OTSI Office of Transport Safety Investigations

RAIL SAFETY INVESTIGATION REPORT

DERAILMENT OF PACIFIC NATIONAL SERVICE MC92

CLIFTON

23 NOVEMBER 2011

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THE OFFICE OF TRANSPORT SAFETY INVESTIGATIONS

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CONTENTS

TABLE OF PHOTOGRAPHS

TABLE OF FIGURES

GLOSSARY OF TERMS

Ballast	Crushed rock packed under and around sleepers to hold track in position, spread weight, and provide drainage.
Ballast crib	The ballasted area between sleepers.
Bog Hole	A block of severely fouled ballast under and around sleepers in which the pumping action of the sleepers draws in more water and fine mud particles causing the bog hole to grow. The engineering properties of the resultant slurry vary with moisture content. When wet, the lubricated particles may lose their load bearing capacity.
Bogie	A structure incorporating suspension elements and fitted with wheels and axles, used to support rail vehicles at or near the ends and capable of rotation in the horizontal plane. It may have two or more axle sets, and may be the common support of adjacent units of an articulated vehicle.
Data Logger	An electronic or tape recording data or event recording device fitted within rolling stock that is capable of recording certain information relating to the operation and movement of the rolling stock.
Down and Up Directions	Travel by rail away from Sydney is referred to as being in the Down direction. Conversely, travel towards Sydney is referred to as being in the Up direction.
Four foot	The area between the rails of a track.
Gauge	The distance between the inside running (or gauge) faces of the two rails, measured between points 16 mm below the top of the rail heads.
Kilometrage	The track distance measured from the buffer stop at No. 1 Platform in Sydney Terminal (Central Station).
Network Control	The function responsible for managing train paths and issuing occupancy authorities.
Pumping	Sleeper movement where the sleeper moves up and down as rail traffic passes over it. This movement often results in the degradation and contamination of the ballast structure or can result from the same.
Train Controller	A qualified worker who authorises, and may issue, occupancies and Proceed Authorities, and who manages train paths to ensure safe and efficient transit of rail traffic in the RailCorp network.
3-pack	Three permanently coupled wagons.

EXECUTIVE SUMMARY

At approximately 11.56pm[1] on 23 November 2011, Pacific National coal service MC92 derailed eight wagons at Clifton. MC92, a 45-wagon train with single locomotives at its front and rear, was fully loaded with coal and was travelling South from the Metropolitan Colliery at Helensburgh to Inner Harbour at Port Kembla where it was to be unloaded. The leading locomotive had just passed Clifton level crossing when an emergency application of the train's brakes occurred automatically and it came to a stand. The rear of the train was still inside the Coalcliff tunnel.

The Driver on the leading locomotive notified the RailCorp Signal Complex at Wollongong that his train was stopped. He then sent his Co-driver back to inspect the train and locate whatever had caused the brakes to apply automatically. The Co-driver found that the train had derailed North of the level crossing and used his two-way radio to alert the Driver. At 12.08am the Driver notified the RailCorp Signal Complex at Wollongong that the train had derailed.

The investigation revealed that the barrel of the No. 3 axle of the eighth position wagon had broken and parted, causing both wheels to derail. As a result, seven wagons following this wagon derailed. The two locomotives and all other wagons remained on the track. Although there were no injuries as a result of the derailment, approximately 470 metres of damaged track needed to be replaced.

The investigation established that the break in the axle was attributable to the propagation of metal fatigue at the site of the fracture. The fatigue fracture was initiated some time prior to the final complete failure of the axle at the derailment site but, due to damage sustained in the derailment, the initiator of the fracture could not be determined.

Full details of the Findings and Recommendations of this investigation are contained in Parts 3 and 4 respectively.

1 All times referred to in this report are in Australian Eastern Daylight Time (UTC +11 hours).

PART 1 FACTUAL INFORMATION

Introduction

1.1 At about 11.56pm on Wednesday 23 November 2011, Pacific National loaded coal service MC92 travelling from Helensburgh to Inner Harbour derailed eight wagons at Clifton (see *Figure 1*). The front portion of the train cleared the Coalcliff tunnel, passed over the Clifton level crossing and came to a stand at kilometrage 61.940. The rear of the train, twelve wagons and the trailing locomotive, remained inside the tunnel. It was established that the leading axle on the trailing bogie of the eighth wagon had broken and initiated the derailment. The coal wagon, number 42702K, was an NHFF type wagon and was the second wagon in a 3-pack of wagons. There were no injuries reported but approximately 470 metres of track was damaged and had to be replaced.

Figure 1: Map of incident location

Location

1.2 The derailment occurred on the single line section between Coalcliff and Scarborough on the Illawarra line. Clifton is a small township in the Illawarra region of NSW, situated on a narrow corridor of land about 500 metres wide between the Illawarra escarpment to the West and the Tasman Sea to the East (see *Figure 2*).

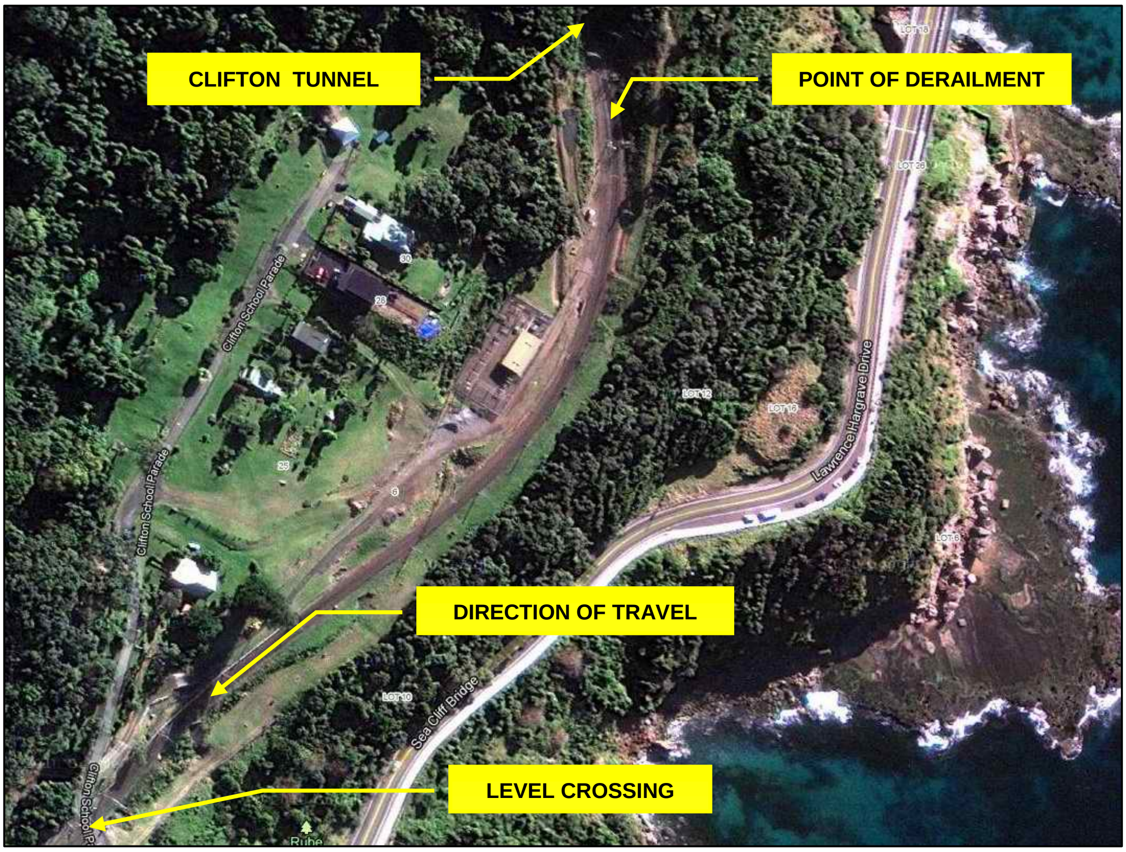


Figure 2: Incident locality

Train Information

1.3 Coal train MC92 was owned and operated by Pacific National, a division of Asciano Limited. It was in a push-pull configuration consisting of a single locomotive (8208) at the lead (see *Photograph 1*) and another single locomotive (8206) at the rear, with 45 loaded coal wagons in-between. The wagons were a mixture of 3-pack NHFF, NHSH and NHJF rakes. Each wagon had an estimated gross mass of about 90 tonnes. The train measured 799 metres and weighed 4740 tonnes.

Photograph 1: Train MC92 past Clifton level crossing

1.4 The wagon with the broken axle, NHFF 42702K, was the eighth wagon of 45 wagons in the train; it was the middle wagon of a rake of three wagons permanently coupled together with bar couplings (see *Photograph 2* right). Both ends of the rake had standard automatic coupler arrangements (see *Photograph 2* left).

Photograph 2: Knuckle coupler and drawbar coupler

Track Information

1.5 The track at Clifton is standard gauge (1435 millimetres) Class 1 track consisting of continuously welded 60 kg/m rail fastened to concrete sleepers using spring fasteners and supported by a bed of ballast. The track is part of the network which is owned and maintained by RailCorp. There is overhead electrical infrastructure to support the operation of electric passenger trains. The double line changes to a single line on the Northern side of the Coalcliff tunnel and then reverts to a double line on the Southern side of the Clifton Level Crossing (see *Figure 3)*.

