Under the Resource Management Act 1991
In the matter of Notices of Requirement to enable the construction, operation and maintenance of the City Rail Link

Between

Auckland Transport

Requiring Authority

and

Auckland Council

Consent Authority

Statement of Evidence of Eric Craig Stevenson

Qualifications and Experience

1. My full name is Eric Craig Stevenson.

2. I currently hold the position of Technical Director at Aurecon New Zealand, a company I joined upon returning to New Zealand in 1998.

3. I hold a Bachelor of Engineering Degree (Honours) and a Master of Engineering Degree in Civil Engineering from the University of Canterbury. I am a member of the Institution of Professional Engineers New Zealand and Institution of Civil Engineers (United Kingdom). I am a Chartered Professional Engineer (New Zealand) and an International Professional Engineer.

4. I have 32 years experience as a practising professional structural engineer involved in engineering design, design management, design coordination and design leadership predominantly within the building sector. My structural engineering knowledge and expertise in the design of building structures and performance assessments is diverse, ranging from single level to high rise buildings. This includes new building developments, as well as assessments and strengthening of existing buildings, building alterations and extensions. My qualifications provide a fundamental understanding of geotechnical matters and my experience in the design of building structures requires me to consider the geotechnical aspects in most of the projects that I am involved in.

5. My local experience includes design leadership and management roles on St Harbour 5 development in Mahuhu Crescent, St Patricks Cathedral Conservation and Refurbishment, Baradene College Arts Science and Technology Building, Westfield St Lukes Expansion, Mercy Ascot Hospital building extensions, refurbishments and strengthening, and existing condition assessments on numerous buildings including buildings adjacent the Britomart Station prior to construction of the station box, and Westfield NZ retail facilities in Auckland, Hamilton and Christchurch.

6. My international experience includes design management leadership roles on the Noi Bai International Airport Terminal 2 building Hanoi and

the North Satellite Concourse and Main terminal buildings at Chek Lap Kok airport, Hong Kong.

Background and role

7. The City Rail Link (CRL) project is a 3.4km underground passenger railway (including two tracks and three underground stations) running between Britomart Station and the North Auckland Line (NAL) in the vicinity of the existing Mount Eden Station. The CRL also requires an additional 850m of track modifications within the North Auckland Line (NAL). The stations included in the CRL NoR have been temporarily named Aotea Station, Karangahape Station, and Newton Station.

8. Aurecon NZ Ltd was engaged by Auckland Transport as Principal Advisor (PA) for the CRL project. The PA is led by Aurecon NZ Ltd and comprises the principal partners of Aurecon NZ Ltd, Mott MacDonald, Jasmax and Grimshaw. The PA reports directly to Auckland Transport's Infrastructure Delivery workstream which is responsible for delivery of the CRL project. The PA is also supporting the Notice of Requirement (NoR) and Property workstreams.

9. My role on the CRL project includes:

   (a) Working with the Noise and Vibration technical experts to determine and assess the effect of noise and ground borne vibration on buildings associated with construction of the CRL within the NoR footprint.

   (b) Working with the Built Heritage expert to identify built heritage structures that may be adversely affected by ground borne vibration and settlement effects.

   (c) The identification and review of building structure types along the CRL corridor that may be affected by ground borne vibration and settlement.

   (d) A preliminary high level assessment of the potential risk and possible level of structural damage to these buildings types.

(e) Advising on proposed mitigation of adverse effects on building structures and structures from noise and ground borne vibration and settlement.

10. I am familiar with the project location, the designation footprint area including indicative track alignment and the locations for each proposed station. I have walked the proposed route and undertaken walking visual surveys of the exterior of representative buildings along the route.

11. I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Consolidated Practice Note (2011), and I agree to comply with it as if this hearing was before the Environment Court. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

12. My evidence will address the following:

(a) Overview of the methodology adopted in predicting vibration and settlement levels and the categorisation of physical effects on buildings and structures;

(b) Identification and assessment of building types along the CRL corridor that may be adversely affected by vibration and settlement effects associated with construction of the CRL;

(c) Preliminary assessment of the potential risk of structural damage to buildings and structures and the extent of potential impact resulting from construction vibration and settlement on these buildings;

(d) Possible mitigation options;

(e) Response to submissions;

(f) Response to Planner's Report; and

(g) Proposed conditions.

13. My evidence includes reference to Mr James Whitlock's Noise and Vibration Technical Report[1] and Mr Bruce Petry's Built Heritage Report[2] and their evidence as applicable.

Summary of Evidence

14. I have assessed the potential adverse effects associated with ground borne vibration resulting from the construction of the CRL as evidenced by Mr Whitlock, and conclude that adverse effects will generally be acceptable (Negligible to Slight[3]) in terms of potential structural damage (i.e. of a superficial or aesthetic extent only).

15. I have assessed the potential adverse effects associated with construction excavation induced settlement along the tunnel alignment as presented by Mr Bill Newns. I conclude that these potential adverse effects will generally be acceptable (Negligible to Slight) in terms of potential structural damage to the majority of buildings[4] within the NoR footprint (i.e. of a superficial or aesthetic extent only). In my view the mitigation of effectscan be achieved by good design and workmanship in respect of the CRL; implementation of preconstruction building condition assessments; and construction phase monitoring of buildings affected by the CRL as provided in the proposed conditions of consent (as amended by Council). A description of typical damage associated with the above damage severity levels is provided in paragraph 23 below.

