriate controls to manage the rail safety risks relating to their part of the overall operation.

All of Queensland Rail's rail safety risk registers were reviewed during the investigation. None of the risk registers revealed a cause or hazard relating to rail wheel slip-slide or adhesion as a contributing factor, in any of the occurrence event classifications of SPAD, proceed authority exceeded, track and civil infrastructure irregularity, collision with infrastructure, rolling stock irregularity and train warning and enforcement. Operator error and inadequate operator route knowledge were shown as causes/hazards in running line collisions with infrastructure, and driver misjudged/completely missed were identified as causes/hazards for SPAD and proceed authority exceeded events.

An analysis of the recurring list of OC-G1 occurrence risk events (2224) that were assigned to each of the 19 group general managers and general managers did not identify any record in the rail safety risk register of causes or hazards associated with train or rolling stock slip-slide related to poor adhesion at the wheel/rail interface.

The occurrence of slip-slide events involving electric passenger trains was well-known in some divisions of Queensland Rail. Within the operations and network divisions, slip-slide events were occurring regularly and were being reported by train drivers to network control. Slip-slide events were occurring on approach to train stations and signals resulting in platform over-runs and SPADs. These occurrences were being recorded and regularly investigated by Queensland Rail staff.

For the month of January 2013, immediately before the collision at Cleveland, there were 25 investigated occurrences where low adhesion was cited as the event cause. There were 19 occurrences where 'human contributed' was listed as the cause and five of these had observed that wet track was a contributing factor.

In all instances, these occurrences precipitated an investigation by supervisory or investigation staff who would interview the train driver, and occasionally the guard and other involved persons. In most instances the investigator was a TMIO who interviewed the train driver. For the majority of these investigations the TMIO would only provide advice to the driver on how to adjust and improve their driving and braking technique to reduce the likelihood of train slides when stopping at station platforms and signals. A review of the TMIO notes and findings found where the track was contaminated with leaves and moisture, the TMIO did not offer an explanation or provide training to the driver on why contamination to the rails may have adversely affected the driver's ability to slow or stop the train while braking under these conditions.

As Reason (1997), points out:

One of the commonest misuses of reactive measures (of safety) is to focus too narrowly upon single events. This leads to countermeasures aimed chiefly at preventing the recurrence of individual failures, particularly human ones⁴⁸.

The train services/operations divisions which systematically undertook the retraining of individual drivers in train braking techniques following each reported slip-slide demonstrated the limitations of this inward focus. By considering each of the events singularly, rather than collectively, the opportunity to detect the broader issue in relation to the combined influence of driving technique, rolling stock features and environmental factors leading to conditions of low adhesion, was missed.

Hopkins (2005) recommends that organisations which aspire to risk awareness:

...must take warnings seriously no matter how tenuous, intermittent or ambiguous. They must avoid dismissing them as normal and to be expected, and when faced with uncertain information, they should default to a presumption of danger rather than a presumption of safety⁴⁹.

Despite the numerous occurrences of slip-slide events being reported, with the IMU160 and SMU260 class trains being significantly over represented in the occurrence statistics, Queensland Rail's risk management processes did not precipitate a broad, cross-divisional, consideration of solutions to the slip-slide issue including an investigation of the factors relating to wheel/rail adhesion. Each division continued to assess and treat each event locally within that division and in isolation.

Beerwah

Queensland Rail's rolling stock engineering division was aware of slip-slide occurrences occurring in its fleet, particularly the IMU160 and SMU260 classes of trains. These issues were highlighted by the series of brake tests that were conducted after the SPAD occurrences of trains 1L13 and H401 near Beerwah on 9 January and 9 March 2009 respectively. These investigations and tests were commissioned by the QR Passenger and QR Network divisions. A risk profile report written

⁴⁸ Reason, J. (1997). *Managing the Risks of Organizational Accidents*. Ashgate: Aldershot. p 117.

⁴⁹ Hopkins, A. (2005). *Safety, Culture and Risk. The Organisational Causes of Disasters*. CCH: Sydney. p22.

by Queensland Rail staff in relation to the Beerwah occurrence on 9 January 2009 made two recommendations:

- That the risk evaluation in this report be reviewed by relevant stakeholders to review and re-evaluate the inherent risk and to validate or reject the inherent risk identified in this report.
- That QRP consult with QR Network to identify similar locations where a similar extreme risk exists and investigate what controls, if any, can reduce the inherent risk.

In preparation for the impending separation of the Queensland Rail passenger business in 2010, a 'Bowtie'⁵⁰ briefing document was developed to reconfirm and identify new rail safety hazards that would exist in the new operation. The bowtie assessment was to be read in conjunction with the Rail Safety Strategic Risk Register with both documents structured around the rail safety notifiable occurrence standard (ON-S1) and guideline OC-G1.

In the functional areas of infrastructure, rolling stock, operations, collisions and safety governance, the pre-separation briefing document did not identify hazards associated with platform overruns, SPADs or collisions with infrastructure as a result of poor adhesion of trains operating over the network. The briefing document did not identify these hazards and had not observed the findings of the two SPAD investigations at Beerwah in 2009 that had been carried out to test the braking performance of the rolling stock and to identify the root cause of recurring train slide events.

Even when divisional investigations had explicitly recommended the need for broader consideration of the identified issues (such as the 'extreme risks' identified following the January 2009 SPAD at Beerwah), it is unclear if, and in what forum, these recommendations were considered at a strategic management level. The ATSB's investigation did not identify any evidence that the findings and recommendations in the Beerwah report⁵¹ had been acted upon by relevant stakeholders in the organisation which suggests strongly that the organisation's strategic risk monitoring and analysis processes were ineffective in this instance.

Other occurrences

Various metropolitan passenger rail services around the world operate trains (and train braking systems) similar to and in some cases identical to Queensland Rail's fleet of IMU160 and SMU260 class trains. Although the networks may be different and subject to differing environmental conditions, there were several occurrences involving trains fitted with disc braking systems experiencing wheel/rail adhesion problems in the years before the accident at Cleveland.

In particular the spate of incidents involving the Siemens Nexus trains in Melbourne, which occurred at around the same time as the Beerwah incidents, appears to have gone unnoticed by Queensland Rail. The Nexus trains, like Queensland Rail's IMU160 and SMU260 class trains, are fully disc-braked and have the same issues relating to braking performance in conditions of low wheel/rail adhesion. The occurrences involving the Nexus trains, and the subsequent investigation and identification of the factors affecting their braking performance, was another opportunity missed for Queensland Rail to identify and actively manage the risks pertinent to their fleet long before the accident at Cleveland.

Buffer stop collision risk

In 2010, the Queensland Government engaged a consultancy service to analyse rail safety risks within Queensland Rail's South East Queensland Network (SEQN). The analysis included an assessment of risks associated with a proposal to implement Automatic Train Protection⁵² (ATP) and also any risks associated with 'doing nothing' in response to the anticipated high level of growth in patronage of the SEQN and the expected strain on the rail safety system. Risk

⁵⁰ The bowtie method is an approach to risk that is designed to link risk control and risk recovery processes.

⁵¹ SPAD at Beerwah 09/01/2009 - NIR09.4364.

⁵² A system that supervises train speed and target speed, alerts driver of the braking equipment, and enforces braking when necessary.

modelling was carried out using representative samples of the SEQN that included the track section from Manly to Cleveland.

Specific hazards were considered in the consultant's risk modelling including train over speed, maintenance activities and SPADs leading to a collision with a buffer stop. The consequence for each of the hazards was assessed using the Fatalities and Weighted Injuries⁵³ (FWI) measurement system.

The risk analysis report presented to the Queensland Government on 19 August 2011 used public train timetables and other data provided by the Department of Transport and Main Roads Rail Safety Regulation Branch (DTMR) when calculating the number of approaches of trains at stations fitted with buffer stops. A speed of less than 30 km/h was used in calculating the consequence of a collision with a buffer stop.

The analysis rated the risk as very low and reported a likelihood of 0.0002 FWI occurrences annually.

A review of the Queensland Rail - Rail Safety Risk Register (updated 23/12/2012) showed six potential causes for the hazard 'Collision with Infrastructure'. These included train out of gauge loading, infrastructure foul of train envelope, infrastructure moves due to excavation work, infrastructure moves foul due to storm or washout, over speeding train and train foul of infrastructure envelope. No hazards had been included in the risk register in relation to a collision with a buffer stop.

An analysis of occurrence data reported by Queensland Rail to the DTMR for the period 1 July 2008 to 1 February 2013 showed there are very few collisions between passenger trains and infrastructure. There were three occurrences where passenger trains had collided with buffer stops; however, these had occurred during low speed train movements in railway yards and not on a running line.

