Shire of Denmark

Denmark Traffic and Evacuation Management Study
Final Report

July 2018

17 July 2018 - Attachment 8.4.1

Executive summary

The Shire of Denmark’s Local Planning Strategy (2011) identifies an additional crossing point of the Denmark River, primarily to support east-west connectivity and future growth to the north of town along Scotsdale Road. However, it has also been suggested that a third river crossing point could improve resilience of the Denmark road network in the case of an emergency event (such as bushfire) and potentially assist in an evacuation.

Using recent traffic data, GHD has developed and calibrated a 2018 AIMSUN traffic model of the Denmark townsite road network, according to the standards set out in the RMS *Traffic Modelling Guidelines, 2013*. This model has subsequently been forecast forward to 2027 and used to assess four options for the west-to-east evacuation of Denmark under emergency conditions, across the Denmark River to the nominal evacuation point at the intersection of South Coast Highway and Denmark-Mount Barker Road. The modelling covers a one-hour peak when the largest number of population, which is estimated to be 20%, would be evacuated.

The evacuation routes assessed were:

- **Option 1 –** Existing South Coast Highway (dual lane) bridge:
  This option adopts the existing dual-lane South Coast Highway bridge as the primary unobstructed route for evacuation towards the east.
- **Option 2 –** Existing Churchill Road (single lane) bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route starts from Scotsdale Road and heads northbound, via Mt Lindesay Road, then turns right to Churchill Road, crosses the Denmark River, then continues eastbound until turning right onto Denmark–Mt Barker Road, back to the intersection with South Coast Highway.
- **Option 3** – East River Road, with new dual lane bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route starts from Scotsdale Road and heads northbound until turning right at or near Riverbend Lane and goes eastward, across a newly constructed dual lane bridge, connecting to East River Road, then turning right to Denmark–Mt Barker Road, back to the intersection with South Coast Highway.
- **Option 4** – Denmark Southern Bypass, with new dual lane bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route for evacuees will be to drive eastbound along a notional southern bypass route that crosses the Denmark River with a dual lane bridge at the approximate location of the existing pedestrian bridge on the Denmark to Nornalup Heritage Rail Trail, near the mouth of the Denmark River. This bypass route is assumed to connect to the South Coast Highway, near the Denmark–Mt Barker Road intersection.

The results from traffic modelling show that:

- The number of vehicles during the peak evacuation period would not exceed the capacity of the road network within the study area. The existing network could accommodate an increase of between 150% (Churchill Road) and 300% (South Coast Highway) in traffic demand before failing.
- Option 1 (South Coast Highway), which uses the existing bridge that crosses the Denmark River via South Coast Highway, would perform satisfactorily as an evacuation route.
- Option 2 (Churchill Road) would be the most time consuming (6.8 times longer mean travel time than Option 1), with the highest average delay because the alternative route is the longest and it would take evacuees much longer to reach South Coast Highway. This could pose a risk to those who evacuate late.
- Option 3 (East River Road) is the next most time consuming route, with a mean travel time that is 1.8 times longer than Option 1.
- Option 4 (Southern Bypass) has the shortest travel time and average delays, and from the traffic operation point of view, would be the most preferred evacuation route. Option 4 would also complement Option 1 (South Coast Highway) as a dual evacuation route.
- The road network capacity under both Option 1 and Option 4 is easily sufficient to accommodate expected peak evacuation hour conditions. However, the network capacity of Option 2 (Churchill Road) and Option 3 (East River Road) is constrained by the operation of the key intersection at Horsley Road and Scotsdale Road.

The traffic modelling also allows for the following key questions to be answered for the Shire:

1. How long would it take to evacuate Denmark in an emergency using the existing infrastructure i.e. South Coast Highway and Churchill Road bridge?

By iteratively running the AIMSUN models under different traffic loading conditions, it is estimated that:

- *Using the existing South Coast Highway bridge, all inhabitants could be orderly evacuated (free of unforeseen chaotic incidents) west-to-east within approximately 1.5 hours; and*
- *Using the existing Churchill Road bridge, all inhabitant could be orderly evacuated (free of unforeseen chaotic incidents) west-to-east within approximately 2 hours.*

Under the Churchill Road bridge scenario, most vehicles need to utilise the Scotsdale Road / Horsley Road roundabout and the heavy northbound traffic would block vehicles arriving from other approaches. By comparison, the South Coast Highway is better at coping with heavier traffic as all intersections are unsignalised, rather than roundabouts.

2. Based on the first point, would there be any improvement from an evacuation perspective if Churchill Road Bridge was upgraded to two lanes?

Based on GHD's modelling and strategic-level assumptions, there would not be any further improvements in a west-to-east evacuation by upgrading the Churchill Road bridge. Based on the assumptions in this report, the traffic during the peak evacuation period would not be heavy enough to create significant congestion that would require an increase of the route's capacity.

3. Based on the first point, would there be any improvement from an evacuation perspective if a second bridge was constructed in the vicinity of East River Road (as per the Local Planning Strategy and GHD options)?

4. Based on the first point, would there be any improvement from an evacuation perspective if a southern bypass road was constructed that roughly followed the rail trail alignment?

The construction of a third bridge crossing, either in the vicinity of East River Road or the near the rail trail alignment, would improve west-to-east evacuation times, especially compared to using the existing Churchill Road bridge.

Comparing all four options, average travel time during evacuation is shortest for the notional Southern Bypass route.

5. Recommendations on any other alternative locations for a crossing point of the Denmark River to achieve the most effective evacuation outcome for the Shire.

Based on the model developed in this report, GHD estimated mean travel times for each of the proposed evacuation routes. Compared to the baseline option (i.e. existing South Coast Highway bridge), mean travel time during an evacuation would be approximately 32% shorter for the notional Southern Bypass route.

Options	Mean travel time (sec) for forecast 2027 population, compared to baseline (Option 1)
Option 1 – South Coast Highway	0
Option 2 – Churchill Road	+ 584%
Option 3 – East River Road	+ 84%
Option 4 – Southern Bypass	- 32%

This result is due to the connection afforded by this option to Denmark residents south of the South Coast Highway, and hence avoids the need to traverse other key intersections within the CBD (e.g. Ocean Beach Road / South Coast Highway, Hollings Road / South Coast Highway).

It is recommended that any other alternative crossing points will be most beneficial on the southern side of South Coast Highway. The notional Southern Bypass route considered for this study assumed an alignment at the approximate location of the existing bridge on the Denmark to Nornalup Heritage Rail Trail. This has the added benefit of connecting with Inlet Drive / Hollings Road as a local connector road.

Further planning efforts should consider the relative connectivity benefits to the existing road network, as well as the financial, environmental and social impacts of a southern crossing point, compared to the currently proposed northern crossing in the vicinity of East River Road.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the Report.

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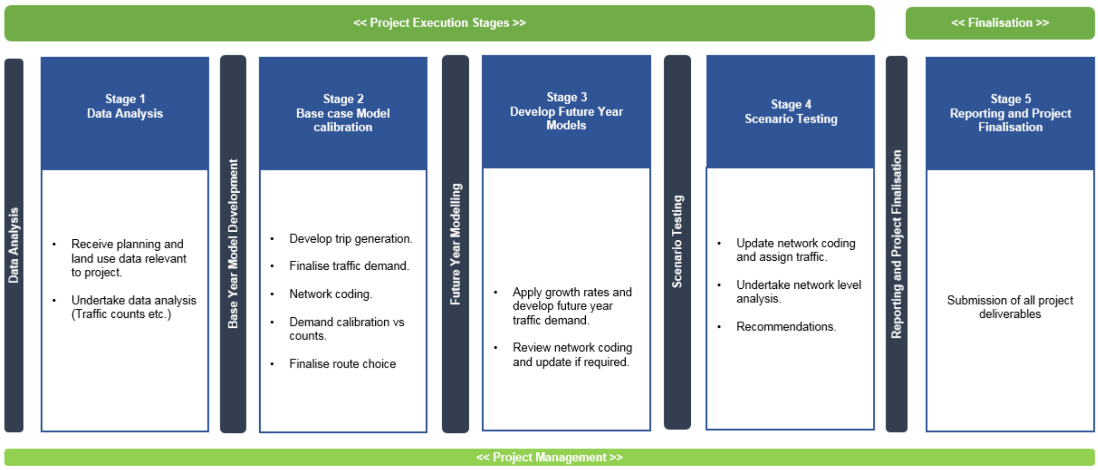
1. Introduction

GHD was commissioned by the Shire of Denmark to provide technical services for modelling traffic movements and emergency response actions in the event of an emergency. The Shire of Denmark has received funding to provide a third crossing point of the Denmark River, primarily to accommodate local traffic movements for residents living to the north of the town's Central Business District (CBD) along Scotsdale Road. In addition to providing improved east-west connectivity for the community and reduced travel distances for residents moving between Mount Barker, Albany and Denmark, the new bridge will also offer an alternative evacuation / access route for the Denmark community in the event of a fire or emergency.

The locality of Denmark is shown in Figure 1.

Figure 1: Aerial image of Denmark, WA

A five-stage delivery approach has been adopted to deliver this project, as shown below.



As part of Stage 1, the GHD modelling team reviewed all planning data provided by the Shire of Denmark and available traffic data including intersection counts, identified bottleneck intersections, and confirmed the extent of the study area.

For Stage 2, GHD developed a Base year AIMSUN model to match 2018 traffic conditions for typical weekday AM and PM peak hours.

Upon the completion of Stages 1 and 2, GHD proceeded to develop future year scenarios for the year 2027 horizon. The modelling tasks included the following:

- Modelling of 2027 AM and PM peaks ("the Future Do-nothing Models"): the purpose of the Future Do-Nothing models is to evaluate the traffic operation within the study area, based on extrapolated future year traffic demand, and identify any necessary network upgrades; and
- Scenario testings of four evacuation management scenarios for 2027 year horizon ("the Evacuation Models"): four evacuation options were compared by evaluating the traffic performance of the evacuation during the peak of the evacuation (i.e. when the largest number of residents would be leaving via the design evacuation routes). The Evacuation Models cover a one-hour long peak, instead of two one-hour peaks like the Base Models.

1.1 Modelling process

The 2018 Base year model was developed using AIMSUN traffic modelling software and was calibrated according to the standard set out in the RMS *Traffic Modelling Guidelines, 2013.*

1.2 Purpose of this report

This purpose of this report is to document the development of the Shire of Denmark microsimulation traffic model. It details the process undertaken to calibrate the peak hour models and specifies the conformance of the models to relevant standards. The report also applies the calibrated model to test four potential evacuation scenarios.

