Maldon to Dombarton Rail Link Feasibility Study

Appendix: Engineering Design
Technical Report

Prepared for the Department of Infrastructure and Transport

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ACIL Tasman
Economics Policy Strategy

ACIL Tasman Pty Ltd

ABN 68 102 652 148
Internet www.aciltasman.com.au

Melbourne (Head Office)
Level 4, 114 William Street
Melbourne VIC 3000

Telephone (+61 3) 9604 4400
Facsimile (+61 3) 9604 4455
Email melbourne@aciltasman.com.au

Brisbane
Level 15, 127 Creek Street
Brisbane QLD 4000
GPO Box 32
Brisbane QLD 4001

Telephone (+61 7) 3009 8700
Facsimile (+61 7) 3009 8799
Email brisbane@aciltasman.com.au

Canberra
Level 1, 33 Ainslie Place
Canberra City ACT 2600
GPO Box 1322
Canberra ACT 2601

Telephone (+61 2) 6103 8200
Facsimile (+61 2) 6103 8233

Email canberra@aciltasman.com.au

Darwin
GPO Box 908
Darwin NT 0801

Email darwin@aciltasman.com.au

Perth
Centa Building C2, 118 Railway Street
West Perth WA 6005

Telephone (+61 8) 9449 9600
Facsimile (+61 8) 9322 3955
Email perth@aciltasman.com.au

Sydney
PO Box 1554
Double Bay NSW 1360

Telephone (+61 2) 9389 7842
Facsimile (+61 2) 8080 8142
Email sydney@aciltasman.com.au

For information on this report

Please contact:

David Greig
Telephone (03) 9604 4414
Mobile 0404 822 320
Email d.greig@aciltasman.com.au

Contributing team members:

Dragan Stamatov (Hyder) Laura Flores (Hyder)

Contents

A Design details

This section of the report outlines the track design, signalling design, civil design including earthworks and drainage, bridges and tunnelling design.

A.1 Track, signalling and civil design

In this section, the design of the track horizontal and vertical alignments, signalling design and civil & drainage design is outlined.

A.1.1 Track design

The track design includes horizontal and vertical track alignments, typical cross section and track structure details, junctions and passing loops and clearance envelopes to the structures.

The route which a train travels and the track is constructed is defined as an alignment. An alignment is defined as:

- the horizontal alignment which defines physically where the route or track goes in a plan view
- the vertical alignment which defines the elevation, rise and fall of the track.

The line will be single bi-directional, Up and Down directions. The Up direction is towards Sydney and Down direction away from Sydney. In this particular line, Down direction is from Dombarton to Maldon, Up direction the opposite, from Maldon to Dombarton.

Horizontal alignment

The horizontal alignment which defines physically where the route or track goes in a plan view consists of series of connected circular curves, transition curves and straights.

When designing horizontal curves, the main objective is to achieve a curve radius that accommodates the desired train speed whilst maintaining a safe, smooth and comfortable ride. Where curves of significantly large radius cannot be achieved, the designer is faced with reducing the allowable speed by imposing sharper horizontal curves.

The minimum horizontal curve radius is in a direct proportional relationship with the maximum train speed, train mass and the centrifugal force applied at the horizontal curves. On this project, the minimum horizontal curve radius is 300m at the Maldon Junction, the connection with the existing Main South Line, and 800m elsewhere excluding the turnouts.

Information on the alignment, which affects the speed, is summarised in the tables below. These tables list the range of parameters (i.e. radius, speed, superelevation, deficiency, transition curves) used in the design and comply with the current design standards. A list of technical terms can be found in the glossary.

Table A1 **Dombarton to Maldon rail line alignment details**

Radius	Super	Speed	Defic.	Trans.	Ea roc	Droc	Ramp
m	mm	kph	mm	m	mm/sec	mm/sec	1 in…
500	0	60	85.10	13	0.00	109.11	Turnout
500	20	60	65.10	20	16.67	54.25	1000
800	50	80	44.56	80	13.89	12.38	1600
4000	20	80	-1.09	80	5.56	-0.30	4000
800	50	80	44.56	80	13.89	12.38	1600
1600	60	100	13.88	80	20.83	4.82	1333
1800	40	100	25.67	80	13.89	8.91	2000
1200	80	100	18.50	80	27.78	6.42	1000
1600	60	100	13.88	80	20.83	4.82	1333
1600	60	100	13.88	80	20.83	4.82	1333
1600	60	100	13.88	80	20.83	4.82	1333
800	80	100	67.75	80	27.78	23.52	1000
800	80	100	67.75	80	27.78	23.52	1000
800	80	100	67.75	80	27.78	23.52	1000
800	80	100	67.75	80	27.78	23.52	1000
800	80	100	67.75	80	27.78	23.52	1000
1200	80	100	18.50	80	27.78	6.42	1000
800	80	100	67.75	80	27.78	23.52	1000
800	80	100	67.75	80	27.78	23.52	1000
300	70	60	71.84	70	16.67	17.10	1000
500	0	60	Com trans	70		500	Turnout

Table A2 **North Fork rail alignment details**

Radius	Super	Speed	Defic.	Trans	Ea roc	D roc	Ramp
m	mm	kph	mm	mm	mm/sec	mm/sec	1 in …
500	0	60	85.10	13	0.00	109.11	Turnout
300	70	60	71.84	70	16.67	17.10	1000
500	35	60	50.10	70	8.33	11.93	2000
500	0	60	85.10	13	0.00	109.11	Turnout

Vertical alignment

The vertical alignment defines the elevation including the rise and fall of the track and vertical curves.

The proposed rail line heading west from Dombarton is negotiating a steep upward gradient from the Illawarra Escapement. The vertical alignment matches the grades and levels of the existing Unanderra to Moss Vale Line at the tie-in point at Dombarton and continues to negotiate the steep gradient through the Avon tunnel at 1 in 30 or 3.3%.

Travelling west beyond the tunnel, the line enters the Sydney Catchment Authority, in undulating country, generally following the ridge with a gradient of approximately 1 in 60 separating the Cordeaux and Avon Rivers. It then crosses the Cordeaux River, leaves the Sydney Catchment Area, passes under a number of roads including busy Picton Road and F5 Freeway and over the partially constructed Nepean River Bridge, before joining the Main South Line near Maldon.

Major constraints for the development of the vertical track alignment for the Maldon to Dombarton rail line are:

- The ruling grade for the section of track from the tunnel portal No.1 to the ridge of the Illawarra Escapement rising 3.30% or 1 in 30
- The gradient at the tie-in with the existing Unanderra to Moss Vale Line near Dombarton and the existing Main South Line near Maldon
- The required vertical clearance at the overbridges and tunnels and requirements for level crossings.

Generally, the length of the vertical curves is 80m with some exception where 120m, 160m and 200m vertical curves have been used, all complying with the current standards.

Typical cross sections

Typical cross sections for track in cut and fill are detailed in the Appendix: Conceptual Drawings. These cross sections indicate the major items included in the design such as the location of maintenance access roads, level crossings, track centres in the passing loops, cut and fill batters, slope and width of the formation and track longitudinal drainage.

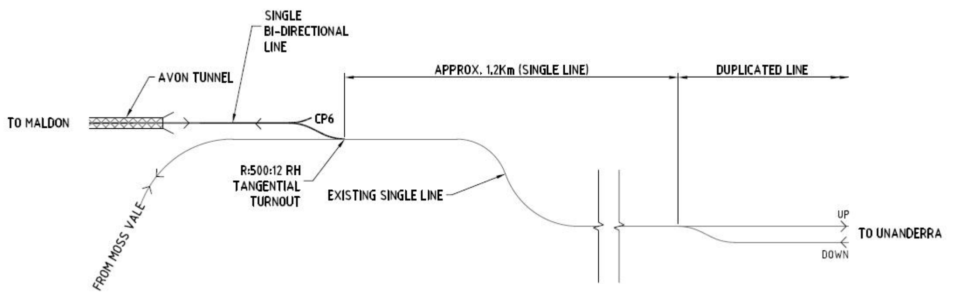
Junctions

There are two junctions on the line:

- Dombarton Junction
  - This junction provides a connection of the new line to the existing Moss Vale - Unanderra Line, a single bi-directional line with a section of the line with double tracks, located approximately 1.2km from the junction, refer figure A.1 below.

- The Dombarton junction will have 2 point ends, one turnout on the Main Line and the other a catch point (CP 6) located on the new branch line to prevent unauthorised movement to the Main Line as this Junction connects to a single line track. A catch point is a vehicle derailing device consisting of one switch unit and throw-off rail that, when operating to protect the main running line, causes wheels of the vehicle to follow the switch and derail in an open and clear landing area.
- The turnout is a standard right hand 500:15 tangential located on the single track section of the existing Unanderra to Moss Vale line, which is approximately 1.2km from the double track section of the line. A turnout is a device that splits a single track into two routes; also referred to as a connection. It is a special trackwork that allows trains to pass from one track on a diverging path. It consists of switch and stockrail assemblies, a 'V' crossing and checkrails, linked together by straight and curved infill rails (closure rails).As shown in the figure below, the turnout is located on the straight section of the existing line.