In conjunction with the design of a buffer stop, an assessment of the risk of a train not being able to stop at a station from a speed greater than the collision design speed should also be considered. The maximum design collision speed of the buffer stop at Cleveland station was 5 km/h with a maximum train weight of 200 t (noting train T842 was about 250 t and travelling at about 31 km/h). This buffer stop would have been expected to resist the impact forces of a train in a low speed roll-away or a minor station stopping point overrun misjudgement by a driver under normal adhesion conditions.

It is common practice for buffer stops to be designed for a speed higher than 5 km/h. The mass of the two IMU or SMU class train units travelling on the Cleveland line was commonly heavier than the design specification of the buffer stop at Cleveland station. It is probable that Queensland Rail's risk management systems did not consider this design criterion for these train configurations arriving at Cleveland station.

Regulatory oversight

In February 2007 the DTMR wrote to Queensland Rail seeking information about braking on their train fleet. The letter was initiated following advice about early braking issues being experienced by the Siemens Nexus trains operating in Melbourne.

The DTMR sought information about whether Queensland Rail's passenger train fleet was equipped with computer controlled train brake systems and if these trains had 'ever experienced any persistent abnormal brake behaviour which could be attributed to brake system design'.

⁵³ A measurement that represents the number of instances that have the equivalence of 1 fatal injury (as used by the RSSB, UK).

Queensland Rail's response described the various braking systems on their fleet and assured the DTMR that Queensland Rail's Rolling stock engineering division 'have high levels of expertise in braking systems' and are capable of minimising potential problems and will act quickly if issues arise.

The response went on to say that the DTMR would be aware from the incident data supplied by Queensland Rail 'that the problems experienced in Melbourne are not occurring on QR trains' and the explanations provided 'give some explanation why such a situation is unlikely to occur here'.

At the time of this correspondence Queensland Rail was only part-way through the process of taking delivery of the IMU160 and SMU260 class trains (2004-2011). Given their relatively short period in service at the time, it is not clear whether or not there would have been any abnormal braking performance trend identifiable in these trains.

Beerwah

Queensland Rail immediately advised the DTMR of the signal passed at danger (SPAD) occurrence at Beerwah on 9 January 2009 under the provisions of the enhanced reporting MoU agreed in July 2004. The occurrence was assessed and recorded in the DTMR's Rail Incident Safety Queensland (RISQ) occurrence database as a Category A occurrence.

The QR Network division commenced an investigation in parallel to an investigation by Passenger Rolling stock Engineering. On completion of the QR Network report, a copy was sent to the DTMR, however the findings and recommendations in the report were not reviewed or monitored and the report was filed. Although the QR Network investigation report noted that 'QR Passenger Rolling stock Engineers have commenced a detailed examination of the operation of the train leading up to and during the event' a copy of the Rolling stock engineering report was not provided to, or requested by, the DTMR.

At the time of the Beerwah SPAD, the *Transport Infrastructure Act 1994* contained provisions which allowed DTMR to follow up on Queensland Rail's investigations by requesting further information or to independently investigate the occurrence themselves. Similarly the NRSAP which formed a condition of Queensland Rail's accreditation, provided for follow up action by the regulator in the form of compliance audits and inspections and if necessary, compliance investigations.

In submission DTMR stated:

In 2009, the Department of Transport and Main Roads had limited opportunity to examine and address the safety issue associated with the incidents at Beerwah. The department was required to rely on the advice provided by Queensland Rail Limited as the accredited railway manager.

And further:

The *Transport Infrastructure Act 1994* (TIA) was not stand alone legislation, as it legislated for a number of modes of transport. The legislation was based on the objectives of the regulator regime at the time with an approach that was more toward the self-regulation end of the regulatory paradigm. The legislation's objectives focused on establishing a regulatory regime that provided for adequate levels of safety, and contributes to overall transport effectiveness and efficiency.

TIA referred and depended heavily on the Australian Standard for Rail Safety (AS4292) to set the regulatory approach. TIA proved a narrow scope regarding compliance activities (e.g. audits) and was limited regarding enforcement options.

At the time of the 2009 Beerwah incidents, TIA limited the investigative activities of the Rail Safety Regulator to what is termed as 'no blame investigations'. This restricted any enforcement options to such choices as suspending the operator's accreditation. The legislation did not provide for compliance or enforcement options.

Beyond the initial notification of the SPAD at Beerwah on 9 January 2009 and receipt of the QR Network report in March 2009, the DTMR did not take further action in relation to the QR Network report. However, a file note recorded:

... the report concluded that the immediate cause of the SPAD event had been a lack of adhesion experienced during the braking procedure of the train which increased the distance required for the train to come to a complete stop.

The Beerwah occurrence in January 2009, and the factors relating to low wheel/rail adhesion identified by the subsequent investigations by Queensland Rail, was probably the first opportunity for the DTMR to identify this safety issue on the Queensland rail network. Although the DTMR had some knowledge of the immediate cause of the Beerwah SPAD, Queensland Rail did not formally advise the DTMR about the multiple and on-going passenger train slip-slide events as they were not classified as notifiable occurrences within ON-S1/OC-G1. If low adhesion had been identified as an on-going safety issue at the time, it is likely that the assessment of the risks arising from the hazard would have resulted in action by the DTMR to ensure that control measures were applied by Queensland Rail.

Investigation report reviews

Since the Beerwah occurrences in 2009, there have been significant changes in the rail safety regulatory regime in Queensland with the *Transport (Rail Safety) Act 2010* and Regulation now in force. In particular, the processes for reviewing occurrence reports and investigations have been significantly enhanced.

In 2010 the DTMR revised an existing work instruction that provided guidance to DTMR rail safety officers (RSO) in the review and assessment of interim and final rail safety investigation reports received from RTOs. The RSOs were also responsible for identifying safety issues contained in the reports and to ensure that the RTO recommendations had been made to remove or reduce the risks associated with those issues. The work instruction called for the establishment of an investigation report Review Committee that included seven DTMR and Rail Safety Regulation Branch employees ranging in seniority from rail safety officers (on a rotational basis) to executive management.

The role of the Review Committee was to oversee and discuss the rail safety issues identified from occurrences that had been presented to them by the RSOs. The committee also ensured that all safety issues had been recognised and adequately addressed and determined if any further action was required by the RTO. The DTMR advised that the 'Review Committee process did not provide a fast enough response to contemporary issues' and remained active for about 12 months before a streamlined process was introduced to manage report findings and safety actions through a schedule of programmed and targeted spot audits.

When the DTMR was presented with a copy of the QR Network - Beerwah report in March 2009, the investigation report review process was immature and the Review Committee had not been established, however the important contributing safety factors noted in that report were not highlighted by DTMR for further attention and follow-up with Queensland Rail.

On 19 December 2012 the DTMR and Queensland Rail agreed to participate in a two month trial for the submission of detailed interim investigation reports for all Category A occurrences. The trial was implemented to reflect sections 93 and 94 of the *Transport (Rail Safety) Act 2010* relating to reporting and investigation obligations. The previous arrangement reflected the accreditation conditions established under the *Transport Infrastructure Act 1994*. A new procedure was drafted by the DTMR for RSOs to follow and a trial period for the agreement ran from 1 January 2013 to 28 February 2013. The DTMR advised that the trial was successful and now forms a standard condition of accreditation for all rail transport operators in Queensland.

DTMR spot and compliance safety audits

The DTMR carries out risk-based audits that assess a rail transport operator's safety management system and may be scoped using occurrence and trend data. Findings arising from investigations carried out by the DTMR or Queensland Rail are also considered for points of review during field and office based safety audits.

A table of safety audits that were reviewed for the QR Passenger operations found these audits did not include significant occurrence events – e.g. Beerwah SPAD and follow-up actions of Queensland Rail including reference/s to the QR Network report that recommended a rolling stock division investigation should be carried out.

A DTMR safety management system (SMS) audit of Queensland Rail Passenger commencing on 15 June 2009 had scheduled 18 audit elements in accordance with the NRSAP. The audit final report was completed on 10 November 2009 and made four significant recommendations requiring Queensland Rail's attention including one for risk management focussing on ensuring that 'timeframes are provided to proposed risk controls as defined in the Queensland Rail Passenger risk register'.

The audit report also stated that Queensland Rail's SMS must provide for a comprehensive list of hazards and associated controls but minimal details were included in the report to show the type of safety risks that had been assessed as not compliant.

More recently, under the provisions of the *Transport (Rail Safety) Act 2010*, the DTMR broadened their risk based methodology to include 11 key elements to provide a more predictive target on audit effort and compliance inspections. These audits are now conducted quarterly; however, previous audit and compliance scoping processes did not detect the existence of wheel slip-slide events and target the potential of this safety risk.

