IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of Resource Consents and Notices of Requirement for the Central Interceptor main project works under the Auckland Council District Plan (Auckland City Isthmus and Manukau Sections), the Auckland Council Regional Plans: Air, Land and Water; Sediment Control; and Coastal, and the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health

STATEMENT OF EVIDENCE OF PETER MILLAR ON BEHALF OF WATERCARE SERVICES LTD

VIBRATION

1. INTRODUCTION

1.1 My full name is Peter James Millar. I am employed by Tonkin & Taylor Ltd, an environmental and engineering consultancy firm, as a senior geotechnical engineer and Tonkin & Taylor's Business Development Manager. I am based in the company's Auckland Office.

1.2 I hold the degree of Masters of Engineering 1st Class from the University of Auckland. I am a Fellow of the Institution of Professional Engineers New Zealand, a member of the New Zealand Geotechnical Society Inc and New Zealand Society for Earthquake Engineering Inc. I was the joint recipient of the first NZ Geotechnical Society Award and have received a Fulton Downer Gold Medal – Presidents Award and the Turner Award from IPENZ.

1.3 I have 37 years post-graduate experience in geotechnical engineering. My Masters' thesis work involved a study of the slope stability and strength of weathered and jointed rock. I was then employed by the Ministry of Works and Development for 17 years during which time I

undertook design for the Rangipo Underground Power Station and tunnels followed by a period of construction supervision of the excavation of the main caverns using blasting techniques. During the latter 10 years of my employment with the Ministry, I was section manager of the geomechanics group, and undertook investigations and geotechnical design on many major hydroelectric and roading projects throughout New Zealand. This included work on a number of tunnel projects as well as geophysical investigations using explosive sources and assessments of construction vibrations.

1.4 Since joining Tonkin & Taylor in 1987, I have provided specialist geotechnical services on many projects in New Zealand and the South-East Asia Pacific region. I was geotechnical group manager from 1992 to 2006 after which I was appointed Managing Director of the Tonkin & Taylor Group. I stepped down from the Managing Director position in 2010 to return to a consulting role. Over the past 23 years I have been responsible for the design of foundations of many of the major building developments in the Auckland CBD, which are constructed in similar geological conditions to the Central Interceptor Project ("**Project**"). I have also held senior technical roles in, and been a Board member of, the Waterview Connection Alliance, responsible for constructing the twin road tunnels on the Western Ring Route, and the Northern Gateway Alliance, which has undertaken construction of both the Albany to Puhoi Motorway and the replacement of the Newmarket Viaduct. I am also currently on the board of the Memorial Park Alliance road underpass project in Wellington.

1.5 Of particular relevance to the Project:

(a) I have provided technical advice on the effects of ground transmitted vibrations for many projects in the Auckland Region. This includes undertaking assessments for the development of a number of quarries, including Hunua, Bombay, Whangaripo, Pokeno, Portland, Hikurangi, Kerikeri and Three Kings. These quarry projects all included the use of blasting techniques, rock breaking and other heavy construction plant.

(b) I have undertaken vibration assessments for a number of tunnel projects in Auckland, including the Waterview (Western Ring Route) Connection Project ("**Waterview Project**"), Vector tunnel and the Hobson Bay tunnel ("**Project Hobson**"), as well as undertaking a review of vibration effects for the proposed Golden Link Project at Waihi.

(c) I have been responsible for determining the vibration effects associated with blasting during the redevelopment of the Brightside Hospital in Epsom, Lunn Ave Quarry at Mt Wellington (also known as Stonefields) and with extensions to the Fulton Hogan yard in the Reliable Way Quarry.

(d) I was also the design engineer responsible for ground improvement works for the assessment of vibration effects and design of strengthened foundations using dynamic compaction for Te Papa Museum in Wellington, Sir Edmund Hillary Retirement Village, construction at Pike's Point, and numerous oil storage tank farms around New Zealand. The effects of generated vibrations were major considerations for all of these projects.

(e) I have carried out many assessments of traffic, rail and construction plant-induced vibrations. These assessments have included site testing for the effects of traffic on the Kerikeri Stone Store, and the effects of traffic on MRI Scanners at Auckland, Hamilton and Tauranga Hospitals.

(f) I have also assisted councils and the NZ Transport Agency ("**NZTA**") on many projects where traffic-induced vibrations have been significant issues for consents, and I have provided advice on the preparation of district plan rules for limiting the effects of vibrations.

Involvement in Central Interceptor Project

1.6 Watercare Services Limited ("**Watercare**") retained Tonkin & Taylor to undertake an assessment of vibration effects for the construction and operation of the Central Interceptor tunnel. The assessment was reported to Watercare in July 2012 and included as Technical Report G ("**Vibration Report**") of Part D of the Central Interceptor Assessment of

Effects on the Environment submitted to the Council in August 2012 ("**AEE**"). I was the primary author of the Vibration Report.

Code of Conduct

1.7 I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Updated Practice Note 2011 which took effect on 1 November 2011. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope of Evidence

1.8 The purpose of my evidence is to address the potential effects of vibration associated with the construction and operation of the Project.

1.9 My evidence is structured as follows:

(a) executive summary;

(b) summary of methodology;

(c) introduction to vibrations;

(d) vibration standards;

(e) construction methodology - sources of vibration;

(f) vibration effects and site criteria;

(g) assessment of estimated vibration effects associated with the Project;

(h) mitigation options and proposed conditions;

(i) Section 92 Response;

(j) response to submissions;

(k) response to Council Pre-hearing Report; and

(l) conclusions.

1.10 I am familiar with the area and geology that the Project covers, and the type of equipment expected to be utilised for the works.

1.11 In preparing my evidence, I have had particular regard to the following briefs of evidence:

(a) The Project overview by Mr Munro.

(b) The concept design evidence presented by Mr Cantrell.

(c) The construction evidence presented by Mr Cooper.

(d) The groundwater and surface settlement evidence presented by Mr Twose. In particular, the geological conditions along the alignment of the main tunnel and link sewers have been determined by geotechnical investigations, and are described in detail in the technical report attached as Technical Report J of Part D - Technical Reports to the AEE.

1.12 These briefs of evidence have set out the proposed Project in detail. I have not therefore included a detailed summary of the technical aspects of the Project and instead rely on information presented those briefs of evidence.

2. EXECUTIVE SUMMARY

2.1 My evidence addresses the likely effects of vibration that will be caused by the construction and operation of the Project.

2.2 The tunnels have been designed to minimise effects of vibration by being located at depth and excavated in weak rock. The principal potential sources of vibration during construction will be use of explosives for blasting of shafts and trenches at sites where basalt rock is present, tunnelling in the East Coast Bays Formation ("**ECBF**"), piling works and operation of heavy construction plant and truck movements. Most sources of vibration will generally occur at the 19 construction sites, limiting the effects to a generally small population along the total alignment.

2.3 To ensure there is no damage to residential structures and sensitive buildings from vibration during the construction of the Project, Watercare's proposed designation and consent conditions (together the "**Proposed Conditions**") limit the transmitted vibration levels to the limits included in the DIN 4150 Standard, applied using a statistical design procedure. Compliance with this recognised standard provides a high level of confidence that vibrations should not cause cosmetic damage to dwellings and includes a much greater margin to prevent structural damage. The Hobson Bay, Rosedale and Vector tunnels have all been successfully completed using similar limits for vibrations.

2.4 The proposed standard set out in Watercare's Proposed Conditions will also ensure that vibrations should not cause unacceptable disturbance to residents. Where works have the potential to cause disturbance, options have been considered to address the effects on residents. It will be important that residents are kept well informed of progress of the works and any activities that may cause disturbance. The post-mitigation assessments for all of the sites show any residual effects to be minor or less than minor.

2.5 During operation of the Central Interceptor tunnel, the generated vibrations will generally be negligible except on rare occasions when maintenance work require access for heavy plant. I conclude that the levels of vibrations transmitted to residential and sensitive structures by maintenance plant will be negligible, such that the effects on people will be less than minor and there is no risk of structural damage. Intermittent higher levels of vibration may be generated by tunnelling related activities such as shunting of muck wagons, handing of segments etc. These activities will need to be managed to limit vibrations, particularly if these are undertaken regularly at some locations. Although the general levels of vibrations should not cause disturbance to people, they may be perceptible to sensitive receivers and it will be important to keep these people informed on progress of the tunnelling as it passes under their location.

2.6 In summary, I consider the proposed works may be undertaken by applying the proposed conditions and standards to manage effects such as to avoid structural damage to properties and troublesome levels of disturbance to people.

3. SUMMARY OF METHODOLOGY

3.1 In this section of my evidence I will briefly describe the methodology used for the assessment undertaken for the Vibration Report.

