Acoustics report

State highway bridge expansion joint noise

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Prepared for

NZ Transport Agency

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URS OPUS

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Introduction

1.1 Scope

Most state highway bridges include expansion joints by the abutments and/or across the deck of the bridge. In their simplest form these joints provide a small gap across the road, but they can also be more sophisticated 'modular' or 'finger' joints with overlapping elements across the gap. Most joints result in audible noise above and below the structure as vehicles pass over the joint. There is also vibration generated. The peaks of noise are more distinctive and have greater potential to cause annoyance for people in the vicinity of the bridge, compared to normal road-traffic noise, which is relatively constant.

The NZ Transport Agency (NZTA) has commissioned URS and Opus to jointly conduct research into noise from bridge expansion joints. The purpose of this research is to determine factors affecting noise generated by joints currently used in New Zealand, and establish options available to minimise noise when new bridge joints are proposed in noise sensitive areas. This work also considers vibration generation but the focus is on noise effects. The noise and vibration generating mechanisms are closely related.

This report includes a review of international literature, and results and analysis from measurements of noise and vibration at selected state highway bridge expansion joints around Wellington, Auckland and Tauranga. This work was required to compare a number of different joint types in a short timeframe. To obtain data in the available time the measurements were primarily conducted with instrumentation mounted on a vehicle to measure noise and vibration as it passed over joints. Additional road-side noise measurements and observations were made at selected sites in Wellington.

The noise performance of a particular expansion joint is affected by a range of factors such as the construction of the bridge deck, surface material, joint type, joint void/box and also the types of vehicles traversing the joint and their speeds[1]. This report has a focus on comparing different types of joint, but it should be kept in mind this is only one of the factors determining noise performance, and is not always the controlling factor.

1.2 Expansion joint selection

Expansion joints are designed to accommodate the horizontal (longitudinal) and to a lesser degree vertical movements that occur within bridge structures. Differential movement across an expansion joint may occur due to factors such as temperature, expansion and contraction of the bridge material and any transverse movement of the bridge deck. The required width of an expansion gap depends on the dynamics of the bridge structure. For short structures with an overall length less than 70 metres (55 metres for steel bridges) expansion joints are not normally required. Table 1-1 lists the acceptable movement for various joint types.

The NZTA Bridge manual[2] includes requirements for expansion joints, specifically in *Section 4.7 Bearings and deck joints*. The Bridge manual requires that the number of deck joints in a structure shall be the practical minimum. For joint gaps exceeding 25 mm the preferred joint is a single elastomeric seal retained by metal nosings. For very long bridges use of several single seal joints is preferred to multiple seal joints (e.g. modular joints). The Bridge manual does not provide advice relating to noise from expansion joints. It does reference vibration excitation of structures generally, but in terms of structural integrity rather than environmental effects.

[1] Silvia Project, Integration of Low-Noise Pavements with other Noise Abatement Procedures, European Commission, 2005.
[2] NZTA Bridge manual, SP/M/022, Third edition, May 2013.

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Table 1-1 Acceptable movement from expansion joints (from BD 33/94)

Joint Type	Total acceptable Longitudinal Movement Min	Max	Maximum acceptable vertical movement between two sides of joint
Buried joint under continuous surfacing	5 mm	20 mm	1.3 mm
Asphaltic plug joint	5 mm	40 mm	3 mm
Nosing joint with poured sealant	5 mm	12 mm	3 mm
Nosing with preformed compression seal	5 mm	40 mm	3 mm
Reinforced elastomeric	5 mm	*	3 mm
Elastomeric in metal runners	5 mm	*	3 mm
Cantilever comb or tooth joint (including modular systems)	25 mm	*	3 mm

* maximum value varies according to manufacturer or type

The choice of joint depends on a number of factors[3]. The Bridge manual requires joints to be selected on the basis of low life-time costs and maintenance requirements, and user safety. The manual also references guidance in the UK Highways Agency document BD 33/94[4], NZTA Research Report 186[5] and the paper *Bridge Deck Expansion Joints*[6]. There is not a prescriptive method to determine the appropriate expansion joint type for a particular bridge.

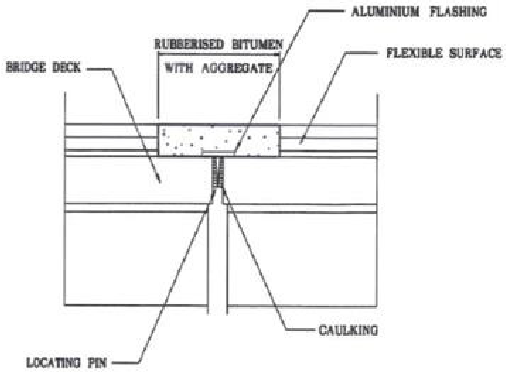
Of more relevance to bridge designers in New Zealand is a recent Austroads report[7], which discusses the Australian and New Zealand experience with different types of expansion joints. That report also includes general background information and a detailed description of different types of joints. Within the Austroads report, qualitative statements are made on the noise performance of different types of joint including:

- Finger joints are considered to have good (low) noise performance.

[3] AS 5100: 2004, Bridge Design, Part 4: Bearings and Deck Joints, 2004
[4] BD 33/94, Expansion Joints for Use in Highway Bridge Decks, UK Highways Agency, 1994.
[5] Bruce, SM, and Kirkcaldie, DK, Performance of Deck Expansion Joints in New Zealand Road Bridges, Research Report No. 186, Transfund New Zealand, 2000.
[6] Burke, MP, Bridge Deck Expansion Joints, National Cooperative Highway Research program Synthesis of Highway Practice 141, Transportation Research Board, Washington DC, 1989.
[7] Design Rules for Bridge Bearings and Expansion Joints, Austroads research report AP-R405-12, 2012.

1 Introduction

- Asphaltic plug joints are considered to have good noise performance but are subject to other constraints.



- Modular joints (without surface plates) are considered to have relatively poor noise performance. (Conversely, it is discussed later how modular joints with surface plates have good noise performance.)

The UK Bridge Joint Association published guidelines[8] which set out the advantages and disadvantages of various joint types based on BD 33/94 guidance, although not in terms of noise. The European Commission issued a mandate[9] for the harmonisation of bridge joint design, which expands on BD 33/94 and includes prioritisation of noise performance behind resistance to mechanical loads, skid resistance and drainage.

Noise characteristics of different joint types are discussed further in Section 2.

1.3 Existing state highway joints

The NZTA maintains a Bridge Data System (BDS) which includes bridge expansion joint information for some state highway bridges. There are 4,581 entries in the BDS and for over half those entries the expansion joint type is recorded in the BDS as summarised in Table 1-2. In most of the remaining cases the database field for the expansion joint has been left blank. Each bridge has one entry in the BDS and it does not record how many joints of the type specified exist on each bridge. For most bridges with expansion joints there will be at least one joint at each end, and therefore the total number of joints on the state highway network will be at least twice the numbers in Table 1-2.

[8] Bridge Joint Association, Standard for mechanical expansion joints, The Bridge Joint Association, BJA/S2/MEJ, May 2003.
[9] European Commission, (Construct 00/409 Revised) Mandate To EOTA Concerning The Execution of Harmonisation Work For An ETA Guideline On Expansion Joints For Road Bridges Related To The Following End Use : Road Bridges, 24 July 2000.

1 Introduction

Table 1-2 Existing state highway joint types

Joint type	Number of entries in BDS
air gap	277
asphaltic plug joint	2
bitumen filled gap	256
elastomeric sealant	1
laminated elastomeric	1
mechanical elastomeric M330 (Multiflex)	1
modular expansion joint	2
none	1446
rubber extrusion + embedded steel plates	74
rubber extrusion unreinforced	184
rubber extrusion unreinforced + embedded steel plates	1
rubber seal (solid)	117
rubber seals + vert. steel plates	95
sealant filled gap	1
steel finger joint with or without rubber	27
steel sliding plate	197
stripseal type	2

Photographs of examples of the main joint types in this table are provided in the measurement result sheets in Appendix A.

Where there is a record against joint type in the BDS, the majority of bridges actually have no expansion joint. The most common joint types where they do exist have no filler (air gap) or are bitumen filled. Rubber extrusions and steel sliding plates make up a significant proportion of the remaining joints. Of the existing state highway bridges the more sophisticated finger or modular joints are generally on newer and/or longer structures such as the Newmarket Viaduct, Mangere Bridge and Tauranga Harbour Bridge.

Literature Review

2.1 Introduction

A search has been conducted for recent journal / conference papers, technical reports and manufacturers' literature concerning bridge expansion joint noise. Older papers referenced by the recent work have also been reviewed where relevant. The findings of this review are presented here in terms of noise and vibration generating mechanisms, low noise joint types and measurement methods.

A number of studies reviewed have investigated the noise generating mechanisms and the relative performance of joint systems on specific bridges. These studies have typically been instigated as a result of noise complaints. The majority of studies have investigated the relative performance of remedial solutions, including the erection of noise barriers[10] around the offending joint and/or the modification or replacement of the joint. There appears to be a paucity of relevant studies which have methodically investigated the generic noise characteristics of a wider range of available joint systems. No consolidated work has been found which has directly compared the performance of different joint types at more than a handful of locations.

2.2 Noise and vibration generation

The literature reviewed does not provide detailed analysis of fundamental noise and vibration generating mechanisms, but various papers hypothesise over likely mechanisms.

A short peak of noise can be generated each time a vehicle tyre passes over an expansion joint. In broad terms the noise is the result of the vehicle tyres striking the face of the expansion joint, or traversing a vertical step between the adjacent road surface and the joint or between the two halves of the joint. The expansion joint noise can occur both above and below the bridge. Generally speaking the highest noise levels occur when the two edges of the joint are either not vertically aligned or the gap is unfilled.

Noise generation can be reduced by creating an even surface for the tyre to traverse. For simple joint types this can be achieved to some extent by using a plug or seal to fill the gap. However the longevity of a plug/seal depends on the material, local traffic and environmental factors. Over time, noise levels can increase as the plug material degrades and the gap width and depth start to grow[11]. Another method is to use a finger joint which can maintain an even surface without relying on components that can degrade. For modular joints an even surface can be achieved by using a design with surface elements that avoid a linear discontinuity across the joint. Examples of this are discussed in Section 2.3.

Van Vliet and van Loon[12] noted that expansion joint noise is usually dominated by the lower frequency range, and the highest noise levels occur for trucks, which may be due to the additional loads and potentially wider contact area of the tyres. Several of the other studies reviewed also noted that the frequency spectra of joint noise is biased below about 800 Hz (for example Donavan and Rymer[13]) and is especially significant for joint voids causing resonances[14]. This is 'secondary' noise from expansion joints generated within the cavity or enclosure below the joint.

[10] Sexton T, Controlling Expansion Joint Noise on the Tacoma Narrows Bridge in Washington State, USA, Internoise, 2011.
[11] Fobo W, Low Noise Emission Expansion Joints with Long Durability, Maurer Schne, 2011
[12] van Vliet WJ and van Loon R, Road Traffic Noise of Expansion Joints assessment method and results. Internoise, 2011.
[13] Donavan P and Rymer B, An Investigation of Noise Generation of Seismic Expansion Joints for Highway Structures. Internoise, 2011.
[14] Clairbois JP, Houtave P and Tréfois V. Specific problems on the use of noise barriers on viaducts. Euronoise 1998.

2 Literature Review

Cavity effects can be exaggerated if a resonance in the cavity coincides with resonances of the structure. For example, Barnard and Cuninghame[15] identified the role of acoustic resonances in the bridge structure, although the study was for one specific bridge. Similarly Ancich[16] hypothesised that tyre impacts excite the expansion joints which produce noise that is amplified within the bridge superstructure. Possible solutions to resonances include the use of damping materials and the introduction of tuned absorbers to the joint cavity.

Martner[17] found that simply enclosing the area under a joint with 200 mm porous material on 2 mm sheet metal significantly reduced sound radiated below the bridge.

2.3 Low noise joints

Various papers reviewed present joints and treatments to joints that are reported to generate lower noise levels. The different methodologies used in the papers reviewed do not allow a direct comparison of noise measurement results between studies.

Spuler *et al*[18] reviewed a number of 'quiet' expansion joints and ways of improving the noise characteristics of existing joints. The joints set out in Figure 2-1 were identified as having good noise characteristics based on subjective and objective assessment.

Figure 2-1 Low noise joints (Spuler *et al*)

Joint type	Photo	Comments
Cantilever joint		• Relatively low initial cost • Compact design with few components • Reduced wear and tear due to fewer impact interfaces and no moving parts, resulting in low maintenance costs • Limited longitudinal movements (300-400 mm) and limited transverse and vertical movements and rotations • Moment loading on the substructure may be significant (depending on the longitudinal movement capacity)
Sliding finger joint		• Costs higher than cantilever finger • Simple, durable, low maintenance (simple maintenance of finger plates) • Allows rotational and vertical movement • Supported structure protects main structure from large moments • Not suited for cycle traffic • Can be adapted to have noise reducing plates

[15] Barnard C.P. and Cuninghame JR, Improving the Performance of Bridge Expansion Joints: Bridge Deck Expansion Joint Working Group Final Report. TRL Report 236, Transport Research Laboratory, 1997.
[16] Ancich EJ, A Study of the Environmental Noise Generation & Propagation Mechanisms of Modular Bridge Expansion Joints. RTA Environmental Technology Report No. 000203, Roads & Traffic Authority of NSW, September, 2000.
[17] Martner O, Noise Emission of Constructions for Bridge-To-Road Crossings. Proc. Inter-Noise 96, pp 211-214, 1996.
[18] Spuler T, Moor G and O'Suilleabhain C, Expansion joints for urban bridges – quiet, reliable and low-maintenance. International Association of Bridge and Structural Engineering, Venice, 2010.

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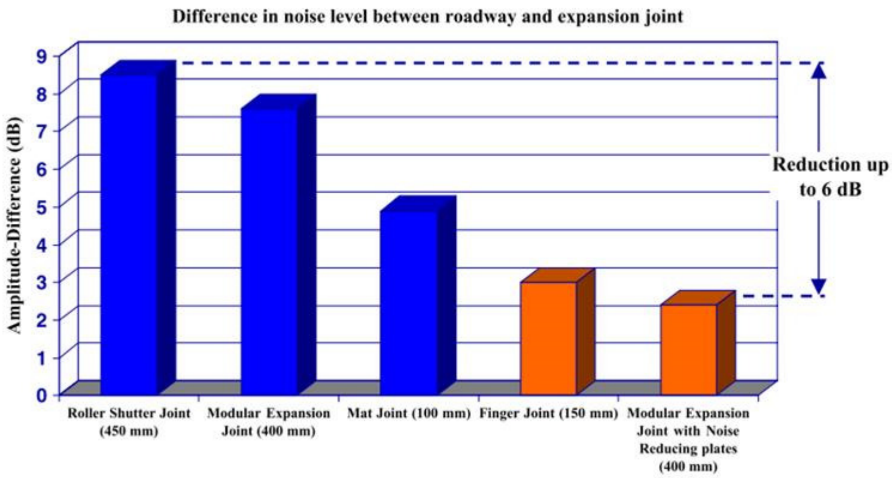
Joint type	Photo	Comments
Modular expansion joint with noise-reducing surface plates		• Relatively high initial costs • Complex system to install • Movement and rotations are possible in all directions and about all main axes • Large longitudinal movements possible • Good over rolling comfort and safety, including cycle traffic
Single gap expansion joint with noise-reducing surface plates		• Low initial and maintenance costs • Compact construction with few components • Limited transverse movements and rotations possible • Good over rolling comfort and safety, including cycle traffic

Spuler *et al* measured the relative noise reduction performance of each system, and quote a noise level reduction, which is assumed to be in terms of the maximum sound pressure level as a vehicle passes over the joint. The results in Figure 2-2 show a reduction of 6 dB can be achieved with a modular joint with noise reduction plates compared to a standard longitudinal 'shutter' joint. It is assumed this level reduction is in terms of newly installed joints. Other studies, as reported below, have identified greater levels of noise reduction for similar low noise joints. The finding that modular joints have good performance contrasts to the Austroads design rules discussed in section 1, which found modular joints to have poor performance. The difference is due to the surface plates.

Figure 2-2 Relative performance of joints (Spuler *et al*)



Another type of low noise joint is the wave shaped design shown in Figure 2-3. This is produced by Maurer Sohne[19], which reports a reduction in maximum noise levels of up to 9 dB.

[19] Maurer Sohne, Noise Reduction of Modular Expansion Joints by mean of rhombic steel plates, Bridge Accessories No.24(GB) sales information, 2001.

2 Literature Review

Figure 2-3 Wave shaped joint (Maurer Sohne)

Similar to the noise reducing plates discussed above, Glaeser et al[20] found that a noise reduction can be achieved by mounting surface elements on top of joint transition segments. Glaser et al tested varying shapes and textures of surface elements, including rhomboidal profiles, 'mushroom' and sinusoidal shapes. They measured noise emissions from the traverse of car tyre in a purpose built laboratory test cell. Tests were made for different speeds and at joint gaps of 25 mm representing summer and 65 mm for winter. It was found that a noise reduction of up to 9 dB could be achieved, when compared to conventional joint surface elements. In general, there was greater noise reduction at lower speeds.

The study by van Vliet and van Loon also reports on measurements of noise from various joint types. Observations were made based on joint type, vehicle classification and speed, and also crossing angle relative to the joint. Variations up to 15 dB were found for different joints and speeds. They noted that a large unevenness around the expansion joint can also lead to noise from movement of goods and body noise from trucks. Different crossing angles were found not to be significant.

2.4 Measurement methods

Almost all of the papers and reports reviewed have considered relative noise levels and to a lesser degree vibration levels between different joint types when used on a particular bridge or test deck. For example, a number of reports state the improvement in sound level which can be expected when a noisy joint is replaced or repaired. Typically maximum noise levels are reduced by 6 to 15 dB. However, there is no standardised approach to reporting noise levels[21,22] therefore the relative performance stated in one report may not necessarily correspond with the performance stated in another for a number of reasons:

- Measurement location and distance from joint;
- Road surface condition and type;
- Noise metric used, $L_{Aeq(t)}$ or L_{AFmax}; and
- Vehicle speeds and types.

Some of the reports use a statistical pass-by[23] approach while others have used a close proximity method[24] whereby the noise level is measured close to the tyre/road contact zone of a test tyre

[20] Glaeser KP, Schwalbe G and Marek. Mitigation the noise emissions of vehicles travelling over bridge expansion joints. Internoise, 2011.
[21] Pijpers RJM, Meetbare geluidseisen en geluidarme oplossingen voor enkelvoudige voegovergangen", TU Delft, October 2005. (translation of key parts)
[22] Kalivoda M, Pilot study on noise from expansion joints on highway bridges, Forum Acusticum, 2005.
[23] ISO 11819-1:1997. Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 1: Statistical Pass-By method, 1997.
[24] ISO 11819-2:1997, Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method (draft), 2012.

mounted either on a trailer or specific vehicle. Donavan and Rymer compared different approaches measuring: close to the tyre/road interface with on-vehicle sound intensity microphones; at the roadside typically at 5.5 metres from the centre of the near lane at the joint; and at the closest residential properties. They observed noticeable differences from vehicle speed and vehicle type close to the joint but not at the residential property.

Van der Poorten and Clairbois[25] made similar findings, for tests with three joints. The results in Table 2-1 shows measurements did not correlate with subjectively quiet and noisy joint types, although this may have been affected by the choice of a long (4 hour) measurement time. Also the road surfaces were different which affected the measurements at 70 metres more than the measurements close to the joints. A poor road surface may provide some masking of noise from a poor joint.

Table 2-1 Differences at varying distances from joints (van der Poorten and Clairbois)

Type of joint	Noise at joint position	Noise 70 m from joint
Noisy	86.0 dB $L_{Aeq(4h)}$	84.5 dB $L_{Aeq(4h)}$
Very Noisy	86.6 dB $L_{Aeq(4h)}$	84.2 dB $L_{Aeq(4h)}$
Quiet	83.4 dB $L_{Aeq(4h)}$	85.8 dB $L_{Aeq(4h)}$

2.5 Summary

From the literature reviewed it has been found that:

- Joint noise can be minimised by maintaining an even running surface.
- Finger joints appear to be inherently low noise types.
- Modular joints with appropriate surface treatment can also be considered a low noise type.
- Previous test data does not provide a reliable basis for predicting the relative performance of different joint types, but it appears that low noise joints can be in the order of 10 dB quieter than conventional joints or poorly installed joints.
- Voids under joints make a significant contribution to noise generated, but can be treated with (resonant) absorbers and enclosures.
- There has not been a consistent measurement methodology used by different researchers for expansion joint noise. Measurements both near to the joint and at a distance have been used.