1.3 Scope and limitations

This report has been prepared by GHD for the Shire of Denmark and may only be used and relied on by the Shire of Denmark for the purpose agreed between GHD and the Shire of Denmark as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than the Shire of Denmark arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

1.4 Report structure

The following sections of this report detail the development and calibration of the Denmark traffic model, and demonstrate the ability of the model to be used to accurately reflect traffic conditions observed in the field.

- Section 2: Study area with a definition of the road network for the model;
- Section 3: Model development and methodology; and
- Section 4: Model calibration, with the details of the calibration procedures and results.

The following sections of this report document the modelling outputs from the Denmark traffic model, with detailed discussion, of scenario testing at the 2027 year horizon.

- Section 5: 2027 Future Do-nothing Models;
- Section 6: 2027 Evacuation Models ; and
- Section 7: Conclusions.

2. Denmark study area

2.1 Background

Denmark is a coastal town located in the Great Southern region on the South Coast of Western Australia, approximately 423 km south-east of Perth. The Shire is home to 5,845 residents (2016 Census data [1]), however the population does increase during tourist seasons (typically summer and Easter holidays) (refer to section 2.4). Denmark is situated on both sides of the Denmark River and access to the Central Business District (CBD) is provided by the South Coast Highway, a state main road that traverses the town. This road link is the primary east-west road in the region and serves as a vital connection between Albany to the east and Walpole to the west.

The Denmark CBD Base traffic model covers two key intersections as identified in Figure 2. **Intersection 1** is located on the west side of the Denmark River, bordered by the following roads:

- Horsley Road to the north;
- Hollings Road to the south; and
- South Coast Highway to the east and west.

On the eastern side of the Denmark River, **Intersection 2** is bordered by the following roads:

- Denmark-Mt Barker Road to the north; and
- South Coast Highway to the east and west.

[1] http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/LGA52730

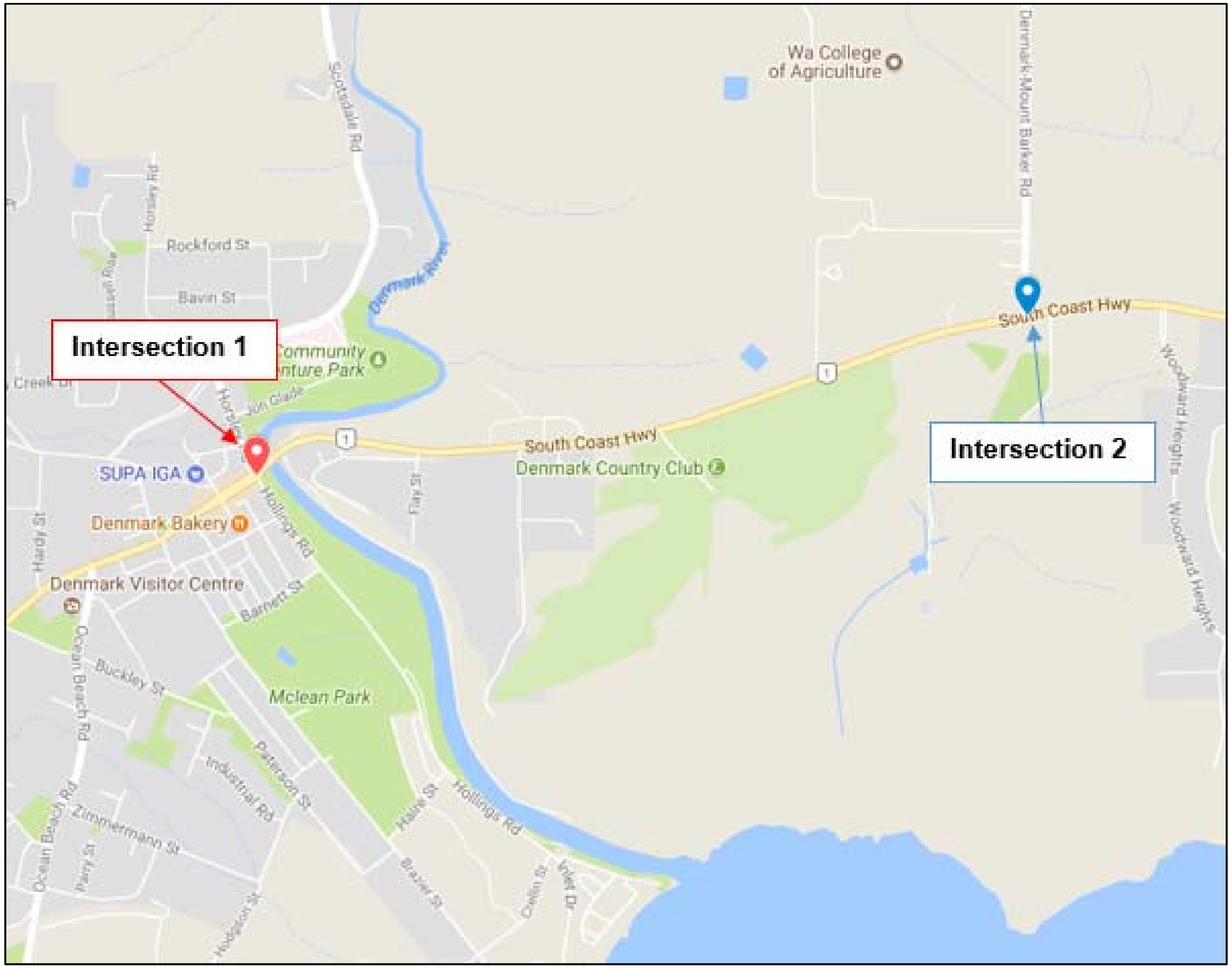


Figure 2: Study area and key intersections for the Denmark Traffic Model

Source*: Google Maps, 2018*

2.2 Road network

The study area of the Denmark CBD traffic model covers a number of key roads within the Denmark town site. These roads are detailed as follows:

2.2.1 Intersection 1

Local roads

Horsley Road and Hollings Road are local roads feeding into the South Coast Highway. Horsley Road connects to the northern region of Denmark and Hollings Road to the south. Both Horsley and Hollings Roads are single carriageways with a single lane in each direction operating at 50 km/h.

The intersection at Horsley Road, Hollings Road and South Coast Highway provides access to residential and commercial properties with a local shopping and café precinct. On the western side of the intersection is Norm Thornton Park and Berridge Park, beside the Denmark River.

2.2.2 Intersection 2

Denmark-Mt Barker Road is an arterial road that connects mostly industrial lots and agricultural farms to the South Coast Highway, and further through to Muir Highway and Mt Barker. This road operates in a 90/110 km/h environment as a single carriageway with a single lane in each direction. There are generally no shoulders with some gravelled verges. At the intersection of Denmark-Mount Barker Road and South Coast Highway lies the Western Australia College of Agriculture.

2.2.3 South Coast Highway

The South Coast Highway is an arterial road that runs in an east-west direction and is part of the Highway 1 network. It is generally a two-way two lane undivided road that runs for approximately 590 kilometres.

Between Intersections 1 and 2, South Coast Highway operates at 50-60 km/h through the built up area of Denmark. Upon leaving the built up area of Denmark on both the east and west sides, the South Coast Highway has a sign posted speed limit of 80-90 km/h.

2.3 Existing traffic conditions

Counters were deployed (by Shire of Denmark) on two separate occasions at the following locations, for one week, to obtain hourly traffic data and vehicle types (Figure 3):

- Scotsdale Road – on the eastern approach to the Horsley Road intersection (roundabout);
- Ocean Beach Road – on the southern approach to the South Coast Highway intersection (T-junction); and
- South Coast Highway – on the western approach to the intersection with Ocean Beach Road.

The sampling periods were:

- Thursday 8 February to Wednesday 14 February, 2018 (i.e. during a normal school week), and
- Monday 16 April to Sunday 29 April, 2018 (i.e. during the Easter school holiday period).

Figure 3: Location of each counter

In addition, cameras were deployed at Intersections 1 and 2 for a 12 hour period (0700 – 1900) on Thursday 8 February to gather detailed traffic data, including detailed intersection turning movements.

2.3.1 Morning peak

Traffic conditions in the morning peak period are predominantly governed by the operation of the South Coast Highway within the study area. The 1-hour morning peak period was observed to occur between 8:00 am – 9:00 am on school days, at both intersections. Refer to Figure 4 and Figure 5. The AM peak hour represents an approximate 13-26% increase on the median daytime traffic volume (7:00 am to 7:00 pm).

The peak period tends to occur slightly later (10:00 am – 11:00 am) on weekends and during school holidays periods.

Movement in both directions along the South Coast Highway is pivotal to the performance of the road network, and has an effect on the prevailing traffic from the suburban areas of Denmark accessing the highway from the north via Horsley and Denmark-Mt Barker Roads and the south via Hollings Road. These three connecting roads must compete with vehicle movements along the South Coast Highway during the morning peak period.

Progress traffic reports on daily vehicle classes, recorded between 7 – 14 February 2018, revealed the main class of vehicles were class 1 (approximately 90%), followed by class 3 (approximately 8%). As expected, on weekdays there is a greater percentage of class 3 vehicles and on weekends there is a greater percentage of class 1 vehicles.