3.2 In summary, the methodology employed to assess the effects of vibration in relation to the Project comprised the following eight broad steps:

(a) Briefing and site tour with Project team.

(b) Reviewing concept designs and proposed construction methodology.

(c) Reviewing the applicability of vibration standards currently applied by Auckland Council and standards previously used in similar projects.

(d) Identifying relevant vibration standards for the Project.

(e) Reviewing geology of the route and adopting representative attenuation characteristics of the materials expected to be encountered.

(f) Identifying the Project construction activities likely to generate significant vibration levels and considering which construction activities will occur at each surface construction site and along the alignment of the tunnels.

(g) Sourcing vibration data from historical measurements of sources relevant to the Project.

(h) Establishing those sensitive receivers who may be affected by vibration from the Project.

(i) Assessing predicted vibration levels against the Project Vibration Standards and identifying the sensitive receivers at risk of exceeding the Project Vibration Standards.

(j) Outlining mitigation options that can be adopted should any vibration levels be found to exceed the Project Vibration Standards.

3.3 This methodology has been used to identify the situations where the construction activities may exceed the Project Vibration Standards, and to identify potential mitigation options that can be adopted in those situations. In short, Watercare's Proposed Conditions include Project Vibration Standards that the contractor will endeavour to meet. However, where it is not possible to meet the Project Vibration Standards, the contractor will need to look at alternative management approaches. Watercare's Proposed Conditions have been drafted to reflect this approach. Therefore, although the contractor may exceed the Project Vibration Standards, they will still be in compliance with Watercare's Proposed Conditions if the process set out in Watercare's Proposed Conditions is being followed.

3.4 I will now explain how this approach has been developed, and why.

4. INTRODUCTION TO VIBRATIONS

4.1 Ground borne vibrations are generated by oscillating motion that is transmitted by contact between particles in the ground. There are two relevant measures of vibration:

(a) Measurements of vibration for the assessment of risk to *structures* are generally measured in terms of peak particle velocity ("ppV"). Velocity is directly related to strain on structures, and ppV (measured in mm/s) indicates the potential for damage to be caused).

(b) The human *body* is primarily responsive to the forces imposed on it. Hence the effect on the human body is related to peak particle acceleration ("**ppA**") rather than directly to velocity.

4.2 Limits for managing vibration may be expressed in either ppV or ppA for any given frequency. Using a regular sinusoidal wave form (a type of mathematical formula), corresponding limits of ppV and ppA can be determined for any given frequency. The use of ppV limits is proposed for this Project instead of ppA. This is because the human body's tolerance to vibration during day-time hours is higher than the tolerance of structures to vibration (this is not true during night-time hours, but is the case during the day). This means that adopting the structural damage criteria provides greater protection to humans during the day-

time than would be provided if the human criteria was proposed. It is therefore, in my opinion, the appropriate approach to adopt.

4.3 The magnitude of the vibrations is influenced by a number of factors, the principal variables being the energy of the source and the distance to the receiver. Other variables which are generally less significant include the geology, the surface topography and groundwater.

4.4 The general prediction model that is used for propagation of vibrations for blasting operations with distance is:

$$ppV = k\left(\frac{D}{\sqrt{E}}\right)^{-n}$$

where k= site constant

D = distance from the source to the receiver

E = Energy of source (often expressed as Maximum Instantaneous Charge Weight ("**MIC**") for blasting)

n = attenuation factor, primarily dependent on geology and groundwater (generally between 0.9 to 1.5 for Auckland geological conditions)

4.5 The site constants (k) are generally determined for each activity based on trials or using experience in similar areas and projects. The predictive models may then be utilised to assess the effects on receivers. For design it is useful to establish the confidence limits of the activities and establish a compliance approach based around these limits. By way of example, for blasting design, the upper 95% confidence limit is targeted to meet the conservative recommendations of limits to protect property from minor damage. In reality, this means targeting an average ppV of 2 to ensure that the maximum ppV is no more than 5.

4.6 This approach has been successfully applied on the Waterview Connection (Western Ring Route) Project. The method promotes and rewards the use of best practice in the construction industry for blasting, whereby contractors who apply high levels of quality control can benefit by targeting higher explosive charge weights. The application of this method, together with an upper "regulatory" limit, has been accepted for the Waterview Project, as demonstrated in the flow chart included in

Appendix A. A similar approach is applied on many of the quarries in Auckland.[1] Similar approaches for predicting propagation of vibrations may also be applied to other construction activities such as piling and tunnel boring equipment used as part of the Project.

5. VIBRATION STANDARDS

5.1 A number of standards are applied for vibrations generated by construction activities and the operation of equipment in New Zealand. These standards include proposed levels for vibration to limit the discomfort or effect on the well-being of occupants of nearby properties (human response standards), as well as to provide protection from damage of structures (building damage standards). As explained in my methodology above, I have reviewed the application of a number of standards in order to develop appropriate Project Vibration Standards for the Project. Set out in **Appendix B** is a summary of the standards that I reviewed in developing the proposed Project Vibration Standards.

5.2 I concluded that the German DIN4150-3:1999 standard is appropriate for setting the vibration limits for this project. This standard is summarised in **Table 2** of **Appendix B**. The recommended limits in the standard are consistent with international best practice and provide a high level of confidence that structural damage to property will be prevented and disturbance to people limited. The limits are also consistent with the vibration standards referenced in the Auckland Council District Plan (Auckland Isthmus Section) and are the same as those applied for the Waterview Project, a similar project.

5.3 As I have noted in **Appendix B**, the DIN 4150-3:1999 standard contains high margins to prevent structural damage and hence there is opportunity where structures are determined by survey to be in sound condition, and by agreement with the owners and occupiers, for a higher limit to be applied, generally up to twice the DIN 4150-3:1999 levels for category 2 (residential) structures. This is consistent with the approach recommended in the Construction Industry Research and Information Association of the United Kingdom ("**CIRIA**") (2011) guidelines (also

[1] An example of such a rule is found in the Auckland City District Plan: Isthmus Section, Rule 8.8.2.7(b).

discussed in **Appendix B**). This approach is proposed in Watercare's Proposed Conditions.

6. CONSTRUCTION METHODOLOGY - SOURCES OF VIBRATIONS

6.1 In this section I explain how the construction of the Project is expected to create vibration effects. The extent of those effects is assessed in the following section of my evidence, together with options for mitigation. This section, however, is focused on potential sources of vibration from the proposed construction methodology.

Tunnelling

6.2 In addition to the information set out in the evidence of Mr Cantrell and Mr Cooper, I have briefly outlined the key aspects of the Project most relevant to the assessment of potential vibration effects, along with the potential sources of vibration effects below.

6.3 The vertical alignments of the main tunnel and link sewers have been located to remain mostly in ECBF along the route, maintaining clearance beneath the strong basalt lava flows and remote from any known volcanic vents. On the southern side of the Manukau Harbour, the main tunnel may encounter ECBF with coarser grained fractions and some faulting is inferred. The main tunnel will also extend into the Tauranga Group soils which are logged as Puketoka Formation. All these materials are relatively low strength and tunnelling will generally require the Earth Pressure Balanced Tunnel Boring Machine ("**EPB TBM**") to be equipped with soft ground cutting tools for these conditions.

6.4 Similar equipment was used in similar conditions for the recently completed Project Hobson and Rosebank tunnels, and there were no issues experienced during these projects. This equipment will generate low level vibrations that will attenuate rapidly and be below perception levels for most people given the depth of the tunnels. The rate of advance is also expected to be high, averaging over 10m/day, so any vibration effect (if perceived) will be short term. Similarly, other tunnel activities such as the operation of mucking (removing excavated material) and tunnel lining installation will also be barely perceptible.

6.5 The link sewers and de-aeration tunnels are expected to be almost entirely excavated within weak ECBF, with Kaawa Formation rock expected only in the section south of Mangere Bridge. Micro-tunnelling methods are expected to be used for excavating Link Sewers 1 and 2, with Link Sewer 3 to be excavated using the TBM and Link Sewer 4 with trenching. De-aeration tunnels will be constructed using a number of possible methods (to be determined by the selected contractor), including:

(a) roadheaders (unshielded, or shielded in poor ground);

(b) hydraulic excavators with rock mill attachment or similar;

(c) digger shields; or

(d) hand mining.

6.6 The main tunnel is not expected to encounter strong basalt rock but may locally approach the interface with the Tauranga Group Sediments. An exception is at Pump Station 23 where Puketoka Formation may be present. Pipe thrusting methods may be required for this connection.

Shafts

6.7 Shafts are to be constructed at each access point extending from the surface to tunnel level. A series of drop shafts are also proposed for the connections to the existing network. The shafts range in size, depending on the construction occurring at the particular site.