[25] Van der Poorten D and Clairbois J-P. Mesures acoustiques des joints sur les viaducts Hesperange, Itzig et Hamn, Papport de mesre JPC-fe-LU0156-RP2003-0026, 2003.

Methodology

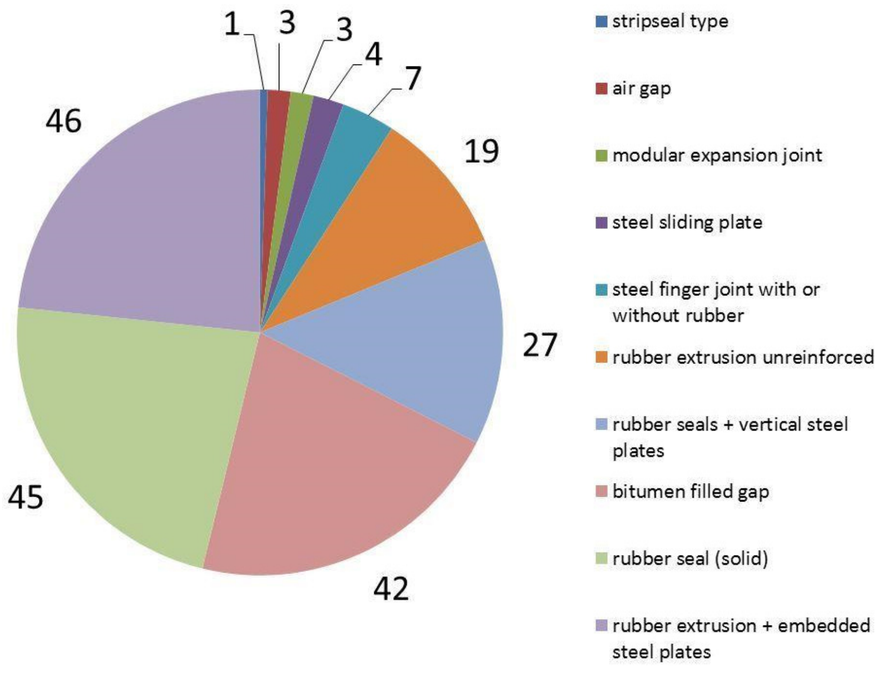
3.1 Introduction

The aim of this report is to evaluate the noise and vibration performance of various expansion joints which are used on state highways in New Zealand. The approach taken has been to make measurements for a relatively large number of joints using vehicle mounted equipment. Additional measurements have been conducted beside and under a sample joint. The vehicle mounted equipment does not directly measure the noise experienced by people in the vicinity of joints, but does show the relative performance of joints which is assumed to be correlated to the noise experienced beside and below the structures.

3.1 Bridge joint types and locations

This study sought data from a range of expansion joint types, including newer types used on recent NZTA projects. A short list was made of approximately 70 bridges in and around Wellington, Auckland and Tauranga. These cities were chosen due to the number of bridges available and the locations of recent joints. The short list was intended to capture a range of different joint types within a practical driving circuit around each city. In proportion to bridge joints on the network, only a minority of joints measured were recently installed with the majority being older. In the end, a total of 63 bridges were measured and 320 measurements were made on 197 joints, including multiple pass-bys on some joints. Appendix B lists the joint type for each bridge. The joints fell into 10 categories in the BDS as shown in Figure 3-1.

Figure 3-1 Number of joint types measured



Bridge locations together with the relevant Bridge Structure Number (BSN) are shown in Figure 3-2, Figure 3-3 and Figure 3-4.

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Figure 3-2 Auckland bridge locations

3 Methodology

Figure 3-3 Wellington bridge locations

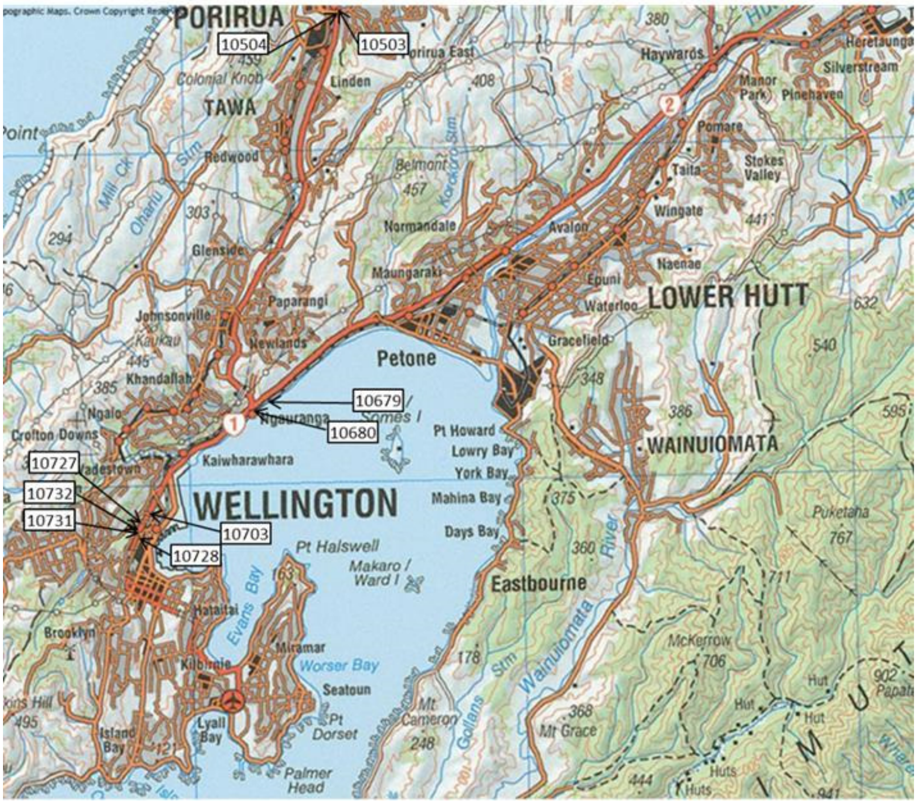
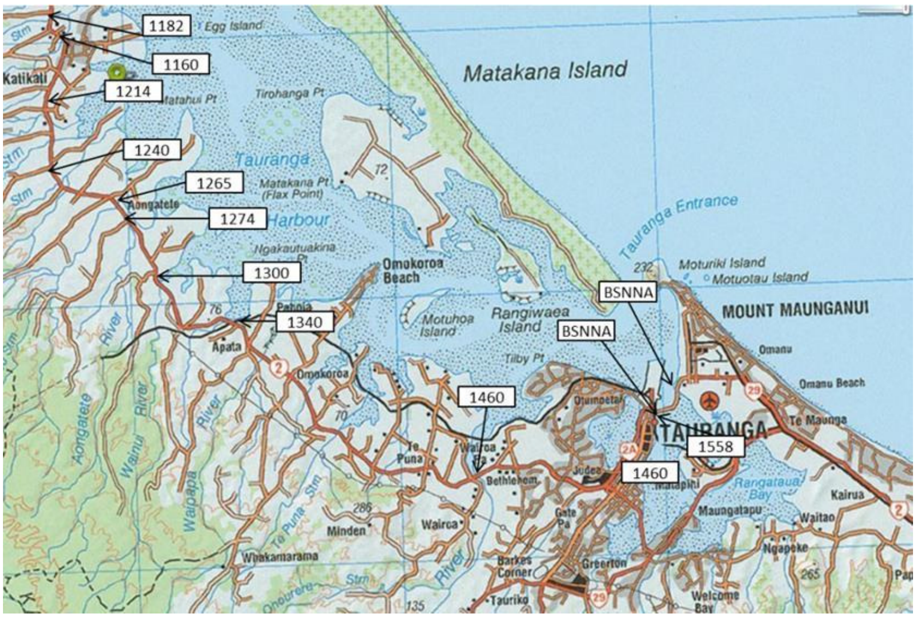


Figure 3-4 Tauranga bridge locations



3.2 Instrumentation

Close proximity measurements

The left, rear wheel of a vehicle was instrumented to allow monitoring of both tyre noise and tyre vibration (acceleration) as the vehicle traversed bridge joints at normal operating speeds. Where possible the vehicle was driven at a reference speed of 80 km/h. The vehicle selected was a Toyota Aurion because it has an independent rear suspension. This feature was considered desirable because it assists in isolating vibrations and noise from the opposite side of the vehicle. The sensors and cameras fitted to the vehicle are described below.

Accelerometer

A triaxial accelerometer was fitted to the left rear suspension arm (Figure 3-5). However, because of sampling rate constraints imposed by the sound measurements, accelerations were recorded for only two directions, longitudinally and vertically. These two channels were each sampled at 550 Hz and bandpass filtered between 1 Hz and 500 Hz.

Figure 3-5 View of accelerometer on lower suspension arm

Microphone

A mini condenser microphone was installed in close proximity behind the rear left tyre, in the lateral centre of the tyre and as low as practically possible (Figure 3-6). The microphone was calibrated to a 1 kHz, 94 dB pistonphone. The calibration factor relating voltage output to pressure was obtained by scaling the voltage output to the known output of the pistonphone i.e. 94 dB, 1 kHz = 1 Pa. The microphone output was sampled at 22 kHz, converted to units of pressure (Pa) and bandpass filtered between 10 Hz and 9 kHz before any further analysis was performed.

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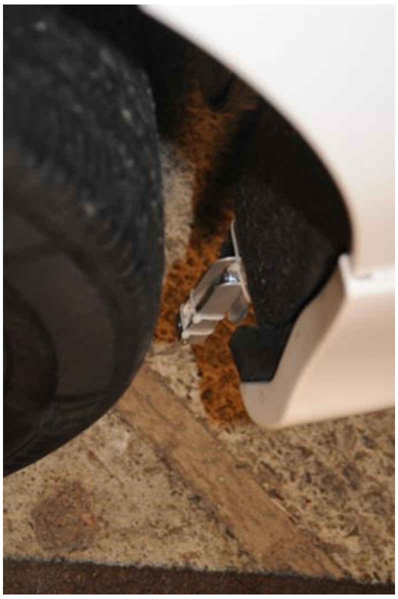
Figure 3-6 Position of microphone relative to rear wheel arch and tyre



GPS

A GPS unit was installed in the rear windscreen, giving location updates and speed measurements every second.

Cameras

Two DVR cameras were utilised. One camera was attached to the front windscreen to provide a drivers view of the bridge to enable reconciliation of the GPS co-ordinates with NZTA's bridge database whenever multiple bridges were encountered on the Auckland and Wellington motorways. The camera employed for this purpose was a GatorTM car recorder camera with a maximum frame rate of 30 frames per second. A second camera was attached to the door of the vehicle to take a direct overhead image of the bridge joint being traversed. A GoProTM Hero 3 Black Edition camera was used for this purpose as it provided a recording resolution of 1080 ×720 pixels at 120 frames per second.

Data acquisition and processing

An IOtech LogBook/360 data acquisition system was used to record output from the GPS unit, accelerometer, microphone and event marker (Figure 3-7). Wherever possible, oversampling was used to improve resolution and reduce signal noise.

Signal processing routines based on the industry standard MATLAB software package were used to digitally filter and analyse the acceleration and sound pressure time histories.

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Figure 3-7 Data acquisition system in rear of passenger compartment

A-weighting of the microphone output was done using an ANSI S142 Class 1 A-weight digital filter, whereas 'un-weighted' corresponded to the microphone output bandpass filtered between 10 Hz and 9 kHz bandpass filtered data. SPL and Leq measures were calculated and a 'Fast' time weighting of 125 ms has been used in generating plots of SPL and Leq.

Event marking

The operator inserted an event marker as a bridge joint was crossed. This marker plus a manual correction were used to locate the 1 second time-window for the joint noise event. Speed and time since the last GPS update were used to estimate the distance since the last recorded GPS position. This assisted in reconciling recorded GPS coordinates to state highway route positions assigned to NZTA BSNs. This reconciliation had to be performed manually.

Photographs

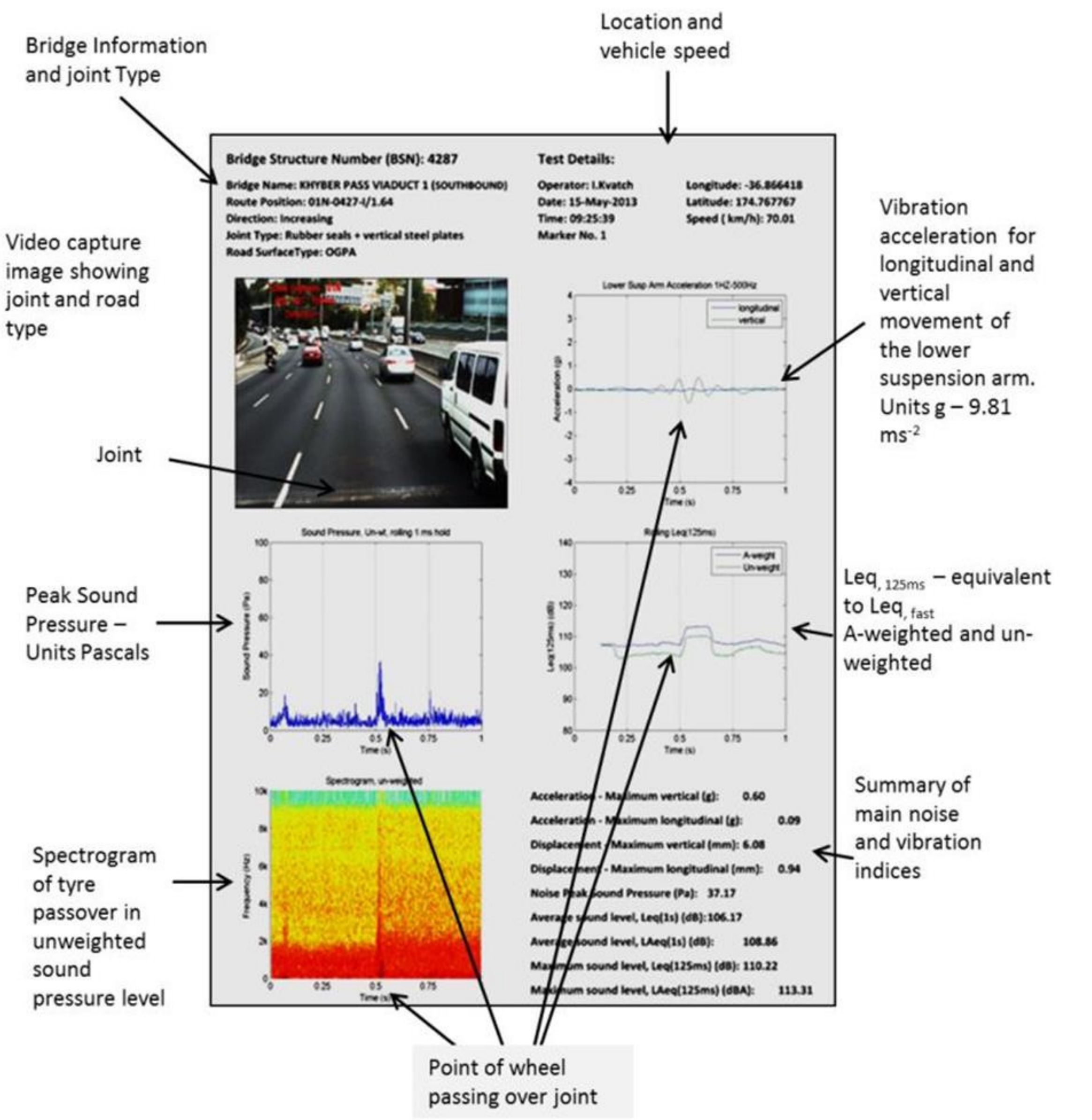
With reference to Figure 3-8, it can be seen that lighting conditions had a significant effect on the quality of the photos taken of the bridge joint by the GoProTM Hero 3, with photo "smear" being a particular issue. To overcome this, right-of-way photos taken during the 2012-2013 road condition survey of the state highway network were used instead as these provided the clearest images of the traversed bridge joints. Also they were indexed to the LRMS addresses of the BSN's so could be located relatively quickly. For each bridge the photograph only shows the first joint, and on the results sheets the photographs do not relate to the actual joint for the second and subsequent joints.

Figure 3-8 Photo of Clifton Terrace bridge joint taken from test vehicle at a speed of 80 km/h

3.3 Results sheets

Appendix A contains a sheet of results for the close proximity measurements of each bridge joint. The parameters on those sheets are shown in Figure 3-9. Appendix B includes the tabulated summary results (also provided as a spreadsheet with this report).

Figure 3-9 Information shown on results sheets

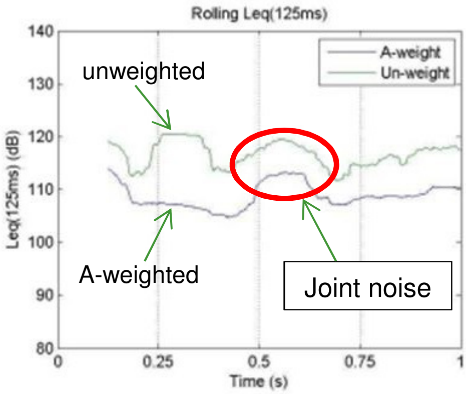


The measurement parameters recorded include the vertical and longitudinal (horizontal) acceleration and displacement vibration magnitudes. Acceleration is defined in terms of the number of g (gravity), which is equivalent to 9.81 m/s^2 and displacement is defined in terms of millimetres. Noise levels presented include linear and A-weighted data, averaged (L_{eq}) over one second and over 125ms, as well as the peak sound pressure. On the results sheets the 125ms data is referred to as $L_{eq(125ms)}$, but in the report text this will be denoted as L_{Fmax}. In the text this will be referenced as L_{ZFmax} for unweighted data and L_{AFmax} for A-weighted data.

3.4 Parameters

A-weighting noise data reduces the contribution of low (mainly below 200 Hz) and high frequencies (mainly above 8000 Hz). This removes some of the system noise, including wind noise, such that the joint event is more evident. This is shown in Figure 3-10 for one of the Newmarket Viaduct joints (BSN 4299) where the A-weighted data shows a noise event that is obscured in the unweighted data. This pattern can be readily observed across measurements for a range of joint types and bridges.

Figure 3-10 Newmarket Viaduct – time history data

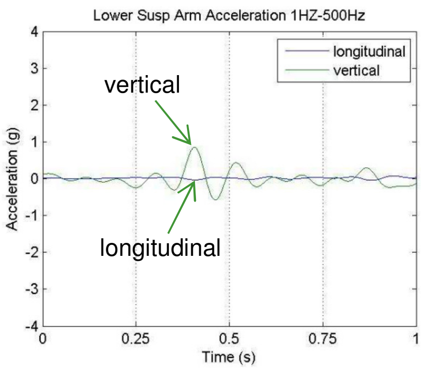


As well as suppressing system noise A-weighting also reduces low frequency noise due to the joints themselves. The comparison of joints using A-weighted data is still considered appropriate to indicate overall trends of performance, but it is accepted that subtleties in frequency response cannot be determined by this method, particularly given the variations around a joint as reported in Section 3.8.

The L_{AFmax} data provides a slightly greater range of values than the $L_{Aeq(1s)}$ data, giving marginally better differentiation between joints. For this report the L_{AFmax} has been used when making comparisons. The peak sound pressure data has not been analysed for this report.

The example vibration time history in Figure 3-11, shows that as expected for transducers mounted on a suspension arm vertical data is always more significant than longitudinal data. No trends have been found in the longitudinal data and comparisons in this report are made using the vertical data.

Figure 3-11 Illustrative vibration data



Vibration was measured using accelerometers and the outputs are reported in terms of the acceleration, and also converted to displacement. As the displacement data is all calculated based on the measured acceleration data the two data sets are correlated. The comparisons made in this report are in terms of the acceleration as that was the quantity measured directly.

