



Shire of Serpentine Jarrahdale
Mundijong Whitby District Structure Plan
Railway Crossing Considerations

May 2016

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1. Introduction

1.1 Background

The Mundijong Whitby District Structure Plan will guide development of residential and commercial areas around the existing Mundijong townsite. The DSP area is bisected by a railway which carries freight (mainly bauxite and alumina) from Pinjarra to Kwinana, and a passenger service between Perth and Bunbury (the Australind).

At the time the DSP was approved, it was expected that the freight rail would be realigned to the west of the development area, leaving only the low frequency (four per day) passenger trains on the existing line through town.

It has now transpired that the freight railway has not been realigned and is unlikely to do so for many years. In the meantime, new development is under way, which will rely on existing and new railway crossings to complete the DSP traffic network.

It is state government policy that new level crossings should not be created, and if a new crossing cannot be avoided then an existing crossing should be closed to compensate. Further, the traffic volumes generated could result in the need for some crossing to be grade separated, which is a significant cost and has environmental and amenity disbenefits.

To address this issue, the Shire of Serpentine Jarrahdale have advertised an amendment to the DSP, and have also devised a number of alternative traffic network options. GHD has been engaged to undertake traffic modelling of each of the options, determine the relevant railway crossing protection warrants, and make recommendations as to a preferred option(s).

1.2 Purpose of this report

The purpose of this report is to review alternative layouts for the district structure plan, with particular emphasis on the levels of protection required at each of the railway crossings within the scheme.

1.3 Scope and limitations

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

GHD otherwise disclaims responsibility to any person other than the Shire of Serpentine Jarrahdale 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 Assumptions

The Mundijong Whitby District Structure Plan covers an area bounded by Bishop Road in the north, the future Tonkin Highway in the west, Mundijong and Watkins Road in the south and South Western Highway on the east, as shown in Figure 1.

The site is bisected by the Kwinana – Pinjarra freight railway and the Perth – Bunbury passenger railway (Australind service) which share a reservation through the structure plan area. Train movement numbers have been provided by Alcoa and Brookfield Rail. Train speed recommendations have been provided by Brookfield Rail.

The Shire of Serpentine Jarrahdale has provided a series of layout options for consideration. These include the approved DSP (Option 1), the recently advertised amendment (Option 2), and alternatives suggested by the Shire (Options 3a, 3b, 3c, 3d, 3e and 4).

Traffic volumes have been estimated, based on output from Main Roads' ROM model, as discussed in Section 4.

The requirements for railway crossing protection are contained in Main Roads' (June 2015) *Railway Crossing Protection in Western Australia* (hereafter referred to as "the policy").

2. Planning context

2.1 Mundijong Whitby District Structure Plan

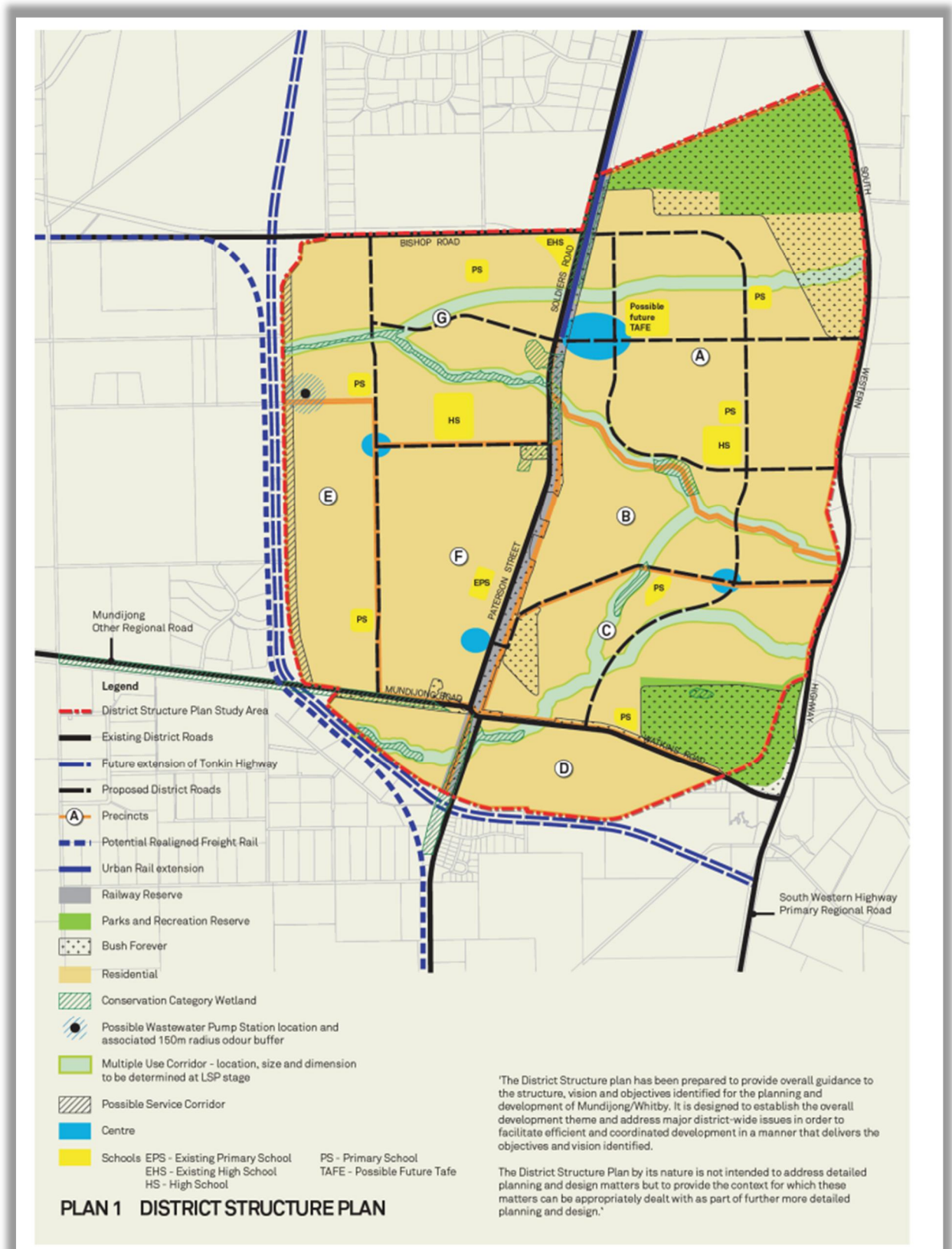


Figure 1: Approved Mundijong Whitby District Structure Plan

3. Railway crossing considerations

3.1 Crossing locations

The locations of all rail crossings discussed in this report are shown in Figure 2.

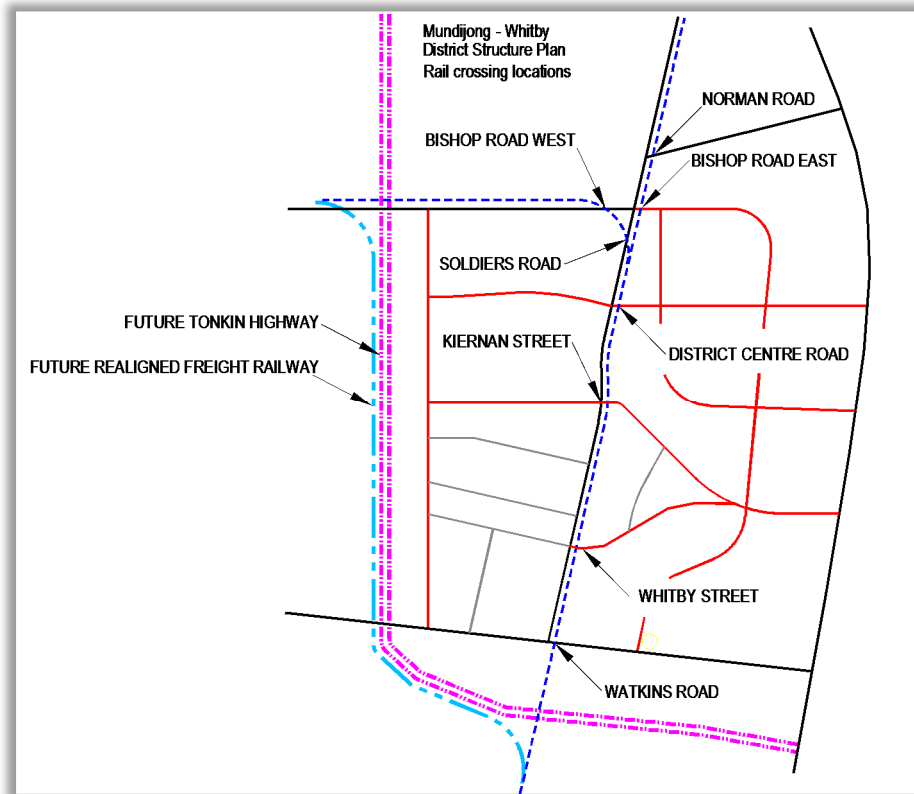


Figure 2: Railway crossing locations

3.2 Policy

We have referred to Main Roads' (June 2015) *Railway Crossing Protection in Western Australia* (hereafter referred to as "the policy"). The policy sets out in detail the factors to be considered when determining the protection to be applied to railway crossings. It also provides mathematical formulae to be applied in determining the warrants for each level of protection (eg flashing lights, boom gates or grade separation).

Main Roads previously initiated an ALCAM assessment of the various crossings, which would provide the appropriate level of control warranted at each, but this was not proceeded with.

The overall aim of the state government policy is not to increase the total number of existing level crossings. In general, this means that new level crossings are only permitted if another existing crossing in the vicinity is closed.

3.3 Exposure & warrants

3.3.1 Calculations

Basic warrants for the provision of different types of railway crossing control are determined from the policy. The basic warrants are:

$C_w < 14,000$	Give way or stop sign
$C_w > 14,000$	Flashing lights
$C_{wb} = C_w * H_v > 700,000$	Boom barrier
$C_{wgr} = C_w * H_v * D_v > 5,000,000$	Grade separation

The definitions of the above are explained in the following paragraphs. The key parameters in the formulae in the Policy are shown in Table 1.

Table 1: Crossing protection parameters

Parameter	Description	Unit
Vt	Train speed	km/h
Nt	Volume of trains	Trains / week
Vv	Speed of vehicular	km/h
AADT	Volume of vehicular traffic	Veh / day
Pv	Percentage heavy vehicles	Expressed as whole number
Gr	Grade factor	Expressed as whole number
Ltl	Train length	metres

The aggregate weighted exposure is given by

$$C_{wgr} = C_w * H_v * D_v \text{ where}$$

C_w is the basic weighted conflict

$$C_w = \frac{V_t * N_t * V_v * AADT}{3600}$$

H_v is the heavy vehicle factor

$$H_v = \frac{\left[1 + \frac{P_v}{5}\right]}{2} * \left[1 + \frac{G_r}{10}\right]$$

D_v is a traffic delay factor

$$D_v = \frac{\left[1 + \frac{\left(21 + \frac{3.6 L_{tl}}{0.9 V_{tl}}\right)}{25}\right]}{2}$$

3.3.2 Train numbers

Information from Alcoa, confirmed by Brookfield, indicates the following daily freight train movements:

- Kwinana to Pinjarra
 - 2 x Alumina Service – 26 wagons = 425 metres
 - 2 x Caustic Service – 16 wagons = 304 metres
 - 9 x Bauxite Service – 56 wagons = 906 metres
- Pinjarra to Kwinana
 - 2 x Alumina Service – 26 wagons = 425 metres
 - 2 x Caustic Service – 16 wagons = 304 metres
 - 9 x Bauxite Service – 56 wagons = 906 metres

In addition, the Australind passenger service operates four trains / day.

