North West Rail Link, Options Review Report – Epping to Franklin Road Stations

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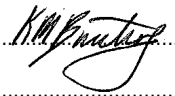
Signed: 

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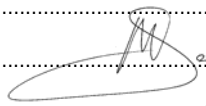
Signed: 

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Introduction

The New South Wales (NSW) Government proposes to develop the North West Rail Link, a new heavy passenger rail line between Rouse Hill and Epping in north-west Sydney, linking to major centres, including the Sydney central business district (CBD), North Sydney, North Ryde, Macquarie Park and Chatswood.

In November 2005, the Transport Infrastructure Development Corporation (TIDC) was directed by the NSW Minister for Transport to undertake the necessary technical studies and reviews to progress the planning and design of the North West Rail Link. TIDC was also directed to undertake the necessary work and documentation for the North West Rail Link project to allow concept approval to be obtained under Part 3A of the NSW *Environmental Planning and Assessment Act 1979*.

TIDC exhibited an Environmental Assessment and Concept Plan (TIDC 2006) for the project between November 2006 and February 2007. That report identified a Reference Scheme and an alternative direct tunnel alignment option for the project between the existing Epping Station and a proposed new station at Franklin Road in Cherrybrook. Submissions received on the Environmental Assessment and Concept Plan, many of which commented on the alternative alignment option, were then analysed and responded to in a Preferred Project Report (TIDC 2007a), which was publicly exhibited from 6 June to 6 August 2007. As well as responding to submissions, the Preferred Project Report also identified a preferred tunnel alignment for the project between the Epping and Franklin Road Stations. The preferred tunnel alignment in the Preferred Project Report, now referred to as the 'green' alignment, would provide the shortest and straightest connection between the Epping and Franklin Road Stations (refer to Section 3.1.2).

More submissions from the public were received in response to exhibition of the Preferred Project Report. Those submissions have now been summarised and responded to in a Supplementary Submissions Report (TIDC 2007b) — the main document to which this Options Review Report is appended.

This Options Review Report reviews the alignment options considered for the proposed North West Rail Link between the existing Epping and Franklin Road Stations. The review focuses on l alignment options considered by TIDC as part of the Environmental Assessment and Concept Plan and Preferred Project Report for the North West Rail Link.

Alignment options

In total, six direct tunnel alignment options have been identified for consideration in this Options Review Report — five between the Epping and Franklin Road Stations (called the green, blue, pink, gold and brown alignments; refer to Figure S-1), and one between the Carlingford and Franklin Road Stations (called the red alignment):

- *the 'blue' alignment* — The blue alignment was included as an alternative alignment to the Reference Scheme in the Environmental Assessment and Concept Plan. An options comparison contained in the Preferred Project Report identified several disadvantages of this alignment relative to the green alignment.

- *the 'green' alignment* — The green alignment is the shortest point to point route between the Epping and Franklin Road Stations. It was identified as the preferred alignment for this section of the project in the Preferred Project Report and is included in the North West Rail Link Concept Plan for which approval is being sought.

- *the 'pink' alignment* — The pink alignment was initially conceived to maximise the length of tunnel located below the M2 Motorway and Epping Reserve. The options comparison contained in the Preferred Project Report identified several disadvantages of this alignment relative to the green alignment.

- *the 'gold' alignment* — The gold alignment was proposed in community submissions to the Preferred Project Report. It would minimise the length of tunnel beneath residential properties by locating the alignment beneath the M2 Motorway, Pennant Hills Golf Course and Pennant Hills Road.

- *the 'brown' alignment* — The brown alignment was proposed in submissions to the Preferred Project Report. It would minimise the length of tunnel beneath residential properties by locating part of the alignment beneath the existing Main North Line rail corridor.

- *the 'red' alignment* — The red alignment was proposed in some community submissions to the Preferred Project Report. It would connect the North West Rail Link to the Carlingford Line at Carlingford Station by passing under Pennant Hills Road from Carlingford Station to Thompsons Corner, and then Castle Hill Road to Franklin Road Station.

These six alignment options are shown in Figure S-1.

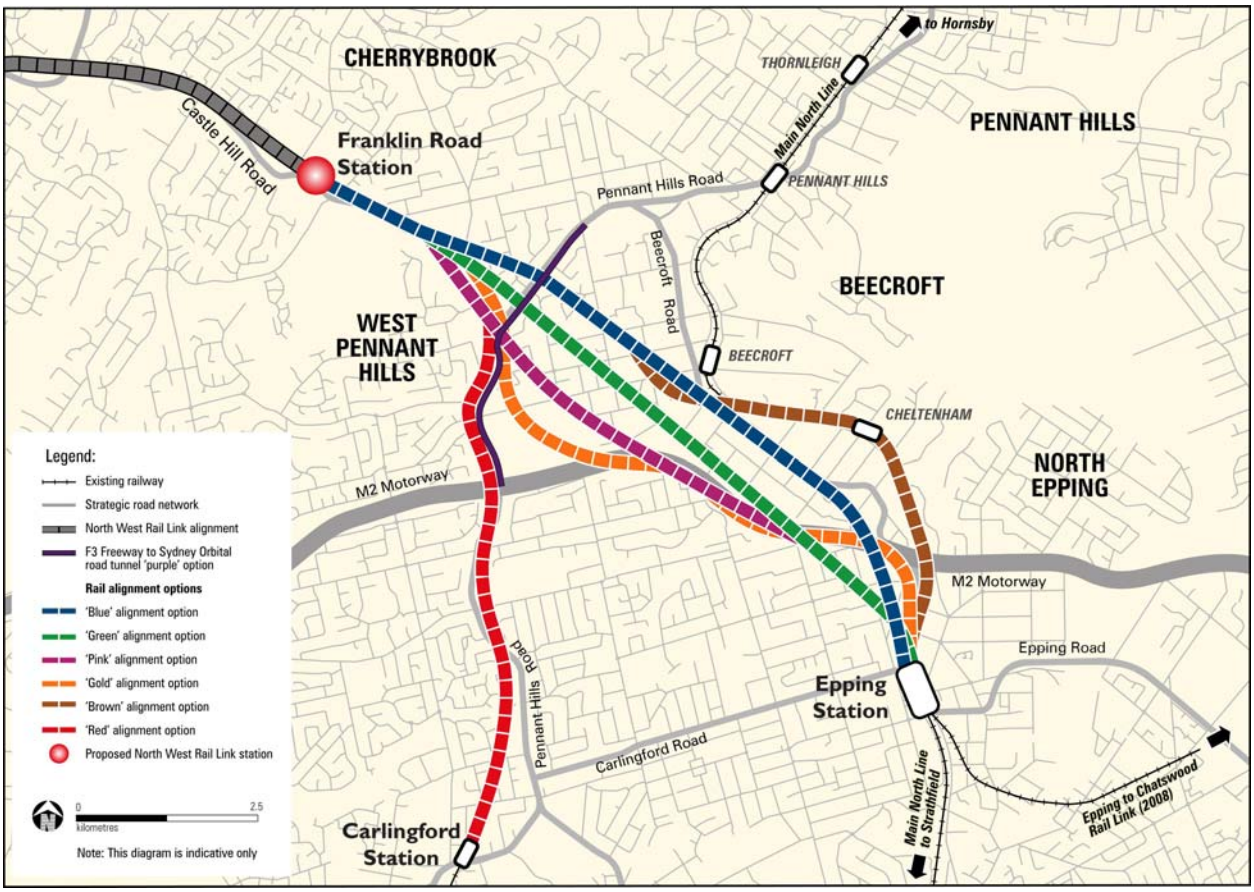


Figure S-1: Direct tunnel alignment options

Comparison of the alignment options

A three-step methodology was used to review and compare the performance of the direct tunnel alignment options:

- Step 1 comprised a review of whether the alignment options would meet the strategic objectives of the North West Rail Link project.
- Step 2 comprised the compiling of performance data for those alignment options that would meet the project objectives. Data was compiled for a comprehensive range of criteria. Specialist property and noise reviews were undertaken (refer to Appendices B and C respectively).
- Step 3 comprised a qualitative comparison of the relative performance of the alignment options.

Following the Step 1 review, it was concluded that the red alignment would not meet the strategic objectives of the project as it would not provide a direct link from north-west Sydney to the global arc centres of Sydney (e.g. North Ryde, Chatswood, St Leonards, North Sydney and the Sydney CBD). All the other alignment options would meet the strategic objectives of the North West Rail Link.

In Step 2, performance data was compiled for a long list of comparison criteria (see Table 4-1), from which the alignment options were shown to display different performances for: tunnel length and, associated with this, journey time, duration of construction works, capital cost, spoil generation and disposal, and operating cost; straightness of the track geometry and, associated with this, maximum track speed, ride quality, maintainability, and maintenance cost; energy use and associated greenhouse gas emissions; the number of dwellings located above each alignment corridor; and impacts to the approved corridor for the Epping to Parramatta Rail Link.

The comparison of options undertaken in Step 3 confirmed that the green alignment is the most direct alignment between the Epping and Franklin Road Stations and, therefore, would have the shortest tunnel length, journey time and construction period; the lowest capital cost; would generate the smallest volume of spoil and, therefore, the least spoil haulage truck movements; and would consume the least energy and generate the least greenhouse gas emissions during construction.

The green alignment also has the greatest length of straight track and, therefore, the most comfortable ride, the best maintainability and the lowest maintenance cost.

The maximum gradient of the green alignment is similar to the maximum gradients of the other alignment options, however, the green alignment is generally at a maximum gradient for shorter distances that the other alignment options. This, combined with the fact that it would have the shortest tunnel length and straightest track, would mean the green alignment has the lowest potential energy consumption during operation and, therefore, the lowest operation and maintenance cost, and the lowest total or life cycle cost including lowest electricity usage and greenhouse gas emissions.

The blue, pink, gold and brown alignments would all have longer tunnels and a greater number of track curves than the green alignment and, therefore, higher capital costs, greater generation of spoil and spoil haulage truck movements, reduced ride quality, longer journey times, worse maintainability, greater energy consumption during operation, higher operation and maintenance costs, and higher life cycle costs including electricity usage.

The gold alignment would have the longest tunnel and also the greatest number of track curves. It is, therefore, the worst performing option in terms of capital cost, construction time, spoil generation and spoil haulage, ride quality, journey time, maintainability, energy consumption during operation, operation and maintenance cost, and life cycle cost including electricity usage.

