Northern Beaches Hospital

Stage 1: Concept Design, Site Clearance & Preparatory Works

Appendix C

Transport Assessment

NORTHERN BEACHES HOSPITAL

Traffic and Transport Impact Assessment

Hyder Consulting Pty Ltd
ABN 76 104 485 289
Level 5, 141 Walker Street
Locked Bag 6503
North Sydney NSW 2060
Australia
Tel: +61 2 8907 9000
Fax: +61 2 8907 9001
www.hyderconsulting.com

HEALTH INFRASTRUCTURE

NORTHERN BEACHES HOSPITAL

Concept Proposal

Traffic and Transport Impact Assessment

Author Damien Chee

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1 INTRODUCTION

1.1 BACKGROUND

The Northern Sydney Area Health District covers the north-eastern quadrant of Sydney and extends north to south from the Hawkesbury River to Sydney Harbour, and east to west from the Pacific Ocean to the western boundaries of the Hornsby and Ryde local government areas. The Northern Beaches is an area within the Northern Sydney Area Health District that covers the Manly, Warringah and Pittwater local government areas. This area extends south to the entrance of Port Jackson (Sydney Harbour), west to Middle Harbour and north to the entrance of Broken Bay.

There are a number of shortcomings in the provision of health services in the Northern Beaches Area. The existing hospitals at Manly and Mona Vale are not well located in relation to the catchment. Also, the current fragmentation of services and the unavailability of particular specialist services at these two hospitals mean that in many instances, patients and carers are required to travel between the two hospitals to access the services they need. In some cases, they need to travel to Royal North Shore Hospital to access specialist treatment.

The Northern Beaches Hospital Project (the Project) involves the development of a new Hospital at Frenchs Forest, as well as a re-configuration of clinical services across the Northern Beaches Health Services Network including Community Health Services. This hospital development is largely driven by the constraints within the existing Manly and Mona Vale hospitals described above. A single, centrally located hospital in this regard, will enable the provision of a wider range of services of higher role delineation, reducing the need for patients to travel outside the Northern Beaches.

The Hospital will be situated in Frenchs Forest approximately 13km north of Sydney Central Business District in the land bounded by Warringah Road to the south, Wakehurst Parkway to the east, Frenchs Forest Road to the north, and Forest High School to the west (Figure 1).

The Northern Beaches Hospital is likely to include 423 beds and approximately 1,000 full time equivalent (FTE) employees across the full range of clinical services and hospital administration. The hospital is likely to comprise a total of 70,000m^2 of floor area. The exact scale and layout of the Hospital is not yet confirmed as this will largely be governed through the procurement of a private sector hospital provider.

Since 2012, Health Infrastructure has worked collaboratively with the NSW Department of Planning and Infrastructure, Transport for NSW and Roads and Maritime Services to address road network planning issues in the vicinity of the hospital site. The work has been coordinated through an Inter-agency Reference Group (IRG) comprised of all four parties. The IRG has worked to identify and address road network issues, primarily to support the delivery of the hospital by 2018.

1.2 SCOPE OF THE DEVELOPMENT

Health Infrastructure is submitting a Concept Approval Planning Application under the Environmental Planning and Assessment Act 1979 for the Northern Beaches Hospital Concept Proposal (application number SSI 13_5982). This Application seeks approval for the staged development of the Northern Beaches Hospital, including:

- Concept approval for the final built form of the hospital including:
    - Bulk excavation works and sub-level car park.

- Construction of a new six to ten storey hospital building with approximately 70,000m^2 of gross floor area, providing emergency, critical care, operating theatres, acute inpatient, maternity and neonatal, paediatrics and adolescents, mental health care services, ambulatory services, clinical and other support services and associated administrative services.
- Staff, patient and visitor car parking.
- External site works, including landscaping and pathways.
- Utility services amplification works;

- Stage 1 site clearance and preparatory works, including the following:
  - Establishment of site office, including temporary connection to services (water, sewer, power);
  - Closure of Bantry Bay Road to the public and establishment of construction traffic management controls;
  - Removal of existing temporary fencing and installation of construction fencing;
  - Clearance of site vegetation including tree stumps, but not including topsoil;
  - Thinning of understorey in retained area of vegetation;
  - Offsite disposal of cleared vegetation (to green waste recycling facility or other beneficial reuse);
  - Site stabilisation (such as erosion and sediment controls) in preparation for subsequent stage works;
  - Site management in the period between completion of the Stage 1 works and commencement of the Stage 2 works.

As noted previously, the final built form of the hospital is still not confirmed and this will largely be determined following the procurement of a private hospital operator. As such, this Application focusses more on the Stage 1 site clearing works, and only discusses the final built form of the hospital in a conceptual manner.

Stage 2 of the Project involves the construction and operation of the hospital in its final built form. This is not covered by the Concept Approval Planning Application.

Figure 1 Locality map

1.3 SCOPE OF THE TRAFFIC AND TRANSPORT IMPACT ASSESSMENT

The Concept Approval Planning Application seeks concept approval for the Northern Beaches Hospital as well as the Stage 1 site clearance works. Stage 2 of the Project, which is for the construction and operation of the hospital, is not included in this Application. As noted previously, the final scale and layout of the hospital development, and hence the key parameters for environmental assessment of the Stage 2 component will be strongly influenced by (i) the eventual hospital operator from the private sector, and (ii) the scale of the hospital development that they are willing to provide.

It is also expected that once a hospital operator has been procured, the Environmental Assessment associated with the operation of the hospital will need to be revised/ re-examined in greater detail. As such, the objectives of this Traffic and Transport Impact Assessment are:

- To provide a preliminary assessment and commentary on likely traffic issues that may arise during the operation of the hospital (ie. the overall concept of the development) following the procurement of a private sector based hospital operator.
- To assess the likely impacts of the Stage 1 site clearance works.

The scope of this Traffic and Transport Impact Assessment has been governed by the relevant Director General Requirements (DGRs) as issued for Application number SSI 13_5982 which are described in Table 1. Table 1 also provides a reference to the relevant section of this report where each DGR is addressed.

Table 1 DGRs relevant to traffic and transport issues.

Item no.	Description	Ref to report section
Northern Beaches Concept Proposal The EIS for the staged infrastructure application for the Northern Beaches Hospital, including Stage 1, must address the following specific matters:		
4	**Transport and Accessibility** Undertake an assessment of the traffic impact of the concept proposal, with particular regard to:	
	▪ Existing road capacity, traffic conditions, expected impacts, including consideration of any additional requirement at times when Wakehurst Parkway is flooded.	Section 3.0 and 4.0
	▪ Road and intersection upgrade requirements, including options to offset the impact of the future hospital development on the road network.	Section 4.7*
	▪ Determine the adequacy of the development to meet the future demand for increased public transport services.	
	▪ Daily and peak traffic movements and impacts on intersections.	Section 4.0*
	▪ Access arrangements to and within the site, including the appropriateness of the location of the main access point.	
	▪ Delivery, servicing and loading arrangements.	
	▪ Pedestrian and bicycle linkages to and within the site.	
	▪ Access for emergency vehicles.	
15	**Stage 1 Site Clearance and Preparatory Works** **Transport and Accessibility**	
	▪ Provide accurate details of daily movements and assess the impacts of the traffic generated on the local road network, including impact on nearby intersections and any potential need for upgrade or road works (if required).	Section 5.0
	▪ Detail proposed car parking arrangements, including parking requirements for Stage 1 Site Clearance and Preparatory Works.	Section 5.2

* Many of these elements including ultimate scale and operation of the hospital can only be confirmed when the private hospital operator has been engaged. At present, many of these are un-confirmed. As such, this Traffic and Transport Impact Assessment has made a number of assumptions in order to conceptualise and assess the likely traffic impacts. Furthermore, many of the access and supporting roadwork solutions will be determined through the ongoing design development work and consultation with RMS and the Department of Planning.

2 EXISTING CONDITIONS

2.1 EXISTING ROAD CONDITIONS

The surrounding road network is shown in Figure 1 and is described in Sections 2.1.1 to 2.1.4.

2.1.1 WARRINGAH ROAD

Warringah Road is a State Road (MR328) under the care and management of Roads and Maritime Services (RMS). It is one of the three strategic arterial routes providing access to the Northern Beaches Peninsula. In the vicinity of the site, this road has a divided road configuration with three lanes per direction and indented turning lanes at key intersections. The road carries approximately 80,000 vehicles/day near the intersection with Forest Way (RTA, 2002) with AM and PM peak hour volumes of 3,250 vehicles/hour and 3,600 vehicles/hour in the peak travel direction (Aecom, 2011). The posted speed limit is 70km/h.

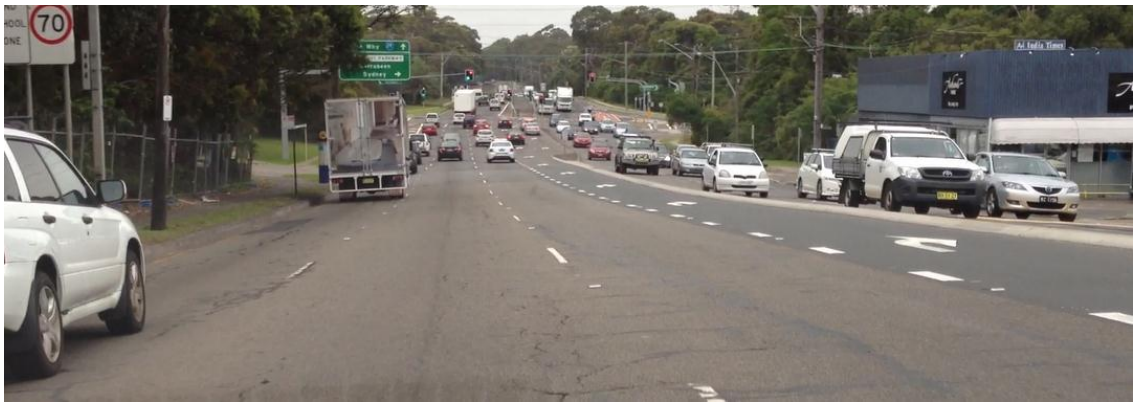

Figure 2 Warrignah Road looking eastbound towards Wakehurst Parkway.

2.1.2 WAKEHURST PARKWAY

This is a State Road (MR397) under the care and management of RMS. It provides an arterial road link between Seaforth and Narrabeen. In the vicinity of the site, this road has a divided road configuration with two northbound lanes, and dual right-turn lanes, a left-turn slip lane, a single through lane, and a dedicated bus lane in the southbound direction. The road carries approximately 21,000 vehicles/day (RTA, 2002) with AM and PM peak hour volumes of 1,250 vehicles/hour and 1,200 vehicles/hour in the peak travel direction (Aecom, 2011). The posted speed limit of 70km/h.

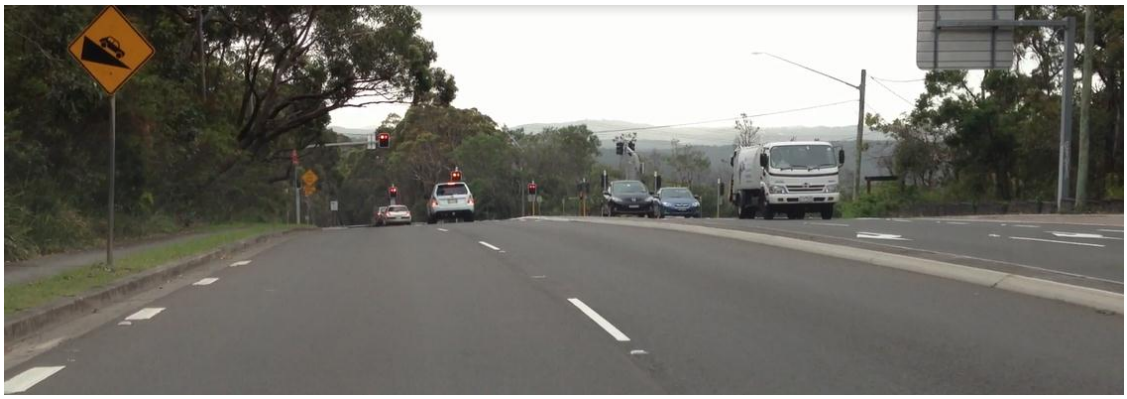

Figure 3 Wakehurst Parkway, looking northbound towards Frenchs Forest Road.

2.1.3 FRENCHS FOREST ROAD WEST/ NAREE ROAD

This is a local road under the care of Warringah Council. As an east-west route it provides a link between Forest Way and Warringah Road. In the vicinity of the site, this road has an undivided two-lane-two-way road configuration with additional lanes provided in the approach to the Wakehurst Parkway intersection. This road carries up to 830 vehicles/hour and 1,016 vehicles/hour in the AM and PM peak periods in the peak travel direction (Aecom, 2011).

