4.7.8 Track Measurements following Misalignment

The following curve track measurements, as per Figure 4.13, were taken prior to the misalignment restoration works at 377.960km.

Figure 4.13 Curve Pull-in Alignment Track Measurements & Representation of Track Alignment following Derailment.
The Curve Rail Temperature Error based on the above alignment measurements can be calculated from RIC’s C2443 welded track stability field calculation Section 18 Appendix A, as shown below.

\[
Ec = A \times 85.5 \times Lc / (L \times R)
\]

where

- \( Ec \) = rail temperature error in degrees C due to curve creep (-ve means too much steel)
- \( A \) = average alignment error in mm (pull-in is considered negative)
- \( Lc \) = length of curve in m (must be within \( L \))
- \( L \) = length of Section to be analysed in m
- \( R \) = radius in m

\[
A = ((10+25)/2 + 0 + 300 + 300 + 100)/5 = 143.5\text{mm}
\]

\[
Ec = 143.5 \times 85.5 \times 100 / (100 \times 402)
\]

**Curve Creep Temperature Error** \( Ec \approx 30°C \)

The Curve Creep Temperature Error of 30°C translates to a rail neutral temperature of 5°C. This value translates to an excess of 142mm of steel within the curve at the 300mm curve pull-in alignment.

### 4.7.9 Track Restoration

**Standard**

The following RIC standards exist in relation to the restoration of a misalignment.

Civil technical Note CTN 02/15 dated 16 August 2002 under Major Adjustment Disturbances requires: “Specific attention is drawn to major adjustment disturbances such as from derailment damage. It is essential to ensure that adjustment has been correctly restored.”

Civil technical Note CTN 02/15 dated 16 August 2002 under Steel Sleepers states: “Make sure steel sleepers are properly ballasted and are not subject to vibration disturbance. If they are disturbed an allowance must be made in the WTSA. The use of the dynamic stabiliser when tamping would be beneficial in helping to stabilise steel sleepers.”

**Restoration Works**

Track restoration works were undertaken in the following manner.

- Initially the track was smooth lined\(^1\) with tractors on 7 November 2002 where a 20km/h speed was applied. The track was reinstated at 21:05 by the local maintainer and the line reopened at 03:23 on 8 November 2002.

---

\(^{1}\) The design neutral temperature of rail is set at 35°C, where the rail length at this temperature is required to be in correct adjustment when positioned on the design alignment. Correct rail adjustment is achieved when no temperature induced longitudinal compressive or tensile stresses are present within the rail at 35°C.

\(^{2}\) Smooth lining of a track is the process of dragging the track back into the correct design alignment with the use of a tractor.
On the morning of 8 November 2002, joints were cut into the rail in order for track machines to realign the track. At this point the track was converted from CWR to jointed welded rail (JWR). The track was left as JWR over the summer period to provide an additional safeguard against the risk of further misalignments. On finalisation of the realignment, a track speed of 40/50km/h was applied.

On 13 November 2002 the track was tamped and a 80/85km/h speed was applied.

Readjustment of the track took place in the early Spring of 2003 where the JWR curve was be converted back to CWR.

As a part of the track restoration process the track was to be realigned, punch marked, cut and jointed. Following this procedure a check of adjustment would then be possible. The rail however was not punch marked and hence a relative check for adjustment of the alignment pre-derailment could not take place.

The following joint gaps were measured at 35°C following installation of the rail joints within the misalignment curve on 8 November, 2002.

<table>
<thead>
<tr>
<th>Km</th>
<th>Down Rail (mm)</th>
<th>Up Rail (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>377.870</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>377.980</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>377.983</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>378.090</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 4.5 – Rail Joints and Gap Measured at 35°C Cut into the Misalignment Curve During Track Restoration

40/50km/h represents two track speeds with the first speed indicating the track speed for freight and the second speed indicating the track speed for XPT, Xplorer and Endeavour trains.
4.7.10 Track Condition 9 Months Post 7th November 2002 Misalignment at 377.960km

**Curve Alignment**

The curve alignment at 377.960km was detected by the Harden Maintenance Team to have pulled in a maximum of 465mm following the curve’s conversion from JWR back to CWR. Refer to Appendix 9.9 detailing the curve alignment measurements taken on 25 August 2003. This curve pull-in was noted by the investigation whilst conducting a visual walking inspection at the misalignment curve on 18 August 2003. Refer to Figures 4.15 and 4.16 depicting the curve alignment and apparent curve pull-in as noted at 377.960km on 18 August 2003.
Steel Sleeper & Ballast Condition

The general ballast compaction within the steel sleeper pods at 377.960km was noted to vary across the sleeper width as indicated in Figure 4.17. This ballast pod depth variation was noted to change from an acceptable depth as displayed in the Down Rail six foot inspection hole to a 90mm loss of compaction depth as viewed in the Up Rail cess side inspection hole. Refer to Figure 4.17 depicting the ballast pod depth check using a finger as per standard inspection requirements.
The ballast condition surrounding the steel sleepers throughout the curve at 377.960km showed further evidence of ballast rounding. Foul ballast was also evident at the 377.960km curve as depicted in Figure 4.18.