Only the green and pink alignments would enable a future extension from Epping to Parramatta within the approved project corridor. The blue, gold and brown alignments would require modifications of the approved Epping to Carlingford alignment and would, therefore, require modifications to that rail corridor.

The brown, gold and pink alignment corridors would be located beneath fewer residential dwellings that the green alignment. However, should the Epping to Parramatta Rail Link proceed, the modifications to the approved Epping to Carlingford alignment required for the gold and brown alignments would result in the Epping to Carlingford rail corridor extending beneath additional dwellings not currently affected by the approved corridor.

Conclusion

Overall, the green alignment is considered to provide the best performance relative to the assessment criteria considered.

The key advantages of the green alignment relative to the other options are:

- It would have the lowest life cycle cost, including a capital cost indicatively between $20 to 60 million less than other options, and reduced ongoing operation and maintenance costs.
- It is shorter than the other four alignments by between 230 and 650 metres.
- It would have the least construction impacts including the shortest construction period, smallest volume of spoil generation (up to 36,000 cubic metres less spoil) and the least spoil haulage truck movements.
- It would provide the best ride quality because it is straighter than the other alignments and has no reverse curves.

The green alignment would also have the following additional advantages:

- It would have the shortest journey time by between 5 and 24 seconds.
- It would require the least maintenance.
- It would consume the least energy and generate the least greenhouse gas emissions during construction and operation.
- It would not impact the approved corridor for the Epping to Parramatta Rail Link.

All the alignment options would be located below residential areas. While the green alignment would be located below a greater number of residential dwellings than three of the other alignments, all the alignments would achieve very low ground-borne noise and vibration levels subject to appropriate track design.

1. Introduction

1.1 Background

North-west Sydney is one of the major growth areas in the Sydney metropolitan region. To improve access to employment and educational opportunities for existing and future residents, and to alleviate the growing traffic congestion in this area, the New South Wales (NSW) Government proposes to develop the North West Rail Link (the project), a new heavy passenger rail line linking Epping with the regional centres of Castle Hill and Rouse Hill.

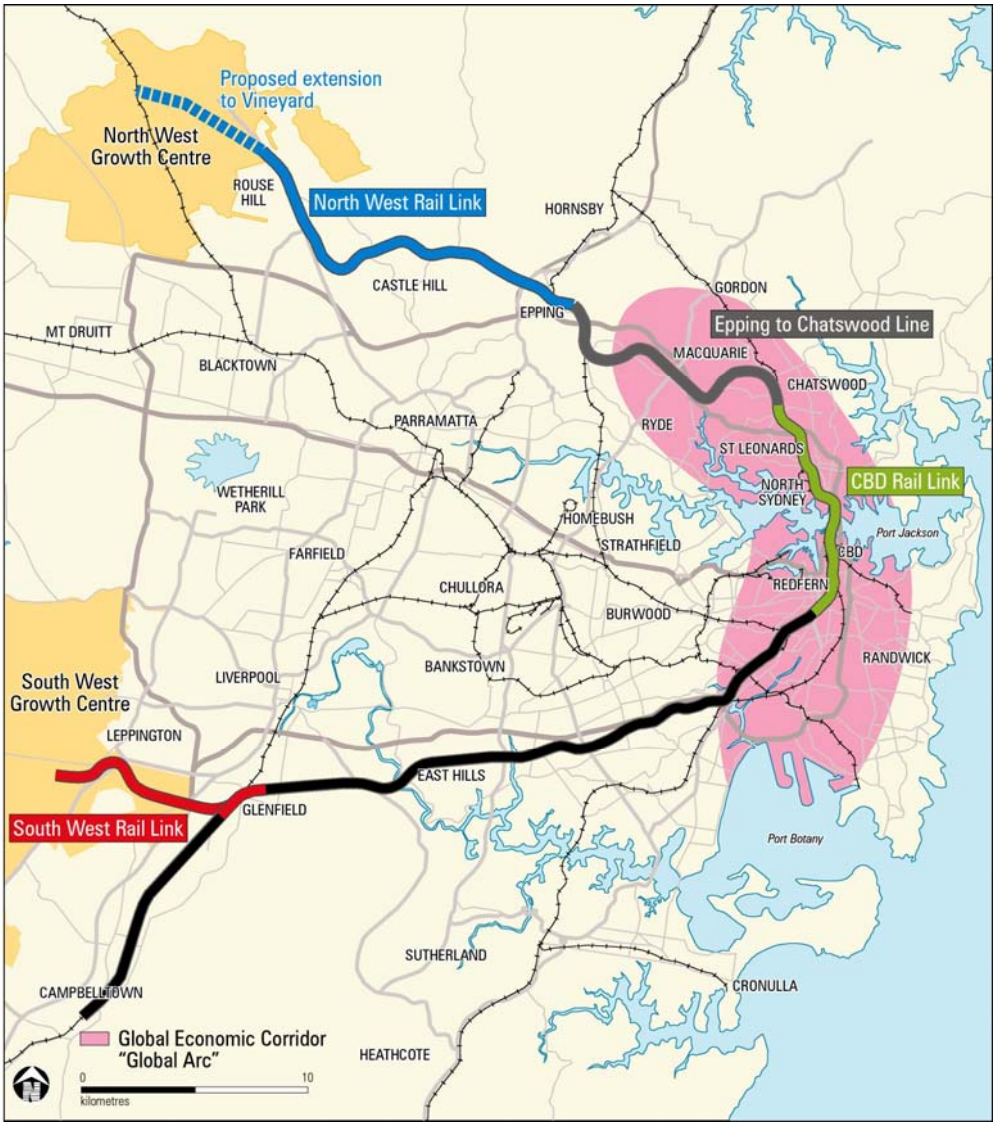
The North West Rail Link would serve the growing population in north-west Sydney and provide direct public transport connections to major centres, including the Sydney central business district (CBD), North Sydney, North Ryde, Macquarie Park and Chatswood.

The project forms part of the Metropolitan Rail Expansion Program, which includes the North West Rail Link, the South West Rail Link and the CBD Rail Link (refer to Figure 1-1).

In November 2005, the Transport Infrastructure Development Corporation (TIDC) was directed by the NSW Minister for Transport to undertake the necessary technical studies and reviews to progress the planning and design of the North West Rail Link. TIDC was also directed to undertake the necessary work and documentation for the project to allow concept approval to be obtained under Part 3A of the NSW *Environmental Planning and Assessment Act 1979*.

An Environmental Assessment and Concept Plan (TIDC 2006) for the North West Rail Link was publicly exhibited from November 2006 to February 2007. That report identified a Reference Scheme and an alternative direct tunnel alignment option for the project between the existing Epping Station and a proposed new station at Franklin Road in Cherrybrook (refer to Section 2.1). Submissions received on the Environmental Assessment and Concept Plan, many of which commented on the alternative alignment option, were then analysed and responded to in a Preferred Project Report (TIDC 2007a), which was publicly exhibited from June to August 2007. As well as responding to submissions, the Preferred Project Report also identified a preferred alignment for the project between the Epping and Franklin Road Stations. The preferred alignment, now referred to as the 'green' alignment, would provide the shortest and straightest connection between Epping and Franklin Road Stations (refer to Section 3.1.2).

More submissions from the public were received in response to exhibition of the Preferred Project Report. Those submissions have now been summarised and responded to in a Supplementary Submissions Report (TIDC 2007b) – the main document to which this Options Review Report is appended. The purpose of this Options Review Report is explained below.



Source: TIDC 2006

Figure 1-1: Metropolitan Rail Expansion Program

1.2 Purpose and scope of this report

The purpose of this Options Review Report is to review the alignment options for the proposed North West Rail Link between the existing Epping Station and a proposed station at Franklin Road in Cherrybrook.

The scope of this report is to:

- Summarise findings of previous investigations into the North West Rail Link alignment options between the Epping and Franklin Road Stations in the period up to and including the preparation of the Preferred Project Report (TIDC 2007a).
- Describe additional direct tunnel alignment options identified in submissions to the Preferred Project Report and during community information sessions held between June and July 2007.

- Present performance data for the identified direct tunnel alignment options to the Department of Planning and the community.
- Transparently assess the relative performance of the direct tunnel alignment options and identify the best performing alignment.

1.3 Methodology

A three-step methodology was used to review and compare the performance of the direct tunnel alignment options:

- Step 1 comprised an assessment of whether the alignment options would meet the strategic objectives of the Metropolitan Rail Expansion Program and North West Rail Link project (refer to Section 4.1). Any alignment options that would not meet the project objectives were not considered further, as achievement of these objectives is a fundamental requirement for the project.
- Step 2 comprised the compiling of performance data for those alignment options that met the project objectives. Data was compiled for a comprehensive range of criteria that included performance measures for construction, potential impacts on the environment, and operation and maintenance concerns (refer to Table 4-1). This data is presented in a tabular format to enable easy comparison of the options relative to each criterion and to each other (refer to Section 4.3 and Table 4-2).
- Step 3 comprised a qualitative comparison of the relative performance of the alignment options. The comparison focused on key benefits and impacts that distinguish the options from one another (refer to Section 4.4). Conclusions are then drawn about the overall relative performance of the alignment options and the preferred alignment option (refer to Section 4.5 and Chapter 5).

1.4 Report structure

This report contains the following Chapters:

- *Chapter 1, Introduction* — provides a brief outline of the background to the project, the scope of this report, and the methodology for describing and comparing the performance of the direct tunnel alignment options.
- *Chapter 2, Alignment option development process* — explains the previous process for development and consideration of the direct tunnel alignment options up to preparation of this Options Review Report.
- *Chapter 3, Descriptions of the alignment options* — contains brief descriptions of each of the direct tunnel alignment options.
- *Chapter 4, Comparison of the alignment options* — presents and defines the criteria used to describe and measure the performance of the direct tunnel alignment options and contains a qualitative comparison of the relative performance of the options, including the preferred alignment option.
- *Chapter 5, Conclusion* — draws conclusions regarding the overall relative performance of the alignment options.

- *Appendix A, Alignment option maps* — two maps are provided showing the alignment of the options between Epping and Franklin Road Stations and the modifications to the approved Epping to Carlingford alignment required for some of the alignment options.
- *Appendix B, Summary of land use and zoning* — provides details of the land use and zoning of properties located above each alignment option between Epping and Franklin Road Stations.
- *Appendix C, Ground-borne noise study* — reviews the potential noise and vibration impacts of the operation each alignment option between Epping and Franklin Road Stations.