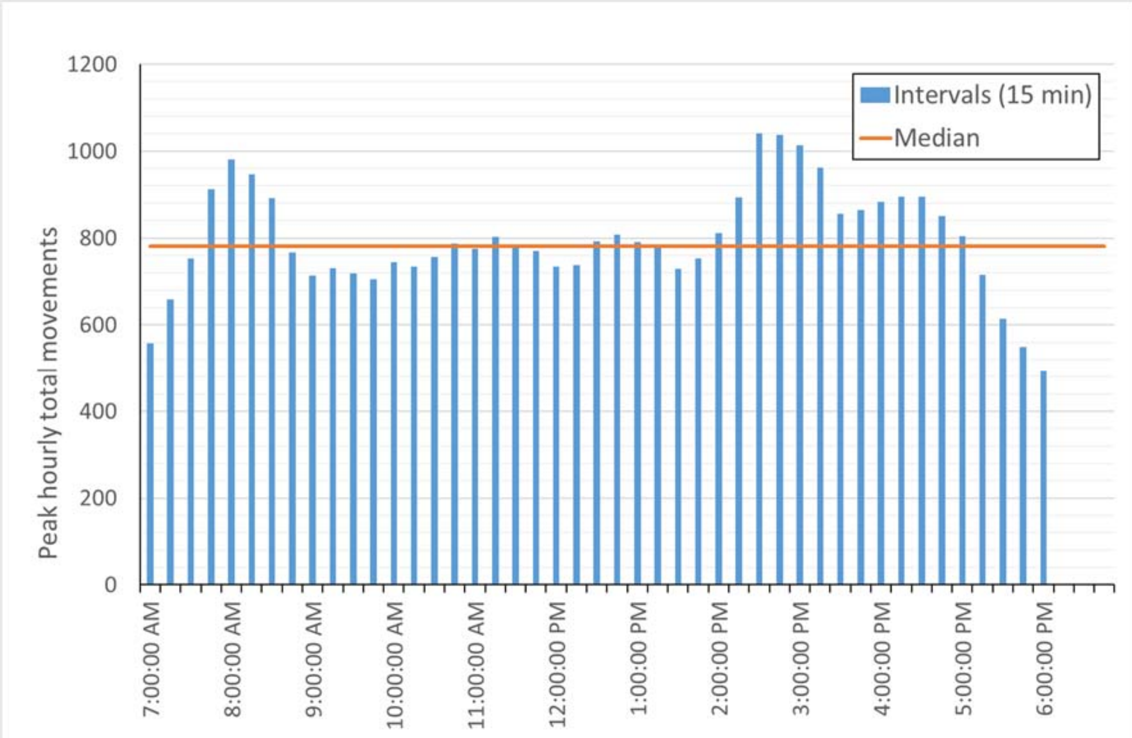


Figure 4: Traffic movements at Intersection 1 – South Coast Highway / Horsley Road / Hollings Road intersection (based on camera data)

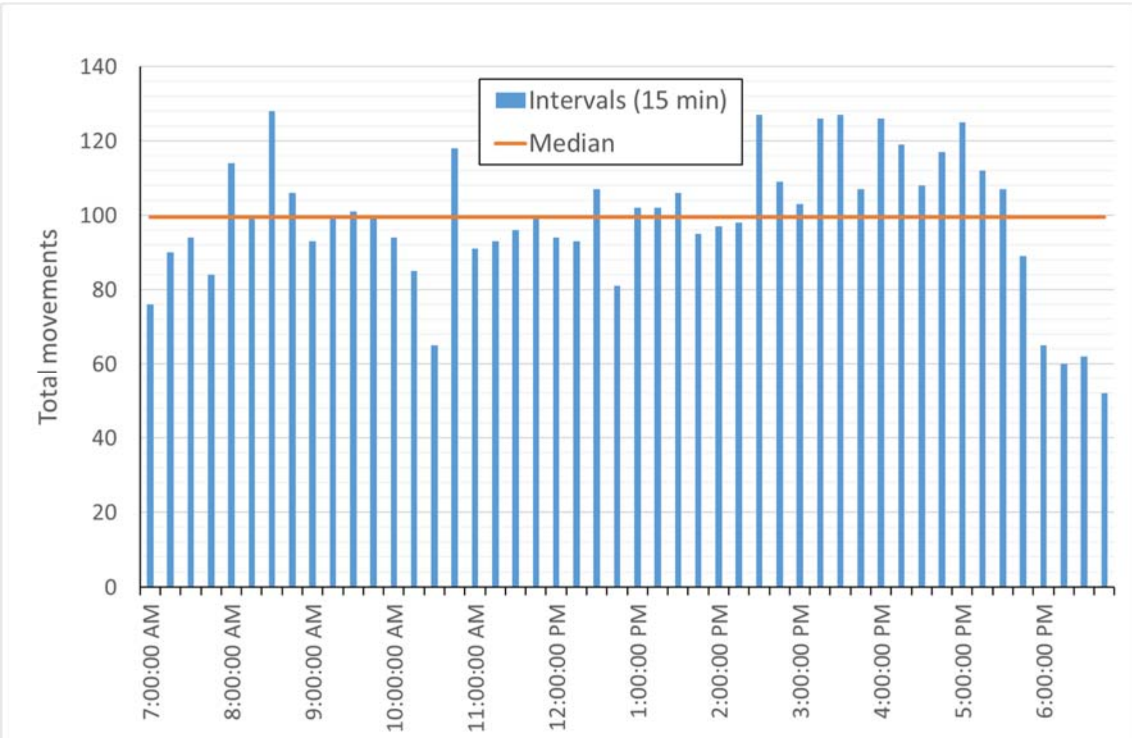


Figure 5: Traffic movements at Intersection 2 – South Coast Highway / Denmark-Mt Barker Road intersection (based on camera data)

2.3.2 Evening peak

Similar to the morning peak, the operation of the South Coast Highway at both intersections is critical to the overall performance of the road network. The 1-hour evening peak period was observed to be at 2:30 pm at Intersection 1 (Horsley and Hollings Roads) and at 2:15 pm for Intersection 2 (Denmark-Mt Barker Road), on school days. Refer to Figure 4 and Figure 5. The PM peak hour represents an approximate 23-36% increase on the median daytime traffic volume (7:00 am to 7:00 pm).

The peak PM period tends to occur earlier on weekends school holidays (i.e. around 12:00 pm – 2:00 pm).

As stated above, the performance of each local road in the study area is affected by traffic movements in both directions along the South Coast Highway.

2.4 Holiday period traffic conditions

To develop an understanding of the difference in traffic conditions between school term and holiday periods, the Shire of Denmark deployed traffic counters at the locations listed in section 2.3 during February 2018 (i.e. in school term) and April 2018 (i.e. during Easter holidays).

Surprisingly, the difference in average and 90th percentile daily total traffic volumes over the two periods was not significant, as shown in Figure 6. Traffic volumes were actually slightly lower during the holiday period.

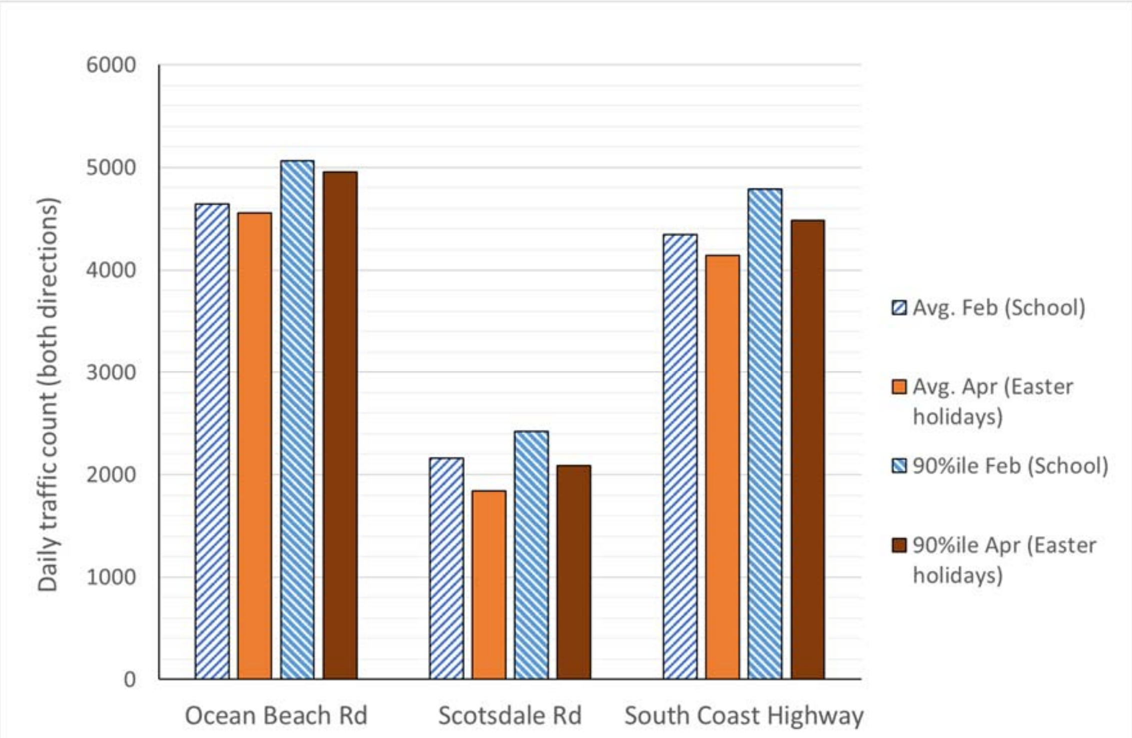


Figure 6: Average and 90th percentile daily traffic count at monitored locations (February and April, 2018)

In the holiday period, peak traffic tends to occur later in the morning, and earlier in the afternoon. This is very similar to the pattern observed on weekends during school term.

To further explore the potential change in population over holiday periods, GHD also analysed average daily water and wastewater data (2010 – 2017) for the Denmark schemes, provided to the Shire of Denmark by Water Corporation.

Wastewater data

Figure 7 illustrates the average weekly inflow of wastewater to the Denmark wastewater treatment plant (WWTP). A typical seasonal profile is evident, with higher inflows in the wetter seasons of winter and spring (i.e. due to stormwater infiltration and ingress into the sewerage system).