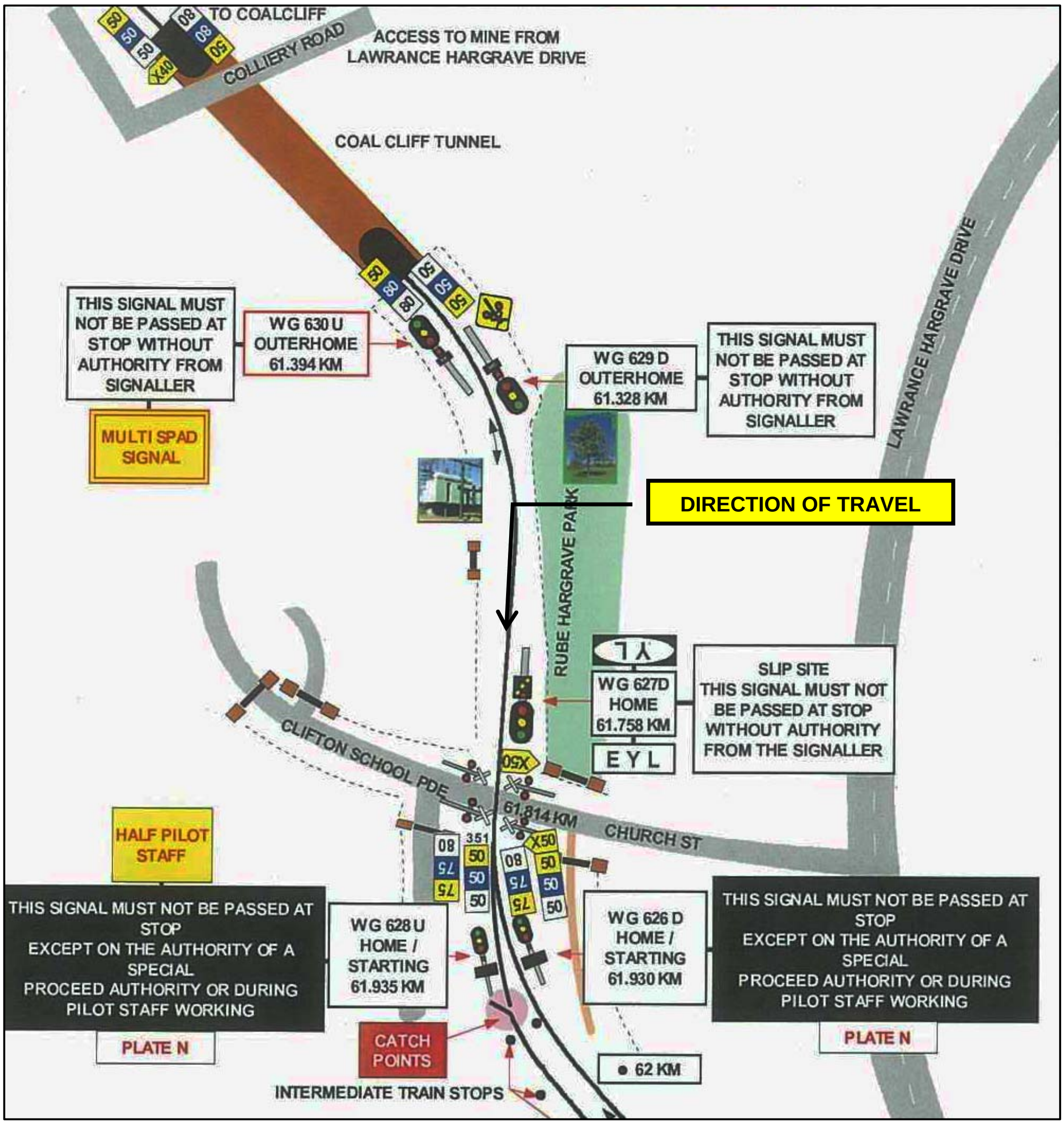


Figure 3: Incident locality

(Diagram courtesy RailCorp)

1.6 The Coalcliff tunnel immediately North of the derailment point is approximately one kilometre long. The tunnel is straight with a rising gradient in the Down direction. Exiting the tunnel, travelling South, the track commences a sweeping right-hand 220 metre radius curve before beginning a long descent which reduces from 1 in 65 to 1 in 206 at the Clifton level crossing (see *Figure 4*).

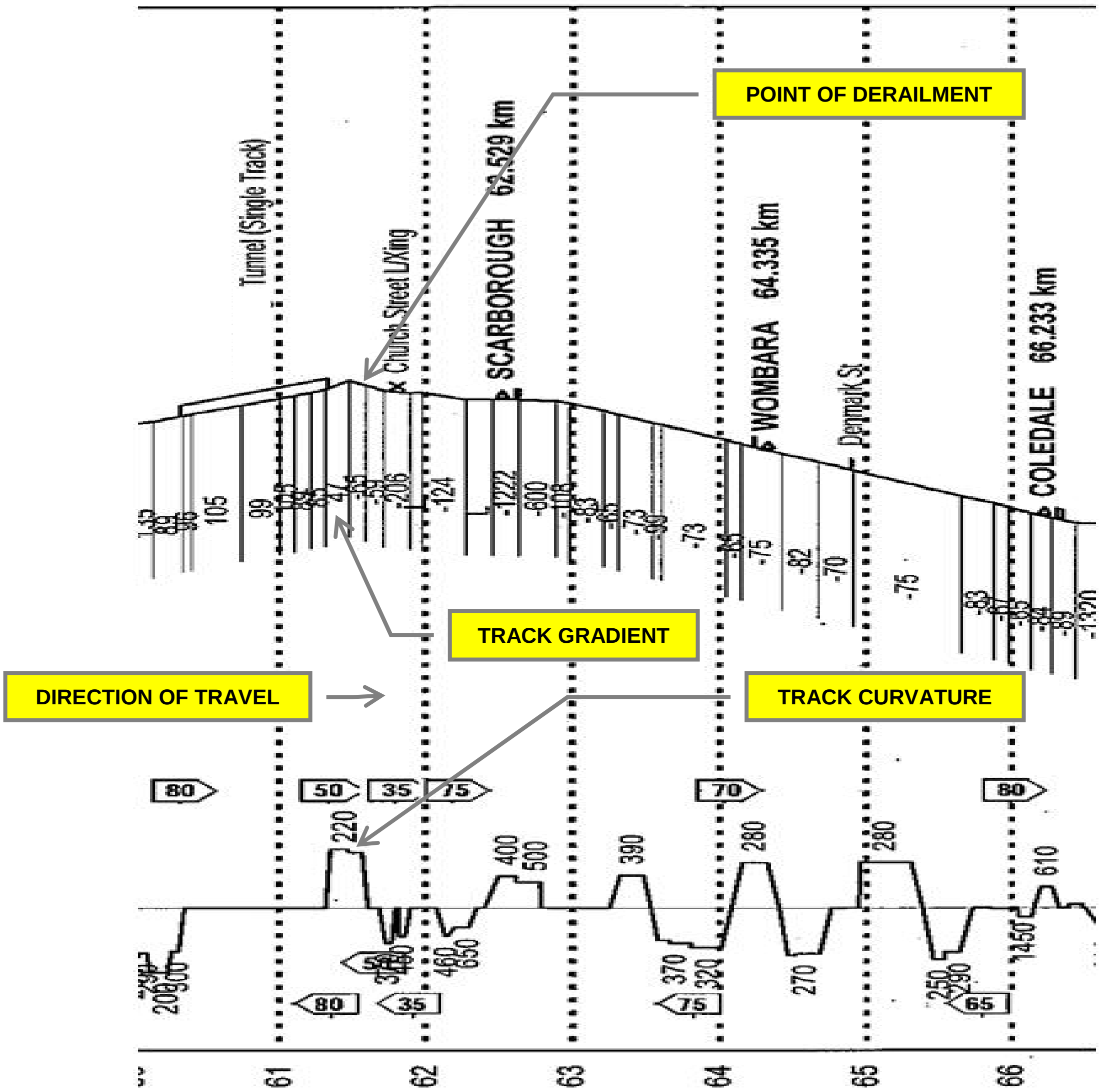


Figure 4: Curve and gradient diagram

Train Crew Information

1.7 The train was crewed by four Pacific National employees from Port Kembla Depot; a driver and co-driver in the leading locomotive and a driver and co-driver in the trailing locomotive. All crew members were within their respective medical and competency assessment periods and were familiar with, and qualified for, the route. Following the incident, the train crew were tested for the presence of drugs and alcohol; all tests returned negative results. The investigation found that the crew operated the locomotives in a competent manner and did not cause or contribute to the derailment.

Environmental Conditions

1.8 The temperature recorded at Bellambi, 14 kilometres to the South, was 15.8 degrees at 3.00pm on 23 November 2011. The crew reported that it was not raining at the time of the derailment although 27 millimetres of rainfall was recorded at Bellambi in the 24-hour period on 23 November 2011.

Before the Derailment

1.9 All four crew members signed on at the Pacific National Depot at Inner Harbour Port Kembla at 5.40pm on Wednesday 23 November 2011 (see *Appendix 2: Event Conditions Chart* for detailed timeline of events). The train crew took charge of MC91 at 6.30pm. After inspecting and preparing the train, MC91 departed Inner Harbour at 7.33pm as scheduled. The trip to Metropolitan Colliery at Helensburgh was incident free. MC91 arrived at Metropolitan Junction at 8.33pm where it entered the colliery and loaded.

1.10 After loading was completed at 11.31pm, the train returned to Metropolitan Junction where it was renumbered MC92 for travel to Inner Harbour and unloading. At Metropolitan Junction, locomotive 8208 became the leading locomotive and 8206 the trailing locomotive.

1.11 Departing Metropolitan Junction, MC92 continued its journey South without incident, passing through Coalcliff Station at 11.51pm and on to the single line section. It entered the Coalcliff Tunnel at 11.53pm travelling at 28 km/h. The posted track speed for freight trains through the tunnel to the level crossing is 50 km/h. Both crews stated that the train was handling normally at this time.

1.12 The Driver stated that, as the leading locomotive approached the Clifton level crossing, the train was travelling about 28 to 30 km/h when he reduced power. Meanwhile, the Driver in the trailing locomotive, who was powering the train into the tunnel, as normal, to assist the train over a short rise, observed the train speed increase, stating to his Co-driver, who was under instruction, *“as soon as you see the speed rising, start powering off”*. Power was reduced to idle at 28 km/h. The actions of both crews were corroborated by data logger evidence.

The Derailment

1.13 Shortly after passing over the level crossing, the Driver of the leading locomotive noticed that the train 'lost the air' causing an emergency brake application which brought the train to a stand (see *Figure 4*). The crew of the trailing locomotive, who were now more than half way through the tunnel, felt "*a big surge and a heavy thump"* into the rear wagon before coming to a stand inside the tunnel.

