

3 EXISTING ROAD NETWORK PERFORMANCE

This Chapter establishes the existing transport network performance in the study area around the Richmond Bridge. Results from traffic surveys are summarised in this section. An assessment of existing network capacity has been undertaken, indicating network deficiencies at key roads and intersections.

3.1 SITE VISIT

A site visit was undertaken on Friday 17th June 2011 to observe the existing traffic and travel pattern within the study area. Both morning (AM) and afternoon (PM) peak period traffic were observed. Site photo showing network issues are shown in Table 3-1. The following is a summary of key findings from site observation.

- Bells Line of Road/ Grose Vale Road Intersection. This is a four leg signalised intersection. There are controlled pedestrian crossings across all the approaches. In the AM peak throughput of across the stoplines on the western and southern approaches are often affected due to slow moving queues on Bells Line of Road eastbound. Bells Line of Road east of Grose Vale Rd has two existing lanes but narrows down to one lane further to the east. Vehicles on the kerbside lane merge to one lane. This downstream merging has some effect in slowing down vehicles (See Photo 1).
- The eastern approach of Bells Line of Road/ Grose Vale Road intersection has one lane leading to three lanes at the stopline. It has a short left and right turn bay dedicated to left turn and right turn vehicles. In the PM peak through traffic in one lane often blocks left turning traffic. (See Photos 3 and 4).
- A significant volume of traffic (about 500 vehicles per hour) use Pitt Lane travelling along the Riverview Street and then turn left into Grose Vale Road. The possible reason can be delays at Bells Line of Road/Grose Vale Road signal. The site observation suggests that Pitt Lane provides an attractive alternative route to motorists rather than using the next signal.
- Kurrajong Road in the eastbound direction immediately after the Richmond Bridge has an uphill gradient. This has the effect of slowing down traffic, particularly if mixed with buses and heavy vehicles.
- In the AM peak right turn vehicles (about 300 vehicles per hour) on Kurrajong Road to Yarramundi Lane often block eastbound through traffic. This obstruction causes a 'knock-on' effect to the heavy eastbound traffic leading congestion on the Bridge (See Photo 2)
- Kurrajong Road / Yarramundi Lane/Old Kurrajong Road Intersection. This is a four leg priority intersection with traffic on Kurrajong Road having priority. All approaches have one single lane. It appears that a significant volume of traffic uses Yarramundi Lane instead of using the downstream signal at Castlereagh Road/Bosworth Street. These appear to be predominantly morning Penrith-bound traffic. There is no dedicated right turning bay which often blocks the eastbound through traffic. In the PM peak vehicles turning left (about 380 vehicles per hour) at the Yarramundi Lane approach also slow down the westbound through traffic on Kurrajong Road. A long queue was observed on Kurrajong Road for westbound traffic and queues often extend to Castlereagh Road/Bosworth Street signal.

- Kurrajong Road / Bosworth Street/March Street signal. In the PM peak westbound traffic experiences significant delays. Queues are observed along Kurrajong Road/March Street up to its intersection with East Market Street. (See Photo 5)

Table 3-1 Network Issues Observed During Site Visit

Photo ID	Location	Photo
1	<p>Bells Line of Road, approximate 100m east of Grose Vale Road.</p> <p>Looking East along Bells Line of Road. Vehicles on the nearside lane have to merge back to form one lane.</p>	
2	<p>Kurrajong Road / Yarramundi Lane intersection.</p> <p>Looking West along Kurrajong Road</p> <p>Eastbound traffic is blocked by the right turning traffic (the first two cars).</p>	

Photo ID	Location	Photo
3	<p>Bells Line of Road, West of Grose Vale Road.</p> <p>Looking East along Bells Line of Road. Through traffic blocks the turning vehicles to the left turning lane.</p>	
4	<p>Bells Line of Road / Grose Vale Road intersection.</p> <p>Looking East along Bells Line of Road. Traffic discharges across the stopline in a single lane.</p>	
5	<p>Kurrajong Road, approximately 600m west of Bosworth Street.</p> <p>Looking East along Kurrajong Road. A long queue is observed during the PM Peak</p>	

3.2 TRAFFIC SURVEY

To satisfy RMS' modelling requirements, Hyder undertook an extensive data collection exercise involving key roads and intersections in the study area. Traffic surveys were undertaken as an input into:

- Micro simulation (Paramics) model calibration and validation.
- Intersection capacity analysis to determine level of service by using SIDRA.

Three types of survey were undertaken to satisfy the needs and purpose of the project. They were:

- Intersection turning movement counts for the critical peak periods.
- Daily automatic traffic counts for a one week period.
- Queue length surveys at critical intersections.

Surveys were undertaken in three stages as follows:

- Stage 1: Survey was undertaken by *Skyhigh* on 17th June 2011 at 12 intersections in the study area. One week of traffic was counted on Richmond Bridge.
- Stage 2: Following the first workshop with RMS and Hawkesbury City Council additional traffic counts were undertaken during the Yarramundi Lane closure. The Yarramundi Lane was closed for road resurfacing between 18th July 2011 and 15th August 2011. Additional traffic counts were undertaken by *Austraffic* at two intersections on 26th July 2011. The traffic data during the Yarramundi Lane closure was used as a sensitivity check through the modelling process.
- Stage 3: Hawkesbury City Council requested traffic counts for an additional three sites. The survey was undertaken by *Austraffic* on 18th August 2011 after Yarramundi Lane reopened to traffic.

Table 3-2 below summarises the traffic surveys undertaken in 2011.

Table 3-2 Summary of Traffic Survey undertaken for Richmond, 2011

Stage	Survey Summary
<p>Stage 1 (June 2011) Normal condition, no road closure</p>	<ul style="list-style-type: none"> ▪ Mid-block tube count for a period of one week for Richmond Bridge; ▪ Intersection turning counts during the morning and afternoon peak periods for 12 intersections including: <ul style="list-style-type: none"> ▪ Bells Line of Road/Grose Vale Road; ▪ Kurrajong Road/Yarramundi Lane; ▪ Kurrajong Road/Bosworth Street; ▪ Castlereagh Road/Lennox Street; ▪ Castlereagh Road/Innals Lane; ▪ Castlereagh Road/Long Street; ▪ Lennox Street/East Market Street; ▪ March Street/East Market Street; ▪ Windsor Street/East Market Street; ▪ Lennox Street/Paget Street; ▪ Windsor Street/Bosworth Street; ▪ March Street/West Market Street; ▪ Figure 3-1 shows locations of 12 intersections and mid-block location.
<p>Stage 2 (July 2011) During Yarramundi Lane closure</p>	<ul style="list-style-type: none"> ▪ Intersection turning counts during the morning and afternoon peak periods for two intersections including: <ul style="list-style-type: none"> ▪ Kurrajong Road / Yarramundi Lane; ▪ Kurrajong Road / Bosworth Street. ▪ Queue length surveys for Kurrajong Road / Bosworth Street intersection.
<p>Stage 3 (August 2011) Normal condition, no road closure</p>	<ul style="list-style-type: none"> ▪ Intersection turning counts and queue length surveys during the morning and afternoon peak periods for three additional intersections; <ul style="list-style-type: none"> ▪ Bells Line of Road / Charles Street; ▪ Lennox Street / Bourke Street; ▪ Windsor Street / Bourke Street. ▪ See Figure 3-1 for locations of the three sites (blue dots).

Figure 3-1 shows the traffic survey locations in the study area.

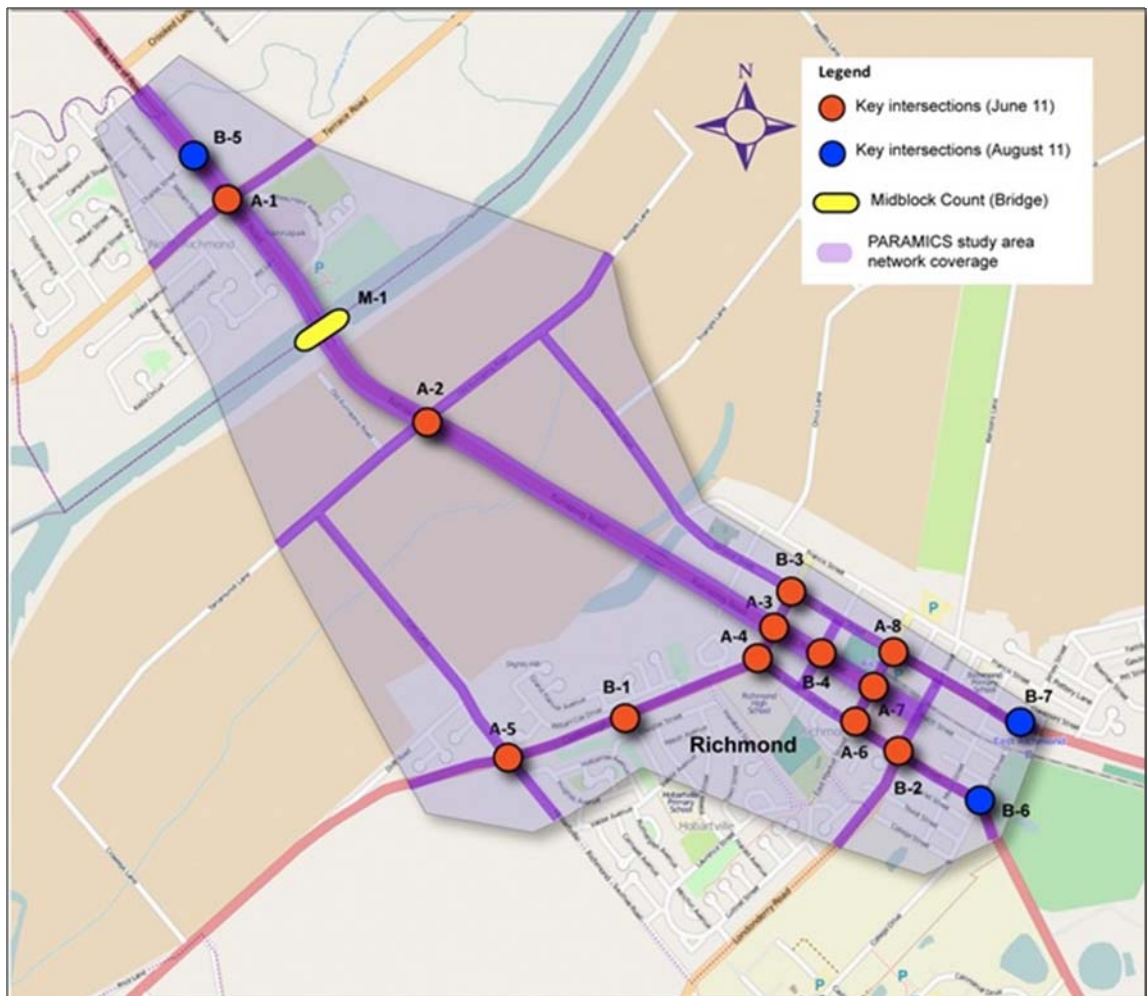


Figure 3-1 Traffic Survey Locations

Note: Intersection A-2 and A-3 were counted again during the Yarramundi Lane closure in July 2011 (Stage 2)

All the intersection classified turning movement counts were undertaken for 3 hours in the AM peak (6 am to 9am) and 3 hours in the PM peak (3pm-6pm) using a video method.

The daily automatic traffic counts (ATC) were conducted for a continuous seven-day period at Bells Line of Road on Richmond Bridge. The ATC survey was conducted as per twelve Austroads standard vehicle classes.

3.3 TRAFFIC RESULTS

This section quantifies the daily and peak hour traffic flows on key roads and intersections within the study area. The intersection turning movement data was used to estimate current capacity problems at key intersections. The traffic data also provides a basis to consider likely traffic changes that would result from future growth and short term improvement options. The results are based on survey data recorded from key roads and intersections in 2011.

3.3.1 TRAFFIC VOLUMES ON RICHMOND BRIDGE

Table 3-3 shows daily traffic volumes on Richmond Bridge for a typical weekday and weekend. The heavy vehicle numbers and proportion to total traffic volume is also shown. The results indicate that:

- Richmond Bridge carries between 27,200 and 30,200 vehicles per day on average weekday.
- Weekend traffic is approximately 15% lower than weekday traffic. The weekend traffic is in the order of 22,400 to 25,800 vehicles per day. The relatively higher traffic volumes in weekend demonstrate the tourism and recreational significance of this route.
- About 1500 heavy vehicles are recorded on the Bridge. The heavy vehicle proportion is about 5% to 6% of total traffic on weekdays. The heavy vehicle proportion during weekends is about of 2 % to 3 % of total traffic.

Table 3-3 Daily traffic volume on the Richmond Bridge

Weekday	Total daily flow [two-way]	Heavy Vehicle %
Monday	27,213	5.7%
Tuesday	27,672	5.7%
Wednesday	28,377	6.1%
Thursday	29,015	5.1%
Friday	30,184	5.3%
Saturday	25,809	3.0%
Sunday	22,400	2.2%

Figure 3-2 below shows the variation of the hourly traffic profile from Monday to Friday on Richmond Bridge. The AM peak spreads over three hours between 06:00 AM and 09:00 AM, with traffic building up sharply between 6.00 AM and 07:00 AM when it reaches its peak. The hour between 07:00 AM and 08:00 AM shows the predominant peak. The PM peak also spreads over three hours between 15:00 PM and 18:00 PM, with traffic volumes gradually starting to build up around 15.00PM. The peak is reached at 17:00 PM before it starts to decline sharply. The hour between 16:00 PM and 17:00 PM shows the predominant peak.

As seen, the peak direction in the morning peak is eastbound towards Richmond. This is mirrored in the afternoon peak with a similar volume of traffic heading westbound towards Kurrajong and beyond. Peak hour traffic volume on Richmond Bridge was in the order of 1400 to 1500 vehicles per direction.

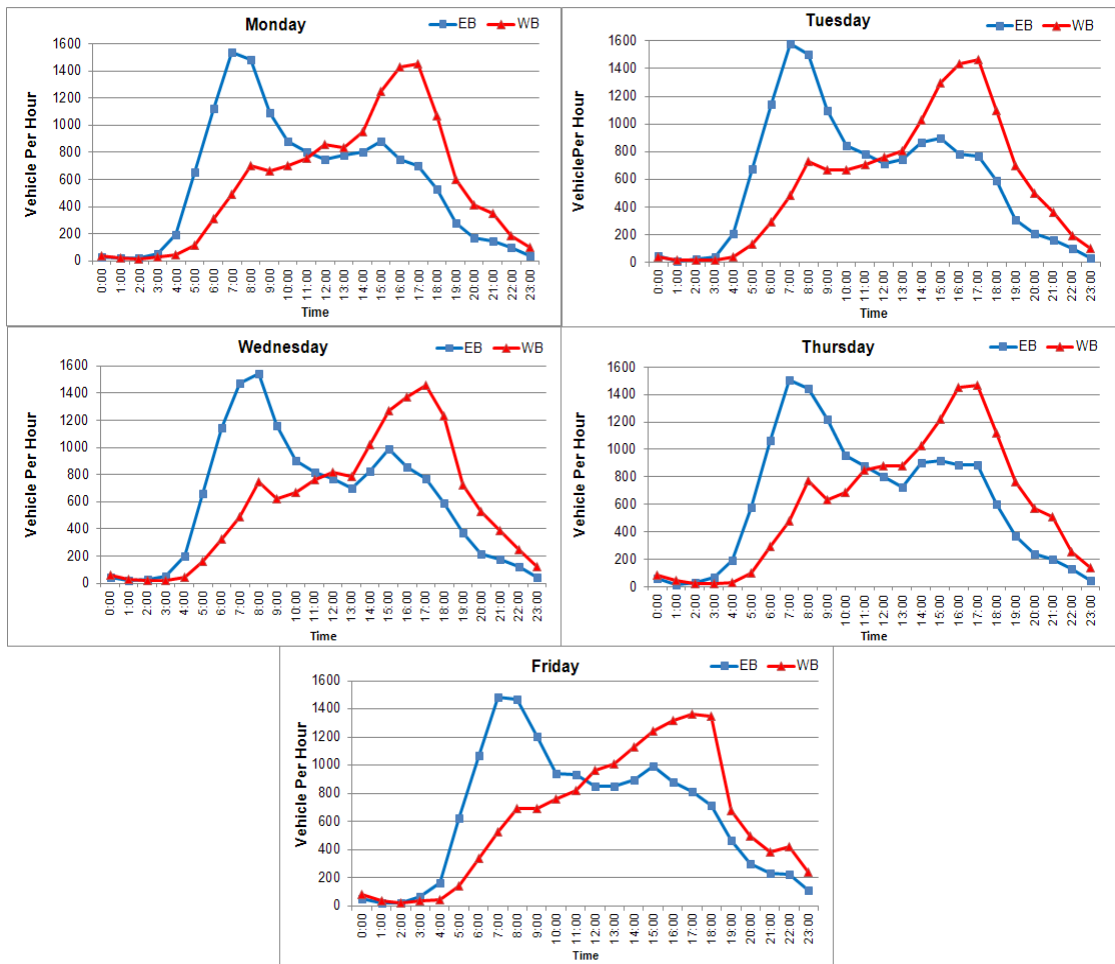


Figure 3-2 Hourly Traffic Profile – Weekdays

3.3.2 PEAK HOUR TRAFFIC VOLUMES AT KEY ROADS

Table 3-4 summarises the morning and afternoon peak hour traffic volumes on key roads in the study area.