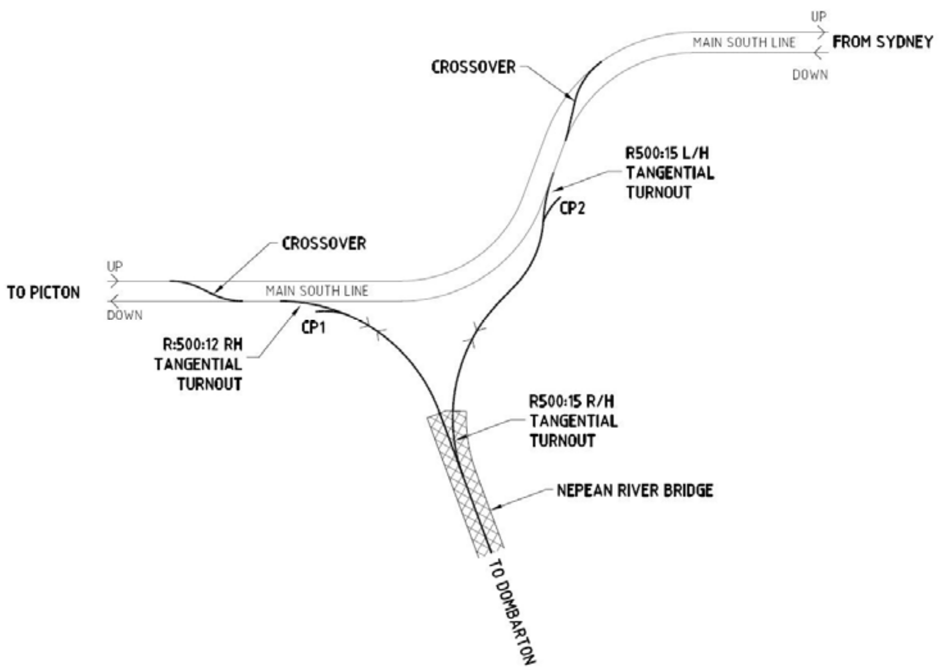
Figure A1 **Dombarton Junction configuration**



- Maldon Junction
  - This junction defines the connection to the Main South Line and is configured as a 'Y 'junction, allowing movements to the North (Sydney) and to the South (Melbourne). The junction will also comprise of two pairs of crossovers installed between the Main South tracks in each direction from the junction in order to allow train movements to or from the single line to the north and south of the junction.
  - Maldon Junction will have a total of 8 point ends including six turnouts and two catchpoints. The catchpoints are placed at the end of each 'Y' junction legs to prevent unauthorised entry onto the Main South Line.
  - Due to insufficient room for trains within the junction, movements from the Main Line signals will authorise trains into the junction and across the first single line section to the home signal at the first crossing loop. The Down Direction movements will be authorised by a home signal located at the approach to the 'Y' junction in the Down direction.

- It is noted that the final design at the junction will need to be closely reviewed as the project advances. This is because the Main South Railway is curved towards Sydney; the length of straight track (required for the connection) is limited to fit one standard turnout and one standard crossover for a 60kph train speed. The figure below provides the configuration of the junction.

Figure A2 **Maldon Junction configuration**



Passing loops

A passing loop (also called a crossing loop) is a set location on a single line railway where trains travelling in opposite directions can pass each other safely.

The original design included three intermediate passing loops with an approximate length of 800m. These loops are shorter than those required to accommodate trains currently operating in the area, in particular, coal trains operating to the Port Kembla coal terminal. This terminal can operate with trains of up to 860m long at the present time with plans for future extension for trains up to 1200m long.

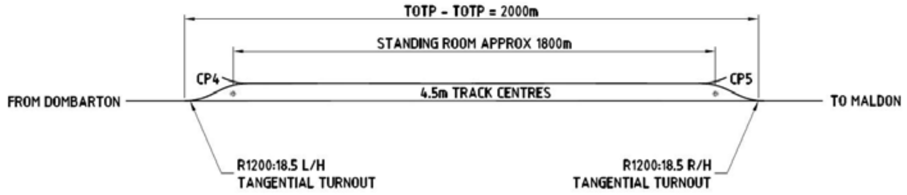
Based on the findings from the operational simulation undertaken by Plateway, two passing loops on the line with approximate length of 1800 m would be appropriate to allow increased capacity of the line:

- Avon Passing Loop

The Avon passing loop (Figure A3) is approximately 2000m long, and measures approximately 1800m from the safety clearance points of the entry to the exit turnouts. It is located at approximately 110.150km to 112.152km, mostly on a straight section of the track with an offset of 4.5m from the Main Line.

The alignment of the loop near the Maldon end turnout has a 1200m curve radius and the whole loop is on a relatively flat gradient of approximately 1 in 200 with a crest vertical curve of 80m in the middle.

Figure A3 **Configuration of Avon passing loop**

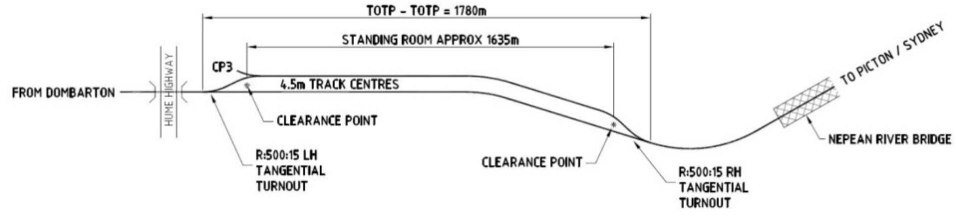


- Wilton Passing Loop

  The Wilton passing loop (Figure A4) is approximately 1780m long and measures 1635m from the safety clearance points of the entry to the exit turnouts. It is located at approximately 129.710km to 131.490km, mostly on a straight section of the track with an offset of 4.5m from the Main Line.

  The alignment of the loop near the Hume Highway Tunnel is straight and continues with a large horizontal curve of approximately 1195m and the whole loop is on a relatively steep gradient of approximately 1 in 66 or 1.5%.

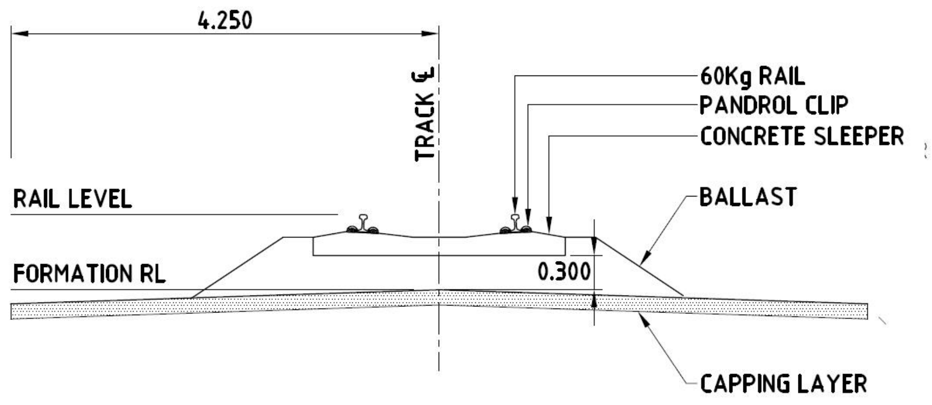
Figure A4 **Configuration of Wilton passing loop**



Track structure

In accordance to ARTC Standard TDS11, Standard Classification of Lines, this line is classified as class 1XC track. In summary, this consists of 60 kg/m of standard continuously welded carbon rail including rail pads sitting on heavy duty concrete bearers connected with resilient fastening system and the whole structure supported on a minimum 300 mm of ballast below the concrete bearers, measured at the rail seat (see Figure A5 below.

Figure A5 **Track structure- ballasted track**



Interface with the gas pipeline easement

The proposed line crosses an existing natural gas pipeline easement which consists of 34 inch steel natural gas pipeline and 8 inch steel ethane gas pipeline, at approximately 127.740km chainage..

In order to maintain the desirable gradients it has been assumed that the gas pipelines will require lowering, which has been reflected in the cost estimate.

A.1.2 Signalling design

The signalling system of this line will be a NSW track detection system.

Approach to the interlocking will be controlled by a typical Distant/ Home Signal configuration.

Departures from the interlocking will be controlled by Home/Starter signals.

Signalling along the line will be a NSW standard single light indication with the interfaces at Maldon being three position and all other being 2 position (Red and Green or in the case of distant signals yellow and green) and running turnouts with subsidiary signals at the passing loops and junctions as required.

Maldon will be controlled by a Microlock computerised based interlocking interfaced into the existing automatic relay based system with a remote control by the Phoenix system.

A CBI Microlock with a CBI at each end of the loop and remote controlled by the Phoenix system will be installed at the Wilton passing loop, the Avon passing loop, and the Dombarton junction.

The interlocking (loops & junctions) track detection system configuration will be Axle Counters. This will include the approach tracks to the passing loops (approaching the distant signal) with the in-section tracks being Micro Tracks.

Utilising Micro Tracks in the in-section will dispense with the need of having a physical cable connection along the length of the line. Design of track circuit lengths over the length of the in-section areas will be required to meet the manufacturer's recommendations and ARTC standards considering that this will be a newly constructed line with the civil configuration being concrete sleepers.

Communications between the interlocking and the ARTC control centre at Junee will be via the ARTC leased 3G Network.

Power Supplies at the crossing loops will be by local supply authorities and with uninterruptable power supplies (designed to meet ARTC standards) except at Maldon where a back up motor generator set is required to be installed due to the Junction being on the main southern line.

The point mechanisms at the passing loops due to the limited powers supply will be 12 DC models.

