Before the Board of Inquiry
Waterview Connection Project

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in the matter of: the Resource Management Act 1991

and

in the matter of: a Board of Inquiry appointed under s 149J of the Resource Management Act 1991 to decide notices of requirement and resource consent applications by the NZ Transport Agency for the Waterview Connection Project

Rebuttal evidence of **Robert Mason (Design Manager)** on behalf of the **NZ Transport Agency**

Dated: 2 February 2011

Hearing start date: 7 February 2011

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REBUTTAL EVIDENCE OF ROBERT MASON ON BEHALF OF THE NZ TRANSPORT AGENCY

INTRODUCTION

1 My full name is Robert Mason. I have a Bachelor of Engineering Degree (Civil) with honours from Auckland University. I am a member of the IPENZ Transportation Group.

2 I am a Technical Director of Transportation in Auckland at Beca Infrastructure Limited (*Beca*) and have over 15 years of experience in Transportation Engineering, including design management, and traffic and road safety engineering both in New Zealand and overseas. I have extensive experience in traffic and road safety engineering, and have also been the design manager on several roading projects.

3 Projects I have worked on include:

3.1 Design Manager for the Waterview Connection Project since 2003 (geometric design review, road safety audit responses and design changes);

3.2 Design Manager for the Glenfield Road Corridor Upgrade (geometric design review, road safety audit responses and design changes);

3.3 Road Safety Manager for the Region 2 State Highway Network Management Contract;

3.4 Road Safety Audit of major motorway projects - Additional Waitemata Harbour Crossing;

3.5 Road Safety Audit of major motorway projects – Bell Block Bypass;

3.6 Road Safety Audit of major motorway projects – Northern Motorway Northcote to Sunnynook Auxiliary lane;

3.7 Road Safety Audit of major expressway projects – SH1 Longswamp to Rangiriri 2 + 1; and

3.8 Road Safety Audit of major expressway projects – SH1 Rangiriri to Ohinewai 4-laning.

4 My rebuttal evidence is given in support of notices of requirement and applications for resource consents lodged with the Environmental Protection Authority (*EPA*) by the NZ Transport Agency (*NZTA*) on 20 August 2010 in relation to the Waterview Connection Project (*Project*).

5 I am familiar with the area that the Project covers, and the State highway and roading network in the vicinity of the Project.

6 I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Consolidated Practice Note (2006), and agree to comply with it. In preparing my evidence, I have not omitted to consider material facts known to me that might alter or detract from my opinions expressed.

PURPOSE OF EVIDENCE

7 The purpose of this rebuttal evidence is to respond to certain aspects of the evidence lodged by submitters primarily regarding the issue of providing a local connection to SH20 at Great North Road Interchange. Specifically, my evidence will respond to the evidence of:

7.1 Sir Harold Marshall (Submitter No. 20-1);[1]

7.2 Mr John Parlane, on behalf of Sir Harold Marshall (Submitter No. 20-2);

7.3 Mr Duncan McKenzie, on behalf of Living Communities (Submitter No. 167-3); and

7.4 Mr Peter McCurdy, on behalf of Star Mills Preservation Society (Submitter No. 199-1).

8 In addition, I will comment on relevant aspects of the Section 42A report prepared by Environmental Management Services (*EMS*) dated 7 December 2010 (*Section 42A Report*) and the Addendum Section 42A Report dated 20 December 2010 (*Addendum Report*).

9 This evidence also includes comments relating to the design of local access issues discussed in expert transport caucusing.[2]

DESIGN OF GREAT NORTH ROAD INTERCHANGE - BACKGROUND

10 Before I respond to the specific proposals by some submitters for on and off ramps to provide local access to SH20 at the Great North Road Interchange, I will provide some relevant background to the NZTA's design of the Interchange. As noted earlier, I have been the Design Manager for the Project since 2003 and, accordingly, I have

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1 References are to the Submitter's Evidence as listed on the EPA website.

2 I attended expert transport caucusing on 21 January and 28 January 2011. As at the date my rebuttal evidence was finalised, the expert report had not been signed, so I have not attached it to my rebuttal.

detailed knowledge of the rationale behind and constraints associated with the current Interchange design.

11 Throughout the development of the design over the past 8 years, the design team has investigated a considerable number of local ramp options along the length of the route between Maioro Street and SH16, including at New North Road, Great North Road (near Blockhouse Bay Road) and at the existing Great North Road interchange.[3]

12 The Great North Road Interchange design is very complex, incorporating new motorway to motorway connections in two directions and existing local road ramp connections. Those all need to be accommodated within a small area with significant constraints. As a result of the design challenges presented, a considerable number of options for the Great North Road Interchange have been investigated, including the provision of local ramp connections. Notwithstanding these extensive investigations, I have not identified a local ramp solution that would be achievable without significant design and safety issues, and significant adverse environmental effects.

13 The key factors that informed and 'constrained' design options for the Great North Road Interchange included:

13.1 The extent of the Coastal Marine Area;

13.2 The location and extent of archaeological sites and heritage area;

13.3 The design and alignment of the Cycleway adjacent to SH16;

13.4 Safety and geometrics for the Great North Road Interchange; and

13.5 Existing designations, particularly to the east: Unitec and Mason Clinic.[4]

14 The nature of these specific elements and the factors considered in the Great North Road Interchange design are discussed in turn

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[3] These various options have been investigated and, are recorded in a number of reports, including: "Final Draft Preliminary Scheme Assessment Report" (March 2002) Beca; "Final Preliminary Scheme Assessment Report" (Sept 2002) Beca; "Options SAR & AEE" (Sept 2003) Beca; "SH20 Avondale Extension Background Report" (April 2005) Beca; "Driven Tunnel Concept Feasibility Report" (July 2006) Connell Wagner; "SH20 Waterview Connection Traffic Modelling Summary Report" (Mar 2007) Beca; "Waterview Connection Driven Tunnel Concept Options Estimate Design Report" (Sep 2007) Connell Wagner.

[4] Unitec is located at 139 Carrington Road (Designation No. D04-10) and the Mason Clinic is located at 81 Carrington Road (Designation No. D04-14) in the Auckland City District Plan (Isthmus Section).

below. I attach a plan that shows the NZTA's proposed design of the Interchange as **Annexure A** to my rebuttal.

Coastal Marine Area

15 All of the ramp connections pass over the Coastal Marine Area (*CMA*) at the Oakley Creek inlet. The design of the Interchange was developed with a view to minimise both the length of bridge that spanned across the CMA and the pier locations within the CMA, while still maintaining adequate ramp geometry. In particular, the design sought to minimise any encroachment of the ramp piers in the 'Oakley Inlet Channel' within the CMA.

Archaeological sites

16 A heritage area is located on the banks of the Oakley Creek inlet (as described in paragraph 29 of Dr Clough's evidence in chief and marked on **Annexure A**). The design of the Interchange was developed so that the ramps avoid this site as much as practicable. While some minor encroachment above the site is necessary to accommodate the eastbound ramp connections (Ramps 3 and 4 are shown on **Annexure A**), the NZTA's archaeologist, Dr Rodney Clough, and the design team identified an appropriate location for these ramps that minimised the impacts on this heritage area.

Cycleway

17 Various options were considered to provide for the cycleway adjacent to SH16 beneath/over Ramp 2. The proposed design for Ramp 2 was considered to provide an appropriate balance between cycleway requirements and visual impacts on Waterview Crescent properties. Any reduction in ramp height may prevent or reduce the feasibility of the cycleway alignment running beneath Ramp 2.[5]

Safety/Geometrics

18 The Great North Road Interchange connects the proposed SH20 motorway with the North Western Motorway (*SH16*). As such, the Interchange must provide ramp connections that tie in with the existing geometry and levels of SH16, to both the east and the west.

19 To the east of the Interchange, Carrington Road passes over the existing SH16 motorway. Therefore, the new connections to the east could either pass over or beneath Carrington Road. However, as Carrington Road is approximately 8m above the existing SH16 motorway, a bridge passing over would therefore require very high and long bridge structures extending east towards the St Lukes

[5] In the option assessment phase, an alternative was considered: requiring the cycleway to be constructed as a boardwalk within the CMA. This was considered less desirable for the cycleway and a resource consent for a boardwalk within the CMA has not been sought.

Interchange. On this basis, it was considered preferable to tie in the eastern ramp connections beneath Carrington Road, at the existing carriageway level, so that the existing clearance beneath Carrington Road is maintained.

20 To the west of the Interchange, the SH16 causeway is to be raised. The Interchange ramps to the west have been designed to tie in with the proposed causeway levels.

21 The design criteria adopted for the Project were initially taken from the NZTA 'Draft State Highway Geometric Design Manual' (*SHGDM*).[6] This manual was developed by the NZTA to amalgamate best practice geometric road design standards and guidelines in one manual. It sets out the design standards and procedures which apply to the State highway network. The purpose of the SHGDM is to ensure that a high degree of uniformity in road design and construction would be maintained across the State highway network, particularly across regional boundaries, and that road design reflect the NZTA's strategic plan for the State highway network.

22 In the absence of direction from the SHGDM on any specific matters, the Austroads design guides have been used. Austroads is an association of New Zealand and Australian road transport and traffic authorities.[7] Austroads' purpose[8] is to contribute to the achievement of improved Australian and New Zealand transport related outcomes by:

22.1 Undertaking nationally strategic research on behalf of Australasian road agencies and communicating outcomes;

22.2 Promoting improved practice by Australasian road agencies;

22.3 Facilitating collaboration between road agencies to avoid duplication; and

22.4 Promoting harmonisation, consistency and uniformity in road and related operations.

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6 "Draft State Highway Geometric Design Manual", NZTA December 2000 (formerly a Transit NZ document). The SHGDM was only issued in Draft, as there followed a move to integrate the Manual with the Austroads guides.