Figure 4.18  Foul Ballast Evident at 377.960km curve as at 18 August 2003.

4.8 Train Control

The system of safeworking on the Up Main South between Harden North Signal Box and Galong Signal Box is Rail Vehicle Detection. Harden North Signal Box is typically attended for all trains. Galong Signal Box is only attended on occasions when vehicle shunting movements or emergency track work is required.

4.9 Environmental factors

4.9.1 General Climatic Conditions

The incident occurred at 16:39 on 7 November 2002. Visibility for the Driver and Observer was clear.

4.9.2 Temperature

WOLO Speed Restrictions

During very hot weather there is a risk that welded track will misalign (buckle). In an effort to manage this risk, the speed of trains travelling over these lines is reduced when high temperatures are predicted. RIC’s Extreme Weather Conditions Standard\(^{14}\) requires the application of a track WOLO speed restriction.

when the air temperature is forecast to reach or exceed 35°C, on days prior to 15 November each year. These restrictions apply from 12:00 to 20:00 on the day they are imposed. There is provision to vary the times and lower the temperature at which they are applied.

The forecast temperature at Yass (closest active weather station to the Harden Maintenance Area) on 7 November was 31°C. There was therefore no requirement to apply a WOLO restriction on 7 November 2002.

The ambient temperatures on 7 November at Yass were taken as:

<table>
<thead>
<tr>
<th>Maximum temperature in 24 hours after 9:00 (local time) in °C</th>
<th>Minimum temperature in 24 hours before 9:00 (local time) in °C</th>
<th>Air temperature observation at 9:00 Local Time in °C</th>
<th>Air temperature observation at 15:00 Local Time in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.5</td>
<td>6</td>
<td>14.5</td>
<td>27.2</td>
</tr>
</tbody>
</table>

Table 4.6 – Ambient Temperatures at Yass on 7 November 2002

**Historic Temperature Review**

Additional temperature information was sourced from the Bureau of Meteorology dating back to 1st January 1994 for the weather station at Yass. Figures 4.19 and 4.20 have drawn on this data to represent climatic conditions:

- At the time of misalignment, and
- Against relevant historic maintenance tasks and misalignment records for the Main South area.

Figure 4.19 below identifies that there had been one day since the beginning of October 2002, and prior to the misalignment date, where the Yass area maximum daily temperature (30.3°C) exceeded the maximum temperature recorded on the date of misalignment (29.5°C).
Figure 4.20 below depicts the minimum temperature for 24hrs taken before 9:00 on the recorded day. This figure identifies that the minimum temperature in the month of October (month of resurfacing works) for the Yass Region had not changed markedly over the last four years. The minimum temperature following resurfacing works was registered as 0°C on 9 October 2002. Cold night time temperatures where also registered on 6th (2°C), 10th (2°C), 18th (2.5°C) and 28th (2.5°C) of October 2002.

Overall maximum and minimum temperature values for the Harden area of 41.8°C and negative 7.5°C were also sourced from the Harden Bundarbo St weather station, which unfortunately ceased recording in 2001.

**4.10 History of Similar Occurrences**

RIC has one record of a misalignment occurring on the Up Main South at 377.900Km on 25 November 1997. The root cause of this misalignment was determined to be inadequate ballast.

RIC also maintains a consolidated register of misalignments dating back to 1992. A review of this database revealed the following:

- 44% of recorded misalignments occur on tight radius curves <400m.
- 67% of recorded misalignments occur on curves <800m.
- 74% of misalignments, where the track has been disturbed within 0-1 month following the disturbance, are associated with track disturbances including surfacing/tie and surfacing works. This value is calculated from 26 misalignments over a total of 35 misalignments, where the track has been disturbed within 0-1 month (Jan 1996 and Nov 2002). These misalignments are a subset of 461 misalignments recorded in the RIC misalignment database between 1996 to 2002 (Nov).
- 76% of recorded misalignments occur with an ambient temperature above 30°C.
4.11 Relevant Safety Regulations

The NSW Rail Safety Act 1993 applies to the matters under investigation by virtue of the savings provisions of the NSW Rail Safety Act 2002 Schedule 5 Clause 12.

4.12 Emergency Response to the Occurrence

The following observations were made relating to the Emergency Response to this incident.

