Appendix C

Traffic and Transport Assessment


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MEMORIAL AVENUE UPGRADE

Traffic and Transport Assessment

Roads and Maritime Services (RMS)

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Report No AA0025-AA006569-R-01

Date 30th June 2014

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Appendices

Revisions

Revision	Date	Description	Prepared by	Approved by
A	30 June 2014	Draft Report for Client's Review	MR & KN	MR
B	2 July 2014	Draft Final addressing RMS comments	MR & KN	MR
C	20 August 2014	Draft Report addressing RMS comments	KN	
D	3 October 2014	Draft Report incorporating Technical Note 7	SM	

1 INTRODUCTION

1.1 Study purpose

The following document is a Traffic and Transport Assessment (hereafter referred to as 'the Study') of the Concept Design of Memorial Avenue upgrade from Old Windsor Road to Windsor Road at Kellyville ('the study area').

Roads and Maritime Services NSW (RMS) proposes to upgrade Memorial Avenue between Old Windsor Road and Windsor Road, a total of 2.2 kilometres in length. The proposed upgrade involves widening and upgrading of Memorial Avenue from its current two lane road to a four lane divided road within a mostly 40 metre wide road reservation, upgrade of signalised intersections with Old Windsor Road, Windsor Road, and the bus T-Way, and new signalised intersections with Arnold Avenue/Free Settlers Drive and Severn Vale Drive.

RMS commissioned Hyder Consulting (Hyder) to prepare a Concept Design and Review of Environmental Factors (REF) for the proposed upgrade. In the course of preparing this report relevant documents associated with the proposal have been reviewed, and potential traffic impacts on the road network have been assessed. The Study provides recommendations to RMS on potential upgrading works at roads and key intersections required to maximise the performance of the upgrade from a traffic point of view.

A consultation process involving RMS constituted an important element of the Study. This included presentation of traffic modelling outcomes to RMS, a value management workshop, and participation in design meetings. During the course of the Study, five technical notes were submitted to RMS with respect to development of the traffic modelling. Feedback from RMS staff was incorporated in the Study development and outcomes at various stages of Hyder's investigation.

This Traffic and Transport Assessment Report has been prepared to support the Review of Environment Factors (REF) submission for the proposed upgrade.

1.2 Road network

Memorial Avenue is a key strategic route and provides access to Blacktown, Glenwood, Stanhope Gardens, Parklea, Baulkham Hills, Castle Hill and Kellyville. The road provides an east-west connection between Old Windsor Road and Windsor Road. It is located in the suburb of Kellyville within The Hills Shire Council LGA. Memorial Avenue is currently (2014) a two-lane, two-way road and carries about 25,000 vehicles per day.

Figure 1-1 below shows the traffic modelling study area.

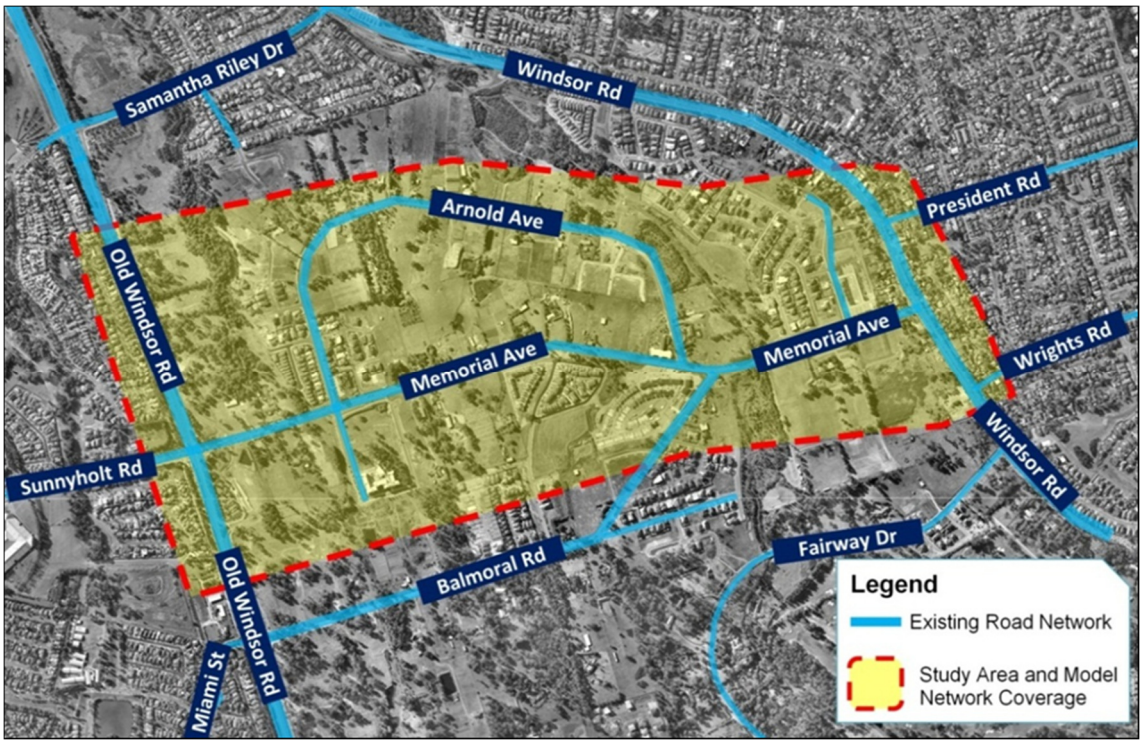


Figure 1-1 Traffic Modelling Study Area

1.3 Study scope and objectives

The scope of the Study is to assess the performance of proposed Memorial Avenue upgrades from a traffic and transport point of view. Traffic modelling results were used to assess the upgrades proposed in the Concept Design. A road based micro-simulation traffic model was developed for the study area using Paramics software. Hyder supplemented this assessment with SIDRA models to assess the performance of individual intersections.

Key objectives of the traffic modelling assessment were to:

- Identify key network issues that affect the performance of Memorial Avenue and adjoining roads;
- Determine level of service of the proposed upgrades taking into account expected traffic growth for 2019, 2026 and 2036;
- Identify interim and long term options for improvements to traffic flow on Memorial Avenue and associated intersections. This included an assessment of at-grade and grade separated solutions based on traffic modelling outcomes;
- Identify the timing of interim and long term intersection upgrades required at Memorial Avenue/Old Windsor Road and Memorial Avenue/Windsor Road intersections; and
- Prepare a Traffic and Transport Assessment Report to inform the Review of Environment Factors (REF) submission for the proposal.

1.4 Concept Design

The Concept Design for the proposal includes the following key features:

- An upgrade from a two lane to a four lane divided road with a central median;
- A posted vehicle speed limit of 70km/h;
- A wide central median to allow for future widening to six lanes, when required in the future;
- Provision for landscaping in the median;
- Shared pedestrian/cyclist paths on both sides of Memorial Avenue;
- Bus priority capability at traffic lights and indented bus bays on both sides of Memorial Avenue; and
- Designated left and right turning lanes at signalised intersections.

1.5 Study approach

Hyder developed a comprehensive study approach specifically to achieve key study objectives. It involved a 2014 traffic survey, traffic data analysis, undertaking analysis based on wide-area strategic traffic modelling data provided from EMME, development of a micro-simulation model using Paramics software, calibration and validation of the Paramics model, identification of network operational issues, and assessment of upgrade proposal from traffic and transport grounds.

An extensive and collaborative consultation process involving RMS constituted an important element of the Study. This included presentation of traffic modelling outcomes to RMS, a value management workshop, and participation in design meetings. During the course of the study, five technical notes were submitted to RMS as follows:

- Technical Note 1 - Traffic Survey Requirements;
- Technical Note 2 - Traffic Modelling Assumptions;
- Technical Note 3 - Balmoral Road Release Area (BRRA) Land Development Assumptions in the EMME Model;
- Technical Note 4 - Paramics Model Development, Calibration & Validation Report; and
- Technical Note 5 - Traffic Performance of New Traffic Signals at Memorial Avenue/ Arnold Avenue and Memorial Avenue/Severn Vale Drive.

Feedback from RMS staff was incorporated into the traffic and transport study findings at various stages of Hyder's investigation.

Key steps in Hyder's modelling approach included the following:

1. **Traffic data, surveys and analysis**. A new traffic survey was conducted in February 2014. This provided key input to base case model development, calibration and validation. Five types of data were collected: intersection turning movement counts, midblock traffic counts, queue length, origin-destination (OD) survey, and travel time survey.
2. **Base case model development, calibration and validation.** The existing base case Paramics model was developed using the February 2014 counts. The base model calibration and validation was undertaken as per the RMS guide.
3. **Existing network performance assessment.** Existing levels of service of key intersections were assessed for both morning (AM) and afternoon (PM) peak traffic conditions.

4 **Future population and employment forecasts for Balmoral Road Release Area (BRRA).** The following data inputs were used in RMS's EMME traffic model:

- The Hills Shire Council's population and employment projections for the BRRA; and
- Population and employment forecast data at travel zone based on Bureau of Transport Statistics (BTS) land use and growth assumptions.

  RMS's EMME model was updated taking into accounts both Council's land use projections and BTS's forecast.

5 **Future base case models development.** In agreement with RMS, future Paramics models were developed for 2019, 2026 and 2036 for AM and PM peak periods. Future year demand trip tables used in Paramics were based on RMS's EMME model.

6 **Assess future traffic performance of proposed upgrades.** This included modelling assessment of the following:

- A four lane Memorial Avenue upgrade as per Concept Design;
- Two new signalised intersections on Memorial Avenue at Arnold Avenue/Free Settlers Drive and Seven Vale Drive; and
- Interim and longer term capacity improvements at the existing Old Windsor Road/Memorial Avenue/Sunnyholt Road and Windsor Road/Memorial Avenue signalised intersections.

1.6 Reference traffic data and modelling

For the purpose of the Study, modelling data were sourced from RMS's Sydney Strategic Model (which operates in EMME software). Hyder used appropriate traffic data from RMS's EMME model relevant to the study area.

In consultation with RMS, a new traffic survey was undertaken to satisfy the need and purpose of the traffic modelling. This included intersection classified turning movement counts (car and heavy vehicle), midblock traffic counts, queue length surveys, travel time surveys and origin-destination (OD) survey. The new traffic survey was undertaken by Skyhigh in February 2014.

To assess network performance, Hyder used Paramics micro simulation modelling software. To assess intersection performance, Hyder used SIDRA modelling software.

1.7 Report structure

The remainder of this report is structured as follows:

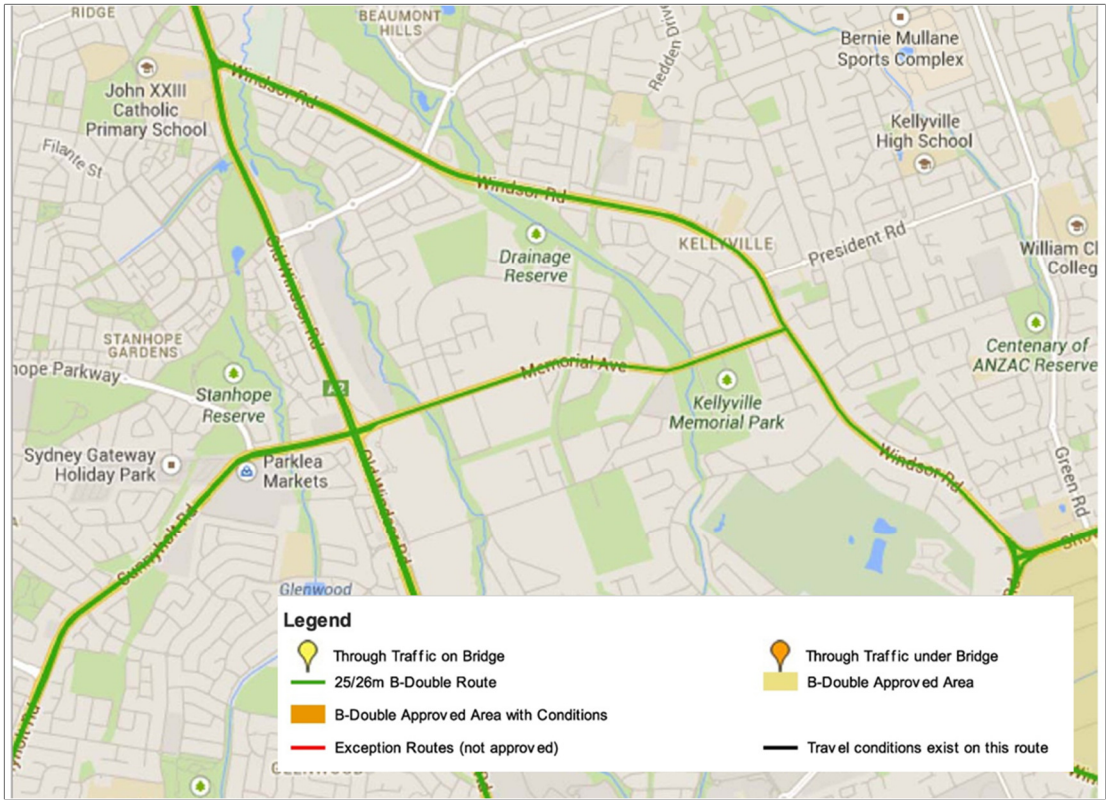
- **Chapter 2** - Existing Traffic and Transport Conditions – Provides the context of existing traffic conditions within the Memorial Avenue Upgrade study area.
- **Chapter 3** - Existing Road Network Performance – Establishes the existing network performance within the study area. Results from traffic surveys are summarised in this section.
- **Chapter 4** - Future Network Performance – Provides an overview of forecast traffic volumes on Memorial Avenue. It also provides detailed modelling results of scenarios tested for upgrade proposal.
- **Chapter 5** - Summary of Findings – provides a summary of key traffic and transportation findings from the Study.

2 EXISTING TRAFFIC AND TRANSPORT CONDITIONS

Existing traffic and transport conditions in the study area are described within this chapter. It provides the regional and local transport context within which the assessment has been undertaken.

2.1 Route and speed environment

Memorial Avenue is a key strategic route and provides access to Blacktown, Glenwood, Stanhope Gardens, Parklea, Baulkham Hills, Castle Hill and Kellyville. The road provides an east-west connection between Old Windsor Road and Windsor Road. It is located in the suburb of Kellyville within The Hills Shire Council LGA. Memorial Avenue is currently a two-lane two-way road and carries about 25,000 vehicles per day (2014). It is designated B-Double route. Figure 2-1 shows designated B-Double routes in the study area sourced from RMS. Other key local roads in the study include Arnold Avenue and Hector Court.



Source: RMS Restricted Access Vehicle Map NSW (map as of 6 June 2014)

Figure 2-1 Designated B-Double Routes in the Study Area

The posted speed limit on Memorial Avenue is currently 70km/h between Old Windsor Road and Arnold Avenue, and 60km/h between Arnold Avenue and Windsor Road. Near the study area, a 60km/h posted speed limit applies to Windsor Road and an 80km/h posted speed limit applies to Old Windsor Road. Posted speed limits in the vicinity of the study area are shown in Figure 2-2.

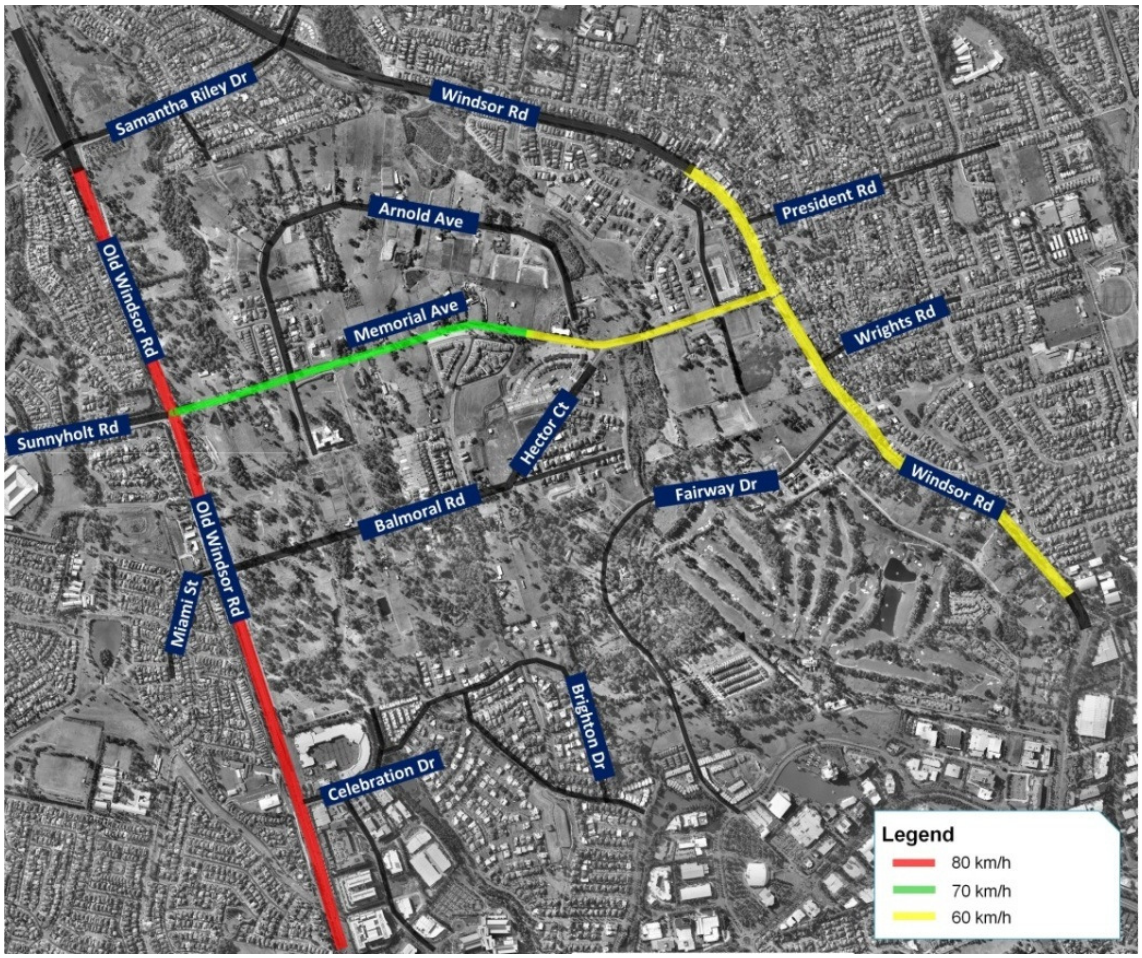
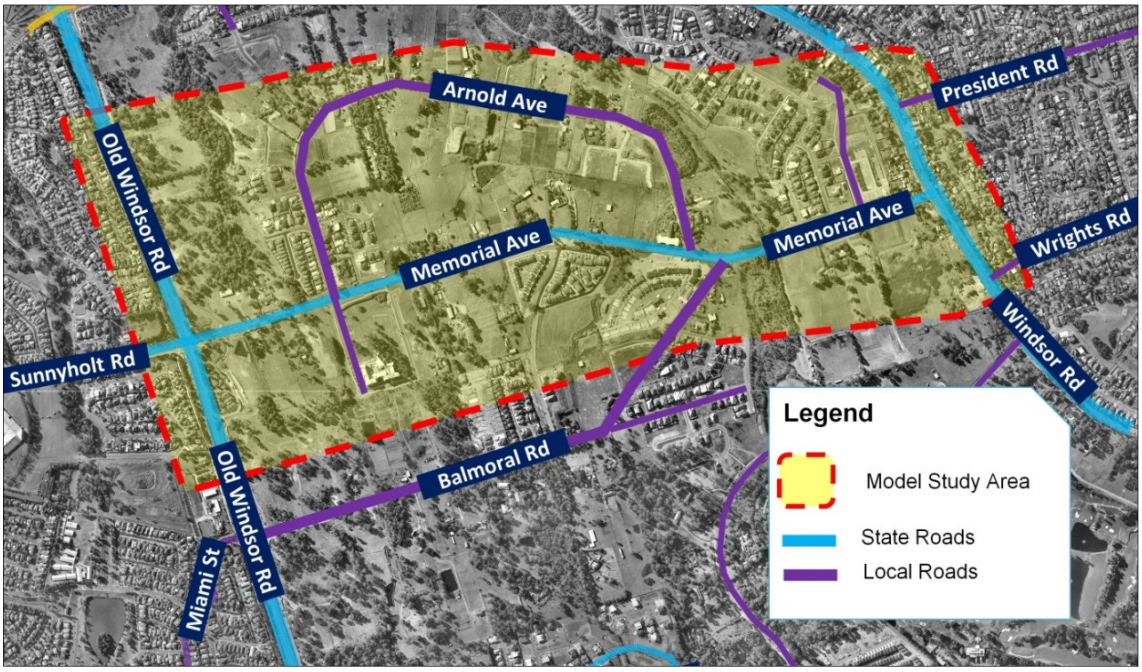


Figure 2-2 Posted Speed Limits in the Study Area

2.2 Road hierarchy

Within the study area, Memorial Avenue, Old Windsor Road and Windsor Road are State Roads. Arnold Avenue and Balmoral Road are local roads. The road hierarchy is shown in Figure 2-3.



Source: RMS (RTA) classified roads map Greater Sydney area 2011

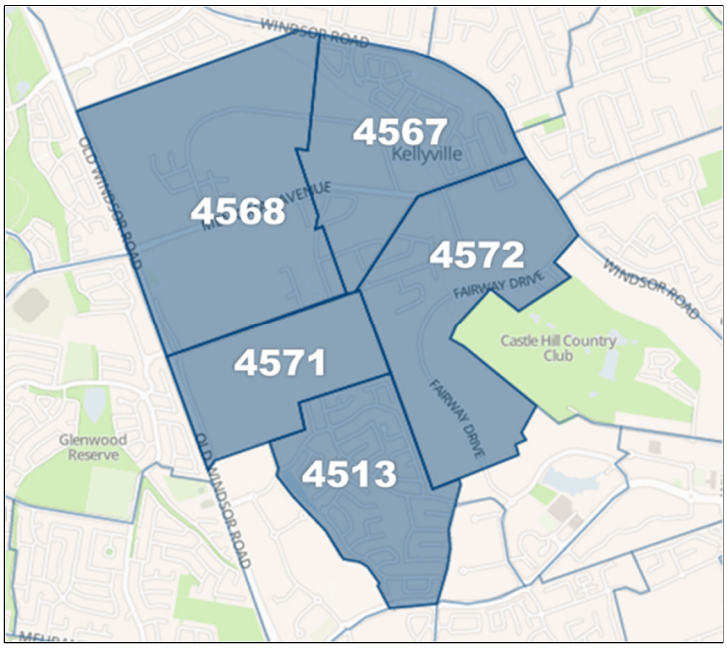
Figure 2-3 Road hierarchy in the study area

2.3 Commuter mode share

The Bureau of Transport Statistics (BTS) provides journey to work data (JTW) for the Sydney Greater Metropolitan Area (GMA) which comprises of a comprehensive sample of commuter travel, collected during the 2011 Census. Work trip origin and destinations are coded to the 2011 travel zones (see Figure 2-4). Table 2-1 summarises the work trips by mode of travel reported for the study area.

In 2011, about 569 residents *travelled from the Memorial Avenue study area to work*. About 13 per cent of people did not travel to work or worked from home on the census day. The Census data showed that around 72 per cent of work trips from the study area were made by motorists in a private vehicle, with 5 per cent of those as car passengers. Approximately 13 per cent of workers travelled by public transport, and 1 per cent walked. Of the 13 per cent public transport users, only 8 per cent trips were made by bus, with the remaining 5 per cent trips were made by train.

Similarly, in 2011 about 432 employees *travelled to the Memorial Avenue study area to work*. From the inbound trip statistics, it can be seen that private vehicles are still by far the dominant mode of transport to work, being about 79 per cent. About 3 per cent of employees travelled by public transport and 1 per cent walked. The percentage of people who did not go to work or worked from home increased to 16 per cent when comparing to outbound trips.



Source: Bureau of Transport Statistics

Figure 2-4 Travel zones in the study area

Table 2-1 Commuter Mode Share, Memorial Avenue Study Area (2011 JTW)

Travel Mode	Outbound trips from study area	% Outbound trips	Inbound trips to study area	% Inbound trips
Car Driver	380	67%	323	75%
Car Passenger	31	5%	18	4%
Train	27	5%	5	1%
Bus	45	8%	8	2%
Walked only	6	1%	4	1%
Other	5	1%	3	1%
Worked at home/ Did not travel/ Not stated	74	13%	70	16%
Total	**569**	**100%**	**432**	**100%**
Selected travel zones (TZ11): 4568,4567,4572,4571,4513 2006 TZ Travel zones: 2715, 2718, 2808				
Data source: 2011 Journey to Work Data				

2.4 Travel patterns

Significant proportions of morning (AM) and afternoon (PM) peak trips to and from the study area are within the local region (The Hills Shire Council LGA) and have an origin or destination in the surrounding LGA's including Blacktown and Parramatta. Analysis of travel patterns from the journey to work (JTW) data indicated that approximately 41% of study area's workers live and work within The Hills Shire Council LGA. From outside The Hills Shire Council LGA, inbound work trips are generally coming to the study area from Blacktown and Rouse Hill which accounts for some 24% of total trips.

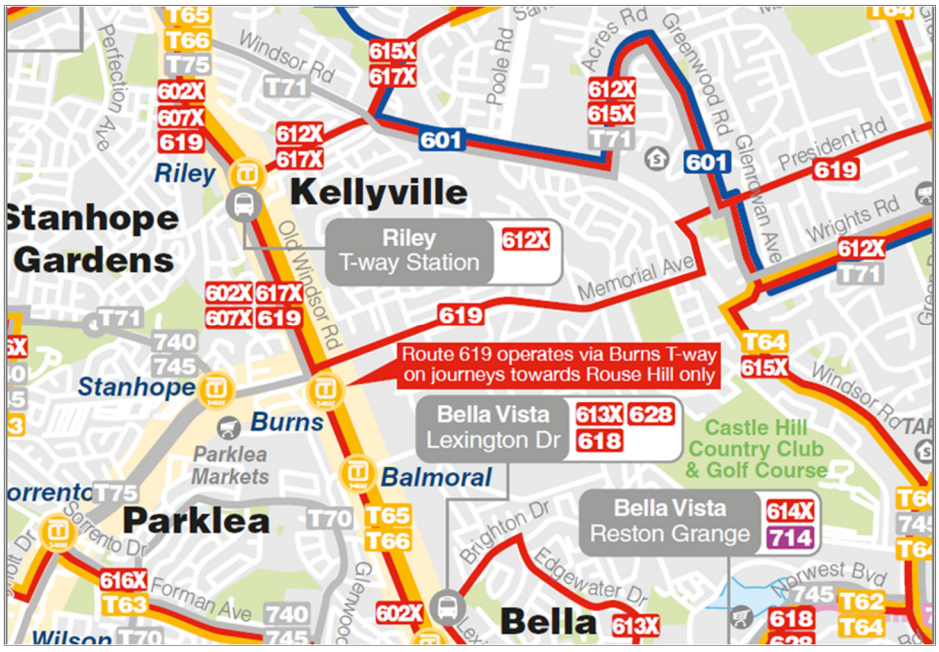
The JTW data indicated about 73% of the study area's residents travelled outside of The Hills Shire Council LGA for work purposes. Of those, about 11% had Central Sydney as a destination. Some 10% of outbound trips had Parramatta as a destination.

2.5 Public transport

The study area is primarily serviced by Hills Buses. Route 619 runs along Memorial Avenue, providing services between Rouse Hill and Macquarie Park. A number of the Hills Bus routes travel along Old Windsor Road, Sunnyholt Road and Windsor Road.

Figure 2-5 shows the existing bus network. Most of the services passing through the study area traverse Old Windsor Road and Windsor Road, and disperse to destinations to the north and south. To the north bus services terminate at Rouse Hill (Routes 607x, 617x, 602x, 612x, 619, T64, T65 and T66) and Riverstone (Route T75). To the south services terminate at Parramatta (Routes T64, T65 and T66). To the east services terminate at Macquarie Park (619) and North Sydney (Route 602x). To the west services terminate at Blacktown (Route T75). Important intermediate locations served by these bus services include Burns Station, located at the corner of Old Windsor Road and Memorial Avenue.

The study area has no direct rail service. The nearest railway station is Blacktown about 10 km from the study area. There is no direct bus service that connects the study area and Blacktown rail station.



Source: Hills District Bus Guide (network map dated of 28 January 2014)

Figure 2-5 Bus services in the study area

2.6 Walking and cycling

There is currently no dedicated footpath along Memorial Avenue. Pedestrian crossing facilities are available at intersections with Old Windsor Road and Windsor Road.

An on-road cycle way is currently provided within the road shoulder on Memorial Avenue. A designated off street cycle way is provided on Old Windsor Road. Figure 2-6 shows the different types of cycle routes in the study area.

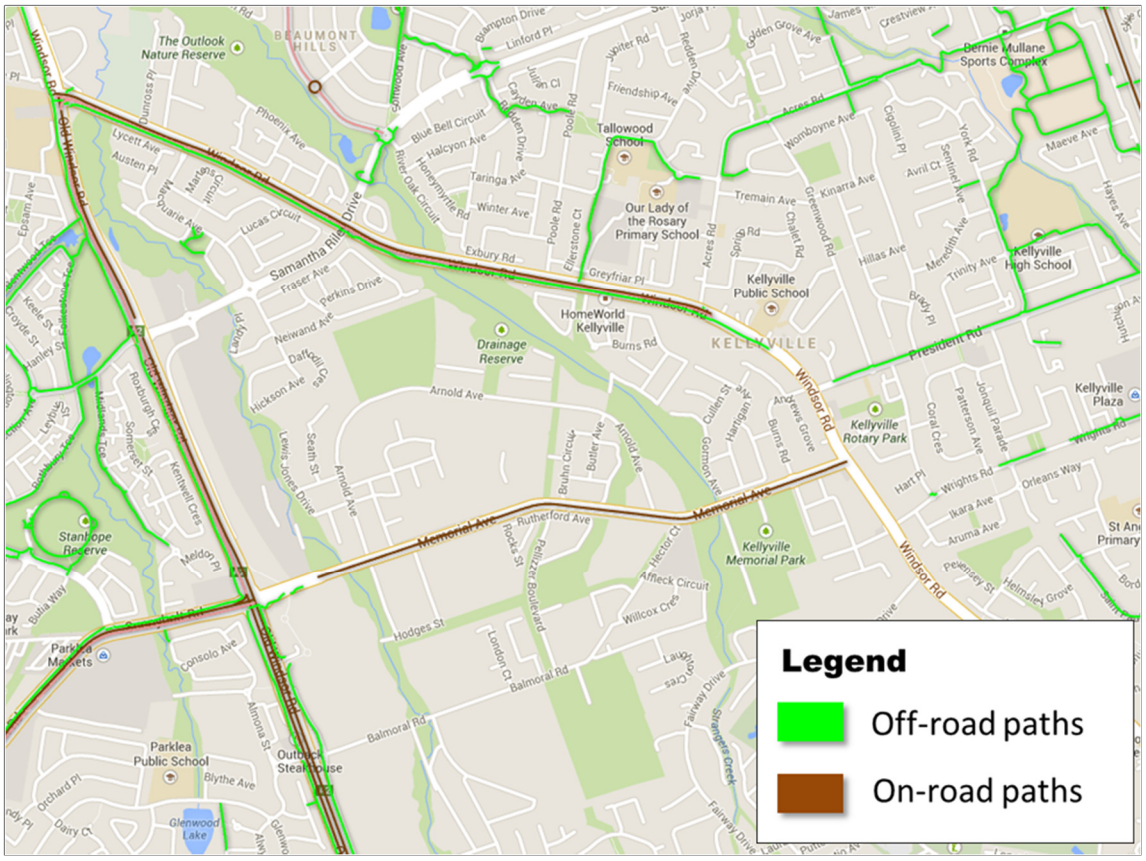


Figure 2-6 Existing Cycleway in the Study Area

Heavy vehicles

Table 2-2 shows the daily number of heavy vehicles recorded during the 2014 traffic survey. Heavy vehicles were counted on Memorial Avenue at Strangers Creek and at Elizabeth Macarthur Creek. The existing number of heavy vehicles in the study area ranges from 1300 to 1700 vehicles per day on weekdays, depending on the location. The proportion of heavy vehicles on Memorial Avenue was found to be approximately 6% to 7% of total traffic.

Table 2-2 Heavy vehicles on Memorial Avenue

Site ID	Road Sections	Daily Traffic (Friday)	Heavy Vehicles (Friday)	% of Total Volume
M-1	Memorial Ave at Strangers Creek	25,200	1,740	7 %
M-2	Memorial Ave at Elizabeth Macarthur Creek	24,600	1,350	6 %

Source: February 2014 traffic survey

2.7 Crash data

Recorded crash data from July 2007 to June 2012 (a period of 5 years) were obtained from RMS. The crash data includes Memorial Avenue for the entire length and the Old Windsor Road/Memorial Avenue/Sunnyholt Road and Windsor Road/Memorial Avenue intersections.

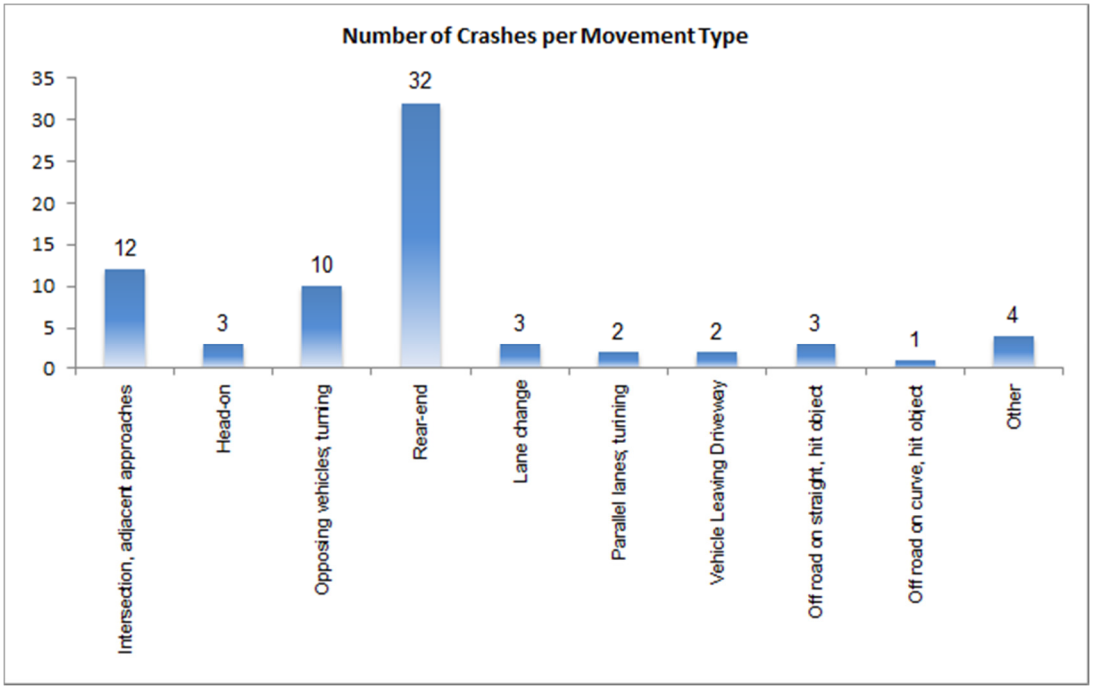
Table 2-3 summarises crash statistics, classified by severity (fatal, injury and non-casualty). There were 72 crashes recorded during the nominated period. Of that 1.4% were fatal, 51.5% of crashes involved injury and 47% were non-casualty (tow-away) crashes. The data show that 54 people were injured and one person was killed during record period.