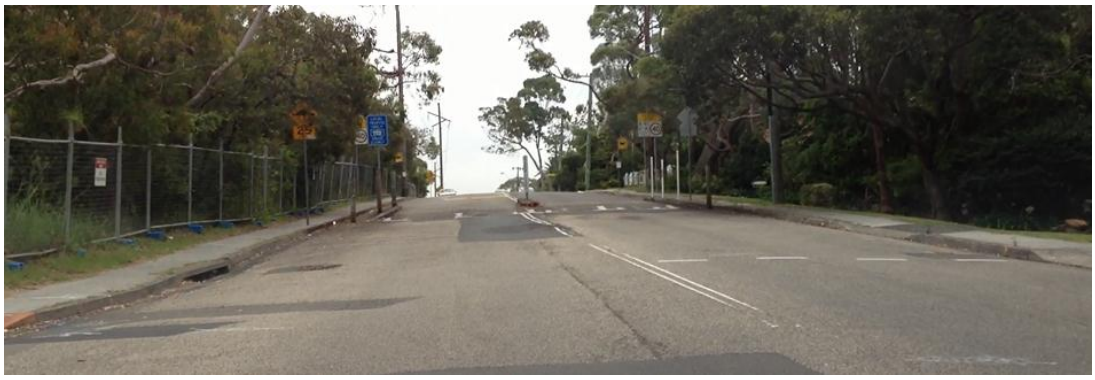

Figure 4 Frenchs Forest Road, looking westbound from Wakehurst Parkway.

2.1.4 BANTRY BAY ROAD

The portion of this road of direct relevance to the Project is the section between Frenchs Forest Road West and Warringah Road. This road bisects the site and will be closed off as part of the development, after being procured from Warringah Council in April 2013. A decision around the timing of closure will be made by Health Infrastructure following consultation with key stakeholders.

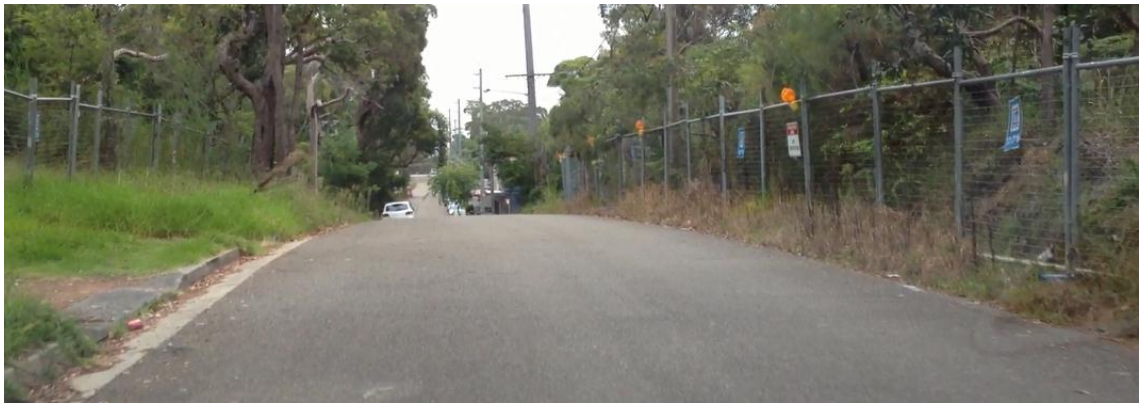

Figure 5 Bantry Bay Road looking south towards Warringah Road.

2.2 EXISTING TRAFFIC CONDITIONS

2.2.1 RMS SURVEYS

RMS have a number of counting stations in the road network surrounding the Project. These have been summarised in Table 2.

Table 2 Traffic volumes recorded and projected from RMS counting stations (RMS, 2002a)

Station no.	Location	2002 AADT (veh/day)	2013 projected AADT (veh/day)
55.051*	Forest Way, north of Warringah Road	46,865	57,180
55.048	Warringah Road, east of Forest Way	80,508	98,220
55.041	Wakehurst Parkway, south of Warringah Road	20,198	24,645

* 2005 data also available as shown in Figure 6.

Station 55.051 on Forest Way north of Warringah Road is a permanent counting station which records traffic volume data continuously. From this station, it is possible to determine year-by-year trends in traffic volumes, 24-hour traffic profile, as well as the distribution of traffic by days of the week. Figure 6 shows the year-by-year trends in traffic volumes at station 55.051 as well as the 2013 traffic volume projection based on historic growth (an assumed linear growth in traffic).

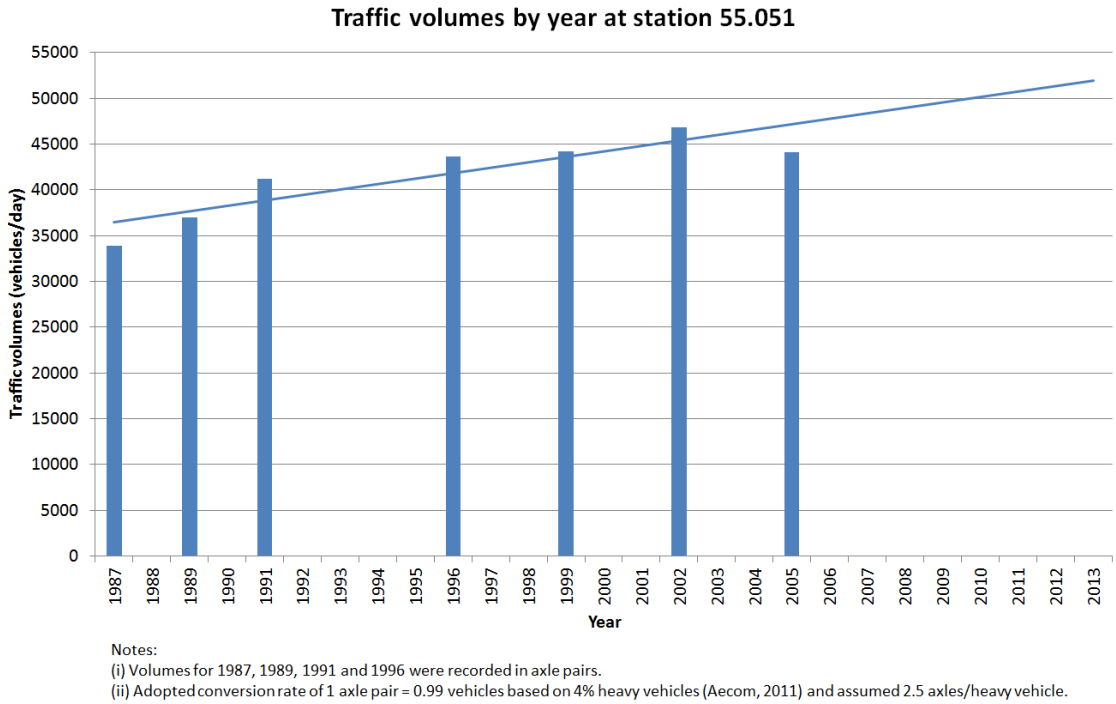

Figure 6 Year-by-year traffic volumes at counting station 55.051.

From Figure 6, an average annual growth rate of 1.8% per annum was derived. As such, this annual growth rate was used to convert the 2002 AADTs in Table 2 to 2013 (present day) volumes. These 2013 projected traffic volumes are also shown in Table 2[1].

2.2.2 INTERSECTION TURNING MOVEMENTS

Aecom (2011) provides details of turning movement surveys carried out at the following intersections which are also shown in Figure 1:

- Warringah Road/ Frenchs Forest Road.

[1] Note that the application of a 1.8% per annum growth rate over the 11 years between 2002 and 2013 is equivalent to a multiplier of 1.22.

- Warringah Road/ Allambie Road.
- Warringah Road/ Wakehurst Parkway.
- Warringah Road/ Hilmer Street.
- Warringah Road/ Forest Way.
- Forest Way/ Naree Road.
- Wakehurst Parkway/ Frenchs Forest Road.

These turning movement surveys were used (where necessary) as starting traffic volumes for the traffic impact assessment.

2.3 EXISTING PUBLIC NETWORK CONDITIONS

The bus routes servicing this area are detailed in Table 3.

Table 3 Existing bus services

Bus no.	Description	Frequency (7-9am)	
		S-W bound	N-E bound
270	Belrose-City: via Warringah Road and Forest Way.	25	7
279-284	Duffys Forest-Chatswood via Warringah Road and Forest Way.	17	10
280	Warringah Mall-Chatswood via Warringah Road and Forest Way.	4	6
L60	Mona Vale-Chatswood via Warringah Road.	3	0
136	Manly-Chatswood via Warringah Road, Forest Way, Frenchs Forest Road East.	9	5
137	Chatswood-Bantry Bay via Warringah Road.	0	1
169	Manly-City via Warringah Road, Forest Way, Frenchs Forest Road East, Wakehurst Parkway.	4	1
E69		17	0
173	Narraweena-Milsons Point via Warringah Road, Forest Way, Frenchs Forest Road East, Wakehurst Parkway.	3	0
142	Allambie Heights-Manly via Skyline shops, Allambie Road, Condamine Street, Manly	2	3
E66	Allambie Heights-City via Skyline shops, Allambie Road, Military Road, Wynyard Station	5	0

2.4 EXISTING PLANNING STRATEGIES

There are a number of regional planning strategies which have relevance to the Northern Beaches Hospital Project and the surrounding land. These are described as follows and have been considered in the determination of likely changes to the road transport system.

2.4.1 DRAFT 2031 METROPOLITAN STRATEGY

In 2013, the NSW Department of Planning and Infrastructure released the draft *2031 Metropolitan Strategy for Sydney*. This Strategy has recognised Frenchs Forest as a potential

Specialised Health Precinct with a key strategy to *capitalise on the growing cluster of hospital and health-related uses with associated research/ business park opportunities to stimulate local jobs*.

2.4.2 2036 METROPOLITAN PLAN

The 2036 Metropolitan Plan for Sydney (NSW Government, 2010) will address the challenges facing Sydney through an integrated, long–term planning framework based on a number of strategic directions and key policy settings, including transport for a connected city, and housing Sydney's population.

This Plan indicates that the North East Sub-region (which covers the entire Northern Beaches area) will experience a growth in employment capacity from 89,000 in 2006 to 112,000 in 2036. This increase in 23,000 jobs represents a 26% increase in employment.

The Plan also outlines a targeted increase of 29,000 new dwellings from 2006 to 2036

2.5 COMPLETED INVESTIGATIONS

A number of investigations have been carried out for road and transport proposals surrounding the Project. These are described as follows and have been considered with regard to likely changes to the road transport system.

2.5.1 FRENCHS FOREST SPECIALISED CENTRE – LOCAL TRANSPORT ASSESSMENT

Aecom (2011) assessed the transport implications of a potential specialised centre at Frenchs Forest. This would consist of a new hospital, ancillary health care services, redeveloped commercial properties and a commercial core that could support between 50,000 and 100,000m^2 of retail floor space.

The study revealed that there are many existing shortcomings in the performance of the road network and recommended that improvements be considered at the following locations:

- Forest Way/ Naree Road intersection.
- Frenchs Forest Road.
- Warringah Road/ Wakehurst Parkway intersection.
- Wakehurst Parkway/ Frenchs Forest Road intersection.
- Warringah Road/ Forest Way intersection.
- Warringah Road.
- Bus priority measures throughout the surrounding network.

2.5.2 NORTHERN BEACHES BUS RAPID TRANSIT – PRE-FEASIBILITY STUDY

Transport for NSW (2012) assessed the feasibility of a Bus Rapid Transit (BRT) system on the North-South Corridor between the Northern Beaches and Sydney CBD as well as the East-West Corridor between Chatswood and Dee Why.

This study examined five BRT options for the East-West Corridor. Transport for NSW is currently considering options for addressing bus priority needs through this corridor.

3 ASSESSMENT OF EXISTING NETWORK CAPACITY

3.1 STUDY AREA

For the purposes of this assessment, the study area was considered to include the following roads and intersections:

- **Roads**
  - Warringah Road, between Forest Way and Wakehurst Parkway.
  - Wakehurst Parkway, between Frenchs Forest Road and Warringah Road.
  - Frenchs Forest Road-Naree Road between Forest Way and Wakehurst Parkway.
- **Intersections**
  - Warringah Road/ Wakehurst Parkway.
  - Wakehurst Parkway/ Frenchs Forest Road.
  - Forest Way/ Naree Road.
  - Warringah Road/ Forest Way.

Whilst traffic generated by the development could potentially impact more distant sections of the road network, this study area was established to provide an indication of the overall likely impact. This study area is within the road network immediately surrounding the proposed hospital and as such it is likely to be directly affected. By contrast, more distant sections of the road network would be heavily influenced by other land use developments and regional transportation demands.

Generally in an urban environment, the performance of the traffic network is most critically governed by the performance of the at-grade intersections. This is because the midblock sections generally have less flow impedances compared with intersections where the traffic from each approach must be time-separated through traffic control measures. In these respects, the assessment of traffic impacts in this subject study area has focussed on the likely performance of the key intersections listed above.

3.2 EXISTING INTERSECTION PERFORMANCE

Using the traffic volumes from Aecom (2011), the existing performance of the four study intersections was simulated using the SIDRA modelling software. A summary of the model outputs is provided in Table 4 with a more detailed assessment in Appendix A. The latter includes input traffic volumes, model outputs and associated commentary.

The traffic performance indicators – Level of Service (LoS), Degree of Saturation (DoS), maximum queue lengths, and average delays, are described in Appendix B.

Table 4 SIDRA model inputs and outputs for the Existing Case.