4.12.1 Incident Detection

The initial detection of this incident occurred within a couple of minutes. This fast detection time was due to the Driver keeping a close vigilance on the rear of his train. Once the incident was detected the Driver gained confirmation from the Observer that the rear of the train had derailed and immediately applied the emergency brake. The Driver's response to the incident was appropriate.

4.12.2 Incident Notification

The Observer notified Control within seconds of determining the rear of 4YN2 had derailed. This notification was actioned prior to the train coming to a stand at 376.000km. The incident notification to Control was considered appropriate.

4.12.3 Safeworking Response

On notification of the incident Control arranged for all trains to be held at Yass Junction and Harden and requested for the rear of 4YN2 to be protected. The derailed vehicle and the second last attached vehicle (RQJW 21983W) were then detached from 4YN2, where the second last vehicle was used as a cover vehicle to RQBY 15028F.

The train crew, in preparation for the train’s departure, then conducted a brake test and train inspection.

Galong Signal Box was switched in and single line working was introduced over the Down Main line at 23:38 under Special Authority Order No. 19.

Safeworking protection was also applied to protect the last two detached wagons before 4YN2 departed at 20:45. RQBY 15028F was later rerailed at 00:30 on 8 November 2002.

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 on duty.

Pilot Staff safeworking was finally cancelled at 03:23 on 8 November 2002.
4.12.4 Track Maintenance Response

Harden North Signal Box contacted track maintenance staff at 17:00.

The Down Main was subsequently certified fit to travel at 17:30 by track maintenance staff with a 10km/h speed restriction applied between 375.00km to 377.00km.

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

4.12.5 Rolling Stock Recovery Response

Pacific National’s First Response Group arrived on site at 19:40 and rerailed RQBY 15028F ready for departure at 20:50.

4.13 Human Factors - Fatigue

The Driver and Observer rosters have been analysed for worker fatigue using the Fatigue Audit InterDyne (FAID) evaluation software.

FAID calculates a fatigue rating using four factors that have emerged from research into shiftwork and fatigue over the last few decades. The specific formulae for this program have been developed and validated by the Centre for Sleep Research at the University of South Australia. The specific determinants of work-related fatigue as used in the FAID model are:

1. The time of day of work and breaks
2. The duration of work and breaks
3. Work history in the preceding seven days
4. The biological limits on recovery sleep.
4.13.1 Train Crew’s Shift Roster Review – Two Weeks prior to Incident.

The Driver and Observer’s shift rosters for two weeks prior to the incident can be referenced in Appendix 9.10. The following fatigue plots and risk level category allocations have also been calculated using the roster information referenced in Appendix 9.10.

![Fatigue Score at 16:39 = 42](image1)

**Figure 4.22** Driver’s Roster Fatigue Plot ≈ Fatigue Score at 16:39 on 7 November 2002 = 42

![Fatigue Score at 16:39 = 15.5](image2)

**Figure 4.21** Observer Roster Fatigue Plot ≈ Fatigue Score at 16:39 = 15.5
Based on the above fatigue plot figures the Driver and Observer fatigue results can therefore be summarised as:

<table>
<thead>
<tr>
<th>Description</th>
<th>Description</th>
<th>Fatigue Score</th>
<th>FAID Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driver</strong></td>
<td>Fatigue Score at 16:39 on 7 November 2002</td>
<td>42</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>Maximum Driver Fatigue Score for Staff Roster one fortnight prior to and including 7 November 2002</td>
<td>94.9</td>
<td>Very High</td>
</tr>
<tr>
<td><strong>Observer</strong></td>
<td>Fatigue Score at 16:39 on 7 November 2002</td>
<td>15.5</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>Maximum Observer Fatigue Score for Staff Roster one fortnight prior to and including 7 November 2002</td>
<td>72.8</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 4.7 – Summary Fatigue Scores for Driver and Observer

Fatigue scores below 80 are considered satisfactory; 80 to 100 suggest a risk assessment of the working should be conducted and scores in excess of 100 are considered problematic.
5.0 ANALYSIS

The following investigation analysis has been derived from the evidence documented in Section 4.0 and corresponding appendices.

5.1 WTSA Track Maintenance Procedures

A number of non-compliances against RIC’s standards and procedures where found by the investigation to have occurred, as identified and discussed in the following sections.

5.1.1 Management of Rail Adjustment – Pre Misalignment

The management of rail adjustment effectively considers three factors. These factors are:

- **Curve Creep** (effects of adjustment on a curve due to deviations on design alignment)
- **Tangent Creep** (effects of adjustment on a curve due to longitudinal rail movement)
- **Residual Steel** (effects of adjustment on a curve due to either the removal or addition of rail during maintenance procedures eg installation of rail closures.)

Based on the evidence obtained during the investigation, the Harden Maintenance Team's management of rail adjustment was consistently applied only to the management of **tangent creep**.

