aulos
ACOUSTICS

Arlington Works, Arlington Road, Twickenham, TW1 2BB

Environmental Noise & Vibration Assessment Report

11 July 2018

Arlington Works, Arlington Road, Twickenham, TW1 2BB

Environmental Noise & Vibration Assessment Report

Arlington Works, Arlington Road, Twickenham, TW1 2BB

Environmental Noise & Vibration Assessment Report

document control

Document Reference	Revision	Title & Revision Comment	Checked	Approved	Date
#0-1796 R2961-633	-	Environmental Noise & Vibration Assessment Report	JT	JT	10.07.2018
	a	Commercial alterations & comments	JT	JT	11.07.2018

Copyright statement

Arlington Works, Arlington Road, Twickenham, TW1 2BB

Environmental Noise & Vibration Assessment Report

Introduction

Aulos Acoustics has been appointed by Sharpe Refinery Service (Hydro-Carbons) Ltd to investigate the environmental noise impact of Arlington Works, Arlington Road, Twickenham, TW1 2BB.

The property is an operating waste oil recycling plant with additional workshops on site.

The current uses are noise-generating in an area of sensitive residential and commercial property, subject to noise from the primary industrial use, workshop noise and vehicles servicing the site. Vibration generation is generally restricted to goods vehicle movement.

The proposed development is for residential properties and small commercial/office units and includes full replacement of the current uses. The proposal includes retention and refurbishment of the existing Victorian cottages.

Residential uses are sensitive to sound and vibration and commercial/office uses may be moderately sensitive.

The application site is adjacent to a railway and some properties will be within 15m of the permanent way. Rail traffic is predominantly passenger trains with local and regional traffic of varying ages of rolling stock. Freight trains use the route on occasion. The track and trackbed appears to be relatively new and of continuous welded rail.

The application site is adjacent to the Twickenham Studios also. These can be sensitive premises although they are likely to have inherently good sound insulation to overcome prevailing ambient noise.

An investigation is required of the effect of noise and vibration on amenity of the future residential and commercial/office property nearby. Further investigation of the effects on existing residential and commercial/office property are required also. The principal sources of concern are:

- Railway
- Aircraft
- Commercial vehicles

The following reports the results and conclusions of the investigation made in accordance with local, regional, national requirements.

Prevailing Noise Climate

The prevailing noise climate affecting the neighbourhood and the application site is determined by railway noise. Aircraft noise will generate additional contributions to the noise climate. Road traffic noise is distant and relatively quiet.

Current uses permitted on site are capable of generating high levels of noise and moderate levels of vibration. These include workshop and industrial noise as well as the persistent continuous cycles of the oil recovery, recycling and tank farm. There are varying levels of goods vehicle traffic currently, which are understood to be relatively significant for a predominantly residential area.

The site is not quiet, in general, but there can be periods of low sound level between trains and aircraft, when workshops are inactive.

Prevailing Vibration Conditions

Vibration on site is generally determined by the railway traffic with perceptible vibration noted at the boundary and at certain locations on site.

Perception is of relatively minor to moderate magnitudes characterised by the passing speed of the trains. There does appear to be a characteristic “rocking” cycle to the felt vibration, probably due to movement over the sleepers and track bed.

Freight trains were noted and experienced, but these did not feel to be of significantly greater magnitude, although they were more persistent and continued for longer.

Other vibration experienced was due to vehicles crossing traffic management ridges at the entrances and where moving on irregular road surface. Vibration was transient and of moderate magnitude.

The reduction in vibration across the site appeared to be relatively rapid with distance from the railway.

Environmental Noise Survey

An environmental noise survey has been completed in general accordance with the requirements of the following documents:-

- BS 7445-1:2003 *Description and measurement of environmental noise. Guide to quantities and procedures* (1)
- BS 7445-2:1991, ISO 1996-2:1987 *Description and measurement of environmental noise. Guide to the acquisition of data pertinent to land use* (2)
- BS 8233:2014 Guidance on sound insulation and noise reduction for buildings (3)
- BS 4142:2014 Methods for rating and assessing industrial and commercial sound (4)

Measurements of the following sound pressure level (Lp) parameters has been completed:-

- Continuous equivalent sound pressure level — Leq,T
- Statistical Lp indices — L10, L50, L90
- Maximum Lp — Lmax

Primary frequency weightings are “A” and all time weightings are FAST. Secondary frequency weighting is “C”. Frequency band spectra have been measured and some measurements have

equivalent SLOW time-weighted results: these may not be reported and are normally for use in design or detailed analysis.

Continuous measurement:-

- Period of measurement, T, was notionally 15-minutes (900 seconds)
- Sample resolution, t, was 15 seconds
- A sample measurement is made and recorded every 15 seconds and the reference results reported for each 15-minute period. The result may be expressed as Leq,T(t) but normally omits the bracketed reference.

Normalisation may be applied for comparison in some circumstances, but if not stated then samples may be presumed to be part of a continuous signal suitable for direct comparison.

The recorded measurement positions are shown on the site measurement location plan 1796/SP1. These are described as follows:-

Position	Description	Source	Meter
M1	Boundary with railway. 3m above ground level. Approximately 2m above railhead. 7m from nearest rail.	Railway; distant road traffic; ambient; occasional aircraft	Norsonic 140 ID: 1664447

Monitoring Survey

Continuous measurements were made between 14:00h 4 June 2018 and 14:30h 6 June 2018 at Position M1.

Complete results have been obtained for these periods and analysed results are reported below.

Attended Periods

The site was attended principally at installation and removal of the equipment with additional periods in attendance for the vibration survey.

Vibration Survey

Vibration was measured on site also in general accordance with the requirements of the following documents:-

- BS 6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings – Part 1 Vibration sources other than blasting* (5)
- ANC Guidelines Measurement & Assessment of Groundborne Noise & Vibration (6)

Measurements of the following vibration parameters have been completed:-

- Vibration Dose Value [VDV]
- Acceleration

- Peak Particle Velocity

The VDV is the parameter of primary importance with respect to BS6472.

Where feasible, peak vibration frequencies have been measured and stored also.

Scanning times were determined by the fastest train pass-bys at approximately 5s. Periods of the VDV are defined by BS6472 as follows:-

- Day 16h 07.00-23.00h
- Night 8h 23.00-07.00h

All VDV are directly measured values in accordance with BS6472 and are, therefore, based on raw acceleration values measured and integrated directly by the vibration meter across the defined frequency range.

The recorded measurement positions are shown on the site measurement location plan 1755/SP1. These are described as follows:-

Position	Description	Source	Meter
V1b	Boundary with railway.	Railway Possible site lorries	Vibrock V9000 Serial #2155 for VDV / a
V1a	Same position; mounting position different		Vibrock V9000 Serial #2153 for PPV / a
V2	Boundary with Twickenham Studio at gate.	Railway Possible site lorries	Vibrock V9000 Serial #2153 for PPV / a

The vibration survey was undertaken in two stages:-

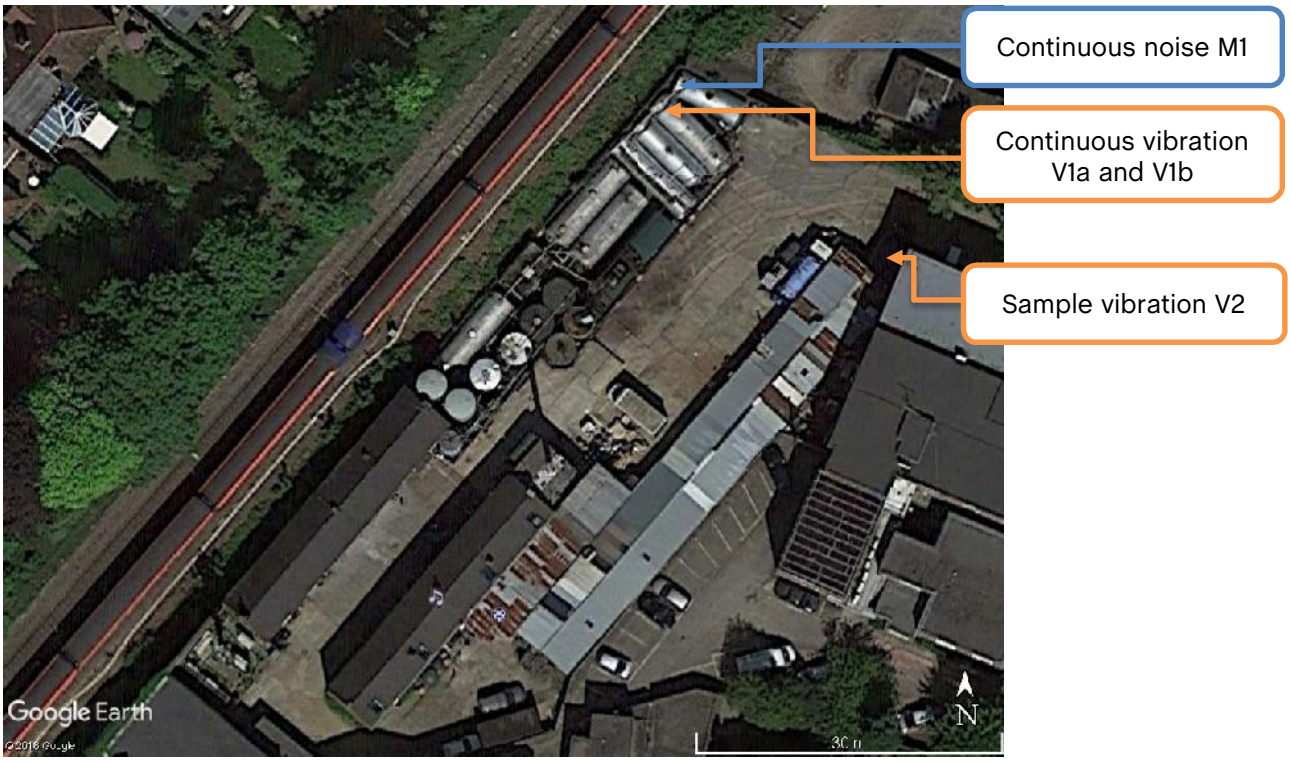
Position V1a	Twin-channel PPV/a transducers only	4 June – 7 June
Position V1b	Twin-channel VDV/a transducers only	8 June 14.14h – 12 June 09.29h

The survey recorded vibration levels from rail traffic at 7m from the railway. Transducers were mounted directly to the site concrete slab within the bunded area of the tank farm. Concrete was in good condition (i.e. not friable and no sound of blown substrate or hollows). There was some old cracking. For the purposes of this field survey, the slab may be considered to be in good contact with the ground due to the long term weight of the tank farm.

Transducers were mounted under sand to a mass of approximately 8kg each. Measurements remained consistent on both transducers at the start of logging.

Measurement Locations

All measurement locations are shown below.



Site Measurement Location Plan 1755/SP1

The results of the measurements and subsequent analysis are reported below and in

- Appendix D Sound
- Appendix E Vibration

Continuous Monitoring

Continuous monitoring results demonstrate the progression of outside sound level over time.

Time history graphs and standard period data have been generated for Position M1 and are reported in Appendix D.1.

The key standard period data reported here are as follows:-

Period, hh.mm	Description	Note	Sensitivity
07.00-19.00	Day		Moderate
19.00-23.00	Evening	Key Period	High
23.00-07.00	Night	Key Period	Very High
07.00-23.00	Day 16h		Moderate – High
24h 07-07.00h	24h		-
08.00-18.00	Working Day		Low – Moderate

Table 1 – Continuous Hours Periods

Position M1 – Boundary With Railway

The outside measurements at Position M1 are highly consistent and well-exposed to the railway noise.

Typically, the ambient sound levels $L_{Aeq,T}$ based on the 15-minute measurements are as follows:-

Period	1	2	3	
	Mon 04 Jun	Tue 05 Jun	Wed 06 Jun	
	LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	
07.00-19.00	70.2	69.9	69.8	dB
19.00-23.00	69.0	69.2		dB
23.00-07.00	65.0	65.0		dB
07.00-23.00	69.7	69.8	69.8	dB
24h 07-07.00h	68.1	68.7	69.8	dB
08.00-18.00	70.1	69.9	69.7	dB

Table 2a – Ambient Sound Levels Outside M1 Façade

The periods known to be exposed to railway noise are during the day and evening periods entirely and during the night for all except the “possession period” in the early morning.

The above are effective façade sound levels due to reflection from the tank farm and wall on which the microphone was mounted. They are at the nearest point to the railway.

The equivalent free-field values are notionally 3dB lower than the above as follows:

Period	1	2	3	
	Mon 04 Jun	Tue 05 Jun	Wed 06 Jun	
	LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	
07.00-19.00	67.2	66.9	66.8	dB
19.00-23.00	66.0	66.2		dB
23.00-07.00	62.0	62.0		dB
07.00-23.00	66.7	66.8	66.8	dB
24h 07-07.00h	65.1	65.7	66.8	dB
08.00-18.00	67.1	66.9	66.7	dB

Table 2b – Ambient Sound Levels Outside M1 Free Field

For the purposes of assessment, the reference sound levels outside free-field are:-

Day L_{day} 67dB
Evening $L_{evening}$ 66dB
Night L_{night} 62dB
Day 16h $L_{Aeq,16h}$ 67dB

The comparable minimum background sound levels are reported in Appendix D.1 also and are as follows:-

Period	1	2	3	
	Mon 04 Jun	Tue 05 Jun	Wed 06 Jun	
	LA90,T(15min)	LA90,T(15min)	LA90,T(15min)	
07.00-19.00	46.0	44.7	43.7	dB
19.00-23.00	41.7	42.7		dB
23.00-07.00	30.8	32.8		dB
07.00-23.00	41.7	42.7	43.7	dB
24h 07-07.00h	30.8	32.8	43.7	dB
08.00-18.00	46.0	44.7	43.7	dB

Table 2b – Background Sound Levels Outside M1 Free Field

Due to the diffuse nature of the background sound climate, reflection is unlikely to be a significant effect. The measured levels are stated as free-field background sound level.

The event sound levels are the maximum sound pressure levels derived from the measurement results. These are more important for consideration of night-time noise where event sound levels are high. In general, terms the typical range of sound levels tends to be within the 50th to 90th

centile range for railway noise. Higher maxima may be considered more unusual and less numerous and, so, will have less effect on changing natural night-time sleeping conditions.

The night-time event sound levels (façade) are reported in Appendix D.1. The typical reference values for consideration in assessment and design, adjusted to free-field, are as follows:

$L_{Amax,FAST\ 90\text{-}centile}$	86dB
$L_{Amax,FAST\ 50\text{-}centile}$	81dB
Standard Deviation	16.7dB
CI [95% confidence]	0.4dB

The observed source of event sound levels are the wheel-rail interaction, which is considered to be consistent with the small confidence interval and the consistency of the maxima. As the trains at this point are slow-moving there is a clear argument that wheel-rail noise is acting as a point source, due to the short sample time. Sound levels of trains over a longer period will act as a line source.

The SLOW time-weighted night-time event sound levels (façade) are reported in Appendix D.1. The typical reference values for consideration in local authority assessment, adjusted to free-field, are as follows:

$L_{Amax,SLOW\ 90\text{-}centile}$	84dB
$L_{Amax,SLOW\ 50\text{-}centile}$	80dB
Standard Deviation	17.0dB
CI [95% confidence]	0.3dB

Variation with Time

The time history of sound levels is reported in Appendix D. these graphs confirm a highly consistent sound climate over the measurement period.

Vibration

Continuous monitoring results demonstrate the progression of outside sound level over time.

The key standard period data reported here are as follows:-

Period, hh.mm	Description	Note	Sensitivity
23.00-07.00	Night	Key Period	Very High
07.00-23.00	Day 16h		Moderate – High

Table 3 – Vibration Periods

These are the defined time periods of BS6472 (5).

Time history graphs and standard period data have been generated for Position V1b and are reported in Appendix E.1. Direct measurement data is reported including weighted VDV and acceleration (using g as unit).

The data has been summarised in Appendix E.2 for the full time periods day and night, including the VDV, maximum peak particle velocity (PPV), acceleration and relevant frequency.

The highest VDV values are as follows for Position V1b:-

Complete Periods 8/06/18-12/06/18	**X / L**	**Y / T**	**Z / V**	
23.00-07.00	0.021	0.01	0.003	$ms^{-1.75}$
07.00-23.00	0.025	0.016	0.003	$ms^{-1.75}$
All Periods				
07.00-23.00	0.035	0.03	0.027	$ms^{-1.75}$

Table 4 – Vibration Dose Value V1b

Acceleration and Velocity values have been compared to V1a results for consistency and remain within the range of expectations, with the same or similar magnitudes of vibration. V1a results are not reported as these were not direct VDV measurements.

Operating frequency received was in the range 38.5-45Hz generally.

The equivalent maximum acceleration values directly measured were:-

Complete Periods 8/06/18-12/06/18	**X / L**	**Y / T**	**Z / V**	
23.00-07.00	0.72	0.44	0.49	ms^{-2}
Frequency	38.50	41.70	45.50	Hz
07.00-23.00	0.86	0.52	0.54	ms^{-2}
Frequency	41.7	50	50	Hz
All Periods				
07.00-23.00	0.86	0.59	0.72	ms^{-2}
Frequency	38.5	45.5	50	Hz

Table 5 – Acceleration V1b

The above are the measured results and are not adjusted for transfer functions within the building. Consideration of the expected transfer functions has been undertaken.

The proposed development substructure is expected to be formed of distributed piles and a ground bearing concrete slab. The superstructure is expected to be concrete as are the floors. The external walls are traditional masonry with steel internal frame.

The buildings are four-storeys high with the third floor being formed of a lightweight insulated cladding system externally.

The expected transfer functions are as follows:-

Ground to Substructure 0dB Equivalent to or better than current ground bearing slab

Substructure to Third Floor -6dB

Floor Resonance	+6dB	"Low frequency" structure
Total	0dB	

Substructure to First Floor	-2dB	
Floor Resonance	+6dB	"Low frequency" structure
Total	+4dB	

Adjustment of the directly measured VDV is not feasible, but given the general relationships between acceleration and VDV defined in BS6472-1, the potential for close to a doubling of VDV is high.

Groundborne sound is expected to be significant due to the transmitted and measured frequency range. The potential for exacerbating transmission is moderate to high due to the elements of steel framed walls (i.e. metsec) and cladding and frame at third floor.,

In addition, where the natural frequency may increase above 8Hz approximately then further resonant conditions and altered attenuation and amplification will occur.

Until such time as clear ground and foundation conditions are known, mitigation of groundborne sound and vibration is recommended.

Elevation Sound Levels

The equivalent sound levels at the elevations have been determined from drawing Ground Floor Site Plan 4786-3-10-P4.

The distance changes are determined with reference to the centre of the permanent way.

Elevation	**Distance, m**	**Change in Attenuation**		
Position M1	**9**	**Line**	**Source**	**Point**
Unit 1 NW	20.4	-4		-7
Unit 1 NE	24.3	-4		-9
Unit 2/3 NW	12.6	-1		-3
Unit 5 NW	12.2	-1		-3
Unit 5 SW	18.7	-3		-6
C1-C4 NW	8.8	0		0
C1-C4 SE	15.5	-2		-5
C5-C7 NW	23	-4		-8
Unit 21	30	-5		-10
Unit 22	37.6	-6		-12
	M	dB		dB

Table 6 – Change in Attenuation with Distance

The "worst case" residential units are Units 2, 3 and 5 facing the railway. The primary reference sound levels outside are expected to be as follows:-

Period	M1	Units 2/3/5 NW	Unit 5 SW	Unit 1 NW/NE	
	LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	
07.00-19.00	67	66	64	63	dB
19.00-23.00	66	65	63	62	dB
23.00-07.00	62	61	59	58	dB
07.00-23.00	67	66	64	63	dB
08.00-18.00	67	66	64	63	dB

Table 7 – Ambient Sound Levels at Elevations Free Field

The event sound levels are expected to be reduced to a greater extent by approximately 2-3dB for the elevations above.

Assessment Considerations

The planning policy framework under which the application site needs to be assessed is defined in the following documents for consistency across Local Planning Authorities:-

National Planning Policy

National planning policy relating to the effects of environmental noise is defined in:-

- National Planning Policy Framework (NPPF) (1)
- Noise Policy Statement for England (NPSE) (2) and Explanatory Note
- Planning Practice Guidance – Noise (7)

The NPPF states:-

11. Conserving and enhancing the natural environment

109. The planning system should contribute to and enhance the natural and local environment by:

- ...
- preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of soil, air, water or noise pollution or land instability; and...

110. In preparing plans to meet development needs, the aim should be to minimise pollution and other adverse effects on the local and natural environment. Plans should allocate land with the least environmental or amenity value, where consistent with other policies in this Framework.

123. Planning policies and decisions should aim to:

- avoid noise from giving rise to significant adverse impacts[27] on health and quality of life as a result of new development;
- mitigate and reduce to a minimum other adverse impacts[27] on health and quality of life arising from noise from new development, including through the use of conditions;
- recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established;[28] and
- identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason.

27 See Explanatory Note to the Noise Policy Statement for England (Department for the Environment, Food and Rural Affairs).
28 Subject to the provisions of the Environmental Protection Act 1990 and other relevant law.

Of particular importance are the constraints placed on development control by the need to ensure design and construction are sustainable.

The Noise Policy Statement for England (NPSE) describes both a policy vision and the following policy aims for the England only:-

Noise Policy Aims

Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- **avoid significant adverse impacts on health and quality of life;**
- **mitigate and minimise adverse impacts on health and quality of life; and •**
- where possible, contribute to the improvement of health and quality of life.

Planning Practice Guidance – Noise (PPG – Noise) provides guidance on the implementation and assessment of these policies as well as particular guidance on the subjective and objective implementation of Observed Adverse Effect Levels.

The descriptions of subjective impact and effect are helpful in providing a clear means of comparison as follows:-

Perception	Examples of outcomes	Increasing effect level	Action
Not noticeable	No Effect	No Observed Effect	No specific measures required
Noticeable and not intrusive	Noise can be heard, but does not cause any change in behaviour or attitude. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.	No Observed Adverse Effect Level (NOAEL)	No specific measures required

		Lowest Observed Adverse Effect Level (LOAEL)	
Noticeable and intrusive	Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
		Significant Observed Adverse Effect Level (SOAEL)	
Noticeable and disruptive	The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant Observed Adverse Effect	Avoid
Noticeable and very disruptive	Extensive and regular changes in behaviour and/or an inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory	Unacceptable Adverse Effect	Prevent

Due regard is given to the Standards and guidance available at present relating to noise, particularly noise affecting residential property and other sensitive buildings.

The over-riding principles of the above documents is:-

- Avoid significant effects or impacts (greater than or equal to SAOEL)
- Mitigate and minimise other effects or impacts (greater than LAOEL)
- Protect areas of tranquillity, low noise level, quiet areas (less than LAOEL)

Wherever possible, the noise climate shall be improved and advantage taken of opportunities to do so.

The London Plan and Ambient Noise Strategy are not expected to require any assessment other than those needed to meet national and local requirements.