16. My assessment identifies a small number of multistorey building structures with piled foundations in relatively close proximity to open cut or station box excavations that may require tight controls on lateral ground displacements and/or mitigation works at their foundation level

[1] CRL Volume 3 Part 1 Noise and Vibration Assessment Report

[2] CRL Volume 3 Part 1 NoR Built Heritage Technical Expert Report

[3] These terms are defined at paragraph 23 of my evidence.

[4] I have assessed the effects on a number buildings considered high risk and estimated that these effects will be no more Slight

to ensure that excavation (soil removal) induced lateral movements, pile moments and axial down drag forces will not result in the capacities of the piles being exceeded and pile failure occurring.

NoR assessment of structural effects

Vibration assessments

17. An assessment of the vibration effects of this project has been undertaken by the vibration technical expert, Mr Whitlock of Marshall Day Acoustics. The Noise and Vibration Assessment Report[5] (N&V Report) details the vibration performance criteria adopted for the project, during both construction and operational phases, and the methodology of assessing the effects of vibration.

18. The N&V Report also identifies that the proposed performance standards and target vibration criteria or limits relating to train operation are "*an order of magnitude below the most stringent building damage criterion applicable to the construction stage…, so compliance with the limits….indicates there is no risk of vibration induced building damage from operation of the CRL.*" I have therefore not considered operational vibration as a significant effect in terms of potential damage to building structures or other structures, nor addressed it in my assessment[6] or my evidence, as it can be adequately addressed through compliance with the targeted operational vibration criterion as outlined in the N&V Report.

19. For construction vibration, Mr Whitlock has adopted the long term vibration limits of the German Standard DIN 4150-3 Table[7]. I note that these vibration limits are significantly lower than the corresponding threshold criteria of the British Standard BS 7385-2[8]. The results of the vibration propagation assessments undertaken by Mr Whitlock are

[5] Volume 3 Part 1 CRL NOR Noise and Vibration Assessment Report

[6] Volume 3 Part 1 CRL NoR Structural Engineering Report

[7] Section 6.2.2 of Volume 3 Part 1 CRL NOR Noise and Vibration Assessment Report.

[8] BS 7385 Part 2 1993: Evaluation and Measurement for Vibration in Buildings: Part 2: Guide to Damage Levels from Groundborne Vibration

detailed in the N&V Report. From the results of the assessment contour maps have been produced of expected vibration emission from construction activities along the CRL route. Contours have been plotted for setback distances from the edge of excavation of the CRL route for the peak particle velocity (PPV) vibration thresholds of 2.5mm/s, 5mm/s and 10mm/s, these being the vibration criteria or threshold appropriate to historic, residential and commercial buildings respectively, adopted from the German Standard DIN 4150-3. For the purposes of my evidence, these contours define the zone of influence of the CRL in respect to construction vibration effects.

20. An inventory has been prepared of those buildings that are within the setback distances from the edge of excavation of the CRL where the vibration threshold criterion will be exceeded.

21. I have undertaken an assessment of the effects resulting from construction vibration on the buildings that are within the relevant construction vibration risk contours. This assessment has been undertaken on the basis of experience, visual walkovers, desktop analysis and general understanding of the age, construction type and condition of each building.

22. I have adopted the Building Damage Classification after Burland (1995), and Mair et al (1996)[9] shown below in my assessment of the effects on buildings. This is an internationally recognised method for categorising the levels of effects on buildings.

[9] A number of publications and papers have been published and presented over various years based on the works of Burland, Mair, Taylor, Rankine and other recognised researchers in ground settlement behaviour and prediction. I refer to these authors in various combinations in my evidence that follows.

23. Building Damage Classification[10]

Category of Damage	Normal Degree of Severity	Description of Typical Damage (Building Damage Classification after Burland (1995), and Mair et al (1996))	General Category (after Burland - 1995)
0	Negligible	Hairline cracks	**Aesthetic Damage**
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior visible upon close inspection. Typical crack widths up to 1 mm.	
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible, some repainting may be required for weather-tightness. Doors and windows may stick slightly. Typical crack widths up to 5 mm.	
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Brick pointing and possible replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired. Typical crack widths are 5 to 15 mm or several greater than 3 mm.	**Serviceability Damage**
4	Severe	Extensive repair involving removal and replacement of walls especially over door and windows required. Window and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably. Some loss of bearing in beams. Utility services disrupted. Typical crack widths are 15 to 25 mm but also depend on the number of cracks.	
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing walls lean badly and required shoring. Windows broken by distortion. Danger of instability. Typical crack widths are greater than 25 mm but depend on the number of cracks.	**Stability Damage**

24. It should be noted that the terms ‘slight’ and ‘moderate’ etc. as presented in paragraph 23 do not necessarily correspond to building owners perceptions. The terminology is widely accepted and the classification system has been adopted by many organisations including the Institution of Structural Engineers and the Institution of Civil Engineers.

25. I have assessed the expected level of effect of construction vibration on all buildings in each of the building categories to be in the range of *Negligible to Slight,* based on the Building Damage Classification introduced at paragraph 23. I consider that the effects would comprise cracking of only an aesthetic or superficial nature to facades, walls, internal linings and/or framing to these buildings.

[10] Mair RJ. Taylor RN, & Burland JB, (1996) Prediction of Ground Movements and Assessments of Risk of Building Damage Due to Tunnelling, Int, Symp. Geotechnical Aspects of Underground Construction in Soft Ground, London

Settlement assessments

26. Construction related settlement is anticipated along the CRL. Tunnel shaft and cut and cover excavations have the potential to induce surface, subsurface and lateral ground movement with resulting effects on nearby structures and their foundations. Excavation induced settlements resulting from stress redistribution from the construction effects of the CRL are expected to occur within several months of excavation.