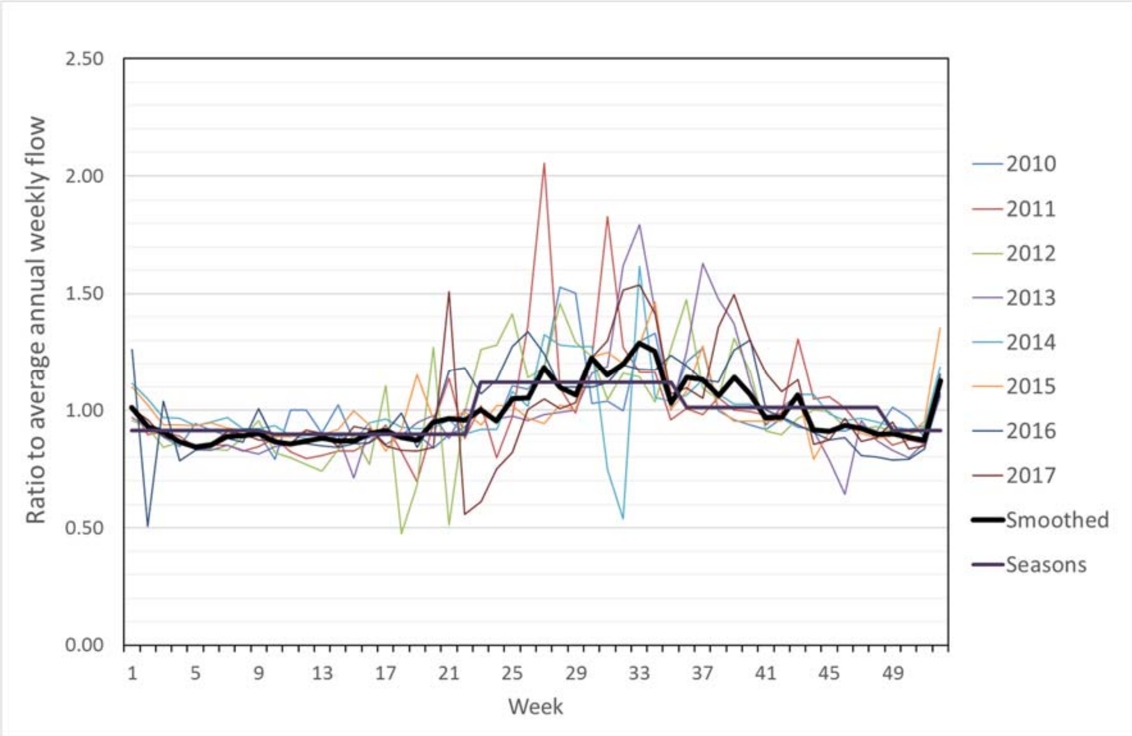


Figure 7: Wastewater inflow to Denmark WWTP

In terms of the typical peak tourist periods for Denmark, the following is evident from the data:

1. There is very little change in wastewater inflows during Easter (autumn), and
2. In the 1st and 52nd weeks of the year (i.e. Christmas / New Year period), there is an approximate 11 – 23% increase in wastewater inflows, compared to the typical background summer median inflow.

Water data

Figure 8 illustrates the weekly outflow of scheme water from the Denmark water treatment plant (WTP). A typical seasonal profile is evident, with higher demand during the warmer/drier season summer period and shoulder autumn/spring periods.

In terms of the typical peak tourist periods for Denmark, the following is evident from the data:

1. There is no discernible (non-season related) change in water demand during Easter (autumn), and

2. In the 1st and 52nd weeks of the year (i.e. Christmas / New Year period), there is an approximate 9 – 18% increase in water demand, compared to the typical background summer median demand.

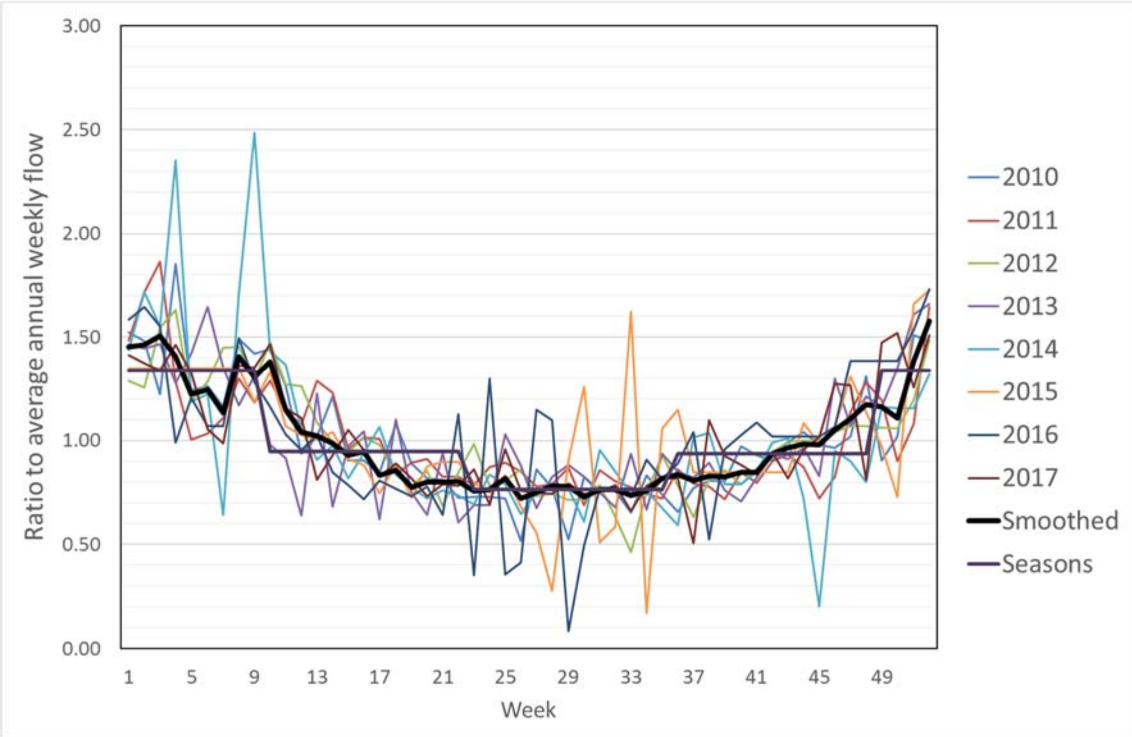


Figure 8: Water outflow from Denmark WTP

Summary

Based on the analysis of this available data, it could be concluded that there is an approximate 10-20% increase in the Denmark population (and hence traffic volume) during the peak summer holiday period (i.e. especially in the last and first weeks of the year); and minimal change in population during the Easter/autumn holiday period. This finding is somewhat contrary to prevailing anecdotal perceptions of Denmark traffic volumes during holiday periods. However, there were no other data sources available for this study to verify these perceptions.

It is recommended that the Shire of Denmark deploy traffic counters in the same locations (refer section 2.3) during the summer holiday period of 2018/19 and the Easter long weekend of 2019.

Based on the available data, it is noted that the estimated 20% increase in population (and hence traffic volume) during the summer holiday period is very similar in magnitude to the daily school-time AM and PM peak hour periods. Therefore, it can be crudely summarised that summer holiday traffic conditions in Denmark are very similar to the peak hour AM and PM traffic conditions experienced each day during school term. This finding is consistent with traffic modelling experience in other holiday locations (e.g. Gold Coast, Newcastle, Gosford).

All subsequent modelling in this study is therefore based on the peak hour AM and PM traffic conditions.

3. Model development

3.1 Introduction

The Denmark microsimulation traffic model was developed using the AIMSUN modelling software. Microsimulation models differ from deterministic traffic models (such as strategic or intersection models) in that each vehicle on the network is modelled individually as a unique and independent agent in real-time. Microsimulation models are particularly useful in modelling congested conditions where traffic demand exceeds available capacity, resulting in queuing that builds up and dissipates over time.

The Denmark microsimulation traffic model was developed using version 8.2.0 of AIMSUN.

3.1.1 Model study area

A plot of the model study area is shown in Figure 9. It centres on the town centre of Denmark with further extension to the north and east.

Because the detailed traffic data covers only two intersections and mid-block counts in the study area, thus for the base year model only the major roads have been included for calibration purposes, and they include:

- South Coast Highway;
- Ocean Beach Road;
- Scotsdale Road;
- Denmark-Mt Barker Road;
- Horsley Road; and
- Price Street.

Other minor roads would be used for future year option testings to evaluate the evacuation plans.

3.1.2 Traffic data

The traffic data used in the development of the Denmark microsimulation traffic model included the following:

- Link counts undertaken from 7 February to 16 February for the following locations:
  – Ocean Beach Road 20 meters south of South Coast Highway;
  – Scotsdale Road 100 meters east of Horsley Road, and
  – South Coast Highway 50 meters west of Ocean Beach Road.
- Intersection turning movement counts undertaken by Austraffic on the 8 February from 7 am to 7 pm. The intersections covered by the survey are listed as follows:
  – Horsley Road / South Coast Highway intersection; and
  – Denmark Mount-Barker Road / South Coast Highway intersection.