Intersection and scenario	LoS	DoS	Max queue	Average delay
Warringah Road/ Wakehurst Parkway Existing case AM peak	D	0.888	277m	48 sec/ veh
Warringah Road/ Wakehurst Parkway Existing case PM peak	F	1.047	512m	83 sec/ veh
Wakehurst Parkway/ Frenchs Forest Road Existing case AM peak	D	0.899	162m	43 sec/ veh
Wakehurst Parkway/ Frenchs Forest Road Existing case PM peak	C	0.895	201m	42 sec/ veh
Forest Way/ Naree Road Existing case AM peak	F	1.544	181m	23 sec/ veh
Forest Way/ Naree Road Existing case PM peak	F	3.281	697m	112sec/veh
Warringah Road/ Forest Way Existing case AM peak	F	2.461	2818m	326 sec/veh
Warringah Road/ Forest Way Existing case PM peak	F	6.570	4432m	956 sec/veh

Notes:

(i) The 2011 traffic volumes sourced from Aecom (2011) were regarded as being equivalent to present day volumes. It should be noted that the application of the 1.8% per annum growth per year would result in a 3.6% growth from 2011 to 2013. However, the 95% peak hour factor adopted in the SIDRA models increased the flow rates for each approach to the intersection by approximately 5.2%. As such, the application of a 95% peak flow factor sufficiently covered any likely increases in traffic volumes due to annual growth.

(ii) A complete description of the traffic performance indicators (level of service (LoS), degree of saturation (DoS), maximum queue length, and average delays is provided in Appendix B).

Warringah Road/ Wakehurst Parkway

The SIDRA model outputs in Table 4 indicate that this intersection is failing under the AM and PM peak periods. In particular, under the PM peak traffic volume demands, the intersection has a modelled level of service of F, maximum queue lengths of 512m and average delays of 83 seconds/vehicle.

These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigating supporting roadwork solutions.

Wakehurst Parkway/ Frenchs Forest Road

The SIDRA models indicate that this intersection is performing with some forced traffic flow (level of service E) in some of the movements. In particular, the right-turn movement from Wakehurst Parkway South, and all movements from Frenchs Forest Road West have poor modelled performance.

These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigating supporting roadwork solutions.

Forest Way/ Naree Road

The obvious failure at this intersection is the lack of entering opportunity afforded to vehicles egressing from Naree Road. In particular, right-turning traffic from this approach would have to select gaps in up to six lanes of traffic. This also affects left-turning traffic from this approach, since there is only a single approach lane. As such, more left-turning traffic would tend to re-distribute down to Rabbett Street.

The right-turning movement from Forest Way South into Naree Road is also a poor performing movement. Without the aid of traffic signals, and due to the heavy flows from the north, this traffic has very little opportunity to cross the southbound traffic stream.

Warringah Road/ Forest Way

There are several aspects leading to the failed performance at this intersection. These include:

- The lack of capacity of the eastbound carriageway of Warringah Road to absorb the heavy left-turning traffic volume demands from Forest Way.
- The strong competition between the westbound right-turn movement from Warringah Road to Forest Way, and the eastbound through movement along Warringah Road. Any phasing adjustments to benefit one movement (through increased green time allocation), is likely to disadvantage the other.

These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are who are investigating supporting roadwork solutions.

3.3 TIME DISTRIBUTION OF TRAFFIC BY HOUR OF DAY

As stated previously, Counting Station 55.051 is a permanent counting station which records traffic volumes continuously throughout the year. This is located on Forest Way to the west of Rabbett Street. Using the hour-by-hour traffic volumes, a 24-hour traffic volume distribution for the average weekday was prepared. Acknowledging that the capacity of a section of road is actually governed by the capacity of its key intersections, the capacity of the northbound and southbound carriageways was approximated as 2160 vehicles/hour/direction. This is based on a maximum service rate of 1800 vehicles/hour/lane (a minimum headway of 2 seconds based on the approach and departures to an intersection), and an assumed 40% of the total signal cycle time that allows for traffic to feed into or out of these two carriageways of Forest Way.

Figure 7 shows the 24-hour traffic volume profile for the northbound carriageway of Forest Way. This is presented as the percentage of overall capacity used by the existing traffic volumes versus the percentage of capacity that is residual or spare capacity which can accommodate more traffic before reaching saturation levels. Figure 8 shows similar information for the southbound carriageway of Forest Way.

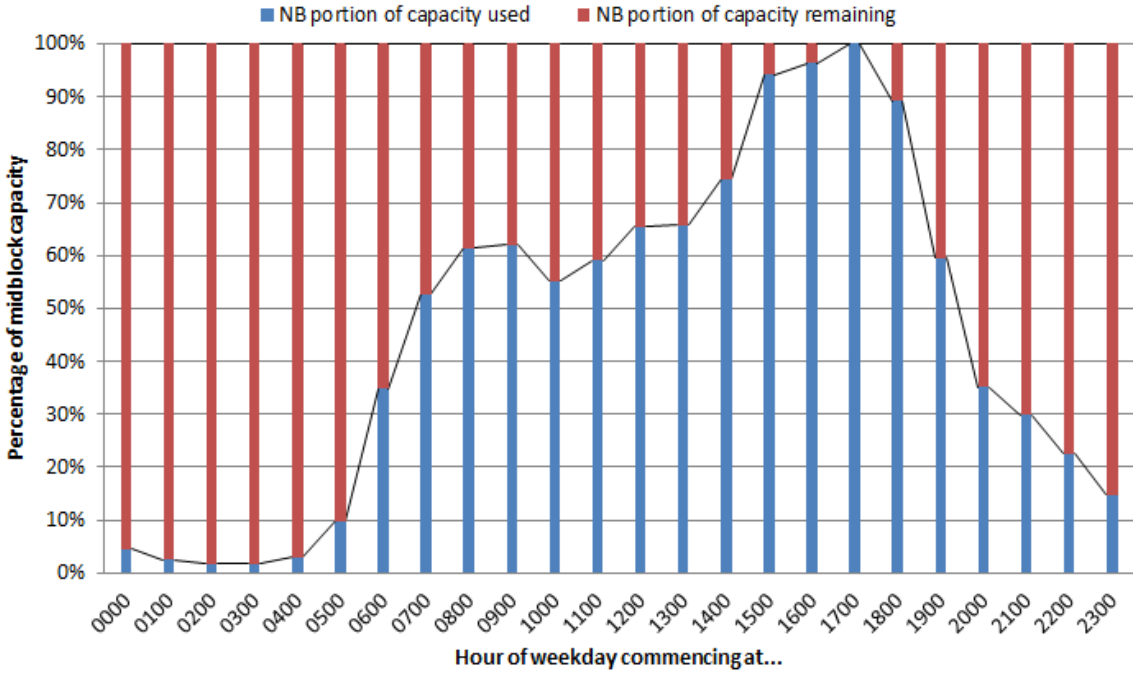

Figure 7 **24-hour profile of capacity used versus capacity remaining – Northbound direction of Forest Way.**

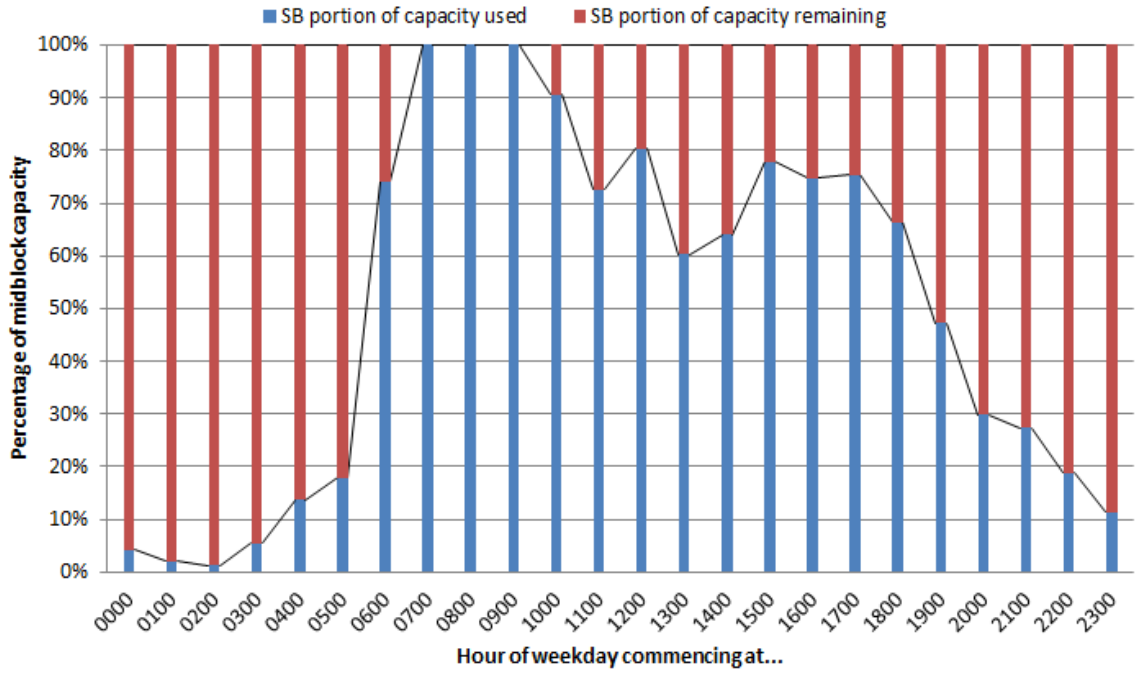

Figure 8 **24-hour profile of capacity used versus capacity remaining – Southbound direction of Forest Way.**

Considering the available capacity in both travel directions, it is clear that there is a period between 1100h and 1400h where there is spare capacity in both travel directions.

Applying this residual capacity analysis to other roads in the study area and assuming a similar 24-hour profile for intersection capacity, it can be concluded that the period between 1100-1400h on weekdays will be most ideal for scheduling of large volume traffic movements from the Site during the Stage 1 clearance works. This is on the basis that the Stage 1 works are carried out with the road and intersections in their current layouts.

4 COMMENTARY ON TRAFFIC IMPLICATIONS OF CONCEPT PROPOSAL

As stated previously, the scale and layout of the hospital development is still uncertain as this will be strongly governed by the private hospital operator who has not yet been engaged. However, for the purposes of conceptualising the likely traffic generation impacts of the hospital in its operational stage, the following assumptions were used:

- The hospital is likely to provide clinical services in emergency, critical care, operating theatres, acute inpatient, maternity and neonatal, paediatrics and adolescents, mental health care services, ambulatory services, clinical and other support services as well as associated administrative services.
- The hospital is likely to include 70,000m^2 of gross floor area
- The hospital is likely to have up to 1,000 full time equivalent (FTE) employees.
- The hospital is likely to provide 423 beds.

Based on the above assumptions, the hospital is likely to have the following traffic generation implications:

- Staff trips to/from work by car, bus, bicycle and walking.
- Servicing and maintenance including deliveries, supplies, waste management including a significant proportion of trucks.
- Patient movements including self-driven, kiss and ride, bus, walking and ambulance.
- Trips generated by visitors.

A commentary on the likely traffic generation and distribution implications of these elements is provided in Sections 4.1 to 4.8.

4.1 STAFF MOVEMENTS

Hyder consulted a number of experts from the Department of Health and Health Infrastructure in with regards to potential travel methods of hospital staff. With the 1,000 full time equivalent positions associated with the hospital, the likely parking and traffic generation implications of the workforce were forecasted using the following key assumptions:

- 80% of the workforce would need to report to the site each day.
- For shift workers, there would be three work shifts per day: (i) 2130-0730h, (ii) 0700-1530h, and (iii) 1330-2200h. There would be overlaps in the shifts.
- 12.5% of the daily shift workers would work in the 2130-0730h shift, 27.5% would work in the 1330-2200h shift, and 60% would work in the 0700-1530h shift.
- For the car parking assessment, 80% of day workers would generate car trips and 100% of night workers would generate car trips.

4.2 PATIENT AND VISITOR MOVEMENTS

Through consultation with relevant subject matter experts in the Northern Beaches Hospital project team, the likely parking and traffic generation implications were forecasted using the following key assumptions:

- Between 0.4-1.0 car visits/ bed/ day depending on the duration of the hospital stay and the acuteness of the patient's injuries/ health condition.

The range of this trip generation rate was determined in consideration of the function of each bed as well as the likely duration of stay for the patient. For example, maternity beds would attract more frequent visitors compared with mental health beds.

4.3 DELIVERIES AND MISCELLANEOUS TRIPS

The following sources of deliveries are anticipated:

- Gifts.
- Equipment and supplies.
- Landscaping and maintenance.
- Waste collection.
- Medical supplies, pathology, and organ deliveries.
- Patient transfers including ambulances.
- Linen
- Food deliveries.

For deliveries, the following trip generation assumptions were used:

- 30 car visits/day for delivery of gifts.
- 20 vehicle visits/day for deliveries and supplies.

Many delivery requirements are not likely to coincide on the same day. As such, traffic generated by deliveries would be well spread out throughout the week.

4.4 PARKING ACCUMULATION AND SUPPLY

Hyder has carried out extensive research in parking generation rates for hospitals as summarised below:

- Warringah Council's (2011) *Development Control Plan* does not provide any specific detail on minimum parking generation/ supply rates for hospitals. Rather, this document states that "comparisons must be drawn with developments for similar purposes".
- RMS's *Guide to Traffic Generating Developments* (RTA, 2002) provided parking generation rates based on a survey of 19 private hospitals in 1994 in the Sydney Region. This document provides two formulae for determining the parking demand based on (i) number of beds or (ii) number of beds and average number of staff per weekday shift. Using these formulae based on the proposed 423 beds and 1000 full time equivalent positions (of which 800 would report to site each day), a peak demand of between 450-540 parking spaces would be required.
- Hyder also carried out investigations regarding the number of parking spaces supplied at other hospitals including Liverpool, The Randwick hospital precinct (Prince of Wales, Prince of Wales Private, Sydney Children's Hospital, Royal Women's Hospital), St. George Public and Private Hospitals, Canterbury, Westmead, Campbelltown, Wollongong and North Shore. These investigations revealed that the number of parking spaces supplied at these hospitals was 1.25 - 4.0 times higher than the number of spaces predicted by the RMS method. This strongly indicates that there is a large degree of

variance in parking supply versus predicted parking demand across the range of hospitals in NSW.

