6 Engineering analysis

This chapter presents the engineering analysis of the Bells Line of Road and Chifley Road between North Richmond and Lithgow. It provides an assessment of the physical characteristics and recent crash history of the road.

6.1 About the engineering analysis

Extent of the engineering analysis

The condition of the existing Bells Line of Road corridor was evaluated from North Richmond to the Great Western Highway at Lithgow. This comprises Bells Line of Road and Chifley Road.

The corridor east of the Hawkesbury River comprises the broader road network between Bells Line of Road and the Sydney motorway network and is relevant to the Plan from the broad perspective of efficient connections. Traffic capacity of the road corridor is the main constraint east of the Hawkesbury River and the Plan is not focused on identifying improvements to the condition of the road network in this section.

How the Bells Line of Road is classified

The Bells Line of Road is classified as a ‘main road’ under the NSW Roads Act 1993 and as a ‘State road’ by RMS (RMS classifies all roads as either State, regional or local roads). State roads are the major arterial links throughout NSW and within major urban areas. They include the main traffic-carrying and linking routes that connect the major urban centres such as Sydney and Newcastle, and the State’s major regional towns.

The Federal Government has an involvement on those State roads which are defined under federal legislation as part of the National Land Transport Network, but Bells Line of Road is not part of this network.

Road corridor sections

To facilitate the analysis, the length of the corridor between North Richmond and Lithgow was divided into 18 sections based on characteristics such as terrain, land use, environment and road conditions, each section having relatively similar characteristics. These sections are listed in Table 6.1 and shown in Figure 6.1.

The engineering analysis was undertaken using data generated from RMS’ computer-based Gipsicam mobile mapping system, which enables existing road characteristics to be assessed at a level of accuracy appropriate for a strategic assessment.

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>North Richmond, between the Hawkesbury River Bridge to Grose Vale Road</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>Grose Vale Road, North Richmond to Kurmond Road, Kurmond</td>
<td>4.3</td>
</tr>
<tr>
<td>3</td>
<td>Kurmond Road to Comleroy Road, Kurrajong</td>
<td>1.7</td>
</tr>
<tr>
<td>4</td>
<td>Comleroy Road to Kurrajong Heights, including Bellbird Hill</td>
<td>6.1</td>
</tr>
<tr>
<td>5</td>
<td>Kurrajong Heights to Bilpin Public School</td>
<td>11.9</td>
</tr>
<tr>
<td>6</td>
<td>Bilpin Public School to Berambling Crescent</td>
<td>9.7</td>
</tr>
<tr>
<td>7</td>
<td>Berambling Crescent to north-eastern part of Mount Tomah Botanic Garden</td>
<td>2.9</td>
</tr>
<tr>
<td>8</td>
<td>West of Mount Tomah Botanic Garden</td>
<td>3.4</td>
</tr>
<tr>
<td>9</td>
<td>Blue Mountains National Park</td>
<td>5.9</td>
</tr>
<tr>
<td>10</td>
<td>Blue Mountains National Park to East of Mount Wilson Road</td>
<td>4.2</td>
</tr>
<tr>
<td>11</td>
<td>West of Mount Wilson Road to the Darling Causeway at Bell</td>
<td>7.4</td>
</tr>
<tr>
<td>12</td>
<td>Darling Causeway at Bell to Valley View Road at Dargan</td>
<td>3.1</td>
</tr>
<tr>
<td>13</td>
<td>Valley View Road at Dargan to railway underpass at Newnes Plateau</td>
<td>3.2</td>
</tr>
<tr>
<td>14</td>
<td>Railway underpass at Newnes Plateau to next railway underpass near Zig Zag Railway</td>
<td>4.1</td>
</tr>
<tr>
<td>15</td>
<td>Railway underpass near Zig Zag Railway to Hartley Valley Road, Corney Town</td>
<td>5.4</td>
</tr>
<tr>
<td>16</td>
<td>Hartley Valley Road to Eddy Street, Lithgow</td>
<td>0.8</td>
</tr>
<tr>
<td>17</td>
<td>Eddy St to Main Street, Lithgow</td>
<td>1.4</td>
</tr>
<tr>
<td>18</td>
<td>Main Street to Great Western Highway, Bowensfels</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Figure 6.1
Location of road sections
6.2 Key road characteristics