Table 3-4 Peak hour traffic volumes at key roads

ID	Location	AM Peak			PM Peak		
		NB/EB	SB/WB	Two-way	NB/EB	SB/WB	Two-way
M-1	Bells Line of Road, Richmond Bridge	1,537	635	2,172	917	1,333	2,250
M-2	Bells Line of Road, west of Gross Vale Road	899	389	1,288	595	741	1,336
M-3	Kurrajong Road, west of Bosworth street	942	489	1,431	652	855	1,508
M-4	March Street, west of East Market street	592	367	959	510	501	1,011
M-5	Lennox Street, west of East Market street	514	240	755	351	576	927
M-6	Windsor Street, west of East Market street	189	152	341	252	299	551
M-7	March Street, east of East Market street	304	173	477	357	350	706
M-8	Castlereagh Road, north of Southee Road	317	143	460	254	480	734
M-9	Yarramundi Lane, south of Kurrajong Road	156	336	492	467	162	629
M-10	Lennox Street, east of Paget Street	556	354	910	472	568	1,041
M-11	Windsor Street, east of East Market Street	550	267	817	492	541	1,033

Note: Northbound (NB), Eastbound (EB), Southbound (SB), Westbound (WB); Peak 1 hour traffic is estimated from AM peak 2 hour and PM peak 3 hour traffic data. Traffic data in the above table represents one hour traffic.

Table 3-4 summarised AM and PM peak traffic volumes on key roads in the study area. Traffic volumes are presented as one hour volumes in both directions and as two-way volumes. The results showed that:

- The highest two-way traffic volume in the study area was observed on Bells Line of Road on Richmond Bridge. The bridge carried about 2,150 to 2,250 vehicles per hour in the AM and PM peak periods respectively. Bells Line of Road at Richmond Bridge showed a typical 'tidal flow' traffic distribution. The eastbound traffic showed the highest peak in the morning, in the order of 1,500 vehicles per hour, while westbound traffic showed highest peak in the evening, in the order of 1,300 vehicles per hour.
- Kurrajong Road, west of Bosworth Street, showed the second highest two-way flow in the study area, carrying about 1,400 to 1,500 vehicles per hour for the AM and PM peak periods. The directional traffic distribution at Kurrajong Road, west of Bosworth Street, showed a similar 'contra flow' pattern with the highest eastbound traffic volume during the morning peak and the highest westbound traffic volumes during the evening peak.
- Bells Line of Road, west of Grose Vale Road, showed one hour two-way traffic volumes in the order of 1,300 vehicles per hour for both the AM and PM peak periods. Similarly to the entire main road section between Richmond and North Richmond, traffic volumes showed a contra flow pattern, with the highest eastbound flow during the AM peak and highest westbound flow during the PM peak.
- The highest one hour two-way traffic volume on March Street was in the order of 950 to 1,000 vehicles per hour west of East Market Street.
- The highest one hour two-way traffic volume on Windsor Street was in the order of 800 to 1,000 vehicles per hour east of East Market Street.

- The highest one hour two-way traffic volume on Lennox Street was in the order of 900 to 1,000 vehicles per hour east of Paget Street.
- The highest one hour two-way traffic volume on Yarramundi Lane was in order of 500 to 600 vehicles per hour south of Kurrajong Road. Yarramundi Lane showed contra flow traffic distribution pattern with highest southbound flow during AM peak and highest northbound flow during PM peak.
- The highest one hour two-way traffic volume on Castlereagh Road was in order of 450 to 700 vehicles per hour north of Southee Road.

Detailed traffic data is shown in **Appendix B**.

3.4 KEY NETWORK ISSUES

3.4.1 RICHMOND BRIDGE

The traffic capacity of Richmond Bridge is assessed using the Austroads' Guideline. The hourly distribution of traffic for the average weekday is shown in Figure 3-3 below. Peak one hour traffic volume on the Richmond Bridge was in the order of 1400 to 1500 vehicles per direction. The Austroads' Guideline has suggested an indicative capacity threshold between 1,400 and 1,600 vehicles per hour per lane for a two lane urban arterial road. The traffic data suggests that Richmond Bridge is close to saturation traffic level.

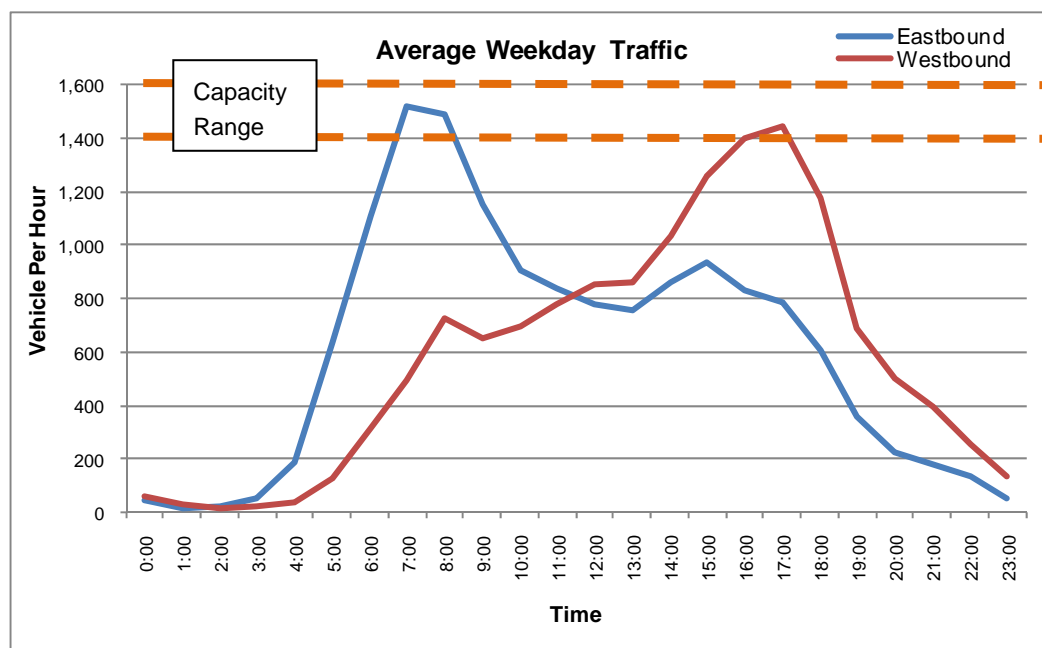


Figure 3-3 Hourly traffic volumes on the Richmond Bridge, June 2011

The posted travel speed on Richmond Bridge and that section of Bells Line of Road/Kurrajong Road are between 60 and 80 km/h. The 2011 travel time data indicates that average travel speed of the section of Bells Line of Road/Kurrajong Road is substantially lower at 10-20km/h, particularly during afternoon peak (PM) in the westbound direction. The average travel speed during morning peak (AM) is recorded between 40 and 50 km/h in the eastbound direction (See Figure 3-4).

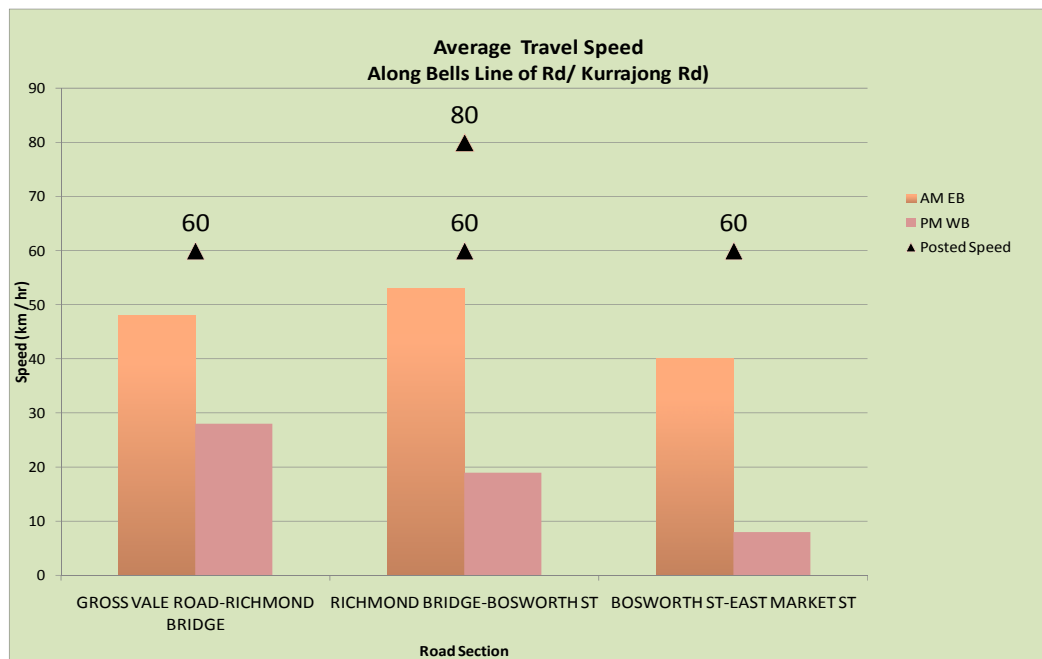


Figure 3-4 Average travel speed of section of Bells Line of Road/Kurrajong Road, March 2011

3.4.2 KEY INTERSECTIONS

The capacity of the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street is strongly influenced by the operation of Richmond Bridge and adjoining key intersections.

A total of 13 intersections within the study area have been analysed (using SIDRA) to determine their respective operating performance. The performance of an intersection can be measured by the intersection average delay per vehicle, which in turns leads to a “level of service” measure for the intersection. These measures are:

- Level of Service A – good operation;
- Level of Service B – good operation with acceptable delays and spare capacity;
- Level of Service C – satisfactory operation;
- Level of Service D – operating near capacity;
- Level of Service E – operating at capacity; incidents at signals will cause excessive delays; and
- Level of Service F – extra capacity required.

The modelling investigation has found that during the morning and afternoon peak period, some turn movements at adjoining key intersections with Bells Line of Road/Kurrajong Road adversely impact Richmond Bridge’s performance. The analysis has identified network operational issues at the following three key intersections:

1. Bells Line of Road/Grose Vale Road (traffic light controlled);
2. Kurrajong Road / Yarramundi Lane / Old Kurrajong Road (sign control); and
3. Kurrajong Road/ Bosworth Street (traffic light controlled).

Figure 3-5 below shows the location of above three intersections. Detailed SIDRA modelling results for 2011 traffic conditions are included in **Appendix B** for both the AM and PM peaks.



Figure 3-5 Locations of adjoining three key intersections

Detailed network operational issues were identified for these three key intersections using the micro-simulation Paramics model.

The turning volumes for the AM and PM peak hours are shown in Figure 3-6 and Figure 3-7 below.

2011 Existing Base Case AM

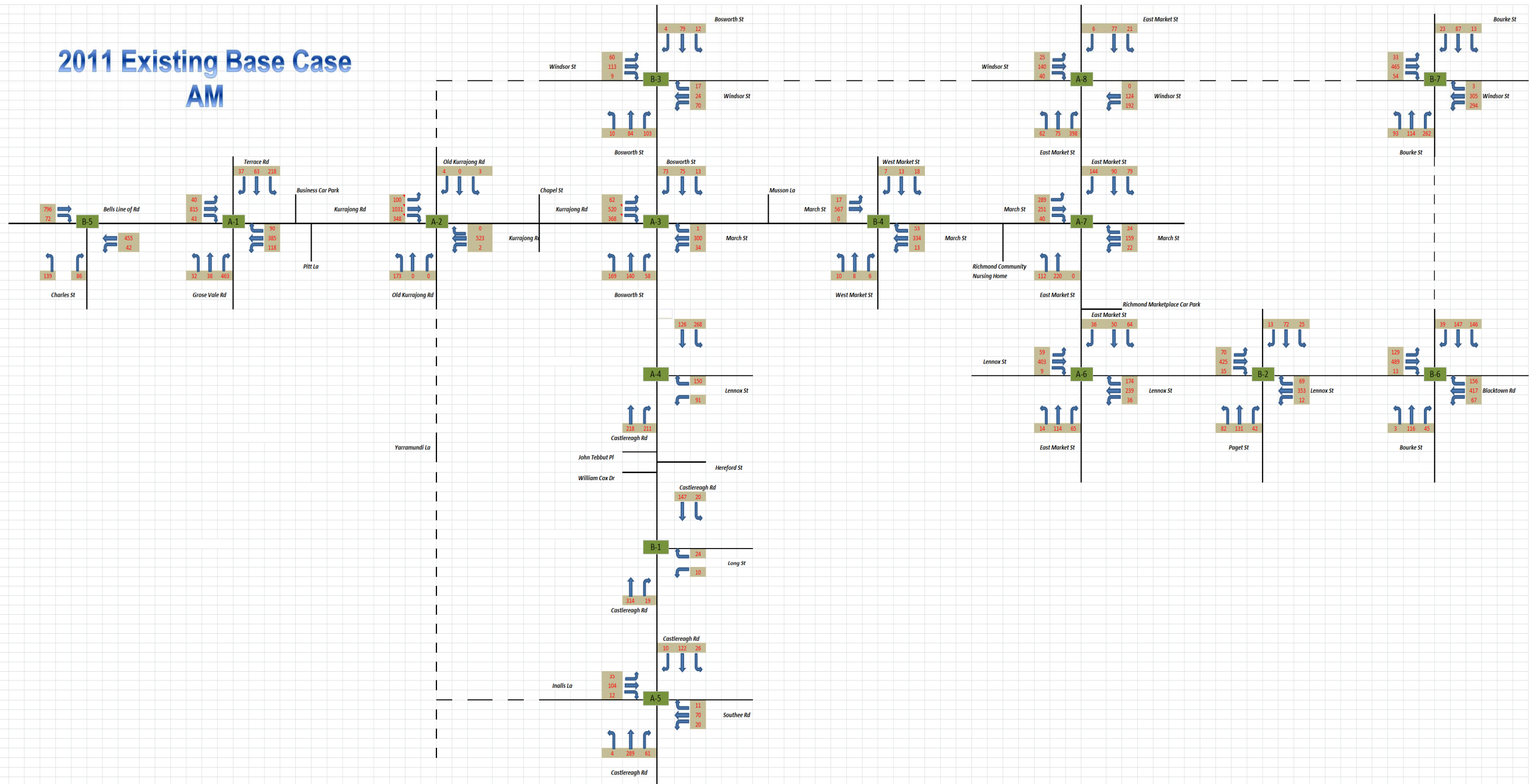


Figure 3-6 2011 AM Peak Existing Base Case, Intersection turning volumes

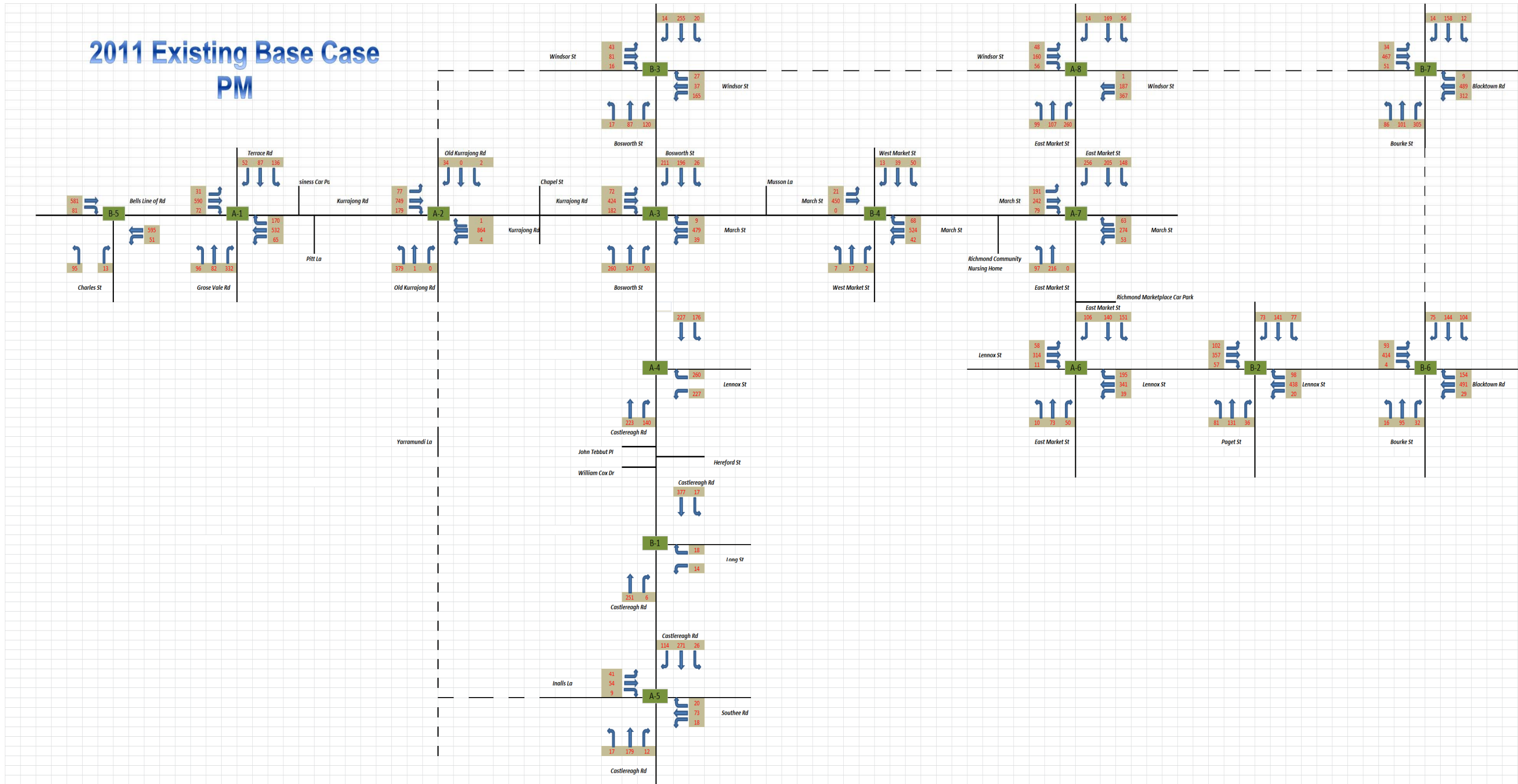


Figure 3-7 2011 PM Peak Existing Base Case, Intersection turning volumes

Key existing network issues for the AM and PM peak periods are presented in Tables 3-5 and 3-6. 'Screenshots' from the Paramics models are shown as Figures 3-8 to 3-17 to illustrate the location and nature of each network issue.