Table 2-3 Severity of Crashes

Crash Severity	Number of Crashes	Percentage	Number of people casualties
Fatal	1	1.4 %	1 killed
Injury	37	51.4%	54 injured
Non-casualty	34	47.2%	n/a
Total	**72**	**100.0%**	**55**

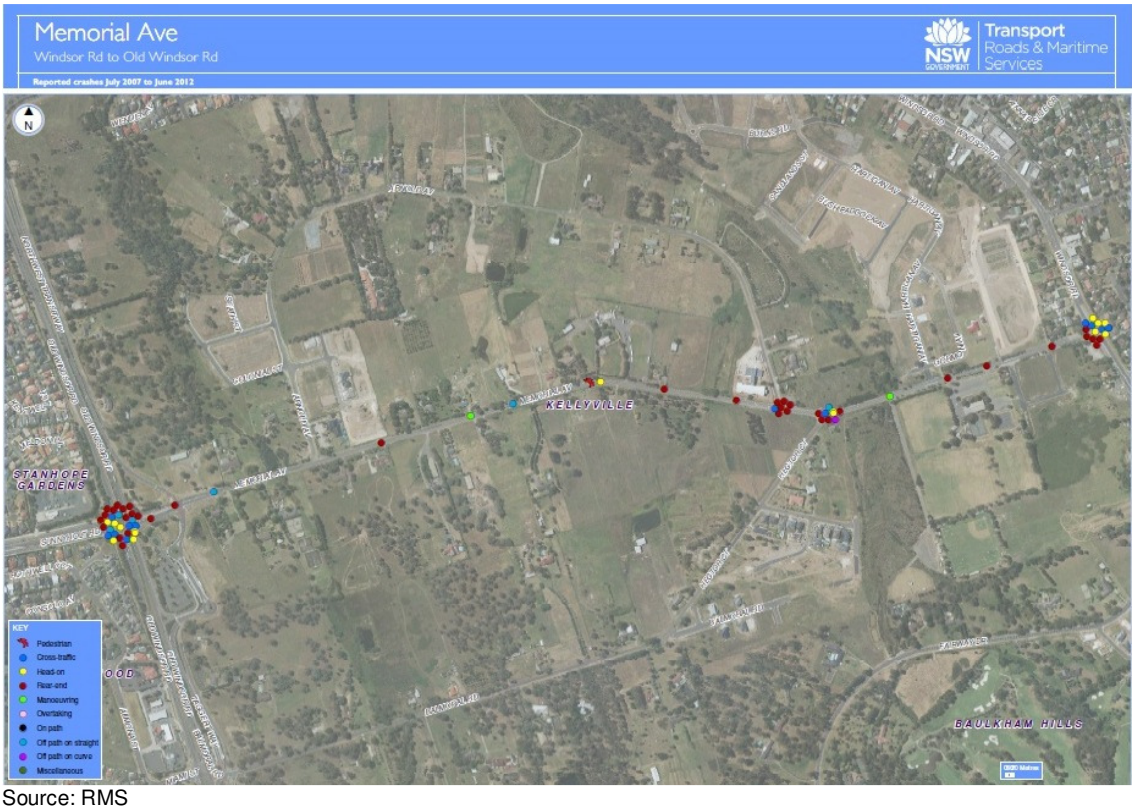
Source: RMS

Figure 2-7 shows the crash statistics for this period by location and type. The location where the highest number of crashes were reported is intersections (78%). The crash type with the highest number of crashes were reported is rear-end (45%). Figure 2-8 shows the crash distribution within the study area for the record period. It is likely that safety will deteriorate along Memorial Avenue and associated intersections in their current configuration for all road users as traffic levels and congestion increase, which is of on-going and significant concern to RMS and the local community.



Source: RMS, Hyder analysis

Figure 2-7 Number of crashes per movement type



Source: RMS

Figure 2-8 Spatial crash distribution 2007-2012 on Memorial Avenue

3 EXISTING ROAD NETWORK PERFORMANCE

This chapter establishes existing transport network performance in the study area. Results of traffic surveys are summarised in this section, and formed the basis of existing level of service assessment.

3.1 Traffic surveys

Five types of survey were undertaken to satisfy the needs and purpose of the study as follows:

- Intersection turning movement counts for critical peak periods;
- Daily automatic traffic counts on midblock locations for a one week period;
- Queue length surveys at critical intersections;
- Midblock (ATC) traffic counts for a one-week period;
- Origin-destination (OD) survey; and
- Travel speed survey.

Appendix A documents detailed traffic survey requirements developed in agreement with RMS staff. The traffic survey was undertaken by Skyhigh in February 2014.

3.1.1 Mid-block traffic counts

Mid-block traffic surveys were conducted on Memorial Avenue at two locations as follows:

- Memorial Avenue at Stranglers Creek; and
- Memorial Avenue at Elizabeth Macarthur Creek.

3.1.2 Intersection counts and queue length surveys

Intersection turning movement counts and queue length surveys were conducted for the AM peak (6:00 AM to 9:00 AM) and the PM peak (3:00 PM to 6:00 PM) for nine intersections as follows:

- I-1 - Old Windsor Road / Sunnyholt Road / Memorial Avenue;
- I-2 - Windsor Road / Memorial Avenue;
- I-3 - Windsor Road / President Road;
- I-4 - Windsor Road / Wrights Road;
- I-5 - Memorial Avenue / Arnold Avenue (West);
- I-6 - Memorial Avenue / Arnold Avenue (East);
- I-7 - Memorial Avenue / Hector Court;
- I-8 - Sunnyholt Road / T-way; and
- I-9 - Memorial Avenue / T-way.

Figure 3-1 below shows the survey locations for midblock counts, intersection counts and queue length surveys.

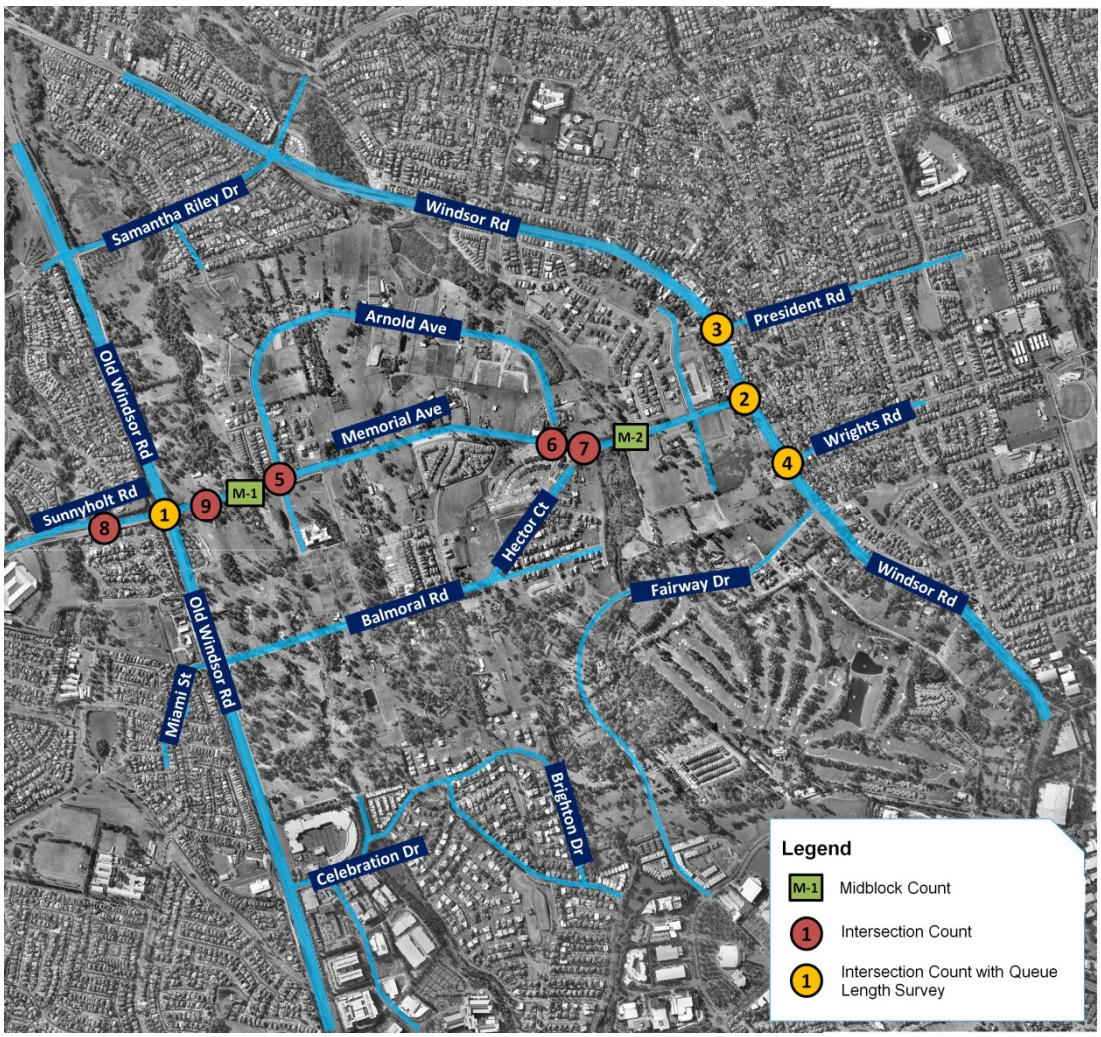


Figure 3-1 Survey locations in Study area

3.1.3 Origin-destination (OD) surveys

Origin-destination (OD) surveys were undertaken for six locations as shown in Figure 3-2:

- Sunnyholt Road west of Old Windsor Road;
- Old Windsor Rd (excluding T-Way Busway) north of Memorial Road;
- Old Windsor Rd (excluding T-Way Busway) south of Memorial Road;
- Windsor Road Immediately north of Memorial Avenue;
- Windsor Road Immediately south of Memorial Avenue and
- Memorial Avenue.

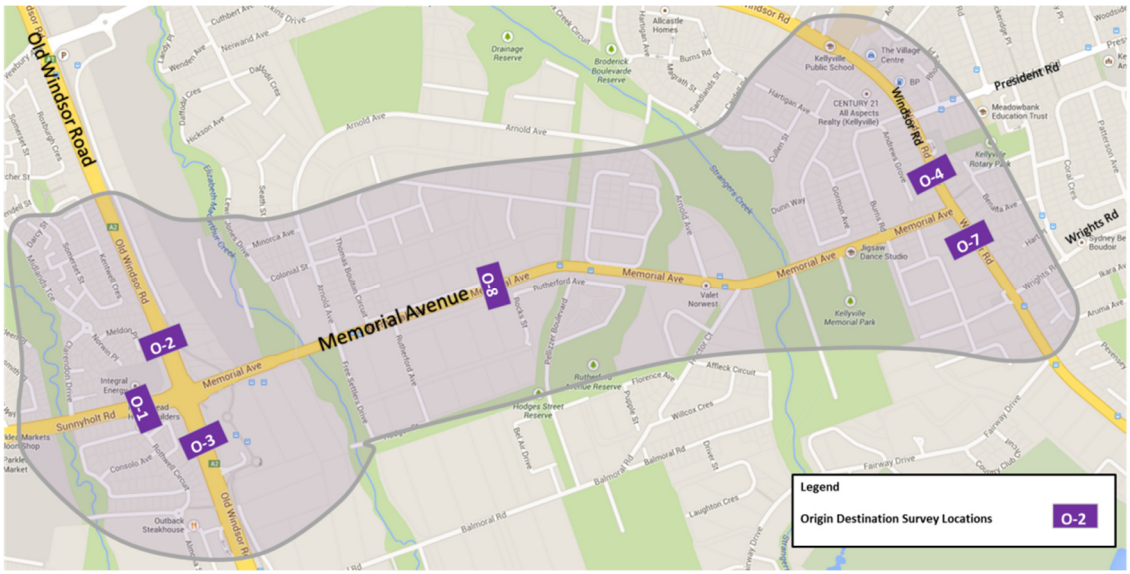


Figure 3-2 Origin-Destination Survey Locations (bi-directional)

3.1.4 Travel Time and Speed Survey

Travel time and speed survey was undertaken on Memorial Avenue between Old Windsor Road and Windsor Road in both eastbound and westbound directions.

3.2 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 assess existing capacity at key intersections within study area. The traffic data also provides a basis to consider likely traffic changes that would result from future growth. The results are based on survey data recorded from key roads and intersections in February 2014.

3.2.1 Weekly traffic profile

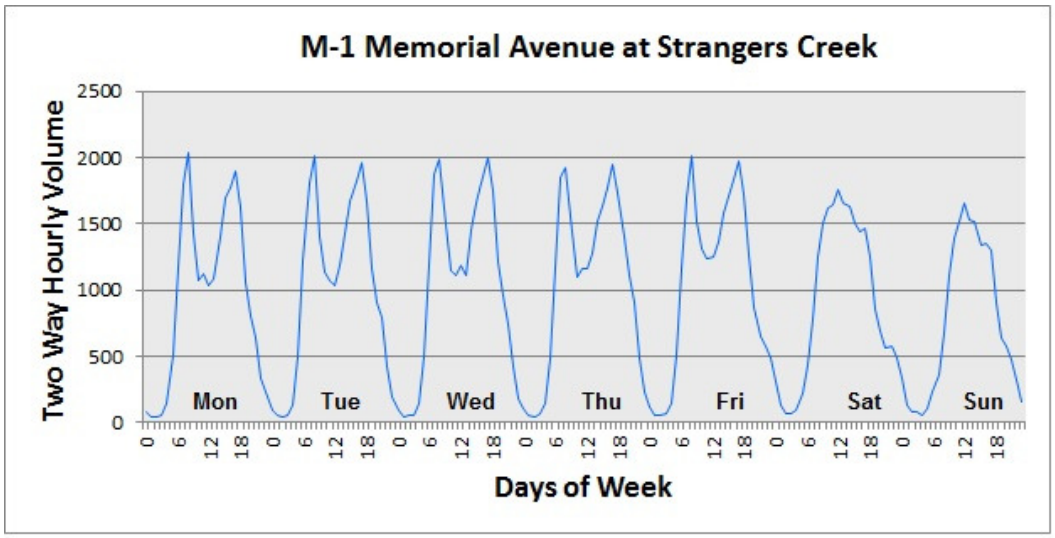
Table 3-1 shows the average daily traffic volumes in the study area for weekdays and the weekend. Average weekly two-way traffic volume profiles are shown on Figure 3-3. The results indicate that:

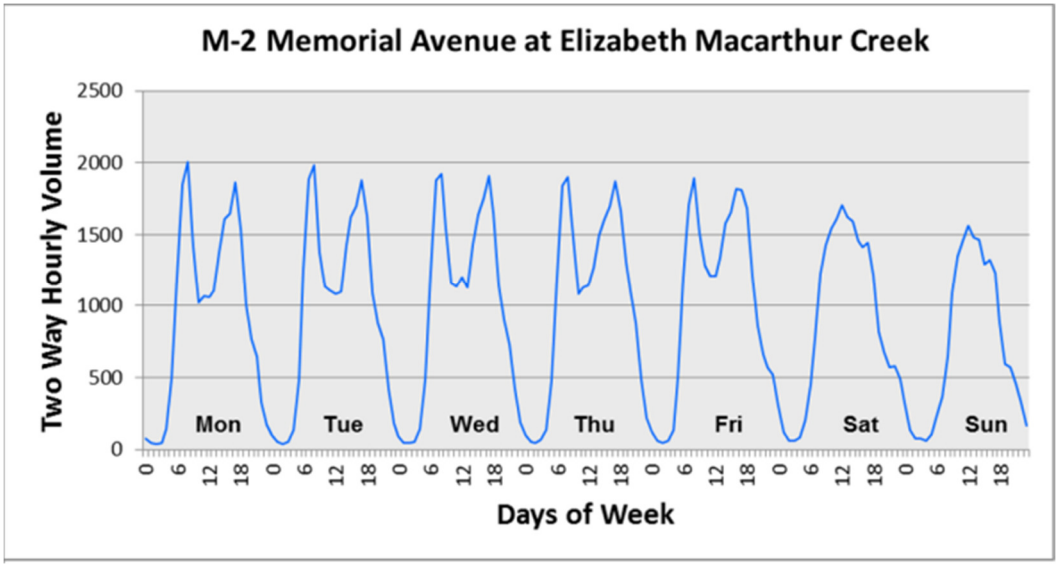
- Memorial Avenue carries about 25,000 vehicles per day on critical day (Friday); and
- Average weekend traffic is approximately 18% lower than weekday traffic.

Table 3-1 Average daily weekday and weekend traffic volumes on key roads

Site ID	Road Sections	Average 7 days	Average Weekday	Average Weekend	Critical day (Friday)	%Traffic Change	
						Friday vs Weekday	Weekend vs Weekday
M-1	Memorial Ave - at Strangers Creek	23,000	24,200	19,900	25,200	+4%	-18%
M-2	Memorial Ave - at Elizabeth Macarthur Creek	22,500	23,700	19,400	24,600	+4%	-18%

Source: January 2014 traffic survey





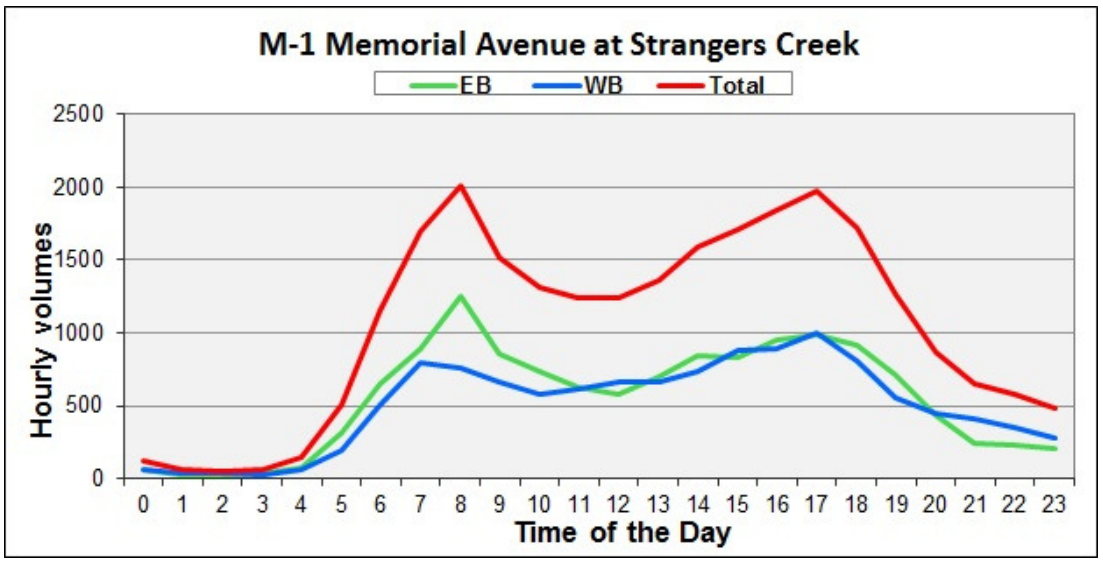
Source: January 2014 traffic survey

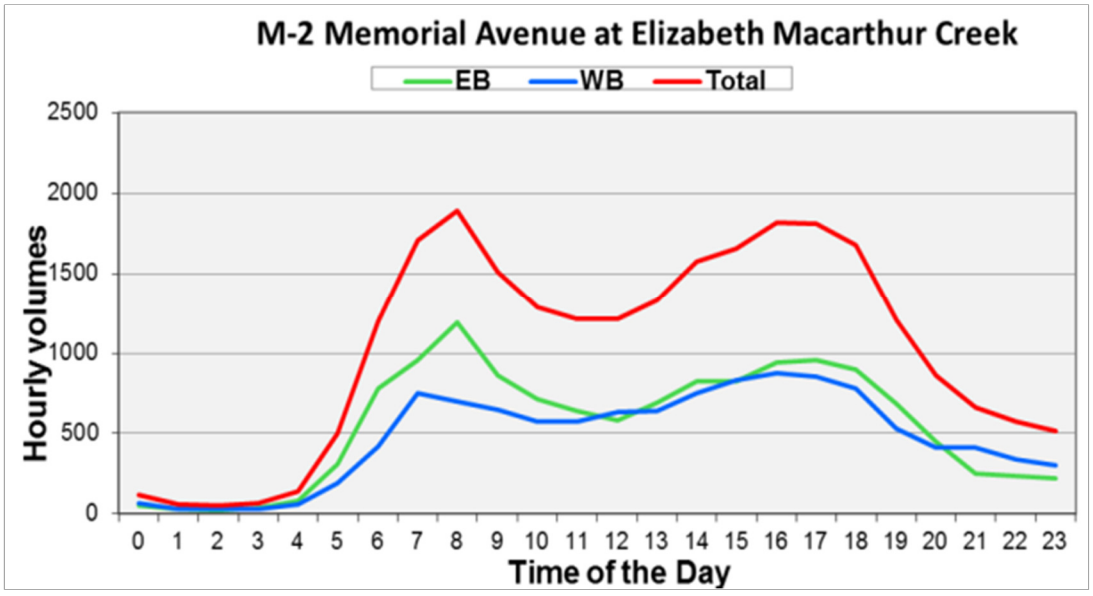
Figure 3-3 Average Weekly Two Way Traffic Volumes on Memorial Avenue

3.2.2 Daily traffic profile

Daily traffic volume profiles for the two surveyed sites are shown on Figure 3-4. The traffic profiles suggest morning and afternoon peak hour durations as follows:

- Morning (AM) peak between 7:00 and 9:00 AM; and
- Afternoon (PM) peak between 4:00 and 6:00 PM.





Source: January 2014 traffic survey

Figure 3-4 Daily Traffic Profiles for Memorial Avenue

3.2.3 Peak hour traffic volumes

Figure 3-5 shows peak hour turning volumes at the two key intersections at Old Windsor Road/Memorial Avenue/Sunnyholt Road and Windsor Road/Memorial Avenue. The following points are noted from peak hour volumes shown:

- Heavy through traffic is observed (1000 veh/h) from Sunnyholt Road to Memorial Avenue during the AM Peak.
- Heavy right turn traffic is observed (1000 veh/h) from Memorial Avenue to Windsor Road during the AM Peak.
- Heavy left turn traffic is observed (750 veh/h) from Windsor Road to Memorial Avenue during the PM Peak.
- Heavy through traffic is observed (800 veh/h) from Memorial Avenue to Sunnyholt Road during the PM Peak.

- Heavy right turn traffic from Memorial Avenue to Windsor Road (1000 veh/h) is opposed by the heavy southbound through traffic (2000 veh/h) during the AM Peak.
- The high through traffic on Old Windsor Road, Windsor Road, Sunnyholt Road, Memorial Avenue and relatively high turning traffic into and out of these roads are significant contributing factors to traffic congestion.

Detailed turning volumes for AM and PM peak hour for all surveyed locations are shown in Appendix B.

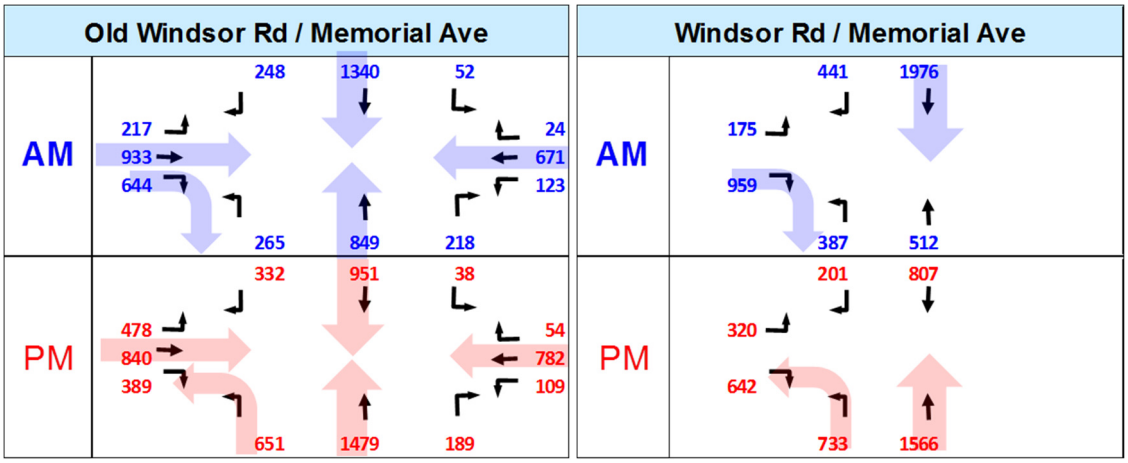


Figure 3-5 Peak Hour Turning Volumes for Two Key Intersections

3.2.4 Origin-destination patterns

The origin-destination trip patterns to and from the study area were estimated using the origin – destination survey. Significantly, about 90% of all traffic passing through Memorial Avenue has origins and destinations outside the study area.

3.2.5 Travel speeds on Memorial Avenue

Travel speed data in Table 3-2 shows that in both the morning and afternoon peaks, travel speeds reduce significantly along the section of Memorial Avenue between Old Windsor Road and Windsor Road. This can be as much as 25 km/h less than the posted speed limit of 60 or 70km/h.

Table 3-2 Travel speeds on Memorial Avenue

Direction	Time Period	Travel Speed on Memorial Avenue (km/h)		
		Maximum	Minimum	Average
Eastbound	AM Peak	60	20	38
	PM Peak	62	31	45
Westbound	AM Peak	55	19	33
	PM Peak	51	13	22

3.3 Paramics modelling

3.3.1 Overview

Paramics models were used to facilitate a more in depth analysis of the operational performance key intersections within the study area. Figure 3-6 shows the Paramics network developed for this study. Paramics models were calibrated and validated according to the RMS's Traffic Modelling Guidelines, Version 1.0, February 2013. The models represented 2014 traffic conditions for both morning (AM) peak and afternoon (PM) peak periods, i.e.:

- The AM peak period between 7:00 AM and 9:00 AM; and
- The PM peak period between 4:00 PM and 6:00 PM.

The model specifically represents traffic for an average weekday by modelling the AM and PM peak periods.

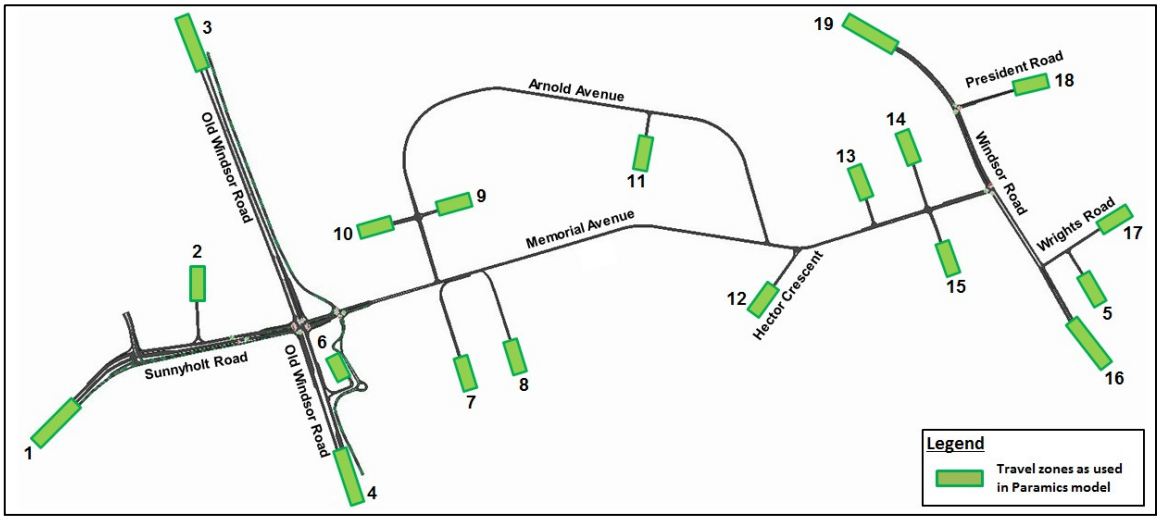


Figure 3-6 Paramics model road network and travel zone system

3.3.2 Traffic demand

The existing demand matrix was estimated using surveyed origin-destination data and intersection turning movement counts. The demand matrix was calibrated to the RMS's Guide standards.

3.3.3 Model calibration and validation

The Paramics modelling was calibrated and validated as per RMS guideline. Detailed Paramics model validation is documented in Appendix C. The analysis documented in Appendix C confirmed that both AM and PM peaks were calibrated and validated adequately and the model was fit for this study purpose.

3.4 Existing network performance

In order to quantify the current road network deficiency within the study area, road network capacity assessment was undertaken. This assessment involved the development and interrogation of purpose built traffic models using Paramics micro-simulation software.

Substantial traffic delays occur in both the morning and afternoon peak periods, resulting in long traffic queues along Old Windsor Road, Windsor Road, Sunnyholt Road and Memorial Avenue. Long delays are caused by current capacity constraints at Old Windsor Road/Sunnyholt Road/Memorial Avenue and Windsor Road/Memorial Avenue intersections.

Figure 3-7 shows queue lengths predicted (shown in red) by Paramics model for both morning and afternoon peak hours.

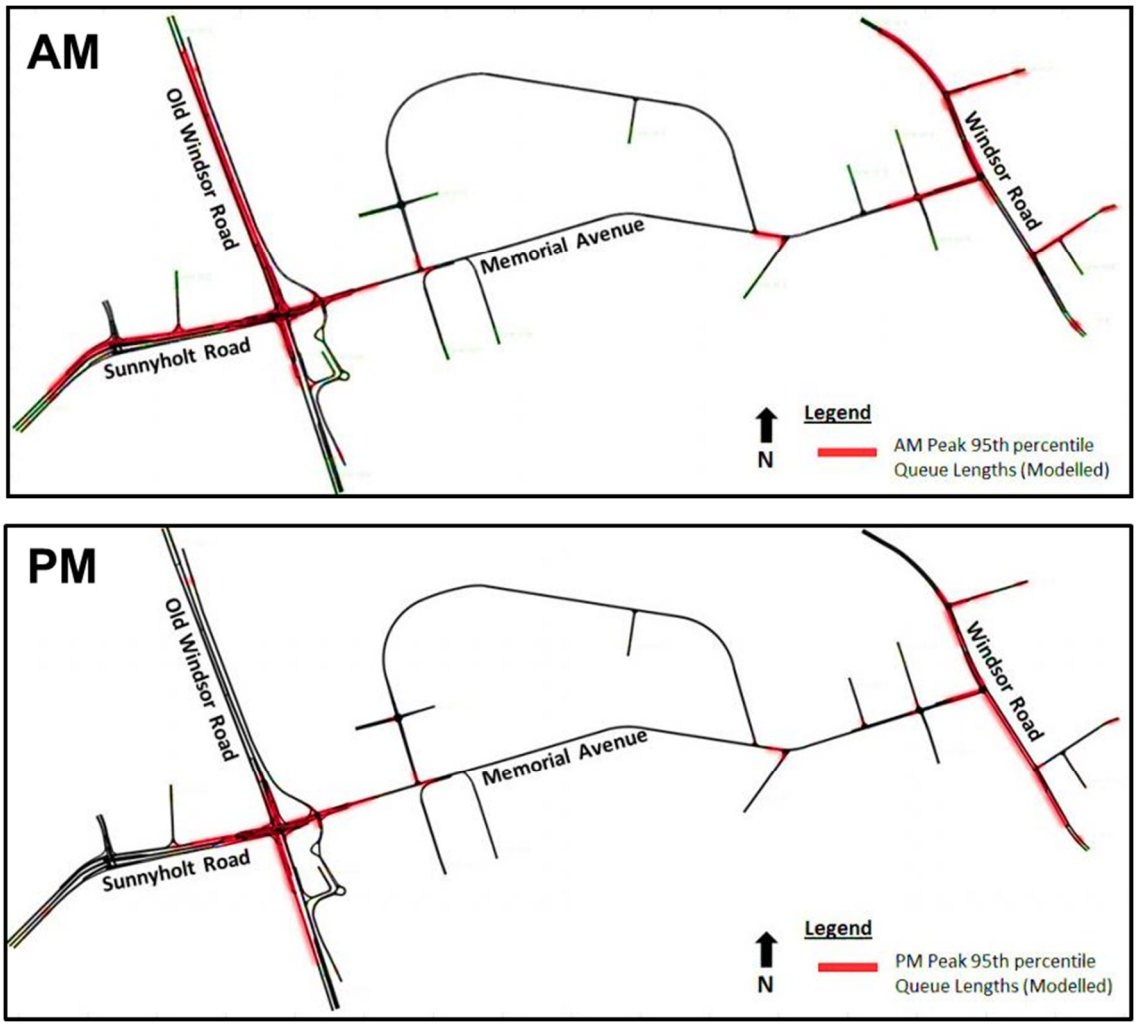


Figure 3-7 Predicted Queues at Critical Parts of Network in AM and PM Peak

The existing network capacity was further investigated for eight key intersections. Level of service (LoS) is reported in accordance with the RMS' guideline (Guide to Traffic Generating Developments, Issue 2.2, RMS, October 2002).

It recommends that for priority intersections such as a roundabout and sign controlled intersections, the level of service (LoS) value is determined by the critical movement with the highest delay whereas for a signalised intersection, LoS criteria are related to the average intersection delay measured in seconds per vehicle.

The performance of an intersection is 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 – average delay per vehicle is less than 14 seconds. Good operation.
- Level of Service B – average delay per vehicle is between 15 and 28 seconds. Good operation with acceptable delays and spare capacity.
- Level of Service C – average delay per vehicle is between 29 and 42 seconds. Satisfactory operation.
- Level of Service D – average delay per vehicle is between 43 and 56 seconds. Operating near capacity.
- Level of Service E – average delay per vehicle is between 57 and 70 seconds. Operating at capacity; incidents at signals will cause excessive delays.
- Level of Service F – average delay per vehicle is more than 70 seconds. Extra capacity required.

Table 3-3 shows existing (2014) level of service results for the eight intersections assessed for both the morning and afternoon peak hours. The analysis determined level of service (LoS) between B and F depending on assessed intersections. The modelling predicted level of service F (over capacity) at the Old Windsor Road/Memorial Avenue/Sunnyholt Road signalised intersection in both the morning and afternoon peak periods. The model predicted level of service D (near capacity) at the Windsor Road/Memorial Avenue signalised intersection.

The modelling predicted poor LoS F at Windsor Road/President Road intersection in the morning peak. The Wrights Road intersection with Windsor Road is at LoS E in the morning peak, particularly for right turn movements out of Wrights Road.

Table 3-3 Existing level of service results

ID	Intersection	Control Type	AM Peak (8 9)		PM Peak (5 6)	
			Delay (sec)	LoS	Delay (sec)	LoS
I-1	Old Windsor Road / Memorial Avenue / Sunnyholt Road	Signal	155	F	74	F
I-2	Windsor Road / Memorial Avenue	Signal	53	D	50	D
I-3	Windsor Road / President Road	Signal	78	F	16	B
I-4	Windsor Road / Wrights Road	Priority (Sign)	70	E	45	D
I-5	Arnold Avenue (West) / Memorial Avenue	Priority (Sign)	29	C	53	D
I-6	Arnold Avenue (East) / Memorial Avenue	Priority (Sign)	20	B	16	B
I-7	Memorial Avenue / Hector Court	Priority (Sign)	21	B	21	B
I-9	Memorial Avenue / T-way	Signal	20	B	35	C

Source: Paramics models;
AM: Model: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2014 Base Case\AM_2014_BC_TZ019_08042014_4\Log\run-008
PM: Model: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2014 Base Case\PM_2014_BC_TZ019_15042014_4\Log\run-017

4 FUTURE NETWORK PERFORMANCE

4.1 Future traffic volumes on Memorial Avenue

Future traffic volumes on Memorial Avenue between Old Windsor Road and Windsor Road 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 EMME. RMS provided traffic forecast for key roads within study area for future time steps in 2016, 2026 and 2036.

Traffic forecasts on Memorial Avenue are prepared for 2019, 2026 (interim) and 2036 (ultimate). The future volumes have taken into account passing traffic due to land development in the North West Growth Centre, new development traffic from about 5,400 dwellings proposed in the Balmoral Road Release Area (BRRA) and potential reduction of car mode attributable to the North West Rail Link. Future growth and land use assumptions for BRRA have been agreed with RMS and are included in Appendix D.

Table 4-1 shows forecast average daily traffic on Memorial Avenue for 2019, 2026 and 2036.

In 2019 traffic on Memorial Avenue is projected about 33,000 vehicles per day. By 2026, traffic is forecast to grow in the order of 42,000 vehicles per day. In 2036, traffic on Memorial Avenue is forecast in the order of 45,000 vehicles per day, almost double 2014 traffic.

Table 4-1 Estimated average daily traffic for 2019, 2026 and 2036 (vehicles)

Road / Location	Existing	Forecast Average Daily Traffic (Vehicles)		
	2014	2019	2026	2036
Memorial Avenue - between Old Windsor Road and Windsor Road	25,000	33,000	42,000	45,000

Source: Hyder's analysis. Future growth were sourced from RMS's Sydney Strategic Model (EMME/2)

4.2 Modelling scenarios

The interim and longer term capacity improvements at Old Windsor Road/Memorial Avenue/Sunnyholt Road traffic signals and Windsor Road/Memorial Avenue traffic signals were determined from scenarios tested as follows:

- *Scenario 1*: Scenario 1 assumes four lanes upgrade (2/2) on the entire length of Memorial Ave. The future lane configurations and network connections are assumed in line with the Concept Design. In this scenario, no upgrades are assumed at Old Windsor Road/Memorial Avenue/Sunnyholt Road traffic signals and Windsor Road/Memorial Avenue traffic signals.
- *Scenario 2*: Scenario 2 is built on scenario 1. In this scenario, at-grade upgrades are tested at the Old Windsor Road/Memorial Avenue/Sunnyholt Road and Windsor Road/Memorial Avenue signalised intersections. Scenario 2 identified the timing and service life of at-grade upgrades.
- *Scenario 3*: Scenario 3 is built on scenario 2. In this scenario, a grade-separated upgrade is tested at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection, and an at-grade upgrade at Windsor Road/Memorial Avenue traffic signals.