6.8 The geological conditions expected to be encountered by the shafts on the main tunnel and link tunnel alignments is highly variable, as described in the evidence of Mr Twose and set out in the Vibration Report. Conditions for excavations range from recent alluvium to very strong basalt rock.

6.9 Where basalt is present in the shafts, excavation will require the use of blasting or rock breaker methods. For excavation works within 30 m of a dwelling, the use of blasting methods will have limited application.

6.10 Where other ground conditions are present, methods will range from the use of pile boring equipment for the small diameter shafts, to the use of perimeter retaining walls using secant piles (a ring of overlapping piles),

diaphragm walls or sheet pile walls through the soft sediments for the large diameter shafts.

***Shallow* works**

6.11 Connections are required between the existing network and the new main tunnel. The connection works will involve a range of methods including trenching and micro-tunnelling.

6.12 The shallow structures and trenching works vary greatly in depth, but may be up to 8 m below ground level in places. Ground conditions are variable but generally located within soft sediments or ECBF except at Western Springs, Mt Albert War Memorial Reserve and Lyon Avenue, where basalt rock is close to the surface. The proposed works at these locations include control chambers and trenched pipelines in the basalt. The excavation in basalt at these locations will require use of rock breakers, possibly supplemented by limited use of blasting where works are deep or there is an advantage in using small charges to loosen the rock and accelerate the work. The equipment used will be similar to that used to excavate the shafts.

7. MONITORING OF VIBRATION EFFECTS AND SITE CHARACTERISTICS

7.1 In order to model and predict the likely vibration effects from the Project, it was necessary to undertake a series of monitoring tests. This included:

(a) site monitoring tests to determine background vibration levels along the alignment and to assess the typical attenuation levels for the ground. Five representative sites were selected along the alignment of the Project;

(b) vibration measurements at facilities associated with Project Hobson, namely at Pump Station 64 (Orakei) and the Victoria Avenue drop shaft to establist typical vibration levels generated at operational facilities similar to those proposed for this Project; and

(c) reviewing Tonkin & Taylor's monitoring database, which includes a number of other projects where blasting of basalt,

has been undertaken and good records have been kept of MIC levels and vibration levels measured at varying distances from the blast. This review enabled us to predict ppV results at a receiver at a given separation distance.

7.2 Each of these steps is explained in brief below.

Site Testing and Background Monitoring

7.3 Staff under my direction undertook a series of site monitoring tests to determine background vibration levels along the alignment and to assess the typical attenuation levels for the ground.

7.4 Vibration measurements were taken at five representative sites:

(a) Western Springs;

(b) Walmsley Park;

(c) Kiwi Esplanade;

(d) Miranda Reserve; and

(e) Dundale Ave.

7.5 The monitoring was undertaken with transducers located for periods close to roads which are currently the most likely source of vibrations in the area. At Western Springs, vibrations generated by the MOTAT tramway were also monitored. For each location instruments were placed in close proximity to the source (1 to 2 m), as well as at distance to provide a measure of attenuation.

7.6 Results of the monitoring are included in Appendix D of the Vibration Report. The results indicate that the maximum source of existing vibrations is generally heavy vehicles, particularly buses. However, these vibration events are relatively infrequent at most sites and, while ppV of up to 3.1 mm/s were measured close to the kerb, the level of vibration attenuated rapidly to less than 0.5 mm/s at a distance of 10 m.

Operational Vibrations

7.7 Monitoring has also been carried out to establish typical vibration levels generated at operational facilities similar to those proposed for this

Project. Measurements were made at facilities associated with Project Hobson, namely at Orakei Domain Pump Station ("**Pump Station 64**") and the Victoria Avenue drop shaft.

7.8 The objective of this study was to assess the magnitude of vibrations that could be expected after commissioning of the main tunnel.

7.9 The operating Pump Station 64 is at the downstream end of Project Hobson. The vibration measurements collected from Pump Station 64 are summarised in detail in the Vibration Report. I concluded that the levels of vibration beyond the pump station building would be imperceptible to the majority of people.

7.10 The Victoria Avenue Drop Shaft connects a branch sewer to the Project Hobson tunnel, approximately 35 m below ground level. Vibration measurements were taken here to assess levels of vibration from the shafts during operations. The levels of vibration were generally low, less than 0.1 mm/s and hence are unlikely to be discernible to people beyond the fencing around this shaft.

Blast vibrations

7.11 Tonkin & Taylor's monitoring database includes a number of other projects where blasting of basalt has been undertaken and good records have been kept of:

(a) MIC levels; and

(b) Vibration levels measured at varying distances from the blast.

7.12 A typical set of results showing blast monitoring plotted on a log-log plot is shown in **Figure 1**.

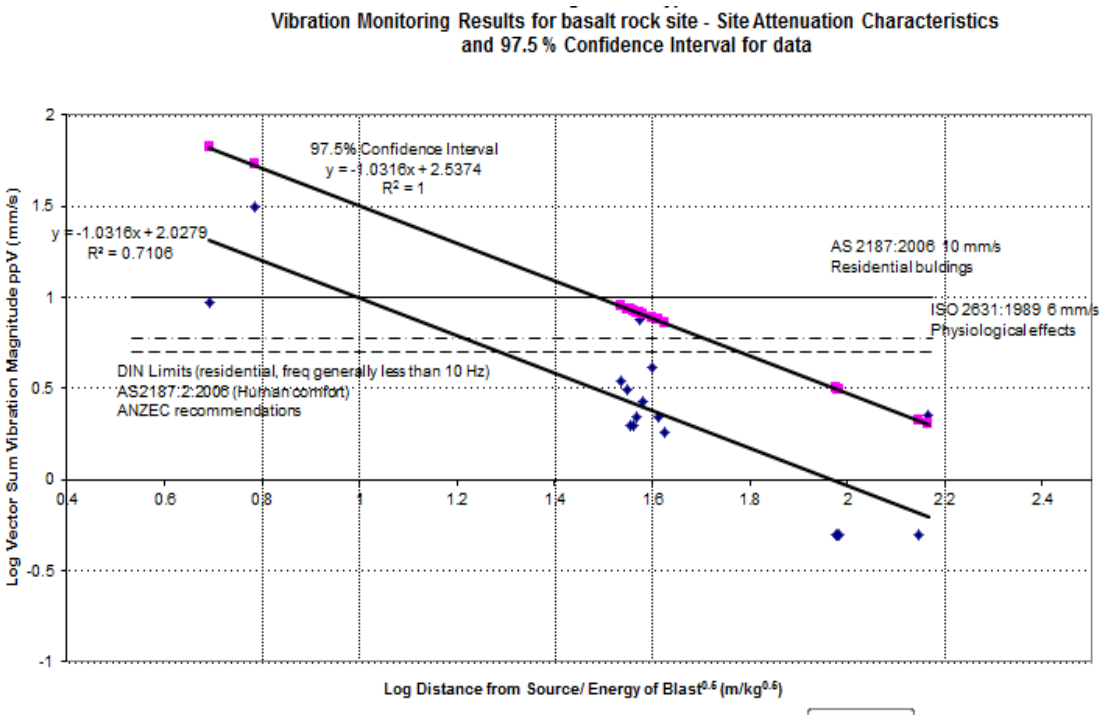

Figure 1: Typical set of results showing blast monitoring

7.13 Regression analyses of results have produced a statistical line of "best fit" providing indicative constants typical of basalt rock vibration characteristics. Using these parameters it is possible to predict ppV results at a receiver at a given separation distance when blasting in basalt. The blasting distance needed to achieve the 5mm/s limit recommended in DIN 4150-3:1999 for residential properties, with 97.5% probability of compliance, using MIC weights of AN60 explosive (which is the type likely to be used for the Project given industry practice), are set out in **Table 1**.

Table 1: Blasting Distances Complying with DIN4150-3:1999 (97.5% Confidence Limits)

Maximum Instantaneous Charge(MIC) kg	Design Distance (m)
0.3	30
1	61
2	86
3	106
5	136
10	193

7.14 These design distances will only need to be complied with at the few sites where basalt is present.

7.15 To achieve adequate fragmentation of the rock, alternative explosive options such as smaller charges to initially loosen the rock supplemented by rock breakers, may need to be considered for areas where sensitive receivers or residential structures are within 80 - 90 m of the basalt.

8. CONSTRUCTION VIBRATION ESTIMATES

8.1 The proposed works will involve the use of heavy construction methods that will utilise plant which generates vibrations at a range of levels. I have considered the main construction activities, and associated equipment proposed to be used, and assessed the likely effects on nearby receivers. I have considered the likely magnitude of any generated vibrations, the duration of the work, the potential effects on sensitive receivers and property, and have evaluated the potential mitigation measures that may be required.