27. Excavation induced settlement is anticipated to have a significantly greater effect on buildings than construction vibration.

28. To obtain an understanding of the anticipated order of effects of excavation induced settlement and inform the concept design and design refinement of the CRL, settlement analyses at a range of locations along the route have been undertaken. From these analysesestimates have been made of the scale of effects on adjacent buildings

29. Settlement resulting from consolidation of soil due to groundwater drawdown or diversion has not been explicitly assessed. This occurs relatively slowly and has a much lower potential adverse effect. It is expected that appropriate mitigation measures can be implemented during the construction phase to minimise this effect. These will need to be comprehensively assessed as part of future resource consents required for the project.

30. Initial Tunnel Boring Machine (TBM) tunnelling induced surface settlements have been estimated based on "greenfield" conditions and by utilising the settlement analysis software XDISP. Estimates of shaft and cut and cover tunnel induced settlements elsewhere along the CRL route have been made using the computer program WALLAP[11]. WALLUP has been utilised to assess the deflection of lateral wall/ground movements at the position of the excavation support walls. The deflection of the walls will create a corresponding volume loss to

[11] WALLAP is a retaining wall analysis program which allows for analyses of both temporary and permanent retaining wall structures including cantilever walls, anchored walls and strutted excavations.

the side of the excavation translated at the surface as a settlement trough. Surface settlement behind the walls has been predicted utilising empirical formulas proposed by Bowles[12].

31. Settlement contour maps were produced from the settlement prediction data with contours plotted along the length of the CRL corridor, overlaid with existing building footprints. For the purposes of my evidence, the 5mm contours define the zone of influence of the CRL in respect to construction settlement effects.

32. I undertook a preliminary "first stage" evaluation of the anticipated order of effects on buildings in the vicinity of the alignment based on a limited number of representative settlement profiles developed at different chainage points over the length of the alignment. Both total settlement and the slope of the ground or differential settlement under the subject building at each profile have been estimated utilising a well-established empirical approach by Burland et al. These have been compared against limiting criteria as recommended by CIRIA (1996)PRO 30 and Burland, Mair et al in categorising the expected order of effects.

33. "Second stage" assessments were then undertaken for representative building types where settlement exceeded 10 mm, and on representative heritage type buildings near the outer edges of the settlement trough. According to Rankin a building experiencing a settlement of less than 10mm and a maximum ground slope of 1:500 has a negligible effect of damage. The 10mm trigger represents the lower end of the settlement range of the "Slight" damage category of the damage assessment criteria that have been adopted for the "first stage" assessment purposes. In this category maximum ground slopes of 1:500 to 1:200 apply which are likely to be sufficient to cause extended cracking (albeit in the aesthetic range) in the more brittle unreinforced brick masonry buildings and older brick infilled concrete frame structures which are prevalent from Karangahape Road Station to Newton Station.

[12] Bowles J E (1998) Foundation Analysis and Design, 4th Edition, McGraw Hill International Book Company, Singapore, 1988.

34. In these second stage assessments, for buildings with shallow foundations the interaction between the ground and building is considered using the empirical method described by Mair, Taylor and Burland. Bending, diagonal and horizontal tensile strains induced on the building are estimated, assuming the building conforms to the greensite settlement trough, by assigning a structural stiffness parameter that is dependent on the flexibility or stiffness (construction type) of the building. Categorisation of the expected order of effects is based on a comparison of both the estimated critical tensile strain and the ground distortion or slope of the ground under the subject buildings with the limiting values of the damage assessment criteria after Burland and Mair et al and Rankin. This approach, though more detailed than the preliminary first stage assessment, is usually still conservative as the building displacement is assumed to conform to the settlement trough. In practice the inherent stiffness of the building will tend to reduce both the resulting deflections, angular distortions and tensile strains.

35. To address the concerns of a number of submitters and as part of an internal due diligence, on-going 'second stage' assessments have been undertaken for a number of additional specific buildings considered more sensitive to the construction of the CRL which are located either within the proposed footprint or close to it. These include shallow founded unreinforced masonry and heritage buildings close to the proposed stations and associated shafts, and two modern multi-storey buildings with piled foundations in close proximity to stations and tunnels. The results of these assessments are summarised in my Response to Submissions.

36. For the purposes of the on-going assessments of the shallow founded buildings, ground settlement profiles including the lateral deformations across tunnel and mined station induced settlement troughs have been predicted using an empirical analytical method proposed by Loganathan and Poulos[13] and the building cross sections plotted against these.

[13] BP 2009 William Barclay Parsons Fellowship Monograph 25 "An Innovative Method for Assessing Tunnelling Induced Risks to Adjacent Structures"

37. I have estimated that the expected level of effects on the selected sample of shallow founded sensitive unreinforced masonry and heritage buildings, located principally on Albert Street and adjacent side streets in the vicinity of the Aotea Station, and in the vicinity of the Karangahape Road and Newton Station, fall within the *Negligible* to *Slight* damage category, The level of damage associated with the these categories is considered to be aesthetic in nature as described in paragraph 23 above.

38. In response to submissions, a more detailed evaluation of the effect of excavation induced settlements on the piled foundations of several modern multi-storey piled buildings has been undertaken. Under my Response to Submissions evidence I provide more detailed discussion on the assessments undertaken and outcome of these.