Table 3-5 Key network issues-AM Peak

ID	Location	Key Issues	Paramics Snapshot
1	Bells Line of Road/Grose Vale Rd Intersection	<ul style="list-style-type: none"> High right turning movements(500 veh/h) from Grose Vale Road to Bells Line of Road. In line with the current situation, the model predicts long queues with low LoS (F). 	Figure 3-8
		<ul style="list-style-type: none"> The bus stop on Bells Line of Road immediately east of Grose Vale Rd. Currently there is no separate bus bay. Buses occasionally block the eastbound kerb side lane. Our site visit indicates occasional kerb side lane blockage due to buses affecting signal operation. According to the available bus time table about ten buses use this bus stop between 7:00 AM and 9:00 AM. 	Figure 3-9
		<ul style="list-style-type: none"> Two eastbound through lanes on Bells Line of Road merge to one lane east of Grose Vale Road. The potential merge impedes eastbound through traffic and affects signal operation. 	
2	Kurrajong Road/Yarramundi Lane intersection	<ul style="list-style-type: none"> Currently there is no exclusive right turn bay on the Kurrajong Road western approach that can accommodate turning traffic into Yarramundi Lane. The high right turning traffic (350 veh/h) on Kurrajong Road to Yarramundi Lane blocks eastbound through traffic. Once traffic is interrupted, eastbound through traffic needs additional time to accelerate. This causes a potential 'knock-on' effect from Yarramundi Lane upstream to the Bridge. 	Figure 3-10 Figure 3-11
3	Kurrajong Road/Bosworth Street intersection	<ul style="list-style-type: none"> Currently there is no exclusive right turn bay on the Kurrajong Road western approach. The eastbound right turn traffic shares one lane with through traffic. The eastbound right turning traffic (370 veh/h) shares one lane with through traffic. Occasional long queues (west of Chapel St) are observed along the western intersection approach. 	Figure 3-12



Figure 3-8 Grose Vale Road approach-Typical AM Peak queue

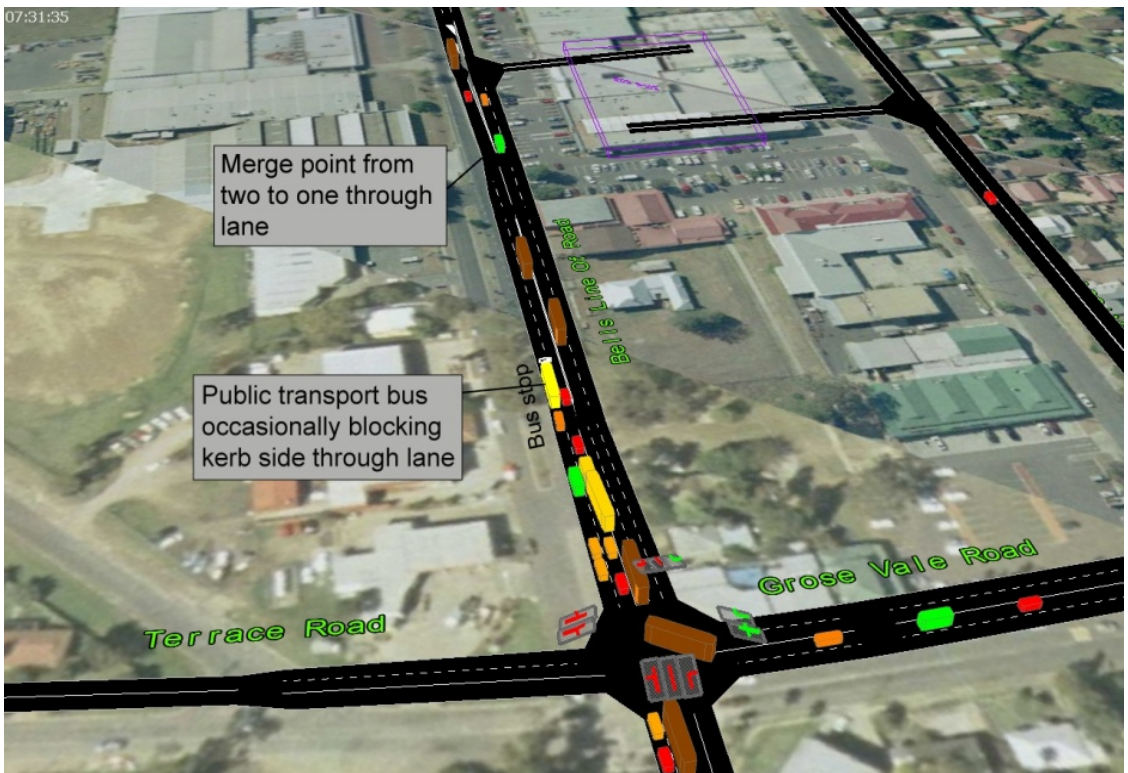


Figure 3-9 Bells Line of Road east of Grose Vale Road-showing bus and merge point issues, AM Peak



Figure 3-10 Right turn from Kurrajong Rd to Yarramundi Lane blocking eastbound through traffic, AM peak



Figure 3-11 Eastbound traffic is occasionally stopped on the bridge due to downstream through traffic interruption at Yarramundi Lane, AM Peak

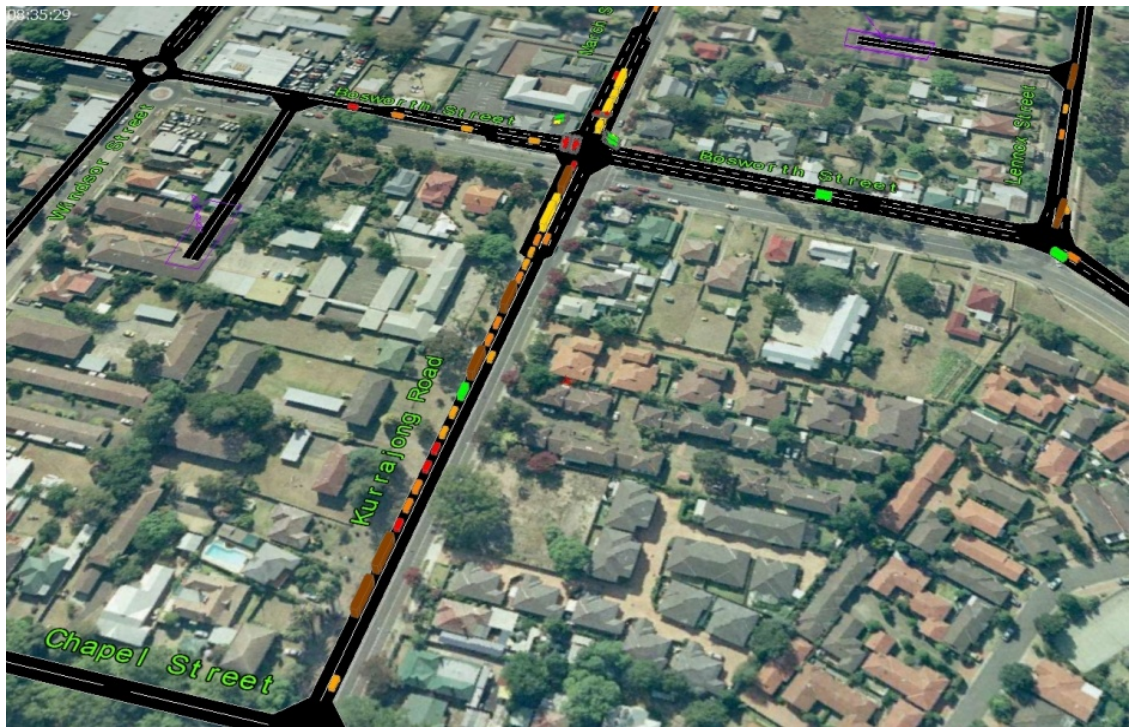


Figure 3-12 Kurrajong Road/Bosworth Street intersection with a typical queue along the western approach, AM Peak

Table 3-6 Key network issues -PM Peak

ID	Location	Key Issues	Paramics Snapshot
1	Bells Line of Road/Grose Vale Rd Intersection	<ul style="list-style-type: none"> Currently there is only one through lane on Bells Line of Road in the westbound direction. It was observed that westbound through traffic experiences long queues and high delays. The model suggests that occasionally the queue extends upstream to the bridge. Westbound traffic that turns left from North Richmond Shopping Centre also causes delays to Bells Line of Road westbound through traffic. 	Figure 3-13 Figure 3-14
2	Kurrajong Road/Yarramundi Lane intersection	<ul style="list-style-type: none"> High left turning traffic (380 veh/h) from Yarramundi Lane tends to force its way out before it merges with Kurrajong Road main stream westbound traffic. The site visit indicated that potential aggressive left turn vehicles frequently impede westbound through traffic. This phenomenon causes a 'knock-on' effect from Yarramundi Lane upstream to Richmond township. The model predicts long queues along Kurrajong Road in the westbound direction (LoS F) as well as long queues on Yarramundi Lane (LoS F). 	Figure 3-15 Figure 3-16
3	Kurrajong Road/Bosworth Street intersection	<ul style="list-style-type: none"> Long queues are observed along March Street in the westbound direction (LoS F). These are residual queues predominantly from westbound traffic interruption (by Yarramundi Lane turning traffic). 	Figure 3-17



Figure 3-13 Bells Line of Road/Grose Vale Rd intersection, typical westbound queue, PM Peak



Figure 3-14 Bells Line of Road/Grose Vale Rd intersection, the westbound queue is occasionally expanded to the bridge, PM Peak



Figure 3-15 Kurrajong Rd/Yarramundi Lane intersection, westbound through traffic is frequently interrupted by aggressive left turning vehicles from Yarramundi Lane, PM peak;

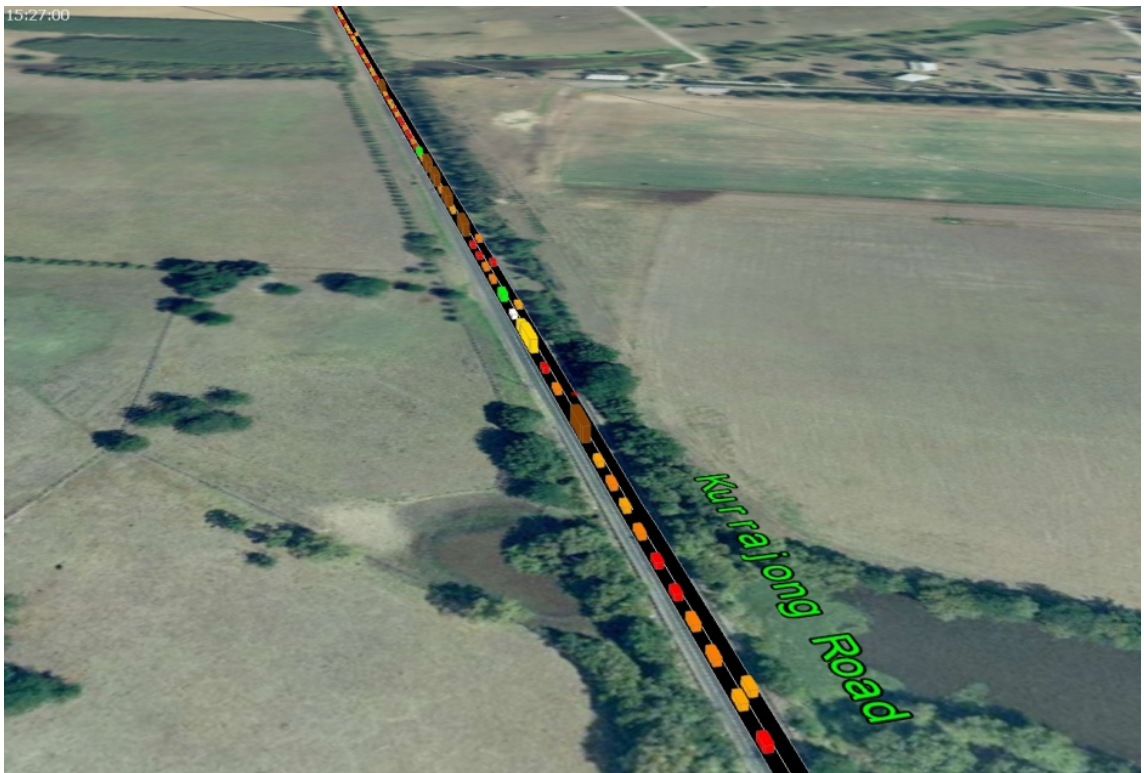


Figure 3-16 Kurrajong Rd, westbound traffic congestion, PM peak



Figure 3-17 Typical PM peak westbound queue along March Street between East Market St and Bosworth St

3.5 SUMMARY OF KEY ISSUES

The traffic analysis for 2011 suggests that Richmond Bridge is close to saturation traffic levels. During the morning and afternoon peak periods, some turning movements at adjoining key intersections with Bells Line of Road/Kurrajong Road also adversely impact the operation of Richmond Bridge's performance. The traffic modelling has identified network operational issues at the following three key intersections:

1. Kurrajong Road / Yarramundi Lane/Old Kurrajong Road (sign control).
2. Bells Line of Road/Grose Vale Road (traffic light controlled).
3. Kurrajong Road/ Bosworth Street (traffic light controlled).

4 PARAMICS MODEL DEVELOPMENT

4.1 OVERVIEW

A Paramics model has been developed to facilitate a more in-depth analysis of the operational impacts of Richmond Bridge and adjoining key intersections. The Paramics models were calibrated and validated according to the RMS' Paramics modelling guidelines. The models represented 2011 traffic conditions for both morning (AM) peak and afternoon (PM) peak periods, i.e.:

- The AM peak period between 7:00 and 9:00.
- The PM peak period between 15:00 and 18:00.

The Paramics model specifically represents traffic for an average weekday, by the way of modelling the AM and PM peak periods. These time period (AM peak between 7:00 and 9:00, PM peak between 15:00 and 18:00) coincide with Sydney Strategic Traffic Model (*STM*) developed by the Bureau of Transport Statistics (*BTS*).

4.2 DEMAND

The initial demand matrix was estimated using Hyder's own Sydney Strategic Transport Model, (SSTM operates in *TransCAD*) using a sub-area technique. The demand in SSTM was obtained from BTS's Sydney Strategic Traffic Model. The demand was further refined using data obtained from RMS' Sydney Strategic Model (operates in *Emme/2*). Further travel zone and network refinements were undertaken for the study area. The demand matrix was calibrated to RMS's standards using the 2011 traffic counts data.

The demand matrix was estimated separately for two vehicle types:

- Cars/light vehicles.
- Rigid and articulated heavy vehicles.

The proportion of heavy vehicles has been taken directly from classified traffic surveys.

Figure 4-1 shows the Paramics model road network and travel zone system.

4.3 MODEL CALIBRATION AND VALIDATION

Detailed Paramics model calibration and validations are documented in **Appendix C**.

The study area Paramics modelling results documented in **Appendix C** confirmed that both the AM and PM peak were calibrated and validated adequately and the model is fit for this study purpose.