8.2 I have assumed in this assessment that surface works undertaken in the initial establishment of the tunnel access works, including excavation of shafts, will generally be limited to daytime hours. Only work directly associated with continuous underground tunnelling will occur at night-

time. Limits are imposed on surface support activities, such as spoil removal and material delivery, in Watercare's Proposed Conditions.

8.3 The activity sources that are expected to be the potential generators of the highest levels of vibrations from the Project are listed in **Table 2** below. The table also identifies the expected distance where the recommended Project Vibration Standards are likely to be met. I have included consideration of the duration of the activities proposed and provided an allowance for increased vibration levels for short term works, such as site establishment activities. Conversely, for longer duration activities, such as shaft excavation, the distances are increased by adopting lower limits in the recommended range.

Table 2: Design distances for construction activities

Work Type	Source	Ground type	Design Distance (m)		Comments
			Structures	People	
Site Establishment	Diggers, Loaders, Trucks etc	TG[2]	3-5	5	Higher tolerance for short term access works.
	Site Buildings Construction	TG	3	3	
	Access Roadworks	TG	3	3	
Shaft Excavation – soft to hard ground	Diggers, Cranes, Trucks	TG	5	5	
	Piling / Diaphragm Wall Equipment	TG / ECBF[3]	10	20	Higher vibrations may be generated by dropping buckets to expel spoil.
	Sheetpile driving (Soft to hard ground)	Alluvium/TG/ECBF	10	15	
Shaft Excavation or trench - Hard	Rock breaker	Av[4] (Basalt)	10	15	

[2] Tauranga Group
[3] ECBF
[4] Auckland Volcanic Field

Rock (Basalt)					
	Blasting	Av	Depends on MIC see Table 4		Need to also consider air over pressure.
	Drilling and Shotcreting	Av	10	10	
Tunnelling	EBPM	ECBF	5	10	Possibility of regenerated noise, see evidence of Mr Cottle.
	Micro-tunnelling	ECBF/TG	10	10	
	Small Road Header	ECBF	6	10	
	Muck Cars and Trains	-	5	10	May increase where shunting occurs
	Vertical Conveyor	-	3	5	
	Crane	-	3	5	
	Tunnel Segments Handling	-	5	10	
Surface Works	Shored Trenches and Shallow Underground Chambers	TG/ECBF	3	5	Blasting
		AV	See blasting vibration standards Table 4		
			10	15	Rockbreaker
	Sheetpiled Trench	Alluvium/TG/ECBF	10	15	
	Vibrating Rollers	-	10	15	Road and Site reinstatement

8.4 This information has been used to identify the sites where the proposed activities may require modification from normal construction practices or where the use of mitigation measures to reduce vibration effects may be required. This information is set out in **Appendix C.** The chart in **Appendix D** depicts the vibration intensities experienced by humans,

and explains my use of vibration levels below. The potential mitigation measures are set out in the next section of my evidence, and submitters' properties are discussed in more detail towards the end of my evidence.

8.5 In summary, it is my opinion that:

(a) For the tunnelling itself, vibration levels are expected to be below perception levels and vibrations generated by associated surface activities, such as delivery of heavy plant and precast elements, should attenuate within 10 m of the source to below perception levels.

(b) For piling and construction activities other than blasting, vibration levels are expected to exceed structural limits within 10 m, be clearly perceptible for people within 20 m of the source and be of no concern beyond that.

(c) For shallow works, the effects of vibrations will impact on people and structures at the same distances, as described in the bullet point above.

(d) Where blasting is proposed, site specific testing at the commencement of the works at each site will determine the design distances and the MIC that can be used. The effects of blasting can be controlled by use of best practice methods together with controls on number of blasts to regular times, with good notice and careful monitoring. Construction planning needs to be developed around a regular programme of blasting (where blasting will be needed because basalt is encountered). Recent experience at the Waterview Project indicates that blasting at 1 to 3 blasts/day at regular notified times is practical and enables residents to be well prepared for the events.

8.6 Based on measurements collected at a similar operational scheme, I am confident that the vibration associated with the operation of the main tunnel will be very low and unlikely to be discernible to most people within a few metres of any structures. In reaching this view I note that the only proposed pump station is to be located within the existing designation at the Mangere Wastewater Treatment Plant ("**Mangere**

WWTP") and is therefore more distant to members of the public than Project Hobson's Pump Station 64.

Airblast Pressure Waves and Flyrock

8.7 For completeness, I briefly mention airblast pressure waves and the potential for flyrock, as they are often issues raised by submitters.

8.8 People's tolerance to blasting is often affected by the cumulative effect of the associated airblast pressure waves. These are sub-audible low frequency waves due to vented gas pressure or air pressure pulses resulting from sudden ground movement that causes rattling of windows and loose ornaments. Depending on the blast design, the confinement of the blasts in the shaft may result in amplification or damping of this effect. This has been addressed further by the noise consultants.

8.9 The use of good practice blasting methods also reduces the potential for flyrock. Uncontrolled flyrock is rare and usually associated with poor control of drilling and loading of holes particularly where there is a free face in close proximity to the hole (lack of adequate burden). The potential for flyrock in a bottom driven shaft is very low and, if there is any potential for this, blasting mats can be utilised to contain the fragmented rock.

9. MITIGATION OPTIONS AND PROPOSED CONDITIONS

Conditions

9.1 As noted above, Watercare's Proposed Conditions are based on the DIN 4150-3:1999 standard and incorporate the statistical flexibility envisaged in the CIRIA (2011) guidelines. I support this approach.

9.2 I consider the works can be designed to be undertaken to comply with the Project Vibration Standards proposed in Watercare's Proposed Conditions. However, construction processes contain inherent risks such that the targeted levels are not always achieved. This requires that a margin of safety be provided in the target levels for "outlier" conditions. Monitoring activities enables the analysis of distribution of the vibration levels generated. This, in turn, enables a statistical approach to be adopted to provide a high level of confidence that limits will not be exceeded. As such, a requirement for 95% compliance with the limits of

DIN 4150:1999 is proposed as a suitable criterion. This means that construction methods that adopt best practice and exercise a high level of control and consistency will benefit by being able to utilise higher target vibration levels, while activities which have lower levels of control or singular events need more conservative target levels to ensure compliance. In short, good operators with a high level of control and consistent results will have a higher level of confidence that the limits can be complied with (and can therefore target a higher vibration level) than a poor operator with less control and inconsistent results. The latter will be restricted to a lower vibration level in order to ensure compliance with the limit 95% of the time.

9.3 In addition to requiring compliance with the limit 95% of the time, the Project Vibration Standards may also include an upper "regulatory" limit for vibrations. This is typically 2 times the DIN 4150:1999 Standard with a maximum ppV of 20mm/s for residential structures. Exceeding this upper regulatory limit triggers activation of a response procedure which is designed to ensure there are no repeats of unplanned events. A flow chart demonstrating how this works is included in **Appendix A.**

9.4 The cause of any non-compliance with the Project Vibration Standards is reported and investigated then changes are made in the methodology where needed to address the magnitude of vibrations generated by the source.

9.5 If full compliance with the Project Vibration Standards cannot be achieved by modifying the method of construction, it may be necessary to consider other methods to reduce the potential vibration effects. These could include:

(a) use of an alternative method of construction with reduced vibration effects;

(b) communication with adjacent affected residents;

(c) coordination with residents to carry out works when they are likely to be out;

(d) isolation of the source, eg use of elastic or rubber packers beneath rails over critical section of rail in the tunnel;

(e) construction of a vibration attenuation barrier between the source and receiver, eg excavation of a trench, installation of a barrier, or series of piles, or open holes to "interfere" with the transmission of the vibrations; and

(f) consultation with affected owners and occupiers to enable increased limits where specific structural evaluation has determined the dwelling is capable of withstanding higher levels of vibration.

9.6 Based on the current design and likely construction methods, I expect the above methods would adequately mitigate any vibration effects generated by the works. In the unlikely scenario where the above methods do not achieve the required level of mitigation, other options could be employed including:

(a) possible temporary relocation of residents during the activity where works are proposed in close proximity to the property. This would be a last resort if no other options are available;

(b) modification of the affected building structure to change the response characteristics, eg installation of bracing to either strengthen the structure or modify the building response frequency. This is not expected to be necessary for this Project; and/or

(c) isolation of very sensitive equipment such as utilising an airbag or floating slab (such as that used by the research institutions).

9.7 While these methods are available, I do not anticipate they will be required based on the current concept design and construction methodology. They are, however, available in the unlikely event they are required.