3.3.3 Train length

Train length L_{tl} is used in the formula

$$D_v = \frac{\left[1 + \frac{\left(21 + \frac{3.6 L_{tl}}{0.9 V_{tl}} \right)}{25} \right]}{2}$$

to determine the traffic delay factor caused by trains passing over a level crossing.

The policy provides that the longest train passing a crossing should be used in the calculation. Given the disparity in trains using the line, from 906 m bauxite trains, down to the Australind (~100 metres) it is considered a weighted average train length would give a more realistic account of the aggregate delays caused by trains. This is because the factor D_v is used as a multiplier with factors which include the *total* number of trains, not just the longest trains.

The following weighted lengths have been adopted:

Train type	Train length L_{tl}	Location
Freight only	740 m	<ul style="list-style-type: none"> • Kwinana – Pinjarra line, north of Mundijong Junction • Kwinana – Pinjarra line, south of Mundijong Junction when passenger and freight trains are considered separately (see section 3.3.4)
Passenger only	100 m	<ul style="list-style-type: none"> • Perth – Bunbury line, north of Mundijong Junction • Kwinana – Pinjarra line, south of Mundijong Junction when passenger and freight trains are considered separately (see section 3.3.4)
Freight & passenger (same speed)	650 m	<ul style="list-style-type: none"> • Kwinana – Pinjarra line, south of Mundijong Junction when passenger and freight trains are considered together

3.3.4 Train speed

Freight trains are limited to 80 km/h and this speed has been adopted for all crossings within the scheme area. It is noted that there are lower limits in some locations, however Brookfield suggest that these may be of a temporary nature and recommend that 80 km/h be used.

Passenger trains are limited to 110 km/h. Existing speed limits and the need for trains to stop at Mundijong station mean that in practice they will not exceed 80 km/h in the scheme area. However Brookfield have requested that a further analysis be undertaken using 80 km/h for freight and 110 km/h for passenger trains. The approach taken is to analyse the freight trains at 80 km/h and passenger trains at 110 km/h, with the weighted conflicts being added together to achieve a unified score. In practice, there was no practical difference in the outcomes (in terms of crossing protection) regardless of whether the passenger train speeds were 80 km/h or 110 km/h.

3.4 Short stacking

The fact that Soldiers / Paterson Road runs close and parallel to the railway raises a concern at adjacent intersections. There is a possibility that vehicle queues at the intersection could extend back across the adjacent level crossing, causing a significant safety hazard. Likewise, vehicles queueing to cross the railway could block the adjacent roadway.

Strategies to overcome this problem include:

-
1. Realignment of the road to increase separation between road and rail

 2. Limitations on turning movements at the intersection (including cul-de-sacing of some intersection legs)

 3. Installation of traffic signals and a hold line on the approach side of the track (see Figure 3).
-

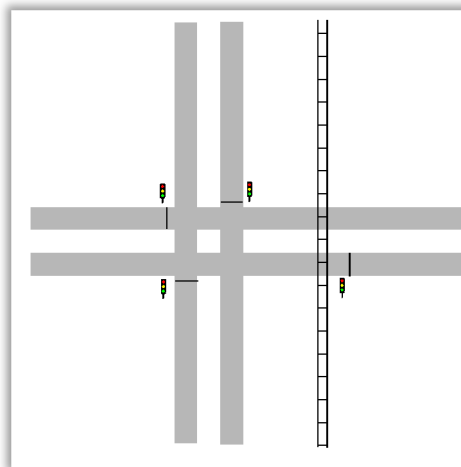


Figure 3: Intersection with approach side signals and hold line

Option 1, realigning the road, may require the acquisition of additional land with consequent costs and disruptions. Turning movement limitations will inevitably result in inconvenience and reduction in intersection capacity, which may have significant impacts on traffic efficiency and local amenity.

Main Roads have advised that trials of Option 3 at a site in the metropolitan area have been unsuccessful and they no longer recommend this option. However, it is considered that this treatment remains suitable for locations with very low train numbers.

A combination of Options 1 and 2 is likely to prove satisfactory, with each of the crossing locations to be examined in detail depending on the overall scheme layout finally adopted.

4. Traffic modelling

In order to provide an understanding of how the proposed developments will impact on the road and rail networks, modelling of the study area was undertaken. The modelling was used to determine the distribution and volume of traffic within the road networks.

Traffic volumes from this model were used in the various formulae to calculate the crossing protection warrants.

4.1 Information Supplied

To help inform the traffic modelling, several pieces of externally supplied data were provided. These include:

- Extract from the ROM model;
- Schematic layouts of proposed road networks

The extract from the ROM model is shown in Figure 4. This data forms the basis for both the traffic generation and distribution for each of the proposed road layouts.

4.2 Model Development

The study area has had minimal development, and as such, there is limited information available to undertake a micro level analysis of the proposed road network layouts. Therefore it was decided to undertake the analysis using a more strategic level of analysis.

For the analysis a model of the road network was developed using industry standard formula for traffic generation, traffic distribution and traffic assignment, which was stored in a spreadsheet. The spreadsheet model was calibrated to conform to the outputs from the ROM model shown in Figure 4.

4.2.1 Traffic Generation

The traffic generated by each zone in the model was taken directly from the ROM model.

4.2.2 Traffic Distribution

Traffic distribution deals with the total number of vehicles travelling between zones within a network, without considering the route that they may take. The routes vehicles will take are considered as part of the traffic assignment outlined in Section 4.2.3. Volumes between each of the zones in Figure 4 were estimated using the Fratar method. Frataring is a statistical process used to ensure that the volumes assigned between each Origin and Destination pair (zone) matches the recorded total flows in and out of each zone. This process assigns volumes into trips between zones through an iterative process whereby the volumes between all zones are adjusted progressively until they match with the recorded total flows (typically within +/- 5%). The Fratar method provides an estimate of volumes for all the possible trips within the study area. The Fratar volumes were then calibrated to the link volumes in the ROMS model shown in Figure 4, through a manual adjustment.

The calibration process compared the volumes shown in Figure 4 to those produced in the spreadsheet model. The comparison was done using the GEH statistic¹, which measures “goodness of fit”. Over 90% of the comparison was considered a good fit by this analysis, this is considered an acceptable result.

¹ The GEH statistic is a measure of the “goodness of fit” between modelled traffic and actual traffic. Its name is derived from Geoffrey E. Havers, who invented the formula.



Figure 4: ROM model data

4.2.3 Traffic Assignment

The assignment of traffic on particular routes through the road network was undertaken using an “All-or-nothing” approach. Traffic was assigned on the shortest path between zones, with the shortest path determined to be the fastest route under free flow conditions.

This was considered an appropriate assumption given high number of unknown variables associated with the proposed road network.

4.3 Summary of Assumptions

As stated previously there is limited information available on the road network due to the project being in the planning stages. Therefore several assumptions were required to complete the analysis, these assumptions include:

- No additional travel demand created outside those detailed in the ROM model.

- All new roads set at 50 km/hr.
- Traffic would take the shortest path between zones.
- Intersection delay, geometric delay and road grades were not considered as part of the traffic assignment.

5. Structure Plan Options

5.1 Option 1 (approved DSP)

5.1.1 Description

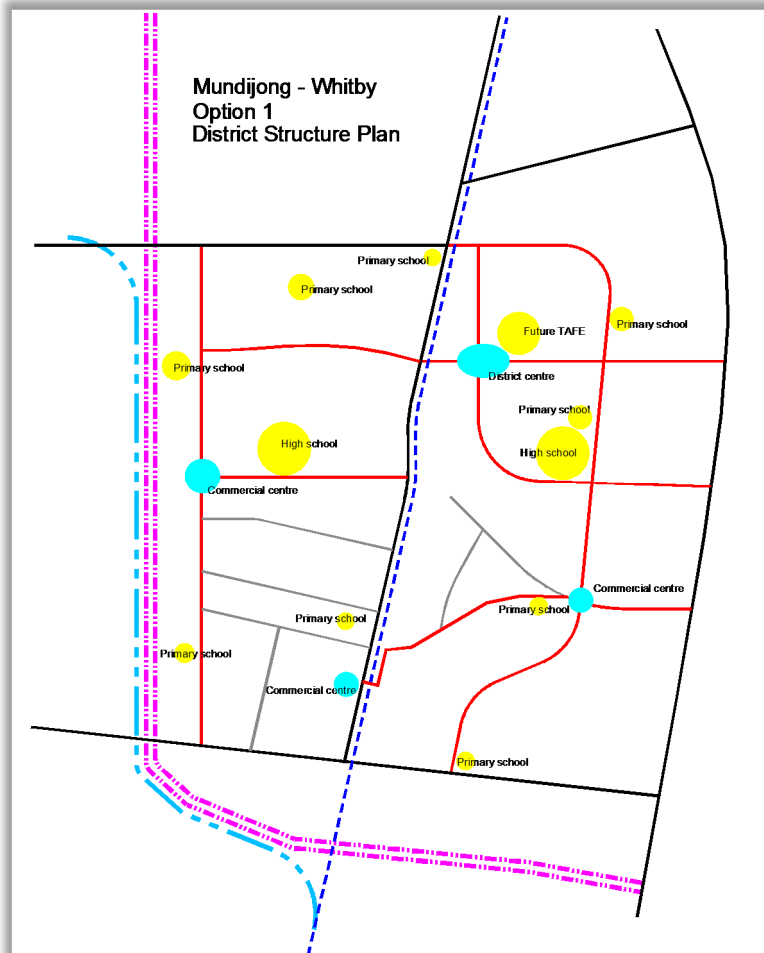


Figure 5: Option 1 - Approved District Structure Plan

The approved DSP has the following key features:

- The freight railway is realigned out of the structure plan area with the passenger service remaining on its current alignment.
- Bishop Road is extended eastwards, crossing the passenger railway to form a major east-west connection at the north of the site
- A new east-west road is created through the district centre
- Kiernan Street level crossing is closed
- A new level crossing is proposed at Whitby Street

Traffic generation is shown at Appendix A.