National Rail Safety Regulator (NRSR)

Commencing on 20 January 2013, the Office of the National Rail Safety Regulator was established to encourage and enforce safe operations and to promote and improve national rail safety. Currently there are four participant jurisdictions of New South Wales, South Australia, Tasmania and the Northern Territory. It is expected that Western Australia, Victoria, Queensland and the Australian Capital Territory will also be regulated by the ONRSR before June 2014.

As well as coordinating the accreditation of rail transport operators (RTO), the NRSR collects occurrence data from RTOs specified within OC-G-1.

Following the collision at Cleveland and in the interests of national consistency the DTMR, as a member in the NRSR National Operations Committee, tabled a proposal that significant wheel slip-slide occurrences should be reported by rail transport operators in the future. It was agreed by the committee that this occurrence type be incorporated within ON-S1/OC-G1 as a specified notifiable occurrence but no advice was provided to quantify what was a 'significant' slip-slide occurrence.

Driver training for braking under conditions of low adhesion

Queensland Rail's driver training is divided into two different modules, Train Management Theory and Train Management Practical. These modules cover the theory and practical aspects of moving, driving, braking and stopping the train. Assessment criteria for practical train management cover, amongst other competencies, the demonstrated ability to initiate braking procedures for the relative traction types and stop the train at the target point in accordance with operational requirements. Notably there is an emphasis placed on using the highest braking rate consistent with passenger comfort and rail conditions to avoid losing time.

Described in the training modules the recommended practice for braking at higher speeds is to place the brake controller into the initial position for a maximum of 3 seconds before moving the

controller into the service zone, half service position. The driver is then required to take into consideration the retardation rate required, having regard to the speed, gradient, track and weather conditions. The distance required to stop the train and the train traction type are included in the driver's decision on the appropriate actions to bring the train to a stop within the target zone, for example a train station platform.

When approaching a station platform with the train brake positioned in the half service position, the driver is called upon to make adjustments to the brake effort in the area known as the decision zone to bring the train to a smooth stop at the required marker. At the conclusion of the stop the brake controller is placed in different positions dependent on the traction type being driven. For example, when driving IMU160 and SMU260 class trains it is recommended that the brake controller is moved back to the initial position as the train speed drops to zero to minimise the possibility of wheel slide; and that the controller remains in at least the initial position at all times while stationary at the platform.

Drivers are required to demonstrate similar stopping sequences at high and low speed while operating different train traction types and correctly anticipating the amount of brake effort to avoid excessive manipulation of the brake controller. The training module indicates that such excessive movements of the brake controller could contribute to the train overshooting a station platform.

In conjunction with the brake methodology, the training module explains the difference between wheel slip and wheel slide and identifies trains fitted with wheel slide protection (WSP).

The training module recommends that during wheel slip drivers should:

- Reduce power to regain traction;
- Avoid excessive movements of the power controller.

In events of wheel slide the driver should:

- Observe the indication of excessive wheel slide on the drivers console/panel in the form of a steady white slip-slide light;
- Use their knowledge of the track and the conditions;
- Regulate the amount of brake effort enough to correct the slide and maintain maximum braking.

The IMU160 / SMU260 Driver's Manual states that in wet weather, and at times when slippery conditions prevail, the driver should ensure that wheel slide will not cause an overshoot of the stopping point. In these conditions the manual recommends that the brake application should be made earlier than would normally be required, but the same braking effort applicable at high speed in dry conditions should be used. This would then allow for a reduction in braking effort at a lower speed when more wheel slide may be experienced.

The Driver's Manual describes that wheel slide will be corrected automatically on individual axles or bogies much faster than the driver could react to it and therefore the brake controller should be left in the position required. Avoiding movement of the brake controller would generally achieve maximum brake pressure at all axles in the minimum time. However if the wheel slide was long and persistent the Drivers Manual indicates that if few wheels were 'finding good conditions' it could be advantageous for the driver to reduce the braking effort slightly.

In effect the Driver's Manual⁵⁴ implies that the brake effort should be reduced to alleviate the wheel slide event and therefore increase the ability of the braking system to bring the train to a stop. The Drivers Manual does not explain the effects of low adhesion at the wheel/rail interface, how low adhesion is a precursor to prolonged wheel slide events and why these elements reduce the likelihood of achieving expected rates of deceleration. The implication that the braking should

⁵⁴ IMU160/SMU260 Driver's Manual 1.12.2, page 36.

commence earlier, without a reduction in speed, does not adequately account for, or explain, the relationship between speed and the distance to safely stop a train under conditions of reduced adhesion.

The experience gained through training, familiarisation and repetition is integral to this aspect of train driving. At various locations on the Queensland Rail network that are used by heavy freight and coal train services, locomotive drivers use line side markers as distance reference points to assist them in braking and controlling their train and to remain below posted speed limits.

On the Queensland Rail Citytrain network distance markers are not provided to assist drivers to relate their actions to relevant track positions. These markers give fixed reference points that can be used by a driver to judge appropriate braking points on approach to stopping and target points under varying climatic conditions. The types of traction units, track conditions and train speeds vary, implying that the driver's knowledge, training and intuition play a vital role in making and educated decision at an appropriate track position to commence the braking sequence. Any further adjustments that are necessary in the train stopping sequence are based on the information available to the driver at the time. If conditions change or the hazards are not readily identifiable (for example slippery rail surfaces) there may be not be sufficient information or time on which the driver can make an informed decision in taking an appropriate course of action to safely stop the train.

With respect to network distance markers Queensland Rail advised:

Queensland Rail has posted track speed boards for all sections of the rail corridor on the SEQ Network. All Drivers are trained and assessed as competent in route knowledge for each rail corridor in regards to track alignment and allowable speeds. Track speed boards are clearly displayed and drivers are required to bring their trains to the controlled speed as posted prior to passing the track speed board. At Cleveland, the track speed board was 25 km/h.

The SEQ does not use line side markers or distance reference points as used in the Queensland coal train network. This is due to the density of general features along the route such as signals, Km posts, speed boards and level crossings etc in SEQ. The driver training uses the existing corridor reference points to develop the driving methodology with the trainee driver and then the application of that methodology is assessed in the driver assessment.

Effectiveness of emergency management response

Design and accessibility of the Emergency Management Specification:

Queensland Rail's Emergency Management Specification contained detailed guidance to staff involved in the management of specific rail transport emergencies. It did not provide guidance on the priority of any of these events which are specified under separate modules of the document. That is, for the collision at Cleveland station, procedures for any one of Overhead Line Equipment, Derailments; Collisions, Evacuations; Defective Rolling stock; or Serious Injuries or Illness on Trains may have applied. With no quick reference decision aids or checklists to refer to, train control personnel were required to interpret ambiguous and incomplete information about a complex situation, based solely on voice communications from a remote location. Then, based on that information, they were required to determine which emergency type was most appropriate, and select the full text module electronically at their workstation to access the appropriate procedure.

The use of standardised procedures for emergencies enables personnel to use rule-based decisions to react quickly and effectively to contain a situation. It permits the considered design of procedures by experts to be efficiently implemented by operators, and has the potential to mitigate the effects of inexperience and misunderstanding of an event.⁵⁵ However, the effectiveness of

⁵⁵ Flin, R., O'Connor, P., & Crichton, M. (2008). *Safety at the Sharp End. A Guide to Non-Technical Skills*. Ashgate: Aldershot. p53

these procedures is influenced by familiarity with, and accessibility of the procedures. In this case, the train control personnel had no quick reference guides or checklists to assist in diagnosing the situation (to then determine which module would apply), nor was the document organised in a way that facilitated ease of identification of required actions and their sequencing. As Burian et al (2005) identify:

Human performance capabilities and limitations under high stress and workload should...influence the design and content of emergency and abnormal checklists and procedures. Obviously, attention should be given to the wording, organization, and structure of these checklists to ensure that directions and information are complete, clear, and easy to follow and understand.⁵⁶

The investigation established that some train control personnel referred to the Derailment procedure, whilst another followed the Overhead Line Equipment Emergency procedure. Other staff did not make use of the Specification, but instead relied on memory and experience to guide their actions. In some instances, this resulted in a lack of clarity as to allocation and priority of responsibilities and tasks, as well as some ineffective communications.

The effective management of an emergency situation from a location remote to the event presents a number of challenges for the train control staff, primarily related to ensuring that timely and accurate information is available, communicated, and understood, and that the response is handled in an efficient and coordinated manner. To that end, it is critical that standard procedures are in place, but it is equally critical that those procedures are designed to accommodate human performance limitations in conditions of high stress and/or workload, and that they are well understood through staff training and well-practised through field based and desk-top exercises.