3.5 Repeatability

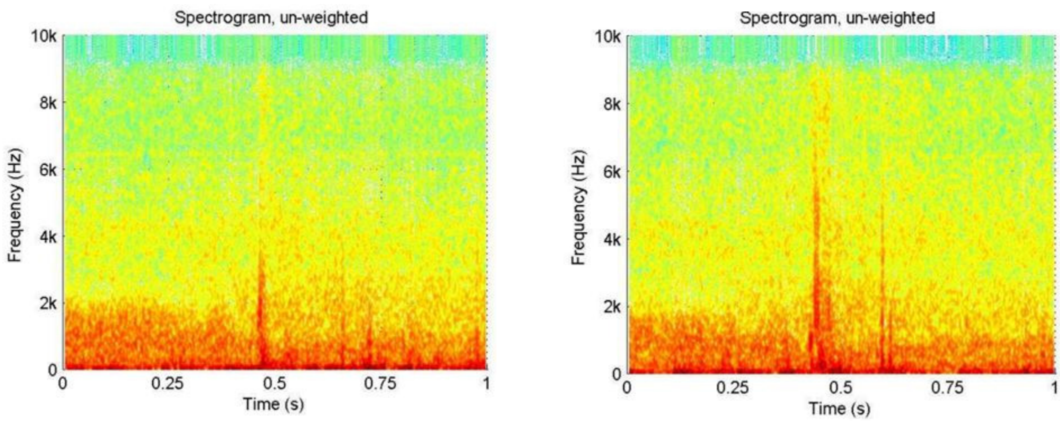
For some of the bridges multiple passes were made of the same joints. In the case of the northbound Mangere Bridge (BSN 129) there were two passes over each of the 5 joints, which are rubber seals with vertical steel plates. These multiple passes provide an indication of the achievable repeatability of the test system. For each of the joints on the northbound Mangere Bridge the differences in maximum noise levels (L_{AFmax} and L_{AZmax}) and percentage difference in the vertical acceleration between the two passes are presented in Table 3-1.

Table 3-1 Difference between two pass-bys on Mangere Bridge

Joint Number	Noise		Vibration
	L_{AFmax} difference	L_{AZmax} difference	Vertical acceleration, difference in g
1	0.6 dB	0.5 dB	14%
2	0.0 dB	0.9 dB	5%
3	0.9 dB	0.5 dB	5%
4	0.7 dB	1.0 dB	12%
5	4.2 dB	0.2 dB	23%

For each of these joints the two pass-bys are within 1 dB, apart from the joint 5, when looking at the A-weighted data. As discussed in Section 3.4, the linear (L_{ZFmax}) data may be obscured by system noise. The spectrograms for each of the two pass-bys over joint 5 on Mangere Bridge are shown in Figure 3-12. Higher levels can be clearly seen from the second pass-by (right-hand graph) as the more pronounced vertical red lines. A number of factors may have influenced the measurement, such as position on the road (road speed was consistent between the two pass-bys). This difference is also reflected in the significant percentage change in the acceleration data.

Figure 3-12 Spectograms of a repeat pass-by



Further analysis has been conducted for all joints where there were multiple pass-bys during the tests. For each multiple pass-by of the same joint, the difference in L_{AFmax} and vertical acceleration was calculated. The average differences for multiple passes on each joint type are shown in Figure 3-13 and Figure 3-14.

3 Methodology

Figure 3-13 Difference in vertical acceleration between multiple pass-bys of the same joint

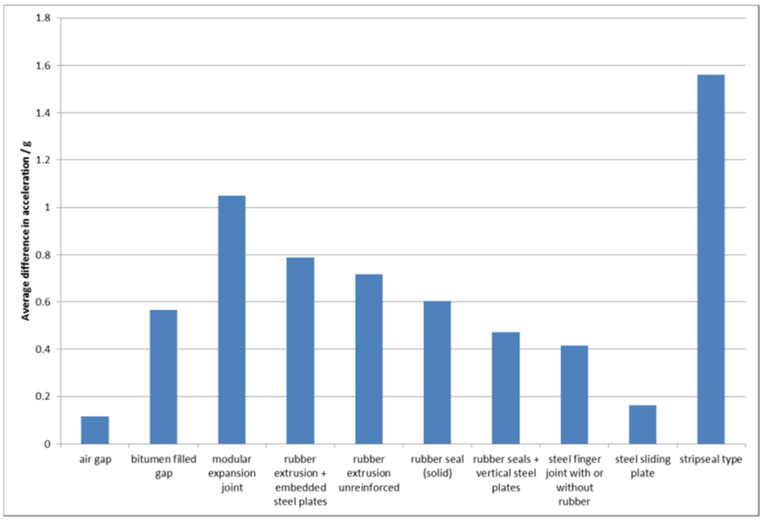
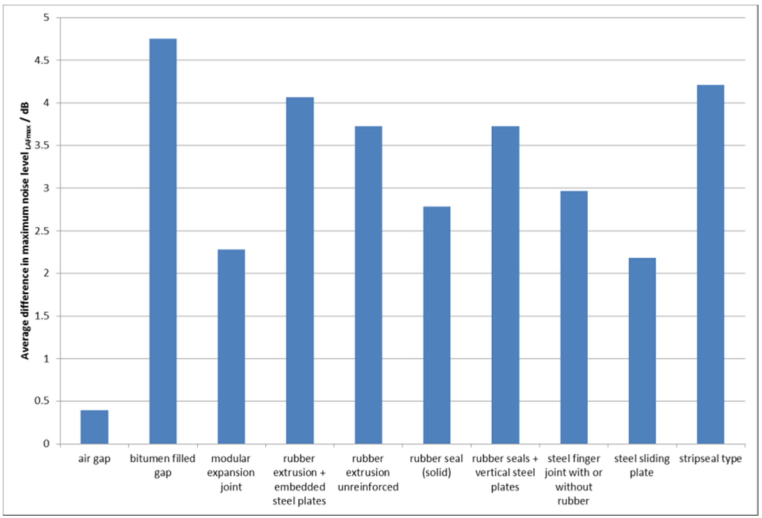


Figure 3-14 Difference in L_{AFmax} between multiple pass-bys of the same joint



Overall for all joint types the average difference between multiple pass-bys of the same joint was 3.1 dB L_{AFmax} (standard deviation 1.3 dB) and 0.65 g (standard deviation 0.43 g).

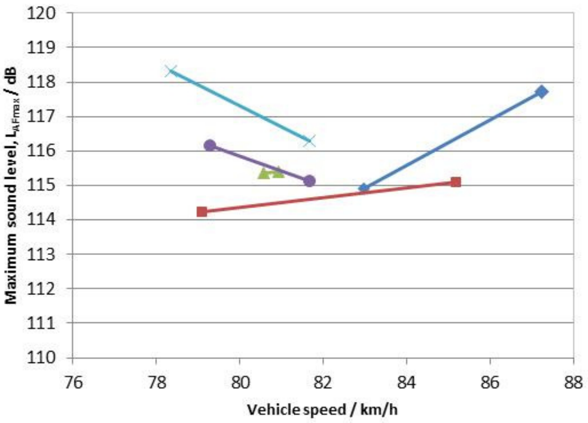
As shown in the Section 3.6, differences appear not to be attributed to speed, and the exact causes remain unknown. Given the limitations in the repeatability of the test method, it is important that any conclusions drawn from the data should relate only to overall trends. Reliance should not be placed on a single sample or measurement of any specific joint.

3.6 Vehicle speeds

On the westbound Upper Harbour Bridge (BSN 62) in Auckland two pass-bys were made over 5 joints with variations in speed ranging up to 6 km/h on individual joints. Figure 3-15 shows the L_{AFmax} values plotted against speed for the 5 joints and two pass-bys. Each line on the graph connects the measurements for one of the 5 joints. Of these 5 measurements one pair are within 0.1 dB of each other, two pairs within 1 dB, one pair within 2 dB and the final pair within 3 dB.

It can be seen that there is no consistent relationship between speed as L_{AFmax} values both increase and decrease with increasing speed over this range. The L_{AFmax} values for the two pass-bys with the greatest variation in speed (79 to 85 km/h) were within 1 dB. The same pattern was found when examining the measured vertical acceleration data.

Figure 3-15 Relationship between vehicle speed and L_{AFmax}



From this data it is concluded that minor variations from the default speed of 80 km/h are not significant. However, insufficient data was obtained over a wider range of speeds to confirm the effect of speed changes between 50 km/h and 100 km/h, compared to the reference speed of 80 km/h used for the tests. In general, the forces generated by a vehicle traversing a joint at lower speeds are expected to be lower than at higher speeds, and therefore lower noise and vibration levels would be expected at 50 km/h compared to 100 km/h.

3.7 Noise floor

To test the sensitivity of the measurement system, analysis was conducted for a section of road without a bridge joint and with a nominally smooth open graded porous asphalt surface. For this test surface, the analysis was conducted for a peak in the measured data, corresponding to a minor defect, bump or other feature in the surface. For that peak the L_{AFmax} value was 113 dB and the vertical acceleration was 0.63 g. These values are higher than measured for some of the bridge joints as shown in Section 4. However, there is also data presented in Section 4 which is significantly lower than these values, notably for the ‘air gap’ joints which were covered by a continuous surface.

The data in Section 4 shows that the measurement system is sensitive to effects of bridge joints, and poorly performing joints can be readily distinguished, at levels significantly higher than those obtained from this section of open graded porous asphalt without a joint. However, this test does indicate that differentiation between better performing joints may be restricted.

3.8 Near field levels

Prior to undertaking close proximity measurements, near field noise measurements were undertaken on 20th May 2013 at Wellington SH1 North end of the Shell Gully overbridge (BSN 10731) for a period of one hour from approximately 1200h to 1300h. Over the period of measurements, weather conditions were appropriate with a light wind of 5 to 10 km/h, ambient temperature about 15 ℃ and atmospheric pressure 1018 - 1020 hPa. The weather data for the Wellington urban area were obtained from the Meteorological Service website.

The measurement procedure was based on NZS 6801:2008. The position of the sound level meter on the bridge and under the bridge is shown in the photographs below. The measurements were made with vehicles using the middle traffic lane. Above the bridge the microphone was approximately 2 metres from the joint and 4 metres from vehicles. Under the bridge the microphone was approximately 4 metres below the middle traffic lane. The joint type is recorded in the BDS as a rubber extrusion with embedded steel plates.

Figure 3-16 Measurement on top of Shell Gully overbridge

Figure 3-17 Measurement under Shell Gully overbridge

3 Methodology

The sound level meter was configured to measure a frequency distribution ($^1/_3$ octave) of L_{Fmax} noise levels from passing cars. Commercial vehicles and buses were ignored. Only cars travelling on the adjacent left lane and middle lane were recorded. The measuring interval was controlled manually when a car was travelling over joints. Typically, the recording interval was within 2 to 3 seconds. The noise levels were recorded from individual cars thereby avoiding the condition when two or more cars were travelling over the joint.

For measurements under the bridge, the wall on the left side could have some effect on the measured noise levels and the frequency distribution. The distance between the wall and a microphone was about 2 m, and the bridge joints were located about 3 to 3.5 m above the microphone.

Representative 1/3 octave plots at both locations are shown below.

Figure 3-18 L_{Fmax} measurements recorded on top of the bridge approximately 4 metres from vehicles

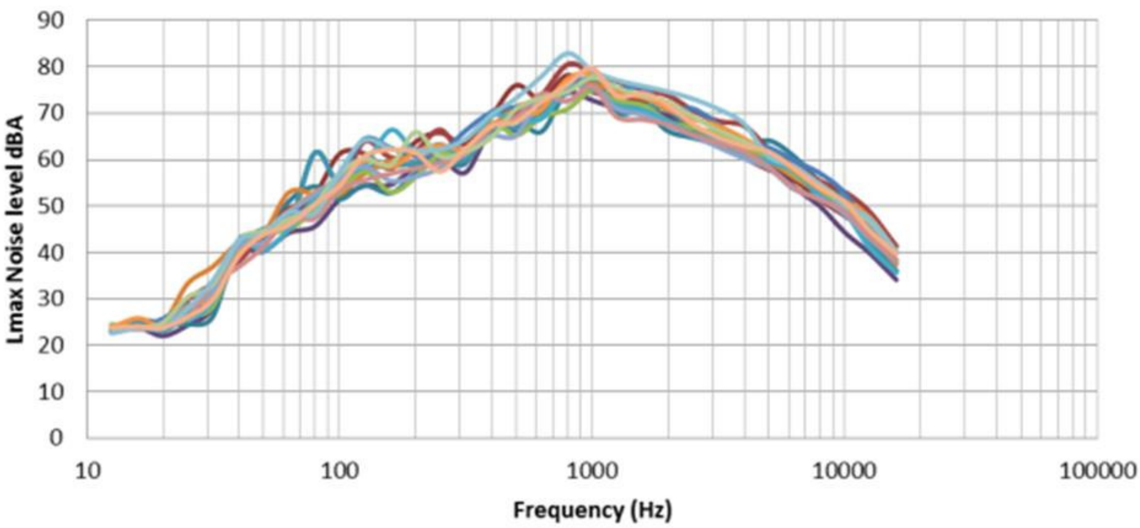
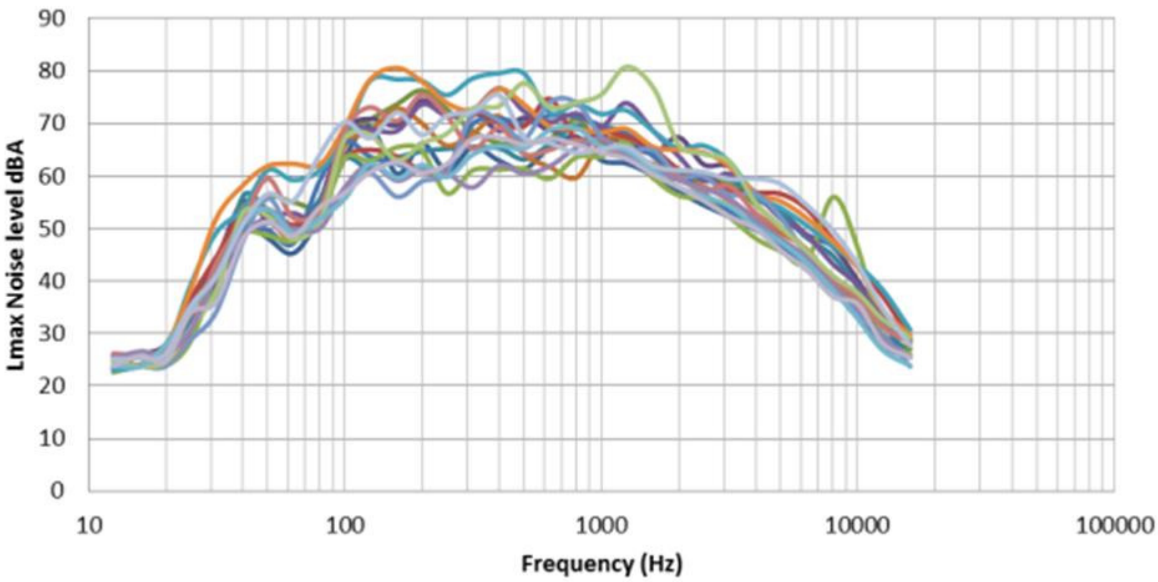


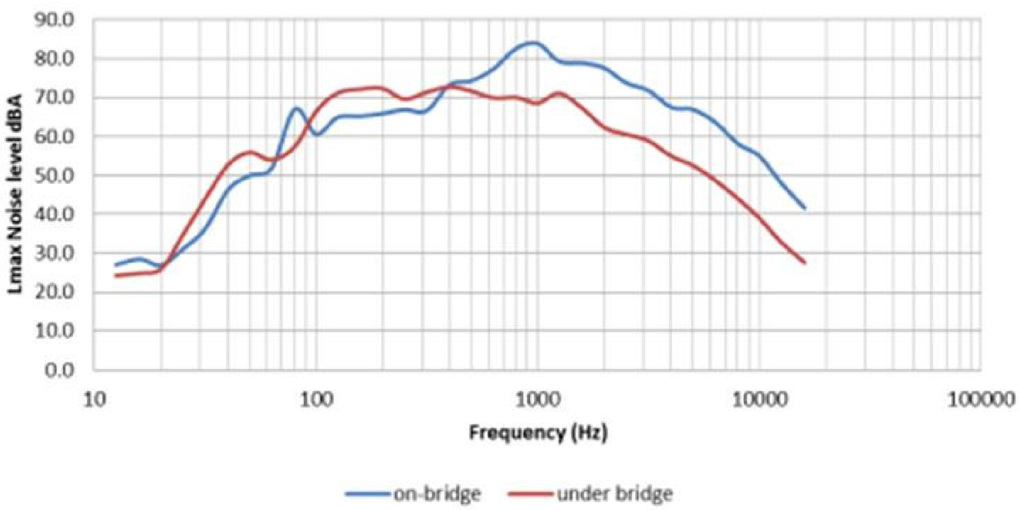
Figure 3-19 L_{Fmax} measurements recorded beneath the bridge



3 Methodology

The resulting average L_{ZFmax} 1/3 octave frequency distributions from light cars are shown in the graph below for the two positions: on the bridge and under the bridge.

Figure 3-20 L_{Fmax} average data from the two measurement locations



The above data suggests that for the Shelly Gully overbridge, low frequency noise below 500 Hz is more dominant in the measurements beneath the bridge than those above the bridge. This may be a result of the reflective nature of the surroundings (presence of walls and stair well) or it may be due to resonance in the deck / joint cavity area as confirmed by the work of others (refer Section 2).

These measurements indicate that the close proximity measurements above bridges may be useful to determine the relative performance of different joint types, but that the noise experienced below bridges may also vary depending on other factors such as the cavity below the joint.

Results

The differences in values measured for joint types reported here can be used to assess the overall trends in relative performance. This can be used to inform selection of joint types. However, the absolute levels of noise and vibration reported are a function of the specific measurement system and should not be used to determine the merits of each joint type. For example, noise levels have been measured at a wheel, but a few metres away the actual levels decrease substantially, as can be seen in Figure 3-8. Hence, noise at houses near joints usually meets criteria recommended by NZS 6802.

The graphs below show the range of maximum A-weighted noise levels, L_{AFmax}, (Figure 4-1) and vertical vibration acceleration (Figure 4-2) for all measured bridge joints. These graphs show the range of data (maximum and minimum) together with the mean value marked within the data range.

Figure 4-1 L_{AFmax} across all bridge joints (measured at the vehicle wheel)

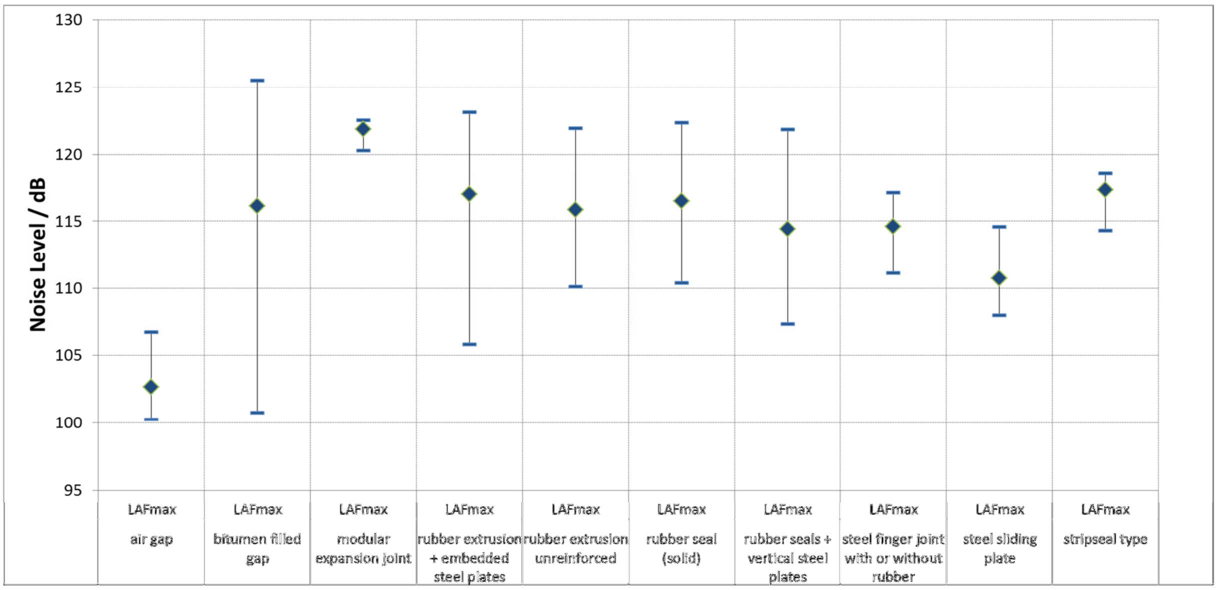
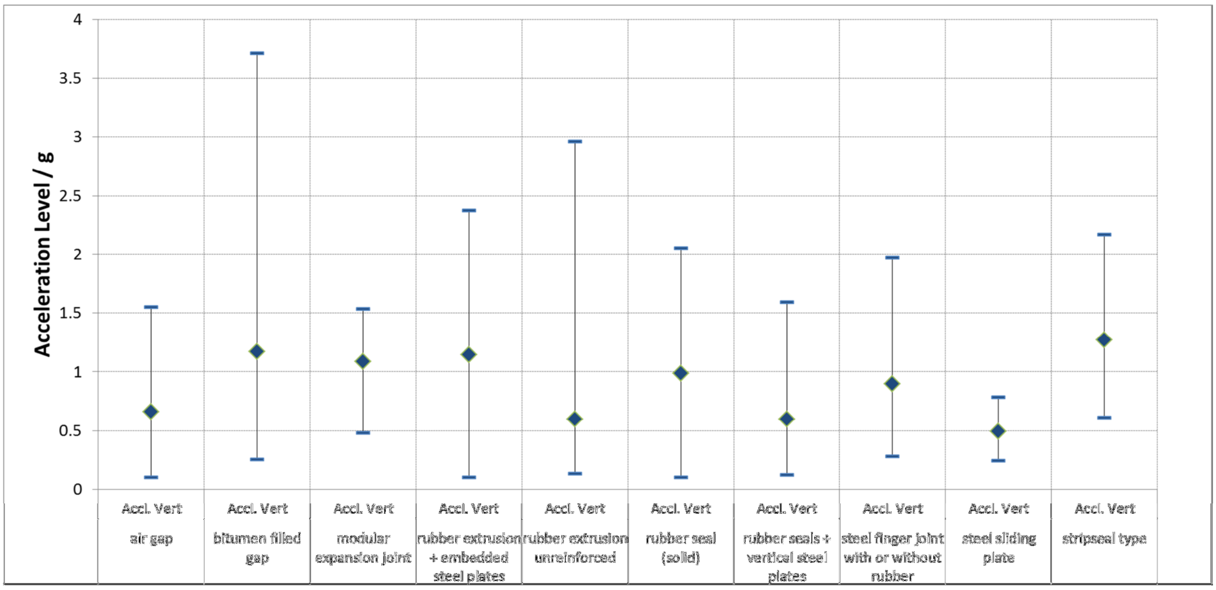


Figure 4-2 Vertical acceleration across all bridge joints (measured on the vehicle suspension)



4 Results

The graphs in Figure 4-1 and Figure 4-2 are indicative of the general pattern of variance for the other noise and vibration parameters given in the results sheets. The graphs show significant variation in noise and vibration levels for some joint types. The types with the greatest variation are generally those with more joints/measurements in the dataset, as set out in Section 3.1. In addition to effects of the measurement system, the variation may be due to different makes or variants of joint type having the same classification in the BDS; or the age of joints; or installation and surface construction/reseal quality. These issues are discussed further with respect to specific examples below. Another key issue with the test methodology is that the joint classification given in the BDS was applied to all joints on a bridge. In some cases this assumption is incorrect, but insufficient information was collected to allow all joints to be correctly classified for the analysis.