Due to this large variance, Hyder then considered a “first principles” approach in deriving the number of parking spaces required. Using the information from Sections 4.1 to 4.3, a parking accumulation model was developed. This considered the expected arrival and departure times based on shift times, as well as the likely duration of stay.

Figure 9 shows the results of the model. As seen, the model predicts a peak parking accumulation of between 800-900 spaces and a day time (0600-1600h) average of 670 spaces. As such, it is recommended that between 800-900 parking spaces be supplied on site and incorporated as part of the final built form of the hospital.

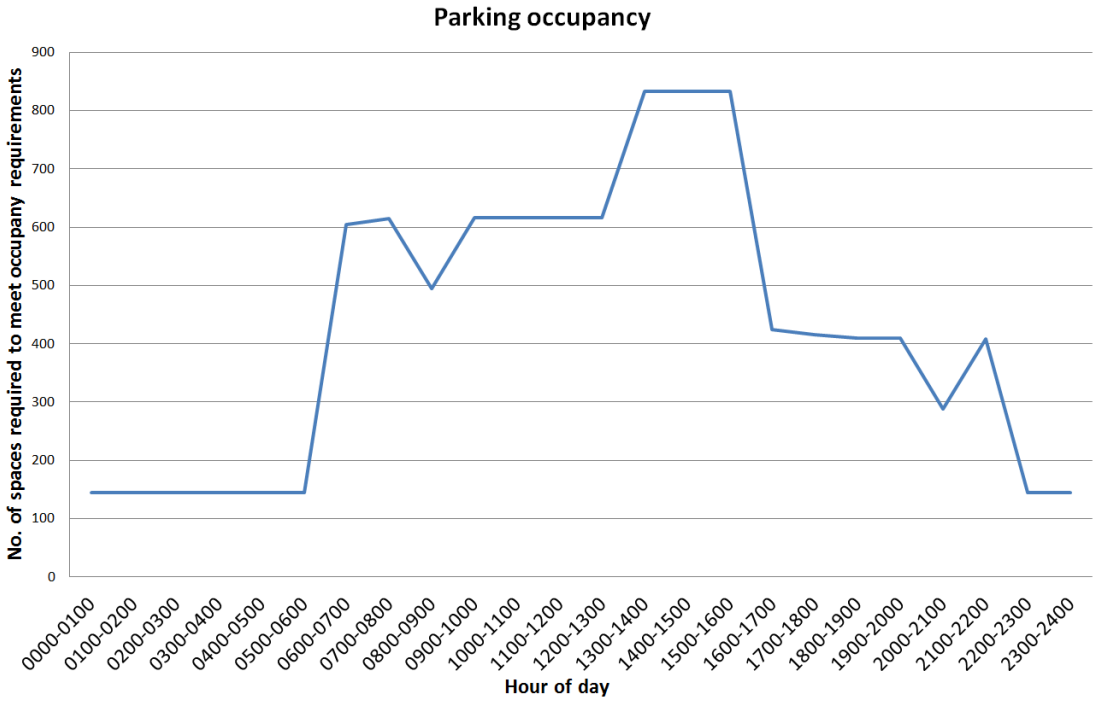

Figure 9 Parking accumulation by time of day.

4.5 TRAFFIC GENERATION AND DISTRIBUTION

The parking accumulation analysis described above was used to forecast the potential traffic generation to the site. This was required to carry out a preliminary assessment of traffic impacts to inform the access/egress requirements of the site.

Whilst the parking accumulation analysis used a 100% car usage factor for conservative reasons, the assessment of traffic impacts considered the likely transport mode choices as shown in Figure 10. This was based on *Journey to Work* data from 2011 Census as sourced from the Bureau of Transport Statistics. The left-hand chart in this figure shows the existing breakdown in transport mode for the Manly and Mona Vale Hospitals. This was used to inform the likely travel mode split for employees of the Northern Beaches Hospital which is shown in the right-hand chart[2]. The key assumption is that with many staff from these existing hospitals

[2] In converting the mode split percentages from the existing hospitals to the new hospital, the following adjustments were made: (i) “Did not work” category was not considered and was deleted and (ii) “Ferry/ tram” and “train” modes were transferred to “bus” since there are no ferries, trams or trains that provide direct access to Frenchs Forest.

being transferred to the new hospital, they will continue to use similar mode choices to get to work.

It is acknowledged that some workers will change residence as a result of being transferred to the new hospital and this may also affect the mode split.

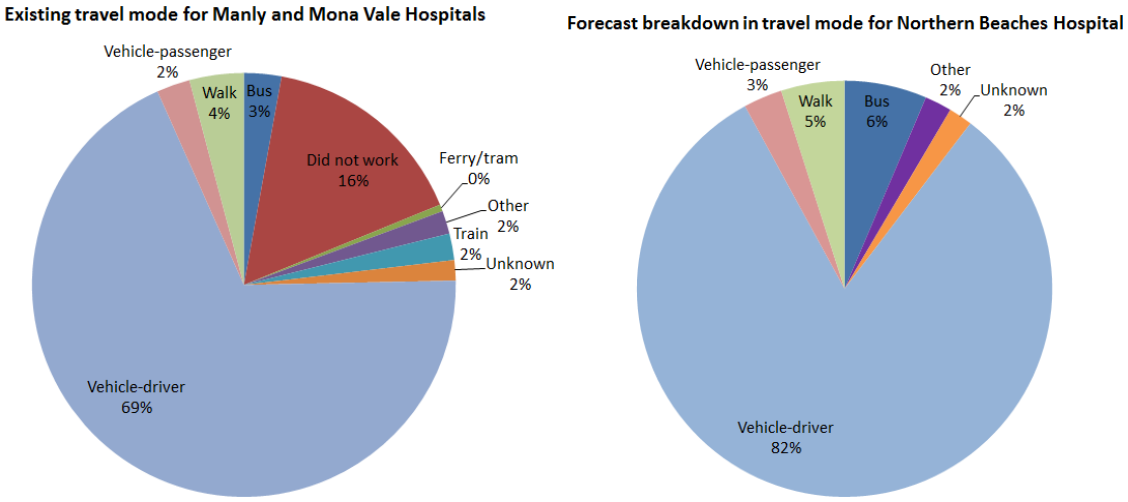

Figure 10 Left: Transport mode split for existing Manly and Mona Vale Hospitals. Right: Forecast transport mode split for Northern Beaches Hospital.

4.6 TRAFFIC DISTRIBUTION

As many of the clinical services for the Northern Beaches Hospital would be transferred from Manly and Mona Vale Hospitals, the spatial distribution of staff trips from these two hospitals was considered for the traffic impact analysis for Northern Beaches Hospital. This assumes that the relative distribution of trips for the Northern Beaches Hospital would be similar to these two existing hospitals.

The *Journey to Work* data from the 2011 census was used to determine the spatial distribution of staff trips from Manly and Mona Vale Hospitals. The diagram in Figure 11 summarises this spatial distribution as applied to Northern Beaches Hospital.

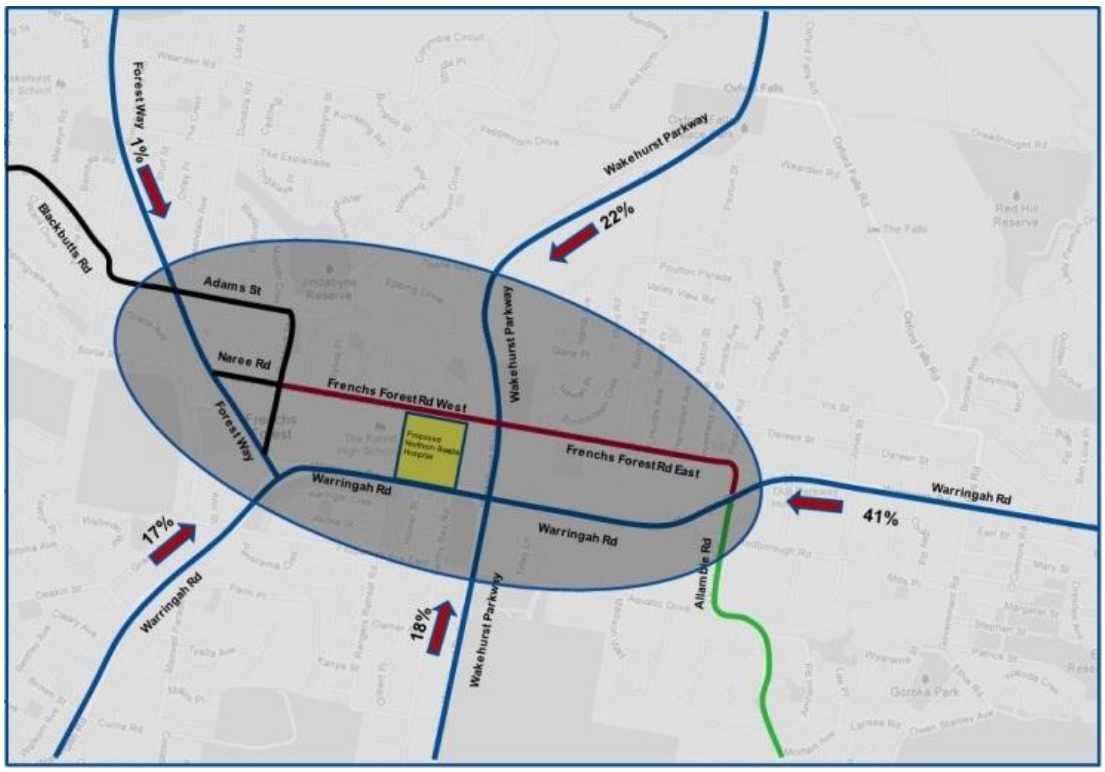

Figure 11 Likely traffic distribution of journey to work trips.

4.7 POTENTIAL IMPACTS TO ROAD CAPACITY

The trip generation and modal split as described in Sections 4.5 and 4.6 were used to determine the car traffic generation associated with the Northern Beaches Hospital. The traffic distribution as described in Section 4.6 was used to determine the “exit paths” from the hospital for egressing traffic. A preliminary traffic impact assessment was thereby carried out for this egressing traffic. This considered the available absorption capacity of the surrounding road network. That is, the capacity of the surrounding network to absorb/ receive additional traffic from the proposed hospital site.

The analysis showed that in the opening year of 2018, there could be up to 900 outbound trips per hour generated by the hospital in the PM peak. Frenchs Forest and Warringah Road would have a combined absorption capacity of 1,320 vehicles/hour. As such, there would be sufficient capacity in these midblocks to absorb the additional outbound traffic from the hospital.

However, as indicated in Section 3, there are existing constraints in the surrounding road network with regards to the capacity of the major intersections to absorb this traffic. This is due to the existing high levels of congestion experienced at those facilities during the AM and PM peak periods.

As stated previously, the existing and future road transportation needs of the surrounding network are being investigated and developed by RMS. This is in collaboration with Health Infrastructure through a formalised Inter-Agency Reference Group including both parties as well as the Department of Planning and Transport for NSW. As these supporting road network solutions are not yet finalised or confirmed, they have not been discussed or assessed in this report.

4.8 MINIMUM ACCESS ARRANGEMENTS

The master planning work associated with the proposed hospital indicated that for effective operation of the hospital, at least two points of access on two separate frontage roads should be provided. Furthermore, ambulance/ ambulant access should be separate from general public/ staff access.

As the final built form of the hospital is still uncertain, the ultimate location and function of the access points is also uncertain. However, conceptually, the following planning principles were adopted by the Interagency Reference Group (consisting of RMS, Health Infrastructure and Transport for NSW and Department of Planning) as a minimum to service the access/egress needs of the hospital:

- The main hospital entrance would be provided on Frenchs Forest Road at the intersection with Gladys Avenue. This is likely to be a signalised intersection with the hospital entrance/egress as the fourth and southern leg to the intersection.
- A secondary access point would be provided on Frenchs Forest Road at least 65m to the east of the main hospital entrance. This separation distance allows the deceleration requirements of each intersection to be wholly contained in the respective midblock – ie. a vehicle would not be required to decelerate prior to the first intersection in order to turn at the second intersection.
- A southern entrance/egress would be provided on Warringah Road to the west of Hilmer Street. This is likely to be a left-in-left-out access for general traffic, with special provisions for right-turn access for ambulances under emergency conditions only.

5 TRAFFIC IMPACTS DURING STAGE 1

The traffic modelling work described in Table 4 clearly indicates that under the existing road conditions and peak period traffic demands, there is very little residual capacity for additional traffic during the peak periods. The capacity deficiencies are due to existing traffic volume demands and the corresponding lack of capacity that exists at the key intersections. As such, RMS is considering supporting roadwork solutions on a network-wide basis. Health Infrastructure is also working in collaboration with RMS in this regards through an established Inter-agency Reference Group.