Preparedness and role of customer service staff in emergency response

Train control and train crew personnel undertake theory and discussion based training and examination on their knowledge of the content of the Specification on an annual or 18 monthly basis respectively. Customer service personnel do not undertake training in emergency response for rail safety emergency events. Their role in a rail emergency was understood to be solely one of initial notification to Train Control, and thereafter to follow direction provided.

In accordance with their training, customer service staff at Cleveland station performed the notification task by placing a call to the network control emergency phone number. However, it should be also recognised that following the collision, it was the station customer service staff who were required to not only ensure that train control personnel were provided with ongoing accurate and relevant information, but also to direct and control the events on-site until the arrival of emergency services personnel, and the appointed 'QR Commander'.

The ATSB's investigation found no:

...evidence of staff at Cleveland station having any Emergency Management Plan or training prior to the date of the incident. Station staff at Cleveland station may have had local operating procedure knowledge but this would have only dealt with fire evacuations.⁵⁷

Interview evidence suggested that Cleveland station staff were well versed in station evacuation procedures, but staff had a limited understanding of other functional areas' roles and responsibilities, or of the processes to be implemented in a rail safety emergency. As a result, the station customer service staff members' capacity to assist in effectively managing the event was compromised.

Shortfalls in training for Queensland Rail's customer service staff to respond appropriately to a rail safety emergency were previously highlighted by the level crossing collision at Banyo in September 2012, wherein lines of communication as well as clarity of communication between

⁵⁶ Burian, B., Barshi, I., & Dismukes, K. (2005). *The Challenge of Aviation Emergency and Abnormal Situations*. NASA Ames Research Center. [128.102.119.100/flightcognition/Publications/BurianTM_final.pdf](https://www.nasa.gov/pubs/20050110main_flightcognition_publications_burian_tm_final.pdf)

⁵⁷ Queensland Rail/ATSB email correspondence 09 Sep 13

station customer service staff, train crew and network control staff were found to be problematic.⁵⁸ On both occasions, the accurate communication of relevant information to network control was compromised by an incomplete understanding of the response requirements on the part of the customer service staff members.

In order to ensure that the information provided to train control is reliable and efficient, and that they are sufficiently equipped to manage the initial response to on-site issues resulting from rail safety events, customer service staff require a more comprehensive understanding of the emergency management response plans and procedures for rail safety emergencies.

Exercising simulated emergencies

The exercising of emergency response plans and procedures by the conduct of simulated events is critical to the ongoing evaluation and review of procedures, and in ensuring that involved personnel are prepared to meet their individual and team responsibilities to ensure an effective and efficient response to a real event.

Interview evidence indicated that of the key personnel involved in responding to this event, one recalled having been involved in one desktop emergency management exercise during his employment with Queensland Rail. However this exercise was related to managing a bomb threat at a station, rather than a rail transport emergency. None of the personnel interviewed could recall participating in any deployment type⁵⁹ (or field) emergency response exercises related to rail safety events within the past 10 years.

This interview evidence was consistent with documented evidence provided by Queensland Rail which demonstrated methodical and comprehensive exercising of customer service and corporate staff emergency response to security related emergency events, but demonstrated limited focus on the exercising of emergency response to rail safety occurrences incorporating train control and train crew personnel. The evidence made available of exercises related to rail safety occurrences was limited to a small number of discussion and desktop exercises, and did not incorporate any combination of train control, train crew, or customer service personnel.

The investigation found that had key personnel at train control, train crew, and customer service personnel been provided with opportunity to exercise their responsibilities, tasks, and communications both within and between functional areas, it is likely that they would have been better equipped to manage the response to the collision in a more coordinated manner.

Actions and interactions of train control personnel

The first notification to train control of the collision came from the train driver to the train control operator over the radio. However, neither the train control operator nor the train control supervisor realised the severity of the event at this point. The train control operator was made aware that the train had collided with the buffer stop, but did not realise from that communication that the train had passed into the station, destroying station infrastructure and causing the overhead power line to collapse.

It was not until the emergency call from the customer service attendant at Cleveland station came through to the emergency phone at the train control centre that the extent of the damage to station infrastructure became apparent. The emergency phone was located at the desk of the train control

⁵⁸ Transport and Main Roads (2013). *Serious Injury Collision, St Vincents Road, Banyo. 14 September 2012. Final report, rail incident investigation TMR 4617.* tmr.qld.gov.au/~media/Safety/railsafety/safetyreports/banyonvestigationreport.pdf

⁵⁹ The hierarchy of exercises ranges from varying levels of Discussion style (seminars, workshops, syndicate progressive, hypothetical) through to Deployment style (drills, functional exercises; field exercises). Australian Emergency Management Institute. (2012). *Managing Exercises*. Handbook 3: Australian Emergency Management Handbook Series. Attorney General's Department. www.em.gov.au/Publications/Australianemergencymanualseries/Pages/ManagingExercises.aspx

supervisor, and that call was consequently taken by the train control supervisor, rather than the train control operator.

The train control supervisor then proceeded to initiate and direct all further emergency response communications and actions, essentially assuming the communication tasks normally allocated to the train control operator, in addition to those higher level coordination tasks allocated to the supervisor. This resulted in the train control supervisor managing numerous phone calls (many of which were non-critical) whilst also trying to carry out the key emergency response communication tasks.

The train control operator continued to provide control services to the other lines under his control, while still maintaining some communications with the train crew. There was no initiation of processes to reallocate the train control operator's extraneous tasks in order to enable him to focus on the emergency response to this event, nor was there any consideration for this to occur documented within the emergency procedures.

Human information processing is limited in that each person has finite cognitive resources available to attend to information or perform tasks during any particular time period. In general, if a person is focussing on one particular task, then their performance on other tasks will be degraded.⁶⁰ Because the train control operator was required to maintain his normal duties for other trains and lines under his control, his attention to the emergency situation was degraded, which compromised his ability to provide appropriate and timely advice and assistance to the train crew. Similarly, voice communication recordings demonstrate the train control supervisor's divided attention between communicating with the on-site staff while simultaneously arranging for responders to deploy to the site.

There was limited communication between the train control supervisor and the train control operator, probably as a result of the multitude of communications being undertaken by the train control supervisor, as well as the train control operator's competing priorities. During the period between the initial notification call from the customer service attendant at Cleveland station at 0940, and 1045 when the power was confirmed as isolated and earthed and Queensland Fire and Rescue Services were seeking to clear underneath the train, the train control supervisor made or received 38 separate phone calls. He spent over 42 minutes of this 65 minute period in communications with people outside of the network control centre, preventing him from ensuring that the train control operator was being provided with up to date information. Because the train crew's communications were with the train control operator rather than the supervisor, this created an opportunity for critical misinformation to be passed to the train crew. Further, customer service staff members and the spare driver at Cleveland station had no further communication or direction from train control after the initial notification phone call at 0940, until the arrival of the incident commander at 1021.⁶¹

Both interview and recorded evidence also indicated that noise levels in the train control centre that morning were such that it was not conducive to the clear thinking required to effectively manage the situation.

The effective management of an emergency situation from a remote location requires clear and well understood standardised procedures and communication protocols both internally and externally. Queensland Rail's emergency management procedure specified roles and responsibilities for a number of key personnel at train control. As the emergency at Cleveland station unfolded, these roles and responsibilities were either not understood, or were informally redistributed, causing confusion and miscommunication. Specifically, the train control operator was not supported to perform his specified communications role, due to continuing responsibilities to control other lines; and the train control supervisor assumed responsibilities outside of his

⁶⁰ Kahneman, D. (2011). *Thinking Fast and Slow*. Farrar, Straus & Giroux: New York.

⁶¹ There was evidence of an attempted call from the train control supervisor to the station master at 1004.

scope, resulting in compromised ability to effectively communicate with the key personnel within the network control centre, and at the accident site.

Managing and communicating OHLE status

The actions of the electrical control personnel in responding to this event were closely in accordance with the procedure outlined in the Specification for OHLE emergencies. Similarly, when communicating to the emergency site about the status of the OHLE, the electrical control operator utilised standard phraseology and direct, clear language, describing the status of the OHLE and its implications for safety.

However, whilst the electrical control personnel demonstrated a sound understanding of standard procedures and terminology related to OHLE, some other personnel did not. A communication between the guard and the train control operator did not incorporate the standardised terminology, resulting in a misunderstanding as to the status of the OHLE. In response to an enquiry from the guard, the train control operator affirmed that the overhead power had been ‘switched off.’ In the confusion of the situation, the guard interpreted this to mean that it was safe, and shortly thereafter proceeded to assist the two passengers from the rear car set to disembark the train onto the platform. The overhead power lines were at that time still considered by the electrical control operator to be live, having been de-energised, but not yet isolated and earthed. This miscommunication therefore had the potential to cause serious injury through electrocution.

