



Rail Safety Investigation Report

ROCKY PONDS

7 November 2002

Pacific National train 4YN2 derailed due to misalignment.



Published by

The Office of Rail Safety Investigation (OTSI)

Issue Date: 2nd June 2004

Reference Number: OR 01/04

CONTENTS

1.0 Executive Summary	7
2.0 Terms Of Reference	10
3.0 Investigation Methodology	11
4.0 Factual Information	12
4.1 Overview	12
4.2 The Occurrence.....	12
4.3 Injuries	14
4.4 Loss or Damage	14
Track	14
Rolling Stock	15
4.5 Workers Involved	15
Train Crew	15
Maintenance Staff Track Patrol.....	15
4.6 Train Information.....	15
4.6.1 Train Consist	15
Train Condition	15
4.6.2 Train Maintenance Status	16
4.6.3 Train Data Logger Information	17
4.6.4 Train Management Standard and Compliance.....	18
4.6.5 Toxicology Information	18
4.7 Track Details	18
4.7.1 Incident Location.....	18
4.7.2 Misalignment Report	18
4.7.3 Track Configuration	19
Steel Sleeper Pattern	19
Rail Closures	20
4.7.4 Track Maintenance Standards	20
RTS 3656 Version 2.0 February, 2002.....	20
C2433 Track Examination: Calculation of Welded Track Stability from Field Information November 2001 Version 2.0.....	21
Civil Technical Notes CTN 02/15 Dated 16 August 2002.....	21
Steel Sleepers – Usage and Installation Standards TS 20540 3 00 SP Dated January 2003.....	22
Adjustment and Field Welding for Continuous Welded Track.- RTS 3650 Version 2.0 February 2002	22
Aluminothermic Welds – Identification, Recording and Reporting RAP 5391 Version 3 May 2002.....	23

4.7.5 Track Condition	23
Anchor Condition.....	23
Ballast Profile Condition.....	23
Ballast Angularity Condition	24
Foul Ballast	25
Rail Weld Alignment	25
Fastener Condition	25
Sleeper Condition	25
Alignment	25
4.7.6 Track Maintenance.....	25
Welded Track Stability Analysis.....	25
Dynamic Stabiliser - Welded Track Stability Analysis.....	26
Track Realignment	26
Rail Welds	27
Weld Alignment Defects	27
Track Patrol Inspections.....	27
Ballast Profile Inspection.....	28
Rail Adjustment	28
4.7.7 Safety Management Audit Results.....	29
Track Exceedent Elimination.....	29
Track Work Programs	29
Rail Adjustment	29
4.7.8 Track Measurements Following Misalignment	30
Curve Creep Temperature Error $E_c \approx 30^\circ\text{C}$	31
4.7.9 Track Restoration	31
Standard	31
Restoration Works	31
4.7.10 Track Condition 9 Months Post 7th November 2002 Misalignment at 377.960km	33
Curve Alignment	33
Steel Sleeper & Ballast Condition.....	34
4.8 Train Control.....	35
4.9 Environmental Factors	35
4.9.1 General Climatic conditions	35
4.9.2 Temperature	35
WOLO Speed Restrictions.....	35
Historic Temperature Review.....	36
4.10 History of Similar Occurrences	37
4.11 Relevant Safety Regulations	38
4.12 Emergency Response To The Occurrence	38
4.12.1 Incident Detection	38
4.12.2 Incident Notification.....	38

4.12.3 Safeworking Response	38
4.12.4 Track Maintenance Response	39
4.12.5 Rolling Stock Recovery Response	39
4.13 Human Factor Fatigue	39
4.13.1 Train Crew's Shift Roster Review – Two Weeks Prior To Incident.	40
5.0 Analysis.....	42
5.1 WTSA Track Maintenance Procedures.....	42
5.1.1 Management of Rail Adjustment – Pre Misalignment	42
5.1.2 Management of Rail Adjustment – Post Misalignment.....	42
5.1.3 Misalignment Management Reporting	43
5.1.4 Use of Trackstab in the Monitoring of Track Stability Analysis.....	43
5.1.5 Curve Pull-in Track Displacement Indicator.....	44
5.2 Track Structure.....	45
5.2.1 Steel Sleepers	45
5.2.2 Track Alignment and Adjustment.....	45
5.2.3 Anchors	46
5.2.4 Sleeper Condition	46
5.3 Climatic Conditions.....	47
5.3.1 Cold Weather Conditions	47
5.3.2 Hot Weather Conditions.....	47
5.4 Train Management.....	47
5.5 Train Condition.....	47
5.6 Combined Misalignment Track Analysis Review	48
6.0 Conclusions.....	50
6.1 Findings.....	50
6.2 Contributing Factors	50
6.3 Related Findings.....	51
6.3.1 Train Management.....	51
6.3.2 Track Maintenance.....	51
6.4 General Safety Related Findings	51
7.0 Post Incident Safety Actions	52
7.1 Post Misalignment Safety Actions Carried Out by RIC.....	52
7.1.1 Interim Track Configuration Change from CWR to JWR.....	52
7.1.2 Low Profile Concrete Re-Sleepering	52
7.1.3 Improved Shoulder Ballast Profile.....	52
8.0 Safety Recommendations	53
8.1 Direct Safety Recommendations	53

8.1.1	Define WTSA rectification work processes to assist maintainers in selecting the most appropriate methods of WTSA track repairs	53
8.1.2	Improve the knowledge of continuously welded rail (CWR) rail adjustment status.....	53
8.1.3	Review the WTSA algorithm considering the impact of steel sleeper & ballast condition	54
8.1.4	Track examination system – Improvements required in the inspection of alignment defects	54
8.1.5	Further stability review of the misalignment site.....	54
8.1.6	Supplementary investigation into the introduction and performance of steel sleepers in the NSW Rail Network.....	54
8.2	General Safety Recommendations	55
8.2.1	Improvements required in the reporting of misalignments and track restoration processes.....	55
8.2.2	Review of dynamic stabilisation resources available to maintainers following resurfacing works.....	55
8.2.3	Pacific National Driver Fatigue Rostering for Relieving Staff.....	55
8.2.4	Mandatory inspection criteria for vehicles involved in main line derailments	55
9.0	Appendices	56
9.1	Track Configuration Review.....	56
9.2	4YN2 Train Consist Information	60
9.3	RQBY Wagon Details.....	61
9.4	Train Register Book – 7th & 8th November 2002 Harden North	62
9.5	Events and Conditions Chart Symbols & Meanings	65
9.6	Events and conditions chart – Rocky Ponds Derailment subject to Misalignment on 7th November 2002	66
9.7	WTSA Results for Location 377.500km	71
9.8	RIC Civil Technical Notes – Misalignment Reporting Requirements.....	72
9.9	377.960km Curve Alignment Measurements Taken on 25 Aug 2003.	76
9.10	Train Crew’s Shift Roster – Two Weeks prior to Incident.....	77
9.11	Welded Track Stability Analysis Pre and Post Misalignment at 377.960km.....	78

1.0 EXECUTIVE SUMMARY

Preliminary Facts

1. In August 2002, the Local Rail Infrastructure Corporation (RIC) maintenance team identified concerns with the track stability on the Up Main line between Harden North and Yass Junction, in the vicinity of 377.960km. The maintenance team's inspection and analysis revealed a curve alignment problem, where the curve at 377.960km was found to have pulled in towards the curve's centre by a maximum of 215mm during the winter months of 2002. To rectify this stability problem, track resurfacing was carried out on the curve on 3 October 2002 where the curve was realigned back to the design alignment.