2. Alignment options development process

Prior to the preparation of this Options Review Report, direct tunnel alignment options for the North West Rail Link between the Epping and Franklin Road Stations were developed and considered at various stages in the environmental assessment process. The process of the alignment options development is explained in this Chapter. Further details are provided in the Environmental Assessment and Concept Plan (TIDC 2006a), the Preferred Project Report (TIDC 2007a) and the Supplementary Submissions Report (TIDC 2007b). More detailed descriptions of the options themselves are provided in Chapter 3.

2.1 Environmental Assessment and Concept Plan

The North West Rail Link Environmental Assessment and Concept Plan (TIDC 2006) described a Reference Scheme for the North West Rail Link that comprised a 3 kilometre quadruplication of the Main North Line between Epping and Beecroft, including a new bridge over the M2 Motorway and upgrade to Cheltenham Station. The Reference Scheme also proposed a dive structure at Cheltenham in the vicinity of the Beecroft Village Green. The alignment then proceeded westwards in tunnel to Franklin Road Station and beyond.

The Environmental Assessment and Concept Plan also included an alternative option to the Reference Scheme between the Epping and Franklin Road Stations. The alternative option, called the Epping to Franklin Road Direct Tunnel Option, included a 6 kilometre long underground rail tunnel between the Epping and Franklin Road Stations. The Direct Tunnel Option would use the new underground platform at Epping Station currently being constructed as part of the Epping to Chatswood Rail Link. It would proceed beneath residential areas and largely follow directly underneath Beecroft Road (refer to Figure 3-1 and Section 3.1.1).

The purpose of including an Epping to Franklin Road Direct Tunnel Option in the Environmental Assessment and Concept Plan as an alternative to the Reference Scheme was to provide an opportunity for stakeholders and the community to consider the benefits and impacts of a direct tunnel connection, relative to the surface alignment proposed in the Reference Scheme.

The Environmental Assessment and Concept Plan was placed on public exhibition from 22 November 2006 to 2 February 2007 in accordance with Section 75H(3) of the *Environmental Planning and Assessment Act 1979*. Written submissions were invited during this period. A total of 1,626 submissions were received during and immediately following public exhibition, including submissions from residents, businesses, community groups, private organisations, NSW Government agencies, councils and others.

2.2 Preferred Project Report

On 19 February 2007, TIDC was directed by the Director-General of the NSW Department of Planning, to respond to the issues raised in the submissions to the Environmental Assessment and Concept Plan in accordance with Section 75H(6) of the *Environmental Planning and Assessment Act 1979*.

TIDC subsequently prepared a Preferred Project Report (TIDC 2007a) that provided responses to the issues raised in the submissions to the Environmental Assessment and Concept Plan. The report also included information about additional studies undertaken following the public exhibition of the Environmental Assessment and Concept Plan, and provided details on proposed modifications to the Concept Plan.

Relevant findings of TIDC's review of the submissions to the Environmental Assessment included:

- A number of submissions objected to the Reference Scheme which proposed surface works (quadruplication) between Epping and a tunnel dive structure in the vicinity of Beecroft Village Green.
- A number of submissions supported a direct tunnel connection between the Epping and Franklin Road Stations, and several identified alternatives to the Epping to Franklin Road Direct Tunnel Option presented in the Environmental Assessment.

The Preferred Project Report identified that a direct tunnel connection between the Epping and Franklin Road Stations would have several advantages over the Reference Scheme. The report noted that the general advantages of a direct tunnel connection relative to a surface connection are that it would:

- *provide physical sectorisation of the North West Rail Link from the Main North Line* — A direct tunnel connection would physically separate the North West Rail Link from the Main North Line. RailCorp, the operator of the CityRail network, has an operating strategy to provide greater sectorisation.
- *have minimal impact on the existing rail network during construction* — A direct tunnel connection would not involve significant interfaces with the Main North Line. In comparison, the Reference Scheme would require substantial construction works adjacent to and interfacing with the Main North Line, including alterations to Cheltenham Station and substantial earthworks. The construction of the Reference Scheme would need extended track possessions of the Main North Line. Overall, a direct tunnel connection would be simpler and quicker to construct than the Reference Scheme. RailCorp indicated its preference for a direct tunnel connection considering risks such as impacts to the existing rail network during construction.
- *provide a more reliable outcome from both an infrastructure and train operation perspective* — A direct tunnel connection would have no crossovers or interfaces with the Main North Line and would, therefore, provide greater reliability of services, rolling stock and fixed assets, and greater certainty of achieving the delivery timetable for the North West Rail Link project. Services on a direct tunnel alignment could also be unaffected during track possessions of the Main North Line (when the overhead power is switched off and trains do not run). RailCorp indicated its preference for a direct tunnel connection considering risks such as cost, operational flexibility, and maintenance and reliability.
- *have a lower capital cost* — A direct tunnel connection would have a lower capital cost than the Reference Scheme due to the complexity of the rail and civil works and track possessions (when the overhead power is switched off and trains do not run) required to undertake surface works within the Main North Line rail corridor. In comparison, a direct tunnel alignment would be simpler and cheaper to construct as it would avoid the need for works within a live rail corridor and would not incur track possession costs.
- *be easier to maintain* — A direct tunnel connection would require less maintenance than a surface connection due to the weather protection of equipment provided by the tunnel.

- *have less impact to the local community and environment* — A direct tunnel connection would avoid some significant impacts to the local community associated with a surface connection, such as clearing of endangered ecological communities, visual impacts, and construction impacts, such as noise, including night and weekend works, spoil truck movements, and temporary changes to access.

The major disadvantage of a direct tunnel connection is that it would not provide a rail connection to the Main North Line and, therefore, would not have the flexibility of the Reference Scheme to reroute trains from the North West Rail Link down the Main North Line. Instead, passengers would have to alight from the North West Rail Link at Epping to board Main North Line trains. However, this disadvantage is also the source of many of the advantages of a direct tunnel connection, as discussed above.

Considering the issues summarised above, the North West Rail Link Concept Plan was modified to include a direct tunnel connection between the Epping and Franklin Road Stations. To support this decision, TIDC undertook a review of potential tunnel alignments as part of the Preferred Project Report. The review considered the following criteria:

- *Rail design including length, track grades, and track curves* — Consideration of line length, maximum grades and track curvature to ensure that the rail line operates effectively and would contribute to the speed and comfort of the journey.
- *Relationship with any future Epping to Parramatta rail tunnel connection* — A direct tunnel connection would use stub tunnels constructed at Epping Station as part of the Epping to Chatswood Rail Link. These stub tunnels were constructed to allow for a future connection between Epping and Parramatta via Carlingford. To ensure that such a future connection is not precluded, new stub tunnels would need to be constructed as part of the project. A corridor for the connection between Epping and Parramatta has already been approved.
- *Constructability, cost and program* — Factors such as length and curvature could lead to increases in cost or the length of time for construction. Also, different alignments could result in different constructability and maintainability issues.
- *Locating the tunnel alignment to maximise the amount of public land (e.g. roads and parks) located above it* — The community would generally prefer that a tunnel be located below public roads and parks rather than under residential properties.
- *Typical tunnel depth* — The depth of a rail tunnel is one factor that influences the level of regenerated noise during operation that may be experienced at the ground surface (TIDC 2007a).

The Preferred Project Report included the results of TIDC's investigation of three feasible alignment options, as follows:

- *The 'blue' alignment* — The blue alignment was the Epping to Franklin Road Direct Tunnel Option presented in the Environmental Assessment and Concept Plan. It would generally follow the alignment of Beecroft Road and Castle Hill Road (refer to Figure 3-1 and Section 3.1.1).
- *the 'green' alignment* — The green alignment would proceed north-west from Epping beneath the M2 Motorway, Cheltenham Park and Beecroft Park before proceeding beneath residential areas of Beecroft. It would be straighter and approximately 200 metres shorter than the blue alignment. The green alignment would be located to the south of the blue alignment (refer to Figure 3-1 and Section 3.1.2).

- *the 'pink' alignment* — The pink alignment would proceed north-west from Epping beneath Epping Reserve, the M2 Motorway and Pennant Hills Golf Course before proceeding beneath residential areas of Beecroft. It would be located to the south of the blue alignment (refer to Figure 3-1 and Section 3.1.3).

The Preferred Project Report identified the green alignment as the preferred tunnel alignment option between the Epping and Franklin Road Stations after comparing the performance of the three options against the above criteria. The advantages of the green alignment described in the Preferred Project Report were that:

- It is shorter and straighter than the blue and pink alignments.
- Relative to the blue alignment, there would be significantly fewer properties above the corridor.
- Relative to the pink alignment, there would be marginally more properties above the corridor, but it would generally be deeper than the pink alignment and, therefore, would have reduced potential for construction and operation noise and vibration impacts to sensitive noise receivers (TIDC 2007a).

The Preferred Project Report modified the Concept Plan for the North West Rail Link to include a direct tunnel alignment following the green alignment between the Epping and Franklin Road Stations. Therefore, the green alignment became part of the Concept Plan for which TIDC is seeking approval.

The Preferred Project Report was placed on public exhibition from 6 June 2007 to 6 August 2007. Several community information sessions were held and written submissions were invited during this period. Over 3,000 submissions were received during and immediately following public exhibition, including submissions from residents, businesses, community groups, private organisations, NSW Government agencies, councils and others.

2.3 Supplementary Submissions Report

On 15 August 2007, TIDC was directed by the Director-General of the NSW Department of Planning to respond to the issues raised in the submissions to the Preferred Project Report, in accordance with Section 75H(6) of the *Environmental Planning and Assessment Act 1979*.

TIDC subsequently prepared a Supplementary Submissions Report (TIDC 2007b) that provided responses to the issues raised in the submissions to the Preferred Project Report. This Options Review Report is appended to that Supplementary Submissions Report.