1.14 The Driver of the leading locomotive stated that he attempted to restore the air pressure and release the brakes. However, being unable to release the brakes, at 11.59pm he notified the RailCorp Signal Complex at Wollongong of the loss of air pressure. He also sent his Co-driver to inspect the train and locate the cause for the loss of air pressure.

After the Derailment

1.15 The Co-driver took a spare air hose and a spanner suspecting that it was an air pipe problem. He found that the train had derailed North of the level crossing and used his two-way radio to inform the Driver. He informed the Driver: *"We have a derailment about 50 metres to the rear of the lead engine, there is no sign of the rear."* At 12.08am the Driver notified the RailCorp Signal Complex at Wollongong that the train had derailed.

1.16 Meanwhile, the trailing locomotive came to a stand about 200 metres from the southern end portal, inside the tunnel. The crew then tried to determine whether a penalty application of the vigilance control equipment or an emergency brake application had occurred. They decided that the train had separated and an emergency brake application had occurred.

1.17 Without train radio or mobile phone coverage inside the tunnel, they were unable to make contact with the crew on the leading locomotive or network control until they left their locomotive. It was possible to use the tunnel phones to connect directly with Wollongong Signal Box. Because of the exhaust fumes from the locomotive they discussed the use of the Self-contained Breathing Apparatus to exit from the tunnel. They decided as there was a wind blowing through the tunnel from the southern end any fumes would likely be blown away. The Driver tried to shut down using the emergency stop button on the No. 2 cab[2], however this did not respond. The engine control and fuel pump switches were also tried without success. The Driver eventually shut down successfully using the stop button in the No.1 cab. They secured their locomotive and commenced walking South out of the tunnel.

1.18 Outside the tunnel, they contacted Wollongong Complex to inform them of the extent of the derailment. The time was recorded as 12.15am. They saw an approaching torchlight and met with the Co-driver of the leading locomotive who was ascertaining the extent of the damage. They assisted in giving an update to the Driver on the leading locomotive and also to the Wollongong Signal Complex.

1.19 OTSI was notified of the incident by RailCorp's on-call officer at 12.32am and two OTSI investigators deployed to the site at daylight to conduct a preliminary inspection.

1.20 An initial examination of the wagons, bogies, and wheelsets was conducted at Clifton upon arrival by the OTSI investigators. This examination found that both wheelsets on the trailing bogie of the eighth wagon derailed (including the broken axle) as did all wheels of the trailing bogie on the ninth wagon; both these wagons remained upright. Completely separating from the ninth wagon, the following five wagons, the tenth to the fourteenth inclusive, completely derailed with these wagons overturning onto their sides. The fifteenth wagon derailed but remained upright.

1.21 A break in the No. 3 axle from the eighth position wagon was identified as an initial causal factor (see *Figure 5*). Half of the broken axle remained in-situ under the wagon with the other half found in the four foot approximately 70 metres away. As this part was exposed to the elements it was covered by plastic to protect it for later examination. A number of bogies, wheelsets and both sections of the broken axle were recovered and examined at Pacific National wagon maintenance facilities at Port Kembla. OTSI investigators witnessed the initial examination of the broken axle by a metallurgist who took samples of the axle for metallurgical examination.

[2] The 82 class locomotive has a cab at each end, designated as the No. 1 and No. 2 cabs.

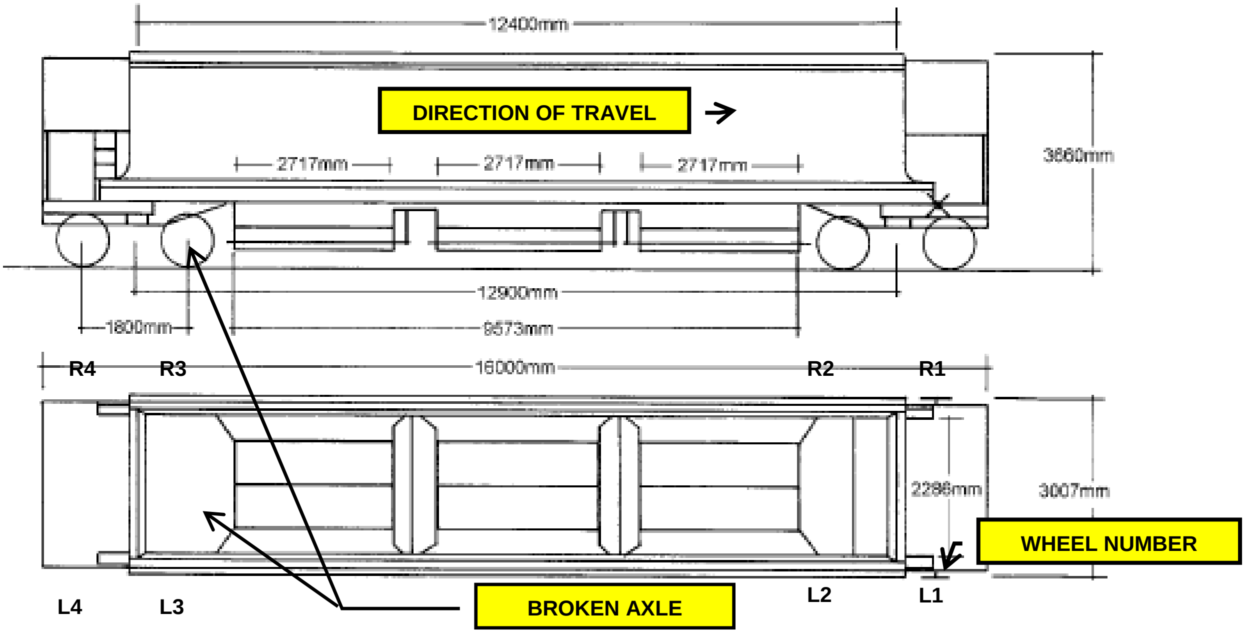
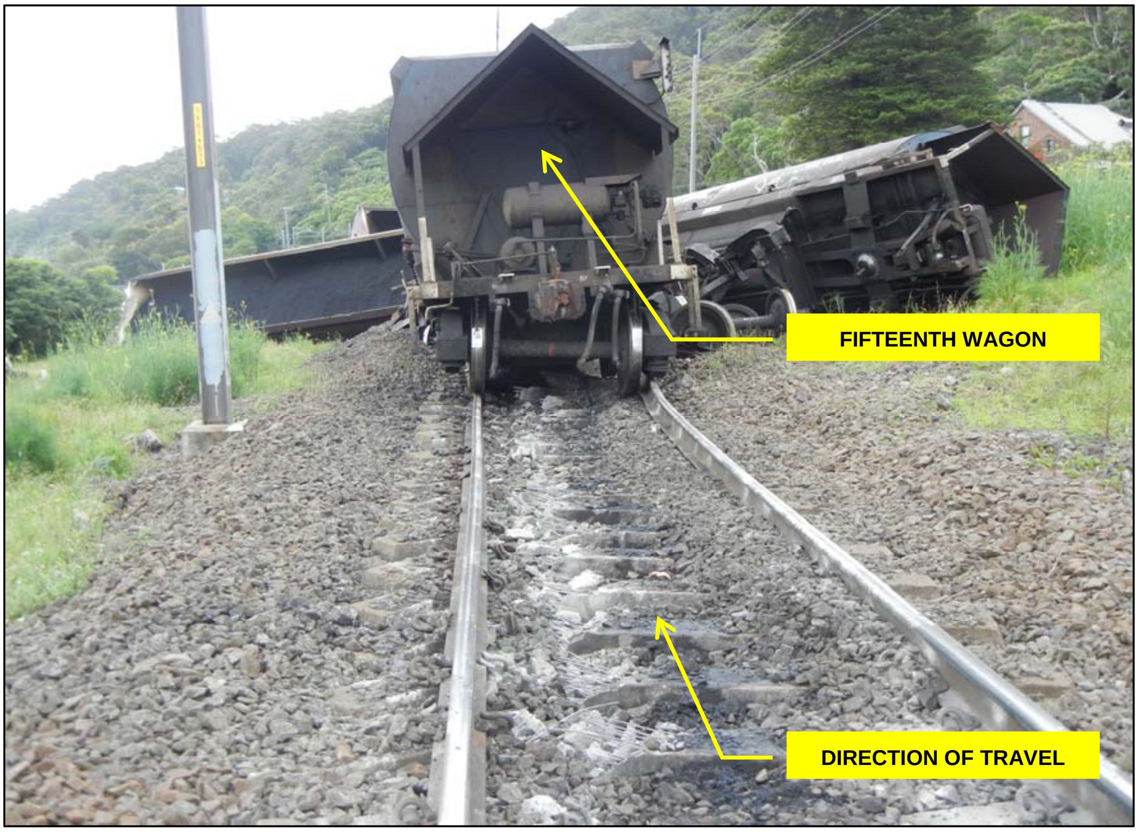