The Accident

2. On Thursday 7 November 2002 at 16:39, Pacific National service 4YN2 (4YN2) travelling from Whyalla to Morandoo derailed at 377.960km on the Up Main line between Harden North and Yass Junction. 4YN2 was travelling at 82km/h at the time of the derailment. RQBY 15208F marshalled last in the train consist (24th vehicle) derailed all wheels on the number 2 bogie. Following the derailment, 4YN2 travelled approximately 1.960km before coming to a stand at 376.000km.
3. Minor track damage and rolling stock damage was sustained due to the derailment. The line was reopened under a 20km/h speed restriction at 20:45, some 4 hours after the incident took place.

Causal Factors

4. Inspection of the track on 7 November 2002 following the derailment revealed a misalignment at 377.960km. Evidence gathered at the misalignment site revealed that the curve had pulled in some 300mm towards the curve's centre causing the misalignment. The curve pull-in movement occurred between the time of the most recent track resurfacing (3 October 2002) and the date of the derailment (7 November 2002).
5. The investigation concluded that 4YN2 derailed at 377.960km as a direct result of the track misaligning under the train's last vehicle. The factors identified as being present at the time of the incident were determined to be:
 - a. the track having reduced lateral stability prior to and during the misalignment (as a result of prior track resurfacing works, pumping steel sleepers, foul ballast and poor sleeper condition) where this reduced lateral track stability was considered to have allowed the 300mm curve pull-in to occur, and
 - b. the rail being out of adjustment prior to the misalignment, where this adjustment error resulted from the curve alignment having pulled in 300mm prior to the misalignment.

6. This curve pull-in would have resulted in an excess of steel within the curve that would have imparted compressive forces within the rails at the incident ambient temperature of 31°C. These compressive forces, coupled with the normal dynamic lateral forces exhibited by rolling stock traversing a curve, would have resulted in the track misaligning and causing the last vehicle of 4YN2 to derail.

Contributing Factors

7. The deteriorated condition of sleepers, the pumping steel sleepers and foul ballast at the misalignment site permitted the curve pull-in to take place.
8. The track inspection and maintenance program together with the life cycle track management system was inadequate for the timely identification and rectification of the deterioration specified above.

Post Incident Safety Actions Carried Out

9. RIC has carried out the following safety actions and remedial works in order to avert the occurrence of a similar incident at 377.960km. To date there has been no further track stability issues at 377.960km.
 - (1) An interim track configuration change from continuously welded rail to jointed welded rail was carried out,
 - (2) 200 Low profile concrete sleepers in a 1 in 4 pattern were installed at the misalignment location prior to November 2003, and
 - (3) 4 tonnes of ballast was laid over 220m along the six foot at 377.960km prior to November 2003. This ballast was laid to help improve the Down Rail side shoulder ballast profile and hence lateral track structure stability at 377.960km.

Safety Recommendations

10. A complete listing of the safety recommendations of this investigation are contained within Section 8.0. It is recommended that the following remedial safety actions be undertaken by the specified responsible entity:

a. Rail Infrastructure Corporation:

- (4) Define Welded Track Stability Analysis (WTSA) rectification work processes to assist maintainers in selecting the most appropriate methods of WTSA track repairs;
- (5) Identify the rail adjustment status of continuously welded rail (CWR). Correct deficiencies in rail adjustment as per standard maintenance processes and procedures;
- (6) Review and amend where necessary the WTSA algorithm considering the impact of steel sleeper & ballast condition;
- (7) Increase the frequency and quality of the track inspection schedule at sites of previously repaired alignment defects;

- (8) Conduct a further stability review of the misalignment site and repair the track structure where necessary;
- (9) Ensure maintainers report misalignments and follow track restoration processes as per standard requirements;
- (10) Ensure dynamic stabilisation resources are made available to maintainers following resurfacing works when specifically required by the maintainer; and
- (11) Define mandatory inspection criteria for vehicles involved in main line derailments as a minimum standard for all Operators.

b. Pacific National:

- (12) Ensure that fatigue rostering assessments are applied to relieving train crew staff.
- (13) Ensure all vehicles involved in main line misalignment derailments are inspected against applicable RIC minimum operating standards for rolling stock. This inspection should determine, where practicable, if the rolling stock has played a contributory role in the misalignment.

Supplementary Investigation

c. The Office of Transport Safety Investigation:

- (14) A supplementary investigation is to be conducted by the *Office of Transport Safety Investigations* into the introduction and performance of steel sleepers in the NSW Rail Network.

2.0 TERMS OF REFERENCE

Date of incident:	7 November 2002
Location:	Rocky Ponds at 377.960km on the Up Main South line.
Details of Incident:	4YN2 Pacific National freight train derailed as a result of a track misalignment.
Type of Inquiry:	Railway Investigation Section 67
Investigator :	Transport Safety & Rail Safety Regulation Division, Ministry of Transport.
Assisting :	Rail Infrastructure Corporation Pacific National
Owning Railway:	Rail Infrastructure Corporation
Operator:	Pacific National
Infrastructure Maintainer:	Rail Infrastructure Corporation

The Executive Director of the Transport Safety & Rail Safety Regulation has authorised the investigation and publication of this report pursuant to the provisions of Sections 67 and 70 of the *Rail Safety Act 2002 NSW*. The Office of Transport Safety Investigation (OTSI) has finalised this investigation pursuant to schedule 5 Section 17 of the *Rail Safety Act 2002 NSW*.

The investigation was commissioned to :

1. Identify all factors that contributed to the occurrence of the incident.
2. Identify whether the incident type should have been anticipated and assess the effectiveness of the risk management strategies adopted.
3. Assess the adequacy of the emergency response to the incident as it affected the safety of all persons involved.
4. Advise on matters arising from the investigation, which would enhance the safety of rail operations.

3.0 INVESTIGATION METHODOLOGY

The investigation has been conducted in accordance with the principles of Australian Standard AS 5022:2001, Guidelines for railway safety investigation.

The objective of the investigation is to determine the circumstances surrounding the accident and provide information to prevent the recurrence of similar events.

The investigation is in no case intended to imply blame or liability. However sufficient factual information is included to support the analysis and conclusions. Some information may reflect on the performance of individuals and organisations, and how their actions have contributed to the outcomes of the matter under investigation.

System safety accident investigation (SSAI) techniques have been applied to structure the investigation and analyse the evidence.

The SSAI approach includes;

- Applying the Reason model to analyse accident causation in terms of latent conditions and active errors.
- Identifying and analysing human factors issues.
- Identifying and analysing the risk management strategies that should have prevented the accident.
- Using events and conditions charting to illustrate the incident.

Information and data has been gathered as evidence for the investigation. This includes:

- Locomotive data logger.
- Review of RIC and Pacific National safety management systems.
- Interviews with personnel involved in the incident.
- Curve and gradient diagram.
- Infrastructure maintenance standards and procedures.
- Infrastructure maintenance records.
- Wagon maintenance history.
- Wagon derailment certification.
- Misalignment track measurements.
- Track configuration information.
- Crew rosters.

4.0 FACTUAL INFORMATION

4.1 Overview

4YN2 derailed the trailing bogie of its last vehicle on the Up Main South in the afternoon of 7 November 2002. Shortly after the derailment the train crew detected dust emanating from the train's rear. The Driver then made an emergency brake application bringing the train to a stand some 2 kilometres after the initial derailment. An inspection of the track revealed a misalignment at the derailment location as depicted in Figure 4.1.