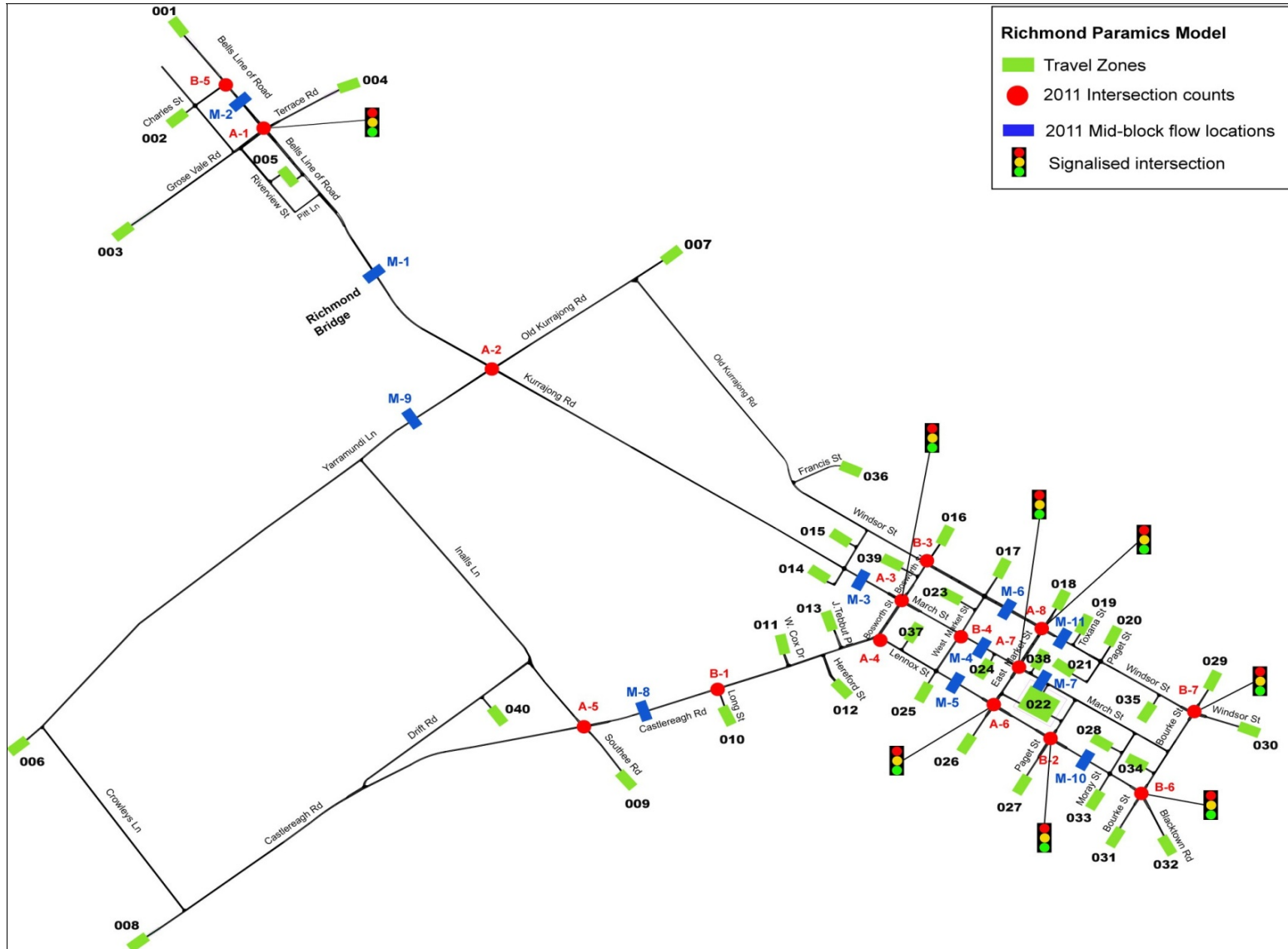


Figure 4-1 The Paramics model network and travel zone system

5 OPTIONS ASSESSMENT

5.1 OPTIONS CONSIDERED

Based on the existing network performance assessment results and modelling investigations, Hyder identified about ten (10) preliminary short term improvement options which have the potential to improve traffic flow of the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street. The short term improvements include a range of localised changes to the following three key intersections to favour the major east west movement of traffic on the section of Bells Line of Road and Kurrajong Road:

- Kurrajong Road / Yarramundi Lane / Old Kurrajong Road.
- Bells Line of Road/Grose Vale Road.
- Kurrajong Road/ Bosworth Street.

The short term options include minor improvements to road and intersections to maintain an acceptable level of traffic operation. These improvements include intersection widening, banning on street parking during peak periods, providing a clearway condition during peak period and similar small works.

Through the model refinement process, some of these options are combined. In consultation with key stakeholders, eight (8) options were shortlisted for detailed assessment. Two options that were rejected were:

- Full closure of Yarramundi Lane.
- A new sign to formalise Pitt Lane as the established traffic route for left turning traffic.

The eight shortlisted options are referred to as Options A to H.

Table 5-1 summarises proposed changes to key intersections for the eight upgrade options A to H.

Table 5-1 Options Considered

Options	Key Intersections	Proposed Changes
Option A	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> ▪ An eastbound right turn ban to Yarramundi Lane during peak period.
Option B	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> ▪ Similar to Option A, an eastbound right turn ban to Yarramundi Lane during peak period. ▪ In addition, an eastbound left turn ban to Old Kurrajong Road during the peak period.
Option C	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> ▪ Option C is a further modification to Option A. Additional improvements are identified to the Kurrajong Rd/Bosworth St intersection. ▪ Similar to Option A, an eastbound right turn ban to Yarramundi Lane during peak period.

Options	Key Intersections	Proposed Changes
	Kurrajong Rd / Bosworth St	<ul style="list-style-type: none"> An additional eastbound exclusive right turn bay from Kurrajong Road to Bosworth Street. A westbound right turn ban from March Street to Bosworth Street.
Option D	Bells Line of Rd/Grose Vale Rd	<ul style="list-style-type: none"> Provide a shared through/left turn lane on Bells Line of Road replacing the existing left turn lane. Provide an additional westbound short through lane on Bells Line of Road, west of Grose Vale Road. This option allows for all movements at the intersection and may require some widening work.
Option E	Bells Line of Rd/Grose Vale Rd	<ul style="list-style-type: none"> Option E is a further modification to Option D. Additional changes include banning on street parking. A right turn ban on Bells Line of Road is proposed to avoid potential widening. Provide a shared through/left turn lane on Bells Line of Road, replacing the existing left turn lane. Provide an additional westbound short through lane on Bells Line of Road, west of Grose Vale Road. Ban on-street parking during peak periods between Pitt Lane and Grose Vale Road. Provide an eastbound right turn ban from Bells Line of Road into Grose Vale Road. Conversion of the existing eastbound right-turn bay to a second westbound through lane. This option tries to avoid the need for widening at the intersection by banning eastbound right turn movements.
Option F	Bells Line of Rd/Grose Vale Rd	<ul style="list-style-type: none"> Option F is a further modification to Option E. The proposed changes to the Bells Line of Rd/Grose Vale Rd intersection are similar to the previous Option E.
	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> An additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane.
Option G	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> Option G is a combination of Options C and E. Proposed changes to the Kurrajong Rd / Yarramundi La / Old Kurrajong Rd intersection are similar to previous Option C. A left turn slip lane out of Yarramundi Lane with an acceleration lane on Kurrajong Road (westbound direction)
	Kurrajong Rd / Bosworth St	<ul style="list-style-type: none"> Proposed changes to Kurrajong Rd / Bosworth St intersections are similar to previous Option C.

Options	Key Intersections	Proposed Changes
	Bells Line of Rd/Grose Vale Rd	<ul style="list-style-type: none"> Proposed changes to Bells Line of Rd/Grose Vale Rd intersection are similar to previous Option E. An eastbound merge kerb side lane to be extended (east of Grose Vale Road intersection).
Option H	Kurrajong Rd / Yarramundi La / Old Kurrajong Rd	<ul style="list-style-type: none"> Unlike previous Options, Option H eliminates the potential eastbound right turn ban to Yarramundi Lane. An additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane. A left turn slip lane out of Yarramundi Lane with an acceleration lane on Kurrajong Road (westbound direction).
	Bells Line of Rd/Grose Vale Rd	<ul style="list-style-type: none"> Proposed changes to Bells Line of Rd/Grose Vale Rd intersection are similar to previous Option E. The eastbound merge be extended (east of Grose Vale Road intersection).

5.2 KEY TRAFFIC CRITERIA

Each option was assessed in terms of key traffic factors which are most likely to influence a decision regarding the best performing option.

Key traffic criteria used to compare performance for each option are:

- Level of Service (LoS): An objective of upgrading key intersections will be to improve or maintain an acceptable level of service (LoS) over the short time period of the upgraded intersection. The analysis included LoS for the Base Case (existing condition) and all options A to F. The LoS are reported at key intersections where relevant.
- Transport network efficiency of the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street. A fundamental objective in upgrading key intersections is to improve the overall network efficiency. This was quantified in terms of average travel speed improvement on Bells Line of Road/Kurrajong Road which would result from improving key intersection capacity.
- Impact on the road network: This factor considers the impact of the upgrade option on other roads in the network. Changes in traffic volumes due to the proposed option are compared against the volumes on the same roads for existing conditions. The impact analysis concentrates on key roads where there is a significant increase or decrease in traffic flows as a consequence of the option being considered. For example, proposed turn bans can impact alternative travel routes. The morning and afternoon peak traffic volumes are shown at key intersections.
- Local accessibility: The upgrading options involve modifications to the intersections of some local roads with Bells Line of Road/Kurrajong Road, which impact local traffic movements. For example, proposed right turn bans for different options will affect the way properties are accessed for residents, service and emergency vehicles routes, and delivery vehicles which service the area. Local road connections are maintained by rationalising and re-routing selected sections of the local road network.






Quantitative measures were identified as being available to assist in the assessment of the performance of each option as described in Table 5-2. All eight options were modelled using Paramics and SIDRA where relevant.

Table 5-2 Quantitative Measures against Key Traffic Criteria

ID	Key Criteria	Modelling tool	Measures
1	Option ability to improve Bells Line of Road/Kurrajong Road eastbound traffic flows;	Paramics	Average travel speed (km/h).
2	Option ability to improve Bells Line of Road/Kurrajong Road westbound traffic flows;	Paramics	Average travel speed (km/h)
3	Vehicle Kilometres of Travel, VKT – Study Area Network	Paramics	Vehicle Kilometre Travel (VKT)
4	Vehicle Hours of Travel, VHT – Study Area Network	Paramics	Vehicle Hour Travel (VHT)
5	Option ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	Level of Service (LoS)
6	Option ability to improve Levels of Service at key intersections.	SIDRA	Level of service (LoS)
7	Impact on adjacent intersections	SIDRA	Levels of Service (LoS) are reported at adjacent intersections in the following areas: Area A – Richmond; Area B – Castlereagh ; Area C – North Richmond

For all eight options, the model was assessed for 2011 traffic conditions. Traffic measures for each option were compared with the base case (existing condition). In consultation with the RMS a five-grade colour code (see Table 5-3) is used to show relative performance of each option compared to base case.

Table 5-3 Relative Performance of each Option

Colour code	Relative performance compared to Base Case
 Green	Improvement
 Light green	Slight Improvement
 White	No Change/Minor Change
 Light red	Slightly Worse
 Red	Worse

5.3 IMPACT ASSESSMENT

This section presents detailed impact assessments of each upgrade option A to H against the key traffic criteria identified in previous Section 5.2. The traffic performance of each option is summarised in tabular form. Proposed changes to key intersections for each option are also shown graphically. Detailed turning volumes and level of service (LoS) data at key intersections for each option is included in Appendix D.

5.3.1 OPTION A

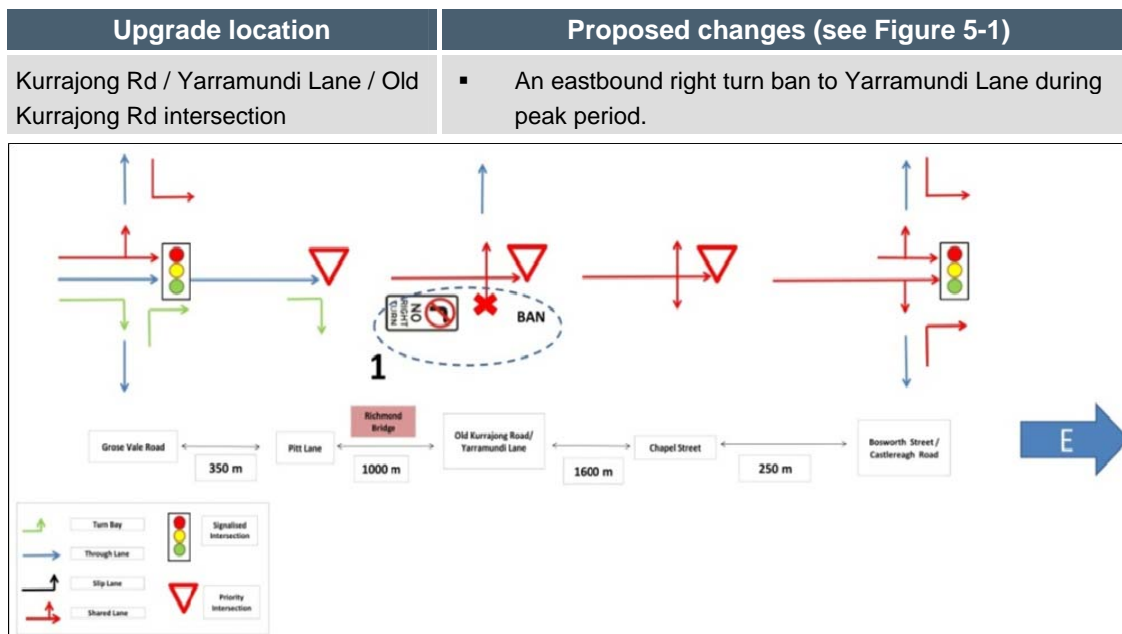


Figure 5-1 Option A Schematic Lane Configuration

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The proposed changes to key intersections for Option A are shown graphically in Figure 5-1. Table 5-4 shows the traffic performance of option A against key criteria.

The following points are noted from Option A results shown in Table 5-4:

- The proposed eastbound right turn ban on Kurrajong Road to Yarramundi Lane would divert additional traffic to the adjacent Kurrajong Road/Bosworth Street intersection. This would increase the right turn demand from Kurrajong Road to Bosworth Street. The model forecasts low LoS (F) at the Kurrajong Road/Bosworth Street intersection. Currently the eastbound right turn on Kurrajong Road is shared with a through traffic lane. To make option A workable, the model suggests the need for an additional eastbound exclusive right turn lane on Kurrajong Road.
- Option A would not improve eastbound traffic flows between Grose Vale Road and East Market Street. The model forecasts a reduction in travel speed (about 35%) for eastbound traffic from 48 km/h (base case) to 31 km/h (Option A).
- Option A would not improve westbound traffic flows between Grose Vale Road and Bosworth Street. The model forecasts no change in average travel speed in westbound direction when compared to base case.
- Option A would slightly increase (up to 3%) the vehicle kilometres of travel (VKT) in the study area network due to the proposed right turn ban on Kurrajong Road to Yarramundi

Lane. The VKT is forecast to increase due to longer distance travel by right turn vehicles via Bosworth Street instead of Yarramundi Lane.

- Option A would significantly increase (up to 35%) the vehicle hours of travel (VHT) in the study area network. The VHT is forecast to increase due to high delays predicted to the Bosworth Street/Kurrajong Road intersection.
- The proposed turn ban in Option A is forecast to change traffic volumes at the following locations when compared to base case:
 - Traffic on Kurrajong Road west of Bosworth Street is forecast to increase in the order of 160 to 270 vehicles per hour (about 10% to 18%) during the PM and AM peak respectively.
 - Traffic on Windsor Street west of East Market Street is forecast to increase in the order of 20 to 80 vehicles per hour (about 4% to 24%) during the PM and AM peaks respectively. Traffic along Old Kurrajong Road and Windsor Street is forecast to increase due to increased delays along Kurrajong Road, particularly during the AM Peak. The forecast traffic increase on Old Kurrajong Road and Windsor Street from the model was in line with actual traffic increases that were counted during the Yarramundi Lane closure in July 2011.
 - Traffic on Yarramundi Lane south of Kurrajong Road is forecast to decrease in the order of 180 to 350 vehicles per hour (about 32% to 67%) during the PM and AM peaks respectively.
 - Traffic on Castlereagh Road south of Bosworth Street is forecast to increase in the order of 180 to 350 vehicles per hour (about 20% to 41%) during the PM and AM peak respectively.
- The proposed turn ban in option A would change the local network connectivity. With few dwellings along the Yarramundi Lane local accessibility will be affected.
- The Option A improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in the Richmond and North Richmond areas. The model forecasts minor impacts to adjacent intersections in the Castlereagh area (see **Appendix D** for detailed traffic volumes and LoS).

Option A modelling results suggest that banning the eastbound right turn on Kurrajong Road to Yarramundi Lane would adversely impact the operation of the Kurrajong Road/Bosworth Street intersection. To make option A workable, the model suggests the need for an additional eastbound exclusive right turn lane on Kurrajong Road at Kurrajong Road/Bosworth Street intersection.