Table 4-2 summarises the future years modelling scenarios tested.

Table 4-2 Network scenarios modelled

Network Scenario		Modelling Years		
Scenario	**Upgrades**	**2019**	**2026**	**2036**
Scenario 1	▪ Memorial Avenue upgrade to four lanes (2/2) ▪ No upgrades at Old Windsor Road/ Memorial Avenue/ Sunnyholt Road and Windsor Road/ Memorial Avenue intersections.	✓	✓	✓
Scenario 2	▪ Memorial Avenue upgrade to four lanes (2/2) ▪ At grade upgrade at Old Windsor Road/Memorial Avenue/Sunnyholt Road ▪ At grade upgrade at Windsor Road/ Memorial Avenue	✓	✓	✓
Scenario 3	▪ Memorial Avenue upgrade to four lanes (2/2) ▪ Grade separation upgrade at Old Windsor Road/ Memorial Avenue/Sunnyholt Road ▪ At grade upgrade at Windsor Road/ Memorial Avenue		✓	✓

Note:

In the 2019 model, no upgrades are assumed at Wrights Road/Windsor Road intersection. A new traffic signal at Wrights Road/Windsor Road intersection was assumed for 2026 and 2036.

✓ - indicates modelling scenarios undertaken for this study.

4.3 Upgrade on Memorial Avenue

The intersection footprints required for the Concept Design are based on future turning volumes estimated for ultimate horizon year 2036. The level of service for new signalised intersections on Memorial Avenue/Arnold Avenue and Memorial Avenue/Severn Vale Drive were estimated for 2019, intermediate year 2026 and ultimate year 2036. Detailed intersection turning volumes and modelling results for 2019, 2026 and 2036 are included in Appendix E.

Amendments to provisional for left turn slip lane splitter islands on Memorial Avenue/Arnold Avenue west approach and Memorial Avenue/Severn Vale Drive south approach have been modelled, and the traffic outcomes adjusted accordingly.

4.3.1 Memorial Avenue/Arnold Avenue (West)/Free Settlers Drive Intersection

Ultimate Layout

Upgrade description

New traffic signals are proposed at Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive. Figure 4-1 below shows the ultimate intersection footprint required at Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive traffic signals.

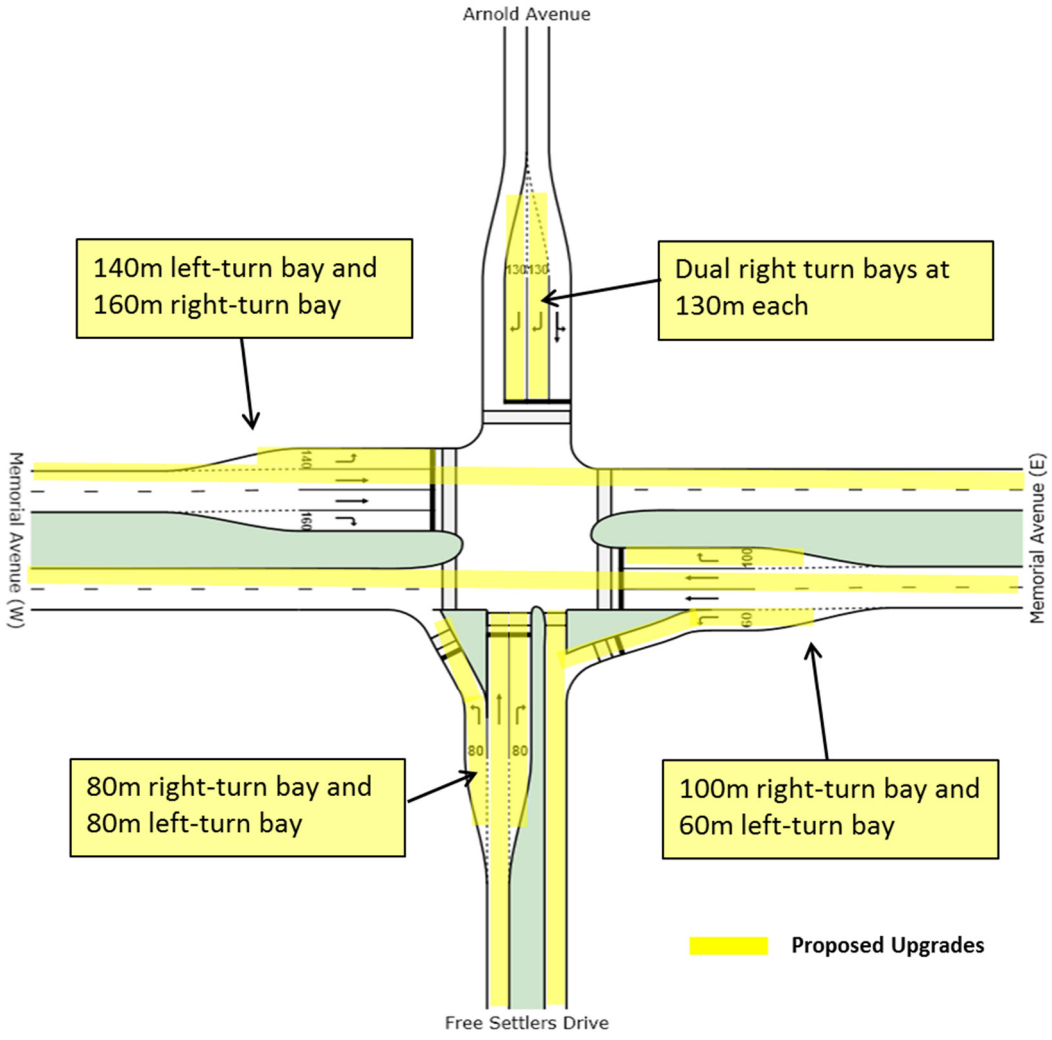


Figure 4-1 Proposed ultimate layout of Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive	New Traffic Signals	New traffic signals including: ▪ Memorial Avenue two lanes (in each direction) for eastbound and westbound direction; ▪ Dual right turn bays at 130m each and a shared left and through lane at Arnold Avenue (North approach); ▪ 100m right turn bay and a 60m signalised left turn slip lane at Memorial Avenue (East approach); ▪ A 80m right turn bay, a 80m signalised left turn slip lane and a single through lane at Free Settlers Drive (South approach); and ▪ 160m right turn bay and a 140m left turn bay at Memorial Avenue (West approach).

Traffic Implications

Future performance of the Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive signalised intersection was assessed for 2019, 2026 and 2036 for both AM and PM peak periods. The identified intersection footprints at Memorial Avenue/ Arnold Avenue (West) traffic signals would provide level of service B in year 2019. Model forecasts level of service C in 2026 and the ultimate year 2036.

Table 4-3 below shows delays and level of service at Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive traffic signals for the AM and PM peaks.

Table 4-3 Forecast levels of service at Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive intersection

ID	Intersection	Control Type	Time Period	2019		2026		2036	
				Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-5	Arnold Avenue / Memorial Avenue	New Traffic Signal	AM	30	C	36	C	40	C
			PM	24	B	32	C	36	C

Source: SIDRA V 6.0.15.4263
Models: F:\AA006569\Traffic Modelling\SIDRA\Sensitivity Test_Aug2014\I-5_modified.sip6

Interim Layout

Upgrade description

Due to current limitations on site, an interim layout is proposed at Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive. The interim intersection layout shown in Figure 4-2 is consistent with Hills Shire Council DCP 2012.

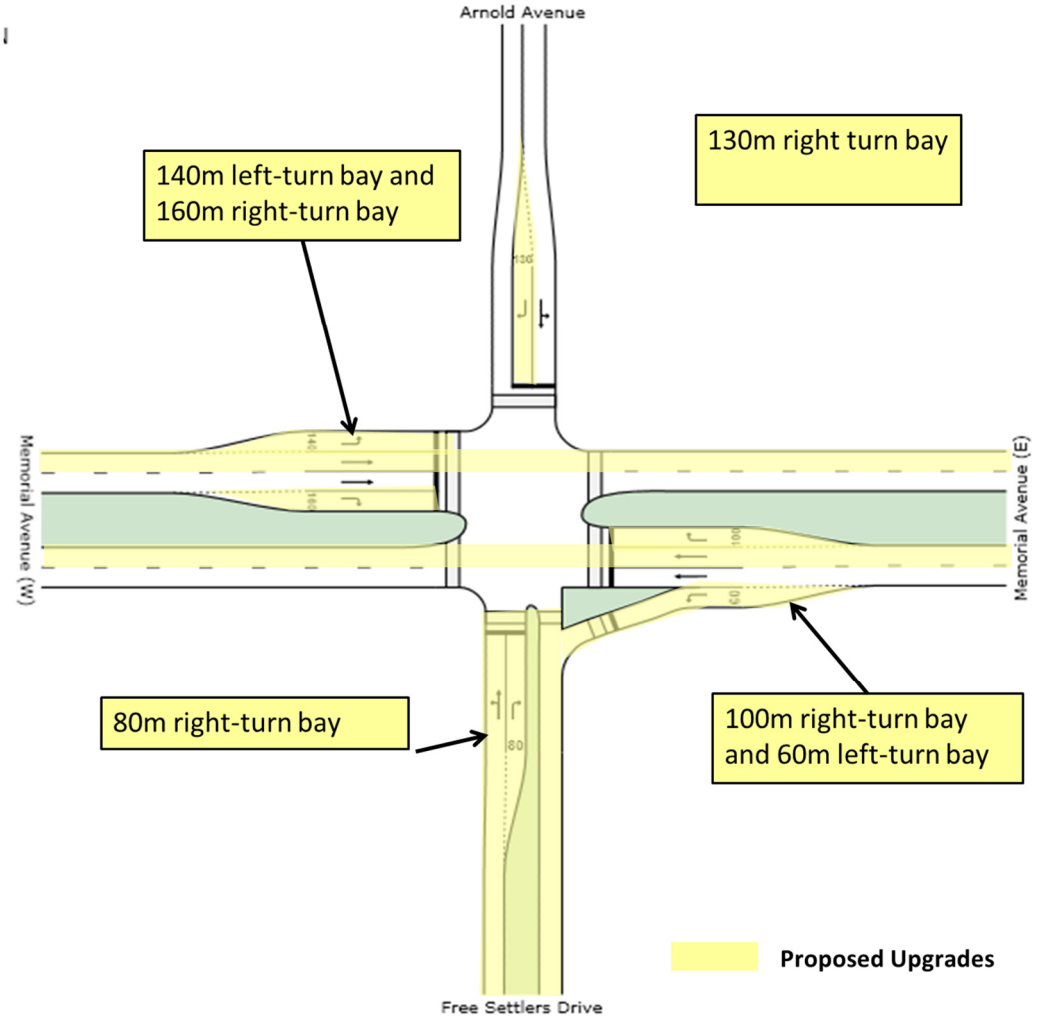


Figure 4-2 Proposed interim layout of Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive	New Traffic Signals	New traffic signals including: ▪ Memorial Avenue two lanes (in each direction) for eastbound and westbound direction; ▪ 130m right turn bay and a shared left and through lane at Arnold Avenue (North approach); ▪ 100m right turn bay and a 60m signalised left turn slip lane at Memorial Avenue (East approach); ▪ A 80m right turn bay and a shared left and through lane at free Settlers Drive (South approach); and ▪ 160m right turn bay and a 140m left turn bay at Memorial Avenue (West approach).

Traffic Implications

Future performance of the Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive signalised intersection was assessed for 2019, 2026 and 2036 for both AM and PM peak periods. The identified interim intersection footprints at Memorial Avenue/ Arnold Avenue (West) traffic signals would provide level of service C in year 2019. Model forecasts level of service D in 2026 and F in the ultimate year 2036.

Table 4-4 below shows delays and level of service at Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive traffic signals for the AM and PM peaks.

Table 4-4 Forecast levels of service at Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive intersection interim layout

ID	Intersection	Control Type	Time Period	2019		2026		2036	
				Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-5	Arnold Avenue / Memorial Avenue	New Traffic Signal	AM	37	C	50	D	102	F
			PM	26	B	32	C	40	C

Source: SIDRA V 6.0.15.4263
Models: F:\AA006569\Traffic Modelling\SIDRA\Sensitivity Test_Sept2014_after MPRC\19092014\I-5_modified.sip6

The above modelling is further documented in Technical Note 7, attached in Appendix F.

4.3.2 Memorial Avenue/Severn Vale Drive intersection

Upgrade Description

New traffic signals are proposed at Memorial Avenue / Severn Vale Drive. **Error! Reference source not found.** below shows the ultimate intersection footprint required at Memorial Avenue / Severn Vale Drive traffic signals.

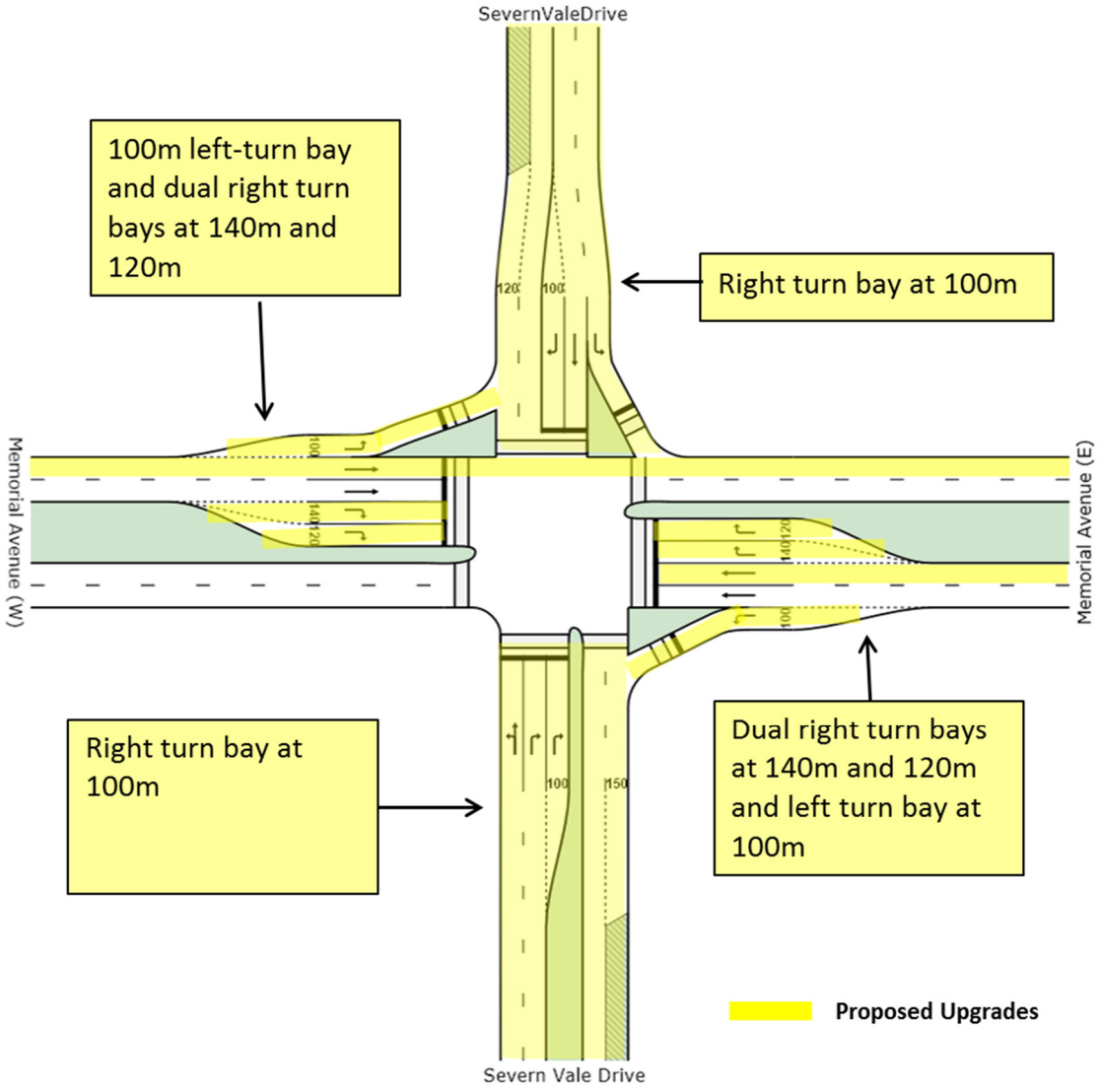


Figure 4-1 Proposed Layout of Memorial Avenue / Severn Vale Drive Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Memorial Avenue / Severn Vale Drive	New Traffic Signals	New traffic signals including: ▪ Memorial Avenue two lanes (in each direction) for eastbound and westbound directions; ▪ A right turn bay at 100m, a left turn signalised slip lane and a single through lane at Severn Vale Drive (North approach); ▪ Dual right turn bays at 140m and 120m and a 100m signalised left turn slip lane at Memorial Avenue (East approach); ▪ Dual right turn lanes with one lane as a short turn lane at 100m and a shared through and left turn lane at Severn Vale Drive (South approach); and ▪ Dual right turn bays at 140m and 120m and a 100m left turn signalised slip lane at Memorial Avenue (West approach).

Traffic implications

Future performance of the Memorial Avenue/ Severn Vale Drive signalised intersection was assessed for 2019, 2026 and 2036 for both AM and PM peak period. The identified intersection footprints at Memorial Avenue/ Severn Vale Drive traffic signals would provide level of service C in 2019 and 2026. The model forecasts level of service D in 2036.

Table 4-5 below shows delays and level of service at Memorial Avenue/ Severn Vale Drive traffic signals for the AM and PM peaks.

Table 4-5 Forecast level of service at Memorial Avenue / Severn Vale Drive intersection

ID	Intersection	Control Type	Peak Period	2019		2026		2036	
				Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-7	Severn Vale Drive / Memorial Avenue	New Traffic Signals	AM	35	C	42	C	52	D
			PM	34	C	41	C	45	D

Source: SIDRA V 6.0.15.4263
Models: \F:\AA006569\Traffic Modelling\SIDRA\Sensitivity Test_Aug2014\I-7_modified.sip6

4.4 Upgrade at Old Windsor Road/Memorial Avenue intersection

Two upgrade solutions are identified at Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection for interim and longer term. These include:

- Existing signalised intersection upgraded at-grade; and
- Grade separation with Old Windsor Road (north-south movements) elevated on viaduct.

4.4.1 Existing signalised intersection upgraded at-grade

Upgrade Description

Through the modelling exercise interim at-grade upgrades were identified at the Old Windsor Road / Memorial Avenue / Sunnyholt Road signalised intersection. Figure 4-2 below shows the proposed intersection footprint required for at Old Windsor Road / Memorial Avenue / Sunnyholt Road traffic signals.

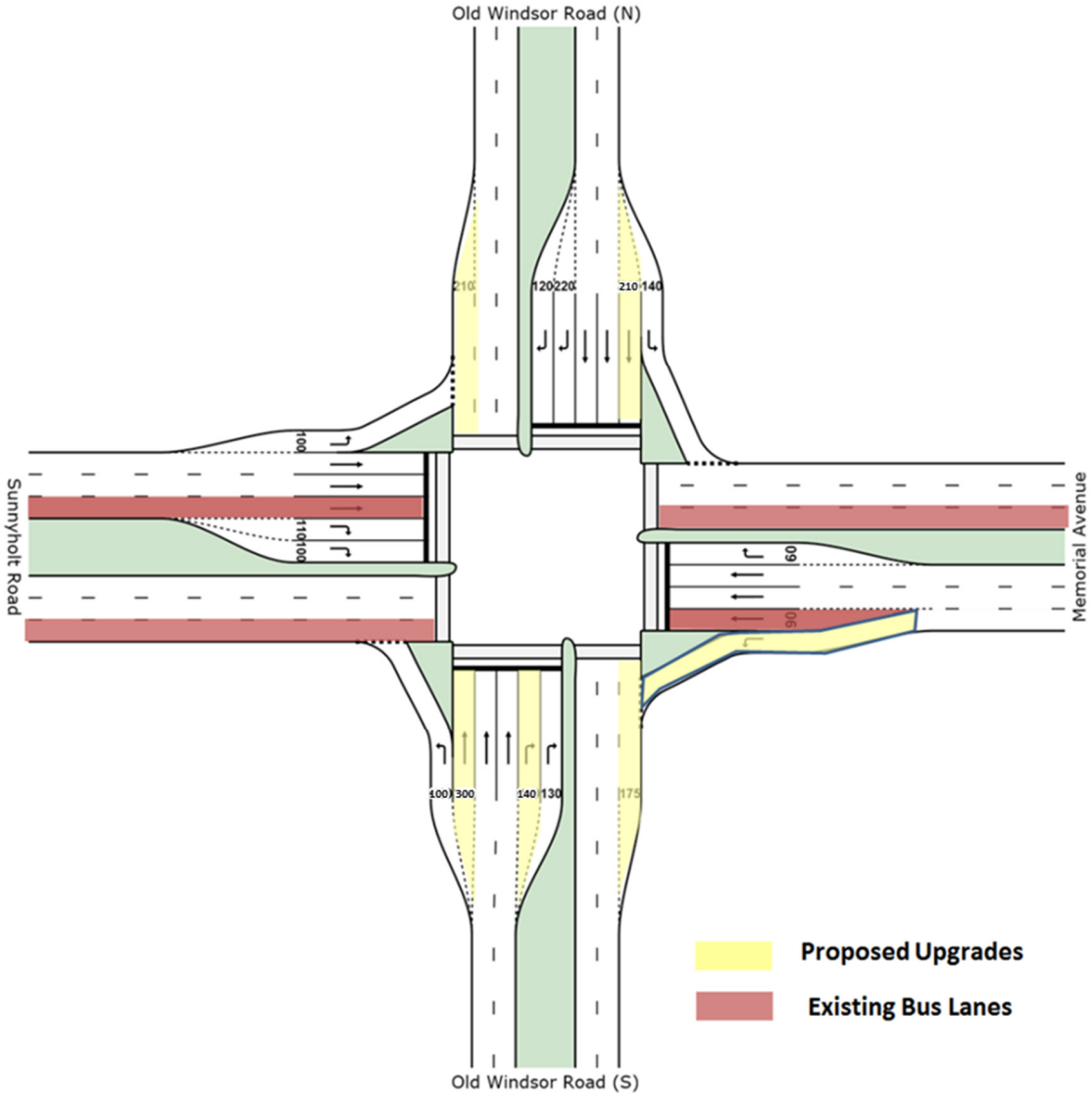


Figure 4-2 Proposed Layout of At Grade Upgrade at Old Windsor Road / Memorial Avenue/ Sunnyholt Road Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Old Windsor Road / Memorial Avenue / Sunnyholt Road	Upgraded Traffic Signals	At grade upgrade including: ▪ Additional southbound through lane at 210m on Old Windsor Road; ▪ Additional southbound exit lane length at 175m on Old Windsor Road; ▪ Additional northbound exit lane at 210m on Old Windsor Road; ▪ Additional northbound through lane at 300m on Old Windsor Road; ▪ Additional right turn lane on Old Windsor Road southern approach at 130m; and ▪ Extending southbound left turn slip lane on Memorial Avenue approach to 235m.

Traffic Implications

Future intersection performance at Old Windsor Road / Memorial Avenue / Sunnyholt Road traffic signals for post upgrade conditions was assessed for 2019, 2026 and 2036 for both AM and PM peak period. The traffic signals upgraded would provide level of service E in 2019. Model forecasts level of service F in year 2026.

Table 4-6 below shows delay and level of service for traffic signals upgraded at Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection for AM and PM peak respectively.

At-grade upgrades to existing traffic signals at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection would substantially improve traffic capacity and level of service. Should at-grade upgrades to Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection proceed concurrently with Memorial Avenue four lane upgrade, then identified upgrades will have a service life up to 2026. The need for grade separation was identified after 2026.

Table 4-6 Forecast level of service of at-grade upgrade at Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection

ID	Intersection	Control Type	Peak Period	2019		2026	
				Average Delay (sec)	LoS	Average Delay (sec)	LoS
I-1	Old Windsor Road / Memorial Avenue / Sunnyholt Road	Upgraded Traffic Signals	AM	69	E	104	F
			PM	62	E	72	F

Note: LoS result is based on Scenario 2
Source: Paramics
Models:
F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2019_Sensitivity
2026 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2026 Future
Spreadsheet: F:\AA006569\Traffic Modelling\PARAMICS\3-Spreadsheets\3- LOS\Final LoS run_12062014;
F:\AA006569\Traffic Modelling\PARAMICS\3-Spreadsheets\3- LOS\2019_Old Windsor Road Adjusted_August 2014

4.4.2 Grade Separation at Old Windsor Road/Memorial Avenue Intersection

Upgrade Description

Modelling analysis identified that grade separation at Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection would be required after 2026. Figure 4-3 below shows an indicative schematic for the proposed grade separation at Old Windsor Road / Memorial Avenue / Sunnyholt Road (Old Windsor Road elevated on viaduct).

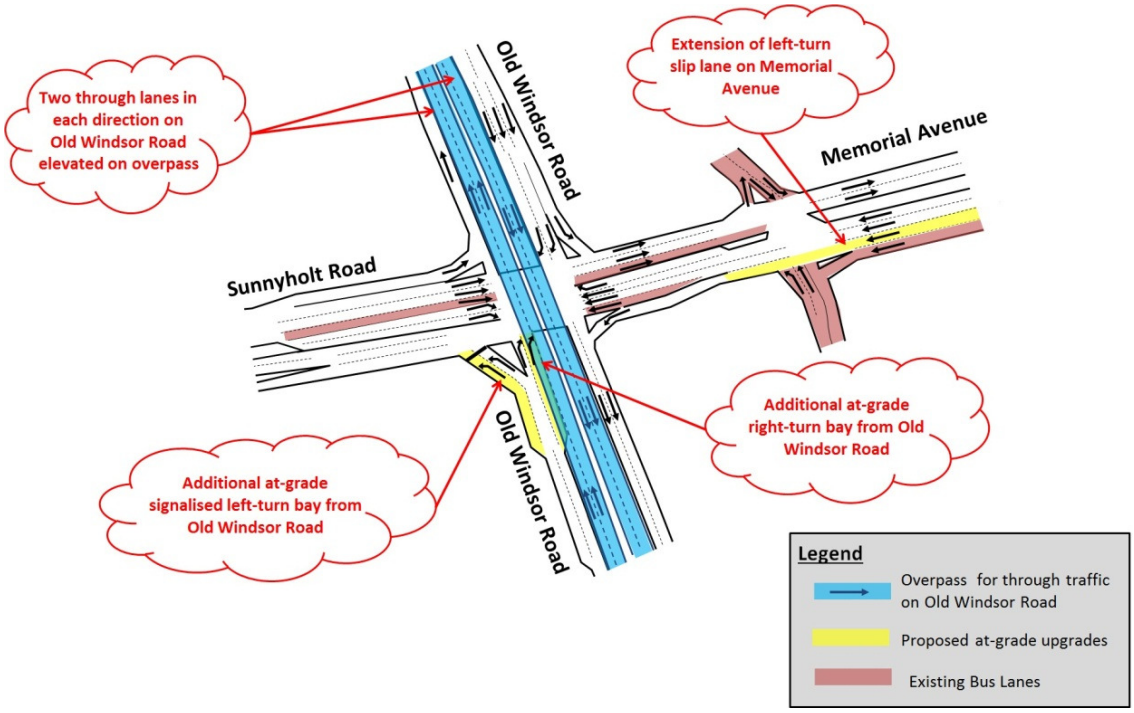


Figure 4-3 Schematic for Grade Separation of Old Windsor Road / Memorial Avenue / Sunnyholt Road Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Old Windsor Road / Memorial Avenue / Sunnyholt Road	Grade Separation Upgrade	Further upgrade to the at grade solution including: ▪ Grade separation upgrade (Old Windsor Road elevated on bridge) and ▪ Additional westbound left turn slip lane (signalised).

Traffic Implications

Future intersection performance at Old Windsor Road / Memorial Avenue / Sunnyholt Road grade-separated for post upgrade conditions was assessed for 2026 and 2036 for both AM and PM peak period. The grade separated upgrades would provide level of service C in 2026 and level of service D in 2036.

Table 4-6 below shows delay and level of service for grade separated upgrade at Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection for AM and PM peak respectively.

The need for grade separation at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection was identified after 2026. The assessment found that grade separated upgrade would provide acceptable level of service C and D in 2036 for morning and afternoon peak periods.

Table 4-7 Forecast Level of Service at Old Windsor Road / Memorial Avenue Intersection with Grade Separation

ID	Intersection	Control Type	Peak Period	2026		2036	
				Average Delay (sec)	LoS	Average Delay (sec)	LoS
I-1	Old Windsor Road / Memorial Avenue / Sunnyholt Road	Grade Separation Upgrade	AM	34	C	46	D
			PM	41	C	45	D

Note: LoS result is based on Scenario 3
Source: Paramics
Models:
2026 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2026 Future
2036 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2036 Future
Spreadsheet: F:\AA006569\Traffic Modelling\PARAMICS\3-Spreadsheets\3- LOS\Final LoS run_12062014

4.5 Upgrade at Windsor Road/Memorial Avenue intersection

Upgrade Description

Through the modelling exercise interim upgrades were identified at Windsor Road/Memorial Avenue traffic signals. Figure 4-4 below shows the intersection footprint required at Windsor Road / Memorial Avenue traffic signals.

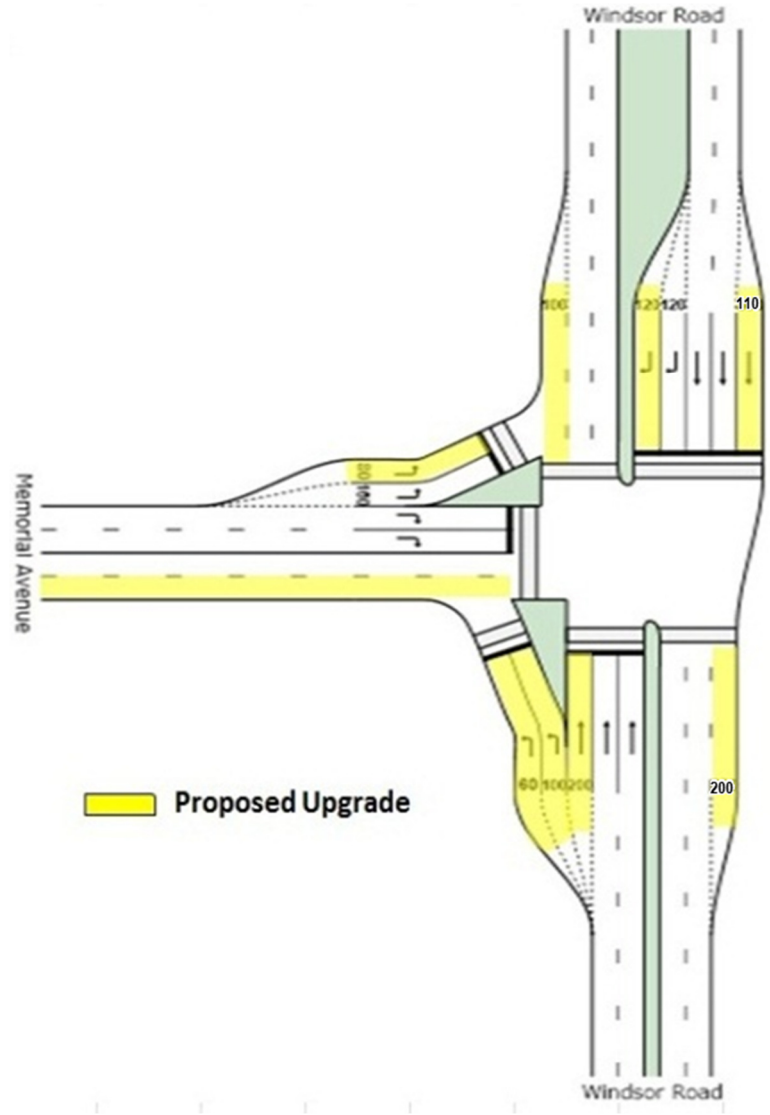


Figure 4-4 Proposed Layout of Windsor Road and Memorial Avenue Intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Windsor Road / Memorial Avenue Intersection	Traffic Signals Upgraded	Intersection upgrade including: ▪ Additional southbound through lane at 110m on Windsor Road; ▪ Additional southbound exit lane at 200m on Windsor Road; ▪ Additional northbound through lane at 260m on Windsor Road (additional lane starts from Wrights Road);

Intersection	Control Type	Indicative Description
		▪ Signalised left turn slip lanes on Windsor Road southern approach are proposed to have gradual widening , starting with the single left turn lane 120m from the stop line and double left turn slip lane starting 60m from the stop line. ▪ Additional northbound exit lane on Windsor Road at 100m; ▪ Additional westbound right turn lane Windsor Road northern approach at 120m; ▪ Additional northbound left turn slip lane; and ▪ Additional westbound exist lane on Memorial Avenue.

Traffic Implications

Future performance of the traffic signals upgraded at Windsor Road / Memorial Avenue intersection was assessed for 2019, 2026 and 2036 for both AM and PM peak period. The identified intersection footprints at Windsor Road / Memorial Avenue traffic signals would provide level of service C/D up to 2026.

In 2036, the ultimate grade separation at Old Windsor Road/ Memorial Avenue intersection would also improve the entire section of Memorial Avenue and the upgraded intersection at Windsor Road/Memorial Avenue. The model predicted level of service C/D at upgraded Windsor Road / Memorial Avenue intersection in 2036.

Table 4-7 below shows delay and level of service for upgraded Old Windsor Road / Memorial Avenue / Sunnyholt Road intersection for AM and PM peak respectively.

Table 4-8 Forecast Level of Service at Windsor Road / Memorial Avenue Intersection

ID	Intersection	Control Type	Peak Period	2019(1)		2026(1)		2036(2)	
				Average Delay (sec)	LoS	Average Delay (sec)	LoS	Average Delay (sec)	LoS
I-2	Windsor Road / Memorial Avenue	Traffic Signals Upgraded	AM	42	D	47	D	49	D
			PM	36	C	39	C	39	C

Note: (1) LoS result is based on Scenario 2, (2) LoS result is based on Scenario 3,
Source: Paramics
Models:
2019 Models: F:\AA006569 \Traffic Modelling\PARAMICS\1-Models\2019 Future
2026 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2026 Future
2036 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\Sensitivity Test_Aug2014
Spreadsheet: F:\AA006569\Traffic Modelling\PARAMICS\3-Spreadsheets\3- LOS\Final LoS run_12062014

The at-grade upgrades to existing traffic signals at Windsor Road/Memorial Avenue intersection would substantially improve traffic capacity and level of service. With upgrades in place, model forecasts acceptable level of service C and D in 2036 for morning and afternoon peak periods. Should at-grade upgrades to the Windsor Road / Memorial Avenue intersection proceed concurrently with Memorial Avenue four lane upgrade, then identified upgrades will have a service life up to 2036.

4.6 Upgrade at Windsor Road/Wrights Road Intersection

Upgrade Description

New traffic signals and associated upgrades are proposed to be constructed at some stage in the future by The Hills Shire Council at the Windsor Road/Wrights Road intersection. Figure 4-5 below shows four way intersection footprints identified at Windsor Road / Wrights Road traffic signals. The western approach will from the new fourth leg of the intersection serving development in this area.