No injuries resulted from the incident. The air temperature recorded close to the time of derailment was 31 °C.



Figure 4.1 Misaligned track at 377.960km

4.2 The Occurrence

The incident occurred at approximately 16:39 on Thursday 7 November 2002 on the Up Main South at 377.960km. On approach to the incident site 4YN2 had just negotiated a climbing 1:74 grade before traversing the crest of a hill at 378.300km and descending down the 1:49 grade to 377.960km. Just prior to the derailment site, the Driver applied the automatic brake with an 80kPa application in order to control the train speed leading into and on the falling grade. Refer to Figures 4.2 & 4.3 detailing the approaching and departing views to the point of derailment and the applicable curve and gradient diagram describing the derailment location respectively.

At 377.960km the last wagon of 4YN2 derailed its trailing bogie. Shortly after the derailment the Driver noticed dust emanating from the train's rear. The Observer also confirmed the presence of dust and identified that the last wagon was derailed and had shifted out from the track. At this point the Driver applied the emergency brake bringing the train to a stand at 376.000km.

Prior to the train coming to a stand, the Observer contacted Junee Train Control (Control) and advised Control of 4YN2's derailed condition. Control then arranged for all trains to be held at Yass Junction and requested for the rear of 4YN2 to be protected from trains on both the Up and Down Main South lines. The Observer then proceeded to the rear of the train to assess for damage, place down safeworking protection and identify any obvious cause of the derailment.

An inspection of the track at 377.960km by 4YN2's Observer and a local track maintainer, revealed the track to be misaligned.

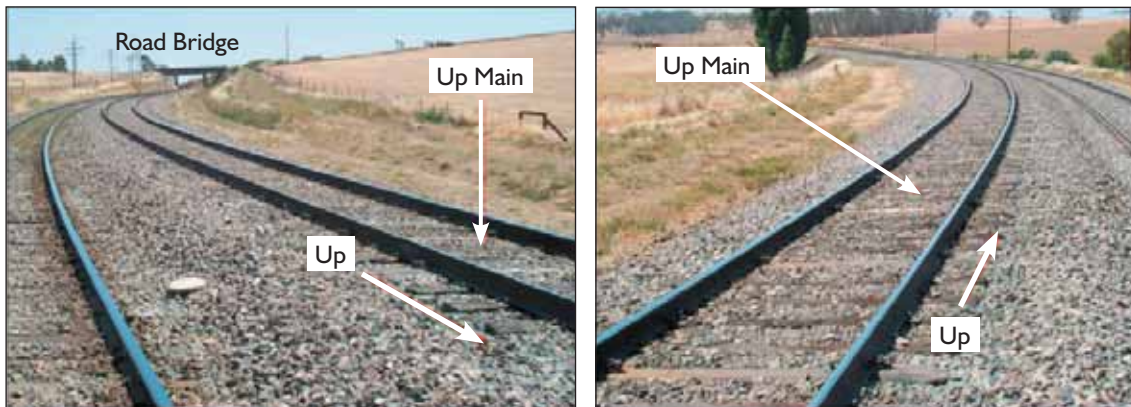


Figure 4.2 Up Main at misalignment location facing down direction (left) ,Up Main at misalignment location facing Up direction (right) following track restoration

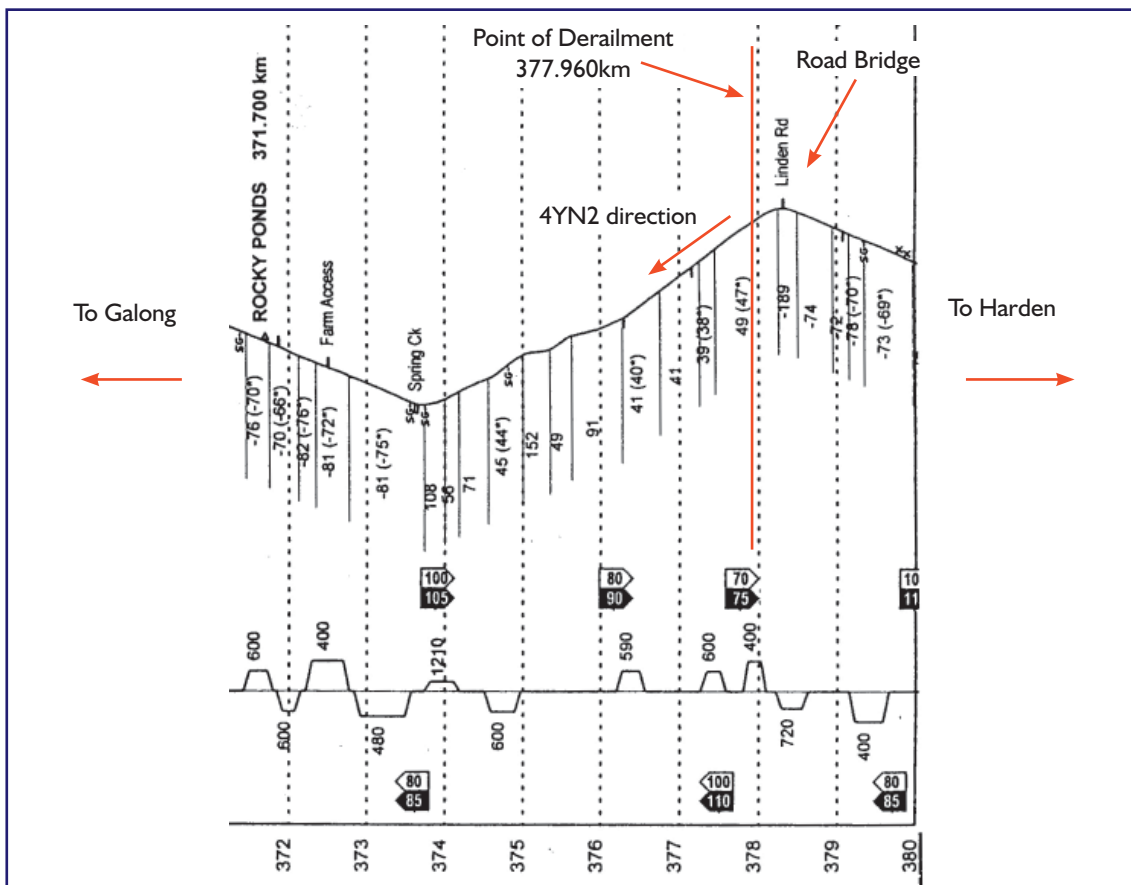


Figure 4.3 Curve and Gradient Diagram

The Observer's inspection also confirmed that the last vehicle (RQBY 15028F) had derailed all wheels of its trailing bogie. The derailed vehicle and the second last vehicle (RQJW 21983W) were then detached from 4YN2. RQJW 21983W was detached from 4YN2 to act as a cover vehicle¹ to RQBY 15028F. The train crew, in preparation for the train's departure, then conducted a brake test and train inspection.

Pilot staff single line working was introduced over the Down Main line at 23:38. Safeworking protection was also applied to protect the last two detached wagons before 4YN2 departed at 20:45.

The Police did not attend the incident to breath test both the Driver and Observer as they were not contacted. Prior to 4YN2's departure the Network Operations Superintendent assessed the train crew as fit to continue duty based on a general sobriety assessment.

Track repairs were subsequently carried out on the misalignment at 377.960km with the track being certified fit for traffic at 21:05 by the local track maintainer. A 20km/h speed restriction was also applied over the misalignment curve at this point.