7 Austroads members are the Australian State Territory road transport and traffic authorities, the Australian Department of Infrastructure and Transport, the Australian Local Government Association and the NZTA.

8 Refer the Austroads Website at http://www.austroads.com.au/about_us.html.

23 The Austroads guides include the Guide to Road Design, which comprises 8 parts on different topics (such as geometric design, intersections and crossing, and interchanges). The Guide to Traffic Management comprises 13 parts, including a guide on intersections, interchanges and crossings. The Austroads guides have been used in conjunction with the SHGDM for the design of the Project. The NZTA has been formally integrating the new Austroads guides into its business since 2010.

24 In my opinion, the SHGDM and the Austroads guidelines represent best practice for State highway design in New Zealand and are appropriate for use in the development of the design for the Project.

25 Speed is the most important parameter in roading design. It is used to select geometric design features, such as alignment and cross section elements. The design alignment must reflect actual operating speeds on the road to allow the safe and efficient movement of traffic. Design speed is used to co-ordinate sight distance, radius, super-elevation and friction demand, so that drivers negotiating each element at that speed will not be exposed to unexpected hazards.

26 Given the geographic and environmental constraints, it is proposed that SH20 will be posted at 80km/hr, and this is expected to be consistent with the speed environment. While it is desirable to have a design speed 10km/h higher than the operating speed, the constraints at the Interchange dictate that in this case, the design speed shall be equal to the operating speed (in line with the minimum requirements of the SHGDM).[9]

27 The minimum radii that can be used for ramps are a function of the design speed and the super-elevation that is applied. The maximum super-elevation that can be applied to system ramps in this speed environment is 7%.[10] Applying this super-elevation to the design speed, the desirable minimum radius is 219m.[11]

28 The NZTA's proposed interchange system ramps have radii in the range of 250m to 362m, which are close to the minimum desirable. Due to the complex nature of the existing Great North Road Interchange, any reduction in ramp radius would impact on the connections with other ramps.

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[9] Section 2.6.2c of the SHGDM.

[10] Austroads Guide to Road Design Part 3: Geometric Design, Table 7.7.

[11] Austroads Guide to Road Design Part 3: Geometric Design, Table 7.5.

29 In order to tie in the horizontal curves of the ramps with the adjacent main alignment geometry, transition curves are used. These integrate with the changing rate of super elevation to provide a smooth alignment, and reduce the risk of vehicles losing control. Sufficient lengths of circular curves and transition curves are required for a safe alignment, and this consequently limits the ability to shorten the curve lengths and reduce the curve radii.

30 The Great North Road Interchange is a complex interchange, with four new system ramps connecting to an existing motorway, while maintaining the existing local connectivity. Any changes to one ramp will have an impact on the geometry of the other ramps due to the need for a consistent alignment at the ramp merges and diverges. In addition, any changes to the vertical or horizontal geometry will have a direct impact on the tunnel geometry.

31 The vertical grades also limit the flexibility at the Interchange. Vertical grades are limited to 3% desirable, 5% absolute maximum.[12] For the proposed design, a 5% grade has been adopted for Ramp 4 to enable it to rise up out of the tunnel and pass over the existing SH16 motorway.

32 There are also limitations on the location of merge and diverge areas, where the system ramps connect to the main motorways. These lengths are defined so as to provide sufficient time for vehicles to observe and interact with through traffic safely. In addition, merge areas should not be located within the tunnel due to the increased safety risk associated with merging traffic, and the proximity of the tunnel to the Interchange therefore constrains the position of the merge.

Unitec and Mason Clinic Designations

33 The area to the south east of the Great North Road Interchange is currently designated for education purposes, and is occupied by Unitec (as shown on **Annexure A**). The design of the Interchange was developed within the existing SH16 motorway designation at this location due to the close proximity of the heritage buildings located on the Unitec site to the proposed designation boundary (Building 1 is a Category A Heritage Building under the NZ Historic Places Trust and protected under the Auckland City District Plan (Isthmus Section).[13] As such, any impact to this building or modification to these protected surrounds was considered a major constraint for the Project.

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[12] Austroads Guide to Road Design Part 4C: Interchanges, section 9.3.1.

[13] First Statement of Evidence of Amelia Linzey, paragraph 82.

PROVISION OF LOCAL ACCESS TO SH20 AT THE GREAT NORTH ROAD INTERCHANGE

34 The statements of evidence of Sir Harold Marshall, Mr Parlane and Mr McKenzie raise concerns over the absence of provision for local access to SH20 at the Great North Road Interchange.[14]

35 Sir Harold proposes that an on ramp from the south side of Carrington Road could be provided in advance of the tunnel portal.[15] He also suggests that provision of an off ramp that could pass over SH16 and then under or over Ramp 3 (being the southbound connection from SH16 (west) to SH20), before joining with the existing off ramp from SH16 to Great North Road.[16]

36 Mr Parlane considers that local road ramps at Great North Road Interchange could be possible and should be investigated further.[17] He considers that motorway ramps are usually provided when a new urban motorway is built, and he considers their omission to be the exception rather than the rule.[18]

37 My evidence will respond to the proposed layouts included in Sir Harold's evidence,[19] and explain why local road connections to SH20 have not been provided.

Interchange spacing

38 Before doing so, I will first address the issue of interchange spacing raised by Mr Parlane (in paragraphs 7 and 8 of his evidence). Mr Parlane considers that not having local ramps onto SH20 is inconsistent with guidelines on interchange spacing. The interchange spacing on the new section of SH20 proposed by this Project is 4.4 km, being from Maioro Street Interchange in the south to the Great North Road Interchange in the north. This spacing accommodates the majority of local connections at the Interchange (being vehicles exiting from SH16 in both directions east and west, and vehicles entering at Great North Road to head both east and west). It is acknowledged that vehicles travelling north from Maioro

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14 Statement of Evidence of Sir Harold, paragraph 9, and the Statement of Evidence of John Parlane, paragraph 6, and the Statement of Evidence of Duncan McKenzie, paragraph 5.4.

15 Statement of evidence of Sir Harold, paragraph 17 and shown in concept plans at paragraph 21.

16 Statement of evidence of Sir Harold, paragraph 28.

17 Statement of evidence of John Parlane, paragraph 23.

18 Statement of evidence of John Parlane, paragraph 6. In response to that comment, I consider that local ramps should be provided where they are reasonably necessary, rather than just because they are 'normally' provided. Mr Murray addresses the issue of 'need' in his Rebuttal evidence, paragraph 83.

19 Statement of evidence of Sir Harold, paragraph 21, 22 and 25.

Street would not be able to exit at either St Lukes Road Interchange or Rosebank Road for approximately 6.7km, and that vehicles could not enter the motorway at Great North Road to head south.[20]

39 Mr Parlane identifies two guidelines that are used to design motorways, being the 'National Association of Australian State Road Authorities' (*NAASRA*) and the 'American Association of State Highway and Transportation Officials' (*AASHTO*). I note that Austroads came into being on 1 July 1989 replacing NAASRA. As noted earlier in my evidence, the Project design has been developed in accordance with the Austroads Guides (which I consider to be more consistent with the New Zealand road environment than the AASHTO Guide).

40 Austroads provides guidance on interchange spacing.[21] A copy of Section 6.3.1 of the Guide to Traffic Management is appended to my rebuttal evidence as **Annexure B**.

41 The Austroads guide for maximum spacing is generally consistent with the former NAASRA guide (stated in the evidence of Mr Parlane).[22] It recommends a "review of traffic service provided by the total road system when spacings exceed 4 km in urban areas".

42 For this Project, traffic analysis has been undertaken to review the traffic effects associated with the provision of local connections, as set out in the evidence of Mr Andrew Murray.[23] This identifies that the provision of a local connection to SH20 at Waterview would provide minimal (and probably detrimental) changes to the total network efficiency. I consider that Mr Murray's expert review satisfies the "review of traffic service" as recommended in the Austroads guide.

43 The Austroads guide also states that the <u>maximum</u> spacing is rarely a consideration in urban areas.[24] (By contrast, minimum spacing is certainly a consideration.) Austroads sets out six factors that

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[20] Mr Parlane states in paragraph 10 of his evidence that the distance between the Maioro Street Interchange and the Rosebank Road Interchange is 7.6km, although I have measured this to be 6.7km from the exit nose of each off ramp.

[21] Section 6.3.1 Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings.

[22] Statement of evidence of John Parlane, paragraph 8.

[23] Andrew Murray EIC, paragraph 110, and Rebuttal at paragraph 77.

[24] Section 6.3.1 Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings (Annexure B).

influence the location and spacing of urban interchanges, and recognises that:[25]

> "...in urban areas there is often limited flexibility regarding the location of the horizontal and vertical alignment of the main freeway and this may influence the feasibility of providing an interchange".