39. I consider the assessment of the potential effects in existing buildings and structures resulting from CRL excavation and construction has been undertaken in accordance with industry practice for the level of project development achieved to date and in view of the typical building stock influenced by the tunnel construction. I consider that the estimated settlement effects along the tunnel alignment will be of an acceptable level in terms of potential structural damage. The potential effects will be of a superficial extent and can be mitigated through good design and workmanship in respect of the CRL and through implementation of preconstruction building condition assessments and construction phase monitoring of all buildings influenced by the CRL.

40. The impact of excavation settlement on adjacent buildings will need to be reassessed (as part of future assessment in support of resource consents to be sought at a later stage). Preliminary first stage assessments along the alignment will provide revised contours and allow buildings of negligible risk to be eliminated from further detailed consideration. Second stage assessments will need to be undertaken for buildings identified in the first stage assessment as requiring further study.

41. Further detailed numerical evaluations will be required of identified higher risk buildings influenced by the CRL from the second stage

assessments once the design and construction aspects of the project have been finalised, particularly of the more sensitive older buildings, including those identified in the Built Heritage Technical Report[14] and of the multi-storey piled buildings adjacent the Aotea Station. These evaluations will need to include consideration of the particular features of each building and the tunnelling and excavation design, including inter alia, building stiffness, foundation types, building orientation, soil/structure interaction, tunnelling and excavation parameters etc.

42. I would normally expect detailed evaluations to provide a reduction in the estimated level of damage or order of effects because of the conservative assumptions used in the first and second stage assessment approaches. These earlier assessment approaches which have been adopted in the assessments completed to date are mainly based on widely accepted simplistic empirical approaches.

43. Whilst future detailed evaluations will be required of buildings influenced by the CRL, mitigation measures as discussed below will need to be implemented as a matter of course in accordance with standard industry practice for all buildings within the zone of influence of the CRL (defined as the vibration threshold contours in respect to construction vibration and the predicted contour for 5mm settlement which I mentioned earlier in my evidence).

Mitigation

Building Condition Surveys

44. The implementation and monitoring of the proposed draft NoR condition (as amended by Council) requiring Building Condition Surveys (Condition 40 and 41) provides for the management and mitigation of the potential adverse effects on building structures resulting from construction vibration identified in the assessments and referred to in my evidence. I agree that the conditions are appropriate for this purpose (including Council's suggested amendments).

Vibration Monitoring

[14] CRL Volume 3 Part 1 NOR Built Heritage Technical Expert Report.

45. The implementation and monitoring of the proposed draft NoR condition requiring Construction Vibration monitoring provides for the management and mitigation of the potential adverse effects on building structures resulting from construction vibration identified in the assessment and referred to in my evidence. I agree that the proposed conditions (as amended by Council) are appropriate for this purpose.

Surface and Structural Settlement Monitoring

46. This relates primarily to settlement resulting from excavation and consolidation of soil due to groundwater drawdown. The recommended mitigation measures below will need to be comprehensively assessed as part of the future resource consents for the project to be developed as part of a future stage of CRL design.

47. For buildings and structures of concern additional monitoring measures will be required which may include settlement monitoring at corners of the buildings and at any points of particular structural concern. Tilt monitoring at the face of the buildings may also be carried out.

48. Monitoring of surface settlement markers will be required as a result of the settlement estimations and pre-construction inspections as indicated above. These will be situated along each tunnel alignment at regular intervals and adjacent to the station structures to measure ground settlement. Transverse arrays to measure settlements transverse to the tunnel alignment will be installed at a lesser frequency. This monitoring will enable a regional monitoring of effects.

Other mitigation options

49. The following mitigation methods, associated with the tunnel and station works, may need to be considered primarily to address effects of ground settlement resulting from excavation or ground water drawdown (therefore subject to future resource consent submissions) and to a significantly lesser extent, potential construction vibration induced damage. These mitigation methods include:

    (a) Reducing the ground deformations associated with a particular construction method or design.

For open cut excavations this may include improving the stiffness of the vertical wall elements through increased thickness or use of stiffer wall systems (e.g. diaphragm walls), use of strutted excavations with struts preloaded or inclined ground anchors behind the walls.

(b) Operating the TBM in its "closed" mode to reduce ground displacement around the open shaft prior to installation and grouting behind the concrete liners.

(c) Changing the characteristics of the ground around the excavation or compensating for ground movement around a particular structure by injecting the surrounding ground with grout.

(d) Local strengthening of existing building structures as appropriate. Strengthening could include, for example, underpinning to foundations utilising perimeter piles and pile caps hooked under the foundations, use of micropiles to strengthen the foundations, installation of ground beams to connect pile caps, temporary strengthening and securing of facades.

(e) For many buildings simple remediation of cracks and redecoration following the construction work will be the most viable option for addressing any damage resulting from construction vibration and or excavation induced settlement. Auckland Transport, will be responsible for all associated repairs (refer to Condition 41, as amended by Council).

Response to Submissions

50. I have read submissions lodged on the NoR which are relevant to my area of expertise and which raise concerns in respect to building damage resulting from vibration and settlement. Concern over building damage has been raised in 19 submissions. In this section of my evidence I will address these submissions.

Submission 51, 177A/B Symonds Street Newtown

51. The submitter has raised a concern in respect to possible vibration impact from the CRL on the basis of recent experience of vibration occurring in his building as the result of traffic running across an alleged drainage pipe buried under Symonds Street. The building is located some 35 m above the crown of the underlying tunnels and as indicated in my assessment[15] it is not at risk of vibration induced damage from CRL construction. The expected surface settlement at the site induced by the TBM tunnelling has also been assessed at between 5 and 10mm and this will have negligible impact on the building.