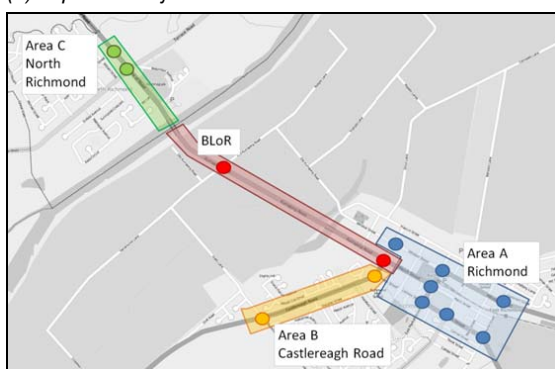
Table 5-4 Traffic Performance of Option A

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option A		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	31 km/h	-35% ▼	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	17 km/h	0%	□
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	40,599	+3% ▲	■
		Paramics	PM	64,826	65,466	+1% ▲	■
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	1,222	+35% ▲	■
		Paramics	PM	2,277	2,944	+29% ▲	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Kurrajong Road / Yarramundi Lane (Priority) ⁽⁵⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS A	-	■
	Kurrajong Road / Bosworth Street (Signals) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS C	LoS F/LoS F	-	■
	Bells Line of Road/Grose Vale Road (Signals) ⁽⁶⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS D	-	□
7	Impact on adjacent intersections ⁽⁷⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	Minor Change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	Slightly Worse	-	■
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	No Change	-	□

Note:

(1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction);(3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Kurrajong Road west approach; (6) LoS is reported for Bells Line Road east approach

(7) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.2 OPTION B

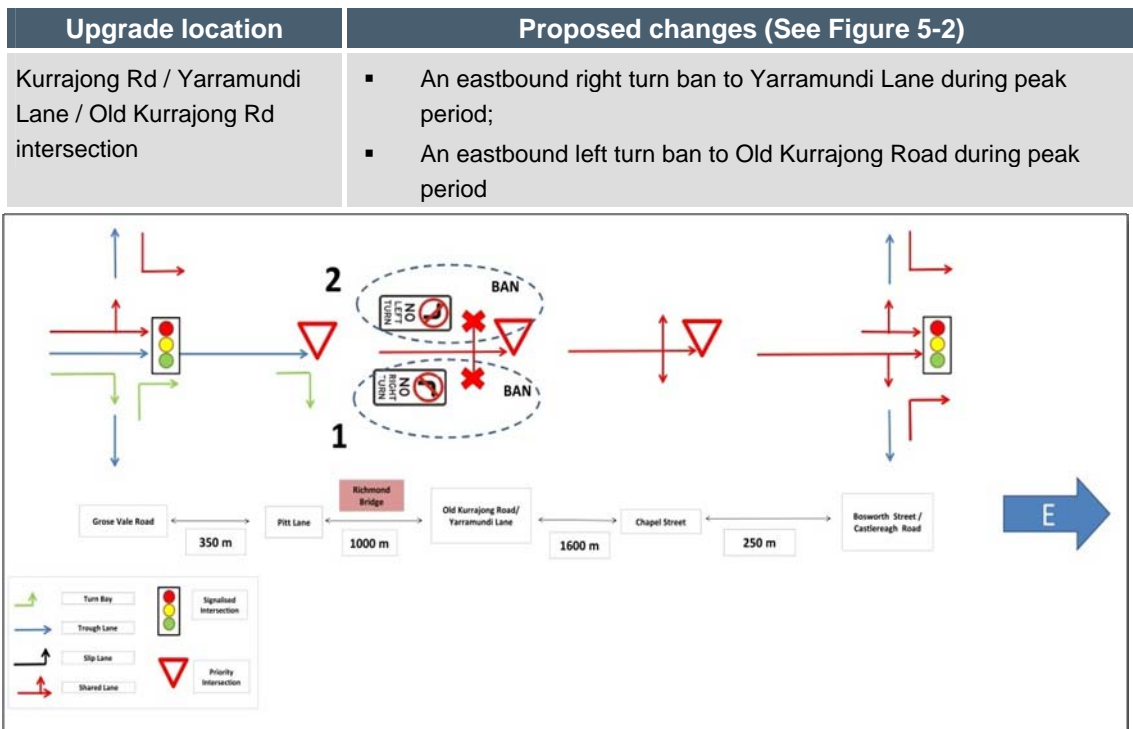


Figure 5-2 Option B Schematic Lane Configuration

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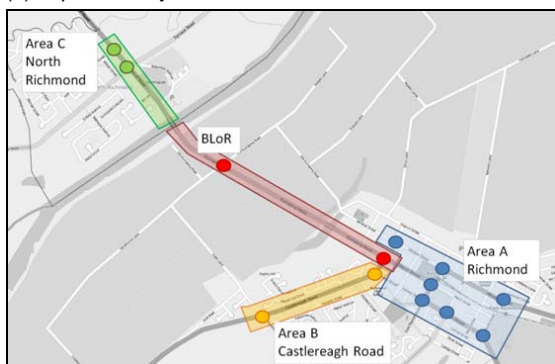
The proposed changes to key intersections for option A are shown graphically in Figure 5-2. Table 5-5 shows the traffic performance of option B against key criteria. The proposed changes to the network for option B are similar to option A except that one additional eastbound left turn ban is proposed to Old Kurrajong Road. The impact to network operations from option B would be similar to option A, albeit marginally greater. Option B would adversely impact the operation of the Kurrajong Road/Bosworth Street intersection. To make option B workable, the model suggests the need for an additional eastbound exclusive right turn lane on Kurrajong Road at Kurrajong Road/Bosworth Street intersection.

Table 5-5 -Option B Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option B		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	26 km/h	-46% ▼	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	16 km/h	-6% ▼	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	40,565	+3% ▲	■
		Paramics	PM	64,826	65,421	+1% ▲	■
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	1,344	+48% ▲	■
		Paramics	PM	2,277	3,784	+66% ▲	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Kurrajong Road / Yarramundi Lane (Priority) ⁽⁵⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS A	-	■
	Kurrajong Road / Bosworth Street (Signals) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS C	LoS F/LoS F	-	■
	Bells Line of Road/Grose Vale Road (Signals) ⁽⁶⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS D	-	□
7	Impact on adjacent intersections ⁽⁷⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	Minor Change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	Slightly Worse	-	■
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	No Change	-	□

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction);(3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Kurrajong Road west approach; (6) LoS is reported for Bells Line Road east approach

(7) Impact on adjacent intersections:



*Relative performance compare to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.3 OPTION C

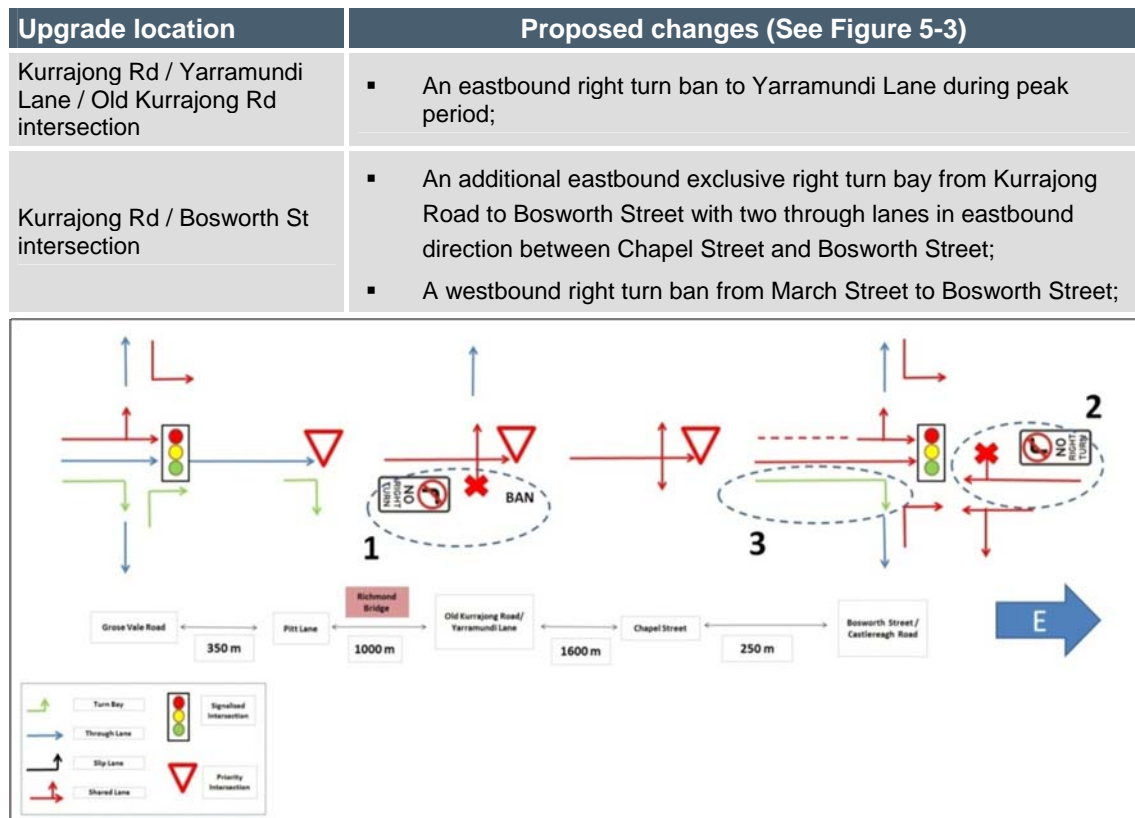


Figure 5-3 Option C Schematic Lane Configuration

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The proposed changes to key intersections for Option C are shown graphically in Figure 5-3. Option C is a further modification to Option A. The identified improvements in option A formed the basis of Option C. In other words, Option C also assumed one additional eastbound exclusive right turn lane on Kurrajong Road, as the need for this improvement was identified in option A. Table 5-6 shows traffic performance of Option C against key criteria.

The following points are noted from Option C results shown in Table 5-6:

- The additional eastbound exclusive right turn on Kurrajong Road is forecast to improve LoS C/D to the Kurrajong Road/Bosworth Street intersection. This improvement would accommodate the increase in right turn demand from Kurrajong Road to Bosworth Street.
- Option C would improve eastbound traffic flows between Grose Vale Road and East Market Street. The model forecasts improvements in travel speeds (about 10%) for eastbound traffic from 48 km/h (base case) to 53 km/h (Option C).
- However, Option C would not improve westbound traffic flows between Grose Vale Road and Bosworth Street. The model forecasts no change in average travel speed in the westbound direction when compared to the base case.
- Similar to Option A, Option C would slightly increase (up to 3%) the vehicle kilometres of travel (VKT) in the study area network due to the proposed right turn ban on Kurrajong Road to Yarramundi Lane. The VKT is forecast to increase due to longer distance travel by right turn vehicles via Bosworth Street instead of Yarramundi Lane.

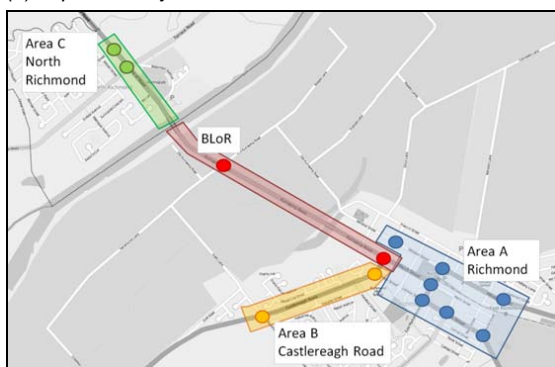
- Unlike Option A, Option C would significantly improve (up to 7%) the vehicle hours of travel (VHT) in the study area network. The VHT is forecast to improve due to additional improvements (an exclusive right turn) being proposed to the Bosworth Street/Kurrajong Road intersection.
- The proposed turn bans in Option C are forecast to change traffic volumes similarly to Option A.
- The Option C improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in the Richmond and North Richmond areas. The model forecasts minor impacts to adjacent intersections in the Castlereagh area (see **Appendix D** for detailed traffic volumes and LoS).

Option C performs relatively better than previous Options A and B. The modelling results from Option C have reaffirmed the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection.

Table 5-6 Option C Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option C		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	53 km/h	+10% ▲	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	17 km/h	0%	□
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	40,543	+3% ▲	■
		Paramics	PM	64,826	65,478	+1% ▲	■
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	897	-1% ▼	■
		Paramics	PM	2,277	2,119	-7% ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Kurrajong Road / Yarramundi Lane (Priority) ⁽⁵⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS A	-	■
	Kurrajong Road / Bosworth Street (Signals) ^{(5) (6)}	SIDRA	AM/PM	LoS B/LoS C	LoS C/LoS B	-	□
	Bells Line of Road/Grose Vale Road (Signals) ⁽⁷⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS D	-	□
7	Impact on adjacent intersections ⁽⁸⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	Minor Change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	Slightly Worse	-	■
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	No Change	-	□

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction);(3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Kurrajong Road west approach;(6) Without additional right turn bay at Bosworth St intersection, model predicts LoS F (Option A). (7) LoS is reported for Bells Line Road east approach
(8) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.4 OPTION D

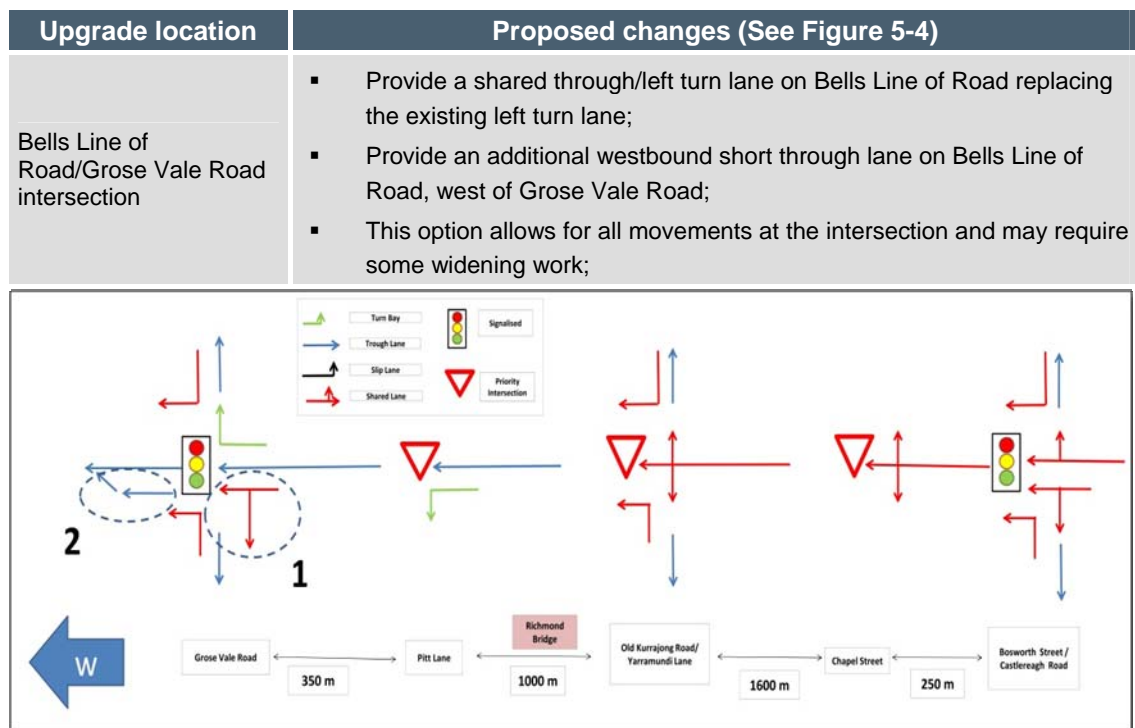


Figure 5-4 Option D Schematic Lane Configuration

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The proposed changes to key intersections for Option D are shown graphically in Figure 5-4.

Unlike Options A to C, Option D is developed with a view to improving westbound flows on this section of Bells Line of Road and Kurrajong Road. The improvement is proposed at Bells Line of Road/Grose Vale Road intersection alone. Table 5-7 shows traffic performance of Option D against key criteria.

The following points are noted from Option D results shown in Table 5-7:

- As expected, Option D would not improve eastbound traffic flows between Grose Vale Road and Bosworth Street. The model forecasts no change in average travel speeds in the eastbound direction when compared to the base case.
- The proposed improvement at Bells Line of Road/Grose Vale Road intersection is forecast to improve LoS for westbound traffic, particularly for the afternoon (PM) peak.
- In general Option D would improve westbound traffic flows between Grose Vale Road and East Market Street in the afternoon peak. The model forecasts slight improvements in travel speed (about 6%) for westbound traffic from 17 km/h (base case) to 18 km/h (Option C). During the afternoon peak, the heavy westbound left turn (about 380 vehicles per hour) from Yarramundi Lane impedes the Kurrajong Road traffic flows, particularly for the section between Bosworth Street and Yarramundi Lane. However, the model shows improvements in traffic flows on Kurrajong Road/Bells Line of Road between Yarramundi Lane and Grose Vale Road. The analysis therefore identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

- In line with predicted travel speed improvement, Option D would slightly improve (up to 2%) vehicle hours of travel (VHT) in the study area network. There will be no change in the vehicle kilometres of travel (VKT) for Option D.
- The Option D improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in the Richmond, North Richmond and Castlereagh Road areas. (see **Appendix D** for detailed traffic volumes and LoS).

