



Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

VIBRATION MONITORING REPORT
JULY 2015

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INTRODUCTION

- 1.1.** Monitoring of construction vibration is being undertaken by FCBC during the construction of the new Forth Crossing and associated road network. This report covers the month of July 2015. The objective of this report is to detail the vibration monitoring that has been undertaken across the site during this period, which has been done so in accordance with the Code of Construction Practice (CoCP), and Noise and Vibration Management Plan (NVMP).
- 1.2.** FCBC carefully risk assesses noise & vibration likely to result from all construction activities, through the production of Plans for Control of Noise & Vibration (PCNVs). During the preparation of PCNVs, vibration prediction assessments are made. These assessments illustrate that no construction plant, equipment or methodology to be used by FCBC are envisaged to induce any levels of vibration at sensitive receptors that would exceed the vibration threshold levels stated in the CoCP. These assessments/predictions have been validated by means of the vibration monitoring results displayed in this report.

2. MONITORING SUMMARY

- 2.1.** Due to the location and sensitivity of vibration monitoring equipment, the exceedances presented in the graphs included in the appendices of this report do not represent levels generated by construction, but rather show local interference around the monitoring equipment. This can include, for example, Residential activity, or indeed any significant movements occurring close to the monitoring equipment.
- 2.2.** According to the BS5228-2 (2009) there is minimal documented proof of actual damage to structures or their finishes resulting from construction, and damage resulting solely from well-controlled construction and demolition vibrations is rare. There are many other mechanisms which cause damage, especially in decorative finishes, and it is often incorrectly concluded that vibrations from construction and demolition sites are to blame. In many cases it is not possible to ascertain the exact source of vibration, though it is possible to rule out construction as a source on an activity basis.
- 2.3.** The works carried out in each of the various construction work areas as well as the related vibration assessments are summarised in Appendix A.
- 2.4.** Considering the distances between the various construction work areas and sensitive receptors as well as working methods utilised, the risk of any damage to structures or nuisance to residents occurring as a result FCBC construction related vibration is highly unlikely.
- 2.5.** The number of threshold exceedances at the various vibration monitoring stations during the period in question are shown in Table 1 below.

Table 1: Exceedances of thresholds set out in the CoCP

July 2015

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s^{-1})	Intermittent (10 mm.s^{-1})	Day ($0.4 \text{ m.s}^{-1.75}$)	Night ($0.2 \text{ m.s}^{-1.75}$)
Linn Mill	0	5	0	1
Butlaw Fisheries	1	2	0	0
Clufflat Brae	1	18	1	1
Dundas Home Farm	0	2	0	0
Echline	1	2	0	0
Inchgarvie Lodge	0	4	0	0
Scotstoun	0	1	0	0
Springfield	0	2	0	0
Tigh-Na-Grian	0	6	0	5
Whinnyhill	4	14	0	1

- 2.6.** Peak Particle Velocity (PPV) is used to measure vibration through a solid surface. When a vibration is measured, the point at which the measurement takes place can be considered to have a particle velocity. This particle vibration will take place in three dimensions (x, y and z).
- 2.7.** The Peak Particle Velocity is the highest velocity that is recorded during a particular event, and as such is appropriate for the measurement of activities such as blasting, piling and compacting. The thresholds for the Forth Replacement Crossing are 5 mm.s^{-1} for continuous construction (e.g. piling), and 10 mm.s^{-1} for intermittent construction (e.g. blasting).
- 2.8.** These thresholds are set to protect against building damage. For this monitoring period, all the exceedances have been investigated thoroughly and appear to have been generated as a result of standalone, instantaneous events arising from local interferences, the exact source of which remains unknown.

- 2.9.** Vibration Dose Value (VDV) is a metric used in vibration monitoring. It is calculated by taking the fourth root of the integral of the fourth power of acceleration after it has been frequency-weighted. The frequency-weighted acceleration is measured in m.s^{-2} and the time period over which the VDV is measured is in seconds. This yields VDV in $\text{m.s}^{-1.75}$.
- 2.10.** The vibration dose value (VDV), a cumulative measurement of the vibration level received over an 8-hour or 16-hour period, is recommended in BS 6472 as the appropriate measure to evaluate human exposure to vibration in buildings in residential and other uses.
- 2.11.** During the monitoring period, vibratory rollers and whacker plates were used intermittently at several locations around the site. No exceedances were recorded as a result of the use of this equipment, where exceedances did occur it resulted from non-project related activity around the monitor.
- 2.12.** In addition, detailed investigation of all exceedances (i.e. review of PPV levels over 30 seconds periods) has shown that each resulted from isolated, non-construction related events, which likely occurred close to the monitoring station.
- 2.13.** Within the Appendix B, there are short gaps of missing data in the PPV and VDV graphs. These occurred due to a number of power supply problems and corrupt files.

3. CONCLUSION

- 3.1.** Considering the distance between FCBC construction works and sensitive receptors, the methods of working utilised and programme of works. The risk of damage to structures or nuisance to residents resulting from vibration is highly unlikely.

- 3.2.** Due to the location and sensitivity of vibration monitoring equipment, the exceedances presented in the graphs included in the appendices of this report are unlikely to be generated by construction, but rather show local interference and maintenance around the monitoring equipment.



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**APPENDIX A – MONITORING LOCATIONS & VIBRATION ASSESSMENTS
FROM RELEVANT PCNVs**

Table 2: Monitoring Locations

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During July 2015
M1	Whinny Hill	Network	<ul style="list-style-type: none"> • Earthworks/Fill placement • New Ferrytoll Road • FT03&FT04 deck works • FT09 works • FT19 Retaining Wall • Roadworks
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck table installation works • North Tower rebar, formwork, concreting works deck table installation works • Pier N1 rebar formwork & concrete works • AVN works
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> • Pier S1 rebar, formwork & concrete works • Cleaning, Blinding pour and Rebar installations at Pier S2 • Central Tower rebar, formwork, concreting works deck table installation works • South Tower rebar, formwork, concreting works deck table installation works
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> • Launch – Install lateral Guides, Launch phase 11 & 12 • Pier S1 rebar, formwork, & concrete works • Central Tower rebar, formwork, concreting works, deck table installation works • South Tower rebar, formwork, concreting works, deck table installation works • Main Carriageway earthworks
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> • Launch – Install lateral Guides, Launch phase 11 & 12 • No night time or Sunday construction in the vicinity • Excavation, Break rock, fill/trim mainline & fill

			launch
M13	Clufflat Brae	Crossing / Network	<ul style="list-style-type: none"> • Launch – Install lateral Guides, Launch phase 11 & 12 • No night time or Sunday daytime construction in vicinity.
M14	Springfield	Network	<ul style="list-style-type: none"> • Launch – Install lateral Guides, Launch phase 11 & 12 N.B. No night time or Sunday daytime construction in vicinity. • Earthworks South Abutment area • Excavation, Break rock, fill/trim mainline & fill launch
M15	Echline	Network	<ul style="list-style-type: none"> • Launch – Install lateral Guides, Launch phase 11 & 12 • No night time or Sunday construction in the vicinity • Earthworks South Abutment area • Excavation, Break rock, fill/trim mainline & fill launch
M16	Scotstoun	Network	<ul style="list-style-type: none"> • Arup access works • Footpath works • Utility works • Concrete finishing works at ESQ04 • B800 North road works including bridge works
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> • Utility works • Concrete finishing works ESQ04 • B800 South road works including bridge works • Main carriageway works

Table 2: The main construction activities undertaken in the locality of each of the vibration monitors during the period of July 2015.

Table 3: PCNV Predicted PPV & VDV Levels

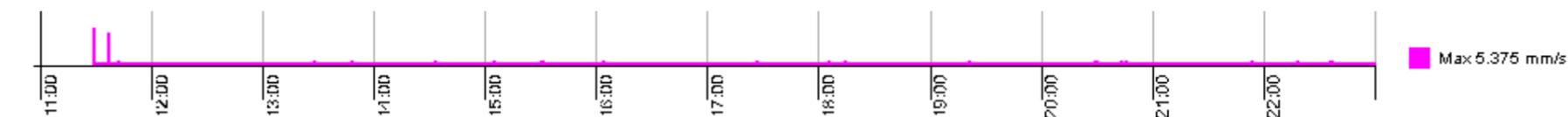
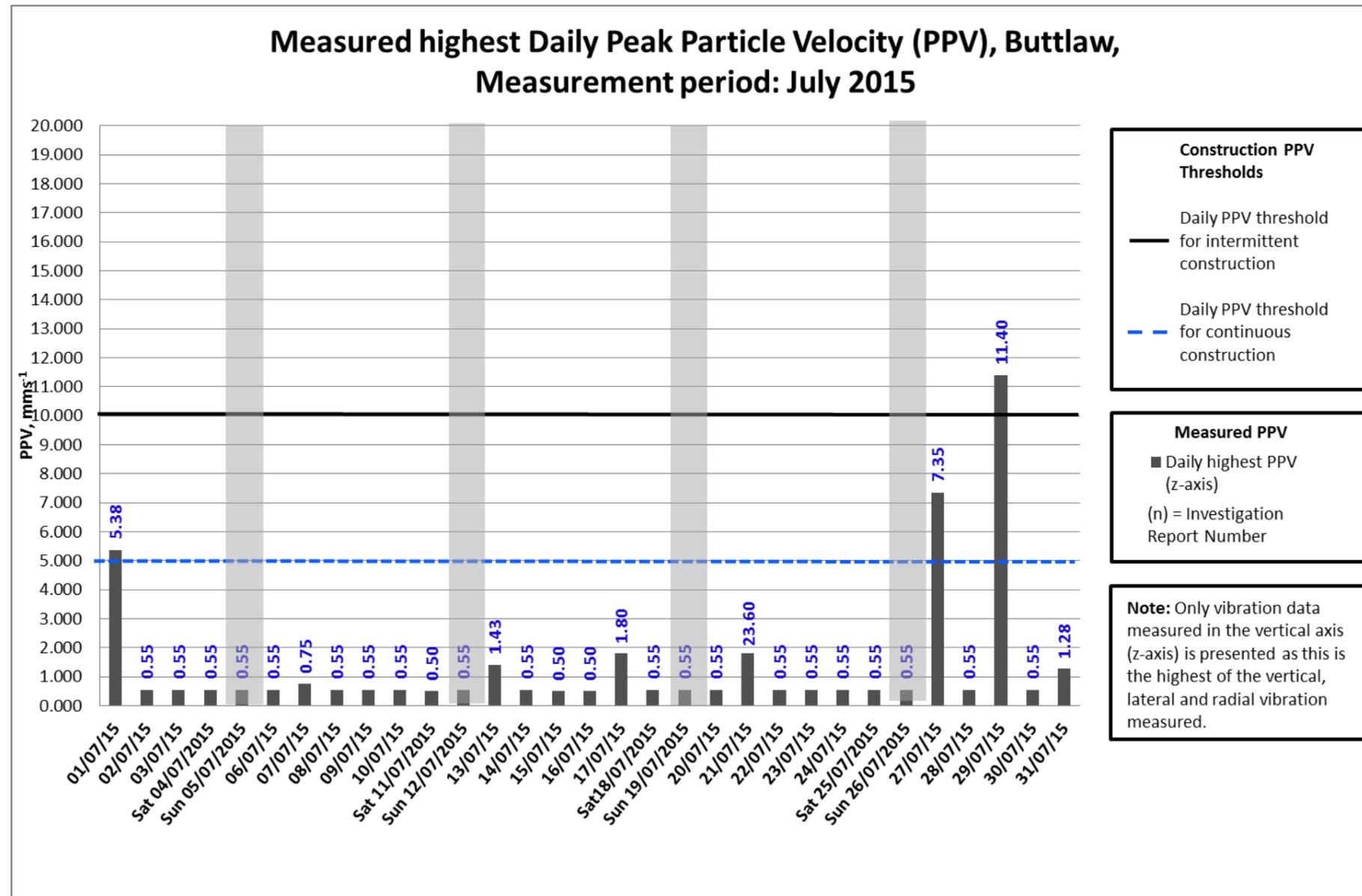
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	2.44	0.37
Dundas	75	2000	Roller/Whacker	0.98	0.33
Echline	40	1000	Roller/Whacker	2.44	0.37
Inchgarvie Lodge	50	40	Roller/Whacker	1.77	0.33
Linn Mill	60	250	Roller/Whacker	1.36	0.33
Scotstoun	40	2000	Roller/Whacker	2.44	0.37
Springfield	50	300	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	180	1800	N/A	-	-

Table 3: The distances from vibration monitors to the closest work areas for both day and night time periods. It also lists worst case PPV and eVDV calculations exhibited at the vibration monitors, resulting from the maximum vibration inducing plant operated at the nearest work areas.

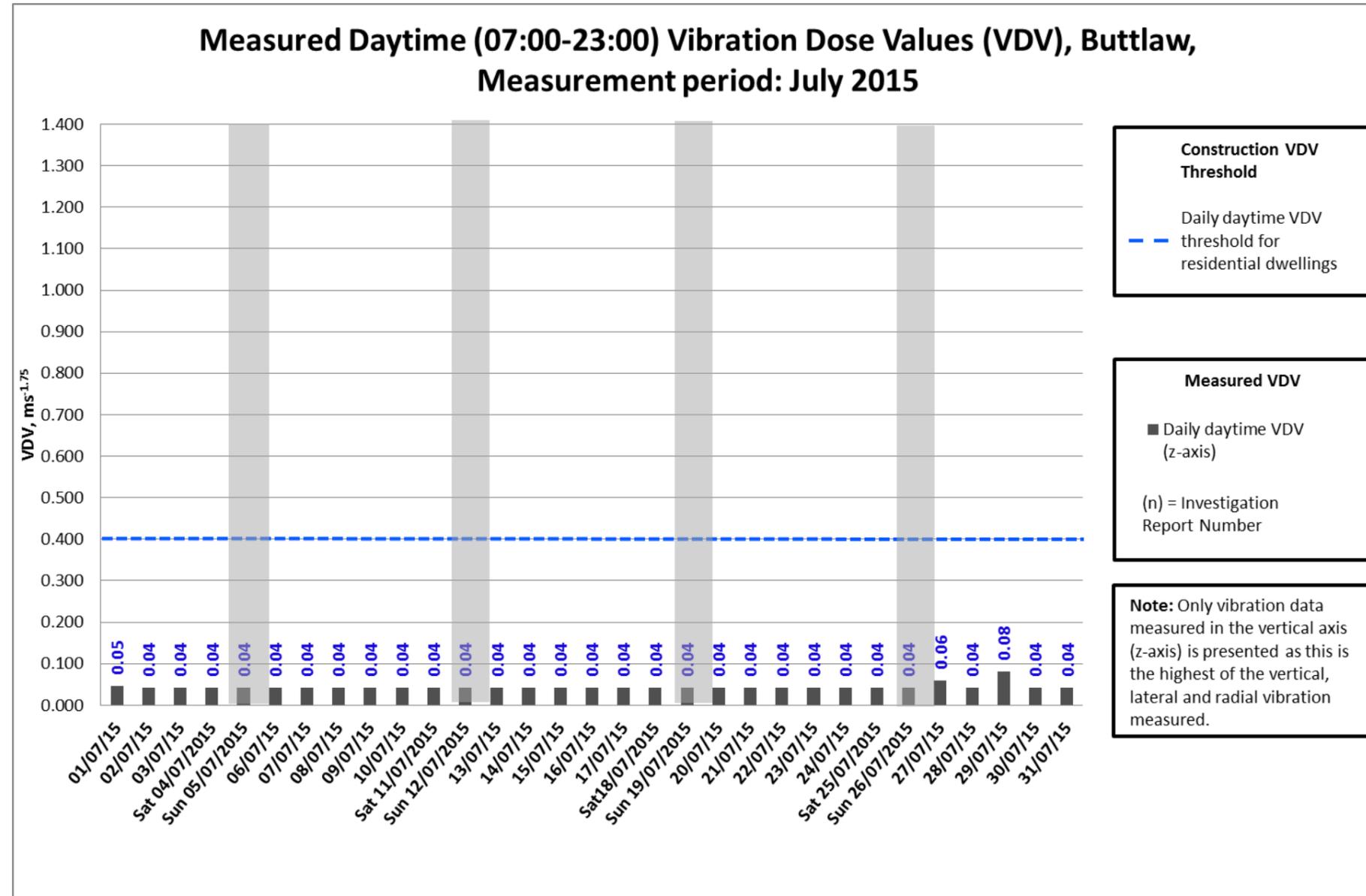
Notes on Table 3

- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 5m, 0.4mm/s @ 20m, 0.1mm/s @ 50m have been discounted due to the distances of use from the closest receptors).
- Vibratory rollers were not operated within 20m of any sensitive receptor.
- Whacker plates were not utilised within 40m of any occupied sensitive receptor.
- All roller eVDV values in the table above are based on the worst case scenario of a vibratory roller remaining in continuous operation for 2 hours an average distance (100m) from the nearest occupied receptors.
- All whacker plate eVDV values in the table above are based on the worst case scenario of a whacker plate remaining in continuous operation for 2 hours a minimum distance from the nearest receptor.