A light Locomotive (DYN2) departed Harden North for the derailment site at 23:30 where this Locomotive connected up to vehicles RQBY 15028F and RQJW 21983W. These vehicles were then transported under a 20km/h speed restriction back to Harden North.

Pilot Staff safeworking was finally cancelled at 03:23 on 8 November 2002.

4.3 Injuries

The train crew sustained no injuries.

4.4 Loss or damage

Track

Minor track damage was sustained due to the derailment. This damage included minor sleeper damage, broken shoulders on steel sleepers. Refer to Figure 4.4 depicting typical sleeper damage sustained during the derailment.



Figure 4.4 Sleeper damage sustained during derailment

¹“Cover vehicle” denotes a vehicle coupled to another defective vehicle for the purpose of ensuring the two vehicles have at least one working handbrake and air brake system between them.

Rolling Stock

The number 2 bogie of RQBY 15028F sustained gouging damage from being dragged in the ballast for approximately 2km. This bogie was replaced prior to the movement of RQBY 15028F from Harden North. No other substantial damage was identified on the derailed RQBY 15028F vehicle. Refer to Figure 4.5 depicting the ballast damage to the trailing bogie of RQBY 15028F.



Figure 4.5 Bogie and Wheel Ballast Gouging Damage Sustained on the No.2 Bogie of RQBY 15028F

4.5 Workers involved

Train Crew

Relevant qualifications and medical records for the train crew were current at the time of derailment.

Maintenance Staff Track Patrol

Relevant qualifications and medical records for the track maintenance staff involved in the track patrol were current at the time of derailment.

Relevant qualifications and medical records for the track maintenance staff involved in the walking inspection were current at the time of the detailed walking inspection.

4.6 Train Information

4.6.1 Train Consist

4YN2 consisted of 2 locomotives and 22 wagons with a trailing load of 1918 tonnes and 520m in length. Ten (10) steel, one (1) limestone and eleven (11) container flat wagons were marshalled on 4YN2. The train consist of 4YN2 indicated all wagons to be within their gross mass loading requirements. The last 12 wagons were not loaded.

Train Condition

PN's first response group from Cootamundra attended the incident and re-railed the trailing bogie of RQBY 15028F. A 20km/h speed restriction was placed on

RQBY 15028F pending a bogie change. Refer to Figure 4.6 depicting vehicle RQBY 15028F and the empty container configuration loaded on this vehicle on 7 November 2002.

PN representatives could not produce inspection records to verify that the train's rolling stock condition was checked prior to its depart. Such an inspection would have determined if the train's condition contributed in any way to initiating the misalignment.



Figure 4.6 Vehicle RQBY 15028F

An inspection of the derailed train by infrastructure maintainer representatives identified a number of suspected mechanical conditions that could have potentially contributed to the occurrence of a misalignment. An inspection to either verify or reject these items was not provided by any of the Pacific National rolling stock representatives that attended the derailment site. The mechanical conditions identified by the infrastructure maintainer representatives included:

- Loose axle liner bolts (bolts in this condition pose the potential to jam the axle box within the pedestal liner)
- Uneven wheel wear (this condition was not defined to any greater extent)
- Bogie springs identified to be almost fully compressed (a measurement between the spring coils not taken)

4.6.2 Train Maintenance Status

4YN2 underwent a full train examination out of Whyalla on 6 November 2002. A copy of this train examination certificate was requested in order to verify that such an inspection took place, however the brake certificate could not be produced by Pacific National.

Nineteen (19) trailing vehicles on 4YN2 held a maintenance status of "O" indicating that each of these wagons were within their normal maintenance schedule and fit to operate. Two of the last five trailing vehicles held a maintenance status of "P1". This maintenance status is indicative of the wagon being over the normal kilometres travelled but within the prescribed allowable kilometres to remain in service. Refer to Appendix 9.2 ("cond" column) to view the train consist and maintenance status of 4YN2.

4.6.3 Train Data Logger Information

The following information has been summarised from Locomotive NR8's data logger on 4YN2 as it passed over the length of track between 378.29km to 375.43km at 16:35 to 16:37 on 7 November 2002.

ID	Time hh:mm:ss	Distance km	Speed Km/h	Brake Pipe kPa	Independent Brake	Event Description
1	16:35:09	378.29	70	503	0	Moved from notch 8 powering to idle.
2	16:35:35	377.75	79	503	0	Applied automatic air brake – reducing pressure from 503kpa to 420kpa.
3	16:36:34	376.47	72	420	0	Released automatic air brake.
4	16:36:42	376.28	73	482	0	Applied automatic brake after noticing dust from rear of the train.
5	16:37:47	375.43	0	344	379	4YN2 lead locomotive stopped at approximately the 375.430km mark.

Table 4.1 – 4YN2 Brake Application Events

Figure 4.7 below identifies the data logger print-out for 4YN2 with reference lines 1 to 5, where these reference lines correspond to the ID data 1 to 5 in Table 4.1.

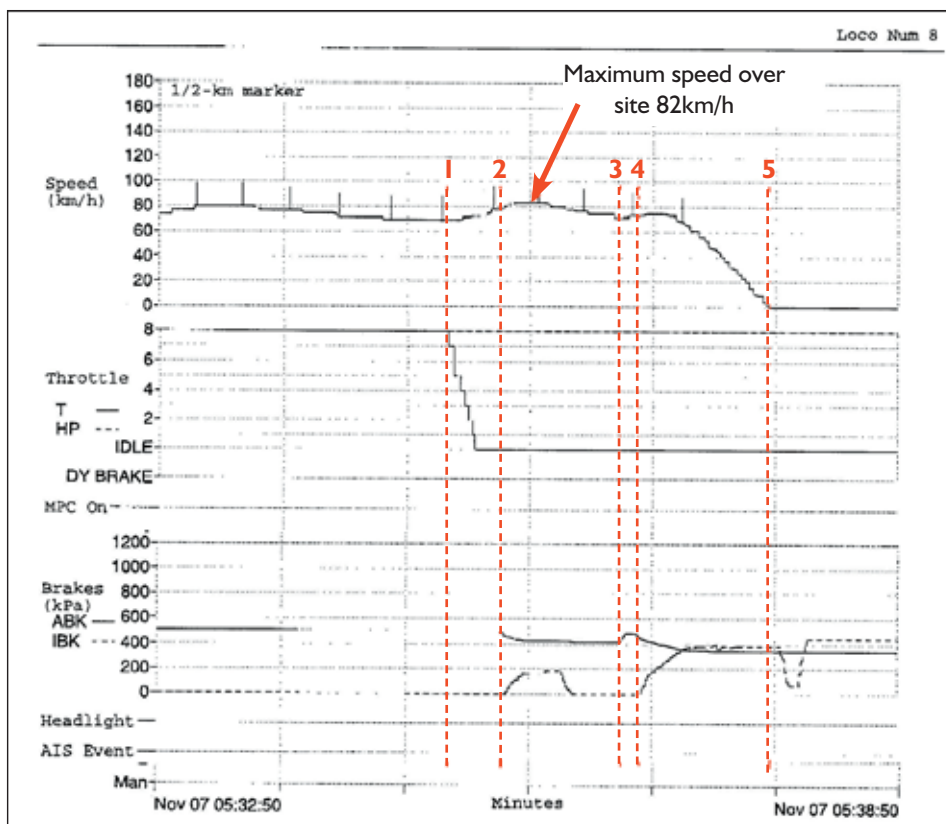


Figure 4.7 4YN2 Data Logger Print Out 7 November at 16:35

Figure 4.7 confirms that the rear of 4YN2 was travelling at approximately 82km/h at the time of derailment. The calculation of this speed is based on the facts that;

- 4YN2 maintained its speed at approximately 82km/h, as measured at the lead locomotive, between 377.66km and 377.23km, and
- 4YN2 was 566m in length effectively resulting in the rear of 4YN2 also maintaining this speed between 378.23km and 377.80km.