Local Planning Requirements

Sound is assessed in London Borough of Richmond Upon Thames with reference to the Supplementary Planning Document Noise Generating and Noise Sensitive Development.

The SPD is intended to implement the requirements of the NPPF, NPSE and PPG Noise and support local policy.

The concept of a Noise Risk Category (NRC) is implemented although it should be noted there is not universal support for the concept or boundary values used in NRC ranges.

The Noise Risk Categories are as follows:-

External Transportation Noise Risk Assessment (measured/predicted, empty site, pre-mitigation)

Noise Risk Category*	Potential Effect if unmitigated	Pre-Planning Application Guidance
0 – Negligible $L_{Aeq,16hr}$ < 50dB $L_{Aeq,3hr}$ < 40dB	No adverse effect on health and quality of life	Development proposal is likely to be acceptable from a noise perspective. Noise assessment /report required to demonstrate no adverse impacts Good acoustic design encouraged to improve existing environment
1 – Low $L_{Aeq,16hr}$ 50-63dB $L_{Aeq,3hr}$ 40-55dB	Adverse effect on health and quality of life	Noise environment likely to cause adverse impacts Noise assessment /report required to demonstrate how adverse impacts will be minimised and how good acoustic design will be implemented. Planning conditions and other measures to control noise are likely to be required.
2 – Medium $L_{Aeq,16hr}$ 63-69dB $L_{Aeq,3hr}$ 55-60dB L_{ASmax} <82dB	Significant adverse effect on health and quality of life	Noise environment likely to cause significant adverse impacts and development may be refused unless Noise assessment /report required to demonstrate how significant adverse impacts will be avoided and other adverse impacts minimised and how good acoustic design will be implemented Planning conditions and other measures to minimise noise will be necessary.
3 – High $L_{Aeq,16hr}$ > 69dB $L_{Aeq,3hr}$ > 60dB L_{ASmax} <82dB	Unacceptable adverse effect on health and quality of life	Noise environment likely to cause unacceptable adverse impacts and development likely to be refused even if a good acoustic design process is followed, unless there is an overriding case for development in the context of Government policy on sustainable development.

Following the NRC assessment there is a defined assessment process which includes internal and external design criteria.

The internal design criteria are those of BS8233:2014 with defined requirement for control of maximum sound pressure level as follows:-

Table 1: Internal Ambient Noise Levels for Dwellings

Situation	Location	07:00 – 23:00 hrs.	23:00 – 07:00 hrs.
Resting	Living room	35 dB LAeq,16 hour	-
Dining	Dining room/area	40 dB LAeq, 16 hour	-
Sleeping (daytime resting)	Bedroom	35 dB LAeq,16 hour	30 dB LAeq, 8 hour
Sleeping	Bedroom	-	45 dB LAMax (several times in any one hour)

(Source: BS8233:2014, page 24, Table 4 "Indoor Ambient Noise Levels")

The external amenity spaces have defined sound levels also where the normal desirable conditions of BS8233:2014 are defined. The SPD does specifically state a target daytime sound

level in amenity spaces of $L_{Aeq,16h}$ 55dB or less. The SPD also recognises the need for relaxation or omission of such targets in cases where there may be wider planning objectives, for example, and states:

"... It is accepted that, in some circumstances it may be appropriate to vary, or not to apply, these goals in order to meet wider planning objectives. ..."

The SPD then refers to the specific guidance of BS8233:2014 (Section 7.7.3.2 Design criteria for external noise), which provides further clarification.

Vibration

Section 9 of the SPD defines the vibration assessment requirements and requires assessment in accordance with BS6472 (5) and compliance with the following Vibration Dose Value limits.

Table 7: Residential Development - Vibration Dose Values

07:00 – 23:00 16 hour day	23:00-07:00 8 hour night
< 0.2 ms-1.75	< 0.1 ms-1.75

These apply at any resident position within the completed building.

The above are the lower bounds of the BS6472-1:2008 Table 1 Vibration dose value limits equivalent to a "low probability of adverse comment". They apply over a full period and are, therefore, cumulative values determined by the highest magnitude and longest duration events.

Peak or highest magnitude vibration criteria are undefined.

Supporting Guidance

The key documents used to determine reasonable criteria and observed effect levels for noise in general are as follows:-

- BS8233:2014 *Sound insulation and noise reduction for buildings-Code of practice* (3)
- *Guidelines for Community Noise.* World Health Organization, 1999 [WHO1999] (3)

Where there are specific sources of noise to take into account other information becomes more relevant. For example, road traffic noise consideration should be guided by the Design Manual for Roads and Bridges (7).

Wherever possible, the use of different effect levels is made, whether based on social surveys of annoyance (e.g. DMRB), established dose-response relationships (e.g. community annoyance outside) or design and construction good practice (e.g. "reasonable" to "good" design range of BS8233).

Less regard is given to assessment methods purporting to represent an objective means of assessing risk of impact or effect on the basis of comparisons to background noise (e.g. BS4142 (4)). The evidence base for these methods is limited and often they do not provide reasonable

correlation with better-supported, noise level threshold methods. It remains relatively easy to "fail" these comparisons, whilst achieving acceptably low sound levels inside.

The preferred basis of assessment for most noise sources is by:

- Absolute sound level of introduced source , LAeq,T
- Cumulative sound level of all sources, LAeq,T
- Change in sound level, ζLAeq,T

Where T is the assessment period most representative of the noise climate and/or the introduced noise source. For example, industrial noise assessment would use a time period relevant to the process operation being considered.

Environmental Noise Assessment

The measured daytime and night-time sound levels indicate a Noise Risk Category 2 site for most elevations and most periods.

The exceptions is the north-west elevation of Units 2 and 3, which may have sound levels 1dB greater than the boundary values of NRC3.

With localised effects of building screening, such as the plane of the façade and the balconies, the small exceedance is likely to be eliminated. The noise exposure at the elevations are expected to be manageable within the scope of a high performance sound insulation scheme.

Openable windows as the sole means of ventilation are not feasible, therefore, whole-flat ventilation schemes will be implemented to ensure effective choice for the residents.

The external sound levels are such that the desirable criteria cannot be attained outside on balconies. The nature of the railway noise source is such that annoyance is less likely to be an issue than for other transportation. The elective use of these areas is also a key mitigating factor.

Mitigation to provide reduced exposure of the balcony elevations and screening of the balconies themselves is proposed and set out below.

It is noted there are several public areas and parks expected to provide lower sound exposure in the area including Marble Hill Park and the wider riverside areas.

With sufficient mitigation of the balconies, there would be a reasonable level of sound exposure on the north-west elevation.

Vibration Assessment

The directly-measured VDV defines values which are well below the SPD limits and the range of low probability of adverse comment.

Even with amplification by the building to the middle floors, these should remain acceptable.

The degree of uncertainty is high, however. Some individual movements generate higher levels of vibration than most. In addition, there is expectation of re-radiated noise being relatively prevalent across the north-west side of the site.

Mitigation is proposed to address the latter due to the prevalent perceptible vibration experienced on site. There is clearly a dominant 40-50Hz signal, which is well within the audible range.

The transfer conditions during measurement risk understating the vibration magnitude in the opinion of the author. The experience of conditions on similar sites indicates that higher VDV values should prevail. The difference in these circumstances is the location of transducer on existing structure.

The combination of altered foundation conditions and amplification in the structure is sufficient to require caution. It is proposed therefore, that mitigation be included within the substructure provisionally, in the form of wide area isolation of the ground bearing slab and pile head isolation. Lateral isolation of any downstands, basements or pits will be required also. Further definition is provided in the mitigation section below.

The specific requirements for mitigation would be confirmed at an early stage in the project by direct measurement of exposed ground conditions and test piles. Accuracy levels would be increased during these measurements, as required for effective design of building isolation.

There remains a possibility that vibration is of the low magnitudes measured here, in which case isolation would be omitted.

External Sound Insulation

The external sound insulation of a building is not defined as a regulatory or statutory requirement.

Best practice design will be applied in accordance with the requirements of the national planning guidance.

Design Mitigation

The overall building design incorporates the following direct measures for mitigation of noise exposure:-

- Buffer zone incorporated in form of separation from railway
- Expressed and profiled elevation providing potential for reduced view of railway
- Units 1, 4, 21 and 22 set back from railway
- Primary orientation of these blocks away from railway
- Acoustically-rated windows and doors to ensure control of weakest elements of the envelope
- Consistent construction to non-vision elements to maintain high standard of sound insulation throughout
- Controlled ventilation scheme by the provision of ducted, mechanical system, or similar, serving all habitable rooms and maintaining varied duty dependent on solar gain expected

- Ability to close the building envelope when needed without loss of air quality or temperature including control of solar gain
- Omission of weak and acoustically-limited direct ventilators, including “trickle” or straight-through vents in windows and doors
- Inclusion of whole-house balanced ventilation system with heat recovery and openings to quiet, points on building where feasible

These included elements of the design will ensure the moderate to high levels of noise are adequately controlled at all times.

Ventilation Assessment

As indicated above, natural ventilation using open windows is unlikely to be viable during the most critical residential use or activity or on the most exposed elevations. Residents may accept these conditions in some circumstances, but allowance needs to be made for reasonable noise control and an effective choice to close windows.

Noise mitigation measures are proposed to ensure scheme provides the requisite standard of sound insulation and an environment consistent with other recent residential developments.

In accordance with BS8233:2014 an alternative scheme of ventilation will be provided to ensure closing the windows does not preclude the required standards of ventilation [See Note 5 Table 4 of BS8233:2014 (3)].

The means of achieving such ventilation will need to take into account The Building Regulations and the implications of the sustainable building design. Allowance should be made for variable solar and heat gain on the building.

The sound insulation requirement is moderate to high when considering the worst case. The prevailing means of providing high sound insulation of the ventilation is a mechanically-assisted scheme such as MVHR units in each flat with additional attenuators. Such units are to be included in the proposed design.

We recommend “trickle” and other straight-through ventilators are omitted and ventilation is provided by alternative routes as these enable optimisation of window and door sound insulation.

Ventilation openings at the roof are acceptable and routing of other ducts to the rear is to be encouraged (away from railway noise).

Acoustic Performance – Ventilation

Acoustic performance shall be as follows for the ventilation scheme if mechanical balanced system utilising fully-ducted supply and extract.

It is estimated that a minimum weighted normalised element level difference, $D_{ne,w}$ of 43dB is required, but critically the following specification minimum normalised element level difference, Dne, shall apply:-

Reference	f, Hz	125	250	500	1000	2000	4000	
VE1 (low performance)		34	39	34	41	31	28	dB
VE6 (moderate performance)		42	43	43	49	54	54	dB

Table 8 – Minimum Normalised Element Level Difference

Reference shall be made to Appendix F for the location of VE6 specification ventilation systems.

In practice, this will be a combination of external ventilation attenuation to control secondary ingress and duct breakout noise, and central MVHR unit / continuous extract with attenuation. The final achieved performance will be a matter of detailed design but allowance shall be made for an exhaust and intake opening for each unit (i.e. for each flat) preferably shielded from the railway, where practical.

The maximum noise emission limits inside recommended for the equipment and the system are as follows:-

Elevation	Speed	Background (minimum) dB(A)	Low dB(A)	High dB(A)	Purge / Boost (maximum) dB(A)
Casing Radiated ‡	LAeq	30	35	40	45
Habitable Sleeping †	LAeq	20	25	30	35
Habitable Non-sleeping †	LAeq	25	28	33	38
Occupied Non-habitable †	LAeq	30	31	36	41
Non-habitable (maximum) †	LAeq	35	40	45	50
Conditions		Normal Range		Summer Range	Exceptional & Emergency

Table 9 – Mechanical Equipment Noise Limits Inside

Note: The above maximum noise limits take into account the expected noise intrusion levels. Standard systems may require adjustment and attenuation treatment .

† @1m from terminal grille in room

‡ @1.5m from casing Located in cupboard adjacent to non-habitable room

The proposed scheme will provide an effective means of acoustically-treated ventilation to ensure the windows may be closed and the air quality and fresh air ventilation will be maintained.

The method of ventilation may be subject to change under detailed design requirements but will require acoustic treatment of openings, ducts and ventilation units, as applicable.

Openable windows are not excluded and will be available for use by future residents to take advantage of quiet periods if so required.

The scheme includes for comprehensive mechanical ventilation systems, or similar, for each flat to enable choice of open windows or mechanical ventilation. The continuous use of MVHR units or similar is an effective means of ventilation when used and maintained in accordance with operating instructions.

Building Envelope Sound Insulation

To achieve the requisite standard of internal noise of LAeq,16h 35-40 dB daytime and LAeq,8h 30-35dB night-time, the following sound level differences are required for the complete building envelope.

Period		Units 2/3/5 NW	Unit 5 SW	Unit 1 NW/NE	
		LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	
		D	D	D	
23.00-07.00		26-31	24-29	23-28	dB
07.00-23.00		26-31	24-29	23-28	dB

Table 10 – Sound Level Difference Required

In addition, control of typical maximum sound pressure levels are required to a reasonable level, based on the LBRuT SPD. The typical night-time range during railway activity periods at Units 2, 3 and 5 is expected to be $L_{Amax,FAST}$ 78-83dB. To attain $L_{Amax,FAST}$ 45dB, as defined, a level difference of 33-38dB is implied for bedrooms.

Such bedroom sound insulation is at the upper range of what is provided within the majority of residential developments, but is feasible.

Implicit in the above results is the potential for different sound insulation systems on each elevation to treat bedrooms and other habitable rooms. Only on elevations facing away from the railway or located at significant distance from it would a common system be feasible.

A modern thermal double or triple glazed system built in conjunction with broadly traditional wall materials will be sufficient to treat the much of the south-east elevations and Units 4, 21 and 22.

Performance will be determined by the lower and mid-frequency noise.

General Construction Approach

Typical thermal double glazing with some acoustically-designed elements will achieve in excess of 25dB(A) level difference. A heavily enhanced standard of sound insulation is required overall for the loudest elevations for bedrooms.

Thermal double glazing incorporating acoustically-laminated panes, Argon-cavity and high quality seals to opening sections would be required for the windows and doors to outside on exposed elevations.

Any module should aim to incorporate panes of different thicknesses / mass of at least 50%. Triple glazing may be deemed beneficial but is not an acoustic requirement.

Frames are to incorporate thermal and acoustic separation and damping and to achieve mass and damping performance at least equivalent to glazing. Sealing and openable sections to incorporate double airtight seals and compression. Use of sliding doors or low quality casements may not be adequate.

It must be noted the above glazing systems require final selection and moderation of the design would be expected. Critically, there are limitations with respect to thermal insulation and sustainable design and construction which may limit the sound insulation available.

Consequently, it is strongly recommended that a lower limiting sound insulation level difference of 40dB(A) for bedrooms at night and 30dB(A) for living rooms be applied where attainable when balanced against other design requirements. These lower limits apply on the most exposed elevations only.

The probable minimum construction range on the most exposed elevations for bedrooms would be represented by a system similar to:-

- 10-13mm acoustic-PVB-laminated glass (e.g. Pilkington Optiphon, etc.)
- 16-24mm Argon-filled cavity thermal & acoustic separation
- 8-9mm acoustic-PVB-laminated glass (e.g. Pilkington Optiphon, etc.)

The probable minimum construction range on the most exposed elevations for other habitable rooms and, potentially, connected rooms to bedrooms (i.e. ensuite bathrooms) would be represented by a system similar to:-

- 8-9mm acoustic-PVB-laminated glass (e.g. Pilkington Optiphon, etc.)
- 16-24mm Argon-filled cavity thermal & acoustic separation
- 6-9mm standard PVB-laminated glass (e.g. Pilkington Optiphon, etc.)

NB: Laminated glass thicknesses above are not stated precisely and some variation may be achievable. See the minimum performance requirements below.

On less exposed elevations systems construction would be represented by:-

- 10mm float glass / or laminated panes
- 16mm Argon filled cavity thermal & acoustic separation
- 6.4mm PVB laminated glass

Specific determination of performance requirements for less exposed elevations has not been completed at this stage.

Further moderation of the systems used may be feasible on less exposed third floor elevations, but not elsewhere.

An internal ambient noise climate much quieter than the BS8233:2014 Table 4 criteria would be expected to result.

The individual noise events, based on typical, night-time maximum sound pressure levels, would be expected to attain the BS8233:2014 Table 4 criteria. Sound levels would be below $L_{Amax,FAST}$ 45dB for approximately 90% of the night-time events and, so, would be unlikely to exceed this level more than “several” times in any night-time hour.

To ensure these conditions are achieved, the external walls and roof would need to maintain a high sound insulation performance throughout. The final construction will be determined by detailed design, but the following allowances have been included.

The preliminary allowances for the walls are:-

- High mass cladding (i.e. exceeding 40kg/m^2 as sheet materials) or outer masonry skin 103mm traditional clay brick or equivalent high mass rendered panel
- 100mm or greater cavity
- Thermal-acoustic insulation
- Acoustic cavity fill of mineral fibre
- Airspace – 50% of acoustic cavity fill depth

Plus either:

- Interstitial layer of 12mm cement bonded particle board
- Metsec frame
- Acoustic cavity fill of mineral fibre (exposed to plasterboard lining)
- Airspace – 50% of acoustic cavity fill depth
- Acoustic resilient clip to inner face of frame
- Two layers of plasterboard staggered and sealed or equal mass of plywood / plasterboard

Or:

- Internal masonry or concrete skin of at least 250 kg/m^2 and higher if plasterboard on dabs or lightweight separating floor/wall construction

Further moderation of the systems used would be feasible on less exposed north-east, south-west and south-east elevations and at third floor level, but not elsewhere.

Lightweight outer cladding sections, where applied, will require significant treatment to attain equivalent performances to the masonry systems or masonry + sheathed frame systems.

Roofs will require equivalent performance to the walls on exposed cladding sections, but some moderation is allowable where roofs are out of sight of railway or slightly screened by parapets.

The ceiling should have a resiliently-bonded perimeter seal over each room. No internal or separating walls should be in direct contact with the ceiling frame or soffit (e.g. resilient contact details only).

An internal noise climate equal to or slightly better than the BS8233:2014 Table 4 criteria would be expected to result.

The final construction will be determined by detailed design, but the following allowances have been included.

The worst-case sound insulation performance requirements have been considered for bedrooms and the living space at first floor on key elevations (north-west). These are considered to be representative of worst-case noise-exposure.

The model calculations of façade sound insulation are provided in Appendix E.

All elements of the walls and windows would be provided with performance substantiation by means of laboratory-tested construction for the complete building element. Test data of components is not an acceptable means of substantiation (e.g. glass performance for windows).

The following minimum sound reduction index, R, performance shall be achieved for the different components and systems of the building envelope.

Reference	f, Hz	125	250	500	1000	2000	4000	
Windows, Doors, Vision								
GWN2 (high performance)		31	37	43	42	46	43	dB
GWN39 (moderate performance)		26	27	34	40	38	46	dB
Walls & Cladding, Non-vision								
EW41 (high performance)		41	48	54	59	60*	60*	dB
Roofs - Non-vision								
RF1		27	37	43	48	52	50	dB

Table 11 – Minimum Sound Reduction Index – Most Exposed Elevation(s)

** Predicted values have been limited to no greater than 60dB to allow for construction variation and flanking limitations.*

The location of windows will need refinement during technical design, but GWN2 applies to worst-case bedrooms on north-west elevation and GWN39 applies to other rooms in dwellings on the same elevation. As an initial allowance, the flank elevations of the larger block should follow the same performance.

It is probable that the smaller block and the south-east elevation of the larger block will be able to use GWN39 windows on all elevations.

The wall sound insulation requirement is relatively high due to the position of the main source and height of the building. It is strongly advised that no direct or indirect connections from outside to the flats are made, including rooflights, ventilation ducts and risers, air conditioning routing, other common service risers and escape routes.

The above estimated performance shall be confirmed during technical design, but will not be reduced unless there is a variation of more than 2dB in requirement for different rooms.

Resultant Internal Sound Level

The above performance would be expected to result in internal sound level equal to or less than those defined in BS8233:2014 Table 4. Maximum sound pressure levels are expected to be equal to or lower than 45dB typically, at the worst case elevation.

Internal Sound Insulation

Sound insulation between dwellings shall achieve at least the requirements of The Building Regulations as defined in Approved Document E.

Location of Rooms

The design allows for optimisation of the general layout of the proposed flats within the limitations of the building and stacking is positive.

Operation of Building

The critical function of the sound insulation and ventilation scheme will be to ensure the windows may remain closed during loud periods of external noise.

The ventilation scheme will need to provided high standards of ventilation fully-compliant with an acceptable scheme under Approved Document F.

MVHR systems are acceptable ventilation methods, but these are not the only options.

Outcome

The general allowances for construction included here and in the design are of moderate acoustic performance and area expected to provide adequate internal sound levels as follows. The outcome for a nominal living space with moderate performance windows on the most exposed elevation is shown also, for comparison:-

Period	Bed	Bed	Nominal Living/Bed	Nominal Living/Bed	
23.00-07.00	21 (45)	22 (46)	26 (53)	28 (54)	$L_{Aeq,T}$ dB(A)
07.00-23.00	26	27	- (31)	- (32)	$L_{Aeq,T}$ dB(A)
Elevation	NW	NW	NW	NW	
Nominal windows	GWN2	GWN2	GWN39	GWN39	

Table 12 – Internal Ambient Sound Level

(35) maximum event sound level on elevation with control of ventilation system, i.e. using high attenuation ventilator

The above comply with the performance guidance of BS8233:2014 and avoid significant adverse effects on future residential amenity.

Any adverse effects are expected to be minor as all normal domestic activity will be protected from interference or disturbance. Annoyance is expected to be maintained at a reasonable level provided future residents have the ability to control noise ingress and maintain their internal environment.

Outside Amenity Space

Where outside space serves a wholly private or traditional amenity function, the objective should be to ensure that the probability of annoyance due to noise is as low as possible.

The general aim is to meet the "desirable" limit of LAeq,16h 50dB outside for such spaces and not exceed 55dB as an "upper limit" [BS8233:2014 clause 7.7.3.2].

The same section of BS8233:2014 recognises that sound levels cannot always be achieved on balconies and in urban areas, for example.

The full exposure would be expected to result in daytime sound levels of 66dB.

The balconies and the elevations in general have projected elements including both the sides and front balustrades. The stair cores also project forward of the elevation. These will reduce both the angle of view and screen noise to a degree.

With solid sides and an imperforate screen to the front of the balconies, noise exposure at each is expected to be reduced to approximately 58dB comprising

Angle of view attenuation	-6dB (25% compared to M1)
Façade shape correction	-2dB (minimum – may reach -3dB to -4dB in some locations)

The soffit of each balcony will need to be solid and treated with a sound absorbent panel of Sound Absorption Class A or B.

The side panels will need to be full height within each balcony and have a mass per unit area of at least 10kg/m^2.

The front balustrade will need a continuous and imperforate panel, cladding or wall with a mass per unit area of at least 12kg/m^2.

Gaps should be sealed.

NB: Alternative treatment of the balconies is feasible to enclose them a "winter gardens", but is not currently proposed. Only by enclosing balconies, even if screens were openable, would be able to attain markedly lower sound levels.