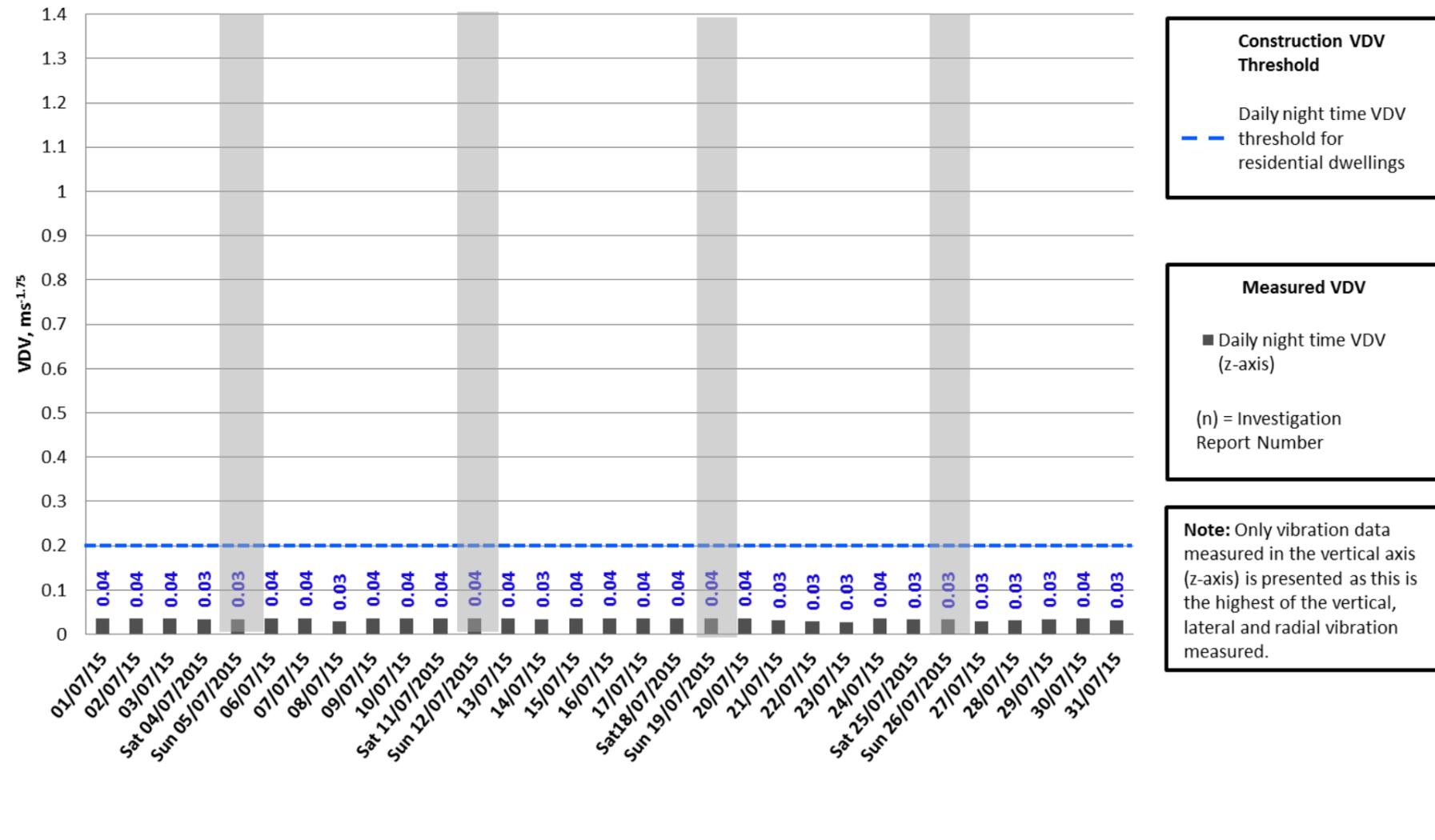
APPENDIX B – VIBRATION GRAPHS



- Exceedance on the 01/07/15 was caused due to data being extracted from the vibration monitor, Graph from that day seen above.
- Exceedance on the 27/07/2015 and the 29/07/2015 were caused due to maintenance being carried out on the adjacent noise monitor.



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Buttlaw, Measurement period: July 2015



Construction VDV Threshold

Daily night time VDV threshold for residential dwellings

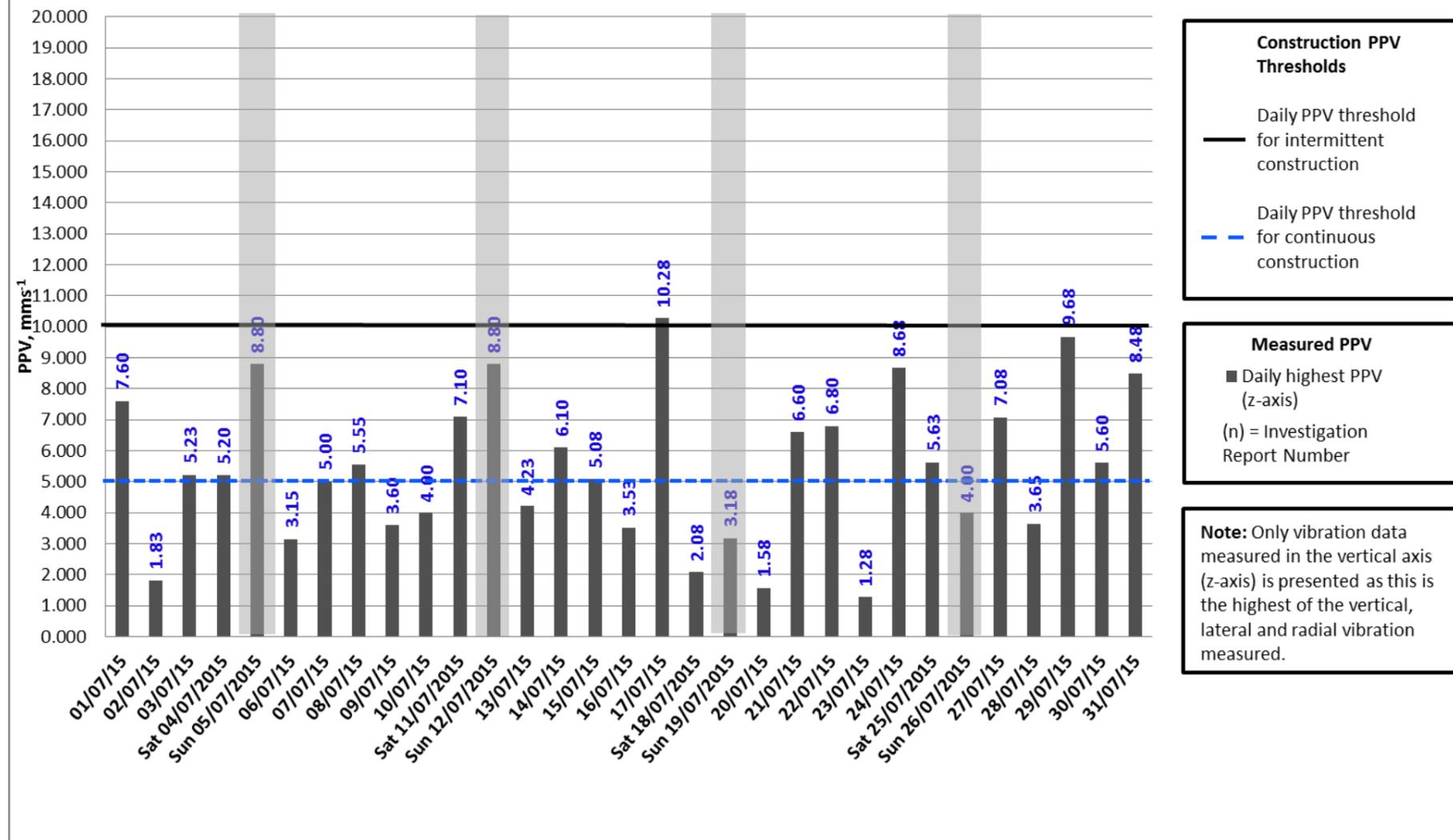
Measured VDV

■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

Measured highest Daily Peak Particle Velocity (PPV), Clufflat Brae, Measurement period: July 2015



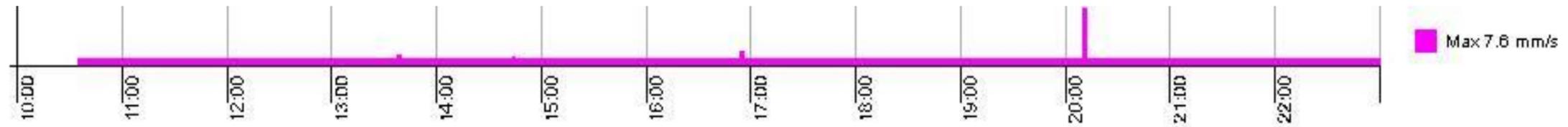
Construction PPV Thresholds

- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

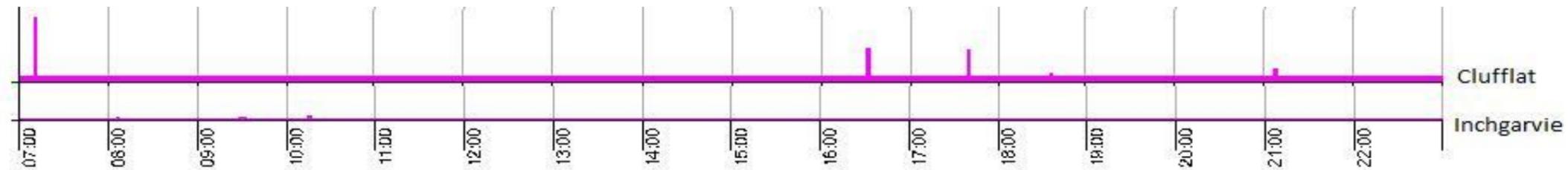
Measured PPV

- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

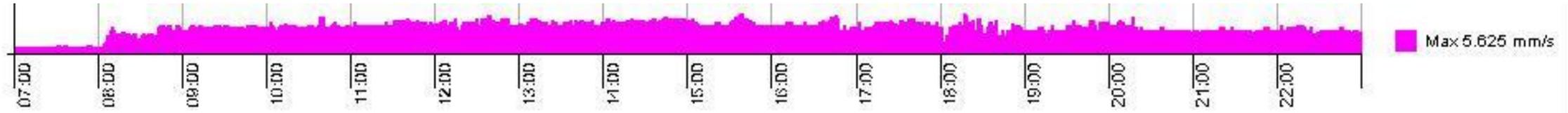
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



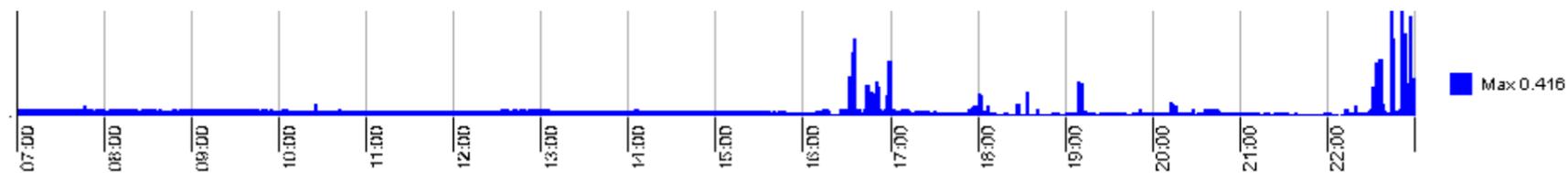
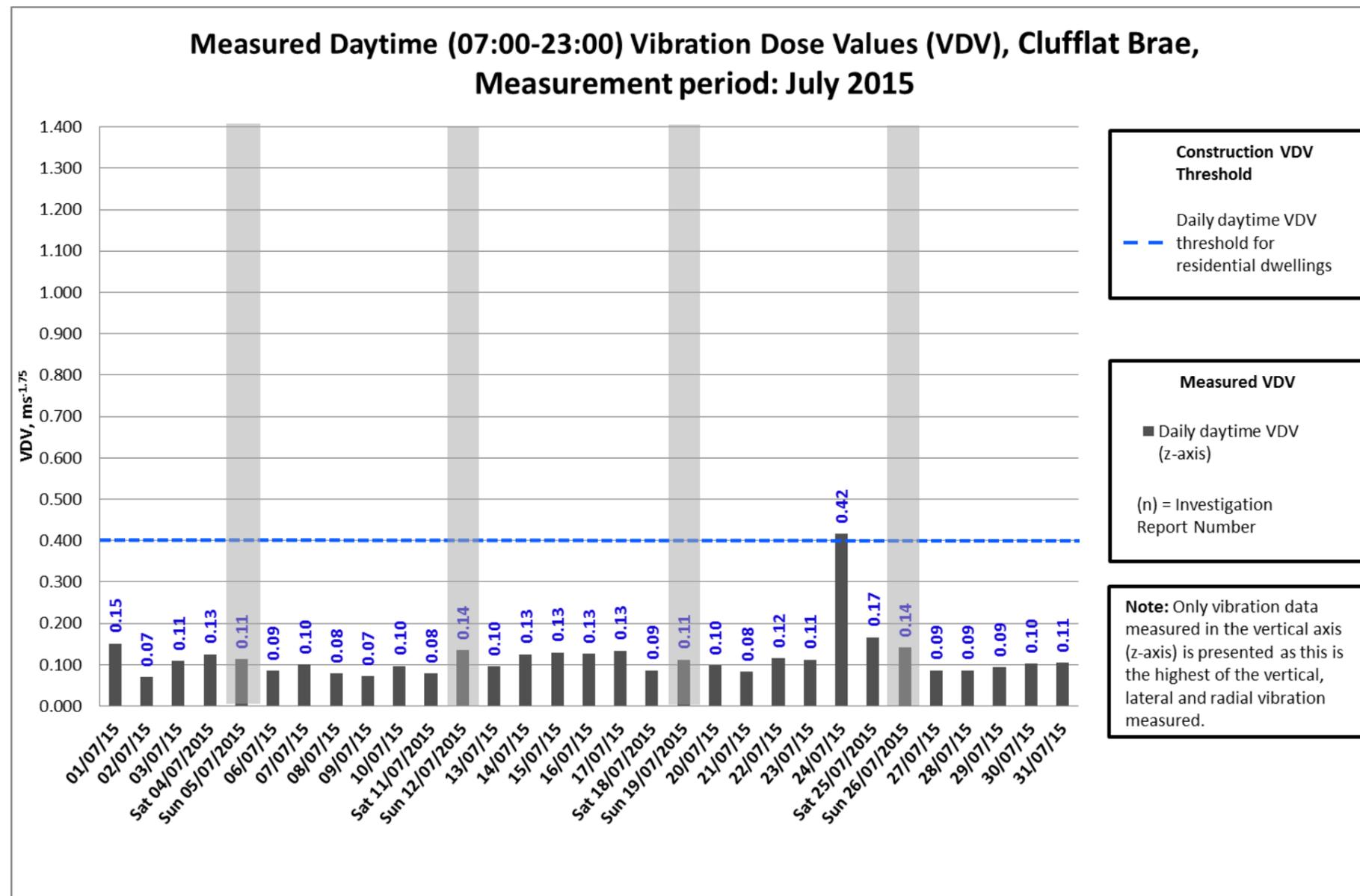
Exceedances on the 01/07/2015, 03/07/2015, 04/07/2015, 05/07/2015, 07/07/2015, 08/07/2015, 11/07/2015, 12/07/2015, 14/07/2015, 15/07/2015, 21/07/2015 and on the 22/07/2015 have been investigated and found to be individual isolated events that are not continuous and that are within the intermittent threshold



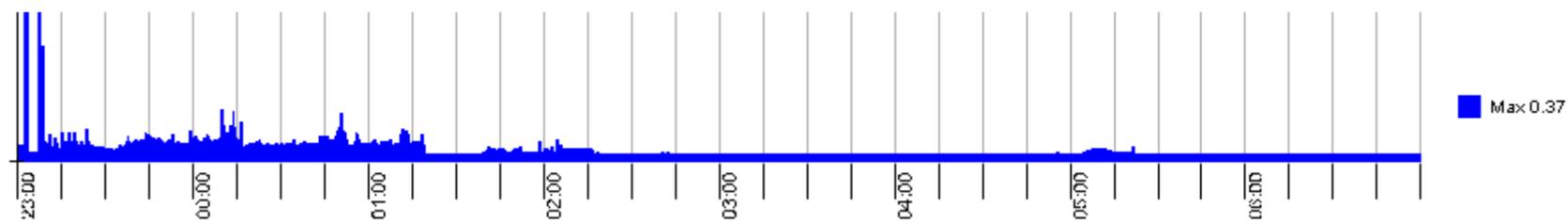
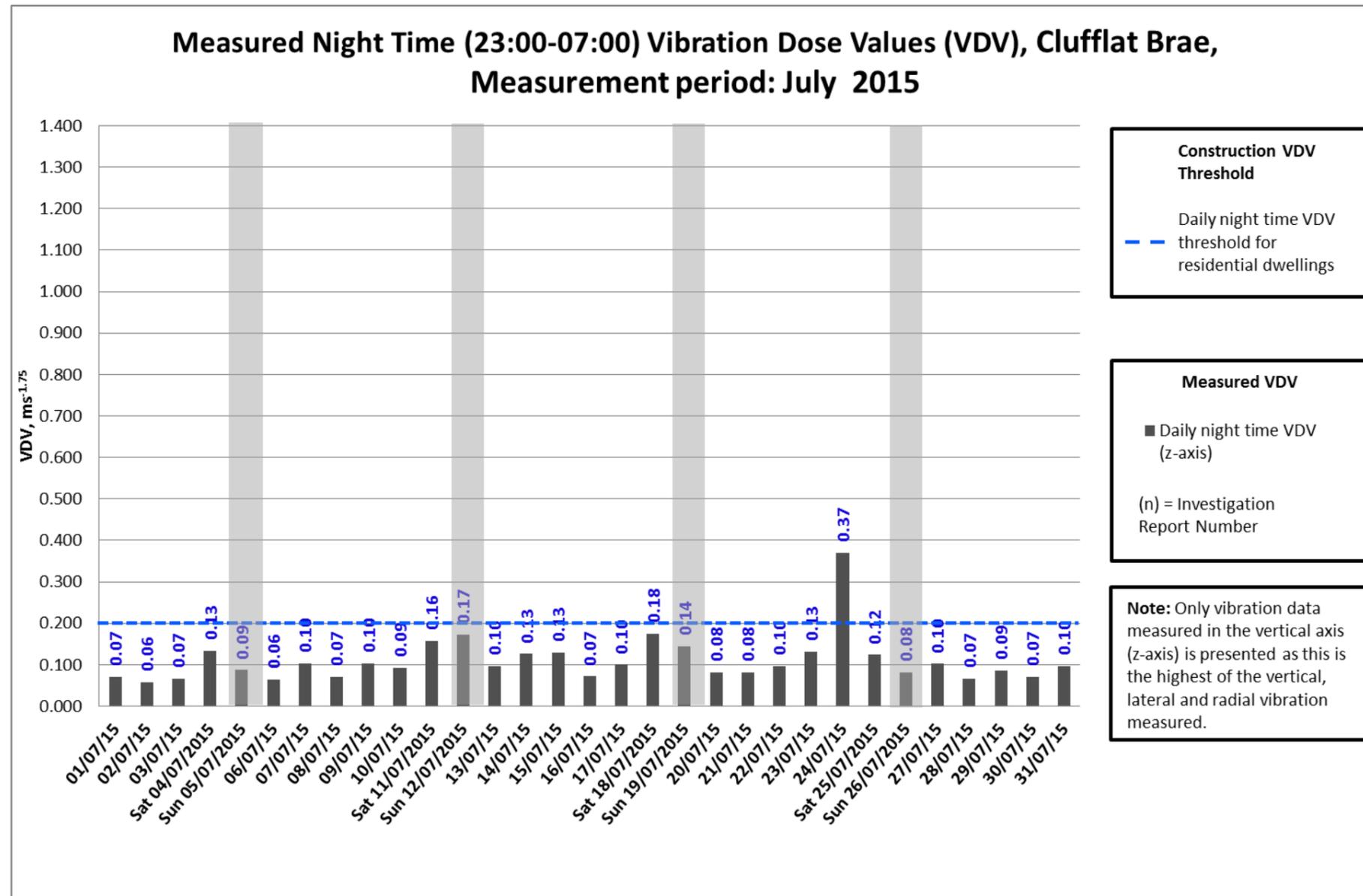
Investigations into the vibration on the 17/07/2015 has found that the exceedance occurred -out of working hours. Also by referencing the graph above from that day on the two monitors, it can be seen that over the 60 meter distance between the two monitors there was no similarity which would indicate that the exceedance was due to localised vibration sources close to the monitor.