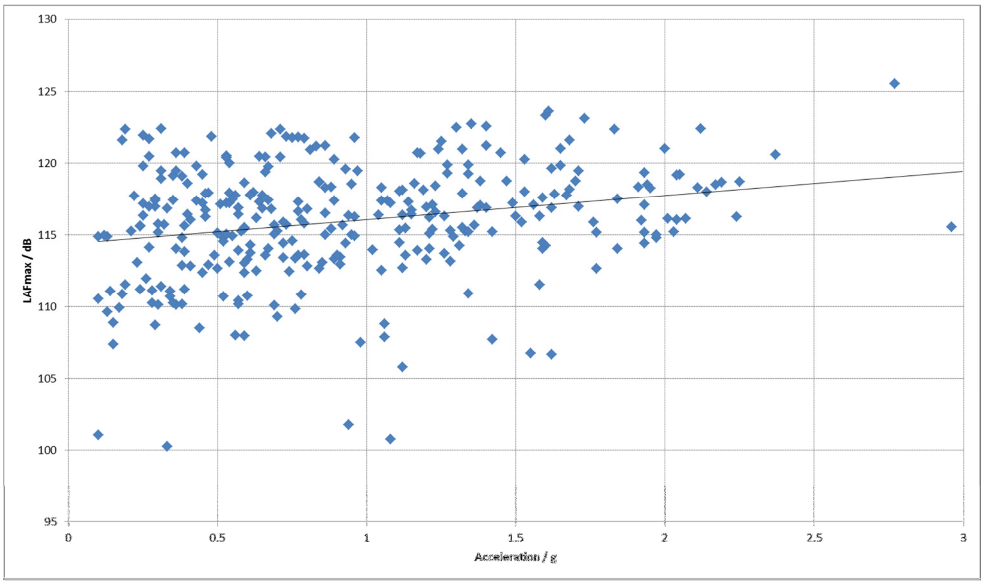
The following observations are made from considering the results in the graphs for all joint types:

- the variations of noise and vibration for specific joint types are often greater than the variations between joint types,
- there are examples of most joint types having noise and vibration at the lower end of the range, and
- there is no clear ranking of all joint types on the basis of this data.

These observations indicate that installation quality, including any subsequent road surface reseals around the joint, may be an important factor in achieving low noise and vibration levels. With appropriate installation quality, potentially most joint types could be used in a noise sensitive area.

In broad terms both the noise and vibration data produce similar comparisons of the different joint types. Figure 4-3 shows the relationship between the noise and vibration levels for all joints, including a best fit line. There is a weak correlation of increasing noise with increasing vibration. Both noise and vibration are generated from the force as the tyre passes over the joint. However, the weak correlation is likely to be due to other factors, such as the specific radiation patterns from the tyre of the test vehicle affecting the measured noise levels. Both noise and vibration are used for further consideration of different joint types.

Figure 4-3 Relationship between noise level and vibration



4 Results

Air gaps

In the graphs the air gap joint type appears to have low noise and vibration characteristics based on measurements of 3 joints at two bridge (BSN 4564 2 joints and BSN 10503 one joint). The levels are lower than the test with a surface without a joint reported in Section 3.7. However, the photograph in Figure 4-4 of BSN 4564 indicates that the road surface at the measured air gap joints actually covers the joints such that there is no physical joint in the road surface.

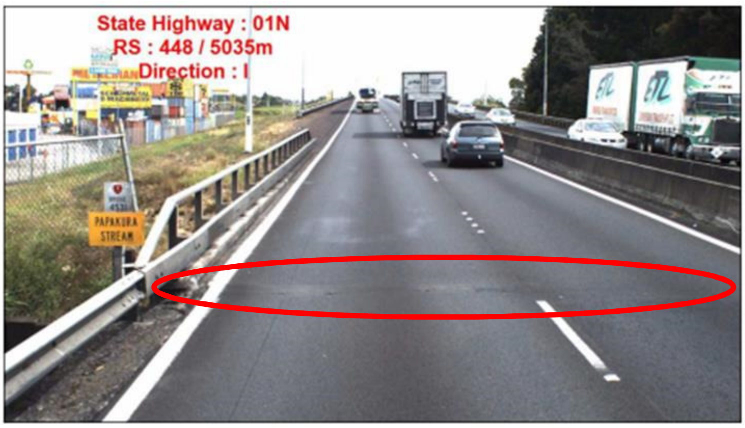
Figure 4-4 Air gap joint covered by road surface

The measurements of these air gap joints are useful in demonstrating that the system is correctly differentiating low noise and vibration 'joints'. However, it is not clear why the noise levels for these joints are lower than for the open graded porous asphalt surface reported in Section 3.7.

Sliding steel plates

Figure 4-1 shows that sliding steel plate joints perform relatively well. The limited spread of results for this joint type is partly due to the small sample size (6 measurements on 4 joints). However, like the air gap joints, examination of the photographs indicates that these joints have again been covered with a continuous surface, as shown in the photograph of Papakura Steam Bridge (BSN 4531) in Figure 4-5.

Figure 4-5 Steel sliding joint covered by road surface



4 Results

Rubber seal joints with vertical steel plates

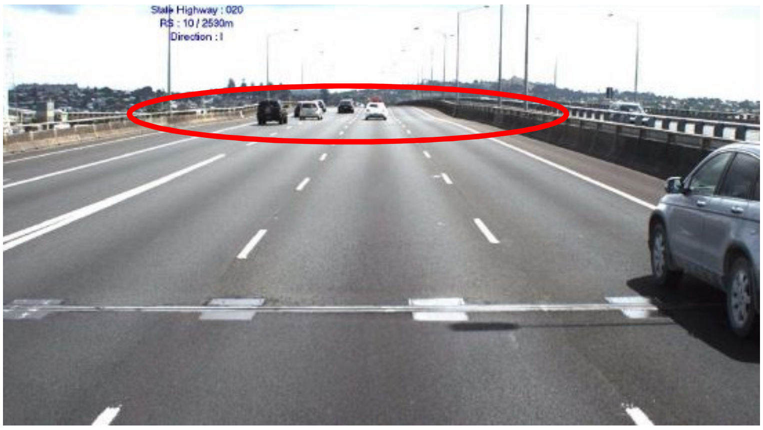
To explore the variations between joints of the same type, the data for rubber seal joints with vertical steel plates has been investigated. This joint type has a range of measured L_{AFmax} values over approximately 14 dB.

One of the better performing joints of this type is on BSN 53 at the intersection of SH20 and SH20B in Auckland, where the joint is at an angle across the bridge as shown in Figure 4-6. The average L_{AFmax} is 111 dB and vertical acceleration is 0.37 g. Potentially, the angle of the joint is reducing the impact of the wheel against the joint, although the angle appears to be slight. A more important factor may be a relatively good installation and junction with the road surface, giving a constant surface height. Visual inspection of the joint would be required to confirm the installation quality.

Figure 4-6 Angled rubber seal joints with vertical steel plates

Poor performing joints of this type are the second, third and fourth joints on the northbound (old) Mangere Bridge (BSN 129). For the second joint the average L_{AFmax} is 122 dB and acceleration is 0.77 g. Figure 4-7 shows the first joint on the bridge, which performs better than the others. The second joint can be seen in the distance as a dip in the road (circled). Subjectively when driving on this bridge this joint makes a pronounced impact, which is reflected in the measured noise levels, but less so in the vibration levels.

Figure 4-7 Rubber seal joints with vertical steel plates on Mangere Bridge



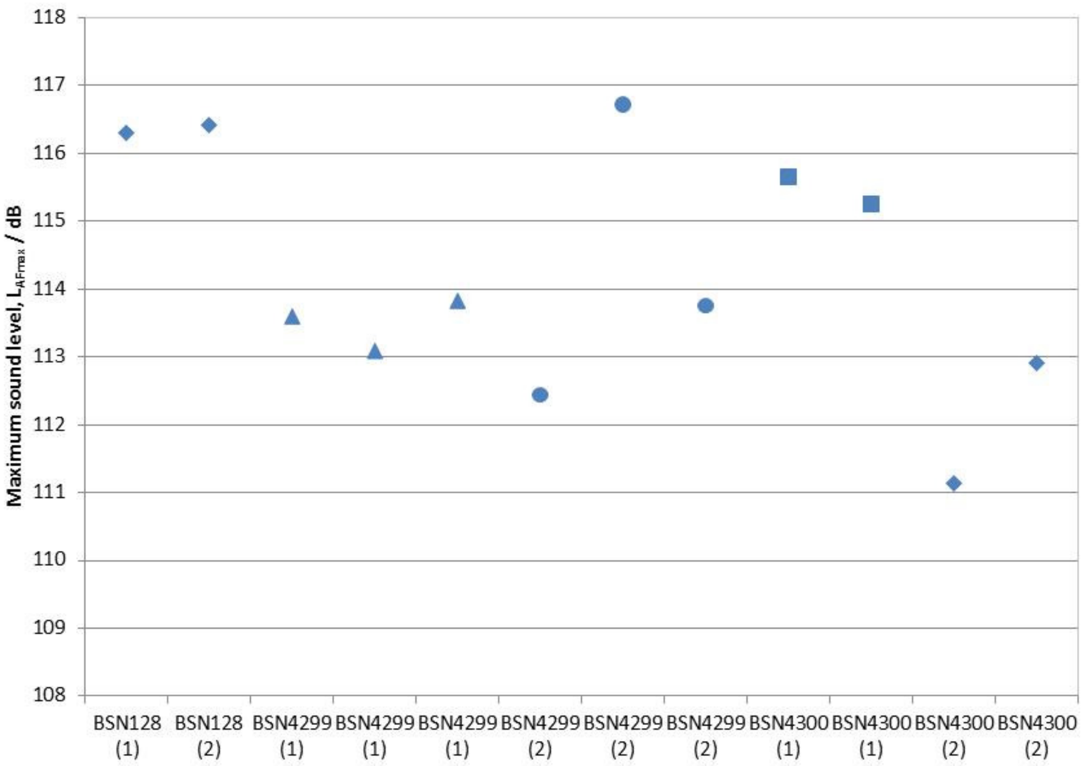
4 Results

Finger joints

There are finger joints on the southbound Mangere Bridge (BSN 128) and both of the Newmarket Viaduct structures (BSN 4299 and 4300). There is also one cantilever finger joint on the (old) westbound Tauranga Harbour Bridge, but that is a different joint type and is not included below.

The literature indicates that a finger joints should perform better than most of the other joint types, but this is not readily seen in the overall data. Noise data for finger joints is shown in Figure 4-8. There were 3 passes made over BSN 4299, two passes over BSN 4300 and one pass over BSN 128. Each structure has 2 joints, indicated in brackets on the x-axis of the graph.

Figure 4-8 Maximum noise levels from finger joints



The first joint on southbound Newmarket Viaduct (BSN 4299) has good repeatability between the 3 passes, within 1 dB, but during the same runs the levels measured for the second joint vary by over 4 dB. It appears that the second pass-by gave an anomalous result for this joint.

The first joint on BSN 4299 is shown in Figure 4-9 and part of the second joint on BSN 128 is shown in Figure 4-10. There are no features evident from these photographs that would give rise to different noise levels, but subjectively when driving over the bridges the finger joints on the Mangere Bridge do cause more impact. This is consistent with the slightly higher measured noise levels.

4 Results

Figure 4-9 Newmarket Viaduct finger joint

Figure 4-10 Mangere Bridge finger joint

The variation between L_{AFmax} data for all the passes of the 7 steel finger joints is less than 6 dB, and the variation in acceleration is within 1.69 g. In the case of Newmarket Viaduct, four of the joints were recently constructed at the same time so could be expected to be consistent. The levels are also similar to the finger joints on Mangere Bridge.

Some installations of other joint types produce lower noise and vibration levels than the steel finger joints. However, narrow steel finger joints appear to be able to provide consistent performance at the lower end of the overall range measured.

4 Results

Modular joints

The only modular joints investigated are two on the eastbound Tauranga Harbour Bridge (BSN 1558). A modular joint comprises parallel plates running across the road as seen in the photograph looking along the joint in Figure 4-11. The joint is relatively wide, which appears to be reflected in the width of the peak in the noise time history in Figure 4-12.

Figure 4-11 Tauranga Harbour Bridge modular joint

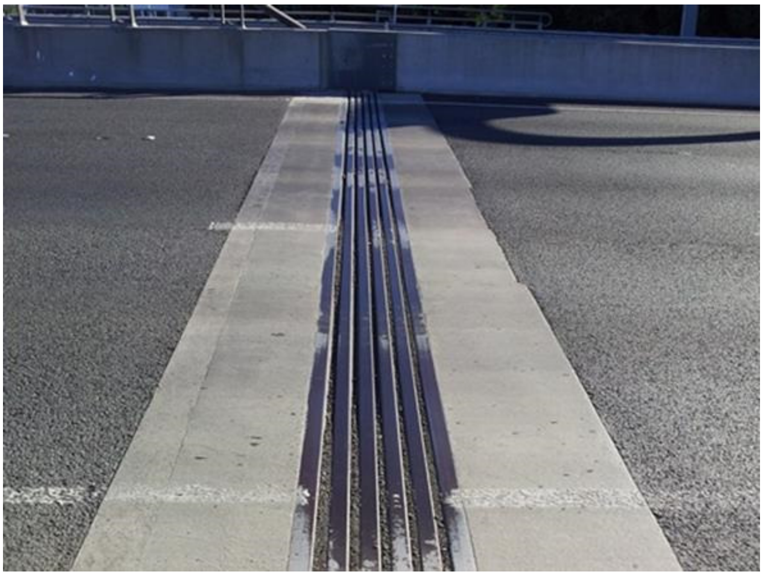
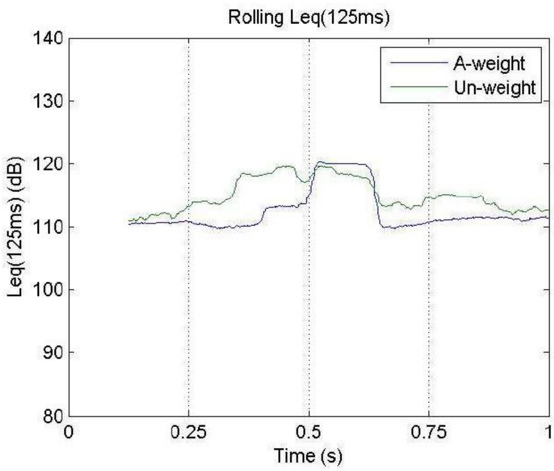


Figure 4-12 Modular joint noise time history



The five measured noise levels for the modular joints were in a narrow range from 120 to 122 dB L_{AFmax} and the vertical acceleration levels were between 0.5 g and 1.5 g. This is consistent with the Austroads report[7], which highlights modular joints as having poor noise performance. However, the literature review in Section 2 found that modular joints can have good noise performance if they include appropriately designed surface plates. There are no surface plates on the modular joints in Tauranga.

Conclusions

5.1 Measurement system

A vehicle based measurement system has been developed to allow comparisons of noise and vibration generated by different bridge expansion joints. The system uses a microphone measuring noise close to one tyre of the vehicle and an accelerometer measuring vibration on a suspension arm. The test vehicle was driven at approximately 80 km/h over a wide range of joints around Auckland, Wellington and Tauranga. All data from these measurements has been collated.

The noise experienced by people in the vicinity of bridges will be different from the noise measured by the test vehicle. Also, the design of the cavity below a joint will further influence the noise experienced. However, the vehicle based measurements provide a tool to compare the relative performance of different joint types. The system was selected to allow comparison of a large number of joints in a short timeframe.

The detailed data obtained during this work could be used for further analysis of bridge joint noise and vibration.

5.2 Joint types

The measurements have shown there to be significant variations in noise and vibration from the same joint types. These variations are greater than the variations between different joint types. Installation and maintenance quality is likely to be a key factor in noise and vibration generation.

The data has not enabled a clear ranking of joint types in terms of noise and vibration.

As could be expected, the joints with the lowest noise and vibration levels are those that have a continuous asphalt surface over the joint.

Six finger joints provided a consistent performance towards the lower end of the range measured. Two modular joints measured generated relatively high noise levels.

5.3 Noise sensitive areas

For future bridges in noise sensitive areas, the following points should be considered:

- Where possible structures should be designed so that the road surface can be continuous,
- Where expansion joints are required steel finger joints appear to have consistent and inherently good (low) noise and vibration performance,
- If modular joints are required they should include noise reducing surface plates,
- Particular attention should be paid to achieving good installation and maintenance quality, which should be a requirement in the contract documents,
- The cavity under the joint should be assessed and if required a barrier should be installed under the joint to close the cavity and acoustic absorption should be installed within the cavity.