Submission 118, 125 Queen Street; Submission 117, Dillworth Building, 22-32 Queen Street; Submission 186, Karori Square, 10 Ruru Street, Mount Eden; Submission 87, St Patricks Cathedral, Square and Presbytery, 43 Wyndham Street.

52. The above submitters have raised concerns in respect to the possibility of detrimental structural effects resulting from the CRL construction. My assessments indicate that the buildings are outside the zone of influence of the CRL (as defined earlier in my evidence) and the risk of either construction vibration or settlement induced damage to any of the buildings is negligible.

Submission 121, George Court Building, 238 Karagahape Road

53. The above submitter has raised concerns in respect to the CRL impacting on the structural integrity of the building.

54. The George Court Building is a scheduled heritage building[16]. It is located approximately 23m directly above the crown of the mined station tunnel and is within close proximity of one of the top down constructed station shafts.

55. My assessment has identified the building to be within the vibration threshold contour for heritage buildings where the 2.5mm/s PPV construction vibration threshold criterion for heritage buildings may be

[15] Appendix C of the CRL Volume 3 Part 1 NOR Structural Engineer Technical Expert Report

[16] CRL Volume 3 Part 1 NoR Built Heritage Technical Expert Report

exceeded. The building does however fall outside of the 5mm/s PPV threshold contour applicable to residential buildings. As noted in Mr Whitlock's evidence, these contours are known to be very conservative and even buildings that lie within their corresponding vibration construction contours have a low risk of superficial damage.

56. The expected maximum surface settlement at the site induced by construction of the tunnel and mining of the Karangahape Road Station has been estimated at 45mm and the differential settlement or ground slope across the site has been estimated at 1:340.

57. I have reviewed the record drawings of the building sourced from the Auckland City property archives. These show the building to comprise 1 1/2 basement levels and 4 upper levels. The building is constructed of reinforced concrete incorporating beam column frames with unreinforced masonry infill to the perimeter, and is founded on reinforced concrete spread footings to the underside of the lower basement. The basement floors against the ground are concrete slabs cast on grade. The building was constructed in or about 1930.

58. Given the building is predominantly reinforced concrete framed construction, I would expect the building to suffer negligible structural damage due to construction vibration (Slight category). Damage of an aesthetic or superficial nature as the result of ground settlement across the site could be expected, including cracking to unreinforced masonry infill panels, façades and plaster overlays, and to internal partitions.

59. Given the proximity of the building to one of the Karangahape Road station shafts, a detailed assessment of the effects of construction induced settlement on the building is required at the detailed design stage once the station's layout/arrangement and construction aspects have been finalised. Alternative construction techniques or methodologies may need to be investigated to reduce the effects of settlement on the buildings. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions, including pre construction

Building Condition surveys and on-going building inspections as discussed in paragraph 45 and 46 above, will provide a means of monitoring and addressing any damage to the building.

Submission 95, Quay West Apartments, 8 Albert Street; Submission 70, Stamford Residences, 26 Albert Street

60. The above submitters have expressed concerns of structural damage due to construction vibration. The submitters' buildings lie inside the construction vibration risk contours for residential and commercial buildings. The anticipated ground settlements at both sites have been assessed at 5mm or less[17], with expected negligible effects on the buildings.

Submission 97, St Patricks Site, Wyndham Street & St Benedict's Site, St Benedict's Street; Submission 87, St Patricks Site, Wyndham Street.

61. The above submitters have expressed concerns of structural damage to the buildings and heritage fabric at both the St Patricks site and the St Benedict's site due to construction vibration and ground deformation generated by the CRL construction.

62. Both sites lie outside the construction vibration risk contours for heritage buildings.

63. The St Patricks site is located at a sufficient distance from the CRL for any construction induced settlements at the site to be negligible.

64. The CRL passes directly under the St Benedict's site, with the crown of the tunnels approximately 25m below the ground surface. The anticipated maximum surface settlement at the site induced by the TBM tunnelling has been assessed at 15mm.[18] Aesthetic damage can be expected, particularly to the church and presbytery buildings which are predominantly constructed of unreinforced masonry construction and will be sensitive to ground movement. Damage could include cracking and isolated fractures in the brickwork walls of the buildings. Given the

[17] Appendix C of the CRL Volume 3 Part 1 NOR Structural Engineer Technical Expert Report

[18] Appendix C of the CRL Volume 3 Part 1 NOR Structural Engineer Technical Expert Report

brittle form of construction of the church and presbytery buildings, I recommend that a detailed assessment of the effects of construction induced settlement on the buildings be undertaken at the detailed design stage once the tunnel alignment and construction aspects have been finalised. Alternative construction techniques or methodologies may need to be investigated to reduce the effects of settlement on the buildings to acceptable levels.

65. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions, including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 45 and 46 above, will provide a means of monitoring and addressing any damage to the building.

Submission 197, Eclipse Apartments, Unit 4B, 156 Vincent Street; Submission 216, Eclipse Apartments, Unit 6G, 156 Vincent Street

66. The above submitters are concerned about the effects of the CRL on the building structure, the latter submitter identifying potential issues of ground movement.