44 Each of the six factors that influence the location and spacing of interchanges is considered below in relation to Sir Harold's proposed SH20 connections:

44.1 *Strategic purpose of the section of freeway/motorway* –The primary function of a motorway is for the movement of traffic, rather than access. I consider the 'strategic purpose' to mean the specific purpose of this motorway (being part of the Western Ring Route (*WRR*)) as distinct from other Auckland motorways. I have therefore considered the objectives of the WRR to identify the strategic purpose of this motorway. I have identified the following WRR objectives[26] which indicate the strategic purpose of this section of motorway:

(a) To enhance inter regional trips and national economic growth and productivity;

(b) To provide an alternative route to SH1;

(c) To improve trip reliability from the west to the south, from the north to the south, and from the CBD to the Airport and south;

(d) To provide for traffic demands by providing new transport capacity for the fast growing western suburbs; and

(e) To enhance the efficiency of the overall network.

44.2 The proposed ramps would not contribute to the above objectives. If able to be designed safely and appropriately, then such ramps may not be contrary to those objectives However, as I will explain, I have significant concerns about safety and the operational problems associated with more connections in an already complex driving environment. On

[25] Section 6.3.1 Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings.

[26] The strategies and priorities relating to the WRR (and therefore the Waterview Connection) are set out in the NZTA's '2010/2013 Statement of Intent' (March 2009), as contained in Assessment of Environmental Effects, Part A, Section 3.2.

that basis, the proposed ramps would not be consistent with the 'strategic purpose' criteria.

44.3 *Network efficiency* – As set out in the EIC of Mr Murray, the provision of a local connection at Waterview would be inefficient and would probably have detrimental impact on the performance and usability of the motorway and local network.[27]

44.4 *Reducing community severance including provision for walking and cycling at interchanges* – The provision of a local road connection at Carrington Road would result in a major intersection being located where currently there is not one. Such an intersection would impact on the safety of cyclists and pedestrians crossing Carrington Road and increase delay to buses using Carrington Road, with consequent community severance effects.

44.5 *Traffic management strategies for abutting areas* – I am not aware of any strategies that include provision of a local road ramp connection to SH20 at Carrington Road. However, the key role for Carrington Road is a cross city route and it forms part of the Quality Transit Network (*QTN*) and regional cycle network.[28] Provision of an intersection on Carrington Road to serve a southbound connection to the motorway will increase turning movements, resulting in increased travel times for buses and introducing an impedance to the existing cycle network.

44.6 *Physical limitations* – As mentioned earlier in my evidence, there are physical constraints at the Great North Road Interchange that limit the opportunity to provide local ramps at Carrington Road. These are discussed further below for each ramp connection suggested by Sir Harold. In addition, 2.5km of the SH20 motorway between Great North Road and Maioro Street will be in tunnels, limiting the opportunity to provide an additional central interchange. As I will explain, a safe ramp alignment cannot be provided for either local road on or off ramps to SH20 without significant design and safety issues and significant adverse environmental effects.[29]

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[27] Andrew Murray EIC paragraph 110; and rebuttal evidence, paragraph 86.

[28] Auckland Regional Arterial Road Plan 2009, ARTA.

[29] The adverse environmental effects are also discussed in Amelia Linzey's rebuttal evidence.

44.7 *Availability of land* – The provision of Sir Harold's proposed southbound on ramp would require additional land currently designated for the Unitec campus, and the northbound off ramp connection would encroach on properties in the Point Chevalier area to the north of the Interchange, as described below.

45 In conclusion, there is no requirement for a maximum interchange spacing in urban areas and, using the Austroads guidance on interchange spacing, I consider that the provision of an intermediate interchange is not supported. It would need to be considered in conjunction with the traffic benefits and the impacts associated with providing such a connection. As noted in Mr Murray's rebuttal evidence, the provision of local ramps to Great North Road Interchange would be inefficient and would result in a negative benefit,[30] while creating adverse impacts on network safety and on the surrounding environment.

46 I now address each of Sir Harold's on and off ramp proposals in more detail below.

SH20 Southbound On Ramp from Carrington Road

47 Sir Harold considers that a southbound on ramp from the south side of Carrington Road could be provided in advance of the tunnel portal.[31] He suggests that the on ramp extend from Carrington Road over the westbound off ramp from SH16 to Great North Road, to join with Ramp 1 as an additional lane.[32] I disagree with both suggestions.

48 The Project design team has developed a concept alignment with appropriate geometry at the location suggested by Sir Harold and has overlaid this onto the design illustrated in Sir Harold's evidence.[33] Sir Harold's alignment and the design team's alignment are both shown on the plan attached as **Annexure C**.

49 Sir Harold suggests that (with his design) the three lanes in the southbound tunnel would then be for; the (new) local road connection from Carrington Road (left lane), the SH16 to SH20 westbound motorway connection Ramp 1 (middle lane), and the

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30 Andrew Murray EIC, paragraph 110; and rebuttal evidence at paragraph 78.

31 Statement of evidence of Sir Harold, paragraphs 13.5 and 17.

32 Statement of evidence of Sir Harold, paragraph 18.

33 Statement of evidence of Sir Harold, paragraph 22.

SH16 to SH20 eastbound motorway ramp connection Ramp 3 (right lane).[34]

50 However, in order to provide sufficient traffic capacity, the NZTA's proposed design includes a two lane connection from the west (being Ramp 3).[35] Therefore, I consider that with a two lane connection to the SH20 tunnel from SH16 west, the ramp suggested by Sir Harold would need to merge with the westbound connection from SH16 to SH20 southeast to form three lanes within the tunnel (as indicated by point 'F' on **Annexure C**).

51 There are a number of design reasons why Sir Harold's proposed on ramp is not feasible, as follows:

51.1 The vertical clearance required dictates the location where the suggested Carrington Road on ramp could first clear the SH16 westbound off ramp to Great North Road. This clearance cannot be provided until approximately 350m from Carrington Road (indicated by point 'D' on **Annexure C**). This compares to the approximately 220m as shown in the paragraph 22 of Sir Harold's evidence, which I disagree with (indicated by point 'B' on **Annexure C**).

51.2 The on ramp alignment suggested by Sir Harold would tie in with the proposed connection from SH16 (east) to SH20 (being Ramp 1) on the inside of a low radius curve (indicated by point 'C' on **Annexure C**). However, where this occurs, it would be difficult for an entering driver on the ramp to see approaching vehicles because of the observation angle. It would also be difficult for the entering driver to judge the length of approaching multi combination vehicles,[36] both resulting in increased accident risk. To avoid this, the merge area would need to be located on the straight alignment further to the south than that suggested by Sir Harold (indicated by point 'E' on **Annexure C**).

51.3 To achieve a ramp merge at the location suggested by Sir Harold, the existing retaining wall at the Unitec property would need to be reconstructed, as the existing wall does not permit a vertical alignment that would allow sufficient sight distance to the merge area. (See **Annexure C**) This would have impacts on the Unitec Heritage Building 1.

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[34] Statement of evidence of Sir Harold, paragraph 19.

[35] Andrew Murray's rebuttal evidence, paragraph 80.

[36] Austroads Guide to Road Design Part 4C: Interchanges section 7.4.

51.4 The on ramp suggested by Sir Harold would require provision of a compound curve (i.e. two adjoining curves with different radii as indicated by point 'A' on **Annexure C**, which in this case would result in a 'tightening' alignment at the location where drivers will be merging with traffic approaching from an acute angle behind them). This would create a safety problem thereby increasing the risk of loss of control crashes.

51.5 Ramp signals are currently being installed on the existing motorway ramps. The length of on ramp proposed by Sir Harold of 350m is not sufficient to accommodate absolute minimum ramp signal stacking requirements, nor the required flatter gradients at the ramp hold lines.

52 Sir Harold has stated that a new Carrington Road on ramp would have much in common with the SH16 on ramp at St Lukes Road,[37] although he acknowledges the "added complication of the SH16 off ramp". What Sir Harold fails to appreciate however is that the challenges in this area involve providing a direct motorway to motorway system ramp,[38] while maintaining the existing local road ramps to Great North Road. This presents a far greater level of complexity than St Lukes Road.

53 The provision of a further local road ramp from Carrington Road adds an additional level of complexity to what is already a highly demanding situation for drivers. The drivers with the highest demands would be those coming from SH16 east where they would need to pass through the complex departure area from SH16 where both the SH20 and Great North Road ramps are closely spaced. The Carrington Road on ramp would then merge on the left shortly after leaving the main motorway which is followed by a merge with southbound traffic from SH16 west within another short distance. They would then be faced with the changing environment of the tunnel entrance. This compares with a single simple on ramp merge at St Lukes Road. Therefore, in my opinion, the two interchanges cannot be compared directly.

54 The Project design team has developed a concept design alignment for the Carrington Road southbound on ramp at the location suggested by Sir Harold. This is shown in **Annexure D** to my rebuttal evidence. While being geometrically feasible, there are however significant adverse impacts associated with this design, as follows:

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[37] Statement of evidence of Sir Harold, paragraph 17.

[38] Compared to a local road connection at St Lukes.

54.1 The operation of an intersection on Carrington Road at this location is likely to be inefficient without considerable upgrade to Carrington Road, and the operation of the adjacent Great North Road intersection will be impacted.[39] (indicated by point 'A' on **Annexure D**).

54.2 The location where the Carrington Road on ramp joins the ramp from SH16 east is positioned adjacent to the ramp connection from SH16 west. I consider this to be unacceptable on safety grounds, as it is likely to cause drivers to fail to notice a lane change taking place on one side while attempting to merge on the other side, resulting in 'sideswipe' crashes.