6

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A

Appendix A Measurement result sheets

Auckland

IDENTIFER	BRIDGE LOCATION
BSN26	PUHINUI STREAM No.1 BRIDGE
BSN26	PUHINUI STREAM No.1 BRIDGE
BSN26	PUHINUI STREAM No.1 BRIDGE
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BSN26	PUHINUI STREAM No.1 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
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BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN27	PUHINUI STREAM No.2 BRIDGE
BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)
BSN53	NORTHBOUND
BSN53	NORTHBOUND
BSN53	NORTHBOUND
BSN53	NORTHBOUND
BSN53	NORTHBOUND
BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
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BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
BSN62	UPPER HARBOUR BRIDGE No.1
BSN82	GREAT NORTH RD BRIDGE No.1
BSN82	GREAT NORTH RD BRIDGE No.1
BSN82	GREAT NORTH RD BRIDGE No.1
BSN82	GREAT NORTH RD BRIDGE No.1
BSN83	GREAT NORTH RD BRIDGE No. 2
BSN83	GREAT NORTH RD BRIDGE No. 2
BSN84	ROSEBANK BRIDGE NO1
BSN84	ROSEBANK BRIDGE NO1
BSN85	ROSEBANK BRIDGE NO2
BSN85	ROSEBANK BRIDGE NO2
BSN85	ROSEBANK BRIDGE NO2
BSN85	ROSEBANK BRIDGE NO2
BSN85	ROSEBANK BRIDGE NO2
BSN85	ROSEBANK BRIDGE NO2
BSN104	WHAU RIVER BRIDGE No.2
BSN104	WHAU RIVER BRIDGE No.2
BSN104	WHAU RIVER BRIDGE No.2
BSN104	WHAU RIVER BRIDGE No.2
BSN105	WHAU RIVER BRIDGE No.1
BSN105	WHAU RIVER BRIDGE No.1
BSN105	WHAU RIVER BRIDGE No.1
BSN107	INTERCHANGE BRIDGE
BSN107	INTERCHANGE BRIDGE
BSN128	MANGERE BRIDGE (SOUTHBOUND)
BSN128	MANGERE BRIDGE (SOUTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN129	MANGERE BRIDGE (NORTHBOUND)
BSN136	LINCOLN BRIDGE NO1
BSN136	LINCOLN BRIDGE NO1
BSN136	LINCOLN BRIDGE NO1
BSN136	LINCOLN BRIDGE NO1
BSN137	LINCOLN BRIDGE NO2
BSN137	LINCOLN BRIDGE NO2
BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)
BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)
BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)
BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)
BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)
BSN4169	TRISTRAM AVE OVERPASS (NORTHBOUND)
BSN4169	TRISTRAM AVE OVERPASS (NORTHBOUND)
BSN4178	WAIRAU ROAD OVERPASS No.1
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE

Appendix A - Measurement result sheets

BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4271	NEWTON No.1 BRIDGE
BSN4281	Grafton Interchange 3A
BSN4281	Grafton Interchange 3A
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4282	GRAFTON INTERCHANGE BRIDGE 1
BSN4283	GRAFTON INTERCHANGE 2
BSN4287	Khyber Pass Viaduct 1 (southbound)
BSN4287	KHYBER PASS VIADUCT 1 (SOUTHBOUND)
BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)
BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)
BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)
BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)
BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)
BSN4299	Newmarket Viaduct 1
BSN4299	Newmarket Viaduct 1
BSN4299	Newmarket Viaduct 1
BSN4299	Newmarket Viaduct 1
BSN4299	Newmarket Viaduct 1
BSN4299	Newmarket Viaduct 1
BSN4300	Newmarket Viaduct 2
BSN4300	Newmarket Viaduct 2
BSN4300	Newmarket Viaduct 2
BSN4300	Newmarket Viaduct 2
BSN4531	Papakura Stream
BSN4533	NIMT RAIL OVERBRIDGE No.1
BSN4535	GREAT SOUTH ROAD BRIDGE No.1
BSN4564	Pahurehure Inlet control stream
BSN4564	Pahurehure Inlet control stream

Wellington

IDENTIFER	BRIDGE LOCATION
BSN10223	LINDALE OVERBRIDGE
BSN10223	LINDALE OVERBRIDGE
BSN10223	LINDALE OVERBRIDGE
BSN10223	LINDALE OVERBRIDGE
BSN10503	PAREMATA HARBOUR BRIDGE (SOUTHBOUND)
BSN10504	PAREMATA HARBOUR BRIDGE (NORTHBOUND)
BSN10504	PAREMATA HARBOUR BRIDGE (NORTHBOUND)
BSN10679	NGAURANGA OVERBRIDGE - SOUTHBOUND
BSN10679	NGAURANGA OVERBRIDGE - SOUTHBOUND
BSN10680	NGAURANGA OVERBRIDGE - NORTHBOUND
BSN10680	NGAURANGA OVERBRIDGE - NORTHBOUND
BSN10703	THORNDON OVERBRIDGE - SOUTHBOUND
BSN10703	THORNDON OVERBRIDGE - SOUTHBOUND
BSN10727	BOWEN STREET OVERPASS (SOUTHBOUND)
BSN10728	BOWEN STREET OVERPASS (NORTHBOUND)
BSN10728	BOWEN STREET OVERPASS (NORTHBOUND)
BSN10731	SHELL GULLY OVERBRIDGE (NORTHBOUND)
BSN10732	SHELL GULLY OVERBRIDGE (SOUTHBOUND)

Appendix A - Measurement result sheets

Tauranga

IDENTIFER	BRIDGE LOCATION
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	AERODROME BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN NA	HARBOUR BRIDGE (WESTBOUND)
BSN162	WAIMAPU STREAM BRIDGE
BSN162	WAIMAPU STREAM BRIDGE
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN269	RUAHIHI BRIDGE (WAIROA RIVER)
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN323	NGAMUWAHINE RIVER BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN330	TE AHARA STREAM (BEACON) BRIDGE
BSN343	KAUKUMOUTITI STREAM (BOULDER BRIDGE)
BSN343	KAUKUMOUTITI STREAM (BOULDER BRIDGE)
BSN388	TUAKOPAI STREAM BRIDGE
BSN388	TUAKOPAI STREAM BRIDGE
BSN388	TUAKOPAI STREAM BRIDGE
BSN388	TUAKOPAI STREAM BRIDGE
BSN1160	TAHAWAI RIVER BRIDGE
BSN1160	TAHAWAI RIVER BRIDGE
BSN1160	TAHAWAI RIVER BRIDGE
BSN1160	TAHAWAI RIVER BRIDGE
BSN1182	URETARA STREAM (WHARAWHARA)
BSN1182	URETARA STREAM (WHARAWHARA)
BSN1182	URETARA STREAM (WHARAWHARA)
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1214	TE REREREATUKAHIA RIVER BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1240	WAITEKOHE STREAM BRIDGE
BSN1265	AONGATETE STREAM BRIDGE
BSN1265	AONGATETE STREAM BRIDGE
BSN1265	AONGATETE STREAM BRIDGE
BSN1265	AONGATETE STREAM BRIDGE
BSN1265	AONGATETE STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1274	WHATAKAO STREAM BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1300	WAINUI RIVER BRIDGE
BSN1340	APATA RAIL OVERBRIDGE
BSN1340	APATA RAIL OVERBRIDGE
BSN1340	APATA RAIL OVERBRIDGE
BSN1340	APATA RAIL OVERBRIDGE
BSN1340	APATA RAIL OVERBRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE

Appendix A - Measurement result sheets

BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1460	WAIROA RIVER BRIDGE
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
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BSN1550	CHAPEL STREET VIADUCT
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BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1550	CHAPEL STREET VIADUCT
BSN1558	HARBOUR BRIDGE (EASTBOUND)
BSN1558	HARBOUR BRIDGE (EASTBOUND)
BSN1558	HARBOUR BRIDGE (EASTBOUND)
BSN1558	HARBOUR BRIDGE (EASTBOUND)
BSN1558	HARBOUR BRIDGE (EASTBOUND)
BSN1571	AERODROME BRIDGE (EASTBOUND)
BSN1571	AERODROME BRIDGE (EASTBOUND)
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE
BSN1601	MAUNGATAPU BRIDGE

Appendix B Tabulated results

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN26-Decr-Marker5-130515101536	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	5	-36.997867	174.860177	63.89	0.91	0.07	9.27	0.74	51.06	109.6	108.9	112.8	113.5
BSN26-Decr-Marker6-130515101536	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	6	-36.99773	174.861637	68.34	0.72	0.06	7.3	0.59	53.3	113.3	110.3	117.1	114.4
BSN26-Incr-Marker1-130515100636	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	1	-36.997875	174.862227	79.27	0.64	0.04	6.46	0.41	65.43	114.4	112.1	118.3	117.3
BSN26-Incr-Marker1-130515101958	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	1	-36.997868	174.862268	79.08	0.68	0.06	6.9	0.65	71.47	114.6	112.3	120.0	116.8
BSN26-Incr-Marker1-130515103305	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	1	-36.9978	174.863157	80.75	0.61	0.06	6.14	0.64	95.63	118.1	113.8	122.0	117.8
BSN26-Incr-Marker2-130515100636	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	2	-36.998012	174.860755	79.08	1.56	0.13	15.8	1.3	80.04	118.1	113.2	120.8	117.1
BSN26-Incr-Marker2-130515101958	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	2	-36.99801	174.860823	76.12	0.93	0.09	9.45	0.92	44.51	110.9	110.8	114.9	114.4
BSN26-Incr-Marker2-130515103305	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	2	-36.9978	174.863157	80.75	1.12	0.06	11.36	0.65	76.48	115.9	112.3	119.5	116.4
BSN26-Incr-Marker3-130515103305	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	3	-36.998008	174.8609	80.75	1.15	0.1	11.66	0.97	64.56	113.9	111.4	118.1	116.7
BSN26-Incr-Marker4-130515103305	BSN26	PUHINUI STREAM No.1 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	4	-36.99808	174.860148	80.75	1.52	0.14	15.41	1.41	60.25	113.6	110.6	117.5	115.9
BSN27-Decr-Marker3-130515101536	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	3	-36.998142	174.856213	43.34	0.77	0.28	7.85	2.82	86.89	115.9	108.1	121.8	113.6
BSN27-Decr-Marker4-130515101536	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	4	-36.998142	174.856935	61.67	0.57	0.07	5.76	0.72	51.06	109.8	107.5	113.1	110.4
BSN27-Decr-Marker5-130515102837	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	5	-36.998165	174.856952	81.67	0.8	0.13	8.14	1.35	89.04	116.5	112.4	121.7	116.8
BSN27-Decr-Marker6-130515102837	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Decreasing	rubber seal (solid)	Asphalt	6	-36.998072	174.85845	79.64	0.86	0.07	8.71	0.74	66.19	117.0	112.7	120.2	116.5
BSN27-Incr-Marker3-130515100636	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	3	-36.998295	174.857565	78.71	1.28	0.07	12.98	0.75	77.88	115.6	110.6	121.0	115.3
BSN27-Incr-Marker3-130515101958	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	3	-36.9983	174.8576	73.34	1.21	0.09	12.22	0.92	40.53	110.5	108.6	115.4	114.0
BSN27-Incr-Marker4-130515100636	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	4	-36.998335	174.856825	79.27	1.97	0.17	19.97	1.67	43.31	113.0	110.2	117.0	114.8
BSN27-Incr-Marker4-130515101958	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	4	-36.998342	174.856628	77.97	1.84	0.18	18.68	1.85	38.8	108.0	109.3	113.7	114.0
BSN27-Incr-Marker5-130515103305	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	5	-36.998322	174.855873	80.56	1.4	0.13	14.17	1.37	82.23	117.4	111.4	122.3	116.9
BSN27-Incr-Marker6-130515103305	BSN27	PUHINUI STREAM No.2 BRIDGE	20 0 2.6	Increasing	rubber seal (solid)	Asphalt	6	-36.998293	174.85512	80.56	0.86	0.1	8.75	1.05	64.07	114.1	109.8	117.4	115.0
BSN30-Decr-Marker1-130515101536	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	1	-36.997608	174.851725	79.64	0.67	0.04	6.78	0.43	121.07	120.6	113.3	125.3	117.4
BSN30-Decr-Marker1-130515102837	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	1	-36.997597	174.851523	80.75	0.53	0.05	5.33	0.52	145.75	122.0	115.9	126.4	120.5
BSN30-Decr-Marker2-130515101536	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	2	-36.997717	174.852208	80.19	1.23	0.13	12.43	1.35	95.03	118.9	113.0	122.8	116.6

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN30-Decr-Marker2-130515102837	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	2	-36.99776	174.85225	80.75	1.11	0.13	11.3	1.29	121	117.1	111.7	121.4	114.5
BSN30-Decr-Marker3-130515102837	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	3	-36.997992	174.85371	79.64	0.95	0.06	9.58	0.58	109.11	119.9	111.9	124.0	115.0
BSN30-Decr-Marker4-130515102837	BSN30	CAVENDISH DRIVE BRIDGE (EASTBOUND)	20 0 3.05	Decreasing	rubber seal (solid)	Asphalt	4	-36.997992	174.85371	79.64	0.89	0.08	9.06	0.78	73.34	117.5	112.8	120.6	117.4
BSN30-Incr-Marker1-130515102119	BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)	20 0 3.05	Increasing	rubber seal (solid)	Asphalt	1	-36.998048	174.852762	77.41	0.92	0.14	9.38	1.39	63.64	110.3	109.9	115.0	115.7
BSN30-Incr-Marker2-130515102119	BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)	20 0 3.05	Increasing	rubber seal (solid)	Asphalt	2	-36.99791	174.852048	78.53	1.76	0.16	17.84	1.65	63.9	110.1	109.7	115.3	115.9
BSN30-Incr-Marker5-130515100636	BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)	20 0 3.05	Increasing	rubber seal (solid)	Asphalt	5	-36.998035	174.852678	79.82	1.13	0.1	11.46	1.03	88.24	112.6	110.8	116.8	115.5
BSN30-Incr-Marker6-130515100636	BSN30	CAVENDISH DRIVE BRIDGE (WESTBOUND)	20 0 3.05	Increasing	rubber seal (solid)	Asphalt	6	-36.997892	174.85196	79.08	1.93	0.14	19.62	1.46	66.74	113.7	110.3	118.4	115.2
BSN53-Incr-Marker1-130515102202	BSN53	NORTHBOUND	20 0 5.35	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.993723	174.843703	78.71	0.59	0.1	5.94	0.97	77.63	117.9	110.4	120.6	113.1
BSN53-Incr-Marker1-130515103432	BSN53	NORTHBOUND	20 0 5.35	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.994188	174.844272	81.12	0.15	0.03	1.52	0.27	42.07	111.6	107.6	114.9	108.9
BSN53-Incr-Marker2-130515102202	BSN53	NORTHBOUND	20 0 5.35	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.993312	174.843173	78.89	0.44	0.05	4.5	0.53	37.22	110.1	106.5	114.2	108.5
BSN53-Incr-Marker2-130515103432	BSN53	NORTHBOUND	20 0 5.35	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.993767	174.843727	80.56	0.69	0.1	7.03	1.06	56.59	114.2	107.7	118.0	110.1
BSN53-Incr-Marker3-130515103432	BSN53	NORTHBOUND	20 0 5.35	Increasing	Rubber seals + vertical steel plates	Asphalt	3	-36.993347	174.843185	80.56	0.39	0.06	4	0.64	53.33	113.6	107.4	118.7	111.2
BSN62-Decr-Marker1-130515114213	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.785448	174.665518	79.45	0.53	0.06	5.33	0.61	112.24	122.8	116.1	126.0	120.4
BSN62-Decr-Marker1-130515115256	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.785498	174.665342	78.89	0.67	0.05	6.78	0.47	78.98	116.3	112.7	119.5	119.8
BSN62-Decr-Marker1-130515120316	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.78546	174.66549	80.01	0.68	0.07	6.85	0.72	177.31	124.5	116.6	128.8	122.0
BSN62-Decr-Marker2-130515114213	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.784302	174.67027	80.93	1.05	0.1	10.63	1	139.25	123.2	114.3	126.5	118.3
BSN62-Decr-Marker2-130515115256	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.78427	174.670295	79.45	0.88	0.07	8.95	0.74	58.28	114.9	110.9	119.2	118.3
BSN62-Decr-Marker2-130515120316	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.784273	174.670272	80.56	0.77	0.07	7.79	0.74	133.9	118.2	111.4	123.8	117.3
BSN62-Incr-Marker1-130515114927	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.78426	174.670943	87.23	0.61	0.09	6.18	0.88	124.01	117.7	112.3	123.8	117.7
BSN62-Incr-Marker1-130515115853	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.78339	174.673985	82.97	0.55	0.05	5.63	0.54	79.42	116.9	111.5	121.5	114.9
BSN62-Incr-Marker2-130515114927	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.784498	174.67	79.08	1.31	0.12	13.32	1.24	84.32	119.4	111.6	122.6	114.2
BSN62-Incr-Marker2-130515115853	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.783727	174.673013	85.19	1.21	0.07	12.29	0.75	114.46	119.5	112.0	122.9	115.1
BSN62-Incr-Marker3-130515114927	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	3	-36.784908	174.668328	80.56	1.22	0.15	12.32	1.56	81.05	118.8	110.2	121.4	115.4

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN62-Incr-Marker3-130515115853	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	3	-36.784108	174.671535	80.93	0.88	0.13	8.97	1.36	75.36	116.7	109.7	120.7	115.4
BSN62-Incr-Marker4-130515114927	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.785088	174.667598	81.67	0.5	0.06	5.08	0.65	80.65	118.2	108.7	121.6	115.1
BSN62-Incr-Marker4-130515115853	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.78452	174.669883	79.27	0.63	0.05	6.36	0.51	84.46	117.4	109.8	121.6	116.2
BSN62-Incr-Marker5-130515114927	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	5	-36.785088	174.667598	81.67	1.58	0.17	16.02	1.73	107.49	116.5	110.1	122.0	116.3
BSN62-Incr-Marker5-130515115853	BSN62	UPPER HARBOUR BRIDGE No.1	18 7 0	Increasing	Rubber extrusion + embedded steel plates	Asphalt	5	-36.784693	174.669185	78.34	1.91	0.22	19.36	2.26	89.55	117.0	111.6	120.6	118.3
BSN82-Incr-Marker1-130515111054	BSN82	GREAT NORTH RD BRIDGE No.1	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.87165	174.708712	79.08	0.67	0.08	6.81	0.85	83.08	117.3	110.5	122.8	114.1
BSN82-Incr-Marker1-130515112859	BSN82	GREAT NORTH RD BRIDGE No.1	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.872185	174.705627	80.38	1.28	0.16	12.98	1.65	59.92	115.5	109.3	118.8	113.2
BSN82-Incr-Marker2-130515111054	BSN82	GREAT NORTH RD BRIDGE No.1	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.871677	174.708218	79.08	0.35	0.04	3.56	0.45	168.39	120.8	112.4	127.6	119.1
BSN82-Incr-Marker2-130515112859	BSN82	GREAT NORTH RD BRIDGE No.1	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.872345	174.704905	80.19	0.22	0.04	2.21	0.39	142.45	120.4	112.5	124.6	117.7
BSN83-Decr-Marker1-130515112408	BSN83	GREAT NORTH RD BRIDGE No. 2	16 0 8.22	Decreasing	Rubber extrusion unreinforced	Asphalt	1	-36.872273	174.704613	78.53	0.56	0.06	5.72	0.56	96.33	118.2	114.9	123.8	117.7
BSN83-Decr-Marker2-130515112408	BSN83	GREAT NORTH RD BRIDGE No. 2	16 0 8.22	Decreasing	Rubber extrusion unreinforced	Asphalt	2	-36.872188	174.70509	78.53	0.62	0.05	6.32	0.5	154.2	123.1	116.2	126.4	118.0
BSN84-Decr-Marker1-130515112234	BSN84	ROSEBANK BRIDGE NO1	16 7 0	Decreasing	Rubber extrusion unreinforced	Asphalt	1	-36.871935	174.684867	79.08	0.25	0.03	2.53	0.34	165.17	126.5	118.5	128.7	121.9
BSN84-Decr-Marker2-130515112234	BSN84	ROSEBANK BRIDGE NO1	16 7 0	Decreasing	Rubber extrusion unreinforced	Asphalt	2	-36.871932	174.686083	78.34	0.38	0.05	3.9	0.48	156.68	122.8	114.4	128.0	119.1
BSN85-Incr-Marker1-130515111254	BSN85	ROSEBANK BRIDGE NO2	16 7 0	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.871943	174.693128	78.53	0.13	0.06	1.31	0.6	124.83	120.6	111.9	124.4	114.9
BSN85-Incr-Marker1-130515111334	BSN85	ROSEBANK BRIDGE NO2	16 7 0	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.861443	174.662275	79.27	0.38	0.05	3.89	0.52	35.43	113.8	108.3	117.0	110.2
BSN85-Incr-Marker1-130515113120	BSN85	ROSEBANK BRIDGE NO2	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.861402	174.662225	80.19	0.36	0.05	3.61	0.48	33	111.9	108.2	115.8	110.1
BSN85-Incr-Marker2-130515111254	BSN85	ROSEBANK BRIDGE NO2	16 7 0	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.871957	174.69239	79.08	0.4	0.03	4.03	0.3	118.28	120.9	113.8	123.9	116.4
BSN85-Incr-Marker2-130515113120	BSN85	ROSEBANK BRIDGE NO2	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.86112	174.661567	79.82	0.72	0.05	7.26	0.47	83.56	114.1	110.7	118.3	115.9
BSN85-Incr-Marker3-130515113120	BSN85	ROSEBANK BRIDGE NO2	16 0 8.22	Increasing	Rubber extrusion unreinforced	Asphalt	3	-36.860868	174.66089	79.64	0.41	0.06	4.14	0.64	91.2	116.1	110.5	120.4	112.8
BSN104-Incr-Marker1-130515113426	BSN104	WHAU RIVER BRIDGE No.2	16 7 3.5	Increasing	Rubber extrusion unreinforced	Asphalt	1	-36.85318	174.641503	80.01	2.96	0.22	30.06	2.19	104.61	119.2	112.1	125.0	115.5
BSN104-Incr-Marker2-130515111334	BSN104	WHAU RIVER BRIDGE No.2	16 7 3.5	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.861075	174.661415	78.71	0.59	0.07	5.94	0.76	72.97	116.2	111.2	118.4	115.4
BSN104-Incr-Marker2-130515113426	BSN104	WHAU RIVER BRIDGE No.2	16 7 3.5	Increasing	Rubber extrusion unreinforced	Asphalt	2	-36.852648	174.640447	79.82	0.45	0.06	4.61	0.62	66.21	115.1	109.7	118.5	112.4
BSN104-Incr-Marker3-130515111334	BSN104	WHAU RIVER BRIDGE No.2	16 7 3.5	Increasing	Rubber extrusion unreinforced	Asphalt	3	-36.860913	174.660968	78.53	0.45	0.08	4.59	0.81	123.73	117.6	111.5	124.9	117.2