67. The CRL tunnel alignment within Vincent Street to the North of Karangahape Road Station lodged with the NoR has been reviewed to increase the offset distance from the Eclipse Apartment building, as noted in Mr Newns evidence. Further analysis has shown that an alignment within the NoR footprint can provide a clear offset of the eastern tunnel of 1 to 2 m from the nearest pile foundation supporting the west side of the building. The eastern tunnel of the indicative alignment lodged with the NOR passed directly under the Eclipse Apartment building.

68. I have reviewed the record drawings of the building sourced from the Auckland City property archives. The building was constructed in or about 2007 and comprises a single basement carpark on grade and 14 apartment floors. The building is constructed of reinforced concrete

incorporating a combination of proprietary precast concrete and metal tray insitu concrete composite floor slabs, concrete beam column framing and concrete shear walls. It is founded on bored cast insitu concrete piles embedded in the underlying East Coast Bay Formation sandstones. The basement floor comprises a concrete slab cast on grade. The building piles are located at or only a few metres immediately above the crown of the adjacent eastern tunnel.

69. The building falls outside the construction vibration risk contour established for the original alignment that is applicable at ground level for residential buildings, but inside the contour applicable at 20m below ground level. It is anticipated that the building will similarly fall within the relevant vibration risk contour at 20m depth for the revised alignment. The risk contours at 20m depth are judged to be applicable where deep pile foundations are present. No amended contours have been established to date to reflect the revised alignment.

70. Further assessments of the effects of ground settlement resulting from tunnel construction in light of my further analysis have been undertaken. The tunnelling excavations will induce vertical and horizontal movement in the ground, imposing additional drag down forces and bending actions on the piles.

71. Finite element analysis was undertaken using the 3D finite element package PLAXIS[19] to predict pile responses and pile deflections as a result of the proposed tunnelling works. This software has been developed for the analyses of deformation, stability and ground water flow in geotechnical engineering. Maximum vertical and horizontal pile displacements induced by the tunnelling were assessed at 5mm and 4mm respectively. The increased axial load and moment demands on the piles, from a combination of the tunnelling induced demands with the existing gravity load demands, were assessed as within the existing capacities of the piles.

[19] PLAXIS is a 2D & 3D finite element program developed for the analyses of deformation, stability and ground water flow in geotechnical engineering

72. The expected level of effects has been estimated as Very Slight on the basis of the Building Damage Classification, introduced at paragraph 23.

73. However, the settlement induced actions on the piles are sensitive to the proximity of the tunnel, ground geotechnical properties and the TBM construction volume loss. I recommend that a detailed assessment of the effects of construction induced settlement on the buildings be undertaken at the detailed design stage once the specific tunnel alignments and construction aspects have been finalised. Where necessary, alternative construction techniques or methodologies may need to be investigated to reduce the effects of settlement on the building's foundations.

74. Any future detailed evaluations required of the building in respect to settlement effects will need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions (as amended by Council), including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 44 and 45 above, will provide a means of monitoring and addressing any damage to the building.

Submission 138, 24 Mount Eden Road

75. The above submitter has expressed concern of the impact of construction on his building.

76. The submitter's building lies outside the construction vibration risk contours for commercial buildings[20]. The CRL traverses at grade in the vicinity of the building and there are unlikely to be any settlement induced effects on the building.

Submission 219, Pitt Street Methodist Church, Wesley Bi Centennial Hall &Pitt Street Buildings; Submission 68, Karangahape Road Business Association, Heritage Buildings to Pitt Street and Karangahape Road; Submission 4, 61-65 Pitt Street

77. The above submitters generally focus on the potential for construction vibration and settlement damage to a number of heritage type buildings in the area. The buildings typically range from shallow founded unreinforced masonry structures, older concrete structures and combinations of the two, commonly incorporating timber floor and light weight timber or steel framed, roof structures.

78. The majority of the buildings lie partly inside the construction vibration risk contour for heritage buildings.[21] The assessed maximum anticipated ground settlements at the sites range between 15-30mm.[22] Further ongoing assessments of the effects of ground settlement resulting from construction of the tunnels and the Karangahape Road Station, and associated shafts have been undertaken for a number of the older heritage buildings on Pitt Street and Karangahape Road. These assessments have identified the expected level of effects to be limited to aesthetic damage, falling into the Slight damage category of the Building Damage Classification described at paragraph 23. However many of the buildings are considered sensitive to the construction works and associated ground movement. This is more the result of their brittle form of construction and/or the poor level of interconnections between facades, floors and roofs which provide the necessary out of plane restraint to perimeter walls and facades.

79. I recommend that detailed assessments of the effect of construction induced settlements on the buildings in close proximity to the station shafts, of particularly brittle construction or in poor existing condition, should be undertaken at or before the detailed design stage once the specific tunnel and station layouts and alignments, and construction aspects have been finalised. Where required, alternative construction techniques, including mitigation works that may include underpinning, will need to be investigated to reduce the impact on the buildings to acceptable levels.

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[20] Appendix H of the CRL Volume 3 Part 1 NOR Noise & Vibration Technical Expert Report

[21] Appendix H of the neither CRL Volume 3 Part 1 NOR Noise & Vibration Technical Expert Report

[22] Appendix C of the CRL Volume 3 Part 1 NOR Structural Engineer Technical Expert Report

80. Any future detailed evaluations required of the buildings in respect to settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions (as amended by Council), including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 44 and 45 above, will provide a means of monitoring and addressing any damage to the building.

Submission 88, Skycity Grand Hotel/Convention Centre, 109-125 Albert Street

81. The above submitter has raised concerns about the effects of construction vibration and structural effects from the construction of the CRL on its properties, particularly the Grand Hotel and Convention Centre building.