The management of **curve creep** was however partially implemented as evidenced by the curve alignment measurements being taken and analysed through the WTSA analysis, together with the identification of curve creep (curve pull-in) on nearby curves that had recently undergone resurfacing works. However since the curve pull-in at 377.960km was not detected prior to the misalignment, there appears to have been some breakdown of the Harden Maintenance Team’s system to control curve creep.

The management of **residual steel** in the 500m misalignment curve section was determined deficient at both the pre and post misalignment stages. No status records of residual creep for the 500m section could be produced. These records would have identified rail measurements either added or removed in the 500m length section relative to the desired rail neutral temperature of 35°C.

5.1.2 Management of Rail Adjustment – Post Misalignment

An adjustment check of the misalignment curve, at the design alignment, was not carried out in accordance with RIC's Civil Technical Note CTN 02/15 dated 16 August 2002 following the misalignment rectification works. As a consequence to this adjustment check not being carried out, the investigation could not determine
whether the track had been in correct adjustment on the resurfacing date of 3 October 2002.

The post misalignment adjustment check during the rectification works would have required:

- Standard 5m punch marks to be inserted in the outer rail face head at each rail joint cut,
- Anchors to be sprung and the rail vibrated to ensure the rail was free to move within the 500m section in which the adjustment is checked.
- Re-measurement of all 5m punch mark distances at the design alignment noting any variances to the original measurement and thereby noting any adjustment errors.

The procedure described above would have added approximately 1 hour to the rectification works and have required no additional staff. This additional time and resource allocation would have allowed the investigation to precisely confirm the curve’s state of adjustment prior to misalignment considering that:

- The misalignment curve was realigned to the design alignment on 3 October 2002, and
- There were no rail closures or thermit welds installed in the curve following the resurfacing date, where such work would have had potential to change the rail length and hence rail adjustment.

### 5.1.3 Misalignment Management Reporting

The misalignment report required under RIC’s civil standards technical note CTN 02/15 dated 16 August 2002 (Appendix 9.8) was not submitted for management review following the misalignment. The track structure information normally contained in this misalignment report would have assisted the investigation in identifying the track structure condition immediately post misalignment. Relevant track structure photographs, notes and measurements of a misalignment all play a vital role in qualifying and quantifying the potential contributing factors relating to the occurrence of a misalignment.

The successful identification and cataloguing of incident evidence is crucial in order for an accurate and comprehensive investigation process to be undertaken.

### 5.1.4 Use of Trackstab in the Monitoring of Track Stability Analysis

The successful use of Trackstab as a tool to manage WTSA priorities requires WTSA track information to be updated for each 500m section on a regular basis. Without accurate information that reflects the current track condition, the system will not provide a representative picture of those locations identified as WTSA priorities. Evidence from the investigation identified that the WTSA information relating to the misalignment curve had not been updated since the original WTSA pre assessment calculated in August 2002.

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RIC’s electronic WTSA program database used to calculate WTSA track stability percentage losses.
Had the misalignment curve been checked (measured) for conformance to the design alignment following the identification of those nearby curves that had pulled-in, the misalignment location would have most likely been identified as a WTSA priority 1 location with a stability loss of approximately 177%. This additional analysis would then have raised concerns to the Harden Maintenance Team and resulted in a preventative maintenance response.

5.1.5 Curve Pull-in Track Displacement Indicator.

RIC maintenance staff have most recently suggested a visual method to assist in the detection of curve creep. This method involves the painting of continuous line in the four foot for the length of a curve or straight that requires a higher frequency of visual inspection. Refer to Figure 5.1 depicting a representative application of this curve creep detection line at 377.960km. The application of this line works on the principle that if the track was to move laterally, the sleeper would displace relative to the ballast, effectively breaking the continuous line. It is considered that track displacements of 50mm or more could be identified on application of this method.

The application of this track displacement indicator would offer a similar benefit in the initial detection of a misalignment. The detection of either a misalignment or curve pull-in from this indicator could also be identified by train drivers and relayed to the appropriate maintenance personnel via the safeworking infrastructure fault reporting system (CAN).

![Figure 5.1 Representative Track Displacement Indicator Overlaid at 377.960km](image-url)
5.2 Track Structure

5.2.1 Steel Sleepers

As noted in Sections 4.7.5 & 4.7.10 a number of steel sleepers were detected to have been pumping within the misalignment curve immediately post misalignment and 9 months following the misalignment. This pumping action over time has effectively rounded the ballast surrounding the steel sleeper, which in turn would have reduced the lateral stability of these sleepers at the time of misalignment. Whilst the WTSA analysis model considers pumping sleepers within the assessment criteria, the impact of pumping steel sleepers on lateral track stability has not necessarily been considered. This additional impact, as identified by the pumping steel sleepers within the misalignment curve, is considered to be:

- A loss of lateral stability due to the removal of ballast from the sleeper pod as a consequence of the steel sleeper rounding the ballast and working this ballast out of the sleeper pod, and

- A loss of lateral stability due to the loss of ballast angularity and this resulting effect on ballast compaction.