Figure 5: NHFF wagon with wheel numbering

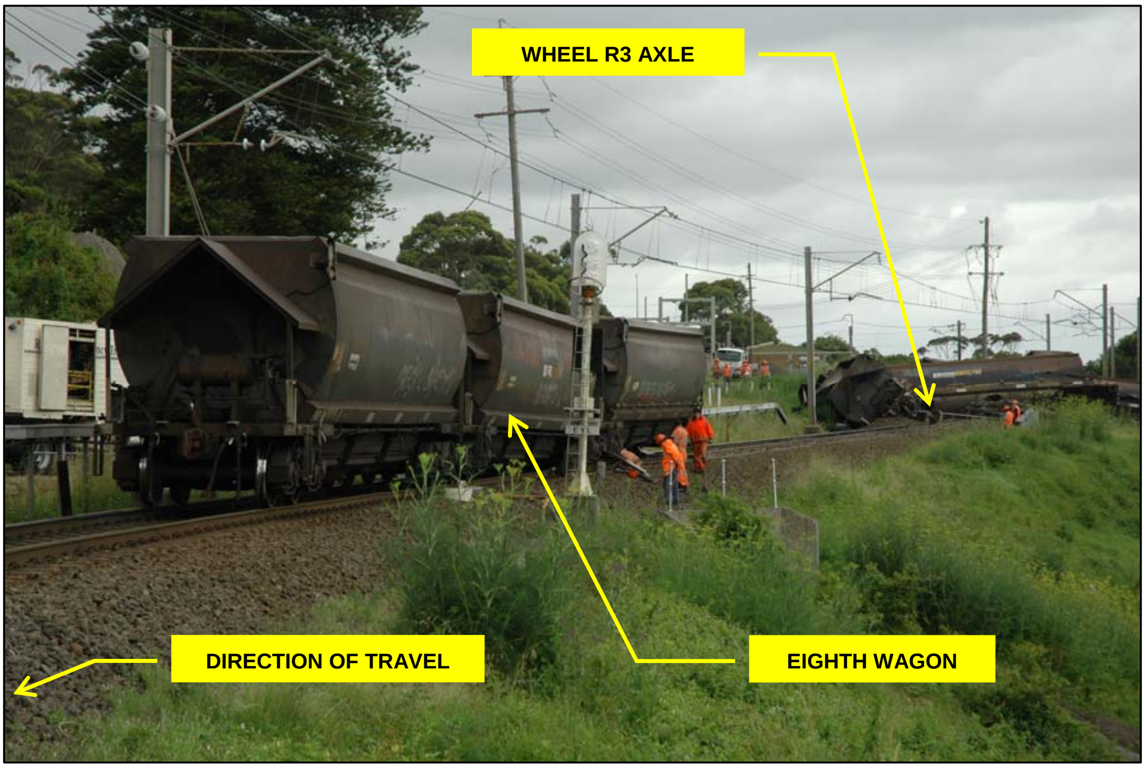
Injuries and Damage

1.22 There were no injuries as a result of the derailment but approximately 470 metres of track and other items of infrastructure were damaged and had to be repaired. The repairs included renewal of the track between kilometrage 61.330 to 61.800, two culverts, various drainage structures and the replacement of geotechnical monitoring equipment.

1.23 There was no damage to the locomotives and the 37 wagons which remained on track. The other eight derailed wagons from the eighth position through to the fifteenth position sustained damage to varying degrees. The damage to derailed wagons that remained upright was minimal while those that overturned had significant structural damage (see *Photograph 3, 4 and 5*).



Photograph 3: Rear of fifteenth position wagon and overturned wagons



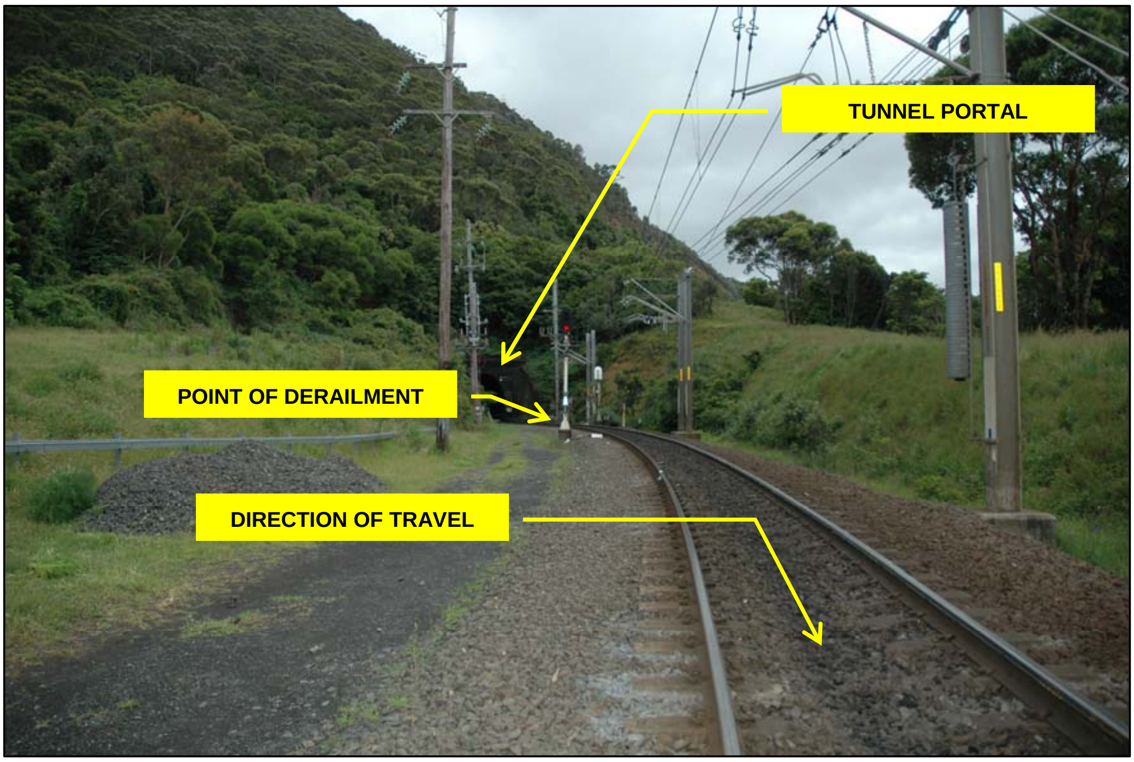
Photograph 4: View from Clifton level crossing

Photograph 5: Broken axle under wagon

PART 2 ANALYSIS

Introduction

2.1 Pacific National Coal Train MC92 derailed because the barrel of the No. 3 axle on the eighth wagon (NHFF 42702K) broke. The breakage caused the wheelset to come apart and both wheels to derail. The left-hand side wheel and axle section detached from the bogie and was tumbled under the trailing wagon. As a consequence, the train derailed as it exited the tunnel at kilometrage 61.351, approximately 23 metres South of the tunnel portal (see *Photograph 6*). The train continued for a further 350 metres in a derailed state, with various wheels running on and damaging the concrete sleepers. Derailment forces also caused the rails to break and detach from the sleepers. The rail breaks occurred at those locations where the rail was welded (or in the heat affected zones of those welds).



Photograph 6: Tunnel portal

Initial axle examination

2.2 The initial examination of the broken axle at the derailment site revealed the following:

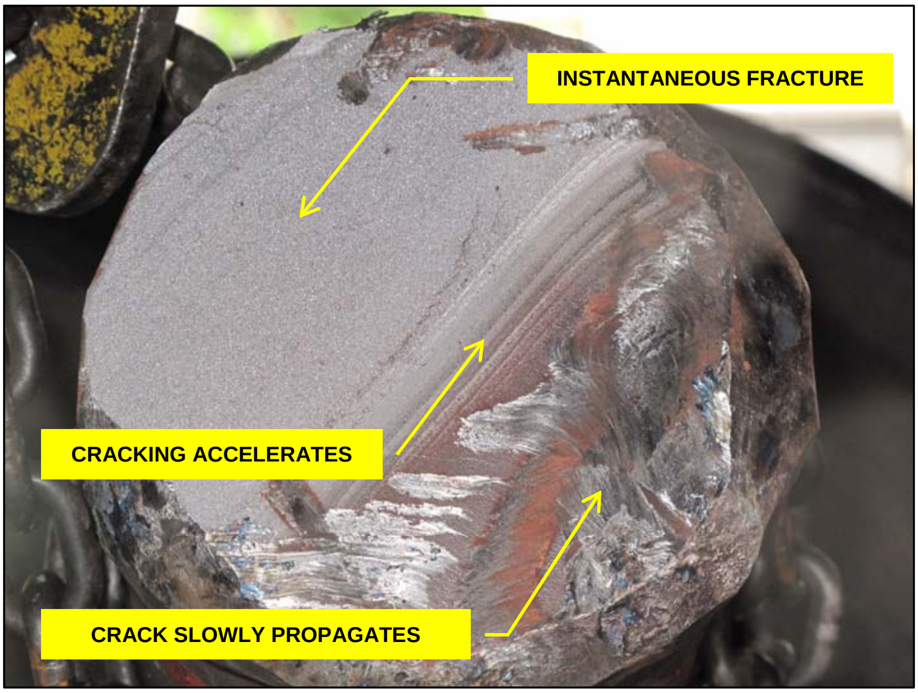
- The axle had broken approximately 490 mm from the inner wheel face of the R3 wheel and approximately 725 mm from the L3 wheel (see *Photograph 7*).

Photograph 7: L3 and R3 wheel and axle stubs

- The break face on the R3 wheel side had severe damage from being tumbled under the train (see *Photograph 8*).

Photograph 8: Close-up of broken axle on R3 wheel end found in the four foot

- The L3 wheel had some damage to the surface face with the circumference edges substantially bevelled by heavy rotational contact with the underside of the wagon during the derailment. The breakage surface exhibited a multiple stage failure with varying rates of cracking as evidenced by ratcheting and beach marks. These marks were clearly evident in the secondary zone of failure where the cracking was seen to accelerate (see *Photograph 9*).



Photograph 9: Close-up of broken axle on L3 wheel end still in wagon

- There were no other visible surface defects on the barrel of the axle apart from those which occurred after the break.

2.3 The following matters were noted following further examination:

- The No. 4 axle, the one adjacent to the broken axle, which was the trailing wheelset of the pair, showed no marking or damage. The other axles on the wagon also showed no sign of marking or damage. (It should be noted that as these inspections were conducted at the derailment site, the parts examined had not been cleaned or wire brushed beforehand).