The condition of the road corridor was assessed based on the key desirable road characteristics for a State road as presented in the Austroads Guide to Road Design (2011) and RMS Supplements to the Austroads Guide (2011). These road standards refer to:

- Speed zones
- Lane widths
- Sealed shoulders
- Grades (slopes)
- Curve radii
- Sight distances
- Clear zones
- Overtaking opportunities
- Rest opportunities

These standards are explained below, and the current condition of the Bells Line of Road is assessed against these standards, where applicable.

It should be noted that the guidelines described below have generally been developed for application to the design and construction of new roads or major upgrades of existing roads. While existing roads would not normally be expected to fully comply with these guidelines, the standards nevertheless provide an indication of the priorities that might be applied to future upgrades and interim works.

It is also noted that for lane widths, shoulder widths and clear zone widths the assessment was based on widths estimated from the Gipsicam video data rather than on-site measurements.

6.2.1 Speed zones

In determining the appropriate signposted speed limit for a section of road, a number of factors are taken into account, including the relative safety of a length of road, the road’s function and whether it is in a rural or urban environment.

Road design recommendations

Speed limits are recommended and signposted by RMS based on the NSW Speed Zoning Guidelines (RMS 2011). These posted speed limits, along with advisory signage, help motorists adjust to the road and drive at a safe speed appropriate to the conditions.

Current situation

RMS rationalised the speed limit zones for part of the Bells Line of Road corridor in October 2008. The reductions provide more consistency in the speed limits along this 78 kilometre length and rationalised the number of speed limit zones along the Bells Line of Road from 22 zones to 18 zones.

The majority of the speed limit zone changes concentrated on removing the 70 kilometre per hour and 90 kilometre per hour zones and reducing them to 60 kilometre per hour and 80 kilometres per hour zones respectively. There were also a number of short 100 kilometre per hour speed limit zones reduced to 80 kilometres per hour. The changes to the speed limit zones came into effect in October 2008.

Figure 6.2 shows the current signposted speed limits.

Speed zone characteristics for the Bells Line of Road include:

- There is only one short section, east of Bell, that has a posted speed limit of 100 kilometres per hour.
- Most central sections have a speed limit of 80 kilometres per hour.
Figure 6.2
Posted speed limits
> The sections east of Bilpin have a speed limit of mostly 60 kilometres per hour with some 80 kilometre per hour sections.
> The sections west of Scenic Hill in Lithgow have a speed limit of 50 kilometres per hour.
> The route has a number of school zones where the speed limit drops to 40 kilometres per hour from 8:00–9:30am and 2:30–4:00pm on gazetted school days.
> In seven sections, the speed limit changes between 60 kilometres per hour and 80 kilometres per hour within the section.

6.2.2 Lane widths

Narrow lanes reduce the lateral clearance between vehicles, which reduces safe travel speeds and road capacity. Narrow lanes are more of a concern when combined with narrow shoulders, tight horizontal curves and steeper grades, and where the proportion of heavy vehicles is quite high, as is the case on the Bells Line of Road.

Road design recommendations

RMS recommends 3.5 metre wide lanes for new two-lane two-way rural roads.

Current situation

Existing lanes on Bells Line of Road are generally narrower than the recommended width, typically 3–3.2 metres wide.

6.2.3 Sealed shoulders

Road shoulders improve road safety by extending the sealed pavement outside the edge of the lane. This allows drivers more width to manoeuvre safely. Together with the verge area, the shoulder also provides a refuge where vehicles can safely stop and be clear of traffic.

Road design recommendations

RMS recommends one metre wide sealed shoulders for new two-lane two-way rural roads where the Annual Average Daily Traffic (AADT) is 2000 vehicles per day or more.