54.3 The merge area for the ramp would occur within the tunnel portal (indicated as point 'E' on **Annexure D**). This results in an increased risk of an accident associated with the merge movement at a location where the changing environment of entering a tunnel places a higher demand on the driving task. On sections of motorways in Auckland, crash studies have shown that there is a greater incidence of crashes associated with merge and diverge areas than the sections between interchanges.[40]

54.4 As noted earlier, the provision of a local connection at Carrington Road would need to encroach on the designation for the Unitec property by approximately 10m (as indicated by point 'B' on **Annexure D**), and would be located within 7m of Building 1, (which is a Category A Heritage Building).

54.5 Furthermore, there is an existing cycleway located adjacent to the existing SH16 motorway (shown in yellow on **Annexure A**). If a new on ramp was to be constructed, this cycleway would need to be relocated further to the south (indicated by point 'C' on **Annexure D**), encroaching further into the Unitec Designation, increasing the extent of land required from Unitec. This cycleway would need to be positioned within the 7m separation between the Carrington Road on ramp and the Unitec Building 1.

55 Accordingly, there would, in my opinion, be significant design and safety issues associated with the concept alignment on ramp shown in **Annexure D** (which seeks to accommodate Sir Harold's

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[39] Andrew Murray EIC at paragraph 108; and Rebuttal at 72.

[40] 2010 AMA Crash Reduction Study – Motorway Link Diagrams, Auckland Motorway Alliance (Beca).

proposal). There would also be other significant adverse impacts, including noise and visual impacts, and the need for an additional crossing of the CMA.[41]

56 In addition, there would be a significant cost impact associated with the provision of an on ramp from Carrington Road. These costs would be associated with the construction of an additional bridge structure over Great North Road and the CMA, the upgrade of Carrington Road and the adjacent intersections, potential widening of Carrington Road bridge, significantly increasing the cross section at the entrance to the tunnel and additional land take. These costs would be in the order of $50 million.

SH20 Northbound Off Ramp to Great North Road

57 Sir Harold also provides a plan that shows a northbound off ramp from SH20 to the Great North Road Interchange. He considers that "an off-ramp location is indeed possible".[42] The Project design team has developed a concept alignment at the location suggested by Sir Harold with appropriate geometry and overlaid this on to the concept illustrated in his evidence.[43] These two alignments are shown in **Annexure E** to my rebuttal evidence.

58 There are a number of design reasons why Sir Harold's proposed off ramp is not feasible, as follows:

58.1 The suggested off ramp would diverge from the right hand side of the connection to SH16 west (Ramp 2 – as indicated by point 'B' on **Annexure E**), which provides for one of the key Western Ring Route connections, and consists of 2 westbound lanes. Sir Harold's proposed off ramp would need to diverge on the outside of a horizontal curve. This creates a safety hazard for a number of reasons:

(a) At this location, the main alignment is on a tight horizontal curve and the greater radii of the diverging off ramp would be perceived by drivers as being the main route;

(b) Due to the tight radii, the higher sight distance requirement for an off ramp would not be achievable, with the result being that drivers who have started to take the off ramp unintentionally would have little opportunity to correct. Any correcting manoeuvres on

[41] These potential impacts are outlined in the rebuttal evidence of Amelia Linzey.

[42] Statement of evidence of Sir Harold, paragraph 25.4.

[43] Statement of evidence of Sir Harold, paragraph 25.

this tight horizontal curve would have a greater chance of losing control than on a straight section of road therefore increasing the likelihood of accidents.

58.2 A diverge to the right would also require slower moving exiting traffic to be in the same lane as faster moving overtaking traffic in the right lane on the SH16 westbound connection. This would cause considerable speed differential, potentially resulting in high speed rear end crashes, creating a significant safety hazard.

58.3 The off ramp diverge would be positioned immediately after the diverge between the system ramps from the SH20 tunnel (being Ramps 2 and 4 – as indicated by point 'A' on **Annexure E**). The absolute minimum separation between ramp noses is 240m,[44] with a greater separation possibly required to provide sufficient weave capacity or to accommodate adequate signing. Therefore, Sir Harold's proposal would not provide sufficient separation between ramp diverges to allow traffic to identify the appropriate ramp diverge and safely move into the correct lane.

58.4 At exit ramps, it is essential that adequate sight distance is provided, so that drivers have sufficient time to comprehend the location of the exit and diverge in a controlled manner. For a standard diverge exit, the sight distance required is 230m at 80km/h,[45] maintained throughout the diverge area.

58.5 The vertical geometry of the NZTA's proposed Ramp 2 incorporates a crest vertical curve which provides a sight distance of 115m[46] (indicated by point 'C' on **Annexure E**). Therefore, a diverge exit from the outside of this curve would not be visible to approaching motorists, creating a significant safety issue. Considering this sight distance requirement and the need to provide sufficient spacing between ramp diverges, I consider that the ramp alignment suggested by Sir Harold presents a significant safety risk that would not be acceptable.

58.6 The horizontal geometry required to accommodate Sir Harold's proposed off ramp would incorporate a reverse

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[44] Table 6.4, Austroads Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings.

[45] Table 7.1, Austroads Guide to Road Design Part 4C: Interchanges.

[46] Equation 18, section 8.6.2, Austroads Guide to Road Design Part 3: Geometric Design.

curve combination (curves either side of point 'D' indicated on **Annexure E**), as the ramp would initially require a left hand curve that would need to transition to a right hand curve of lower design speed. As mentioned above, this horizontal curve combination would be hidden by the crest vertical curve, resulting in insufficient visibility of the road alignment ahead, and therefore an unsafe design.

58.7 The minimum horizontal curve radius for a ramp with a design speed of 80km/h is 230m.[47] The ramp alignment suggested by Sir Harold incorporates a curve with a radius of approximately 130m (indicated by point 'E' on **Annexure E**), which would create a design speed inconsistent with that of the approaching motorway, thereby increasing the risk of crashes.

59 As identified above, there are a number of design requirements that would need to be achieved to accommodate an off ramp as proposed by Sir Harold. Given the high speed environment of the Interchange, insufficient sight distance to the diverge area, and the poor geometry required to accommodate such a ramp, it is my opinion that an off ramp in the area proposed by Sir Harold could not be provided without significantly impacting adversely on the safety of the Interchange.

60 The Project design team has developed a concept design for the Great North Road northbound off ramp from SH20 at a similar location to that suggested by Sir Harold. This is shown in **Annexure F** to my rebuttal evidence. While being geometrically feasible, there are numerous impacts associated with this design as follows:

60.1 The diverge taper would begin a considerable distance into the northbound tunnel (indicated by point 'A' on **Annexure F**), requiring vehicles to change lanes within the tunnel. This is undesirable as it increases the risk of a weave accident within the tunnel.

60.2 The diverge for the local road exit would be located in close proximity to the bifurcation between the two system ramps to SH16 in either direction (indicated by point 'B' on **Annexure F**). There would not be enough time within the tunnel to clearly advise motorists (through signing) which lane they should be in for the diverge, resulting in an increased risk of lane changing crashes.

[47] Table 8.1, Austroads Guide to Road Design Part 4C: Interchanges.

60.3 As the Great North Road off ramp would need to be at the same grade as the westbound connection from SH20 to SH16, through the diverge area, the elevation of the westbound ramp would need to be higher than currently proposed (indicated by point 'D' on **Annexure F**). This will likely have a greater visual impact than the proposed option.[48]

61 The concept option developed (in **Annexure F**) includes a large sweeping curve that loops around the Interchange. This is required to accommodate the vertical separation necessary for this off ramp to pass over Ramp 2.[49] This shows the first location where there is sufficient clearance for the off ramp to clear Ramp 2, and the off ramp cannot cross over Ramp 2 any further south. The radius cannot be reduced, due to the resultant speed difference from the approach (as mentioned in paragraph 58.7 above), and there are significant safety issues associate with a ramp diverging from the left (as explained in my rebuttal).

62 In addition, there would be a significant cost impact associated with the provision of an off ramp from the SH20 tunnel to Great North Road. These costs would be associated with the provision of a long high bridge structure over the existing SH16 (indicated by point 'E' on **Annexure F**), realignment of the existing eastbound off ramp from SH16 (indicated by point 'F' on **Annexure F**), and significant widening within the tunnel (indicated by point 'C' on **Annexure F**). The cost of these ramps would be approximately $125 million.

63 In addition to the design and cost constraints, there would be significant environmental impacts associated with the ramp alignment. These impacts include visual effects associated with the height of the ramp, additional encroachment into the designation, bridge piers located within the CMA (associated with the very long, high skew crossing required) and visual and noise impacts on adjacent properties.

Summary – Local road connections to SH20

64 In response to Sir Harold's suggested ramp connections, it is my opinion that provision of the local road ramp connections in the area proposed would result in significant safety issues, as well as other environmental impacts and increased costs, and are therefore not justified.

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[48] Rebuttal evidence of Amelia Linzey.

[49] A series of cross sections would show the difference in level between the off ramp and the main SH16 connection to the west (Ramp 2), as the off ramp would need to climb to a height of approximately 8m above Ramp 2.

65 Throughout the development of the design, I can confirm that a considerable number of local ramp options have been investigated along the length of the route between Maioro Street and SH16 including at New North Road, Great North Road (near Blockhouse Bay Road) and at the existing Great North Road Interchange. As outlined earlier, there are numerous reports outlining the assessment of alternative options.