Community submissions to the Preferred Project Report identified further direct tunnel alignment options between the Epping and Franklin Road Stations. These additional alignment options were subsequently named the 'gold, 'brown' and 'red' alignments, which are summarised as follows:

- *the 'gold' alignment* — The gold alignment would proceed north-west from Epping and under the M2 Motorway, the Pennant Hills Golf Course, Pennant Hills Road to Thompsons Corner, and then Castle Hill Road to Franklin Road Station. It would mostly be located to the south of all the other alignment options. The gold alignment would be located beneath residential properties between Pennant Hills Golf Course and Pennant Hills Road and along Castle Hill Road (refer to Figure 3-1 and Section 3.1.4).
- *the 'brown' alignment* — The brown alignment would proceed from Epping under the Main North Line rail corridor. South of Beecroft Station, it would exit from the Main North

Line railway corridor and connect to the blue alignment. It would then proceed along the blue alignment to the Franklin Road Station (refer to Figure 3-1 and Section 3.1.5).

- *the 'red' alignment* — The red alignment would connect the North West Rail Link to the Carlingford Line at Carlingford Station. It would largely be located under Pennant Hills Road from Carlingford Station to Thompsons Corner, and then Castle Hill Road to Franklin Road Station. The red alignment would most likely be located beneath residential properties at various locations along Pennant Hills Road (refer to Figure 3-1 and Section 3.1.6).

As discussed in Section 1.2, Chapter 4 of this Options Review Report (which forms part of the Supplementary Submissions Report) compares the performance of the green, blue, pink, gold, brown and red alignments options.

3. Descriptions of the alignment options

In total, six direct tunnel alignment options have been identified for consideration in this Options Review Report — five between the Epping and Franklin Road Stations (the green, blue, pink, gold and brown alignments), and one between the Carlingford and Franklin Road Stations (the red alignment).

More detailed descriptions of the alignment options are provided below and in Figure 3-1. The alignments are shown in detail in Figure A-1 in Appendix A. All tunnel depths described below are approximate only and relate to the proposed track level.

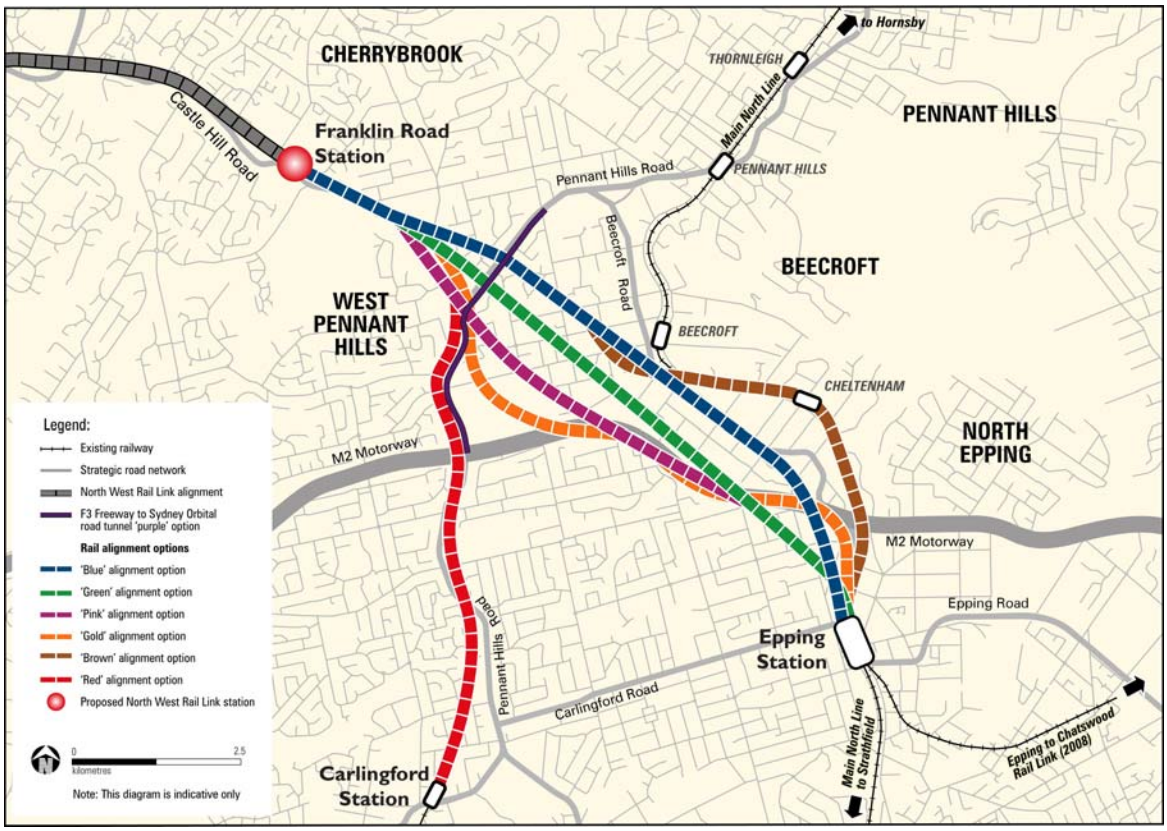


Figure 3-1: Direct tunnel alignment options

3.1.1 Blue alignment

The blue alignment was the Epping to Franklin Road Direct Tunnel Option presented in the Environmental Assessment and Concept Plan (TIDC 2006).

From Epping, the blue alignment would proceed in a northerly direction beneath Devlins Creek at a tunnel depth of approximately 13 metres, increasing to approximately 35 metres under Kandy Avenue in Beecroft. The alignment would continue in a northerly direction under the M2 Motorway at a depth of approximately 22 metres, increasing to a depth of approximately 43 metres under Lyne Road in Cheltenham. It would then follow the alignment of Beecroft Road between Cheltenham Road in Cheltenham and Welham Street in Beecroft at a depth of approximately 59 metres. Under Beecroft Primary School, the tunnel depth would be approximately 49 metres, before reaching a shallow point at Devlins Creek near Hull Road in Beecroft of approximately 24 metres. The alignment would then continue in a

north-westerly direction to the proposed Franklin Road Station. The tunnel depth would increase rapidly to approximately 59 metres at Pennant Hills Road. At Castle Hill Road in West Pennant Hills, the tunnel depth would be approximately 54 metres.

3.1.2 Green alignment

The green alignment was proposed as the shortest point to point tunnel connection between the Epping and Franklin Road Stations.

From Epping, the green alignment would proceed in a north-westerly direction beneath Devlins Creek at a tunnel depth of approximately 13 metres, increasing to approximately 30 metres under the M2 Motorway. The alignment would follow the M2 Motorway to Cheltenham Park in Cheltenham. In the vicinity of Cheltenham Road, the tunnel depth would be approximately 27 metres. It would then continue in a north-westerly direction to the south of Castle Howard Road, with the tunnel depth increasing to approximately 39 metres, crossing beneath Murray Farm Road, Kenwick Lane, Copeland Road, Hull Road, Hannah Street, Fearnley Park, Chapman Avenue and Grace Avenue in Beecroft to Thompsons Corner. At Copeland Road, the tunnel depth would be approximately 53 metres, reaching a shallow point under Fearnley Park of approximately 34 metres. It would then follow the ridgeline and Castle Hill Road in West Pennant Hills to the proposed Franklin Road Station. The tunnel depth would increase rapidly to approximately 71 metres at Pennant Hills Road. At Castle Hill Road the tunnel depth would be approximately 54 metres.

3.1.3 Pink alignment

The pink alignment was initially conceived to maximise the length of tunnel located beneath the M2 Motorway and Epping Reserve.

From Epping, the pink alignment would initially follow the green alignment, passing in a north-westerly direction beneath Devlins Creek at a tunnel depth of approximately 13 metres, increasing to approximately 30 metres under the M2 Motorway. At the M2 Motorway, the proposed pink and green alignments diverge. The pink alignment would follow the M2 Motorway up to Burns Road South in Beecroft. It would then cross beneath Burns Road South at a depth of approximately 20 metres, Pennant Hills Golf Course at a depth of approximately 18 metres, Copeland Road at a depth of approximately 27 metres, Hannah Street, Carlisle Crescent, and Grace Avenue to Thompsons Corner. It would then follow the ridgeline and Castle Hill Road in West Pennant Hills to the proposed Franklin Road Station. The tunnel depth would increase rapidly to approximately 68 metres at Pennant Hills Road. At Castle Hill Road the tunnel depth would be approximately 54 metres.

3.1.4 Gold alignment

The gold alignment was initially conceived to maximise the length of the tunnel beneath the M2 Motorway, Pennant Hills Golf Course and Pennant Hills Road.

From Epping, the gold alignment would pass in a north-westerly direction beneath Devlins Creek at a tunnel depth of approximately 13 metres and then closely follow the alignment of the M2 Motorway at depths ranging from approximately 33 metres to up to approximately 49 metres at Burns Road South in Beecroft. From Burns Road South, the gold alignment would cross beneath the Pennant Hills Golf Course in a north-westerly direction at depths of up to approximately 66 metres. It would then cross Copeland Road at a depth of

approximately 53 metres and the western end of Penrhyn Avenue. The gold alignment would follow Pennant Hills Road from Hannah Street in Beecroft at a depth of approximately 68 metres to Thompsons Corner at a depth of approximately 74 metres. It would then follow the ridgeline and Castle Hill Road in West Pennant Hills. At Castle Hill Road the tunnel depth would be 51 metres.

3.1.5 Brown alignment

The brown alignment would be located beneath the Main North Line rail corridor between Epping and Cheltenham.

From Epping, the brown alignment would follow beneath the existing Main North Line rail corridor in a northerly direction, passing under the M2 Motorway in Cheltenham at a tunnel depth of approximately 19 metres. At Beecroft Village Green, the brown alignment would leave the Main North Line rail corridor at a depth of approximately 50 metres and proceed in a north-westerly direction along the same horizontal and vertical alignment as the blue alignment. The brown alignment would cross Beecroft Road and then pass under Beecroft Primary School at a tunnel depth of approximately 49 metres, before reaching a shallow point at Devlins Creek of approximately 24 metres near Hull Road in Beecroft. The alignment would then continue in a north-westerly direction to the proposed Franklin Road Station. The tunnel depth would increase rapidly to approximately 59 metres at Pennant Hills Road. At Castle Hill Road in West Pennant Hills the tunnel depth would be approximately 54 metres.

3.1.6 Red alignment

The red alignment would follow a substantially different alignment to the other direct tunnel alignment options, because it would connect the proposed Franklin Road Station to Carlingford Station instead of Epping Station. The red alignment would largely be located beneath Pennant Hills Road between Thompsons Corner and Carlingford Station. It would pass underneath the M2 Motorway at the south-western corner of Pennant Hills Golf Course.