9.8 I note that the Project Vibration Standards include substantial safety margins to limit the risk of damage. In practical terms, no structural damage is likely within a distance of half that given in **Tables 1** and **2**.

9.9 Construction Noise and Vibration Management Plan(s) ("**CNVMP**") will be prepared and complied with during the works (Watercare's proposed designation conditions ("**Proposed Designation Conditions**") CNV.1 -

5). The CNVMP(s) will be designed to minimise the effects on health and limit discomfort to people, as well as ensure the risk of damage to structures is less than minor. I consider the CNVMP(s) will adequately provide for the management of potential vibration effects.

Consideration of sensitive receivers and potential for damage to neighbouring properties

9.10 I have undertaken an initial assessment of the potential effects of vibrations generated by the construction of the Project on adjacent properties. This has involved reviewing the likely construction methods, the levels of vibration that they will generate and estimating the design distances using upper bound (95%) confidence levels where vibration levels will exceed the Project Vibration Standards for both structural damage and sensitive receivers. The adoption of upper bound confidence levels provides an appropriately conservative outcome.

9.11 An assessment of potential unmitigated vibration effects on neighbouring properties is set out in the table in **Appendix C**. Separation distances to neighbouring properties have been identified and vibration effects predicted based on construction methods and ground condition information provided in **Table 2**. The risk of vibrations impacting on residents or structures has been assessed for each of the required construction activities using the following classifications:

(a) Low Risk – May be perceptible to residents but should not cause disturbance. Risk of damage less than minor. For example, there may be some rattling of loose objects, with the level of vibration being similar to children jumping around the floor.

(b) Moderate Risk – May cause moderate level of concern to residents and minor discomfort but should be acceptable for limited periods. No risk to health. Minor risk of cosmetic damage to dwellings but no risk of structural damage. Condition surveys of closest structures recommended. For example, loose objects may be displaced particularly if vibrations are continuous, with the level of vibration being similar to that experienced when a door slams.

(c) High Risk – May be acceptable to receivers for occasional short term events. Likely to cause significant discomfort and concern if vibrations are continuous. Minor risk to health to sensitive receivers who may require mitigation measures or relocation. Moderate risk of cosmetic damage but low risk of damage to structural elements. Condition surveys of all potentially affected structures recommended. For example, loose objects are likely to topple, with the level of vibration being similar to when the washing machine is out of balance on a spin cycle.

(d) Very High Risk – Potential risk to health and relocation recommended. Significant risk to sensitive structures. Condition surveys of all structures recommended and application of further mitigation measures required.

9.12 In summary, **Appendix C** identifies that many of the properties are classified as being at "Low" risk of experiencing vibration effects. There are, however, a number of properties, where, without mitigation, the classification levels are higher.

9.13 In saying that, while there is a risk of vibration effects at these sites, I consider the effects of vibration on these properties can generally be mitigated by control of construction methods to limit vibration levels at the source. This is clearly shown in the final column of **Appendix C** which sets out the residual vibration effects post-mitigation. The post-mitigation assessments for all of the sites show any residual effects to be minor or less than minor.

9.14 As noted above, where the works are to be undertaken over a short period and there is low risk of structural damage, it may be an option to also consult with residents on a level of acceptable exceedance and proceed at that level if the affected resident supports this. If necessary, other mitigation measures may also be considered, as described above.

10. SECTION 92 RESPONSE

10.1 In the Council's request for further information under section 92, the Auckland Council's advisor, Styles Group, recommended the following

be considered as a modification to the draft conditions that had been supplied by Watercare:

i) That in the event of non-compliance, the vibration limit regime and flow chart be amended for situations where a structure – specific structural evaluation has found that a particular structure is capable of withstanding greater levels of vibration than the DIN4150 limits or twice thereof.

And/or

ii) The Vibration Assessment is expanded to include a section that demonstrates that the proposed works can be carried out within the currently proposed constraints with a high level of confidence. Particular examples should include blasting and piling activities within 10-15 m of a dwelling whilst achieving acceptable levels of progress.

10.2 I agree with the first suggestion. The DIN 4150-3:1999 standard is conservatively based and the majority of structures should have the capacity to sustain significantly higher levels of vibration without damage. If a condition survey is undertaken, and the owners and occupants of a residential structure are supportive, I agree that it should be possible to safely increase the limits. This has the advantage that the works can be progressed in a shorter period and I consider it to be an appropriate alternative management and mitigation measure in accordance with the Proposed Designation Condition CNV.5 with regard to construction vibration.

10.3 With respect to the second request, I undertook analyses which confirmed that small MICs of 0.3 kg should achieve 97.5% compliance with DIN4150-3:1999 at a setback distance of 30m and with higher levels of control may be feasible at 20m. My experience at Brightside Hospital showed that blasting was feasible at less than 15 m without causing damage to nearby structures. The use of small charges should allow loosening of the basalt rock and accelerate excavation by alternative, but slower, methods such as rock breakers. Rock breaker and piling equipment may be safely used at closer distances than 15 m as summarised in **Table 2** above. I am confident that the works can be undertaken to achieve the DIN4150-3:1999 limits 95% of the time, with an upper regulatory limit to be complied with 100% of the time.

11. RESPONSE TO SUBMISSIONS

11.1 Vibration has been identified as a concern in a number of the submissions received on the Project. The following responses have been prepared based on Watercare's Proposed Conditions which propose to restrict vibration levels to the DIN 4150-3:1999 Standard at the nearest dwellings or commercial structures and implement mitigation measures.

Western Springs

11.2 Tawa Farms Limited own the property on which the Caltex service station is located at 790-802 Great North Road, Western Springs. The service station includes a number of underground fuel storage tanks ("**USTs"**) in the north eastern corner of its site and an oil interceptor tank, all of which are within 25 m of the proposed construction shaft. The commercial limits of the DIN 4150-3:1999 will be adequate to ensure the risk of damage to USTs is less than minor. This Project Vibration Standards will also limit the use of blasting to small charges to loosen the rock and supplement the primary use of rock breaking equipment. See also **Table 2** for the design distances for construction activities at this site.

11.3 If requested and authorised by the owner, detailed condition survey of the Caltex assets should be carried out prior to work commencing, as per Watercare's Proposed Designation Condition CVN.5(b).

Mt Albert War Memorial Reserve

11.4 A number of submitters raised concerns in relation to vibration effects at the Mt Albert War Memorial Reserve site (both the Reserve site and Car Park site).

11.5 Basalt rock is present to a depth of about 10 - 11 m at this location. A combination of rock breakers and small charges are expected to be used for fracturing the basalt rock. This stage of excavation is likely to take 3 to 4 weeks for each shaft. Below the basalt, conventional piling and excavation equipment will be used to advance the shafts to the depth of the tunnel. The principal source of vibration is the excavation of the basalt rock, which is expected to take 3 to 4 weeks for each of the shafts.

11.6 A summary of the effects on the submitter's properties and other properties in proximity to the works is given in **Appendix C** and the locations of these addresses can be seen on Drawings **AEE-MAIN-2.1A** and **AEE-MAIN-2.2** pages 39 and 50 of the Hearing Drawing Set. I briefly respond to the concerns individually by address below:

(a) *19 Wairere Avenue. Archer, Hamish and Michelle:* There is a low to moderate risk of vibration effects for the Reserve site, as different activities generate different effects. This risk involves a less than minor effect on structures but is likely to cause some disturbance to occupants. It may be possible to mitigate the latter to minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site reduces the effects on occupants at this site to clearly perceptible, but not likely to cause disturbance.

(b) *15 Wairere Avenue. Boyd, Anne and Robin*: There is a moderate risk of vibration effects for the Reserve site as the nearest shaft is 45 m from dwelling. This involves a less than minor effect on structures but is likely to cause some disturbance to occupants. It may be possible to mitigate this disturbance to minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. However, this would lengthen the duration of works and expose the residents to both vibration and noise for a longer period. The Car Park site reduces the effects on occupants at this site to clearly perceptible, but not likely to cause high level of disturbance.

(c) *23 Wairere Avenue. Boyle, Stephanie and Jeffrey:* There is a low risk of vibration effects for the Reserve site because the site is 80 m from the nearest shaft. This involves a less than minor effect on structures but is likely to cause some disturbance to occupants. The Car Park site reduces the effects on occupants at this site to clearly perceptible, but not likely to cause disturbance.

(d) *32 Wairere Ave. Henrys, Gemma Louise*: There is a low risk of vibration effects for the Reserve site because the site is over 120 m from nearest shaft. There is no risk of damage but the

vibration will be clearly perceptible. The distance is greater for the Car Park site such that there is no risk of damage.

(e) *1 Rossgrave Terrace. Burnett, Joy:* As this site is over 150 m from nearest shaft at both sites, this involves less than minor vibration effects.