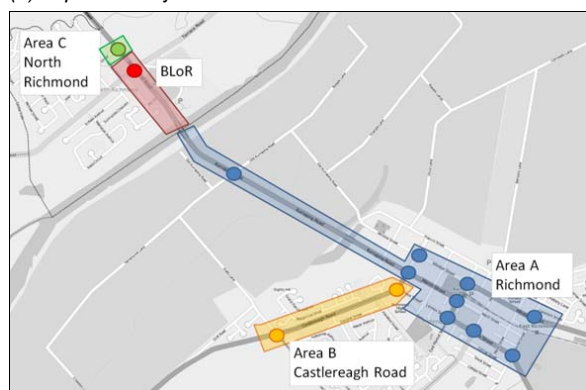
In general, Option D is forecast to improve westbound traffic flows between Grose Vale Road and East Market Street in the afternoon peak. The proposed improvement at the Bells Line of Road/Grose Vale Road intersection is forecast to improve LoS for westbound traffic, particularly for the afternoon (PM) peak. To achieve efficient traffic flows in the westbound direction, the analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

Table 5-7 Option D Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option D		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	48 km/h	0%	□
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	18 km/h	+6% ▲	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	39,228	0%	□
		Paramics	PM	64,826	64,829	0%	□
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	914	0%	□
		Paramics	PM	2,277	2,237	-2% ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Kurrajong Road / Yarramundi Lane (Priority) ⁽⁵⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS B	-	□
	Kurrajong Road / Bosworth Street (Signals) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS C	LoS B/LoS C	-	□
	Bells Line of Road/Grose Vale Road(Signal) ⁽⁶⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS B	-	■
7	Impact on adjacent intersections ⁽⁷⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	No change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	No change	-	□
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	No change	-	□

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction);(3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach; (5) LoS is reported for Kurrajong Road west approach; (6) LoS is reported for Bells Line of Road east approach;

(7) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse

5.3.5 OPTION E

Upgrade location	Proposed changes (See Figure 5-5)
Bells Line of Road/Grose Vale Road intersection	<ul style="list-style-type: none"> Provide a shared through/left turn lane on Bells Line of Road replacing the existing left turn lane. Provide an additional westbound short through lane on Bells Line of Road, west of Grose Vale Road. Ban on-street parking during peak periods between Pitt Lane and Grose Vale Road, thus creating a clearway. An eastbound right turn ban from Bells Line of Road into Grose Vale Road. Conversion of the existing eastbound right-turn bay to a second westbound through lane. This option tries to avoid the need for widening at the intersection by banning the east bound right turn movement;

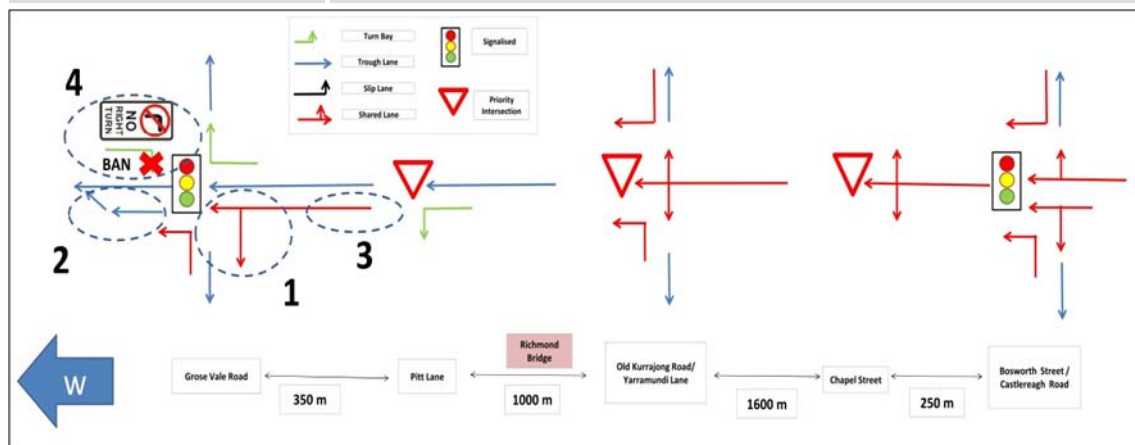


Figure 5-5 Option E Schematic Lane Configuration

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The proposed changes to key intersections for option E is shown graphically in Figure 5-5.

Option E is a further modification to Option D. Additional changes include banning on street parking on the eastern approach of Bells Line of Road/Grose Vale Road intersection. A right turn ban on Bells Line of Road is proposed to avoid potential widening. Table 5-8 shows traffic performance of Option E against key criteria.

The impact to network operations from Option E would be similar to Option D. In general, Option E is forecast to improve westbound traffic flows between Grose Vale Road and East Market Street in the afternoon peak. The proposed improvement at the Bells Line of Road/Grose Vale Road intersection is forecast to improve LoS for westbound traffic particularly in the afternoon (PM) peak. To achieve efficient traffic flows in the westbound direction, the analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

The proposed right turn ban from Bells Line of Road to Grose Vale Road would redirect additional traffic to the adjacent intersection at Bells Line of Road with Charles Street. Currently the Charles Street intersection has priority control. The model forecasts traffic increases to Charles Street in order of 40 to 70 vehicles per hour. The queue length for right turning traffic into Charles Street would not exceed the provided right turn bay on Bells Line of Road. From a traffic operation perspective, the proposed right turn ban can be justified. However, this ban can

impact local accessibility in North Richmond including access to the North Richmond Shopping Centre from the west. Prior to implementation of the proposed right turn ban, it is recommended that RMS undertakes community consultation.

Table 5-8 -Option E Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option E		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	48 km/h	0%	□
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	18 km/h	+6% ▲	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	39,235	0%	□
		Paramics	PM	64,826	64,840	0%	□
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	897	-1% ▼	■
		Paramics	PM	2,277	2,210	-3% ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Kurrajong Road / Yarramundi Lane (Priority) ⁽⁵⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS B	-	□
	Kurrajong Road / Bosworth Street (Signals) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS C	LoS B/LoS C	-	□
	Bells Line of Road/Grose Vale Road(Signal) ⁽⁶⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS B	-	■
7	Impact on adjacent intersections ⁽⁷⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	No change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	No change	-	□
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	Slightly Worse	-	■

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction); (3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach; (5) LoS is reported for Kurrajong Road west approach; (6) LoS is reported for Bells Line of Road east approach;

(7) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.6 OPTION F

Upgrade location	Proposed changes (See Figure 5-6)
Bells Line of Road/Grose Vale Road	<ul style="list-style-type: none"> Proposed changes are as per previous Option E
Kurrajong Road / Yarramundi Lane/Old Kurrajong Road	<ul style="list-style-type: none"> An additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane.

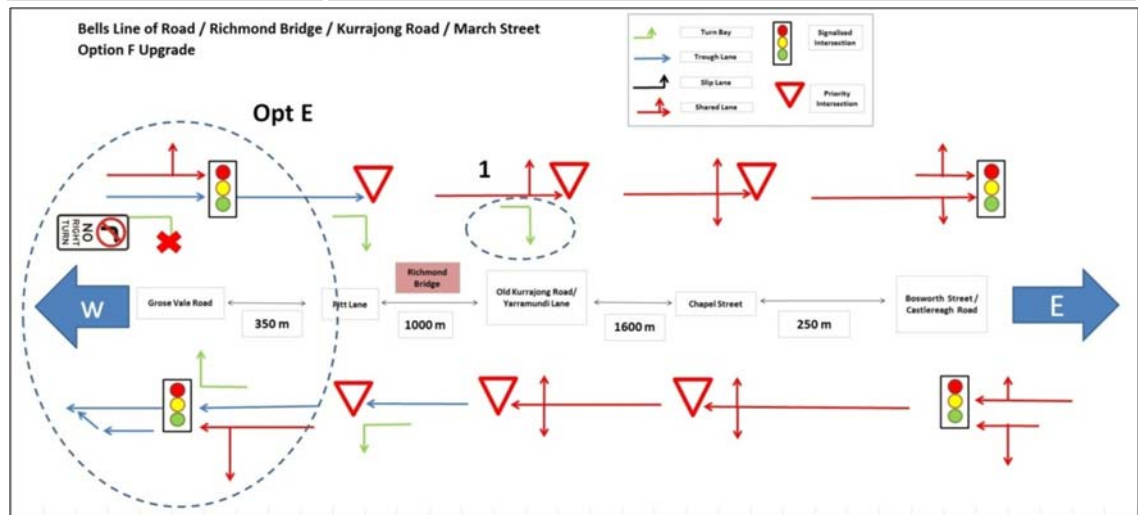


Figure 5-6 Option F Schematic Lane Configuration

Spreadsheets Path: F:\AA004249\ID-Calculations\Traffic and Modelling\Data Processing\Test Option\Test Options Diagram_RevA.xlsx

The proposed changes to key intersections for Option F are shown graphically in Figure 5-6. Option F is a further modification to Option E. The proposed changes to the Bells Line of Rd/Grose Vale Rd intersection are similar to the previous Option E. Option F is developed with the view that intersection widening to Kurrajong Road/Bosworth Street (as per Option C) may have timing implications due to the need for potential property acquisitions. In that context, intersection widening work may not be implemented in the immediate short term (0-5 years). In addition, the proposed east bound right turn ban on Kurrajong Road to Yarramundi Lane may have potential accessibility issues to the local community. Instead, in Option F, an additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane is proposed.

Table 5-9 shows the traffic performance of Option E against key criteria:

- In general Option F would improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peak.
- Similarly to Option E, the model forecasts slight improvements in travel speeds (about 6%) for westbound traffic from 17 km/h (base case) to 18 km/h (Option F). During the afternoon peak, the heavy westbound left turn (about 380 vehicles per hour) from Yarramundi lane impedes the Kurrajong Road traffic flows, particularly for the section between Bosworth Street and Yarramundi Lane. The analysis therefore identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.
- The additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane is forecast to improve eastbound traffic flows on Kurrajong Road. The model

forecasts improvements in travel speed (about 6%) for eastbound traffic from 48 km/h (base case) to 51 km/h (Option F) in the morning peak.

- In line with the predicted travel speed improvement, Option F would slightly improve (up to 3%) vehicle hours of travel (VHT) in the study area network. There will be no change in the vehicle kilometres of travel (VKT) for Option F.
- The Option F improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in the Richmond and Castlereagh Road areas. The model forecasts minor impacts to adjacent intersections in North Richmond (see **Appendix D** for detailed traffic volumes and LoS).

In general, Option F is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Minor improvement is forecast for westbound traffic. To achieve efficient traffic flows in the westbound direction, the analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

Table 5-9 -Option F Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option F		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	51 km/h	+6 % ▲	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	18 km/h	+6 % ▲	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	39,313	0%	□
		Paramics	PM	64,826	64,846	0%	□
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	894	-1% ▼	■
		Paramics	PM	2,277	2,218	-3% ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS F/LoS D	-	□
6	Ability to improve key intersections Level of Service at:						
	Bells Line of Road/Grose Vale Road (Signal) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS B	-	■
	Kurrajong Road/Yarramundi Lane (Priority) ⁽⁶⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS B	-	■
	Kurrajong Road / Bosworth Street (Signals) ⁽⁷⁾	SIDRA	AM/PM	LoS B/LoS C	LoS B/LoS C	-	□
7	Impact on adjacent intersections ⁽⁸⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	No Change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	No Change	-	□
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	Slightly Worse	-	■

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction); (3) Average Speed from East Market Street to Grose Vale Road (westbound direction);(4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Bells Line of Road east approach;(6) LoS is reported for Kurrajong Road west approach; (7) LoS is reported for Kurrajong Road west approach (8) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.7 OPTION G

Upgrade location	Proposed changes (See Figure 5-7)
Bells Line of Road/Grose Vale Road	<ul style="list-style-type: none"> Proposed changes as per previous Option E; The eastbound merge lane to be extended (east of Grose Vale Road intersection);
Kurrajong Road/Yarramundi Lane/Old Kurrajong Road	<ul style="list-style-type: none"> Proposed changes as per previous Option C; Provide a left turn slip lane out of Yarramundi Lane with acceleration lane on Kurrajong Rd;
Kurrajong Road/Bosworth St	<ul style="list-style-type: none"> Proposed changes as per previous Option C;

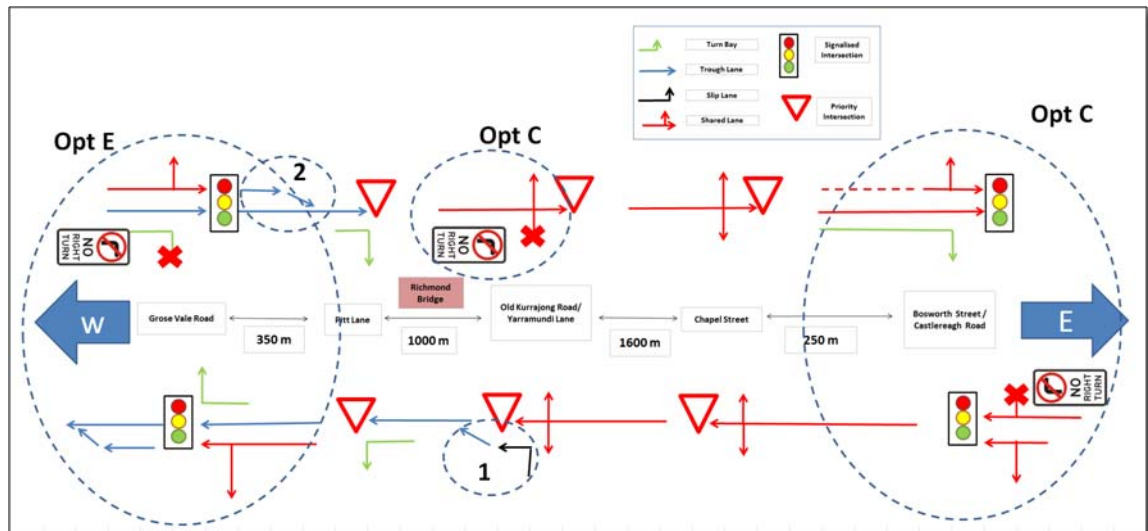


Figure 5-7 Option G Schematic Lane Configuration

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The proposed changes to key intersections for Option G are shown graphically in Figure 5-7. In general, Option G is a combination of the previous Options C and E. Two additional improvements are proposed in option G, based on modelling outcome from previous Options C and E. They are:

- A left turn slip lane out of Yarramundi Lane with an acceleration lane on Kurrajong Road (westbound direction).
- The eastbound merge kerb side lane to be extended (east of Grose Vale Road intersection).

Table 5-10 shows traffic performance of Option G against key criteria:

- In general Option G would improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peak.
- The model forecasts significant improvements in travel speed (about 171%) for westbound traffic from 17 km/h (base case) to 46 km/h (Option G). The improved traffic flows are triggered by the combined effect of a left turn slip lane out of Yarramundi Lane and an acceleration lane on Kurrajong Road.
- Unlike previous options, the extension of the eastbound merge (east of Grose Vale intersection) is forecast to improve Grose Vale Road traffic particularly in the morning peak.

- Similarly to Option C, the additional eastbound exclusive right turn bay from Kurrajong Road to Bosworth Street is forecast to improve eastbound traffic flows on Kurrajong Road. The model forecasts improvements in travel speed (about 10%) for eastbound traffic from 48 km/h (base case) to 53 km/h (Option G) in the morning peak.
- In line with predicted travel speed improvement for westbound traffic, Option G would improve (up to 32%) vehicle hours of travel (VHT) during the afternoon peak in the study area network. There will be a minor increase (about 3%) of vehicle kilometres of travel (VKT) for Option G.
- The Option G improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in Richmond. The model forecasts minor impacts to adjacent intersections in the North Richmond and Castlereagh areas (see **Appendix D** for detailed traffic volumes and LoS).

In general, Option G is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Option G performs better than the previous Options C and E alone.