5.1.2 Railway crossings

This option has been modelled under the following scenarios:

1. Freight railway is relocated out of the structure plan area, passenger service continues to run through Mundijong
2. Both freight and passenger trains run through Mundijong

For each scenario, we have considered the following cases:

- a. Passenger trains run at 80 km/h
- b. Passenger trains run at 110 km/h

Number of crossings

Table 2 indicates the crossings under each scenario:

Table 2: Option 1 - Crossings

Scenario (Total crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Existing (5 crossings)	Existing crossing	No crossing	Existing crossing	Existing crossing	No crossing	Existing crossing	No crossing	Existing crossing
1 (5 crossings)	Existing crossing removed	New crossing	Existing crossing retained	Existing crossing removed	New crossing	Existing crossing removed	New crossing	Existing crossing retained
2 (7 crossings)	Existing crossing retained	New crossing	Existing crossing retained	Existing crossing retained	New crossing	Existing crossing removed	New crossing	Existing crossing retained

It is seen that if the freight railway is not realigned, then the approved DSP would result in two additional rail crossings, contrary to the government's policy.

Rail crossing warrants

Crossing protection warrants have been calculated in accordance with the railway crossing policy, with the outcomes summarised in Table 3.

Table 3: Option 1 - Crossing warrants

Scenario	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Passenger trains limited to 80 km/h								
1		Flashing lights	Flashing lights		Flashing lights		Flashing lights	Flashing lights
2	Boom gate	Flashing lights	Flashing lights	Grade separation	Boom gate		Boom gate	Boom gate
Passenger trains limited to 110 km/h								
1		Flashing lights	Flashing lights		Flashing lights		Flashing lights	Flashing lights
2	Boom gate	Flashing lights	Flashing lights	Grade separation	Boom gate		Boom gate	Boom gate

5.1.3 Discussion

If the freight railway is realigned away from the DSP area, only the low frequency passenger service remains, and the appropriate level of protection for each crossing is flashing lights.

If the freight railway is retained in situ, there is a nett increase of two crossings, contrary to the government's policy. Boom gates are required at all crossings except Bishop East (flashing lights) and Soldiers Road (grade separation). It should be noted that a grade separation at Soldiers Road would have knock-on effects for the District Centre Road intersection and railway crossing.

Soldiers Road is assumed to carry 8% heavy vehicles. If this number was reduced to 6% then boom gates would be warranted, not grade separation.

5.2 Option 2 (Advertised amendment)

5.2.1 Description

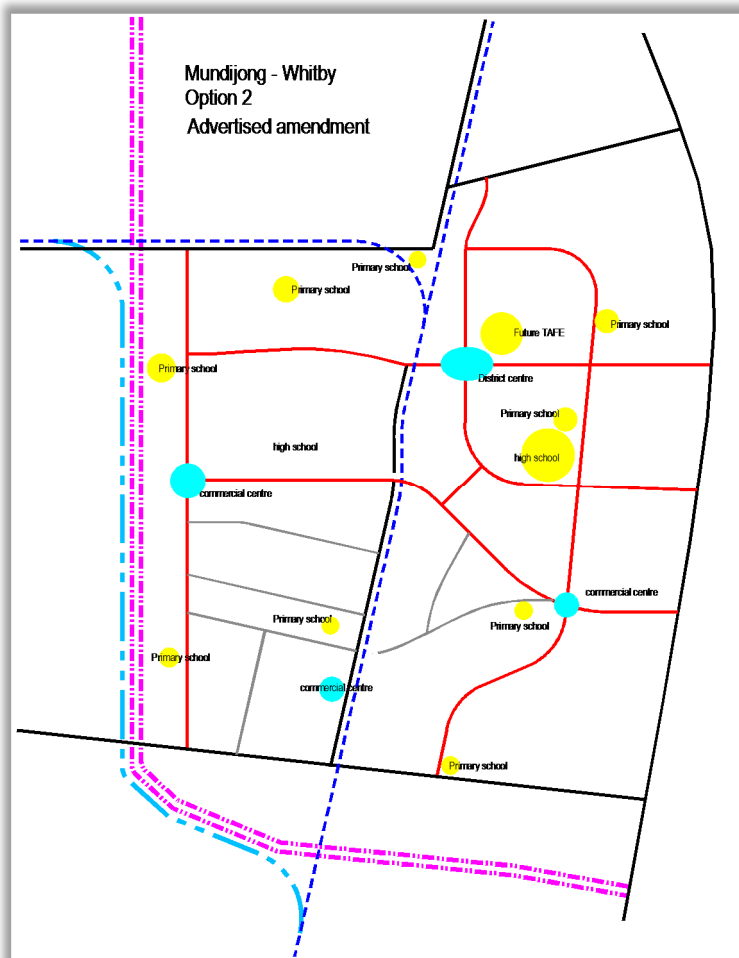


Figure 6: Option 2 (Advertised amendment)

This option overcomes the limitations on level crossings by deleting the eastward extension of Bishop Road and substituting a circuitous route via Norman Road.

- Soldiers / Paterson Road is segmented with several sections cul-de-saced, to avoid four-way intersections with short stacking issues
- A new District Centre Road is provided
- Kiernan Street and Watkins Road level crossings are maintained

Traffic volumes are included at Appendix A.

5.2.2 Railway crossings

For this option, we have considered the following cases:

- a. Passenger trains run at 80 km/h
- b. Passenger trains run at 110 km/h.

Number of crossings and crossing protection warrants

Table 4 indicates the crossings under this option. It is seen that the total number of crossings is unchanged from the existing.

Table 4: Option 2 – Crossings and warrants

Scenario (Total crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Option 2 (5 crossings)	Existing crossing retained	No crossing	Existing crossing retained	Existing crossing removed	New crossing	Existing crossing retained	No crossing	Existing crossing retained
Passenger trains 80 km/h	Boom gate		Flashing lights		Boom gate	Boom gate		Grade separation
Passenger trains 110 km/h	Boom gate		Flashing lights		Boom gate	Boom gate		Grade separation

5.2.3 Discussion

It is seen that grade separation is warranted only at Watkins Road. In the scenario that passenger trains are limited to 80 km/h, Watkins Road is only just over the $c_{wgr} = 5,000,000$ threshold. Further, if heavy vehicles fell from the assumed 8% to 7% then boom gates would be warranted, not grade separation, for both passenger train speed scenarios (80 and 110 km/h).

5.3 Option 3a & 3b

5.3.1 Description

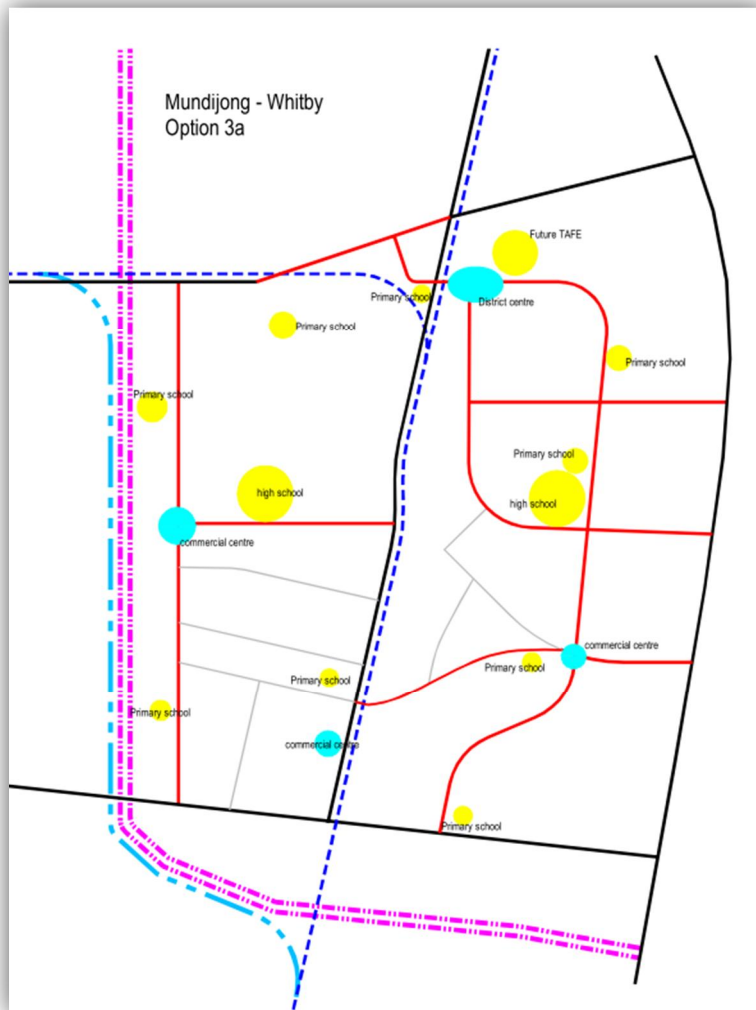


Figure 7: Option 3a / 3b

These options are identical except that Bishop Road West is grade separated over the railway in Option 3b. Key features of the option include:

- Bishop Road is realigned to connect directly with Norman Road
- Soldiers / Paterson Road is retained as the main north-south link
- The district centre is moved northwards and the east west District Centre Road is deleted
- The Kiernan Street level crossing is closed and replaced by the Whitby Street crossing

Traffic volumes are included at Appendix A.

5.3.2 Rail crossings

For this option, we have considered the following cases:

- a. Passenger trains run at 80 km/h
- b. Passenger trains run at 110 km/h.

Number of crossings and crossing protection warrants

Table 5 indicates the crossings under this option. It is seen that the total number of crossings is unchanged from the existing.

Table 5: Option 3a & 3b – Crossings and warrants

Scenario (Total crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Option 3 (6 crossings)	3a. Existing retained 3b. Grade separated	New crossing	Existing crossing retained	Existing crossing retained	No crossing	Existing crossing removed	New crossing	Existing crossing retained
Passenger trains 80 km/h	Grade separation	Flashing lights	Flashing lights	Boom gate			Boom gate	Boom gate
Passenger trains 110 km/h	Grade separation	Flashing lights	Flashing lights	Boom gate			Boom gate	Grade separation

5.3.3 Discussion

This option increases the number of crossings by one (3a) or none (3b). However, under both scenarios (3a and 3b) the Bishop Road west crossing will require grade separation due to traffic volumes and accordingly there is no net increase.

Watkins Road requires a grade separation in the scenario where passenger trains can run at 110 km/h. However it is only slightly above the threshold and would not require grade separation if there is a small reduction in traffic (eg 8,400 veh/day instead of 8,600) or if the percentage of heavy vehicles falls to 7% from the assumed 8%.