Current situation

Using Gipsicam video footage the existing sealed shoulder widths have been assessed for each section. The proportion of each section where the width of sealed shoulders on the Bells Line of Road is less than one metre is shown in Figure 6.3. About 84 per cent of the route has sealed shoulders less than one metre wide; of this, 34 per cent has sealed shoulders less than 200 millimetres wide. Sections with around 50 per cent or more of the length having sealed shoulders less than 200 millimetres wide are the two Mount Tomah sections (7 and 8), the two Blue Mountains National Park sections (9 and 10), and the Darling Causeway to Newnes Plateau sections (14 and 15). These sections are generally mountainous with a narrow formation width where widening the shoulder would be likely to require extensive earthworks.

The remainder of the route (about 16 per cent) has a shoulder greater than one metre wide but very little of the rural two-lane two-way sections have the 2–3 metre desirable shoulder widths. The sections with shoulders wider than one metre are in the lower speed, urbanised sections of North Richmond (to the east) and Lithgow–Bowenfels (to the west).
Figure 6.3
Corridor performance - sealed shoulder widths
6.2.4 Grades

Steep grades (or slopes) are typically of most concern when combined with sharp horizontal curves as this contributes to increased safety risk. Steep grades also influence transport efficiency, particularly for heavy vehicles.

Road design recommendations

Both Austroads and RMS suggest a desirable maximum grade of seven per cent in rolling terrain for an operating speed of 80 kilometres per hour.

Both Austroads and RMS also acknowledge that it is desirable to limit the length of sections with steep grades so that a loaded truck can operate without an unreasonable reduction in speed. For sections of road with grades greater than those given in Table 6.2, Austroads recommends that a risk analysis to identify operational and safety effects should be undertaken to determine the most appropriate treatment.

Table 6.2 Desirable maximum grades

<table>
<thead>
<tr>
<th>Grade (%)</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–3</td>
<td>1800</td>
</tr>
<tr>
<td>3–4</td>
<td>900</td>
</tr>
<tr>
<td>4–5</td>
<td>600</td>
</tr>
<tr>
<td>5–6</td>
<td>450</td>
</tr>
<tr>
<td>Greater than 6</td>
<td>300</td>
</tr>
</tbody>
</table>

Current situation

The Bells Line of Road features rolling and mountainous terrain with many locations where lengths of grades exceed the Austroads desirable maximum lengths for new roads. The steepest sections, where sustained grades in excess of 10 per cent extend for more than 300 metres, are at:

> Section 7 – Mount Tomah (1100 metres at 11 per cent).
> Section 8 – Mount Tomah (350 metres at 11.5 per cent)
> Section 9 – Blue Mountains National Park (300 metres at 10.0 per cent)
> Section 10 – Blue Mountains National Park (300 metres at 10.1 per cent)
> Section 15 – descent into Lithgow (375 metres at 10.0 per cent)
> Section 15 – descent into Lithgow (300 metres at 10.7 per cent)

The route is generally rolling terrain elsewhere. Grades do however fluctuate and exceed the Austroads recommendations both in terms of the maximum grades and the lengths of steep grades.

The steep sections mentioned above generally coincide with tight horizontal geometry, which may exacerbate the potential safety risk.

The measure of performance of the sections within the corridor was the proportion of the length of each section where the grade exceeds the desirable maximum grade of seven per cent in rolling terrain, as shown in Figure 6.4.

6.2.5 Curve radius

The curve radius of a road refers to how sharply curved the road is. The higher the speed of the road, the larger the curve radius needs to be. Tight curves at higher speeds can lead to an increase in the number of vehicles losing control and leaving the roadway.
Figure 6.4
Corridor performance – grades (greater than 7%)
Road design recommendations

Austroads guidelines for new roads recommend desirable minimum radius curves for a given design speed. The Austroads recommendations are shown in Table 6.3.

Table 6.3 Desirable minimum radius curves

<table>
<thead>
<tr>
<th>Operating speed (km/h)</th>
<th>Desirable minimum curve radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>85–95</td>
</tr>
<tr>
<td>80</td>
<td>190–230</td>
</tr>
<tr>
<td>100</td>
<td>410–440</td>
</tr>
</tbody>
</table>

Current situation

Curvature along the route was estimated from the Gipsicam data and can be summarised as follows:

> About two per cent of the length comprises curves with radii less than 95 metres (suitable for 60 kilometres per hour or less).
> About 15 per cent of the length comprises curves with radii less than 230 metres (suitable for 80 kilometres per hour or less).
> About 37 per cent of the length has curve radii less than 440 metres (suitable for 100 kilometres per hour or less).