66 As I have explained, the Great North Road Interchange design is very complex, incorporating new motorway to motorway connections in two directions, and existing local road ramp connections, that all need to be accommodated within a small area with significant constraints. As a result of the design challenges presented, we have investigated a considerable number of options for the Great North Road interchange, including the provision of local ramp connections. I have also considered alternative ramp alignments for local road connections in this area, including the concept designs for on and off ramps shown in **Annexures D** and **F**, and alignments directly from Great North Road.[50] Notwithstanding all of those investigations, I have not identified a solution that could be achievable without significant design and safety issues and significant adverse environmental effects.

Utilising the area within the current eastbound on ramp for the ramps

67 The evidence of Mr McKenzie on behalf of Living Communities states:[51]

> "...that a more fundamental redesign of the interchange could have avoided this extent of incursion into Waterview, possibly through a more intensive use of the open space area north of SH16. It could also have provided greater connectivity to SH20 for the local area."

68 As I have explained above, the NZTA's proposed design of Great North Road Interchange incorporates geometry that has been developed through consideration of the various site constraints. Moving the Interchange ramp connection further north to utilise the existing SH16 loop ramp (as proposed by Mr McKenzie) would result in a number of subsequent significant impacts.

69 The location of the northern tunnel portal is governed by geotechnical ground conditions, and there is a need to provide

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[50] The first draft concept design plans for the southbound on ramp was provided to attendees at the first expert transport caucusing session (on 21 January 2011), with final concept plans for both the on and off ramps provided at the second session (on 28 January 2011).

[51] Statement of evidence of Duncan McKenzie, paragraph 5.5.

sufficient distance for the ramps to climb out of the tunnel and extend over the CMA and the existing SH16 motorway. The connections from the tunnel extend to the west and east of the Interchange.

70 The northbound connection from the tunnel to SH16 east (Ramp 4) is required to cross the connection from SH16 west to the SH20 tunnel (Ramp 3). (See **Annexure A**.) This currently occurs adjacent to Waterview Park, to enable both ramps to have minimal clearance over the existing SH16 motorway. If this connection were moved further north, these two ramps would cross over the SH16 motorway together, requiring one of the ramps to be twice as high above the motorway. This would potentially result in a significant visual and noise impact for the residents of Point Chevalier, and increased construction costs associated with the high ramps.

71 As a reduction in the curve radii for the ramps would compromise the operation and safety of the motorway, any movement of the ramps further north (i.e. towards the vacant area of the eastbound on ramp loop) would need to maintain similar radius curves as currently proposed. To do so would both require the extension of Ramps 3 and 4 into the Point Chevalier Community (potentially impacting on about 50 properties), and potentially result in the need for a greater extent of reclamation north of the causeway to accommodate Ramp 3 (extending over a length of approximately 300m).

72 Any movement of the ramps further north would also require the westbound Ramps 1 and 2 to extend over the existing SH16 motorway before curving back to tie in with the westbound lanes. As a result, the ramps would need to be increased in height to clear the existing motorway (which is not currently required for NZTA's proposal). This in turn would require additional length of ramp, extending the tie in further west into the CMA (increased reclamation), and impacting on Carrington Road Bridge to the east.

73 As the heights of these ramps (Ramps 1 and 2) would need to be increased by about 8m, there would potentially be additional noise and visual impacts for residents.

74 Given the geometric impacts mentioned above, it is my opinion that the area within the SH16 eastbound on ramp would not provide an opportunity to reduce the extent of encroachment into the Waterview area (as suggested by Mr McKenzie), nor provide greater connectivity to SH20 for the local area.

75 During transport caucusing on 28 January 2011, I explained these issues to Mr McKenzie, and he accepted that moving the portal further north would require the Interchange to be moved a similar distance, with significant effects on the area north of the Interchange (i.e. Point Chevalier.)

Summary – Mr McKenzie's proposal

76 Mr McKenzie's proposal for moving the Interchange connections further north to utilise the area within the SH16 eastbound on ramp loop, is not feasible as it raises the following fundamental design and safety issues:

76.1 Sufficient distance is required for the ramps to climb out of the tunnel and extend over the existing SH16 motorway, and this is unlikely to change through using the area within the eastbound on ramp loop;

76.2 If the ramp connections were moved further north to utilise the area within the SH16 eastbound on ramp loop:

(a) Ramps 3 and 4 would cross over the SH16 motorway together, requiring one of the ramps to be twice as high above the motorway;

(b) Ramps 1 and 2 would need to be increased in height to pass over the existing motorway;

(c) Ramps 3 and 4 would extend into the Point Chevalier Community; and

(d) A greater extent of reclamation would be required to accommodate Ramp 3.

76.3 The tie in of all ramps would need to be extended further to the west and east along SH16, resulting in greater impact on the CMA. It would also conflict with the Carrington Road Bridge; and

76.4 A reduction in the curve radii for the system ramp connections between SH20 and SH16 would compromise the operation and safety of the motorway.

PROPOSAL TO EXTEND THE TUNNEL NORTH UNDER TIDAL OAKLEY CREEK

77 Mr Peter McCurdy's evidence (on behalf of Star Mills Preservation Group) proposes that the SH20 tunnels are extended north under tidal Oakley Creek to join SH16 within the SH16 corridor.[52]

78 Mr McCurdy's proposal would require the four separate ramp connections to extend from SH20 as tunnel; resulting in major diverges to be located within the tunnel. Merge and diverge areas in tunnels are not desirable due to the increased risk of an accident, and the greater consequences of an accident occurring in the tunnel.

79 To achieve the suggested alignment, the ramps would need to pass beneath the Oakley Creek bed, allowing for sufficient vertical clearance between the creek bed and the top of the tunnel. This would require the road surface to be approximately 25m beneath the Creek bed (further geological investigations would be required to confirm the actual depth).

80 Horizontal clearance in tunnels is more restricted than on open sections of motorway due to the tunnel walls. Therefore, the radii required to provide stopping sight distance in tunnels should be determined based on truck stopping distance, as there is no advantage gained by trucks from their higher eye height.[53] Therefore, the minimum radius that can be provided for an 80km/hr design speed and 1m shoulder is 821m,[54] which is significantly greater than the proposed minimum radius of 250m currently proposed for Ramp 1.

81 Applying the above design criteria, if undergrounded, the ramp tunnels would need to extend further to the east and west along SH16 before coming to the surface.

82 As a result, to the west, the tunnel would need to surface within the CMA, requiring a large amount of reclamation for both the portal and associated construction activities. This would be required on either side of the existing causeway to accommodate both the west and eastbound ramps.

83 To the east, a deep portal excavation would be required either side of the SH16 motorway, requiring a significantly greater construction area (and therefore additional land) than is currently proposed for the Project.

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[52] Statement of evidence of Peter McCurdy, paragraph 5.2.

[53] Section 4.4, Austroads Guide to Road Tunnels Part 2: Planning, Design and Commissioning.

[54] Appendix A, Austroads Guide to Road Tunnels Part 2: Planning, Design and Commissioning.

84 The construction of a tunnel for each of the ramps would also result in over 3km of additional tunnel length, with a construction area required at the end of each tunnel, and the provision of four tunnel portals in the north (rather than the current single portal). This would result in greater effects on the environment and a significant increase in construction risk and cost.

85 The problems with Mr McCurdy's suggested option are so considerable that the option of tunnelling beneath Oakley Creek would not proceed to further design. For these reasons, I do not consider that Mr McCurdy's suggested extension of the tunnel under Oakley Creek would warrant any further investigation.

COMMENTS ON THE SECTION 42A REPORTS

86 I have reviewed the Section 42A Report and Addendum Report and have addressed the issues raised relating to local road connections at the Great North Road Interchange in this rebuttal evidence.

87 Paragraph 10.6.41 of the Section 42A Report considers that the effects of the Carrington Road southbound link merit further scrutiny and assessment. In response, I have outlined above the design issues and significant adverse safety impacts of this connection, and prepared concept design plans to demonstrate the geometric layout that would be required.

88 Paragraph 3.3.2 of the Addendum Report requests that "a scheme showing a south bound SH20 on ramp local connection from Carrington Road should be drawn up in preliminary design terms to demonstrate the issues of concern". As discussed above, a concept plan is included as **Annexure D** to my rebuttal evidence to demonstrate the impacts of such a ramp connection. It is considered that the level of design provided is sufficient to identify the various adverse effects and a further level of design is not necessary.