It should be noted that enclosing balconies would reduce the construction and performance specification for the windows of adjoining rooms.

Given the elective nature of balconies and their perceived desirability, sometimes despite very high sound levels, such reasonable conditions are acceptable. Approximately 50% or more people would be expected to report the achievable sound levels as good conditions.

Balconies on the south-east (front) elevation would be expected to achieve daytime ambient sound levels of 50-55dB due to distance and building screening attenuation.

Balconies on the north-west elevation of the Small Block would be expected to achieve daytime ambient sound levels of 52-55dB due to distance, angle of view and façade shape / screening attenuation.

Whilst measured Vibration Dose Values are below the required limits for residential development stated in the LBRuT SPD, there is a probability of amplification in the structure and ground-borne noise is expected to be perceptible.

In addition, individual train movements are indicating moderate and perceptible vibration, which is a cause for caution.

The measurements were made on existing ground-bearing concrete. The conditions of measurement were acceptable, but on forming a new piled sub-structure and ground-bearing slab conditions are at risk of change.

To overcome potential amplification and groundborne noise, a provision for vibration isolation has been recommended.

Under the current proposals, this may take the form of:-

- Wide area isolation layer to ground bearing slab
- Pile head/footings lateral isolation
- Pile head/footings horizontal isolation
- Lateral area isolation to any formed pits, basements or other changes in level of main slab
- Secondary isolation to junctions with ground at walls, services and access points

The lowest common forcing frequency of railway movements is 38Hz. Forcing frequency is generally in the range 40-50Hz.

To ensure effective isolation a maximum natural frequency of 8Hz shall be sought for the building isolation.

The above necessitates engineering design measurement on site when trial pits and piles are formed. These will enable the accurate design and selection of building isolation methods and materials.

These may also enable elimination of building isolation requirements where the ostensibly low magnitude vibration can be confirmed.

Commercial Use

The current commercial use was not highly active during the noise and vibration survey.

Activity could not be separated from the more prevalent railway movements.

The removal of an industrial and light industrial site from an area of sensitive buildings, including dwellings and Twickenham Studios, is an improvement to the noise climate. Workshops, including two car body workshops, will be removed in favour of residential and commercial/office premises. Goods vehicle movements, some of which are large and medium vehicles, will be

reduced to the less problematic scale needed to service dwellings and commercial/office premises.

Whilst the exact degree of improvement is not quantifiable, such improvements are only rarely attainable and must be considered positively in the context of current planning policy encouraging such improvements.

The commercial/office premises will require sound insulation mitigation to a similar standard as that required for living rooms during the day. The provision of similar cladding and window/door performance is advisable, although the final performance will be subject to technical design.

Window / door performance should exceed Weighted Sound Reduction Index Rw 35dB on exposed elevations.

Cladding / wall and roof performance should exceed Weighted Sound Reduction Index Rw 47dB on exposed elevations.

The provision of a closed ventilation system is recommended also to maintain internal sound levels expected of modern offices. Air conditioning may be needed, but is not included as part of the assessment.

Vibration isolation of the premises is unlikely to be necessary. Vibration Dose Value ranges of acceptability are approximately twice those for residential. Provided the engineering design measurements confirm test pit/pile vibration magnitudes as currently expected, isolation would not be needed.

NB: Protection against individual trains and groundborne noise may be deemed prudent and no analysis of structural amplification has yet been completed. If included then a similar standard of isolation would be required as recommended for the dwellings. Retained buildings are more difficult to isolate and may require floor replacement and wall lining, if needed at all.

Planning Assessment

With the requisite mitigation measure, Significant Adverse Effects would be avoided in accordance with the requirements of national, regional and local planning policy.

Reasonable noise exposure in private, outside amenity space is feasible provided a degree of screening and restricted view of the railway is implemented.

Ground-borne vibration and noise is ostensibly acceptable, but to ensure conditions remain so following implementation of a new substructure, building isolation is currently proposed.

Detailed engineering measurement is required at trial pit and pile stage to ensure accurate conditions are incorporated into the design.

Elimination of building isolation may be feasible only if current vibration magnitudes are confirmed and noise is low.

The removal of the current, wholly industrial / light industrial commercial use represents a positive benefit for the local area. The inclusion of some commercial/offices is unlikely to lead to significant noise in comparison. The removal represents a rare opportunity to improve the noise climate.

Conclusions

Aulos Acoustics has completed an investigation of the environmental noise and vibration exposure expected of the application site at Arlington Works, Arlington Road, Twickenham, TW1 2BB.

The Local Planning Authority is LB Richmond Upon Thames. The investigation has taken due account of the national, regional and local planning policy relating to noise affecting the amenity and use of neighbouring sensitive buildings, including residential buildings.

The application site is a potential noise-sensitive use requiring an investigation of the effect of noise impact on amenity of future residents.

An environmental noise and vibration survey was completed and is reported herein.

The ambient noise levels are moderate to high. These will be reduced at the proposed building elevations due to distance, reduced angles of view to the road, façade shape and building screening. Despite this positive situation, ingress through open windows would cause recommended noise limits to be exceeded.

A noise mitigation scheme is required which will include an alternative means of ventilation to open windows.

The sound intrusion to key room types on the most exposed elevation has been examined and minimum sound insulation requirements determined. Comparison has been made with typical, representative construction systems and performance calculated. (see Appendix F).

High sound insulation performance systems are capable of providing reasonable internal sound levels during day and night. Moderate performance systems may be used in living rooms and rooms connected to bedrooms.

The expected outcome of noise mitigation is a range of internal noise levels as follows:-

Period	Bed	Bed	Nominal Living/Bed	Nominal Living/Bed	
23.00-07.00	21 (45)	22 (46)	26 (53)	28 (54)	$L_{Aeq,T}$ dB(A)
07.00-23.00	26	27	- (31)	- (32)	$L_{Aeq,T}$ dB(A)
Elevation	NW	NW	NW	NW	
Nominal windows	GWN2	GWN2	GWN39	GWN39	

Table 13 – Internal Ambient Sound Level

(35) maximum event sound level on elevation with control of ventilation system, i.e. using high attenuation ventilator

Once treated as defined, the above internal sound levels comply with the guideline noise limits of BS8233:2014.

The achieved performance above complies with the performance guidance of BS8233:2014 and avoid significant adverse effects on future residential amenity. The LBRuT target for night-time event sound levels will be achieved for the vast majority of the period (i.e. approximately 90-95% of the events below the target).

Any adverse effects are expected to be minor to negligible as all normal domestic activity will be protected from interference or disturbance. Annoyance is expected to be maintained at a

reasonable level provided future residents have the ability to control noise ingress and maintain their internal environment.

Groundborne vibration and noise is expected to be of low magnitude and meet the LBRuT target, based on the results of the survey.

Potential changes in ground, substructure and amplification conditions has the potential to increase noise and vibration to the point of minor impact. Caution is recommended in the context and a building isolation system has been proposed as a provisional item within the design.

Detailed investigation of final ground and pile conditions is recommended to confirm or eliminate the building isolation.

In addition to the protection of future residents, the development is expected to result in positive change in ambient noise due to the removal of light industrial and industrial noise sources.

Such effects represent an unusual opportunity to improve the acoustic environment.

The minimum sound insulation requirements have been calculated and are reported above. These are of high to moderate, performance but will still require careful design, specification and construction.

Technical design and product selection will enable development of the precise scheme of sound insulation and allow a full substantiation process to take place.

The building envelope, internal construction and finishes are all subject to detailed, technical design. These integrated elements will be designed to achieve the requirements of The Building Regulations and, where appropriate, other environmental or sustainability requirements.

The design shall achieve the external sound insulation requirements defined within this Report.

Significant variations due to construction degradation are not expected and have been allowed for in calculation of minimum performance, which is provided in more detail within the report.

Outside space is expected to provide a reasonable environment due to the benefits of façade shape and restricted open view of the railway. Specific mitigation measures have been recommended to optimise noise exposure at the balconies.

The overall impact assessment for the site concludes that, with the mitigation in place, the proposed development would have no significant adverse effect on future residents.

Significant adverse effects on residential amenity would be avoided. Other adverse effects are minimised by providing adequate sound insulation and alternative ventilation to open windows. The acoustic environment at existing residential property and the adjacent studios would be improved. The requirements of national, regional and local planning policy are achieved.

James Tomalin MIOA

Appendix A- Glossary

Term	Description	
Sound	Physical oscillation of air or other material which is normally detected by the ear as a complex, time-varying and detailed description of the environment around the listener. Interpretation and subjective filtering of sound by the brain results in comprehension, emotional response and physical reactions to sound. Sound can also be detected by touch when transmitted in a solid medium and be perceived as motion at very low frequencies (i.e. vibration).	
Noise	Generally defined as unwanted sound, which as a highly subjective description is subject to wide interpretation. Some describe noise as harsh or dissonant conditions, but such descriptions tend to be value-based and will vary from person to person.	
Ambient Noise	The noise climate heard over a period of time due to all normal sources, in the absence of extraneous or atypical sounds. Used to describe noise in the absence of the introduced sound, generally.	
Ambient Noise Level	Describes the average noise level of the ambient noise over a stated period of time, e.g. hourly noise	
	Parameter: A-weighted Continuous Equivalent Sound Pressure Level determined over the time period T. Expressed in decibels / A-weighted decibels	$L_{eq,T}$ or $L_{Aeq,T}$ dB(A) or dB
Note:	Used in the reports generically to represent both current noise climate and noise level of vehicle noise to encourage direct comparison	
Leq,T	the notionally-steady sound level having the same acoustic energy as the time varying sound pressure level over the same period	
Background Noise	The underlying noise climate in the absence of an introduced or extraneous noise. Describes the quieter periods in the noise climate.	
Background Noise Level	Describes the “average minimum” level of the background noise climate over a stated period of time	
	Parameter: A-weighted Statistical Index 90% Sound Pressure. The quietest decile of the sound pressure levels or level exceeded for 90% of the time period, T Expressed in decibels / A-weighted decibels	$L_{90,T}$ or $L_{A90,T}$ dB(A) or dB
Acoustic screening	Physical barrier to sound formed by fence, wall, building or other structure, which has the effect of reducing the sound transmitted.	
Individual Event Noise	The noise of a distinctive event with the varying noise climate, usually a transient activity, such as a vehicle pass-by, aircraft flyover or similar, rather than an isolated impulsive noise.	
Event Noise Level	Highest noise level during the event as measured under particular conditions of time-weighting	
	Parameter: A-weighted Maximum Sound Pressure Level with FAST or SLOW time weighting Expressed in decibels / A-weighted decibels	$L_{Amax,FAST}$ or $L_{Amax,F}$ $L_{Amax,SLOW}$ or $L_{Amax,S}$ dB(A) or dB
Event Frequency	The number of times an individual event of a similar type occurs in the time period under consideration. Important descriptor as the impact of Individual Event Noise is dependent on changes in both level and event frequency.	
Time Weighting	The sampling rate at which a sound level meter measures the time-varying sound pressure level: originally described how fast the needle moved on analogue meters. Ensures the measurements respond to the type of noise source accurately and are representative. FAST = 125ms sampling rate = 480 samples / minute SLOW = 1s sampling rate = 60 samples / minute	

Appendix B - References

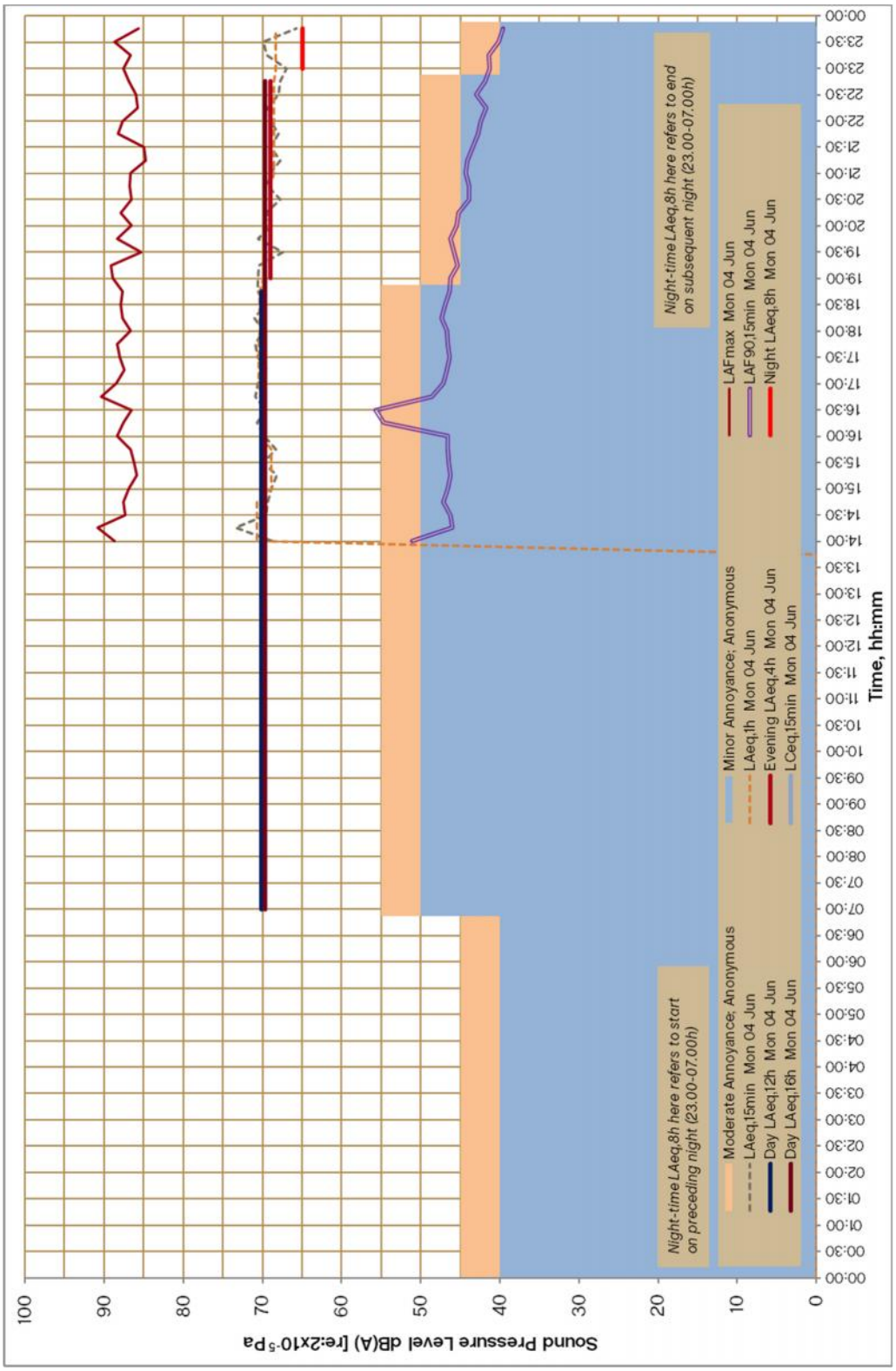
1. BSI. *BS 7445-1:2003 Description and measurement of environmental noise. Guide to quantities and procedures.* London : BSI, 2003. Standard. BS 7445-1:2003.
2. —. *BS 7445-2:1991, ISO 1996-2:1987 Description and measurement of environmental noise. Guide to the acquisition of data pertinent to land use.* London : BSI, 1991. Standard. Current UK standard. EN ISO standard is updated. BS 7445-2:1991.
3. —. *BS 8233:2014 Guidance on sound insulation and noise reduction for buildings.* London : BSI, 2014. Standard.
4. —. *BS4142:2014 Methods for rating and assessing industrial and commercial sound.* EH/1, BSI. London : BSI, 2014. p. 80, Standard. ISBN 978 0 580 80051 1.
5. BSI GME/21/6. *BS 6472-1:2008 'Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting'.* London : BSI, 2008. p. 28, Standard. ISBN 978 0 580 53027 2.
6. ANC. *ANC Guidelines Measurement & Assessment of Groudnborne Noise & Vibration Second Edition.* s.l. : ANC, 2012. Guidelines. ISBN 978-0-9572543-0-5.
7. HM Government. *National Planning Policy Framework.* DCLG, HM Government. London : HM Government, 2012. p. 65, Policy. ISBN 9781409834137.
8. —. *Noise Policy Statement for England (NPSE).* London : DeFRA, 2010. p. 10, Policy. NPSE2010.
9. —. *Planning Practice Guidance – Noise ID30.* DCLG. London : HM Government, 2014. Guidance. Active guidance.
10. World Health Organization. *Guidelines for Community Noise.* SDE, PHE, OEH, WHO. Geneva : World Health Organization, 1999. Guidelines.
11. The Highways Agency et al. *Design Manual for Roads and Bridges Volume 11 Environmental Assessment Section 3 Environmental Assessment Techniques Part 7 HD 213/11 - Revision 1 Noise & Vibration.* London : Highways Agency et al, 2011. p. 65, Guidance. HD213/11.
12. BSI. *BS8233:1999 'Sound insulation and noise reduction for buildings-Code of practice'.* B/209/18, BSI. London : BSI, 1999. p. 56, Standard. 15/08/99. ISBN 0 580 33009 5.
13. World Health Organization Europe. *Night Noise Guidelines for Europe.* Regional Office for Europe, WHO. Geneva : WHO, 2009. p. 154, Guidelines. ISBN 978 92 890 4173 7.
14. BSI. *BS 7445-3:1991, ISO 1996-3:1987 Description and measurement of environmental noise. Guide to application to noise limits.* London : BSI, 2003. Standard. ISO edition already updated.
15. —. *BS4142:1997 'Method for rating industrial noise affecting mixed residential and industrial areas'.* EH/1, BSI. London : BSI, 1997. p. 20, Standard. ISBN 0 580 28300 3.
16. HM Government. *Calculation Of Road Traffic Noise: 1988.* DoT – Welsh Office, HM Government. London : HMSO, 1988. Calculation method. ISBN 0 11 550847 3.

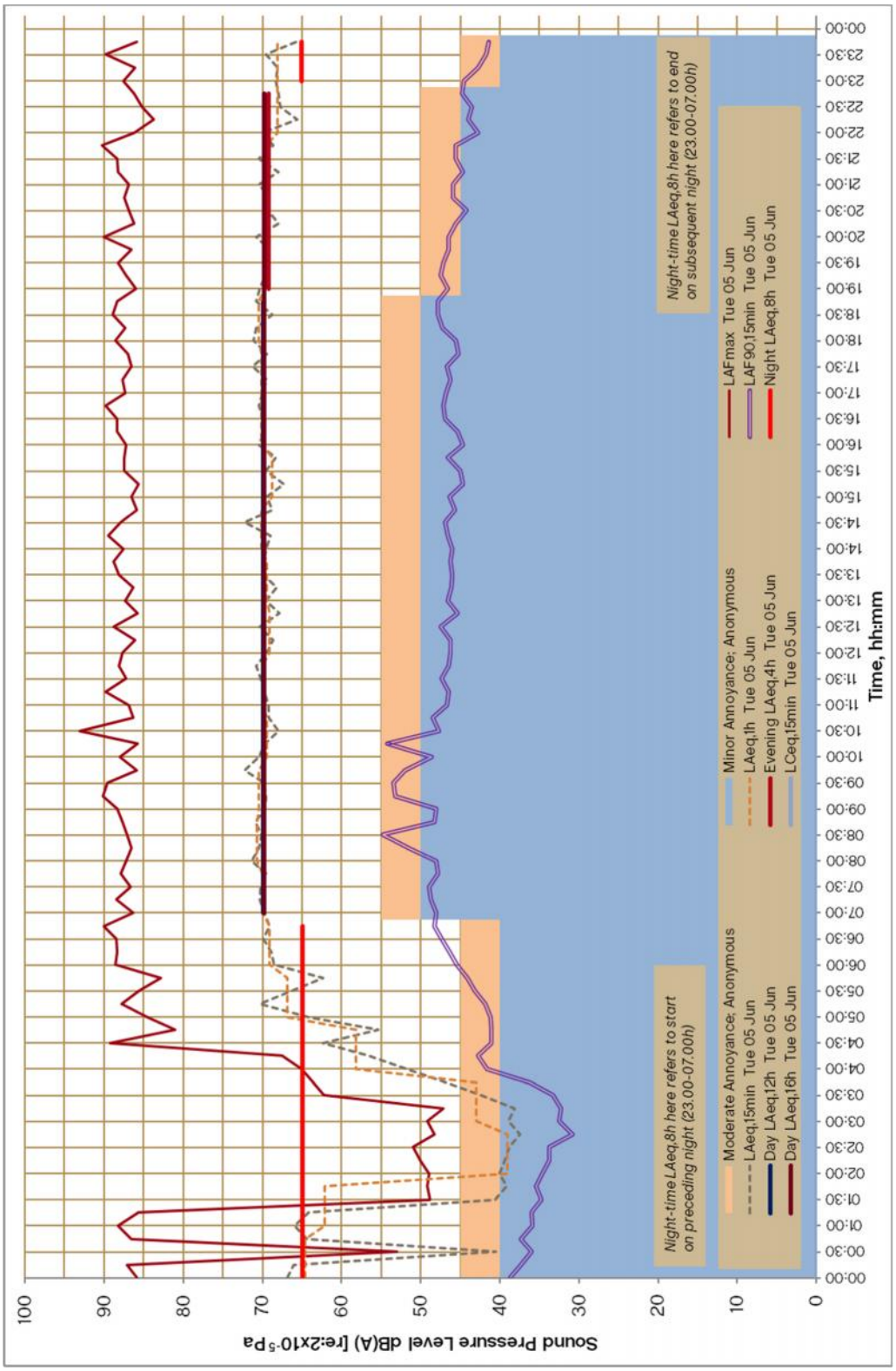
17. Greater London Authority. *The London Plan - Spatial Development Strategy for Greater London - Consolidated with Alterations since 2004.* GLA. London : Greater London Authority, 2008. p. 508, Planning Policy. planning,policy,. ISBN: 978 1 84781 129 5.
18. —. *Sounder City - The Mayor's Ambient Noise Strategy.* GLA. London : GLA, 2004. p. 320, Strategy. planning, strategy, sources. ISBN 1 85261 594 X.
19. —. *The London Plan - Spatial Development Strategy for Greater London.* London : Greater London Authority, July 2011. Policy. ISBN 978 1 84781 451 7.