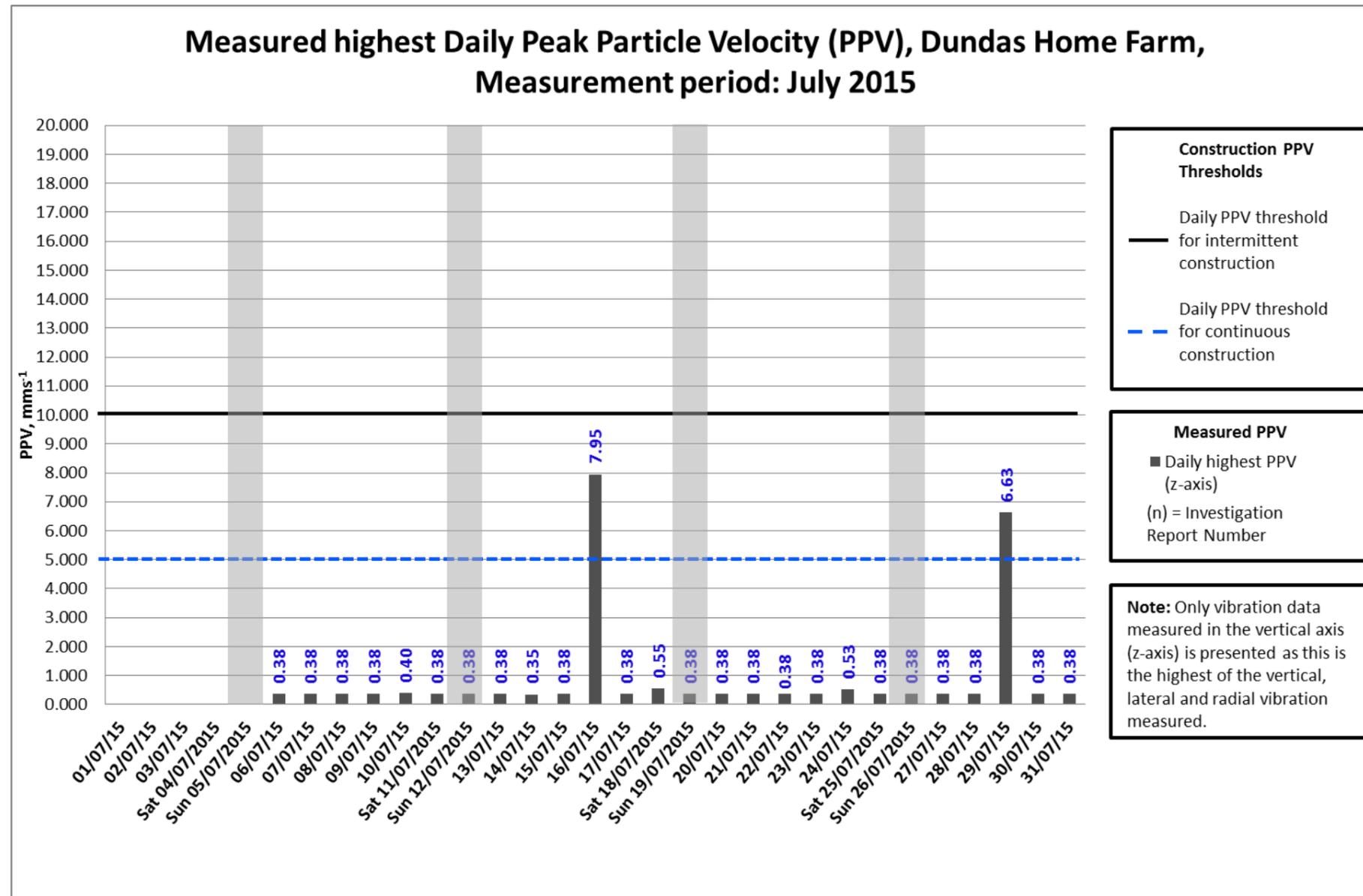
Exceedances on the 24/07/2015, 25/07/2015, 27/07/2015, 29/07/2015 and on the 31/07/2015 have been investigated and found to be constant throughout working and non-working periods indicating that it is unlikely to be construction related.



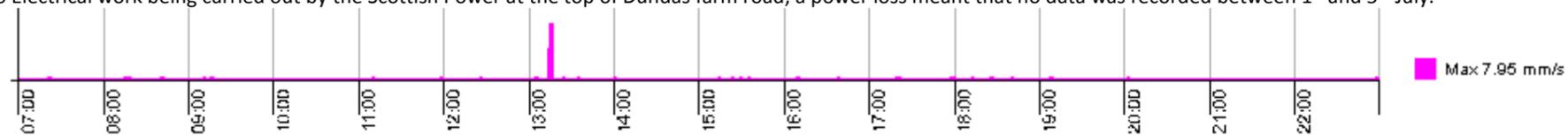
Exceedance on the 24/07/2015 starts at 16:30hrs and continues into the night. Due to the times of the vibration it is apparent that it was not caused by construction works but more likely to be activity close to the monitor (graph shown above).



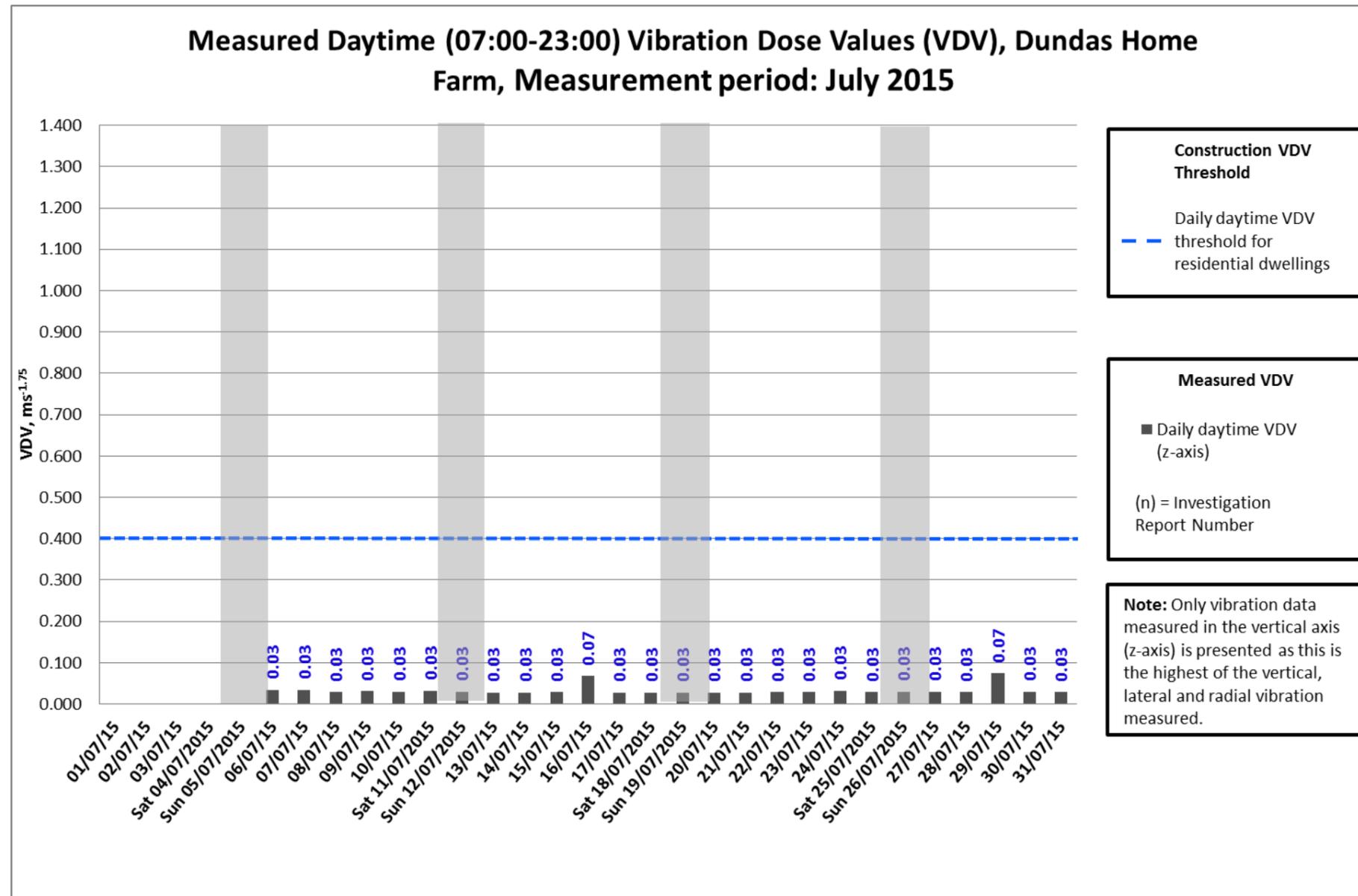
The Exceedance on the 24/07/2015 was a continuation of the event from the VDV daytime graph, and not caused by any construction activities (graph shown above).



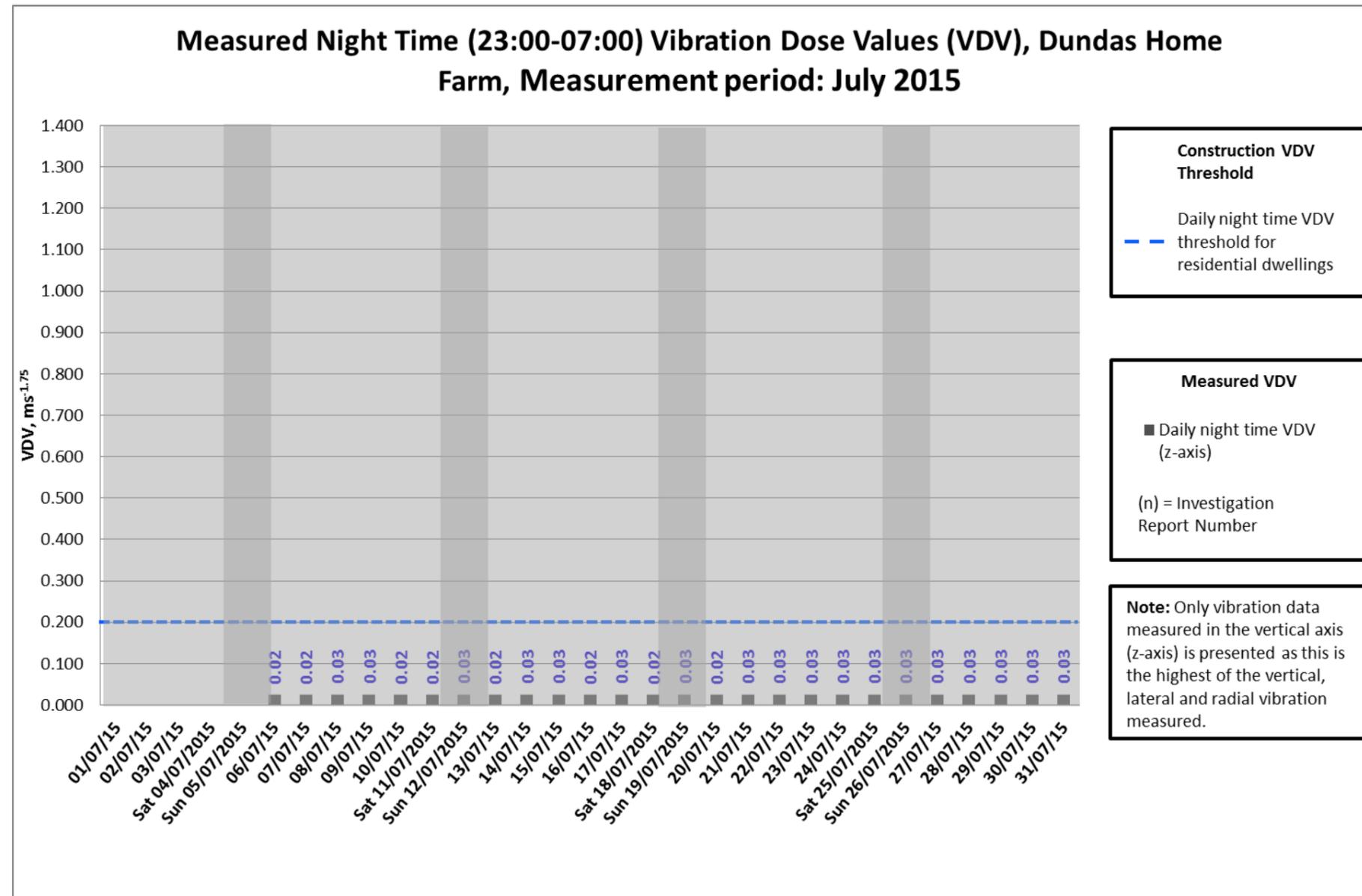
Due to Electrical work being carried out by the Scottish Power at the top of Dundas farm road, a power loss meant that no data was recorded between 1st and 5th July.



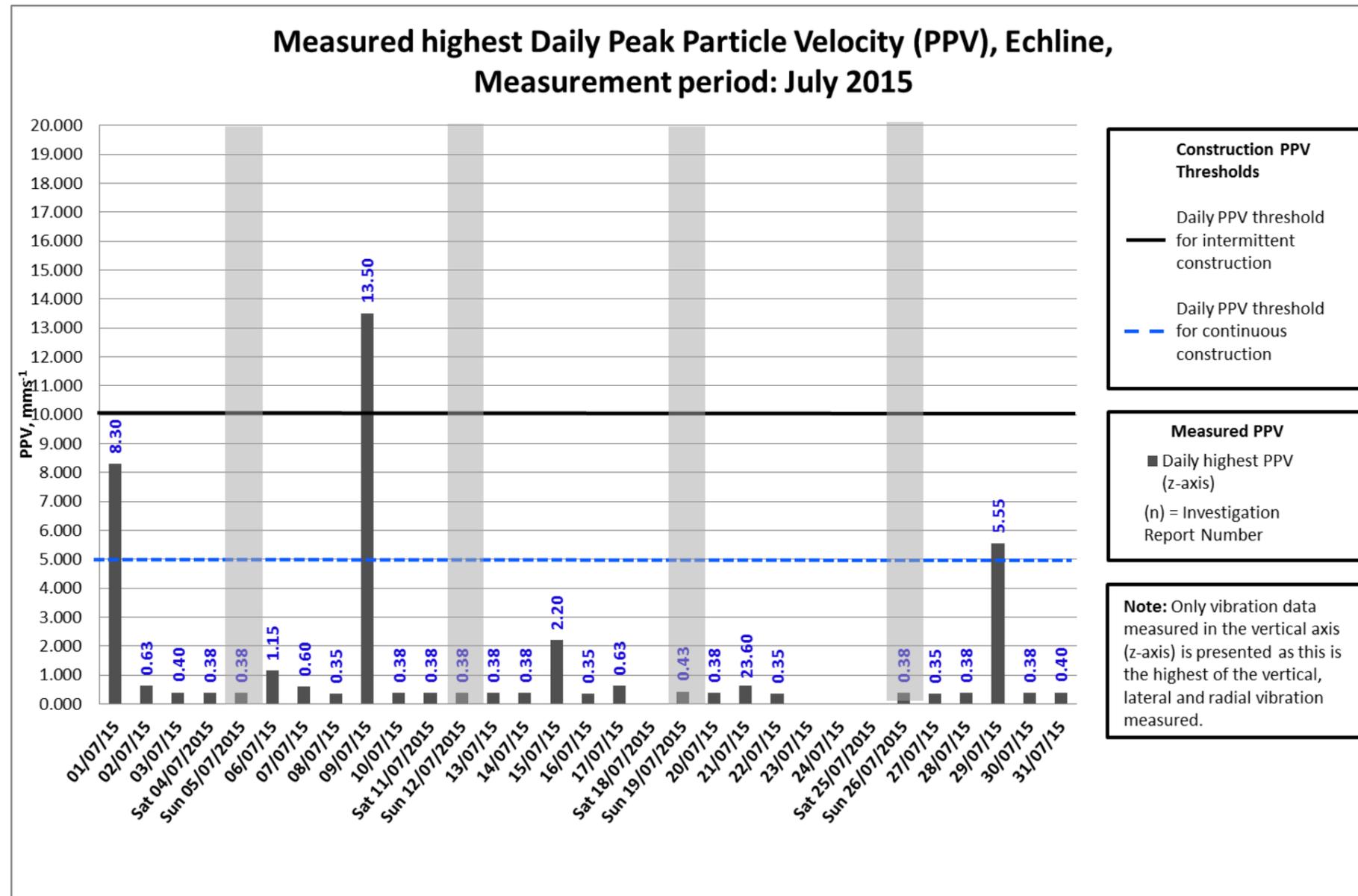
The exceedances occurring on the 16/07/2015 and the 29/07/2015 were caused by maintenance works being carried out on the vibration monitor, and had no connection with construction works.