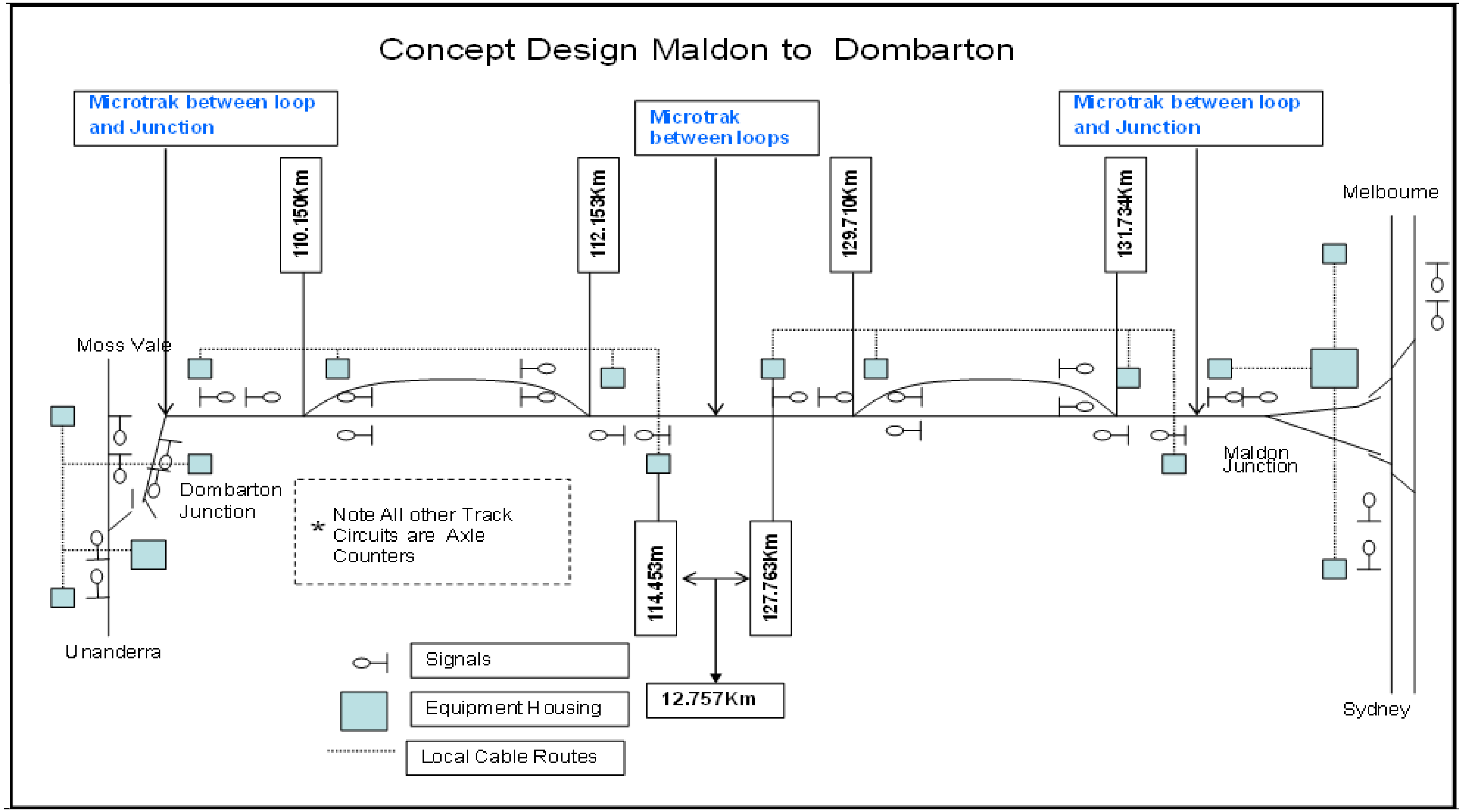
The point mechanisms at both Maldon and Dombarton junctions will be 110v type M84 claw lock type (recommended).

Interfaces

Maldon Junction will connect to the Up and Down Main lines. This will require interfacing into the existing signalling system, a track detection automatic signalling system that would require upgrading..

The Dombarton Junction will interface into the existing single line signalling system that would also require upgrading to a Microlock CBI (see Concept Design below).

Figure A6 **Concept signalling arrangement**



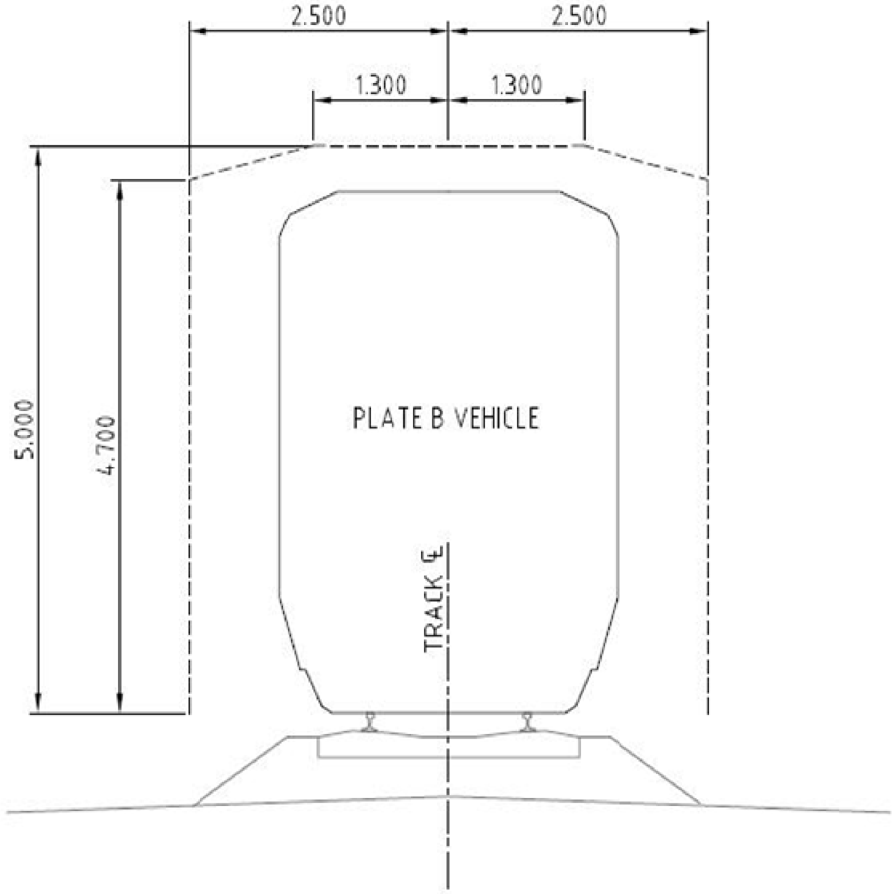
A.1.3 Clearances

Two rolling stock outlines have been considered in this study, one being Plate B as shown on Figure A7 and the other is the larger Plate F shown on Figure A8

- Plate B Rolling Stock Outline.

Plate B is a traditional outline and lies almost within the maximum height and maximum width of the RailCorp Wide Electric Outline. Plate B height is 4191mm with a width of 3251mm. Locomotives manufactured in Australia have smaller bodies than their US equivalents, though the engines inside are similar, to fit within Plate B.

Figure A7 **Structure gauge- Plate B rolling stock**

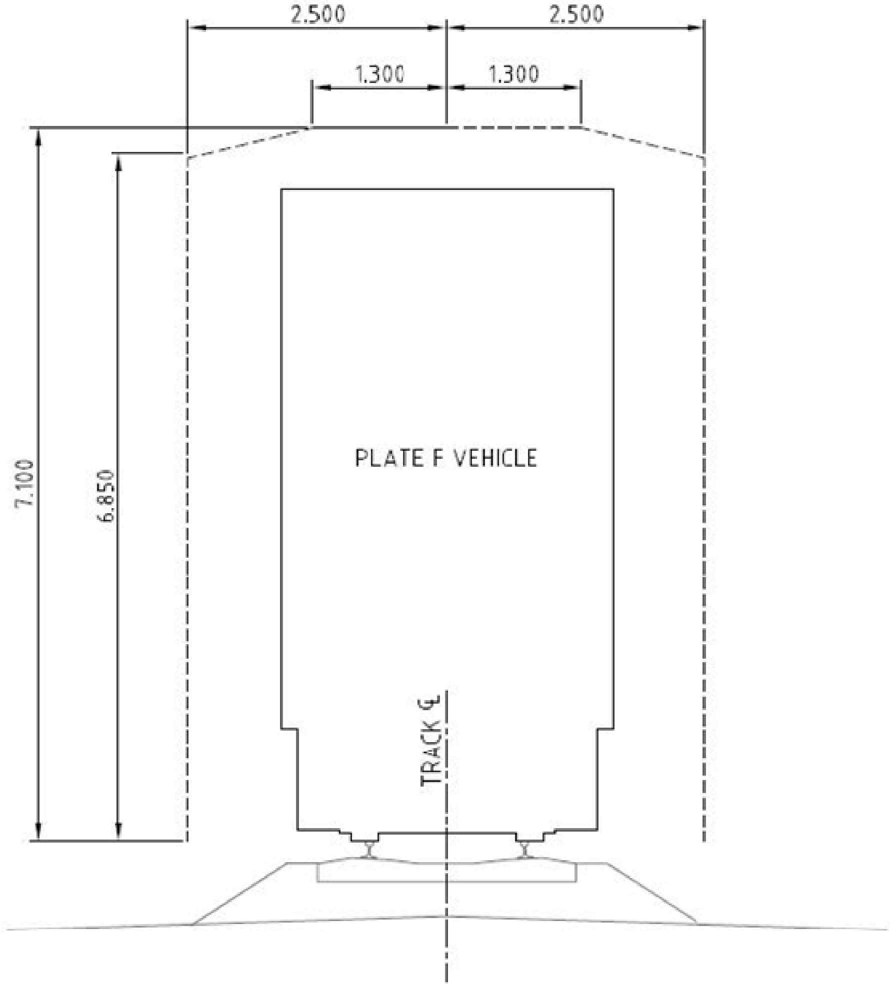


- Plate F Rolling Stock Outline

The Plate F structure outline, which sets a 7100mm minimum structure height, has been used as the standard on the ARTC network for some years. It allows double stacking of containers and the use of standard "off the shelf" American locomotives as seen in the Pilbara.

For the purpose of this study the cost estimate is based on Plate F clearance but an alternative cost has been provided for Plate B.

Figure A8 **Structure gauge- Plate F rolling stock**



A.1.4 Civil design

In this section of the report, the infrastructure components of the new line including Maintenance Access Roads, deviation to the existing roads and level crossings are discussed.

Maintenance access roads

Maintenance access roads are provided at the loop location only on both sides, parallel with the loop and the main line, at the formation level. The structure of the access roads is approximately 500mm structural compacted fill with 150mm capping material on the top.

Deviation to the existing fire roads

Most of the existing fire roads are crossing the design alignment at sharp angles; to improve visibility it is proposed to realign the roads to cross the line at 90 degrees. The realignment is approximately 50 to 100m on each side of the rail track. The roads are compacted gravel, not sealed, crossing the track at level with the top of the rail line.

Deviation to the existing Janderra lane

The Janderra Lane is an existing road south from Picton Road crossing the proposed Railway Line at approximately 128.200km chainage at 75 degrees, then joining Emma Lane at a right angle. Approximately 300m of the road has been realigned and regraded to cross the rail line at 90 degrees and maintain enough vertical clearance for Plate 'F' rolling stock envelope.

Level crossings

There are two types of level crossings:

- Fire Road Level Crossings
  - In total, there are 12 level crossings on the fire roads, all 6m standards ARTC steel level crossings.
- Maintenance Access Road Level Crossings
  - There are three maintenance access roads level crossings, two at the Avon Passing Loop, at each end of the loop, and one at the Dombarton side of Wilton Passing Loop. These crossings are ARTC standard 6.0m wide level crossings made of steel as well.
  - There is no level crossing on the Maldon end of the passing loop because the points of the turnout are located on a deep approaching embankment to the Nepean River Bridge. The width of the proposed maintenance access roads is 4.0m, widening to 6.0m at the level crossings.