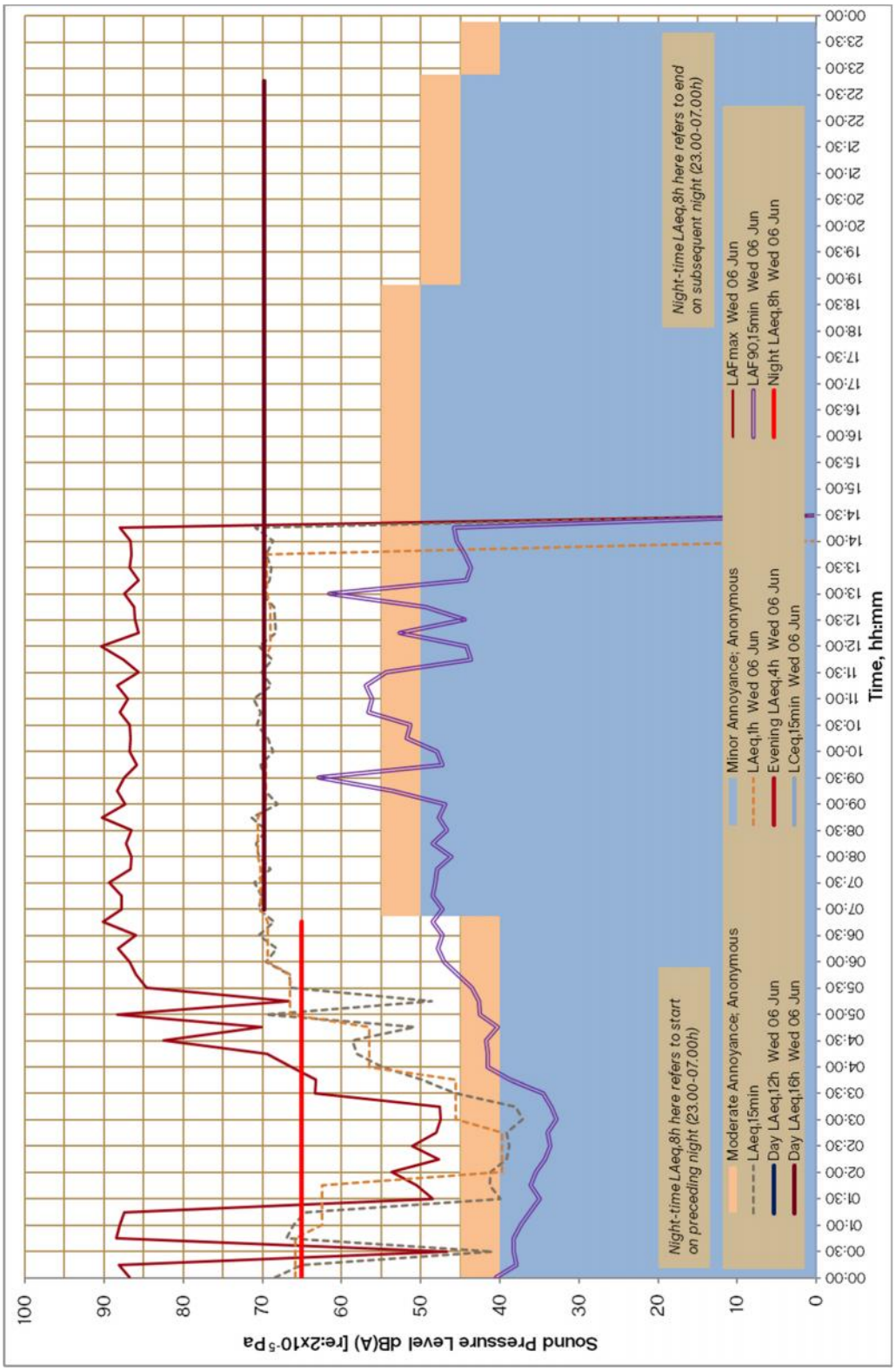
Appendix C Omitted

Appendix D Continuous Monitoring Results

Position M1 – Time History


Sound Pressure Level dB(A) [re:2x10-5Pa
100
90
80
70
60
50
40
30
20
10
0
Time, hh:mm
00:00
23:30
23:00
22:30
22:00
21:30
21:00
20:30
20:00
19:30
19:00
18:30
18:00
17:30
17:00
16:30
16:00
15:30
15:00
14:30
14:00
13:30
13:00
12:30
12:00
11:30
11:00
10:30
10:00
09:30
09:00
08:30
08:00
07:30
07:00
06:30
06:00
05:30
05:00
04:30
04:00
03:30
03:00
02:30
02:00
01:30
01:00
00:30
00:00
Night-time LAeq,8h here refers to start on preceding night (23.00-07.00h)
Night-time LAeq,8h here refers to end on subsequent night (23.00-07.00h)
Moderate Annoyance; Anonymous
Minor Annoyance; Anonymous
LAeq,15min Mon 04 Jun
LAeq,1h Mon 04 Jun
Day LAeq,12h Mon 04 Jun
Evening LAeq,4h Mon 04 Jun
Day LAeq,16h Mon 04 Jun
LCeq,15min Mon 04 Jun
LAFmax Mon 04 Jun
LAF90,15min Mon 04 Jun
Night LAeq,8h Mon 04 Jun


Sound Pressure Level dB(A) [re:2x10-5Pa
Time, hh:mm
Night-time LAeq,8h here refers to start on preceding night (23.00-07.00h)
Night-time LAeq,8h here refers to end on subsequent night (23.00-07.00h)
Moderate Annoyance; Anonymous
Minor Annoyance; Anonymous
LAeq,15min Tue 05 Jun
LAeq,1h Tue 05 Jun
Day LAeq,12h Tue 05 Jun
Evening LAeq,4h Tue 05 Jun
Day LAeq,16h Tue 05 Jun
LCeq,15min Tue 05 Jun
LAFmax Tue 05 Jun
LAF90,15min Tue 05 Jun
Night LAeq,8h Tue 05 Jun


Sound Pressure Level dB(A) [re:2x10-5Pa
100
90
80
70
60
50
40
30
20
10
0
Time, hh:mm
00:00
23:30
23:00
22:30
22:00
21:30
21:00
20:30
20:00
19:30
19:00
18:30
18:00
17:30
17:00
16:30
16:00
15:30
15:00
14:30
14:00
13:30
13:00
12:30
12:00
11:30
11:00
10:30
10:00
09:30
09:00
08:30
08:00
07:30
07:00
06:30
06:00
05:30
05:00
04:30
04:00
03:30
03:00
02:30
02:00
01:30
01:00
00:30
00:00
Night-time LAeq,8h here refers to end on subsequent night (23.00-07.00h)
Night-time LAeq,8h here refers to start on preceding night (23.00-07.00h)
Minor Annoyance; Anonymous
Moderate Annoyance; Anonymous
LAeq,1h Wed 06 Jun
LAeq,15min
Evening LAeq,4h Wed 06 Jun
Day LAeq,12h Wed 06 Jun
LCeq,15min Wed 06 Jun
Day LAeq,16h Wed 06 Jun
LAFmax Wed 06 Jun
LAF90,15min Wed 06 Jun
Night LAeq,8h Wed 06 Jun

A-weighted Ambient & Background Sound Level

Period	1	2	3	4	5	6	7 Log Mean	Mean	
	Mon 04 Jun LAeq,T(15min)	Tue 05 Jun LAeq,T(15min)	Wed 06 Jun LAeq,T(15min)	N/A LAeq,T(15min)	N/A LAeq,T(15min)	N/A LAeq,T(15min)	N/A LAeq,T(15min)	LAeq,T(15min)	LAeq,T(15min)	
07.00-19.00	70.2	69.9	69.8					70.0	70.0	dB(A)
19.00-23.00	69.0	69.2						69.1	69.1	dB(A)
23.00-07.00	65.0	65.0						65.0	65.0	dB(A)
07.00-23.00	69.7	69.8	69.8					69.7	69.7	dB(A)
24h 07-07.00h	68.1	68.7	69.8					68.9	68.8	dB(A)
08.00-18.00	70.1	69.9	69.7					69.9	69.9	dB(A)
09.00-23.00	69.7	69.7	69.6					69.6	69.6	dB(A)
09.00-00.00	69.6	69.6	69.6					69.6	69.6	dB(A)
09.00-01.00	69.3	69.4	69.6					69.4	69.4	dB(A)
09.00-02.00	69.0	69.2	69.6					69.3	69.3	dB(A)
23.30-06.00	39.0	38.1						38.6	38.6	dB(A)
	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)

Period	1	2	3	4	5	6	7 Minimum	Mean	
	Mon 04 Jun LA90,T(15min)	Tue 05 Jun LA90,T(15min)	Wed 06 Jun LA90,T(15min)	N/A LA90,T(15min)	N/A LA90,T(15min)	N/A LA90,T(15min)	N/A LA90,T(15min)	LA90,T(15min)	LA90,T(15min)	
07.00-19.00	46.0	44.7	43.7					43.7	44.8	dB(A)
19.00-23.00	41.7	42.7						41.7	42.2	dB(A)
23.00-07.00	30.8	32.8						30.8	31.8	dB(A)
07.00-23.00	41.7	42.7	43.7					41.7	42.7	dB(A)
24h 07-07.00h	30.8	32.8	43.7					30.8	35.8	dB(A)
08.00-18.00	46.0	44.7	43.7					43.7	44.8	dB(A)
09.00-23.00	41.7	42.7	43.7					41.7	42.7	dB(A)
09.00-00.00	39.6	41.4	43.7					39.6	41.6	dB(A)
09.00-01.00	36.0	37.9	43.7					36.0	39.2	dB(A)
09.00-02.00	34.8	35.0	43.7					34.8	37.8	dB(A)
23.30-06.00	30.8	48.9						30.8	39.9	dB(A)
	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)

Maximum Sound Pressure Level Analysis

	Period	1					2				
		Mon 04 Jun					Tue 05 Jun				
	LAmax,FAST	Maximum Highest	95th %ile	90th %ile Typical Highest	50th %ile Median	Mean	Maximum Highest	95th %ile	90th %ile Typical Highest	50th %ile Median	Mean
Day	07.00-19.00	90.8	90.8	90.2	87.7	87.8	93.1	90.0	89.6	87.6	87.7
Evening	19.00-23.00	89.1	#NUM!	89.0	86.8	86.9	90.3	#NUM!	90.2	86.9	87.1
Night	23.00-07.00	90.0	89.5	88.7	85.0	73.5	90.2	89.9	88.5	83.6	72.5
Day 16h	07.00-23.00	90.8	90.5	89.0	87.6	87.4	93.1	90.2	89.7	87.4	87.6
den	DEN	90.8	89.7	88.7	86.7	80.9	93.1	90.1	89.5	87.2	82.5
24h AM	24h 07-07.00h	90.8	89.7	88.7	86.7	80.9	93.1	90.1	89.5	87.2	82.5
24h	24h 00-00.00h	90.8	90.3	88.9	87.6	87.4	93.1	90.0	89.5	87.2	82.9
LHR Day	06.00-23.30	90.8	90.4	88.9	87.6	87.4	93.1	90.1	89.8	87.5	87.6
Effect. Day	06.00-22.30	90.8	90.5	89.0	87.6	87.4	93.1	90.2	89.8	87.6	87.7
LHR Night	23.30-06.00	89.3	89.1	88.4	74.3	70.1	89.8	89.3	88.4	68.0	69.1
Typical	06.00-18.00	90.8	#NUM!	90.5	87.6	87.8	93.1	90.1	89.8	87.7	87.7
Long	07.00-19.00	90.8	90.8	90.2	87.7	87.8	93.1	90.0	89.6	87.6	87.7
Office	08.00-18.00	90.8	#NUM!	90.5	87.6	87.8	93.1	90.2	89.8	87.5	87.7
Service	08.00-20.00	90.8	90.7	89.8	87.7	87.8	93.1	90.0	89.6	87.5	87.7
Very Long	06.00-00.00	90.8	90.3	88.9	87.6	87.4	93.1	90.1	89.8	87.5	87.6
Standard	09.00-23.00	90.8	90.5	89.0	87.6	87.4	93.1	90.2	89.8	87.5	87.6
Long	09.00.00.00	90.8	90.3	88.9	87.6	87.4	93.1	90.2	89.8	87.5	87.6
Late	09.00-01.00	90.8	90.1	88.8	87.2	86.5	93.1	90.2	89.8	87.5	86.9
Very Late	09.00-02.00	90.8	89.8	88.7	87.0	85.0	93.1	90.2	89.8	87.5	85.9
Full Service	06.00-00.00	90.8	90.3	88.9	87.6	87.4	93.1	90.1	89.8	87.5	87.6
		dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)

Std Deviation	CI 95% confidence
1.2	0.5
1.3	0.6
16.7	0.4
1.3	0.4
23.8	0.4
23.8	0.4
1.3	0.4
1.3	0.4
1.3	0.4
16.8	0.5
1.3	0.6
1.2	0.5
1.3	0.6
1.3	0.5
1.3	0.4
1.3	0.4
1.3	0.4
5.3	0.4
9.0	0.3
1.3	0.4

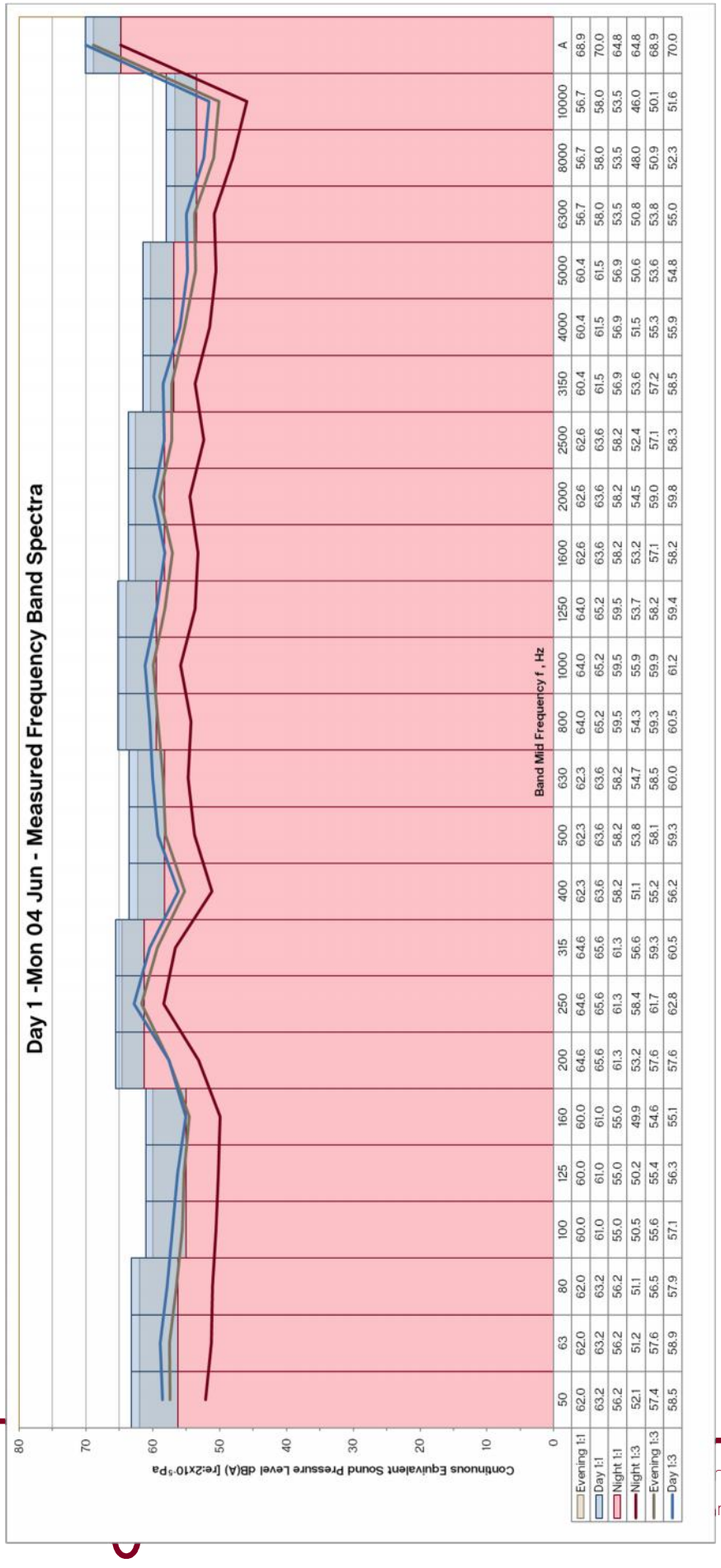
	Std Deviation	CI 95% confidence
45.0	1.4	0.4
	1.6	0.7
	16.7	0.5
	1.5	0.3
	1.5	0.3
	1.5	0.3
	11.8	0.3
	1.5	0.3
	1.5	0.3
	16.7	0.5
	1.4	0.4
	1.4	0.4
	1.5	0.4
	1.4	0.4
	1.5	0.3
	1.6	0.4
	1.6	0.4
	5.3	0.3
	8.2	0.3
	1.5	0.3

Maximum Sound Pressure Level Analysis

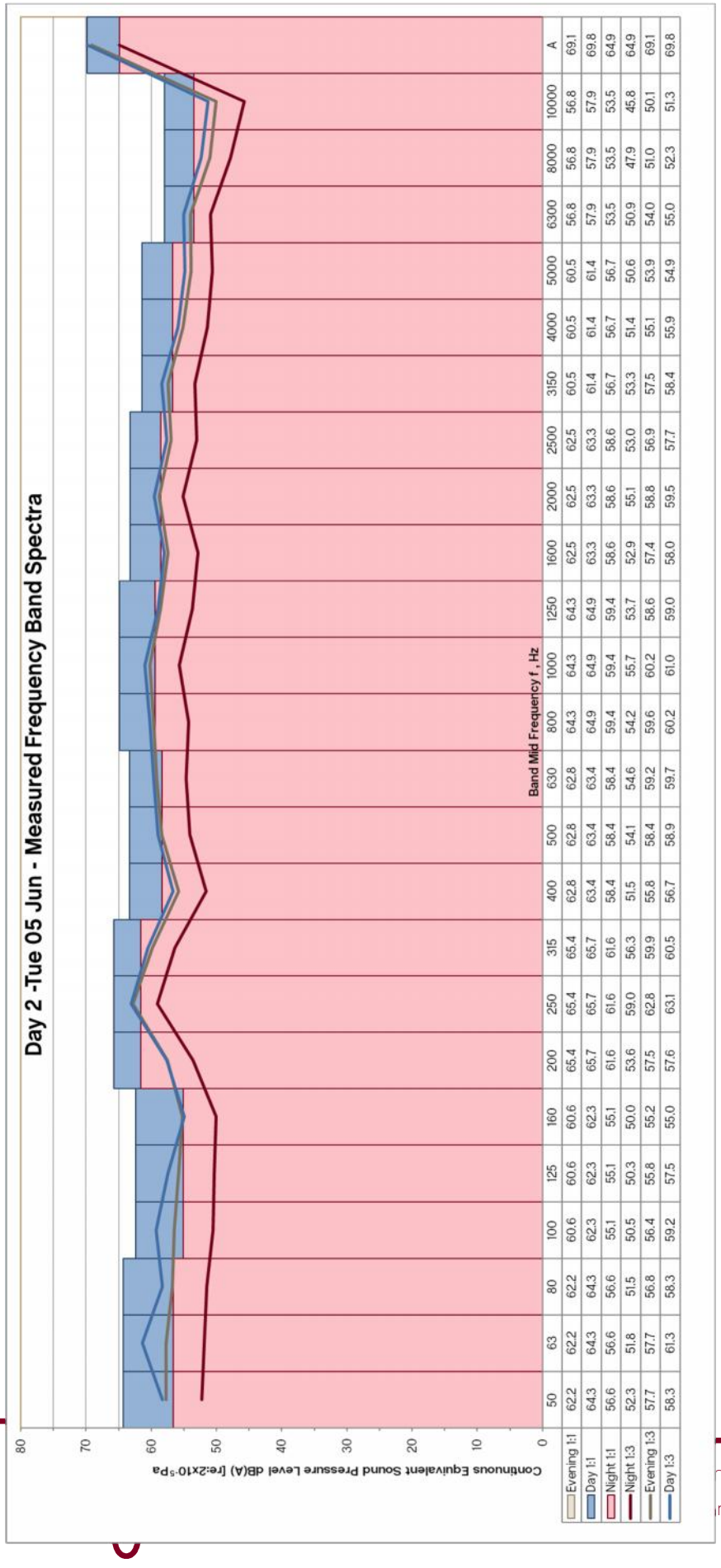
	Period	1					2				
		Mon 04 Jun					Tue 05 Jun				
	LAmax,FAST	95th %ile	90th %ile Typical Highest	50th %ile Median	Std Deviation	CI 95% confidence	95th %ile	90th %ile Typical Highest	50th %ile Median	Std Deviation	CI 95% confid
Day	07.00-19.00	90.8	90.2	87.7	1.2	0.5	90.0	89.6	87.6	1.4	0.4
Evening	19.00-23.00	#NUM!	89.0	86.8	1.3	0.6	#NUM!	90.2	86.9	1.6	0.7
Night	23.00-07.00	89.5	88.7	85.0	16.7	0.4	89.9	88.5	83.6	16.7	0.5
Day 16h	07.00-23.00	90.5	89.0	87.6	1.3	0.4	90.2	89.7	87.4	1.5	0.3
den	DEN	89.7	88.7	86.7	23.8	0.4	90.1	89.5	87.2	1.5	0.3
24h AM	24h 07-07.00h	89.7	88.7	86.7	23.8	0.4	90.1	89.5	87.2	1.5	0.3
24h	24h 00-00.00h	90.3	88.9	87.6	1.3	0.4	90.0	89.5	87.2	11.8	0.3
LHR Day	06.00-23.30	90.4	88.9	87.6	1.3	0.4	90.1	89.8	87.5	1.5	0.3
Effect. Day	06.00-22.30	90.5	89.0	87.6	1.3	0.4	90.2	89.8	87.6	1.5	0.3
LHR Night	23.30-06.00	89.1	88.4	74.3	16.8	0.5	89.3	88.4	68.0	16.7	0.5
Typical	06.00-18.00	#NUM!	90.5	87.6	1.3	0.6	90.1	89.8	87.7	1.4	0.4
Long	07.00-19.00	90.8	90.2	87.7	1.2	0.5	90.0	89.6	87.6	1.4	0.4
Office	08.00-18.00	#NUM!	90.5	87.6	1.3	0.6	90.2	89.8	87.5	1.5	0.4
Service	08.00-20.00	90.7	89.8	87.7	1.3	0.5	90.0	89.6	87.5	1.4	0.4
Very Long	06.00-00.00	90.3	88.9	87.6	1.3	0.4	90.1	89.8	87.5	1.5	0.3
Standard	09.00-23.00	90.5	89.0	87.6	1.3	0.4	90.2	89.8	87.5	1.6	0.4
Long	09.00.00.00	90.3	88.9	87.6	1.3	0.4	90.2	89.8	87.5	1.6	0.4
Late	09.00-01.00	90.1	88.8	87.2	5.3	0.4	90.2	89.8	87.5	5.3	0.3
Very Late	09.00-02.00	89.8	88.7	87.0	9.0	0.3	90.2	89.8	87.5	8.2	0.3
Full Service	06.00-00.00	90.3	88.9	87.6	1.3	0.4	90.1	89.8	87.5	1.5	0.3
		dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)		dB(A)