An actual account of the ballast condition and ballast compaction surrounding those sleepers immediately post misalignment would have assisted the investigation in determining whether these factors played a definitive role in the mechanism of misalignment.

5.2.2 Track Alignment and Adjustment

Evidence from the track measurements taken post derailment identified that the misalignment curve at 377.960km had pulled in towards the curve’s centre by a maximum of 300mm (refer to Figure 4.12). Calculation of the rail neutral temperature at this new alignment indicated a rail neutral temperature of 5°C. Experience has shown that where rail is subject to full sunlight the rail temperature is usually 15 to 20°C higher than the corresponding shade air temperatures recorded by the Bureau of Meteorology. With an ambient temperature of 31°C, it is possible that the misalignment curve may have been out of adjustment by 41°C (allowing for an increase of 15°C in rail temperature above the ambient temperature and subtracting the rail neutral temperature (31+15-5)=41°C). This temperature error indicates that the rail would have been in an extreme case of compression between the two curve transition points spanning some 292m. Over this distance the rail adjustment error would have equated to approximately 142mm of excess steel within the curve prior to the misalignment.

The actual adjustment status of the misalignment curve’s 500m section could not be accurately quantified. The investigation therefore could not conclude as to whether the 500m section was in a correct state of adjustment after resurfacing works were conducted in October 2002. Considering the number of closures...
found within the misalignment curve (14 in total), and also considering that these closures were installed without 5m reference punch marks, it is likely that the 500m section was out of adjustment following the resurfacing works conducted on 3 October 2002. Should the 500m rail section adjustment have been deficient in steel, the curve would have also been more likely to have pulled in following the resurfacing works.

Track alignment and rail adjustment are interdependent to the extent that any realignment of the track will affect rail adjustment by either raising or lowering the rail neutral temperature. This action (realignment) and reaction (change in rail adjustment at the new alignment) maintenance process is reliant upon the rail being in adjustment at the new alignment. Should the rail not be in correct adjustment at the new alignment, residual rail stresses will result.

A check of the rail adjustment status prior to a major track realignment would seem prudent in order to ensure residual adjustment stresses are considered. If the rail adjustment status is not known, the track maintainer should check the rail adjustment after major realignment works take place. This requirement is essentially defined within RIC’s Civil Technical CTN 02/15 dated 16 August 2002 under “Major Adjustment Disturbance”. RIC should consider providing further guidance to the track maintainer in defining a “Major Adjustment Disturbance”. RIC could consider using an appropriate alignment WTSA % stability loss value to define when a check of adjustment is required after realigning sections of track as part of the WTSA rectification program.

5.2.3 Anchors

The anchor condition, in terms of anchor placement, varied along the misalignment curve ranging from correct placement of the anchor to poor placement. An assessment of the anchor condition within the WTSA analysis was evaluated as “good”.

Whilst there were isolated anchors identified as in “poor” condition, the overall effect of these anchors on the mechanism of misalignment is considered small.

5.2.4 Sleeper Condition

The sleeper condition at the misalignment curve was identified as “poor” at various locations within the misalignment curve at the final inspection of 377.960km on 18 August 2003. The effect of having poor sleepers within the curve at 377.960km would add to the potential loss of lateral stability experienced at the location.
5.3 Climatic Conditions

5.3.1 Cold Weather Conditions

Following the resurfacing works conducted on 3rd October 2002 the Yass-Harden area experienced a number of cold nights ranging from 0°C to 2.5°C. These low temperatures would have contributed to the curve pulling in 377.960km prior to the misalignment. The cold nights experienced between 3 October 2002 and 28 October 2002 were not however unseasonal and are likely to be experienced in the area during the month of October. As noted in Figure 4.19 consistently lower temperatures were recorded for the month of October during the calendar years of 2000 and 2001.

5.3.2 Hot Weather Conditions

As discussed in Section 4.9.2 it is likely that the ambient temperature recorded on the misalignment date was the maximum temperature to have been reached in the Harden area in the lead up to the Summer period of 2002.

It is worthy to note that the misalignment occurred on one of the hottest days, if not the hottest day, since the track had been disturbed due to resurfacing works.

5.4 Train Management

All train management actions of the Driver were determined to comply with the Pacific National’s train management standard requirements.

The train’s load was also verified to be within approved limits in terms of each vehicle’s maximum gross tonnage allowance and the marshalling of loaded and unloaded vehicles throughout the train.