- Other wagons and axles on MC92 were examined immediately following the accident at Clifton and later at Port Kembla. Minor surface defects were observed on two other axles (see *Photographs 10 & 11*). Both occurred in a region of the axle where it was apparent that brake gear had rubbed on the barrel of the axle. However, these defects were within limits set in Pacific National's Wagon Maintenance

Manual. The manual specifies that remedial action is only required when specified defects exceed three millimetres in depth. It states that: *"there shall be no transverse or circumferential scoring, grooves, gouges, scratches, chisel marks or similar indentations which are more than 3 mm deep. Such defects which are less than 3 mm deep shall be handled as follows: sharp edged defects (width less than three times the depth) shall be marked for immediate workshop attention, and other defects (width more than three times the depth) may be marked for minor repair attention."*

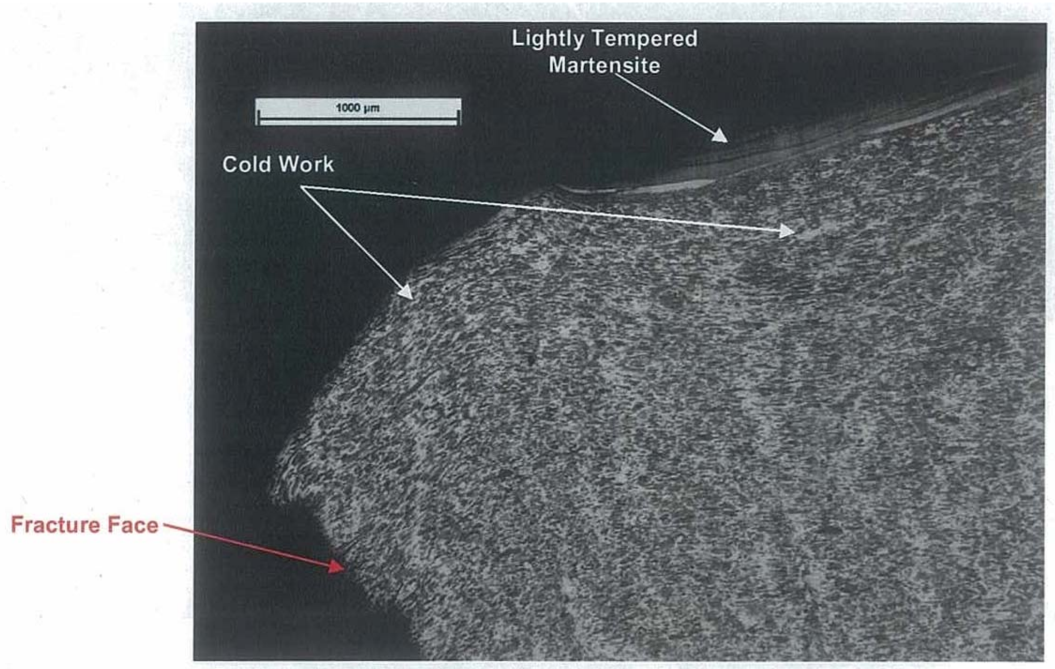
Photograph 10: Axle marking from brake gear (No.1 axle from wagon 42824F)

Photograph 11: Axle marking from brake gear (No.1 axle from wagon 42778F)

Metallurgical axle examination

2.4 Pacific National contracted a metallurgical examination of the broken axle by Bureau Veritas, an independent testing and certification body. Their examination noted the following:

- The failure of the axle had occurred by rotational bending fatigue mechanisms in a pronounced unidirectional manner. This was indicative of conditions of low stress concentration and low nominal stress.
- There were no significant levels of non-metallic inclusions or other features in the microstructure (see *Photograph 12*). There was also no evidence of any internal flaws at or adjacent to the fracture face.



Photograph 12: Cross section at failure intersection. Magnification X25

(courtesy Bureau Veritas)

- There was no evidence of any abnormal condition which had initiated the fatigue cracking. The fracture initiation site was not visible due to severe mechanical damage.
- The fatigue crack had propagated slowly through approximately 45% of the cross section then accelerated through a further 8% of the cross section before final instantaneous fracture (see *Photograph 9*).

- The carbon content (0.41%) of the axle material was slightly below specification.[3] The carbon content should have been between 0.45 - 0.59%.
- The tensile strength was determined to be 743 MPa, in excess of the specified minimum 610 MPa.

2.5 Bureau Veritas noted that breakage of this axle and one at Waterfall in 2008 appeared virtually identical. After the 2008 incident they had recommended that Pacific National initiate a program of non-destructive testing using magnetic particle or ultrasonic testing for the detection of fractures in its axles.

Potential mechanisms for axle failure

2.6 The initiator for breakage of the axle could not be determined due to the subsequent damage to the surface area of the break. A number of mechanisms which can create initiation points that may eventually lead to axle breakage include the following:

- internal faults from casting defects;
- external dents or grooves caused by ballast strike;
- collisions with stray objects including pieces of track infrastructure;
- wagon components, usually brake linkages or levers, rubbing on the axle;
- damage during handling and/or transport between and within maintenance facilities; or
- post derailment or incident damage.

All these faults may act as stress raisers which, under fatigue or repeated loads, may initiate a fracture leading to complete failure. According to an inspection criterion for the exposed surfaces of axles:

> *"The likelihood of fatigue crack formation increases with the sharpness of the surface imperfection. Imperfections with smooth, radiussed contours are generally not harmful, but those with very strong discontinuities have a strong likelihood of crack formation. It is possible to repair imperfections caused by*

3 The current standard is the Association of American Railroads Manual of Standards and Recommended Practices - Section M - *Locomotives and Locomotive Interchange Equipment*, 2008.

isolated pitting and/or ballast induced damage by remedial grinding to remove all raised lips." [4]

2.7 Freight axles are designed to have an infinite fatigue life which is achieved by manufacturing the axle from the appropriate materials and with the correct dimensions. The stresses during normal service conditions do not usually exceed the predicted design limits. However, if a localised stress exceeds the fatigue limit then this can initiate fatigue cracking.

2.8 Overloading or uneven loads can also increase the cyclical loading experienced by the axle which potentially reduces the life of the axle. At the Metropolitan Colliery, wagons are loaded on a visual basis only and there is no weighbridge between the colliery and Port Kembla. Following the derailment, Pacific National conducted spring deflection comparison testing on loaded wagons and estimated the gross mass of the wagons at about 90 tonnes. This is within the parameters set out in RailCorp's Train Operating Conditions Manual.

Wagon and axle maintenance and inspection

2.9 The maintenance requirements for Pacific National's freight wagons are contained in their Wagon Maintenance Manual (WMM 01-01_04). The maintenance and inspection program for Pacific National coal wagons is conducted at intervals set out in an annex (WMM 01-01c_04). The various maintenance and inspection levels are as follows:

- Safety Inspections. These inspections are carried out by competent terminal operators or locomotive drivers. Known as FX or GX inspections, these are visual safety inspections conducted before each train journey. However, these inspections do not generally extend to inspecting the condition of the axles, mainly due to time constraints or difficulties with being able to see the axles. Accordingly, the main responsibility for examining axles rests with wagon maintainers during heavier inspections.
- Preventative Maintenance (PM) Inspections, also known as Unit Train Maintenance (UTM). The maintenance on these types of coal wagons is scheduled for every 42 days and is carried out by wagon

4 Freight Rail Engineering – Traction and Rolling Stock Section (TRS 1447.00), 1994.

maintainers. The requirements for these inspections are contained in WMM 01-02.

- P Inspections. These are based on distance travelled with the requirements contained in WMM 01-03.
- A & B Inspections. These require the wagon to be lifted off its bogies and can be based on either time or distance travelled. The 'A inspection' checklist is contained in WMM 01-04 while the 'B inspection' checklist is contained in WMM 01-05.
- Wagon Inspection at Wheelset Change. This inspection is only conducted after wheelsets are changed and requires various items of the wagon body to be inspected and tested in accordance with the check sheet contained in WMM 01-06. It does not require any bogie components to be inspected.
- Scheduled Maintenance. This maintenance is scheduled every 3 years. The checklists that relate to this inspection are contained in WMM 01-17_02 and WMM 01-09_04.

2.10 While the PM, P and A&B inspections all have specific check sheets which include a Category titled 'Wheels and Axles', there are no specific details for conducting an inspection or reference to any Engineering Instructions for axle inspections. Further, there is no requirement during the wheelset change-out to inspect the condition of the wheelsets and axles, prior to installation, for damage sustained during transport and handling. While the checklist WMM 01-09_04 contains the heading for 'Axle Barrels Checked' and refers to the more detailed instructions (WMM 09-03_08), it too does not extend to inspection of the barrel in-service or after transport and handling.

2.11 WMM 09-03_08 'Axles' is the standard which defines requirements for axles returned to workshops for inspection, testing and overhaul. This standard requires that:

> *"All wheels and axles that enter the workshop shall be inspected for defects in compliance with the procedures and limits prescribed below. Axles shall be inspected and tested in accordance with this standard whenever bearings are removed during reconditioning of the wheelset.*
>
> *Axles are to be closely examined for the presence of gouges, grooves and cracks in the body between the wheel seats, for cracks on the*

wheel seat adjacent to the wheel hub, and for the presence of crevice corrosion at the wheel hub seat interface.

Axles are to be inspected for visible defects on the portion between the wheel-seats. There shall be no transverse or circumferential scoring, grooves, gouges, scratches, chisel marks or similar indentations which are more than 3mm deep."

2.12 The procedure for testing of axles in the manual states that:

"Axles shall be tested for the presence of flaws and failures as specified hereafter by using ultra-sonic and/or magnetic particle (wet or dry procedures.)"

Pacific National contracts some maintenance and inspection of wheelsets to UGL Rail Services (UGL). The subject failed wheelset was last overhauled by UGL who inspected the axle using a fluorescent magnetic particle test.

2.13 Section 2.4.4.1 of the standard also requires that:

"An electronic record is to be kept by the service provider of axle inspection and testing including axle number, date of inspection, type of test carried out and the results of each axle for a minimum period of 12 years."

The records for the testing of the axle were provided by Pacific National and identified the axle as being manufactured in 1976.

2.14 Wagon maintenance records indicated that the wagon involved in the derailment, NHFF 42702K, had undergone a routine 42-day UTM on 28 October 2011. There is no record of any faults found with the wagon or the wheelset during this inspection. There is no requirement for any inspection of the axle barrel, unless a significant defect is observed and recognised.

2.15 The last three-year scheduled maintenance and inspection on the wheelset was conducted on 23 November 2010 at the UGL 'Maintrain' facility at Auburn. The documentation provided indicated that the axle had passed this test. The wheels were refitted then installed under the wagon on 30 November 2010. The wheelset had therefore been in service for about one year following this inspection.