4.6.4 Train Management Standard and Compliance

Pacific National's Train Management Participants Notes dated February 1999 Page 2.13 provides guidance in the application of the automatic train brake. These notes stipulate:

"After the air brake has been applied it must not be released until:

- *The brake pipe pressure has been reduced by at least 70kPa – releasing the air brake following a minimum reduction (50kPa) can cause sticking brakes at the rear of a long train.*
- *At least 10 seconds have elapsed after the brake pipe pressure has ceased exhausting from the brake valve – this ensures that the application has become effective at the rear of the train and that the brake pipe pressure has stabilised before a release is initiated."*

As noted in Section 4.6.3, the automatic brake application initiated at 377.75km was 80kPa and the application was held for 59 seconds. Compliance with the train handling management standard described above is therefore identified.

Compliance with the track speed of 80km/h at 377.96km, for the entire length of 4YN2 (566m), was generally achieved with a slight over speed of approximately 2km/h for the train's rear half as it passed over the misalignment site.

4.6.5 Toxicology information

The Pacific National Driver and Observer were not breath tested.

4.7 Track Details

4.7.1 Incident Location

The derailment occurred on the Up Main South line approximately 3km north of Cunningar at 377.960km.

4.7.2 Misalignment Report

RIC's Civil Technical Notes as issued by Safety & Standards CTN 02/15 dated 16 August 2002 requires the following:

Reporting Requirements

“The following information is to be supplied. It is essential that reports are timely accurate and complete.....

Misalignment Forms (Form 1 from AP .5363) are required two days from the occurrence of any misalignment.....

*A full misalignment investigation should be carried out for each misalignment on mainline track class 1 to 3, in line with the **Misalignment Investigation Report**..... The findings of the investigation should be included on the Form 1 report.*

Major Adjustment Disturbances

Specific attention is drawn to major adjustment disturbances such as from derailment damage. It is essential to ensure that adjustment has been correctly restored.

Following the misalignment the Harden Maintenance Manager did not submit a misalignment form in accordance with CTN 02/15. Refer to Appendix 9.8 to review these misalignment reporting forms.

A check of rail adjustment over the 500m section in which the misalignment curve was situated was not carried out in accordance with the “Major Adjustment Disturbances” requirement specified above.

4.7.3 Track Configuration

The misaligned curve consisted of mainly timber sleepers with approximately 1 in 4 steel ties supporting 53kg rail. The point of derailment was on a 402m radius left-hand curve located on a descending 1 in 49 grade. Track speed for freight is 80km/h approaching the misalignment site increasing to 100km/h at 377.490km.

Steel Sleeper Pattern

At the standard sleeper spacing of 600mm and with a recommended steel sleeper pattern of 1 in 4, for curves less than 600m radius, there should be 1 steel sleeper spaced every 2.4m. A review of the number of steel sleepers in place on the misalignment curve can be referenced within Appendix 9.1.

This review highlighted that there were 37 steel sleepers out of 106 steel sleepers laid between the two curve transition points of 379.095km and 377.803km. This pattern approximates to an installation pattern of 1 steel sleeper in every 3 sleepers laid. RIC’s Steel Sleepers - Usage and Installation Standard TS 20540 3 00 SP does allow for variation in this pattern subject to the following:

“A variation in the tie pattern of one steel sleeper (from the recommended pattern) is still considered to be pattern as long as the pattern is generally maintained (eg 1 in 4 would allow odd sleepers to be 3rd or 5th sleeper) except that clumping is prohibited.”

The review also highlights 2 instances where a clumping² installation pattern of steel sleepers has occurred at 378.020km and 377.846km.

Rail Closures

A review of the location and number of rail closures³ installed in the misalignment curve can be referenced within Appendix 9.1. This review indicated that 14 closures had been inserted within the misalignment curve between the transition points at 378.095km and 377.803km. Reference punch marks⁴ were not visible on the outside head of the rail at each of these rail closures. This fact indicates that either the closures were installed prior to the issue of RIC's 5m punch mark standard or there has been no compliance with the 5m punch mark standard at this location.⁵

4.7.4 Track Maintenance Standards

RIC utilise a number of standards to manage the issue of track misalignment. These standards are contained within RIC's Civil Engineering Standards, Engineering Practices Manual and Civil Technical Notes.

References to six RIC standards / procedures are worth noting for further review in the analysis section of this report.

RTS 3656 Version 2.0 February, 2002

Causes of Misalignment

This standard sets out the procedures necessary to effect temporary and permanent repairs to misalignments on welded track. The track related causes of misalignment are also detailed in this standard. Frequently the cause is a combination of several factors. These factors can be summarised as:

No.	Factor
1	Track disturbed by resurfacing, ballasting, cleaning and PRS, etc
2	Track is incorrectly adjusted
3	Track has insufficient ballast
4	Track has foul ballast or glazed ballast bed
5	Track has incorrect anchoring pattern and or insufficient anchoring or effective anchors ineffective due to positioning or "sprung anchors"
6	Sleepers and fastenings are defective
7	Insufficient superelevation or sharp "kink" in curves
8	Trains exceeding speed boards
9	Sleepers not firmly packed

Table 4.2 – Causes of Misalignments

C2433 Track Examination: Calculation of Welded Track Stability from Field Information November 2001 Version 2.0

The Welded Track Stability Analysis (WTSA) is part of RIC's Track Examination System. The WTSA process is concerned with the stability and adjustment of welded rail. The process is carried out in the late winter/early spring each year in an effort to identify all sections of welded rail where stability may have been reduced, and there exists a possibility the track could misalign in warm weather. Detailed procedures covering the measurement and analysis of welded track stability are covered in RIC Standards C2442, C2443 & RC 2442.

Section 4.0 Stability Limits of this standard specifies the priority 1 and 2 percentage bands where a Priority 1 WTSA analysis exists when the percentage stability loss is greater than 55%. A Priority 2 WTSA analysis exists when the percentage stability loss is greater than 40% and less than or equal to 55%.

Section 6.0 Special protective actions of standard C2433 specifies "Where the loss of stability due to track disturbance and ballast deficiencies exceeds 55% evasive action should include the use of appropriate speed restrictions when the ambient temperature exceeds 25°C."

C2433 also specifies in Section 6 "Where the loss of stability due to track disturbance and ballast deficiencies only exceeds 40% evasive action should include the use of appropriate speed restrictions when the ambient temperature exceeds 30°C."

Civil Technical Notes CTN 02/15 Dated 16 August 2002

Lines with weak track structure and/or poor condition

Class 4 and 5 lines have restricted speeds and special actions are usually taken in summer. These should continue. Other lines with similar problems should be considered for additional restrictions in summer.

On lines which feature sharp curves, where alignment is difficult to maintain, it is recommended that additional measures be taken to stabilise the tracks, including:-

- Use of dynamic stabiliser when tamping

² Clumping of steel sleepers is where there are two or more adjacent steel sleepers.