A.1.5 Earthworks

The bulk of earthwork, drainage and civil works are completed from the western portal of the Avon Tunnel to the special catchment area boundary.

Figure A9 and Figure A10 provide the section of track where cuttings and embankments are completed with bottom ballast laid.

Figure A9 **Track of constructed section**

Figure A10 **Track of constructed section in cut**

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Figure A11 **Track of constructed section in fill**

From the western portal to the end of the line, at Maldon Junction, the proposed earthworks for construction are shown on **Error! Not a valid bookmark self-reference.** and Figure A13

Figure A12 **Typical section in cut**

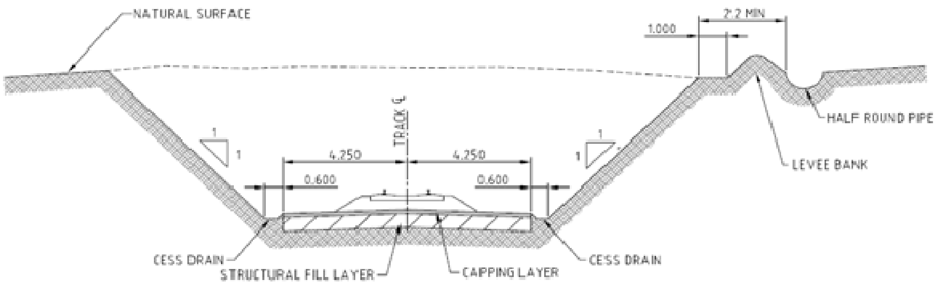
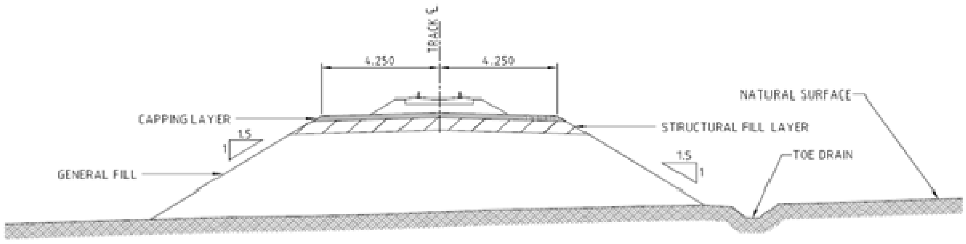


Figure A13 **Typical section in fill**



A.1.6 Drainage

Most of the minor waterway crossings have been constructed. It was estimated that approximately 50 waterway crossings were constructed and that an additional 19 waterway crossings are required to be constructed in order to complete the cross drainage works.

Hyder has undertaken hydrologic and hydraulic assessments of the waterway crossings that have been constructed (or in some cases those designed and not constructed) along the existing track alignment.

The cross drainage pipes were sized for waterways crossings between 127.235km and 132.465km where the railway has not yet been constructed. The assessment determined which of the designed crossings comply with the 50 Year ARI hydrologic design standard, currently the minimum performance requirement set by RailCorp and a generally adopted standard by ARTC, and those where larger structures are necessary to meet the current hydrological requirements.

Hydrologic assessment

The proposed railway is located within the plateau divided by the Nepean River and its tributaries which have their headwaters in the Illawarra escarpment. The proposed rail alignment approximately follows the catchment crest between Avon and Cordeaux Rivers Systems and crosses both Cordeaux and Nepean Rivers. The rail line avoids the southern part of the Lake Avon between approximately 98.500km and 111.500km crossing the headwaters of several small waterways which flow to Lake Avon.

It was estimated that 50 cross drainage systems have been constructed and 19 cross drainage systems need to be constructed for the completion of the project. In addition, the existing cross drainage culverts located with the proposed passing loop and embankments that require widening may require extension.

The capacities of some existing cross drainage systems were checked to ensure compliance with current ARTC standards, engineering industry standards and codes of practice. The cross drainage systems were sized for locations where railway works have not been completed.

Hyder used a combination of a 25m topographic survey grid sourced from the NSW Department of Lands and the aerial survey to delineate and estimate the size of the catchments that discharge to the proposed project area.

It should be noted that the retarding effects of the existing farm dams and other dams located within the catchments were not taken into account in the flow estimation. This is considered to be a conservative approach since it produces the highest estimation of peak flow.

The Probabilistic Rational Method (PRM), for small to medium-sized rural catchments in NSW as detailed in the Australian Rainfall & Runoff (AR&R), was used to determine peak design discharges at the proposed railway for the 50 year ARI (average recurrence interval). The Intensity-Frequency Duration (IFD) data used in the PRM assessment was obtained from the Bureau of Meteorology (BoM) based on the latitude and longitude coordinates for the site (west of Denman). The IFD data is presented in Table A1. The peak discharge rates derived from this assessment are presented in Table A2.

In Table A1, the duration is the period to time that drainage occurs in a fixed period of time

Table A3 **Intensity frequency duration data**

	Duration	
	2 Years	50 Years
Time		
1 Hour	27.73	50.46
12 Hours	4.91	8.56
72 Hours	1.35	2.53
Geographical Factor	4.33	15.97
Skewness	0.32	
Runoff Coefficiency (10 yr ARI*)	0.55	

Note: IFD data derived for Latitude 31.25S, Longitude 150.675E

* Runoff coefficient obtained from ARR Volume 2

Table A4 **Estimated Peak Flow Rates**

Cross Drainage Location (Kilometrage)	Approximate Catchment Area (Ha)	Approximate 50 yr ARI Discharge (m3/s)
104.865km	3.9	0.92
106.500km	3.3	0.81
111.070km	6.3	1.36
112.048km	9.7	1.93
113.864km	11.5	2.21
114.168km	20.9	3.53
117.706km	19.8	3.38
121.031km	5.8	1.28
122.192km	4.9	1.12
126.740km	46	6.6
127.235km	25.5	4.13
127.587km	9.3	1.86
128.025km	12.6	2.38
128.246km	7.8	1.62
128.610km	9.2	1.85
129.190km	9.3	1.87
130.430km	22.1	3.69
130.930km	3.4	0.83
131.070km	4.6	1.06
131.320km	1.7	0.46
131.470km	1.4	0.39
131.650km	2.4	0.62
132.465km	10.6	2.07

Hydraulic assessment

The peak flow rates derived from the hydrological analysis were compared with the estimated flow capacities of the existing cross drainage systems to determine whether the existing cross drainage culverts comply with current standards.

A number of the existing cross drainage culverts were assessed to confirm their capacity. Those culverts included in the assessment were selected based on the worst case setting, for example, small culverts draining relatively large catchments. The ground contours were examined to identify the largest catchments draining to these cross drainage culverts.

The hydraulic performance assessment was undertaken using Culvert Master. Culvert Master is software capable of calculating:

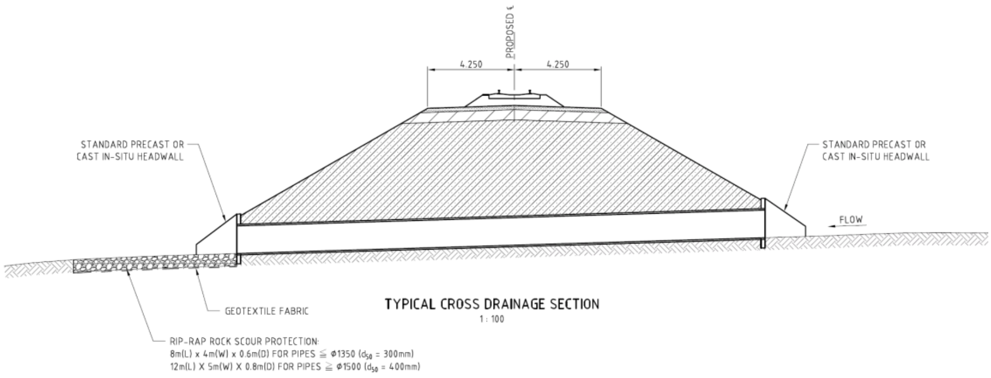
- Headwater depth for a pipe or box culvert.
- Stage/discharges for a pipe or box culvert, a weir or pipe/weir or box culvert/weir combination.

In general, the cross drainage capacities were estimated following the criteria and assumptions outlined below:

- Maximum headwater allowable is top of rail level or the level that would allow runoff to escape to another cross drainage system catchment
- Culverts were assumed flowing full under inlet control
- Culvert entry loss coefficient (Ke) equal to 0.5 for square cut end and headwall and wingwalls
- Culvert details such as length and gradient slope were not provided in the survey. For modelling purposes culverts were assumed to be 20m long and graded at 1%
- A minimum 50Yr ARI level of service to be provided for all cross drainage structures
- Culverts were assumed to be free of blockage.

A typical section of the cross drainage culverts is depicted in the figure below.

Figure A14 Typical Cross Drainage Section



Hydraulic assessment results

As mentioned above, a number of the existing cross drainage culverts were selected and assessed to confirm their capacity. The cross drainage pipes were sized for waterways crossed by the section of railway between 127.235km and 132.465km.

The following table presents the results for the hydraulic assessment of the selected existing cross drainage culverts and the new cross drainage culverts.

Table A5 **Cross drainage culvert details**

Cross Drainage Location (Kilometrage)	Pipe Size/Diameter (mm)	Pipe Type*	Approximate 50 yr ARI Discharge (m3/s)	Computed Headwater Depth (m) **	Capacity (Y/N)
104.865km	600	CP	0.92	0.9	Y
106.500km	750	CSP	0.81	1	Y
111.070km	3 x 600	CP	1.36	0.8	Y
112.048km	1200	CSP	1.93	1.9	Y
113.864km	1050	CSP	3.53	1.8	Y
114.168km	1350	CSP	3.53	1.8	Y
117.706km	1200	CSP	3.38	2.2	Y
121.031km	1050	CSP	1.28	1.1	Y
122.192km	1200	CP	1.12	1	Y
126.740km	1200	CP	6.6	5	Y
127.235km	1350	CP	4.13	2	Y
127.587km	1200	CP	1.86	1.2	Y
128.025km	1500	CP	2.38	1.3	Y
128.246km	1200	CP	1.62	1.1	Y
128.610km	1200	CP	1.85	1.2	Y
129.190km	1200	CP	1.87	1.2	Y
130.430km	2 x 1200	CP	3.69	1.2	Y
130.930km	900	CP	0.83	0.9	Y
131.070km	1050	CP	1.06	1	Y
131.470km	600	CP	0.39	0.7	Y
131.650km	1050	CP	0.62	0.9	Y
132.465km	1350	CP	2.07	1.2	Y

* CP is for concrete pipe and CSP for corrugated steel pipe.