Land uses along Pennant Hills Road between Thompsons Corner and Carlingford Station are predominantly residential, as well as some educational, retail, commercial, community and public open space land uses.

The operation of the red alignment would be significantly different to the other direction tunnel alignment options as trains from the North West Rail Link would proceed to the Sydney CBD via the Carlingford and Main Western Lines.

If the Epping to Carlingford rail tunnel connection was constructed, passengers would have the opportunity to change trains at Carlingford and proceed to the Sydney CBD via this connection and the Epping to Chatswood Rail Link.

4. Comparison of the alignment options

4.1 Project objectives

The strategic objectives of the North West Rail Link project are to:

- Enhance public transport along an established and growing corridor of travel demand by:
  - directly linking the north-west region and 'global arc' centres of Sydney, including the Sydney CBD (refer to Figure 1-1)
  - increasing access to the rail network across Sydney
  - providing a spine for integrated public transport in north-west Sydney.
- Provide a local focus for employment and population growth patterns by:
  - improving public transport access to centres, including Castle Hill, the Norwest Business Park, and Rouse Hill
  - facilitating transit oriented development and reducing urban sprawl.
- Improve public transport service quality by:
  - reducing journey times
  - providing 'all day' service
  - increasing passenger comfort and service reliability
  - providing rail network congestion relief on the Richmond Line and the Western Line, including relieving overcrowding on trains.
- Support positive changes to travel behaviour by:
  - reducing car dependency
  - providing opportunities to walk to rail stations
  - reducing journey time between Rouse Hill Station and Town Hall Station to less than 1 hour (TransportNSW 2002).

It is a fundamental requirement that the alignment options meet the project's strategic objectives.

The red alignment would link the North West Rail Link to the Carlingford Line at Carlingford. It would not provide a direct link from north-west Sydney to the global arc centres of Sydney (e.g. North Ryde, Chatswood, St Leonards, North Sydney and the Sydney CBD). Accordingly, the red alignment would not meet the strategic objectives of the North West Rail Link. In accordance with the methodology outlined in Section 1.3 for the review and comparison of the alignment options, the red alignment option was excluded from further consideration.

Aside from not meeting the strategic objectives of the North West Rail Link, other disadvantages of the red alignment are that:

- It does not provide direct access between north-west Sydney and the key centres of Macquarie Park, Macquarie University and North Ryde that are soon to become part of the CityRail network with the opening of the Epping to Chatswood Rail Line.
- There would be insufficient capacity on both the Carlingford and Main Western Lines to accommodate the forecast demand for North West Rail Link train services during peak periods, resulting in the need for a significant and costly amplification of these corridors.
- It would increase journey times between north-west Sydney and the global arc centres of Sydney and, as a result, make rail a less attractive option.

The blue, green, pink, gold and brown alignment options would all meet the strategic objectives of the North West Rail Link.

4.2 Comparison criteria

The criteria used to compare the performance of the alignment options are defined and described in Table 4-1.

Table 4-1: Comparison criteria

Criteria	Definition and description
Construction criteria	
Tunnel length	This refers to the tunnel length between the Epping and Franklin Road Stations. On balance, a shorter tunnel length and, therefore, a shorter track length between the Epping and Franklin Road Stations is desirable, as it would reduce journey times, operation and maintenance costs, and also the duration of construction works.
Tunnel depth	Tunnel depth is the distance between ground level and the rail track (i.e. approximately 1 metre from the bottom of the 7 metre diameter rail tunnel). Tunnel depth is a relevant performance criterion, as the wheel-rail interface would be the key source of ground-borne vibration. The tunnel depths described in this report are approximate only. The tunnel depths shown in Table 4-2 focus on the sections of the alignment options east of Pennant Hills Road where the tunnel depths of the alignments are most varied. The tunnel depth of the Concept Plan (once approved) would be subject to detailed design.
Capital cost	Capital cost is the cost of developing a project. It includes construction, plant and equipment and material costs. Capital cost estimates have been prepared as part of the investigation of the alignment options. The capital cost estimates for tunnelling works are based on assumed unit tunnel boring costs and would be subject to further investigation. Different alignments could result in different constructability issues, such as difficult geological conditions for boring, and the need to pass beneath sensitive areas (e.g. shallow conditions under a waterbody). This could result in a change in construction methodology or an increase in the length of time of construction and the capital cost. These risks to the capital cost would be quantified during the detailed design phase of the project.
Engineering design	The engineering design is the physical design of the tunnels and associated structures, including emergency egresses and ventilation methods and sites. Generally, a simpler engineering design would result in reduced project risk.
Construction site and	This refers to the method of construction of the tunnels and the location

Criteria	Definition and description
method	from which the tunnels would be accessed during their construction. Different construction sites and methods would have the potential for different environmental impacts.
Potential impacts on the environment	
Environmental impact	There are a range of potential environmental impacts associated with the construction of the project, including: ▪ potential impacts to endangered ecological communities and archaeological heritage items at construction sites ▪ potential noise, traffic and air quality impacts in the vicinity of construction sites ▪ greenhouse gas emissions resulting from equipment, plant and vehicles ▪ disposal of spoil off-site ▪ potential noise and vibration impacts to sensitive noise receivers located above the alignment during tunnel boring works. The duration of construction is largely dependent on the quantity of spoil that must be removed during tunnelling works. Differences in the volume of spoil for the alignment options were estimated for the options based on: ▪ tunnels of 7.4 metre excavated diameter ▪ a bulking factor (volume increase during excavation) for sandstone/shale of 1.6 ▪ density of fill (sandstone/shale spoil) of 2 tonnes per cubic metre. Differences in the number of spoil haulage truck movements for the alignment options were estimated based on a standard truck with a capacity of 19.5 cubic metres bulked volume (24.6 tonnes). Each truck trip to and from the construction site was counted as a separate truck movement. Differences in the duration of the tunnelling works for the alignment options were estimated based on an average tunnel boring machine travel rate of 175 metres per week (TIDC 2006). Environmental impacts associated with the operation of the project include greenhouse gas emissions from electricity usage.
Community and social impacts	Community and social impacts include amenity disruptions in the vicinity of construction sites.
Property purchase	Surface property purchases would be required for any construction sites, with permanent acquisitions required for ventilation facilities or maintenance vehicle accesses proposed on private property.
Operation and maintenance criteria	
Maximum track speed	Maximum track speed is the maximum speed at which a train can safely travel along a section of track. Maximum track speed is measured at the maximum cant deficiency, which is the elevation of the outside rail minus the elevation of the inside rail of the curved track. The geometry of an alignment has the potential to restrict the maximum speed at which trains can safely travel along the tracks. Alignment geometries that could affect the maximum track speed include tight and reverse curves.
Journey time	Journey time is the time it would take for a train to travel between Epping and Franklin Road Stations. Differences in the journey times of the options were estimated by applying

Criteria	Definition and description
	an assumed travel speed of 80 kilometres per hour to the differences in the tunnel lengths.
Ride quality	Ride quality is a qualitative measure of passenger comfort while travelling through the section of tunnel between Epping and Franklin Road Stations. Ride quality is reduced at reverse curves, where the change in direction of the train as it emerges from one curve and enters another curve in the opposite direction can cause discomfort to seated and standing passengers.
Impacts to the approved Epping to Carlingford rail corridor	As discussed in Section 2.1, a corridor for a future rail line connection between Epping and Parramatta via Carlingford has already been approved. It is desirable that the direct tunnel option between the Epping and Franklin Road Stations minimises the need for modifications to the approved Epping to Carlingford rail corridor.
Maximum gradient	The maximum gradient of a railway line establishes the peak electricity load requirement of the rolling stock and, therefore, the electrical supply requirement. A higher maximum gradient would result in a higher peak load, higher electrical supply equipment rating, and extra infrastructure and operating costs. There is also potential for long sections of high grade track to result in wear and early burn out of the electric motors on rolling stock.
Maintainability	Maintainability refers to the frequency and scale of maintenance works. Straight rail track geometry results in less wear of the rails than curved track. As the curvature of rail tracks increases, there is an increase in the wear and unevenness of wear of the tracks and, therefore, the need for increased frequency of routine inspection of fastenings as well as additional maintenance works.
Operation and maintenance cost	Operation and maintenance cost is the day-to-day cost of running and maintaining an asset so that it performs its intended use during its useful life. Operation and maintenance costs form an important component of the life cycle cost of the project. Operation and maintenance cost for a railway includes electricity costs, maintenance inspections, and repair and replacement costs for items such as track, sleepers and overhead wiring. Maintenance costs are strongly correlated with maintainability.
Emergency egress	Emergency egress refers to the method for evacuating train passengers and crew and maintenance workers from a tunnel in the event of an emergency.
Ventilation	Underground railway lines require ventilation of stations and also tunnels to provide fresh air to passengers and line-side workers. Ventilation is also required in the event of a fire to extract smoke and flames in the opposite direction of the train and to permit passengers, crew or maintenance workers to safely evacuate.
Operational functionality and flexibility	Operational functionality and flexibility refers to the ability for normal train operations to be rerouted during an incident or maintenance works and to accommodate an increase in the frequency of train services.
Sectorisation	RailCorp's operating strategy is to provide sectorisation of the Sydney metropolitan rail network, which means separating the network into discrete sectors that can operate independently. The benefits of sectorisation include improved service reliability, and greater capacity to increase service frequency and network capacity.
Maintenance vehicle access	Maintenance vehicle access refers to the location at which maintenance vehicles are able to access a rail corridor. High accessibility to a rail corridor enables quicker and easier access for maintenance vehicles.