³ "Rail closures" are short lengths of rail (usually no more than approximately 2m in length) that are welded into the rail to replace rail lengths identified with rail defects.

⁴ Small indentations are punched on the cess side head of the rail using a steel punch. These two punch marks are applied to the rail at a standard spacing of 5 metres. The rail closure or thermit weld is located at the approximate midpoint of the two punch marks. Punch marks effectively record a defined length of the rail prior to the rail being cut for the removal and insertion of a rail closure or thermit weld. Rail maintenance staff then utilise these reference marks to ensure that no addition or reduction in the length of rail occurs between the two reference punch marks when either the rail closure or thermit welds are inserted within the rail.

⁵ RIC Standard Adjustment and Field Welding for Continuous Welded Track RTS.3650 – Version 2.0, February 2002, Appendix 5 Page 12 requires the use of 5m reference punch marks. Prior to the issue of this standard the requirement for punching rails existed for welding rail closures as per the Rail Services Australia Engineering Practices under RCSI 24 January 2000.

- Additional ballast especially on shoulders (but clear of train trips)
- Additional speed restrictions in hot weather.

Steel Sleepers – Usage and Installation Standards TS 20540 3 00 SP Dated January 2003

1 General Description

Steel sleepers behave differently to conventional track sleepers, mainly because they are relatively light in comparison to their rigidity. They rely on the ballast to provide support and to add to their effective mass.

6.3 Sleeper Support after Installation

Ballast pods of all steel sleepers shall be full to the top of the inspection hole and ballast within the sleeper shall be “tight” (as determined by attempting to move the ballast in the vicinity of the inspection hole with a finger).

7.2 Follow Up Inspection Requirements

The satisfactory installation of steel sleepered PRS should also be verified by review of its in service performance. This should include identification of any obvious problems during track patrol inspections, the results of the track geometry recording car and assessment during detailed walking inspections including:-

- Sample check that ballast in pods are still to standard (minor ballast settlement and a low level of loosening is permissible, typically ballast in the inspection hole can be moved with a finger but the movement shall be restricted).
- Visually assess if ballast profile is still to standard.
- Visually assess that the deflection of steel sleepers and timber sleepers under load is consistent and no more than 5mm.
- Visually inspect for any signs of ballast disturbance.

Adjustment and Field Welding for Continuous Welded Track.- RTS 3650 Version 2.0 February 2002

5.0 Rail defect repair – “Rail out – Rail In” method (Appendix 5)

It is preferable to check the correct rail adjustment whenever welding operations are undertaken in CWR track. When this, however, is not practical it is essential that rail adjustment is not changed. In its simplest terms this means.

$$\text{RAIL IN} = \text{RAIL OUT}$$

The procedures necessary to achieve this are detailed in Appendix 5 for the repair of defects.

Appendix 5 (extract)

1. Place two punch marks on the outside head of the rail (one each side of the section of rail to be removed nominally 5.0m apart).

Aluminothermic Welds – Identification, recording and reporting RAP 539 I
Version 3 May 2002.

7.0 Completion of Form (Weld Return Form Appendix 1)

The information required in order to complete a rail return form includes recording punch mark measurements before and after a weld is undertaken. A requirement also exists for an independent rail flaw detection officer to record that punch marks have been applied to the rail and that the measurement between the punch marks is consistent with the value recorded on the weld return form.

4.7.5 Track Condition

The track condition at the misalignment site is described in the following track configuration categories:

Anchor Condition

The anchor condition as assessed in the pre misalignment WTSA report was noted as “good”, resulting in a 2% loss of stability as calculated in C2443 Table 5. A review of the anchor condition post derailment, and following track restoration did however identify some anchors spaced away from the sleeper edge. Refer to Figure 4.8 depicting a rail anchor spaced away from the sleeper edge. A small number of those anchor placements depicted in Figure 4.8 would still result in a WTSA assessment of “good” depending on the overall anchor condition of the 500m section.

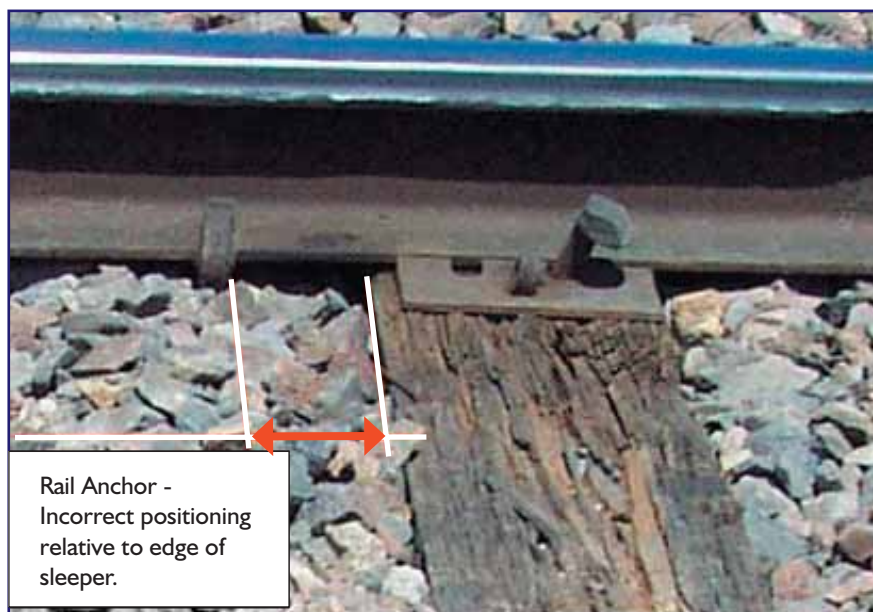


Figure 4.8
Incorrectly positioned anchor located within misalignment site.

Ballast Profile Condition

The ballast profile as identified following the derailment was considered “full” for both shoulder⁷ and crib⁸ throughout the misalignment site. Refer to Figure 4.9 depicting typical ballast profile throughout the misalignment site.

⁶ “Full” denotes an acceptable level of ballast surrounding the sleepers.

⁷ “Shoulder” denotes the ballast profile present at the ends of a sleeper.

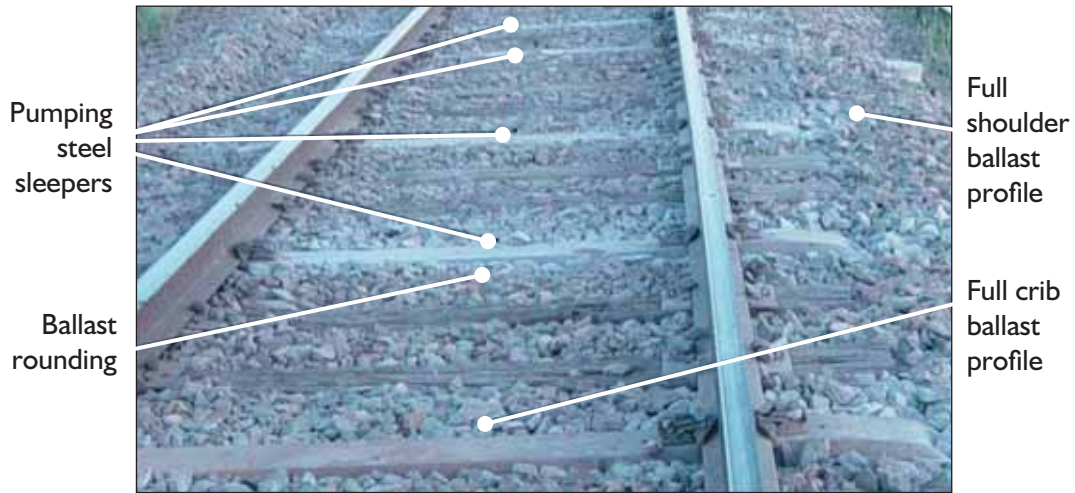


Figure 4.9 Typical Shoulder and Crib Ballast Profile throughout Misalignment Site.