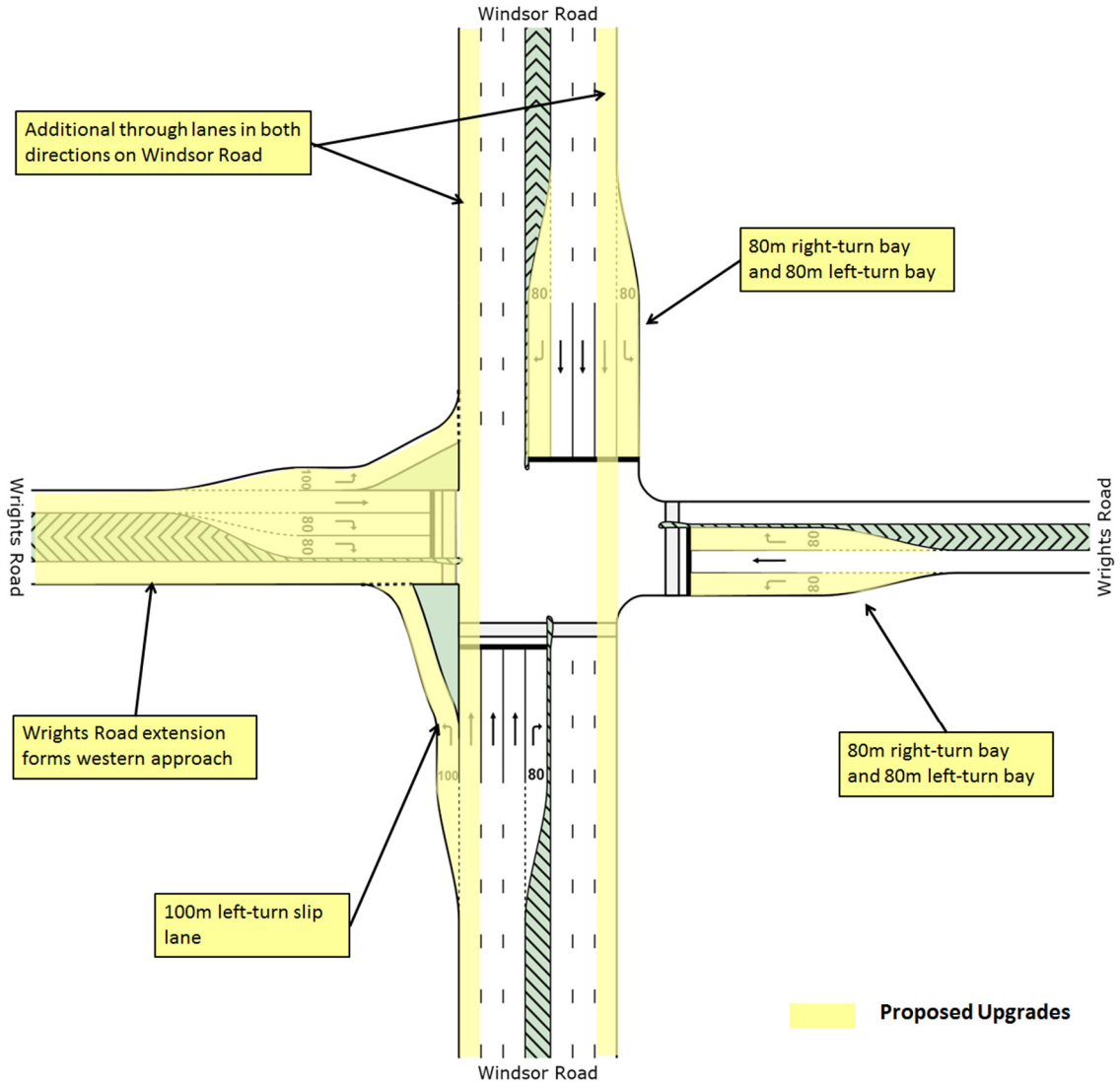


Figure 4-5 Proposed layout of Windsor Road and Wrights Road intersection

The following lane configurations are proposed based on traffic modelling:

Intersection	Control Type	Indicative Description
Windsor Road / Wrights Road	New Traffic Signals	A four way signalised intersection upgrade including: ▪ The western approach (new road) becomes the fourth leg of signalised intersection; ▪ Provide southbound double right turn bay at 80m on Wrights Road; ▪ Provide northbound right turn bay at 80m with slip lane on Wrights Road; ▪ Additional southbound through lane on Windsor Road; ▪ Additional northbound through lane on Windsor Road; ▪ Additional southbound exit lane on Windsor Road; ▪ Additional northbound exit lane on Windsor Road; ▪ Provide eastbound left turn bay with slip lane from Windsor Road to Wrights Road; ▪ Provide westbound right turn bay at 80m on Windsor Road; ▪ Provide eastbound left turn bay at 80m on Windsor Road; ▪ Provide northbound right turn bay at 80m on Wrights Road; ▪ Provide southbound right turn bay at 80m on Wrights Road.

Traffic Implications

Future traffic performance of the new four way traffic signals at Windsor Road / Wrights Road was assessed for 2026 and 2036 for both AM and PM peak period. The identified four way intersection footprints at Windsor Road / Wrights Road traffic signals would provide level of service B in 2026 and 2036 respectively.

Table 4-8 below shows delay and level of service for upgraded Windsor Road / Wrights Road intersection for AM and PM peak respectively.

Table 4-9 Forecast Level of Service at Windsor Road / Wrights Road Intersection

ID	Intersection	Control Type	Peak Period	2026		2036	
				Average Delay (sec)	LoS	Average Delay (sec)	LoS
I-2	Windsor Road / Wrights Road	New Four way Traffic Signals	AM	19	B	18	B
			PM	16	B	17	B

Note: (1) LoS result is based on Scenario 3
Source: Paramics
Models:
2019 Models: F:\AA006569 \Traffic Modelling\PARAMICS\1-Models\2019 Future
2026 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2026 Future
2036 Models: F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2036 Future
Spreadsheet: F:\AA006569\Traffic Modelling\PARAMICS\3-Spreadsheets\3- LOS\Final LoS run_12062014

4.7 Impact on other travel modes

4.7.1 Bus services

With the Memorial Avenue upgrade in place, there will be no impact to current bus routes. The existing Burns T-way that runs parallel to Old Windsor Road and the dedicated bus lanes at the Old Windsor Road/Memorial Avenue intersections would be retained.

The Concept Design proposes dedicated bus lanes with bus priority at traffic signals and indented bus bays on both sides of Memorial Avenue. Bus priority lanes (i.e. queue-jump lanes) will be provided at new traffic signals on Memorial Avenue at Arnold Avenue and Severn Vale Drive to allow buses a head start in the east/west directions along Memorial Avenue. This will provide more efficient operation of bus services. Figure 4-6 shows bus priority lanes proposed at Arnold Avenue and Severn Vale Drive intersections.

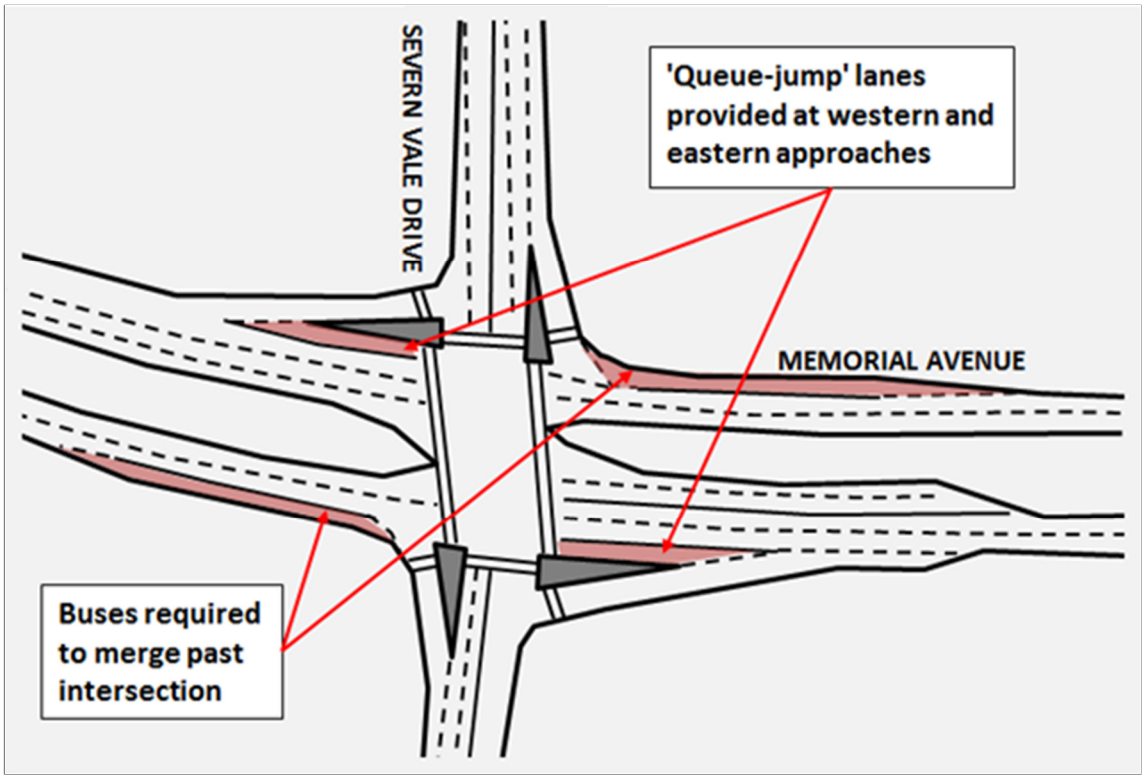


Figure 4-6 Bus priority lanes provided at Arnold Avenue and Severn Vale Drive intersections

4.7.2 Pedestrians and Cyclists

Provision of an off road shared pedestrian/cyclist path on both sides of Memorial Avenue between Old Windsor Road and Windsor Road is proposed as part of the project. Pedestrian crossings will be provided on all approaches at new traffic signals at Memorial Avenue / Arnold and Memorial Avenue / Severn Vale Drive. A refuge island will be provided at the Memorial Avenue / Burns Road intersection across the Burns Road. These pedestrian crossing facilities will provide connectivity between north and south of Memorial Avenue.

Figure 4-7 shows proposed pedestrian and cyclist facilities along Memorial Avenue.

The proposed intersection upgrades at Old Windsor Road / Memorial Avenue / Sunnyholt Road and Windsor Road / Memorial Avenue would retain the existing cyclist and pedestrian crossing facilities. Existing pedestrian crossings at Burns T-way intersection (southern approach) would be retained.

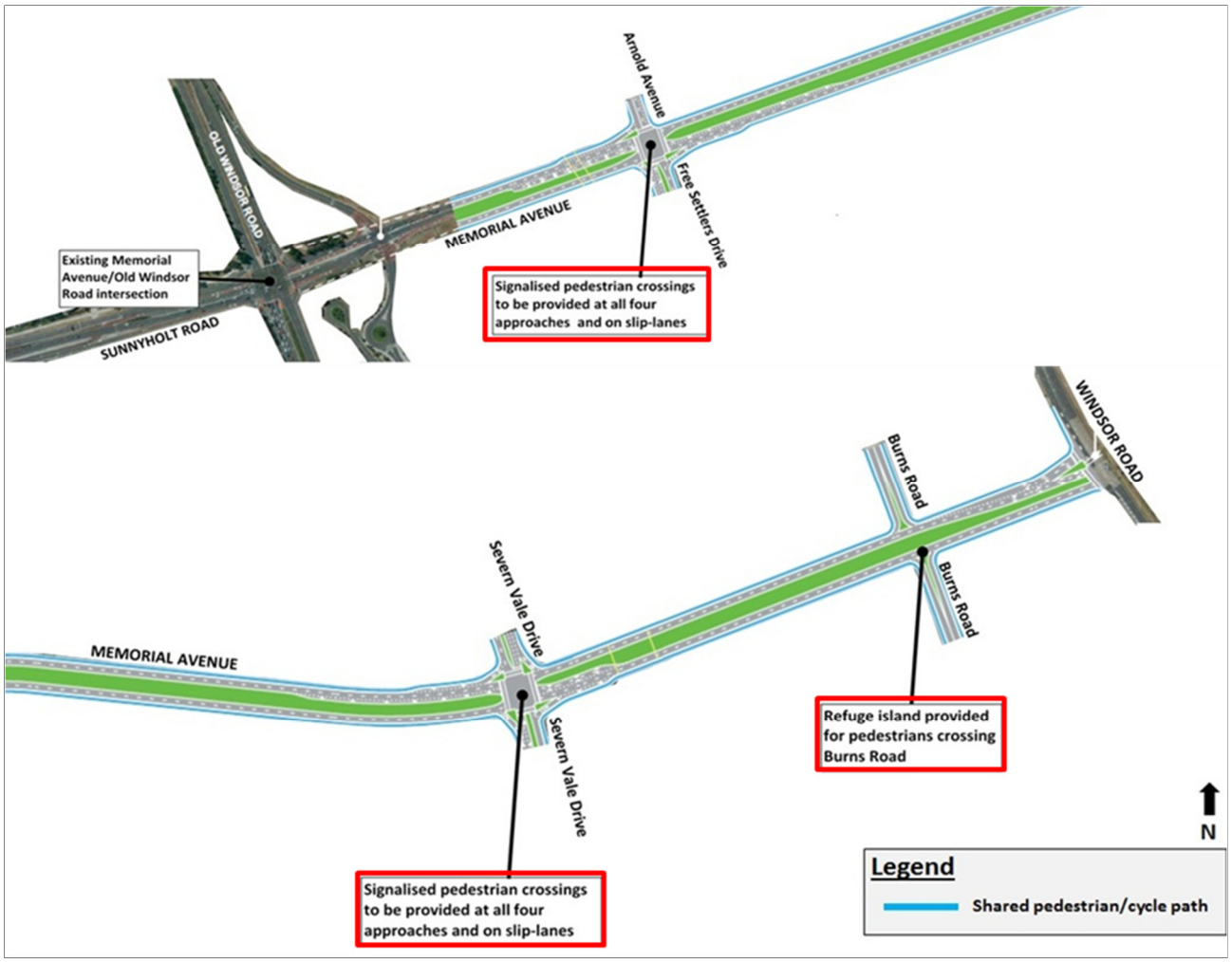


Figure 4-7 Proposed Provisions for Pedestrian and Cyclists

5 SUMMARY OF FINDINGS

Overview

Memorial Avenue is a key strategic route and provides access to Blacktown, Glenwood, Stanhope Gardens, Parklea, Baulkham Hills, Castle Hill and Kellyville. The road provides an east west connection between the Old Windsor Road and Windsor Road. It is located in the suburb of Kellyville within The Hills Shire Council Local Government Area (LGA). Memorial Avenue is currently a two-lane two-way road. It is designated B Double route for trucks up to 26 metres long.

Roads and Maritime Services NSW (RMS) is planning an upgrade of the Memorial Avenue from Old Windsor Road to Windsor Road to improve traffic flow and safety. The proposed upgrade involves widening Memorial Avenue to four lanes (two lanes in each direction) and associated upgrades to key intersections with Old Windsor Road, Windsor Road, Arnold Avenue and Severn Vale Drive.

The purpose of Hyder's traffic and transport study was to assess the performance of Memorial Avenue and assess the likely performance of the proposed upgrades. A road based micro-simulation traffic model was developed for the study area using the Paramics software. Hyder supplemented this assessment with SIDRA models to assess the performance of individual intersections.

Both Paramics and SIDRA models were used to identify:

- Key network issues that affect the performance of Memorial Avenue and adjoining roads;
- Long term options for improvements to traffic flow, including an assessment of the likely performance of intersection upgrade options (at-grade versus grade separation); and
- Identify the timing of interim and long term intersection upgrades required at both Memorial Avenue/Old Windsor Road and Memorial Avenue/Windsor Road intersections.

A consultation process involving RMS constituted an important element of the Study. This included presentation of traffic modelling outcomes to RMS, a value management workshop, and participation in design meetings. During the course of the Study, five technical notes were submitted to RMS with respect to development of the traffic modelling as follows:

- Technical Note 1 – Traffic Survey Requirements;
- Technical Note 2 – Traffic Modelling Assumptions;
- Technical Note 3 – Balmoral Road Release Area (BRRA) Land Development Assumptions in the EMME Model;
- Technical Note 4 – Paramics Model Development, Calibration & Validation Report; and
- Technical Note 5 – Traffic Performance of New Traffic Signals at Memorial Avenue / Arnold Avenue and Memorial Avenue / Severn Vale Drive.

Feedback from RMS staff was incorporated in the traffic and transport study findings at various stages of Hyder's investigation.

Key issues

In 2014, Memorial Avenue between Old Windsor Road and Windsor Road carried about 25,000 vehicles per day. This includes approximately 1,700 heavy vehicles (7% of total traffic). In the morning and afternoon peak periods Old Windsor Road / Sunnyholt Road / Memorial Avenue and Windsor Road / Memorial Avenue intersections carried significant traffic volumes. The turning traffic into and out of Memorial Avenue, Sunnyholt Road, Windsor Road and Old

Windsor Road varied from 100 vehicles to 1,000 vehicles in one hour. The high through traffic on Old Windsor Road, Windsor Road, Sunnyholt Road, Memorial Avenue and relatively high turning traffic into and out of these roads are significant contributing factors to traffic congestion. In both morning and afternoon peak, travel speeds reduce significantly along the section of Memorial Avenue between Old Windsor Road and Windsor Road. This can be as much as 25km/h less than the posted speed limit (60-70km/h).

Substantial traffic delays occur in both morning and afternoon peak periods, resulting in long traffic queues along Old Windsor, Windsor Road, Sunnyholt Road and Memorial Avenue. The long delays are caused by current capacity constraints at Old Windsor Road/Sunnyholt Road/Memorial Avenue and Windsor Road/Memorial Avenue intersections.

The modelling has predicted a traffic level of service F (over capacity) at Old Windsor Road/Memorial Avenue/Sunnyholt Road traffic signals in both morning and afternoon peak periods. The model predicted level of service D (near capacity) at the Windsor Road/Memorial Avenue traffic signals.

Future traffic volumes on Memorial Avenue

Future traffic volumes on Memorial Avenue (*sourced from RMS's EMME model*) have taken into account passing traffic growth due to land developments in the North West Growth Centre, new development traffic from about 5,400 dwellings proposed in Balmoral Road Release Area, and potential reduction of car mode attributable to the North West Rail Link. Traffic forecasts were prepared for three future years of 2019, 2026 (interim) and 2036 (ultimate). In 2019 traffic on Memorial Avenue is projected about 33,000 vehicles per day. By 2026, traffic is forecast to grow in the order of 42,000 vehicles per day. In 2036, traffic on Memorial Avenue is forecast in the order of 45,000 vehicles per day, almost double that of today's traffic.

Memorial Avenue upgrade

The Concept Design of the Memorial Avenue upgrade proposes key access and egress points to the Balmoral Road Release Area via two new signalised intersections at Arnold Avenue and Severn Vale Drive. The intersection footprints at the Arnold Avenue and Severn Vale Drive were determined based on forecast traffic flows for 2019, 2026 and 2036. Intersection modelling results suggested that traffic signals at Arnold Avenue/Memorial Avenue and Severn Vale Drive/Memorial Avenue would operate at an acceptable level of service during the morning and afternoon peak hour. Both traffic signals would perform level of service C or above in 2019 and level of service D or better in ultimate year 2036 and therefore provide adequate capacity and operational efficiency in the long-term.

Interim and Longer Term Upgrades

Interim and longer term capacity improvements at the Old Windsor Road/Memorial Avenue/Sunnyholt Road signalised intersection and the Windsor Road/Memorial Avenue signalised intersection were identified by assessing three modelling scenarios as follows:

- *Scenario 1*: Scenario 1 assumed a four lane upgrade (2/2) on the entire length of Memorial Ave. The future lane configurations and network connections are assumed in line with the Concept Design. In this scenario 1, no upgrades are assumed at the Old Windsor Road/Memorial Avenue/Sunnyholt Road signalised intersection and Windsor Road/Memorial Avenue signalised intersection. Scenario 1 identified the need for 'at-grade' improvements at two existing signalised intersections with Memorial Avenue at Old Windsor Road and Windsor Road.
- *Scenario 2*: Scenario 2 is built on scenario 1. In this scenario, at grade upgrades was tested at Old Windsor Road/Memorial Avenue/Sunnyholt Road and Windsor Road/Memorial Avenue signalised intersection. Scenario 2 identified the timing and service life of at grade

upgrades. The modelling of scenario 2 also identified the need for a grade separation at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection.

- *Scenario 3*: Scenario 3 is built on scenario 2. In this scenario, a grade separated upgrades was tested at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection. This scenario tested at-grade upgrades at Windsor Road/Memorial Avenue signalised intersection.

The traffic modelling scenarios assessment found that:

1. At-grade upgrades to the existing signalised intersection at Old Windsor Road/Memorial Avenue/Sunnyholt Road would substantially improve traffic capacity and level of service. The upgrade consists of widening Old Windsor Road at both northern and southern approaches and departures and extension of the left turn slip lane on Memorial Avenue approach. With these upgrades in place, the model forecasts level of service E in 2019 for morning and afternoon peak periods.

2. Should at-grade upgrades to Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection proceed concurrently with Memorial Avenue four lane upgrade, then the identified intersection upgrades will have a service life up to 2026.

3. The need for grade separation at Old Windsor Road/Memorial Avenue/Sunnyholt Road intersection is identified after 2026. The assessment found that a grade separated upgrade would provide acceptable levels of service C and D in 2036 for the morning and afternoon peak periods respectively.

4. At-grade upgrades to the existing signalised intersection at Windsor Road/Memorial Avenue would substantially improve traffic capacity and level of service. The upgrade consists of widening Windsor Road at both northern and southern approach and departure sides. With these upgrades in place, the model forecasts an acceptable level of service C and D in 2036 for morning and afternoon peak periods; and

5. Should at-grade upgrades to Windsor Road/Memorial Avenue intersection proceed concurrently with Memorial Avenue four lane upgrade, then the identified intersection upgrades will have a service life up to 2036.

APPENDIX A

TRAFFIC SURVEY AND DATA REQUIREMENTS (TECHNICAL NOTE 1)

Memorial Avenue Upgrade - Traffic and Transport Assessment

Date of Submission: 24th of January 2014

Technical Note 1 – Updated Traffic Survey Requirements

Hyder engaged Skyhigh to undertake the traffic survey commencing on Monday 10th February 2014. Hyder met RMS on 29 January14 discussing traffic survey sites and program. In agreement with RMS, traffic survey sites have been reviewed. It was agreed that turning movement counts at two intersections with Old Windsor Road / Memorial Avenue / Sunnyholt Road (I-1) and Windsor Road / Memorial Avenue (I-2) will be conducted over 2 days period on Tuesday 11th February 2014, and Wednesday 12th February 2014. Two additional bus only TCS (traffic signals) sites are included in the survey. They are:

- TCS 4093 (bus only) signals on Sunnyholt Road;
- TCS 4083 (bus only) signals on Memorial Av.

The followings provide detail of the traffic surveys.

- Table 1 shows the survey dates.
- Table 2 summarises the traffic surveys.
- Tables 3 to Table 6 summarises the survey locations.
- Figures 1 to 4 show survey locations graphically.

Table 1 Data for Survey

Survey Type	Dates	Intersection Counts
1. Intersection movement counts	Tuesday 11th, February, 2014	All 9 intersections showed in Figure 1.
	Wednesday12th, February, 2014	▪ Old Windsor Road / Memorial Avenue / Sunnyholt Road (I-1) and ▪ Windsor Road / Memorial Avenue (I-2)
2. Intersection queue length surveys	Tuesday 11th, February, 2014	4 intersections as per Figure 2.
3. Midblock tube counts	Monday 10th February to Sunday 17th February, 2014	2 locations (M1 and M3) as per Figure 1.
4. Origin destination (OD) surveys	Tuesday 11th, February, 2014	6 sites as per Figure 3.
5. Travel Time survey	Tuesday 11th, February, 2014	One route as per Figure 4.

Table 2 Traffic Survey Type

Survey Type	Quantity	Survey Method	Time Period
1. Intersection movement counts including pedestrian (see Table 3 for locations)	9 intersections	▪ Movement counts using video camera. ▪ Classification counts (cars, buses and heavy vehicles)	▪ AM peak 3 hours: 6am to 9am ▪ PM peak 3 hours: 3pm to 6pm
2. Intersection queue length surveys (see Table 3 for locations)	4 intersections	▪ Queue length survey by using video camera.	▪ AM peak 3 hours: 6am to 9am ▪ PM peak 3 hours: 3pm to 6pm
3. Midblock tube counts (see Table 4 for locations)	2 locations	▪ Traffic counts using automatic tube count (ATC) method. ▪ Vehicle classification, as per Austroads 12 vehicle classes. ▪ Record period 7 day, 24 hours	▪ 7 days / 24 hours
4. Origin destination (OD) surveys (see Table 5 for locations)	6 locations (bi-directional)	▪ OD survey using video record. ▪ Classification survey (cars, buses and heavy vehicles)	▪ AM peak 3 hours: 6am to 9am ▪ PM peak 3 hours: 3pm to 6pm
5. Travel time surveys (see Table 6 for routes)	1 route (bi-directional)	▪ Travel time survey using GPS record. ▪ Require minimum 5 runs. ▪ Require statistic in maximum, minimum and average.	▪ AM peak 3 hours: 6am to 9am ▪ PM peak 3 hours: 3pm to 6pm

Table 3 Intersection Survey Locations (see Figures 1 and 2)

ID	Intersection	Control Type	Intersection Movement Counts	Pedestrian Counts	Queue Length Survey
I-1	Old Windsor Road / Memorial Avenue	Signal	Full Counts	Yes	Yes
I-2	Windsor Road / Memorial Avenue	Signal	Full Counts	Yes	Yes
I-3	President Road / Windsor Road	Signal	Full Counts	Yes	Yes
I-4	Wrights Road / Windsor Road	Priority	Full Counts		Yes
I-5	Memorial Ave / Arnold Ave (West)	Priority	Turning Movements In and Out		
I-6	Memorial Ave / Arnold Ave (East)	Priority	Turning Movements In and Out		
I-7	Memorial Avenue / Hector Crescent	Priority	Turning Movements In and Out		

ID	Intersection	Control Type	Intersection Movement Counts	Pedestrian Counts	Queue Length Survey
I-8	T-way signal on Sunnyholt Road (TCS 4093)	T-way Signal	Bus Movements only		
I-9	T-way signal on Memorial Avenue (TCS 4083)	T-way Signal	Bus Movements only		

Table 4 Midblock Tube (ATC) Count Locations (see Figure 1)

ID	Road	Location
M-1	Memorial Avenue	At Elizabeth Macarthur Creek
M-3	Memorial Avenue	At Strangers Creek

Table 5 Origin-Destination Survey Locations (see Figure 3)

ID	Road	Location (bi directional)
O-1	Sunnyholt Road	West of Old Windsor Road
O-1	Sunnyholt Road	West of Old Windsor Road
O-2	Old Windsor Rd (excluding T-Way Busway)	North of Memorial Road
O-3	Old Windsor Rd (excluding T-Way Busway)	South of Memorial Road
O-4	Windsor Road	Immediately north of Memorial Avenue
O-7	Windsor Road	Immediately south of Memorial Avenue
O-8	Memorial Avenue	Midblock

Table 6 Travel Time Survey Routes (see Figure 4)

ID (see Figure 5)	Route
Route 1	Memorial Avenue between Old Windsor Road and Windsor Road

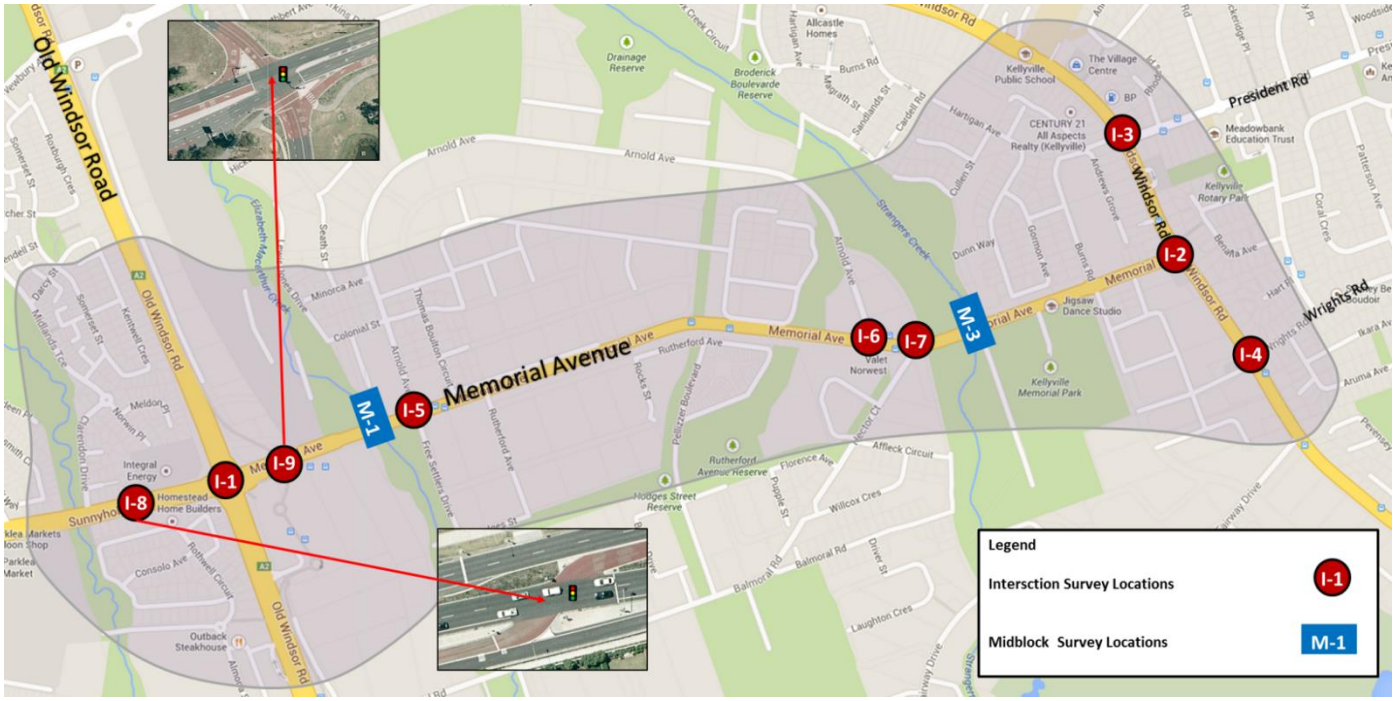


Figure 1 Traffic Count Locations - Intersection and Midblock

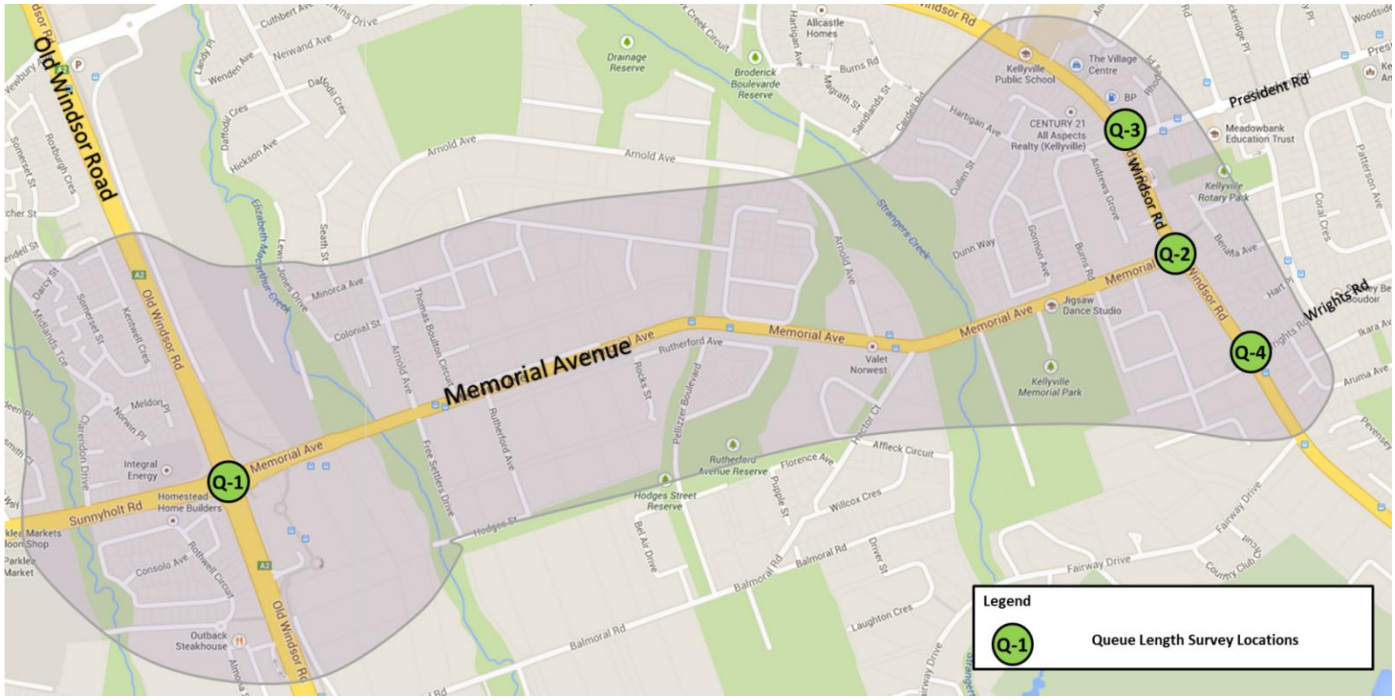


Figure 2 Queue Length Survey Locations

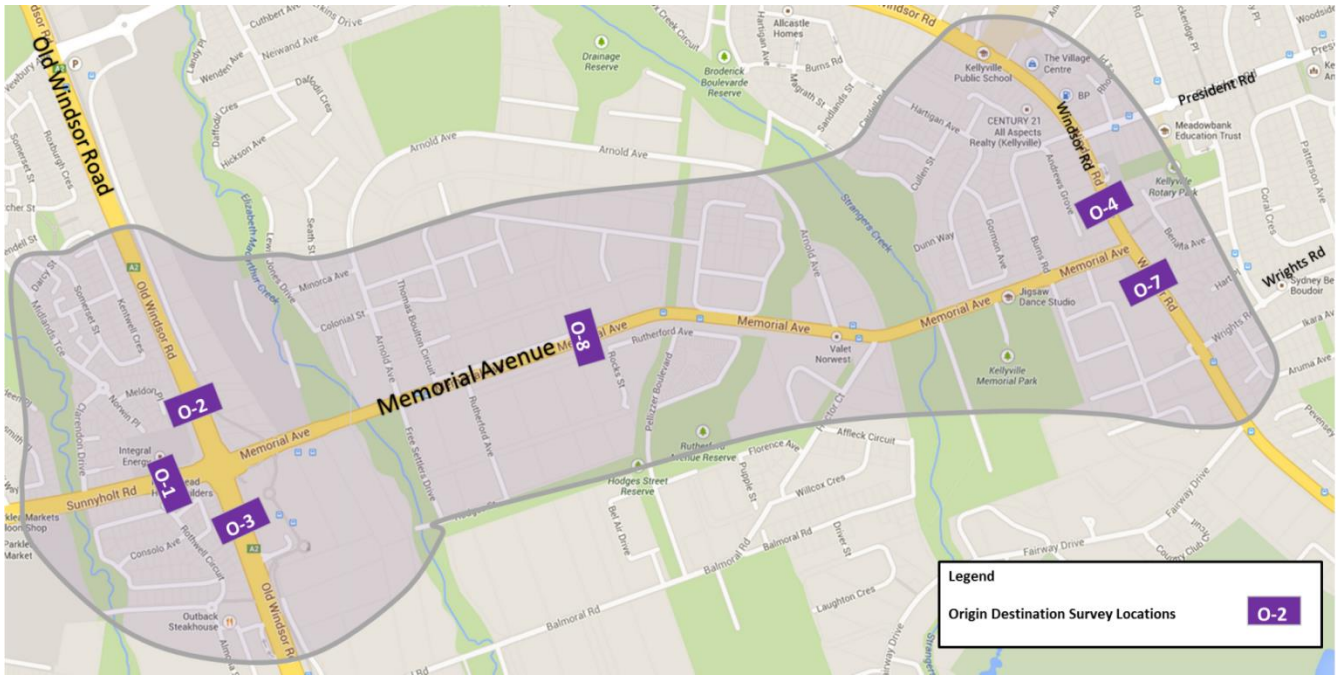


Figure 3 **Origin Destination Survey Locations (bi-directional)**

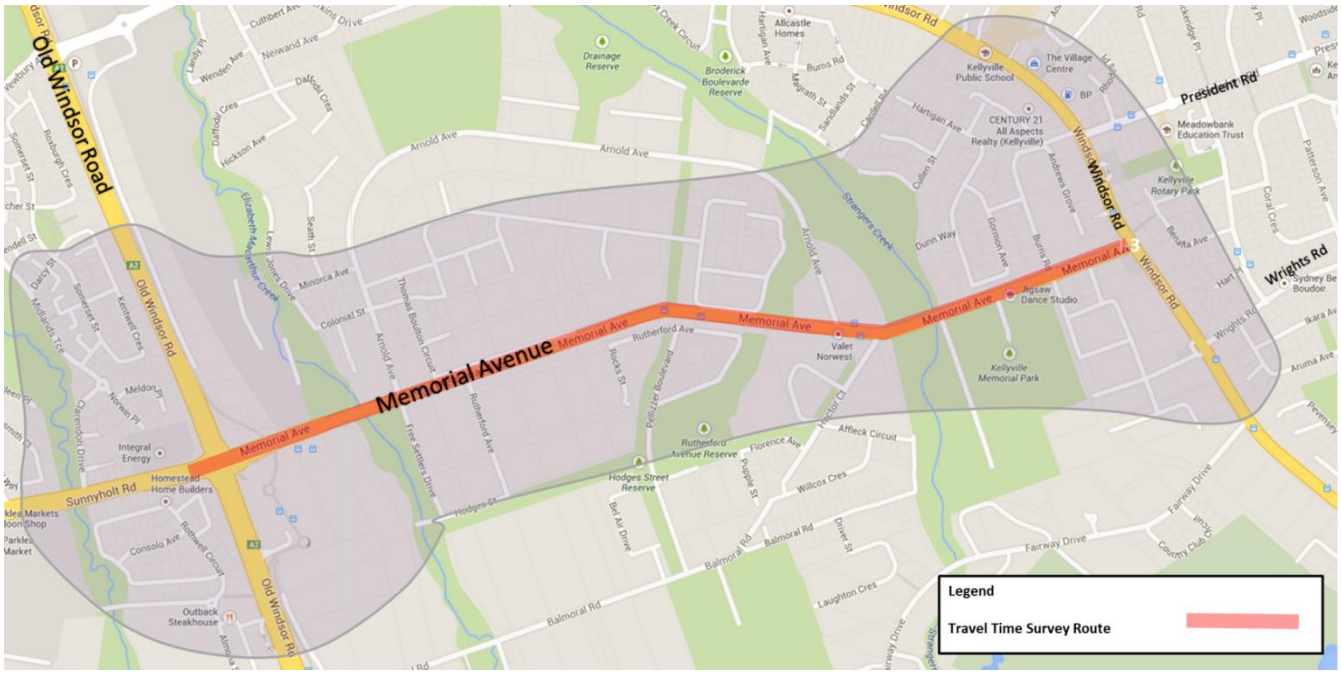
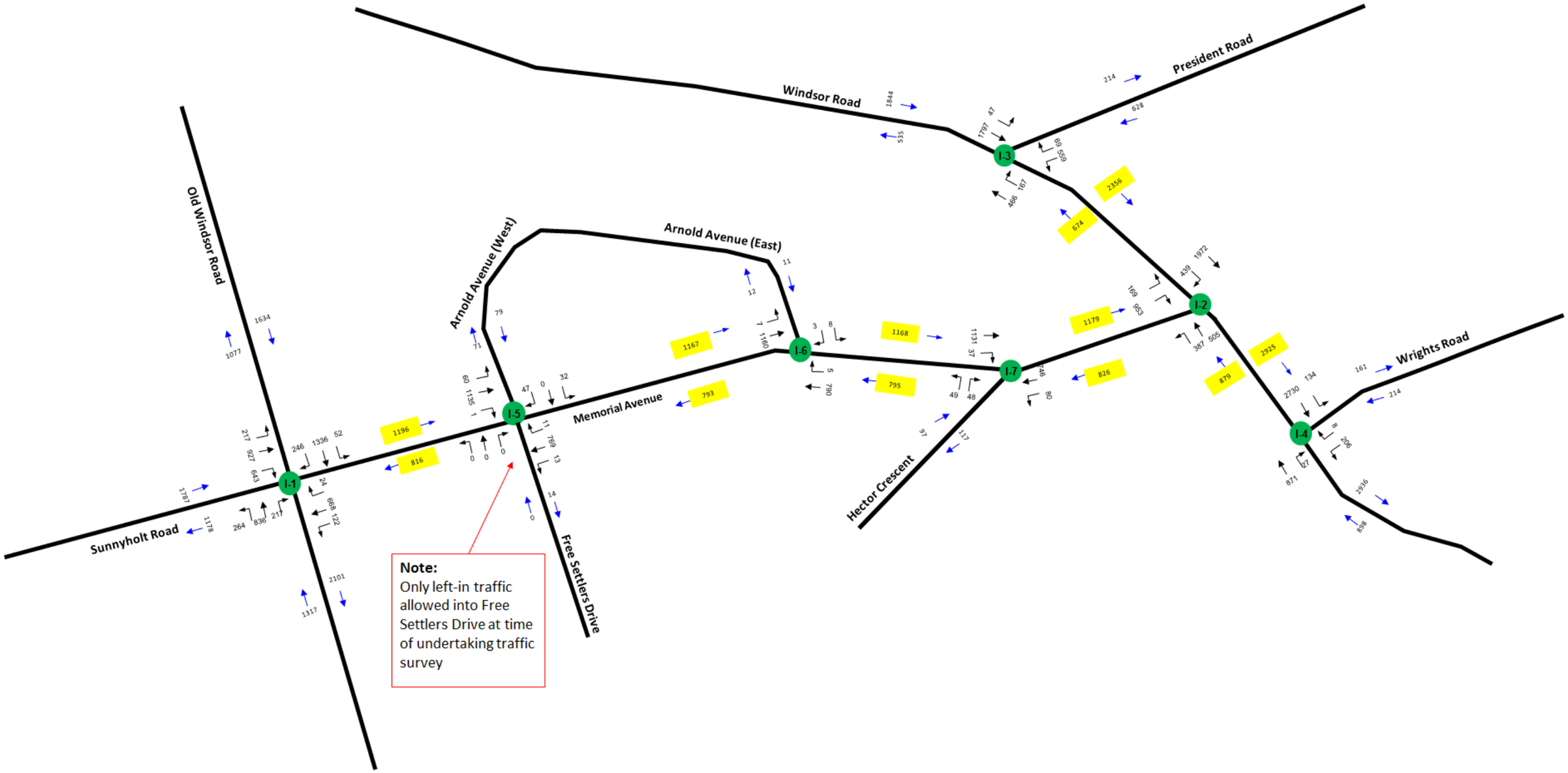