Table 5-10 -Option G Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option G		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	53 km/h	+10 % ▲	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	46 km/h	+171 % ▲	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	40,530	+3 % ▲	■
		Paramics	PM	64,826	65,470	+1 % ▲	■
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	895	-1 % ▼	■
		Paramics	PM	2,277	1,558	-32 % ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS D/LoS D	-	■
6 Ability to improve key intersections Level of Service at:							
	Bells Line of Road/Grose Vale Road (Signal) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS B	-	■
	Kurrajong Road/Yarramundi Lane (Priority) ⁽⁶⁾⁽⁷⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS A	-	■
	Kurrajong Road/Bosworth Street (Signal) ⁽⁶⁾⁽⁸⁾	SIDRA	AM/PM	LoS B/LoS C	LoS C/LoS B	-	■
7 Impact on adjacent intersections ⁽⁹⁾							
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	Minor Change	-	■
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	Slightly Worse	-	■
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	Slightly Worse	-	■

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction); (3) Average Speed from East Market Street to Grose Vale Road (westbound direction); (4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Bells Line of Road east approach;(6) LoS is reported for Kurrajong Road west approach (7) The left turn slip lane out of Yarramundi Lane is expected to improve westbound traffic operation on Kurrajong Road particularly during PM peak. However, SIDRA model forecasts similar LoS for both Base Case and improved case (Option G). This is potentially a limitation of SIDRA. Paramics suggest improvement on Kurrajong Road traffic triggered by left turn slip lane out of Yarramundi Lane. (8) Without additional right turn bay at Bosworth St intersection, model predicts LoS F (Option A). (9) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
■	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.8 OPTION H

Upgrade location	Proposed changes (See Figure 5-8)
Bells Line of Road/Grose Vale Road	<ul style="list-style-type: none"> Proposed changes as per previous Option E; The eastbound merge lane to be extended (east of Grose Vale Road intersection).
Kurrajong Road/Yarramundi Lane/Old Kurrajong Road	<ul style="list-style-type: none"> Proposed changes as per previous Option F; Provide a left turn slip lane out of Yarramundi Lane with acceleration lane on Kurrajong Road (westbound direction)

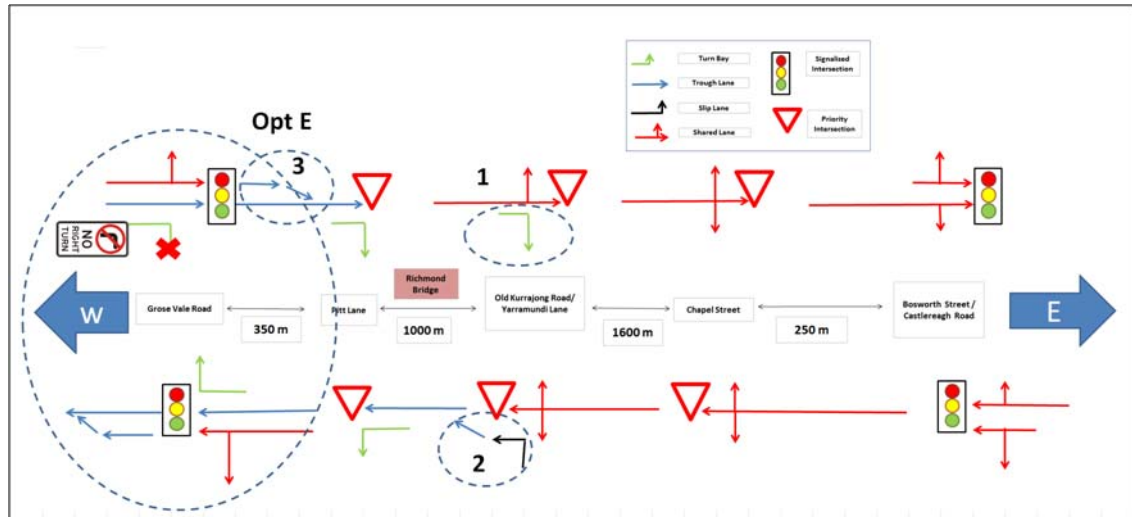


Figure 5-8 Option H Schematic Lane Configuration

The proposed changes to key intersections for option H are shown graphically in Figure 5-8. In general, Option H is a further modification to the previous options E/ F. Unlike previous options, option H eliminates the potential eastbound right turn ban to Yarramundi Lane. In option H, no improvement is proposed to the Kurrajong Road/Bosworth Street intersection.

Two additional improvements are proposed in Option H, based on modelling outcome from previous Options E/F. They are:

- A left turn slip lane out of Yarramundi Lane with an acceleration lane on Kurrajong Road (westbound direction).
- The eastbound merge kerb side lane is to be extended (east of Grose Vale Road intersection).

Table 5-11 shows traffic performance of option H against key criteria.

- In general Option H would improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peak.
- The model forecasts significant improvements in travel speeds (about 171%) for westbound traffic from 17 km/h (base case) to 46 km/h (option H). The improved traffic flows are triggered by the combined effect of a left turn slip lane out of Yarramundi Lane and an acceleration lane on Kurrajong Road.
- The model forecasts improvements in travel speeds (about 4%) for eastbound traffic from 48 km/h (base case) to 50 km/h (Option H).

- Unlike previous options, the extension of the eastbound merge (east of Grose Vale intersection) is forecast to improve Grose Vale Road traffic flows, particularly in the morning peak.
- In line with the predicted travel speed improvements for westbound traffic, Option H would improve (up to 31%) vehicle hours of travel (VHT) during the afternoon peak in the study area network. There will be no change in vehicle kilometres of travel (VKT) for Option H.
- The Option H improvement is unlikely to change traffic volumes and associated LoS at other adjacent intersections in the Richmond and Castlereagh Road areas. The model forecasts minor impacts to the adjacent intersection in North Richmond (see **Appendix D** for detailed traffic volumes and LoS).

In general, Option H is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Option H performs better than all other options tested.

Table 5-11 Option H Performance Assessment

ID	Traffic Criteria	Modelling Tool	Time Period	Measures		Change [%]	Relative Performance *
				Base Case ⁽¹⁾	Option H		
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	Paramics	AM	Avg Speed ⁽²⁾ :48 km/h	50 km/h	+4 % ▲	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	Paramics	PM	Avg Speed ⁽³⁾ :17 km/h	46 km/h	+171 % ▲	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	Paramics	AM	39,229	39,215	0 %	□
		Paramics	PM	64,826	64,798	0 %	□
4	Vehicle Hours Travelled, VHT – Study Area Network	Paramics	AM	906	895	-1 % ▼	■
		Paramics	PM	2,277	1,562	-31 % ▼	■
5	Ability to improve Grose Vale Road traffic flows ⁽⁴⁾	SIDRA	AM/PM	LoS F/LoS D	LoS D/LoS D	-	■
6	Ability to improve key intersections Level of Service at:						
	Bells Line of Road/Grose Vale Road (Signal) ⁽⁵⁾	SIDRA	AM/PM	LoS B/LoS D	LoS B/LoS B	-	■
	Kurrajong Road/Yarramundi Lane (Priority) ⁽⁶⁾⁽⁷⁾	SIDRA	AM/PM	LoS A/LoS B	LoS A/LoS B		■
	Kurrajong Road/Bosworth Street (Signal) ⁽⁸⁾	SIDRA	AM/PM	LoS B/LoS C	LoS C/LoS B	-	□
7	Impact on adjacent intersections ⁽⁹⁾						
	Area A-Richmond	SIDRA	AM/PM	LoS A to C	No Change	-	□
	Area B-Castlereagh Road	SIDRA	AM/PM	LoS A to B	No Change	-	□
	Area C-North Richmond	SIDRA	AM/PM	LoS A to C	Slightly Worse	-	■

Note: (1) Base case means existing traffic conditions in 2011; (2) Average Speed from Grose Vale Road to East Market Street (eastbound direction); (3) Average Speed from East Market Street to Grose Vale Road (westbound direction); (4) Level of Service (LoS) is reported for Grose Vale Road approach;(5) LoS is reported for Bells Line of Road east approach;(6) LoS is reported for Kurrajong Road west approach (7) The left turn slip lane out of Yarramundi Lane is expected to improve westbound traffic operation on Kurrajong Road particularly during PM peak. However, SIDRA model forecasts similar LoS for both Base Case and improved case (Option G). This is potentially a limitation of SIDRA. Paramics suggest improvement on Kurrajong Road traffic triggered by left turn slip lane out of Yarramundi Lane;(8) LoS is reported for Kurrajong Road west approach; (9) Impact on adjacent intersections:



*Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.3.9 BEST PERFORMING OPTION

This section summarises key results for each option in terms of the network performance indicators. Each option was assessed in terms of key traffic factors which are most likely to influence a decision on the best performing option. Previous Sections 5.3.1 to 5.3.8 documented traffic performance of eight (8) short term improvement options which have the potential to improve traffic flows on the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street. The short term improvements include a range of localised changes to the following three key intersections that favours major east west movement of traffic on the section of Bells Line of Road and Kurrajong Road:

- Kurrajong Road / Yarramundi Lane / Old Kurrajong Road.
- Bells Line of Road/Grose Vale Road.
- Kurrajong Road/ Bosworth Street.

The short term options include minor improvements to roads and intersections to maintain an acceptable level of traffic operation. These improvements include intersection widening, banning on street parking during peak periods thus creating clearway conditions during the peak periods and similar small works.

Table 5-12 summarises the network performance of eight short term improvement options.

Results and conclusions from the eight options testing are summarised below:

- Options A and B would not improve eastbound and westbound traffic flows between Grose Vale Road and East Market Street. The modelling analysis suggested that banning eastbound right turns on Kurrajong Road to Yarramundi Lane would adversely impact the operation of the Kurrajong Road/Bosworth Street intersection. The modelling outcome of Options A and B identifies the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection.
- The identified improvement (one eastbound exclusive right turn lane on Kurrajong Road) in Options A and B formed the basis of Option C. Option C performs relatively better than previous Options A and B. The modelling results from Option C have reaffirmed the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection. With this improvement in place, Option C would improve eastbound traffic flows between Grose Vale Road and East Market Street.
- Unlike Options A to C, Options D and E are developed with a view to improving westbound flows of this section of Bells Line of Road and Kurrajong Road. In general, both Options D and E would improve westbound traffic flows between Grose Vale Road and East Market Street in the afternoon peak. The proposed improvements at Bells Line of Road/Grose Vale Road intersection are forecast to improve Levels of Service for westbound traffic, particularly in the afternoon peak. To achieve efficient traffic flows in the westbound direction, the analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.
- Option F is developed with the view that intersection widening to the Kurrajong Road/Bosworth Street (as per Option C) may have timing implications due to the need for potential property acquisitions. In that context, intersection widening work may not be implemented in the immediate short term (0-5 years). In addition, the proposed eastbound right turn ban on Kurrajong Road to Yarramundi Lane may have potential accessibility issues for the local community. Instead, in Option F, an additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane is proposed. In general, Option F is forecast to improve both eastbound and westbound traffic flows

between Grose Vale Road and East Market Street in the morning and afternoon peaks. Minor improvements are forecast for westbound traffic. To achieve efficient traffic flows in the westbound direction, the Option F analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

- In general, Option G is a combination of previous Options C and E. Option G is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Option G performs better than the previous Options C and E alone. However, in Option G, the proposed eastbound right turn ban on Kurrajong Road to Yarramundi Lane may have potential accessibility issues for the local community. In addition, the provision of exclusive right turn bay on Kurrajong Road to Bosworth Street may have time implications due to the need for potential property acquisition.
- Option H is a further modification to previous Options E and F. The analysis found that Option H performed relatively better than other competing options for the following reasons:
 - Unlike previous Options (A, B, C, and G), Option H eliminates potential east bound right turn bans to Yarramundi Lane. Instead, improvements are proposed to the Kurrajong Road/Yarramundi Lane intersection that improves turning traffic performance in and out of Yarramundi Lane. This would also improve local accessibility to Yarramundi Lane.
 - Option H alone would improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks.
 - Compared to other competing options, Option H has addressed most of the key traffic criteria being used. Of the seven key criteria, Option H shows improvement in six criteria (see Table 5-12).
 - Option H would not alter the existing traffic patterns thus minimising the impact on other adjacent roads and intersections.
 - In general, improvements identified to Kurrajong Road / Yarramundi Lane / Old Kurrajong Road and Bells Line of Road/Grose Vale Road intersections in Option H are relatively easy to implement in the short term.

Option H has been identified as the preferred option and further analysed for future traffic conditions as stated in Section 5.4.

Table 5-12 Relative performance of upgrade options compared to base case

ID	Traffic Criteria	Time Period	Options considered							
			A	B	C	D	E	F	G	H
1	Ability to improve Bells Line of Road <u>eastbound</u> traffic flows	AM	■	■	■	□	□	■	■	■
2	Ability to improve Bells Line of Road <u>westbound</u> traffic flows	PM	□	■	□	■	■	■	■	■
3	Vehicle Kilometres Travelled, VKT – Study Area Network	AM	■	■	■	□	□	□	■	□
		PM	■	■	■	□	□	□	■	□
4	Vehicle Hours Travelled, VHT – Study Area Network	AM	■	■	■	□	■	■	■	■
		PM	■	■	■	■	■	■	■	■
5	Ability to improve Grose Vale Road traffic flows	AM/PM	□	□	□	□	□	□	■	■
6	Ability to improve key intersection Level of Service with:									
	Bells Line of Road/Grose Vale Road (Signal)	AM/PM	□	□	□	■	■	■	■	■
	Kurrajong Road/Yarramundi Lane (Priority)	AM/PM	■	■	■	□	□	■	■	■
	Kurrajong Road/Bosworth Street (Signal)	AM/PM	■	■	□	□	□	□	□	□
7	Impact on adjacent intersections									
	Area A-Richmond	AM/PM	□	□	□	□	□	□	□	□
	Area B-Castlereagh Road	AM/PM	■	■	■	□	□	□	■	□
	Area C-North Richmond	AM/PM	□	□	□	□	■	■	■	■

Relative performance compared to Base Case	
■	Improvement
■	Slight Improvement
□	No Change/Minor Change
■	Slightly Worse
■	Worse

5.4 FUTURE NETWORK PERFORMANCE

5.4.1 TRAFFIC GROWTH

Future traffic growth on the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street (the study area) will be influenced by the combination of passing (through) and local traffic growth. Future traffic growth in the study area was sourced from RMS's Sydney Strategic Model (which operates in Emme/2). RMS provided traffic forecasts at key roads for each time period up to 2016 and 2021. Both morning and afternoon peak hour traffic was assessed in the future years. Table 5-13 shows growth in peak hour traffic related to population and employment increases in the study area.

Table 5-13 Annual growth rates between 2011 and 2021 in the Richmond study area

Time Steps	Average annual growth rate
2011-2016 (5 years)	1.8 %
2011-2021 (10 years)	1.6 %

In the next 5 years (until 2016), peak hour traffic is forecast to grow by approximately 1.8% per annum. In the next 10 years (until 2021), the traffic model forecasts peak hour growth in the order of 1.6% per annum. The future growth in study area was in line with historical growth data observed on Richmond Bridge. Between 2008 and 2011, traffic growth on Richmond Bridge was approximately 1.6% per annum.

The future traffic growth up to 2021 is reported at eleven key locations in the study area. Detailed traffic forecasts on key roads are included in **Appendix D**. Table 5-14 shows the traffic forecast up to 2021 in Richmond Bridge and mid-block locations between the three key intersections.

In 2021, the model forecasts eastbound traffic volumes on the Richmond Bridge in the order of 1800 vehicles in the morning peak. In the afternoon peak westbound traffic on the Bridge is forecast to be in the order of 1600 vehicles. Similar traffic volumes are forecast on the approach road section of Bells Line of Road/Kurrajong Road between Grose Bells Road and Yarramundi Lane. The future traffic volume (2021) on Bridge and approach roads suggests the need for two through traffic lanes in the peak direction.

Table 5-14 Traffic forecast between 2011 and 2021 at key Locations

Mid-Block Section			Peak Hour Traffic Volumes		
			2011	2016	2021
Bells Line of Rd from Grose Vale Rd to Richmond Bridge	AM	EB	1,513	1,661	1,780
		WB	651	713	806
	PM	EB	874	979	1,044
		WB	1,305	1,458	1,585
Richmond Bridge	AM	EB	1,513	1,661	1,780
		WB	651	713	806
	PM	EB	874	979	1,044
		WB	1,305	1,458	1,585
Kurrajong Rd from Richmond Bridge to Yarramundi Lane	AM	EB	1,513	1,661	1,780
		WB	651	713	806
	PM	EB	874	979	1,044
		WB	1,305	1,458	1,585
Kurrajong Rd from Yarramundi Lane to Bosworth St	AM	EB	1,070	1,161	1,255
		WB	517	565	613
	PM	EB	709	765	822
		WB	858	964	1,040

Source: Hyder's future Paramics model. In Paramics, future demand was sourced from RMS Sydney Strategic Model (Emme/2). **Note:** Eastbound (EB), Westbound (WB).

5.4.2 FURTHER ANALYSIS OF OPTION H

In consultation with stakeholders, Option H was slightly modified and reassessed with a clearway condition on Kurrajong Road between Chapel Street and Bosworth Street. Traffic analysis suggested that the proposed clearway on Kurrajong Road would also improve performance of the Kurrajong Road/Bosworth Street intersection. The kerbside lane would provide additional capacity for through traffic during the peak period. Currently, eastbound right turn traffic shares one lane with through traffic. With clearway conditions in place, the model shows increased use of the kerbside lane for eastbound through traffic, leaving more available capacity for the right turning vehicles.

The improvements identified in Option H were assessed for future traffic conditions in 2016 and 2021. The growth data in the future Paramics model for Option H was assumed in line with the growth figure documented in previous Section 5-4.1. Consistent with previous assessments (see Section 3.4.2), future network operational issues for Option H were reassessed at three key intersections and Richmond Bridge. Key points to note:

- The 2016 model predicts satisfactory operation to the Kurrajong Road/Bosworth Street intersection. For western approach traffic, the level of service is predicted between C and

D during the peak hour. In 2021, the model predicts low level of service F for western approach traffic.

- The analysis suggests the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection after 2016. The proposed upgrade is forecast to provide a good level of service (A and B) to western approach traffic up to 2021.
- In the future, Grose Vale Road approach traffic is forecast with a low LoS F.

Table 5-15 shows future traffic performance of proposed improvements at relevant approach roads.

In general, the analysis found that the proposed improvements would maintain an acceptable level of service for key intersections and Richmond Bridge, over the short time period (0-10 years). Detailed future network performance of proposed improvements for 2016 and 2021 traffic conditions are included in **Appendix D**.