5.4 Option 3c & 3d

5.4.1 Description

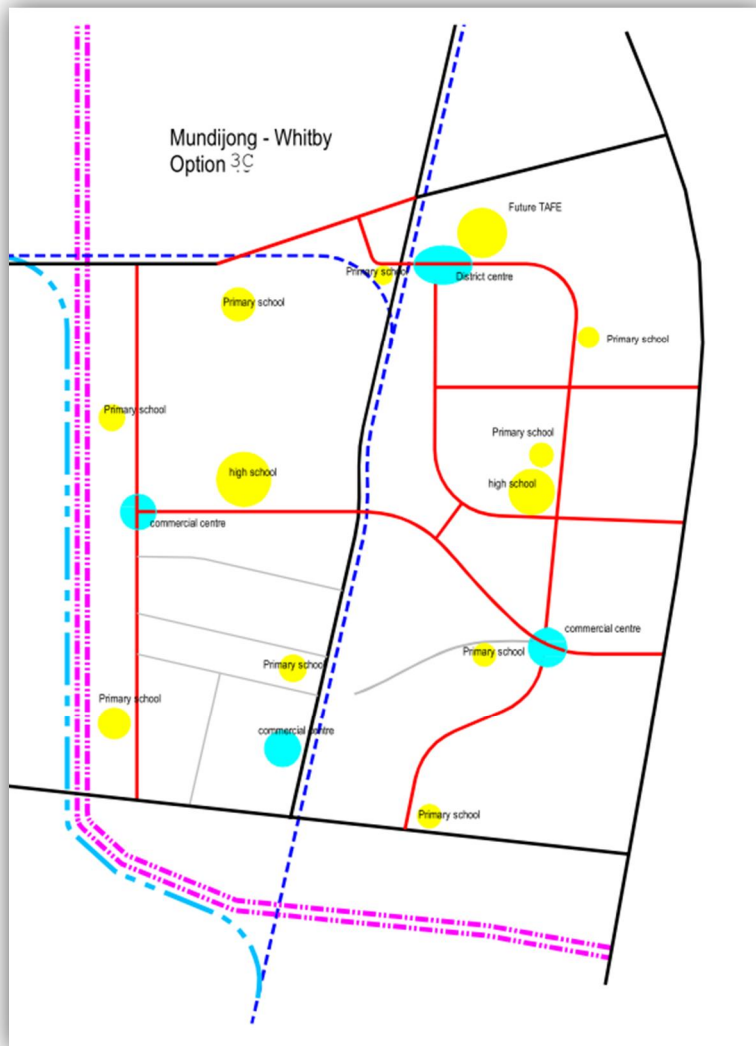


Figure 8: Option 3c & 3d

These options are identical to Options 3a and 3b except that the Kiernan Street crossing is reinstated and the Whitby Street crossing deleted. Under Option 3d the Bishop Road west crossing is grade separated.

5.4.2 Railway crossings

For this option, we have considered the following cases:

- Passenger trains run at 80 km/h
- Passenger trains run at 110 km/h.

Number of crossings and crossing protection warrants

Table 6 indicates the crossings under this option. It is seen that the total number of crossings is unchanged from the existing.

Table 6: Option 3c & 3d – Crossings and warrants

Scenario (Total level crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Option 3 (6 crossings)	Existing crossing retained	New crossing	Existing crossing retained	Existing crossing retained	No crossing	Existing crossing retained	No crossing	Existing crossing retained
Passenger trains 80 km/h	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Boom gate
Passenger trains 110 km/h	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Grade separation

5.4.3 Discussion

It is seen that this option increases the number of crossings by one (3c) or none (3d). However, under both scenarios (3c and 3d) the Bishop Road west crossing will require grade separation, thus retaining the existing number of crossings.

Bishop Road west and Kiernan Street will require grade separation under all scenarios. Watkins Road is very close to the threshold for grade separation falling either just over or just under $c_{whr} = 5,000,000$ depending on the particular scenario.

5.5 Option 3e

5.5.1 Description

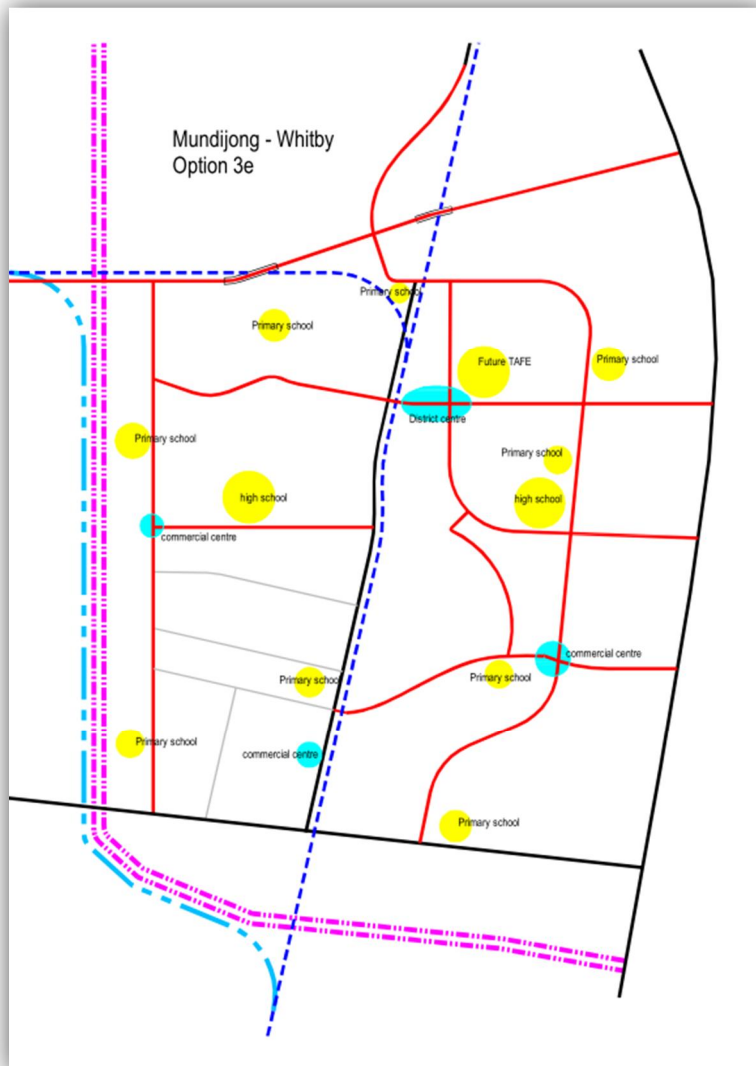


Figure 9: Option 3e

This option is similar to Options 3a – 3d with the following key exceptions:

- The east west District Centre Road is included
- Soldiers Road is deviated westwards to create a four-way junction with Bishop Road
- Bishop Road west and Norman Road crossings are grade separated

5.5.2 Railway crossings

For this option, we have considered the following cases:

- a. Passenger trains run at 80 km/h
- b. Passenger trains run at 110 km/h.

Number of crossings and crossing protection warrants

Table 7 indicates the crossings under this option. It is seen that the total number of level crossings is unchanged from the existing.

Table 7: Option 3e - railway crossings

Scenario (Total level crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Option 3e (5 crossings)	Existing crossing grade separated	New crossing	Existing crossing grade separated	Existing crossing retained	New crossing	Existing crossing removed	New crossing	Existing crossing retained
Passenger trains 80 km/h	Boom gate	Flashing lights	Flashing lights	Boom gate	Grade separation		Boom gate	Grade separation
Passenger trains 110 km/h	Boom gate	Flashing lights	Flashing lights	Boom gate	Grade separation		Boom gate	Grade separation

5.5.3 Discussion

Under this layout, traffic / train volumes do not warrant grade separations at either Bishop Road west or Norman Road crossings. Both these crossings could revert to level crossings based on the warrants.

The District Centre Road and Watkins Road need to be grade separated. There is a very clear case at District Centre Road, but Watkins Road is only slightly over the threshold.

5.6 Option 4

5.6.1 Description

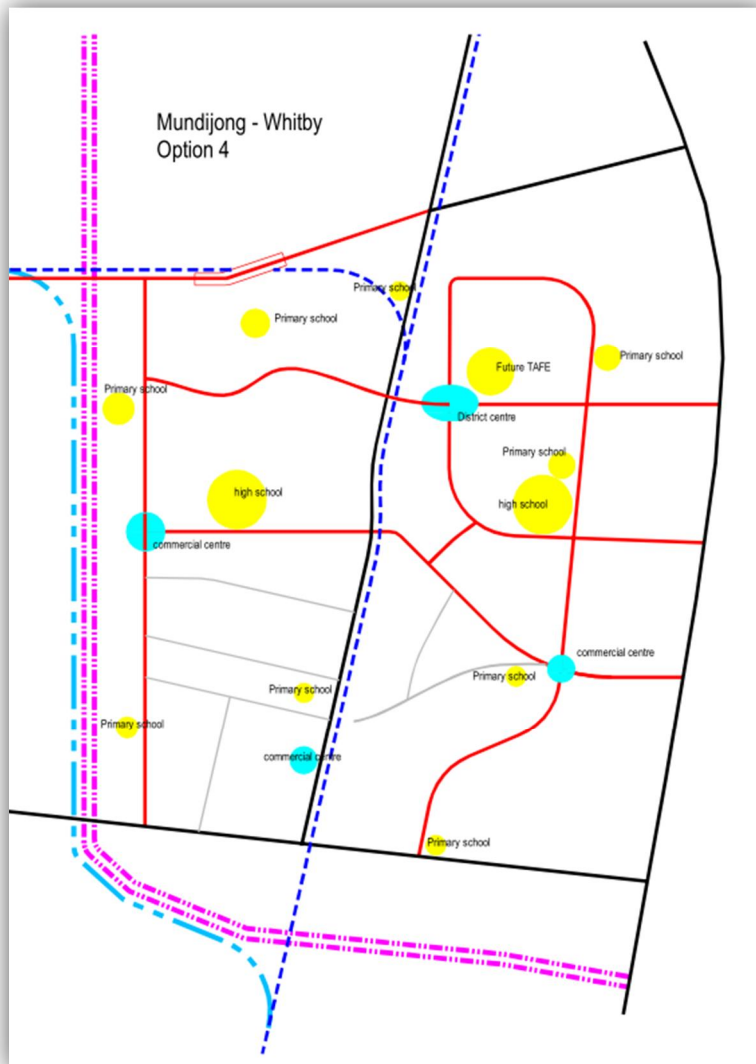


Figure 10: Option 4

Under Option 4:

- Bishop Road is deviated to meet Norman Road
- Bishop Road west crossing is grade separated
- Bishop Road east crossing is deleted
- Kiernan Street crossing is retained
- There is no crossing at Whitby Street

5.6.2 Railway crossings

For this option, we have considered the following cases:

- a. Passenger trains run at 80 km/h
- b. Passenger trains run at 110 km/h.

Number of crossings and crossing protection warrants

Table 8 indicates the crossings under this option. Because Bishop Road west is grade separated, the total number of level crossings remains unchanged.

Table 8: Option 4 - railway crossings

Scenario (Total crossings)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Option 4 (4 crossings)	Existing crossing grade separated	No crossing	Existing crossing retained	Existing crossing retained	New crossing	Existing crossing retained	No crossing	Existing crossing retained
Passenger trains 80 km/h	Boom gate		Flashing lights	Boom gate	Boom gate	Boom gate		Boom gate
Passenger trains 110 km/h	Boom gate		Flashing lights	Boom gate	Boom gate	Boom gate		Boom gate

5.6.3 Discussion

Based on traffic and train volumes, the grade separation at Bishop Road west is not warranted. However, by grade separating this crossing, the total number of level crossings in the scheme remains unchanged.

Under this option, traffic is distributed so that grade separations are not warranted at any crossing. However it should be noted that District Centre, Kiernan and Watkins are all very close to the $C_{wgr} = 5,000,000$ threshold for grade separation.