** Computed headwater depth in metres resulted for 50 year ARI flows.

The hydraulic assessment of the existing and proposed cross drainage structures determined that they have the required conveyance capacity to

discharge 50Yr ARI design flows. This is indicated by the far right column of the table shown above.

A full list of the cross drainage structures is provided in the table below.

Table A6 Maldon to Dombarton Existing and Proposed Cross Drainage Culverts

No.	Kilometrage	Structure Details	Approximate Length* (m)	Constructed (Y/N)
1	98.320km	1/2100 x 2100 concrete box	55	Y
2	102.460km	4/1200 x 1800 concrete box	25	Y
3	102.800km	1/3220 x 2780 corrugated ste	30	Y
4	102.980km	2/2100 corrugated steel pipes	55	Y
5	103.600km	1/3220 x 2780 corrugated ste	50	Y
6	103.862km	2/1200 corrugated steel pipes	50	Y
7	104.386km	1/1050 corrugated steel pipe	25	Y
8	104.780km	1/3220 x 2780 corrugated steel fauna underpass	35	Y
9	104.865km	1/900 concrete pipe	45	Y
10	104.945km	1/675 concrete pipe	30	Y
11	105.933km	1/1350 corrugated steel pipe	35	Y
12	105.980km	1/3220 x 2780 corrugated steel fauna underpass	25	Y
13	106.305km	1/3220 x 2780 corrugated ste	45	Y
14	106.450km	1/900 concrete pipe	55	Y
15	106.500km	1/750 corrugated steel pipe	30	Y
16	106.950km	1/1350 concrete pipe	25	Y
17	107.190km	1/900 concrete pipe	25	Y
18	107.270km	1/900 concrete pipe	20	Y
19	107.835km	2/900 concrete pipes	20	Y
20	107.945km	1/900 concrete pipe	35	Y
21	108.215km	2/675 concrete pipes	20	Y
22	108.625km	2/675 concrete pipes	25	Y
23	108.798km	1/1200 corrugated steel pipe	40	Y
24	109.130km	1/900 concrete pipe	15	Y
25	109.400km	3/900 concrete pipes	20	Y
26	110.108km	2/1350 corrugated steel pipes	20	Y
27	110.740km	3/900 concrete pipes	15	Y
28	111.070km	3/600 concrete pipes	30	N
29	111.601km	1/1350 corrugated steel pipe	15	Y
30	112.048km	1/1200 corrugated steel pipe	20	N
31	112.500km	4/675 concrete pipes	15	Y
32	113.059km	1/1050 corrugated steel pipe	15	N
33	113.864km	1/1050 corrugated steel pipe	20	Y
34	114.168km	1/1350 corrugated steel pipe	30	Y
35	114.498km	1/1200 corrugated steel pipe	35	Y
36	114.610km	1/900 concrete pipe	20	N
37	114.762km	1/1500 corrugated steel pipe	20	N
38	115.280km	1/2100 corrugated steel pipe (fauna underpass)	20	Y
39	115.315km	1/1200 corrugated steel pipe	40	Y
40	115.425km	1/900 concrete pipe	35	Y
41	115.893km	1/1500 corrugated steel pipe	70	Y
42	115.950km	1/2100 corrugated steel pipe (fauna underpass)	30	Y
43	117.060km	1/1200 concrete pipe	20	N
44	117.100km	1/900 concrete pipe	25	Y
45	117.706km	1/1200 corrugated steel pipe	40	Y
46	118.173km	1/1050 corrugated steel pipe	35	Y
47	119.405km	1/1200 corrugated steel pipe	25	Y
48	121.031km	1/1050 corrugated steel pipe	20	N
49	121.600km	1/1500 corrugated steel pipe	25	Y
50	122.192km	1/1200 concrete pipe	25	Y
51	123.410km	4/1200 x 1800 concrete box	12	Y
52	124.520km	1/1050 concrete pipe	25	Y
53	124.840km	1/1800 corrugated steel pipe	79	Y
54	125.215km	1/1050 corrugated steel pipe	27	Y
55	125.820km	1/1800 corrugated steel pipe	69	Y
56	126.155km	1/1050 concrete pipe	22	Y
57	126.785km	1/1800 corrugated steel pipe	53	Y
58	127.235km	1/1350 concrete pipe	45	N
59	127.587km	1/1350 concrete pipe	20	N
60	128.025km	1/1500 concrete pipe	20	N
61	128.246km	1/1200 concrete pipe	20	N
62	128.610km	1/1200 concrete pipe	20	N
63	129.190km	1/1200 concrete pipe	20	N
64	130.430km	2/1200 concrete pipes	25	N
65	130.930km	1/900 concrete pipe	25	N
66	131.070km	1/1050 concrete pipe	45	N
67	131.470km	1/600 concrete pipe	40	N
68	131.650km	1/1050 concrete pipe	60	N
69	132.465km	1/1350 concrete pipe	30	N

Water quality and erosion control

Previous studies identified that soils located within the project area are highly erodible and an effective soil conservation management plan must be implemented to minimise erosion and maintain water quality. Effective surface drainage, minimal vegetation clearing/ site disturbance and vegetation stabilisation would be required to achieve these objectives.

In addition, a review of previous studies indicates that a number areas located within cuttings require a final trim, application of erosion protection measures and installation of catch drains at the top of the cutting. The addition of catch drains at the top of cuttings and protection of the cutting face is required to stop/prevent erosion and ensure the instability of these areas.

The proposed railway is located within the plateau divided by the Nepean River and its tributaries which have their headwaters in the Illawarra escarpment. The proposed rail alignment approximately follows the catchment crest between Avon and Cordeaux Rivers Systems and crosses both Cordeaux and Nepean Rivers.

The section of the railway between approximately 99.000km and 126.500km is located within land managed by the Sydney Catchment Authority (SCA). The rail line avoids the southern part of the Lake Avon between approximately 102.000km and 111.500km crossing the headwaters of several small waterways which flow to Lake Avon (a drinking water dam).

The SCA requires neutral or beneficial effect on water quality for developments located within the drinking water catchment. The railway section located within the SCA managed land may require water quality treatment devices to comply with SCA's guidelines and the existing drainage systems may need to be modified to ensure that track runoff pass through the proposed water quality treatment device.

It is assumed that the rail section between approximately 102.000km and 111.500km that discharges runoff to Lake Avon is likely to require a good standard of water treatment prior to discharge into the natural waterways. This assumption will need to be confirmed with the SCA and the environmental assessors.

Railway track drainage

Track drainage systems or open drains will need to be included in the design of the earthworks. These drains will convey railway runoff to water quality devices (WQDs).

In general, cess drains are provided where the railway is in cut and these drains will suffice to convey runoff to WQDs. Where the rail is in fill, an open drain will need to be provided at the toe of the embankment to intercept and convey runoff to WQDs. The open drain systems will need to ensure that separation of railway runoff from external (clean) runoff is provided.

All external runoff would need to be directed to the cross drainage systems and discharge to the natural waterways. In brief, any open drains will need to be part of the earthworks design. Required sizes for the open drains may vary along the rail depending on the longitudinal grades and catchment sizes. Sizes will need to be estimated in the next stages of the project design.

Scour protection

All open drains will need to be grassed with an appropriate grass type (for the soil type and climatic conditions) in order to provide erosion protection. The establishment of grass will require a period of watering and will be aided with the use of organic fibre mesh or synthetic woven materials at steep locations where channel grades are high. Alternatively, the open channels could be hydro seeded with native grasses.

At locations where flow velocities in open drains are high or where longitudinal grades exceed 5%, additional erosion control measures will need to be implemented. Such measures will include the installation of check dams, using appropriate channel lining such as shotcrete, riprap, rock mattress, turf reinforcement matting, etc. It is anticipated that the outlet of all pipes crossing the rail will require erosion control measures

WQDs (Water Quality Devices)

As a ‘rule of thumb’ and generally in the early phases of the design, the area required for WQBs may be estimated to be between 2%-5% of the catchment contributing runoff. This is a starting point in sizing WQBs as their final sizes will depend on other information including the location of the proposed WQB, expected pollutant loads, the level of treatment required, rainfall intensities, catchment characteristics and various other details.

It is likely that new access roads would need to be constructed to provide access to WQDs as existing fire trails will not be sufficient for construction and maintenance vehicles.

Further investigation is required in the next phase of the project to confirm the assumptions made above.

A.2 Bridges

There are six bridges associated with the Maldon to Dombarton railway, as follows (commencing from the Maldon end):

- Railway bridge over Nepean River (approach viaducts and main bridge)
- Hume Highway twin bridges over M-D railway (to be replaced by a tunnel as shown on the design drawings in 'conceptual drawings' appendix)
- Condell Park Road bridge over M-D railway
- Picton Road bridge over M-D railway
- Janderra Lane bridge over M-D railway
- Railway bridge over Cordeaux River.

The review considered issues such as applicability of previous bridge designs, in relation to current design standards and also whether the form of construction was still feasible/cost-effective.

In regard to the existing viaduct construction at the proposed Nepean River crossing, structural analysis work was carried out to check if the viaduct is theoretically adequate to support the current design loading.

Also, a basic review of culverts and fauna underpasses was carried out. The listing of existing culverts and fauna underpasses is as follows:

- 2 concrete box culverts
- 21 concrete pipe culverts
- 27 corrugated steel pipe culverts
- 5 corrugated steel arch fauna underpasses.

A.2.1 Railway bridge over Nepean River

The railway bridge over the Nepean River comprises approach viaducts on both sides of the river and a concrete balanced cantilever bridge across the river valley itself. The viaducts have been constructed; however, there is currently no bridge across the river valley.

Approach viaducts

All viaduct spans are existing structures, completed in the mid 1980s.

The Dombarton-side approach viaduct comprises of ten spans and the Maldon-side approach viaduct comprises of two spans.

Each span consists of three simply-supported prestressed concrete 'I' girders with a composite reinforced concrete cast in-situ deck slab, except at the first

span of the Maldon-side approach viaduct, where the deck tapers to include four prestressed concrete 'I' girders.