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN105-Decr-Marker1-130515112056	BSN105	WHAU RIVER BRIDGE No.1	16 7 3.5	Decreasing	Rubber extrusion unreinforced	Asphalt	1	-36.859177	174.656713	82.6	1.05	0.09	10.6	0.87	87.56	116.4	110.0	120.0	112.5
BSN105-Decr-Marker2-130515112056	BSN105	WHAU RIVER BRIDGE No.1	16 7 3.5	Decreasing	Rubber extrusion unreinforced	Asphalt	2	-36.85952	174.65763	80.75	0.8	0.06	8.06	0.63	79.15	116.7	108.9	122.1	112.9
BSN105-Decr-Marker3-130515112056	BSN105	WHAU RIVER BRIDGE No.1	16 7 3.5	Decreasing	Rubber extrusion unreinforced	Asphalt	3	-36.859772	174.658295	78.71	0.72	0.07	7.31	0.67	79.47	118.3	110.3	121.7	113.4
BSN107-Incr-Marker1-130515103742	BSN107	INTERCHANGE BRIDGE	20 0 10.5	Increasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.96333	174.800203	78.15	0.49	0.07	4.95	0.69	73.28	114.9	109.7	119.2	113.6
BSN107-Incr-Marker2-130515103742	BSN107	INTERCHANGE BRIDGE	20 0 10.5	Increasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.962292	174.799503	79.27	0.79	0.07	8.04	0.76	65.29	114.6	109.8	118.1	113.6
BSN128-Decr-Marker1-130515104332	BSN128	MANGERE BRIDGE (SOUTHBOUND)	20 10 2.53	Decreasing	Steel finger joint with or without rubber	Asphalt	1	-36.930877	174.786472	80.56	0.94	0.08	9.49	0.83	147.44	122.7	113.4	126.4	116.3
BSN128-Decr-Marker2-130515104332	BSN128	MANGERE BRIDGE (SOUTHBOUND)	20 10 2.53	Decreasing	Steel finger joint with or without rubber	Asphalt	2	-36.934723	174.789048	80.38	0.57	0.07	5.75	0.7	82.41	116.8	111.3	121.8	116.4
BSN129-Incr-Marker1-130515104021	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.936635	174.789393	79.82	0.54	0.06	5.46	0.65	59.13	114.1	108.0	116.8	113.1
BSN129-Incr-Marker1-130515104932	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.936682	174.789397	78.89	0.63	0.07	6.41	0.76	59.78	113.9	107.7	116.3	112.5
BSN129-Incr-Marker2-130515104021	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.935863	174.789125	80.01	0.79	0.06	8.04	0.6	119.8	114.8	114.0	119.3	121.7
BSN129-Incr-Marker2-130515104932	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.93592	174.789138	78.89	0.75	0.05	7.62	0.51	111.85	112.7	113.7	118.4	121.7
BSN129-Incr-Marker3-130515104021	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	3	-36.934313	174.788605	80.75	0.77	0.1	7.82	0.99	101.72	114.2	113.5	118.6	121.8
BSN129-Incr-Marker3-130515104932	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	3	-36.934202	174.788553	79.45	0.81	0.09	8.24	0.91	81	114.2	112.7	118.1	120.9
BSN129-Incr-Marker4-130515104021	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	4	-36.932468	174.7876	80.56	0.73	0.08	7.39	0.84	88.55	115.3	113.9	119.2	121.8
BSN129-Incr-Marker4-130515104932	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	4	-36.932395	174.787545	79.45	0.83	0.09	8.4	0.96	89.07	114.6	113.2	118.2	121.2
BSN129-Incr-Marker5-130515104021	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	5	-36.931317	174.786565	80.93	0.65	0.06	6.55	0.62	76.43	116.4	110.7	120.7	116.8
BSN129-Incr-Marker5-130515104932	BSN129	MANGERE BRIDGE (NORTHBOUND)	20 10 2.53	Increasing	Rubber seals + vertical steel plates	Asphalt	5	-36.931422	174.786675	79.82	0.5	0.04	5.08	0.45	76.36	116.4	108.7	120.5	112.7
BSN136-Incr-Marker1-130515111628	BSN136	LINCOLN BRIDGE NO1	16 7 6.57	Increasing	Steel sliding plate	Asphalt	1	-36.854498	174.644078	79.27	0.78	0.07	7.92	0.71	59	114.2	109.7	118.1	110.8
BSN136-Incr-Marker1-130515113524	BSN136	LINCOLN BRIDGE NO1	16 7 6.57	Increasing	Steel sliding plate	Asphalt	1	-36.846695	174.629518	71.3	0.29	0.05	2.96	0.53	65.79	112.6	106.3	116.8	108.7
BSN136-Incr-Marker2-130515111628	BSN136	LINCOLN BRIDGE NO1	16 7 6.57	Increasing	Steel sliding plate	Asphalt	2	-36.85405	174.643258	79.45	0.75	0.04	7.57	0.36	60.86	114.5	110.3	117.7	114.6
BSN136-Incr-Marker2-130515113524	BSN136	LINCOLN BRIDGE NO1	16 7 6.57	Increasing	Steel sliding plate	Asphalt	2	-36.846452	174.629185	72.41	0.56	0.04	5.7	0.44	43.34	113.7	105.5	119.3	108.0
BSN137-Decr-Marker1-130515111940	BSN137	LINCOLN BRIDGE NO2	16 7 6.57	Decreasing	Rubber seal (solid)	Asphalt	1	-36.851173	174.637813	78.89	0.1	0.05	1.06	0.5	67.8	115.3	108.4	119.7	110.6
BSN137-Decr-Marker2-130515111940	BSN137	LINCOLN BRIDGE NO2	16 7 6.57	Decreasing	Rubber seal (solid)	Asphalt	2	-36.851495	174.638448	80.38	0.14	0.02	1.46	0.17	64.72	115.4	108.4	118.5	111.1

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN4168-Incr-Marker1-130515121043	BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)	1N 414 2.81	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.768962	174.741412	80.19	1.26	0.11	12.72	1.11	137.96	120.6	112.5	125.0	116.3
BSN4168-Incr-Marker1-130515121712	BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)	1N 414 2.81	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.772202	174.74281	81.67	0.12	0.05	1.21	0.52	86.25	117.1	110.9	121.9	115.0
BSN4168-Incr-Marker1-130515122449	BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)	1N 414 2.81	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.76987	174.741818	80.38	0.65	0.08	6.61	0.81	115.02	119.5	112.0	125.4	117.8
BSN4168-Incr-Marker2-130515121043	BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)	1N 414 2.81	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.769332	174.741605	80.19	0.41	0.04	4.2	0.43	95.35	119.7	112.3	124.0	116.0
BSN4168-Incr-Marker3-130515121043	BSN4168	TRISTRAM AVE OVERPASS (SOUTHBOUND)	1N 414 2.81	Increasing	Rubber seals + vertical steel plates	Asphalt	3	-36.770445	174.742185	80.38	0.29	0.05	2.96	0.53	125.43	122.3	113.5	127.0	117.0
BSN4169-Decr-Marker1-130515121306	BSN4169	TRISTRAM AVE OVERPASS (NORTHBOUND)	1N 414 2.81	Decreasing	Rubber seals + vertical steel plates	Asphalt	1	-36.782768	174.74932	80.93	0.35	0.05	3.56	0.48	45.54	112.8	108.5	115.7	110.3
BSN4169-Decr-Marker2-130515121306	BSN4169	TRISTRAM AVE OVERPASS (NORTHBOUND)	1N 414 2.81	Decreasing	Rubber seals + vertical steel plates	Asphalt	2	-36.782043	174.748862	81.12	0.76	0.08	7.67	0.79	52.79	113.9	108.4	118.8	109.8
BSN4178-Incr-Marker2-130515122539	BSN4178	WAIRAU ROAD OVERPASS No.1	1N 414 3.8	Increasing	Steel sliding plate	Asphalt	2	-36.780072	174.74781	80.93	0.34	0.04	3.44	0.38	57.13	117.5	108.4	120.3	111.1
BSN4271-Decr-Marker1-130515124319	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.859068	174.756565	79.45	1.65	0.2	16.76	2.02	103.27	116.7	113.4	119.7	121.0
BSN4271-Decr-Marker2-130515124319	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.85855	174.756252	76.3	1.6	0.18	16.27	1.8	70.77	114.5	108.6	121.0	114.2
BSN4271-Decr-Marker3-130515124319	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	3	-36.858203	174.756055	77.04	0.3	0.07	3.06	0.74	57.68	111.3	109.4	115.5	115.2
BSN4271-Decr-Marker4-130515124319	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.85731	174.75565	75.38	0.32	0.07	3.19	0.71	65.7	111.8	109.7	115.5	115.7
BSN4271-Decr-Marker5-130515124319	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	5	-36.856358	174.755632	77.97	0.78	0.15	7.92	1.51	55.26	111.0	110.1	115.7	116.0
BSN4271-Decr-Marker7-130515131516	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	7	-36.860252	174.75924	87.6	1.59	0.14	16.16	1.42	62.22	114.0	108.9	117.7	114.0
BSN4271-Decr-Marker8-130515131516	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	8	-36.860232	174.758698	87.04	1.58	0.11	15.98	1.07	45.75	111.0	107.3	114.3	111.5
BSN4271-Decr-Marker9-130515131516	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	9	-36.860095	174.757958	80.19	0.38	0.08	3.85	0.8	49.37	113.5	109.6	118.8	114.8
BSN4271-Decr-Marker10-130515131516	BSN4271	NEWTON No.1 BRIDGE	1N 427 0.39	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	10	-36.859572	174.756973	75.93	0.24	0.04	2.46	0.38	82.12	114.8	109.9	118.7	115.6
BSN4281-Incr-Marker1-130515092447	BSN4281	Grafton Interchange 3A	1N 427 1.03	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.860115	174.762035	75.38	0.13	0.04	1.34	0.43	35.72	105.8	107.5	108.9	109.6
BSN4281-Incr-Marker2-130515092447	BSN4281	Grafton Interchange 3A	1N 0427 1.03	Increasing	Rubber seals + vertical steel plates	Asphalt	2	-36.860115	174.762035	75.38	0.17	0.03	1.71	0.3	26.44	103.8	106.7	108.3	109.9
BSN4282-Decr-Marker1-130515123255	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-36.860332	174.762333	80.38	0.52	0.05	5.32	0.51	74.04	115.0	110.0	119.6	114.8
BSN4282-Decr-Marker2-130515123255	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-36.860332	174.762333	80.38	0.23	0.03	2.37	0.27	111.41	117.7	110.3	122.3	113.1
BSN4282-Decr-Marker3-130515123255	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	3	-36.860332	174.762333	80.38	0.1	0.04	1.06	0.38	133.9	117.6	111.5	123.5	114.9
BSN4282-Decr-Marker3-130515124154	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	3	-36.862983	174.764635	76.67	0.9	0.11	9.11	1.08	52.06	112.8	109.4	117.8	113.6

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN4282-Decr-Marker4-130515123255	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.860332	174.762333	80.38	2.25	0.22	22.86	2.26	127.15	122.2	113.4	127.9	118.7
BSN4282-Decr-Marker4-130515124154	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.86206	174.763738	77.78	0.18	0.1	1.79	1.02	65.83	113.2	108.6	116.8	110.9
BSN4282-Decr-Marker4-130515131516	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	4	-36.864047	174.766173	80.38	0.19	0.03	1.91	0.33	68.62	112.7	109.7	116.2	111.5
BSN4282-Decr-Marker5-130515131516	BSN4282	GRAFTON INTERCHANGE BRIDGE 1	1N 427 1.16	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	5	-36.861292	174.762903	81.86	1.2	0.11	12.18	1.1	70.68	115.5	110.7	118.1	113.3
BSN4283-Incr-Marker3-130515092447	BSN4283	GRAFTON INTERCHANGE 2	1N 0427 1.19	Increasing	Rubber seals + vertical steel plates	Asphalt	3	-36.860312	174.762467	77.04	0.6	0.15	6.06	1.54	33.79	105.0	106.2	110.7	110.7
BSN4287-Incr-Marker1-130515092539	BSN4287	Khyber Pass Viaduct 1 (southbound)	1N 0427 1.64	Increasing	Rubber seals + vertical steel plates	Asphalt	1	-36.866418	174.767767	70.01	0.6	0.09	6.08	0.94	37.17	106.2	108.9	110.2	113.3
BSN4287-Incr-Marker5-130515123255	BSN4287	KHYBER PASS VIADUCT 1 (SOUTHBOUND)	1N 427 1.64	Increasing	Rubber seals + vertical steel plates	Asphalt	5	-36.863952	174.766272	80.93	0.73	0.1	7.38	1.01	69.36	111.3	109.6	115.8	115.7
BSN4288-Decr-Marker1-130515124154	BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)	1N 427 1.64	Decreasing	Rubber seals + vertical steel plates	Asphalt	1	-36.866823	174.767783	75.93	0.24	0.06	2.4	0.58	89.24	115.0	110.0	120.5	115.6
BSN4288-Decr-Marker1-130515131516	BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)	1N 427 1.64	Decreasing	Rubber seals + vertical steel plates	Asphalt	1	-36.866953	174.767785	80.19	0.26	0.07	2.61	0.74	52.18	114.1	109.3	118.1	112.0
BSN4288-Decr-Marker2-130515124154	BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)	1N 427 1.64	Decreasing	Rubber seals + vertical steel plates	Asphalt	2	-36.86519	174.767142	72.23	0.59	0.23	6.02	2.3	35.72	111.8	106.2	115.6	108.0
BSN4288-Decr-Marker2-130515131516	BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)	1N 427 1.64	Decreasing	Rubber seals + vertical steel plates	Asphalt	2	-36.866953	174.767785	80.19	0.59	0.06	6	0.64	112.99	116.6	109.3	121.1	112.4
BSN4288-Decr-Marker3-130515131516	BSN4288	KHYBER PASS VIADUCT 2 (NORTHBOUND)	1N 427 1.64	Decreasing	Rubber seals + vertical steel plates	Asphalt	3	-36.864678	174.766793	80.19	0.89	0.1	9.04	0.99	61.9	116.8	110.4	120.4	113.3
BSN4299-Incr-Marker1-130515092624	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	1	-36.872238	174.774345	77.04	0.66	0.1	6.69	1.03	40.11	109.1	109.5	114.3	113.6
BSN4299-Incr-Marker1-130515123455	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	1	-36.872335	174.774378	78.89	0.85	0.08	8.66	0.79	80.06	116.4	109.2	120.8	113.1
BSN4299-Incr-Marker1-130515130949	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	1	-36.872225	174.774252	79.27	0.39	0.06	3.9	0.6	70.76	117.5	110.2	120.6	113.8
BSN4299-Incr-Marker2-130515092624	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	2	-36.874012	174.778462	79.45	0.74	0.07	7.53	0.73	38.78	106.9	108.4	109.9	112.4
BSN4299-Incr-Marker2-130515123455	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	2	-36.875673	174.780718	79.27	0.46	0.08	4.69	0.77	126.27	119.9	112.9	122.8	116.7
BSN4299-Incr-Marker2-130515130949	BSN4299	Newmarket Viaduct 1	1N 0427 2.75	Increasing	Steel finger joint with or without rubber	Chip seal	2	-36.874588	174.779425	79.82	0.61	0.09	6.18	0.96	93.3	119.5	111.2	122.7	113.8
BSN4300-Decr-Marker1-130515123959	BSN4300	Newmarket Viaduct 2	1N 0427 2.75	Decreasing	Steel finger joint with or without rubber	Chip seal	1	-36.876095	174.780925	79.45	0.69	0.07	7.04	0.69	57.77	115.1	111.3	118.5	115.7
BSN4300-Decr-Marker1-130515131330	BSN4300	Newmarket Viaduct 2	1N 0427 2.75	Decreasing	Steel finger joint with or without rubber	Chip seal	1	-36.877638	174.78221	78.34	0.7	0.07	7.14	0.68	58.15	113.4	110.3	119.0	115.3
BSN4300-Decr-Marker2-130515123959	BSN4300	Newmarket Viaduct 2	1N 0427 2.75	Decreasing	Steel finger joint with or without rubber	Chip seal	2	-36.872542	174.774505	78.53	0.28	0.11	2.86	1.08	42.8	112.7	108.4	115.6	111.1
BSN4300-Decr-Marker2-130515131330	BSN4300	Newmarket Viaduct 2	1N 0427 2.75	Decreasing	Steel finger joint with or without rubber	Chip seal	2	-36.873852	174.777593	79.82	0.47	0.09	4.72	0.88	49.16	112.7	109.2	117.8	112.9
BSN4531-Incr-Marker1-130515094020	BSN4531	Papakura Stream	1N 0448 5.12	Increasing	Steel sliding plate	Asphalt	1	-37.029315	174.91015	89.82	0.24	0.07	2.48	0.75	27.83	109.1	110.2	112.6	111.2