The train control operator only became aware that this was a safety issue after being incidentally informed by another controller who had overheard that the lines were only de-energised. The status of the overhead power lines had either (a) not been clearly communicated to the train control operator by either the electrical control operator, or the train control supervisor, or (b) in the confusing, high workload situation, the train control operator did not grasp the meaning of the information in terms of electrical safety and the implications for evacuation of passengers. When the train control operator was later informed, he passed this information to the train driver. The driver informed the guard and the remaining passengers, who then remained inside the train until evacuated by emergency services personnel.

Acknowledging the criticality of ensuring the safety of OHLE via the deployment of a linesman to perform the isolation and earthing functions, the time taken to undertake this function was almost a full hour after the collision event occurred. Had the train crew or passengers sustained more serious and time critical injuries as a result of the collision, the time delay to ensure the electrical safety of the site may have compromised the recovery and treatment of those people.

Criticality of efficient and standard communication protocols

In the course of the investigation, a number of communication issues during the initial emergency response became apparent, both within the train control centre, and between train control and the emergency site.

The location and accessibility of various communications equipment in the train control centre led to the informal redistribution of communication tasks documented in the Emergency Management Specification. The Specification identifies the train control operator as being the central point of communication between network control and the emergency site, with higher level associated support activities being undertaken by the supervisor and manager. However, customer service staff have no available means of direct communications with the train control operator; the emergency line is accessed by the train control supervisor.

The number and complexity of communications undertaken by the train control supervisor inhibited his ability to effectively manage communication of key information with the train control operator and with staff at the emergency site. Further, the train control operator’s responsibilities were divided between managing the emergency and providing control services to other trains on the network; compromising his attention to providing the central communications function.

Communication between the train control supervisor and the train control operator was degraded due to both staff members' workloads. This lack of coordination at network control led to uncoordinated and inconsistent communication with various staff at the site, and specifically resulted in inaccurate information being passed to the guard regarding the status of the OHLE.

There was no appointment of an on-site coordinator at the site to act as a central point of communication during the initial response.⁶² Communications to network control from the site originated from a number of different staff, including the customer service attendant, the spare driver, the driver, and the guard, all of whom were performing different tasks with limited coordination. The spare driver was the only Queensland Rail employee apart from the train crew who identified himself during communications with train control (he was still later in the same communication, mistaken for the guard by personnel at train control). As a result, the train control supervisor had limited ability to ensure that direction provided to personnel on site had been enacted or passed on to other staff at the site.

Customer service staff knowledge of the most direct and effective means of communication with network control was variable, as was their knowledge about the type of information required, and communication protocols required. There was considerable confusion at the site as to the status of the OHLE and implications for electrical safety.

Voice communications between train control and Queensland Rail staff at the emergency site were characterised by informal and passive language, as well as non-standardised phraseology. In general, the communication techniques employed did not foster confirmation of understanding between the parties, which led to misunderstandings with regard to the status of the OHLE, but also to incomplete and ambiguous messages being passed. For example, when the train control operator became aware that the status of the OHLE was such that it was not yet electrically safe to disembark passengers, his communication of this to the train driver was, 'I'd be very inclined not to let anyone out onto that platform, Mate; even though we've had word that it's been isolated...', whereas the criticality of this message was better suited to a more directive communication style. There was also evidence of the train control operator conducting several communications at the one time, which created inefficient and sometimes confusing communications.

Opportunities for organisational learning about emergency management

In contrast to Queensland Rail's Train Operations Internal Debrief, the ATSB investigation found that the procedures detailed within Queensland Rail's Emergency Management Specification were not entirely reflected in the actions of train control personnel who managed the response to the event. Whilst the overall management of the emergency response was effective, a number of shortfalls became apparent, particularly with regard to allocation of tasks between the train control operator and the train control supervisor, as well as effectiveness of communication within train control and between train control and the site, hampered by the lack of clear identification of an on-site coordinator. Much of this can be attributed to a lack of familiarity with the procedures, and not having had opportunity to test the effectiveness of the procedures in a cross-divisional exercise. Further, the role of customer service staff in responding to a rail transport emergency occurring at a station was not sufficiently considered and prepared for.

⁶² An onsite coordinator was appointed at 1021 with the arrival on site of Queensland Rail incident management staff. This appointment was not initiated by the train control operator, nor by the train control supervisor, but by the manager, rail operations response unit, who communicated this to the train control supervisor. This person was also then generally referred to as the incident commander in further communications from train control.

Findings

From the evidence available, the following findings are made with respect to collision of train T842 with the station platform at Cleveland and should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance.

A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- Local environmental conditions resulted in the formation of a contaminant substance on the rail running surface that caused poor adhesion between the train's wheels and the rail head.
- **Queensland Rail's risk management procedures did not sufficiently mitigate risk to the safe operation of trains when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion. [Safety issue]**
- **Poor wheel/rail adhesion was not recognised as a risk in any of Queensland Rail's risk registers and therefore this risk to the safety of rail operations was not being actively managed. [Safety issue]**
- **Despite numerous occurrences of slip-slide events in the years leading up to the accident at Cleveland, Queensland Rail's risk management processes did not precipitate a broad, cross-divisional, consideration of solutions to the issue including an investigation of the factors relating to poor wheel/rail adhesion. [Safety issue]**
- **Queensland Rail's strategic risk monitoring and analysis processes were ineffective in precipitating appropriate safety action to the findings and recommendations of their investigations into the Beerwah SPADs in 2009 which identified wheel/rail adhesion issues. [Safety issue]**
- **Queensland Rail's strategic risk monitoring and analysis processes were ineffective in identifying safety issues pertinent to their fleet from rail safety occurrences in other jurisdictions involving poor wheel/rail adhesion. [Safety issue]**
- **The mass of the two IMU or SMU class train units travelling on the Cleveland line was commonly heavier than the design specification of the buffer stop at Cleveland station. It is probable that Queensland Rail's risk management systems did not consider this design criterion for these train configurations arriving at Cleveland station. [Safety issue]**

Other factors that increased risk

- **The Queensland Rail driver's manual did not explain the effects of low adhesion at the wheel/rail interface, how low adhesion is a precursor to prolonged wheel slide events and why these elements reduce the likelihood of achieving expected braking rates. [Safety issue]**
- During the period immediately following the collision there were a series of communication issues which resulted in incomplete information being provided to key personnel. This resulted in the train control operator and train guard miscommunicating the status of the downed overhead power lines, leading to the guard permitting some passengers to exit the train before emergency services had ensured it was safe to do so.
- **The successful management of an emergency event from a remote location is critically dependent on clear and effective communication protocols. Communications within train control, and between train control and Cleveland station, were not sufficiently coordinated and resulted in misunderstandings at the Cleveland station accident site. [Safety issue]**
- **Emergency management simulation exercises to test the preparedness of network control staff, train crew, and station customer service staff to respond cooperatively to rail safety emergencies had not been undertaken in accordance with the Queensland Rail Emergency Management Plan. [Safety issue]**

- **The Queensland Rail internal emergency debrief following the Cleveland station collision identified issues related to working with external agencies but did not address critical communication shortfalls within train control and between train control and the staff located at the Cleveland station accident site. [Safety issue]**
- The Department of Transport and Main Roads did not adequately review and assess Queensland Rail's investigation into the Beerwah SPADs in 2009 to ensure that Queensland Rail had processes in place to control the significant safety risks associated with wheel/rail adhesion.
- **The national rail occurrence standard and guidelines (ON-S1/OC-G1) do not include significant train wheel slip/slide occurrences as a notification category/type which has the potential to lead to rail safety regulators being unaware of significant and/or systemic safety issues related to wheel/rail adhesion. [Safety issue]**

Other findings

- Analysis of the train driver's actions on approach to Cleveland station with respect to speed and braking indicates that they were consistent with sound driving practice and did not contribute to the accident.
- Analysis of available data found that the operation of the braking systems on train T842 was consistent with the test train and system design parameters.
- Deceleration and stopping distance tests of IMU 160 and SMU 260 class trains were not carried out strictly in accordance with procedures and instructions developed by the train manufacturer or brake equipment supplier.
- Some wheel and rail samples were contaminated but this did not prevent examination and discovery of valid information. Samples should be collected by the application of sound forensic scientific principles as soon as possible and where practical before the accident scene is disturbed.
- Components of the on-board data from train T842 were unreliable but in this instance data from other sources was available for validation purposes. Ideally, data recording systems should be maintained and periodically audited to ensure currency and accuracy.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

Directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Queensland Rail provided a response on 1 March 2013 detailing the initiation of targeted precautionary mitigation strategies in response to the collision of train T842 at Cleveland station on 31 January 2013. On 24 May 2013, in accordance with s25A (2) of the *Transport Safety Investigation Act 2003*, Queensland Rail provided an update to their initial response within 90 days of the publication of the ATSB's preliminary report and these responses are contained in the appendices of this report.