5.1 SPOIL MANAGEMENT

Appendix F to the *Master Planning Concept Design Report* for the Northern Beaches Hospital (MSJ-HDR, 2012) indicated that during Stage 1 of the Project, approximately 40,000m^2 of land would be cleared. This would include clearing of all trees (including stumps) and mulching on site. The mulch would be retained for erosion control purposes, for re-use as landscaping and also to reduce the bulk volumes for any residual amounts that would not be required for the Stage 2 works. There is no topsoil strip planned as part of the Stage 1 works and as such there is no earth spoil that needs to be exported or stockpiled.

As such, the volume of spoil that would need to be exported from site would be kept to a minimum and there would be negligible traffic impacts in these respects.

5.2 PARKING SUPPLY AND DEMAND

On-site parking demands will be generated by the construction workforce during the Stage 1 site clearing works. Workers that would be required to regularly attend this site would include:

- Project management staff.
- Plant operators such as dozers, excavators, mulchers etc.
- Environmental management staff.

Initially, on-site parking demands could be met by using Bantry Bay Road. The 230m length of this road would provide 25-30 light vehicle parking spaces along one side of the road. Some of this road length could also be designated as a layover area for trucks awaiting a scheduled load/pickup. It should also be noted a Northern Beaches Hospital Project Office has already been established on Aquatic Drive and has a generous parking supply. This would also reduce the on-site parking demands as Health Infrastructure staff and contractors would be able to walk to the site from the Project Office.

Once the land clearing process is underway, some of the cleared land could be set aside as parking provision for the remainder of the Stage 1 works. The preference would be to locate this in an area not subject to inundation, and where the land is relatively flat and compacted. The parking demands would not need a formal hard stand as long as appropriate safety and environmental management (eg. erosion control) were put in place. This is also to minimise any abortive works such as demolishing and disposing of asphalt/ concrete. This is also in consideration of the uncertainty of the final built form of the hospital and hence the difficulty in integrating such infrastructure with the final layout of the hospital.

It is likely that the designated truck and plant parking areas would follow the location of the clearing works.

5.3 GENERAL TRAFFIC MANAGEMENT MEASURES FOR STAGE 1

With minimal spoil generation and proposed re-use of mulch on site, the traffic generation implications of the Stage 1 clearance works would be minimal. However, notwithstanding this, the following traffic management measures would be encouraged in order to minimise the impacts on the surrounding network:

- Scheduling deliveries and consignments to be outside of the weekday AM and PM peak periods. This may also include provisions for truck layover as they wait for appropriate loading/unloading/dispatch times. The analysis in Section 3.3 indicates that the period between 1100-1400h on weekdays is most ideal as there is demonstrable spare capacity during these periods to absorb additional traffic without reaching network saturation levels.
- Scheduling construction traffic including delivery of plant and construction materials for outside the weekday AM and PM peak periods. See previous bullet point with regard to preferred time slots for scheduling traffic movements.
- Careful construction programming including scheduling of intense construction periods for school holiday periods. This may also consider alternative start and end times for work shifts.
- Encouraging workers to car pool or use public transport.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCEPT PROPOSAL

The ultimate scale of the hospital and its final built form are still uncertain as this will be strongly governed by the private hospital operator who has not yet been engaged. Once engaged, Health Infrastructure will continue to work with the private hospital operator to confirm the traffic generation potential that would result from their proposed hospital layout and scale. Health Infrastructure will also continue to collaborate with RMS regarding supporting roadwork solutions.

For the purposes of carrying out a preliminary assessment on the operational phase of the hospital, for the purposes of a concept application, it was assumed that the hospital would have a gross floor area of 70,000m^3, 423 beds, and up to 1,000 FTE employees. During the operational phase, the key traffic generators would be staff journeys to and from work, as well as deliveries and visitors.

Travel mode choices and geographical distribution of traffic were informed by statistics from the 2011 Census. This considered the transport mode choices and likely places of residence of employees at the existing two hospitals at Manly and Mona Vale. This assessment indicates that there may be a peak parking accumulation demand between 800-900 parking spaces and an average day-time accumulation of 670 parking spaces.

Although the preliminary assessment indicates that there is sufficient midblock capacity in Warringah Road and Frenchs Forest Road to absorb the traffic generated from this hospital, there is also strong modelling evidence that the key intersections surrounding the site will not be able to do so. These include the Warringah Road/ Wakehurst Parkway, Wakehurst Parkway/ Frenchs Forest Road, Warringah Road/ Forest Way, and Forest Way/ Naree Road intersections. The existing levels of congestion experienced at these intersections will severely inhibit their effectiveness in accommodating the additional traffic volumes generated by the hospital.

These existing traffic capacity shortcomings have been recognised and RMS are developing supporting roadwork solutions to address these. This is also in light of the plans for wider precinct land use development. Health Infrastructure is working in collaboration with RMS, Transport for NSW and Department of Planning, through an Inter-Agency Reference Group in these respects. This cross departmental collaboration will continue throughout the planning phase of the Northern Beaches Hospital.

6.2 STAGE 1

The site clearance and preparatory works will have minimal spoil generation due to the following:

- The trees and stumps that will be cleared will be mulched on site and re-used for erosion control and landscaping. The mulching will also reduce the bulk volume of residual material that needs to be exported (if no longer required) in Stage 2.
- There is no topsoil strip proposed for Stage 1. As such, there would be minimal earth spoil that would need to be exported from site during this stage.

As such, there would be minimal impacts on the surrounding road network during this stage.

Notwithstanding this, a number of traffic management practices would be encouraged during Stage 1. This would include scheduling traffic consignments in non-peak periods.

6.3 STAGE 2

A more comprehensive Traffic and Transport Impact Assessment will be carried out as part of the Stage 2 Application. This would be following the procurement of a private hospital operator when the final built form of the hospital would be more certain.

7 REFERENCES

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Bureau of Transport Statistics (2011) *Journey to Work data from 2011 Census*.

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NSW Health (2007) *2006 Clinical Services Plan*.

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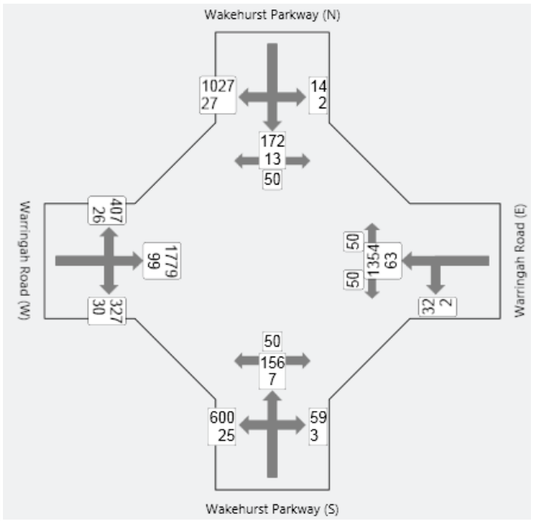
RTA (2002) *Traffic volume data 2002 – Sydney Region.*

RTA (2002) *Guide to Traffic Generating Developments*.

Warringah Council (2011) *DCP Appendix 1: Car parking requirements* on website http://eservices2.warringah.nsw.gov.au/ePlanning/Public/XC.Plan/Book.aspx?vid=14332

APPENDIX A: DESCRIPTION OF TRAFFIC PERFORMANCE INDICATORS

Table A1 SIDRA model inputs and outputs for the Existing Case.

<table>
<tr><th>Intersection and scenario</th><th>Input traffic volumes (note i)</th><th>SIDRA model outputs</th><th>Summary of model outputs</th><th>Commentary</th></tr>
<tr><td>Warringah Road/ Wakehurst Parkway
Existing case AM peak</td><td> 
</td><td>Warringah Road/ Wakehurst Parkway: 2011 existing case AM.
Signals - Fixed Time Cycle Time = 115 seconds (Practical Cycle Time)
Movement Performance - Vehicles
<table>
<tr><th>Mov ID</th><th>Turn</th><th>Demand Flow veh/h</th><th>HV %</th><th>Deg. Satn v/c</th><th>Average Delay sec</th><th>Level of Service</th><th>95% Back of Queue Vehicles veh</th><th>95% Back of Queue Distance m</th><th>Prop. Queued</th><th>Effective Stop Rate per veh</th><th>Average Speed km/h</th></tr>
<tr><td colspan="12">South: Wakehurst Parkway (S)</td></tr>
<tr><td>1</td><td>L</td><td>658</td><td>4.0</td><td>0.824</td><td>39.5</td><td>LOS C</td><td>12.4</td><td>89.7</td><td>1.00</td><td>0.91</td><td>18.2</td></tr>
<tr><td>2</td><td>T</td><td>172</td><td>4.3</td><td>0.824</td><td>60.1</td><td>LOS E</td><td>11.9</td><td>86.5</td><td>1.00</td><td>0.92</td><td>23.8</td></tr>
<tr><td>3</td><td>R</td><td>65</td><td>4.8</td><td>0.376</td><td>64.4</td><td>LOS E</td><td>3.6</td><td>26.1</td><td>0.98</td><td>0.76</td><td>12.2</td></tr>
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<tr><td colspan="12">East: Warringah Road (E)</td></tr>
<tr><td>4</td><td>L</td><td>36</td><td>5.9</td><td>0.877</td><td>66.0</td><td>LOS E</td><td>23.5</td><td>171.3</td><td>1.00</td><td>1.03</td><td>24.5</td></tr>
<tr><td>5</td><td>T</td><td>1492</td><td>4.4</td><td>0.877</td><td>56.5</td><td>LOS D</td><td>23.6</td><td>171.4</td><td>1.00</td><td>1.01</td><td>24.7</td></tr>
<tr><td>Approach</td><td></td><td>1527</td><td>4.5</td><td>0.877</td><td>56.7</td><td>LOS E</td><td>23.6</td><td>171.4</td><td>1.00</td><td>1.01</td><td>24.7</td></tr>
<tr><td colspan="12">North: Wakehurst Parkway (N)</td></tr>
<tr><td>7</td><td>L</td><td>17</td><td>12.5</td><td>0.028</td><td>19.5</td><td>LOS B</td><td>0.4</td><td>2.8</td><td>0.47</td><td>0.69</td><td>29.4</td></tr>
<tr><td>8</td><td>T</td><td>195</td><td>7.0</td><td>0.336</td><td>20.5</td><td>LOS B</td><td>6.0</td><td>44.4</td><td>0.82</td><td>0.67</td><td>31.3</td></tr>
<tr><td>9</td><td>R</td><td>1109</td><td>2.6</td><td>0.888</td><td>59.7</td><td>LOS E</td><td>34.4</td><td>245.9</td><td>1.00</td><td>0.98</td><td>17.3</td></tr>
<tr><td>Approach</td><td></td><td>1321</td><td>3.3</td><td>0.888</td><td>53.4</td><td>LOS D</td><td>34.4</td><td>245.9</td><td>0.97</td><td>0.93</td><td>18.6</td></tr>
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<tr><td>10</td><td>L</td><td>456</td><td>6.0</td><td>0.253</td><td>9.6</td><td>X</td><td>X</td><td>X</td><td>X</td><td>0.65</td><td>41.6</td></tr>
<tr><td>11</td><td>T</td><td>1977</td><td>5.3</td><td>0.865</td><td>41.3</td><td>LOS C</td><td>37.8</td><td>276.5</td><td>0.99</td><td>0.98</td><td>29.6</td></tr>
<tr><td>12</td><td>R</td><td>376</td><td>8.4</td><td>0.872</td><td>74.1</td><td>LOS F</td><td>11.9</td><td>89.2</td><td>1.00</td><td>0.97</td><td>11.9</td></tr>
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<tr><td>All Vehicles</td><td></td><td>6552</td><td>4.8</td><td>0.888</td><td>47.6</td><td>LOS D</td><td>37.8</td><td>276.5</td><td>0.92</td><td>0.94</td><td>23.9</td></tr>
</table></td><td>LoS = D
DoS = 0.888
Max queue = 277m
Av. Delay = 48s</td><td rowspan="2">These SIDRA model outputs indicate that this intersection is failing under the AM and PM peak periods. In particular, under the PM peak traffic volume demands, the intersection has a modelled level of service of F, maximum queue lengths of 512m and average delays of 83 seconds/vehicle.
The critical movements contributing to this poor performance are the right-turn movements from Warringah Road West and Wakehurst Parkway North. Furthermore, the right-turns from Wakehurst Parkway North are the third highest volume movement which is rare for a turning movement. In terms of demand volume, it is only out-ranked by the eastbound and westbound through movements along Warringah Road. This is a critical factor as it makes it difficult to balance the relative demands of each approach of the intersection. Any increase in relative “green time” allocated to the southbound right-turning movement from Wakehurst Parkway would inevitably lead to a reduction in “green time” allocated to the eastbound and westbound through movements along Warringah Road. Similarly, if more “green time” is allocated to the eastbound and westbound through movements on Warringah Road, it will come at the expense of reduced green time for the Wakehurst Parkway. Furthermore, the increased green time for the through movements may be of little overall benefit if other signalised intersections upstream and downstream of this intersection cannot handle the increase traffic bulking.
These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigation road network infrastructure upgrade requirements.</td></tr>
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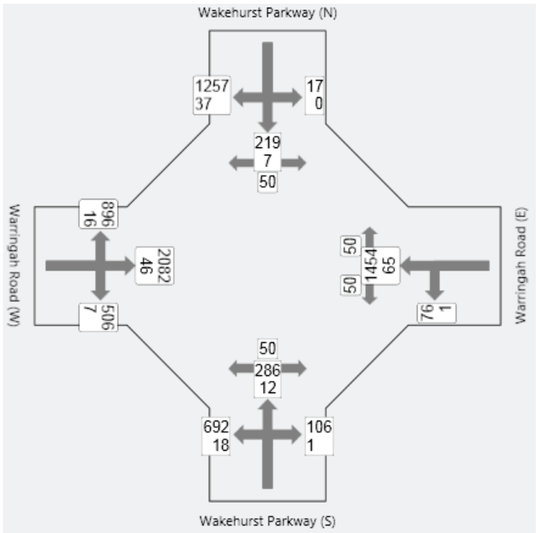
Existing case PM peak</td><td> 
</td><td>Warringah Road/ Wakehurst Parkway: 2011 existing case PM.
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Movement Performance - Vehicles
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<tr><td>Approach</td><td></td><td>1174</td><td>2.8</td><td>0.929</td><td>55.7</td><td>LOS D</td><td>18.3</td><td>130.6</td><td>1.00</td><td>0.96</td><td>17.5</td></tr>
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<tr><td>4</td><td>L</td><td>81</td><td>1.3</td><td>1.040</td><td>117.2</td><td>LOS F</td><td>35.9</td><td>259.0</td><td>1.00</td><td>1.23</td><td>15.8</td></tr>
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<tr><td>9</td><td>R</td><td>1362</td><td>2.9</td><td>1.047</td><td>135.8</td><td>LOS F</td><td>71.3</td><td>511.4</td><td>1.00</td><td>1.22</td><td>8.8</td></tr>
<tr><td>Approach</td><td></td><td>1618</td><td>2.9</td><td>1.047</td><td>118.1</td><td>LOS F</td><td>71.3</td><td>511.4</td><td>0.97</td><td>1.14</td><td>9.9</td></tr>
<tr><td colspan="12">West: Warringah Road (W)</td></tr>
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</table></td><td>LoS = F
DoS = 1.047
Max queue = 512m
Av. Delay = 83s</td></tr>
</table>