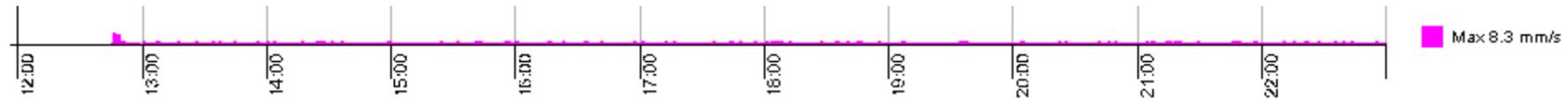


Due to Electrical work being carried out by Scottish Power at the top of Dundas farm road, no data was recorded between 1st and 5th July.

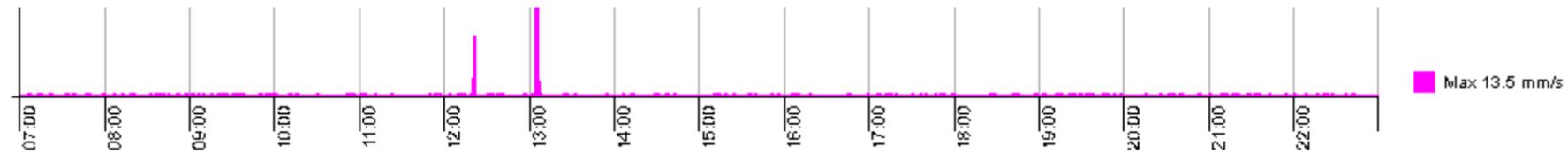


Due to Electrical work being carried out by Scottish Power at the top of Dundas farm road, no data was recorded between 1st and 5th July.



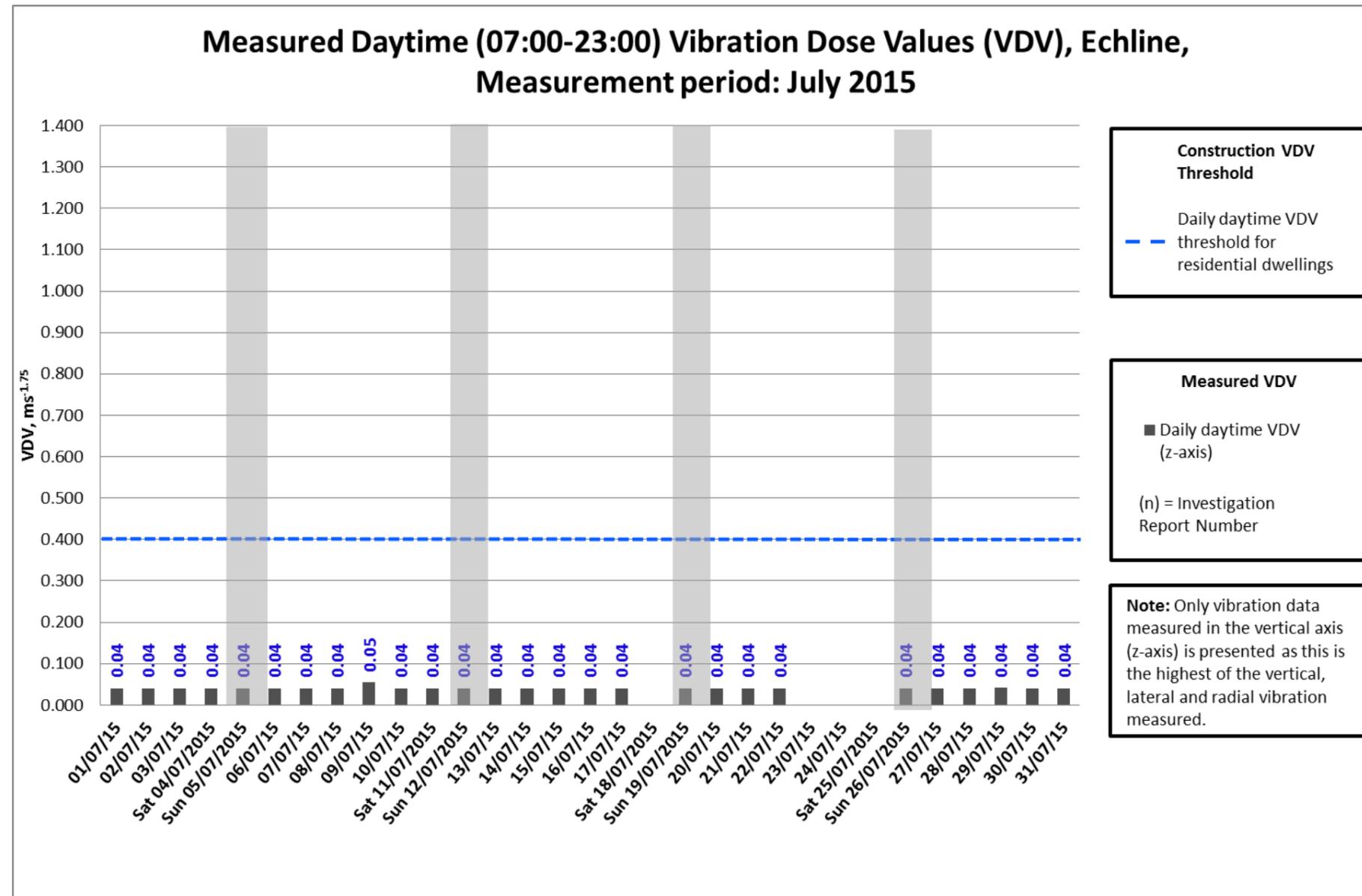


As seen from above (on the 01/07/2015) the exceedances on the 01/07/2015 and the 29/07/2015 was caused due to maintenance works being carried out on the vibration monitor, and has no connection with construction works.

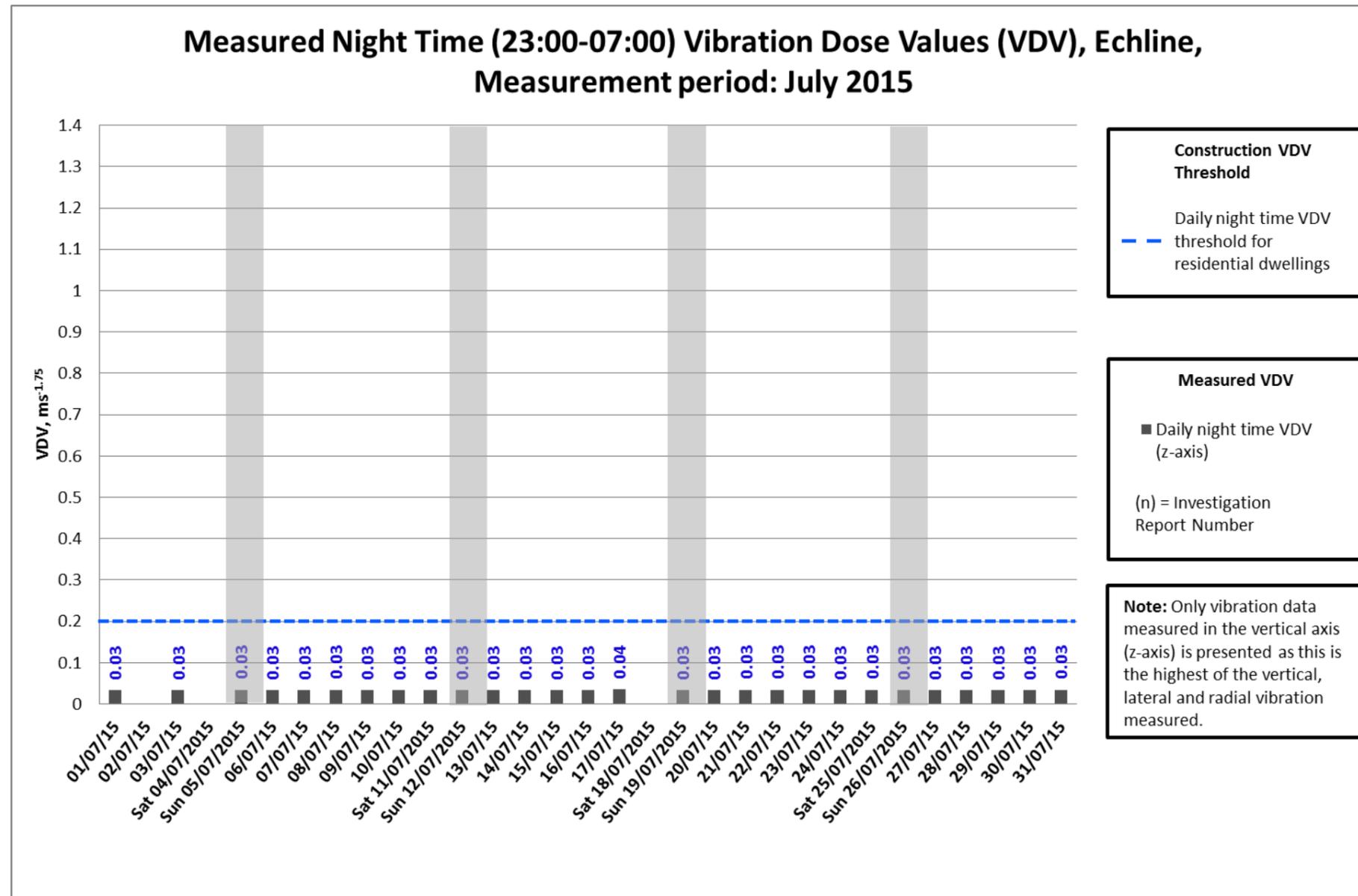


After investigating the exceedance which occurred on the 29/07/2015, the results are inconclusive, but as can be seen from the graph above from that day, it appeared to be an isolated event which is more likely to be caused by events close or near by the monitor rather than construction related. This exceedance was however- found to be within the intermittent threshold.

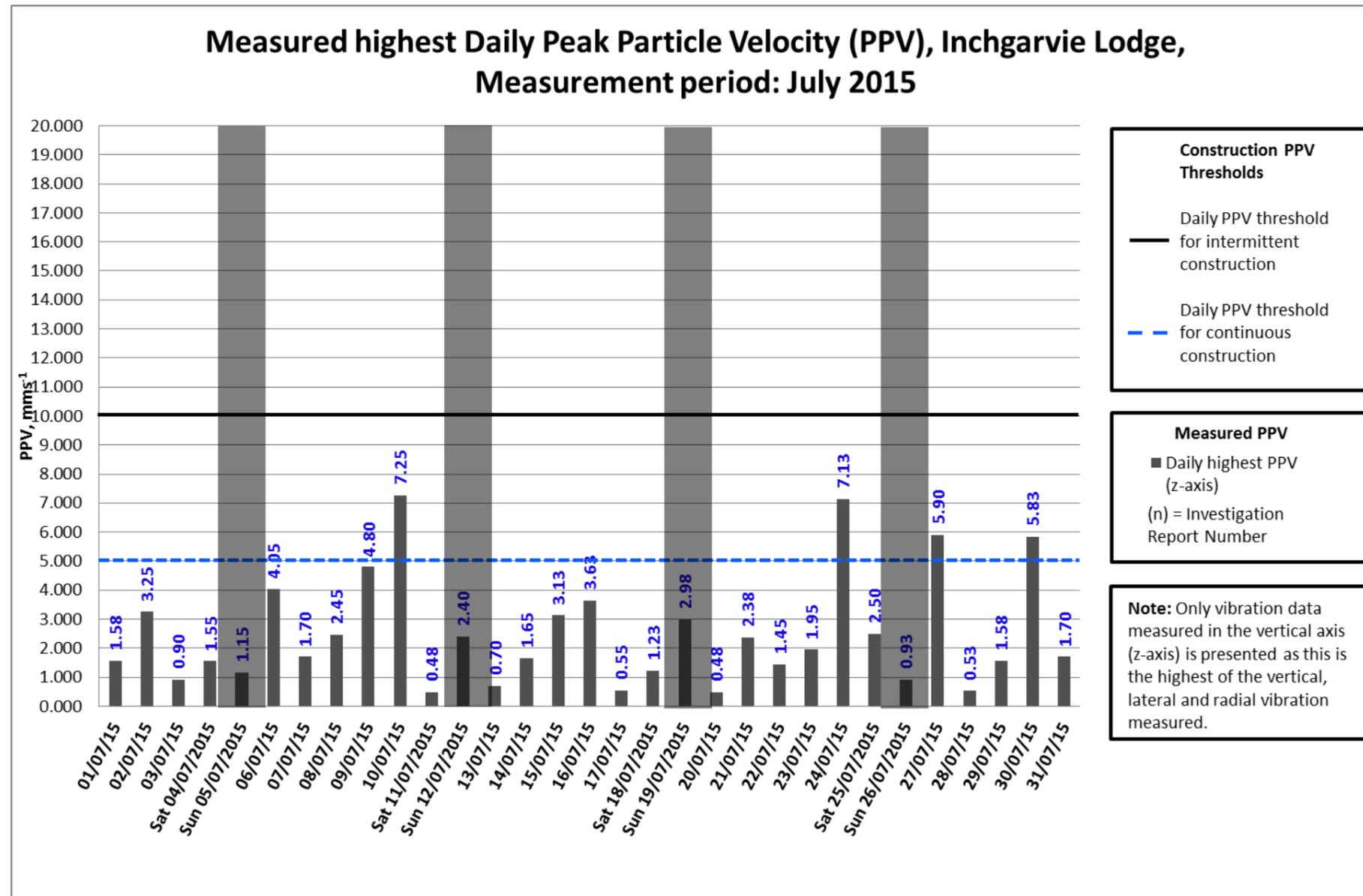
Missing data on the -18/07/2015, 23/07/2015, 24/07/2015 and the 25/07/2015 was due to corrupt data on the vibration monitor.



Missing data on the- 18/07/2015, 23/07/2015, 24/07/2015 and the 25/07/2015 was due to data being corrupt on the vibration monitor.

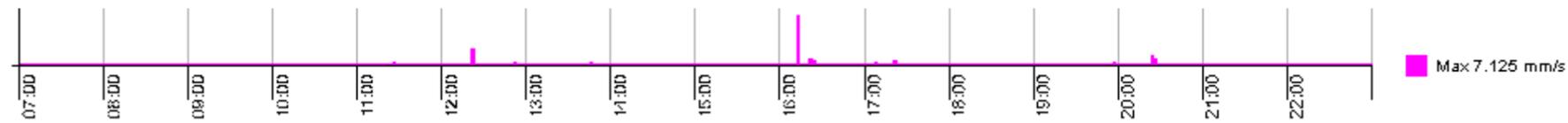


Missing data on the -18/07/2015, 23/07/2015, 24/07/2015 and the 25/07/2015 was due to data being corrupt on the vibration monitor.





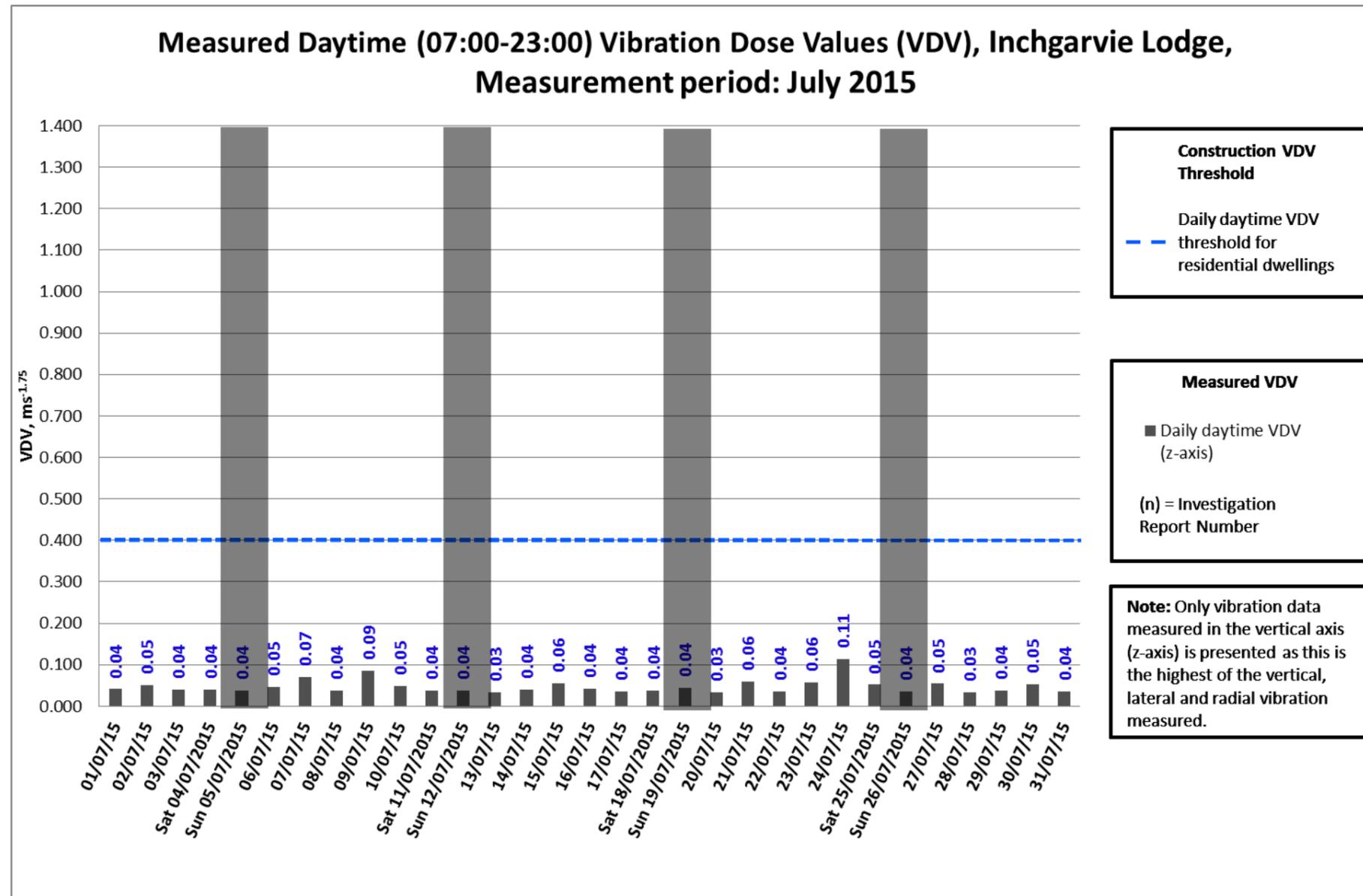
Exceedance on the 10/07/2015 has been investigated and found to have occurred outside of construction working hours.