Management of risk associated with poor adhesion

Number:	RO-2013-005-SI-01
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - Passenger - Metropolitan
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

Queensland Rail's risk management procedures did not sufficiently mitigate risk to the safe operation of trains in circumstances when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion.

Response to safety issue by Queensland Rail

Queensland Rail has implemented a procedure for Network maintenance staff to identify, treat and prevent rail contaminants at source. Network Control are advised when contaminants are identified and these are removed as soon as it is safe and practicable to do so. The procedure has been communicated to relevant Queensland Rail staff and a cross-divisional standard has been implemented which details the specific actions required whenever a wheel slide occurs and/or rail contaminants are identified.

Queensland Rail is currently trialling a sanding system on a 3-car unit to determine whether this technology mitigates the risks of wheel slide by improving adhesion at the wheel rail interface. Stage 1 of the testing is now complete with a preliminary report due for completion in December 2013. Pending results of the trials, Queensland Rail anticipates calling tenders for the supply and fitment of a sanding system to railcars by the end of January 2014.

ATSB comment in response:

The ATSB notes that Queensland Rail trialling a system to mitigate the risk of reduced wheel/rail adhesion due to environmental conditions, but the solution is yet to be fully implemented.

The ATSB is satisfied that the action proposed by Queensland Rail will, when complete, adequately address the safety issue. The ATSB will monitor the progress of the proposed safety action.

Current status of the safety issue:

Issue status: Details of the current status of this safety issue are available at www.atsb.gov.au.

Assessment and recording of rail safety risks

Number:	RO-2013-005-SI-03
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

Poor wheel/rail adhesion was not recognised as a risk in any of Queensland Rail’s risk registers and therefore this risk to the safety of rail operations was not being actively managed.

Response to safety issue by Queensland Rail

Queensland Rail has implemented a Discipline Head Framework. The Discipline Head framework includes separate risk registers for each of nine specific disciplines. The development of these registers takes into account risks, causes and controls identified in current Queensland Rail risk registers. The controls identified in these registers form the Queensland Rail Safety and Environment Management System.

Each discipline head is responsible for identifying discipline specific risks and controls. To ensure a cohesive approach to risk management, risk registers are shared between discipline heads to ensure that no gaps exist in the identification, assessment and control of safety risks. This process ensures that cross-discipline risks are identified, assessed and controlled.

ATSB comment in response:

The ATSB notes that Queensland Rail has implemented a system of discipline specific risk registers with processes to ensure cross-discipline risks are identified, assessed and controlled. However, no evidence was provided that demonstrated poor wheel/rail adhesion had been recognised as a risk under the new risk management framework.

ATSB safety recommendation to Queensland Rail:

Action number: RO-2013-005-SR-014

Action status: Monitor

The Australian Transport Safety Bureau recommends that Queensland Rail undertake further work to ensure poor wheel/rail adhesion is recognised, assessed and controlled under the new risk management framework.

Cross divisional recognition of rail safety risks

Number:	RO-2013-005-SI-04
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

Despite numerous occurrences of slip-slide events in the years leading up to the accident at Cleveland, Queensland Rail's risk management processes did not precipitate a broad, cross-divisional, consideration of solutions to the issue including an investigation of the factors relating to poor wheel/rail adhesion.

Response to safety issue by Queensland Rail

Following the collision at Cleveland, Queensland Rail implemented procedures to manage and reduce the incidence of wheel slide events. The procedures applied to rail traffic crew, network control officers, network maintenance staff, rolling stock engineers and rail safety management staff. Research conducted by two universities on wheel/rail contamination and work by the Wheel Rail Interface Working Group prepared a standard for the management of wheel slide events. This standard (Management of Rail Traffic Wheel Slide Events) applies to all Queensland Rail business groups and train operations. All instances of wheel slide on the network are reported and recorded. The new standard requires every wheel slide event greater than 6-cars (about 150 m) to be investigated including analysis of train event recorder information to determine the probable cause.

ATSB comment in response:

The ATSB notes that a new standard for the management of wheel slide events has been implemented with respect to recording wheel slide events, but is not yet mature at assessing, reviewing and implementing solutions associated with poor wheel/rail adhesion.

The ATSB is satisfied that the action taken by Queensland Rail will adequately address the safety issue. The ATSB will monitor the progress of the safety action.

Current status of the safety issue:

Issue status: Details of the current status of this safety issue are available at www.atsb.gov.au.

Application of safety actions from internal investigations

Number:	RO-2013-005-SI-05
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

Queensland Rail's strategic risk monitoring and analysis processes were ineffective in precipitating appropriate safety action to the findings and recommendations of their investigations into the Beerwah SPADs in 2009 which identified wheel/rail adhesion issues.

Response to safety issue by Queensland Rail

Qld Rail is implementing a newly developed Governance Risk and Compliance (GRC) project. The GRC project is designed to improve access and the quality of our governance, risk and compliance systems across all functional and corporate functions. The GRC will provide clear accountability of required actions including timeframes for completion. A number of existing systems will be decommissioned and consolidated under the GRC project.

The GRC system houses the outcomes and remedial actions stemming from rail safety investigations which will be monitored and tracked through to completion to ensure all relevant actions are undertaken, within the prescribed timeframes. The GRC system provides a systemic risk management database with greater visibility across the organisation to ensure adequate linkages of identified corporate risks and controls to mitigate those risks.

ATSB comment in response:

The ATSB notes that the new Governance Risk and Compliance system is yet to be fully implemented so that findings of investigations which identify safety issues can be appropriately actioned and monitored.

ATSB safety recommendation to Queensland Rail

Action number: RO-2013-005-SR-016

Action status: Monitor

The Australian Transport Safety Bureau recommends that Queensland Rail undertake further work to address this safety issue.

Awareness of rail safety occurrences in other jurisdictions affecting rail fleet type

Number:	RO-2013-005-SI-007
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

Queensland Rail's strategic risk monitoring and analysis processes were ineffective in identifying safety issues pertinent to their fleet from rail safety occurrences in other jurisdictions involving poor wheel/rail adhesion.

Response to safety issue by Queensland Rail

The Interim Appraisal Report of the Wheel Rail Interface Working Group has identified a range of measures to better identify and subsequently mitigate risks associated with specific types of rolling stock within our fleet including learnings from other jurisdictions nationally and internationally. Queensland Rail advised that further work in relation to these learnings is to be undertaken.

ATSB comment in response:

The ATSB notes that Queensland Rail continues to research and where appropriate implement findings and recommendations from investigations of wheel slide events from other jurisdictions and learnings of Wheel Rail Interface Working Group.

The ATSB is satisfied that the action proposed by Queensland Rail will, when completed, adequately address the safety issue. The ATSB will monitor the progress of the proposed safety action.

Current status of the safety issue:

Issue status: Details of the current status of this safety issue are available at www.atsb.gov.au.

Buffer stop design criterion

Number:	RO-2013-005-SI-006
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - Passenger - Metropolitan
Who it affects:	All infrastructure owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

The mass of the two IMU or SMU class train units travelling on the Cleveland line was commonly heavier than the design specification of the buffer stop at Cleveland station. It is probable that Queensland Rail's risk management systems did not consider this design criterion for these train configurations arriving at Cleveland station.

Response to safety issue by Queensland Rail

The technical design of the buffer stop at Cleveland station at 31 January 2013 was 5 km/h with a 200 t train service. Friction element buffer stops have been installed at Cleveland stations that are now able to arrest a train weight of 255 t with a maximum impact speed of 15 km/h.

Permanent speed boards displaying 15 km/h at the approach to Cleveland Station have been installed to align with the newly installed buffer stops.

ATSB comment in response:

The ATSB is satisfied that the action taken by Queensland Rail addresses this safety issue.

Action status: Closed

Driver’s manual explanation of effects and control of low adhesion

Number:	RO-2013-005-SI-09
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip-slide protection control.

Safety issue description:

The Queensland Rail driver’s manual did not explain the effects of low adhesion at the wheel/rail interface, how low adhesion is a precursor to prolonged wheel slide events and why these elements reduce the likelihood of achieving expected braking rates.