The remaining 63 per cent of the length comprises curves with radii greater than 460 metres or lengths of straights between curves, where horizontal geometry is not a constraint on operating speeds.

Sections with the highest proportion of their length comprising curves with radii less than 230 metres based on available sight distance (suitable for 80 kilometres per hour or less) are:

> Section 4 – Comleroy Road to Peck Road in Kurrajong Heights, including Bellbird Hill (29 per cent of the section).
> Section 7 – North-eastern part of Mount Tomah (25 per cent of the section).
> Section 10 – East of Mount Wilson Road, Blue Mountains National Park (23 per cent of the section).
> Section 15 – Newnes Plateau and Clarence (33 per cent of the section).

The remaining 63 per cent of the length comprises curves with radii greater than 230 metres. The measure of performance was the proportion of the length of each section which comprised curves suitable for 80 kilometres per hour or less, as shown in Figure 6.5.

6.2.6 Sight distances

Sight distance refers to the length of road that a driver can see ahead at any given point. It is mainly affected by crests (vertical curves), but can also be reduced by bends in the road (horizontal curves), particularly where there is vegetation or other restrictions close to the road on the inside of the curve.

The aim of providing adequate sight distance is to ensure that drivers are able to perceive potential hazards and react within sufficient time to be able to stop or otherwise avoid these hazards.
Figure 6.5
Corridor performance – curvature
Sight distance restrictions can also occur at intersections and driveways where vehicles trying to enter the main roadway are unable to see far enough in one or both directions to be able to safely turn onto or cross the road.

Road design recommendations
Austroads guidelines for sight distances include formulae for stopping sight distance and overtaking sight distance. Overtaking sight distance requirements are considerably greater than those for stopping sight distance, which is the normal minimum requirement. As an example of stopping sight distance guidelines, a motorist travelling at 80 kilometres per hour requires a stopping sight distance of 100 metres to react and stop on seeing a hazard on the roadway. At 60 kilometres per hour the stopping sight distance reduces to 60 metres.

Current situation
Some sections of the Bells Line of Road have a large proportion of their length affected by crest vertical curves which restrict sight distance.

Sections with the highest proportion of their length suitable for a design speed of 60 kilometres per hour or less based on available sight distance (but signposted at 60 kilometres per hour or more) are as follows:

> Section 4 – Comleroy Road to Peck Road in Kurrajong Heights, including Bellbird Hill (5 per cent of the section).
> Section 9 – Blue Mountains National Park (five per cent of the section).
> Section 16 – Vale of Clwydd (17 per cent of the section).

Sections with the highest proportion of their length suitable for a design speed of 80 kilometres per hour or less (but signposted at 80 kilometres per hour or more) are as follows:

> Section 4 – Comleroy Road to Peck Road in Kurrajong Heights, including Bellbird Hill (28 per cent of the section).
> Section 8 – South-western part of Mount Tomah (51 per cent of the section).
> Section 9 – Blue Mountains National Park (21 per cent of the section).

6.2.7 Clear zones
A clear zone is a term used to describe an unobstructed, relatively flat area beyond the outer edge of the travelling lane that allows a driver to stop safely or regain control of their vehicle if it leaves the road. Adequate clear zones increase the likelihood that a vehicle that leaves the roadway can make a safe recovery rather than crash, and also mitigate the severity of crashes that do occur.

Road design recommendations
The clear zone distance is normally measured at right angles to the edge of the outer running lane and varies depending on traffic speed, the slope of the verge and the traffic volume.

For typical traffic volumes on the Bells Line of Road, and with a flat verge, the desirable clear zone recommended by RMS design guide supplements for a new road varies from three metres at 60 kilometres per hour to five metres at 80 kilometres per hour and nine metres at 100 kilometres per hour.