Robert Mason
February 2011

ANNEXURE A – GREAT NORTH ROAD INTERCHANGE: PROPOSED LAYOUT

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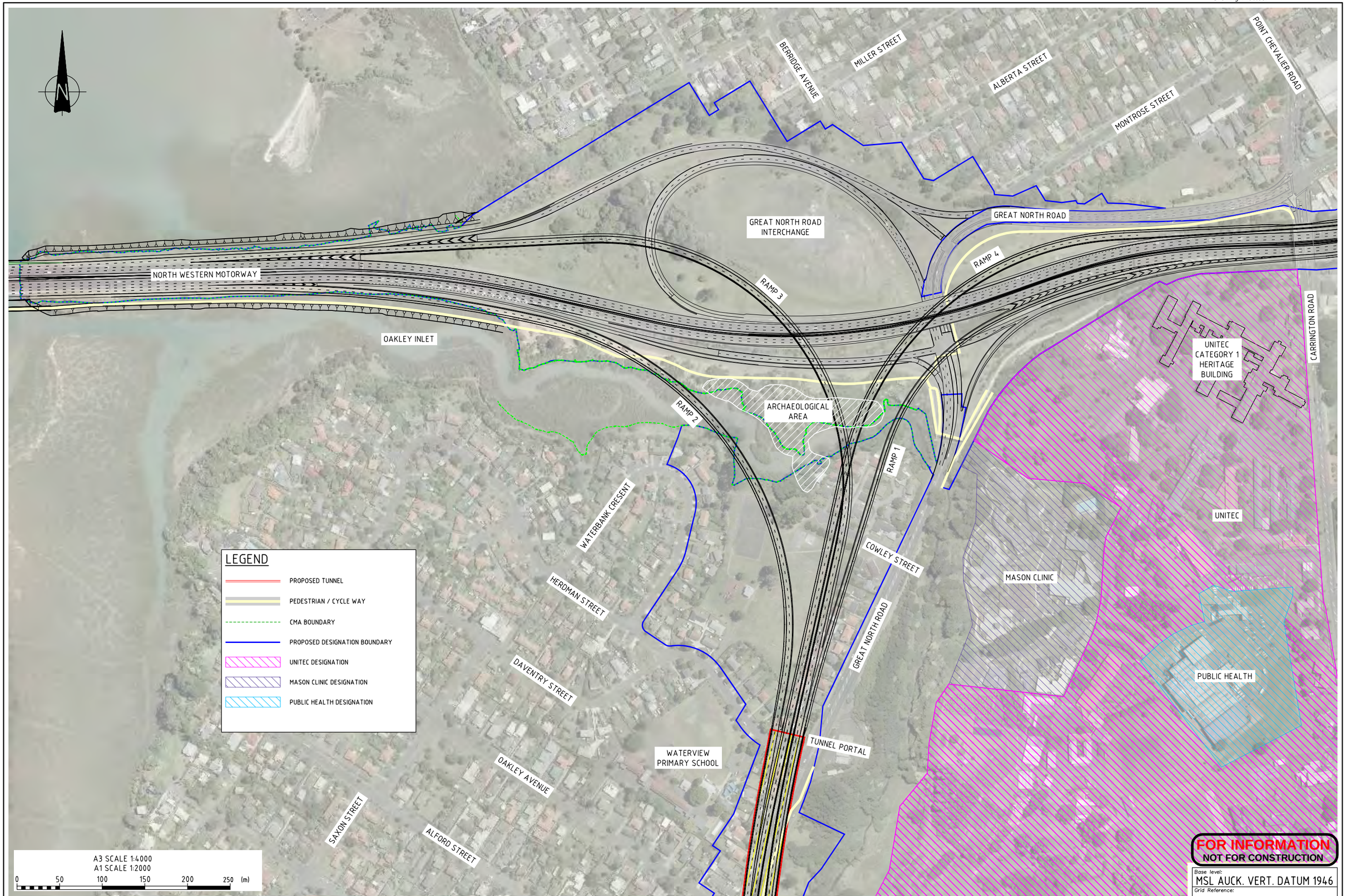

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NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: WATERVIEW CONNECTION PROJECT SH16 / SH20

Title: PROPOSED GNR INTERCHANGE

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ANNEXURE B – AUSTROADS "GUIDE TO TRAFFIC MANAGEMENT PART 6: INTERSECTIONS, INTERCHANGES, AND CROSSINGS" – SECTION 6.3.1 SPACING OF INTERCHANGES

6.2.2 Warrants

A numerical warrant for the provision of an interchange or grade separation is difficult to specify due to the wide variety of circumstances that may apply at each site. A decision on whether or not to build an interchange must be based on a broad assessment of all relevant factors and sound engineering judgment. The justification for an interchange should be established from a comprehensive traffic study of the proposed road network with the aims of optimising road safety, traffic service and community interests.

Interchanges may be proposed to:

- provide access across and to a freeway
- provide uninterrupted traffic flow between intersecting freeways/motorways
- increase capacity by replacing critical intersections on an expressway or arterial road
- separate conflict points between traffic movements that have high relative speeds
- suit particular topography where an interchange can be built at justifiably additional cost to an at-grade intersection
- provide for traffic generated by future land development via existing or future intersecting arterial roads.

An interchange must be provided where:

- the major intersecting road is a freeway or motorway, or a major arterial road
- all practicable forms of at-grade treatments would be unsafe or would not meet level of service objectives for major traffic flows
- an economic analysis demonstrates that it is justified
- provision of at-grade intersections in an otherwise grade separated facility would result in a combination of treatments not expected by motorists and lead to unsafe operating conditions.

6.3 Route considerations

6.3.1 Spacing of interchanges

The location of interchanges is usually determined by road network requirements for accessibility and route interconnectivity. Therefore, they are often located where a major road intersects with other arterial roads or significant local rural roads. Interchanges may also be located to provide convenient access to and from developments that generate large volumes of traffic (e.g. theme parks, raceways). The physical suitability of the site is also an important factor.

Rural freeways/motorways

In rural areas the minimum desirable spacing of interchanges is 5 km to 8 km, depending on the configuration of the roads being intersected by the freeway. The desirable maximum spacing is less definite but is dependent on the level of service required for local access and the relative costs, benefits and difficulties of providing frontage and local access roads compared to an interchange. However, a spacing greater than 12 km should be adopted only after a review of traffic service afforded by the abutting road network.

Where freeways/motorways bypass rural towns, the location and number of interchanges is normally based on the level of accessibility required between the freeway and the town. This may be an issue for smaller settlements that are economically dependent on tourism.

Urban freeways/motorways

The location and spacing of interchanges in urban road networks is influenced by many factors including:

- the strategic purpose of the section of freeway
- network efficiency in provision for traffic movement between the freeway and major arterial roads
- reducing community severance, including provision for walking and cycling at interchanges
- traffic management strategies for abutting areas
- physical limitations on the ability to provide connections (ramps)
- availability of land.

In urban areas there is often limited flexibility regarding the location of the horizontal and vertical alignment of the main freeway and this may influence the feasibility of providing an interchange or a particular form of interchange and the spacing that results.

Every entry ramp and exit ramp creates some disturbance to traffic flow on a freeway and the effects of this disturbance are experienced for some distance (known as the influence area) both upstream and downstream of the ramp/freeway terminal. The desirable spacing of interchanges in urban areas should therefore be based on a traffic analysis of the likely traffic operating conditions in the design year. (Refer to Part 3 of the Guide to Traffic Management and TRB, 2000.)

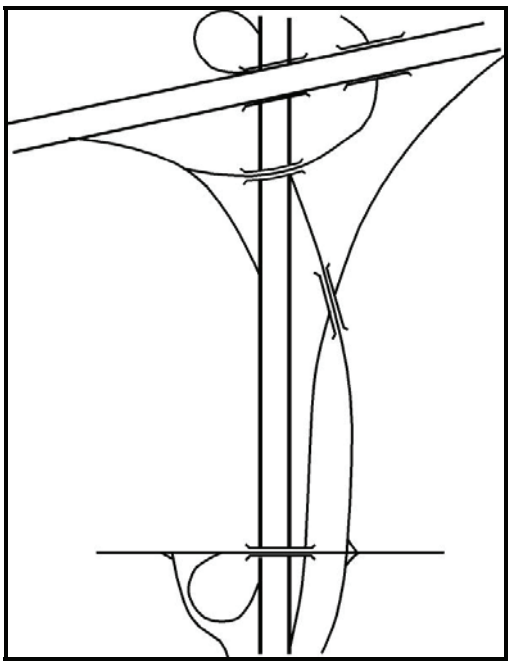
The disturbance to traffic flow on the freeway can be critical where a high-volume on-ramp precedes a high-volume off-ramp and the freeway is operating near capacity. In such cases, weaving manoeuvres can cause operational and safety problems if the proposed distance between interchanges is too short. Care should be taken to ensure that adequate separation of the ramps (and hence interchange spacing) is provided, based on a weaving analysis.

The desirable minimum spacing of interchanges should be based on the spacing of ramps (discussed in Section 6.6.6) plus the length of entry and exit ramps (including tapers) needed to meet operational and safety requirements at the interchanges (e.g. acceleration, queuing at signals). The absolute minimum spacing between successive urban freeway interchanges is 1.5-2.0 km. This is based on the minimum lengths required to accommodate ramps, merge and diverge tapers at ramps, auxiliary lanes and minimum separation between the entry and exit tapers. The guiding principle is that a spacing at least equal to the desirable minimum (based on traffic analysis) should be achieved, and that a greater spacing than this should be adopted where practicable. If the absolute minimum dimension cannot be achieved, a solution based on providing a single interchange with a second diverge off the initial diverge should be considered.

The effectiveness of interchange exit signage and the distance required for a driver to change lanes is also an important factor with respect to spacing, as there is a greater potential for driver confusion when advance signs for one interchange have to be placed close to or within a preceding interchange.

In restricted situations it may be necessary to choose a form of interchange that increases separation (e.g. one that has loop ramps rather than diamond ramps). Where interchanges must be located at a very close spacing it may be necessary to grade separate (or ***braid)*** ramps as illustrated in Figure 6.1. Alternatively, it may be possible to provide service roads between the two interchanges, allowing one entry and one exit ramp in each direction to service the two interchanges.

Maximum spacing is rarely a consideration in urban areas. A review of traffic service provided by the total road system is recommended when spacings exceed 4 km in urban areas.



Source: AASHTO 2004

Figure 6.1: An example of braided ramps

6.3.2 Consistency of interchange form

Driver perception of the ease of negotiating interchanges from both the major and minor roads is an important factor in efficiency of operation and the safety of the network. This can be achieved through the use of a consistent form of interchange, but it is also achieved by a consistent approach to the placement and signing of ramps. For example, drivers expect to exit to the left and they expect the ramp to start in advance of the grade separation structure. If this feature is incorporated regardless of the form of the interchange beyond the exit, consistency will have been achieved. This is illustrated in Figure 6.2. A similar approach should be taken to consideration of entrance ramps.