Response to safety issue by Queensland Rail

Train drivers are trained to drive to the environmental conditions including effective use of the train’s wheel slip-slide protection system. Following the Cleveland collision, rail traffic crew (RTC) received a safety critical notice detailing the train handling procedure for low adhesion conditions specific to the IMU160/SMU 260 class. Debriefing sessions were provided to RTC on the learnings from the Cleveland collision incident regarding wheel/rail adhesion. Updates regarding progress on the recommendations of the Rail Interface Working Group were also provided to the RTC on a regular basis.

Under Queensland Rail's Safety and Environment Management System, a standard details the required actions for RTC, network control, network maintenance staff, rolling stock engineers and rail safety management following a wheel slide event. These actions were documented following the release of the ATSB's preliminary report into the Cleveland collision incident and communicated to relevant stakeholders. The procedures have also been incorporated in Queensland Rail's Train Management Manual.

ATSB comment in response:

The ATSB is satisfied that the action taken by Queensland Rail addresses this safety issue.

Action status: Closed

Effective coordination of emergency communications

Number:	RO-2013-005-SI-10
Issue owner:	Queensland Rail Limited
Operation affected:	Rail – Operations Control
Who it affects:	All railway network owners and operators responsible for the management and coordination of operational training and emergency communications.

Safety issue description:

The successful management of an emergency event from a remote location is critically dependent on clear and effective communication protocols. Communications within train control, and between train control and Cleveland station, were not sufficiently coordinated and resulted in misunderstandings at the Cleveland station accident site.

Response to safety issue by Queensland Rail

Queensland Rail has implemented an Emergency Preparedness and Response Plans (EPRP) for all City Network Stations. Training has been conducted and a process put in place to ensure the contents of the EPRP are reviewed and discussed regularly at focus group meetings and toolbox talks.

Queensland Rail continues to develop and implement a single integrated process to address communication protocols within the network control centre and between the network control centre and an emergency site. The process includes incident management, site preservation and protection during response and recovery.

ATSB comment in response:

The ATSB notes that Queensland Rail continues to develop effective internal communication protocols to prevent misunderstandings between staff during an emergency incident response.

ATSB safety recommendation to Queensland Rail

Action number: RO -2013-005-SR-021

Action status: Monitor

The Australian Transport Safety Bureau recommends that Queensland Rail undertake further work to address this safety issue.

Emergency management exercises

Number:	RO-2013-005-SI-11
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All railway network owners and operators responsible for the management and coordination of operational training and emergency communications.

Safety issue description:

Emergency management simulation exercises to test the preparedness of network control staff, train crew, and station customer service staff to respond cooperatively to rail safety emergencies had not been undertaken in accordance with the Queensland Rail Emergency Management Plan

Response to safety issue by Queensland Rail

Queensland Rail has conducted two cross-business emergency exercises including a tunnel evacuation in October 2013 and a strategic desktop exercise in December 2013. Representatives from operations, customer corporate and the emergency services were participants in both

exercises. The Emergency Management Unit has implemented site specific Emergency Preparedness and Response Plans at all SEQ stations including the development of localised incident management teams for local exercises. Short emergency scenario exercises have been developed for local managers to encourage cross-business participation.

Queensland Rail has developed a single integrated process to address communication protocols within the network control centre and between the network control centre and an emergency site.

Queensland Rail provided the ATSB with a copy of the Emergency Exercise Schedule for years 2013 and 2014. The schedule demonstrates the inclusion of internal business units and personnel working with external agencies for rail safety and security desk top and field type exercises. The schedule is regularly reviewed and adapted in accordance with operational requirements based on identified and emerging risks.

ATSB comment in response:

The ATSB is satisfied that the action taken by Queensland Rail addresses this safety issue.

Action status: Closed

Post emergency debrief and findings

Number:	RO-2013-005-SI-12
Issue owner:	Queensland Rail Limited
Operation affected:	Rail - All
Who it affects:	All railway network owners and operators responsible for the management and coordination of operational training and emergency communications.

Safety issue description:

The Queensland Rail internal emergency debrief following the Cleveland station collision identified issues related to working with external agencies but did not address critical communication shortfalls within train control and between train control and the staff located at the Cleveland station accident site.

Response to safety issue by Queensland Rail

Queensland Rail has implemented an Emergency Preparedness and Response Plans (EPRP) for all City Network Stations and continues to implement an integrated process for addressing communication protocols during emergence incident response.

Lessons learnt during incident debriefing will be captured in Queensland Rail's newly developed Governance Risk and Compliance (GRC) system which will replace a number of existing systems currently capturing this information.

ATSB comment in response:

The ATSB notes that Queensland Rail is developing a Governance Risk and Compliance system and that this system aims to address communication shortfalls between staff located at network control and accident sites.

ATSB safety recommendation to Queensland Rail

Action number: RO -2013-005-SR-023

Action status: Monitor

The Australian Transport Safety Bureau recommends that Queensland Rail undertake further work to address this safety issue.

Occurrence notification standard and guideline

Number:	RO-2013-005-SI-08
Issue owner:	The Office of the National Rail Safety Regulator
Operation affected:	Rail - All
Who it affects:	Railway safety regulators and railway network owners and operators responsible for the classification and review of railway occurrence notifications.

Safety issue description:

The national rail occurrence standard and guidelines (ON-S1/OC-G1) do not include significant train wheel slip/slide occurrences as a notification category/type which has the potential to lead to rail safety regulators being unaware of significant and/or systemic safety issues related to wheel/rail adhesion. [Safety issue]

Response to safety issue by the Office of the National Rail Safety Regulator

The ONRSR agrees to review and include more explicit guidance on slip-slide events in the appropriate existing categories of the ON-S1 Standard and OC-G1 Guidelines.

The ONRSR will furthermore consider the need to establish a specific category for slip-slide occurrences as part of the national data strategy review.

ATSB comment in response:

Action status: Closed

General details

Occurrence details

Date and time:	31 January 2013 0940	
Occurrence category:	Accident	
Primary occurrence type:	Collision	
Location:	Cleveland railway station, Brisbane, Queensland	
	Latitude: 27° 31.455' S	Longitude: 153° 15.975' E

Train: T842

Train operator:	Queensland Rail Limited	
Registration:	T842	
Type of operation:	Rail - Passenger - Metropolitan	
Persons on board:	Crew – 2	Passengers – 17
Injuries:	Crew – 1	Passengers – Multiple minor injuries
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Bureau of Meteorology
- Queensland Rail Limited
- Queensland Department of Transport and Main Roads

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Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to: Queensland Rail Limited, the Department of Transport and Main Roads and the Office of the National Rail Safety Regulator.

Submissions were received from Queensland Rail Limited, the Department of Transport and Main Roads and the Office of the National Rail Safety Regulator. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A - Safety issues update

Queensland Rail's response to the ATSB's preliminary report published on 13 March 2013

The formation of a Wheel Rail Interface Working Group. The Working Group, sponsored by the Executive General Managers - Rail Operations and Safety, Assurance and Environment, is tasked to specifically identify and assess any potential wheel rail interface risks, particularly for Queensland Rail's fleet of IMU160/SMU260 class trains being operated in certain conditions, and to determine if any further engineering, administrative or other safety risk controls should be considered and implemented.

The Working Group comprises a range of internal and external stakeholders including rolling stock, rail network, and train service delivery engineers, technicians and managers; key rail union representatives from the Rail Tram and Bus Union and Australian Federated Union of Locomotive Employees; and an experienced independent rail safety risk management consultant. The Working Group is also supported by a range of subject matter expertise including for program, risk, safety and human resource management and train manufacturer Bombardier. It is important to note that Queensland's Rail Safety Regulator also has a nominated observer on the Working Group to ensure Queensland Rail continues to effectively manage its rail safety risks.

The Working Group's key deliverables, as outlined within its Terms of Reference are to develop:

A list of evidence based hazards and the likelihood of future risk associated with IMU160 and SMU260 class units

- A plan of control, addressing future risk, prioritised and classified as short, medium and long term controls
- Any plan of control needs to provide mitigation strategies which focus on safety, customer service and service continuity.

One of the Working Group's first tasks was to develop a comprehensive risk assessment of any potential wheel rail interface issues for the IMU160/SMU260 class of trains operating on the network and their associated safety risk controls. The risk assessment was independently validated and recommended a number of precautionary risk controls to be adopted, in addition to existing controls, whilst further medium and longer term testing and assessments continued. These precautionary risk controls include:

Identify and treat track rail-head contaminants at any localised black spot locations.

- Build track contaminant risk identification into routine track inspection processes to help inform track gangs to be on the lookout for related contaminants.
- Assess whether current vegetation control processes have the potential to cause or contribute to contamination of the rail.
- Ensure there are no parts of the network where train crews are exposed to acute reductions in line speed without receiving advance graduated speed reduction notice.
- Provide train crews of IMU160/SMU260 fleets with enhanced train handling advice that when approaching stop signals and other critical points, that they should aim to reduce speed to 50% of line speed when observing a single yellow signal and, not exceed 30 km/per hour when within 150 metres of red signals/critical stopping points, unless a lower speed is indicated, in which case the lower speed applies.