Current situation
Along the Bells Line of Road, clear zones are less than the desired width and obstacles such as trees and rock cuttings are often located too close to the outer edge of the travel lane.

The measure of performance was the proportion of the length of each section which has adequate clear zones for 60 kilometres per hour or less, as shown in Figure 6.6. The clear zone width of
Figure 6.6
Corridor performance – clear zones
three metres or 60 kilometres per hour was chosen as a more representative indicator since the higher clear zone width of five metres for 80 kilometres per hour is rarely available on the Bells Line of Road corridor.

Sections with over 50 per cent of their length with a clear zone adequate for 60 kilometres per hour or less (but signposted at higher than 60 kilometres per hour) are as follows:

- Section 4 – Comleroy Road to Peck Road in Kurrajong Heights, including Bellbird Hill (62 per cent of the section).
- Section 6 – Bilpin Public School to Berambing Crescent (57 per cent of the section).
- Section 13 – Valley View Road at Dargan to railway underpass at Newnes Plateau (56 per cent of the section).

6.2.8 Overtaking opportunities

Overtaking opportunities are important on rural roads, especially in difficult topography with steep grades and tight curves.

Road design recommendations

Requirements for overtaking lanes including location, length and line marking vary according to particular site conditions. On two-lane two way roads, the availability of overtaking opportunities depends on sight distance and gaps in the opposing traffic stream. As opposing traffic volume increases, overtaking opportunities become restricted even if sight distance is adequate. On an existing road, overtaking opportunities can be increased either by improved alignment or by the provision of overtaking lanes. Both Austroads and RMS provide guidelines for assessing the need for overtaking lanes. For a road such as Bells Line of Road, RMS guidelines would typically recommend that overtaking lanes should be provided at spacings of 10–15 kilometres. For 80 kilometres per hour the RMS minimum recommended length of an overtaking lane is 600 metres.

Current situation

The Bells Line of Road corridor has difficult topography as well as a mix of traffic types and, therefore, desired speeds. However, there are long lengths in the central part of the corridor where there are no overtaking lanes. In particular, there is a 25 kilometre-long section between Kurrajong Heights and Mount Tomah where there is no overtaking lane in either direction.

Overtaking lane locations are shown in Figure 6.7.

6.2.9 Rest opportunities

Rest opportunities help drivers to manage fatigue. They are particularly important for drivers travelling longer distances.

Road design recommendations

RMS’ rest area policy recommends rest area spacings based on whether the rest area is intended for light vehicles or trucks. Light vehicle rest areas are recommended to be spaced between 50 kilometres (for a major road) and 160 kilometres (for a minor road) apart. Major truck rest areas are recommended to be spaced between 100 kilometres (for a major road) and 160 kilometres (for a minor road) apart.

Current situation

While RMS does not provide rest areas along the corridor, there are a number of rest opportunities provided by attractions and retail outlets, including fruit stalls, Mount Tomah Botanic Garden and the Zig Zag Railway.
Figure 6.7
Location of overtaking lanes
6.3 Crash analysis

A crash analysis was undertaken, based on data for the five year period 2006–2010 for the Bells Line of Road corridor (including Chifley Road) between North Richmond and Lithgow. Key crash statistics and a section-by-section analysis are presented below. A separate technical paper, *Bells Line of Road Long Term Strategic Plan – 2006–2010 Crash Analysis* (Arup 2012), provides more detail on crash characteristics.

### Key crash statistics

From 2006–2010, police reported 466 crashes. These included:

- Nine fatal crashes that resulted in 13 fatalities.
- 178 injury crashes that resulted in a further 227 injured.