6.3.3 Route continuity and consistency

An important element of consistency is route continuity. Drivers expect to travel a designated (i.e. numbered and/or named) route in a directional path and for it to be treated as a through route. They expect to be able to adopt consistent behaviour throughout the route. Route continuity simplifies the driving task because it:

- reduces lane changes
- simplifies signing
- delineates the through route
- reduces the driver's search for directional signing.

ANNEXURE C – SH20 CARRINGTON ROAD SOUTHBOUND ON RAMP: INTERCHANGE – SIR HAROLD'S OPTION

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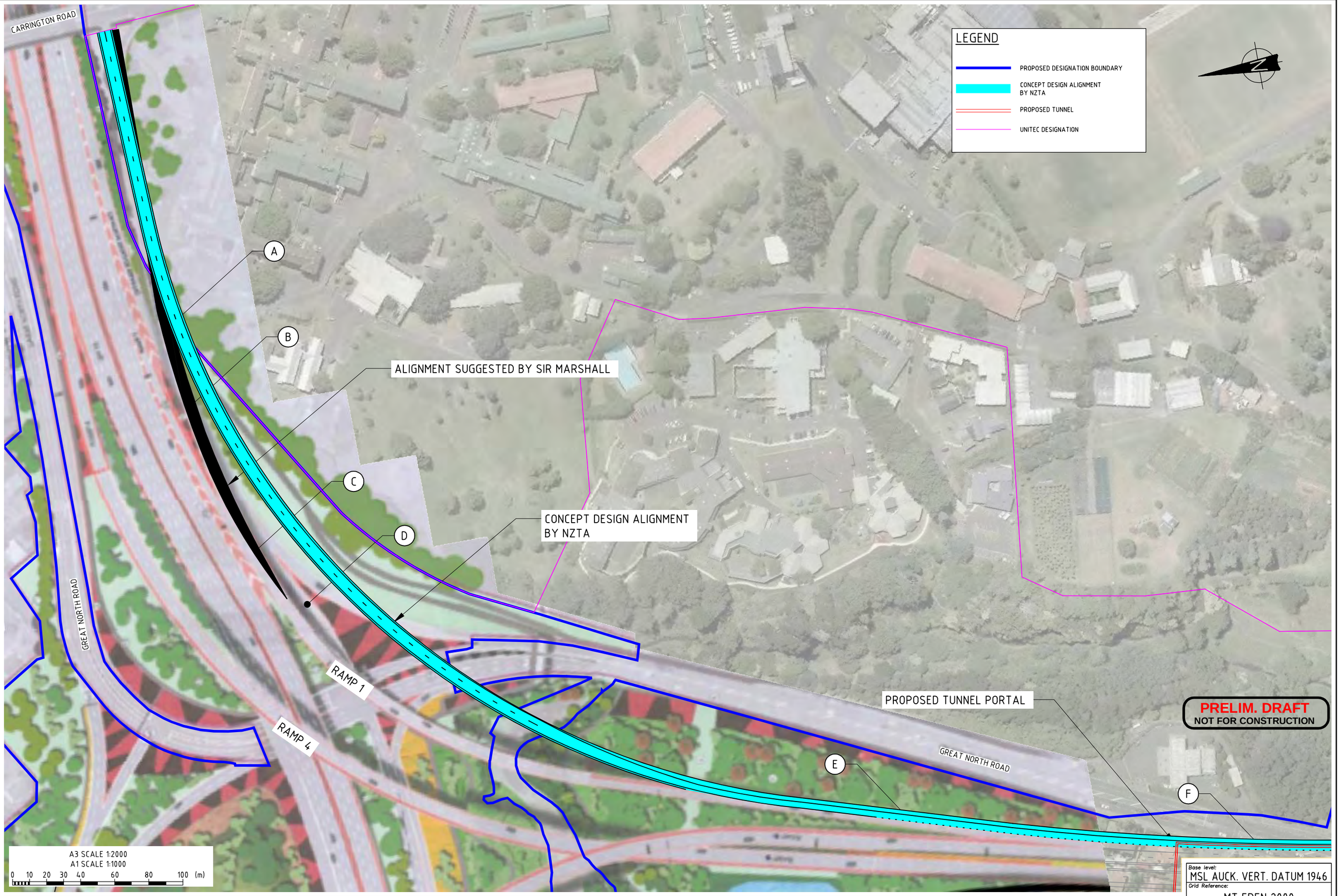

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NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: WATERVIEW CONNECTION PROJECT
SH16 / SH20

Title: OPTION DEVELOPMENT
SH20 CARRINGTON RD SBD ON RAMP
SIR MARSHALL OPTION (120-1)

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ANNEXURE D – SH20 CARRINGTON ROAD SOUTHBOUND ON RAMP: CONCEPT DESIGN

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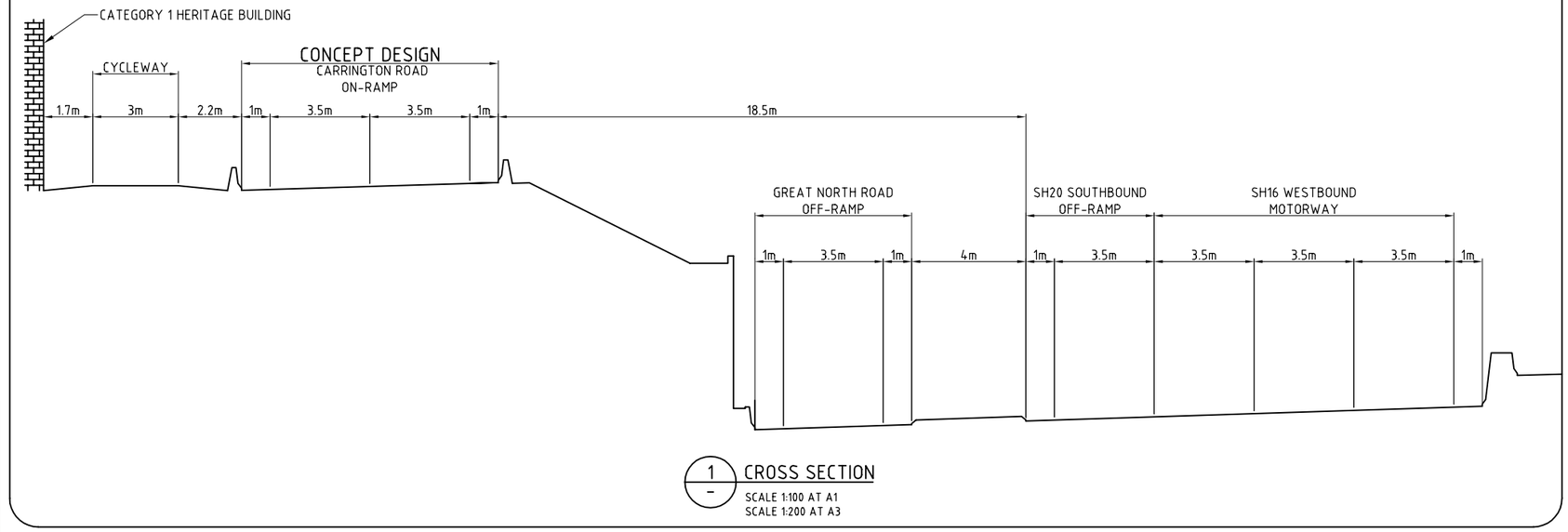

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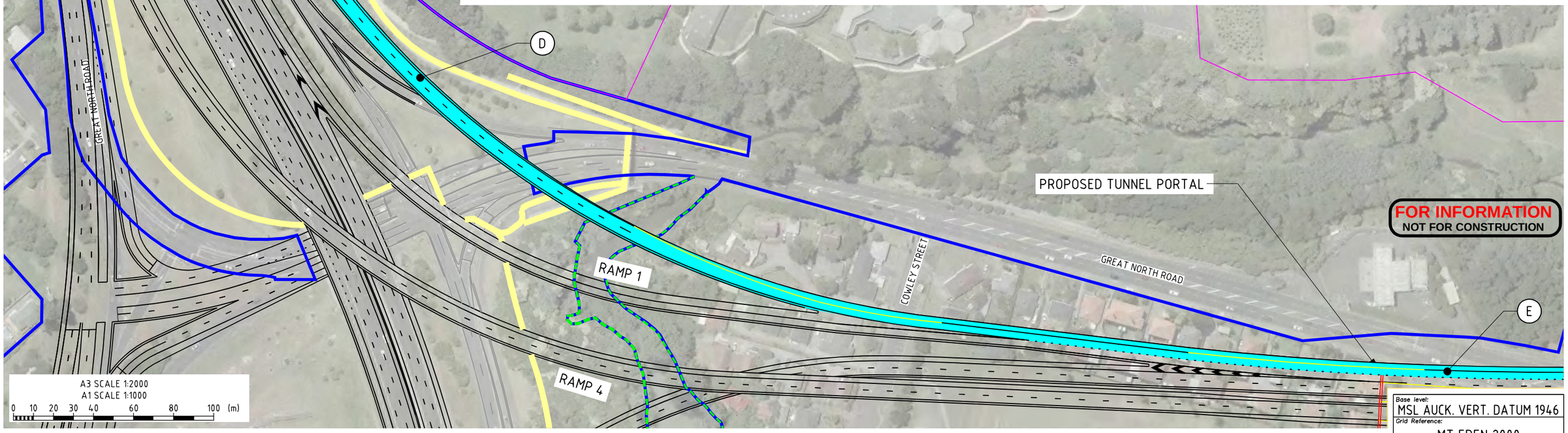