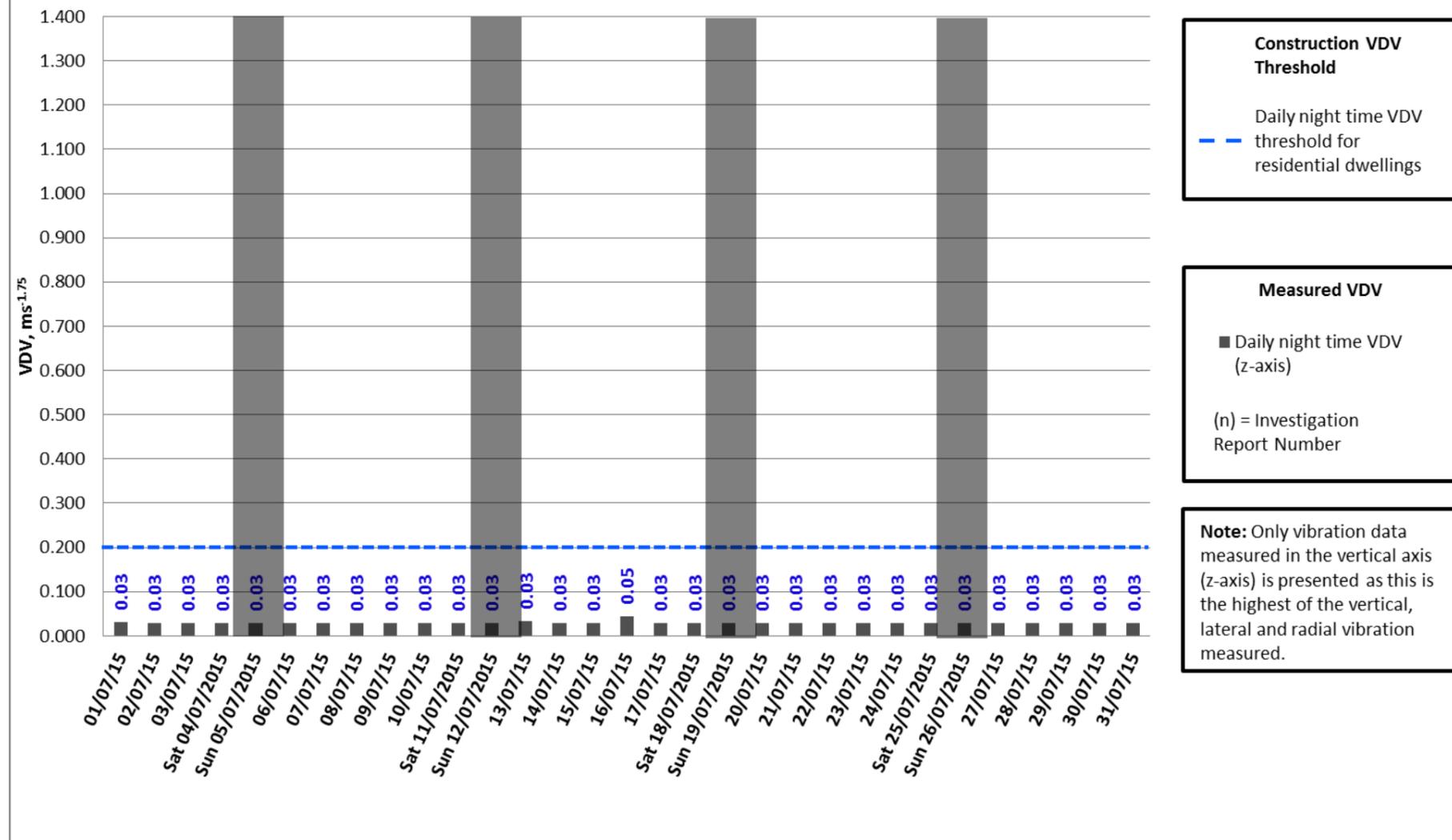
Exceedance on the 24/07/2015, consisted of two separate isolated events at 12.20 and 16.15. Both occurred during working hours. Referencing the vibration data alongside the noise monitor data for this location, there was no abnormality recorded in the noise log data. It should be noted that an extension is being built on a property adjacent to the vibration monitor which is considered to be the likely source of the vibration.



Exceedance on the 27/07/2015 and the 30/07/2015 (30/07/2015 as seen from above), was investigated and found to be an exceedance occurring outside of working hours, and not due to construction related activity.



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: July 2015



Construction VDV Threshold

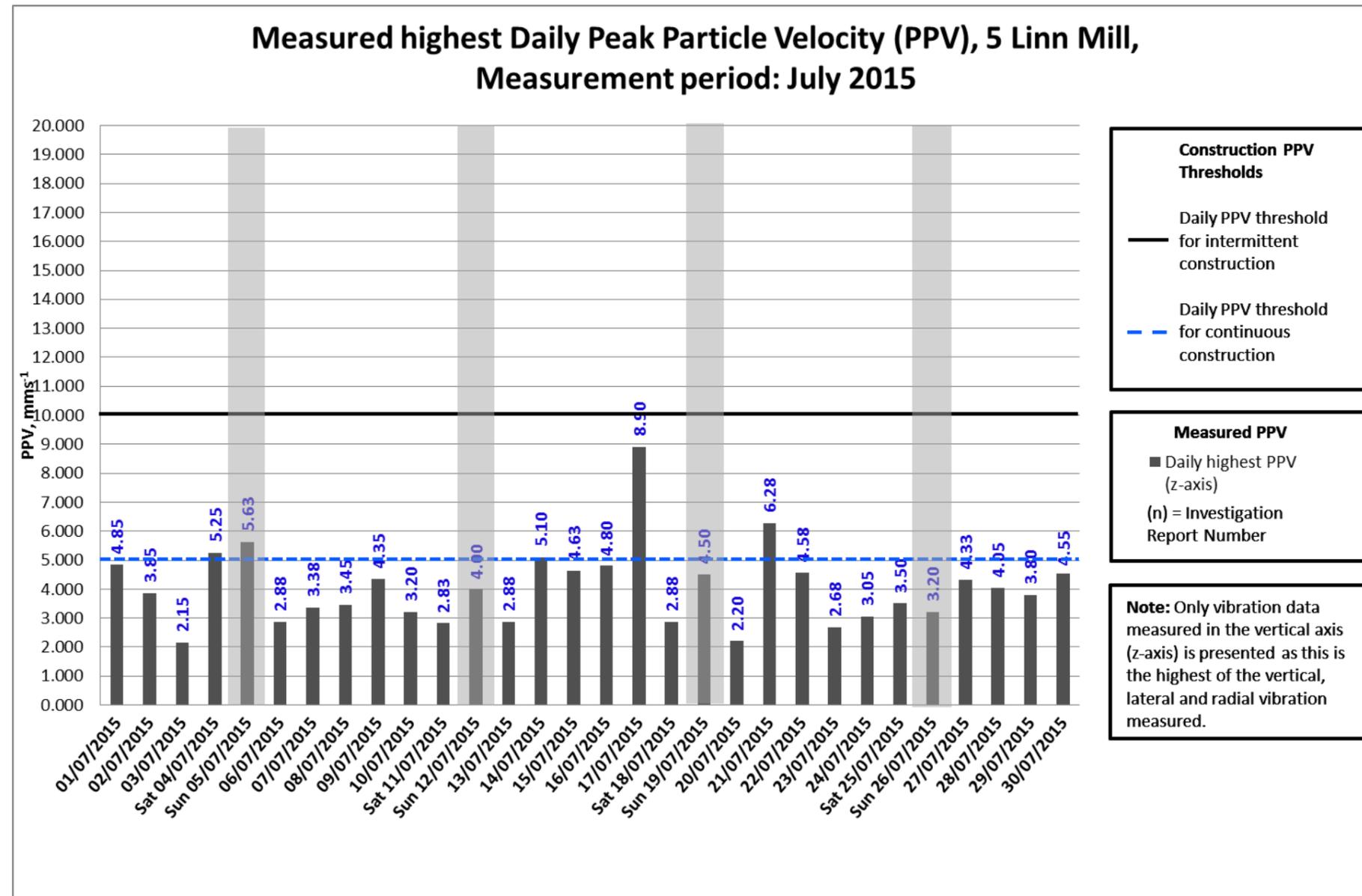
Daily night time VDV threshold for residential dwellings

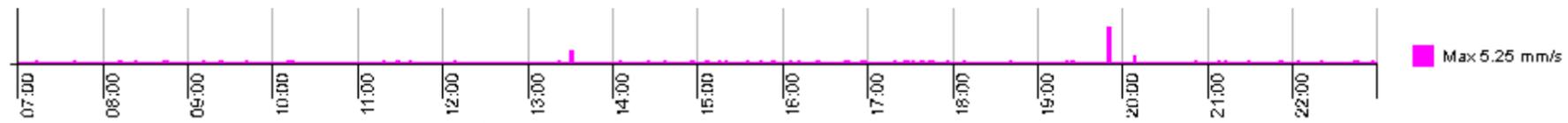
Measured VDV

■ Daily night time VDV (z-axis)

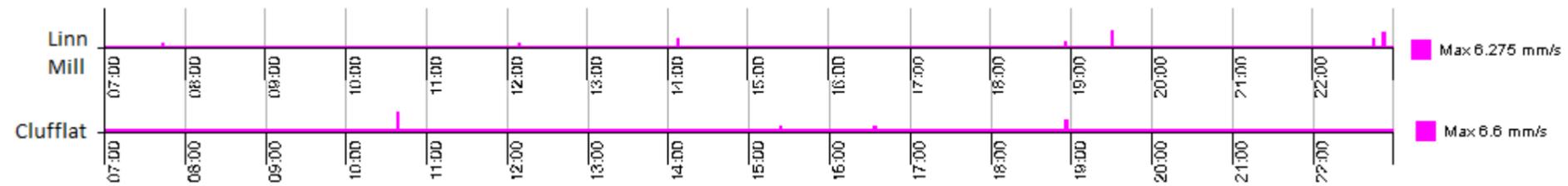
(n) = Investigation Report Number

Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

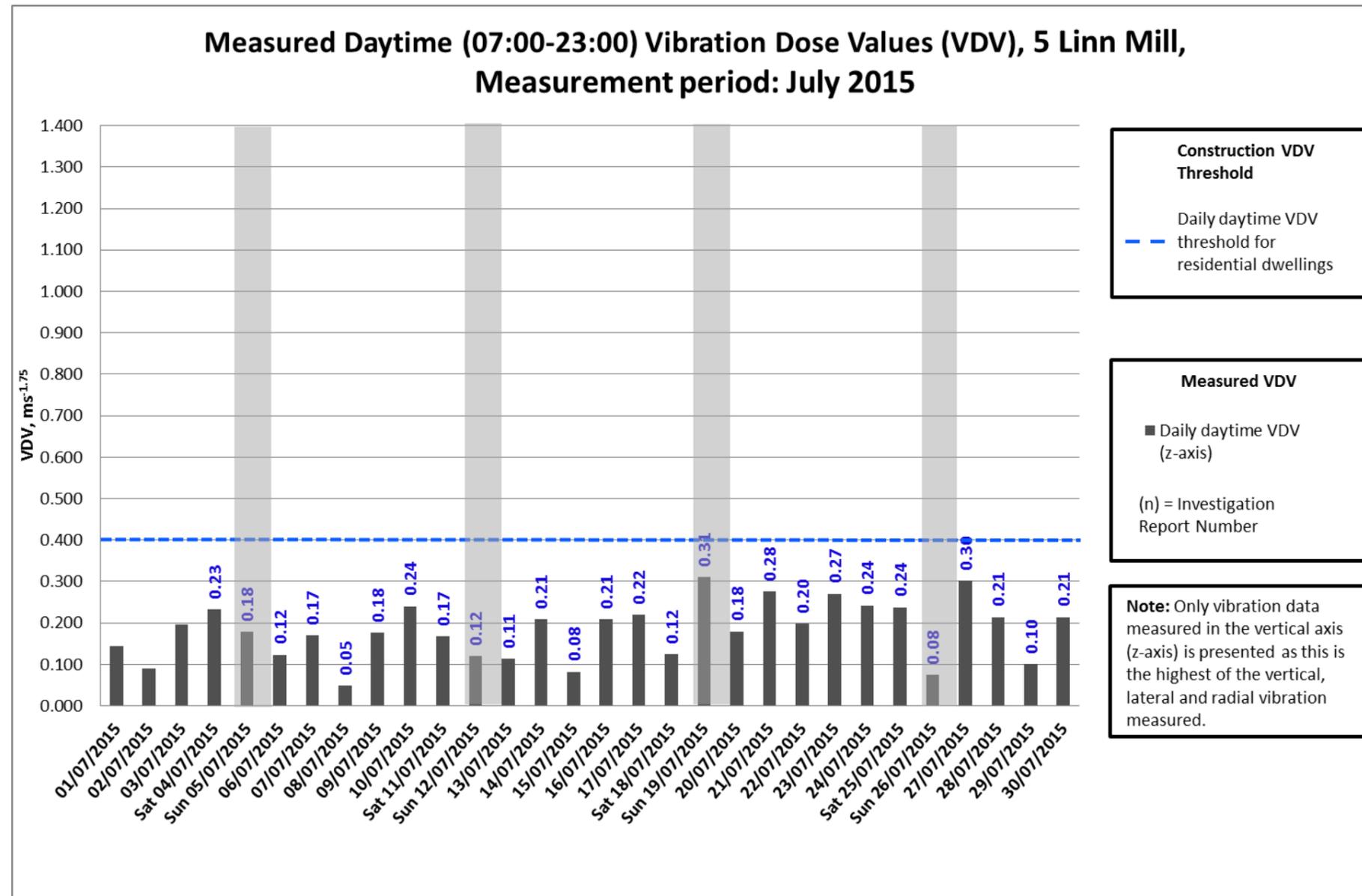


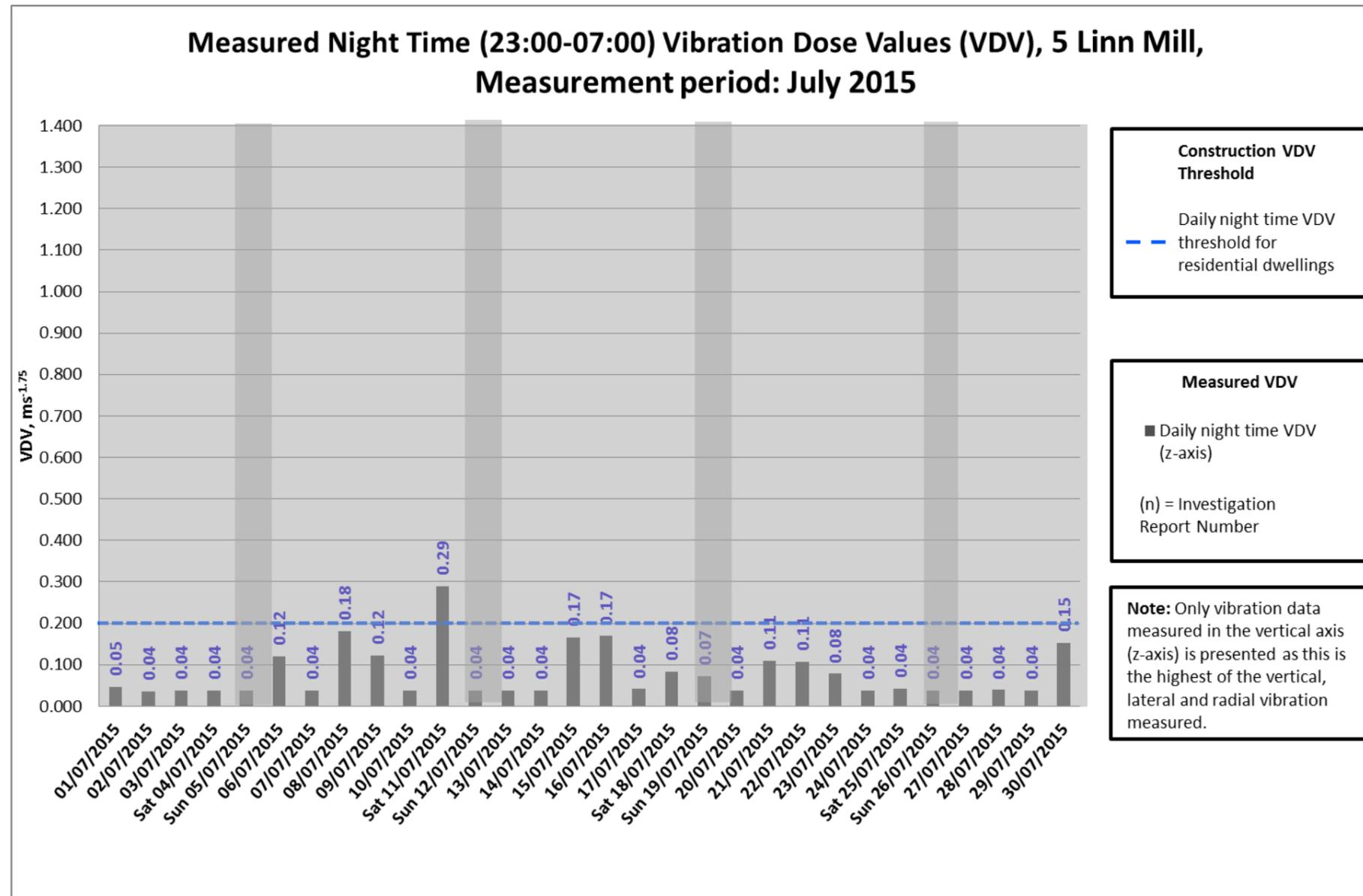


Exceedances on the 04/07/2015, 05/07/2015 and on the 14/07/2015 (graph above from the 04/07/2015) have been investigated and found to be out with working hours, and -therefore are unlikely to be related to construction.