5.5 Train Condition

The mainline derailment inspection processes within Pacific National do not explicitly specify the inspection and reporting requirements of a train involved in a mainline derailment. Pacific National’s Safety Health & Environment (SHE) Manual Section 5.1 Page 11 of 34 requires the following to be documented “For Serious Incidents”:

- Photographs
- Relevant notes
- Diagrams
- Data logger downloads
- Locomotive, wagon and vehicle registration numbers

RIC’s Derailment Investigation Manual at Section 4.1.5 Examine the Vehicles notes the following with relation to a misalignment incident.
“In the case of misalignment of track occurring under the train, then all vehicles ahead of the derailed vehicles must be examined prior to the release of that portion of the train. The examination in this case need not include detailed depot examination if the bogie conditions, such as wheels and bolster gib wear, can be assessed on site.”

No specific examination document was provided by Pacific National specifying that an inspection of those vehicles ahead of the derailed vehicle had taken place in order to assess and confirm that no relevant rolling stock components were identified as faulty. A number of specific mechanical faults within any one of the vehicles traversing a potential misalignment site could significantly contribute to initiating the mechanism of a misalignment.

Such rolling stock mechanical conditions may include:

- Side bearer condition (critical for speeds greater than 80km/h)
- Snubber wear
- King/Queen casting wear and security
- Axle box jamming
- Excessive axle box clearances
- Wheel flats
- Spring condition
- Vehicle overload

Whilst the majority of these items are inspected as a part of the Full Mechanical Inspection within RIC’s Train Operating Conditions Manual, the capture and certification of such an inspection following a main line derailment is not required within either the Pacific National or RIC Derailment Investigation procedures. The level of competence required of the rail safety worker required to carry out such an inspection is also not specified.

It is worth noting that a train inspection carried out by RIC’s track maintainers identified potentially faulty rolling stock components that could contribute to the mechanism of a misalignment. No photographs and records were however captured during this inspection and therefore could not form part of the investigation analysis. The communication of these potential defects to a qualified wagon examiner on site would have been ideal, in order to confirm or discount the condition of these items and their potential impact on the mechanism of misalignment.

5.6 Combined Misalignment Track Analysis Review

The investigation has concluded that the derailment on 7 November 2002 was caused by the track misaligning under PN service 4YN2.

Those factors considered to have contributed to the mechanism of misalignment include:

- Track resurfacing works which took place on the misaligned curve 35 days prior
to the misalignment date, where these works are considered to have weakened the lateral stability of the track structure.

- Following the track resurfacing works the Yass-Harden area experienced a number of cold nights ranging from 0°C to 2.5°C. These low temperatures would have contributed in curve pulling in at 377.960km prior to the misalignment.

- The ambient temperature at the time of misalignment was potentially the hottest temperature at the location since the track was resurfaced, indicating the influence of thermal stresses being prevalent at the time of misalignment.

- A number of pumping steel sleepers were identified throughout the misalignment curve. These pumping steel sleepers exhibited significant ballast rounding often along the entire perimeter of the sleeper. The ballast condition and compaction of these pumping steel sleepers is thought to have reduced the lateral track stability during the period of initial curve pull-in and track misalignment.

- Foul ballast was identified within the misalignment curve, as evident in Figure 4.18, where the presence of this type of ballast effectively reduces the interlocking properties of the sleeper to ballast interface. Foul ballast also reduces ballast compaction, which again reduces the track's lateral stability.

- The sleeper condition at the misalignment curve was identified as “poor” at various locations within the misalignment curve adding to the potential loss of lateral stability experienced at the location.

- The misaligned curve was determined to have pulled in prior to the misalignment which would have effectively resulted in the rail neutral temperature being lowered from a design of 35°C to approximately 5°C. The combination of this low rail neutral temperature at the new alignment and the ambient temperature experienced at the time of misalignment would have generated high compressive stresses within the rail. These high compressive stresses are then thought to have ultimately buckled the rail while the last vehicle of 4YN2 passed over the misalignment site.

The occurrence of this incident has highlighted a fundamental breakdown of track maintenance processes where both the tack condition inspection and life cycle track management regimes have failed at a basic level. The extent of track curve pull-in that would have been present prior to the misalignment should have been detected by the track inspection system. Likewise the pumping steel sleepers, foul ballast and poor sleeper condition at the misalignment site should not have reached their state of deteriorated condition leading up to the misalignment.
6.0 CONCLUSIONS

6.1 Findings

The investigation concluded that 4YN2 derailed at 377.960km as a direct result of the track misaligning under the train’s last vehicle.

Those factors that were determined to have directly contributed to the occurrence of the incident included:

• The track having reduced lateral stability prior to and during the misalignment (as a result of prior 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.
• 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.