82. I have reviewed the record drawings of the building sourced from the Auckland City property archives. The building is a 24 storey commercial and hotel building. It does not incorporate any basement levels. It is constructed utilising a combination of reinforced concrete frames and shear walls with structural steel framing to its upper floors. The building is supported on groups of bored cast in situ piles founded approximately 4 m below the base slab of the adjacent Aotea Station in unweathered East Coast Bay Formations. The building boundary to the east is in close proximity of the proposed Aotea Station.

83. The Grand Hotel and Convention Centre building along Albert Street lies partly inside the construction vibration risk contour for residential and commercial buildings[23]. The maximum anticipated ground settlements at the site have been assessed at 15-20mm[24.]

84. Two dimensional finite element analysis modelling was undertaken using the finite element package PLAXIS to predict pile responses and pile deflections as a result of the proposed excavation works associated with the adjacent Aotea Station. The analysis has shown that in order to ensure that the increased axial load, moment and shear

[23] Appendix H of the neither CRL Volume 3 Part 1 NOR Noise & Vibration Technical Expert Report

[24] Appendix C of the CRL Volume 3 Part 1 NOR Structural Engineer Technical Expert Report

demands on the piles adjacent the Aotea Street frontage caused by ground displacement are within the pile capacities, the pile displacement will need to be limited to the order of 12mm. This may require mitigation measures such as the provision of additional tie beams between the pile caps on the Albert Street frontage.

85. Lower Albert Street to the east side of the station is approximately 6m below the ground level at the west side of the station. I consider the effects of the excavation works for the Aotea Station will result in ground movement that could impose additional loads on the foundation piles of the building during the construction phase. I recommend that a detailed assessment of the effects of the CRL construction on the building and its foundations be undertaken at the detailed design stage once the specific station layouts and alignments, and construction aspects have been finalised. Where required, alternative construction techniques, including mitigation works, will need to be investigated to reduce the effects on the building to acceptable levels.

86. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions (as amended by Council), including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 45 and 46 above, will provide a means of monitoring and addressing any damage to the building.

87. The submitters of other properties between Federal Street and Hobson Street lie outside the zone of influence of the CRL (as defined earlier in my evidence). The risk of either construction vibration or settlement induced damage to any of the buildings is negligible.

88. A number of other modern multilevel commercial buildings with piled foundations located nearby, along the length of the Aotea Station, have not been assessed to date. These may exhibit the same issues in respect to the need to minimise the lateral displacement of the piles fronting Albert Street to ensure the expected effects will be acceptable, although to a lesser extent. Several of the buildings incorporate

basement levels and/or tie beams that reduce the effect of any lateral movement of the ground on their underlying piles

Submission 236, Albert Plaza, 87-89 Albert Street

89. The above submitter has raised concerns about the effects of construction vibration and settlement on the building's structural integrity, including the building superstructure and the possible loss of building support associated with the excavation works.

90. I have reviewed the record drawings of the building sourced from the Auckland City property archives. The building is a 13 storey commercial building, incorporating 2 basement levels. It is a reinforced concrete framed structure founded on bored cast in situ concrete piles founded in unweathered ECBF. The piles are found approximately 2m below the proposed base slab of the adjacent Aotea Station. The piles adjacent to the Albert Street frontage are 5m clear of the proposed Aotea Station.

91. The submitter's building lies partly inside the construction vibration risk contour for residential and commercial buildings. The maximum anticipated ground settlement at the site has been assessed at 15mm.

92. Given the presence of the two basement levels reducing the pile lengths exposed to possible construction effects, and the increased clearance of the building's foundations from the Aotea Station box, I believe the expected level of effects is likely to be of lesser magnitude compared to that for the nearby Sky City building.

93. However, I would agree that the building may be at risk from the effects of settlement and from the impact of excavation works at the adjacent Aotea Station. The impact of these works may include ground movement imposing additional loads on the piles and possibly impacting on their structural integrity. I recommend that a detailed assessment of the effects of the CRL construction on the building and its foundations be undertaken at the detailed design stage once the specific tunnel and station alignments, layouts and construction aspects have been finalised. Where required, alternative construction techniques, including mitigation works that may include underpinning,

will need to be investigated to reduce the impact on the building's foundations to acceptable levels.

94. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions (as amended by Council), including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 44 and 45 above, will provide a means of monitoring and addressing any damage to the building.

Submission 211, Zurich House, 21 Queen Street

95. The CRL passes immediately adjacent to the north face of Zurich House at depth of approximately 10m.

96. The building lies partly inside the construction vibration risk contour for residential and commercial buildings. The maximum anticipated ground settlement at the site has been assessed at 8mm.

97. I have reviewed the record drawings of the building sourced from the Auckland City property archives. The building is a 24 storey commercial building, incorporating one basement level. It is a reinforced concrete framed structure over the lower 15 levels, with a steel framed construction for the upper levels. These floors were a later extension to the original building. The building is founded on bored cast in situ piles. The piles are typically found above the base of the adjacent CRL tunnels. A small 600mm diameter pile in the north west corner supporting the lower level of the building is within 600mm of the proposed tunnel. The adjacent 1000mm diameter pile to the main tower is within 1400mm of the proposed tunnel.

98. The adjacent CRL tunnels are to be constructed using a cut and cover approach. This will result in horizontal and vertical ground movement that will impose additional loads on the building's piles.