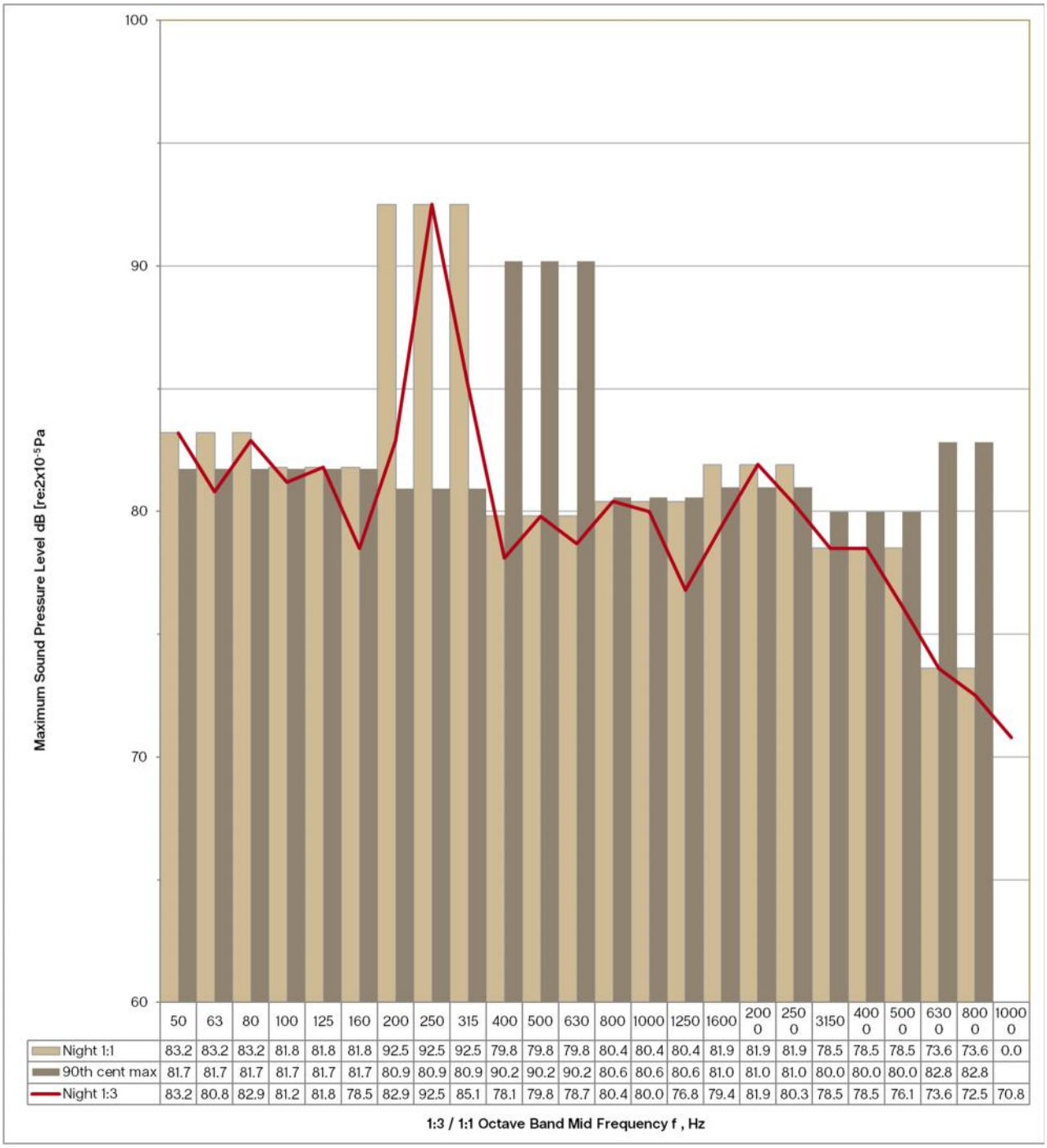
Maximum Sound Pressure Level Analysis

	Period	1					2				
		Mon 04 Jun					Tue 05 Jun				
	LAmax,SLOW	95th %ile	90th %ile Typical Highest	50th %ile Median	Std Deviation	CI 95% confidence	95th %ile	90th %ile Typical Highest	50th %ile Median	Std Deviation	CI 95% confide
Day	07.00-19.00	88.7	87.1	86.3	0.9	0.4	87.9	87.6	86.1	1.0	0.3
Evening	19.00-23.00	#NUM!	87.0	85.5	1.2	0.4	#NUM!	88.2	85.4	1.4	0.5
Night	23.00-07.00	87.8	87.0	83.7	17.0	0.3	87.8	86.6	81.6	16.9	0.3
Day 16h	07.00-23.00	87.8	87.0	86.1	1.1	0.3	88.0	87.7	86.0	1.1	0.2
den	DEN	87.6	86.9	85.4	23.0	0.3	87.9	87.3	85.6	1.1	0.2
24h AM	24h 07-07.00h	87.6	86.9	85.4	23.0	0.3	87.9	87.3	85.6	1.1	0.2
24h	24h 00-00.00h	87.6	87.1	86.1	1.1	0.3	87.9	87.3	85.7	12.0	0.2
LHR Day	06.00-23.30	87.7	86.9	86.1	1.1	0.3	88.0	87.7	86.1	1.1	0.2
Effect. Day	06.00-22.30	87.9	87.0	86.3	1.1	0.3	88.1	87.7	86.1	1.1	0.2
LHR Night	23.30-06.00	87.4	86.8	71.0	17.1	0.3	87.3	86.4	64.7	16.8	0.4
Typical	06.00-18.00	#NUM!	87.6	86.3	1.0	0.4	88.1	87.7	86.1	1.0	0.3
Long	07.00-19.00	88.7	87.1	86.3	0.9	0.4	87.9	87.6	86.1	1.0	0.3
Office	08.00-18.00	#NUM!	87.6	86.3	1.0	0.4	88.0	87.6	86.0	0.9	0.3
Service	08.00-20.00	88.5	87.4	86.3	1.0	0.4	87.9	87.2	86.1	0.9	0.3
Very Long	06.00-00.00	87.6	87.1	86.1	1.1	0.3	88.0	87.7	86.1	1.1	0.2
Standard	09.00-23.00	87.8	87.0	86.1	1.1	0.3	88.1	87.6	86.0	1.1	0.3
Long	09.00.00.00	87.6	87.1	86.1	1.1	0.3	88.0	87.6	86.0	1.1	0.2
Late	09.00-01.00	87.6	87.0	85.9	5.3	0.3	88.0	87.6	85.9	5.1	0.2
Very Late	09.00-02.00	87.6	86.9	85.8	9.1	0.3	88.0	87.6	85.9	8.1	0.2
Full Service	06.00-00.00	87.6	87.1	86.1	1.1	0.3	88.0	87.7	86.1	1.1	0.2
		dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)		dB(A)



	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	A
Evening 1:1	62.0	62.0	62.0	60.0	60.0	60.0	64.6	64.6	64.6	62.3	62.3	62.3	64.0	64.0	64.0	62.6	62.6	62.6	60.4	60.4	60.4	56.7	56.7	56.7	68.9
Day 1:1	63.2	63.2	63.2	61.0	61.0	61.0	65.6	65.6	65.6	63.6	63.6	63.6	65.2	65.2	65.2	63.6	63.6	63.6	61.5	61.5	61.5	58.0	58.0	58.0	70.0
Night 1:1	56.2	56.2	56.2	55.0	55.0	55.0	61.3	61.3	61.3	58.2	58.2	58.2	59.5	59.5	59.5	58.2	58.2	58.2	56.9	56.9	56.9	53.5	53.5	53.5	64.8
Night 1:3	52.1	51.2	51.1	50.5	50.2	49.9	53.2	58.4	56.6	51.1	53.8	54.7	54.3	55.9	53.7	53.2	54.5	52.4	53.6	51.5	50.6	50.8	48.0	46.0	64.8
Evening 1:3	57.4	57.6	56.5	55.6	55.4	54.6	57.6	61.7	59.3	55.2	58.1	58.5	59.3	59.9	58.2	57.1	59.0	57.1	57.2	55.3	53.6	53.8	50.9	50.1	68.9
Day 1:3	58.5	58.9	57.9	57.1	56.3	55.1	57.6	62.8	60.5	56.2	59.3	60.0	60.5	61.2	59.4	58.2	59.8	58.3	58.5	55.9	54.8	55.0	52.3	51.6	70.0


Day 2 -Tue 05 Jun - Measured Frequency Band Spectra
Continuous Equivalent Sound Pressure Level dB(A) [re:2x10-5Pa
Band Mid Frequency f , Hz
50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 A
Evening 1:1 62.2 62.2 62.2 60.6 60.6 60.6 65.4 65.4 65.4 62.8 62.8 64.3 64.3 64.3 62.5 62.5 62.5 60.5 60.5 56.8 56.8 56.8 56.8 69.1
Day 1:1 64.3 64.3 64.3 62.3 62.3 62.3 65.7 65.7 65.7 63.4 63.4 64.9 64.9 64.9 63.3 63.3 63.3 61.4 61.4 57.9 57.9 57.9 57.9 69.8
Night 1:1 56.6 56.6 56.6 55.1 55.1 55.1 61.6 61.6 61.6 58.4 58.4 59.4 59.4 59.4 58.6 58.6 58.6 56.7 56.7 53.5 53.5 53.5 53.5 64.9
Night 1:3 52.3 51.8 51.5 50.5 50.3 50.0 53.6 59.0 56.3 51.5 54.1 54.6 54.2 55.7 53.7 52.9 55.1 53.0 53.3 51.4 50.6 50.9 47.9 45.8 64.9
Evening 1:3 57.7 57.7 56.8 56.4 55.8 55.2 57.5 62.8 59.9 55.8 58.4 59.2 59.6 60.2 58.6 57.4 58.8 56.9 57.5 55.1 53.9 54.0 51.0 50.1 69.1
Day 1:3 58.3 61.3 58.3 59.2 57.5 55.0 57.6 63.1 60.5 56.7 58.9 59.7 60.2 61.0 59.0 58.0 59.5 57.7 58.4 55.9 54.9 55.0 52.3 51.3 69.8



	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
Night 1:1	83.2	83.2	83.2	81.8	81.8	81.8	92.5	92.5	92.5	79.8	79.8	79.8	80.4	80.4	80.4	81.9	81.9	81.9	78.5	78.5	78.5	73.6	73.6	0.0
90th cent max	81.7	81.7	81.7	81.7	81.7	81.7	80.9	80.9	80.9	90.2	90.2	90.2	80.6	80.6	80.6	81.0	81.0	81.0	80.0	80.0	80.0	82.8	82.8	
Night 1:3	83.2	80.8	82.9	81.2	81.8	78.5	82.9	92.5	85.1	78.1	79.8	78.7	80.4	80.0	76.8	79.4	81.9	80.3	78.5	78.5	76.1	73.6	72.5	70.8

Appendix E - Vibration Monitoring Results

Day			1			2			3			4			5		
	File Event		2			4			6			8			10		
	Start		08/06/2018			09/06/2018			10/06/2018			11/06/2018			12/06/2018		
	Daytime VDV	0.032	0.03	0.027	0.001	0.002	0.003	0.001	0.002	0.002	0.025	0.016	0.002	0.035	0.02	0.002	
	Start	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	
	07:00					0.001	0.001	0.001	0	0.001	0.001	0.011	0.005	0.001	0.017	0.009	0.001
	08:00					0	0.001	0.001	0.001	0	0.001	0.017	0.008	0.001	0.014	0.009	0.001
	09:00					0.001	0.001	0.001	0	0.001	0	0.013	0.003	0.001	0.02	0.012	0
	10:00					0	0.001	0.001	0	0.001	0.001	0.008	0.003	0.001			
	11:00					0	0.001	0.001	0	0.001	0	0.01	0.008	0			
	12:00					0	0.001	0.001	0	0.001	0.001	0.007	0.003	0.001			
	13:00					0	0.001	0.001	0	0	0.001	0.007	0.005	0.001			
	14:00					0	0.001	0.001	0.001	0	0.001	0.006	0.002	0.001			
	15:00	0.024	0.025	0.025	0	0.001	0.001	0	0.001	0.001	0.001	0.006	0.002	0.001			
	16:00	0.013	0.005	0.001	0	0.001	0.001	0	0.001	0.001	0.001	0.011	0.004	0.001			
	17:00	0.007	0.007	0.001	0	0.001	0	0	0.001	0.001	0.001	0.007	0.005	0.001			
	18:00	0.007	0.01	0.001	0	0.001	0.001	0	0.001	0.001	0.001	0.015	0.013	0.001			
	19:00	0.015	0.011	0.001	0	0.001	0.001	0	0	0.001	0.001	0.008	0.005	0.001			
	20:00	0.015	0.015	0.001	0	0.001	0.001	0	0	0.001	0.001	0.014	0.01	0.001			
	21:00	0.016	0.013	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001	0.018	0.009	0.001			
	22:00	0.016	0.008	0.001	0	0.001	0.001	0.001	0	0.001	0.001	0.012	0.008	0.001			
	23:00																
Peak Event		L	T	V	L	T	V	L	T	V	L	T	V	L	T	V	
ms-1	PPV	2.175	0.95	1.15	0.05	0.05	0.05	0.38	0.2	0.1	2.15	1.075	0.875	2.375	1.275	0.8	
g	a	0.08	0.05	0.06	0.008	0.005	0.005	0.028	0.025	0.013	0.088	0.053	0.055	0.08	0.06	0.073	
ms-2	a	0.785	0.490	0.588	0.078	0.049	0.049	0.275	0.245	0.127	0.863	0.520	0.539	0.785	0.588	0.716	
Hz	f	38.5	50	50	45.5	0	0	45.5	50	50	41.7	62.5	50	38.5	45.5	55.6	

Transducer Co-ordinate Equivalence

X	Perpendicula L	Longitdunal
Y	Parallel to rai T	Transverse
Z	Vertical V	Vertical

Applies to generated results only

Night			1		2			3			4			5		
	File Event		3		5			7			9			10		
	Start		08/06/2018		09/06/2018			10/06/2018			11/06/2018					
	Daytime VDV	0.014	0.01	0.003	0.005	0.002	0.002	0.012	0.006	0.002	0.021	0.01	0.002			
	Start	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
	23:00	0.007	0.002	0.001	0	0.001	0	0	0.001	0.001	0.01	0.006	0.001			
	00:00	0.011	0.008	0.001	0	0.001	0.001	0	0	0	0.011	0.003	0.001			
	01:00	0	0	0.001	0	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001			
	02:00	0	0	0.001	0.003	0	0.001	0	0.001	0.001	0	0.001	0.001			
	03:00	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
	04:00	0	0.001	0.001	0.003	0.001	0.001	0	0.001	0.001	0.004	0.001	0.001			
	05:00	0	0	0.001	0	0.001	0.001	0.008	0.005	0.001	0.014	0.007	0.001			
	06:00	0.001	0	0.001	0	0.001	0.001	0.009	0.002	0	0.013	0.006	0.001			
	07:00	0	0	0	0	0	0	0	0	0	0.013	0.006	0.001			

Peak Event		L	T	V	L	T	V	L	T	V	L	T	V	L	T	V
ms-1	PPV	1.5	0.0875	0.0675	0.775	0.45	0.375	1.25	0.65	0.625	2.025	0.925	0.6			
g	a	0.053	0.04	0.043	0.05	0.038	0.038	0.068	0.04	0.043	0.073	0.045	0.05			
ms-2	a	0.520	0.392	0.422	0.490	0.373	0.373	0.667	0.392	0.422	0.716	0.441	0.490			
Hz	f	38.5	41.7	45.5	45.5	55.6	50	41.7	55.6	50	38.5	45.5	62.5			

Transducer Co-ordinate Equivalence

X	Perpendicula	L	Longitdunal
Y	Parallel to rai	T	Transverse
Z	Vertical	V	Vertical

Applies to generated results only

Appendix F Building Envelope Calculation

Elevation Sound Level

For the purposes of the façade sound insulation calculation the following sound levels at the stated measurement position shall apply to the stated elevation:-

			L1,ff [dB re 2x10-6 Pa] @Octave Band Mid Frequency [Hz]									
Elevation	Position	Measured dB(A)	63	125	250	500	1k	2k	4k	8k	Spectra
M1	Day		67.0	64.3	62.3	65.7	63.4	64.9	63.3	61.4	57.9	69.8
M1	Night		62.0	56.6	55.1	61.6	58.4	59.4	58.6	56.7	53.5	64.9
M1	Night Max		86.0	83.2	81.8	92.5	79.8	80.4	81.9	78.5	73.6	88.4
NW Unit 2/3/5	Day	-2.8	66.0	60.5	58.5	61.9	59.6	61.1	59.4	57.6	54.1	66.0
NW Unit 2/3/5	Night	-2.9	61.0	52.8	51.2	57.8	54.5	55.5	54.7	52.8	49.6	61.0
NW Unit 2/3/5	Night Max	-2.4	83.0	77.8	76.4	87.1	74.4	75.0	76.5	73.1	68.2	83.0

All free-field sound pressure levels on flat reflecting plane
Additional allowance is made for façade reflection variation where appropriate.

Sound Insulation Datasheet

Optional systems for sound insulation of building envelope are as follows:-

			Sound Insulation X @Octave Band Mid Frequency [Hz]								
Element	Ref.	Parameter, X	63	125	250	500	1k	2k	4k	8k	w
Window	GWN2	R	27	31	37	43	42	46	43	40	
or Door	GWN39	R	23	26	27	34	40	38	46	42	37
	GWN43	R	18	22	17	24	37	41	38	35	29
Wall or	EW4	R	28	34	34	40	56	58	58	55	45
Cladding	EW41	R	29	41	48	54	59	65	65	60	61
		R									
Roof /	RF2	R	20	22	37	43	49	57	55	50	
Ceiling		R									
		R									
Ventilator	VE1	Dne	34	34	39	34	41	31	28	20	
	VE6	Dne	43	42	43	43	49	64	55	50	
		Dne									

Construction

See report

Model Rooms

Elevation NW Units 2, 3 &5

			FFL Bedroom	FFL Corner Bedroom			
Floor Area			10.4	7.9	Sf	m^2	
Volume			26	19.8	V	m^3	
Wall Surface Area (approx 7:4 ratio)			34	28.5	Sw	m^2	
Envelope Elements	Façade		12	17	Sfa	m^2	includes all façade elements
	Roof		0	0	Sro	m^2	exposed area only
	Window / Door		5.3	5.3	Swi	m^2	only vision elements or similar
	Non-vision		6.7	11.7	Sew	m^2	other elements
	Roof Ceiling		0	0	Src	m^2	only ceiling of room if roof applicable
Ventilation	Type	Central Ventilation					
Number		Direct to room	1.0	1.0	Ne		

Building Element Sound Insulation			Level [dB re 2x10-6 Pa] @Octave Band Mid Frequency [Hz]							
		dB(A)	63	125	250	500	1k	2k	4k	8k
Rrc Roof / Ceiling	Not applicable	-	-	-	-	-	-	-	-	-
Rwi Window / Door	GWN2	-	27	31	37	43	42	46	43	40
Rew Non-vision	EW41	-	29.3	41	48	54	59	65	65	60
Dne Ventilation	VE6	-	43	42	43	43	49	64	55	50
FFL Bedroom										
Rcomp			-28	-33.5	-38.5	-41.8	-44.1	-49.4	-46	-42.8
Average α	Furnished		0.4	0.35	0.2	0.2	0.15	0.15	0.15	0.1
Sα	Furnished		21.9	19.2	11	11	8.22	8.22	8.22	5.48
10 log S/ Sα			-2.62	-2.04	0.39	0.39	1.64	1.64	1.64	3.4
Variation			3	3	3	3	3	3	3	3
D	Total Level Difference		-27.6	-32.5	-35.2	-38.4	-39.4	-44.7	-41.4	-36.3
FFL Corner Bedroom										
Rcomp			-28.4	-34.7	-39.8	-43.2	-45.5	-50.8	-47.5	-44.2
Average α	Furnished		0.4	0.35	0.2	0.2	0.15	0.15	0.15	0.1
Sα	Furnished		17.7	15.5	8.86	8.86	6.65	6.65	6.65	4.43
10 log S/ Sα			-0.18	0.4	2.83	2.83	4.08	4.08	4.08	5.84
Variation			3	3	3	3	3	3	3	3
D	Total Level Difference		-25.6	-31.3	-34	-37.4	-38.5	-43.7	-40.4	-35.4

Elevation - Loudest

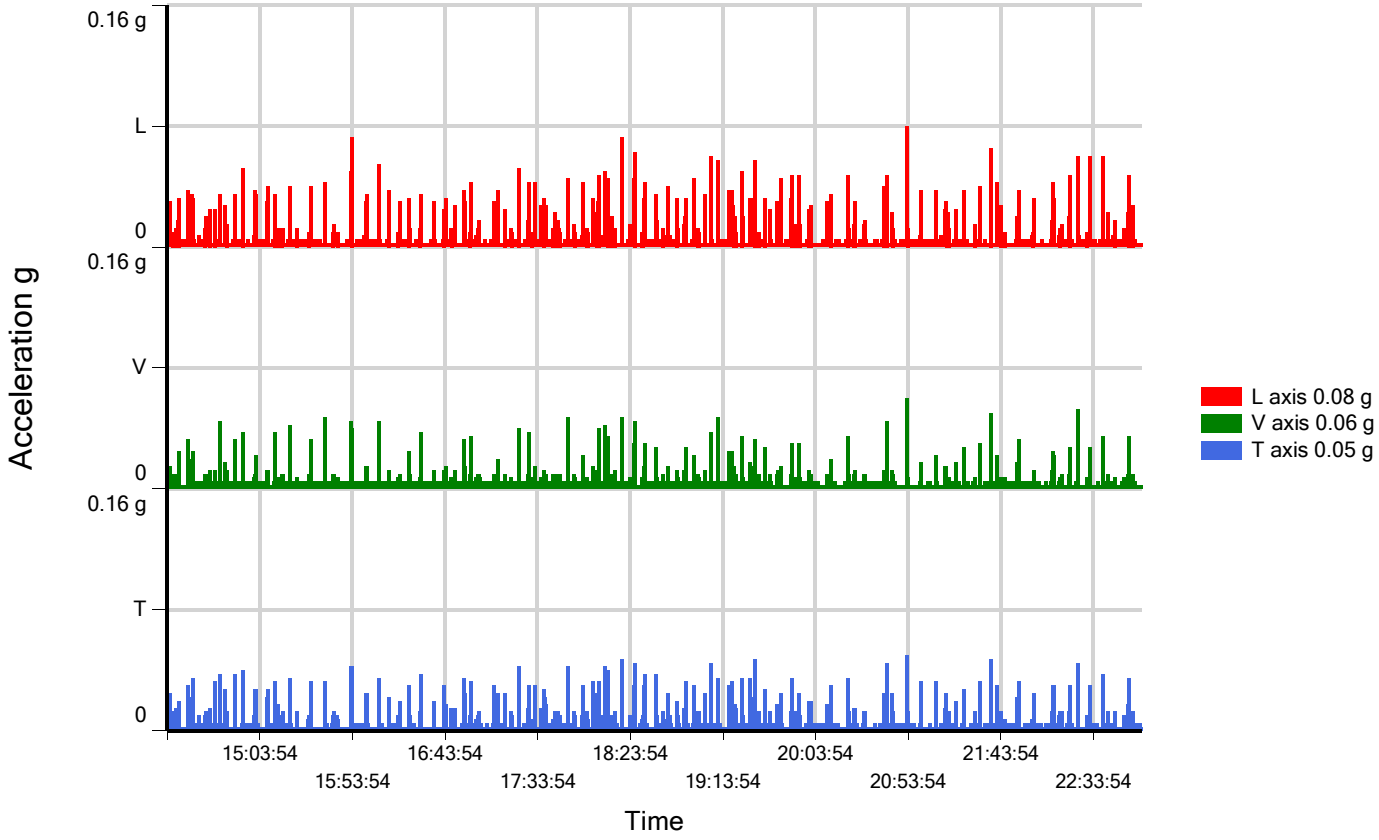
			Level [dB re 2x10-6 Pa] @Octave Band Mid Frequency [Hz]							
		dB(A)	63	125	250	500	1k	2k	4k	8k
Source Sound Level										
Day	Leq,16h,ff	67.0	64.3	62.3	65.7	63.4	64.9	63.3	61.4	57.9
Night	Leq,8h,ff	62.0	56.6	55.1	61.6	58.4	59.4	58.6	56.7	53.5
Night	Lmax,FAST, ff	86.0	83.2	81.8	92.5	79.8	80.4	81.9	78.5	73.6
Level Difference										
FFL Bedroom	D	-	-27.6	-32.5	-35.2	-38.4	-39.4	-44.7	-41.4	-36.3
FFL Corner Bedroom	D		-25.6	-31.3	-34.0	-37.4	-38.5	-43.7	-40.4	-35.4
Internal Sound Level										
FFL Bedroom	Leq,16h	30	37	30	31	25	25	19	20	22
FFL Corner Bedroom	Leq,16h	31	39	31	32	26	26	20	21	23
FFL Bedroom	Leq,8h	25	29	23	26	20	20	14	15	17
FFL Corner Bedroom	Leq,8h	26	31	24	28	21	21	15	16	18