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

6.2 Contributing Factors

The following contributing factors, in addition to those direct factors described above, were also considered to have played a part in the occurrence of this incident:

• Track resurfacing work had taken place on the misaligned curve 35 days prior to the misalignment date. This resurfacing work would have effectively reduced the lateral track stability at the time of misalignment.
• Following the track resurfacing works the Yass-Harden area experienced a number of cold nights ranging from 0°C to 2.5°C. These low temperatures would have assisted the curve to pull-in at 377.960km prior to the misalignment.
• The new curve alignment would have resulted in a reduction of the rail neutral temperature to approximately 5°C, where the curve would have been in a state of compression at rail temperatures above 5°C.
• The ambient temperature recorded at the misalignment site shortly after the incident was 31°C. It is likely that this temperature was the hottest temperature recorded in the Harden area since the resurfacing work was carried out on 3 October 2002.
• The rail adjustment status of the curve was unknown where 14 closures existed within the 402m radius curve (292m in length). Each of these closures would present as a potential source of adjustment error if they were not installed in accordance with the principle of steel in = steel out.
The track maintenance inspection system did not detect that the misaligned curve had pulled in prior to the misalignment on 7 November 2002.

Anchor condition varied from good to poor throughout the misalignment curve.

Foul ballast existed throughout the misalignment curve.

Sleepers of poor condition were identified throughout the misalignment curve.

6.3 Related Findings

The investigation has determined the following related findings:

6.3.1 Train Management

- Pacific National Train 4YN2 derailed at 16:39 on 7 November 2002 on the Up Main South at 377.960km due to a track misalignment. This misalignment occurred under the rear bogie of the last vehicle.
- The train speed, train load and train braking management were all determined to be within standard operating requirements.
- A general mechanical inspection of the entire train, as carried out by the train crew, did not identify any noticeable train defects on 4YN2 prior to the train's departure from the misalignment site.
- No post misalignment rolling stock maintenance records were identified on those vehicles forming 4YN2 to confirm all vehicles on the train had been inspected prior to the train's departure.

6.3.2 Track Maintenance

- WOLO speed restrictions were not required on the Up Main South as the forecast temperature for the Harden area on 7 November was 31°C. RIC's speed restriction WOLO standard does not require application of a WOLO speed restriction until the forecasted ambient temperature exceeds 35°C.
- Ballast shoulder and crib profiles met standard requirements.
- The management of tangent rail creep met standard requirements.

6.4 General Safety Related Findings

The investigation found that the following matters did not contribute to the incident, but had the potential to affect rail safety.

- The Driver's fatigue rating indicated a very high level of fatigue for 2 of the 14 days assessed prior to the incident date (87.7 on 5 November and 94.9 on 6 November). The Driver's roster was scheduled on the basis of relieving permanent rostered staff and would be considered an irregular roster.
- RIC's Derailment Investigation Manual and Pacific National's Incident Investigation Manual do not explicitly define rolling stock inspection reporting criteria documentation required following a misalignment related derailment. The level of competency required to carry out such an inspection is also not specified.
7.0 POST INCIDENT SAFETY ACTIONS

7.1 Post Misalignment Safety Actions Carried Out by RIC

The Harden Maintenance Team initiated the following safety actions in an effort to improve the track structure stability at 377.960km following the incident.

7.1.1 Interim Track Configuration Change from CWR to JWR

Immediately post misalignment the Harden Maintenance Team converted the track from CWR to JWR in order to provide an interim measure to reduce the influence of tangential rail stresses associated with high temperatures over the 2002/2003 summer period.

7.1.2 Low Profile Concrete Re-Sleepering

200 Low profile concrete sleepers in a 1 in 4 pattern were installed at the misalignment location prior to November 2003.

7.1.3 Improved Shoulder Ballast Profile

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.
8.0 SAFETY RECOMMENDATIONS

8.1 Direct Safety Recommendations

The following safety recommendations are made to RIC management in order to avert the occurrence of similar misalignment incidents.

8.1.1 Define WTSA rectification work processes to assist maintainers in selecting the most appropriate methods of WTSA track repairs

It is recommended that RIC develop a standard maintenance process to assist maintainers in assessing the most appropriate actions required to rectify WTSA stability loss contributing factors. Such a process would need to consider the various options available to the maintainer in rectifying WTSA stability loss contributing factors and those checks required of the maintainer before any such options are implemented.

As an example, the rectification of a high percentage stability loss in which track alignment forms the major contributing factor would need to consider:

- Track lateral structure prior to and following realignment,
- Tangent Creep,
- Adjustment errors, and
- Anchor condition.