The following key points were noted from the data, primarily by comparing the Bells Line of Road data with crash data for the Sydney and Western regions for the same period:

- Based on the number of crashes and the estimated AADT volumes for each section of Bells Line of Road, the crash rate is approximately 54 crashes per 100 million vehicle kilometres or approximately 1 fatal crash per 100 million vehicle kilometres. These rates are relatively high, around twice the typical rates for rural roads in NSW.
- Speeding is the highest contributing factor for crashes and is recorded as a contributing factor in a much higher percentage of crashes than either fatigue or alcohol. It is further noted that speeding was recorded as a contributing factor for a much higher proportion of crashes compared to the Sydney and Western regions.
- Crashes on curves (off-road on a curve, off-road on curve hitting an object and out of control on curve) represent a much higher proportion of crashes compared to the Sydney and Western regions.
- Head-on crashes (not involving an overtaking movement) also represent a much higher proportion of crash movements compared to the Sydney and Western regions. As would be expected, head-on crashes have the highest severity (in terms of casualties) compared to other crash types.

### Table 6.4 Crash statistics by section (2006–2010)

Crash data from the RMS crash database.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Section Length</th>
<th>No. Crashes in 5 years</th>
<th>No. of Fatal Crashes in 5 Years</th>
<th>2011 AADT (approx)</th>
<th>Crashes per 100MVkm</th>
<th>Fatal Crashes per 100MVkm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.827</td>
<td>10</td>
<td>0</td>
<td>27,240</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4.269</td>
<td>42</td>
<td>0</td>
<td>16,210</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.662</td>
<td>26</td>
<td>2</td>
<td>13,500</td>
<td>63</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>6.054</td>
<td>30</td>
<td>1</td>
<td>12,147</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>11.941</td>
<td>38</td>
<td>0</td>
<td>4,800</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>9.655</td>
<td>15</td>
<td>2</td>
<td>3,999</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>2.874</td>
<td>18</td>
<td>0</td>
<td>3,301</td>
<td>104</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>3.408</td>
<td>12</td>
<td>1</td>
<td>3,300</td>
<td>58</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>5.855</td>
<td>10</td>
<td>0</td>
<td>3,500</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>4.161</td>
<td>22</td>
<td>1</td>
<td>3,400</td>
<td>85</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>7.402</td>
<td>39</td>
<td>2</td>
<td>3,443</td>
<td>84</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>3.051</td>
<td>3</td>
<td>0</td>
<td>3,273</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>3.198</td>
<td>4</td>
<td>0</td>
<td>3,400</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>4.083</td>
<td>13</td>
<td>0</td>
<td>3,500</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>5.405</td>
<td>114</td>
<td>0</td>
<td>3,687</td>
<td>313</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>0.786</td>
<td>7</td>
<td>0</td>
<td>7,000</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>1.397</td>
<td>14</td>
<td>0</td>
<td>10,400</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>1.662</td>
<td>49</td>
<td>0</td>
<td>18,000</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>77.69</strong></td>
<td><strong>466</strong></td>
<td><strong>9</strong></td>
<td><strong>54</strong></td>
<td></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>
Figure 6.8
Location of crashes 2006-2010
> The proportion of crashes that occurred in the rain was much higher than in the Sydney and Western regions. Similarly, a significantly higher proportion of crashes occurred when the road surface was wet compared to the Sydney and Western regions.
> The proportion of accidents occurring at intersections was low compared to the Sydney and Western regions.
> Motorcycles are involved in a higher proportion of total crashes compared to the Sydney and Western regions. This may be due in part to Bells Line of Road being a popular motorcycle route.
> Compared to the Sydney and Western regions, a high proportion of crashes occurred during the weekend.

6.3.2 Section-by-section analysis

The 18 sections of the Bells Line of Road were evaluated in terms of key crash characteristics and a summary of the analysis is presented in Table 6.4. Locations of crashes are shown in Figure 6.8.

The table shows that some sections of the road have a very high crash rate, mainly sections 7, 10, 11, 15 and 18. Section 15 stands out as having a very poor record in terms of crashes, with 313 crashes per 100 million vehicle kilometres. Sections 5 and 6, while not having a high overall crash rate, experienced an unusually high proportion of crashes on Fridays.

Further assessment of these sections is provided below.

Sections 5 and 6 (Kurrajong Heights to Mount Tomah Botanic Garden)

These sections are the closest fully rural road sections to Sydney, and are within the National Park. While the geometry in these sections is reasonable and the overall crash rates are relatively low, one characteristic common to both sections is that a relatively high proportion of crashes within these sections occur on Fridays.