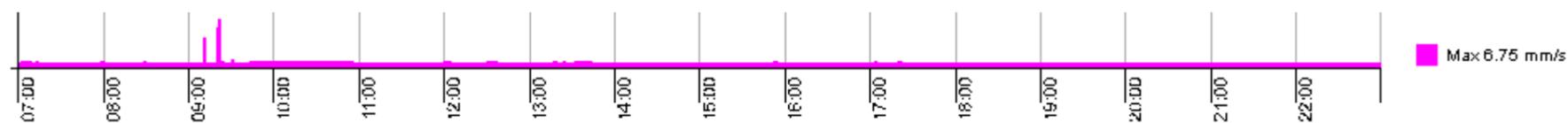
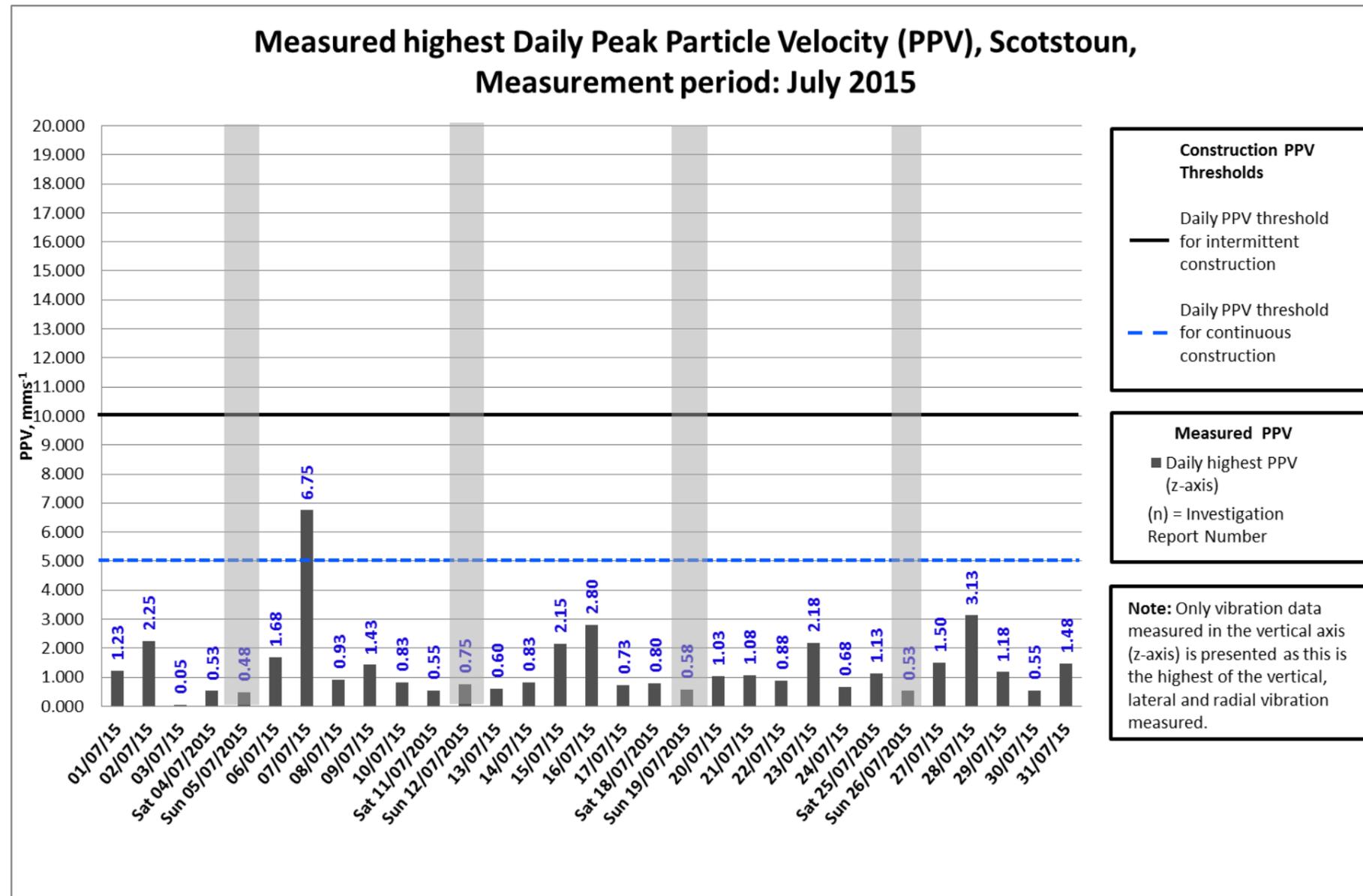


Exceedances on the 17/07/2015 and the 21/07/2015 (graph above from the 21/07/2015) have been investigated and found not to be related to construction activities. Linn mill monitor is 165 metres from the closest works, Clufflat is 200 metres from the same works.

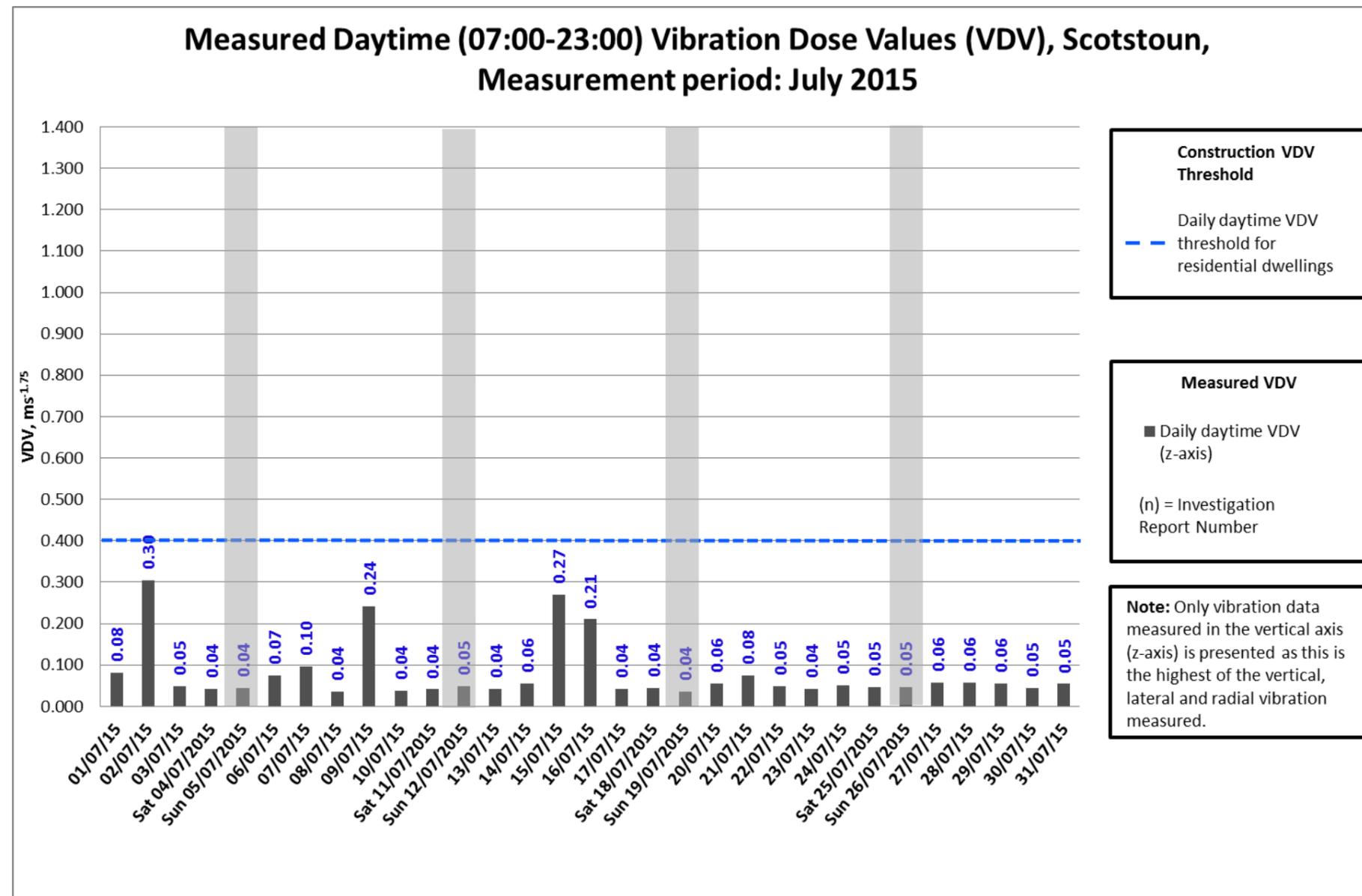




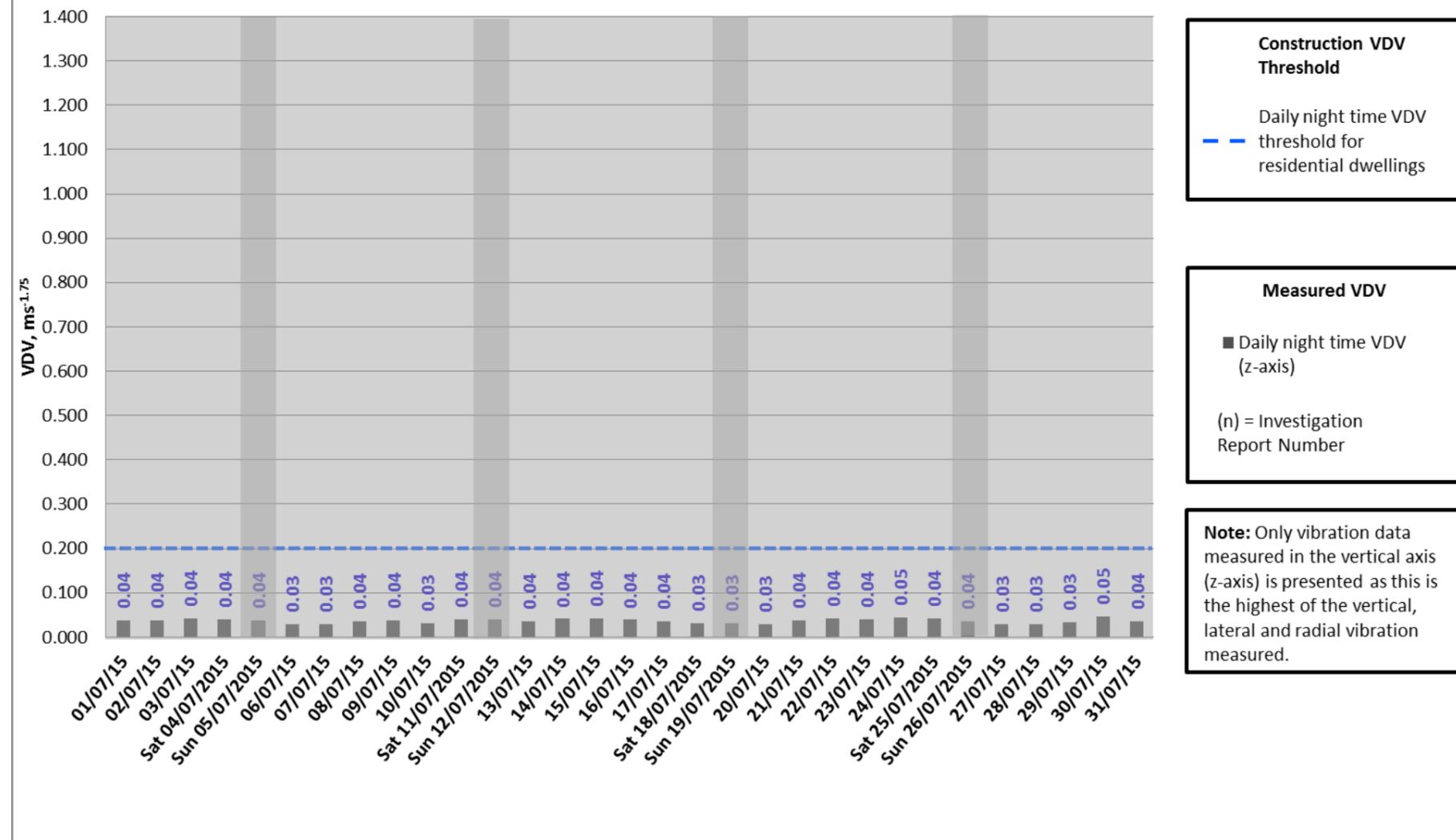
Exceedance on the 11/07/2015 has been investigated and has been found to be an isolated event not related to construction works due to the time of the exceedance.



An investigation into the exceedance on the 07/07/2015 has been inconclusive in identification of the possible source of vibration. The exceedance was however intermittent in nature, which falls within the exceedance level.



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: July 2015



Construction VDV Threshold

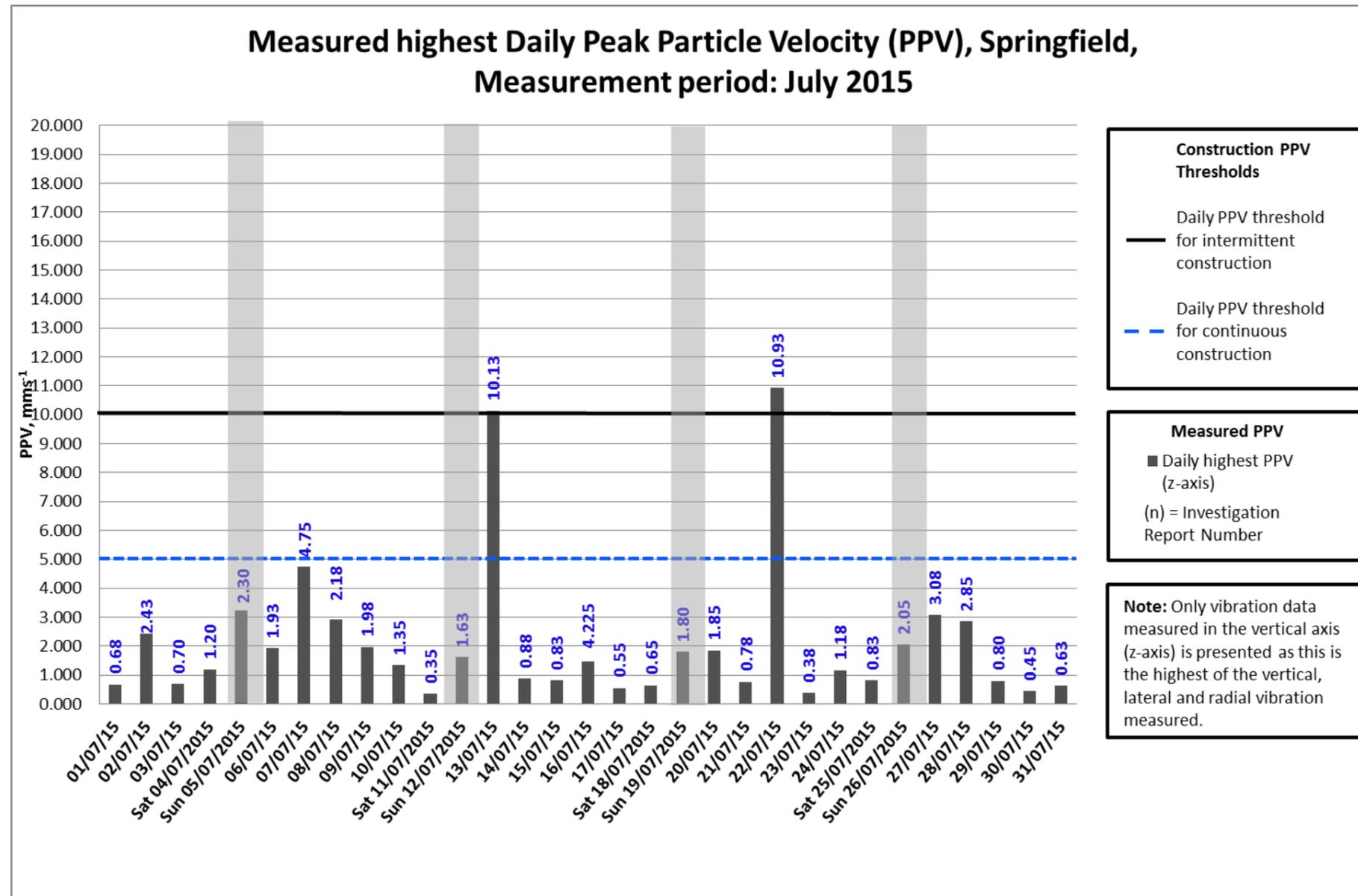
Daily night time VDV threshold for residential dwellings

Measured VDV

■ Daily night time VDV (z-axis)