Criteria	Definition and description
Ground-borne noise and vibration	The operation of trains on railway track within tunnel is a source of ground-borne noise and vibration. The NSW Department of Environment and Climate Change's (2007) *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* identifies 35 dBA $L_{A\ max}$ as the ground-borne noise trigger level above which further investigation of potential noise impacts inside buildings and identification of feasible and reasonable mitigation measures is recommended (refer to Appendix C).
Number of residential dwellings located over the alignment corridor	As discussed in Section 2.1, TIDC understands that, in general, the community would prefer that a tunnel be located below public roads and parks rather than under residential properties. This preference is due to community perceptions about potential impacts to property values and the potential for construction and operational noise and vibration impacts. Table 4-2 and Appendix B identify the number of residential dwellings located over the 60 metre wide alignment corridor for each alignment option.
Vertical clearance of the proposed F3 Freeway to Sydney Orbital road tunnel	The Commonwealth Government proposes the development of a road to link the F3 Freeway at Wahroonga to the Sydney Orbital. The preferred corridor for the link is the 'purple' option, which is mostly in tunnel, and would connect the F3 Freeway at Wahroonga to the M2 Motorway at the Pennant Hills Road interchange. Other alignment options considered for the connection are the 'blue' and 'yellow' options. So as not to preclude the future development of any of these alignments, it is desirable that the alignment options for the Epping to Franklin Road Stations section of the North West Rail Link have a vertical clearance from the each option of at least two tunnel diameters.
Vertical clearance of peripheral M2 Motorway supporting structures and potential impacts	The M2 Motorway and its associated peripheral structures, including Murray Farm Road overbridge, Kent Street pedestrian overbridge, Beecroft Road flyover, and the Main North Line rail overbridge, are significant infrastructure elements that are supported by different civil structures, such as viaduct or bridges with deep footings and piles. In the vicinity of these structures, the construction of a rail tunnel would introduce significant project risk, particularly where piles support these structures. Project risk would result in increased construction costs and time. There is also the potential for the closure of roads (or rail) whilst construction is occurring in the vicinity.

4.3 Performance of the alignment options

TIDC and its consultants have undertaken investigations to determine the relative performance of the alignment options against each of the criteria discussed in Section 4.2. The investigations included establishing engineering models for each of the alignments to determine their horizontal and vertical alignments and design characteristics, including length, gradient, and curvature. Other studies were undertaken to assess potential ground-borne noise and vibration issues for the alignment options (refer to Appendix C) and to count the number of dwelling located above each alignment option (refer to Appendix B).

The investigations identified that the performance of the alignment options was the same or very similar for some criteria, as follows:

- *tunnel depth* — The alignment options would be located beneath residential dwellings at a range of depths (see Table 4-2). The study of ground-borne noise and vibration found that compliance with the ground-borne noise trigger levels would be achieved at all locations for all alignment options for a floating slab track design (refer to Appendix C and the discussion of the ground-borne noise and vibration criteria in Table 4-1 and below).

- *engineering design* — All the alignment options would comprise twin bored tunnels with emergency cross passages and, potentially, ventilation shafts at the alignment midpoint between the Epping and Franklin Road Stations.
- *construction site and method* — All the alignment options would be constructed by a tunnel boring machine that would likely be launched from a site west of or at Franklin Road Station.
- *environmental impacts* — All the alignment options would have the same potential impacts on biodiversity and archaeological heritage items at the construction site mentioned above. The construction noise, traffic, air quality and waste impacts of the options would differ and are described in Table 4-2.
- *community and social impacts* — All the alignment options would provide improved access to and within north-west Sydney, improved access to employment and services, and employment opportunities resulting from construction and operation of the project and rail associated development. All the options would also potentially increase social interaction and provide greater potential for the development of a local identity by providing a social focal point. All the options would result in similar reductions in car dependency. The amenity impacts and journey times of the options would differ and are described in Table 4-2.
- *property purchase* — All the options would require surface property acquisitions at the proposed Franklin Road Station precinct and for emergency egress and ventilation facilities.
- *emergency egress* — All the options would provide a similar level of emergency egress.
- *ventilation* — The ventilation design would be the same for all the alignment options and would likely comprise an intermediate ventilation shaft. The optimal location for the ventilation shaft is within the central 10% of the length of tunnel between Epping and Franklin Road Stations. This equates to an approximately 650 metre length of the tunnel alignment. The exact location of the ventilation shaft would be determined during the detailed design of the Concept Plan (once approved).
- *operational functionality and flexibility* — All the alignment options would provide the same operational functionality and flexibility by including a facing crossover north of Epping Station. The crossover would provide a facility for turnback operations so that trains travelling to Epping from Rouse Hill via the North West Rail Link could terminate at Epping and return to Rouse Hill.
- *sectorisation* — All the alignment options would achieve the objective of sectorisation by connecting directly to the Epping to Chatswood Rail Link at Epping. The North West Rail Link would form part of a new sector that would also comprise the Epping to Chatswood Rail Link, CBD Rail Link and South West Rail Link. None of the alignment options would connect with or impact train operations on the Main North Line, which would form part of a different sector.
- *maintenance vehicle access* — For all the alignment options, maintenance vehicles would access the Epping to Franklin Road Stations section of tunnel via the Main North Line down dive structure constructed at Epping as part of the Epping to Chatswood Rail Link.

- *ground-borne noise* — Ground-borne noise modelling of the alignment options indicates that ground-borne noise can be mitigated through track design (refer to Appendix C). As a result, ground-borne noise would not distinguish between the performance of the alignment options.

The alignment options differ in their performance relative to all of the other criteria discussed in Section 4.2. These differences can be used to differentiate between the options. The assessed performance of the options against these 'differential criteria' is outlined in Table 4-2.

Table 4-2: Performance of the alignment options relative to differential criteria

Differential criterion	Green alignment	Blue alignment	Pink alignment	Gold alignment	Brown alignment
Construction					
Tunnel length (down line, kilometres)	5.950 kilometres	6.265 kilometres	6.180 kilometres	6.600 kilometres	6.600 kilometres
Tunnel depth (rail level to surface, metres)	Ranging from 13 metres immediately north of Epping Station to 53 metres under Copeland Road	Ranging from 13 metres immediately north of Epping Station to 59 metres under Beecroft Road	Ranging from 13 metres immediately north of Epping Station to 27 metres under Copeland Road	Ranging from 13 metres immediately north of Epping Station to 66 metres under Pennant Hills Golf Course and 53 metres under Copeland Road	Ranging from 19 metres at the M2 Motorway to 50 metres under Beecroft Village Green and 49 metres under Beecroft Primary School.
Capital cost (for comparison purposes only)	Approx. $590 million (least expensive option due to shortest tunnel length)	Approx. $620 million (greater than the green alignment due to the increased tunnel length)	Approx. $610 million (greater than the green alignment due to the increased tunnel length)	Approx. $650 million (equal highest initial cost estimate due to the proposed tunnel length)	Approx. $650 million (equal highest initial cost estimate due to the proposed tunnel length)
Potential impacts on the environment					
Environmental impact	*Spoil* ▪ Shortest tunnel length and, therefore, least spoil requiring off-site disposal	▪ Longer tunnel length relative to the green alignment would result in approximately 13,750 cubic metres more spoil requiring off-site disposal than the green alignment	▪ Longer tunnel length relative to the green alignment would result in approximately 7,900 cubic metres more spoil requiring off-site disposal than the green alignment	▪ Longest tunnel length and, therefore, the largest volume of spoil requiring off-site disposal; approximately 36,850 cubic metres more spoil would require off-site disposal than the green alignment	▪ Longest tunnel length and, therefore, the largest volume of spoil requiring off-site disposal; approximately 36,850 cubic metres more spoil would require off-site disposal than the green alignment
	Traffic ▪ Shortest tunnel length and, therefore, least requirement for off-site disposal of spoil and associated truck movements and traffic impacts	▪ Longer tunnel length relative to the green alignment would result in approximately 1,400 additional truck movements and other traffic impacts	▪ Longer tunnel length relative to the green alignment would result in approximately 800 additional truck movements and other traffic impacts	▪ Longest tunnel length and, therefore, the greatest number of truck movements and potential for traffic impacts; there would be approximately 3,800 additional truck movements and other traffic impacts relative to the green alignment	▪ Longest tunnel length and, therefore, the greatest number of truck movements and potential for traffic impacts; there would be approximately 3,800 additional truck movements and other traffic impacts relative to the green alignment
	Energy ▪ Shortest tunnel length and, therefore, lowest construction energy consumption and lowest generation of greenhouse gas emissions	▪ Longer tunnel length relative to the green alignment would result in greater construction energy consumption and greenhouse gas emissions	▪ Longer tunnel length relative to the green alignment would result in greater construction energy consumption and greenhouse gas emissions	▪ Longest tunnel length and, therefore, the greatest construction energy consumption and greenhouse gas emissions	▪ Longest tunnel length and, therefore, the greatest construction energy consumption and greenhouse gas emissions
	▪ Shortest tunnel length and similar but generally shorter maximum gradient results in lowest operational electricity use and, therefore, greater greenhouse gas emissions	▪ Longer tunnel length and a similar but longer maximum gradient results in greater operational electricity use than the green alignment and, therefore, greater greenhouse gas emissions	▪ Longer tunnel length and an equal but longer maximum gradient results in greater operational electricity use than the green alignment and, therefore, greater greenhouse gas emissions	▪ Longest tunnel length and the highest and longest maximum gradient results in the greatest operational electricity use and, therefore, the greatest greenhouse gas emissions	▪ Longest tunnel length and a similar but longer maximum gradient results in greater operational electricity use than the green alignment and, therefore, greater greenhouse gas emissions
	Air quality ▪ Shortest tunnel length and, therefore, least potential for air quality impacts associated with construction vehicle emissions and dust generation from spoil handling	▪ Longer tunnel length would result in greater potential for air quality impacts than the green alignment, due to increased construction vehicle movements and volumes of spoil	▪ Longer tunnel length would result in greater potential for air quality impacts than the green alignment, due to increased construction vehicle movements and volumes of spoil	▪ Longest tunnel length and, therefore, the greatest potential for air quality impacts due to increased construction vehicle movements and volumes of spoil	▪ Longest tunnel length and, therefore, the greatest potential for air quality impacts due to increased construction vehicle movements and volumes of spoil