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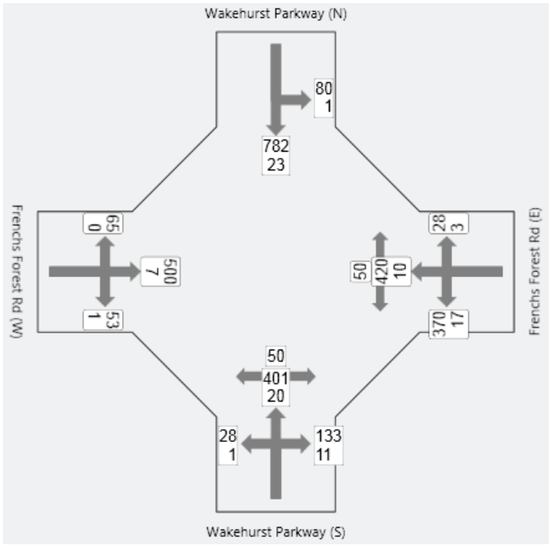
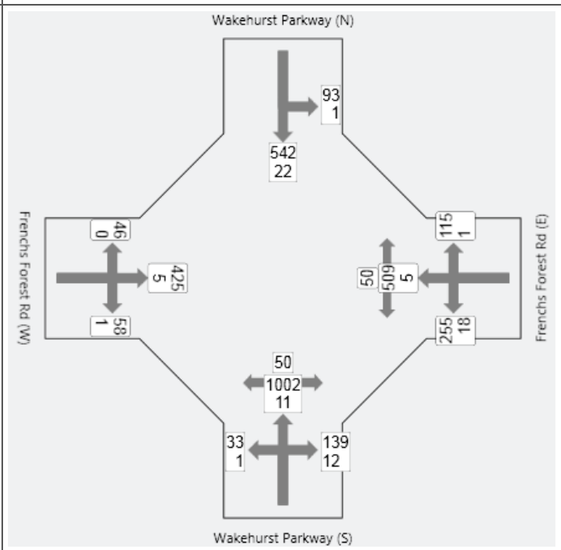
<th>Intersection and scenario</th>
<th>Input traffic volumes (note i)</th>
<th>SIDRA model outputs</th>
<th>Summary of model outputs</th>
<th>Commentary</th>
</tr>
<tr>
<td>Wakehurst Parkway/ Frenchs Forest Road
Existing case AM peak</td>
<td> 
</td>
<td>Wakehurst Parkway/ Frenchs Forest Road: 2011 existing case AM.
Signals - Fixed Time Cycle Time = 95 seconds (Practical Cycle Time)
Movement Performance - Vehicles
<table>
<tr><th>Mov ID</th><th>Turn</th><th>Demand Flow veh/h</th><th>HV %</th><th>Deg. Satn v/c</th><th>Average Delay sec</th><th>Level of Service</th><th>95% Back of Queue Vehicles veh</th><th>95% Back of Queue Distance m</th><th>Prop. Queued</th><th>Effective Stop Rate per veh</th><th>Average Speed km/h</th></tr>
<tr><td colspan="12">South: Wakehurst Parkway (S)</td></tr>
<tr><td>1</td><td>L</td><td>31</td><td>3.4</td><td>0.367</td><td>32.5</td><td>LOS C</td><td>7.1</td><td>51.9</td><td>0.69</td><td>0.99</td><td>24.5</td></tr>
<tr><td>2</td><td>T</td><td>443</td><td>4.8</td><td>0.367</td><td>24.2</td><td>LOS B</td><td>7.2</td><td>52.8</td><td>0.69</td><td>0.58</td><td>30.9</td></tr>
<tr><td>3</td><td>R</td><td>152</td><td>7.6</td><td>0.899</td><td>65.1</td><td>LOS E</td><td>8.1</td><td>60.4</td><td>1.00</td><td>0.97</td><td>9.4</td></tr>
<tr><td>Approach</td><td></td><td>625</td><td>5.4</td><td>0.899</td><td>34.5</td><td>LOS C</td><td>8.1</td><td>60.4</td><td>0.77</td><td>0.70</td><td>23.5</td></tr>
<tr><td colspan="12">East: Frenchs Forest Rd (E)</td></tr>
<tr><td>4</td><td>L</td><td>407</td><td>4.4</td><td>0.608</td><td>21.0</td><td>LOS B</td><td>8.1</td><td>58.7</td><td>0.87</td><td>0.82</td><td>28.8</td></tr>
<tr><td>5</td><td>T</td><td>453</td><td>2.3</td><td>0.852</td><td>42.7</td><td>LOS D</td><td>22.6</td><td>161.6</td><td>1.00</td><td>1.02</td><td>18.5</td></tr>
<tr><td>6</td><td>R</td><td>33</td><td>9.7</td><td>0.132</td><td>35.5</td><td>LOS C</td><td>1.1</td><td>8.5</td><td>0.77</td><td>0.71</td><td>26.1</td></tr>
<tr><td>Approach</td><td></td><td>893</td><td>3.5</td><td>0.852</td><td>32.5</td><td>LOS C</td><td>22.6</td><td>161.6</td><td>0.93</td><td>0.92</td><td>22.3</td></tr>
<tr><td colspan="12">North: Wakehurst Parkway (N)</td></tr>
<tr><td>7</td><td>L</td><td>85</td><td>1.2</td><td>0.889</td><td>61.9</td><td>LOS E</td><td>16.5</td><td>117.8</td><td>1.00</td><td>1.03</td><td>25.3</td></tr>
<tr><td>8</td><td>T</td><td>847</td><td>2.9</td><td>0.889</td><td>53.6</td><td>LOS D</td><td>16.6</td><td>118.9</td><td>1.00</td><td>1.02</td><td>26.9</td></tr>
<tr><td>Approach</td><td></td><td>933</td><td>2.7</td><td>0.889</td><td>54.4</td><td>LOS D</td><td>16.6</td><td>118.9</td><td>1.00</td><td>1.02</td><td>26.7</td></tr>
<tr><td colspan="12">West: Frenchs Forest Rd (W)</td></tr>
<tr><td>10</td><td>L</td><td>68</td><td>0.0</td><td>0.851</td><td>55.0</td><td>LOS D</td><td>16.8</td><td>118.6</td><td>1.00</td><td>1.02</td><td>24.8</td></tr>
<tr><td>11</td><td>T</td><td>534</td><td>1.4</td><td>0.851</td><td>47.3</td><td>LOS D</td><td>16.8</td><td>118.9</td><td>1.00</td><td>1.02</td><td>22.4</td></tr>
<tr><td>12</td><td>R</td><td>57</td><td>1.9</td><td>0.851</td><td>54.9</td><td>LOS D</td><td>16.8</td><td>118.9</td><td>1.00</td><td>1.02</td><td>23.8</td></tr>
<tr><td>Approach</td><td></td><td>659</td><td>1.3</td><td>0.851</td><td>48.8</td><td>LOS D</td><td>16.8</td><td>118.9</td><td>1.00</td><td>1.02</td><td>22.8</td></tr>
<tr><td>All Vehicles</td><td></td><td>3109</td><td>3.2</td><td>0.899</td><td>42.9</td><td>LOS D</td><td>22.6</td><td>161.6</td><td>0.93</td><td>0.93</td><td>24.2</td></tr>
</table></td>
<td>LoS = D
DoS = 0.899
Max queue = 162m
Av. Delay = 43s</td>
<td rowspan="2">The SIDRA models indicate that this intersection is performing with some forced traffic flow (level of service E) in some of the movements. In particular, the right-turn movement from Wakehurst Parkway South, and all movements from Frenchs Forest Road West have poor modelled performance.
Frenchs Forest Road West is an obvious weak link in the intersection’s overall capacity. This approach has two feeder lanes. However, these diverge from a single approach lane approximately 40m west of the intersection. The demand volumes of 534 vehicles/hour and 463 vehicles/hour in the through direction are required to transit through the intersection in approximately 20% of the overall cycle time. In one-hour, the total green time would be in the order of 720 seconds. This requires vehicles to transit at headways of 1.2 seconds or less which is far smaller than the minimum headways of 2 seconds per vehicle.
The right-turn movements from Wakehurst Parkway South have relatively smaller demand volumes of 152 and 159 vehicles/hour in the AM and PM peak periods respectively. As such, there is little justification for adjusting the signal phasing to improve this movement. Especially when this will come at the expense of other movements.
These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigation road network infrastructure upgrade requirements.</td>
</tr>
<tr>
<td>Wakehurst Parkway/ Frenchs Forest Road
Existing case PM peak</td>
<td> 
</td>
<td>Wakehurst Parkway/ Frenchs Forest Road: 2011 existing case PM.
Signals - Fixed Time Cycle Time = 100 seconds (Practical Cycle Time)
Movement Performance - Vehicles
<table>
<tr><th>Mov ID</th><th>Turn</th><th>Demand Flow veh/h</th><th>HV %</th><th>Deg. Satn v/c</th><th>Average Delay sec</th><th>Level of Service</th><th>95% Back of Queue Vehicles veh</th><th>95% Back of Queue Distance m</th><th>Prop. Queued</th><th>Effective Stop Rate per veh</th><th>Average Speed km/h</th></tr>
<tr><td colspan="12">South: Wakehurst Parkway (S)</td></tr>
<tr><td>1</td><td>L</td><td>36</td><td>2.9</td><td>0.854</td><td>45.9</td><td>LOS D</td><td>26.5</td><td>187.5</td><td>0.96</td><td>0.99</td><td>19.6</td></tr>
<tr><td>2</td><td>T</td><td>1066</td><td>1.1</td><td>0.854</td><td>37.4</td><td>LOS C</td><td>26.6</td><td>187.9</td><td>0.96</td><td>0.93</td><td>23.8</td></tr>
<tr><td>3</td><td>R</td><td>159</td><td>7.9</td><td>0.895</td><td>67.0</td><td>LOS E</td><td>8.9</td><td>66.2</td><td>1.00</td><td>0.96</td><td>9.1</td></tr>
<tr><td>Approach</td><td></td><td>1261</td><td>2.0</td><td>0.895</td><td>41.4</td><td>LOS C</td><td>26.6</td><td>187.9</td><td>0.96</td><td>0.93</td><td>21.5</td></tr>
<tr><td colspan="12">East: Frenchs Forest Rd (E)</td></tr>
<tr><td>4</td><td>L</td><td>287</td><td>6.6</td><td>0.382</td><td>18.5</td><td>LOS B</td><td>5.2</td><td>38.2</td><td>0.73</td><td>0.77</td><td>30.6</td></tr>
<tr><td>5</td><td>T</td><td>541</td><td>1.0</td><td>0.864</td><td>42.6</td><td>LOS D</td><td>28.4</td><td>200.2</td><td>1.00</td><td>1.02</td><td>18.6</td></tr>
<tr><td>6</td><td>R</td><td>122</td><td>0.9</td><td>0.454</td><td>34.3</td><td>LOS C</td><td>4.3</td><td>30.5</td><td>0.77</td><td>0.76</td><td>26.4</td></tr>
<tr><td>Approach</td><td></td><td>951</td><td>2.7</td><td>0.864</td><td>34.2</td><td>LOS C</td><td>28.4</td><td>200.2</td><td>0.89</td><td>0.91</td><td>22.0</td></tr>
<tr><td colspan="12">North: Wakehurst Parkway (N)</td></tr>
<tr><td>7</td><td>L</td><td>99</td><td>1.1</td><td>0.691</td><td>47.1</td><td>LOS D</td><td>10.2</td><td>72.7</td><td>0.99</td><td>0.88</td><td>30.1</td></tr>
<tr><td>8</td><td>T</td><td>594</td><td>3.9</td><td>0.691</td><td>43.5</td><td>LOS D</td><td>10.8</td><td>78.2</td><td>0.99</td><td>0.85</td><td>30.4</td></tr>
<tr><td>Approach</td><td></td><td>693</td><td>3.5</td><td>0.691</td><td>44.0</td><td>LOS D</td><td>10.8</td><td>78.2</td><td>0.99</td><td>0.85</td><td>30.3</td></tr>
<tr><td colspan="12">West: Frenchs Forest Rd (W)</td></tr>
<tr><td>10</td><td>L</td><td>48</td><td>0.0</td><td>0.855</td><td>59.4</td><td>LOS E</td><td>15.2</td><td>107.4</td><td>1.00</td><td>1.02</td><td>23.8</td></tr>
<tr><td>11</td><td>T</td><td>453</td><td>1.2</td><td>0.855</td><td>51.7</td><td>LOS D</td><td>15.2</td><td>107.4</td><td>1.00</td><td>1.02</td><td>21.4</td></tr>
<tr><td>12</td><td>R</td><td>62</td><td>1.7</td><td>0.855</td><td>59.4</td><td>LOS E</td><td>15.1</td><td>107.2</td><td>1.00</td><td>1.02</td><td>22.7</td></tr>
<tr><td>Approach</td><td></td><td>563</td><td>1.1</td><td>0.855</td><td>53.2</td><td>LOS D</td><td>15.2</td><td>107.4</td><td>1.00</td><td>1.02</td><td>21.7</td></tr>
<tr><td>All Vehicles</td><td></td><td>3467</td><td>2.3</td><td>0.895</td><td>41.9</td><td>LOS C</td><td>28.4</td><td>200.2</td><td>0.96</td><td>0.93</td><td>23.5</td></tr>
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Max queue = 201m
Av. Delay = 42s</td>
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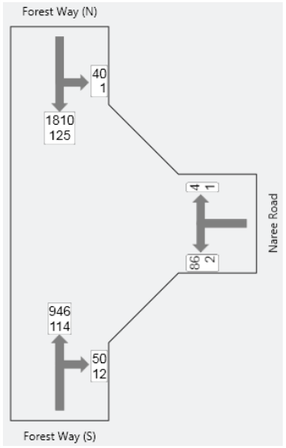
<th>Intersection and scenario</th>
<th>Input traffic volumes (note i)</th>
<th>SIDRA model outputs</th>
<th>Summary of model outputs</th>
<th>Commentary</th>
</tr>
<tr>
<td>Forest Way/ Naree Road
Existing case AM peak</td>
<td> 
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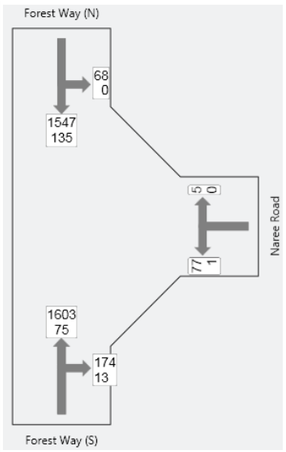
<td>Forest Way/ Naree Road: 2011 existing case AM.
Giveway / Yield (Two-Way)
Movement Performance - Vehicles
<table>
<tr><th>Mov ID</th><th>Turn</th><th>Demand Flow veh/h</th><th>HV %</th><th>Deg. Satn v/c</th><th>Average Delay sec</th><th>Level of Service</th><th>95% Back of Queue Vehicles veh</th><th>95% Back of Queue Distance m</th><th>Prop. Queued</th><th>Effective Stop Rate per veh</th><th>Average Speed km/h</th></tr>
<tr><td colspan="12">South: Forest Way (S)</td></tr>
<tr><td>2</td><td>T</td><td>1116</td><td>10.8</td><td>0.306</td><td>0.0</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.00</td><td>70.0</td></tr>
<tr><td>3</td><td>R</td><td>65</td><td>19.4</td><td>1.088</td><td>209.7</td><td>LOS F</td><td>7.1</td><td>58.3</td><td>1.00</td><td>1.52</td><td>7.3</td></tr>
<tr><td>Approach</td><td></td><td>1181</td><td>11.2</td><td>1.088</td><td>11.6</td><td>NA</td><td>7.1</td><td>58.3</td><td>0.06</td><td>0.08</td><td>49.4</td></tr>
<tr><td colspan="12">East: Naree Road</td></tr>
<tr><td>4</td><td>L</td><td>93</td><td>2.3</td><td>1.544</td><td>608.2</td><td>LOS F</td><td>25.3</td><td>180.5</td><td>1.00</td><td>2.55</td><td>2.0</td></tr>
<tr><td>6</td><td>R</td><td>5</td><td>20.0</td><td>1.000[4]</td><td>907.3</td><td>LOS F</td><td>2.2</td><td>17.9</td><td>1.00</td><td>1.08</td><td>1.3</td></tr>
<tr><td>Approach</td><td></td><td>98</td><td>3.2</td><td>1.544</td><td>624.2</td><td>LOS F</td><td>25.3</td><td>180.5</td><td>1.00</td><td>2.48</td><td>1.9</td></tr>
<tr><td colspan="12">North: Forest Way (N)</td></tr>
<tr><td>7</td><td>L</td><td>43</td><td>2.4</td><td>0.371</td><td>8.8</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>1.41</td><td>47.8</td></tr>
<tr><td>8</td><td>T</td><td>2037</td><td>6.5</td><td>0.371</td><td>0.0</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.00</td><td>70.0</td></tr>
<tr><td>Approach</td><td></td><td>2080</td><td>6.4</td><td>0.371</td><td>0.2</td><td>NA</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.03</td><td>69.4</td></tr>
<tr><td>All Vehicles</td><td></td><td>3359</td><td>8.0</td><td>1.544</td><td>22.4</td><td>NA</td><td>25.3</td><td>180.5</td><td>0.05</td><td>0.12</td><td>36.9</td></tr>
</table></td>
<td>LoS = F
DoS = 1.544
Max queue = 181m
Av. Delay = 23s</td>
<td rowspan="2">The obvious failure at this intersection is the lack of entering opportunity afforded to vehicles emerging from Naree Road. In particular, right-turning traffic from this approach would have to select gaps in up to six lanes of traffic. Under randomised, non-platooned flow conditions, this is a significant challenge and hence results in modelled delays of up to 900 seconds (15 minutes) for this traffic stream. It is acknowledged that in real-life conditions, very few drivers would be prepared to wait for such gaps. Drivers attempting the right-turn would sooner abort the right-turn for a left-turn towards the south or a u-turn back down Naree Road. Alternatively, drivers may attempt more hazardous entering movements such as selecting substandard gaps or attempting a staged crossing where they edge out into the southbound carriageway of Forest Way as a first stage, and then enter gaps in the northbound carriageway from the unprotected position in the middle of the road.
The lack of gaps and entering opportunity for right-turning traffic from Naree Road also affects left-turning traffic from this approach, since there is only a single approach lane. As such, more left-turning traffic would tend to re-distribute down to Rabbett Street.
The right-turning movement from Forest Way South into Naree Road is also a poor performing movement. Without the aid of traffic signals, and due to the heavy flows from the north, this traffic has very little opportunity to cross the southbound traffic stream.</td>
</tr>
<tr>
<td>Forest Way/ Naree Road
Existing case PM peak</td>
<td> 
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<td>Forest Way/ Naree Road: 2011 existing case PM.
Giveway / Yield (Two-Way)
Movement Performance - Vehicles
<table>
<tr><th>Mov ID</th><th>Turn</th><th>Demand Flow veh/h</th><th>HV %</th><th>Deg. Satn v/c</th><th>Average Delay sec</th><th>Level of Service</th><th>95% Back of Queue Vehicles veh</th><th>95% Back of Queue Distance m</th><th>Prop. Queued</th><th>Effective Stop Rate per veh</th><th>Average Speed km/h</th></tr>
<tr><td colspan="12">South: Forest Way (S)</td></tr>
<tr><td>2</td><td>T</td><td>1766</td><td>4.5</td><td>0.466</td><td>0.0</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.00</td><td>70.0</td></tr>
<tr><td>3</td><td>R</td><td>197</td><td>7.0</td><td>3.281</td><td>2132.1</td><td>LOS F</td><td>93.9</td><td>696.5</td><td>1.00</td><td>3.36</td><td>0.8</td></tr>
<tr><td>Approach</td><td></td><td>1963</td><td>4.7</td><td>3.281</td><td>213.8</td><td>NA</td><td>93.9</td><td>696.5</td><td>0.10</td><td>0.34</td><td>8.0</td></tr>
<tr><td colspan="12">East: Naree Road</td></tr>
<tr><td>4</td><td>L</td><td>82</td><td>1.3</td><td>0.908</td><td>123.5</td><td>LOS F</td><td>4.6</td><td>32.8</td><td>0.99</td><td>1.36</td><td>8.5</td></tr>
<tr><td>6</td><td>R</td><td>5</td><td>0.0</td><td>1.000[4]</td><td>903.7</td><td>LOS F</td><td>2.1</td><td>15.0</td><td>1.00</td><td>1.07</td><td>1.4</td></tr>
<tr><td>Approach</td><td></td><td>87</td><td>1.2</td><td>1.000</td><td>170.5</td><td>LOS F</td><td>4.6</td><td>32.8</td><td>0.99</td><td>1.34</td><td>6.5</td></tr>
<tr><td colspan="12">North: Forest Way (N)</td></tr>
<tr><td>7</td><td>L</td><td>72</td><td>0.0</td><td>0.331</td><td>8.7</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>1.33</td><td>47.8</td></tr>
<tr><td>8</td><td>T</td><td>1771</td><td>8.0</td><td>0.331</td><td>0.0</td><td>LOS A</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.00</td><td>70.0</td></tr>
<tr><td>Approach</td><td></td><td>1842</td><td>7.7</td><td>0.331</td><td>0.3</td><td>NA</td><td>0.0</td><td>0.0</td><td>0.00</td><td>0.05</td><td>68.9</td></tr>
<tr><td>All Vehicles</td><td></td><td>3893</td><td>6.1</td><td>3.281</td><td>111.8</td><td>NA</td><td>93.9</td><td>696.5</td><td>0.07</td><td>0.22</td><td>13.1</td></tr>
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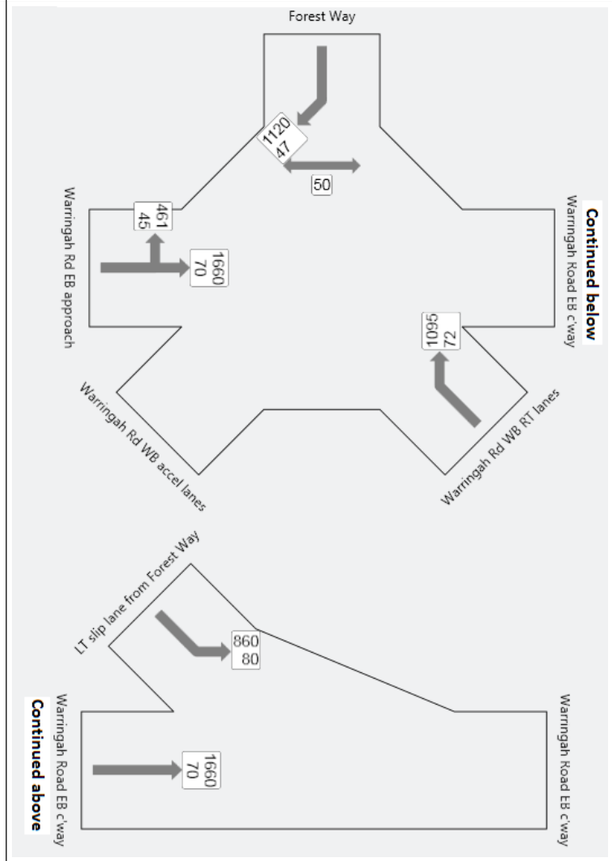
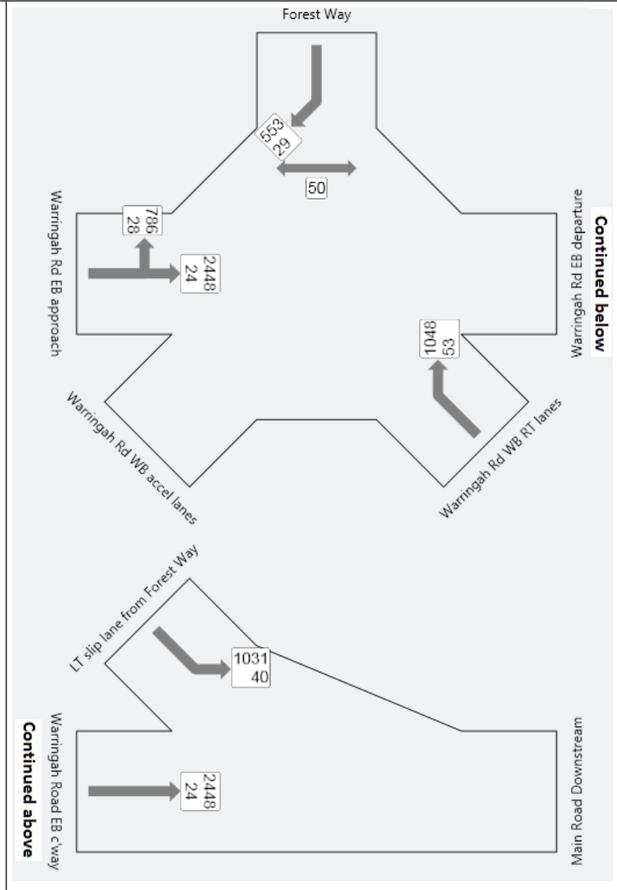
<td>LoS = F
DoS = 3.281
Max queue = 697m
Av. Delay = 112s</td>
</tr>
</table>