Applies to elevations:-	All	Below BS8233:2014 Table 4 values for residential of:-	
		Day	35 dB
		Night	30 dB

Appendix G Vibration Output Results

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

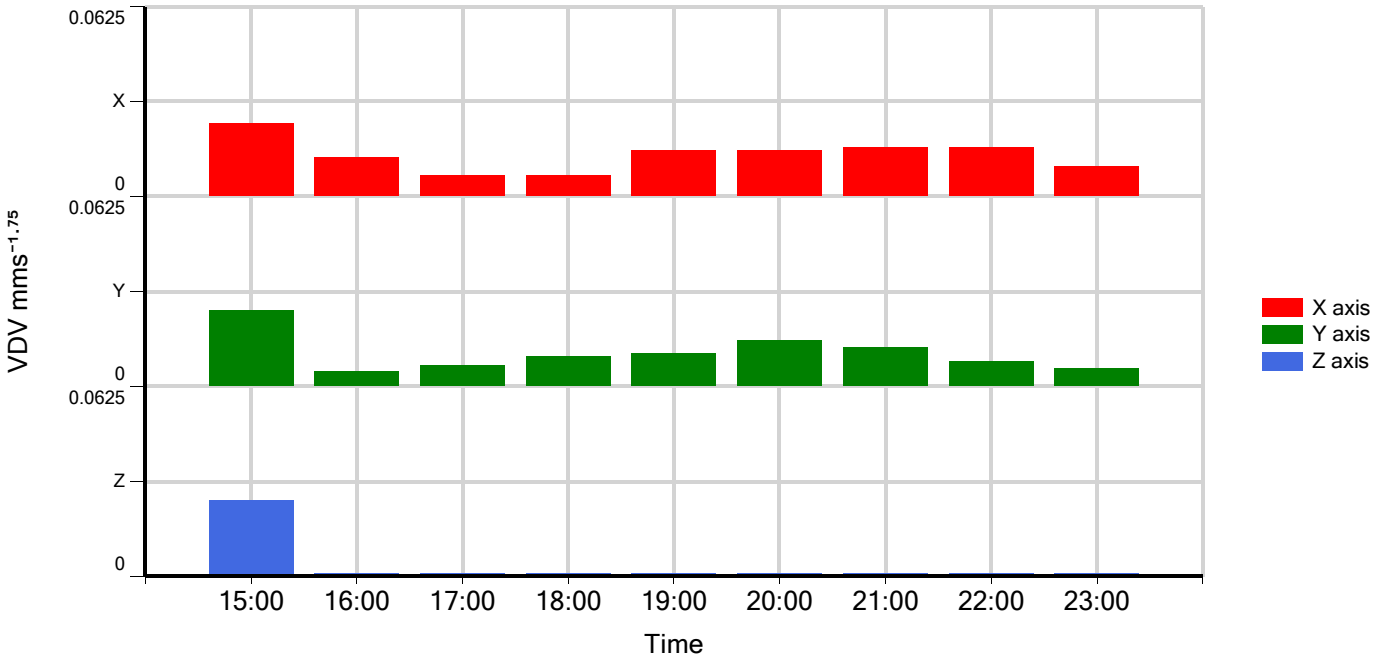


Event Number	2
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	8/6 /2018
Start Time	14:13:54
Stop Time	23:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	2.175 mms^{-1}	38.5 Hz	0.08 g	0.013 mm
Vertical Max	0.95 mms^{-1}	50 Hz	0.06 g	0 mm
Transverse Max	1.15 mms^{-1}	50 Hz	0.05 g	0.006 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Hour Data Location

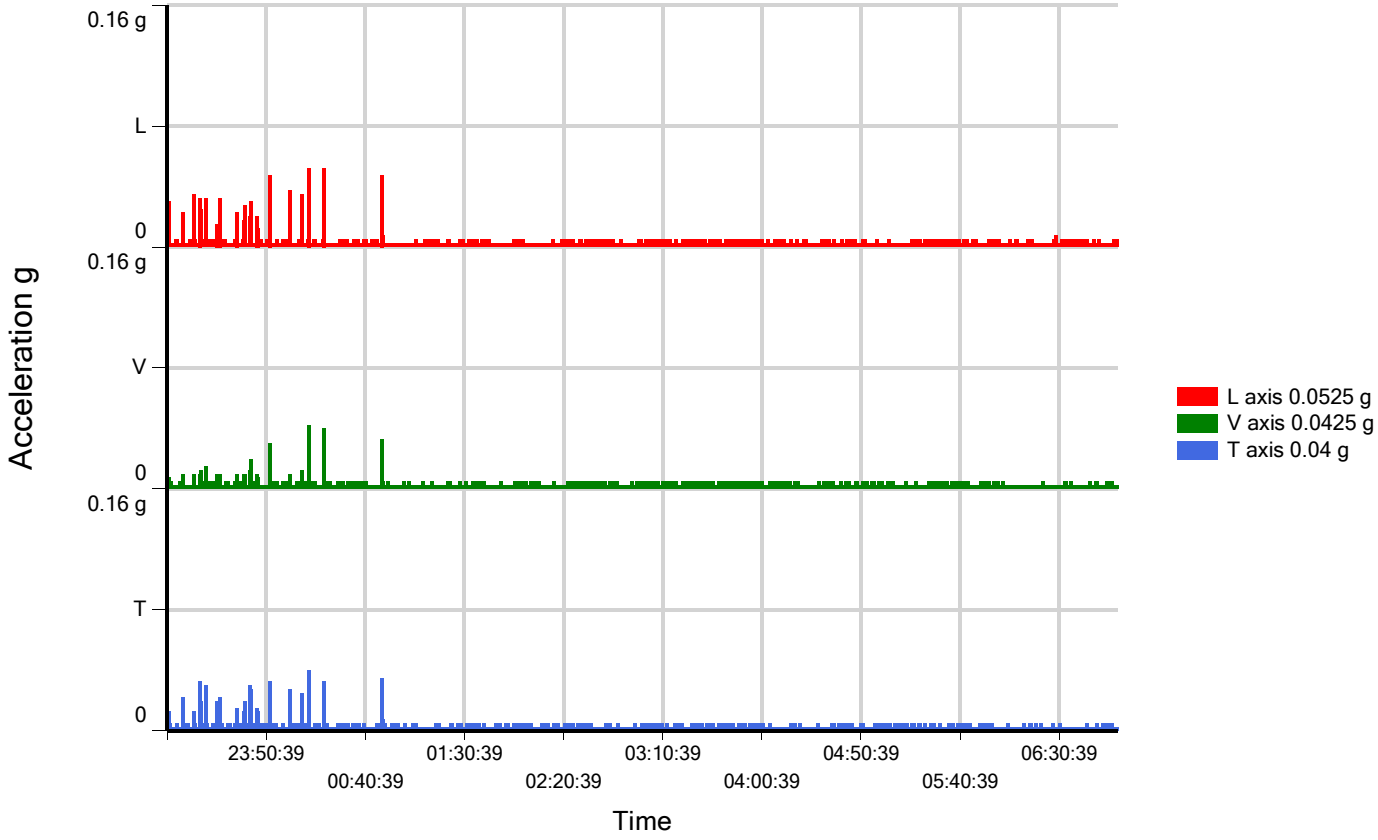


Start Date	8/6 /2018
Start Time	14:13:54
Stop Time	23:00:00

1 Hour VDV	X	Y	Z
15:00:00	0.024	0.025	0.025
16:00:00	0.013	0.005	0.001
17:00:00	0.007	0.007	0.001
18:00:00	0.007	0.01	0.001
19:00:00	0.015	0.011	0.001
20:00:00	0.015	0.015	0.001
21:00:00	0.016	0.013	0.001
22:00:00	0.016	0.008	0.001
23:00:00	0.01	0.006	0.001

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

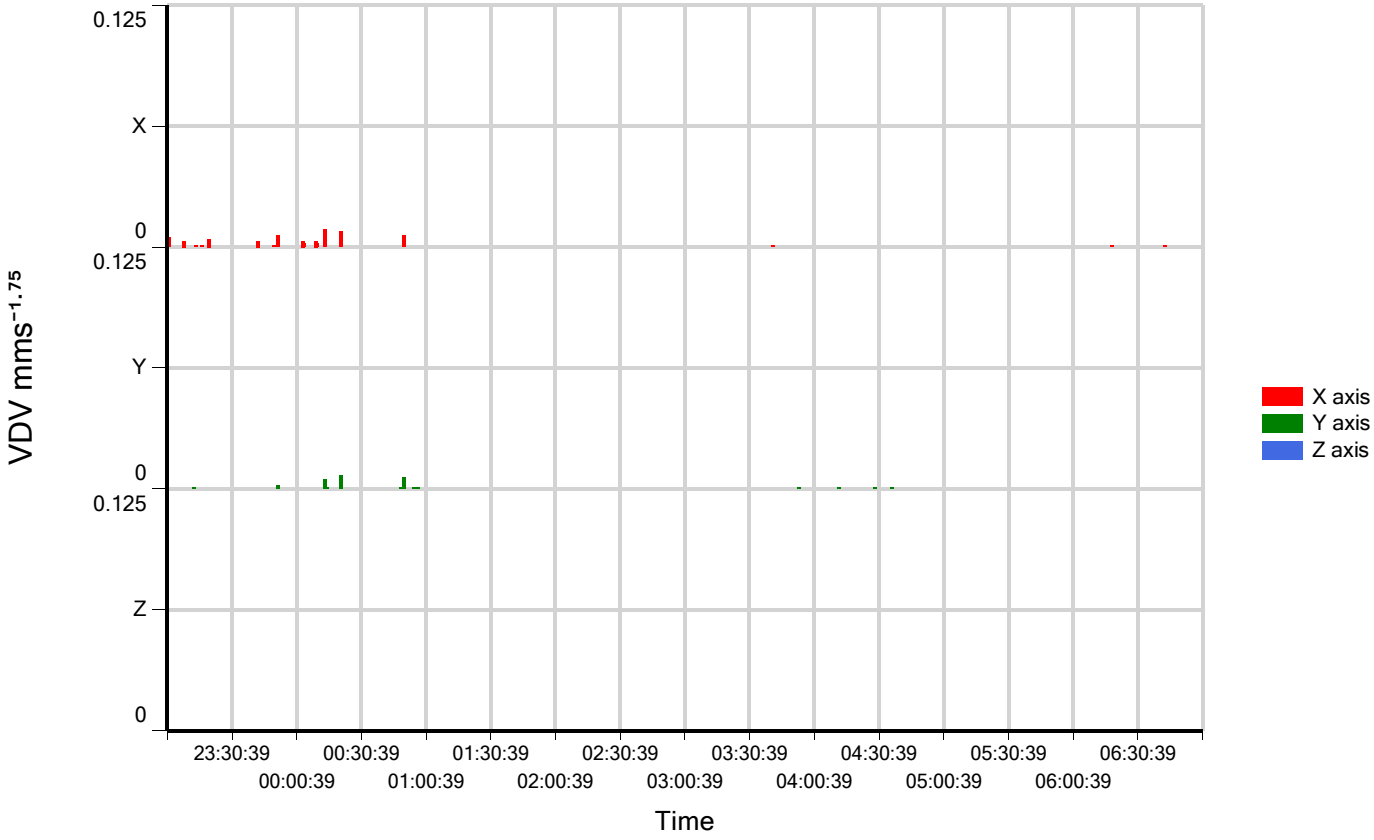


Event Number	3
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	8/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	1.5 mms^{-1}	38.5 Hz	0.053 g	0.006 mm
Vertical Max	0.675 mms^{-1}	41.7 Hz	0.043 g	0 mm
Transverse Max	0.875 mms^{-1}	45.5 Hz	0.04 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

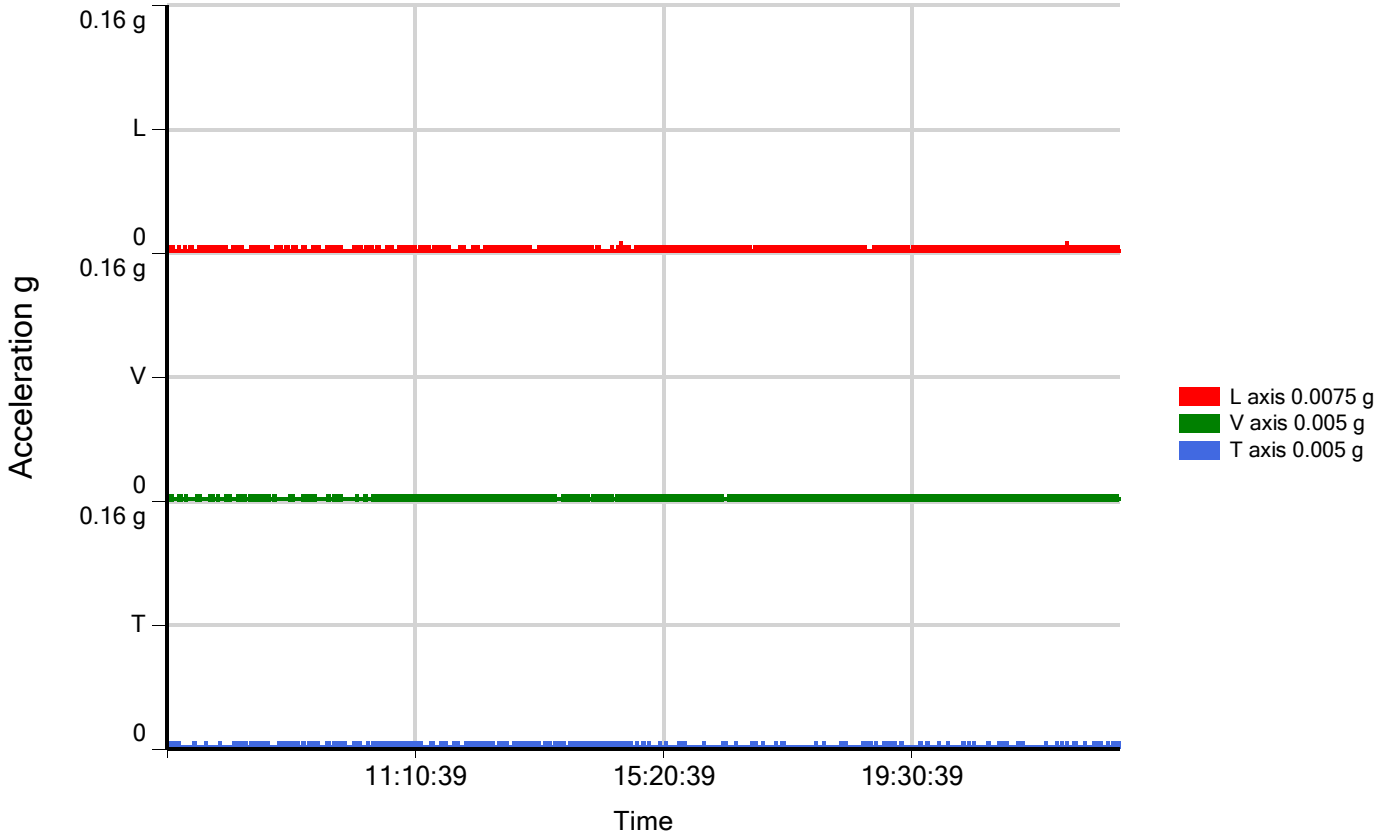


Event Number	3
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	8/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel A - VDV	8 Hour VDV	Event VDV
X Axis	$0.014mms^{-1.75}$	$0.011mms^{-1.75}$
Y Axis	$0.01mms^{-1.75}$	$0.008mms^{-1.75}$
Z Axis	$0.003mms^{-1.75}$	$0.002mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

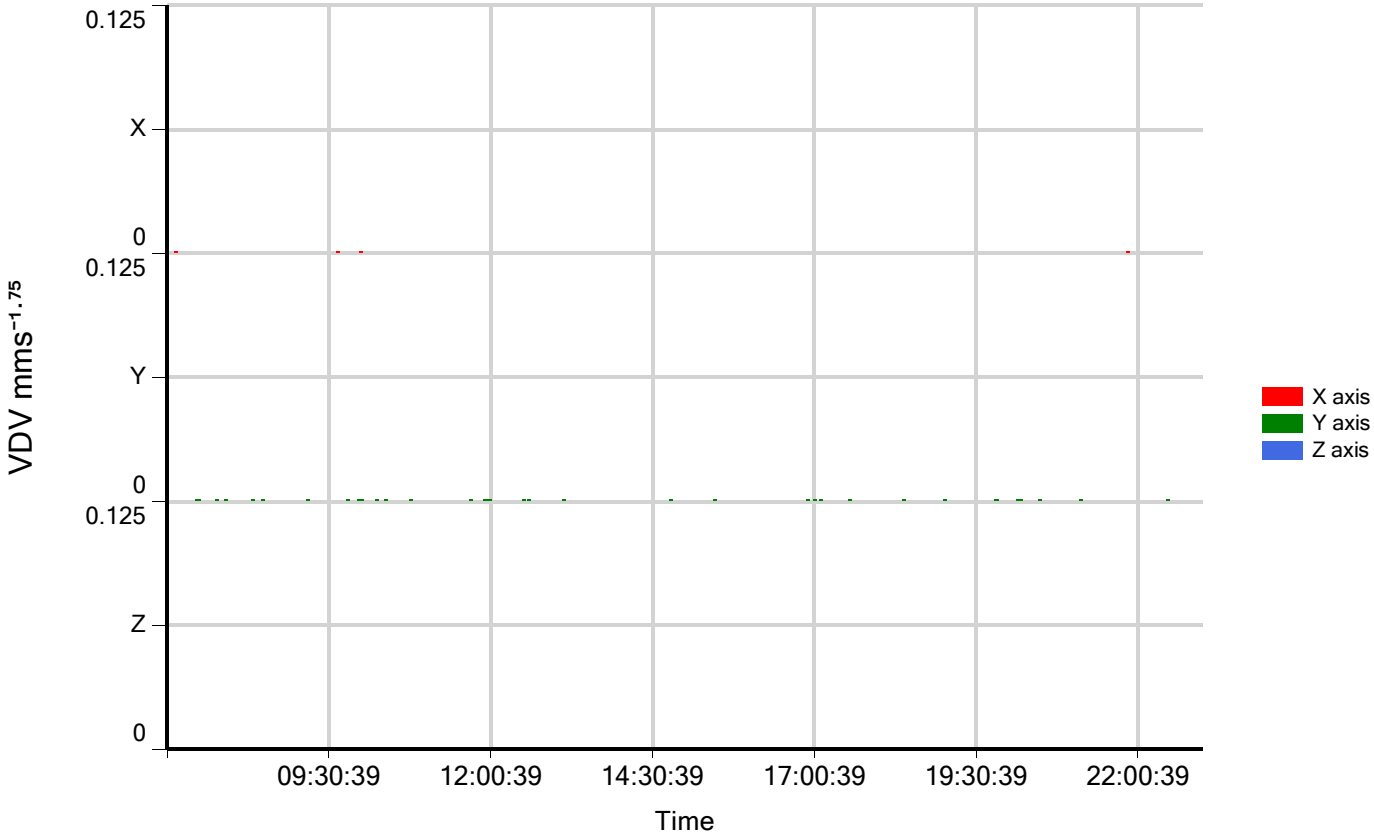


Event Number	4
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	9/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	0.05 mms^{-1}	45.5 Hz	0.008 g	0 mm
Vertical Max	0.05 mms^{-1}	0.04 Hz	0.005 g	0 mm
Transverse Max	0.05 mms^{-1}	0.03 Hz	0.005 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