2.16 The inspection of the axle barrel by UGL is detailed in its Engineering Instruction (MJI-EN03 Rev.22). Another instruction (MJI-EG13 Rev.3) describes the process for using fluorescent magnetic particles to detect surface discontinuities in axles. Each inspection is documented and signed off by a technician who is qualified in the process. According to the UGL Engineering Instruction (MJI-EG13 3): *"The person having responsibility for the inspection shall have been trained in the technical instruction as detailed in the Maintrain CCI-Pope "Magnetic particle testing of rail axles" course. Any person that has not operated the test bench for a period of more than 12 months shall have to be retrained in the CCI-Pope course. In addition all personnel undertaking inspection of magnetic particle indications shall have current visual acuity …".* UGL provided the documentation to verify that the test was performed and that the technician who performed the test had undertaken the necessary training to operate the machinery.

2.17 The current Australian Standard for Non-destructive Testing - Qualification and certification of personnel (AS 3998 – 2006) specifies the qualification and certification of personnel involved in non-destructive testing. It states that: "*The candidate shall fulfil the minimum requirements of vision and training prior to the qualification examination and shall fulfil the minimum requirements for industrial experience prior to certification."* The technician undertaking the Non-destructive Testing at Maintrain was certified according to the requirements of AS 3998.

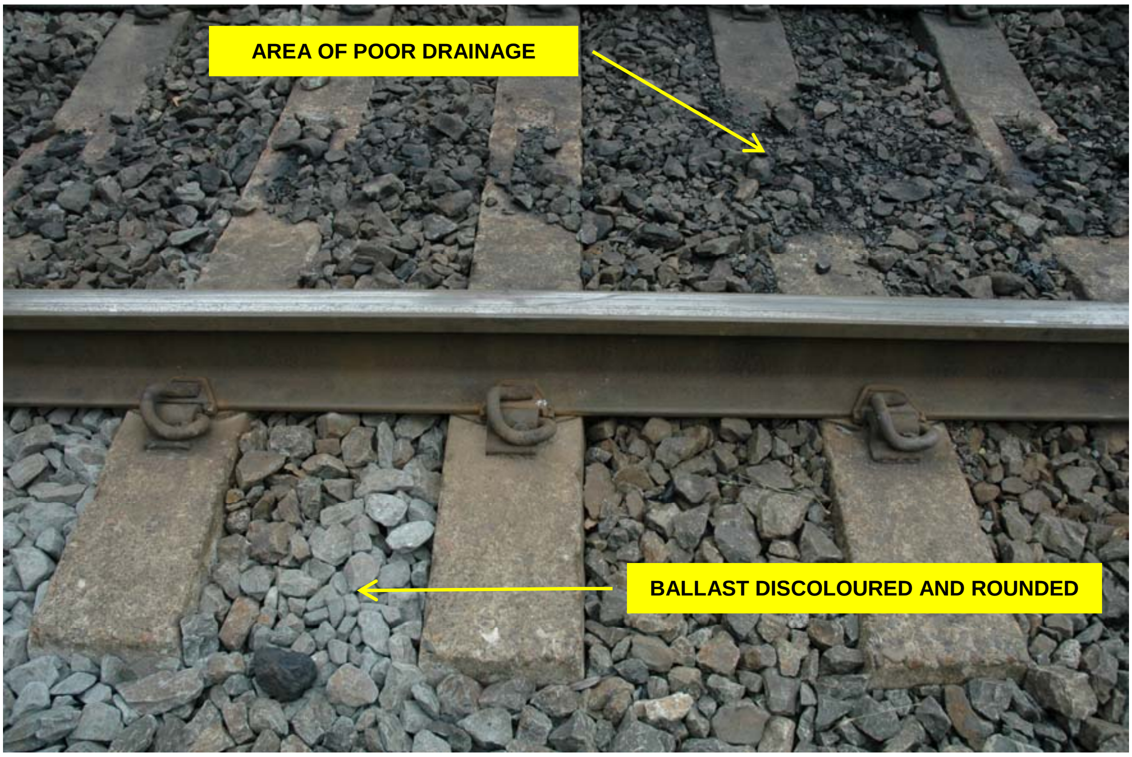
2.18 The UGL documentation for the inspection and testing of axles undertaken during the last regular maintenance cycles gave details for the axle inspection. However, the only indication that a non-destructive test has been conducted is a pass/ fail in the item 'UV Test'.

2.19 A compliance inspection conducted by the Independent Transport Safety Regulator (ITSR), which is also discussed later in this report, found a number of deficiencies with the inspection of axles, particularly those about to be fitted to rolling stock after inspection and testing. They found that *"existing in-service maintenance and inspection regimes for rolling stock do not generally require an examination of the axle barrel surface".* The results of the ITSR inspection provided evidence that axles with significant defects were not being detected in accordance with the standard during scheduled maintenance processes. ITSR did not identify the companies involved with this compliance inspection.

2.20 **Auditing**. In the past three years, four internal audits were conducted on the axle inspection process (the wheel line) by UGL. The audit documentation which was supplied, detailed information on what was audited and explained what corrective actions were to be completed. However, an external audit conducted by Pacific National on 10 October 2011 of the wheelset inspection process used by UGL did not provide any detail regarding adherence to the standard examined as part of the audit.

Track examination

2.21 The area of track between where the two locomotives came to a stand was inspected following the incident. Around the area of the tunnel portal there was evidence of minor track pumping with foul and rounded ballast in the ballast crib and on the ballast shoulder (see *Photograph 13*), both in the locality of the derailment and also along the track towards the level crossing.



Photograph 13: Track around area of derailment

2.22 There was also significant wear and metal flow occurring on the gauge face of the rail in the locality of the derailment (see *Photograph 14*). At this point of the track there is the start of a right-hand curve where the lateral forces on the outside rail are increased which is evidenced by the wear on the gauge face of the rail. This area of track was relatively unaffected by the derailment with some damage to the sleepers caused by the wheels from the broken axle running on the surface.

2.23 Further along the track, about 250 metres in the Down direction, the rails detached from the sleepers and both rails fractured. At this point, substantial damage to the track occurred and five wagons, the tenth to fourteenth, were spread off the track and overturned. It is not known why the rail became unsecured from the sleepers; however, the large forces involved in the derailment were evident from the position of the wagons.

Photograph 14: Metal flow and wear on gauge face of the down rail

2.24 RailCorp's track maintenance and inspection records for the three months prior were reviewed. These records showed the track was inspected and maintained in accordance with RailCorp's standards.

2.25 Pacific National engaged an external party to conduct an inspection of the track infrastructure. This was conducted immediately following the derailment. They reported that the track twist and gauge showed no exceedents of base operating standards. However, it was noted that there was a minor bog hole in the area of the derailment. The report stated *"this is typical of a drainage issue and can most certainly be characterised with poor or failed sub-grade in a small patch. This localised issue would be partly hanging (not fully supporting) the track on one side and would most certainly further deflect under load. This further deflection was not measured but would increase the dynamic forces applied at this point to the wagon and its components."*

2.26 It is likely that the area of track where the derailment occurred is an area where there was an increase in the loading on the already partially-fractured axle to the point of completing the fracture. The axle examination showed that there were a number of phases in the axle breakage. The axle was already partially fractured before it reached this area where the final instantaneous fracture occurred. It cannot be determined how long from initiation that the propagation of the fatigue crack took to reach the point of complete failure. However, the final breakage was likely to have resulted when there was an increase in the loading conditions such as a curve, a track deflection or at a set of points.

Actions of train crew

2.27 The train crew in both locomotives were managing MC92 within guidelines and acted promptly following the incident. MC92 was recorded as travelling at approximately 28 km/h at the time of the incident, well below the posted speed of 50 km/h.

2.28 When the Driver in the leading locomotive notified Wollongong Complex of the loss of air pressure at 11.59pm the conversation was recorded as:

> Driver to Area Controller: *"Wollongong Complex from MC92 over."*
>
> Area Controller to Driver: *"Complex receiving MC92, over."*
>
> Driver to Area Controller: *"Yeah, we have come to a stand here just outside Coalcliff tunnel, we've lost our air, over."*
>
> Area Controller to Driver: *"OK, MC92, yeah, if you could let us know when you find the problem there, I'll let South Coast Control there know, over."*
>
> Driver to Area Controller: *"Received that."*

2.29 All communications reviewed were in accordance with Network Rules and Network Procedures.[5] The Area Controller had visibility of the position of other trains on his control system and blocked signals appropriately to ensure that MC92 was protected from other trains.

Other broken axle incidents

2.30 A broken axle is an infrequent occurrence. A search of records by the ITSR showed that since 1989, at the commencement of records, there were nine other reported occasions where a broken axle occurred during operation in NSW. A list of these nine incidents and a brief description of each is shown in *Appendix 3*. Three of these incidents are outlined in more detail below.

2.31 **Waterfall Broken Axle.** A recent similar incident occurred at Waterfall on 10 October 2010, also with a Pacific National coal service. In this instance, five wagons of a loaded coal train (CA64) derailed between Heathcote and Waterfall. It was found that the lead axle on wagon NHVF 35255 had broken and separated. The left-hand side of the wheelset dropped off into the four foot and cartwheeled under five wagons causing extensive damage.

2.32 The broken wagon axle was metallurgically examined by Bureau Veritas. They found: *"the failure of the axle had occurred by rotational bending fatigue under conditions of low nominal stress and low stress concentration. This cracking had slowly progressed until approximately 50% of the section was cracked. The crack then accelerated for a further 15% of the section before final overload fracture through the remaining section. There was no evidence of surface damage at the fracture initiation zone, although these features would have been destroyed by mechanical bruising subsequent to fracture. The (axle) material did not meet the carbon level requirements of the specified AAR M101 Grade F."* The carbon content was 0.36%, less than the specified 0.45 – 0.59%. A Brinell hardness test concluded that the axle tensile strength was 570 MPa, 40 MPa below the 610 MPa specified.