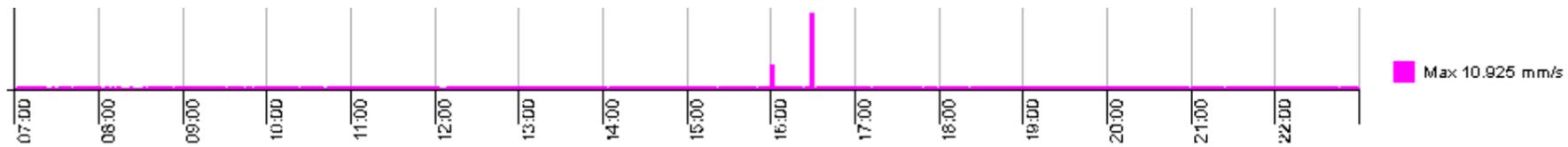
(n) = Investigation Report Number

Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



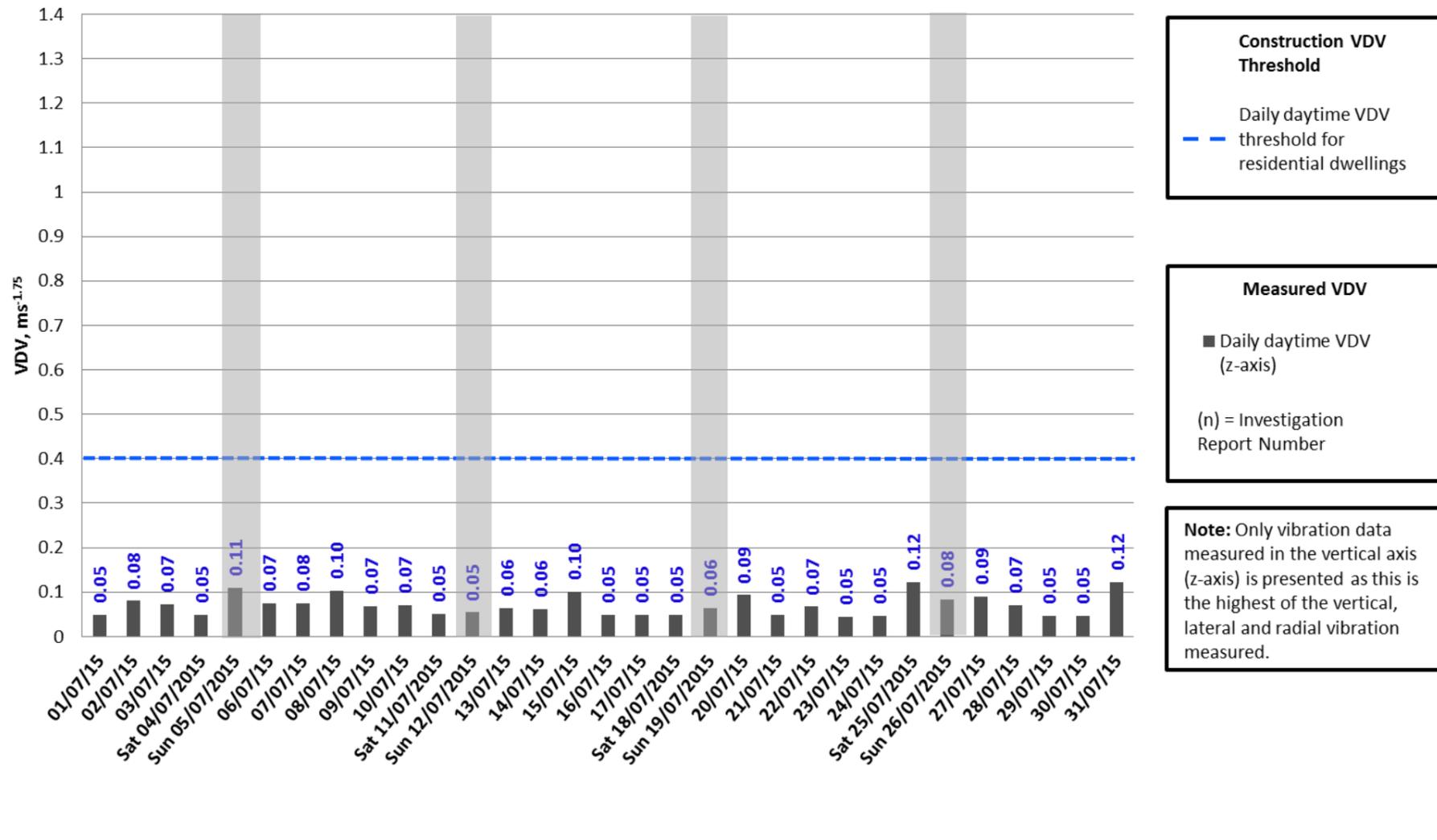


Exceedance on the 13/07/2015 has been investigated and found not to be construction related. Due to the intervening distance between the works and the Springfield monitor, a vibration level of such magnitude would also be expected to have been picked up on other monitors in that area i.e. Clufflat and Linn Mill. Subsequent analysis revealed no such similarities for the time period in question.



Exceedance on the 22/07/2015 has been investigated and found that the vibration is likely to have been caused during maintenance work on the noise monitor, which is in close proximity to the vibration monitor.

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield, Measurement period: July 2015



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

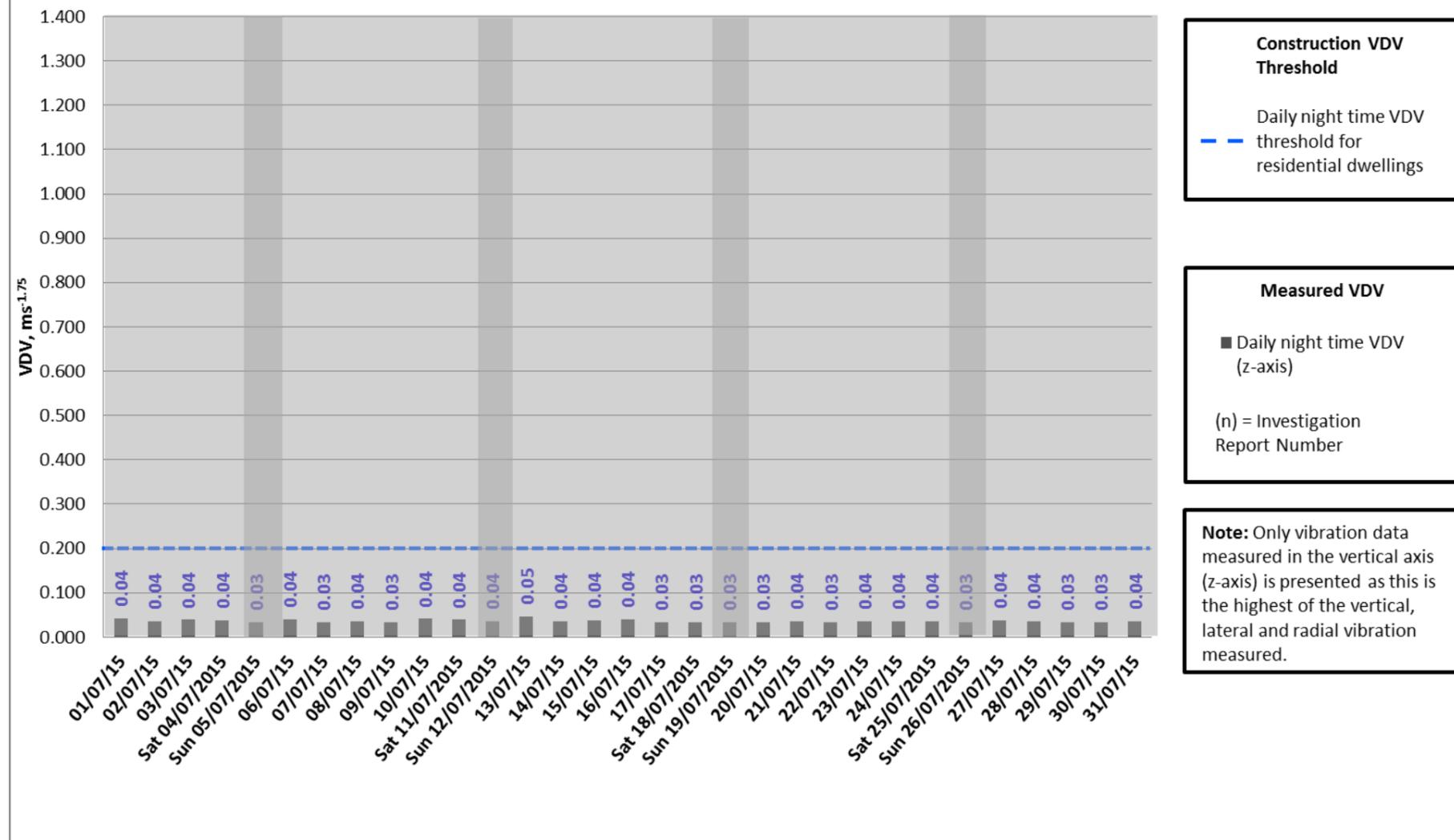
Measured VDV

■ Daily daytime VDV (z-axis)

(n) = Investigation Report Number

Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Springfield, Measurement period: July 2015



Construction VDV Threshold

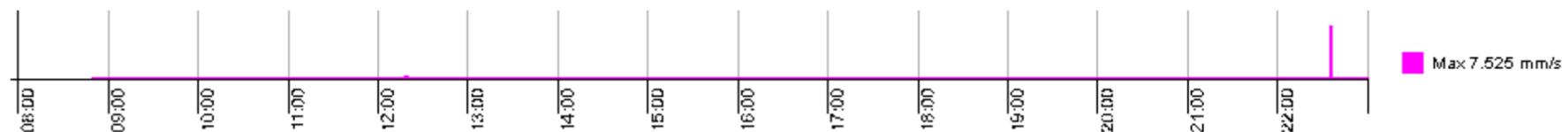
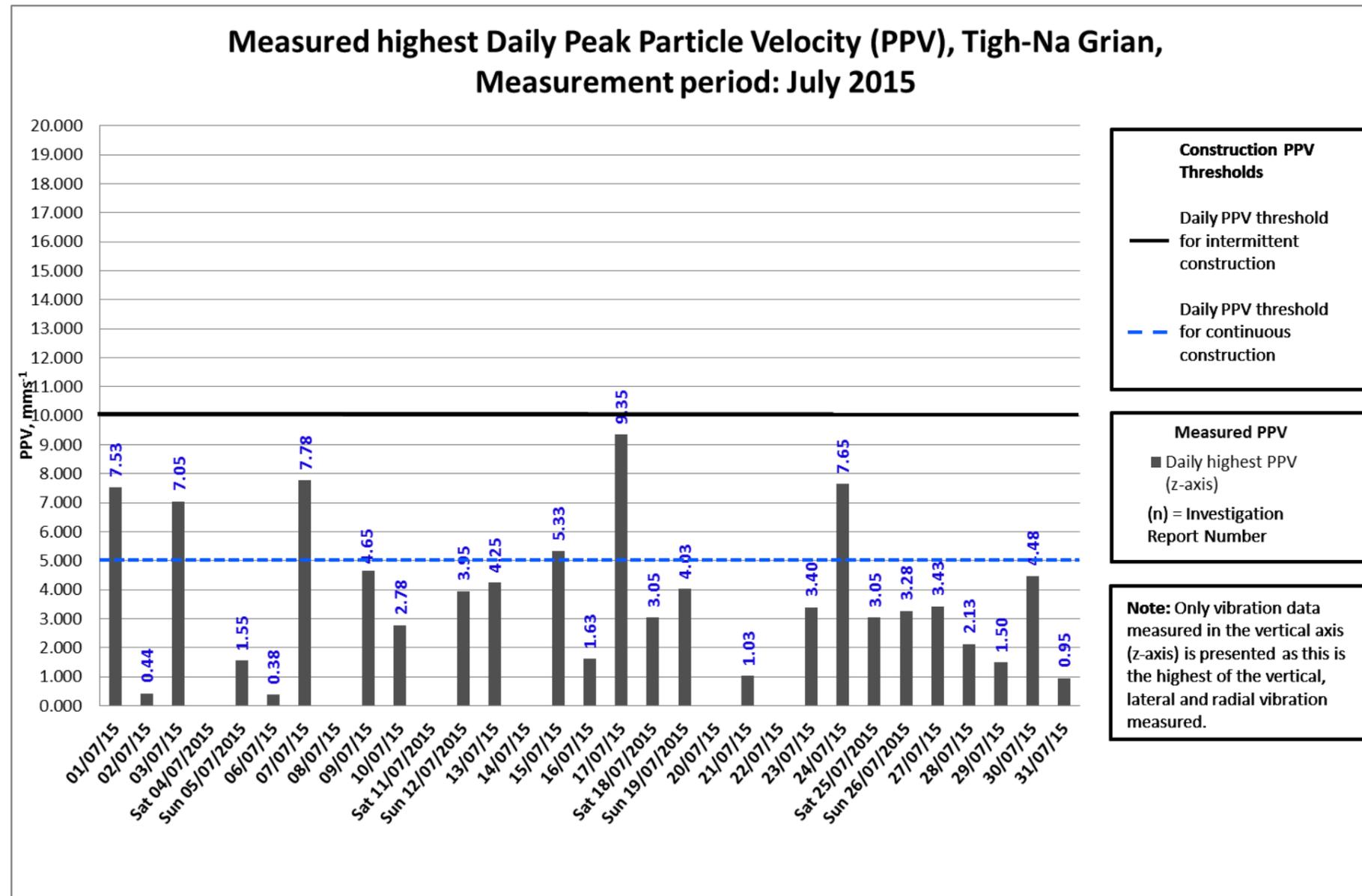
Daily night time VDV threshold for residential dwellings

Measured VDV

■ Daily night time VDV (z-axis)

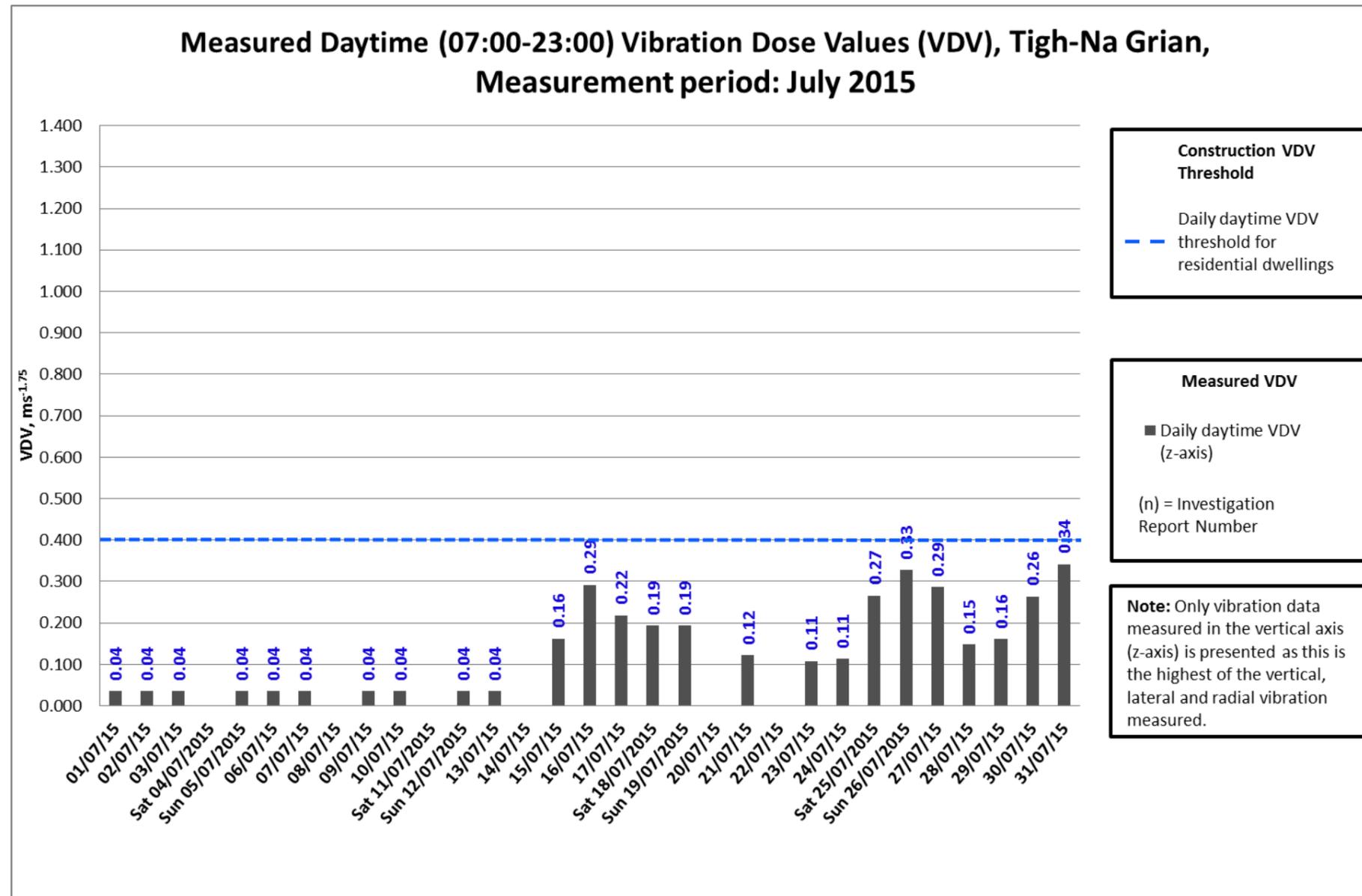
(n) = Investigation Report Number

Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

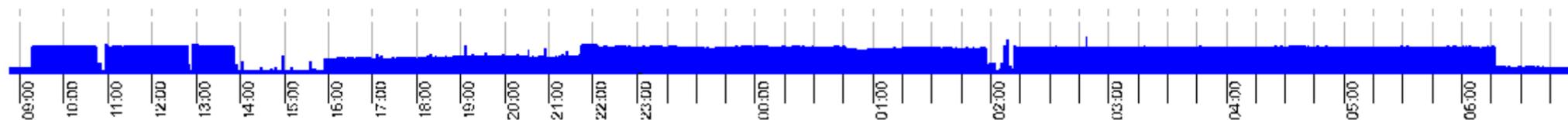
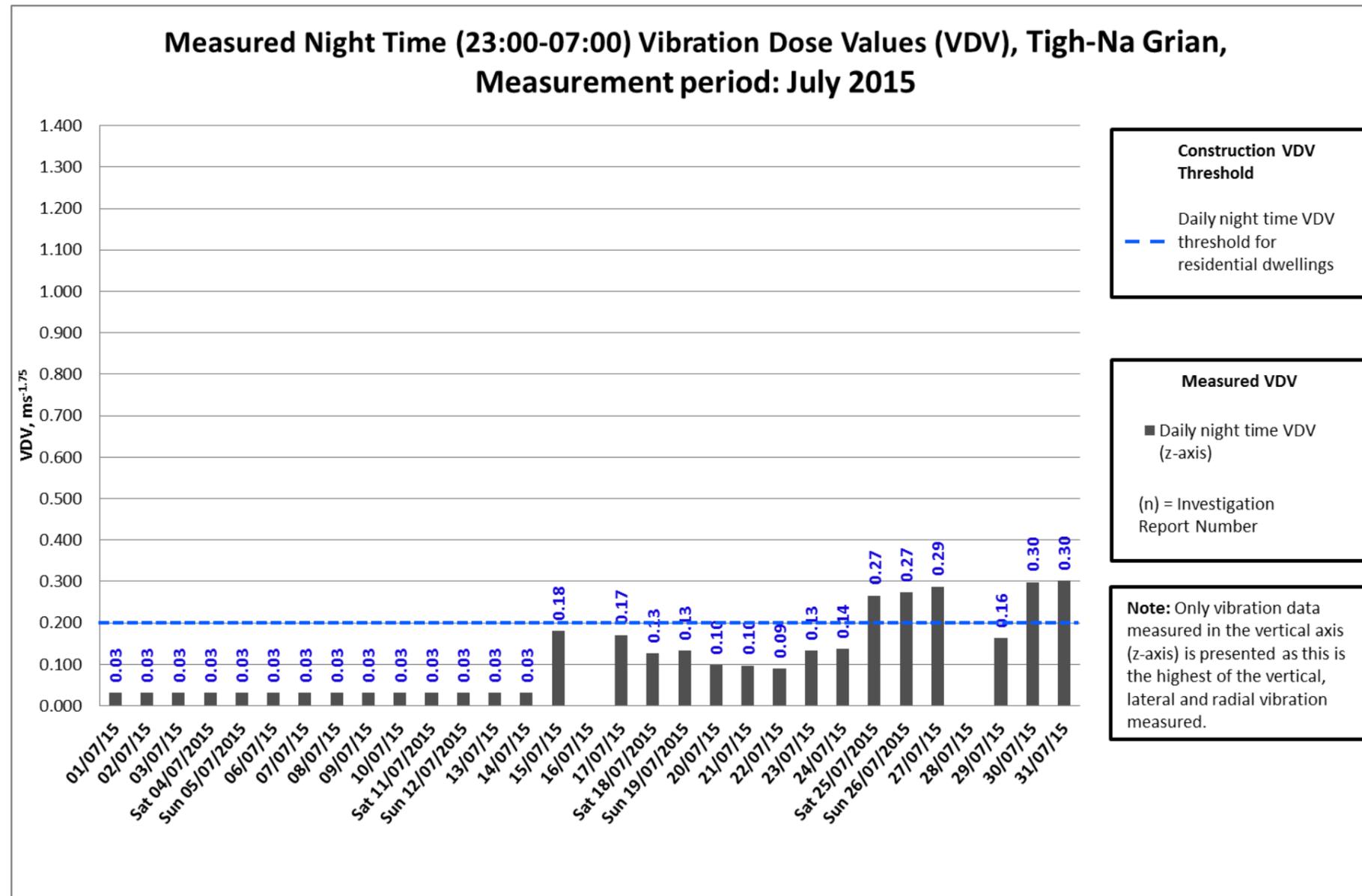