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN4533-Incr-Marker2-130515094020	BSN4533	NIMT RAIL OVERBRIDGE No.1	1N 448 5.38	Increasing	rubber seal (solid)	Asphalt	2	-37.03223	174.910162	79.27	0.21	0.03	2.16	0.27	111.83	116.1	112.1	120.4	115.3
BSN4535-Incr-Marker1-130515094401	BSN4535	GREAT SOUTH ROAD BRIDGE No.1	1N 448 5.63	Increasing	rubber seal (solid)	Asphalt	1	-37.051585	174.917757	105.56	0.19	0.03	1.91	0.34	147.21	121.4	117.1	127.7	122.3
BSN4564-Decr-Marker1-130515100111	BSN4564	Pahurehure Inlet control stream	1N 0448 8.38	Decreasing	Air gap	Other	1	-37.037747	174.910068	71.3	0.1	0.02	1.05	0.22	8.34	100.0	99.9	101.1	101.0
BSN4564-Decr-Marker2-130515100111	BSN4564	Pahurehure Inlet control stream	1N 0448 8.38	Decreasing	Air gap	Other	2	-37.037747	174.910068	71.3	0.33	0.05	3.34	0.46	10.9	101.3	99.1	104.0	100.3
BSN10223-Decr-Marker1-130527130456	BSN10223	LINDALE OVERBRIDGE	1N 1012 10.25	Decreasing	Bitumen filled gap	Asphalt	1	-40.911287	175.016412	65	0.54	0.05	5.5	0.49	122.62	120.0	112.8	125.1	117.2
BSN10223-Decr-Marker2-130527130456	BSN10223	LINDALE OVERBRIDGE	1N 1012 10.25	Decreasing	Bitumen filled gap	Asphalt	2	-40.911113	175.016555	73.15	1.17	0.12	11.82	1.24	94.89	116.4	110.7	120.3	113.9
BSN10223-Incr-Marker1-130527130329	BSN10223	LINDALE OVERBRIDGE	1N 1012 10.25	Increasing	Bitumen filled gap	Asphalt	1	-40.908645	175.018967	82.23	0.66	0.09	6.66	0.9	148.72	123.3	116.0	126.5	120.4
BSN10223-Incr-Marker2-130527130329	BSN10223	LINDALE OVERBRIDGE	1N 1012 10.25	Increasing	Bitumen filled gap	Asphalt	2	-40.908802	175.018797	81.67	0.38	0.05	3.82	0.51	86.99	117.0	109.8	120.7	112.9
BSN10503-Incr-Marker2-130527123552	BSN10503	PAREMATA HARBOUR BRIDGE (SOUTHBOUND)	1N 1035 15.27	Increasing	Air gap	Conrete	2	-41.104078	174.869707	51.12	1.55	0.23	15.67	2.33	29.88	107.0	101.3	110.4	106.7
BSN10504-Decr-Marker1-130527123252	BSN10504	PAREMATA HARBOUR BRIDGE (NORTHBOUND)	1N 1035 15.27	Decreasing	Rubber seals + vertical steel plates	Asphalt	1	-41.104237	174.869468	53.15	1.06	0.19	10.71	1.94	70.78	111.4	102.9	116.6	107.9
BSN10504-Decr-Marker2-130527123252	BSN10504	PAREMATA HARBOUR BRIDGE (NORTHBOUND)	1N 1035 15.27	Decreasing	Rubber seals + vertical steel plates	Asphalt	2	-41.102968	174.869832	52.23	1.42	0.21	14.43	2.1	39.36	107.6	101.8	111.7	107.7
BSN10679-Incr-Marker1-130527120305	BSN10679	NGAURANGA OVERBRIDGE - SOUTHBOUND	1N 1060 7.88	Increasing	Rubber extrusion + embedded steel plates	Asphalt	1	-41.24616	174.814975	81.86	0.84	0.06	8.57	0.56	80.32	114.5	110.9	118.4	118.7
BSN10679-Incr-Marker2-130527120305	BSN10679	NGAURANGA OVERBRIDGE - SOUTHBOUND	1N 1060 7.88	Increasing	Rubber extrusion + embedded steel plates	Asphalt	2	-41.24801	174.813938	81.49	0.55	0.08	5.59	0.79	99.18	116.4	111.0	120.4	117.5
BSN10680-Decr-Marker1-130527114248	BSN10680	NGAURANGA OVERBRIDGE - NORTHBOUND	1N 1060 7.88	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-41.247973	174.81302	80.01	0.36	0.06	3.7	0.65	163.97	122.0	114.9	126.8	120.7
BSN10680-Decr-Marker2-130527114248	BSN10680	NGAURANGA OVERBRIDGE - NORTHBOUND	1N 1060 7.88	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-41.246907	174.814205	79.82	1.34	0.12	13.55	1.23	154.53	121.3	113.9	124.9	119.9
BSN10703-Incr-Marker1-130527114938	BSN10703	THORNDON OVERBRIDGE - SOUTHBOUND	1N 1068 2.24	Increasing	Bitumen filled gap	Asphalt	1	-41.276617	174.77339	86.12	1.62	0.16	16.38	1.6	107.39	116.7	112.2	119.7	119.6
BSN10703-Incr-Marker2-130527114938	BSN10703	THORNDON OVERBRIDGE - SOUTHBOUND	1N 1068 2.24	Increasing	Bitumen filled gap	Asphalt	2	-41.276617	174.77339	86.12	1.77	0.16	17.94	1.66	123.08	117.0	109.8	121.4	112.7
BSN10727-Incr-Marker1-130527120634	BSN10727	BOWEN STREET OVERPASS (SOUTHBOUND)	1N 1068 4.66	Increasing	Rubber extrusion + embedded steel plates	Asphalt	1	-41.279087	174.77346	82.23	1.59	0.15	16.13	1.56	125.24	118.6	111.6	122.6	114.5
BSN10728-Decr-Marker1-130527121228	BSN10728	BOWEN STREET OVERPASS (NORTHBOUND)	1N 1068 4.66	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	1	-41.278163	174.773197	79.45	1.34	0.11	13.62	1.16	66.34	114.4	108.0	120.0	110.9
BSN10728-Decr-Marker2-130527121228	BSN10728	BOWEN STREET OVERPASS (NORTHBOUND)	1N 1068 4.66	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-41.277355	174.77313	81.86	0.36	0.07	3.67	0.73	152.05	122.7	114.4	127.6	119.5
BSN10731-Decr-Marker2-130527121132	BSN10731	SHELL GULLY OVERBRIDGE (NORTHBOUND)	1N 1068 5.11	Decreasing	Rubber extrusion + embedded steel plates	Asphalt	2	-41.284628	174.772735	86.67	1.34	0.13	13.54	1.32	53.16	116.7	110.2	118.7	115.2
BSN10732-Incr-Marker2-130527120634	BSN10732	SHELL GULLY OVERBRIDGE (SOUTHBOUND)	1N 1068 5.11	Increasing	Rubber extrusion + embedded steel plates	Asphalt	2	-41.280922	174.773628	80.56	1.12	0.13	11.36	1.31	23.27	107.3	102.2	110.4	105.8
BSN1550-Incr-Marker1-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	1	-37.666193	176.181035	72.6	1.29	0.09	13.09	0.95	94.56	118.4	112.1	123.3	114.9

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN1550-Incr-Marker3-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	1	-37.666048	176.181098	76.49	0.91	0.07	9.21	0.75	97.94	116.6	111.1	119.0	113.0
BSN1550-Incr-Marker5-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	1	-37.666005	176.181182	77.41	1.13	0.11	11.48	1.14	70.67	114.6	111.1	119.1	113.6
BSN1558-Incr-Marker7-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	1	-37.668567	176.180228	84.82	0.84	0.08	8.47	0.82	79.73	118.3	111.0	121.5	112.7
BSN NA-Decr-Marker2-130516090928	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	stripseal type	Asphalt	1	-37.675	176.177252	86.3	2.17	0.16	22.01	1.61	80.8	118.0	114.6	120.2	118.5
BSN NA-Decr-Marker3-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	stripseal type	Asphalt	1	-37.673263	176.179718	85.93	1.19	0.1	12.03	1.02	97.19	117.3	113.4	122.7	118.1
BSN1550-Decr-Marker5-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	stripseal type	Asphalt	1	-37.674943	176.177257	87.04	1.23	0.09	12.52	0.88	119.16	118.9	114.2	124.1	118.4
BSN1550-Decr-Marker7-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	stripseal type	Asphalt	1	-37.671108	176.179813	0	0.61	0.09	6.16	0.91	70.54	117.1	112.8	120.6	114.3
BSN1550-Decr-Marker8-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	stripseal type	Asphalt	1	-37.674975	176.177092	85.56	1.14	0.16	11.58	1.62	80.81	115.6	112.9	118.0	117.3
BSN1550-Incr-Marker2-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	2	-37.666855	176.180547	76.3	0.43	0.04	4.37	0.37	157.69	121.4	116.4	125.0	119.8
BSN1550-Incr-Marker4-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	2	-37.666722	176.180527	81.86	0.33	0.03	3.34	0.35	126.64	120.7	113.5	124.8	116.8
BSN1558-Incr-Marker6-130516090527	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	2	-37.666652	176.180582	80.01	0.27	0.08	2.78	0.78	93.84	119.8	113.0	124.6	117.0
BSN NA-Decr-Marker1-130516090928	BSN NA	AERODROME BRIDGE (WESTBOUND)	2 151 5.94	Decreasing	Rubber seal (solid)	Asphalt	2	-37.66943	176.180197	86.67	0.27	0.06	2.72	0.61	167.74	123.7	116.5	127.5	120.5
BSN NA-Decr-Marker1-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	steel finger joint with or without rubber	Asphalt	3	-37.674522	176.17162	89.82	1.22	0.08	12.34	0.82	99.8	119.1	114.8	122.9	117.1
BSN1550-Decr-Marker4-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	steel finger joint with or without rubber	Asphalt	3	-37.675163	176.17504	83.53	1.93	0.31	19.52	3.17	84.48	116.3	111.4	119.6	114.4
BSN1550-Decr-Marker6-130516091306	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	steel finger joint with or without rubber	Asphalt	3	-37.67491	176.173015	85.38	1.92	0.26	19.49	2.59	63.34	115.8	112.4	119.3	116.0
BSN1460-Decr-Marker1-130516092021	BSN NA	HARBOUR BRIDGE (WESTBOUND)	2 151 4.73	Decreasing	steel finger joint with or without rubber	Asphalt	3	-37.67455	176.171812	85.75	1.97	0.35	19.98	3.58	74.92	116.0	111.7	120.0	115.0
BSN162-Incr-Marker2-130516122803	BSN162	WAIMAPU STREAM BRIDGE	29 13 3.19	Increasing	Bitumen filled gap	Chip seal	2	-37.739858	176.145672	83.71	0.9	0.17	9.08	1.7	113.22	119.2	109.6	122.8	113.6
BSN162-Incr-Marker3-130516122803	BSN162	WAIMAPU STREAM BRIDGE	29 13 3.19	Increasing	Bitumen filled gap	Chip seal	3	-37.739812	176.145413	84.45	1.62	0.3	16.45	3.02	57.45	109.8	102.0	114.9	106.7
BSN269-Incr-Marker1-130516123718	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.781693	176.050978	87.23	2.11	0.25	21.35	2.58	114.99	121.8	115.9	125.7	118.3
BSN269-Decr-Marker1-130516123858	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.78168	176.050977	85.38	2.24	0.25	22.74	2.54	110	120.8	114.5	125.5	116.3
BSN269-Incr-Marker1-130516123956	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.781665	176.050953	86.3	2.19	0.27	22.17	2.76	161.89	119.7	114.6	125.4	118.7
BSN269-Incr-Marker2-130516123718	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.78065	176.051412	87.41	1.95	0.32	19.82	3.2	140.81	121.7	115.6	125.0	118.3
BSN269-Decr-Marker2-130516123858	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.780677	176.05139	83.71	1.84	0.37	18.69	3.8	106.53	118.6	113.8	121.8	117.5

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN269-Incr-Marker2-130516123956	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Decreasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.780647	176.051363	85.56	1.73	0.34	17.5	3.45	174.31	125.5	118.7	129.9	123.1
BSN269-Decr-Marker1-130516124034	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.780455	176.051528	86.12	1.93	0.25	19.56	2.49	112.86	120.5	114.1	125.8	119.3
BSN269-Incr-Marker1-130516124134	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.780385	176.051573	87.23	2.14	0.24	21.66	2.42	80.18	119.2	114.4	123.3	118.0
BSN323-Incr-Marker1-130516124425	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	1	-37.780367	176.05159	88.9	2.04	0.25	20.65	2.5	117.39	121.0	115.6	125.3	119.2
BSN269-Decr-Marker2-130516124034	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.78126	176.051132	86.49	1.94	0.24	19.64	2.41	159.78	123.2	116.3	126.4	118.5
BSN269-Incr-Marker2-130516124134	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.781215	176.051145	89.27	2.07	0.25	20.95	2.5	76.25	115.9	113.3	117.9	116.1
BSN323-Incr-Marker2-130516124425	BSN269	RUAHIHI BRIDGE (WAIROA RIVER)	29 21 5.96	Increasing	Rubber extrusion + embedded steel plates	Chip seal	2	-37.781188	176.051157	89.08	2.12	0.23	21.48	2.38	155.47	123.5	117.4	128.5	122.4
BSN330-Incr-Marker1-130516124531	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Decreasing	Rubber extrusion unreinforced	Asphalt	1	-37.817445	176.015557	87.04	0.31	0.05	3.17	0.49	152.31	123.6	115.7	128.4	119.5
BSN330-Decr-Marker1-130516124649	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Decreasing	Rubber extrusion unreinforced	Asphalt	1	-37.817628	176.014875	85.75	1.32	0.11	13.35	1.11	150.28	122.8	115.4	127.1	121.0
BSN330-Incr-Marker2-130516124531	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Decreasing	Rubber extrusion unreinforced	Asphalt	2	-37.817295	176.016088	88.71	0.59	0.05	6.03	0.55	122.65	119.8	111.3	123.2	115.5
BSN330-Decr-Marker2-130516124649	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Decreasing	Rubber extrusion unreinforced	Asphalt	2	-37.817485	176.015378	85.19	0.35	0.04	3.58	0.37	157.5	121.4	113.5	124.8	117.4
BSN323-Decr-Marker1-130516124801	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Increasing	Rubber extrusion unreinforced	Asphalt	1	-37.81649	176.018752	89.64	0.29	0.03	2.92	0.29	142.71	120.9	112.7	125.6	117.4
BSN323-Incr-Marker1-130516124820	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Increasing	Rubber extrusion unreinforced	Asphalt	1	-37.815803	176.019903	88.34	0.29	0.03	2.95	0.32	141.12	123.8	113.9	127.4	117.5
BSN323-Decr-Marker2-130516124801	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Increasing	Rubber extrusion unreinforced	Asphalt	2	-37.81649	176.018752	89.64	0.25	0.03	2.56	0.32	152.86	121.2	111.8	125.3	117.2
BSN323-Incr-Marker2-130516124820	BSN323	NGAMUWAHINE RIVER BRIDGE	29 21 11.41	Increasing	Rubber extrusion unreinforced	Asphalt	2	-37.816083	176.019458	89.08	0.27	0.04	2.69	0.38	82.77	117.3	109.7	121.4	114.1
BSN330-Incr-Marker1-130516125136	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Decreasing	Bitumen filled gap	Chip seal	1	-37.81991	176.008472	86.49	1.68	0.09	17.07	0.95	140.9	123.9	116.3	128.7	121.6
BSN343-Incr-Marker1-130516125501	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Decreasing	Bitumen filled gap	Chip seal	1	-37.819912	176.008478	84.45	1.61	0.14	16.32	1.42	189.85	126.8	120.4	128.8	123.6
BSN330-Incr-Marker2-130516125136	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Decreasing	Bitumen filled gap	Chip seal	2	-37.819943	176.009292	86.67	1.62	0.23	16.46	2.35	132.8	121.0	112.5	125.4	116.9
BSN343-Incr-Marker2-130516125501	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Decreasing	Bitumen filled gap	Chip seal	2	-37.819938	176.00928	84.64	1.4	0.19	14.16	1.94	153.69	123.6	115.4	128.9	121.2
BSN388-Decr-Marker1-130516130040	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Increasing	Bitumen filled gap	Chip seal	1	-37.819972	176.010053	82.97	1.38	0.11	13.97	1.1	141	121.6	114.8	126.1	118.7
BSN388-Incr-Marker1-130516130252	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Increasing	Bitumen filled gap	Chip seal	1	-37.819998	176.009948	85.93	1.35	0.11	13.69	1.14	184.61	126.6	119.0	129.4	122.7
BSN388-Decr-Marker2-130516130040	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Increasing	Bitumen filled gap	Chip seal	2	-37.81994	176.008993	83.9	1.5	0.12	15.18	1.18	85.88	117.2	113.0	120.8	116.3
BSN388-Incr-Marker2-130516130252	BSN330	TE AHARA STREAM (BEACON) BRIDGE	29 21 12	Increasing	Bitumen filled gap	Chip seal	2	-37.819963	176.009135	85.38	1.65	0.13	16.76	1.31	156.97	122.5	115.3	129.1	119.8

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN330-Decr-Marker1-130516132319	BSN343	KAUKUMOUTITI STREAM (BOULDER BRIDGE)	29 21 13.36	Increasing	Bitumen filled gap	Chip seal	1	-37.822888	175.99983	70.75	0.25	0.04	2.5	0.4	103.05	120.7	112.2	123.0	116.3
BSN330-Decr-Marker2-130516132319	BSN343	KAUKUMOUTITI STREAM (BOULDER BRIDGE)	29 21 13.36	Increasing	Bitumen filled gap	Chip seal	2	-37.822983	175.999605	75.93	0.34	0.04	3.49	0.42	121.53	117.7	108.5	122.3	110.7
BSN323-Decr-Marker1-130516132344	BSN388	TUAKOPAI STREAM BRIDGE	29 21 17.85	Decreasing	Bitumen filled gap	Chip seal	1	-37.850417	175.960068	89.82	0.66	0.1	6.74	1.01	140.91	123.9	116.4	126.3	119.4
BSN323-Decr-Marker2-130516132344	BSN388	TUAKOPAI STREAM BRIDGE	29 21 17.85	Decreasing	Bitumen filled gap	Chip seal	2	-37.850273	175.960283	89.27	0.39	0.04	3.98	0.37	151.29	123.5	116.4	127.0	120.7
BSN269-Decr-Marker1-130516132715	BSN388	TUAKOPAI STREAM BRIDGE	29 21 17.85	Increasing	Bitumen filled gap	Chip seal	1	-37.848372	175.963645	83.53	0.46	0.05	4.65	0.55	135.44	122.6	115.2	126.6	117.9
BSN269-Decr-Marker2-130516132715	BSN388	TUAKOPAI STREAM BRIDGE	29 21 17.85	Increasing	Bitumen filled gap	Chip seal	2	-37.848612	175.963213	83.53	0.57	0.05	5.75	0.55	82.83	118.3	110.2	121.7	113.9
BSN1460-Decr-Marker2-130516092021	BSN1160	TAHAWAI RIVER BRIDGE	2 116 0	Decreasing	Rubber seal (solid)	Chip seal	1	-37.534233	175.914265	82.78	0.97	0.04	9.81	0.4	135.3	123.5	116.0	127.7	119.5
BSN1300-Decr-Marker1-130516093534	BSN1160	TAHAWAI RIVER BRIDGE	2 116 0	Decreasing	Rubber seal (solid)	Chip seal	2	-37.533543	175.914832	83.16	2.05	0.15	20.79	1.5	146.31	124.3	118.1	127.7	119.2
BSN1300-Decr-Marker2-130516093534	BSN1160	TAHAWAI RIVER BRIDGE	2 116 0	Increasing	Rubber seal (solid)	Chip seal	1	-37.533503	175.914892	87.41	0.27	0.06	2.71	0.59	178.57	126.5	119.1	128.6	121.7
BSN1274-Decr-Marker1-130516093741	BSN1160	TAHAWAI RIVER BRIDGE	2 116 0	Increasing	Rubber seal (solid)	Chip seal	2	-37.533887	175.914648	84.82	0.71	0.1	7.17	1.03	147.51	123.3	115.9	128.5	120.4
BSN1274-Decr-Marker2-130516093741	BSN1182	URETARA STREAM (WHARAWHARA)	2 116 2.29	Decreasing	Bitumen filled gap	Chip seal	1	-37.551073	175.917167	53.52	0.98	0.12	9.89	1.22	74.19	113.0	103.7	118.1	107.5
BSN1182-Decr-Marker1-130516094836	BSN1182	URETARA STREAM (WHARAWHARA)	2 116 2.29	Increasing	Bitumen filled gap	Chip seal	1	-37.550605	175.916645	45.56	1.08	0.15	10.99	1.52	28.8	105.3	98.0	110.8	100.8
BSN1160-Decr-Marker1-130516095135	BSN1182	URETARA STREAM (WHARAWHARA)	2 116 2.29	Increasing	Bitumen filled gap	Chip seal	2	-37.550765	175.916837	44.45	0.94	0.1	9.51	1.01	27.05	108.1	98.1	112.9	101.8
BSN1160-Decr-Marker2-130516095135	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Decreasing	Rubber seal (solid)	Chip seal	1	-37.577547	175.911063	82.78	1.67	0.12	16.96	1.22	73.29	117.6	114.5	120.4	117.7
BSN1160-Incr-Marker1-130516100235	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Decreasing	Rubber seal (solid)	Chip seal	2	-37.577165	175.910872	82.23	1.34	0.19	13.63	1.91	105.61	120.5	116.4	124.4	119.3
BSN1160-Incr-Marker2-130516100235	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Increasing	Rubber seal (solid)	Chip seal	1	-37.576847	175.910752	74.08	1.93	0.29	19.6	2.96	106.38	117.0	115.4	121.1	117.1
BSN1182-Incr-Marker2-130516100400	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Increasing	Rubber seal (solid)	Chip seal	1	-37.576765	175.910702	86.12	1.71	0.19	17.35	1.91	50.34	116.2	116.1	118.0	117.0
BSN1182-Incr-Marker1-130516100400	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Increasing	Rubber seal (solid)	Chip seal	2	-37.5772	175.910932	76.3	1.07	0.15	10.89	1.54	150.63	121.0	115.3	124.5	117.4
BSN1214-Incr-Marker1-130516100753	BSN1214	TE REREREATUKAHIA RIVER BRIDGE	2 116 5.43	Increasing	Rubber seal (solid)	Chip seal	2	-37.577158	175.910905	85.19	1.15	0.13	11.65	1.28	58.83	115.6	114.7	118.2	116.4
BSN1214-Incr-Marker2-130516100753	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Decreasing	Rubber seal (solid)	Chip seal	1	-37.599798	175.916123	83.53	0.59	0.08	5.96	0.78	145.05	123.3	116.2	125.8	118.6
BSN1214-Decr-Marker1-130516100854	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Decreasing	Rubber seal (solid)	Chip seal	2	-37.599447	175.91584	83.16	0.18	0.06	1.85	0.56	176.08	126.5	118.3	130.7	121.6
BSN1214-Decr-Marker2-130516100854	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Increasing	Rubber seal (solid)	Chip seal	1	-37.599005	175.9155	86.86	1.32	0.19	13.43	1.92	77.09	117.6	113.5	121.2	115.5
BSN1214-Incr-Marker2-130516100943	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Increasing	Rubber seal (solid)	Chip seal	1	-37.598898	175.915423	87.23	1.24	0.15	12.61	1.51	176.93	123.4	116.5	128.0	120.9