(f) *67 Asquith Avenue. Colloff, Bruce:* As this property is over 80 m from the nearest shaft at the Reserve site, there will be no damage to structures from blasting effects but vibrations will be clearly perceptible. The property is further from the Car Park site and vibration effects would be less than minor.

(g) *16 Wairere Avenue. Craig, Nicola*: As this site is over 90 m from the nearest shafts for either layout, there will be no damage to structures but vibrations will be clearly perceptible.

(h) *25 Wairere Avenue. Curnow, Tony and Hume, Helen*: As this site is over 90 m from the nearest shaft at the Reserve site, there will be no damage to structures from blasting effects but vibrations will be clearly perceptible.

(i) *2/21 Asquith Avenue. Jones, Stuart*: As this site is 350 m from the nearest shaft, there will be less than minor vibration effects.

(j) *18 Wairere Avenue. Jotti, D and Eades, J:* As this site is over 90 m from the nearest shafts for either layout, there will be no damage to structures but vibrations will be clearly perceptible.

(k) *65 Asquith Avenue. Kedge, Sally and Kerridge, Peter*: There is a moderate risk of vibration effects as the site is 45 m from the nearest shaft for the Reserve site. This involves a low risk to structures but is likely to cause disturbance to occupants. It may be possible to mitigate this disturbance to a less than minor effect by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site reduces effects on occupants at this site to clearly perceptible but not likely to cause a high level of disturbance.

(l) *3/61 Asquith Avenue. Laraman, Denise*: As this site is 110 m from the nearest shaft for both sites there will be no damage to structures but vibrations will be clearly perceptible.

(m) *65c Asquith Avenue. McAlwee, Pip Tony and Alexandra*: As this site is 28 m from the nearest shaft for the Reserve site, there will be a minor effect on structures and it would be likely to cause disturbance to occupants. The effect on structures and disturbance may be possible to mitigate to less than minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site reduces the effects on occupants at this site to clearly perceptible, but not likely to cause high level of disturbance.

(n) *17 Wairere Avenue. Mellor, I:* As this site is 50 m to the nearest shaft for the Reserve site, there will be moderate effects. This involves a low risk to structures but is likely to cause disturbance to occupants. It may be possible to mitigate the disturbance to less than minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site increases the distance to 80 m and reduces the effects on occupants at this site to clearly perceptible, but not likely to cause a more than a minor level of disturbance.

(o) *2/63 Asquith Avenue. Sannum, Melanie:* As this site is 75 m from the Reserve site there will be low vibration effects. This involves a low risk to structures but is likely to cause some disturbance to occupants. It may be possible to mitigate the disturbance to less than minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site increases the distance to 120 m and reduces effects on occupants at this site to clearly perceptible, but not likely to cause disturbance.

(p) *20 Wairere Avenue. Stark, Gary and Katrina*: As this site is 90 m from the nearest shaft for the Reserve site and further from the Car Park site, there will be no damage to structures from blasting effects for either location but the vibrations will be clearly perceptible.

(q) 9 *Wairere Avenue. Corbett Gary (Community of Refuge Trust)*: As this site is 50 m to the nearest shaft for the Reserve site, there will be moderate vibration effects. This involves low risk to structures but is likely to cause minor disturbance to occupants. This may be possible to mitigate to less than minor effects by the primary use of rock breakers and only limited use of small charges to loosen the rock. The Car Park site reduces the distance to the nearest shaft to 30 m and will involve moderate to high effects. Use of explosives will be limited to loosening the rock and effects may cause some disturbance on occupiers at this site. During construction it is recommended that the contractor work with the landowner to identify the best method to achieve an acceptable level of progress while limiting disturbance to the occupants. This approach has been used successfully on the Waterview Project.

(r) *65b Asquith Avenue. Zhang, Rosy Wei, George & Jack*: As this site is only 18 m from the nearest shaft for the Reserve site there is a high risk of exceedance of vibration limits without mitigation. This property is the closest and therefore is the most exposed to the effects of vibrations. Utilisation of rock breakers and limited use of explosives will be used to loosen rock but the latter may result in cosmetic damage. Vibrations are also likely to cause disturbance of occupiers but are not of sufficient magnitude or duration to cause fatigue. Basalt rock excavation in the shaft closest to the dwelling would be best undertaken while this dwelling was unoccupied. The alternative Car Park site increases the distance to 75 m thereby reducing the effects to a low risk of damage from the use of blasting but vibrations will be clearly perceptible, but not likely to cause disturbance.

11.7 Overall, the effects at the Mt Albert War Memorial Reserve sites will require careful management of the works to mitigate effects on the closest dwellings and close coordination with residents to control the level of discomfort. The basalt rock is deep and close to ground level and, while it may be excavated by rock breakers complying with the DIN4150-3:1999 Standard, this will be slow and there are strong advantages to accelerate this by loosening the rock with small explosive

charges. The Car Park site has least effect on residents in proximity to the reserve but will have greater impact on the three residential units at 9 Wairere Avenue and the Community Centre.

Lyon Avenue

11.8 Two submissions have been lodged in relation to the Lyon Avenue site which raise concerns in relation to vibration. These are the St Lukes Gardens Apartments Body Corporate and the St Lukes Gardens Apartments Progressive Society Inc.

11.9 At this site small charges will be used where practical to reduce the requirement for rock breaking equipment. Charge weights and rock breaker plant capacities will be limited to comply with the DIN 4150-3:1999 residential limits. No damage to structures is expected. I also note that the St Lukes Gardens Apartments are founded on rock. This means the buildings have a higher tolerance to vibrations than the standards assume, which means the buildings are able to cope better with vibrations than the standards anticipate. The expected level of vibration for these buildings is, however, well below the levels where even cosmetic damage can occur.

11.10 I acknowledge that works may cause some short-term disturbance of the closest residents who may be present during the hours of work. While use of blasting to loosen rock would create vibration effects that may be more pronounced than those created using other techniques such as rock breaking, it offers the benefit of a shorter duration and less vibration (overall). Therefore, the use of blasting would greatly reduce the period of disturbance overall to nearby residents.

Haverstock Road

11.11 Two submissions were received raising concerns of vibration effects at the Haverstock Road site. These are the New Zealand Institute for Plant and Food Research ("**Plant and Food Research**") and the Institute of Environmental Science and Research ("**ESR**"). Works are proposed at this site approximately 60 m from nearest buildings. The thin layer of basalt rock at this site is expected to be removed by rock breakers, while the underlying soils will require the use of piling equipment. I understand that Plant and Food Research has various equipment that is sensitive to vibration effects. However, due to the 60 m distance from

the buildings containing sensitive equipment, vibration effects associated with the proposed works at the Plant and Food Research and ESR buildings are expected to be less than minor.

May Road

11.12 Two submissions have been lodged in relation to the May Road site which raise concerns in relation to vibration. These are the submission of Moi Moi Ong and Foodstuffs. I briefly respond to the concerns individually by address below.

51 Marion Avenue, Moi Moi Ong.

11.13 The surface works include 2 shafts to be excavated in the property immediately to the north of 51 Marion Avenue. The closest works to the occupied dwelling is 25 m and is expected to involve excavation through a 3 - 5 m layer of rubbly basalt rock. The primary method of excavation for the basalt will be ripping and rock breakers but, where strong basalt is present, the use of small charges to loosen the rock will accelerate the work.

11.14 At a distance of 25 m, there will be a minor effect on structures but blasting would be likely to cause a moderate to high level of disturbance to occupants. During construction it is recommended that the selected contractor work with the landowner to identify the best method to achieve an acceptable level of progress while limiting disturbance to the occupants. This approach has been used successfully on the Waterview Project.

11.15 Piling and retention works for the underlying Tauranga Group soils is expected to be undertaken using conventional construction equipment for which the effects are expected to be less than minor.

11.16 The Link Sewer 3 tunnel will be constructed at about 65 - 70 m below the property and the effects of the tunnelling works are expected to be negligible.

Foodstuffs

11.17 The Foodstuff Head Office and distribution centre is located to the west of the May Road construction site. The closest occupied structures are 60m from the ellipse working shaft. There are residential structures

closer to the site than this. As a result, excavations using blasting and other construction methods will be controlled by those closer residential structures. As a result, that while vibrations may be perceptible at Foodstuffs' property, they will not cause any disturbance and effects on structures will be less than minor.

Keith Hay Park

11.18 Two residents lodged submissions raising vibration concerns at the Keith Hay Park site:

(a) 18 Gregory Place. Whitehead, George and Maureen; and

(b) 47a Arundel Street. Puertollano, Paul and Maria.