Figure 4 **Travel Time Survey Routes (bi-directional)**

APPENDIX B

INTERSECTION TURNING MOVEMENT COUNTS

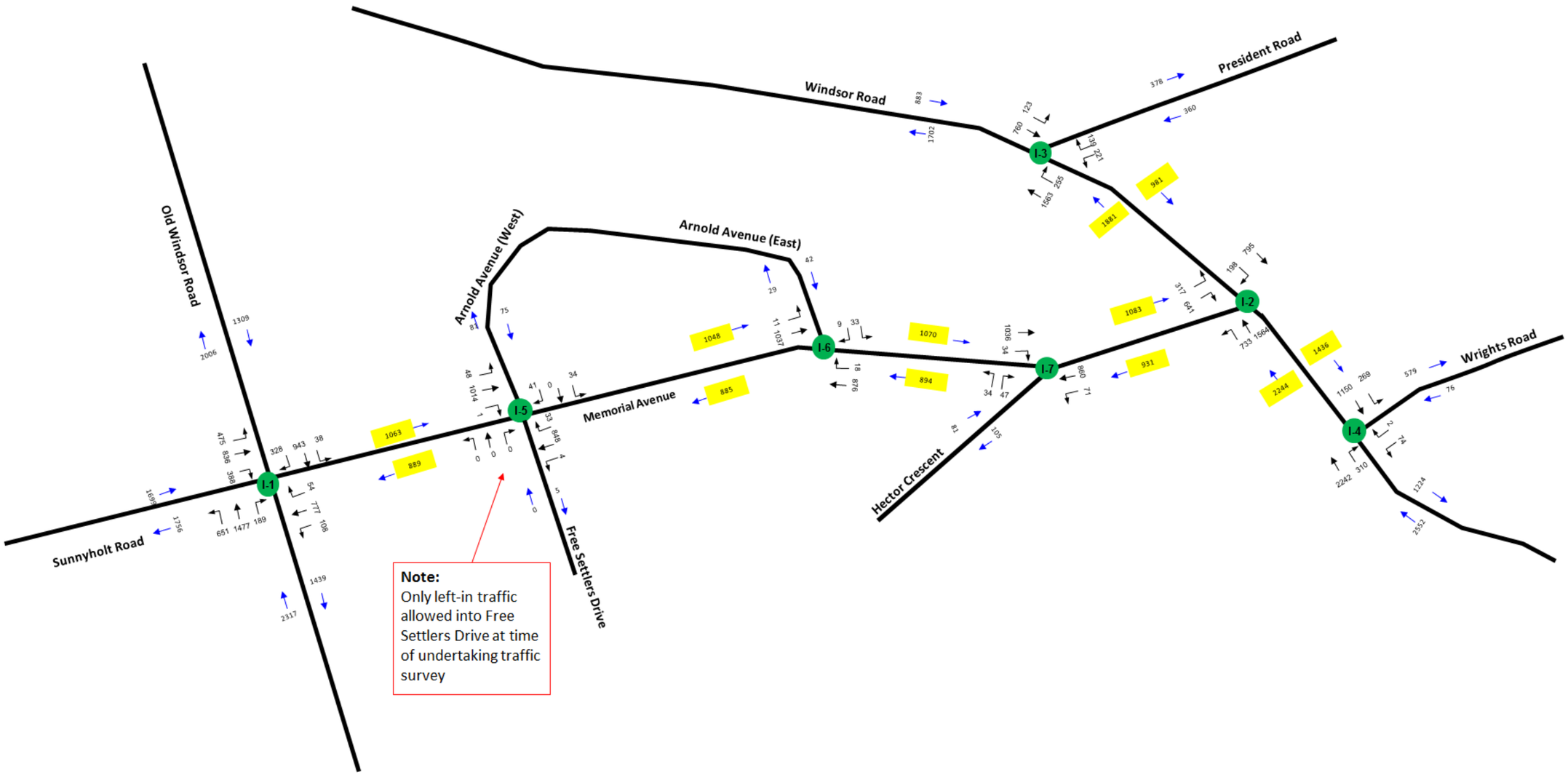
Turning Volumes for AM Peak Hour (Existing 2014)



Note: The highest peak hour for AM was 7:15 AM to 8:15 AM

Survey by Skyhigh Traffic Survey Company on 11th February 2014

Turning Volumes for PM Peak Hour (Existing 2014)



Note: The highest peak hour for PM was 4:15 PM to 5:15 PM

Survey by Skyhigh Traffic Survey Company on 11th February 2014

APPENDIX C

TRAFFIC MODELLING ASSUMPTIONS AND PARAMICS MODEL DEVELOPMENT, CALIBRATION AND VALIDATION REPORT (TECHNICAL NOTES 2 AND 4)

Memorial Avenue Upgrade - Traffic and Transport Assessment

Date of Submission: 19th of March 2014

Technical Note 2: Traffic Modelling Assumptions

1 Purpose of This Technical Note

This Technical Note 2 has been updated since original submission on 19 March14. Modelling data and information superseded since March 2014 were removed or updated as relevant.

The purpose of this Technical Note 2 was to summarise key traffic modelling assumptions which formed the basis of Memorial Avenue upgrade. As per the study brief a Paramics model was developed by Hyder.

2 Model Study Area

The model study area includes about 2.2 km long Memorial Avenue corridor between Old Windsor Road and Windsor Road. Figure 1 below shows model study area.

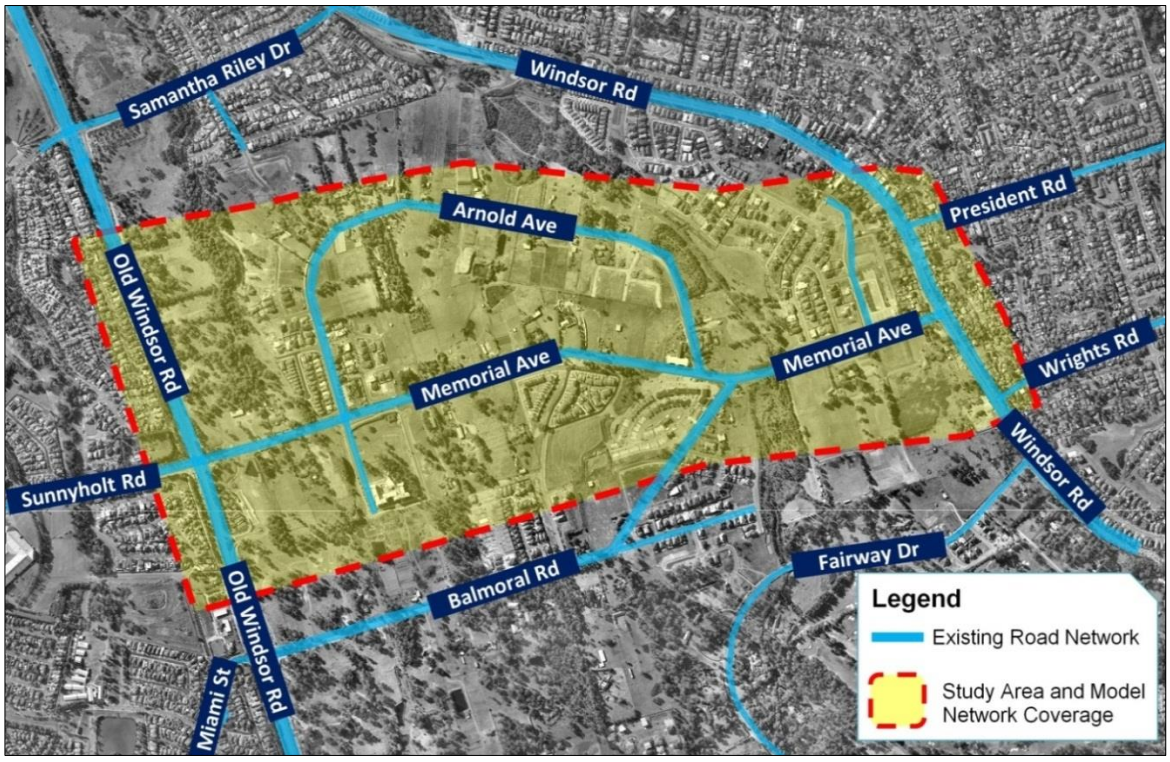


Figure 1 Model Study Area

3 Road Hierarchy

For modelling purpose a road hierarchy is defined for the study area. Memorial Avenue, Old Windsor Road and Windsor Road are State Roads. The remaining roads within the study area are classified as local roads including Arnold Ave, Balmoral Road. Figure 2 below shows road network hierarchy for modelling purpose.

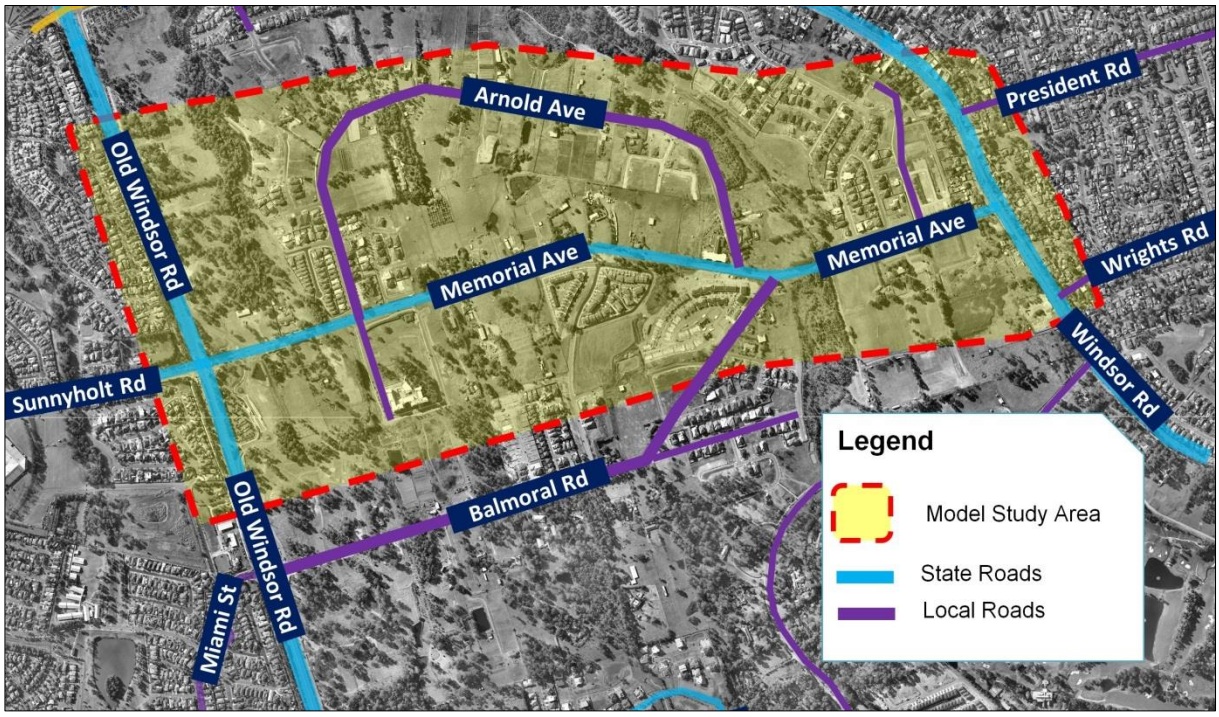


Figure 2 Road Network Hierarchy in the Model Study Area

4 Traffic Modelling

The Paramics micro-simulation traffic models were developed for base case (2014), 2019, interim (2026) and ultimate (2036) years, for AM, PM peak periods traffic conditions.

Paramics modelling includes an assessment of existing and future traffic conditions on the Memorial Avenue including key intersections within the study area. The following assumptions were made for modelling purpose:

- Base Case. The base case is defined as traffic conditions as per 2014;
- Future year 2019
- Future interim year 2026 ; and
- Future ultimate year 2036.

4.1 Paramics Model

The traffic model was built using the latest version of Paramics software V6.9. Both morning and afternoon peak periods are modelled including:

- AM Peak period (two-hours) between 7:00-9:00; and
- PM Peak period (two-hours) between 16:00-18:00.

In addition, a pre loading “warm-up” period for 30 minutes and post peak “cool down” period for 30 minutes will be applied in the AM and PM peak periods. The demand trip table includes two vehicle types:

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

The calibration and validation criteria are based on the latest RMS modelling guideline *Traffic Modelling Guidelines, V.1.0, RMS, February 2013*.

4.2 Data Input

Following data sources were used in Paramics model development, calibration and validation:

- New traffic survey data including intersection movement counts, intersection queue length surveys, mid-block ATC counts, travel time and origin-destination (OD) surveys in the study area. New traffic surreys have been undertaken from 10th February 2014 to 17th February 2014.
- Geo-referenced aerial photography.
- Population and employment forecast data for the study area at travel zone, provided by RMS.
- Traffic modelling plots for 2011/12, 2016, 2026 and 2036 from RMS’s EMME Sydney Strategic Traffic Model. The EMME plots represent AM peak 2 hours volumes. RMS also provided daily traffic plots.
- Discussions with RMS indicated that EMME modelling used trip tables from BTS. The BTS trip tables include potential car traffic reductions in the study area due to North-West Rail Link project.
- SCATS Intersection Diagnostic Monitor (IDM) data and Traffic Control Signal plans provided by RMS. The IDM was run by RMS on the same day of traffic survey.
- Public transport data.
- Site visit undertaken by Hyder staff on Thursday, 6th February 2014 to observe traffic conditions (morning and afternoon) and issues associated with congestion/network operations.

4.3 Future Road Upgrade

Hyder reviewed the EMME model network plots provided by RMS.

Table 1 below shows timing of road upgrade projects assumed in RMS’s EMME model.

Table 1 Road Upgrade Projects assumed in RMS's EMME model

ID Ref	Road Upgrade	2026	2036
1	Memorial Avenue upgrade to four lanes (two-lanes in each direction) between Old Windsor Road and Windsor Road	✔	✔
2	Left in/Left out access at Burns Road on both sides of Memorial Avenue	✔	✔
3	Windsor Road upgrade to six lanes (three lanes in each direction) between Memorial Avenue and Showground Road	✔	✔
4	New link (Free Settlers Drive) between Memorial Avenue/Arnold Avenue (west) intersection and Balmoral Road	✔	✔
5	New link (Severn Vale Drive) between Memorial Avenue intersection and Balmoral Road and Fairway Drive	✔	✔
6	New link (Severn Vale Drive) between Memorial Avenue and Arnold Avenue (east)	✔	✔
7	Existing Hector Court will be converted to cul-de-sac (closed) south of Memorial Avenue	✔	✔
8	Existing Arnold Avenue east will be converted to cull-de-sac (closed) north of Memorial Avenue	✔	✔
9	New link (Ainsford Drive) between Arnold Avenue and Samantha Riley Drive	✔	✔
10	New link between Balmoral Road and Fairway Drive	✔	✔
11	New link between Balmoral Road and Celebration Drive	✔	✔

No future upgrades are proposed on the Old Windsor Road adjacent to the study area. Future new connections identified in RMS's EMME model are consistent with the Structure Plan for Balmoral Road Release Area, prepared by Hills Shire Council in 2012.

Figure 3 below shows graphically the location of future network upgrades assumed in RMS's EMME model.

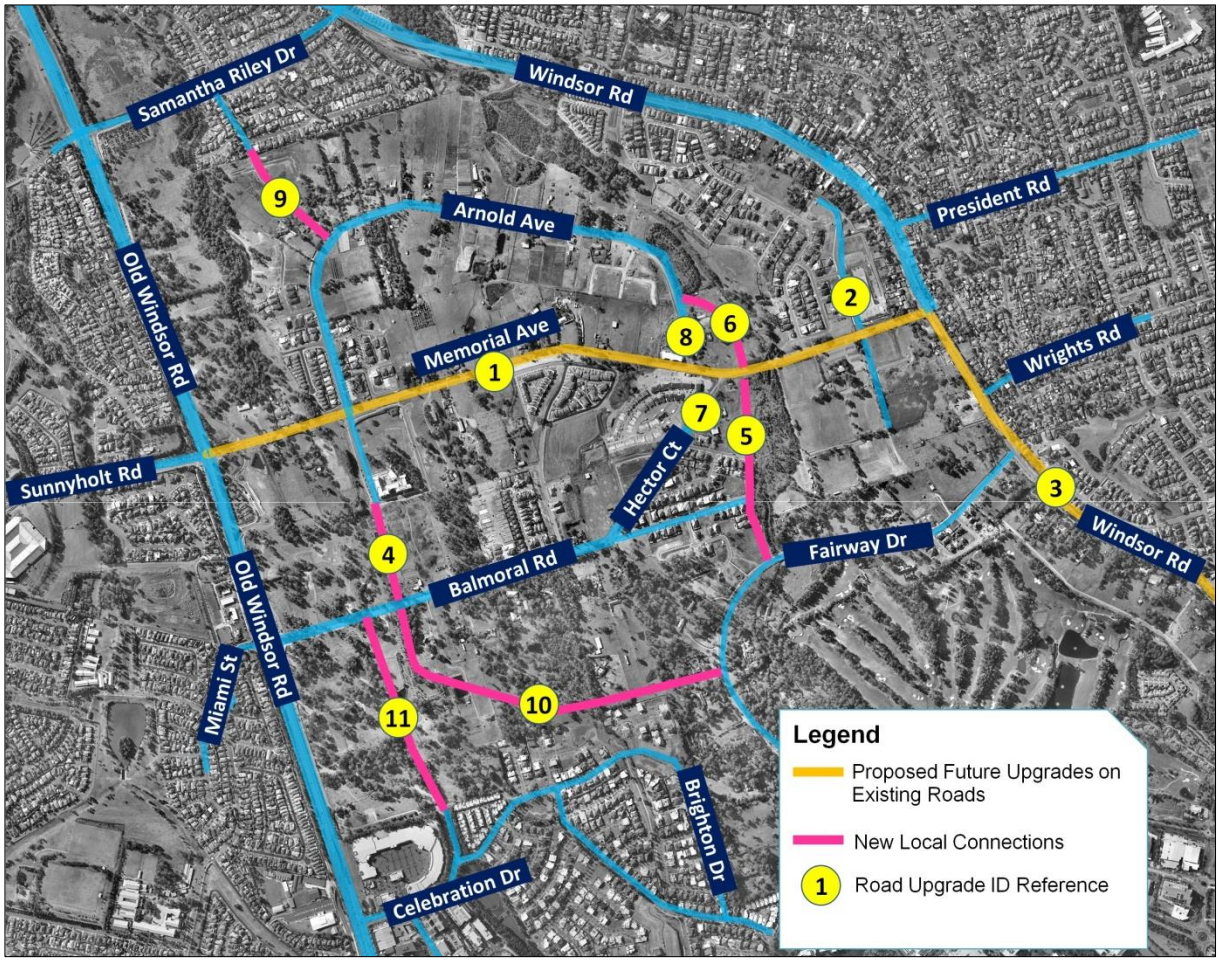


Figure 3 Future Road Upgrades

4.4 Future Traffic Growth

The population and employment projections are reported at travel zone level (refer to Figure 4).

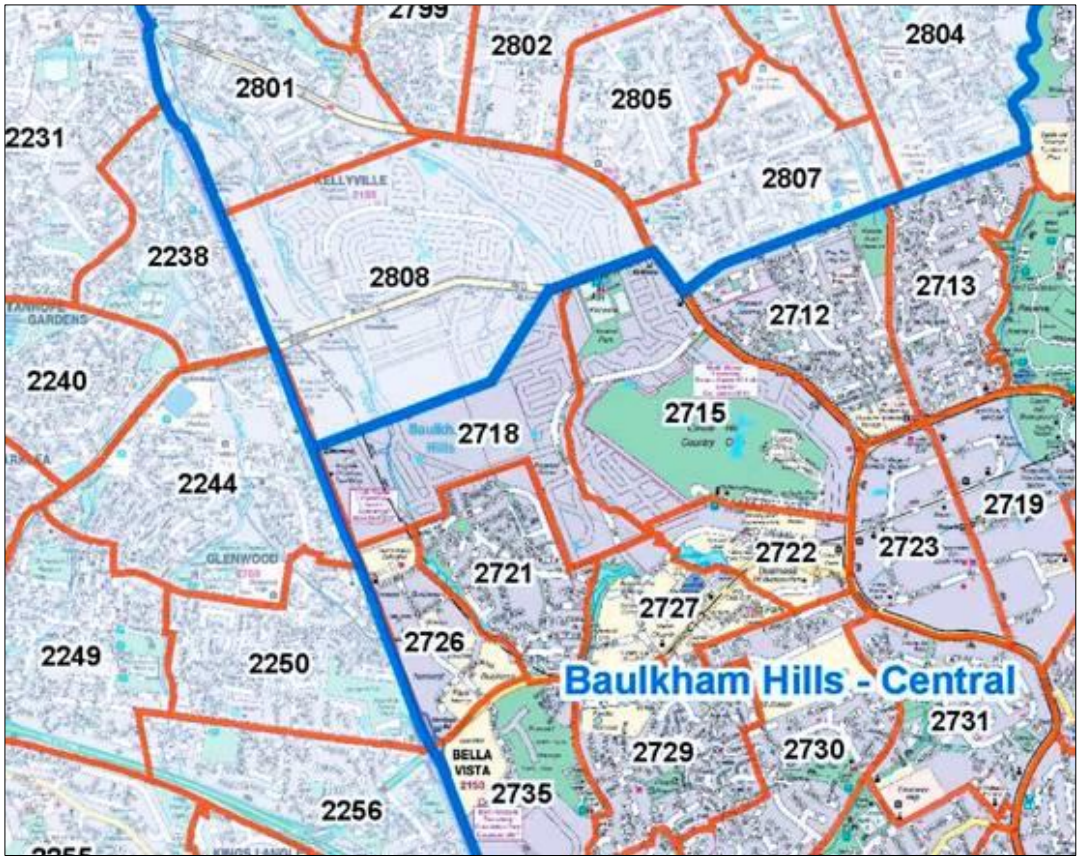


Figure 4 Travel Zones

Table 2 and Table 3 summarise population and employment growth for forecast year between 2016 and 2036 at 5 years intervals. The population and employment change compared to existing base case 2011 are also showed in Tables 2 and 3.

Table 2 Population Growth within Study Area

BTS Travel Zone ID	2011/12	2016	2021	2026	2031	2036
2715 Castle Hill Country Club	282	1,722	1,888	2,075	2,311	2,639
2718 Kellyville Christmas Tree Farm	131	1,298	1,432	1,584	1,775	2,041
2808 (1) The Village Centre	312	3,029	3,493	4,199	4,531	4,840
Total	**725**	**6,049**	**6,813**	**7,858**	**8,617**	**9,520**
Population increase compared to 2011		5,324	6,088	7,133	7,892	8,795
%		61%	69%	81%	90%	100% (2)

Source: RMS. Note : 1: The highest growth is predicted at TZ 2808 immediately adjacent to Memorial Av. 2: The model assumed that in 2036, Balmoral Road Release Area would be fully developed. In 2016, about 61% would be developed, followed by 69% in 2021, 81% in 2026 and 90% in 2031.

Table 3 Employment Growth within Study Area

BTS Travel Zone ID	2011/12	2016	2021	2026	2031	2036
2715 Castle Hill Country Club	76	138	151	166	185	209
2718 Kellyville Christmas Tree Farm	72	103	114	126	140	162
2808 (1) The Village Centre	370	483	557	669	720	769
Total	**518**	**724**	**822**	**961**	**1,045**	**1,140**
Employment increase compared to 2011		724	822	961	1,045	1,140
%		64%	72%	84%	92%	100%

Source: RMS.

Three travel zones 2715, 2718 and 2808 represent the entire Balmoral Road Release Area. However travel zone 2808 represents the core area (adjacent to Memorial Avenue) where significant growth is predicted (refer to Table 2).

The existing population and employment at Balmoral Road Release Area is very low. By 2016, about 5,300 additional populations are projected within the entire Balmoral Road Release Area (refer to Table 2). The population projections indicate that by 2016 a substantial development (about 61%) will occur in Balmoral Road Release Area. The full development within Balmoral Road Release Area is projected to occur by 2036.

Memorial Avenue Upgrade - Traffic and Transport Assessment

Date of Submission: 30th of April 2014

Technical Note 4: Paramics Model Development, Calibration & Validation Report

1 Introduction

This Technical Note 4 documents existing Base Case Paramics model development, model calibration and validation results for 2014 traffic conditions.

2 Paramics Model Development

The Paramics model was calibrated and validated based on the latest RMS modelling guideline *Traffic Modelling Guidelines, V.1.0, RMS, February 2013*.

The model represents existing 2014 traffic conditions for:

- AM Peak period (two-hours) between 7:00-9:00; and
- PM Peak period (two-hours) between 16:00-18:00.

In addition, a pre loading "warm-up" period for 30 minutes and post peak "cool down" period for 30 minutes were applied to AM and PM peak periods.

2.1 Data Sources

The following data sources were used in Paramics model development, calibration and validation purposes:

- New traffic survey data including intersection movement counts, intersection queue length surveys, midblock ATC counts, travel time and origin-destination (OD) surveys in the study area. New traffic surreys were undertaken from 10th February 2014 to 17th February 2014;
- Geo-referenced aerial photography;
- SCATS Intersection Diagnostic Monitor (IDM) data and Traffic Control Signal plans provided by RMS. The IDM was run by RMS on the same day of traffic survey;
- Public transport data; and
- Site visit undertaken by Hyder staff on Thursday, 6th February 2014 to observe traffic conditions (morning and afternoon).

2.2 Software and Plug-in Used

Paramics Version 6.9.1 was used. Azalient Plug-in software (Version 6.9.0.H01) was used to provide additional functionality in the developed models.

2.3 Road Network Coding

Hyder utilised aerial photo images to code the road network for the existing base case. The geo-referenced aerial photography provided adequate information for network coding including road length, lane width, number of lanes, lane discipline and intersection configurations.

The relevant sections of North-West Transit Way (T-way) within the study area were included.

Road network distances within the model have been checked and coded in proper scale under recommended Lambert 94 coordinate system.

All link-types and categories are coded based on RMS guidelines. Figure 1 shows Base Case Paramics model network coverage and travel zone system (highlighted in green).

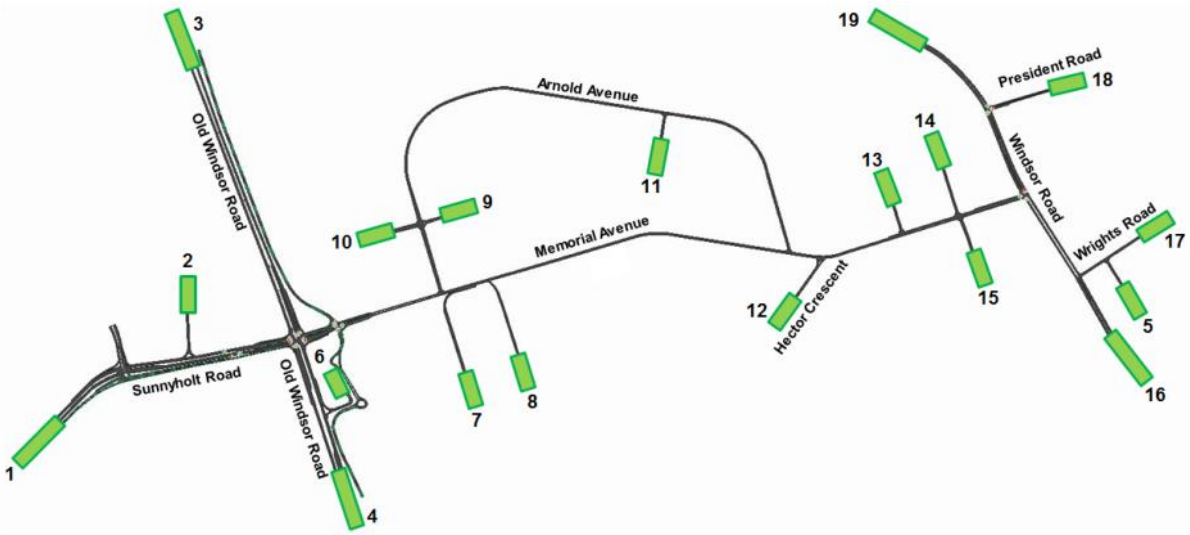


Figure 1 Base Case Paramics Model Network and Travel Zone System

2.4 Traffic Signals

There are five signalised intersections (including two signalised intersections with T-way) within the model study area. The signals are coded as per IDM data provided by RMS.

2.5 RMS Standard Files Incorporated in the Model

The Following RMS's standard Paramics files were incorporated in the Paramics models:

- Configuration;
- Vehicles;
- Categories;
- Acceleration; and
- Behaviour.

2.6 Paramics Demand Matrix

2.6.1 Demand Data

The demand matrix was estimated using surveyed Origin-Destination (OD) data and intersection turning movement counts.

The demand matrix was calibrated to the RMS's Guide standards.

The proportion of heavy vehicles and vehicle types was taken directly from available classified traffic data.

2.6.2 Travel Zones

The existing Paramics model has a total of 19 travel zones covering the study area (refer to previous Figure 1).

2.6.3 Demand Profile

In order to ensure that the correct numbers of vehicles are released into the network as per defined time slices, a demand profile was constructed. Temporal traffic profiles were developed for 15 minute periods based on surveyed traffic data.

Figures 2 and 3 show traffic profile for modelled two hours in AM Peak (7:00-9:00) and modelled two hours in PM Peak (4:00-6:00).