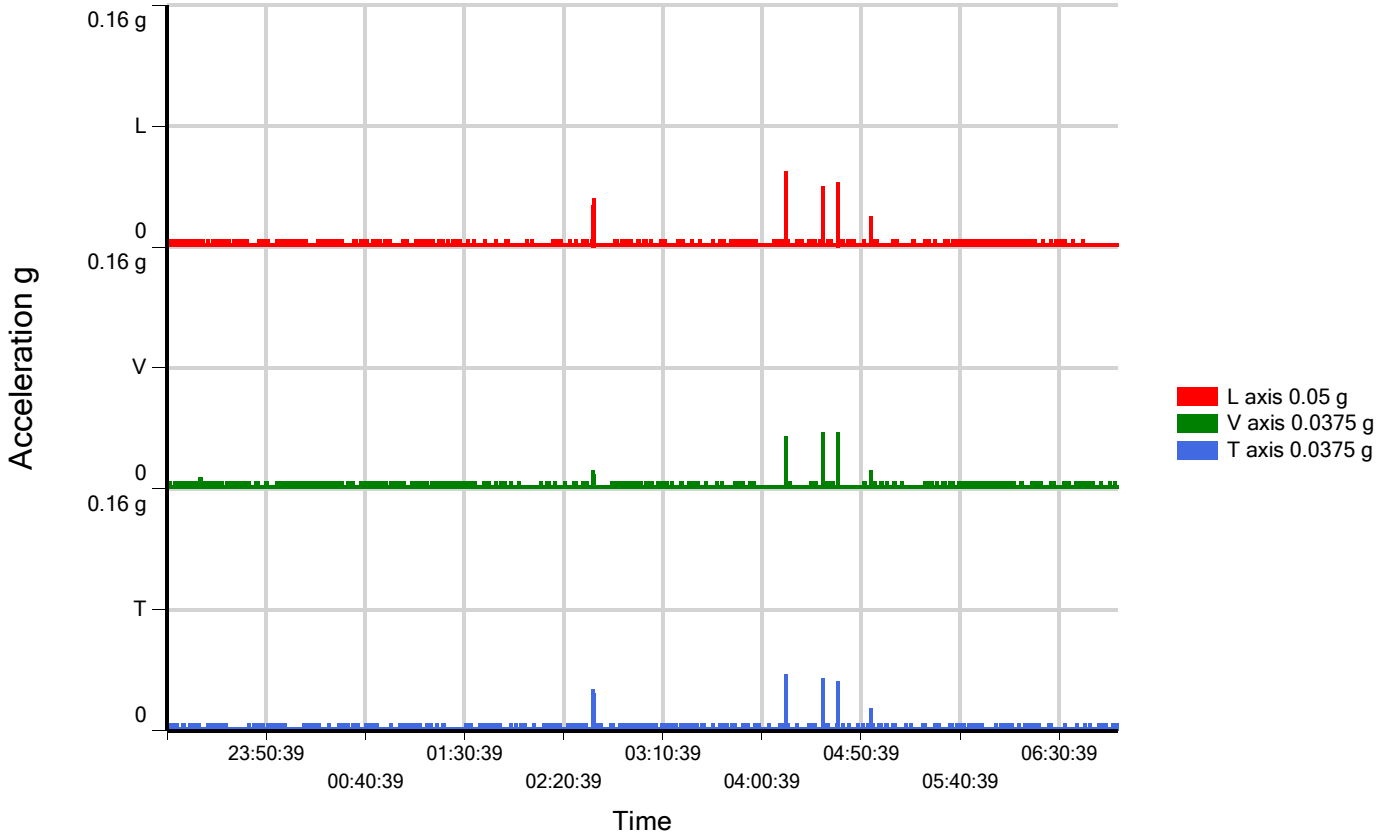


Event Number	4
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	9/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel A - VDV	16 Hour VDV	Event VDV
X Axis	0.001$mms^{-1.75}$	0.001$mms^{-1.75}$
Y Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$
Z Axis	0.003$mms^{-1.75}$	0.003$mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

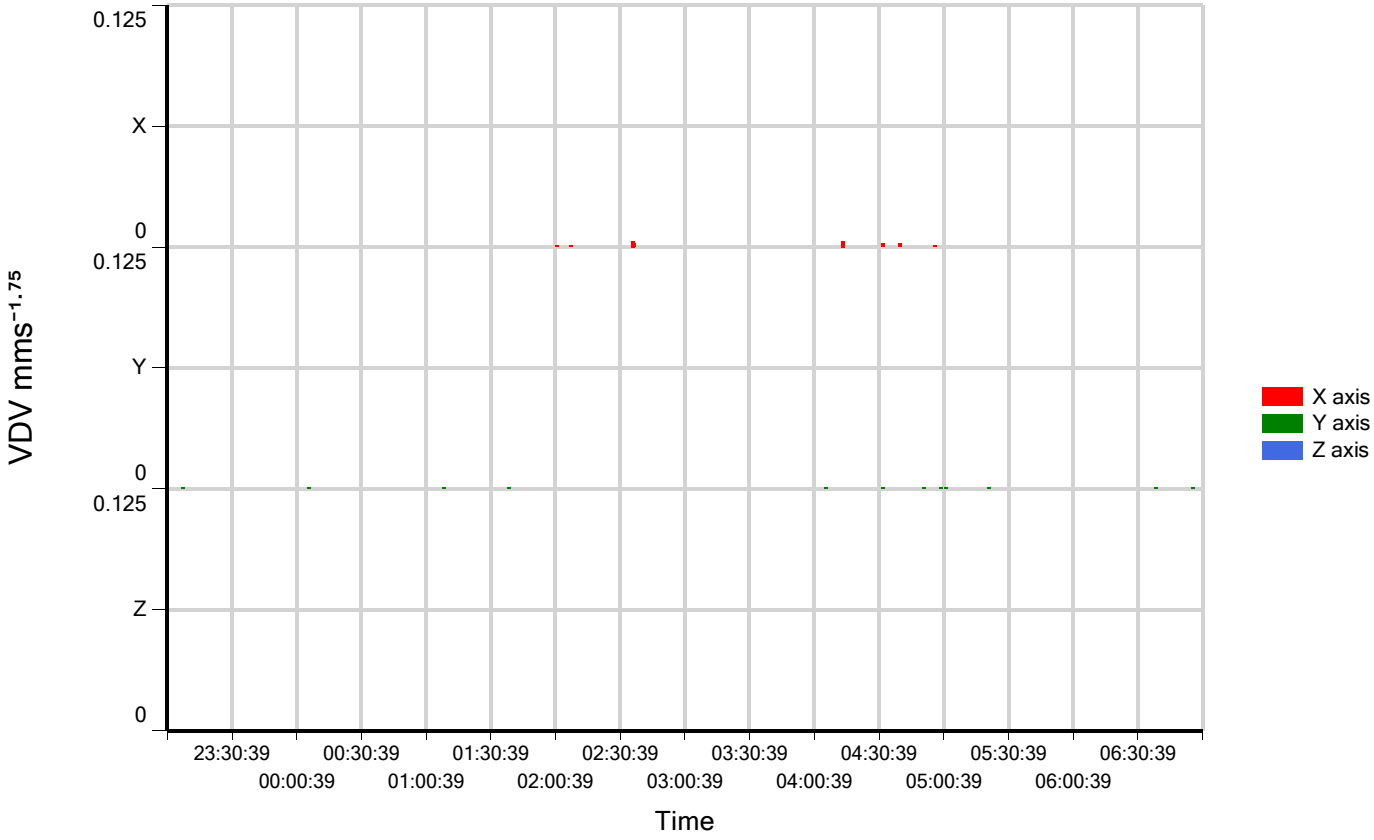


Event Number	5
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	9/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	0.775 mms^{-1}	45.5 Hz	0.05 g	0 mm
Vertical Max	0.375 mms^{-1}	50 Hz	0.038 g	0 mm
Transverse Max	0.45 mms^{-1}	55.6 Hz	0.038 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

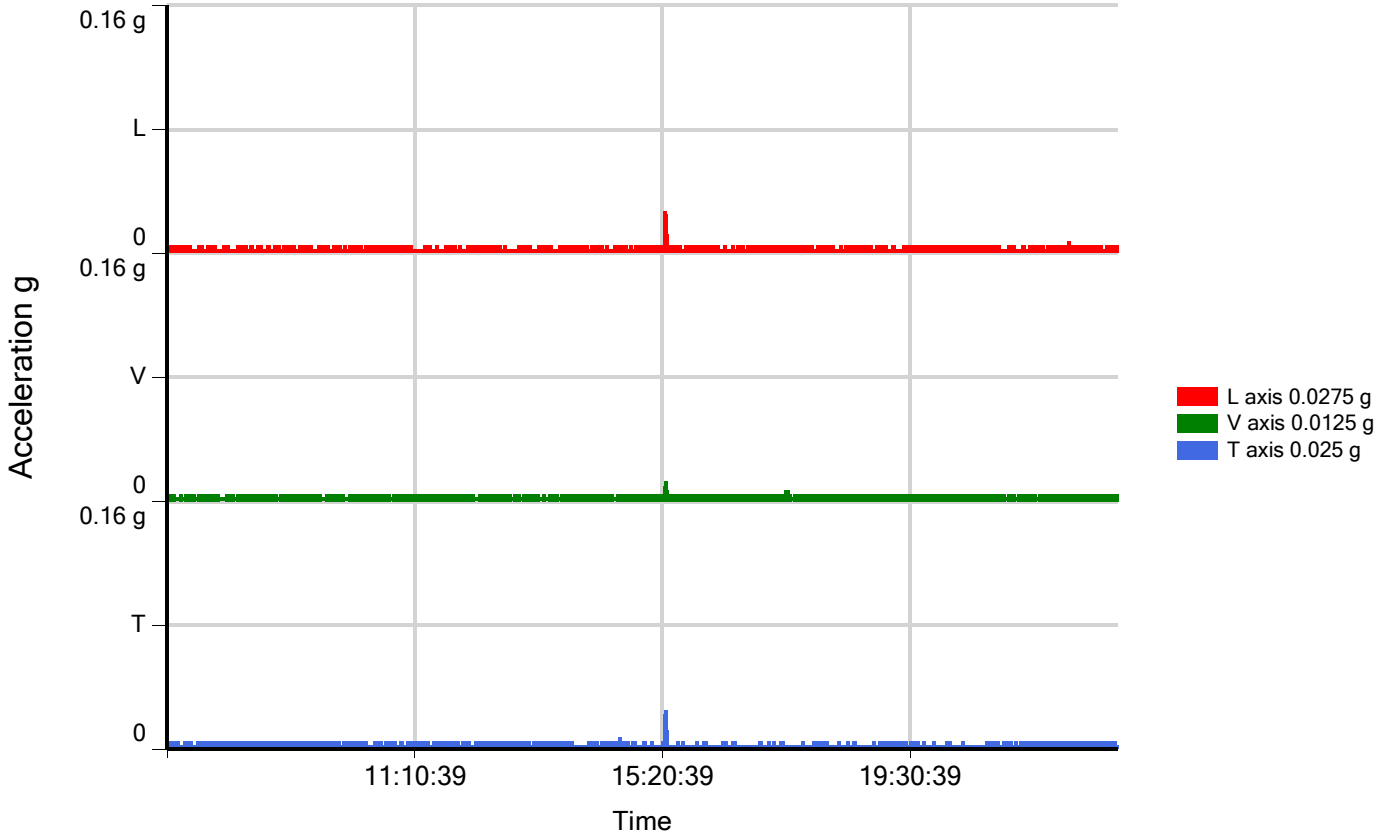


Event Number	5
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	9/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel A - VDV	8 Hour VDV	Event VDV
X Axis	0.005$mms^{-1.75}$	0.004$mms^{-1.75}$
Y Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$
Z Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

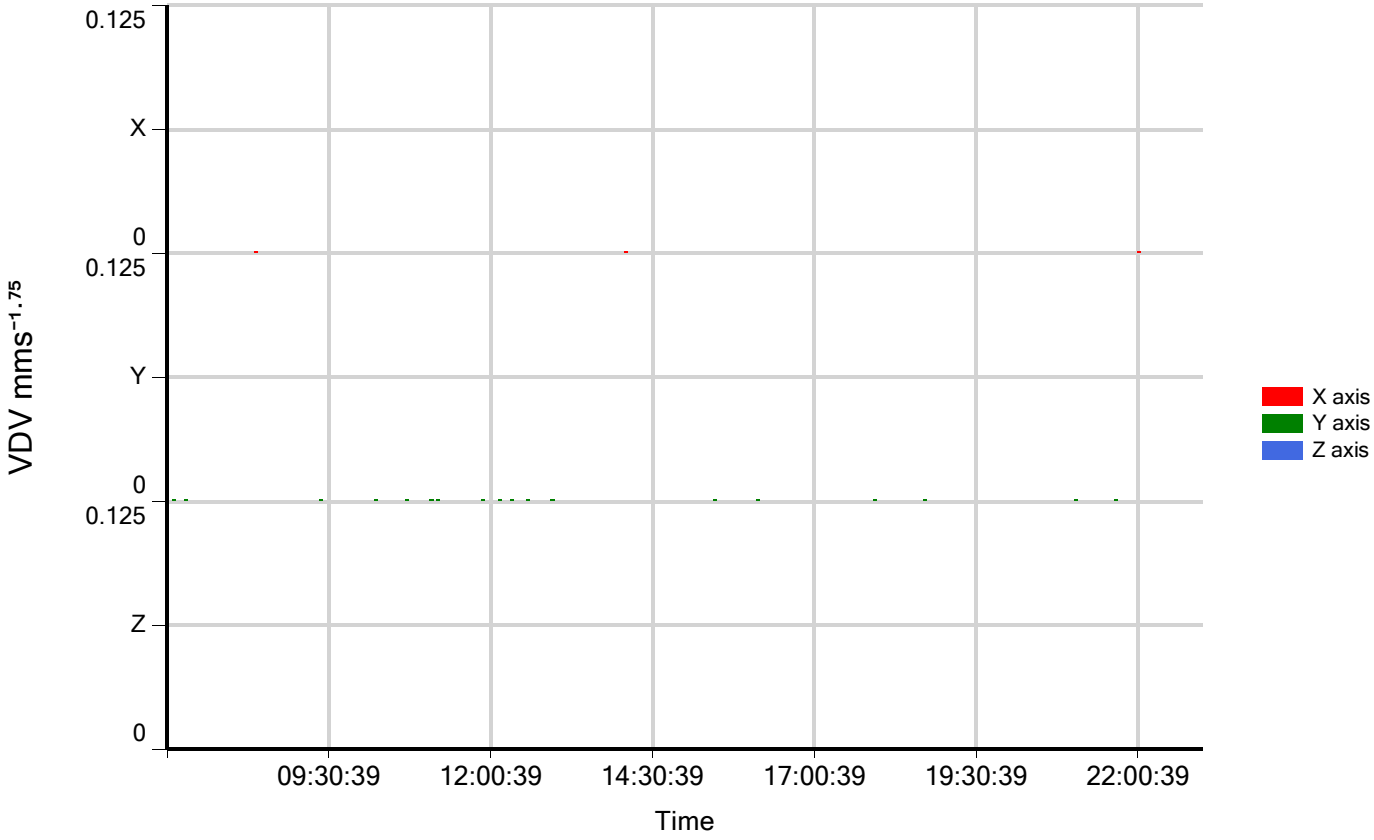


Event Number	6
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	10/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	0.35 mms^{-1}	45.5 Hz	0.028 g	0 mm
Vertical Max	0.1 mms^{-1}	50 Hz	0.013 g	0 mm
Transverse Max	0.2 mms^{-1}	50 Hz	0.025 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

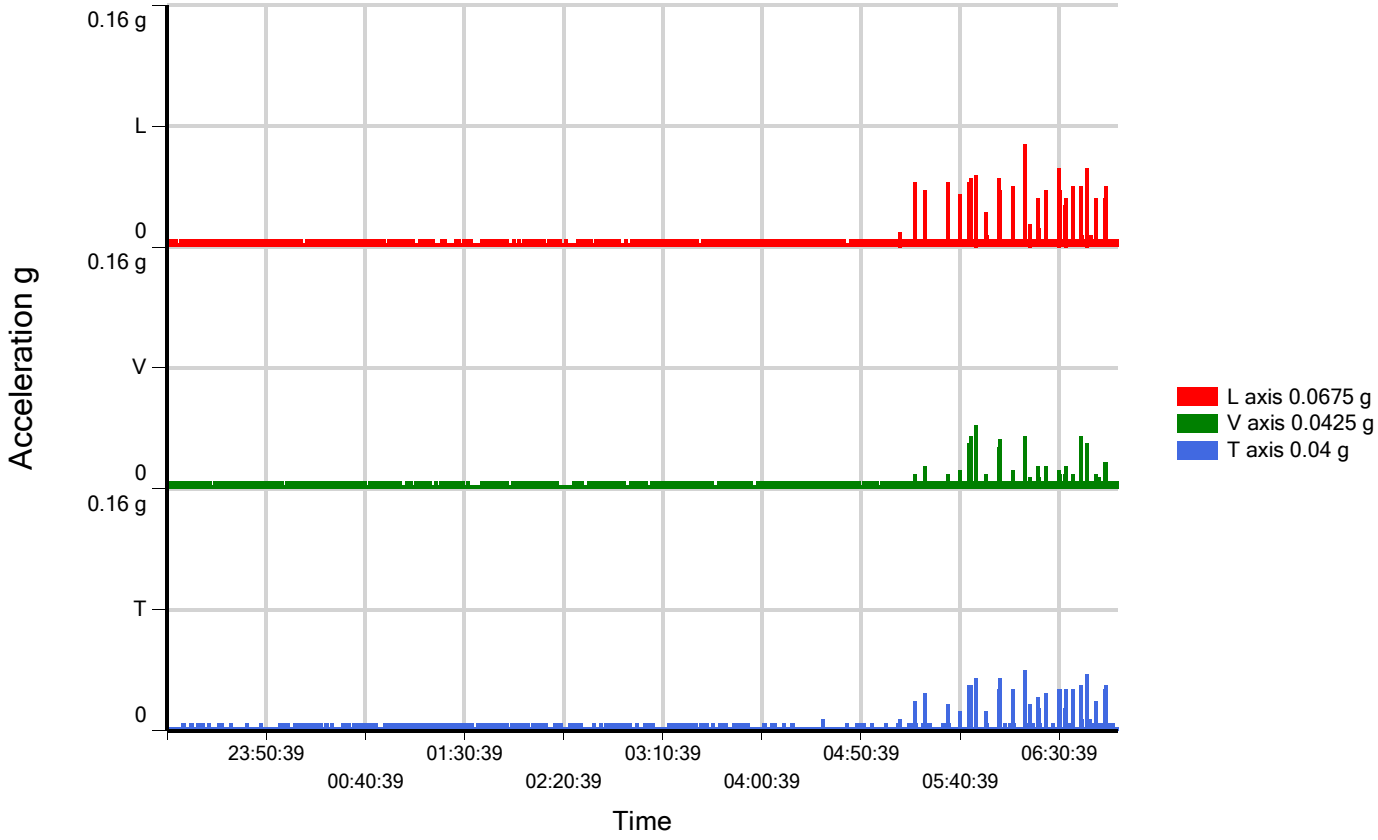


Event Number	6
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	10/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel A - VDV	16 Hour VDV	Event VDV
X Axis	0.001$mms^{-1.75}$	0.001$mms^{-1.75}$
Y Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$
Z Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

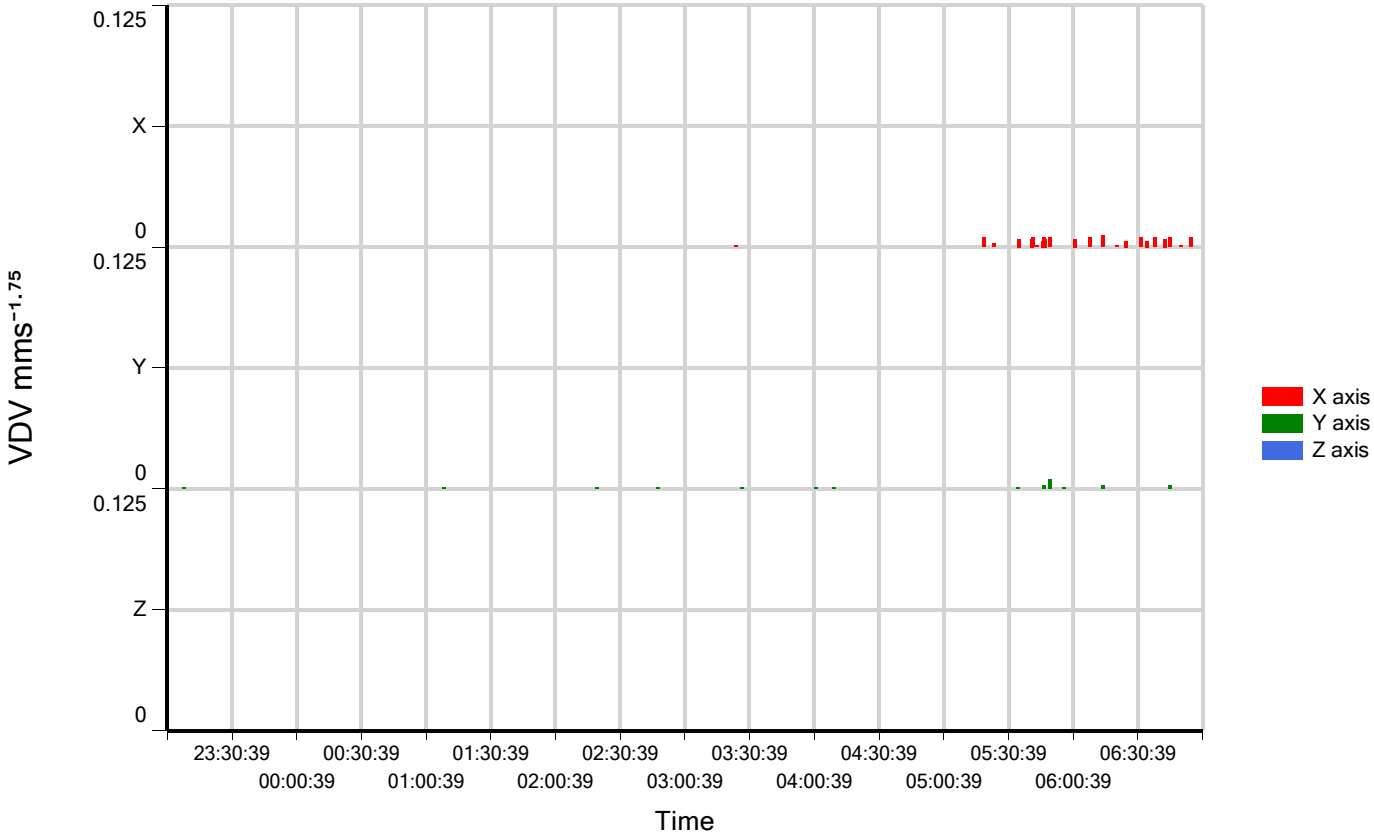


Event Number	7
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	10/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	1.25 mms^{-1}	41.7 Hz	0.068 g	0.006 mm
Vertical Max	0.625 mms^{-1}	55.6 Hz	0.043 g	0 mm
Transverse Max	0.65 mms^{-1}	50 Hz	0.04 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