6. Summary and conclusions

6.1 Overview

The Shire of Serpentine Jarrahdale has engaged GHD to review a number of alternatives for the road network within the Mundijong Whitby DSP.

The review has included the following tasks:

- Undertake traffic modelling to determine traffic volumes on key road links, and especially at railway crossings
- Review the Main Roads policy on railway crossing protection (the Policy)
- Undertake analysis in accordance with the Policy, to determine the warrants for protection at each crossing for each option, under several scenarios.

6.2 Crossing protection warrants

In accordance with advice from Brookfield Rail, each crossing which has both passenger and rail traffic (ie District Centre Road, Kiernan Street, Whitby Street and Watkins Road) has been analysed with passenger trains limited to 80 km/h (same as freight trains) and 110 km/h. In most instances there is little difference between the warrants under these scenarios. However at Watkins Road, grade separation is required for options 3a, 3b and 3c for 110 km/h passenger trains.

It should be noted that in many instances, the traffic and train volumes are such that the weighted conflict c_{wgr} is very close to the 5,000,000 threshold for grade separation. A small change in traffic volumes or the assumed percentage of heavy vehicles could push the results either way. In these instances, a further review is warranted to determine whether the expense and community impacts of grade separation are outweighed by the safety and efficiency benefits.

The results of the crossing protection analysis are set out in Table 9.

Table 9: Summary of crossing protection warrants





Scenario 1: Passenger trains limited to 80 km/h

Option	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
1		Flashing lights	Flashing lights		Flashing lights		Flashing lights	Flashing lights
1*	Boom gate	Flashing lights	Flashing lights	Grade separation	Boom gate		Boom gate	Boom gate
2	Boom gate		Flashing lights		Boom gate	Boom gate		Grade separation
3a / 3b	Grade separation	Flashing lights	Flashing lights	Boom gate			Boom gate	Boom gate
3c	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Boom gate
3d	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Boom gate
3e	Boom gate	Flashing lights	Flashing lights	Boom gate	Grade separation		Boom gate	Grade separation
4	Boom gate		Flashing lights	Boom gate	Boom gate	Boom gate		Boom gate

Scenario 2: Passenger trains limited to 110 km/h

Option	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
1		Flashing lights	Flashing lights		Flashing lights		Flashing lights	Flashing lights
1*	Boom gate	Flashing lights	Flashing lights	Grade separation	Boom gate		Boom gate	Boom gate
2	Boom gate		Flashing lights		Boom gate	Boom gate		Grade separation
3a / 3b	Grade separation	Flashing lights	Flashing lights	Boom gate			Boom gate	Grade separation
3c	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Grade separation
3d	Grade separation	Flashing lights	Flashing lights	Boom gate		Grade separation		Boom gate
3e	Boom gate	Flashing lights	Flashing lights	Boom gate	Grade separation		Boom gate	Grade separation
4	Boom gate		Flashing lights	Boom gate	Boom gate	Boom gate		Boom gate

* Freight railway retained through Mundijong

	Existing crossing retained		Existing crossing removed		No crossing		New crossing
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6.3 Comparison of options

Option	Level crossings	Increase	Grade separations	Comment
Existing	5	0	0	
1	5	0	0	Relies on freight railway being realigned
1*	6	1	1	One additional level crossing – does not comply with policy
2	4	-1	1	Complies with policy but sub-optimal road layout
3a / 3b	4	-1	2	Complies with policy but expensive
3c	3	-2	3	Complies with policy but most expensive in terms of grade separations
3d	4	-1	2	Complies with policy but expensive
3e	5	0	2	Complies with policy but expensive
4	5	0	1	Complies with policy if Bishop Road West is grade separated