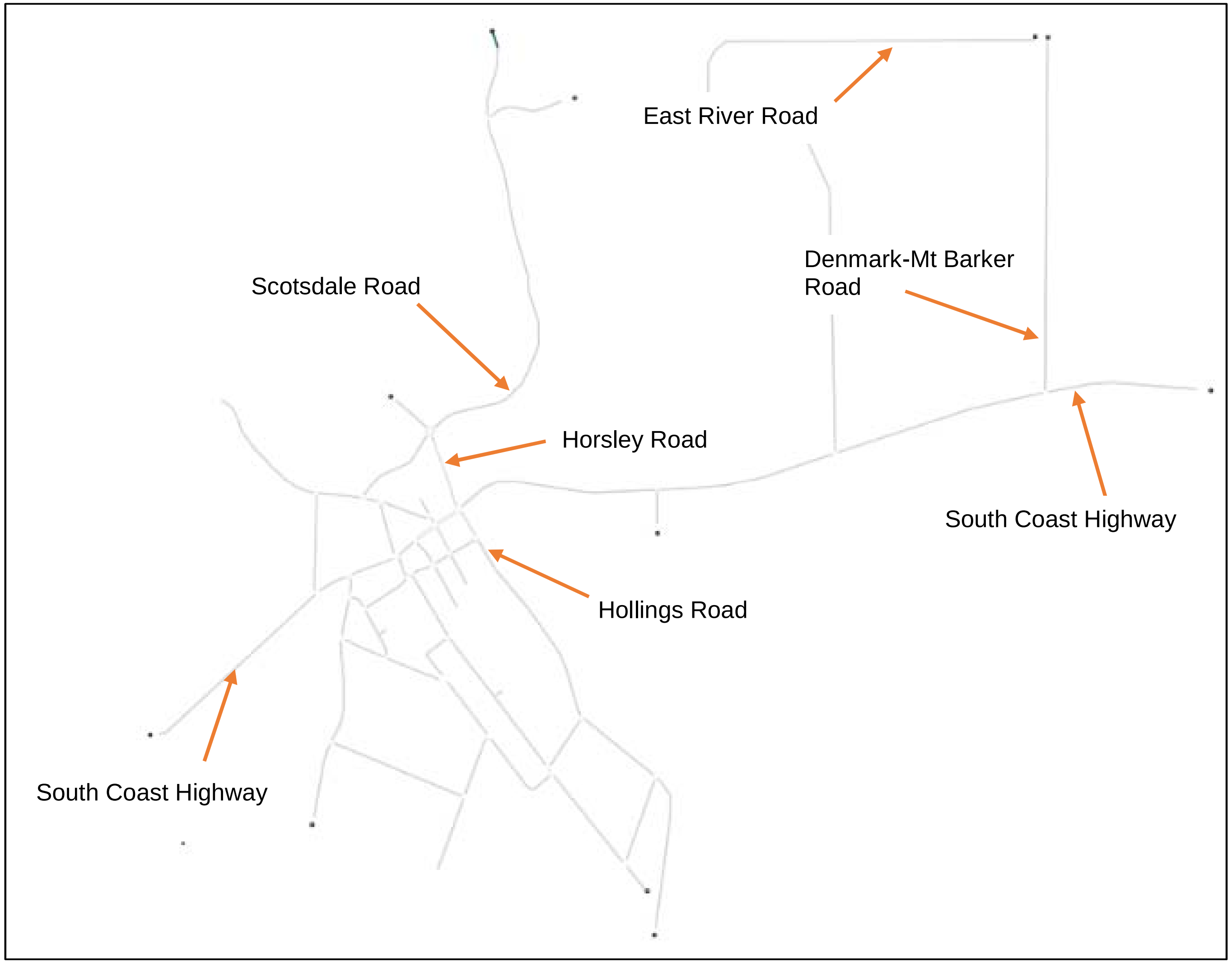


Figure 9: Denmark microsimulation model area

3.1.3 Temporal coverage

The Denmark microsimulation model covers the following analysis time periods:

- Morning peak between 7:30 – 9:30 am; and
- Evening peak between 2:30 – 4:30 pm.

The first 30 minutes of each of the modelled periods is the “warm-up” period, and the last 30 minutes of each modelled period is the “cool-down” period. The middle hour long period of each peak was evaluated for the calibration of base year models.

3.1.4 Traffic demand profile

Because data from the traffic survey does not cover the entire study area, it is not possible to accurately estimate matrices for the base year models. Therefore we compared all the one-hour peak link volumes which locate near the cordon of the study area and the intersection turn volume data, and observed the gap between intersections to estimate the turns at other intersections of the model using assumptions for several turn movements in order to balance the traffic. The peak hour demands were derived from this balanced traffic. It is recommended that in order to build a more robust model, turn counts at all key intersections should be conducted to ensure good calibration.

3.1.5 Vehicle mix

The traffic demand matrices were developed based on the turning movement counts undertaken by Austraffic in February 2018. The survey split the counting of vehicles into two types:

- Light vehicles; and
- Heavy vehicles

The proportion between light vehicles and heavy vehicles in the traffic demand was estimated based on the intersection survey data during the peak periods.

3.2 Contingency

According to *RMS Traffic Modelling Guidelines, 2013*, it is necessary to obtain turn counts for AM and PM peaks to calibrate base year model and travel time survey data for model validation. The data sources would not be able to achieve the criteria as the survey data was not enough to estimate the traffic demand of the study area without assumptions and there is no travel time survey. In order to have full confidence with the model, we recommend to conduct extensive surveys for turn counts at key intersections, as well as a travel time survey for validation purposes.

4. Model calibration

4.1 Overview

Calibration was undertaken for the morning and evening peak periods based on a comparison against hourly turning movements.

4.2 Model stability

The flow of traffic and the associated traffic conditions are randomly variable phenomena, and the microsimulation model attempts to capture this variability by varied release of traffic into the network. Whether or not a vehicle is released from a zone in any given second is dependent on the outcome of a random number generator, and this generator is controlled by the seed value. The same model run under different seed values will result in a different simulation result. For this reason, microsimulation models are generally run using a range of seed values, with results being reported for each individual seed value and the average of the simulated runs. The Denmark microsimulation model was run under the standard RMS seed values of 28, 560, 2849, 7771 and 86524.

4.3 Calibration statistics

Model calibration was undertaken on the basis of comparison of modelled and observed traffic volumes. The GEH statistic is used in the calibration of traffic models to compare the difference between observed and modelled traffic flows. The GEH statistic is defined as follows:

$$GEH = \sqrt{\frac{(V_{Observed} - V_{Modelled})^2}{\left(0.5 \times (V_{Observed} + V_{Modelled})\right)}}$$

Based on the calibration and validation guidelines presented in RMS *Traffic Modelling Guidelines, 2013*, a calibrated model must conform to the following requirements:

- Flow comparisons with GEH greater than 10 explained;
- At least 85 percent of flow comparisons with GEH less than 5;
- Slope of between 0.9 and 1.1; and
- Coefficient of Determination (R^2) between 0.9 and 1.0.

From the traffic data detailed in Section 3.1.2, a total of 18 individual turning counts were used in the calibration of the model. Barred turns were omitted from the turning count comparison. The turning count comparisons for the morning and evening peak periods are shown in Table 1.

Table 1: GEH turning count comparisons

Period	Number of movements with GEH			
	<3	<5	<10	>10
Morning peak				
8:00 - 9:00 am	18 (100%)	0 (0%)	0 (0%)	0 (0%)
Evening peak				
3:00 - 4:00 pm	18 (100%)	0 (0%)	0 (0%)	0 (0%)

The ratio of modelled to observed flows, or the slope of the linear relationship between modelled and observed flows, is determined using a least squares analysis of all turning movements in the model and is shown in Figure 10 and Figure 11. Also shown on the graphs is the Coefficient of Determination (R^2) representing the strength of the linear relationship between the modelled and observed traffic flows.

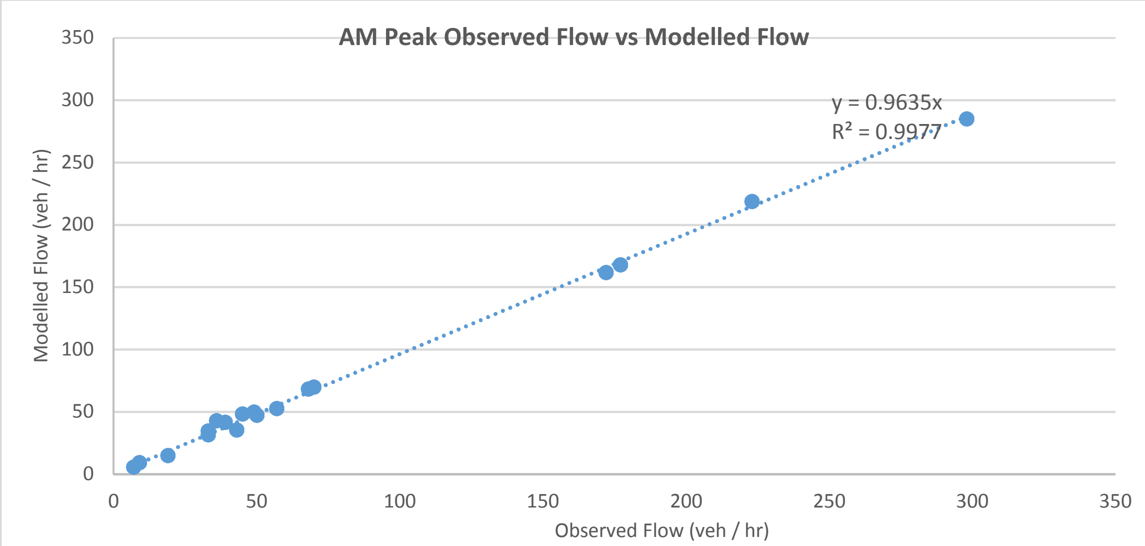


Figure 10: AM peak turn flow correlation

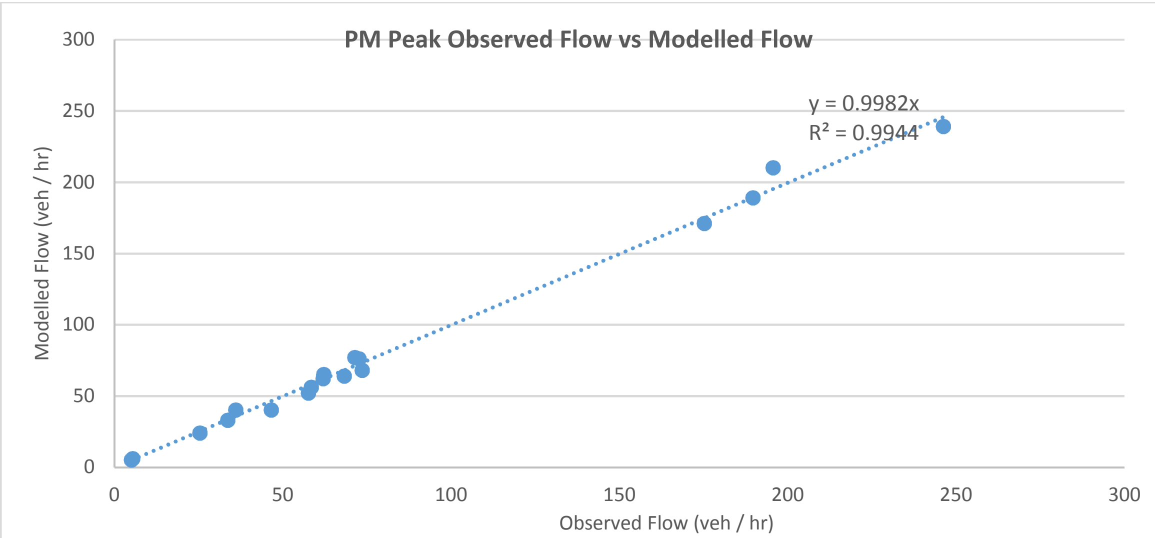


Figure 11: PM peak turn flow correlation

Analysis of the turning flow comparisons, the slope of the linear relationship and the Coefficient of Determination for the morning and evening peak periods shows that the model is well calibrated and conforms to the requirements set out in the RMS *Traffic Modelling Guidelines, 2013*. A detailed list of turning movement comparisons is provided in Appendix A.

Because there is no data for validation, there is no discussion on the validation process for this report.

4.4 Conclusion

Comparison of the observed and modelled turning movement volumes showed that the model was well calibrated according to the calibration standards set out in the RMS *Traffic Modelling Guidelines, 2013*.

For the purpose of this study, the base year model should be adequate for the evaluating different future evacuation strategies under emergency conditions.