2.33 Pacific National's internal investigation into the Waterfall incident made two recommendations. The first was that audits of the manufacturing specifications and quality documentation of the axle's supplier be conducted to confirm compliance with Pacific National's required standards. The second

5 RailCorp Network Rules NGE 204 *Network Communication* November, 2008 V.3 and Network Procedures NPR 721 *Spoken and Written Communication,* 2010 V.4.

recommendation was for Pacific National to review its Wagon Maintenance Manual procedures and update them if necessary. As a result of these recommendations a review of axle management was conducted by Interfleet. The review made a number of recommendations to change the Wagon Maintenance Manual. According to Pacific National, the recommendations were incorporated into the Manual.

2.34 Part of this review was into the rate of axle barrel breakages. This study of axle fractures over a ten year period (1998-2008) found the rate of occurrences fell statistically below that which was expected.[6] The fact that the rate of occurrences fell statistically well below expectations could be indicative that the axle barrel areas were not being thoroughly examined. Evidence for this is supported by a compliance inspection conducted by ITSR where a number of axles with non-compliant defects were detected in service even though they had only recently been through an inspection process.[7]

2.35 **Kinalung broken axle.** Another Pacific National broken axle incident occurred on 23 December 2006 when a freight service experienced a broken axle at kilometrage 1041.700 while travelling towards Broken Hill between Kinalung and Menindee. The metallurgical report into the fracture again found that extensive damage to the fracture face made identification of the initiation point impossible to determine.

2.36 **Harden broken axle.** On 9 February 2006, a RailCorp XPT passenger train ST22 travelling from Melbourne to Sydney derailed while approaching Harden. An investigation conducted by the Australian Transport Safety Bureau found that the power car axle had completely fractured due to the initiation and propagation of a fatigue crack. It was found that the likely initiator for the fatigue crack was an embedded particle as a result of a track ballast strike.[8] It should be noted that this was a passenger service train which has a motorised axle, a type which is different to those found on freight wagons.

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6 Interfleet Technology Report, Pacific National – Whole of Life Axle Management Review p.5. 2008.

7 ITSR Transport Safety Alert, *Catastrophic failure of freight axles in the barrel* area, TSA no. 40, issued 12 April 2012.

8 ATSB Rail Occurrence Investigation Report 2006002 *Derailment of XPT Passenger Train ST22, 9 February 2006*.

Other safety matters

2.37 **Tunnel communication.** The trailing locomotive stopped in the tunnel as a result of the derailment and despite repeated attempts, the crew were unable to make radio contact with either the front of the train or Network Control. Communication was only possible once the train crew had walked clear of the tunnel. This issue is addressed in further detail in the Remedial Actions section of this Report.

2.38 **Inability to shutdown.** The train crew in the trailing locomotive (8206) were unable to shut down their locomotive after they had lost air and had come to a stand. The Driver stated that when he tried to shut the engine down: *"the emergency stop button on 8206 No.2 end did not respond; we then tried to switch off the engine control and fuel pump switches to off, still did not shut locomotive down, due to the switches being left in the "on" position, in No.1 cab…"*. This was overcome when the Driver went to the No. 1 cab and shutdown from that position. The emergency stop button should function from both positions.

2.39 **Wagon loading.** As there is no weighing facility at the Metropolitan Colliery or along the line to Port Kembla, there is the potential for coal overloading. It was evident from the on-site inspection of the wagons that the coal was saturated with water which would increase the weight of the load. Pacific National estimated the weight of a number of wagons at the derailment site using spring deflections. Using the spring rates and the average deflections, an estimate of a gross mass of 90 tonnes (+/- 7 tonnes) per wagon was made which would be within the maximum permitted loading of 25 tonnes per axle.

2.40 **Fatigue.** There were no issues identified with fatigue or rostering of the train crew of MC92.

Research

2.41 **Research into the effect of human factors in axle inspection.** The rail industry in the UK believes that current axle inspection regimes are inefficient and have started conducting research to improve efficiency while maintaining current levels of safety. In May 2011, the Rail Safety and Standards Board[9]

[9] The Rail Safety and Standards Board Ltd (RSSB) is a UK based not-for-profit company owned and funded by major stakeholders in the railway industry, but is independent of any one party.

conducted an initial scoping study into the effects of human factors in axle inspection. The scoping study selected ultrasonic axle testing as the study focus, as this common non-destructive testing technique is widely used in depots and at overhaul, and human factors issues are recognised in this area.[10]

2.42 The work was based on a human reliability assessment approach which investigated the role of human performance in the inspection process. The analysis aimed to predict and record the types of human error which can occur during a task and the factors which will influence those errors. The work involved visits to five sites where non-destructive testing axle inspection was undertaken. Discussions with relevant industry personnel were also conducted.

2.43 The study found that *"the clearest improvements to inspection reliability are likely to arise from task re-design. This re-design could minimise the impacts of human error. Some examples of errors relevant to current inspection techniques, which could be removed through task re-design are: manual variability when manipulating inspection probes; reducing inspector vigilance for faults over a shift; and failure to identify faults which may be masked by other visual signals presented on the inspection equipment. This finding is based on information gained from human error quantification, which identifies the factors which will have the biggest impact on human reliability."*

2.44 From this scoping study a research plan is proposed which is intended to deliver benefits to the rail industry.

Remedial actions

2.45 Since the collision, Pacific National has instituted a number of safety actions, those relevant to the accident being:

- A precautionary check on all 75ES (25 tonne) wheelsets using ultrasonic non-destructive testing.
- A review of the Wagon Maintenance Manual to determine if the addition of ultrasonic testing to axle checking is required.

[10] Rail Safety and Standards Board Ltd, Research Brief - *Research into the effect of human factors in axle inspection*, T774, May 2011.

- Calculations are to be developed and material fatigue data collected to determine the degree of safety outlined in the Association of American Railroad guidelines.
- Alternative means of communication between locomotives in tunnels to the outside will be explored.
- A review of safe egress by train crew from tunnels will be conducted.
- An evaluation of the current procedures that allow drivers to disembark from locomotives where there is a risk from live electricity cables will be conducted.
- A risk assessment will be conducted on the multiple unit shutdown button and the control/engine switches.

2.46 **RailCorp.** The issue of communication black spots, in areas such as the Coalcliff tunnel, is recognised. RailCorp is currently undertaking an 1800MHz spectrum renewal and have commenced construction of the first of 250 new towers required for the digital train radio system (DTRS) network. The DTRS, which will use GSM-R technology, is being installed across 250 sites on the Corporation's network including 60 sites in rail tunnels.[11] This new DTRS will enhance communications between trains and network control in an emergency as well as enable communication between other staff for rail operations on the RailCorp network.

2.47 The remedial track replacement work conducted following the derailment addressed any track issues present in the locality of the derailment prior to the incident.

2.48 **ITSR.** In March 2012, the ITSR conducted compliance inspections on a number of wagons in service. Approximately 80 axles were inspected for evidence of defects. Three of these axles, which had all been recently inspected at a major overhaul maintenance centre, were found with significant defects. These axles were removed from service. A number of other actions were undertaken by ITSR in addition to these inspections. These actions included:

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11 ITSR Implementation of the NSW Government's response to the Final Report of the Special Commission of Inquiry into the Waterfall Rail Accident Reporting period: October - December 2011, Report 28, accessed on 9 February 2012, http://www.transportregulator.nsw.gov.au/rail/publications/reports/waterfall_reports/waterfall-reports-2012/waterfall-quarterly-report-october-december-2011 .

- a review of existing intervention periods and inspection criteria for the exposed surfaces of freight axles;
- a stakeholder discussion about sampling, monitoring and attention requirements of post-workshop bogies and wheelsets;
- a review of current transportation techniques of bogies and wheelsets; and
- observation of ultrasonic testing of wagons in service.

As a result of these inspections a transport safety alert was issued on 12 April 2012 by the ITSR.[12]

2.49 The ITSR is conducting further audits as part of its investigation into these matters and is considering broad aspects of potential causal factors such as transportation, storage and return to service inspection programs as potential causal factors for defects in axles / wheelsets. Also, the ITSR is sampling freight axles for evidence of stress corrosion activity on the journal fillet radius. Further, the ITSR is embarking on a non-destructive test program (ultrasonic) focussing on sampling those axles most susceptible to having sub-surface defects.

[12] ITSR Transport Safety Alert, *Catastrophic failure of freight axles in the barrel* area, TSA no. 40, issued 12 April 2012.

PART 3 FINDINGS

Causation

3.1 The derailment of MC92 was a consequence of the barrel of the No. 3 axle of the eighth wagon breaking. This breakage caused the wheelset to derail which subsequently resulted in eight wagons fully or partially derailing.

Contributing Factors

3.2 The axle broke due to the initiation and propagation of metal fatigue at the site of the fracture. The fatigue fracture was initiated some time prior to the final complete failure of the axle at the derailment site but, due to consequential damage around the axle circumference, a determination could not be made about the initiator for this fatigue failure.

3.3 The axle, which was about 50% fractured at the time of the incident, finally failed while being subjected to normal cyclic loading.

Other Safety Issues

3.4 The current inspection standards for Unit Train Maintenance do not emphasise the examination of the axle barrel.

3.5 The two or three year interval (depending on kilometres travelled) between the non-destructive testing of axles may exceed the time taken from the initiation of a stress raiser to the ultimate failure of an axle.

3.6 The train crew on the trailing locomotive were inside the cab of their locomotive which was stationary inside the Coalcliff Tunnel, with no effective means of communication. The Coalcliff Tunnel is a known black spot for communications.

3.7 There is potential for wagons to be overloaded as there is no measurement of the weight of the wagons at the loading terminal, or along the track, until the unloading facility at Inner Harbour Port Kembla.

3.8 The shutdown button and the control/engine switches in the trailing locomotive of MC92 were ineffective in shutting down the engine following the derailment.

PART 4 RECOMMENDATIONS

To improve the safety of its operations and prevent a recurrence of this type of accident, it is recommended that the following remedial safety actions be undertaken by Pacific National.

4.1 Complete and evaluate the effectiveness of the ultrasonic non-destructive testing program on all 75ES (25 tonne) wheelsets.