99. The maximum anticipated ground settlement at the site has been assessed at 5 to 8mm.

100. I believe that the building may be at risk from the effects of settlement and from the impact of excavation works including ground movement, imposing additional loads on the piles and possibly impacting on their structural integrity. I recommend that a detailed assessment of the effects of the CRL construction on the building and its foundations be undertaken at the detailed design stage once the specific tunnel and station alignments and construction aspects have been finalised. Where required, alternative construction techniques, including mitigation works will need to be investigated. These may include grouting of the ground in the gap between the building and the tunnel wall and around the critical piles to reduce the impact on the building's foundations to acceptable levels.

101. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions (as amended by Council), including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 45 and 46 above, will provide a means of monitoring and addressing any damage to the building.

Submission 79 Mediaworks, 2 and 3 Flower Street, Newton

102. The above submitter has raised concerns about the effects of construction vibration and noise on the facility.

103. The TV3 Building is located approximately 10m directly above the crown of the mined tunnel to the down track and is within a few metres of the mined tunnel cross over box. My assessment has identified the building to be within the vibration threshold contour for heritage, residential and commercial buildings.

104. The expected maximum surface settlement at the site induced by construction of the mined tunnel and mining of the Karangahape Road Station has been estimated at 27mm and the differential settlement or ground slope across the site at 1:1700. Lateral ground movement of 13mm has been estimated.

105. I have reviewed the record drawings of the building sourced from the Auckland City property archives. These show the building to comprise 4 separate interconnected structures, varying up to 5 storeys in height, each incorporating a partial basement. The structures are of reinforced concrete construction, incorporating beam column frames with unreinforced masonry infill to the perimeter. Three structures are founded on pad and strip footings and one on bored concrete piles. The basement floors against ground are concrete slabs cast on grade. The four connected structures were constructed in 1957, 1963, 1967 and 1977.

106. Given the building is predominantly of reinforced concrete framed construction, I would expect the building to suffer negligible structural damage due to construction vibration (Very Slight category). Damage of an aesthetic or superficial nature (Slight) as the result of ground settlement across the site could be expected, including cracking to unreinforced masonry infill panels, façades, and to internal partitions.

107. Given the proximity of the building to the mined tunnel immediately below and the adjacent entry portal, a detailed assessment of the effects of construction induced settlement on the building is required at the detailed design stage once the station's layout/arrangement and construction aspects have been finalised. Alternative construction techniques or methodologies may need to be investigated to reduce the effects of settlement on the buildings to acceptable levels. Any future detailed evaluations required of the building in respect of settlement effects will be need to be addressed in future resource consent applications for the project. However, the implementation of the mitigation measures as presented in the proposed draft NoR Conditions including pre construction Building Condition surveys and on-going building inspections as discussed in paragraph 45 and 46 above, will provide a means of monitoring and addressing any damage to the building.

Response to Planner's Report

108. I have read the Auckland Councils Planners Report (City Rail Link Notice of Requirements- Report to Commissioners)[25] and associated reports by their Technical Experts.[26] I have focussed on the parts which are relevant to my area of expertise and provide my comments below.

109. I note that Tonkin and Taylor and Styles Group both acknowledge the appropriateness of the adopted selection criteria (of DIN 4150-3) for defining risk contours for the management of structural damage resulting from vibration construction, as proposed in the MDA Report and adopted in the Structural Engineering Report for assessment of vibration effects. They also acknowledge that the criteria are conservative and should be treated as a guideline limit only.

110. Tonkin and Taylor acknowledge that the cut and cover segment contours derived in respect to construction settlement are reasonably conservative based on their own spot checks.

111. Tonkin and Taylor also conclude that the settlement contours for the bored tunnel alignments are reasonable but not very conservative. The estimated settlement contours associated with the bored tunnel excavation have been derived assuming a volume loss of 1 to 1.5%. Given the tunnelling is almost entirely within the East Coast Bays formation ground material (weak sedimentary rock) this is considered reasonable. Mr Newns addresses this issue in greater detail in his evidence.

112. The Planners have identified a number of submitters that expressed concerns about settlement on individual buildings. I have addressed these in the Response to Submissions section of my evidence.

113. I acknowledge and support the Auckland Councils Planners suggested amendments and additions to the proposed NoR draft conditions

[25] Primarily Section 9.4 “Structural Integrity,” pages 86 – 90 and Section 9.11 “Built heritage,” pages 134 – 152.

[26] Auckland Council Reports: Attachment F, Noise and Vibration Technical Report, Styles Group and Attachment G, Structural Integrity Report, Tonkin and Taylor.

including Condition No. 21 (including 21B) and No. 40 relating to Construction Vibration and No. 41 relating to Building Condition Surveys.

Proposed Conditions

114. I have reviewed the CRL Proposed Draft Notice of Requirement Conditions (as amended by Council), notably those that are relevant to my area of expertise.

115. The Auckland Council Planner has proposed several amendments and additions which I have reviewed and discussed in paragraph 113 above. As noted I would recommend their inclusion in the Proposed Draft Conditions.

116. I otherwise acknowledge that the proposed conditions should be sufficient to address submitters' concerns in respect of the potential effect of construction vibration causing damage to individual buildings.

Conclusion

117. Overall, I consider the potential effects of the Project on built structures generated by ground borne vibration resulting from the construction of the CRL and associated with construction excavation induced settlement along the tunnel alignment will generally be acceptable and able to be managed through the conditions proposed and through future stages of detailed design and construction.

Eric Craig Stevenson

2 July 2013