5. 2027 future "do-nothing" models

5.1 Assumptions

Prior to considering the various evacuation models, the Future Year Base models were tested to ascertain the necessity of road infrastructure improvement within the study area for the 2027 year horizon. There is no information available from any strategic models that would provide information on changes in trip generation or land use. Consequently, GHD has made the following assumptions for the evaluation of 2027 Future Year Base models:

- Population growth for Denmark is estimated to be 2.2% per annum, based on the long-term (2006 – 2016) population statistics from the Australian Bureau of Statistics (ABS)[2]. This coincides with the high range estimate of population growth from the Western Australian Planning Commission[3]. This is used to derive the traffic demand matrices for both AM and PM peaks, extrapolating from the 2018 year horizon.
- Because the matrices for the 2018 year horizon were constructed by ignoring the minor roads of the study area and focusing on the major corridors and intersections such as the South Coast Highway / Horsley Road intersection, it means that by extrapolating future year matrices, we would still not be able to make any assumptions for the traffic demands. Therefore the future year analysis covers the same number of roads as the 2018 base year model, and it includes the following roads:
  – South Coast Highway;
  – Ocean Beach Road;
  – Scotsdale Road;
  – Denmark-Mt Barker Road;
  – Horsley Road; and
  – Price Street.
- The Denmark microsimulation model was run under the standard RMS seed values of 28, 560, 2849, 7771 and 86524.

The network for the Future Do-Nothing Models is the same as the 2018 Year models (refer to Figure 9).

5.2 Modelled outputs and discussion

A number of different evaluation outputs available from the AIMSUN software were utilised to provide output results:

- Network outputs: Statistical results derived from all vehicle movements across the entire modelled network. Outputs include total number of vehicles, average speed, average delay per kilometre, and average density.

The following table summarises the network outputs for the future "do-nothing" year and compares them to the results of the 2018 Base Year models.

[2] ABS (July 2017), 3218.0 Regional Population Growth, Australia.
[3] WAPC (August 2015), Western Australia Tomorrow: Population report No.10.

Table 2: Modelled outputs of Future Year model vs 2018 Base model

Model	Total vehicles (veh)	Average speed (km/ hr)	Average delay (sec / km)	Density (veh / km)
2027 AM	1,359	60.07	5.11	1.61
2018 AM	1,242	60.38	4.72	1.45
2027 PM	1,396	60.18	5.40	1.65
2018 PM	1,273	60.48	5.03	1.50

The results have indicated that the growth of traffic around the Denmark townsite will have limited impact to the traffic operation by comparison with the modelled outputs of 2018 Base Models. The average speed and average delay has no significant changes and the density has only increased by a tiny margin.

We could therefore conclude that traffic demand would not directly impact the traffic operation within the study area and there is no urgent need to upgrade key intersections and road corridors.

6. 2027 evacuation models

6.1 Evacuation options

GHD has assessed four options for the west-to-east evacuation of Denmark under emergency conditions, across the Denmark River. These options were coded into the AIMSUN model to evaluate the traffic operation of each.

The four different options are as follows:

- **Option 1 –** Existing South Coast Highway (dual lane) bridge:
  This option adopts the existing dual-lane South Coast Highway bridge as the primary unobstructed route for evacuation towards the east.
- **Option 2 –** Existing Churchill Road (single lane) bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route starts from Scotsdale Road and heads northbound, via Mt Lindesay Road, then turns right to Churchill Road, crosses the Denmark River, then it continues eastbound until it turns right onto Denmark–Mt Barker Road, back to the intersection with South Coast Highway.
- **Option 3** – East River Road, with new dual lane bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route starts from Scotsdale Road and it goes northbound until it turns right at or near Riverbend Lane and goes eastward, across a newly constructed dual lane bridge, connecting to East River Road, then it turns right to Denmark–Mt Barker Road, back to the intersection with South Coast Highway.
- **Option 4** – Denmark Southern Bypass, with new dual lane bridge:
  This option assumes that the eastern approach to the South Coast Highway bridge is closed (due to emergency conditions). Hence, the alternative route for evacuees will be to drive eastbound along a notional southern bypass route that crosses the Denmark River with a dual lane bridge at the approximate location of the existing bridge on the Denmark to Nornalup Heritage Rail Trail, near the mouth of the Denmark River. This bypass route is assumed to connect to the South Coast Highway, near the Denmark–Mt Barker Road intersection.
  Refer to Appendix B for possible route alignment options of a southern bypass.

The following are the AIMSUN networks for the four different evacuation options, and the red line indicates the evacuation route.

Figure 12: Model network for Option 1 (South Coast Highway)

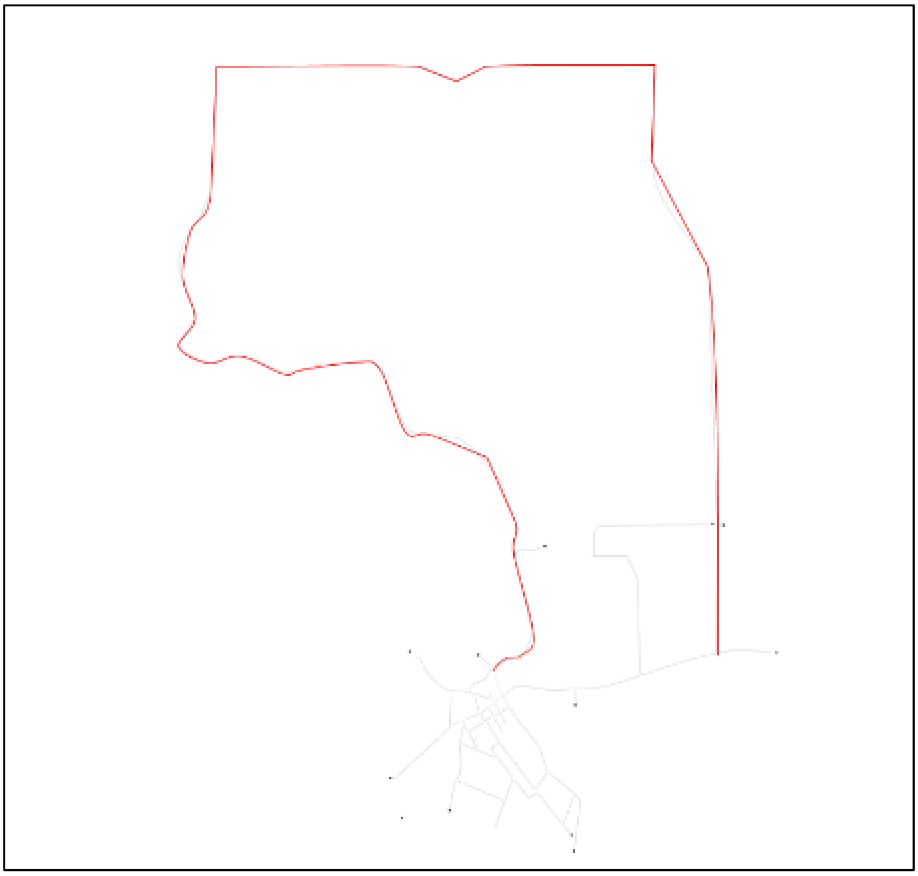


Figure 13: Model network for Option 2 (Churchill Road)

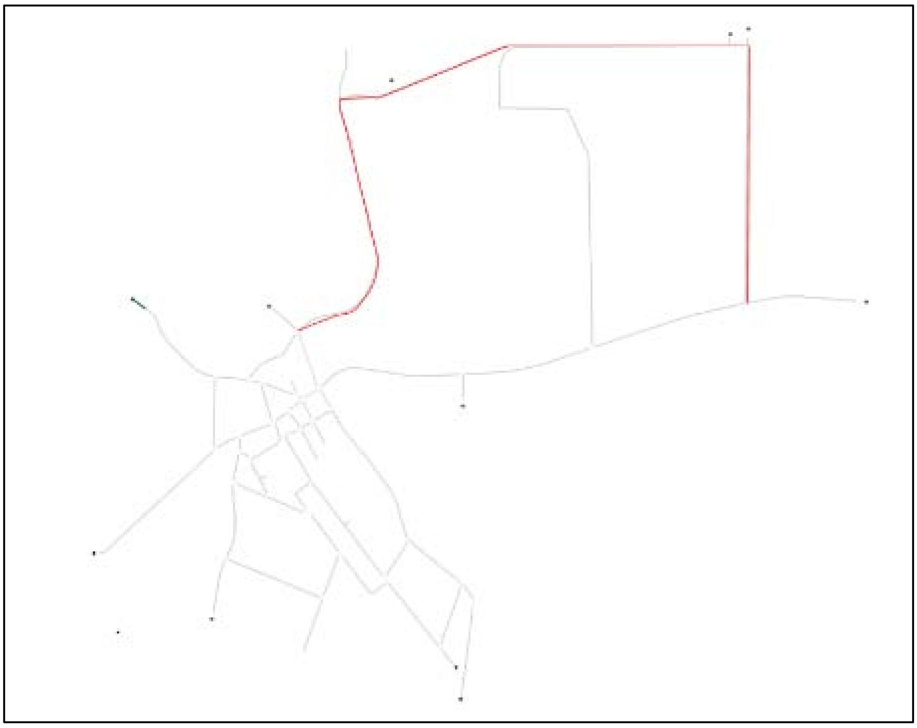


Figure 14: Model network for Option 3 (East River Road)

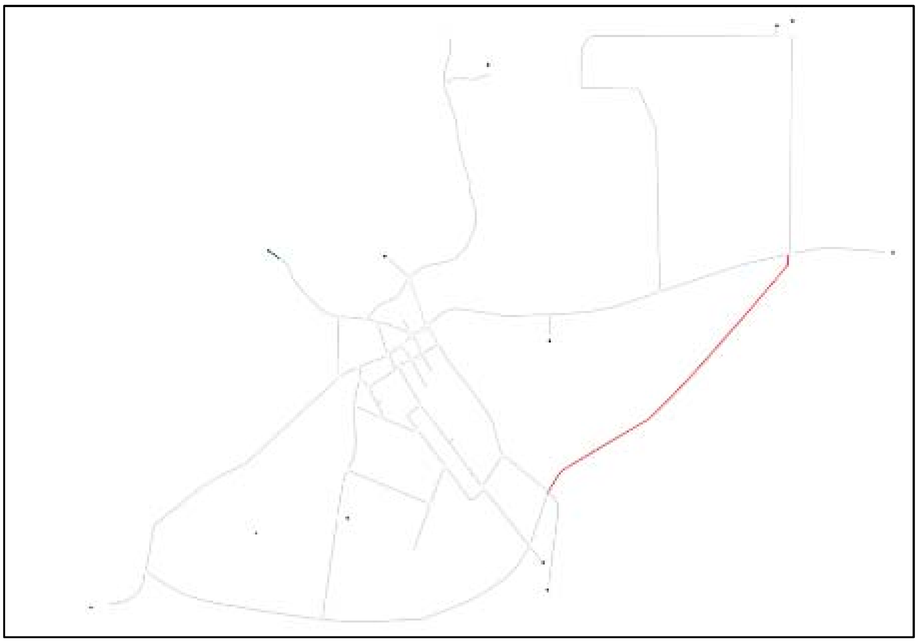


Figure 15: Model network for Option 4 (Southern Bypass)

6.2 Data availability and assumptions

As discussed in section 5.1, GHD used population data from the Australian Bureau of Statistics (ABS) to estimate the growth rate of the Shire of Denmark to derive the 2027 population. This is used to also derive the peak traffic demand matrix for the Evacuation Models.