Appendices

Appendix A – Traffic volumes

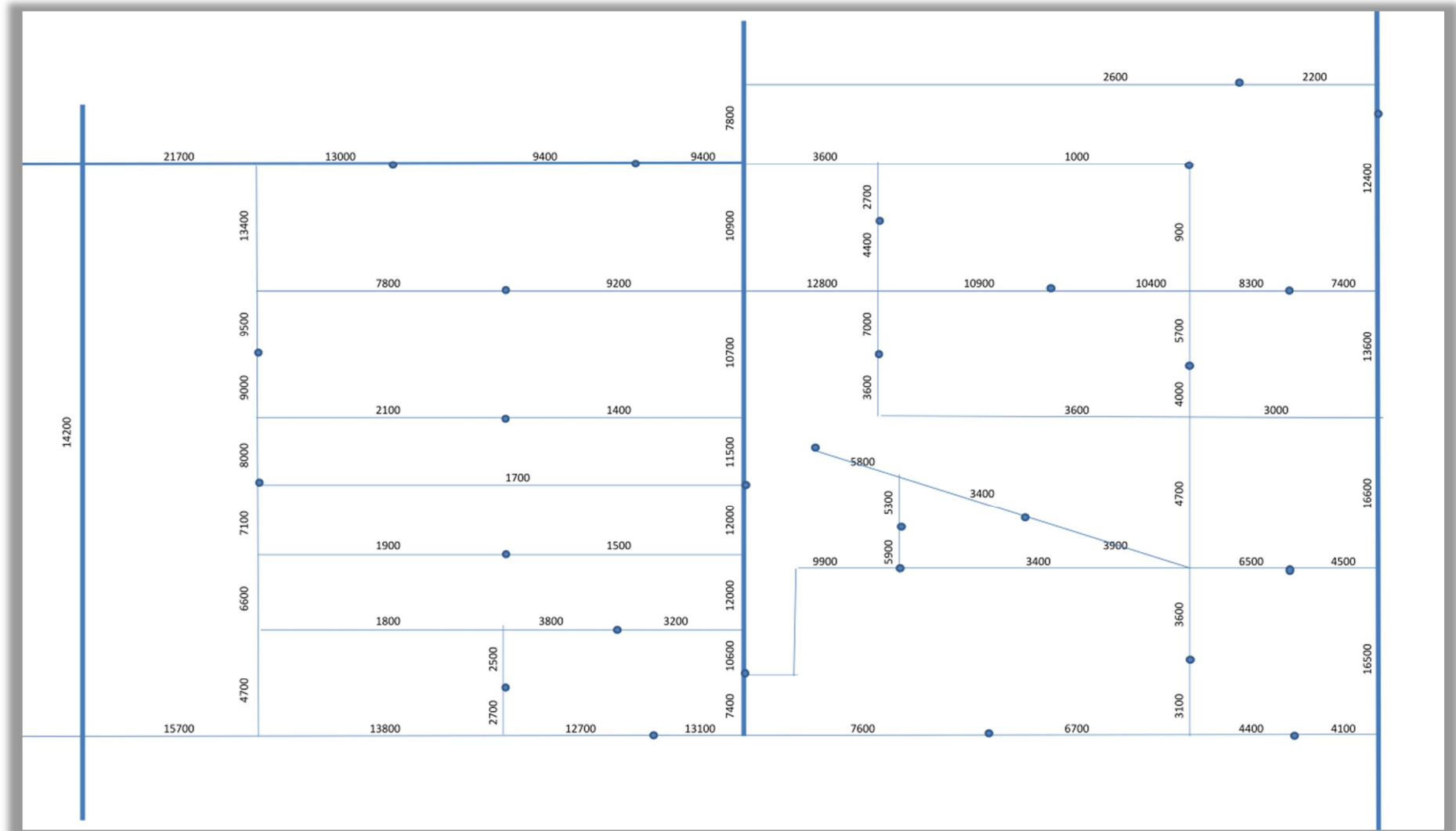


Figure 11: Traffic volumes - Option 1

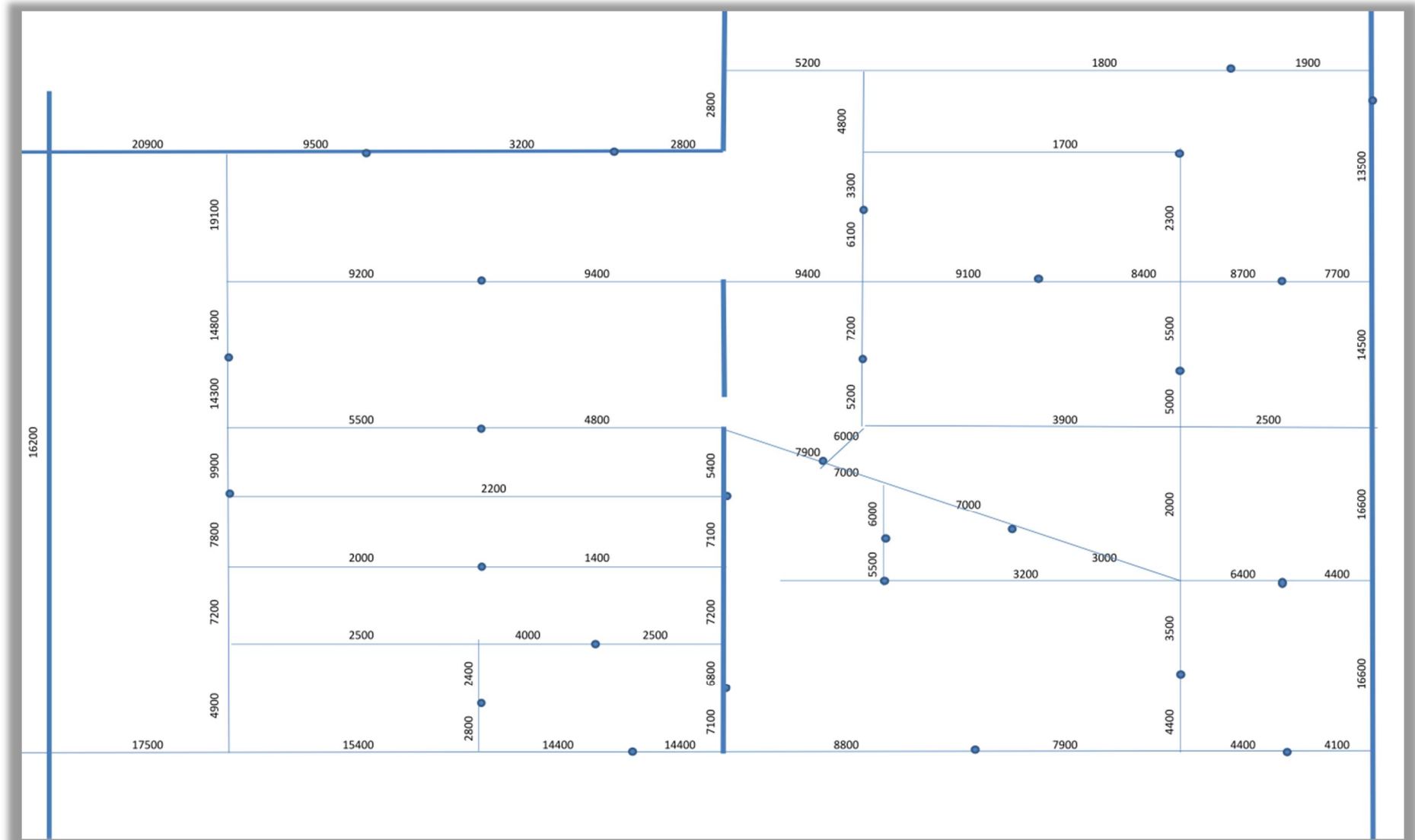


Figure 12: Traffic volumes - Option 2

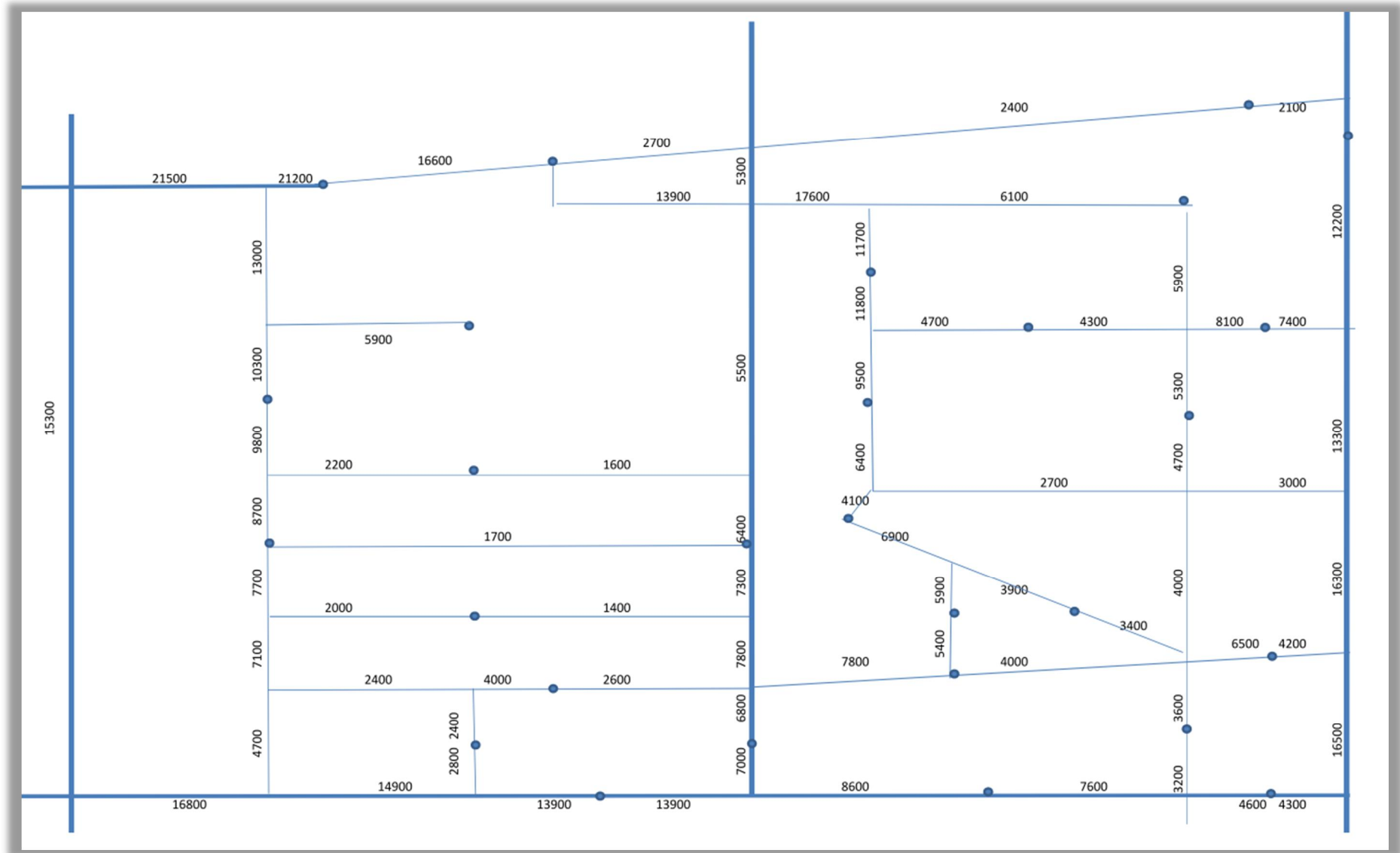


Figure 13: Traffic volumes - Option 3a & 3b

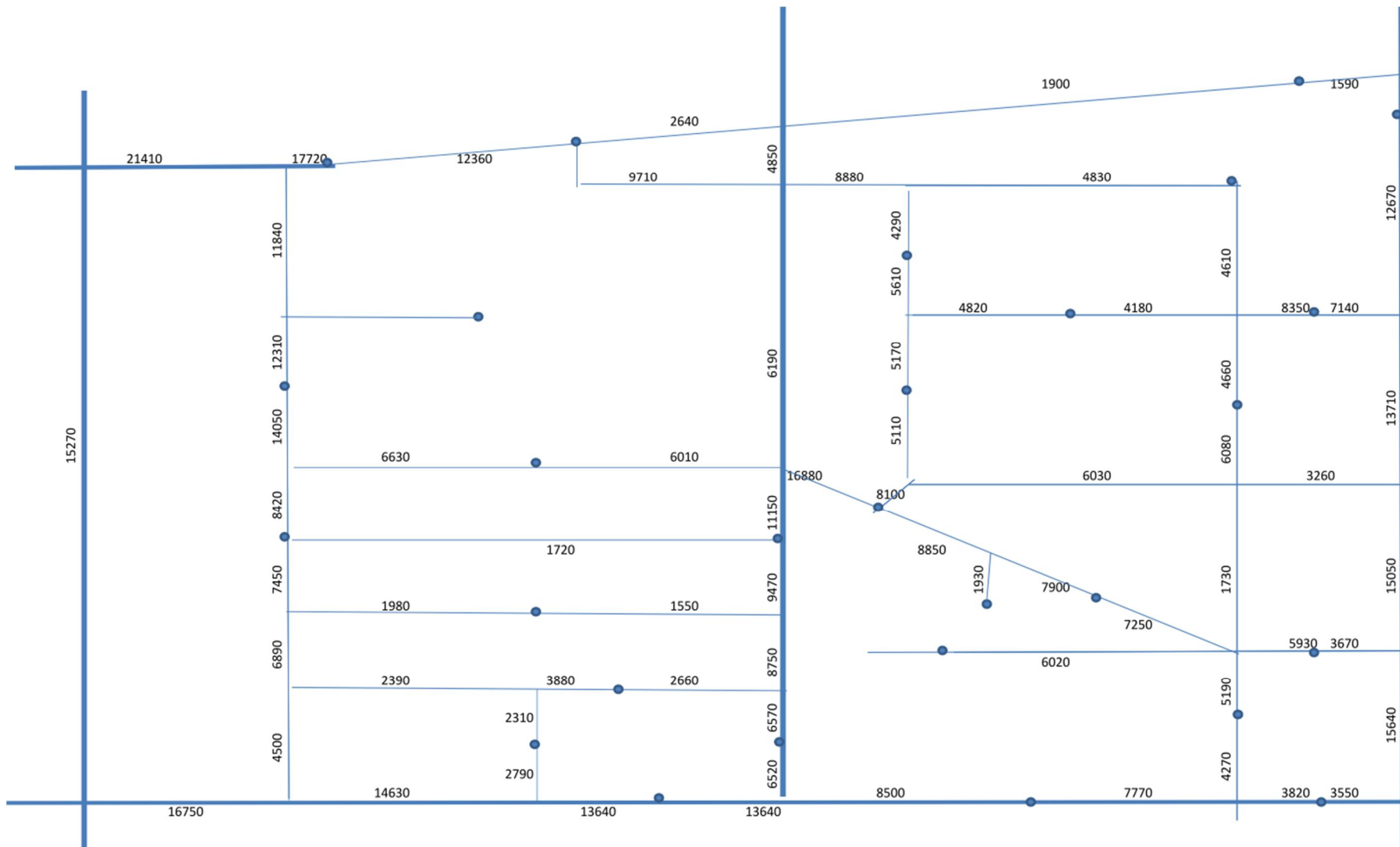


Figure 14: Traffic volumes - Option 3c

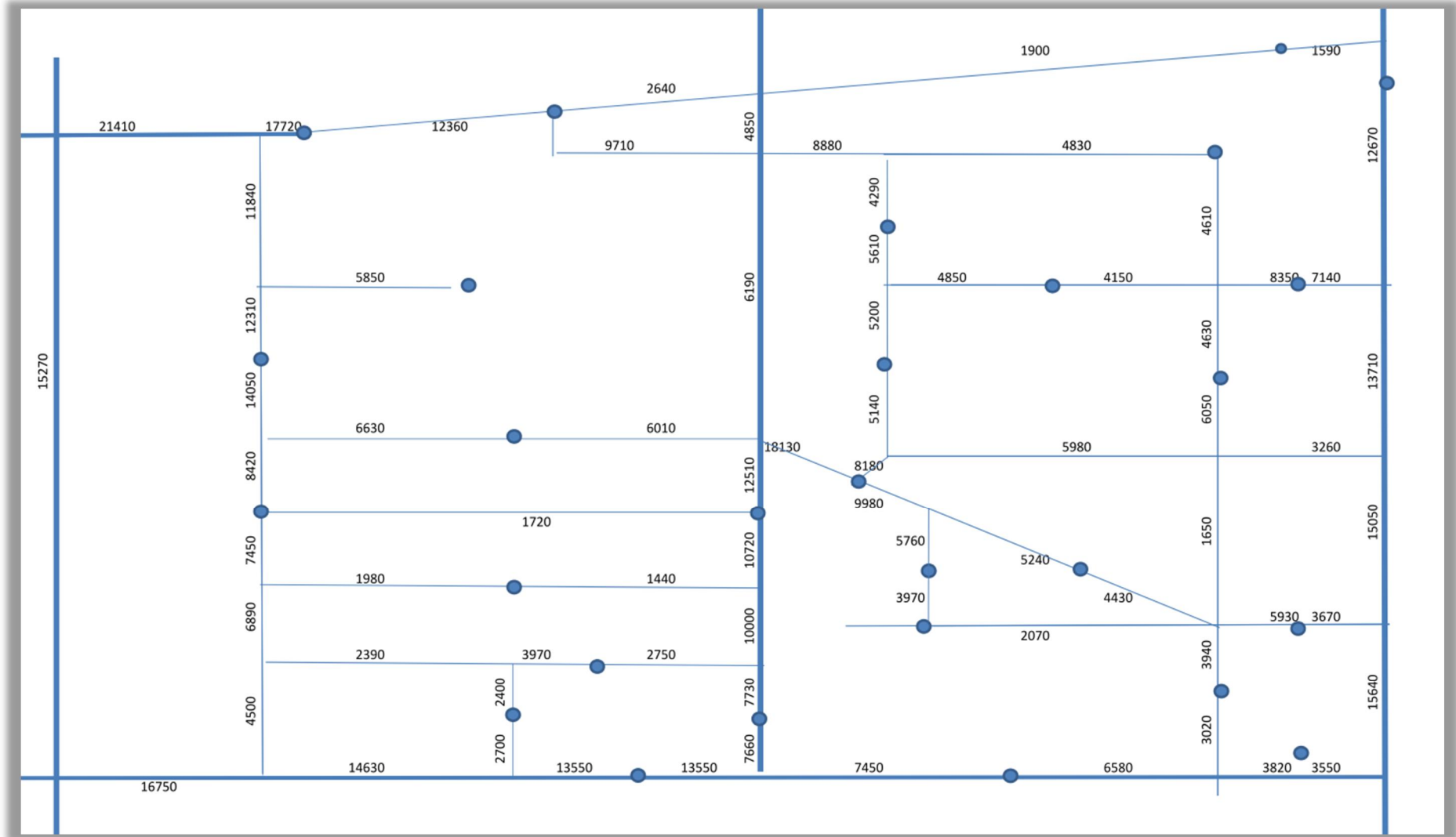


Figure 15: Traffic volumes - Option 3d

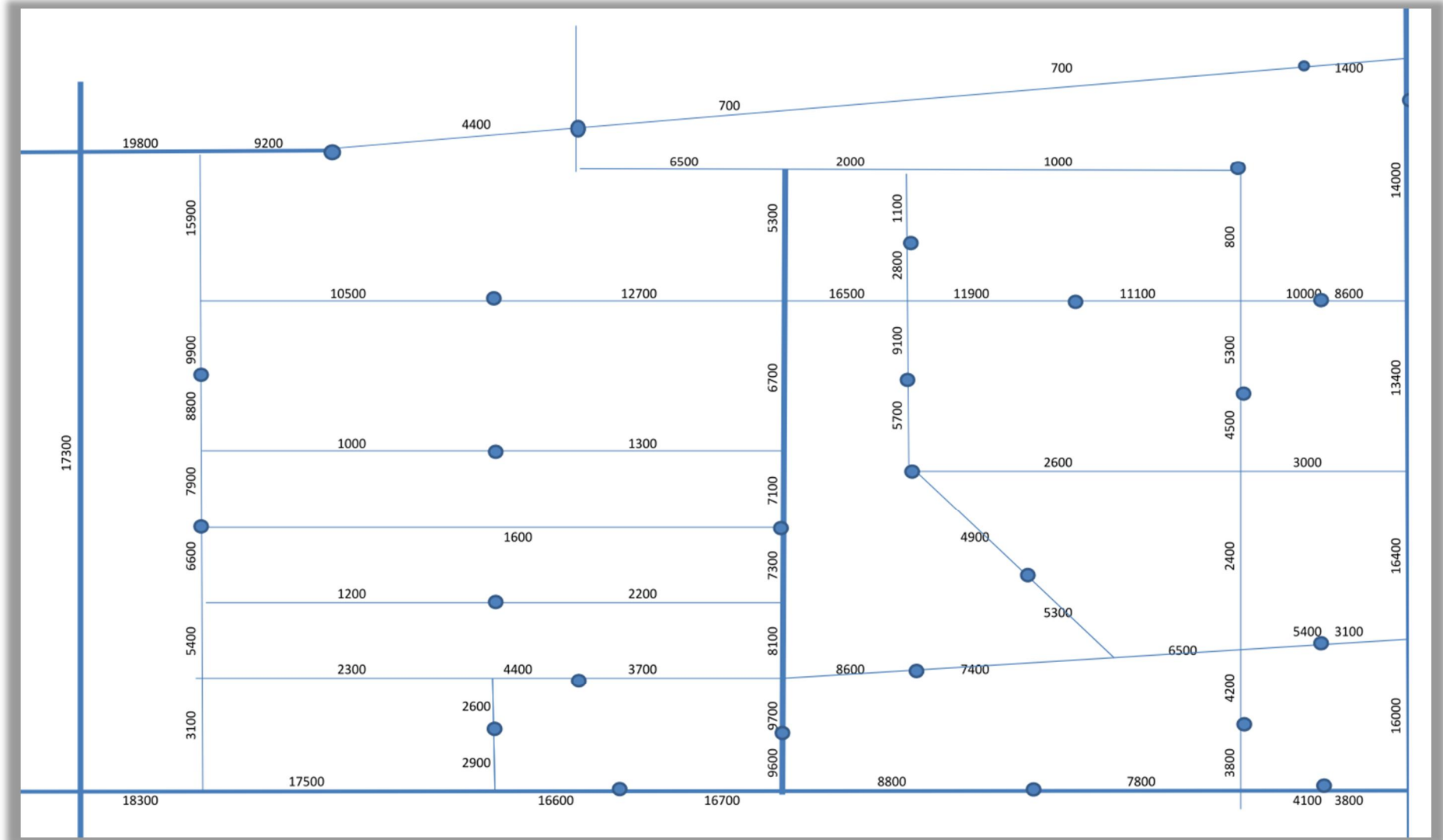


Figure 16: Traffic volumes - Option 3e

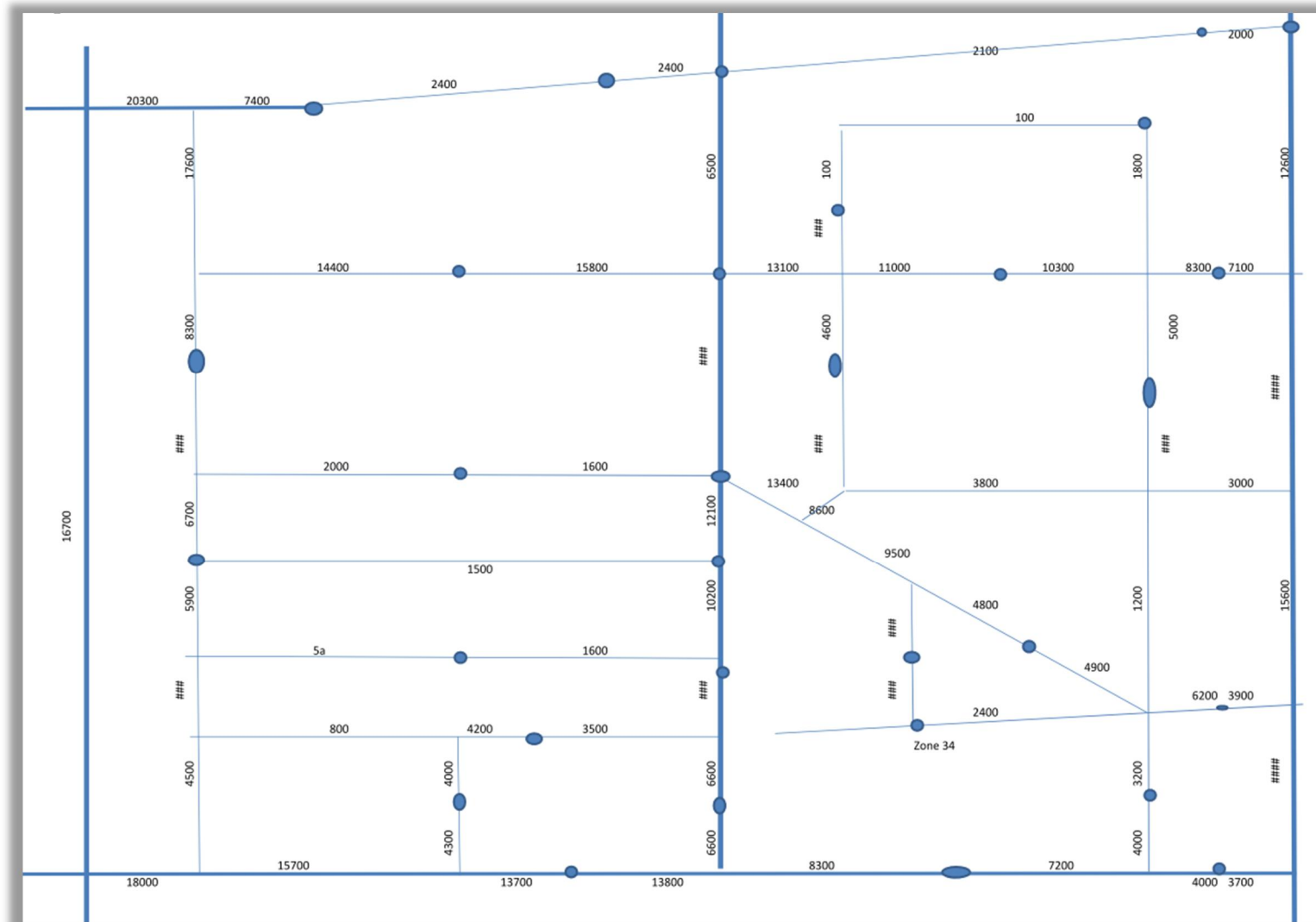


Figure 17: Traffic volumes - Option 4

Appendix B – Rail crossing calculations

	Existing crossing closed
	No crossing

Option 1 (Approved DSP)

Passenger trains limited to 80 km/h

Option 1 (Railway relocated)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed		80	80		80		80	80
Nt No of trains		28	28		28		28	28
Vv Vehicle speed		50	60		50		50	60
AADT Vehicle traffic		3,600	2,600		12,800		9,900	7,600
Pv Percentage heavies		8	8		5		5	8
Gr Grade factor								
Ltl Train length		100	100		100		100	100
Cw		112,000	97,067		398,222		308,000	283,733
Hv		1.30	1.30		1.00		1.00	1.30