The piers are either 2400mm or 2800mm diameter reinforced concrete circular columns (with hammer head headstocks) supported on pad footings founded on high-level rock. Each abutment consists of a reinforced concrete headstock, including integral ballast wall and wing wall arrangement, on twin tapered walls and connecting web wall, supported on a pad footing founded on high-level rock. The approach embankment (locally completed) spills through the open abutment frame as a batter slope.

Based on the existing bridge design drawings, the following was investigated:

- Theoretical structural capacity of the superstructure
- Ballast kerb height
- Deck width
- Walkway width.

The viaduct was designed for contemporary railway design load, being M270 (plus Impact) loading, in accordance with the ANZRC Railway Bridge Design Manual 1974.

The current design loading for proposed bridges on heavy-haul coal lines is 350LA (plus Dynamic Load Allowance) railway loading. A theoretical structural analysis check of the existing load-carrying capacity was carried out using a grillage analysis to determine load distribution effects to each girder. It was found that the existing superstructure has adequate theoretical structural capacity to carry the current, higher railway design loading.

The ballast kerb height, deck width between ballast kerbs, and walkway width all complied with the current geometric standard, being ARTC Engineering Standard BDS 06 Structures – Design Standards and BDS 04 Underbridge Walkways.

It is noted, however, that the existing walkway surface would be approximately 600mm above the underside of sleeper (BDS 04 requires walkway surface at or below underside of sleeper). However, this requirement seems more relevant to transom top bridges. For ballast top bridges, as proposed here, the normal standard is to set the walking surface of the walkway level with the top of the ballast kerb. The existing walkways along the approach viaducts satisfy this requirement.

Main bridge

Currently, there is no bridge across the Nepean River gorge that connects the two existing approach viaducts described above. A post-tensioned concrete

box girder balanced cantilever bridge was designed in the mid 1980s, however, construction was not completed.

The design consists of a three span (47.3m, 90.0m, 52.3m) balanced cantilever superstructure supported on two tall reinforced concrete piers on pad footings founded on rock. The box girder depth varies from 4500mm at mid span of the centre span (and at ends of the bridge) to 7200mm at the piers.

A preliminary structural analysis check was carried out on the design, comparing load effects caused by the original design loading (that is, M270 (plus Impact) loading) to that imposed by the current 350LA (plus Dynamic Load Allowance) railway loading. It was found that the current standard loading imposed a higher bending moment on the bridge. A detailed structural capacity check would be necessary to determine if the original design reinforcement is sufficient or whether it has to be increased, together with a possible increase in box girder depth.

Similar to the approach viaducts, the ballast kerb height, deck width between ballast kerbs, and walkway width all complied with the current geometric standard, being ARTC Engineering Standard BDS 06 Structures – Design Standards and BDS 04 Underbridge Walkways.

It is noted, however, that the proposed walkway surface would be approximately 600mm above the underside of sleeper (BDS 04 requires walkway surface at or below underside of sleeper). However, this requirement seems more relevant to transom top bridges. For ballast top bridges, as proposed here, the normal standard is to set the walking surface of the walkway level with the top of the ballast kerb. The proposed walkways along the main spans satisfy this requirement. As balanced cantilever bridge construction involves entirely cast in-situ concrete placement, batching will either be from established plants at Campbelltown or a plant established on site.

In conclusion, a concrete box girder balanced cantilever bridge is still considered most appropriate for this site, as the topography and proposed span lengths make this a suitable form of bridge construction. The existing viaduct spans are in good condition and as they have been assessed as theoretically adequate for the current railway design loading, no strengthening is required. The viaduct approach spans are considered appropriate to be incorporated into the overall bridge structure across the Nepean River.

A.2.2 The Condell Park road bridge over M-D railway

Condell Park Road is a lightly trafficked sealed rural road. At the time of the original design of the Maldon to Dombarton railway, a detail design of the proposed bridge that would carry Condell Park Road over the railway was carried out.

Original design

Currently, there is no bridge at this site, however, a detailed design at this location was completed in the mid 1980s, comprising a single-span (21.5 metres long between bearings) post-tensioned concrete voided slab bridge. While this is still a feasible form of superstructure construction, it is not considered the most practical bridge solution for this site.

It is noted the original design was for a carriageway width of 5 m.

The abutments (the points where two structures meet) comprised spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

The design traffic loading was T44 Standard Vehicle Loading, in accordance with NAASRA Bridge Design Specification 1976, which is significantly lighter than the current SM1600 load spectrum for road bridges, in accordance with AS 5100 Bridge design. Also, the traffic barriers railings do not comply with current geometric and structural design standards.

A temporary side track would be envisaged, to allow construction of the bridge on the existing road alignment.

Updated design

The updated design proposes a single-span (25.1 metres long between bearings) bridge over the Maldon to Dombarton railway, utilising 1500mm deep pre-tensioned Super-T girders with a composite reinforced concrete deck slab. A span bridge is a bridge suspended according to the length of their main span (i.e., the length of suspended roadway or railway between the bridge's towers).

Given the anticipated low traffic volume and vehicle composition using Condell Park Road, Regular Performance Level traffic barriers are proposed.

The carriageway width for this updated design was increased to 8 m, in accordance with Table 3.11-2 of RTA of NSW Road Design Guide (February 2000).

Similar to the original design, the abutments comprise spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

Excavation for the railway cutting beneath the twin bridges would be carried out as per the original design.

Structure clearance envelope 'B' is clear of the underside of the proposed bridge superstructure, however, structure clearance envelope 'F' encroaches the underside of the proposed bridge superstructure by approximately 400mm. In order for the proposed bridge to clear structure clearance envelope 'F', Condell Park Road would have to be raised over the proposed railway line, including the approaches to the bridge.

A.2.3 Picton Road bridge over M-D Railway

Picton Road is a heavily trafficked road, particularly by articulated vehicles. At the time of the original design of the Maldon to Dombarton railway, a detail design of the proposed bridge that would carry Picton Road over the railway was carried out.

Original design

Currently, there is no bridge at this site; however, a detailed design at this location was completed in the mid 1980s, comprising a single-span (26.1 metres long between bearings) post-tensioned concrete voided slab bridge. To allow staged construction, each carriageway comprised separate voided slab superstructures. While this is still a feasible form of superstructure construction, it is not considered the most practical bridge solution for this site.

The abutments (the points where two structures meet) comprised spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

The design traffic loading was T44 Standard Vehicle Loading, in accordance with NAASRA Bridge Design Specification 1976, which is significantly lighter than the current SM1600 load spectrum for road bridges, in accordance with AS 5100 Bridge design. Also, the traffic barriers railings do not comply with current geometric and structural design standards.

Updated design

The updated design proposes a single-span (26.3 metres long between bearings) bridge over the Maldon to Dombarton railway, utilising 1500mm deep pre-tensioned Super-T girders (a support beam used in construction) with a composite reinforced concrete deck slab.

Separate bridge superstructures are also proposed for each carriageway, thereby allowing for staged construction using a temporary side track for one traffic

direction at any one time. The final abutting decks would interface along the middle of a central median of the combined bridge deck.

Due to the high traffic volume and amount of heavy vehicles using Picton Road, Medium Performance Level traffic barriers are proposed.

Similar to the original design, the abutments comprise spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

Excavation for the railway cutting beneath the twin bridges would be carried out as per the original design.

Both structure gauge clearance envelopes 'B' and 'F' clear the underside of the proposed bridge superstructure.

A.2.4 Janderra Lane bridge over M-D railway

Janderra Lane is a lightly trafficked sealed rural road. At the time of the original design of the Maldon to Dombarton railway, a detail design of the proposed bridge that would carry Janderra Lane over the railway was carried out.

In order to provide the required vertical clearance to the railway line, Janderra Lane was proposed to be diverted to a higher crossing point location.

Original design

Currently, there is no bridge at this site; however, a detailed design at this location was completed in the mid 1980s, comprising a single-span (21.7 metres long on curve between bearings) horizontally curved post-tensioned concrete voided slab bridge.

The curved road alignment resulted from the diversion of Janderra Lane, as its current road alignment clashes with the proposed railway, requiring significant raising or lowering of Janderra Lane, which is not practical.

Given the horizontally curved alignment across the proposed bridge, cast in-situ voided slab construction is suitable for this site.

It is noted the original design was for a carriageway width of 5 m.

The abutments comprised spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

The design traffic loading was T44 Standard Vehicle Loading, in accordance with NAASRA Bridge Design Specification 1976, which is significantly lighter than the current SM1600 load spectrum for road bridges, in accordance with

AS 5100 Bridge design. Also, the traffic barriers railings do not comply with current geometric and structural design standards.

Updated design

The updated design proposes a straight single-span (19.3 metres long) bridge over the Maldon to Dombarton railway, utilising 1200mm deep pre-tensioned Super-T girders with a composite reinforced concrete deck slab.

Given the anticipated low traffic volume and vehicle composition using Janderra Lane, Regular Performance Level traffic barriers are proposed.

The carriageway width for this updated design was increased to 8 m, in accordance with Table 3.11-2 of RTA of NSW Road Design Guide (February 2000).

Similar to the original design, the abutments (the point where two structures meet) comprise spill-through type on bored reinforced concrete cast-in-place piles socketed into bedrock.

Excavation for the railway cutting beneath the twin bridges would be carried out as per the original design.

Structure clearance envelope ‘B’ is clear of the underside of the proposed bridge superstructure, however, structure clearance envelope ‘F’ encroaches the underside of the proposed bridge superstructure by approximately 1 m (maximum). In order for the proposed bridge to clear structure clearance envelope ‘F’, the diverted Janderra Lane would have to be raised above the existing surface.

A.2.5 Railway bridge over Cordeaux River

Two (2) structure options were considered for the railway bridge over the Cordeaux River gorge. One comprised a concrete arch, as originally proposed, and the other a balanced cantilever form of construction.

Option 1 – Concrete arch

A segmental concrete open-spandrel arch bridge was designed in the mid 1980s, however, construction never commenced. Currently, there is no bridge across the Cordeaux River gorge.

The design proposed consists of a single 132 metre long segmental concrete arch supporting three wall piers at each side of the crown. The superstructure comprises twin precast reinforced concrete ‘U’ girders with a composite reinforced concrete deck slab. There are four approach spans on the Dombarton side of the main arch span and two on the Maldon side.