11.19 The dwellings are 15 m and 30 m from the nearest shafts respectively. As there is no basalt rock expected at this site, the shafts will be formed by piling methods. There will be no risk of structural damage associated with these works. Vibrations will be clearly perceptible and may cause some disturbance at distances of less than 15 m. The dwellings occupied by the two submitters are beyond 15 m and are not expected to experience any disturbance due to vibration effects from the works.

Transpower Transmission Towers and Substations

11.20 Transpower transmission lines cross the main tunnel alignment in a number of areas of the tunnel routes. There are no shafts within 60 m of a tower and no basalt requiring excavation in any of these locations. There are, however, a number of towers in close proximity to the horizontal alignment of the main tunnel and link sewers. The Mt Roskill sub-station is also in close proximity to a link sewer.

Transmission Towers

11.21 I would expect that a transmission tower has been constructed to an adequate level of structural integrity so that it could be subject to at least the Commercial Building Vibration Standards (see **Figure 1**) and be resilient from any localised vibrations resulting from tunnelling. The tunnel excavation will be between 25 - 50 m below ground surface where the tower bases are close to the alignment. As the transmission towers are required to be constructed to particular standards, the effects of the tunnelling works on Transpower's transmission towers are

expected to be less than minor. I understand that Watercare's Proposed Designation and Consent Conditions require a CNVMP to be prepared prior to the commencement of works (CNV.1, CM.2(l) and 1.10) and I would anticipate that any vibration effects would be adequately managed and controlled under the CNVMP.

Mount Roskill substation

11.22 Link Sewer 3 passes within approximately 40 m of the Mt Roskill substation, at a depth of approximately 50 m. There are no shafts within 300 m of the substation. I also note that the Vector tunnel access shaft at the Penrose substation is within 30 m of the substation structures. Blasting methods were used to excavate the basalt rock for the construction of that access shaft. Hence, I expect the effects from transmitted vibrations will be less than minor at the Mt Roskill substation.

11.23 Again, I note that Watercare's Proposed Conditions which require a CNVMP (Proposed Designation Condition CNV.1 - 5, and Proposed Consent Condition 1.10) and I would anticipate that any vibration effects on Transpower's substation would be adequately managed and controlled under the CNVMP.

Summary

11.24 I conclude that the effects of construction vibrations generated by the tunnelling and associated works on properties owned or occupied by the submitters will generally be within the limits of the DIN4150-3:1999 Standard which is the proposed Project Vibration Standard in Watercare's Proposed Conditions. There are a small number of properties where thick basalt rock is present close to the ground surface and shaft excavations are proposed which will require mitigation to ensure vibration levels meet the standard or are within agreed increased levels. Options to increase the rate of excavation, allowing for short periods of increased discomfort may also be possible if supported by the residents.

12. RESPONSE TO COUNCIL PRE-HEARING REPORT

12.1 A review of noise and vibration effects has been undertaken by Styles Group for Auckland Council. The review, titled Central Interceptor Scheme Review of Noise and Vibration Effects, 24 June 2013, notes

several points about the vibration standards that have been recommended to be included in Watercare's Proposed Conditions. I have read, and will respond to that review below. I have also reviewed the relevant parts of the Council Pre-hearing Report.

12.2 In summary, the Council Pre-hearing Report concludes as follows:

> Overall the vibration effects arising from tunnelling are expected to be less than minor. This is confirmed in the technical memorandum by Mr Styles (Styles Group) for the Council (memorandum dated 24 June 2013).[5]

> Having regard to the matters outlined above, and Mr Styles' assessment, it is considered that the effects of construction vibration can be adequately avoided, remedied or mitigated by requiring the preparation of CNVMP for each construction site. The operational vibration effects can be addressed through compliance with the proposed vibration conditions.[6]

12.3 I respond to that review, and the Council Pre-hearing Report below.

Operational Standards

12.4 Mr Styles considers that operational vibration limits are not necessary because the operation of the Project is not expected to generate any appreciable ground-borne vibration. He concludes that the assessment of vibration limits are therefore restricted to controlling construction effects only.[7]

12.5 I agree. Neither Watercare, nor the Council, propose any such controls at the operational stage.

Commentary on Proposed Standards

12.6 Mr Styles concurs that the proposed structural standards (ie vibration conditions to control effects on structures) will control vibration levels during normal working hours of 0700 – 2200, and that human annoyance should not be the controlling criteria for vibrations in this period.

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5 Council Pre-hearing Report at page 78.
6 Council Pre-hearing Report at page 128.
7 Central Interceptor Scheme Review of Noise and Vibration Effects, 24 June 2013, Styles Group, page 5.

12.7 Mr Styles agrees that the DIN4150:1999 standard is applicable and appropriate for the control of building damage. Mr Styles comments that:[8]

> Aside from blasting, I consider that the T&T Report sets out a very comprehensive description of the current vibration levels, predicted / estimate vibration levels and mitigation options. There are no aspects of these sections of the assessment that I disagree with.
>
> Putting blasting aside, I see no reason that the DIN4150 limits cannot be complied with in all cases and on this basis I consider the vibration effects to be acceptable or reasonable.

Largely Accepted Conditions

12.8 The proposed conditions proposed relating to the control of vibration effects are set out in Watercare's Proposed Designation Conditions CNV.1 to CNV.7. Watercare's Proposed Designation Conditions CNV.1, CNV.2 and CNV.7 have been accepted by the Council.

12.9 Proposed Designation Condition CNV.5 is the primary condition relating to construction vibration effects. Watercare has proposed a number of minor amendments to this condition and also accepted a number of minor amendments to this condition which were proposed in the Council Pre-hearing Report.

12.10 These conditions, and the amendments proposed to them, are shown in the Proposed Designation Conditions attached to the evidence of Ms Petersen.

Amendments sought by the Council to the Proposed Conditions

<u>Human Response Standards</u>

12.11 Mr Styles considers a limit relating to human annoyance may be necessary if work is undertaken at night. Mr Styles recommends an additional limit of 0.3 mm/s be imposed for night works when vibrations are measured inside the affected dwellings. This corresponds to the level of perception for most people.

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[8] Central Interceptor Scheme Review of Noise and Vibration Effects, 24 June 2013, Styles Group, page 10.

12.12 Mr Styles also recommends that the measurements be undertaken in accordance with the Norwegian Standard NS8176E:2005 which includes a statistical analysis of the maximum value over a period of exposure with an upper 95% confidence limit. This method is commonly applied for traffic induced vibrations which is expected to be applicable for potential activities which occur at night, ie there will not be any piling, rock-breaking or blasting works outside normal working hours.

12.13 This recommendation is not adopted in the Council Pre-hearing Report, or included in Watercare's Proposed Designation Conditions and is not accepted by Watercare.

12.14 I discuss the potential need for imposing a night time standard in detail in **Appendix B**. As explained in **Appendix B**, I originally proposed a similar multi-standard approach be taken for the Waterview Project. However, this was considered unnecessary and overly complicated by the Board of Inquiry. With the exception of tunnelling, no works are proposed outside normal construction hours. I therefore consider there is no need to impose a standard to control night time works. Not imposing a standard would be consistent with both the approach taken in the Waterview Project and also with the Pre-hearing Report. I am therefore not suggesting such a control be imposed. However, if one were to be imposed, I would recommend the use of NZS/ISO 2631-2:1989, for the reasons explained in **Appendix B**, rather than the Norwegian Standard suggested by Mr Styles.

Building Standards

12.15 Mr Styles does not support the use of statistical application of the DIN 4150-3:1999 standard limits and seeks that any such reference be removed from the proposed conditions (Proposed Designation Conditions CNV.2, 5, 5B, 5C, and 6; and Proposed Consent Conditions 1.10(b), (p), (s), 1.10B, 1.10C, 1.10D). I do not agree with this recommendation and submit that this would be unnecessarily restrictive. Furthermore, the statistical approach I have recommended has been widely used in New Zealand, including within Auckland. Its application promotes use of best practice with a high level of control for blasting and other construction works. I have discussed the reasons for this in my evidence above, and in further detail in **Appendix B**. Allowing the use of a statistical approach is consistent with the conditions that are being

used for the Waterview Connection Project, and the CIRIA (2011) guidelines discussed in **Appendix B**.