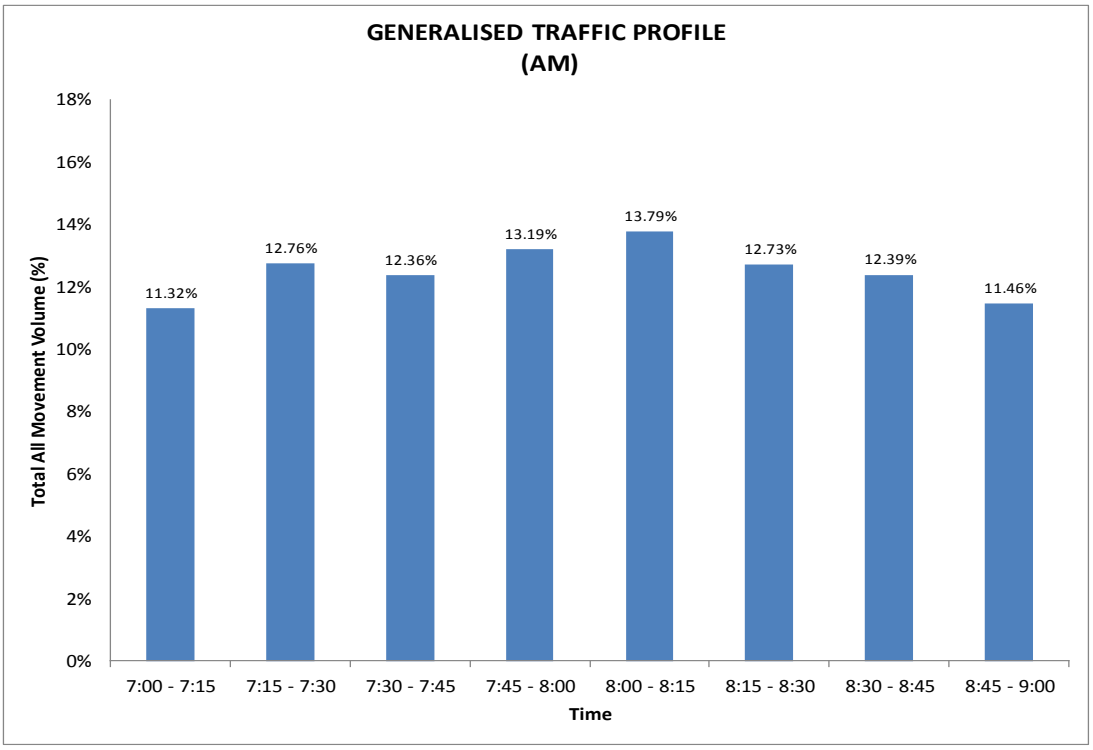


Figure 2 Traffic Profile, AM Peak, 7:00-9:00 (Source: 2014 Traffic Data)

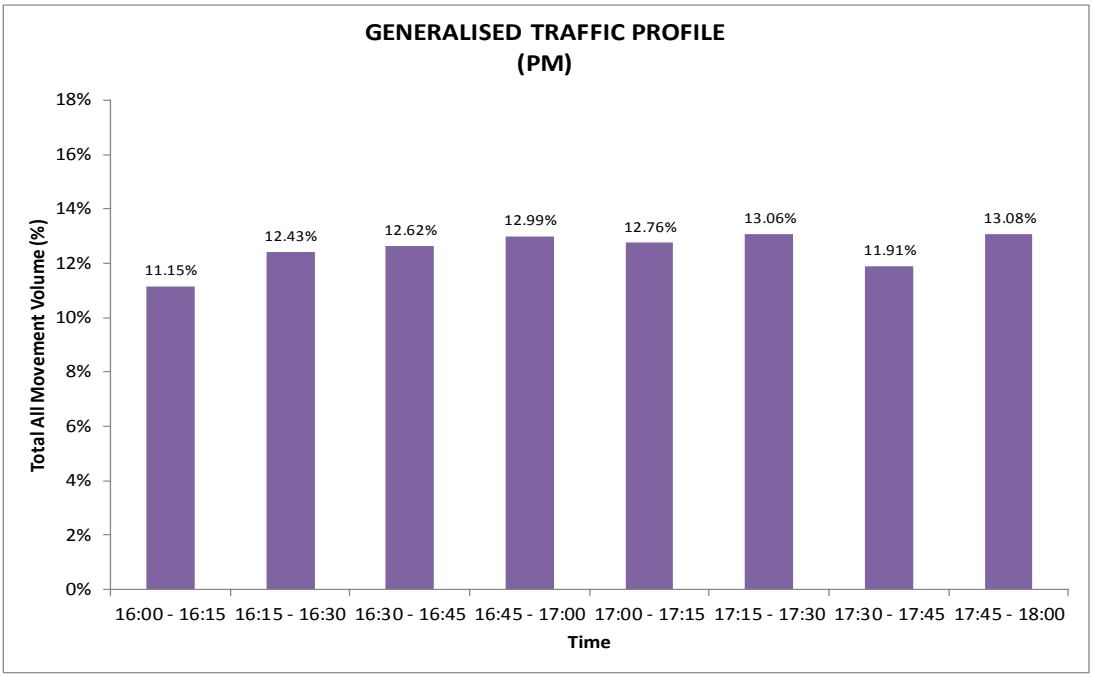


Figure 3 Traffic Profile, PM Peak, 4:00-6:00 (Source: 2014 Traffic Data

2.6.4 Public Transport

The public transport services within the study area have been coded and included in the model. Bus frequencies and recent time tables for each bus route have been sourced form Transport for NSW (www.transportnsw.info) and Busways (www.busways.com.au/travelling-with-us/timetable-search) web sites. Table 1 summarises current bus routes and frequencies for AM (7:00-9:00) and PM (4:00-6:00) peak periods.

Table 1 Public Transport (Bus) Services

Bus Route ID	Route description	Bus Frequency (two way)	
		AM Peak 7:00 9:00	PM Peak 4:00 6:00
607x	Rouse Hill Town Centre to City	12	10
617x	Rouse Hill to City	9	5
T65	Parramatta to Rouse Hill Town Centre	12	14
T66	Parramatta to Rouse Hill	7	10
T75	Blacktown to Rouse Hill and Riverstone	10	10
602x	Rouse Hill to North Sydney	7	6
612x	Kellyville to Milsons Point	4	5
619	Rouse Hill Town Centre to Macquarie Park	8	7
T64	Parramatta to Rouse Hill Town Centre	14	11
615x	North Kellyville to City	7	4

Source: www.transportnsw.info

3 Model Calibration

Model calibration is the process that develops and adjusts model parameters to adequately reflect the observed traffic behaviour. The model calibration criteria were based on Traffic Modelling Guidelines, RMS, Version 1.0, February 2013.

The model validation provides an independent check of the calibrated model to assess its accuracy and confirm its 'fit for the project purpose'. For this study, model was validated against surveyed travel time data and observed queue lengths. The following sections provide a summary of calibration results.

3.1 Calibration Criteria

Eight key intersections in the study area were included in the base case model calibration.

Observed intersection turning volumes were compared with the modelled intersection turning volumes for AM and PM peak periods. Comparison assessment is undertaken based on the core area modelling criteria as per RMS Guide and detailed in Table 2.

Table 2 Micro-simulation link and turn target calibration / validation criteria (core area)

Topic	Calibration Criteria	Target
Link or Turn	Difference in link flow within 10 for flows <99 vph	100%
	Difference in link flow within 10% for flows 100-999 vph	100%
	Difference in link flow within 100 for flows 1,000-1,999 vph	100%
	Difference in link flow within 5% for flows >2,000 vph	100%
	100 per cent of observations to be within tolerance limits (GEH Statistic less than 5 of all individual modelled flow)	100%
	R^2 value to be included with plots of observed vs modelled hourly flows required	>0.95

Table 3 and Figure 4 below show the list and location of key intersections included in the model calibration process.

Table 3 Key intersections in the study area included in model calibration

ID	Intersection	Control Type
1	Old Windsor Road/Memorial Avenue	Signal
2	Windsor Road/Memorial Avenue	Signal
3	Windsor Road/President Avenue	Signal
4	Windsor Road/Wrights Road	Priority
5	Arnold Avenue (West)/Memorial Avenue	Priority
6	Arnold Avenue (East)/Memorial Avenue	Priority
7	Memorial Avenue/Hector Crescent	Priority
9	Memorial Avenue/T-way	Signal

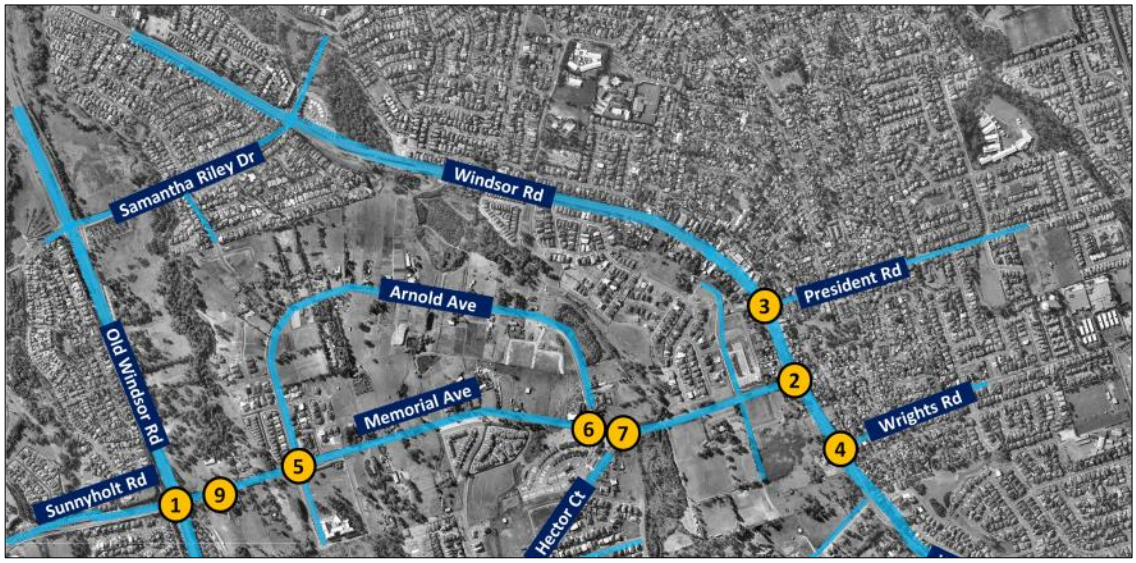


Figure 4 Key intersections included in the model calibration

3.2 Calibration Results for the AM Peak

Intersection turning volumes have been assessed based on the calibration criteria. Approximately 51 turning movements at 8 intersections were included in model calibration.

Table 4 summarises the calibration results for the AM Peak model.

Table 4 2013 AM Peak Model Calibration Summary

Model Calibration, Intersection Turning Movements			
Total number of turn flows:	51 (8 intersections)		
Number of flows less than 99 vph	*19*		
Number of flows between 100 and 999 vph	*24*		
Number of flows between 1,000 and 1,999 vph	*7*		
Number of flows more than 2,000 vph	*1*		
Meet the assessment criteria:	**Target**	**Achieved**	**Status**
Difference in link flow within 10 for flows <99 vph	100%	100%	Pass
Difference in link flow within 10% for flows 100-999 vph	100%	100%	Pass
Difference in link flow within 100 for flows 1,000-1,999 vph	100%	100%	Pass
Difference in link flow within 5% for flows >2,000 vph	100%	100%	Pass
100 per cent of observations to be within tolerance limits (GEH Statistic less than 5 of all individual modelled flow)	100%	100%	Pass
R^2 value to be included with plots (See Figure 5)	>0.95	0.99	Pass

Model AM_2014_BC_TZ019_08042014_4; F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2014 Base Case

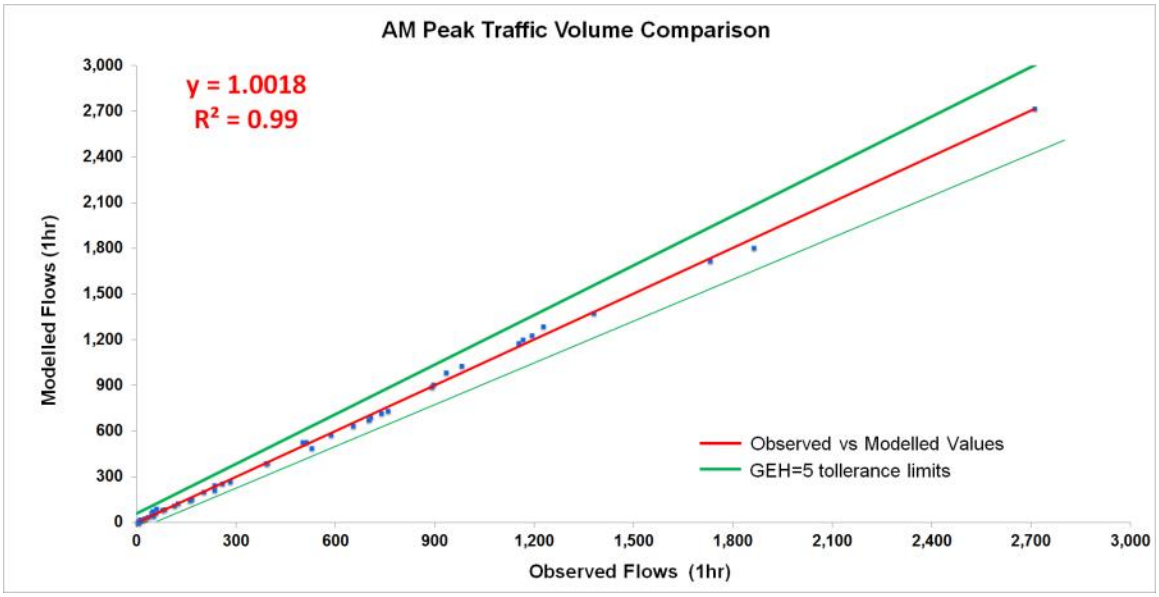


Figure 5 Observed vs Modelled Intersection Turning Flows, Existing AM Peak

The results from above assessment confirmed that AM Peak model satisfied the core area calibration criteria.

3.2.1 Model Stability

Figure 6 below shows the AM Peak variation of number of vehicles released in the network every at 15-minute interval and five different seeds [1]. The model was run for five 'seed' values as per RMS' guidelines. The five seeds values were 560, 28, 7771, 86524, and 2849.The results showed minor traffic variations for all seed values. This confirms that base case model is stable.

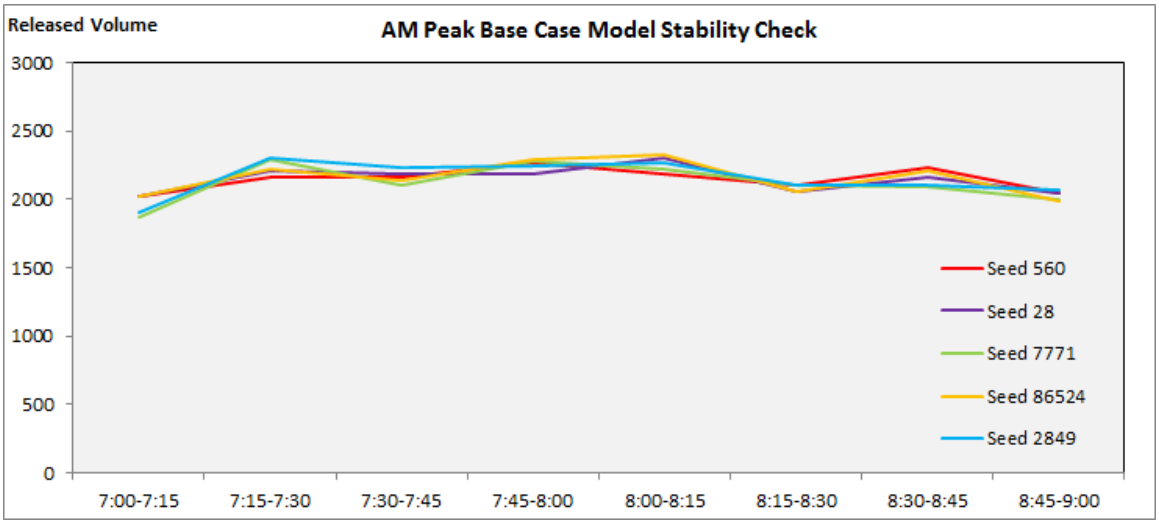


Figure 6 Model Stability Check – 7:00-9:00 h, AM Peak

[1] Seed value specifies the value used by the random number generator. Identical networks simulated using the same processor will return the same results using the same seed value.

3.3 Calibration Results for the PM Peak

Intersection turning volumes have been assessed based on the calibration criteria. Approximately 51 turning movements at 8 intersections were included in model calibration.

Table 5 summarises the calibration results for the PM Peak model.

Table 5 2013 PM Peak Model Calibration Summary

Model Calibration **Intersection Turning Movements**			
Total number of turn flows:	51 (8 intersections)		
Number of flows less than 99 vph	*17*		
Number of flows between 100 and 999 vph	*29*		
Number of flows between 1,000 and 1,999 vph	*4*		
Number of flows more than 2,000 vph	*1*		
Meet the assessment criteria:	**Target**	**Achieved**	**Status**
Difference in link flow within 10 for flows <99 vph	100%	100%	Pass
Difference in link flow within 10% for flows 100-999 vph	100%	100%	Pass
Difference in link flow within 100 for flows 1,000-1,999 vph	100%	100%	Pass
Difference in link flow within 5% for flows >2,000 vph	100%	100%	Pass
100 per cent of observations to be within tolerance limits (GEH Statistic less than 5 of all individual modelled flow)	100%	100%	Pass
R^2 value to be included with plots (See Figure 7)	>0.95	0.99	Pass

Model PM_2014_BC_TZ019_15042014_3; F:\AA006569\Traffic Modelling\PARAMICS\1-Models\2014 Base Case

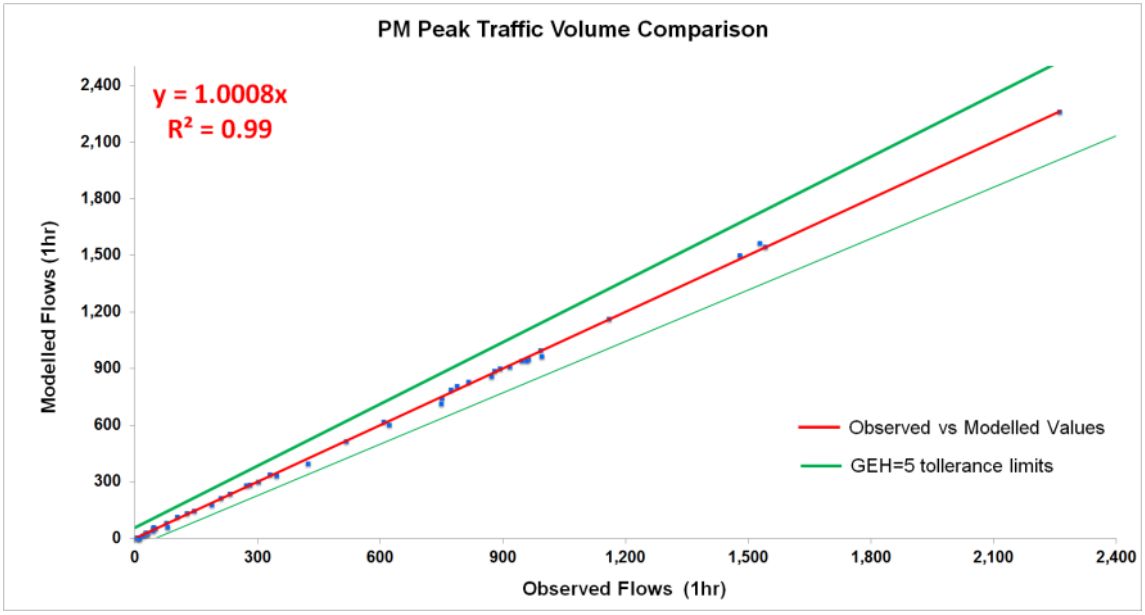


Figure 7 Observed vs Modelled Intersection Turning Flows, Existing PM Peak

The results from above assessment confirmed that PM Peak model satisfied core area calibration criteria.

3.3.1 Model Stability

Figure 8 below shows the PM Peak variation of number of vehicles released in the network every at 15-minute interval and five different seeds. The model was run for five 'seed' values as per RMS' guidelines. The five seeds values were 560, 28, 7771, 86524, and 2849.

The results showed minor traffic variations for all seed values. This confirms that base case model is stable.

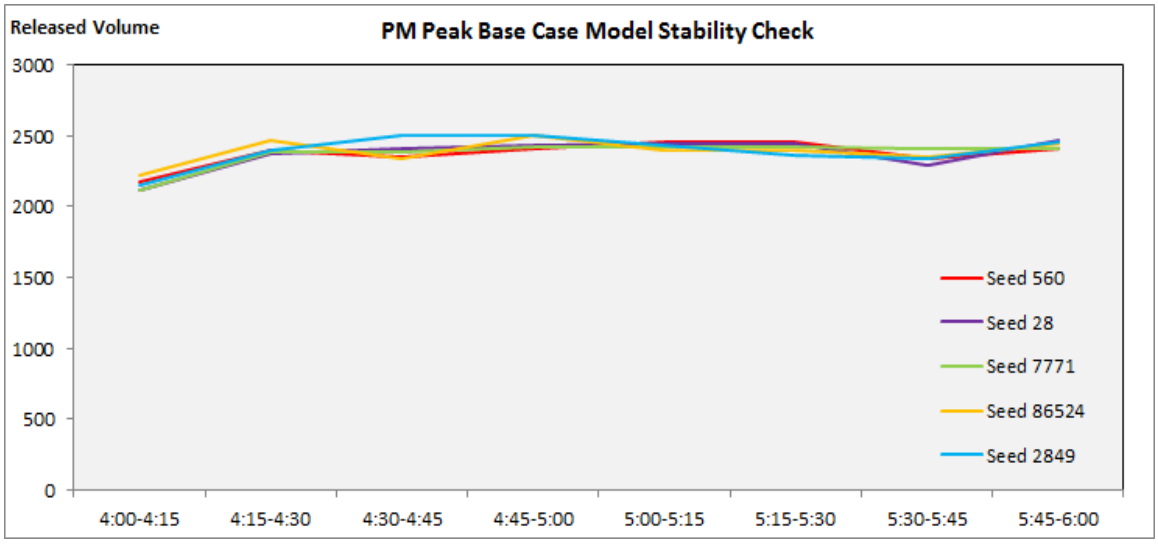


Figure 8 Model Stability Check – 4:00-6:00 h, PM Peak

4 Model Validation

Model validation has been undertaken as per RMS guideline. Both AM and PM Peak models have been validated for travel time and queue length data.

Figure 9 shows travel time survey route along Memorial Avenue in eastbound and westbound direction.

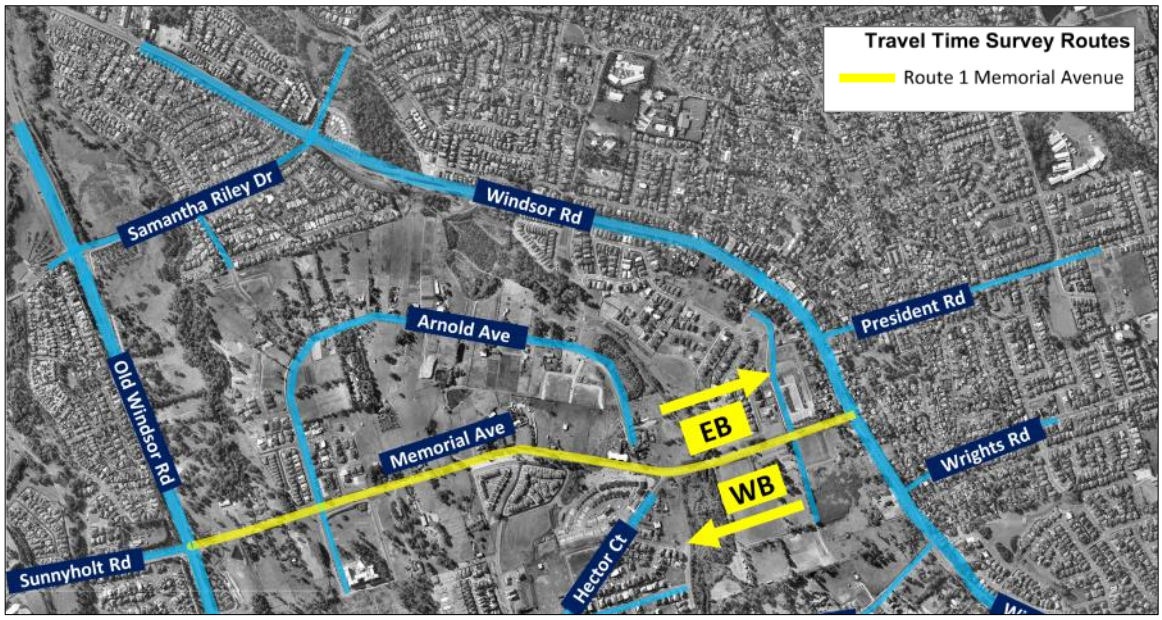


Figure 9 Travel Time Survey Route along Memorial Avenue

4.1 Travel Time Validation

Observed and modelled travel times, as cumulative values, were compared in eastbound and westbound direction along Memorial Avenue between Old Windsor Road / Memorial Avenue and Windsor Road / Memorial Avenue signalised intersections (Approximately 2.2 km long section).

Comparison assessment is undertaken based on RMS travel time validation criteria target that average modelled journey time needs to be within 15 % of average observed journey time for individual sections along the route.

Figures 10 to 13 below show cumulative time-distance graph of modelled and observed travel time data along the route for AM and PM peak periods.

The modelled travel time (red line) is within the upper (+15%) and lower (-15%) boundary of observed average travel time values and followed the same trend with the survey travel time data at each section.

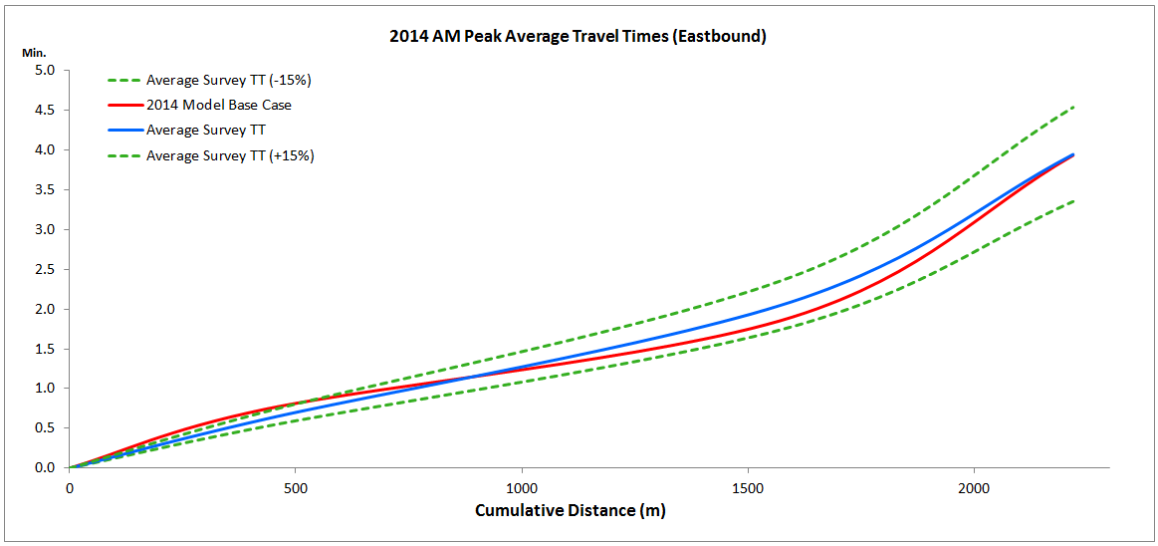


Figure 10 Model Validation, Memorial Avenue EASTBOUND Travel Times – AM Peak

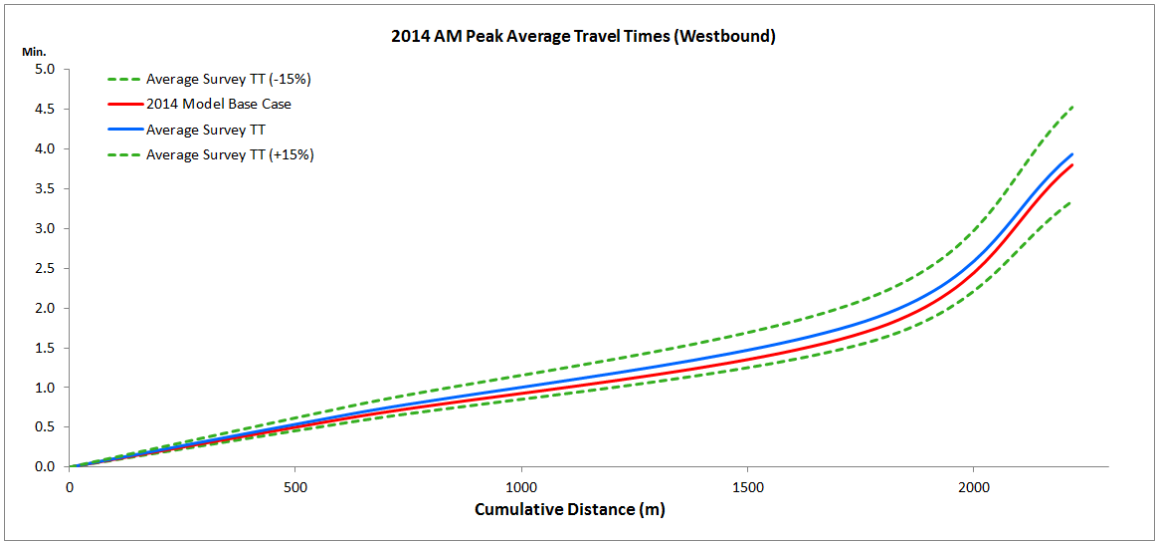


Figure 11 Model Validation, Memorial Avenue WESTBOUND Travel Times – AM Peak

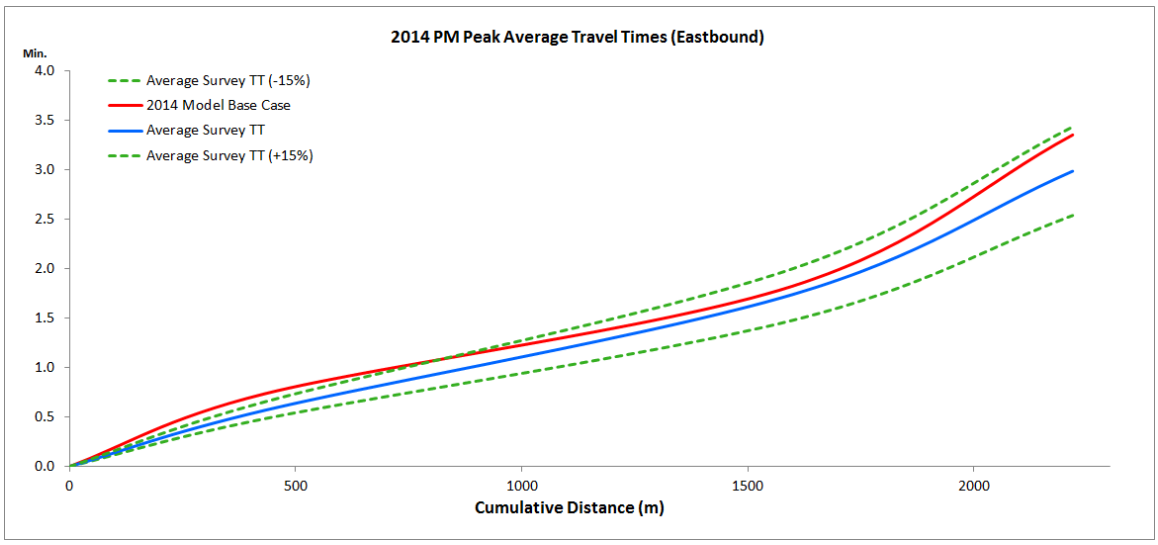


Figure 12 Model Validation, Memorial Avenue EASTBOUND Travel Times – PM Peak

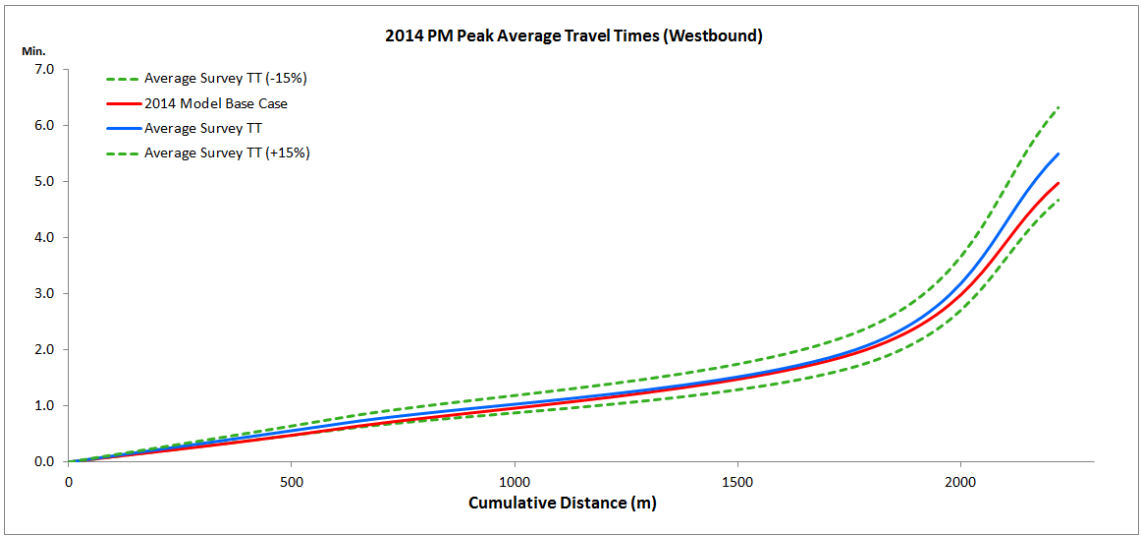


Figure 13 Model Validation, Memorial Avenue WESTBOUND Travel Times – PM Peak

4.2 Queue Length Validation

As stated in the RMS modelling guideline, counting or calculating queue length is a subjective exercise since queued vehicles will often still be moving slowly and it will not always be clear what criteria should be used to constitute a queue during surveys.

For that reason RMS does not have mandatory statistical guideline criteria for queue length comparison.

For the purpose of model validation with queue length data, we analysed queue length data undertaken by Skyhigh in February 2014 and observed queues by Hyder's staff during site visit on Thursday, 6th of February 2014.

During site visit longer slow moving queues were observed on Old Windsor Road, Windsor Road and Sunnyholt Road approaches with Memorial Ave in both AM and PM peak periods. The slow moving queues on these roads were not recorded by the survey data. The survey recorded stopped vehicles (zero speed) as queues. The survey data showed relatively shorter queues on Old Windsor Road, Windsor Road and Sunnyholt Road approaches due to excusion of slow moving queues. Figures 14 and 15 below show observed queue lengths in AM peak and PM peak respectively.

Figures 16 and 17 show modelled queue length reporetd as 95th percentile queue for AM and PM peak respectively.