Table 5-15 Performance Assessment of Proposed Improvements at Key Intersections

Intersection	Approach	Time Period	Level of Service (LoS)			
			2011 Existing	Option H		Option H with exclusive right turn bay at Kurrajong Rd
				2016	2021	2021
Kurrajong Road/Bosworth Street (traffic light)	Kurrajong Road western approach	AM	LoS B	LoS C	LoS C	LoS A
		PM	LoS C	LoS D	LoS F	LoS B
Grose Vale Rd/Bells Line of Road (traffic light)	Grose Vale Road approach	AM	LoS F	LoS F	LoS F	LoS F
		PM	LoS D	LoS D	LoS E	LoS E
	Bells Line of Road eastern approach	AM	LoS B	LoS C	LoS D	LoS D
		PM	LoS D	LoS C	LoS C	LoS C
Kurrajong Road/Yarramundi Lane (sign control)	Kurrajong Road western approach	AM	LoS B	LoS A	LoS A	LoS A
	Kurrajong Road eastern approach	PM	LoS F	LoS A	LoS A	LoS A

Source: Existing 2011 LoS results are obtained from SIDRA model except Kurrajong Road/Yarramundi Lane. For Kurrajong Road/Yarramundi Lane intersection 2011 LoS was obtained from Paramics taking into account upstream and downstream queues. Future 2016 & 2021 LoS results are obtained from Paramics models.

5.4.3 RECOMMENDED OPTION

The proposed staging of the recommended Option is summarised in Table 5-16 and graphically shown in Figure 5-9. The strategic concept sketches prepared by RMS for the proposed intersection improvements are included in **Appendix A**.

Table 5-16 Proposed staging of recommended Option

Time Frame	Upgrade location	Recommended Upgrade
0-5 years Up to 2016	Bells Line of Road/Grose Vale Road	<p>Proposed upgrade as per Option H;</p> <ul style="list-style-type: none"> ▪ Provide a westbound shared through/left turn lane on Bells Line of Road, east of Grose Vale Road replacing the existing left turn lane. ▪ Provide an additional westbound short through lane on Bells Line of Road, west of Grose Vale Road. ▪ Ban on-street parking during peak periods between Pitt Lane and Grose Vale Road. ▪ Implement an eastbound right turn ban from Bells Line of Road into Grose Vale Road. ▪ Conversion of the existing eastbound right-turn bay to a second westbound through lane. ▪ Eastbound merge be extended (east of Grose Vale Road intersection).
	Kurrajong Road/Yarramundi Lane/Old Kurrajong Road	<p>Proposed upgrade as per Option H;</p> <ul style="list-style-type: none"> ▪ An additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane. ▪ Provide a left turn slip lane out of Yarramundi Lane with an acceleration lane on Kurrajong Road (westbound direction).
	Kurrajong Road	<ul style="list-style-type: none"> ▪ Provide a clearway condition between Chapel Street and Bosworth Street during the peak period.
5-10 years 2016-2021	Kurrajong Rd / Bosworth Street	<ul style="list-style-type: none"> ▪ Widening of the intersection. Provide an exclusive eastbound right turn bay at Kurrajong Road/Bosworth Street intersection; ▪ Possible right turn ban from March Street to Bosworth Street (north).

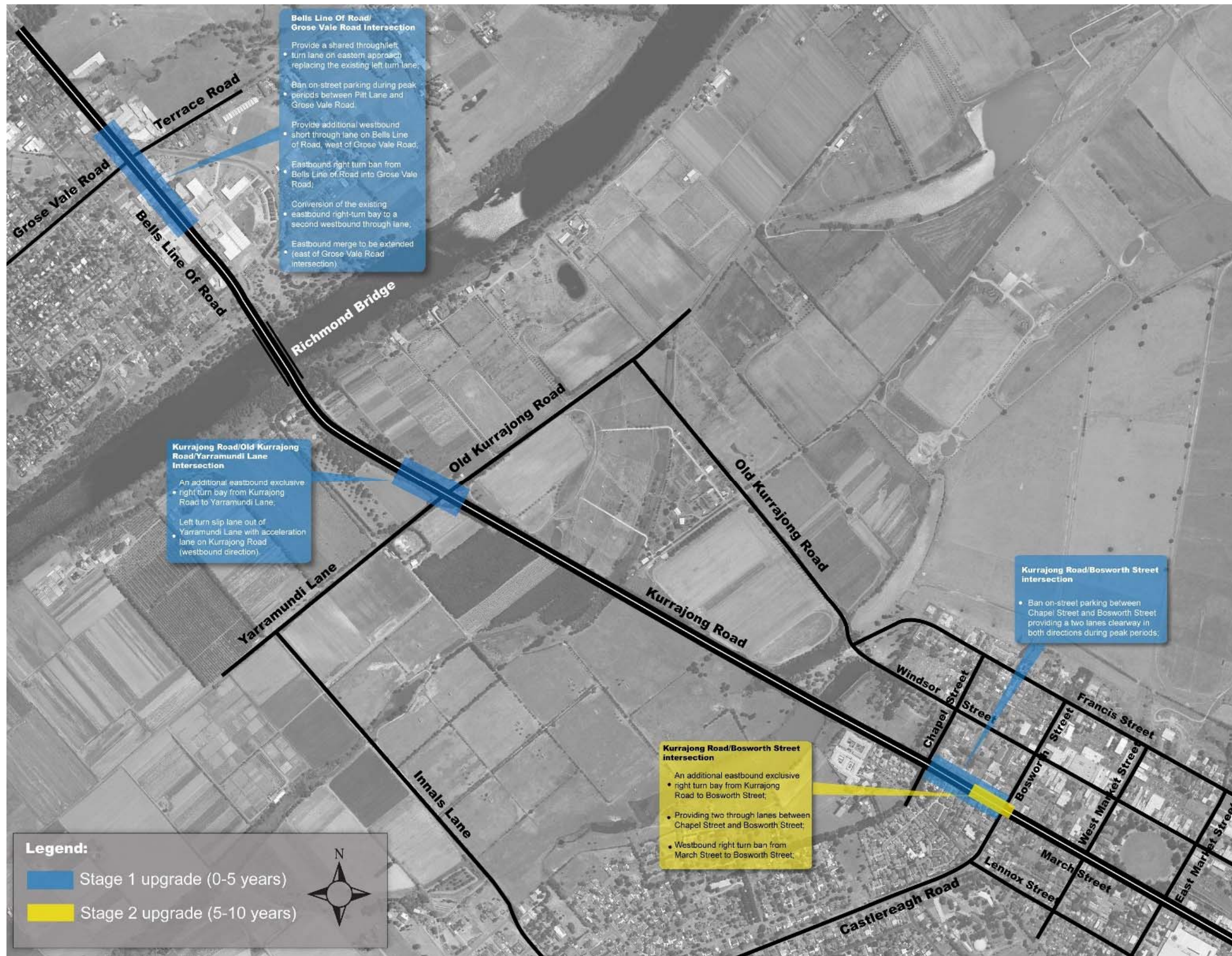


Figure 5-9 Proposed staging of the recommended Option

5.4.4 POSSIBLE TIDAL FLOW SCHEME ON RICHMOND BRIDGE

In 2011, Richmond Bridge carried about 27,000 vehicles per day as stated in Section 3.3.2 of this report. During the morning and afternoon peak hour the Bridge carries about 1,400 to 1,500 vehicles per direction (either eastbound or westbound). The existing traffic profile on the Bridge suggests a typical tidal flow pattern, with a heavy eastbound flow in the morning (about 1,500 vehicles in one hour). A significantly low volume is observed in the westbound direction (about 700 vehicles in one hour) in the morning peak.

In 2021, the model forecasts an eastbound traffic volume on Richmond Bridge in the order of 1,800 vehicles in the morning peak. Similar traffic volumes are forecast on the approach road section of Bells Line of Road/Kurrajong Road between Grose Vale Road and Yarramundi Lane. The future traffic volume (2021) on the bridge and approach roads suggests the need for two through traffic lanes in the peak direction, hence a tidal flow scheme could be considered.

The possible tidal flow system on Richmond Bridge may provide some complexities and challenges for traffic management particularly regarding right and left turn movements and turn bays on the section of Bells Line of Road between Grose Vale Road and the Bridge. The tidal flow system may not be effective in improving traffic flows if future traffic on the Bridge in both directions leads to a balanced flow due to unexpected land use changes in the Richmond and North Richmond areas.

RMS has commenced the investigation of a strategic concept options study for Richmond Bridge and Approaches. It is recommended possible further investigation of tidal flow scheme be undertaken as part of that study to select the best option that provides best value for money.

6 SUMMARY AND RECOMMENDATIONS

6.1 KEY FINDINGS

6.1.1 OVERVIEW

The Bells Line of Road provides an important link between the Sydney Basin and the Central West Region of New South Wales. It provides a supplementary east-west regional link supporting the Great Western Highway in carrying commuter traffic, and acts as an alternative route. The eastern end of the Bells Line of Road corridor provides access to Richmond and the rapidly growing North-West Growth Sector of Sydney. This section of the route includes Richmond Bridge which is the only Hawkesbury River crossing serving the entire residential catchment of North Richmond, Kurrajong, Bilpin, Bell and beyond. During the morning and afternoon peak hours this section of Bells Line of Road experiences considerable levels of traffic congestion. Traffic congestion is experienced on the two lane Richmond Bridge (one lane each direction) and adjoining approach roads between North Richmond and Richmond.

The purpose of Hyder's study is to assess the performance of Richmond Bridge and section of Bells Line of Road/ Kurrajong Road between Grose Vale Road and East Market Street (the study area). A road based micro-simulation traffic model was developed for the study area. For the micro-simulation model, Hyder used *Paramics* software. For assessing individual intersection capacity, Hyder used *SIDRA* software.

Both *Paramics* and *SIDRA* models provided an assessment tool to identify:

- Key network issues that affect the performance of Richmond Bridge and adjoining approach roads.
- Short term options for improvements to traffic flow. Each option was assessed in terms of key traffic factors which are most likely to influence the decisions on the best performing option.

A consultation process involving RMS and key stakeholders constituted an important element of this study. Three stakeholder workshops were undertaken over the course of this project. The stakeholder group was made up of representatives from following organisations:

- Roads and Maritime Services (RMS);
- Transport for NSW; and
- Hawkesbury City Council.

6.1.2 KEY ISSUES

The analysis was based on new traffic data collected between June and August 2011. In 2011, Richmond Bridge carried approximately 26,200 vehicles per day. This included approximately 1500 heavy vehicles (more than 5% of the total traffic). Peak hour traffic volumes on Richmond Bridge were in the order of 1400 to 1500 vehicles per direction. The traffic analysis suggests that Richmond Bridge is close to saturation traffic levels.

During the morning and afternoon peak period, some turning movements at adjoining key intersections with Bells Line of Road/Kurrajong Road also adversely impact the operation of the Richmond Bridge. The traffic modelling has identified network operational issues at the following three key intersections:

1. Bells Line of Road/Grose Vale Road (traffic light controlled).

2. Kurrajong Road / Yarramundi Lane / Old Kurrajong Road (sign control).
3. Kurrajong Road/ Bosworth Street (traffic light controlled).

6.1.3 OPTIONS CONSIDERED

Three technical workshops were conducted with RMS and key stakeholders. Based on modelling investigations, Hyder has identified some ten preliminary short term improvement options. In consultation with stakeholders, eight options have been shortlisted for detailed assessment. These are referred to as Options A to H. The eight options were assessed under 2011 traffic conditions for both morning and afternoon peak periods.

Section 5.3 in this report documented the traffic performance of eight short term improvement options which have the potential to improve traffic flows on the section of Bells Line of Road and Kurrajong Road between Grose Vale Road and East Market Street. Each option was assessed in terms of the key traffic factors which are most likely to influence a decision on the best performing option. The short term options included minor improvements to the road and intersections to maintain an acceptable level of traffic operation. These improvements included intersection widening and banning on-street parking during peak periods, thus imposing clearway conditions during peak periods. The proposed improvements at the three key intersections would favour the major east-west movement of traffic on this section of Bells Line of Road and Kurrajong Road.

Quantitative measures were identified as being available to assist in the assessment of the performance of each option as described in Table 5-2 of this report.

6.1.4 OPTIONS RESULTS

Results and conclusions from eight options testing are summarised below:

- Options A and B would not improve eastbound and westbound traffic flows between Grose Vale Road and East Market Street. The modelling analysis suggested that banning eastbound right turns on Kurrajong Road to Yarramundi Lane would adversely impact the operation of the Kurrajong Road/Bosworth Street intersection. The modelling outcome of Options A and B identifies the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection.
- The identified improvement (one eastbound exclusive right turn lane on Kurrajong Road) in Options A and B formed the basis of Option C. Option C performs relatively better than previous Options A and B. The modelling results from Option C have reaffirmed the need for an additional eastbound exclusive right turn lane on Kurrajong Road at the Kurrajong Road/Bosworth Street intersection. With this improvement in place, Option C would improve eastbound traffic flows between Grose Vale Road and East Market Street.
- Unlike Options A to C, Options D and E are developed with a view to improving westbound flows of this section of Bells Line of Road and Kurrajong Road. In general, both Options D and E would improve westbound traffic flows between Grose Vale Road and East Market Street in the afternoon peak. The proposed improvements at Bells Line of Road/Grose Vale Road intersection are forecast to improve Levels of Service for westbound traffic, particularly in the afternoon peak. To achieve efficient traffic flows in the westbound direction, the analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.
- Option F is developed with the view that intersection widening to the Kurrajong Road/Bosworth Street (as per Option C) may have timing implications due to the need for potential property acquisitions. In that context, intersection widening work may not be

implemented in the immediate short term (0-5 years). In addition, the proposed eastbound right turn ban on Kurrajong Road to Yarramundi Lane may have potential accessibility issues for the local community. Instead, in Option F, an additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane is proposed. In general, Option F is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Minor improvements are forecast for westbound traffic. To achieve efficient traffic flows in the westbound direction, the Option F analysis identifies the need for an additional left turn slip lane from Yarramundi Lane to Kurrajong Road.

- In general, Option G is a combination of previous Options C and E. Option G is forecast to improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks. Option G performs better than the previous Options C and E alone. However, in Option G, the proposed eastbound right turn ban on Kurrajong Road to Yarramundi Lane may have potential accessibility issues for the local community. In addition, the provision of exclusive right turn bay on Kurrajong Road to Bosworth Street may have time implications due to the need for potential property acquisition.
- Option H is a further modification to previous Options E and F. The analysis found that Option H performed relatively better than other competing options for the following reasons:
 - Unlike previous Options (A, B, C, and G), Option H eliminates potential east bound right turn bans to Yarramundi Lane. Instead, improvements are proposed to the Kurrajong Road/Yarramundi Lane intersection that improves turning traffic performance in and out of Yarramundi Lane. This would also improve local accessibility to Yarramundi Lane.
 - Option H alone would improve both eastbound and westbound traffic flows between Grose Vale Road and East Market Street in the morning and afternoon peaks.
 - Compared to other competing options, Option H has addressed most of the key traffic criteria being used. Of the seven key criteria, Option H shows improvement in six criteria (see Table 5-12).
 - Option H would not alter the existing traffic patterns thus minimising the impact on other adjacent roads and intersections.
 - In general, improvements identified to Kurrajong Road / Yarramundi Lane / Old Kurrajong Road and Bells Line of Road/Grose Vale Road intersections in Option H are relatively easy to implement in the short term.

Option H has been identified as the preferred option and was further assessed for future traffic conditions in 2016 and 2021. The analysis suggests the need for additional eastbound exclusive right turn lane on Kurrajong Road at Kurrajong Road/Bosworth Street intersection after 2016.

6.2 RECOMMENDATIONS

The proposed improvements as outlined below and graphically shown in Figure 5.9 can be delivered in two stages. These improvements would maintain an acceptable level of service to key intersections including the Richmond Bridge over the short time period (up to 10 years).

Time Frame	Upgrade location	Recommended Upgrade
0-5 years Upto 2016	Bells Line of Road/Grose Vale Road	<p>Proposed upgrade as per Option H;</p> <ul style="list-style-type: none"> ▪ Provide a westbound shared through/left turn lane on Bells Line of Road, east of Grose Vale Road replacing the existing left turn lane. ▪ Provide an additional westbound short through lane on Bells Line of Road, west of Grose Vale Road. ▪ Ban on-street parking during peak periods between Pitt Lane and Grose Vale Road. ▪ Implement an eastbound right turn ban from Bells Line of Road into Grose Vale Road. <ul style="list-style-type: none"> • Conversion of the existing eastbound right-turn bay to a second westbound through lane. • Eastbound merge be extended (east of Grose Vale Road intersection).
	Kurrajong Road / Yarramundi Lane / Old Kurrajong Road	<p>Proposed upgrade as per Option H;</p> <ul style="list-style-type: none"> ▪ An additional eastbound exclusive right turn bay from Kurrajong Road to Yarramundi Lane. ▪ Provide a left turn slip lane out of Yarramundi Lane with acceleration lane on Kurrajong Road (westbound direction).
	Kurrajong Road	<ul style="list-style-type: none"> ▪ Provide a clearway condition between Chapel Street and Bosworth Street during the peak period.
5-10 years 2016-2021	Kurrajong Rd / Bosworth Street	<ul style="list-style-type: none"> ▪ Widening of the intersection. Provide an exclusive eastbound right turn bay at Kurrajong Road/Bosworth Street intersection; ▪ Possible right turn ban from March Street to Bosworth Street (north).

The traffic profile on this section of the road including the bridge suggests a typical tidal flow pattern. The traffic flow on Richmond Bridge is close to saturation level. The future traffic volume (2021) on the bridge and approach roads suggests the need for two through traffic lanes in the peak direction, hence a tidal flow scheme could be considered.

RMS has commenced the investigation of a strategic concept options study for Richmond Bridge and Approaches. It is recommended that as part of that study, a tidal flow scheme be further investigated to select the option that provides value for money.