Differential criterion	Green alignment	Blue alignment	Pink alignment	Gold alignment	Brown alignment
Community and social impacts (including construction duration)	Shortest tunnel length and, therefore, the shortest construction period and least potential for disruption during construction due to traffic, noise, vibration, and dust	Increased tunnel length (relative to green alignment) would result in approximately one week of additional tunnel boring, thereby increasing traffic, noise and dust impacts	Increased tunnel length (relative to green alignment) would result in approximately one week of additional tunnel boring, thereby increasing traffic, noise and dust impacts	Longest tunnel length would result in approximately three weeks of additional tunnel boring relative to the green alignment, thereby increasing traffic, noise and dust impacts	Longest tunnel length would result in approximately three weeks of additional tunnel boring relative to the green alignment, thereby increasing traffic, noise and dust impacts
Operation and maintenance					
Maximum track speed as a result of track geometry (kilometres per hour with maximum cant deficiency)	Minimum track radius of 800 metres beneath the Koala Park Sanctuary in West Pennant Hills, resulting in a maximum track speed of 116 kilometres per hour through this curve	Minimum track radius of 800 metres beneath Chapman Avenue in Beecroft, resulting in a maximum track speed of 116 kilometres per hour through this curve	Minimum track radius of 800 metres beneath Austral Avenue in Beecroft, resulting in a maximum track speed of 116 kilometres per hour through this curve	Minimum track radius of 700 metres beneath Pennant Hills Golf Course, resulting in a maximum track speed of 108 kilometres per hour through the curve Several reverse curves would also affect passenger ride quality	Minimum track radius of 600 metres beneath Cheltenham Station in Cheltenham, resulting in a maximum track speed of 100 kilometres per hour through this curve
Journey time	Shortest tunnel length and least curves would result in shortest journey time	Increased tunnel length would result in a journey time approximately 9 seconds longer than the green alignment	Increased tunnel length would result in a journey time approximately 5 seconds longer than the green alignment	Longest tunnel length would result in the longest journey time, which would be approximately 24 seconds longer than the green alignment	Longest tunnel length would result in the longest journey time, which would be approximately 24 seconds longer than the green alignment
Ride quality	Straightest track geometry resulting in the greatest passenger comfort	Track geometry less straight than the green alignment, resulting in reduced passenger comfort	Track geometry less straight than the green alignment, resulting in reduced passenger comfort	Least straight of the alignments, resulting in the lowest level of passenger comfort. Multiple reverse curves could potentially cause passengers to experience discomfort	Track geometry less straight than the green alignment, resulting in reduced passenger comfort
Impacts to the approved Epping to Carlingford rail corridor (also refer to Figure A-2 in Appendix A)	No impact on the approved Epping to Carlingford rail corridor	Would extend outside of the approved Epping to Carlingford rail corridor	No impact on the approved Epping to Carlingford rail corridor	Would extend outside of the approved Epping to Carlingford rail corridor	Would extend outside of the approved Epping to Carlingford rail corridor
Maximum gradient (%)	2.8% for approximately 550 metres from Epping Station and 2.4% over a length of approximately 3.8 kilometres for the long section of tunnel	2.8% for approximately 700 metres from Epping Station and 2.1% over a length of approximately 4.7 kilometres for the long section of tunnel	2.8% for approximately 700 metres from Epping Station and 2.4% over a length of approximately 3.7 kilometres for the long section of tunnel	2.9% over a length of approximately 3.1 kilometres from Pennant Hills Golf Course to the proposed Franklin Road Station	2.8% for approximately 800 metres from Epping Station and 2.1% over a length of approximately 4.5 kilometres for the long section of tunnel from underneath Cheltenham Station to Franklin Road Station
Maintainability	Straightest track geometry, resulting in the lowest potential for maintenance	Track geometry less straight than the green alignment, resulting in greater potential for maintenance	Track geometry less straight than the green alignment, resulting in greater potential for maintenance	Least straight of the alignments, resulting in greatest potential for maintenance. Multiple reverse curves would cause uneven wear and potential for more rigorous inspection of fastenings	Track geometry less straight than the green alignment, resulting in greater potential for maintenance
Operation and maintenance cost	Lowest operation and maintenance cost due to straightest and shortest alignment and, therefore, best maintainability and lowest energy consumption	Likely to have higher operation and maintenance costs than the green alignment due to worse maintainability and a longer tunnel, resulting in greater energy consumption	Likely to have higher operation and maintenance costs than the green alignment due to worse maintainability and a longer tunnel, resulting in greater energy consumption	Likely to have the highest operation and maintenance cost as a result of having the worst maintainability, longest tunnel length and steepest gradient	Likely to have higher operation and maintenance costs than the green alignment due to worse maintainability and a longer tunnel, resulting in greater energy consumption
Number of residential dwellings located over the alignment corridor	Approximately 339 dwellings would be located over the 60 metre wide rail corridor between Epping and Franklin Road Stations	Approximately 504 dwellings would be located over the 60 metre wide rail corridor between Epping and Franklin Road Stations; this is 165 more dwellings than the green alignment. Also, should the Epping to Parramatta Rail Link proceed, modification of the approved Epping to Carlingford alignment would be required and, as a result, this alignment would extend beneath additional dwellings not currently affected by the approved	Approximately 312 dwellings would be located over the 60 metre wide rail corridor between Epping and Franklin Road Stations; this is 27 fewer dwellings than the green alignment	Approximately 263 dwellings would be located over the 60 metre wide rail corridor between Epping and Franklin Road Stations; this is 76 fewer dwellings than the green alignment. However, should the Epping to Parramatta Rail Link proceed, modification of the approved Epping to Carlingford alignment would be required and, as a result, this alignment would extend beneath additional dwellings not currently affected by the approved	Approximately 229 dwellings would be located over the 60 metre wide rail corridor between Epping and Franklin Road Stations; this is 110 fewer dwellings than the green alignment and the fewest dwellings located over any of the alignment option corridors. However, should the Epping to Parramatta Rail Link proceed, modification of the approved Epping to Carlingford alignment

Differential criterion	Green alignment	Blue alignment	Pink alignment	Gold alignment	Brown alignment
		corridor and not included in the preceding dwelling numbers (currently not quantified)		corridor and not included in the preceding dwelling numbers (currently not quantified)	would be required and, as a result, this alignment would extend beneath an additional 125 dwellings not currently affected by the approved corridor and not included in the preceding dwelling numbers
Vertical clearance of the proposed F3 Freeway to Sydney Orbital road tunnel	Approximately 24 metres vertical clearance of the purple alignment	Approximately 15 metres vertical clearance of the purple alignment	Approximately 20 metres vertical clearance of the purple alignment	Approximately 34 metres vertical clearance of the purple alignment	Approximately 15 metres vertical clearance of the purple alignment
	Vertical clearances of the blue and yellow alignments are yet to be determined	Vertical clearances of the blue and yellow alignments are yet to be determined	Vertical clearances of the blue and yellow alignments are yet to be determined	Vertical clearances of the blue and yellow alignments are yet to be determined	Vertical clearances of the blue and yellow alignments are yet to be determined
Vertical clearance of peripheral M2 Motorway supporting structures and potential impacts	There would be potential project risk at the Kent Street pedestrian overbridge. There would be a potential need for temporary closure of the overbridge during construction	There would be potential project risk at the Beecroft Road flyover. There would be a potential need for temporary closure of Beecroft Road at the flyover during construction	There would be potential project risk at the Murray Farm Road overbridge and Kent Street pedestrian overbridge. There would be a potential need for temporary closure of these overbridges during construction	There would be potential project risk at the Murray Farm Road overbridge, Kent Street pedestrian overbridge and Beecroft Road flyover. There would be a potential need for temporary closure of these overbridges and the flyover during construction	There would be potential project risk at the Main Northern Line rail overbridge. There would be a potential need for temporary closure of the Main Northern Line during construction. Alternatively, construction at this location could be restricted to a scheduled track possession

Sources: TIDC 2006, TIDC 2007a

4.4 Comparative performance of the alignment options

Table 4-2 identifies that the key differences in the performance of the five direct tunnel alignment options are:

- tunnel length and, associated with this, capital cost, spoil generation and disposal, duration of construction works, journey time, and operating cost
- straightness of the track geometry and, associated with this, maximum track speed, ride quality, maintainability, and maintenance cost
- the number of dwellings located above each alignment corridor and the tunnel depth under these properties
- impacts to the approved Epping to Carlingford rail corridor.

The other comparison criteria shown in Table 4-1 did not distinguish between the alignment options. For example, all the alignment options are likely to have the same construction site and method, provide the same operational flexibility and functionality, and achieve very low ground-borne noise and vibration levels subject to appropriate track design.

The green alignment is the most direct alignment between the Epping and Franklin Road Stations and, therefore, has the shortest tunnel length, journey time and construction period; the lowest capital cost; would generate the smallest volume of spoil and, therefore, the least spoil haulage truck movements; and would consume the least energy during construction.

The green alignment also has the greatest length of straight track and, therefore, most comfortable ride, best maintainability and lowest maintenance cost.

The maximum gradient of the green alignment is similar to the maximum gradients of the other alignment options, however, the green alignment is generally at a maximum gradient for shorter distances that the other alignment options. This, combined with the fact it would have the shortest tunnel length and straightest track, would result in the green alignment having the lowest energy consumption during operation and, therefore, the lowest operation and maintenance cost, and the lowest total or life cycle cost.

The blue, pink, gold and brown alignments would all have longer tunnels and a greater number of track curves than the green alignment and, therefore, higher capital costs, greater generation of spoil and spoil haulage truck movements, reduced ride quality, longer journey times, worse maintainability, greater energy consumption during operation, higher operation and maintenance costs, and higher life cycle costs.

The gold alignment would have the longest tunnel and also the greatest number of track curves. It is, therefore, the worst performing option in terms of capital cost, spoil generation and spoil haulage, ride quality, journey time, maintainability, energy consumption during operation, operation and maintenance cost, and life cycle cost. The gold alignment would also have the greatest project risk as it would be located in the vicinity of piles for the Murray Farm Road overbridge, Kent Street pedestrian overbridge and Beecroft Road flyover.

Only the green and pink alignments would enable a future extension from Epping to Parramatta to be constructed within the approved project corridor. The blue, gold and brown alignments would require modifications to the approved Epping to Carlingford alignment and would, therefore, require modifications to the approved rail corridor.

The pink, gold and brown alignment corridors would be located beneath fewer residential dwellings that the green alignment. However, for the gold and brown alignments only, should the Epping to Parramatta Rail Link proceed, provision would need to be made for a tunnel alignment outside the approved Epping to Carlingford corridor. This alignment would extend beneath additional dwellings not currently affected by the approved corridor. As a result, the gold and brown alignments would result in location of a greater number of dwellings above rail tunnels than is indicated in Table 4-2.