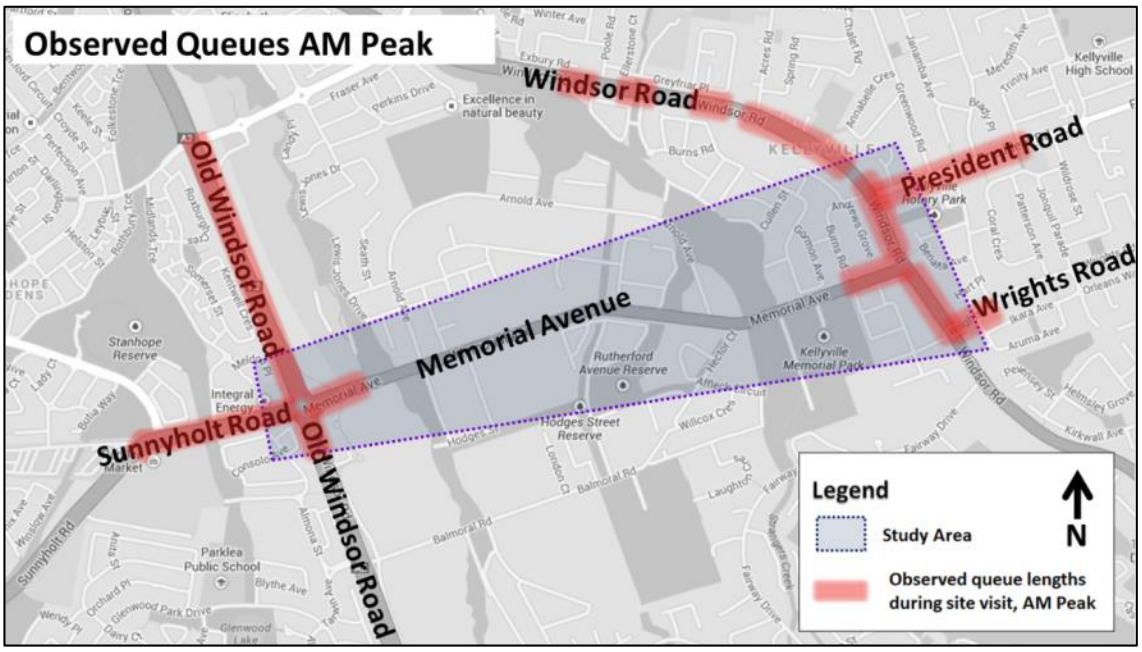


Figure 14 Observed queue lengths during site visit, AM Peak

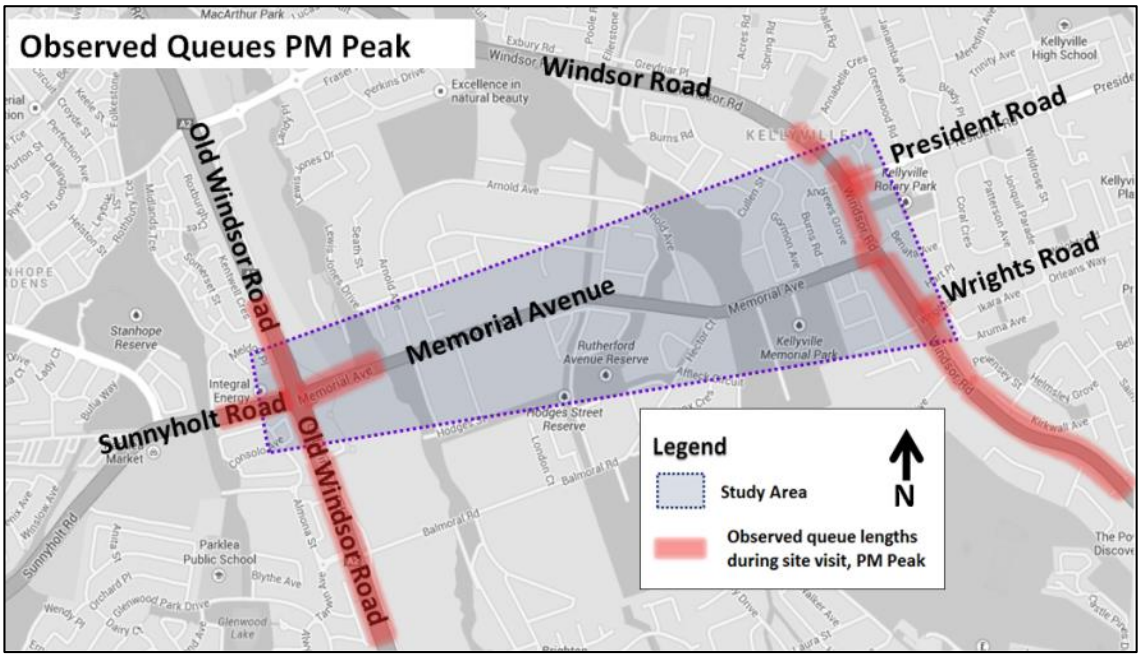


Figure 15 Observed queue lengths during site visit, PM Peak

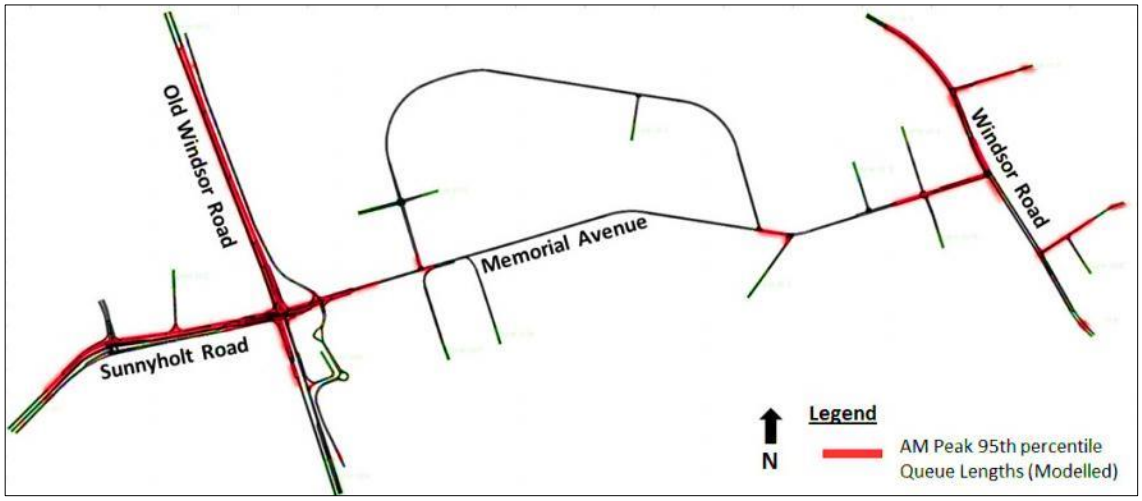


Figure 16 Base Case Model- 95th percentile queue length, AM Peak

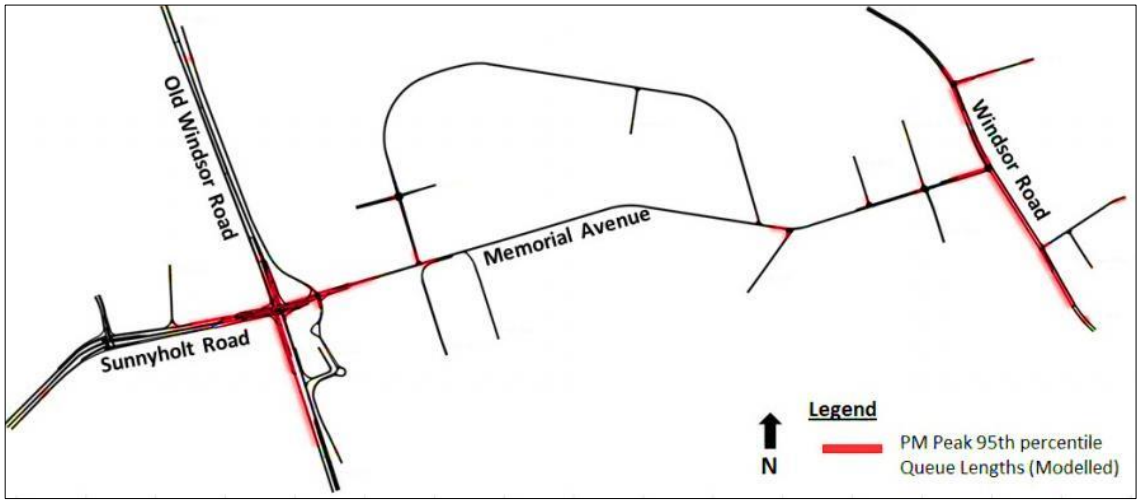


Figure 17 Base Case Model -95th percentile queue length, PM Peak

This analysis indicated that modelled queue lengths in AM and PM Peak are representative and adequately reflect existing traffic condition in the study area road network.

5 Summary

The AM and PM peak Paramics model has been calibrated and validated as per RMS guideline. The modelling results confirms that both AM and PM peak base case Paramics models have been adequately calibrated and validated for 2014 traffic conditions and model is fit for the study purpose.

Turning Volume Comparisons - Calibration

Table 1 AM Peak

	Approach	Movement ID	Turn	2014 Counts/ Estimated	2014 Modelled	GEH
				AM 1HR *	**AM 1HR**	
				Total	**Total**	
I-1 Memorial Avenue/Old Windsor Road/Sunnyholt Road	***North***	I-1-1	R	283	268	0.9
		I-1-2	T	1,380	1,374	0.2
		I-1-3	L	58	62	0.5
	East	I-1-4	R	25	25	0.0
		I-1-5	T	587	576	0.4
		I-1-6	L	125	124	0.1
	South	I-1-7	R	236	242	0.4
		I-1-8	T	892	888	0.1
		I-1-9	L	260	257	0.2
	West	I-1-10	R	655	635	0.8
		I-1-11	T	934	983	1.6
		I-1-12	L	235	211	1.6
I-2 Memorial Avenue/Windsor Road	***North***	I-2-1	R	394	388	0.3
		I-2-2	T	1,863	1,803	1.4
	South	I-2-8	T	512	527	0.7
		I-2-9	L	391	388	0.1
	West	I-2-10	R	981	1,029	1.5
		I-2-12	L	167	151	1.3
I-3 Windsor Road / President Road	***North***	I-3-2	T	1,731	1,715	0.4
		I-3-3	L	48	49	0.2
	East	I-3-4	R	78	81	0.3
		I-3-6	L	528	488	1.8
	South	I-3-7	R	161	146	1.2
		I-3-8	T	502	526	1.0
I-4 Windsor Road / Wrights Road	***North***	I-4-2	T	2,710	2,719	0.2
		I-4-3	L	114	109	0.5
	East	I-4-4	R	6	8	0.8
		I-4-6	L	202	201	0.1
	South	I-4-7	R	25	28	0.5

	Approach	Movement ID	Turn	2014 Counts/ Estimated	2014 Modelled	GEH
		I-4-8	T	896	905	0.3
I-5 Memorial Avenue/Arnold Avenue (West)	***North***	I-5-1	R	51	43	1.3
		I-5-3	L	34	37	0.5
	East	I-5-4	R	19	18	0.1
		I-5-5	T	707	691	0.6
		I-5-6	L	17	20	0.6
	West	I-5-11	T	1,167	1,201	1.0
		I-5-12	L	59	88	3.4
I-6 Memorial Avenue/Arnold Avenue (East)	***North***	I-6-1	R	3	0	2.5
		I-6-3	L	11	20	2.2
	East	I-6-4	R	11	21	2.3
		I-6-5	T	739	714	0.9
	West	I-6-11	T	1,193	1,229	1.0
		I-6-12	L	8	0	3.9
I-7 Memorial Avenue/Hector Cr	***East***	I-7-5	T	700	673	1.1
		I-7-6	L	85	85	0.1
	South	I-7-7	R	45	61	2.1
		I-7-9	L	50	63	1.7
	West	I-7-10	R	50	73	2.9
		I-7-11	T	1,154	1,175	0.6

Table 2 PM Peak

	Approach	Movement ID	Turn	2014 Counts/ Estimated	2014 Modelled	GEH
				PM 1HR *	**PM 1HR**	
				Total	**Total**	
I-1 Memorial Avenue/Old Windsor Road/Sunnyholt Road	***North***	I-1-1	R	346	334	0.7
		I-1-2	T	996	963	1.0
		I-1-3	L	31	30	0.1
	East	I-1-4	R	50	52	0.3
		I-1-5	T	750	744	0.2
		I-1-6	L	104	113	0.9
	South	I-1-7	R	188	177	0.8
		I-1-8	T	1,480	1,501	0.6
		I-1-9	L	622	603	0.8
	West	I-1-10	R	424	396	1.4
		I-1-11	T	773	787	0.5
		I-1-12	L	517	515	0.1
I-2 Memorial Avenue/Windsor Road	***North***	I-2-1	R	210	213	0.2
		I-2-2	T	816	829	0.4
	South	I-2-8	T	1,542	1,545	0.1
		I-2-9	L	749	713	1.3
	West	I-2-10	R	609	618	0.4
		I-2-12	L	301	301	0.0
I-3 Windsor Road / President Road	***North***	I-3-2	T	787	807	0.7
		I-3-3	L	128	135	0.6
	East	I-3-4	R	145	146	0.0
		I-3-6	L	233	235	0.2
	South	I-3-7	R	273	280	0.4
		I-3-8	T	1,528	1,566	0.9
I-4 Windsor Road / Wrights Road	***North***	I-4-2	T	1,159	1,163	0.1
		I-4-3	L	282	284	0.1
	East	I-4-4	R	4	5	0.5
		I-4-6	L	77	83	0.7
	South	I-4-7	R	329	337	0.4
		I-4-8	T	2,261	2,261	0.0
I-5	***North***	I-5-1	R	45	54	1.2

	Approach	Movement ID	Turn	2014 Counts/ Estimated	2014 Modelled	GEH
Memorial Avenue/Arnold Avenue (West)		I-5-3	L	29	24	0.8
	East	I-5-4	R	26	30	0.7
		I-5-5	T	872	858	0.5
		I-5-6	L	4	3	0.6
	West	I-5-11	T	946	941	0.1
		I-5-12	L	45	58	1.8
I-6 **Memorial Avenue/Arnold Avenue (East)**	***North***	I-6-1	R	9	0	4.3
		I-6-3	L	25	21	0.9
	East	I-6-4	R	18	15	0.7
		I-6-5	T	892	899	0.2
	West	I-6-11	T	962	950	0.4
		I-6-12	L	12	0	4.9
I-7 **Memorial Avenue/Hector Cr**	***East***	I-7-5	T	880	886	0.2
		I-7-6	L	79	61	2.2
	South	I-7-7	R	45	39	0.9
		I-7-9	L	31	28	0.6
	West	I-7-10	R	30	29	0.1
		I-7-11	T	957	941	0.5

APPENDIX D

BALMORAL ROAD RELEASE AREA (BRRA) LAND DEVELOPMENT ASSUMPTIONS IN THE EMME MODEL (TECHNICAL NOTE 3)

Memorial Avenue Upgrade - Traffic and Transport Assessment

Date of Submission: 28th of March 2014

TECHNICAL NOTE 3:
BALMORAL ROAD RELEASE AREA (BRRA) LAND DEVELOPMENT ASSUMPTIONS IN THE EMME MODEL

1 Purpose of This Technical Note

This Technical Note 3 has been updated since original submission on 28 March14. Modelling data and information superseded since March 2014 were removed or updated as relevant.

This technical note presents proposed land use modifications to EMME model. In a meeting with RMS dated 24th March 2014, Hyder identified the need to update EMME model forecast for the following reasons:

- The Baulkham Hills Council (BHC) has provided residential population/dwelling estimates for Balmoral Road Release Area (BRRA). Council's new estimate has showed about 12,000 population for BRRA. The EMME forecast used 8,795 population for BRRA. The new estimate by Council indicates about 36% more population to previous land use used in EMME.
- Regarding households/dwellings data, EMME assumed 3,145 households increase for BRRA. However, Council's new estimate is 5,423 dwellings for BRRA. The new households estimate by Council is about 70% higher than previously used in EMME.
- Regarding timing, BHC estimates that by 2016, about 43% development would occur in BRRA. The full development (100%) is predicted to occur by 2024.

The land use forecast has been prepared at three travel zones (TZ 2715, 2718, 2808). Additionally trip ends growth factors are estimated and to be applied directly to previous EMME trip tables.

2 Data Inputs

Following data inputs are used in this analysis:

- Council's population and employment forecast data for (BRRA)
- RMS's population and employment forecast data for the study area at travel zone and
- RMS made available to Hyder traffic modelling plots for AM Peak traffic volumes for 2011/12, 2016, 2026 and 2036 from RMS's EMME Sydney Strategic Traffic Model.

3 Data Review and Results

In EMME model trip generation rates for BRRA were found between 0.59 and 0.83 peak hour trips per household. Average trip generation rate for BRRA (three travel zones) was found 0.75 peak hour trips per household. This appears to be consistent with the RMS trip generation guidelines for residential developments. The trip generation rates in EMME for BRRA should be retained. In EMME model the BRRA has been split into three travel zones as per following percentages:

- 31% zone TZ2715 (Castle Hill Country Club);
- 19% zone TZ2718 (Kellyville Christmas Three Farm); and
- 50% zone TZ2808 (The Village Centre, Memorial Avenue).

The above zone splits were retained in EMME model for new forecast.

Based on new land use forecast, trip ends adjustment factors are estimated and to be applied to EMME AM trip table.

Two scenarios were assessed:

1. Scenario 1. Optimistic forecast. This assumes that full (100%) BRRA will be developed by 2024. This is in line with Council's prediction.
2. BTS forecast. This assumes that full (100%) BRRA will be developed by 2036.

Scenario 1 provides a worst case situation and may trigger the need for early upgrading requirements at both intersections with Memorial Avenue at Old Windsor Road and Windsor Road. The Scenario 2 represents BTS forecasts.

The below Tables show **additional growth factors** applied to previous EMME trip tables.

Scenario 1 Full 100% development by 2024 as per Council

Table 9 Factors to adjust EMME travel zone trip table to be consistent with council land use forecast

Development Completed %	43%	100%	100%
	2016	2026	2036
TZ 2715	1.2	2.2	1.6
TZ 2718	1.2	2.2	1.7
TZ 2808	1.2	2.0	1.8

Scenario 2 Full 100% development by 2036

Table 9 Factors to adjust EMME travel zone trip table to be consistent with council land use forecast

Development Completed %	43%	80%	100%
	2016	2026	2036
TZ 2715	1.2	1.8	1.6
TZ 2718	1.2	1.8	1.7
TZ 2808	1.2	1.6	1.8

APPENDIX E

TRAFFIC PERFORMANCE OF NEW TRAFFIC SIGNALS AT MEMORIAL AVENUE/ARNOLD AVENUE AND MEMORIAL AVENUE/SEVERN DALE DRIVE (TECHNICAL NOTE 5)

Memorial Avenue Upgrade - Traffic and Transport Assessment

Date of Submission: 14th of May 2014

Updated on 20th August 2014

Technical Note 5:

Traffic Performance of New Traffic Signals at Memorial Avenue/ Arnold Avenue and Memorial Avenue/Severn Vale Drive

1 Purpose of this Technical Note

This Technical Note 5 has been updated since original submission on 14 May14. Modelling data and information superseded since May 2014 were removed or updated as relevant.

This Technical Note 5 has been prepared to report estimated future traffic volumes at the proposed location of two new traffic signals at Memorial Avenue/Arnold Avenue and Memorial Avenue/Severn Vale Drive. The future level of service for both traffic signals has been estimated using SIDRA software.

The key input from traffic modelling to the 20% Concept Design development of the road design is the length and number of turning lanes at each of the intersections, given the property constraints associated with the project.

It is intended that intersection footprints documented in this Technical Note 4 form the basis of the 20% Concept Design.

2 Growth Assumptions

Hyder previously documented traffic growth assumptions for Memorial Avenue upgrade in Technical Note 2. Future traffic volumes were estimated for 2019 (opening year of upgrade), 2026 and 2036. Traffic growth data was sourced from RMS's Sydney Strategic Traffic Model (EMME2). The growth assumptions in EMME2 were updated based on residential population/dwelling estimates for Balmoral Road Release Area (BRRA) provided by The Hills Shire Council. The traffic growth assumed that about 43% of BRRA development would occur by 2019. About 80% of BRRA development would occur by 2026. Full 100% of BRRA development is assumed to occur by 2036. The timing of BRRA assumptions were in line with Bureau of Transport Statistics (BTS) forecast.

3 Ultimate Intersection Footprints on Memorial Avenue

The intersection footprints required for 20% Concept Design are based on future turning volumes estimated for ultimate horizon year 2036. The level of service for two new traffic signals on Memorial Avenue/ Arnold Avenue and Memorial Avenue/Severn Vale Drive were estimated for 2019 (opening year of the upgrade), intermediate year 2026 and ultimate year 2036.

Amendments to provisional for left turn slip lane splitter islands on Memorial Avenue/Arnold Avenue west approach and Memorial Avenue/Severn Vale Drive south approach have been modelled, and the traffic outcomes adjusted accordingly.

3.1 Memorial Avenue/ Arnold Avenue Intersection

Figure 1 below shows ultimate intersection footprint required at Memorial Avenue/ Arnold Avenue traffic signals.

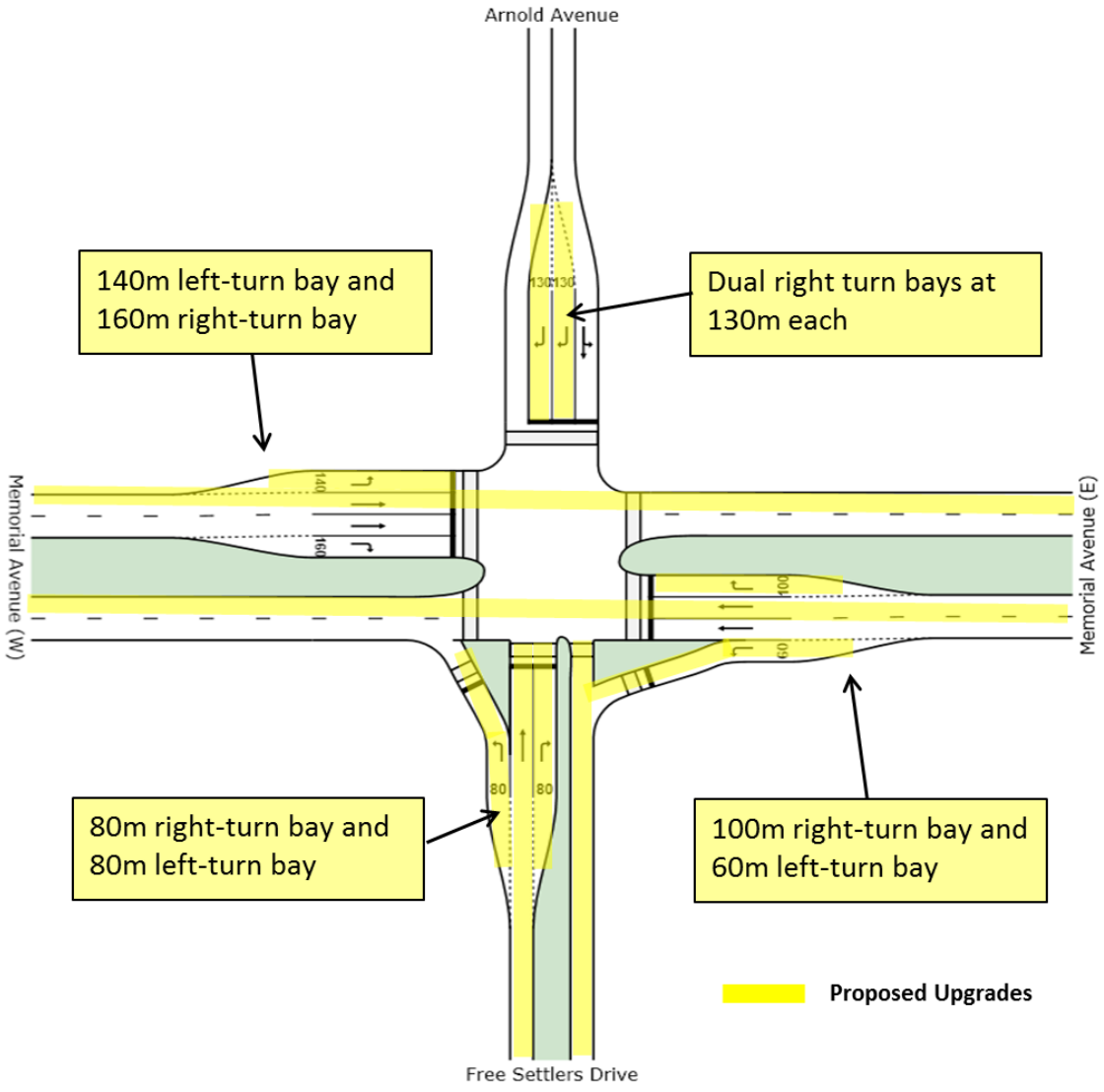


Figure 1 Proposed Layout of Memorial Avenue / Arnold Avenue Intersection

The following lane configurations are proposed based on SIDRA traffic modelling:

- Memorial Avenue two lanes (in each direction) for eastbound and westbound direction;
- Dual right turn bays at 130m each and a shared left and through lane at Arnold Avenue (North approach);
- 100m right turn bay and a 60m signalised left turn slip lane at Memorial Avenue (East approach);
- A 80m right turn bay, a 80m signalised left turn slip lane and a single through lane at Free Settlers Drive (South approach); and
- 160m right turn bay and a 140m left turn bay at Memorial Avenue (West approach).

Table 1 below shows the future performance of Memorial Avenue/ Arnold Avenue traffic signals for 2019, 2026 and 2036 for both AM and PM peak period. The identified intersection footprint (as per Figure 1) at Memorial Avenue/ Arnold Avenue traffic signals is forecast to provide level of service B at opening year 2019. Model forecasts level of service C for the ultimate year 2036.

Detailed intersection turning volumes and associated SIDRA modelling results (DoS, Queue length) for 2019, 2026 and 2036 are included in Appendix A. The predicted queue lengths from SIDRA were checked against the provided turning bays at Memorial Avenue/Arnold Avenue signals. The predicted queues would contain within the provided turning bays (as per Figure 1) at Memorial Avenue/Arnold Avenue signals until 2036.

The modelling analysis suggested that identified intersection footprint at Memorial Avenue/ Arnold Avenue traffic signals would provide adequate capacity and operational efficiency in the long-term.

Table 1 Intersection Performance at Memorial Avenue/ Arnold Avenue Signals

ID	Intersection	Peak	2019		2026		2036	
			Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-5	Arnold Avenue / Memorial Avenue	AM	30	C	36	C	40	C
I-5	Arnold Avenue / Memorial Avenue	PM	24	B	32	C	36	C

Source: SIDRA V 6.0.15.4263

Models: F:\AA006569\Traffic Modelling\SIDRA\Sensitivity Test_Aug2014\I-5_modified.sip6

3.2 Memorial Avenue/ Severn Vale Drive Intersection

Figure 2 below shows ultimate intersection footprint required at Memorial Avenue/ Severn Vale Drive traffic signals.

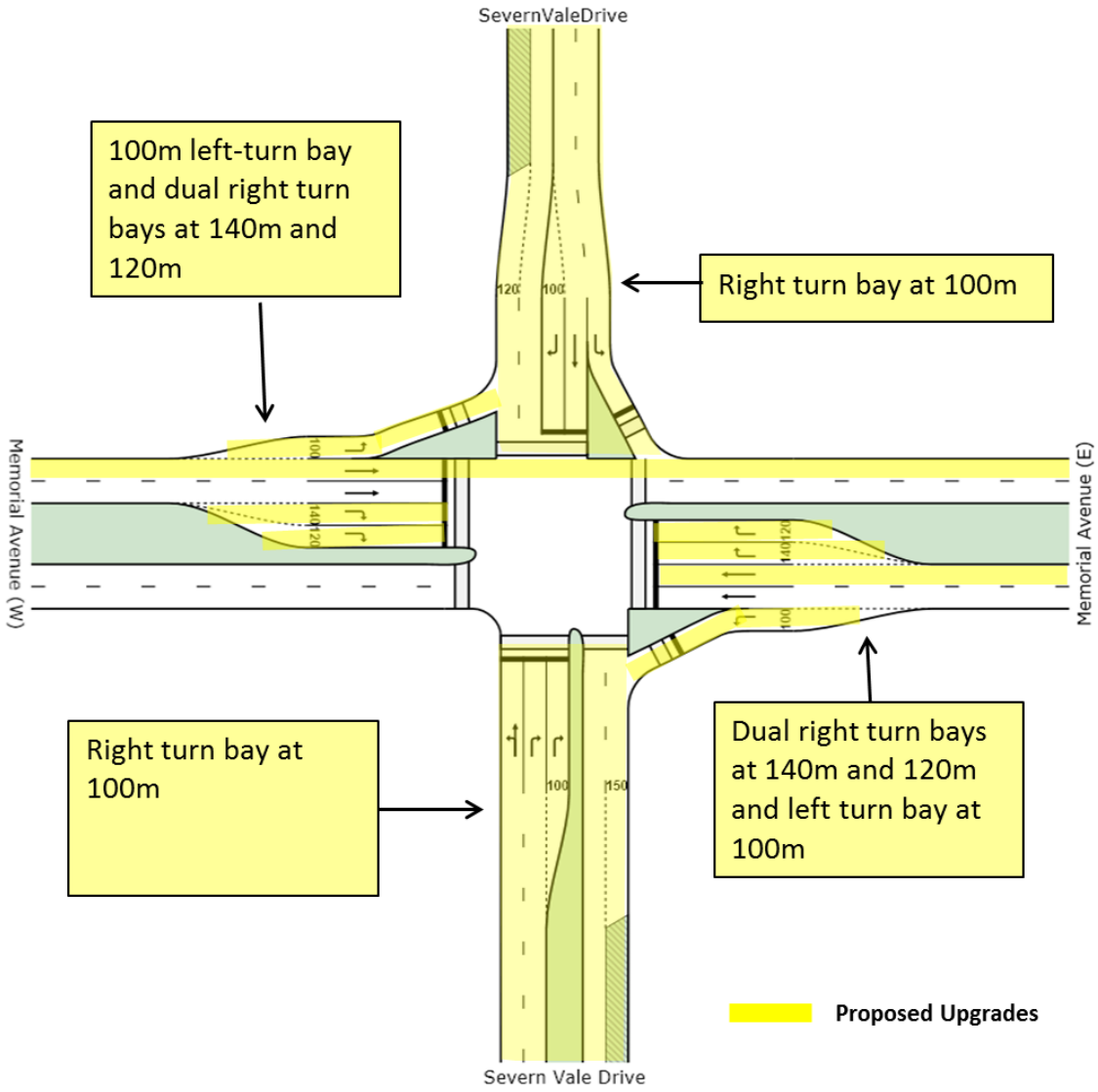


Figure 2 Proposed Layout of Memorial Avenue / Severn Vale Drive Intersection

The following lane configurations are proposed based on SIDRA traffic modelling:

- Memorial Avenue two lanes (in each direction) for eastbound and westbound directions;
- A right turn bay at 100m, a left turn signalised slip lane and a single through lane at Severn Vale Drive (North approach);
- Dual right turn bays at 140m and 120m and a 100m signalised left turn slip lane at Memorial Avenue (East approach);
- Dual right turn lanes with one lane as a short turn lane at 100m and a shared through and left turn lane at Severn Vale Drive (South approach); and
- Dual right turn bays at 140m and 120m and a 100m left turn signalised slip lane at Memorial Avenue (West approach).

Table 2 below shows the future performance of Memorial Avenue/ Severn Vale Drive traffic signals for 2019, 2026 and 2036 for both AM and PM peak period. The identified intersection footprint (as per Figure 2) at Memorial Avenue/ Severn Vale Drive traffic signals is forecast to provide level of service C at opening year 2019. Model also forecasts level of service D in 2036.

Detailed intersection turning volumes and associated SIDRA modelling result (DoS, Queue length) for 2019, 2026 and 2036 are included in Appendix A. The predicted queue lengths from SIDRA were checked against the provided turning bays at Memorial Avenue/ Severn Vale Drive signals. The predicted queues would contain within the provided turning bays (as per Figure 2) at Memorial Avenue/ Severn Vale Drive signals until 2036.

The modelling analysis suggested that identified intersection footprint at Memorial Avenue/ Severn Vale Drive traffic signals would provide adequate capacity and operational efficiency in the long-term.

Table 2 Intersection Performance at Memorial Avenue/ Severn Vale Drive Signals

ID	Intersection	Peak	2019		2026		2036	
			Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-7	Severn Vale Drive / Memorial Avenue	AM	35	C	42	C	52	D
I-7	Severn Vale Drive / Memorial Avenue	PM	34	C	41	C	45	D

Source: SIDRA V 6.0.15.4263

Models: F:\AA006569\Traffic Modelling\SIDRA\Sensitivity Test_Aug2014\I-7_modified.sip6

4 Key Findings

This Technical Note 5 documents future turning volumes at proposed two new traffic signals at Memorial Avenue/Arnold Avenue and Memorial Avenue/Severn Vale Drive. The key input from traffic modelling to the 20% Concept Design development of the road design is the length and number of turning lanes at each of the intersections, given the property constraints associated with the project.

Two intersections in association with the Memorial Avenue upgrade project were assessed under forecast flows and based on four lane upgrade option. In the Memorial Avenue upgrade project, the key access and egress points to Balmoral Road Release Area would be made via two new traffic signals at Arnold Avenue and Severn Vale Drive.

Intersection upgrade was tested for 2019 (opening year of four lane upgrade), 2026 and ultimate 2036 traffic conditions using SIDRA software. The intersection modelling results suggested that both assessed traffic signals would operate at an acceptable level of service during the morning and afternoon peak hour. Both traffic signals would perform at level of service C or above at opening year 2019 and level of service D or better for ultimate year 2036 and therefore provide adequate capacity and operational efficiency in the long-term.

ATTACHMENT 5A

Estimated Future Traffic Volumes

Traffic volumes at Memorial Avenue / Arnold Avenue and Memorial Avenue / Severn Vale Dr intersections were estimated for the future years 2019 (opening year), intermediate horizon 2026 and ultimate horizon 2036. Figure A1 below shows the estimated turning volumes at the two new signals at Memorial Avenue with Arnold Avenue and with Severn Vale Drive.

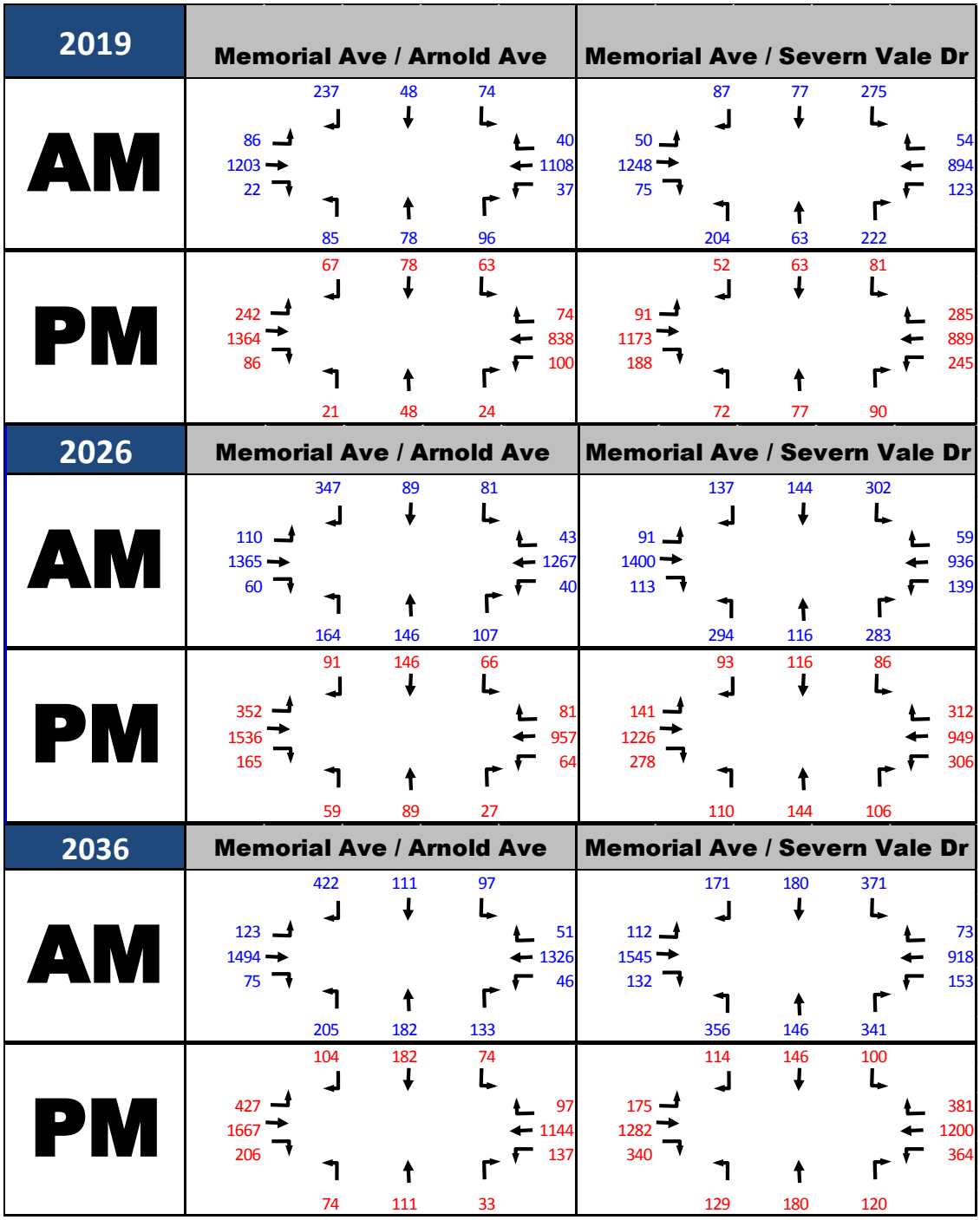


Figure A1 Estimated Traffic Counts for Future Years 2019, 2026 and 2036

Detailed SIDRA Modelling Results – 2019 2026 & 2036

RESULTS FOR MEMORIAL AVENUE/ARNOLD AVENUE INTERSECTION

Modelling Results for 2019

AM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	205	5.0	0.521	42.3	LOS C	9.9	72.6	0.93	0.81	26.8
8	T1	182	5.0	0.574	64.5	LOS E	12.8	93.3	0.97	0.80	19.0
7	R2	133	5.0	0.523	74.9	LOS F	9.5	69.1	0.98	0.80	19.4
Approach		520	5.0	0.574	58.4	LOS E	12.8	93.3	0.96	0.81	21.7
East: Memorial Avenue (E)											
6	L2	46	3.0	0.040	15.0	LOS B	0.9	6.3	0.40	0.69	45.8
5	T1	1326	6.0	0.747	26.7	LOS B	33.1	243.9	0.73	0.66	37.0
4	R2	51	3.0	0.543	90.4	LOS F	4.0	28.4	1.00	0.75	17.2
Approach		1423	5.8	0.747	28.6	LOS C	33.1	243.9	0.73	0.66	35.8
North: Arnold Avenue											
3	L2	97	5.0	0.633	63.3	LOS E	13.2	96.6	0.98	0.85	21.0
2	T1	111	5.0	0.633	55.7	LOS D	13.2	96.6	0.98	0.85	21.0
1	R2	422	5.0	0.829	82.8	LOS F	16.4	119.5	1.00	0.90	18.2
Approach		630	5.0	0.829	75.1	LOS F	16.4	119.5	0.99	0.88	19.0
West: Memorial Avenue (W)											
12	L2	123	3.0	0.108	15.6	LOS B	2.5	17.8	0.42	0.73	45.1
11	T1	1494	6.0	0.836	29.1	LOS C	42.5	312.8	0.82	0.75	35.4
10	R2	75	3.0	0.799	94.4	LOS F	6.1	43.6	1.00	0.84	16.7
Approach		1692	5.6	0.836	31.0	LOS C	42.5	312.8	0.80	0.76	34.3
All Vehicles		4265	5.5	0.836	40.0	LOS C	42.5	312.8	0.82	0.75	29.3