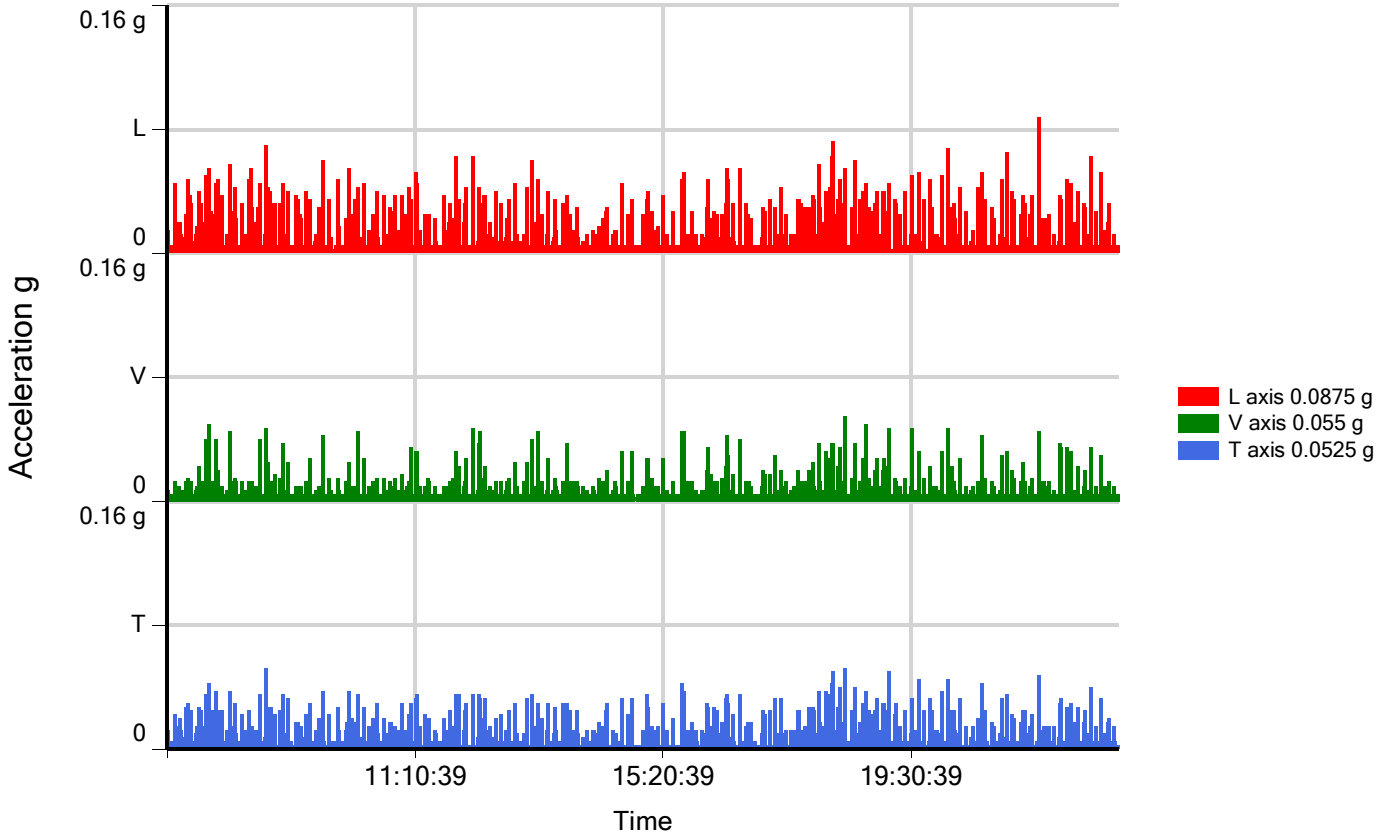


Event Number	7
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	10/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel A - VDV	8 Hour VDV	Event VDV
X Axis	$0.012mms^{-1.75}$	$0.01mms^{-1.75}$
Y Axis	$0.006mms^{-1.75}$	$0.005mms^{-1.75}$
Z Axis	$0.002mms^{-1.75}$	$0.002mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

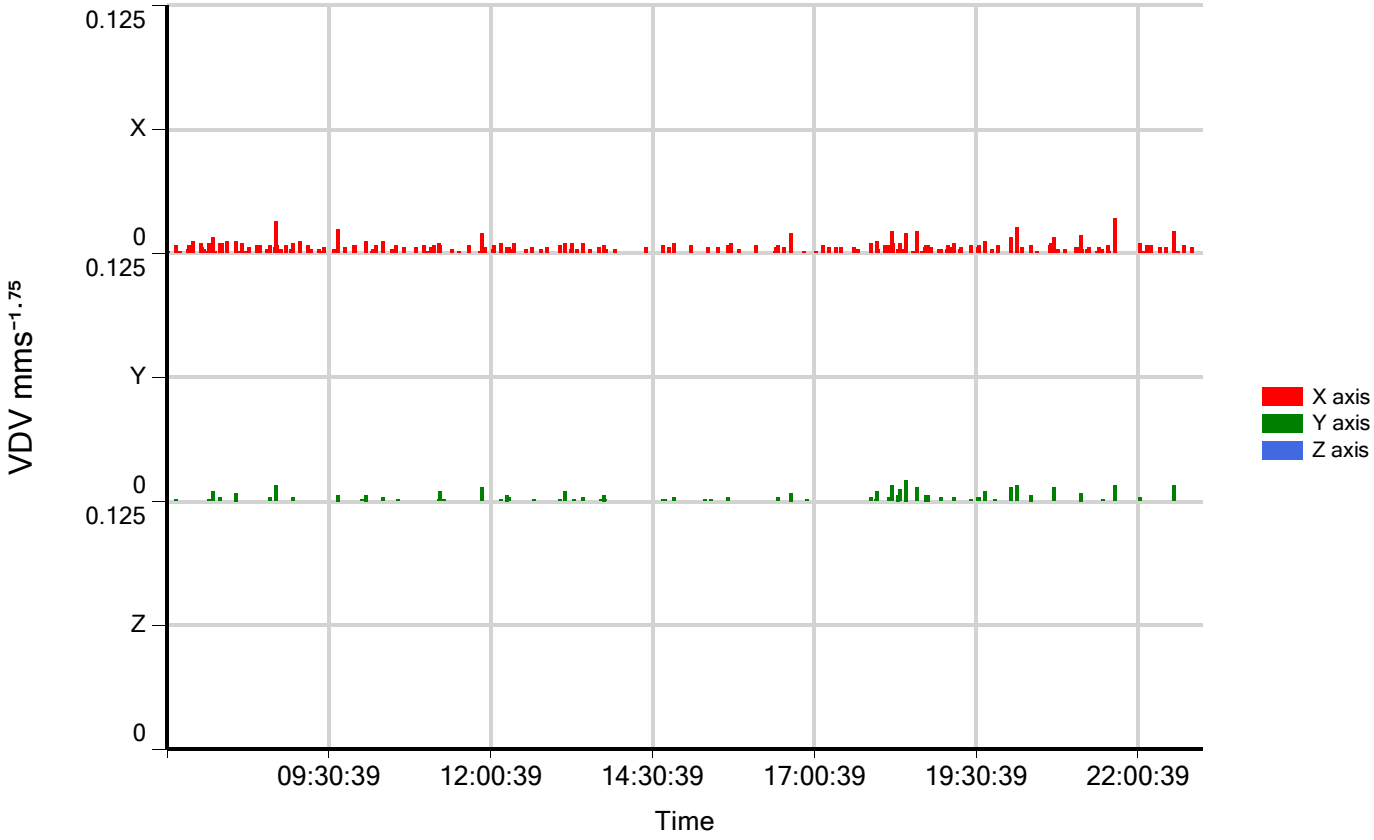


Event Number	8
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	11/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	2.15 mms^{-1}	41.7 Hz	0.088 g	0.013 mm
Vertical Max	0.875 mms^{-1}	62.5 Hz	0.055 g	0 mm
Transverse Max	1.075 mms^{-1}	50 Hz	0.053 g	0.006 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

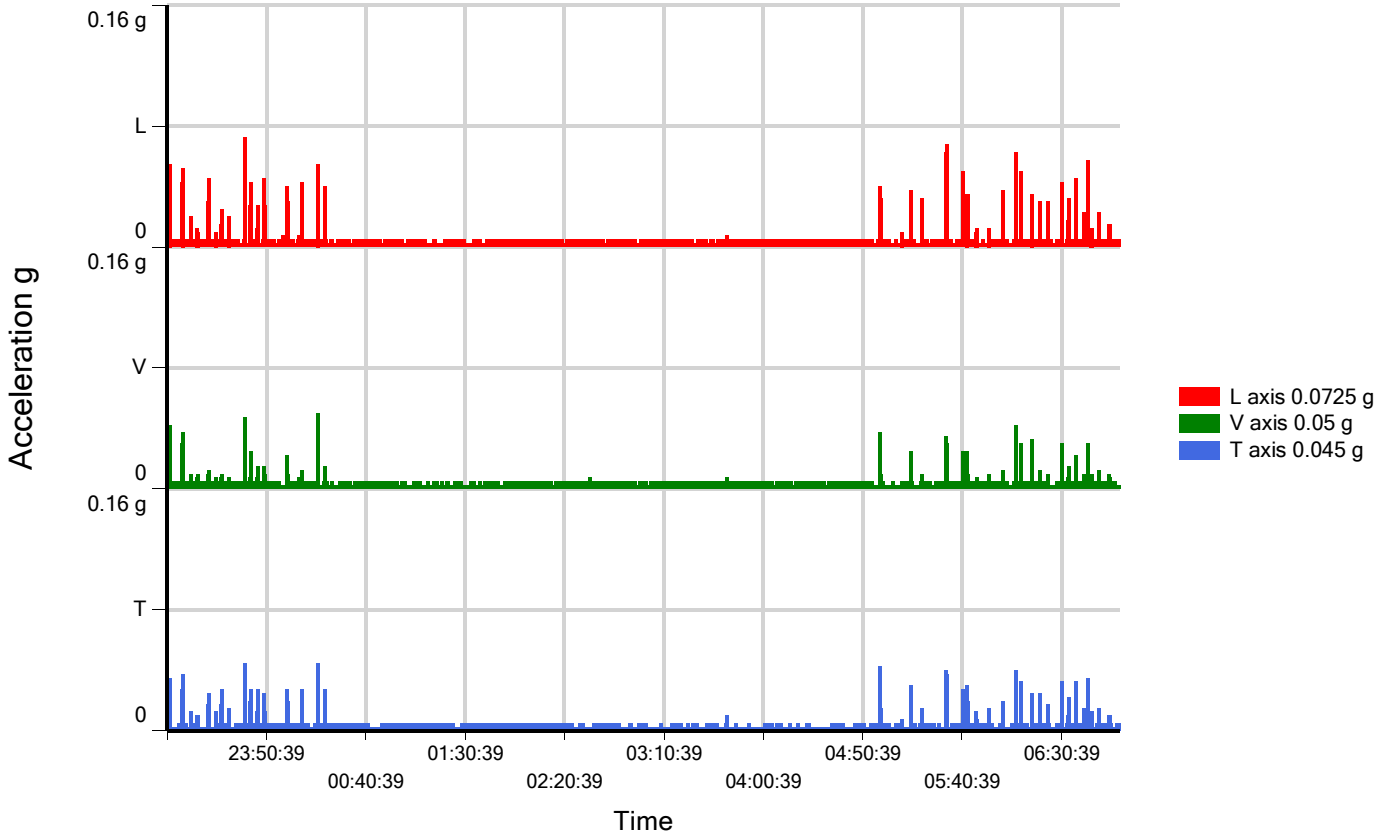


Event Number	8
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	11/6 /2018
Start Time	7:00:39
Stop Time	23:00:00

Channel A - VDV	16 Hour VDV	Event VDV
X Axis	0.025$mms^{-1.75}$	0.025$mms^{-1.75}$
Y Axis	0.016$mms^{-1.75}$	0.016$mms^{-1.75}$
Z Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

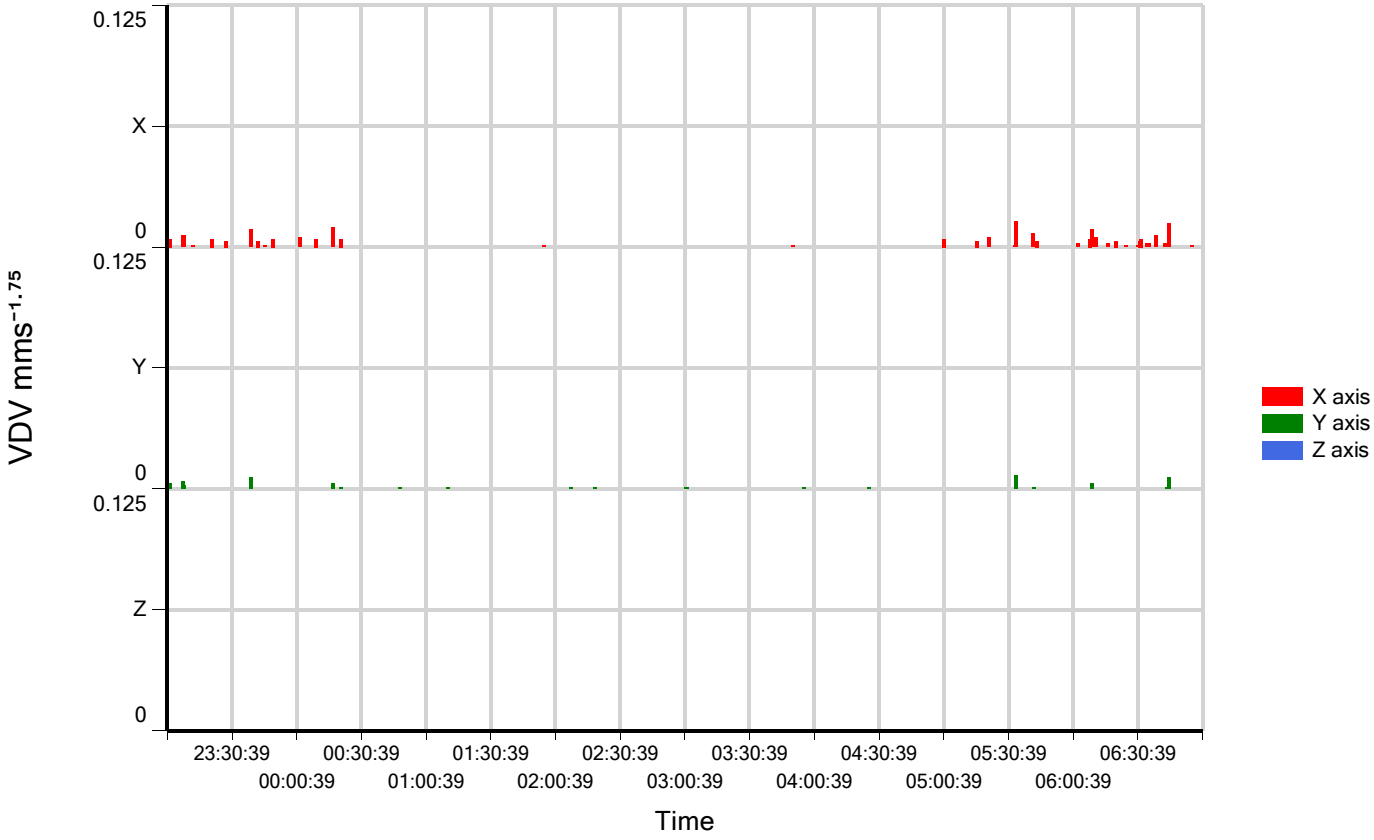


Event Number	9
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	11/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	2.025 mms^{-1}	38.5 Hz	0.073 g	0.013 mm
Vertical Max	0.6 mms^{-1}	62.5 Hz	0.05 g	0.006 mm
Transverse Max	0.925 mms^{-1}	45.5 Hz	0.045 g	0 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location

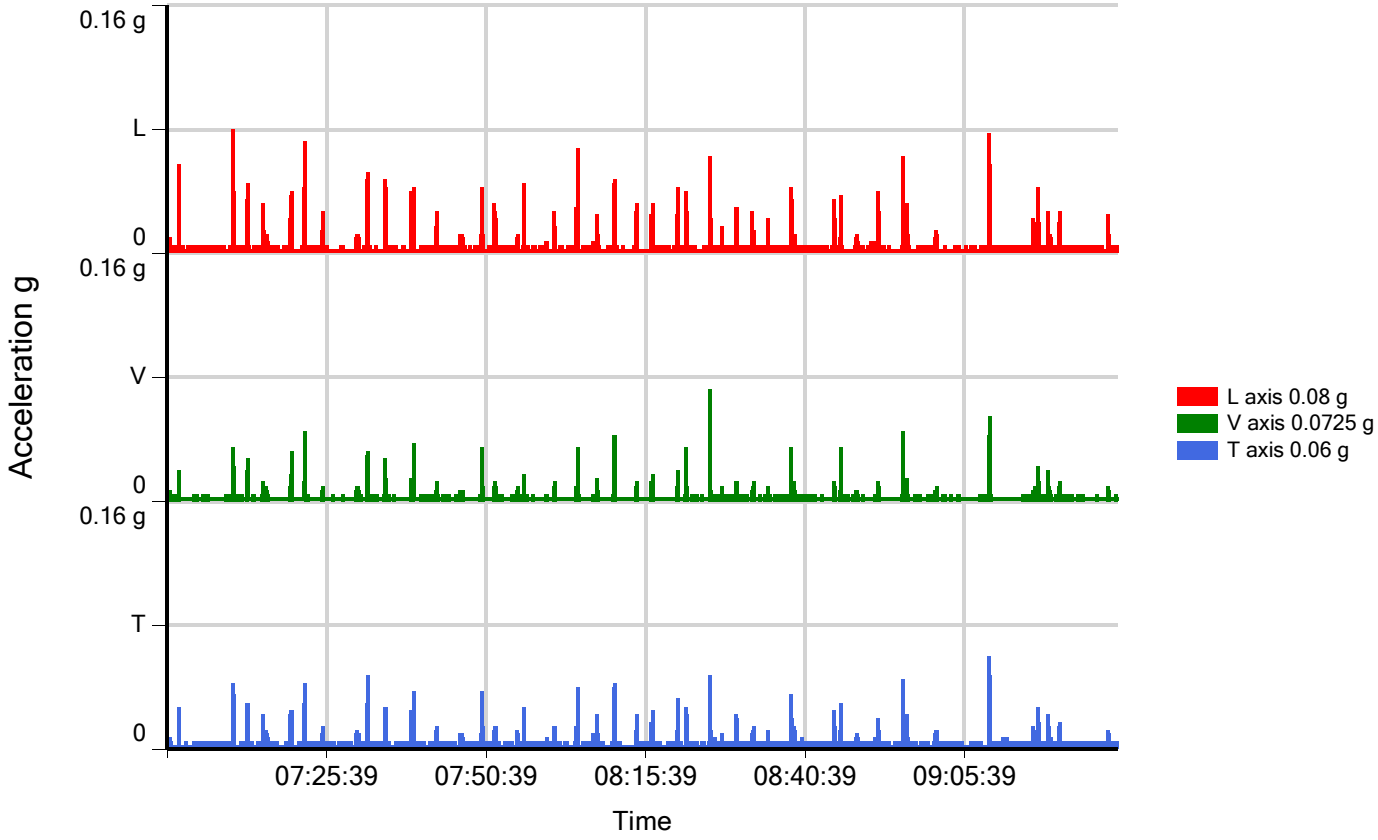


Event Number	9
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	11/6 /2018
Start Time	23:00:39
Stop Time	7:00:00

Channel A - VDV	8 Hour VDV	Event VDV
X Axis	0.021$mms^{-1.75}$	0.018$mms^{-1.75}$
Y Axis	0.01$mms^{-1.75}$	0.009$mms^{-1.75}$
Z Axis	0.002$mms^{-1.75}$	0.002$mms^{-1.75}$

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

Continuous Graph Location

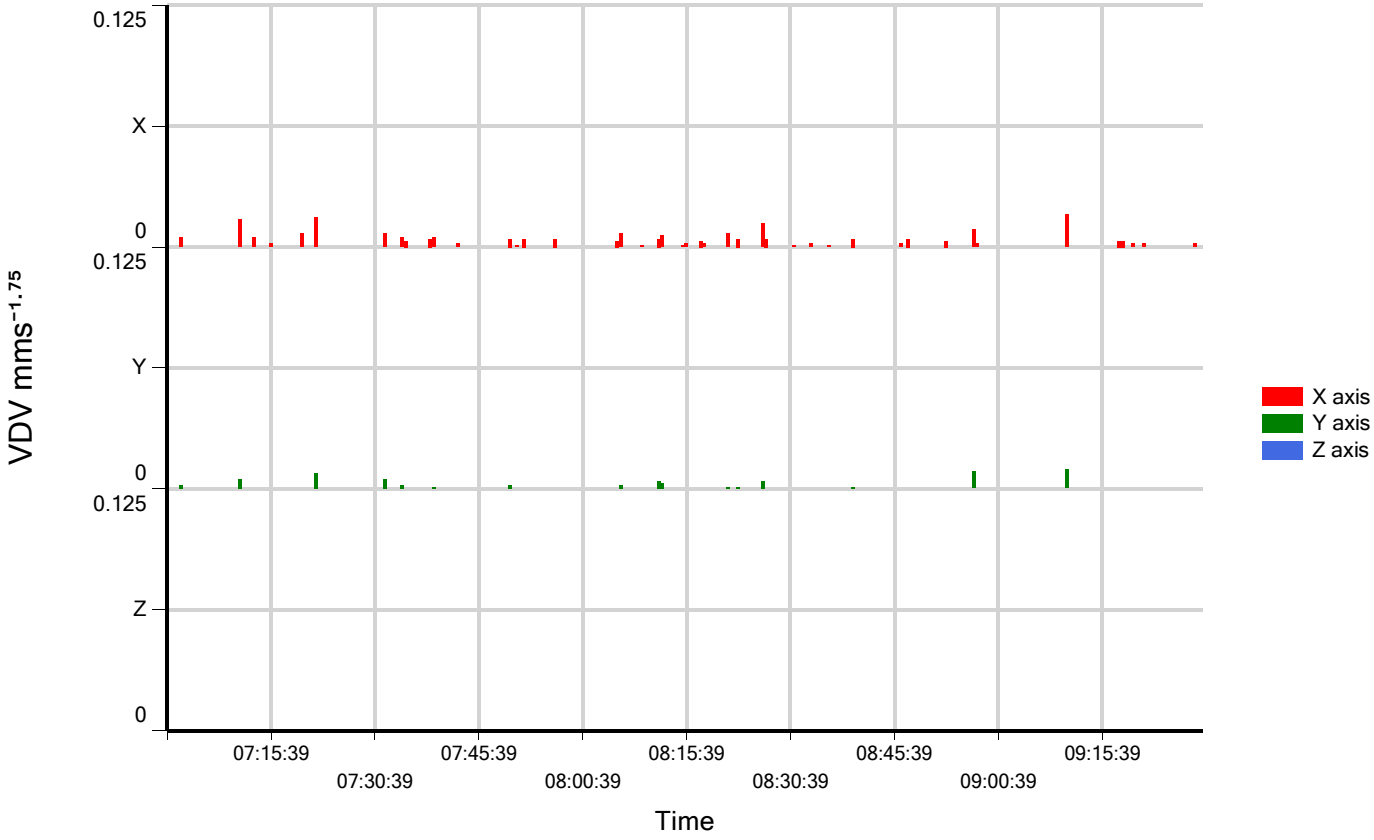


Event Number	10
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	12/6 /2018
Start Time	7:00:39
Stop Time	9:29:37

Channel B	PPV	Frequency	Acceleration	Displacement
Longitudinal Max	2.375 mms^{-1}	38.5 Hz	0.08 g	0.013 mm
Vertical Max	0.8 mms^{-1}	55.6 Hz	0.073 g	0 mm
Transverse Max	1.275 mms^{-1}	45.5 Hz	0.06 g	0.006 mm

V9000 Seismograph Serial Number 2155 Calibrate by: 6/2019

VDV Graph Location



Event Number	10
Serial Number	2155
Event Type	VDV A ,Cont. B
Monitoring Mode	Ch A VDV $mms^{-1.75}$ Ch B Acceleration g
Start Date	12/6 /2018
Start Time	7:00:39
Stop Time	9:29:37

Channel A - VDV	16 Hour VDV	Event VDV
X Axis	0.035$mms^{-1.75}$	0.022$mms^{-1.75}$
Y Axis	0.02$mms^{-1.75}$	0.012$mms^{-1.75}$
Z Axis	0.002$mms^{-1.75}$	0.001$mms^{-1.75}$