Intersection and scenario	Input traffic volumes (note i)	SIDRA model outputs	Summary of model outputs	Commentary
Warringah Road/ Forest Way Existing case AM peak		Warringah Road/ Forest Way: 2011 existing case AM: Intersection 1: EB+WB RT+SB RT Signals - Fixed Time Cycle Time = 160 seconds (Practical Cycle Time) **Movement Performance - Vehicles** South East: Warringah Rd WB RT lanes 23 R 1228 6.2 1.042 151.6 LOS F 47.9 353.0 1.00 1.19 8.6 Approach 1228 6.2 1.042 151.6 LOS F 47.9 353.0 1.00 1.19 8.6 North: Forest Way 9 R 1228 4.0 1.036 111.5 LOS F 50.5 366.1 1.00 1.18 13.6 Approach 1228 4.0 1.036 111.5 LOS F 50.5 366.1 1.00 1.18 13.6 West: Warringah Rd EB approach 10 L 533 8.9 0.214 18.2 LOS B 7.0 52.6 0.37 0.73 30.5 11 T 1821 4.0 1.032 130.0 LOS F 69.8 505.6 1.00 1.31 13.9 Approach 2354 5.1 1.032 104.7 LOS F 69.8 505.6 0.86 1.18 14.8 All Vehicles 4811 5.1 1.042 118.4 LOS F 69.8 505.6 0.93 1.18 12.6 Warringah Road/Forest Way: 2011 existing case AM: Intersection 2 WB + SB LT Giveway / Yield (Two-Way) **Movement Performance - Vehicles** North West: LT slip lane from Forest Way 2 T 989 8.5 2.461 1332.4 LOS F 375.1 2817.2 1.00 11.99 0.8 Approach 989 8.5 2.461 1332.4 LOS F 375.1 2817.2 1.00 11.99 0.8 West: Warringah Road EB c'way 1 T 1821 4.0 0.319 0.0 LOS A 0.0 0.0 0.00 0.00 70.0 Approach 1821 4.0 0.319 0.0 NA 0.0 0.0 0.00 0.00 70.0 All Vehicles 2811 5.6 2.461 469.1 NA 375.1 2817.2 0.35 4.22 2.0	LoS = F DoS = 2.461 Max queue = 2818m Av delay = 326s	There are several aspects leading to the failed performance at this intersection. These include: ▪ The lack of capacity of the eastbound carriageway of Warringah Road to absorb the heavy left-turning traffic volume demands from Forest Way. In particular, in the PM peak period, more than 1100 left turning vehicles per hour from Forest Way are attempting to enter a lane that carries more than 600 vehicles/hour (assuming even lane utilisation). The combined flow of 1700 vehicles/ hour equates to average headways of 2.1 seconds which is substantially less than the critical gap of 3 seconds for such a high-speed merge. ▪ The strong competition between the westbound right-turn movement from Warringah Road to Forest Way, and the eastbound through movement along Warringah Road. Both of these approaches have similar physical capacity with three approach lanes each. Both streams also have high traffic volume demands. Therefore any phasing adjustments to benefit one movement (through increased green time allocation), is likely to disadvantage the other. These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigation road network infrastructure upgrade requirements.