However, other information that would be useful for the Evacuation Models was not available, therefore GHD made the following assumptions:

- The population of the Shire of Denmark is assumed to be evacuated to the east of the South Coast Highway / Denmark–Mt Barker Road intersection (i.e. towards Albany).
- Based on a review of all adopted Structure Plans, subdivision approvals and local planning strategy data (including assumed future land development), the assumed high-level population distribution for Denmark is shown below.

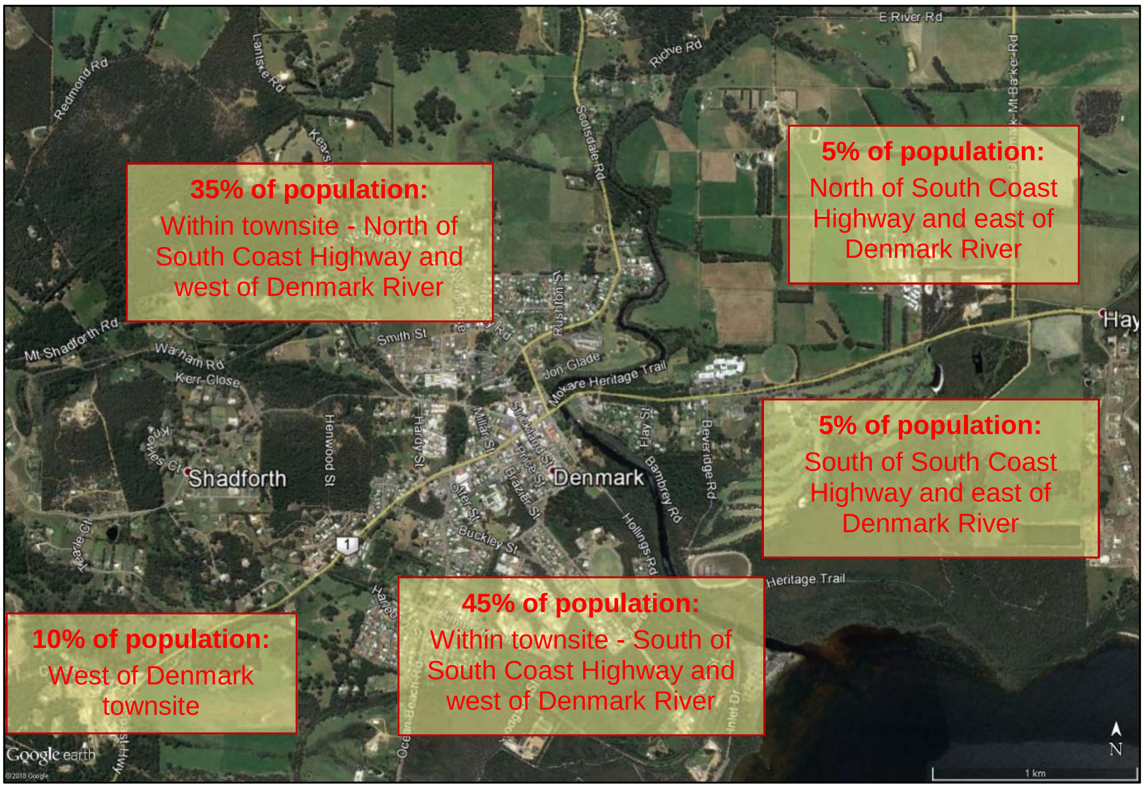


Figure 16: Geographical population distribution

- It is assumed that there would two broad types of household in the Shire, based on high-level demographics – i.e.:
  – 65.7% of the population belong to families with children/dependents and hence each vehicle takes (on average) four people during the evacuation; and
  – 34.3% of the population would be couples with no children/dependents, and hence each vehicle takes (on average) two people during the evaluation.
- Characterisation of people's evacuation behaviour during emergency conditions is difficult. However, several literature sources indicate the only 60-70% of the total population is likely to evacuate, even when placed under evacuation orders[4]. It is also known that not all people evacuate immediately, with some people responding immediately to an evacuation order, but many others not responding immediately for various reasons (e.g. not aware of the evacuation order, needing to make arrangements to be able to evacuate, or choosing not to evacuate).

[4] Archibald, E., McNeil, S. (2012). Learning from traffic data collected, before, during and after a hurricane, *IATSS Research*, 36(1): 1-10.
Baker, E. (1991). Hurricane evacuation behaviour, *International Journal of Mass Emergencies and Disasters*, 9(2): 287-310.
Paul, B. (2008). Hazard warnings and compliance with evacuation orders: The case of Bagladesh's Cyclone Sidr, Kansas State University, Manhattan KS.

- As a reasonable estimate, it is assumed that **<u>20% of the total Shire population</u>** would be evacuated during the peak hour of the evacuation, and the remainder would be evacuated during the rest of the evacuation period. The modelling addresses the peak hour of the evacuation when the largest proportion of the total population would evacuate from the Shire of Denmark, i.e. this is when the traffic would be the most congested compared with the rest of the evacuation period.
- It is assumed that the evacuation is orderly and free of unforeseen chaotic incidents and therefore if the traffic operation during the peak period is without major issues, then the rest of the evacuation period would also be satisfactory in terms of traffic operation.
- During the evacuation, the model assumes that drivers would choose the best, or most efficient available route(s) for evacuation. Therefore some minor roads, which were not modelled in the 2018 Base Models, were included in the model and used to choose the most desirable routes.
- It should be noted that the opposite direction of the road can also be utilised for evacuation under emergency conditions. However, this analysis is not covered within this study.

6.3 Outputs and analysis

A number of different evaluation outputs available from the AIMSUN software were utilised to provide output results:

- Network outputs: Statistical results derived from all vehicle movements across the entire modelled network. Outputs include total number of vehicles, average speed, average delay per kilometre, and average density.
- Travel times: Statistical results derived from sub-paths which summarised the travel time for evacuation route from the CBD to the South Coast Highway / Denmark–Mt Barker Road intersection.

6.3.1 Single evacuation route

The following table summarises the network outputs for all four evacuation options, assuming that in each case, that option is the sole evacuation route.

Table 3: Network outputs for the evacuation options

Options	Total vehicles (veh)	Average speed (km/ hr)	Average delay (sec / km)	Density (veh / km)
Option 1 – South Coast Highway	506	67.6	3.76	0.65
Option 2 – Churchill Road	498	73.6	5.46	1.72
Option 3 – East River Road	503	66.0	6.68	1.05
Option 4 – Southern bypass	504	71.9	4.93	0.51

The following table summarises the travel time of the evacuation routes from the CBD to the South Coast Highway / Denmark–Mt Barker Road intersection, assuming that in each case, that option is the sole evacuation route.

Table 4: Modelled outputs for the evacuation route

Options	Total vehicles (veh)	Mean travel time (sec)	Mean stop time (sec)	Average delay (sec)
Option 1 – South Coast Highway	457	143.9	0.0	9.23
Option 2 – Churchill Road	448	982.7	0.3	107.66
Option 3 – East River Road	432	265.1	0.5	33.31
Option 4 – Southern bypass	464	98.0	0.4	8.35

The results from the above show that:

- The number of vehicles during the peak evacuation would not exceed the capacity of the road network within the study area.
- Option 2 (Churchill Road) would be the most time consuming route, with the highest average delay because the alternative route is the longest and it would take evacuees much longer to reach South Coast Highway. This could pose a risk to those who evacuate late.
- Option 3 (East River Road) is the next most time consuming route, with a mean travel time that is 1.8 times longer than Option 1.
- Option 4 (Southern Bypass) has the shortest travel time and average delay, and from the traffic operation point of view, would be the most preferred evacuation route.
- Option 1 (South Coast Highway), which uses the existing bridge that crosses the Denmark River via South Coast Highway would also perform satisfactorily.

6.3.2 Dual evacuation routes

In the preceding analysis, Options 2, 3 and 4 assumed the existing bridge on South Coast Highway was closed. However, the Shire also wanted to understand the evacuation conditions if dual evacuation routes were available. Hence, the models were re-run to evaluate how much traffic the existing South Coast Highway bridge would attract from the alternative evacuation route. The model allowed dynamic assignment for vehicles to choose the best available route.

The following table compares the number of vehicles that would utilise the alternative evacuation route, with and without the South Coast Highway bridge being open.

Table 5: Usage of alternative evacuation routes, with or without the South Coast Highway bridge being open

Alternative route	Total vehicles using alternative evacuation route with **OPEN** South Coast Highway bridge	Total vehicles using alternative evacuation route with **CLOSED** South Coast Highway bridge
Option 2 – Churchill Road	Negligible	448
Option 3 – East River Road	Negligible	432
Option 4 – Southern bypass	281	458

The results have shown that because the alternative evacuation routes for Options 2 and 3 are significantly longer, most traffic would most likely choose to South Coast Highway bridge to save time.

For Option 4, a significant number of vehicles coming from south of the South Coast Highway would likely use the alternative evacuation route.