Dv		1.02	1.02		1.02		1.02	1.02
Cw(x)		148,512	128,710		406,187		314,160	376,230

Option 1 (Railway retained)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80	80		80	80
Nt No of trains	182	28	28	182	210		210	210
Vv Vehicle speed	60	50	60	60	50		50	60
AADT Vehicle traffic	9,400	3,600	2,600	10,900	12,800		9,900	7,600
Pv Percentage heavies	8	5	8	8	5		5	8
Gr Grade factor								
Ltl Train length	740	100	100	740	650		650	650
Cw	2,281,067	112,000	97,067	2,645,067	2,986,667		2,310,000	2,128,000
Hv	1.30	1.00	1.30	1.30	1.00		1.00	1.30
Dv	1.66	1.02	1.02	1.66	1.57		1.57	1.57
Cw(x)	4,922,542	114,240	128,710	5,708,054	4,689,067		3,626,700	4,343,248

Passenger trains limited to 110 km/h

Option 1 (Railway relocated)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed		110	110		110		110	110
Nt No of trains		28	28		28		28	28
Vv Vehicle speed		50	60		50		50	60
AADT Vehicle traffic		3,600	2,600		12,800		9,900	7,600
Pv Percentage heavies		5	8		5		5	8
Gr Grade factor								
Ltl Train length		100	100		100		100	100
Cw		154,000	133,467		547,556		423,500	390,133
Hv		1.00	1.30		1.00		1.00	1.30
Dv		0.99	0.99		0.99		0.99	0.99
Cw(x)		152,880	172,245		543,573		420,420	503,485