Intersection and scenario	Input traffic volumes (note i)	SIDRA model outputs	Summary of model outputs	Commentary
Warringah Road/ Forest Way Existing case PM peak		Warringah Road/ Forest Way: 2011 existing case PM: Intersection 1: EB+WB RT+SB RT Signals - Fixed Time Cycle Time = 160 seconds (Practical Cycle Time) **Movement Performance - Vehicles** Mov ID | Turn | Demand Flow veh/h | HV % | Deg. Satn v/c | Average Delay sec | Level of Service | 95% Back of Queue Vehicles veh | 95% Back of Queue Distance m | Prop. Queued | Effective Stop Rate per veh | Average Speed km/h South East: Warringah Rd WB RT lanes 23 R 1159 4.8 0.974 111.2 LOS F 38.5 280.9 1.00 1.07 11.2 Approach 1159 4.8 0.974 111.2 LOS F 38.5 280.9 1.00 1.07 11.2 North: Forest Way 9 R 613 5.0 0.966 79.0 LOS F 21.7 158.4 1.00 1.04 17.8 Approach 613 5.0 0.966 79.0 LOS F 21.7 158.4 1.00 1.04 17.8 West: Warringah Rd EB approach 10 L 857 3.4 0.331 18.9 LOS B 12.5 89.8 0.41 0.75 29.6 11 T 2602 1.0 0.971 77.4 LOS F 83.6 589.8 1.00 1.11 20.3 Approach 3459 1.6 0.971 62.9 LOS E 83.6 589.8 0.85 1.02 21.1 All Vehicles 5231 2.7 0.974 75.5 LOS F 83.6 589.8 0.90 1.03 17.9 Warringah Road/Forest Way: 2011 existing case PM: Intersection 2 WB + SB LT Giveway / Yield (Two-Way) **Movement Performance - Vehicles** Mov ID | Turn | Demand Flow veh/h | HV % | Deg. Satn v/c | Average Delay sec | Level of Service | 95% Back of Queue Vehicles veh | 95% Back of Queue Distance m | Prop. Queued | Effective Stop Rate per veh | Average Speed km/h North West: LT slip lane from Forest Way 2 T 1127 3.7 6.570 5041.8 LOS F 613.5 4431.6 1.00 8.51 0.2 Approach 1127 3.7 6.570 5041.8 LOS F 613.5 4431.6 1.00 8.51 0.2 West: Warringah Road EB c'way 1 T 2602 1.0 0.448 0.0 LOS A 0.0 0.0 0.00 0.00 70.0 Approach 2602 1.0 0.448 0.0 NA 0.0 0.0 0.00 0.00 70.0 All Vehicles 3729 1.8 6.570 1524.1 NA 613.5 4431.6 0.30 2.57 0.6	LoS = F DoS = 6.570 Max queue = 4432m Av delay = 956s	There are several aspects leading to the failed performance at this intersection. These include: ▪ The lack of capacity of the eastbound carriageway of Warringah Road to absorb the heavy left-turning traffic volume demands from Forest Way. In particular, in the PM peak period, more than 1100 left turning vehicles per hour from Forest Way are attempting to enter a lane that carries more than 600 vehicles/hour (assuming even lane utilisation). The combined flow of 1700 vehicles/ hour equates to average headways of 2.1 seconds which is substantially less than the critical gap of 3 seconds for such a high-speed merge. ▪ The strong competition between the westbound right-turn movement from Warringah Road to Forest Way, and the eastbound through movement along Warringah Road. Both of these approaches have similar physical capacity with three approach lanes each. Both streams also have high traffic volume demands. Therefore any phasing adjustments to benefit one movement (through increased green time allocation), is likely to disadvantage the other. These existing shortcomings in traffic capacity have been recognised by Roads and Maritime Services (RMS) who are investigation road network infrastructure upgrade requirements.

Notes:

(iii) The 2011 traffic volumes sourced from Aecom (2011) were regarded as being equivalent to present day volumes. It should be noted that the application of the 1.8% per annum growth per year would result in a 3.6% growth from 2011 to 2013. However, the 95% peak hour factor adopted in the SIDRA models increased the flow rates for each approach to the intersection by approximately 5.2%.

(iv) With the input traffic volumes depicted, the first figure is the number of light vehicles per hour. The second figure is the number of heavy vehicles per hour. The figures in the SIDRA output table has accounted for the 95% peak flow factor (ie. increased by 5.2%).

(v) A complete description of the traffic performance indicators (level of service, degree of saturation, maximum queue length, and average delays is provided in Appendix A).

APPENDIX B: DESCRIPTION OF TRAFFIC PERFORMANCE INDICATORS

The SIDRA intersection simulation software is used to determine the likely traffic performance indicators including level of service (LoS), degree of saturation (DoS), average delay and maximum queue length (represented by 95th percentile queue length). At signalised and roundabout intersections, the LoS criteria are related to average intersection delay (seconds per vehicle). At sign controlled intersections (give way and stop), the LoS is based on the average delay (seconds per vehicle) for the worst movement. The following table summarises the intersection LoS criteria.

Level of Service	Average Delay (seconds per vehicle)	Traffic Signals, Roundabout	Give Way and Stop Signs
A	Less than 14	Good operation	Good operation
B	15 to 28	Good with acceptable delays and spare capacity	Acceptable delays and spare capacity
C	29 to 42	Satisfactory	Satisfactory, but accident study required
D	43 to 56	Operating near capacity	Near capacity and accident study required
E	57 to 70	At capacity. At signals, incidents will cause excessive delays. Roundabouts require other control mode	At capacity; requires other control mode
F	Greater than 71	Unsatisfactory with excessive queuing	Unsatisfactory with excessive queuing; requires other control mode

Source: RTA Guide to Traffic Generating Developments (2002).

Degree of saturation (DoS)

DoS is defined as the ratio of demand flow to capacity, and therefore has no unit. As it approaches 1.0, extensive queues and delays could be expected. For DoS greater than 1.0, a small increment in traffic volumes would result in an exponential increase in delays and queue length. For a satisfactory situation, the DoS should be less than the nominated practical degree of saturation, usually 0.90. The intersection DoS is based on the movement with the highest ratio.

Average delay

Delay is the difference between interrupted and uninterrupted travel times through the intersection and is measured in seconds per vehicle. The delays include queued vehicles decelerating and accelerating to and/or from stop, as well as delays experienced by all vehicles negotiating the intersection. At signalised and roundabout intersections, the average intersection delay is usually reported and is taken as the weighted average delay by summing the product of the individual movement traffic volumes and their corresponding calculated delays and dividing these by the total number of vehicles entering the intersection. At sign controlled intersections, the average delay for the worst movement is usually reported.

Maximum queue length

Queue length is the number of vehicles waiting at the hold line and is usually quoted as the 95th percentile back of queue, which is the value below which 95 percent of all observed queue lengths fall. For signalised intersections, it is measured as the number of vehicles per traffic lane at the start of the green period, when the traffic starts moving again after a red signal. The intersection queue length is usually taken from the movement with the longest queue length.

Explanation of SIDRA model outputs

An example of a SIDRA model output is provided below. An explanation of the model outputs follows the table.

Kamilaroi Highway/ Mine Access Road intersection 2028 AM peak operational
Giveway / Yield (Two-Way)

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Kamilaroi Hwy S											
4	L	65	3.2	0.036	14.2	NA[9]	NA[9]	NA[9]	0.00	0.74	73.1
5	T	268	14.1	0.150	0.0	LOS A	0.0	0.0	0.00	0.00	110.0
Approach		334	12.0	0.150	2.8	LOS A	0.0	0.0	0.00	0.14	100.2
North: Kamilaroi Hwy N											
11	T	268	14.1	0.150	0.0	LOS A	0.0	0.0	0.00	0.00	110.0
12	R	97	2.2	0.112	15.8	LOS B	0.5	3.7	0.39	0.78	62.7
Approach		365	11.0	0.150	4.2	LOS B	0.5	3.7	0.10	0.21	95.4
West: Mine Access Road											
1	L	97	2.2	0.234	12.1	LOS A	1.1	8.1	0.50	0.75	54.6
3	R	65	3.2	0.235	12.2	LOS A	1.1	8.1	0.50	0.84	54.6
Approach		162	2.6	0.235	12.2	LOS A	1.1	8.1	0.50	0.79	54.6
All Vehicles		861	9.8	0.235	5.1	NA	1.1	8.1	0.14	0.29	84.8

"South: Kamilaroi Hwy S": This indicates that the approach in question is the southern approach to the intersection, which is the Kamilaroi Highway South approach.

L, T, R: Refer to the *left-turn*, *through*, and *right-turn* movements in that approach respectively.

Demand flow: is the traffic volume for the corresponding turning movement.

HV%: means the percentage of heavy vehicles in the corresponding traffic stream.

Deg Satn: Refers to the degree of saturation (DoS) for that turning movement. See the explanation for DoS provided in this Appendix.

Average delay (seconds/vehicle): Traffic delay consists of dynamic delay and static delay. Dynamic delay consists of the time taken for a vehicle to slow down, negotiate through the intersection, and then speed up to the target speed of the intersection departure. This is particularly prominent for turning movements as there is significant deceleration and acceleration involved. Static delay is the delay incurred when the vehicle is in a queue and is not moving.

LoS: Refers to Level of Service as explained in this Appendix.

95% back of queue: This is the queue length in vehicles and in metres which is only exceed for 5% of the time. This is regarded as the maximum queue length for design purposes.

Prop queued: This refers to the proportion of traffic in the corresponding traffic stream that is queued.

Effective stop rate per vehicle: This is the average number of stops per vehicle. This considers vehicles in a queue and whether they progress to the front of the queue via series of start-stops (move ups) in which case there would be a high stop rate, or whether the vehicle tends to progress toward the queue head in one go. For priority-controlled intersections (not traffic signals) where queue progression is largely related to the

randomness of gap availability and gap acceptance, there tends to be a relatively higher effective stop rate for vehicles in the low priority movements.

Average speed: The average speed of vehicles in the corresponding traffic stream.