6.3.3 Network capacity limit

The analysis in section 6.3.1 was based on the assumption that 20% of the population would depart from the Denmark modelled area during the peak 1-hour evacuation period. To test the capacity limits of the road network during the peak evacuation hour, the following has been undertaken:

- Identified key intersections for each option along the evacuation route; and
- Evaluated the level of service (LOS) for each intersection as the traffic demand was increased incrementally.
  - The LOS at each intersection is characterised by the average queue delay for vehicles approaching the intersection (i.e. seconds per vehicle). Based on Austroads thresholds for unsignalised intersections[5], a LOS worse than category "D" (i.e. greater than average queue delay of 25 – 35 seconds) is considered to be a failure point, whereby the intersection requires upgrading to accommodate greater traffic volumes.

The key intersections identified for each option are shown in Table 6.

Table 6: Key intersections on each evacuation route

Options	Key intersections
Option 1 – South Coast Highway	• South Coast Highway / Strickland Street • South Coast Highway / Horsley Road / Hollings Road • South Coast Highway / Denmark – Mount Barker Road
Option 2 – Churchill Road	• South Coast Highway / Horsley Road • Horsley Road / Scotsdale Road • South Coast Highway / Denmark – Mount Barker Road
Option 3 – East River Road	• South Coast Highway / Horsley Road • Horsley Road / Scotsdale Road • South Coast Highway / Denmark – Mount Barker Road
Option 4 – Southern bypass	• Crellin Street / Inlet Drive / Bypass (Future) • Crellin Street / Brazier Street / Bypass (Future) • South Coast Highway / Denmark – Mount Barker Road

Table 7 shows the modelling results for the network capacity limits.

[5] Highway Capacity Manual, 2010. Transportation Research Board of the National Academy of Sciences, http://hcm.trb.org/?qr=1

Table 7: Network capacity limits for each option

Options	Percentage increase in demand before any key intersection would have LOS worse than category D	Total vehicles in peak evacuation hour at capacity limit	% of population that could be evacuated in the peak hour
Option 1 – South Coast Highway	300%	1,518	60%
Option 2 – Churchill Road	150%	747	30%
Option 3 – East River Road	150%	755	30%
Option 4 – Southern bypass	230%	1,159	46%

Note:

- Current peak AM and peak PM traffic counts on South Coast Highway are approx. 400 vehicles per hour (based on February 2018 traffic count data).

The modelling has shown that Option 2 (Churchill Road) and Option 3 (East River Road) are the least capable of handling an increase of traffic, under emergency conditions. This is due to the limited capacity of the Horsley Road / Scotsdale Road intersection, which is a roundabout. A significant number of vehicles approach this intersection from the north and west, and must give way to the vehicles coming from the southern approach, before all exiting to the eastern approach. To increase the capacity for these evacuation routes, it would require an upgrade / modification at the Horsley Road / Scotsdale Road intersection (such as traffic signals), or (more likely) the implementation of emergency traffic management controls.

Option 1 can accommodate more vehicles than Option 4 (Southern bypass) because there are more intersections along South Coast Highway to share the burden of the vehicles that are moving towards the evacuation routes.

7. Conclusions

GHD was commissioned to develop a microsimulation traffic model of the Denmark town to understand the traffic impacts under emergency evacuation conditions.

Before testing the various evacuation scenarios, GHD first extrapolated the peak hour traffic to 2027 to ascertain if it was necessary to upgrade key intersections within the study area. However, the results have shown that such upgrades would not be necessary as estimated traffic during the peaks is still low and no major queueing or congestion was observed.

GHD has subsequently assessed four options for the west-to-east evacuation of Denmark under emergency conditions, across the Denmark River. The modelling covers a one-hour peak when the largest number of population, which is estimated to be 20%, would be evacuated. By comparing the modelled outputs, Option 1 (South Coast Highway) and Option 4 (Southern Bypass) are shown to be the most time efficient paths for the evacuees. Option 4 (Southern bypass) would also complement Option 1 (South Coast Highway) as a dual evacuation route.

The road network capacity under both Option 1 and Option 4 is easily sufficient to accommodate expected peak evacuation hour conditions. However, the network capacity of Option 2 (Churchill Road) and Option 3 (East River Road) is significantly constrained by the operation of the key intersection at Horsley Road and Scotsdale Road.

Appendices

Appendix A – GEH summary

AM peak

Intersection	Approach	Turn	Modelled Volume	Surveyed Volume	GEH
South Coast Highway / Denmark - Mount Barker Road Intersection	Denmark - Mt Barker Road (N)	LT	9	9	0.132
	Denmark - Mt Barker Road (N)	RT	32	33	0.246
	South Coast Highway (W)	Through	162	172	0.790
	South Coast Highway (W)	LT	50	49	0.142
	South Coast Highway (E)	RT	6	7	0.474
	South Coast Highway (E)	Through	168	177	0.685
South Coast Highway / Horsley Road Intersection	Hollings Road (S)	RT	47	50	0.402
	Hollings Road (S)	Through	15	19	0.970
	Hollings Road (S)	LT	48	45	0.498
	South Coast Highway (E)	LT	43	36	1.114
	South Coast Highway (E)	RT	53	57	0.594
	South Coast Highway (E)	Through	219	223	0.269
	Horsley Road (N)	Through	35	33	0.309
	Horsley Road (N)	LT	68	68	0.048
	Horsley Road (N)	RT	35	43	1.214
	South Coast Highway (W)	RT	42	39	0.410
	South Coast Highway (W)	Through	285	298	0.750
	South Coast Highway (W)	LT	70	70	0.024

PM peak

Intersection	Approach	Turn	Modelled Volume	Surveyed Volume	GEH
South Coast Highway / Denmark - Mount Barker Road Intersection	Denmark - Mt Barker Road (N)	LT	5	6	0.251
	Denmark - Mt Barker Road (N)	RT	58	52	0.756
	South Coast Highway (W)	Through	190	189	0.044
	South Coast Highway (W)	LT	36	40	0.649
	South Coast Highway (E)	RT	5	5	0.000
	South Coast Highway (E)	Through	175	171	0.319
South Coast Highway / Horsley Road Intersection	Hollings Road (S)	RT	74	68	0.666
	Hollings Road (S)	Through	34	33	0.104
	Hollings Road (S)	LT	71	77	0.650
	South Coast Highway (E)	LT	58	56	0.317
	South Coast Highway (E)	RT	62	65	0.351
	South Coast Highway (E)	Through	246	239	0.462
	Horsley Road (N)	Through	25	24	0.282
	Horsley Road (N)	LT	68	64	0.517
	Horsley Road (N)	RT	62	62	0.000
	South Coast Highway (W)	RT	47	40	1.003
	South Coast Highway (W)	Through	196	210	1.011
	South Coast Highway (W)	LT	73	76	0.394

Appendix B – Denmark Southern Bypass – possible route alignments

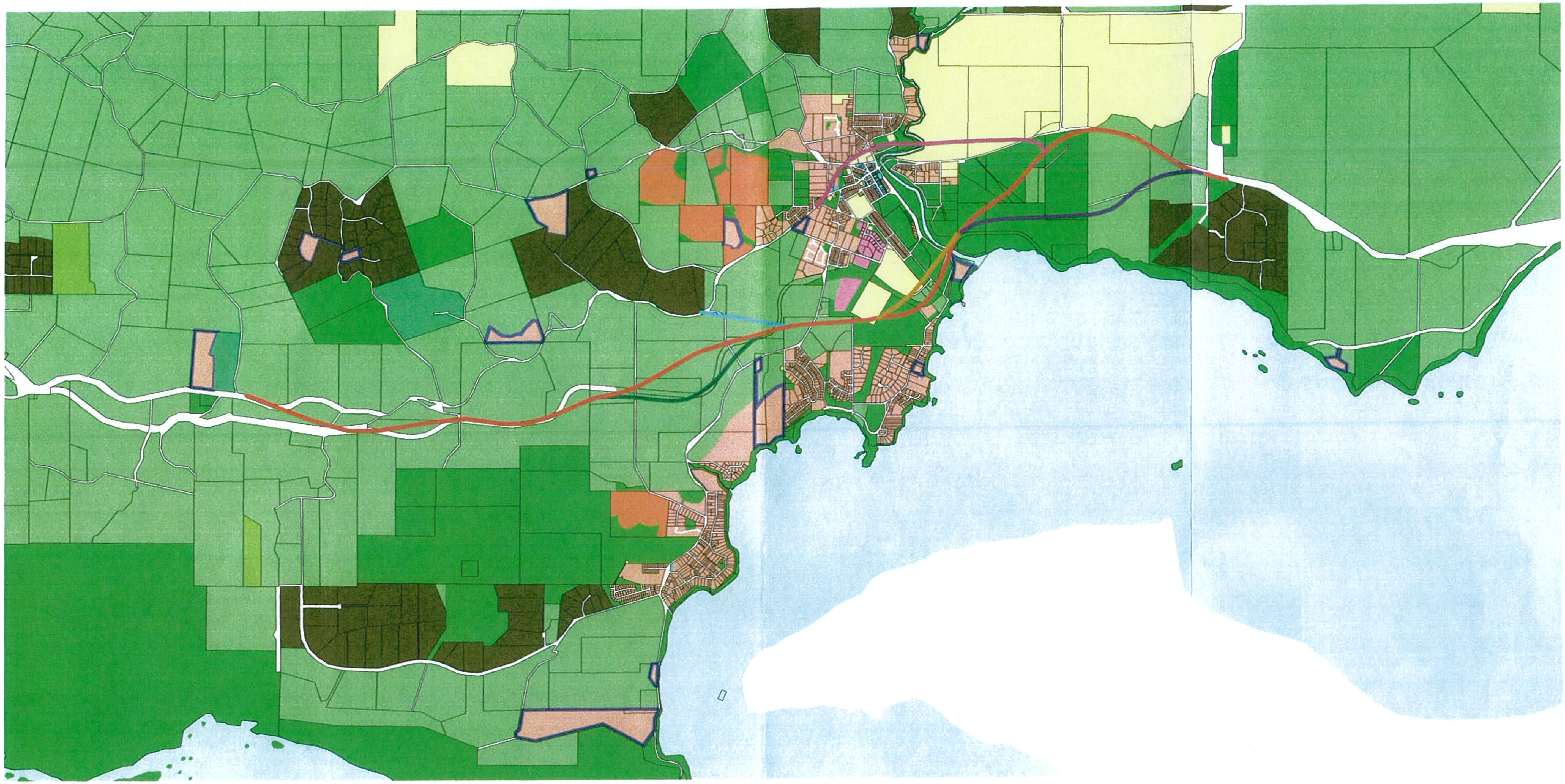


FIGURE 1
Denmark Bypass Options

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