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN1214-Incr-Marker1-130516100943	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Increasing	Rubber seal (solid)	Chip seal	2	-37.599183	175.915653	86.67	0.36	0.03	3.62	0.34	56.09	114.8	112.9	117.1	114.0
BSN1240-Incr-Marker1-130516101137	BSN1240	WAITEKOHE STREAM BRIDGE	2 116 8.07	Increasing	Rubber seal (solid)	Chip seal	2	-37.599257	175.915727	86.67	0.25	0.07	2.53	0.66	147.55	120.0	115.2	126.3	119.8
BSN1240-Incr-Marker2-130516101137	BSN1265	AONGATETE STREAM BRIDGE	2 116 10.56	Decreasing	Rubber seal (solid)	Chip seal	1	-37.607753	175.942353	81.49	1.08	0.12	10.99	1.19	62.09	116.7	115.1	121.4	117.2
BSN1240-Decr-Marker1-130516101330	BSN1265	AONGATETE STREAM BRIDGE	2 116 10.56	Decreasing	Rubber seal (solid)	Chip seal	2	-37.607492	175.941947	83.16	2.01	0.14	20.4	1.39	38.53	114.0	112.8	116.1	116.1
BSN1240-Decr-Marker2-130516101330	BSN1265	AONGATETE STREAM BRIDGE	2 116 10.56	Decreasing	Rubber seal (solid)	Chip seal	3	-37.607222	175.941533	85.19	0.69	0.07	6.99	0.67	59.87	115.4	113.2	117.9	115.0
BSN1240-Incr-Marker1-130516101438	BSN1265	AONGATETE STREAM BRIDGE	2 116 10.56	Increasing	Rubber seal (solid)	Chip seal	1	-37.605037	175.938297	89.27	1.45	0.12	14.74	1.19	174.06	123.8	115.9	128.3	120.7
BSN1240-Incr-Marker2-130516101438	BSN1265	AONGATETE STREAM BRIDGE	2 116 10.56	Increasing	Rubber seal (solid)	Chip seal	2	-37.605317	175.938748	90.19	1.42	0.12	14.43	1.2	133.32	120.0	112.1	124.3	115.2
BSN1265-Incr-Marker1-130516101613	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	1	-37.613473	175.947877	80.38	1.02	0.11	10.29	1.11	47.12	115.1	112.6	117.5	114.0
BSN1265-Decr-Marker1-130516101820	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	1	-37.613483	175.94785	80.38	1.2	0.17	12.17	1.74	113.63	119.4	112.5	124.4	116.9
BSN1265-Decr-Marker3-130516101820	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	1	-37.613505	175.947863	86.12	0.84	0.08	8.55	0.79	152.58	123.1	116.3	126.6	118.7
BSN1265-Incr-Marker2-130516101613	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	2	-37.612825	175.947268	81.49	0.51	0.09	5.19	0.95	71.24	116.2	114.6	118.9	117.1
BSN1265-Decr-Marker2-130516101820	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	2	-37.61291	175.947315	70.75	0.57	0.19	5.8	1.88	38.65	111.1	108.0	115.2	110.2
BSN1274-Incr-Marker1-130516102025	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Decreasing	Bitumen filled gap	Chip seal	2	-37.612997	175.947392	82.41	0.79	0.11	7.98	1.14	82.72	118.1	113.7	121.2	115.8
BSN1274-Incr-Marker2-130516102025	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Increasing	Bitumen filled gap	Chip seal	1	-37.61251	175.946998	82.41	1.11	0.08	11.28	0.78	72.69	116.8	113.5	119.7	115.4
BSN1274-Decr-Marker2-130516102129	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Increasing	Bitumen filled gap	Chip seal	1	-37.613177	175.947613	85.19	1.18	0.14	11.99	1.44	158.01	123.5	116.0	129.1	120.6
BSN1274-Decr-Marker1-130516102129	BSN1274	WHATAKAO STREAM BRIDGE	2 116 11.41	Increasing	Bitumen filled gap	Chip seal	2	-37.613167	175.947603	81.3	1.12	0.09	11.34	0.89	54.17	116.7	111.4	120.1	112.7
BSN1274-Decr-Marker1-130516102309	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Decreasing	Bitumen filled gap	Chip seal	1	-37.634348	175.96012	88.53	3.71	0.16	37.64	1.66	126	120.8	115.0	125.4	117.3
BSN1274-Incr-Marker1-130516102415	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Decreasing	Bitumen filled gap	Chip seal	1	-37.634352	175.960043	88.16	2.77	0.21	28.1	2.12	164.04	126.5	120.4	131.1	125.5
BSN1274-Decr-Marker2-130516102309	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Decreasing	Bitumen filled gap	Chip seal	2	-37.634223	175.959893	86.67	1.37	0.15	13.93	1.53	97.15	116.3	114.4	121.7	116.9
BSN1300-Incr-Marker1-130516102559	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Decreasing	Bitumen filled gap	Chip seal	2	-37.634225	175.959815	88.16	1.6	0.22	16.23	2.19	179.84	125.5	119.4	129.5	123.3
BSN1300-Incr-Marker2-130516102559	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Increasing	Bitumen filled gap	Chip seal	1	-37.631615	175.956873	83.34	2.03	0.2	20.59	2.01	88.97	118.9	112.7	123.6	115.2
BSN1300-Decr-Marker2-130516102718	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Increasing	Bitumen filled gap	Chip seal	1	-37.631693	175.95687	85.75	1.83	0.12	18.51	1.27	155.69	124.6	118.0	128.5	122.3
BSN1300-Decr-Marker1-130516102718	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Increasing	Bitumen filled gap	Chip seal	2	-37.632025	175.956972	83.16	3.04	0.39	30.83	3.93	120.82	121.2	114.7	126.6	118.8

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN1300-Incr-Marker1-130516102840	BSN1300	WAINUI RIVER BRIDGE	2 130 0	Increasing	Bitumen filled gap	Chip seal	2	-37.631905	175.956942	86.12	3.15	0.36	31.91	3.67	174.98	125.0	117.1	127.4	120.4
BSN1300-Incr-Marker2-130516102840	BSN1340	APATA RAIL OVERBRIDGE	2 130 4.03	Decreasing	Bitumen filled gap	Chip seal	1	-37.646532	175.989565	87.6	1.7	0.13	17.25	1.34	152.26	123.6	115.9	125.9	118.7
BSN1340-Incr-Marker1-130516103148	BSN1340	APATA RAIL OVERBRIDGE	2 130 4.03	Decreasing	Bitumen filled gap	Chip seal	2	-37.6464	175.989333	88.9	0.96	0.09	9.75	0.86	171.91	124.6	117.0	127.7	121.7
BSN1340-Incr-Marker2-130516103148	BSN1340	APATA RAIL OVERBRIDGE	2 130 4.03	Increasing	Bitumen filled gap	Chip seal	1	-37.64601	175.988708	77.23	0.86	0.11	8.68	1.09	174.11	123.8	116.5	126.7	121.2
BSN1340-Decr-Marker1-130516103319	BSN1340	APATA RAIL OVERBRIDGE	2 130 4.03	Increasing	Bitumen filled gap	Chip seal	2	-37.646238	175.989105	77.78	1.25	0.08	12.66	0.86	156.7	123.7	116.1	128.7	121.5
BSN1340-Decr-Marker2-130516103319	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	1	-37.69692	176.098458	81.67	0.52	0.1	5.3	0.97	84.07	114.9	110.8	118.3	114.6
BSN1460-Incr-Marker2-130516104750	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	1	-37.69827	176.09581	86.49	0.53	0.06	5.36	0.61	93.31	115.3	111.6	120.0	115.0
BSN1460-Decr-Marker2-130516104854	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	1	-37.698337	176.095657	85.93	0.58	0.07	5.87	0.74	101.05	118.6	113.2	121.9	115.2
BSN1460-Incr-Marker1-130516104750	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	2	-37.697887	176.096538	78.34	0.31	0.04	3.16	0.38	152.27	123.4	116.4	126.0	118.9
BSN1460-Decr-Marker1-130516104854	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	2	-37.699177	176.094015	81.12	0.15	0.08	1.49	0.82	31.81	108.7	106.6	111.5	107.4
BSN1460-Incr-Marker1-130516104946	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Decreasing	Rubber seals + vertical steel plates	Chip seal	2	-37.69916	176.094022	87.78	0.3	0.05	3.07	0.53	123.07	118.8	112.9	122.6	115.8
BSN1460-Incr-Marker2-130516104946	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Increasing	Rubber seals + vertical steel plates	Chip seal	1	-37.699462	176.093393	80.01	1.59	0.16	16.13	1.65	97.08	116.9	113.4	121.3	117.6
BSN1460-Decr-Marker2-130516105037	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Increasing	Rubber seals + vertical steel plates	Chip seal	1	-37.699335	176.093637	85.01	1.12	0.09	11.35	0.89	136.13	120.9	114.9	125.1	118.1
BSN1460-Decr-Marker1-130516105037	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Increasing	Rubber seals + vertical steel plates	Chip seal	2	-37.698555	176.09518	85.38	0.43	0.06	4.38	0.56	116.3	118.4	113.0	123.9	117.4
BSN1460-Incr-Marker2-130516105246	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Increasing	Rubber seals + vertical steel plates	Chip seal	2	-37.698528	176.09522	85.38	0.47	0.04	4.73	0.39	136.21	120.2	113.4	125.1	117.9
BSN NA-Decr-Marker1-130516110005	BSN1460	WAIROA RIVER BRIDGE	2 146 0	Increasing	Rubber seals + vertical steel plates	Chip seal	2	-37.69843	176.095402	85.75	0.46	0.05	4.62	0.49	161.18	121.3	113.0	126.7	116.2
BSN NA-Decr-Marker3-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.67402	176.170355	89.27	1.05	0.17	10.68	1.75	131.75	121.5	114.6	124.6	117.4
BSN1550-Decr-Marker8-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.675003	176.173452	84.64	0.96	0.17	9.75	1.74	60.89	115.2	110.5	118.3	114.9
BSN1550-Incr-Marker5-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.67491	176.173015	85.38	0.96	0.23	9.73	2.32	70.68	115.6	111.1	120.4	116.2
BSN NA-Decr-Marker3-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.674002	176.16909	82.04	1.16	0.11	11.8	1.15	77.29	115.3	112.8	119.7	118.6
BSN1550-Decr-Marker4-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.674072	176.169027	84.08	0.45	0.08	4.58	0.83	133.68	121.8	114.7	125.5	119.2
BSN1550-Incr-Marker1-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.674682	176.172167	85.56	1.04	0.16	10.58	1.61	105.95	116.2	111.9	121.7	116.4
BSN1558-Incr-Marker7-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.674703	176.172242	86.3	1.27	0.18	12.84	1.79	110.7	115.6	113.0	120.6	119.3
BSN1550-Decr-Marker4-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.674638	176.167725	84.64	0.57	0.11	5.8	1.16	61.63	117.6	111.7	120.9	116.9

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN1550-Decr-Marker5-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	6	-37.674617	176.167872	86.3	1.27	0.11	12.9	1.16	135.5	120.4	115.3	123.9	119.9
BSN1550-Incr-Marker2-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	6	-37.674105	176.170758	83.34	0.53	0.08	5.39	0.84	75.13	117.9	112.0	122.1	117.2
BSN NA-Decr-Marker1-130516110732	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	6	-37.67422	176.171017	87.04	0.4	0.05	4.04	0.52	86.45	116.8	112.9	119.6	118.6
BSN1550-Decr-Marker5-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	6	-37.675545	176.166223	85.93	2.04	0.25	20.73	2.52	84.51	118.0	111.4	122.8	116.0
BSN1550-Decr-Marker6-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	7	-37.675855	176.165908	88.34	0.95	0.11	9.63	1.14	132.9	121.9	115.3	123.8	118.6
BSN1550-Incr-Marker3-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	7	-37.674102	176.168817	77.41	1.77	0.14	17.94	1.38	55.47	115.7	111.2	119.2	115.2
BSN NA-Decr-Marker2-130516110732	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	7	-37.674118	176.168727	83.53	1.63	0.12	16.51	1.26	110.96	119.1	113.1	123.5	117.8
BSN1550-Decr-Marker6-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	7	-37.675545	176.166223	85.93	1.53	0.12	15.5	1.26	86.19	117.9	112.3	122.0	118.0
BSN1550-Decr-Marker7-130516110005	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	8	-37.67639	176.1654	89.27	2.37	0.24	24.03	2.43	160.17	123.2	116.5	125.8	120.6
BSN1550-Incr-Marker4-130516110535	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	8	-37.674535	176.16793	83.53	2	0.17	20.3	1.76	83.08	116.7	114.1	120.2	121.0
BSN NA-Decr-Marker1-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Decreasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	8	-37.674585	176.167828	84.64	1.68	0.12	17.01	1.24	155.61	119.7	114.1	124.5	118.2
BSN1550-Decr-Marker7-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	1	-37.67917	176.163915	85.19	0.39	0.1	3.96	1.02	131.21	119.3	112.9	121.4	115.6
BSN1550-Incr-Marker4-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	1	-37.676802	176.164997	83.16	0.54	0.07	5.43	0.72	93.69	118.9	113.0	122.3	117.9
BSN NA-Decr-Marker1-130516111615	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	1	-37.676712	176.165042	87.41	0.54	0.07	5.43	0.68	156.7	122.7	115.5	127.2	120.0
BSN1550-Decr-Marker8-130516111040	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	2	-37.678578	176.164188	83.71	1.21	0.15	12.31	1.56	82.29	117.2	111.9	121.0	116.2
BSN1558-Incr-Marker5-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	2	-37.676067	176.165502	84.08	1.36	0.13	13.82	1.29	85.42	118.3	111.6	121.0	115.7
BSN NA-Decr-Marker2-130516111615	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	2	-37.676135	176.16544	87.6	1.11	0.09	11.28	0.91	145.2	122.5	114.4	127.1	118.0
BSN1550-Incr-Marker1-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	3	-37.676953	176.164928	88.53	1.38	0.11	14.03	1.06	63.72	115.0	112.0	118.0	117.0
BSN1558-Incr-Marker6-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	3	-37.674813	176.167303	84.45	1.17	0.07	11.91	0.71	166.64	125.1	117.2	128.1	120.7
BSN NA-Decr-Marker1-130516111908	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	3	-37.674138	176.16849	82.23	0.93	0.08	9.41	0.79	151.58	119.8	113.6	126.7	119.6
BSN1550-Incr-Marker2-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.675832	176.165737	86.49	0.86	0.09	8.77	0.93	80.67	113.0	112.1	117.0	118.3
BSN1571-Incr-Marker1-130516111448	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.674085	176.168598	84.27	0.89	0.06	8.98	0.66	143.78	119.8	114.6	123.5	120.3
BSN NA-Decr-Marker1-130516112405	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	4	-37.673858	176.169732	82.78	1.47	0.21	14.86	2.15	89.16	115.8	112.6	118.5	118.7
BSN1550-Incr-Marker3-130516111336	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.674992	176.167033	89.27	1.32	0.16	13.36	1.63	60.45	115.2	112.2	119.2	117.9
BSN1571-Incr-Marker2-130516111448	BSN1550	CHAPEL STREET VIADUCT	2 151 4.04	Increasing	Rubber extrusion + embedded steel plates	Stone Mastic Asphalt	5	-37.673857	176.169905	85.19	1.49	0.18	15.08	1.86	69.77	116.2	112.5	118.5	117.2

Appendix B - Tabulated results

Filename	BSN	Name	Route Position	Direction	Joint Type	Road Surface	Marker	Latitude	Longitude	Speed (km/h)	Accel Vert Max (g)	Accel Long Max (g)	Disp Vert Max (mm)	Disp Long Max (mm)	Peak Sound Pressure (Pa)	$L_{eq(1s)}$ (dB)	$L_{Aeq(1s)}$ (dB)	L_{ZFmax} (dB)	L_{AFmax} (dB)
BSN1550-Decr-Marker4-130516112500	BSN1558	HARBOUR BRIDGE (EASTBOUND)	2 151 4.73	Increasing	Modular expansion joint	Asphalt	5	-37.674203	176.17124	83.71	0.48	0.09	4.87	0.93	106.66	120.0	115.3	124.3	121.8
BSN NA-Decr-Marker2-130516112405	BSN1558	HARBOUR BRIDGE (EASTBOUND)	2 151 4.73	Increasing	Modular expansion joint	Asphalt	6	-37.67424	176.168333	82.23	0.71	0.1	7.21	1.05	91.52	116.5	115.3	120.0	122.3
BSN1550-Decr-Marker5-130516112500	BSN1558	HARBOUR BRIDGE (EASTBOUND)	2 151 4.73	Increasing	Modular expansion joint	Asphalt	6	-37.674987	176.176523	83.34	1.4	0.13	14.15	1.29	112.65	116.6	115.3	120.9	122.5
BSN NA-Decr-Marker1-130516112500	BSN1558	HARBOUR BRIDGE (EASTBOUND)	2 151 4.73	Increasing	Modular expansion joint	Asphalt	7	-37.674872	176.173168	85.56	1.53	0.15	15.48	1.49	76.62	115.5	113.8	119.6	120.2
BSN NA-Decr-Marker3-130516112500	BSN1558	HARBOUR BRIDGE (EASTBOUND)	2 151 4.73	Increasing	Modular expansion joint	Asphalt	7	-37.674982	176.176548	85.38	1.3	0.13	13.16	1.37	102.4	119.1	115.7	122.6	122.4
BSN1550-Decr-Marker6-130516112500	BSN1571	AERODROME BRIDGE (EASTBOUND)	2 151 5.94	Increasing	Bitumen filled gap	Asphalt	1	-37.66979	176.180105	66.49	1.06	0.13	10.77	1.33	37.08	112.1	107.2	115.0	108.8
BSN1550-Decr-Marker7-130516112500	BSN1571	AERODROME BRIDGE (EASTBOUND)	2 151 5.94	Increasing	Bitumen filled gap	Asphalt	2	-37.668947	176.18014	68.15	0.7	0.09	7.09	0.92	30.65	111.1	107.5	113.1	109.3
BSN1601-Incr-Marker1-130516121753	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Decreasing	Bitumen filled gap	Other	1	-37.71001	176.187655	88.9	0.64	0.1	6.48	1.02	146.93	124.5	116.9	127.6	120.5
BSN1601-Incr-Marker2-130516121753	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Decreasing	Bitumen filled gap	Other	2	-37.71001	176.187655	88.9	0.31	0.04	3.17	0.44	148.42	125.3	118.0	130.1	122.4
BSN1601-Incr-Marker3-130516121753	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Decreasing	Bitumen filled gap	Other	3	-37.70905	176.188268	85.19	1.71	0.14	17.37	1.4	168.84	122.3	116.0	127.5	119.5
BSN1601-Incr-Marker4-130516121753	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	1	-37.706275	176.190037	84.82	0.76	0.08	7.69	0.84	74.27	117.0	111.6	120.8	113.4
BSN1601-Incr-Marker1-130516122144	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	1	-37.706238	176.190092	81.67	0.77	0.09	7.78	0.89	91.33	117.8	112.5	122.6	116.6
BSN1601-Decr-Marker1-130516122023	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	2	-37.706838	176.189685	83.9	0.28	0.03	2.79	0.34	40.1	114.1	109.2	117.7	110.3
BSN1601-Incr-Marker2-130516122144	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	2	-37.706615	176.189843	84.27	0.52	0.08	5.3	0.78	63.41	115.4	109.8	118.2	110.7
BSN1601-Decr-Marker2-130516122023	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	3	-37.707592	176.189213	84.08	0.31	0.04	3.17	0.39	86.96	116.2	109.5	119.2	111.4
BSN1601-Incr-Marker3-130516122144	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	3	-37.707963	176.188985	86.67	0.3	0.06	3	0.57	41.27	115.5	109.4	118.9	110.1
BSN1601-Decr-Marker3-130516122023	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	4	-37.708903	176.188388	83.53	1.33	0.12	13.5	1.19	91.73	117.5	111.8	121.9	115.2
BSN1601-Incr-Marker4-130516122144	BSN1601	MAUNGATAPU BRIDGE	29 6 4.52	Increasing	Bitumen filled gap	Other	4	-37.70893	176.18838	85.93	1.26	0.16	12.8	1.67	80.25	117.6	111.4	120.5	113.7