This form of bridge construction is still feasible and lies within the ideal span range of arch bridges, however, arch structures of this configuration have not been constructed in Australia recently it is an expensive form of structure type.

Option 2 – Balanced cantilever

As an alternative to the arch bridge of Option 1, a post-tensioned concrete box girder balanced cantilever bridge is proposed. A cantilever bridge is built using structures that project the bridge horizontally into space, so that the bridge is supported on only one end.

The design comprises a three span (66.0m, 120.0m, 66.0m) balanced cantilever superstructure supported on two reinforced concrete piers on pad footings founded on rock. Pier 1, on the Dombarton side of Cordeaux River, is approximately 30 metres high, while Pier 2, on the Maldon side of Cordeaux River is approximately 60 metres high.

It is noted that Pier 1 here coincides with the location of the proposed arch footing (of Option 1), on the Dombarton side of the Cordeaux River, however, Pier 2 is some 12 metres closer to the river, and approximately 30 metres lower down the gorge, than the location of the proposed arch footing (of Option 1), on the Maldon side of the Cordeaux River.

It is noted that the lower pier is still above normal water level in Cordeaux River. From an environmental aspect, there will be no river disturbance or other major impact. The box girder depth varies from 6 m (approximately) at mid span of the centre span (and at ends of the bridge) to 9.6 m (approximately) at the piers.

The box girder is commonly used for highway flyovers and for elevated structures of light rail transport. Normally it comprises either structural steel, or a composite of steel and reinforced concrete.

As balanced cantilever bridge construction involves entirely cast in-situ concrete placement, and due to the relative remoteness of this site, a concrete batching plant would likely be established on site.

A concrete box girder balanced cantilever bridge alternative is considered most appropriate and cost-effective for this site, as the topography and proposed span lengths make this a suitable form of bridge construction.

Also, balanced cantilever construction techniques have advanced over recent years, providing a cheaper solution compared to the rarely chosen arch form of bridge construction.

A.2.6 Culverts and fauna underpasses

There are 27 corrugated steel culverts ranging from 750mm diameter to 1800mm diameter Hel-Cor pipes. A culvert is a device used to channel water. There are also five corrugated steel pipe arch fauna underpasses, 3.22 m span x 2.78 m rise. These steel structures have been in place since the early 1980s, presumably without being inspected or provided with any form of routine maintenance.

These types of structures require regular inspection to detect abrasion of the invert and consequent corrosion. If there is severe corrosion present, then culvert replacement would be recommended. For the cost estimate purpose it is assumed that the steel underpasses and steel culverts will require replacement which will also ensure the life span of the structures.

Also, there are 21 concrete pipe culverts installed. They are all located along the railway alignment where the earthworks contracts are known to have been completed before the project was terminated.

There are two identical multi-cell reinforced concrete box culvert structures (4 cells, each cell 1.2 m high by 1.8 m wide), presumably designed to ANZRC Bridge Design Manual 1974. Typically, small span structures are structurally adequate for current railway loading. Therefore, these structures are assumed to be structurally adequate.

A.3 Avon Tunnel

This section assesses the design of the Avon tunnel and describes the assumptions made for the tunnel support assessment at the feasibility stage.

The Avon tunnel is near a crossing loop located on the existing Unanderra to Moss Vale Line and is named from the Avon Reservoir adjacent to the western portal of the tunnel.

A.3.1 Original tunnel design

The tunnel was originally designed by Snowy Mountains Engineering Corporation (SMEC) in 1984.

The construction work completed on the tunnel includes access roads and the tunnel portals preparation. The tunnel itself, approximately 4 km has not been constructed.

The location of the No. 1 or eastern portal is at Chainage 98.3 km with some initial tunnel excavation is shown on Figure A14.

Figure A144 **Eastern portal of the Avon tunnel**

The No. 2 or western portal is located at Ch 102.3 km with an elevation of 429m. A section of open excavation has commenced but was filled with water on recent inspection as shown on Figure A15.

Figure A155 **Western portal to Avon tunnel**

The original design was planned to take 3100 tonne coal trains, measuring 31 wagons in length from New South Wales western and south-western mines to the Port Kembla Coal Loader. The capacity was considered to be 24 trains in each direction per 24 hours for an electrified line. The original design had no ventilation allowance because of its electrification.

Permanent support for the tunnel as shown in the original design and drawings consists of systematic fully grouted rockbolts, mesh and plain shotcrete. The amount of the designed support varied along the tunnel considering the rock mass categories.

Generally, temporary support of tunnel excavation is provided by rock-bolts during construction. This support transfers load from an unstable exterior, to the much stronger interior of the rock mass. Permanent support is provided by a concrete lining of varying thickness depending upon the stability of the ground.

Based on the original design documentation the support provided delivers a good and safe route, as well as the most environmentally acceptable.

A.3.2 Geological information

A detailed description of the geology of the region is given in the "Geological Report of the Avon Tunnel" 1987 by Snowy Mountain Engineering Corporation (SMEC). The geological information described in this report is primarily based on the paper on the Maldon Port Kembla Port Railway (Ref 6.1).

Specifically for the 1987 tunnel investigation eleven bore holes were drilled, which ranged from 35 metres to 304 metres in depth. Five holes were vertical and six inclined at angles from 45 degrees to 70 degrees, in order to intersect faults, and dykes.

The investigation included field and laboratory mechanical testing performed on in-site, jacking sites, and on drill hole cores. These tests were detailed in the 1987 Geological Report.

The proposed tunnel traverses a line of cliffs separating the narrow coastal plain from the inland plateau. This means that the rock mass through which the tunnel is to be driven is made up of sedimentary rocks consisting mainly of sandstone with narrow interlayers of siltstone and claystone. These are considered to be typical of the area.

The proposed tunnel is expected to be driven through the Scarborough, Bulgo and Hawkesbury sandstones. Thus, the design of the tunnel support will need to be flexible enough to suit the change of the ground conditions, and comply with standard specifications.

The key features of the investigation are summarised as follows:

- Underneath the tunnel at a depth varying from 80m at the No. 1 portal to 250 metres at the No. 2 portal are Illawarra Coal measures.
- The rock mass surrounding the tunnel is made up of sedimentary rocks consisting mainly of sandstone with narrower interlayers of siltstone and claystone. Dykes, sills and faults exist throughout the area traversed by the tunnel.
  - Sills and dykes are formed when magma intrudes into rock. Sills form where magma intrudes between layers, they run parallel to the layer. Dykes form when magma intrudes into a rock along lines of weakness such as fractures and fissures.
  - Dykes cut beds and range in size from a few cm to several km. The igneous rocks forming these dykes and sills are either dolerite or

  syenite. The most appropriate option of the tunnel support design will adapt to these conditions

- There are two faults with displacements ranging from 0.3 to 1.6 metres.
- The general dip of the sandstone and coal beds is about 1 degree to the northwest. The tunnel rises at about 2 degrees (track gradient 3.33%) against this dip, giving a relative incline of 3 degrees.
- Coal mining in the immediate area of the tunnel prior to 1971 has caused some subsidence as evidenced by "open up" of the sandstone rock blocks.
  - The Wongawilli seam has been mined to first extraction over the full tunnel length, with total extraction over limited areas under No1 portal and the western third of the tunnel. Further mining activity is frozen in the vicinity of the tunnel alignment.
- The Flying Fox Creek is at about the same alignment of the tunnel with a minimum cover of about 40m.
- There is no significant groundwater inflow towards the coal mine workings.

As explained in the previous chapter, the most appropriate option includes the design of the tunnel support that can adapt to these geological conditions.

A.3.3 Assessed ground conditions

The geological ground condition along the tunnel alignment was assessed using the available information. For the purpose of this study, it is anticipated that three typical categories of ground conditions may be encountered for tunnel support design, as described in the table below:

Table A7 **Geological condition**

Categories	Length	Geological Condition
A	1000m	Bulgo & Hawkesbury sandstone, good quality
B	2000m	Bulgo, Hawkesbury & Scorbrough sandstone, medium quality
C	600m	Stanwell park claystone and other poor quality rocks
Transition zone	400m	Transition between categories B and C

The above categories are considered to be typical based on limited site investigation and interpretation between all the boreholes drilled. Thus variation of the categorised ground conditions along the tunnel alignment is inevitable. Subsequently the design tunnel support will need to be flexible enough to suit the change of the ground conditions.

A.3.4 Tunnel geometrical requirement

To comply with the standard requirements the proposed vertical gradient of the tunnel is to be 1 in 30 throughout the entire 4 km long tunnel alignment travelling to the west from Port Kembla.

The tunnel cross-sectional geometry, in particular the invert of the tunnel is developed to suit different categories of ground conditions as described in section above. The track alignment requirements need to consider that the western portal is at an elevation of 427 m; while the eastern portal is at an elevation of 295 m.

The maximum height and width of the tunnel for the considered locomotives and their loads (for both Plate B and Plate F locomotive envelopes) is developed as shown on the sketches below. They comply with the standard specifications to ensure safe passage through the tunnel.

The potential softening or need of reinforcement of the subgrade resulting from the seepage water and dynamic loading from the tunnelling train will need to be considered in the next stage of design development.