Further review showed that a high proportion of these Friday crashes are occurring at night and so may be due to Sydney drivers leaving for the weekend and being unfamiliar with the road at night.

Section 7 (Berambing to Mount Tomah Botanic Garden)

The road in this section climbs up Mount Tomah and has steep grades combined with tight geometry and narrow shoulders. Notable crash characteristics include:

> 10 out of the 18 crashes, or 56 per cent of crashes, occurred at the weekend, compared to 37 per cent for the entire Bells Line of Road, which is already high compared to the Sydney and Western regions.
> 17 to 20 year olds were controlling the vehicle in 6 of the 18 crashes in this section, or 33 per cent of crashes, compared to 17 per cent for Bells Line of Road overall.

Section 10 (Blue Mountains National Park to Mount Wilson Road)

The road in this section has poor horizontal geometry, narrow shoulders and some sections of steep grade with reduced shoulder widths. This section has three tight radius bends, which accounts for a cluster of crashes in the vicinity. Notable crash characteristics include:

> Speeding was a contributing factor in 18 out of the 22 crashes, or 82 per cent, compared to 56 per cent for Bells Line of Road, which is already high compared to the Sydney and Western regions. These crashes could be associated with the difficult road geometry, with drivers driving with excessive speed for the prevailing road conditions.
> 18 out of the 22 crashes, or 75 per cent, occurred on a curve, compared to 50 per cent for Bells Line of Road.

**Section 11 (Mount Wilson Road to Darling Causeway at Bell)**
While the road in this section has generally acceptable horizontal and vertical geometry, shoulder widths and clear zones are restricted. Notable crash characteristics include:
> Speeding was the contributing factor in 31 out of the 39 crashes, or 80 per cent, compared to 56 per cent for Bells Line of Road, which is already high compared to the Sydney and Western regions.
> 22 out of the 39 crashes, or 56 per cent, occurred when it was raining, compared to 38 per cent for Bells Line of Road.
> 20 out of the 39 crashes, or 51 per cent, of crashes involved a casualty (fatality or injury) compared to 37 per cent for Bells Line of Road.
> 15 out of the 38 crashes, or 39 per cent, occurred on a Sunday, compared to 18 per cent for Bells Line of Road.
> 14 out of the 39 crashes, or 36 per cent, occurred between 1pm and 3pm, compared to 15 per cent for Bells Line of Road.

There are also two locations points where crash clusters are located on tight horizontal and vertical curves which are combined with overtaking lanes. This combination of factors may be contributing to the number of crashes at these two locations.

**Section 15 (From Zig Zag Railway to Hartley Valley Way)**
The road in this section has very poor horizontal and vertical geometry, with restricted shoulder widths. The road descends about 200 metres as it approaches Lithgow. Crashes were fairly consistent along the descent, with four crash clusters at sharp bends with steep grades. Notable crash characteristics include:
> Speeding was the contributing factor in 104 out of the 114 crashes, or 91 per cent, compared to 56 per cent for Bells Line of Road, which is already high compared to the Sydney and Western regions.
> 97 out of the 114 crashes, or 85 per cent, occurred on a curve, compared to 50 per cent for Bells Line of Road.
> 96 out of the 114 crashes, or 84 per cent, involved a single vehicle, compared to 58 per cent for Bells Line of Road.
> 79 out of the 114 crashes or 69 per cent occurred when it was raining, compared to 38 per cent for Bells Line of Road. Although the crash rate in this section is very high, the crash severity (crash involving a fatality or injury) is low, with no fatalities. Seventeen out of the 114 crashes, or 15 per cent, involved a casualty (fatality or injury), compared to 39 per cent for Bells Line of Road.