Option 1 (Railway retained)	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins		
Vt Train speed	80	110	110	80	80	110	80	110	80	110
Nt No of trains	182	28	28	182	182	28	182	28	182	28
Vv Vehicle speed	60	50	60	60	50	50	50	60	60	60
AADT Vehicle traffic	9,400	3,600	2,600	10,900	12,800	12,800	9,900	9,900	7,600	7,600
Pv Percentage heavies	8	5	8	8	5	5	5	5	8	8
Gr Grade factor										
Ltl Train length	740	100	100	740	740	100	740	100	740	100
Cw	2,281,067	154,000	133,467	2,645,067	2,588,444	547,556	2,002,000	423,500	1,844,267	390,133
Hv	1.30	1.00	1.30	1.30	1.00	1.00	1.00	1.00	1.30	1.30
Dv	1.66	0.99	0.99	1.66	1.66	0.99	1.66	0.99	1.66	0.99
Cw(x)	4,922,542	152,880	172,245	5,708,054	4,840,391		3,743,740		4,483,412	

Option 2

Passenger trains limited to 80 km/h

Option 2	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80		80		80	80		80
Nt No of trains	182		28		210	210		210
Vv Vehicle speed	60		60		50	50		60
AADT Vehicle traffic	3,200		5,200		9,400	7,900		8,800
Pv Percentage heavies	8		8		5	5		8
Gr Grade factor								
Ltl Train length	740		100		650	650		650
Cw	776,533		194,133		2,193,333	1,843,333		2,464,000
Hv	1.30		1.30		1.00	1.00		1.30
Dv	1.66		1.02		1.57	1.57		1.57
Cw(x)	1,675,759		257,421		3,443,533	2,894,033		5,029,024

Passenger trains limited to 110 km/h

Option 2	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80		110		80 110	80 110		80 110
Nt No of trains	182		28		182 28	182 28		182 28
Vv Vehicle speed	60		60		50 50	50 50		60 60
AADT Vehicle traffic	3,200		5,200		9,400 9,400	7,900 7,900		8,800 8,800
Pv Percentage heavies	8		8		5 5	5 5		8 8
Gr Grade factor								
Ltl Train length	740		100		740 100	740 100		740 100
Cw	776,533		266,933		1,900,889 402,111	1,597,556 337,944		2,135,467 451,733
Hv	1.30		1.30		1.00 1.00	1.00 1.00		1.30 1.30
Dv	1.66		0.99		1.66 0.99	1.66 0.99		1.66 0.99
Cw(x)	1,675,759		344,490		3,554,662	2,987,429		5,191,319

Option 3a / 3b

Passenger trains limited to 80 km/h

Option 3a / 3b	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80			80	80
Nt No of trains	182	28	28	182			210	210
Vv Vehicle speed	60	60	60	60			50	60
AADT Vehicle traffic	16,600	17,600	2,400	5,300			7,800	8,600
Pv Percentage heavies	8	5	5	5			5	8
Gr Grade factor								
Ltl Train length	740	100	100	740			650	650
Cw	4,028,267	657,067	89,600	1,286,133			1,820,000	2,408,000
Hv	1.30	1.00	1.00	1.00			1.00	1.30
Dv	1.66	1.02	1.02	1.66			1.57	1.57
Cw(x)	8,692,999	670,208	91,392	2,134,981			2,857,400	4,914,728

Passenger trains limited to 110 km/h

Option 3a / 3b	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80			80 110	80 110
Nt No of trains	182	28	28	182			182 28	182 28
Vv Vehicle speed	60	50	60	60			50 50	60 60
AADT Vehicle traffic	16,600	17,600	2,400	5,300			7,800 7,800	8,600 8,600
Pv Percentage heavies	8	5	8	5			5 5	8 8
Gr Grade factor								
Ltl Train length	740	100	100	740			740 100	740 100
Cw	4,028,267	547,556	89,600	1,286,133			1,577,333 333,667	2,086,933 441,467
Hv	1.30	1.00	1.30	1.00			1.00 1.00	1.30 1.30
Dv	1.66	1.02	1.02	1.66			1.66 0.99	1.66 0.99
Cw(x)	8,692,999	558,507	118,810	2,134,981			2,949,613	5,073,335

Option 3c

Passenger trains limited to 80 km/h

Option 3c	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80		80		80
Nt No of trains	182	28	28	182		210		210
Vv Vehicle speed	60	60	60	50		50		60
AADT Vehicle traffic	12,360	8,880	1,900	6,190		16,880		8,500
Pv Percentage heavies	8	5	5	8		5		8
Gr Grade factor								
Ltl Train length	740	100	100	740		650		650
Cw	2,999,360	331,520	70,933	1,251,756		3,938,667		2,380,000
Hv	1.30	1.00	1.00	1.30		1.00		1.30
Dv	1.66	1.02	1.02	1.66		1.57		1.57
Cw(x)	6,472,619	338,150	72,352	2,701,288		6,183,707		4,857,580

Passenger trains limited to 110 km/h

Option 3c	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80		80 110		80 110
Nt No of trains	182	28	28	182		182 28		182 28
Vv Vehicle speed	60	50	60	60		50 50		60 60
AADT Vehicle traffic	12,360	8,880	1,900	6,190		16,880 16,880		8,500 8,500
Pv Percentage heavies	8	5	5	5		5 5		8 8
Gr Grade factor	0	0	0	0		0 0		0 0
Ltl Train length	740	100	100	740		740 100		740 100
Cw	2,999,360	276,267	70,933	1,502,107		3,413,511 722,089		2,062,667 436,333
Hv	1.30	1.00	1.00	1.00		1.00 1.00		1.30 1.30
Dv	1.66	1.02	1.02	1.66		1.66 0.99		1.66 0.99
Cw(x)	6,472,619	281,792	72,352	2,493,497		6,383,266		5,014,343

Option 3d

Passenger trains limited to 80 km/h

Option 3d	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80		80		80
Nt No of trains	182	28	28	182		210		210
Vv Vehicle speed	60	50	60	60		50		60
AADT Vehicle traffic	12,360	8,880	1,900	6,190		18,130		7,450
Pv Percentage heavies	8	5	8	5		5		8
Gr Grade factor								
Ltl Train length	740	100	100	740		650		650
Cw	2,999,360	276,267	70,933	1,502,107		4,230,333		2,086,000
Hv	1.30	1.00	1.30	1.00		1.00		1.30
Dv	1.66	1.02	1.02	1.66		1.57		1.57
Cw(x)	6,472,619	281,792	94,058	2,493,497		6,641,623		4,257,526

Passenger trains limited to 110 km/h

Option 3d	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80		80 110		80 110
Nt No of trains	182	28	28	182		182 28		182 28
Vv Vehicle speed	60	50	60	60		50 50		60 60
AADT Vehicle traffic	12,360	8,880	1,900	6,190		18,130 18,130		7,450 7,450
Pv Percentage heavies	8	5	5	5		5 5		8 8
Gr Grade factor	0	0	0	0		0 0		0 0
Ltl Train length	740	100	100	740		740 100		740 100
Cw	2,999,360	276,267	70,933	1,502,107		3,666,289 775,561		1,807,867 382,433
Hv	1.30	1.00	1.00	1.00		1.00 1.00		1.30 1.30
Dv	1.66	1.02	1.02	1.66		1.66 0.99		1.66 0.99
Cw(x)	6,472,619	281,792	72,352	2,493,497		6,855,960		4,394,924

Option 3e

Passenger trains limited to 80 km/h

Option 3e	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80	80		80	80
Nt No of trains	182	28	28	182	210		210	210
Vv Vehicle speed	60	60	60	60	50		50	60
AAADT Vehicle traffic	4,400	2,000	700	6,700	16,500		8,600	8,800
Pv Percentage heavies	8	5	8	5	5		5	8
Gr Grade factor								
Ltl Train length	740	100	100	740	650		650	650
Cw	1,067,733	74,667	26,133	1,625,867	3,850,000		2,006,667	2,464,000
Hv	1.30	1.00	1.30	1.00	1.00		1.00	1.30
Dv	1.66	1.02	1.02	1.66	1.57		1.57	1.57
Cw(x)	2,304,169	76,160	34,653	2,698,939	6,044,500		3,150,467	5,029,024

Passenger trains limited to 110 km/h

Option 3e	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80	80	80	80	80 110		80 110	80 110
Nt No of trains	182	28	28	182	182 28		182 28	182 28
Vv Vehicle speed	60	50	60	60	50 50		50 50	60 60
AAADT Vehicle traffic	4,400	2,000	700	5,300	16,500 16,500		8,600 8,600	8,800 8,800
Pv Percentage heavies	8	5	5	5	5 5		5 5	8 8
Gr Grade factor	0	0	0	0	0 0		0 0	0 0
Ltl Train length	740	100	100	740	740 100		740 100	740 100
Cw	1,067,733	62,222	26,133	1,286,133	3,336,667 705,833		1,739,111 367,889	2,135,467 451,733
Hv	1.30	1.00	1.00	1.00	1.00 1.00		1.00 1.00	1.30 1.30
Dv	1.66	1.02	1.02	1.66	1.66 0.99		1.66 0.99	1.66 0.99
Cw(x)	2,304,169	63,467	26,656	2,134,981	6,239,567		3,252,138	5,191,319

Option 4

Passenger trains limited to 80 km/h

Option 4	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80		80	80	80	80		80
Nt No of trains	182		28	182	210	210		210
Vv Vehicle speed	60		60	60	50	50		60
AAADT Vehicle traffic	2,400		2,100	6,500	13,100	13,400		8,300
Pv Percentage heavies	8		8	5	5	5		8
Gr Grade factor								
Ltl Train length	740		100	740	650	650		650
Cw	582,400		78,400	1,577,333	3,056,667	3,126,667		2,324,000
Hv	1.30		1.30	1.00	1.00	1.00		1.30
Dv	1.66		1.02	1.66	1.57	1.57		1.57
Cw(x)	1,256,819		103,958	2,618,373	4,798,967	4,908,867		4,743,284

Passenger trains limited to 110 km/h

Option 4	Bishop West	Bishop East	Norman	Soldiers	District Centre	Kiernan	Whitby	Watkins
Vt Train speed	80		80	80	80 110	80 110		80 110
Nt No of trains	182		28	182	182 28	182 28		182 28
Vv Vehicle speed	60		60	60	50 50	50 50		60 60
AAADT Vehicle traffic	2,400		2,100	6,500	13,100 13,100	13,400 13,400		8,300 8,300
Pv Percentage heavies	8		5	8	5 5	5 5		8 8
Gr Grade factor								
Ltl Train length	740		100	740	740 100	740 100		650 100
Cw	582,400		78,400	1,577,333	2,649,111 560,389	2,709,778 573,222		2,014,133 426,067
Hv	1.30		1.00	1.30	1.00 1.00	1.00 1.00		1.30 1.30
Dv	1.66		1.02	1.66	1.66 0.99	1.66 0.99		1.57 0.99
Cw(x)	1,256,819		79,968	3,403,885	4,953,838	4,498,231		4,661,054

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	Paul Fisher	Alex Piper	<i>Alex Piper</i>	Paul Fisher	<i>Paul Fisher</i>	27-4-16
0	Paul Fisher	Alex Piper	<i>Alex Piper</i>	Paul Fisher	<i>Paul Fisher</i>	16-5-16

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