All exceedances have been investigated and have been found to be individual 'intermittent' exceedances and not constant (reference graph above from the 01/07/2015). The source of the vibration is unknown but all exceedances are within thresholds.

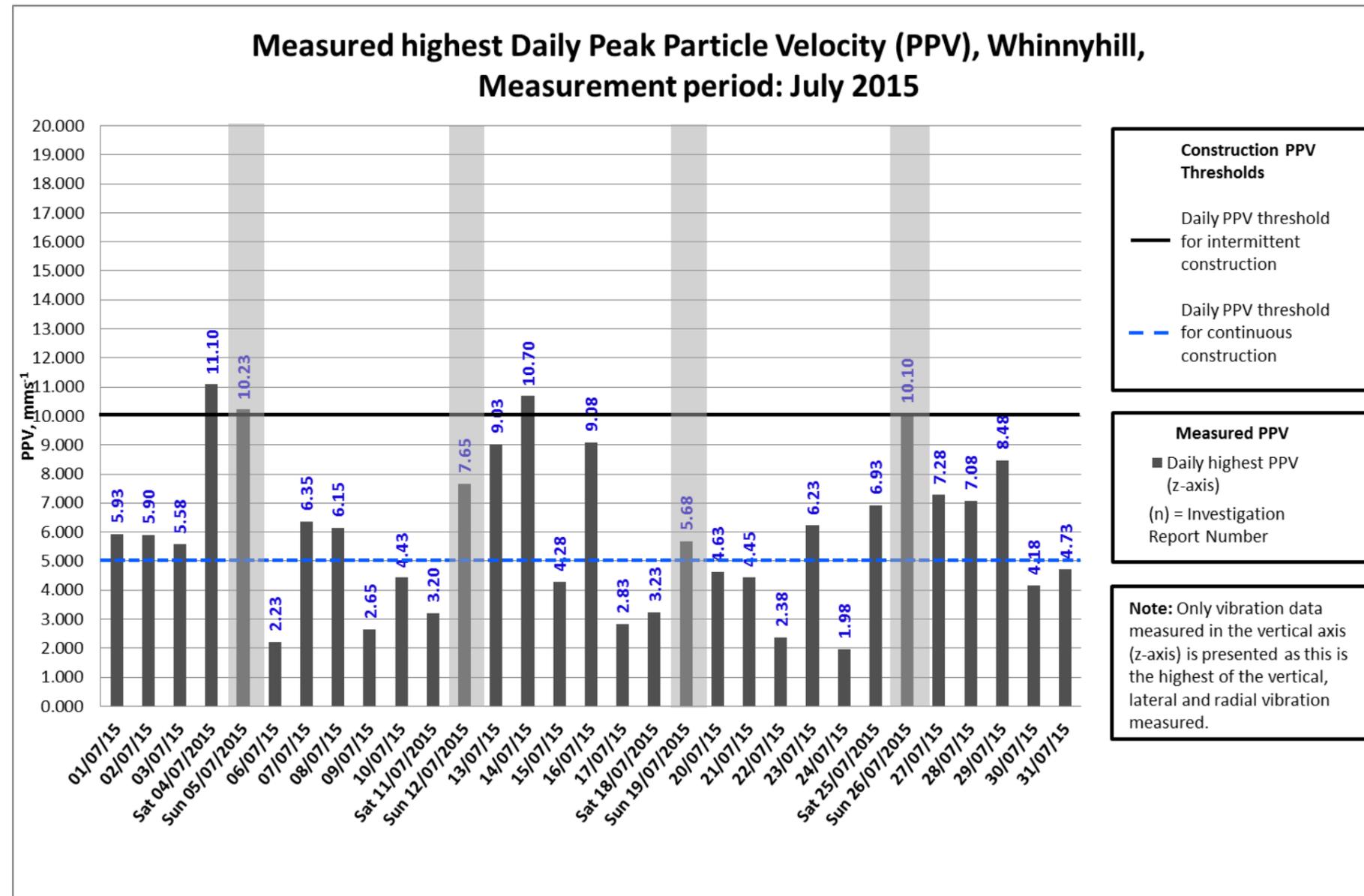
Data missing on the 04/07/2015, 08/07/2015, 11/07/2015, 14/07/2015, 20/07/2015 and 22/07/2015 is due to corrupt data on the monitor.



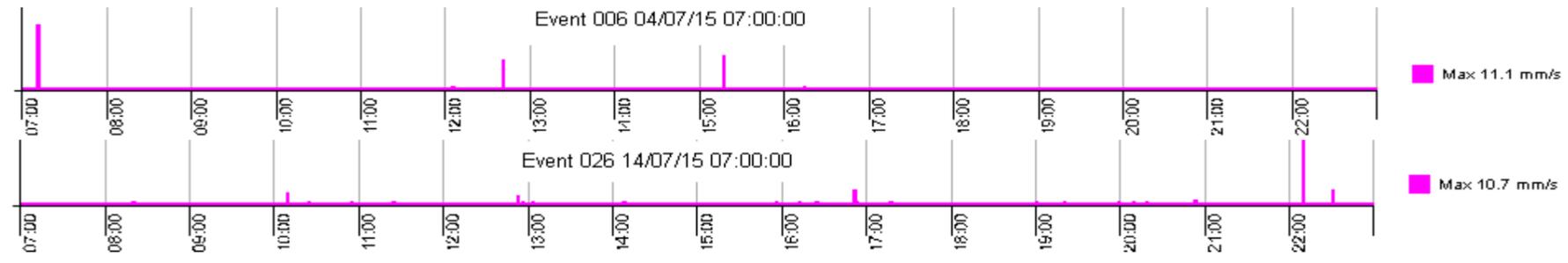
Data missing on the 04/07/2015, 08/07/2015, 11/07/2015, 14/07/2015, 20/07/2015, and 22/07/2015 is due to corrupt data on the monitor.



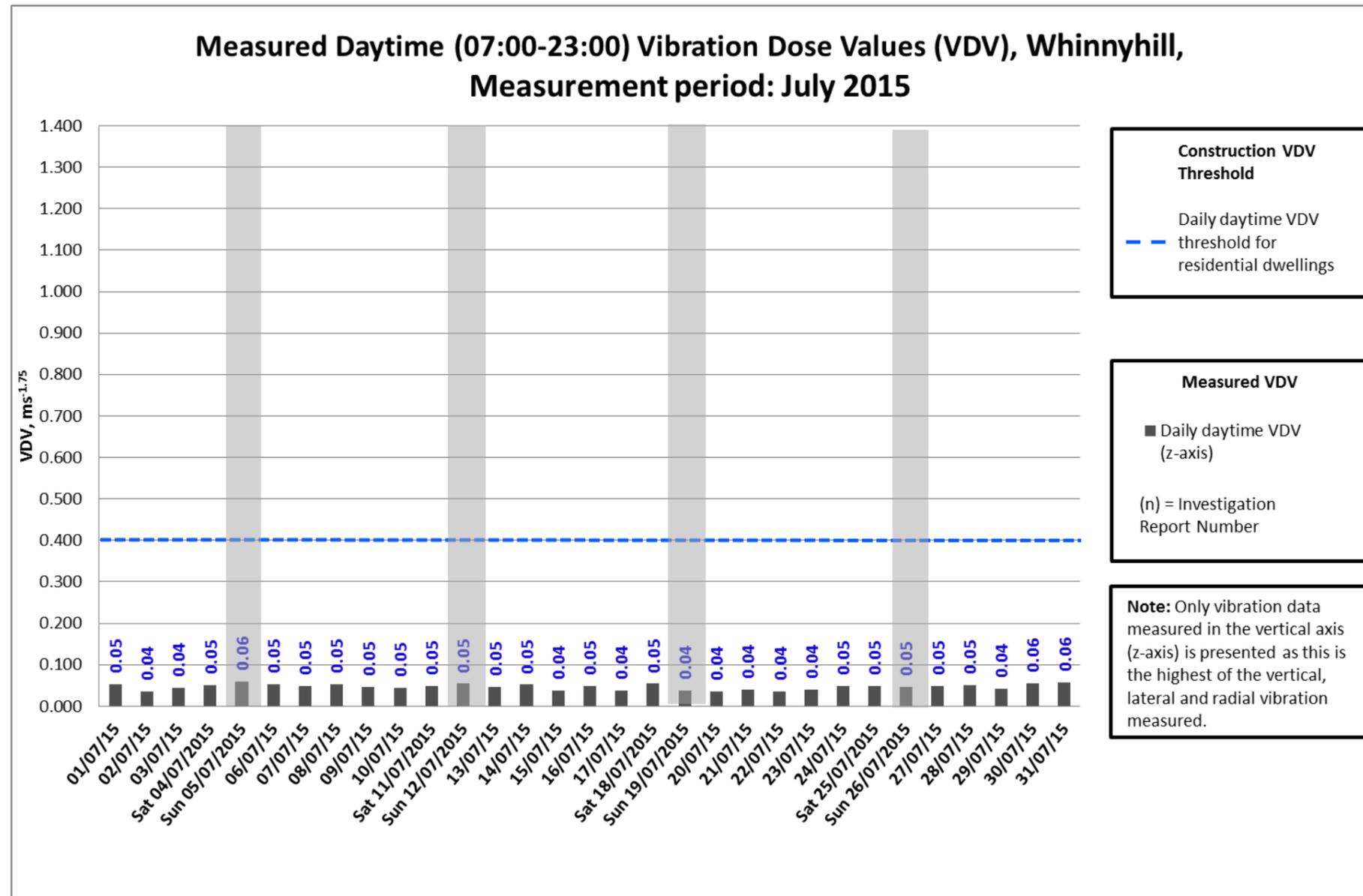
Investigations into the vibration exceedances that started on the 25/07/2015 to the 31/07/2015 (trend starts on the 15/07/2015) have proved inconclusive. However it is noted that the vibration is constant during day and night periods. All construction work within a 300 meter radius of the monitor has been investigated and found not to be using any vibration inducing equipment. The noise monitor at this location during similar times shows no matching trend or noise exceedances related to construction.

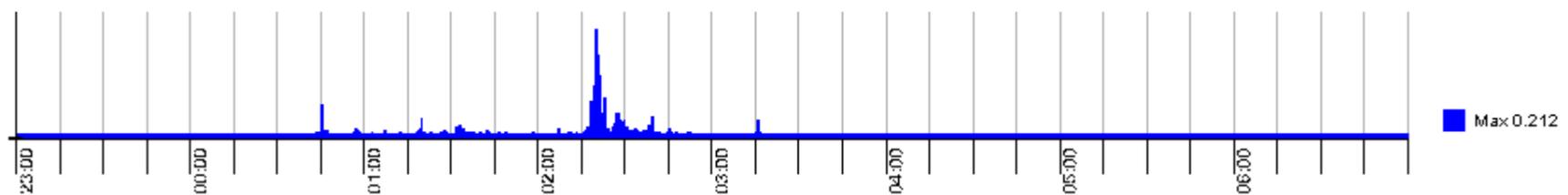
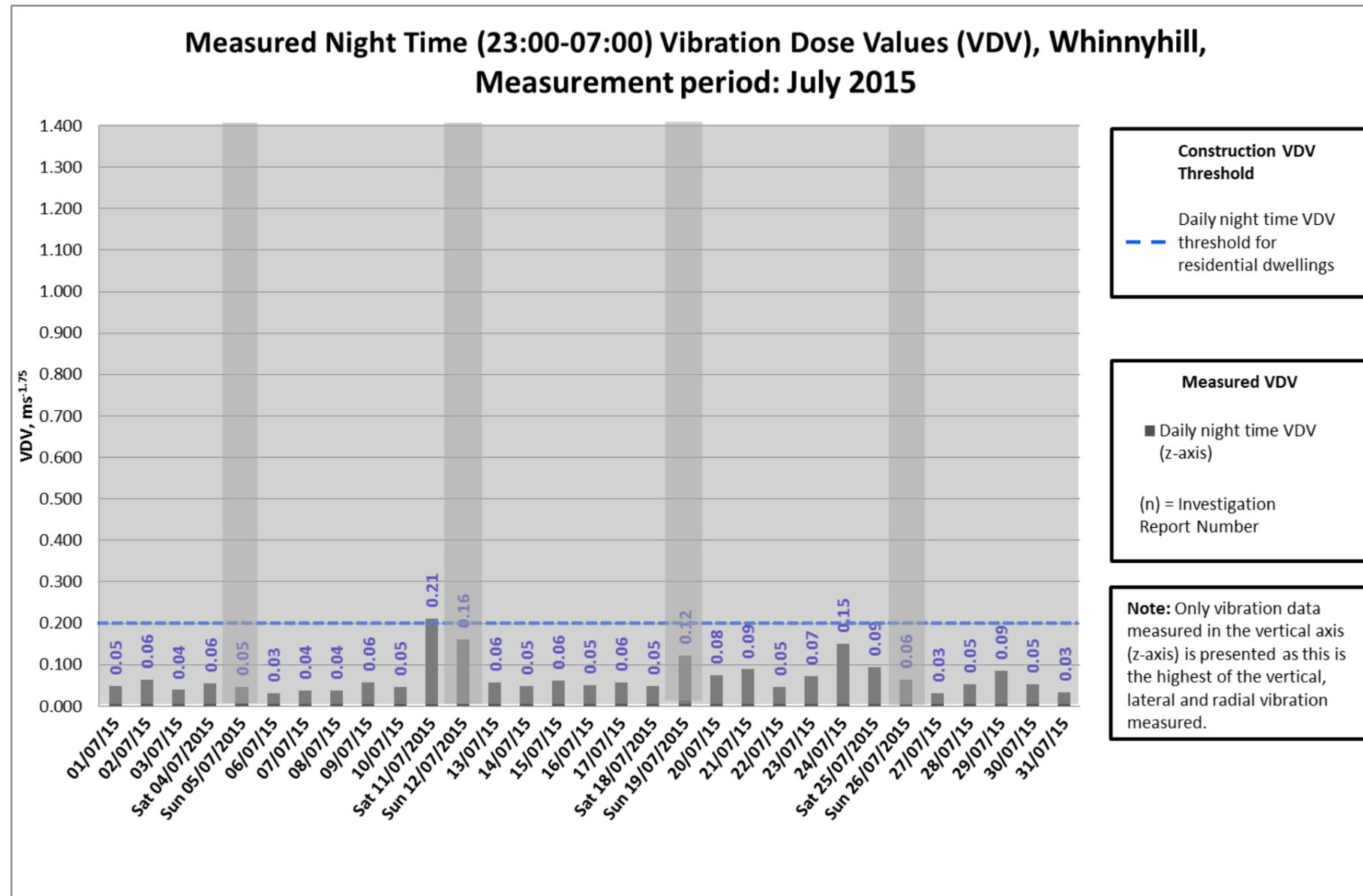


Exceedances on the 01/07/2015, 02/07/2015, 03/07/2015, 04/07/2015, 07/07/2015, 08/07/2015, 12/07/2015, 13/07/2015, 14/07/2015, 16/07/2015, 19/07/2015, 23/07/2015, 25/07/2015, 27/07/2015, 28/07/2015 and on the 29/07/2015 have been investigated and have been found to be isolated events (graph above from the 01/07/2015). The source of the vibration is unknown due to the intervening distance from the closest works (140 meters) it is highly unlikely to be construction related. Due to the sensitivity of the monitors, it is more likely the vibration was caused due to localised vibration sources near or close to the monitor.



Exceedances on the 04/07/2015 and on the 14/07/2015 have been investigated and found to be out with working hours (as seen above) and highly unlikely to be related to construction.





The vibration exceedance on the 11/07/2015 has been investigated. The exceedance occurred out with construction working hours.