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NZ TRANSPORT AGENCY
WAKA KOTAHI

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SH16 / SH20

Title: OPTION DEVELOPMENT
SH20 CARRINGTON RD SBD ON RAMP
CONCEPT DESIGN

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ANNEXURE E – SH20 GREAT NORTH ROAD NORTHBOUND OFF RAMP: SIR HAROLD'S OPTION

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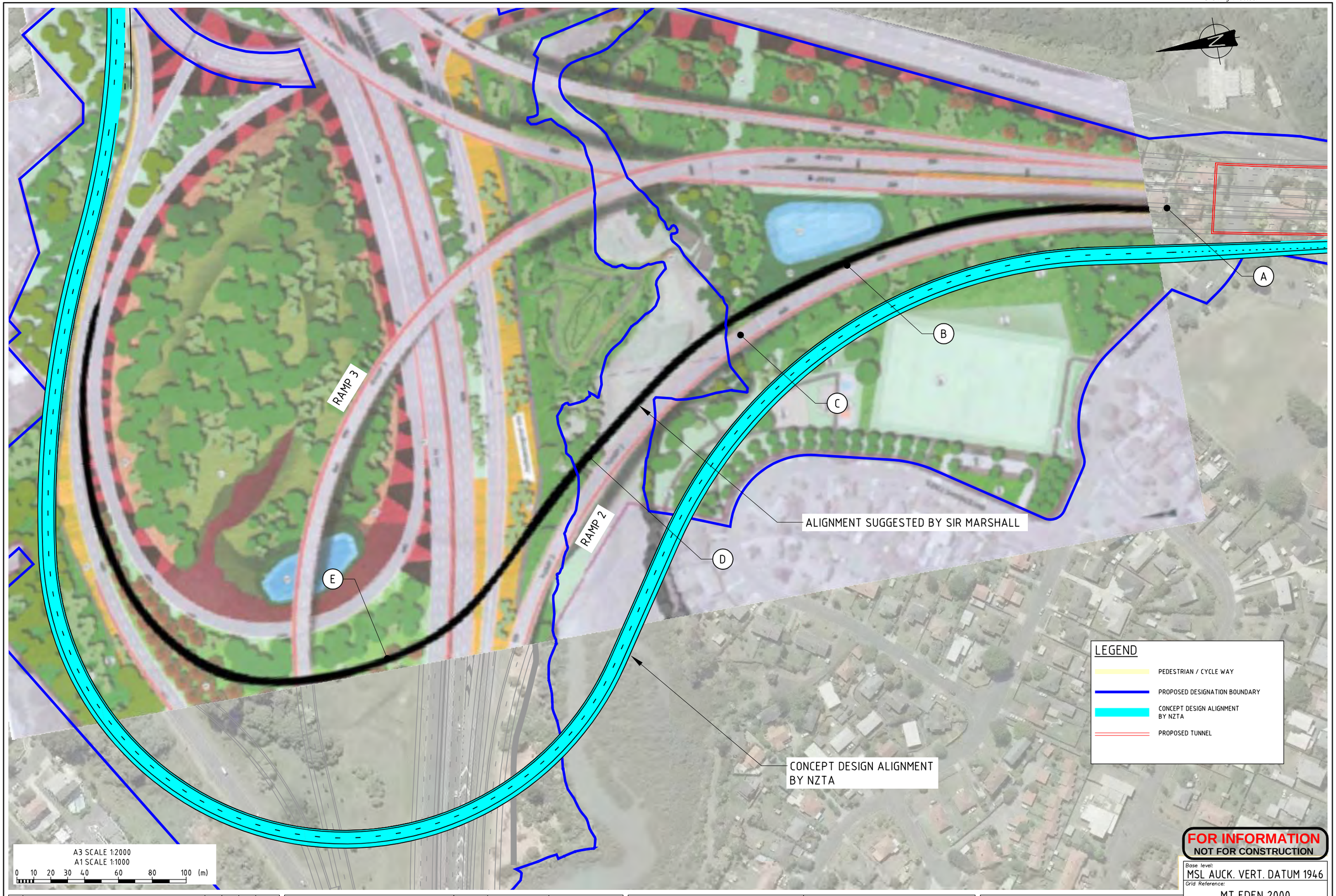

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NZ TRANSPORT AGENCY
WAKA KOTAHI

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SH16 / SH20

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SH20 CARRINGTON RD SBD OFF RAMP
SIR MARSHALL OPTION (120-1)

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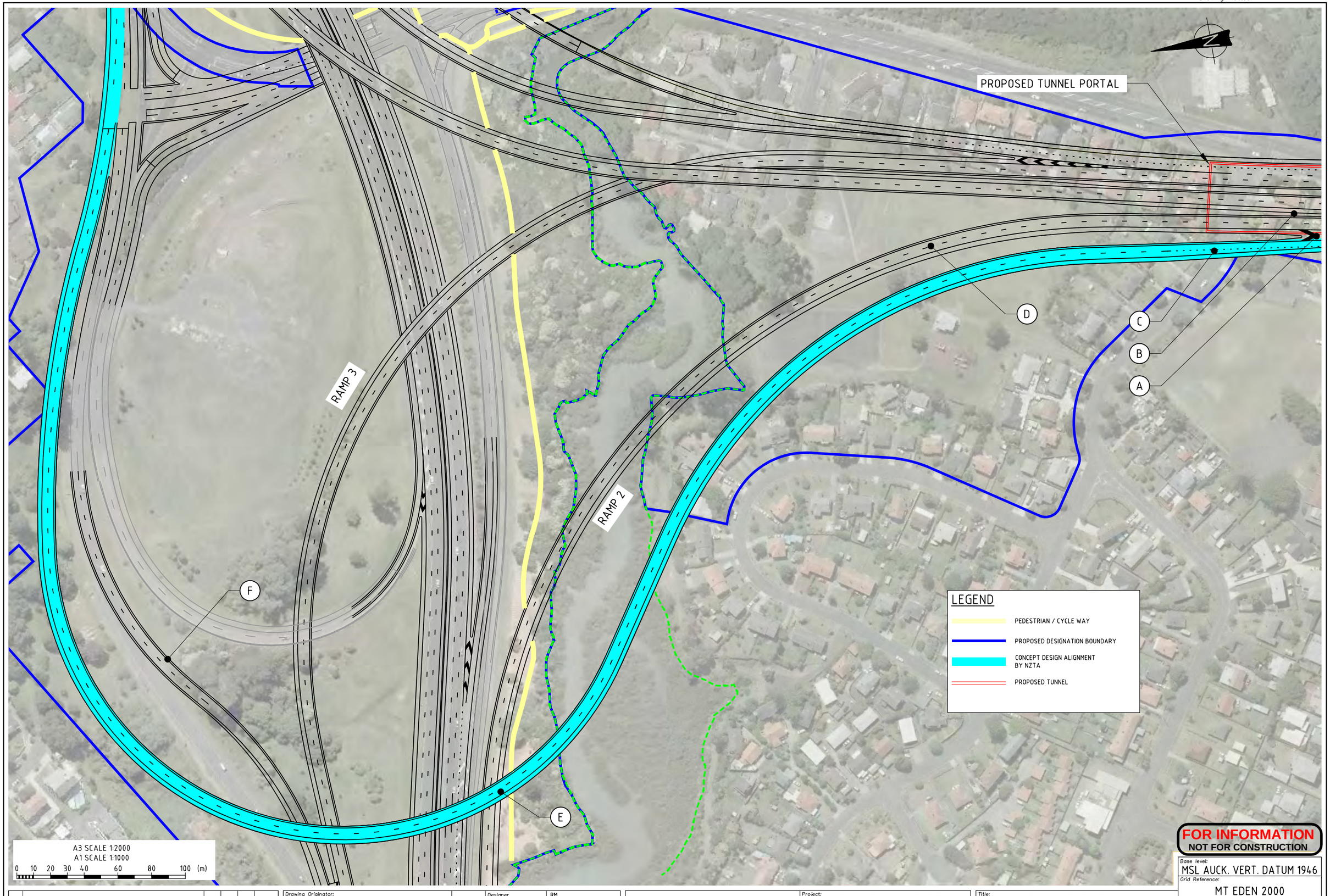
ANNEXURE F – SH20 GREAT NORTH ROAD NORTHBOUND OFF RAMP: CONCEPT DESIGN



FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
C	ISSUED FOR INFORMATION	ME			01.02.11
B	ISSUED FOR INFORMATION	ME			27.01.11
A	ISSUED FOR REVIEW	ME			26.01.11

Drawing Originator:

Original Scale (A1) 1: 1000
Reduced Scale (A3) 1: 2000

Designer	RM
Reviewer	BM
Drafting Checked	ME
Consultant Approval	AL

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: WATERVIEW CONNECTION PROJECT SH16 / SH20

Title: OPTION DEVELOPMENT SH20 CARRINGTON RD SBD OFF RAMP CONCEPT DESIGN

Base level: MSL AUCK. VERT. DATUM 1946
Grid Reference: MT EDEN 2000
Originator No.
Project No. 20.1.11-3-D-C-109-424
Rev. C

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