**Section 18 (Main Street to Great Western Highway)**
This section passes adjacent to the retail and commercial centre of Lithgow and extends through to the Great Western Highway, all in a 50 kilometre per hour zone. The horizontal and vertical geometry is good. A comparison of crash data for this section with Bells Line of Road as a whole shows that:
> 43 out of 49 crashes, or 86 per cent, involve multiple vehicles, compared to 42 per cent for Bells Line of Road overall.
> 31 out of 49 crashes, or 43 per cent, are located at intersections, compared to 17 per cent for Bells Line of Road.
> 18 out of 38 crashes, or 47 per cent, are rear-end crashes, compared to 12 per cent for Bells Line of Road.
> 16 out of 49 crashes, or 33 per cent, occurred on a Thursday, compared to 11 per cent for Bells Line of Road.
> 13 out of 49 crashes, or 27 per cent, occurred in the McLean Period G (Thursday to Friday 3pm to 9pm), compared to 11 per cent for Bells Line of Road.
> 10 out of 49 crashes, or 20 per cent, involve either pedestrian or cyclist, compared to 4 per cent for Bells Line of Road.
These high percentages of crash types compared to Bells Line of Road as a whole reflect the higher levels of congestion in this section, with many intersections, large number of turning movements and the stop-start nature of the traffic. Late night shopping on Thursdays may also be contributing to the higher crash rates during this time period.

6.4 Engineering analysis – overview

The key points from the engineering analysis are that:

> The Bells Line of Road from North Richmond to Lithgow features a wide variety of road characteristics and changing speed limits.

> There are many locations where the existing horizontal and vertical road geometry falls below current new road standards and guidelines. In particular this includes tight horizontal curves, steep grades, and sharp crest curves affecting sight distance.

> Overtaking opportunities are restricted by the horizontal and vertical geometry and there are few overtaking lanes. In particular, there is a 25-kilometre-long section between Kurrajong Heights and Mount Tomah where there is no overtaking lane in either direction.

> For most of the corridor the road cross-section is also below current new road standards and guidelines. This includes lane widths, sealed shoulder widths and clear zone widths.

As a consequence of the above, the Bells Line of Road has a poor crash record. At about 54 crashes per 100 million vehicle kilometres travelled, or 21 casualty crashes per 100 million vehicle kilometres travelled the crash rates are considerably higher than the typical rates for rural roads in NSW. Particular features of the high crash rates are:

> Speeding is the highest contributing factor for crashes and is recorded as a contributing factor for a much higher proportion of crashes than in the overall Sydney Region or Western region.

> Crashes on curves represent a much higher proportion of crashes compared to the Sydney and Western regions.

> Head-on crashes (not involving an overtaking movement) also represent a much higher proportion of crash movements compared to Sydney and Western regions.

> Crashes in the rain or when the road surface is wet are a much higher percentage of crashes compared to the Sydney and Western regions.

> Motorcycles are involved in a higher proportion of total crashes compared to the Sydney and Western regions.

> Compared to the Sydney and Western regions, a high percentage of crashes occurred during the weekend.

While Bells Line of Road as a whole has a poor crash record and certain crash types and characteristics are over-represented, there are some sections of the Bells Line of Road where there appear to be particular problems contributing to even higher crash rates. These are summarised below:

> Section 7 (Berambing to Mount Tomah Botanic Garden), which has poor geometry and a high crash rate. A high proportion of crashes occurred at the weekend, and a high proportion of crashes involved 17 to 20 year old drivers.

> Section 10 (Blue Mountains National Park to Mount Wilson Road), which has poor geometry and a high crash rate. Speeding was a high contributing factor and 75 per cent of crashes occurred on a curve.

> Section 11 (Mount Wilson Road to Darling Causeway at Bell), which has average geometry but a poor crash record. Speeding was a major contributing factor and many crashes occurred when it was raining. A high proportion of crashes
involved a casualty (fatality or injury) and a high proportion occurred on Sundays. There are also two locations in this section where crash clusters are located on tight horizontal and vertical curves which are combined with overtaking lanes.

Section 15 (From Zig Zag Railway to Hartley Valley Way) has poor horizontal and vertical geometry, with restricted shoulder widths. Crash rates are extremely high, with four crash clusters at sharp bends with steep grades. Speeding was a contributing factor in 91 per cent of the 114 crashes, and 85 per cent of crashes occurred on a curve. Most were single vehicle crashes and most were when it was raining. However the crash severity (proportion of crashes involving a fatality or injury) is low, with no fatalities.