PM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.148	43.4	LOS D	3.8	27.9	0.79	0.74	26.5
8	T1	111	5.0	0.388	68.4	LOS E	8.1	59.2	0.95	0.76	18.4
7	R2	33	5.0	0.506	97.7	LOS F	2.8	20.4	1.00	0.73	16.3
Approach		218	5.0	0.506	64.3	LOS E	8.1	59.2	0.90	0.75	20.2
East: Memorial Avenue (E)											
6	L2	137	3.0	0.131	17.4	LOS B	2.9	21.0	0.48	0.72	43.5
5	T1	1144	6.0	0.565	18.6	LOS B	21.3	156.8	0.51	0.46	43.1
4	R2	97	3.0	0.419	81.1	LOS F	7.1	50.8	0.94	0.78	18.6
Approach		1378	5.5	0.565	22.9	LOS B	21.3	156.8	0.54	0.51	39.8
North: Arnold Avenue											
3	L2	74	5.0	0.881	86.2	LOS F	21.1	154.3	1.00	0.98	17.0
2	T1	182	5.0	0.881	78.6	LOS F	21.1	154.3	1.00	0.98	17.0
1	R2	104	5.0	0.797	101.4	LOS F	4.6	33.2	1.00	0.85	15.8
Approach		360	5.0	0.881	86.7	LOS F	21.1	154.3	1.00	0.94	16.7
West: Memorial Avenue (W)											
12	L2	427	3.0	0.408	24.5	LOS B	13.4	96.4	0.59	0.83	37.8
11	T1	1667	6.0	0.893	28.5	LOS C	49.6	365.4	0.75	0.72	35.9
10	R2	206	3.0	0.890	95.8	LOS F	17.9	128.6	1.00	0.92	16.5
Approach		2300	5.2	0.893	33.8	LOS C	49.6	365.4	0.74	0.76	32.9
All Vehicles		4256	5.3	0.893	36.3	LOS C	49.6	365.4	0.71	0.69	31.2

Modelling Results for 2026

AM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows		Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
		Total	HV				Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.148	43.4	LOS D	3.8	27.9	0.79	0.74	26.5
8	T1	111	5.0	0.388	68.4	LOS E	8.1	59.2	0.95	0.76	18.4
7	R2	33	5.0	0.506	97.7	LOS F	2.8	20.4	1.00	0.73	16.3
Approach		218	5.0	0.506	64.3	LOS E	8.1	59.2	0.90	0.75	20.2
East: Memorial Avenue (E)											
6	L2	137	3.0	0.131	17.4	LOS B	2.9	21.0	0.48	0.72	43.5
5	T1	1144	6.0	0.565	18.6	LOS B	21.3	156.8	0.51	0.46	43.1
4	R2	97	3.0	0.419	81.1	LOS F	7.1	50.8	0.94	0.78	18.6
Approach		1378	5.5	0.565	22.9	LOS B	21.3	156.8	0.54	0.51	39.8
North: Arnold Avenue											
3	L2	74	5.0	0.881	86.2	LOS F	21.1	154.3	1.00	0.98	17.0
2	T1	182	5.0	0.881	78.6	LOS F	21.1	154.3	1.00	0.98	17.0
1	R2	104	5.0	0.797	101.4	LOS F	4.6	33.2	1.00	0.85	15.8
Approach		360	5.0	0.881	86.7	LOS F	21.1	154.3	1.00	0.94	16.7
West: Memorial Avenue (W)											
12	L2	427	3.0	0.408	24.5	LOS B	13.4	96.4	0.59	0.83	37.8
11	T1	1667	6.0	0.893	28.5	LOS C	49.6	365.4	0.75	0.72	35.9
10	R2	206	3.0	0.890	95.8	LOS F	17.9	128.6	1.00	0.92	16.5
Approach		2300	5.2	0.893	33.8	LOS C	49.6	365.4	0.74	0.76	32.9
All Vehicles		4256	5.3	0.893	36.3	LOS C	49.6	365.4	0.71	0.69	31.2

PM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows		Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
		Total	HV				Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.148	43.4	LOS D	3.8	27.9	0.79	0.74	26.5
8	T1	111	5.0	0.388	68.4	LOS E	8.1	59.2	0.95	0.76	18.4
7	R2	33	5.0	0.506	97.7	LOS F	2.8	20.4	1.00	0.73	16.3
Approach		218	5.0	0.506	64.3	LOS E	8.1	59.2	0.90	0.75	20.2
East: Memorial Avenue (E)											
6	L2	137	3.0	0.131	17.4	LOS B	2.9	21.0	0.48	0.72	43.5
5	T1	1144	6.0	0.565	18.6	LOS B	21.3	156.8	0.51	0.46	43.1
4	R2	97	3.0	0.419	81.1	LOS F	7.1	50.8	0.94	0.78	18.6
Approach		1378	5.5	0.565	22.9	LOS B	21.3	156.8	0.54	0.51	39.8
North: Arnold Avenue											
3	L2	74	5.0	0.881	86.2	LOS F	21.1	154.3	1.00	0.98	17.0
2	T1	182	5.0	0.881	78.6	LOS F	21.1	154.3	1.00	0.98	17.0
1	R2	104	5.0	0.797	101.4	LOS F	4.6	33.2	1.00	0.85	15.8
Approach		360	5.0	0.881	86.7	LOS F	21.1	154.3	1.00	0.94	16.7
West: Memorial Avenue (W)											
12	L2	427	3.0	0.408	24.5	LOS B	13.4	96.4	0.59	0.83	37.8
11	T1	1667	6.0	0.893	28.5	LOS C	49.6	365.4	0.75	0.72	35.9
10	R2	206	3.0	0.890	95.8	LOS F	17.9	128.6	1.00	0.92	16.5
Approach		2300	5.2	0.893	33.8	LOS C	49.6	365.4	0.74	0.76	32.9
All Vehicles		4256	5.3	0.893	36.3	LOS C	49.6	365.4	0.71	0.69	31.2

Modelling Results for 2036

AM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.148	43.4	LOS D	3.8	27.9	0.79	0.74	26.5
8	T1	111	5.0	0.388	68.4	LOS E	8.1	59.2	0.95	0.76	18.4
7	R2	33	5.0	0.506	97.7	LOS F	2.8	20.4	1.00	0.73	16.3
Approach		218	5.0	0.506	64.3	LOS E	8.1	59.2	0.90	0.75	20.2
East: Memorial Avenue (E)											
6	L2	137	3.0	0.131	17.4	LOS B	2.9	21.0	0.48	0.72	43.5
5	T1	1144	6.0	0.565	18.6	LOS B	21.3	156.8	0.51	0.46	43.1
4	R2	97	3.0	0.419	81.1	LOS F	7.1	50.8	0.94	0.78	18.6
Approach		1378	5.5	0.565	22.9	LOS B	21.3	156.8	0.54	0.51	39.8
North: Arnold Avenue											
3	L2	74	5.0	0.881	86.2	LOS F	21.1	154.3	1.00	0.98	17.0
2	T1	182	5.0	0.881	78.6	LOS F	21.1	154.3	1.00	0.98	17.0
1	R2	104	5.0	0.797	101.4	LOS F	4.6	33.2	1.00	0.85	15.8
Approach		360	5.0	0.881	86.7	LOS F	21.1	154.3	1.00	0.94	16.7
West: Memorial Avenue (W)											
12	L2	427	3.0	0.408	24.5	LOS B	13.4	96.4	0.59	0.83	37.8
11	T1	1667	6.0	0.893	28.5	LOS C	49.6	365.4	0.75	0.72	35.9
10	R2	206	3.0	0.890	95.8	LOS F	17.9	128.6	1.00	0.92	16.5
Approach		2300	5.2	0.893	33.8	LOS C	49.6	365.4	0.74	0.76	32.9
All Vehicles		4256	5.3	0.893	36.3	LOS C	49.6	365.4	0.71	0.69	31.2

PM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.148	43.4	LOS D	3.8	27.9	0.79	0.74	26.5
8	T1	111	5.0	0.388	68.4	LOS E	8.1	59.2	0.95	0.76	18.4
7	R2	33	5.0	0.506	97.7	LOS F	2.8	20.4	1.00	0.73	16.3
Approach		218	5.0	0.506	64.3	LOS E	8.1	59.2	0.90	0.75	20.2
East: Memorial Avenue (E)											
6	L2	137	3.0	0.131	17.4	LOS B	2.9	21.0	0.48	0.72	43.5
5	T1	1144	6.0	0.565	18.6	LOS B	21.3	156.8	0.51	0.46	43.1
4	R2	97	3.0	0.419	81.1	LOS F	7.1	50.8	0.94	0.78	18.6
Approach		1378	5.5	0.565	22.9	LOS B	21.3	156.8	0.54	0.51	39.8
North: Arnold Avenue											
3	L2	74	5.0	0.881	86.2	LOS F	21.1	154.3	1.00	0.98	17.0
2	T1	182	5.0	0.881	78.6	LOS F	21.1	154.3	1.00	0.98	17.0
1	R2	104	5.0	0.797	101.4	LOS F	4.6	33.2	1.00	0.85	15.8
Approach		360	5.0	0.881	86.7	LOS F	21.1	154.3	1.00	0.94	16.7
West: Memorial Avenue (W)											
12	L2	427	3.0	0.408	24.5	LOS B	13.4	96.4	0.59	0.83	37.8
11	T1	1667	6.0	0.893	28.5	LOS C	49.6	365.4	0.75	0.72	35.9
10	R2	206	3.0	0.890	95.8	LOS F	17.9	128.6	1.00	0.92	16.5
Approach		2300	5.2	0.893	33.8	LOS C	49.6	365.4	0.74	0.76	32.9
All Vehicles		4256	5.3	0.893	36.3	LOS C	49.6	365.4	0.71	0.69	31.2

RESULTS FOR MEMORIAL AVENUE/ SEVERN VALE DRIVE INTERSECTION

Modelling Results for 2019

AM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	194	3.0	0.607	63.0	LOS E	15.8	113.4	0.90	0.82	21.3
8	T1	60	3.0	0.607	55.4	LOS D	15.8	113.4	0.90	0.82	21.3
7	R2	211	3.0	0.621	80.3	LOS F	7.6	54.5	0.99	0.80	18.6
Approach		465	3.0	0.621	69.9	LOS E	15.8	113.4	0.94	0.81	20.0
East: Memorial Avenue (E)											
6	L2	117	3.0	0.099	18.9	LOS B	3.1	22.5	0.40	0.71	42.2
5	T1	849	6.0	0.441	18.1	LOS B	13.8	101.3	0.49	0.43	43.6
4	R2	51	3.0	0.353	89.3	LOS F	2.0	14.0	1.00	0.71	17.4
Approach		1017	5.5	0.441	21.7	LOS B	13.8	101.3	0.50	0.48	40.7
North: SevernValeDrive											
3	L2	261	3.0	0.526	56.9	LOS E	16.2	116.1	0.90	0.83	22.9
2	T1	73	3.0	0.198	54.5	LOS D	4.2	30.0	0.82	0.64	21.0
1	R2	83	3.0	0.487	79.0	LOS F	5.8	41.8	0.97	0.77	18.8
Approach		417	3.0	0.526	60.9	LOS E	16.2	116.1	0.90	0.78	21.6
West: Memorial Avenue (W)											
12	L2	48	3.0	0.040	18.4	LOS B	1.2	8.7	0.38	0.69	42.6
11	T1	1186	6.0	0.615	20.5	LOS B	23.2	170.9	0.59	0.53	41.4
10	R2	71	3.0	0.490	90.1	LOS F	2.7	19.5	1.00	0.73	17.3
Approach		1304	5.7	0.615	24.2	LOS B	23.2	170.9	0.60	0.55	38.8
All Vehicles		3203	4.9	0.621	34.8	LOS C	23.2	170.9	0.66	0.59	31.7

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PM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	68	3.0	0.447	69.0	LOS E	9.1	65.3	0.91	0.77	19.9
8	T1	73	3.0	0.447	61.3	LOS E	9.1	65.3	0.91	0.77	19.9
7	R2	86	3.0	0.511	88.5	LOS F	3.3	23.5	1.00	0.74	17.5
Approach		227	3.0	0.511	73.9	LOS F	9.1	65.3	0.94	0.76	18.9
East: Memorial Avenue (E)											
6	L2	233	3.0	0.214	23.1	LOS B	7.7	55.5	0.49	0.75	38.9
5	T1	845	6.0	0.438	18.3	LOS B	13.8	101.9	0.49	0.43	43.5
4	R2	271	3.0	0.596	77.8	LOS F	9.5	68.1	0.97	0.80	19.2
Approach		1348	4.9	0.596	31.1	LOS C	13.8	101.9	0.58	0.56	34.6
North: SevernValeDrive											
3	L2	77	3.0	0.131	45.9	LOS D	4.0	28.5	0.74	0.74	25.7
2	T1	60	3.0	0.198	60.0	LOS E	3.7	26.3	0.86	0.66	19.9
1	R2	49	3.0	0.590	89.2	LOS F	3.8	27.4	1.00	0.76	17.4
Approach		186	3.0	0.590	61.9	LOS E	4.0	28.5	0.85	0.72	21.1
West: Memorial Avenue (W)											
12	L2	86	3.0	0.079	21.8	LOS B	2.6	18.8	0.44	0.71	39.8
11	T1	1114	6.0	0.579	20.2	LOS B	21.2	156.0	0.56	0.51	41.7
10	R2	179	3.0	0.393	75.7	LOS F	6.0	43.2	0.93	0.78	19.6
Approach		1379	5.4	0.579	27.5	LOS B	21.2	156.0	0.60	0.56	36.7
All Vehicles		3141	4.9	0.596	34.4	LOS C	21.2	156.0	0.63	0.58	32.3

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Modelling Results for 2026

AM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	279	3.0	0.767	61.7	LOS E	25.3	181.6	0.94	0.86	21.5
8	T1	110	3.0	0.767	54.0	LOS D	25.3	181.6	0.94	0.86	21.5
7	R2	269	3.0	0.792	84.3	LOS F	10.2	73.1	1.00	0.88	18.0
Approach		658	3.0	0.792	69.6	LOS E	25.3	181.6	0.96	0.87	19.9
East: Memorial Avenue (E)											
6	L2	132	6.0	0.125	22.4	LOS B	4.1	30.4	0.47	0.72	39.4
5	T1	890	6.0	0.515	25.0	LOS B	18.1	133.2	0.61	0.54	38.3
4	R2	56	6.0	0.394	89.6	LOS F	2.1	15.8	1.00	0.72	17.3
Approach		1078	6.0	0.515	28.0	LOS B	18.1	133.2	0.61	0.57	36.3
North: SevernValeDrive											
3	L2	287	3.0	0.483	50.4	LOS D	16.6	119.5	0.85	0.82	24.5
2	T1	137	3.0	0.290	49.0	LOS D	7.4	53.0	0.78	0.64	22.3
1	R2	130	3.0	0.767	83.4	LOS F	9.8	70.1	1.00	0.86	18.2
Approach		554	3.0	0.767	57.8	LOS E	16.6	119.5	0.87	0.79	22.1
West: Memorial Avenue (W)											
12	L2	86	6.0	0.082	22.0	LOS B	2.6	19.3	0.45	0.71	39.7
11	T1	1331	6.0	0.777	29.6	LOS C	35.3	259.8	0.79	0.72	35.2
10	R2	107	6.0	0.754	93.1	LOS F	4.2	31.3	1.00	0.81	16.8
Approach		1525	6.0	0.777	33.6	LOS C	35.3	259.8	0.79	0.73	33.1
All Vehicles		3815	5.1	0.792	41.8	LOS C	35.3	259.8	0.78	0.72	28.5

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PM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	105	3.0	0.635	66.4	LOS E	15.6	111.9	0.93	0.81	20.4
8	T1	137	3.0	0.635	58.8	LOS E	15.6	111.9	0.93	0.81	20.4
7	R2	101	3.0	0.378	81.4	LOS F	3.6	25.8	0.97	0.75	18.5
Approach		342	3.0	0.635	67.8	LOS E	15.6	111.9	0.94	0.79	19.7
East: Memorial Avenue (E)											
6	L2	291	6.0	0.275	24.0	LOS B	10.1	74.3	0.52	0.76	38.2
5	T1	902	6.0	0.501	22.5	LOS B	17.2	126.5	0.57	0.51	40.1
4	R2	297	6.0	0.892	95.2	LOS F	12.3	90.3	1.00	0.96	16.6
Approach		1489	6.0	0.892	37.2	LOS C	17.2	126.5	0.65	0.65	31.5
North: SevernValeDrive											
3	L2	82	3.0	0.138	45.1	LOS D	4.1	29.8	0.74	0.75	26.0
2	T1	110	3.0	0.298	55.8	LOS D	6.5	46.6	0.85	0.68	20.7
1	R2	88	3.0	0.663	84.1	LOS F	6.6	47.2	1.00	0.81	18.1
Approach		280	3.0	0.663	61.6	LOS E	6.6	47.2	0.86	0.74	21.0
West: Memorial Avenue (W)											
12	L2	134	6.0	0.127	22.5	LOS B	4.2	30.9	0.47	0.72	39.4
11	T1	1165	6.0	0.647	24.8	LOS B	25.8	189.7	0.66	0.60	38.3
10	R2	264	6.0	0.795	85.9	LOS F	10.0	73.9	1.00	0.86	17.9
Approach		1564	6.0	0.795	34.9	LOS C	25.8	189.7	0.70	0.65	32.6
All Vehicles		3675	5.5	0.892	40.9	LOS C	25.8	189.7	0.71	0.67	29.2

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Modelling Results for 2036

AM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	338	3.0	0.910	76.4	LOS F	38.2	274.3	1.00	0.99	18.8
8	T1	139	3.0	0.910	68.8	LOS E	38.2	274.3	1.00	0.99	18.8
7	R2	324	3.0	0.903	95.8	LOS F	13.7	98.4	1.00	1.04	16.5
Approach		801	3.0	0.910	83.0	LOS F	38.2	274.3	1.00	1.01	17.8
East: Memorial Avenue (E)											
6	L2	145	3.0	0.137	23.3	LOS B	4.7	33.9	0.48	0.73	38.8
5	T1	872	6.0	0.519	26.9	LOS B	18.6	136.8	0.63	0.56	37.1
4	R2	69	3.0	0.483	91.2	LOS F	2.7	19.4	1.00	0.73	17.1
Approach		1087	5.4	0.519	30.5	LOS C	18.6	136.8	0.63	0.59	34.9
North: SevernValeDrive											
3	L2	352	3.0	0.578	51.8	LOS D	21.4	153.3	0.88	0.84	24.1
2	T1	171	3.0	0.348	49.3	LOS D	9.4	67.6	0.79	0.65	22.2
1	R2	162	3.0	0.905	93.1	LOS F	13.4	96.3	1.00	1.00	16.9
Approach		686	3.0	0.905	60.9	LOS E	21.4	153.3	0.89	0.83	21.5
West: Memorial Avenue (W)											
12	L2	106	3.0	0.100	22.9	LOS B	3.4	24.2	0.47	0.72	39.0
11	T1	1468	6.0	0.904	43.5	LOS D	51.7	380.5	0.91	0.91	28.9
10	R2	125	3.0	0.874	97.9	LOS F	5.2	37.2	1.00	0.88	16.2
Approach		1700	5.6	0.904	46.3	LOS D	51.7	380.5	0.89	0.89	27.8
All Vehicles		4273	4.6	0.910	51.5	LOS D	51.7	380.5	0.85	0.83	25.3

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PM Peak

Movement Performance Vehicles

Mov ID	ODMov	Demand Flows Total	Demand Flows HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Severn Vale Drive											
9	L2	123	3.0	0.726	66.8	LOS E	19.5	140.0	0.96	0.84	20.3
8	T1	171	3.0	0.726	59.1	LOS E	19.5	140.0	0.96	0.84	20.3
7	R2	114	3.0	0.392	80.4	LOS F	4.1	29.5	0.99	0.76	18.6
Approach		408	3.0	0.726	67.4	LOS E	19.5	140.0	0.97	0.81	19.8
East: Memorial Avenue (E)											
6	L2	346	3.0	0.340	27.3	LOS B	13.4	96.5	0.58	0.78	36.1
5	T1	1140	6.0	0.690	30.4	LOS C	28.6	210.2	0.75	0.67	34.8
4	R2	362	3.0	0.878	91.1	LOS F	14.7	105.5	1.00	0.94	17.1
Approach		1848	4.9	0.878	41.7	LOS C	28.6	210.2	0.77	0.75	29.4
North: SevernValeDrive											
3	L2	95	3.0	0.145	41.6	LOS C	4.6	33.1	0.71	0.75	27.0
2	T1	139	3.0	0.351	54.8	LOS D	8.1	58.4	0.85	0.69	20.9
1	R2	108	3.0	0.745	84.7	LOS F	8.2	58.6	1.00	0.85	18.0
Approach		342	3.0	0.745	60.6	LOS E	8.2	58.6	0.86	0.75	21.2
West: Memorial Avenue (W)											
12	L2	166	3.0	0.163	25.2	LOS B	5.7	41.2	0.51	0.74	37.4
11	T1	1218	6.0	0.737	31.4	LOS C	32.0	235.6	0.79	0.71	34.3
10	R2	323	3.0	0.784	82.8	LOS F	12.0	86.4	1.00	0.86	18.4
Approach		1707	5.1	0.784	40.5	LOS C	32.0	235.6	0.80	0.74	30.0
All Vehicles		4304	4.6	0.878	45.2	LOS D	32.0	235.6	0.81	0.75	27.5

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APPENDIX F

ALTERNATE LOCAL ROAD CROSS SECTION AT MEMORIAL AVENUE / ARNOLD AVENUE (WEST) / FREE SETTLES DRIVE INTERSECTION (TECHNICAL NOTE 7)

Technical Note 7: Alternate Local Road Cross Section at Memorial Avenue / Arnold Avenue (west) / Free Settles Drive Intersection

Date of Submission: 24th of January 2014

This Technical Note 7 has been prepared to report of sensitivity test on Memorial Avenue / Arnold Avenue.

RMS has asked Hyder to undertake sensitivity analysis should Arnold Avenue West, Free Settlers be upgraded as per the Hill Shire Council DCP 2012 with a cross section consisting of a 4.5m verge, 12m carriageway and 3.5m verge.

Figure 1 shows alternate cross section and lane configurations at Memorial Avenue / Arnold Avenue.

Table 1 below shows SIDRA result for sensitivity test at Memorial Avenue/ Arnold Avenue (West) / Free Settlers Drive traffic signals for the AM and PM peaks.

Sensitivity analysis shows the alternate intersection footprints at Memorial Avenue/ Arnold Avenue (West) traffic signals would provide level of service C and D in year 2019 and 2026. Model forecasts level of service F in the ultimate year 2036.

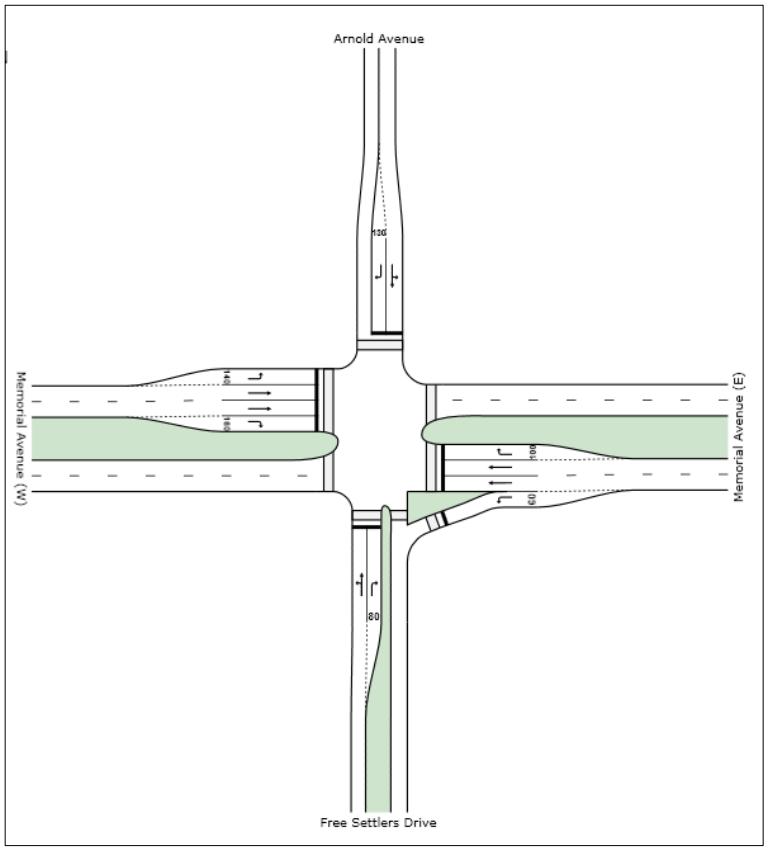

Figure 1 Alternate cross section and lane configurations at Memorial Avenue / Arnold Avenue

Table 1 Forecast levels of service at Memorial Avenue / Arnold Avenue (West) / Free Settlers Drive intersection

ID	Intersection	Control Type	Time Period	2019		2026		2036	
				Average Delay (sec)	LOS	Average Delay (sec)	LOS	Average Delay (sec)	LOS
I-5	Arnold Avenue / Memorial Avenue	New Traffic Signal	AM	37	C	50	D	102	F
			PM	26	B	32	C	40	C

Detailed SIDRA Results

2019 AM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	85	5.0	0.435	48.8	LOS D	8.1	58.8	0.92	0.81	24.5
8	T1	78	5.0	0.435	41.2	LOS C	8.1	58.8	0.92	0.81	24.5
7	R2	96	5.0	0.316	62.7	LOS E	5.8	42.4	0.92	0.78	21.6
Approach		259	5.0	0.435	51.7	LOS D	8.1	58.8	0.92	0.80	23.3
East: Memorial Avenue (E)											
6	L2	37	3.0	0.034	15.6	LOS B	0.7	5.2	0.43	0.69	45.1
5	T1	1108	6.0	0.707	30.8	LOS C	27.0	199.1	0.78	0.70	34.6
4	R2	40	3.0	0.513	84.6	LOS F	2.9	20.5	1.00	0.73	18.0
Approach		1185	5.8	0.707	32.2	LOS C	27.0	199.1	0.78	0.70	33.9
North: Arnold Avenue											
3	L2	74	5.0	0.313	37.5	LOS C	4.8	35.2	0.89	0.76	28.1
2	T1	48	5.0	0.313	29.9	LOS C	4.8	35.2	0.89	0.76	28.1
1	R2	237	5.0	0.781	70.7	LOS F	15.9	116.4	1.00	0.88	20.1
Approach		359	5.0	0.781	58.4	LOS E	15.9	116.4	0.96	0.84	22.2
West: Memorial Avenue (W)											
12	L2	86	3.0	0.080	16.2	LOS B	1.7	12.4	0.45	0.73	44.6
11	T1	1203	6.0	0.760	32.0	LOS C	31.1	228.8	0.83	0.74	33.9
10	R2	22	3.0	0.282	83.3	LOS F	1.5	11.0	0.99	0.71	18.3
Approach		1311	5.8	0.760	31.8	LOS C	31.1	228.8	0.80	0.74	33.9
All Vehicles		3114	5.6	0.781	36.6	LOS C	31.1	228.8	0.82	0.74	30.9

2019 PM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	21	5.0	0.173	39.0	LOS C	2.9	21.0	0.85	0.69	27.5
8	T1	48	5.0	0.173	31.3	LOS C	2.9	21.0	0.85	0.69	27.5
7	R2	24	5.0	0.289	75.4	LOS F	1.5	11.3	1.00	0.71	19.3
Approach		93	5.0	0.289	44.4	LOS D	2.9	21.0	0.89	0.70	24.7
East: Memorial Avenue (E)											
6	L2	100	3.0	0.102	17.5	LOS B	2.2	15.7	0.51	0.71	43.4
5	T1	838	6.0	0.454	17.5	LOS B	12.6	92.9	0.53	0.46	43.9
4	R2	74	3.0	0.651	76.4	LOS F	4.8	34.4	1.00	0.79	19.4
Approach		1012	5.5	0.651	21.8	LOS B	12.6	92.9	0.56	0.51	40.5
North: Arnold Avenue											
3	L2	63	5.0	0.340	39.6	LOS C	6.1	44.3	0.88	0.75	27.3
2	T1	78	5.0	0.340	31.9	LOS C	6.1	44.3	0.88	0.75	27.3
1	R2	67	5.0	0.808	80.5	LOS F	4.6	33.5	1.00	0.88	18.5
Approach		208	5.0	0.808	49.9	LOS D	6.1	44.3	0.92	0.79	23.5
West: Memorial Avenue (W)											
12	L2	242	3.0	0.247	18.8	LOS B	5.9	42.1	0.56	0.76	42.2
11	T1	1364	6.0	0.738	21.5	LOS B	28.1	206.5	0.72	0.65	40.3
10	R2	86	3.0	0.757	78.1	LOS F	5.7	40.9	1.00	0.83	19.1
Approach		1692	5.4	0.757	24.0	LOS B	28.1	206.5	0.71	0.68	38.6
All Vehicles		3005	5.4	0.808	25.7	LOS B	28.1	206.5	0.68	0.63	37.0

2026 AM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	164	5.0	0.780	68.7	LOS E	22.0	160.3	0.99	0.89	20.0
8	T1	146	5.0	0.780	61.1	LOS E	22.0	160.3	0.99	0.89	20.0
7	R2	107	5.0	0.267	58.8	LOS E	6.4	46.9	0.87	0.78	22.4
Approach		417	5.0	0.780	63.5	LOS E	22.0	160.3	0.96	0.86	20.6
East: Memorial Avenue (E)											
6	L2	40	6.0	0.041	18.2	LOS B	0.9	7.0	0.48	0.69	42.7
5	T1	1267	6.0	0.856	40.4	LOS C	41.0	301.7	0.88	0.83	30.1
4	R2	43	6.0	0.664	88.1	LOS F	3.4	24.7	1.00	0.82	17.5
Approach		1350	6.0	0.856	41.3	LOS C	41.0	301.7	0.87	0.83	29.7
North: Arnold Avenue											
3	L2	81	5.0	0.381	58.8	LOS E	10.4	75.7	0.88	0.77	22.0
2	T1	89	5.0	0.381	51.2	LOS D	10.4	75.7	0.88	0.77	22.0
1	R2	347	5.0	0.817	69.1	LOS E	24.5	178.7	0.98	0.90	20.4
Approach		517	5.0	0.817	64.4	LOS E	24.5	178.7	0.95	0.86	20.9
West: Memorial Avenue (W)											
12	L2	110	6.0	0.089	16.6	LOS B	2.5	18.8	0.35	0.72	44.2
11	T1	1365	6.0	0.908	49.2	LOS D	49.9	367.0	0.94	0.95	26.9
10	R2	60	6.0	0.778	88.6	LOS F	4.8	35.5	1.00	0.89	17.4
Approach		1535	6.0	0.908	48.4	LOS D	49.9	367.0	0.90	0.93	27.1
All Vehicles		3819	5.8	0.908	49.7	LOS D	49.9	367.0	0.90	0.88	26.0

2026 PM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	59	5.0	0.677	83.4	LOS F	9.9	72.4	1.00	0.94	17.5
8	T1	89	5.0	0.677	75.7	LOS F	9.9	72.4	1.00	0.94	17.5
7	R2	27	5.0	0.148	76.7	LOS F	1.9	13.8	0.94	0.72	19.1
Approach		175	5.0	0.677	78.5	LOS F	9.9	72.4	0.99	0.91	17.8
East: Memorial Avenue (E)											
6	L2	64	6.0	0.266	45.7	LOS D	2.9	21.5	0.94	0.74	27.4
5	T1	957	6.0	0.581	29.5	LOS C	22.4	164.8	0.68	0.60	35.5
4	R2	81	6.0	0.621	88.2	LOS F	6.2	45.5	1.00	0.85	17.5
Approach		1102	6.0	0.621	34.8	LOS C	22.4	164.8	0.72	0.63	32.7
North: Arnold Avenue											
3	L2	66	5.0	0.628	71.3	LOS F	14.9	109.0	0.98	0.82	19.4
2	T1	146	5.0	0.628	63.6	LOS E	14.9	109.0	0.98	0.82	19.4
1	R2	91	5.0	0.295	67.8	LOS E	5.7	41.6	0.87	0.77	20.6
Approach		303	5.0	0.628	66.5	LOS E	14.9	109.0	0.94	0.80	19.7
West: Memorial Avenue (W)											
12	L2	352	6.0	0.284	13.6	LOS A	5.9	43.2	0.40	0.75	47.1
11	T1	1536	6.0	0.788	23.1	LOS B	38.2	280.9	0.72	0.67	39.2
10	R2	165	6.0	0.432	25.9	LOS B	4.9	35.7	0.59	0.76	36.9
Approach		2053	6.0	0.788	21.7	LOS B	38.2	280.9	0.66	0.69	40.1
All Vehicles		3633	5.9	0.788	32.1	LOS C	38.2	280.9	0.72	0.69	33.1

2036 AM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	205	5.0	1.039	197.9	LOS F	51.7	377.4	1.00	1.51	9.2
8	T1	182	5.0	1.039	190.3	LOS F	51.7	377.4	1.00	1.51	9.2
7	R2	133	5.0	0.332	59.6	LOS E	8.1	59.4	0.88	0.79	22.2
Approach		520	5.0	1.039	159.9	LOS F	51.7	377.4	0.97	1.32	10.9
East: Memorial Avenue (E)											
6	L2	46	3.0	0.037	16.6	LOS B	1.1	7.7	0.34	0.69	44.2
5	T1	1326	6.0	0.878	43.4	LOS D	44.3	326.3	0.92	0.88	28.9
4	R2	51	3.0	0.976	111.2	LOS F	4.5	32.3	1.00	0.96	14.6
Approach		1423	5.8	0.976	45.0	LOS D	44.3	326.3	0.90	0.88	28.3
North: Arnold Avenue											
3	L2	97	5.0	0.465	60.0	LOS E	13.0	94.9	0.91	0.79	21.7
2	T1	111	5.0	0.465	52.4	LOS D	13.0	94.9	0.91	0.79	21.7
1	R2	422	5.0	0.993	124.0	LOS F	44.3	323.6	1.00	1.16	13.7
Approach		630	5.0	0.993	101.5	LOS F	44.3	323.6	0.97	1.04	15.5
West: Memorial Avenue (W)											
12	L2	123	3.0	0.098	16.6	LOS B	2.9	20.6	0.35	0.73	44.2
11	T1	1494	6.0	1.025	139.1	LOS F	91.8	675.4	1.00	1.45	13.2
10	R2	75	3.0	1.027	187.6	LOS F	9.6	68.6	1.00	1.21	9.5
Approach		1692	5.6	1.027	132.3	LOS F	91.8	675.4	0.95	1.39	13.6
All Vehicles		4265	5.5	1.039	102.0	LOS F	91.8	675.4	0.94	1.16	16.3

2036 PM Peak

Movement Performance Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Free Settlers Drive											
9	L2	74	5.0	0.845	93.0	LOS F	13.9	101.6	1.00	1.08	16.3
8	T1	111	5.0	0.845	85.3	LOS F	13.9	101.6	1.00	1.08	16.3
7	R2	33	5.0	0.181	77.1	LOS F	2.3	16.9	0.95	0.73	19.0
Approach		218	5.0	0.845	86.7	LOS F	13.9	101.6	0.99	1.03	16.6
East: Memorial Avenue (E)											
6	L2	137	3.0	0.139	20.2	LOS B	3.9	27.8	0.52	0.73	41.1
5	T1	1144	6.0	0.723	31.7	LOS C	30.4	223.4	0.75	0.68	34.2
4	R2	97	3.0	0.731	90.6	LOS F	7.5	53.9	1.00	0.91	17.1
Approach		1378	5.5	0.731	34.7	LOS C	30.4	223.4	0.75	0.70	32.6
North: Arnold Avenue											
3	L2	74	5.0	0.760	75.1	LOS F	19.0	138.6	1.00	0.88	18.7
2	T1	182	5.0	0.760	67.4	LOS E	19.0	138.6	1.00	0.88	18.7
1	R2	104	5.0	0.337	68.3	LOS E	6.6	48.1	0.88	0.78	20.5
Approach		360	5.0	0.760	69.2	LOS E	19.0	138.6	0.96	0.85	19.2
West: Memorial Avenue (W)											
12	L2	427	3.0	0.337	13.9	LOS A	7.5	53.6	0.43	0.76	46.9
11	T1	1667	6.0	0.924	38.3	LOS C	56.1	412.8	0.81	0.83	31.1
10	R2	206	3.0	0.618	32.7	LOS C	6.7	48.1	0.75	0.81	32.9
Approach		2300	5.2	0.924	33.3	LOS C	56.1	412.8	0.73	0.82	33.1
All Vehicles		4256	5.3	0.924	39.5	LOS C	56.1	412.8	0.77	0.79	29.8