Ballast Angularity Condition

A number of pumping⁹ steel sleepers were identified throughout the misalignment site. The ballast condition near these pumping steel sleepers varied, in terms of the individual ballast angularity¹⁰. Refer to Figure 4.10 depicting ballast condition evident in the vicinity of pumping steel sleepers within the misalignment curve. Note the loss of ballast angularity close to the pumping steel sleeper located on the misalignment curve.

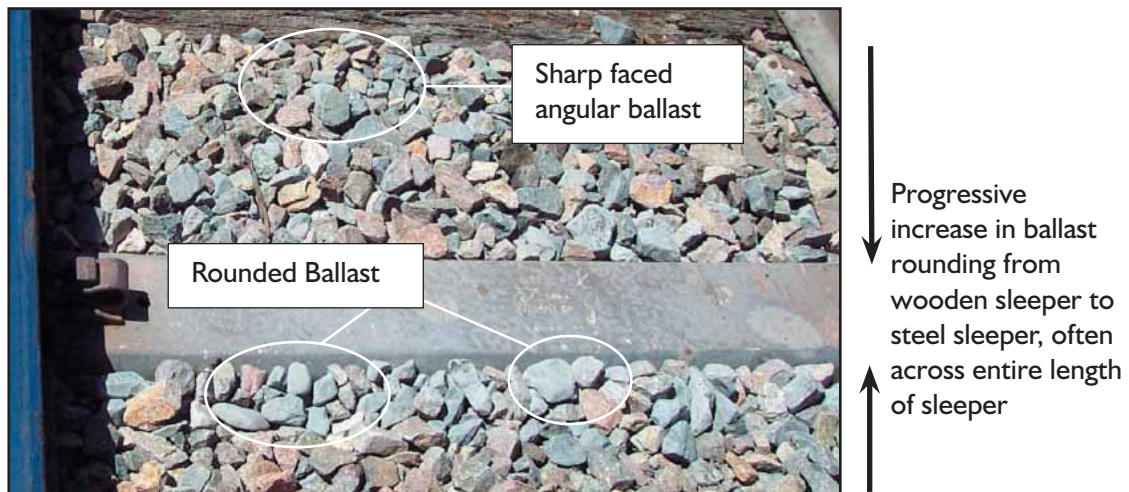


Figure 4.10 Rounded Ballast Evident Close to Pumping Steel Sleepers at Misalignment Site.

⁸ “Crib” denotes the depth of ballast between two adjacent sleepers, relative to the top surface of each adjacent sleeper. A full crib of ballast is identified when the ballast’s surface is level with the top surface of each adjacent sleeper.

⁹ “Pumping” denotes a sleeper that moves vertically up and down as rail traffic passes over the sleeper. This movement often results in the degradation and contamination of the ballast structure.

¹⁰ Adequate ballast angularity is required in order for the ballast to lock in together and maintain acceptable ballast compaction. Adequate ballast angularity is also required in order for the ballast to lock into the timber sleeper surface. Ballast stability effectively reduces as ballast angularity reduces.

Foul Ballast

A short length of track (20m) exhibited a high degree of foul ballast within the WTSA 500m length at approximately 378.300km (refer to Figure 4.11) and as such was registered within the WTSA calculation for the 500m section. This length of track is located some 350m from the misalignment site, being located on the down side of Linden Road bridge (Refer to Figure 4.3). The foul ballast at this point was not considered to have had any influence on the misalignment curve. Foul ballast however was detected in the immediate vicinity of 377.960km at an inspection carried out in August 2003 as depicted in Figure 4.18.

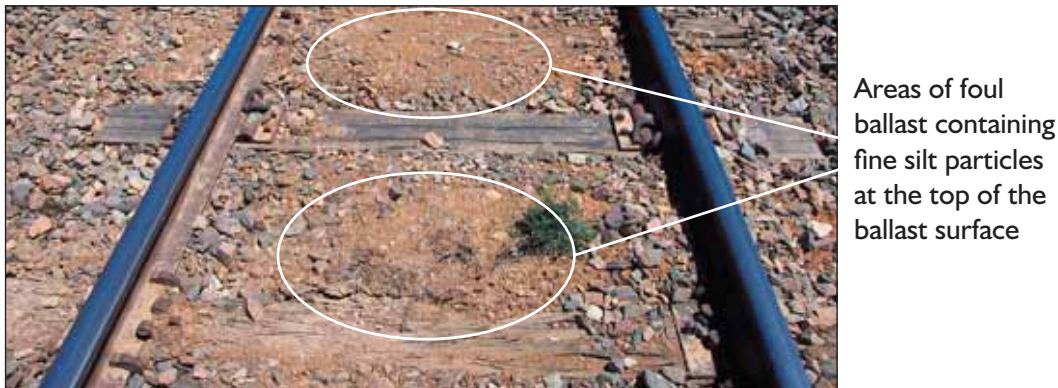


Figure 4.11 – Foul ballast identified within the 500m WTSA section at 378.300km.

Rail Weld Alignment

All rail welds on the misalignment curve were determined to meet standard requirements.

Fastener Condition

The fastener condition over the misalignment site varied from satisfactory to poor.

Sleeper Condition

The sleeper condition over the misalignment site varied from satisfactory to poor.

Alignment

No defects were detected with the track alignment at 377.960km prior to the passage of 4YN2. No obvious alignment problems had been detected on the last two track patrol runs over the misalignment site that occurred on 4 November 2002 and 7 November 2002. The Harden Maintenance Team maintenance records were also reviewed, indicating that no misalignment at 377.960km had been recorded prior to 7 November 2002.

4.7.6 Track Maintenance

Welded Track Stability Analysis

Pre and post misalignment welded track stability analysis reviews were undertaken by the local RIC maintenance team over the 500m section of track in which the

misalignment curve is located. Post misalignment calculations identified that the curve at 377.960km would have had a high degree of track instability when considering the curve pull-in alignment of 300mm. Refer to Appendix 9.11 describing these welded track stability analysis reviews.

The investigation noted that the maintainer had not updated the WTSA records following the resurfacing works conducted on 3 October 2003. Updates of the WTSA records at 377.960km did not occur until after the misalignment had occurred. The maintenance team did not appear to be using the TrackStab analysis program to maintain an updated account of WTSA priorities.

Accounts were provided by maintenance staff that the curve at 377.960km was however being monitored with respect to the threat of curve pull-in. This monitoring was carried out in response to those other curves that were detected to have pulled in following the resurfacing works carried out in the area during early October 2002. Refer to Appendix 9.8 detailing the WTSA priority analysis for the curve at 377.500km (misalignment curve).

Dynamic Stabiliser - Welded Track Stability Analysis

As per CTN 02/15 dated 16 August 2002 the use of a dynamic stabiliser is recommended for curves “*where alignment is difficult to maintain*”. The Harden Team Manager has historically used the dynamic stabiliser in accordance with the technical note’s recommendation. The dynamic stabiliser however has not been made available in the Southern region since 1998 due to the cost of its operation and its limited availability.