4.5 Preferred alignment option

The Preferred Project Report (TIDC 2007a) identified the green alignment as the preferred alignment for the North West Rail Link project between the Epping and Franklin Road Stations. An options comparison is presented in Table 4-2 and Section 4.4 for the green alignment, other alignment options contained in the Preferred Project Report, and those alignment options proposed in community submissions to the Preferred Project Report that would meet the strategic objectives of the project. The options comparison demonstrates that, the green alignment would provide the overall best performance against a range of construction, environmental and operation and maintenance criteria.

5. Conclusion

This report has considered five direct tunnel connection alignment options for the Epping to Franklin Road Stations section of the North West Rail Link project. A direct tunnel connection was also considered between the Carlingford and Franklin Road Stations; however, this alignment option would not meet the strategic objectives of the North West Rail Link project and was not, therefore, considered in detail (refer to Section 4.1).

The relative performance of the five alignment options was assessed against a range of criteria, including construction impacts, impacts to surrounding areas, and operation and maintenance issues (refer to Sections 4.2 and 4.3). Based on the comparison of the performance of the alignment options, the green alignment is considered to provide the overall best performance.

The key advantages of the green alignment relative to the other options are:

- It would have the lowest life cycle cost, including a capital cost indicatively between $20 to 60 million less than other options, and reduced ongoing operation and maintenance costs.
- It is shorter than the other four alignments by between 230 and 650 metres.
- It would have the least construction impacts including the shortest construction period, smallest volume of spoil generation (up to 36,000 cubic metres less spoil) and the least spoil haulage truck movements.
- It would provide the best ride quality because it is straighter than the other alignments and has no reverse curves.

The green alignment would also have the following additional advantages:

- It would have the shortest journey time by between 5 and 24 seconds.
- It would require the least maintenance.
- It would consume the least energy and generate the least greenhouse gas emissions during construction and operation.
- It would not impact the approved corridor for the Epping to Parramatta Rail Link.

All the alignment options would be located below residential areas. While the green alignment would be located below a greater number of residential dwellings than three of the other alignments, all the alignments would achieve very low ground-borne noise and vibration levels subject to appropriate track design.

References

Department of Environment and Climate Change's (2006), *Assessing Vibration – A Technical Guide*

Department of Environment and Climate Change 2007, *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects*

TIDC 2006, *Metropolitan Rail Expansion Program, North West Rail Link Environmental Assessment and Concept Plan*

TIDC 2007a, *Metropolitan Rail Expansion Program, North West Rail Link Preferred Project Report*

TIDC 2007b, *Metropolitan Rail Expansion Program, North West Rail Link Supplementary Submissions Report*

TransportNSW 2002, *Connecting Communities, North West Rail Link Overview Report*

Appendix A

Alignment options map

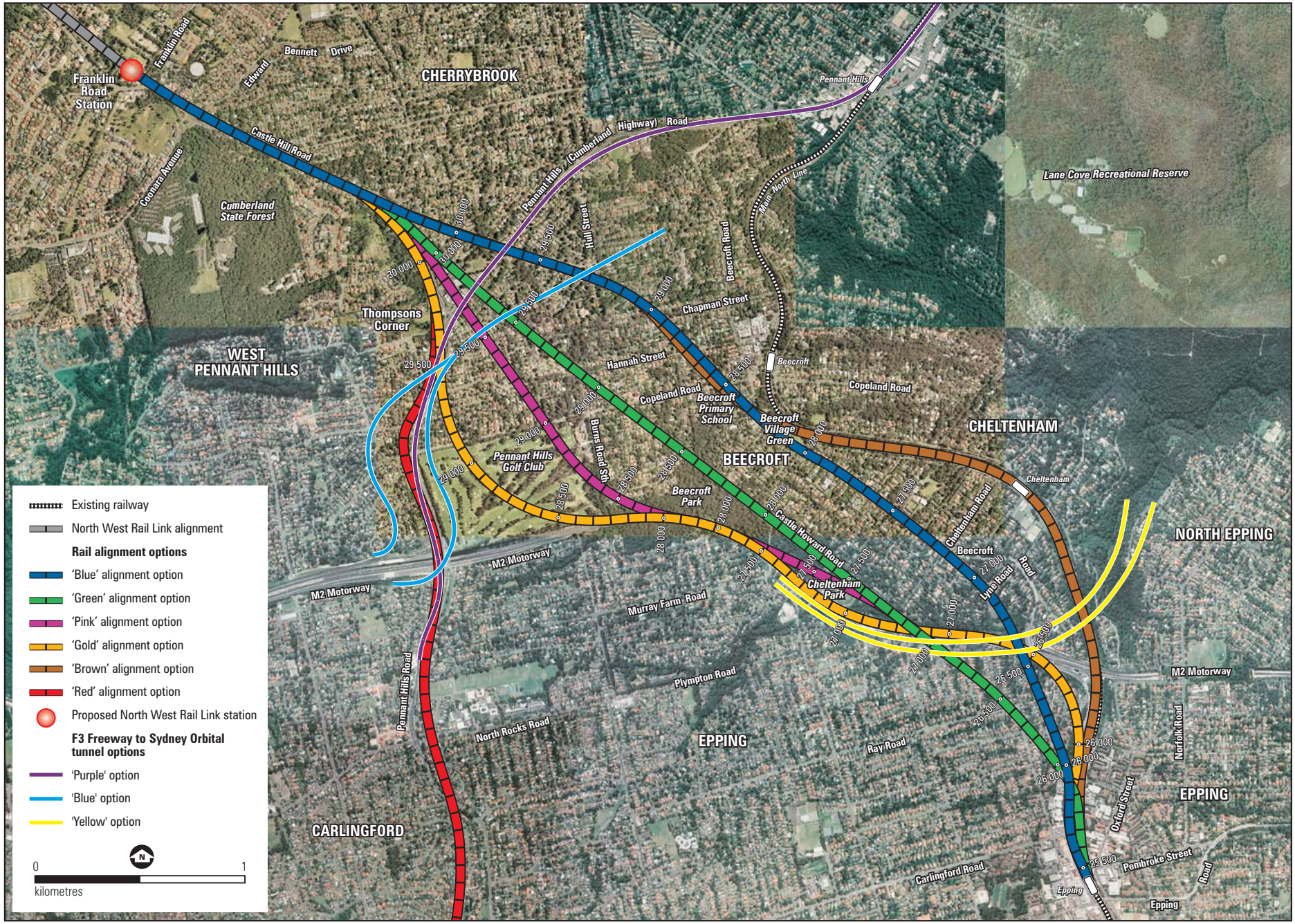


Figure A-1 Direct tunnel alignment options

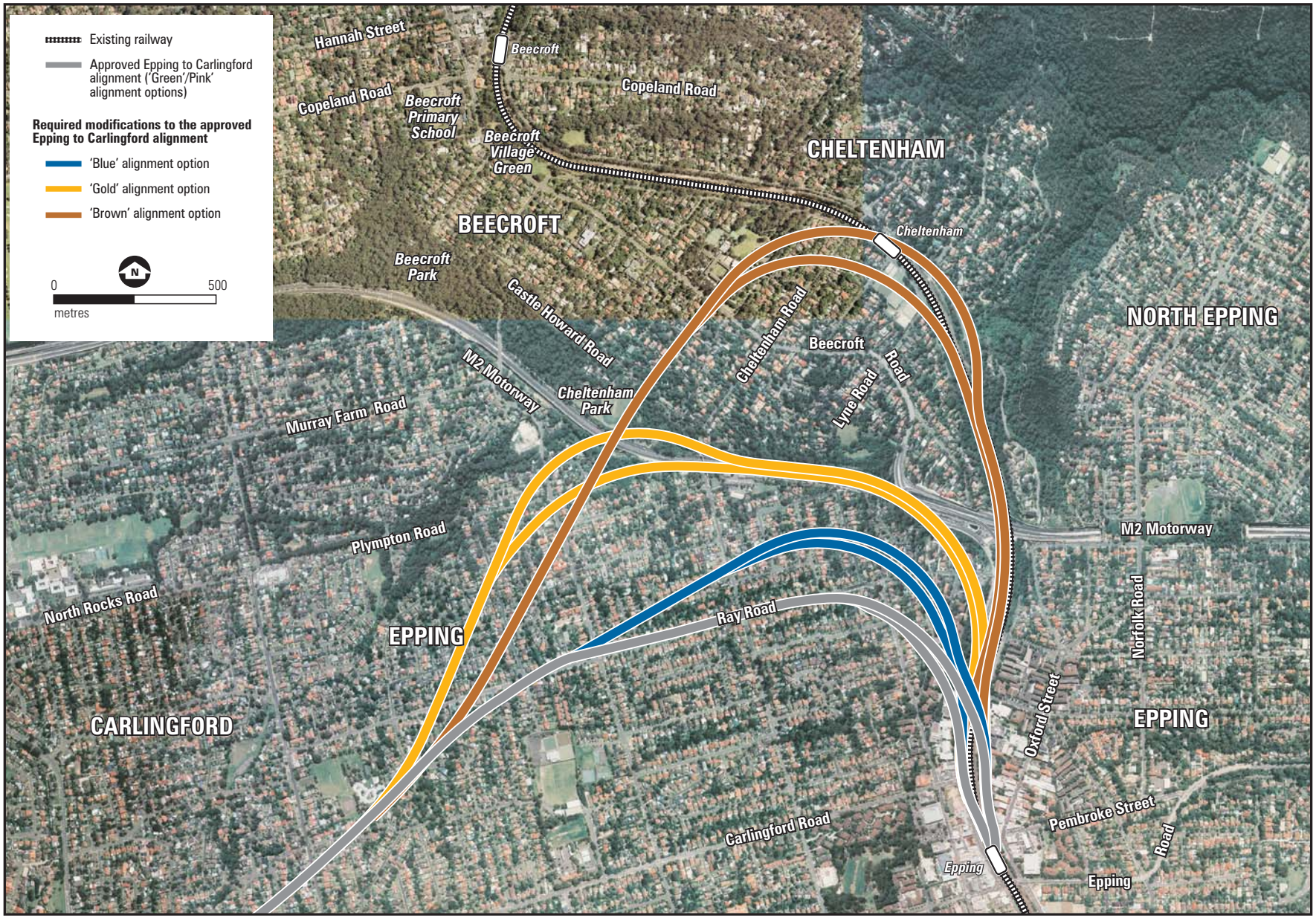


Figure A-2 Required modifications to the approved Epping to Carlingford alignment

Appendix B

Land use details

Appendix C

Ground-borne noise study