4.2 Include in all inspection standards for Unit Train Maintenance the requirement to visually inspect axles immediately before fitting to wagons.

4.3 Revise the scheduling requirements of preventative maintenance to improve the effectiveness of the current regime in detecting surface and sub-surface defects in wagon axles. This revision should address the technical benefit of incorporating axle barrel inspections during Unit Train Maintenance.

4.4 Revise current non-destructive testing methods and practices as a form of inspection for wagon axles.

4.5 Assess the frequency and effectiveness of audits conducted on contractors to provide for satisfactory assurance that axles are being inspected according to Australian Standards and the Workshop Maintenance Manual.

4.6 Review locomotive communication systems to ensure that there is effective communications inside tunnels to network control.

4.7 Conduct a risk analysis to establish if the existing method of determining axle loads is appropriate where there are no weighing facilities at the loading area or along the track. If the risk analysis identifies any inadequacies in the current method, take action to remedy this.

4.8 Review the operation of locomotive shutdown buttons to confirm their effectiveness and undertake remedial action if the review identifies any deficiencies.

PART 5 APPENDICES

Appendix 1: Sources and Submissions

Sources of Information

- Asciano Limited
- Bureau of Meteorology
- Independent Transport Safety Regulator
- RailCorp
- Rail Safety and Standards Board
- UGL Rail Services

Submissions

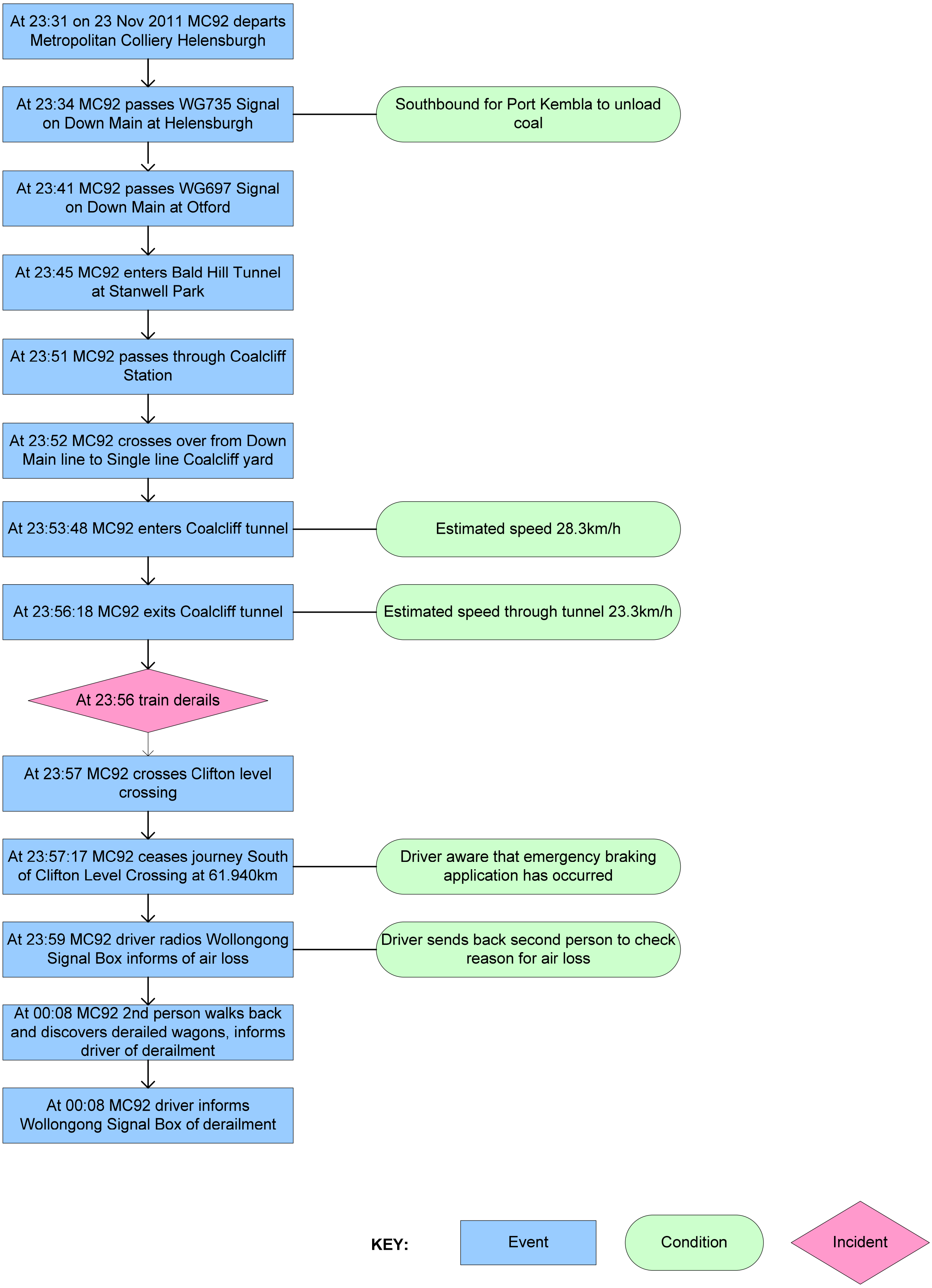
The Chief Investigator forwarded a copy of the Draft Report to the Directly Involved Parties (DIPs) to provide them with the opportunity to contribute to the compilation of the Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and to submit recommendations for amendments to the Draft Report that they believed would enhance the accuracy, logic, integrity and resilience of the Investigation Report. The following DIPs were invited to make submissions on the Draft Report:

- Asciano Limited
- Independent Transport Safety Regulator
- RailCorp
- UGL Rail Services Pty Ltd

Submissions were received from all four DIPs.

The Chief Investigator considered all representations made by DIPs and responded to the author of each of the submissions advising which of their recommended amendments would be incorporated in the Final Report, and those that would not. Where any recommended amendment was excluded, the reasons for doing so were explained.

Appendix 2: Event Conditions Chart



Appendix 3: Broken Axle Events

These events exclude occurrences where the broken axle is associated with a screwed journal and also incidents that appear to involve track machines. The search was for data from the start of records (1989) to present.

DATE	LOCATION	INCIDENT DESCRIPTION	TRAIN TYPE	ORGANISATION
21/11/1989	HORNSBY	At 5:32am the guard of run 256 observed smoke coming from car 3102 set M3. Examination revealed No.1 axle was overheated. Axle was found to be broken between axle gear and inside face of No.1 wheel.	PASSENGER	RAILCORP - CITY RAIL
16/03/1992	KOOTINGAL	At 4:30pm axle of SX71 broke at 474.000km.	FREIGHT	FREIGHTCORP
16/11/1992	ANTIENE	At 7:45pm 4472 freight service derailed 272.100km due to broken axle.	FREIGHT	FREIGHTCORP
22/03/1993	MOUNT MURRAY	At 2:20am axle of wagon NGPF 36198 on 2W74 broke at distance 126.300km.	FREIGHT	FREIGHTCORP
16/08/1993	WENTWORTHVILLE	BK52 coal train became derailed 28.580km due to a fractured axle on wagon NHFF 43028.	FREIGHT	FREIGHTCORP
26/04/1998	STANMORE	SP24 derailed car EB2511 at 5.060km and came to a stand at 4.752km on the up main line. The cause was a fractured axle on No.1 bogie.	PASSENGER	RAILCORP - COUNTRYLINK
9/02/2006	HARDEN	An XPT passenger train ST22 derailed. The trailing wheelset of the trailing bogie of the leading power car had derailed. The axle of the derailed wheel was found to have completely sheared with a crack in the radius relief area between the gear and wheel seats.	PASSENGER	RAILCORP - COUNTRYLINK
24/12/2006	KINALUNG	Pacific National freight service 7NY3 had a broken axle on the trailing bogie on the 20th wagon RKDF 20455P in the Kinalung - Menindee section.	FREIGHT	PACIFIC NATIONAL
10/10/2008	WATERFALL	Pacific National Coal service CA64 had a broken axle on the leading axle of the 10th wagon NHVF 35225. The 11th and 12th wagons also derailed.	FREIGHT	PACIFIC NATIONAL

References

Australian Standards

AS1171, *Non-destructive testing—Magnetic particle testing of ferromagnetic products, components and structures*, 1998.

AS 3998, *Non-destructive testing – Qualification and certification of personnel*, 2006.

AS ISO/IEC 17024, *Conformity assessment – general requirements for bodies operating certification of persons*, 2004.

Freight Rail

Freight Rail Engineering – Traction and Rolling Stock Section (TRS 1447.00) 1994.

Independent Transport Safety Regulator

TSA No. 40, *Catastrophic failure of freight axles in the barrel area,* 12/04/12.

Waterfall Implementation Report 28, *Implementation of the NSW Government's response to the Final Report of the Special Commission of Inquiry into the Waterfall Rail Accident*, Reporting period: October - December 2011.

Pacific National

WMM 01-01_04	*Maintenance of Freight Wagon,* 17/12/09.
WMM 01-01c_04	*Annex C – Bulk Services Division (Coal)*, 28/03/11.
WMM 01-02_06	*PM Inspections 'On* Train*'*, 18/05/09.
WMM 01-03_10	*P Inspection*, 20/04 /11.
WMM 01-04_12	*A Inspection*, 20/04/11.
WMM 01-05_13	*B Inspection* 20/04/11.
WMM 01-06_03	*Wagon Inspection at Wheelset change,* 6/08/10.
WMM 01-07_02	*WS Inspection – One piece Bogie,* 20/02/06.
WWM 01-17_02	*Coal SM*, 9/03/11.
WMM 01-18_02	*UTM/OK Spare Inspection,* 18/05/11.
WMM 09-03_8	*Axles*, 29/09/09.
WMM 14-01_04	*Freight Wheel 'No Go-Go' Gauge*, 27/07/07.

UGL Rail Services

MJI-EN03 22	*PN Wheelsets – Inspect, Repair, Assembly & Scrapping*, 21/11/08.
MJI-EG13 3	*Fluorescent Magnetic Particle Testing of Railway Axles,* 28/03/06.