Each of these items would pose a risk of contributing to a misalignment following the track being disturbed, and would therefore need to be considered in those monitoring actions required following WTSA rectification works.

8.1.2 Improve the knowledge of continuously welded rail (CWR) rail adjustment status

It is recommended that RIC ensure a process exists that requires the infrastructure maintainer to keep accurate records of CWR rail adjustment status. A monitoring process should also be considered to ensure these records are kept up to date.

Where the adjustment status of CWR is unknown or believed to be inaccurate, RIC should ensure that they implement a program to determine the adjustment status of this CWR track.

It is recommended that the Harden Maintenance Team ensure compliance with the requirements to punch mark each rail weld in accordance with the RIC standard RAP 5391 Version 3 May 2002, as a first step to ensuring that pre-welding rail adjustment is maintained. The Harden Maintenance Team is to also monitor, on an ongoing basis, compliance against all the reporting requirements of RAP 5391 Version 3 May 2002. Deviations from these reporting requirements should be highlighted so that appropriate action can be taken to ensure the integrity of welds carried out by the applicable maintenance staff.
8.1.3 Review the WTSA algorithm considering the impact of steel sleeper & ballast condition

It is recommended that RIC review the lateral WTSA stability loss values associated with steel sleepers that exhibit a reduction of ballast pod depth and / or exhibit degrees of ballast rounding around the steel sleeper perimeter.

8.1.4 Track examination system – Improvements required in the inspection of alignment defects

It is recommended that RIC assess the requirement to have both the Hi-Rail Driver and Observer qualified to inspect for rail alignment defects. Having both Hi-Rail crew qualified would assist in detecting defects around tight radius curves. The inspection of a tight radius left-hand curve would be more accurately carried out from the Driver’s position thereby reducing parallax errors and rail head obstructions that are prevalent when conducting the inspection from the Observer’s position.

RIC may alternatively consider reviewing the acceptability of using a painted line in the four foot to assist in the detection of curve pull-in and / or the detection of misalignments.

It is also recommended that RIC ensure a more rigorous examination system is put in place to detect for rail alignment defects following resurfacing works carried out to address alignment stability concerns. RIC may also consider increasing the frequency of track inspections following resurfacing works carried out to address alignment stability concerns.

8.1.5 Further stability review of the misalignment site

It is recommended that the Harden Maintenance Team ensure the track structure components and rail adjustment at 377.960km are to standard requirements following the concrete resleepering program and in preparation for the summer of 2003/2004.

It is also recommended that the Harden Maintenance Team implement a program to monitor the curve at 377.960km, and other known curve pull-in locations, for potential curve pull-in.

8.1.6 Supplementary investigation into the introduction and performance of steel sleepers in the NSW Rail Network

The Office of Transport Safety Investigation is to conduct a supplementary investigation into the introduction and performance of steel sleepers in the NSW Rail Network. This investigation would seek to identify the basis on which steel sleepers where introduced into the network and whether their introduction has increased the likelihood of track structure failures to any significant extent.
8.2 General Safety Recommendations

The following safety recommendations are made to Rail Infrastructure Corporation and Pacific National in order to improve rail safety management as identified within this misalignment investigation.

8.2.1 Improvements required in the reporting of misalignments and track restoration processes

It is recommended that RIC formalise their track restoration civil technical note requirements into a standard, where this standard would identify the key processes that must be carried out when reinstating misaligned track. In particular the requirement to carry out a check of rail adjustment during the rectification works is to be formalised within this standard along with the misalignment reporting requirements.

8.2.2 Review of dynamic stabilisation resources available to maintainers following resurfacing works

It is recommended that RIC determine if there is a need for additional dynamic stabiliser machinery to be made available to the maintenance areas considering:

• that in the order of 74% of recorded misalignments, that have occurred within 1 month of a track disturbance, are associated with track disturbances including surfacing/tie and surfacing works,
• that the use of a dynamic stabiliser is recommended by the RIC Civil Standards where alignment is difficult to maintain, and
• that RIC maintenance areas, in particular within the southern region, prefer to use this machinery but have not been able to do so since 1998.

8.2.3 Pacific National Driver Fatigue Rostering for Relieving Staff

It is recommended that Pacific National ensure the rostering of relief staff undergoes the same fatigue scheduling process as for permanent staff rosters.

8.2.4 Mandatory inspection criteria for vehicles involved in main line derailments

It is recommended that RIC produce a mandatory inspection criteria for vehicles involved in main line derailments. Such an inspection criteria should assist the Operator in identifying the rolling stock components requiring inspection, depending on the type of derailment and the potential contributing factors identified at the time of derailment.

The level of competence required by a rail safety worker to carry out such an inspection should also be specified together with the requirement for the inspection to be carried out prior to the train departing the incident site.

It is recommended that Pacific National 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.