- Review current driver training processes and adapt training materials to specifically address any identified class IMU160/SMU260 unique characteristics.
- Encourage train crew to report all excessive wheel slip occurrences on IMU160/SMU260 fleet.
- Monitor and further analyse data logger information of trains, as per new explanatory procedure if they are subject to an excessive wheel slip occurrence.
- Continue research to ascertain whether IMU160/SMU260 class train brakes are releasing long enough in wheel slip scenarios for the wheel sets to recover prior to the brake system reapplying brakes.
- Research wheel cleansing modification opportunities.
- Review planned new generation rolling stock specifications to ensure current wheel slip lessons learnt are considered.
- Review train crew training around:
 - Known fleet specific hazards and fleet characteristics; and
 - Defensive driving techniques

Queensland Rail's Executive General Management had no hesitation in accepting all of these recommended precautionary controls and ordered their immediate implementation.

- Queensland Rail continues to test and assess wheel rail interface risks around its IMU160/SMU260 class fleet including reviewing what possible further controls should be implemented.
- In addition to these wheel rail interface controls and processes, Queensland Rail also provided a Critical Safety Alert to staff regarding the importance of both providing and following documented Safety Management System instructions whenever an incident is or may be impacted by overhead electrical infrastructure.

Queensland Rail also continues to fully support and coordinate with the ATSB in its ongoing investigation.

Appendix B – Other investigations

RAIB - Esher, United Kingdom

At approximately 0630 on Friday 25 November 2005, train 1A12, passed signals WK338 and WK336 at danger on the up fast line between Esher and Hampton Court Junction. Train 1A12 stopped under the Hampton Court Junction flyover, having passed signal WK338 by a distance of approximately 1050 m and signal WK336 by a distance of approximately 200 m. After passing signal WK336 at danger, train 1A12 approached to within 200 metres of train 2F08, a service from Woking to Waterloo, which had crossed from the up slow to the up fast line at Hampton Court Junction. Nobody was injured in the incident and there was no damage to the infrastructure or rolling stock.

The findings of the RAIB investigation into the incident found the immediate cause of the incident was low adhesion on the up fast line between Hersham station and Hampton Court Junction. (The SPAD at Esher occurred on the worst day for adhesion-related incidents during autumn 2005, with 42 incidents being recorded nationally).

Causal factors were:

The presence of contaminants on the rail head of the up fast line which resulted in a level of adhesion no higher than 0.03 being available over a distance of approximately 2000 metres where train 1A12 was braking for signal WK338 at danger (paragraph 71

No rail head treatment of the up fast line between Woking and Surbiton (paragraph 53). This factor has already been satisfactorily addressed by Network Rail (paragraph 92).

The following factors were considered to be contributory:

Neither Network Rail nor SWT had any knowledge of the low adhesion conditions on the up fast line between Hersham and Esher until train 1A12 was required to slow in the area (paragraph 57). The Part 3 report addresses the issue of monitoring for low adhesion conditions.

The professional driving policy of SWT was not optimal for low adhesion conditions, given the characteristics of the sanding equipment on the Class 450 EMU (paragraph 49). The Part 3 report addresses professional driving in low adhesion conditions

RAIB - Lewes, United Kingdom

Shortly after 1907 on Wednesday 30 November 2005, train 2D45 passed signal LW9, located at the end of Platform 3 at Lewes station, at danger. After passing Signal LW9 at danger, train 2D45 ran through 75 points which were not set for the passage of the train. Train 2F21 had departed from platform 5 at Lewes station on time at 1907 and was approaching 76 points when the driver heard train 2D45 approaching and, realising that the two trains were on a conflicting route, stopped some 30 m from the point of conflict. Train 2D45 ran through 77 points (which had been set for train 2F21 to depart from Platform 5 towards Seaford), stopping with the front of the train approximately 30 metres beyond the points. There were no reported injuries in the incident and points 75 and 77 were damaged when the train ran through them. The immediate cause of the incident was found to be low adhesion on the rail head of the down line between Falmer Bank and Lewes.

The investigation found the causal factors were:

- The presence of contaminants on the rail head of the down line resulted in an average level of adhesion of less than 0.02 available over the section of line where train 2D45 was braking.
- The configuration of the sanding system of the Class 377 train unit only allowed for ten seconds sanding throughout the entire period that train 2D45 was sliding. (Limitations in the period of sanding while trains are WSP active had been recognised. A program to

extend the sanding duration up to 60 s had been commenced, although this train unit had not been modified at the time of this occurrence).

- The change in weather conditions immediately before train 2D45 ran over the down line between Falmer Bank and Lewes exacerbated the effects of the contamination that already existed on the rails.

In addition, the following factors were considered to be contributory:

The professional driving policy of the operator, which did not take account of the benefits of rapidly increasing braking under low adhesion conditions and the gradient of 1 in 84 on Falmer Bank.

RAIB - Review of adhesion-related incidents during autumn 2005

The RAIB carried out an investigation into the causes of adhesion related station overruns and Signal Passed At Danger (SPAD) incidents during autumn 2005. The investigation found the immediate cause of the SPAD incidents that occurred at Esher on 25 November 2005 and Lewes on 30 November 2005 was poor adhesion between wheel and rail. In both instances the trains involved had failed to stop within normally expected distances, despite the systems on the train performing in accordance with their specifications and the drivers correctly implementing the professional driving policy.

These events were components of an increasing number of adhesion related SPAD incidents and a significant increase in the number of adhesion-related station overrun incidents on the national rail network during autumn 2005, as compared with autumn 2004.

It was found that there was no single immediate cause of the increase in adhesion related incidents during autumn 2005; however there are a number of causal factors:

The immediate causes, contributory factors and issues for concern included:

- Significant lengths of low adhesion were experienced on a number of occasions during autumn 2005 and it is possible that they are now occurring more frequently than has been previously thought to be the case.
- A method for identifying low adhesion areas that was biased towards historical data rather than current conditions or risk.
- Different methods of rail head treatment being employed across the network, arising from uncertainty over the optimum method.
- Inconsistent performance in the prediction of days when the risk of low adhesion incidents was high.

The application of sand is one of the most effective ways of modifying the level of adhesion available to trains experiencing difficulties. However, not all units are equipped with the facility to lay sand and some are specifically excluded by standard GM/RT2461.

The TOCs' understanding of the characteristics of new rolling stock, which affected the way in which drivers were briefed about handling trains in low adhesion conditions and which was not optimal for the configuration of WSP and sanding equipment provided on modern trains.

Recommendations were divided between those that could be implemented in the short term and those that could be implemented in the medium/long term. They related to the following areas:

- measuring and understanding low adhesion conditions;
- methods for determining rail head treatment, including where and how to treat;
- short term and real time prediction of low adhesion conditions including the use of the capabilities of modern rolling stock to provide real time data on adhesion conditions;
- enhancements to standards addressing braking and sanding parameters and configuration;

- configuration of WSP systems and the simulation of WSP performance;
- testing of alternative methods of stopping trains that do not solely rely on the wheel/rail interface;
- rolling stock sanding parameters and configuration;
- development of appropriate professional driving policies;
- investigation into adhesion-related incidents.

Further information and copies of these investigation reports are available from the RAIB website:
www.raib.gov.uk

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Glossary

- Regenerative Brake- This form of braking is when the traction motors are switched over to act as generators and therefore convert the kinetic energy of the train into electricity. In regenerative braking the electricity generated is recycled back into the overhead power supply if there is a difference in potential. This type of braking is affected by traffic density.⁶³
- Friction Brake - Friction braking is achieved by increasing the air pressure in disc brake units (brake cylinders) mounted adjacent to every wheel. An increase in brake cylinder pressure will result in a proportional increase in force being applied to brake blocks that contact the disc brake rotors fitted to the axles resulting in an increase in friction braking effort and an increase in the deceleration rate of the train.⁶³
- Anti-compounding - The parking brake unit is fitted with an anti-compound valve. The anti-compound valve prevents the addition of the force from the parking brake unit to the force from the service brake unit should they both be applied simultaneously.⁶³

⁶³ Rolling stock Engineering QR Services Report, Document No. 200907/P, Version 1.0, Dated 25.08/2009. Source Queensland Rail

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report

Rail Occurrence Investigation

Collision of passenger train T842 with station platform
Cleveland, Queensland, 31 January 2013

RO-2013-005

Final – 20 December 2013