12.16 In my opinion, it would be appropriate to include conditions allowing for a statistical approach consistent with those applied to the Waterview Project (appropriately modified for application to this project). Watercare has proposed amendments to Proposed Designation Condition CNV.6 (which was originally inserted by the Council), as well as the introduction of new Proposed Designation Conditions CNV.5A and CNV.5B to reflect this as follows:

> CNV.5A The Guideline vibration limits set out in DIN 4150-3:1999 may be exceeded for up to 5% of the blasts as measured over any twenty blasts on the foundation of any building outside the designation boundary. However, no blasting activities shall exceed 10mm/s irrespective of the frequency of the blast material, unless CNV.6 applies.
>
> CNV.5B Construction activities identified in the Central Interceptor - Vibration Assessment, Tonkin & Taylor, July 2012 as being at a "High Risk" of exceeding the DIN 4150-3:1999 shall be conducted so that not more than 5% of the activities undertaken (measured over at least 20 representative samples of the relevant activity on any residential building) exceed the relevant criterion in DIN 4150-3:1999 and no activity shall exceed 10mm/s irrespective of the frequency of the activity measured, unless CNV.6 applies.
>
> CNV.6 The Guideline vibration limits set out in DIN4150-3:1999 must not be exceeded more than 5% of the time except where the Requiring Authority can demonstrate to the satisfaction of the Council:
>
> (a) that the receiving building(s) are capable of withstanding higher levels of vibration and what the new vibration limit is. The investigation required to demonstrate this must include an assessment of the building(s) by a suitably experienced and qualified structural engineer and a full pre-condition survey; and
>
> (b) that the Requiring Authority has agreed with the building owner(s), that a higher limit may be applied.

Flexibility in approach

12.17 Mr Styles supports the provision for flexibility to exceed the DIN4150 limits if agreement is obtained from neighbours and other appropriate precautions are taken. Mr Styles recognises that methods other than blasting are available to complete the work within the limits of the DIN4150 standard, but agrees that blasting can provide a preferable method to accelerate progress and minimise other effects. He concludes:[9]

> Overall I support that compliance with the DIN4150 guideline limits should be required, unless agreement with the owner(s) of neighbouring buildings are amenable to allowing higher limits, and where the appropriate pre and post condition surveys and vibration monitoring are undertaken. This is important as there will likely be situations where compliance may not be possible, and if the conditions require compliance rigidly, significant delays and costs could be incurred in changing methods or plant when the building is likely to be capable of withstanding much higher levels of movement.

12.18 As a consequence of that advice the Council proposed the insertion of Proposed Designation Condition CNV.6, set out above, in the Pre-hearing Report. I agree that this further flexibility is appropriate but consider that a small amendment, shown as being underlined above, is required to clarify that a statistical approach is being applied by the proposed conditions and the further flexibility is over and above that.

12.19 Mr Styles recommends that unless the circumstances set out in Proposed Designation Condition CNV.6 are met, compliance with the DIN standard should be mandatory. As set out above, a statistical approach is being proposed to the application of these conditions, as well as flexibility to breach the standards in certain situations as set out in CNV.6 above. As discussed earlier in my evidence, there are likely to be circumstances where compliance is not reasonable and exceedances will be allowed to occur, while still mitigating adverse effects to an acceptable level.

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[9] Central Interceptor Scheme Review of Noise and Vibration Effects, 24 June 2013, Styles Group, page 7.

Comment made on Specific Submissions

12.20 Mr Styles, in his Report, also comments on several specific submissions with respect to vibration.

Plant and Food Research and ESR

12.21 The Plant and Food Research and the ESR submissions are referred to. I have addressed these submissions in my evidence above and conclude that the vibration levels at the distance from the works will be within the tolerance levels for sensitive scientific equipment.

12.22 I do, however, concur with the Styles Review that early consultation is appropriate to ensure sensitive equipment is not affected. I therefore propose an amendment to Proposed Designation Condition CNV.5, as proposed by the Council in the Pre-hearing Report and shown in the Watercare Proposed Designation Conditions, as follows:

> CNV.5 The CNVMP shall also describe measures adopted to meet the requirements of German Standard DIN4150-3:1999, and as a minimum shall address the following aspects with regard to construction vibration:
>
> ...
>
> ~~f~~)(e) identification of any particularly sensitive activities in the vicinity of the proposed works (e.g. commercial activity using sensitive equipment such as radiography or mass-spectrometry) including Plant and Food Research (at 118-120 Mt Albert Road, Mt Albert)), the Institute of Environmental Science and Research (Hamptead Road, Sandringham) and Caltex Western Springs (at 778-802 Great North Road, Grey Lynn);

Tawa Farms

12.23 Submission 741 refers to Tawa Farms property that contains underground storage tanks at the Caltex service station on the site. Specific detail as to the effects of vibration on storage tanks in response to this submission have been discussed above. This is one of the properties specifically listed in Proposed Designation Condition CNV.5(e) above.

Mt Albert War Memorial Reserve - Car Park site

12.24 Further evidence has also been requested on the effects of vibration for the alternative Mt Albert War Memorial Reserve Car Park site. In particular, further information has been requested on the impacts on the Community of Refuge Trust tenants at 9 Wairere Avenue. This is addressed in detail above. I conclude that the risk of damage to this property is minor but that the occupants in the closest unit, number 4, are likely to experience moderate to high levels of disturbance. During construction it is therefore recommended that the contractor and Requiring Authority work with the landowner to identify the best method to achieve an acceptable level of progress while limiting disturbance to the occupants of that property.

Summary of amendments to the Proposed Conditions

12.25 A number of amendments are proposed by Styles, in the Council Pre-hearing Report and subsequently by Watercare to the Proposed Designation Conditions in relation to vibration effects. The amendments proposed are set out in the Proposed Designation Conditions attached to the evidence of Ms Petersen. I am satisfied that these conditions adequately provide for the management of potential adverse vibration effects.

12.26 In summary:

(a) *CNV.1:* The Pre-hearing Report has proposed an amendment to require that a CNVMP be prepared for each site. This is not accepted by Watercare who has proposed an amendment requiring a CNVMP for each "Project or relevant Project stage".

(b) *CNV.2:* None.

(c) CNV.5:

(i) The Council has proposed the deletion of (b) and (c). Watercare agrees that this detail is unnecessary as it is required in the CMP.

(ii) The Council has proposed a minor amendment to (e) which is accepted by Watercare.

(iii) The Council has proposed a new (d) relating to post condition surveys which is accepted by Watercare.

(iv) The Council has proposed an amendment to (e) which is accepted and added to by Watercare.

(v) The Council has proposed an amendment to (g) which is accepted by Watercare.

(d) *CNV.5A*: Watercare has proposed this new condition to address the statistical application of DIN 4150-3:1999.

(e) *CNV.5B*: Watercare has proposed this new condition to address the statistical application of DIN 4150-3:1999.

(f) *CNV.6:* The Council originally proposed this new condition which is accepted by Watercare with a small number of minor amendments to ensure consistency within the Construction Noise and Vibration Conditions in the Proposed Conditions as a whole.

Summary on the Proposed Conditions

12.27 In summary, the Styles Report is largely in agreement with the assessment undertaken in relation to vibration effects, the standards proposed to avoid, remedy or mitigate any effects and the conditions proposed to ensure this occurs. The Styles Report, and Pre-hearing Report conclude:[10]

> In terms of construction vibration, the amendments I have suggested to the conditions will ensure that the levels of vibration will not give rise to damage to buildings (as defined in DIN4150). The conditions also provide for a range of mitigation measures including pre-condition surveys, monitoring and consultation. I consider that if the conditions (including my amendments) are complied with, the vibration effects arising from construction will be reasonable and acceptable.

[10] Central Interceptor Scheme Review of Noise and Vibration Effects, 24 June 2013, Styles Group, at page 16 and Council Pre-hearing Report at page 127.

13. CONCLUSIONS

13.1 Once operational, the vibrations generated by the Central Interceptor and associated infrastructure will be negligible, except on the rare occasions where maintenance work requires access for heavy plant. The effects on people will be less than minor and there will be no risk of structural damage to buildings.

13.2 The Project has been designed to minimise effects of vibration by being located at depth and excavated in weak rock. The primary potential vibration effects associated with the Project relate to the construction activities required at the various proposed construction sites involved. These activities include the use of blasting techniques where basalt is present, tunnelling in the ECBF, piling works, the operation of heavy construction plant and truck movements.

13.3 To ensure there is no damage to residential structures and sensitive buildings from vibrations associated with the Project, Watercare's Proposed Conditions limit the transmitted vibration levels to the limits included in the DIN 4150-3:1999 Standard. Compliance with this highly recognised standard will provide a high level of confidence that no damage will occur. This standard will also ensure that vibrations should not cause unacceptable disturbance to residents. It is both desirable and necessary to adopt a statistical approach to compliance, with further exceedances possible when agreement is reached with the relevant owners and no structural damage will occur to buildings.

13.4 In summary, I consider that Watercare's Proposed Conditions will enable the construction works to be undertaken in a way which manages effects such that structural damage to properties and unacceptable disturbances to people will be avoided.

Peter Millar

12 July 2013