Figure A16 **Typical Avon Tunnel cross sections for Type F rolling stock**

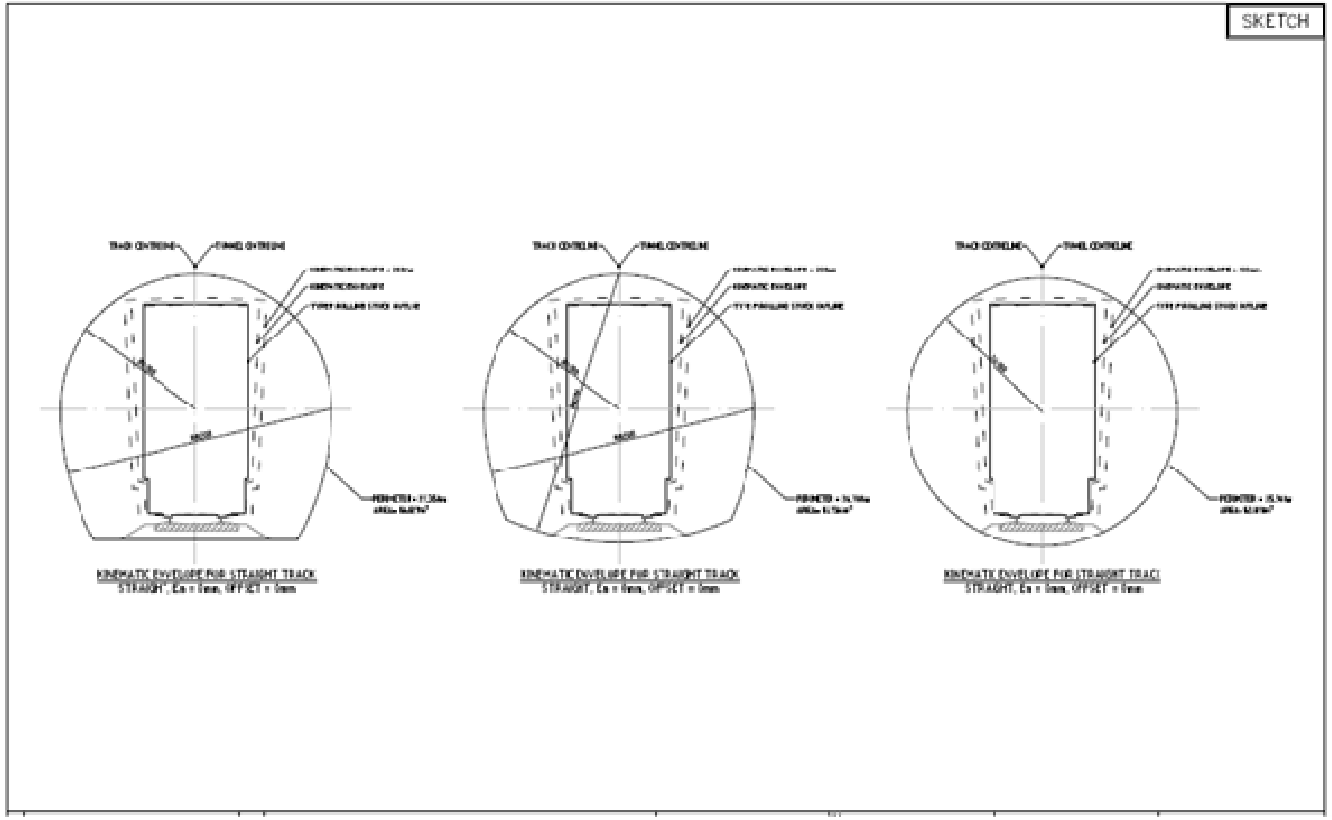
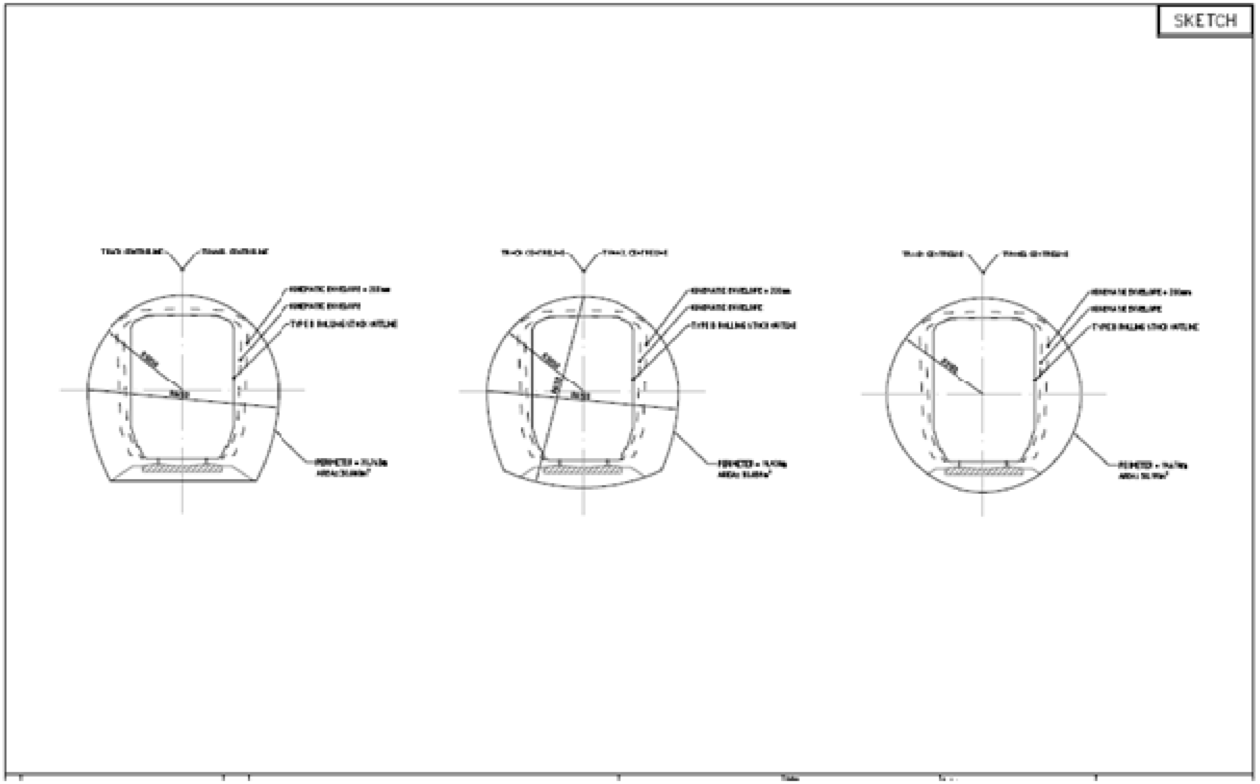


Figure A17 **Typical Avon Tunnel cross sections for Type B rolling stock**



The geometrical requirements discussed above were then used for assessing the following:

- required tunnel excavation
- construction tolerances
- the thickness of the tunnel support lining
- the drainage provision around the tunnel and collection of seepage along the tunnel alignment was also considered.

A.3.5 Tunnel construction method and issues

Three tunnel excavation methods have been assessed for the purpose of this feasibility study. They are the following:

- Drill and blast
- Roadheader (also called a boom-type roadheader, or just header machine, is an excavating equipment used to move the machine forward into the rock)
- Tunnel Boring Machine (TBM)

Drill and blast methods are usually used for tunnel excavation where the rock strength is relatively high and the use of roadheader excavation production rate is much lower. In addition, the modern regulation of tunnel safety would require additional machines for the installation of the tunnel support, after drilling and blasting, so that the overall production rate is lower than the roadheader's excavation production rate.

Roadheader is commercially available and has a wide range of applications within the current Australian tunnelling market. This advantage would result in an overall average tunnel excavation rate equal to or greater than the Tunnel Boring Machine (TBM).

The TBM is technically feasible and has the greatest production rate once the establishment is completed. Due the length of the tunnel being about 4000m, the longer procurement time and highest capital cost the TBM is ranked to be second among the three tunnel excavation methods.

One of the critical issues with the geological assessment is whether there is any hydraulic connection of the tunnel alignment to the Avon Reservoir and the Flying Fox Creek. It is anticipated that as most of the tunnel is in Sandstone rock, given the steep gradient of the tunnel, an upslope tunnel excavation is ideal to control the groundwater inflow.

Disposal of the tunnel spoil was also considered at this study. One consideration is that there is a demand for the spoil at Port Kembla for the purpose of reclamation work. Alternatively it may be disposed as a mound in the vicinity of the tunnel portal as the original design provides.

A.3.6 Tunnel support design

The tunnel support design is based on the requirements set out in the NSW WorkCover Code of Practice for Tunnels under Construction 2006. One of the key requirements is that no personnel shall be working under unsupported tunnel roof.

Both temporary and permanent tunnel support systems were considered for this feasibility study to cater for the anticipated ground conditions that are likely to occur along the alignment. The tunnel support system is flexible enough to be adjusted on site to suit the actual ground condition encountered during excavation.

The key elements of the tunnel support system proposed comprise:

- Rockbolts of varying length to suit different shapes and sizes of tunnels
- Steel Fibre Reinforced Shotcrete (SFRS) applied layer by layer
- Drainage network installed in the tunnel crown and side walls where apparent seepage or geological features are identified.

The Sketches, presented in Appendix: Concepts and Drawings, are based on the tunnel construction method using Roadheader. Two types of roadheaders were considered:

1) Mitsui S200 or equivalent for Plate B rolling stock tunnel

2) Mitsui S300 or equivalent for Plate F rolling stock tunnel.

Three classes of tunnel permanent support were designed to suit the corresponding ground categories A, B and C for cost estimate purpose, and for this level of the feasibility study.

The permanent tunnel support can be used where the ground movements are controlled, and the long term durability of the rockbolt and shotcrete system is not compromised. However additional temporary tunnel support may be envisaged for other types of geological conditions. These may include the following:

- Spot bolting for Category A rock mass
- Spot bolting, mesh and/or shotcrete for Category B rock mass
- Mesh, shotcrete, spiling bars or canopy tube plus steel sets or lattice girders for Category C rock mass

The invert of the tunnel has been assumed to be of concrete slab in order to minimise the long term maintenance costs, although some section for the tunnel may require the use of ballast (where feasible).

The geometrical requirements discussed above were then used for assessing the following:

- required tunnel excavation,
- construction tolerance,
- the thickness of the tunnel support lining,
- the drainage provision around the tunnel and collection of seepage along the tunnel alignment was also considered.

A.3.7 Tunnel ventilation consideration

The original design for tunnel ventilation considered the use of electrified trains. The use of such trains does not require a tunnel ventilation system.

For the purpose of this study it is assumed that diesel locomotives will be using the line which is a current practice on the adjacent lines.

Loaded trains will be travelling downhill towards Port Kembla which reduces the pollution generation in the tunnel. It is assumed trains travelling uphill will mostly be empty trains lighter than the downhill coal trains.

The ventilation analysis showed that purge time of the tunnel would be approximately 30min which should accommodate train use in early years. without requirement for tunnel ventilation. However for the cost estimate tunnel ventilation fans have been allowed for provision of tunnel ventilation which will reduce the purge time and hence allow greater train frequency as traffic builds up.

Alternative ventilation systems considered in the study included portal doors and vertical ventilation shafts. Both these options would be at a higher cost then ventilation fans.