The use of a dynamic stabiliser on a curve that has recently undergone resurfacing improves the track stability loss by an immediate 10%. One month following the resurfacing works the track stability reduces a further 11% if a dynamic stabiliser has initially been used. The effect of this improvement in stability provides a number of benefits. In particular, with respect to the prevention of curve pull-in, it would be less likely for a curve to pull-in following resurfacing works carried out in conjunction with a dynamic stabiliser than without a dynamic stabiliser.

Had the dynamic stabiliser been used following the resurfacing works at 377.960km the track stability loss would have reduced by approximately 21 % at the time of misalignment.

Track Realignment

The misalignment curve had been previously identified as a priority 1 WTSA location (stability loss of 74%), as part of the pre-summer welded track stability analysis. The main contributing factor in this analysis was curve alignment, where the curve at 377.960km was found to have moved in towards the curve’s centre by a maximum of 215mm during the winter months of 2002. To rectify this stability problem, track resurfacing was programmed and carried out on 3 October 2002 at the misalignment curve and a number of other curves identified with alignment WTSA problems.

Re-alignment of the curve to within +/- 15mm of the design alignment was achieved.

Following track resurfacing work on 3 October 2002, the area experienced three nights of cold weather registering minimum temperatures between 0°C and 2.5°C. A number of surrounding curves that had previously undergone resurfacing works were detected to have pulled in after these cold nights at the locations identified in Table 4.3. Track maintenance staff on routine track patrol observed these curve pull-in locations.

Location	Line
403.750km – 403.700km	Up Main
396.480km – 396.400km	Up Main
368.400km – 368.500km	Dn Main

Table 4.3 – Curves identified to have pulled in following resurfacing works and cold nights in October (Main South)

Rail Welds

Weld records were reviewed during the investigation to determine if recent rail welds had been inserted in the vicinity of 377.960km. These records indicated four (4) transverse defects that had been removed as per Table 4.4.

Km	Removed Date
377.980km	6/11/1997
377.900km	29/1/1998
377.800km	8/07/1998
377.860km	16/03/2000

Table 4.4 – Most Recent Rail welds carried out on the misalignment curve

Weld Alignment Defects

Weld alignment records were reviewed during the investigation to determine if recent rail welds had been identified with alignment failures. No weld alignment defects were recorded prior to the derailment.

Track Patrol Inspections

Routine track patrols were conducted in the mornings of 4 November 2002 and 7 November 2002. These inspections did not detect any noticeable track misalignments.

RIC's process control plan PCPCIV01B Examination of Track – Hi Rail Track Patrol Revision 3.1 Issued date 2001 identifies the requirement for a track patrol to:

- “4. Obtain T6400 and commence Hi Rail patrol.
 - One qualified employee examining tracks with assistance of second employee...”
- “5. Undertake a visual examination of the track and right away that ensures...
 - There are no major geometry exceedences or derailment potential locations (without suitable protection)”

The accuracy of detecting track defects around tight radius left-hand curves would reduce for an Observer due to the parallax sighting errors and rail head obstructions that are apparent when conducting the inspection from the Observer's position. Refer to Figure 4.12 depicting the Observer's view from a hi-rail.

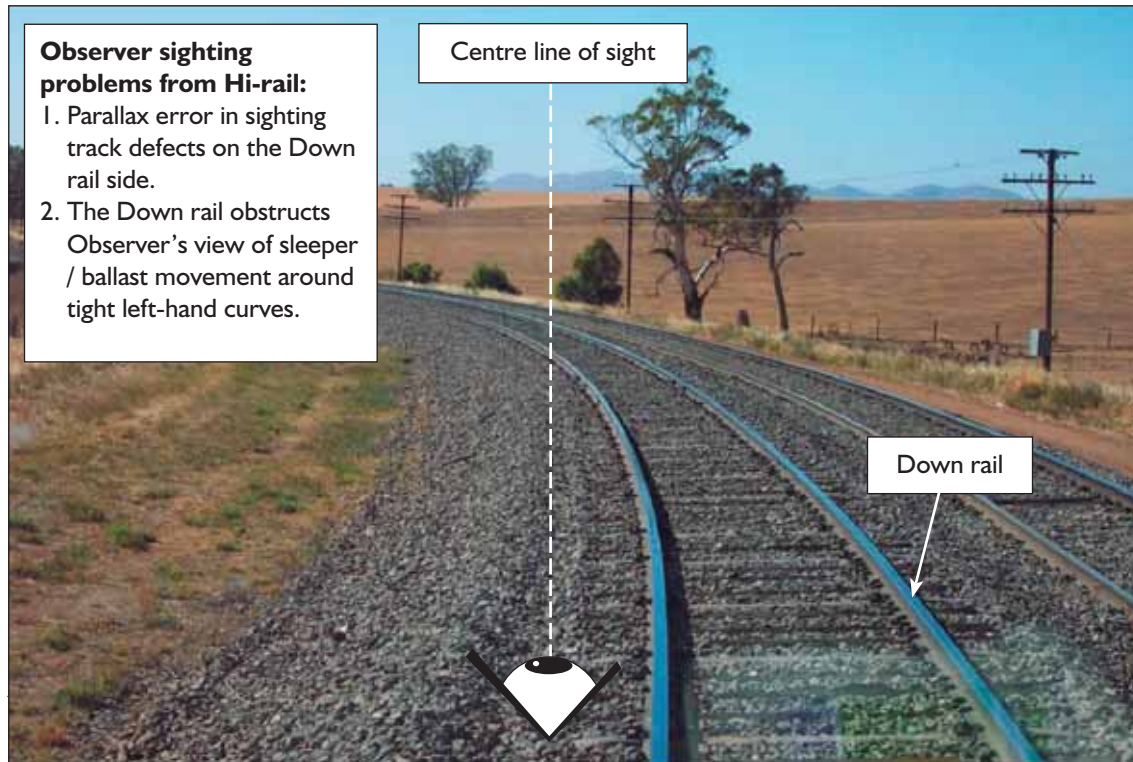


Figure 4.12 View from Observer's seat in Hi-rail at 377.960km

Ballast Profile Inspection

As a part of the pre-summer welded track stability analysis, maintenance staff conducted a review of ballast deficiencies. The track maintainer carried out such an inspection at the 377.960km site. No ballast work was required at the site following this inspection indicating that a ballast deficiency was not observed at the site at that time.

Rail Adjustment

The Harden Maintenance Team could not provide records to substantiate the status of rail adjustment over the 500m section in which the track misalignment occurred. Historically the StateRail Freight Country Regions policy had been for the maintainer to check adjustment of a 500m section following the installation of a closure or weld.

4.7.7 Safety Management Audit Results

A recent RIC safety audit conducted on the Harden Maintenance Team identified the following issues relating to the management of WTSA.

Track Exceedent Elimination

- There is no readily available, defined and recorded system to ensure the removal of WTSA Priority locations (P1 and P2). No audit trail exists to ensure that the correct processes were used, and that trained and competent staff have authorised and approved the work.

Track Work Programs

- There is no formal Project track stability analysis and subsequent management of risk procedure for proposed works. No audit trail exists to ensure that the correct processes were used, and that trained and competent staff have authorised and certified the work.
- Resurfacing “after” sheets are not timely and are poorly completed.

Rail Adjustment

- Welders are poor at completing welding returns and these are often incorrect or vital information is missing. Poorly completed returns are not checked for the inclusion of all information to confirm that the required adjustment is in place.