



Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT
AUGUST 2014**

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Contents

- 1. Introduction**
- 2. Monitoring Summary**
- 3. Conclusion**

Appendices:

Appendix A: Vibration Assessments from Relevant PCNVs

Appendix B: PPV and VDV Graphs

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 August 2014. 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, doors being slammed, 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

August 2014

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s ⁻¹)	Intermittent (10 mm.s ⁻¹)	Day (0.4 m.s ^{-1.75})	Night (0.2 m.s ^{-1.75})
Linn Mill		1		1
Butlaw Fisheries	2			
Clufflat Brae	6			
Dundas Home Farm	1	3	1	
Echline	3			
Inchgarvie Lodge	4	3	1	
Scotstoun				
Springfield		1		
Tigh-Na-Grian	2	4		1
Whinnyhill	1	3		

- 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. Due to the distances between the work areas and any sensitive receptors, none of the exceedances in VDV levels can be associated with the use of vibratory rollers or whacker plates.
- 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 as a result of device calibration.

3. CONCLUSION

- 3.1.** Considering the distance between FCBC construction works and sensitive receptors, and the methods of working utilised, 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 do not represent levels generated by construction, but rather show local interference 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 August 2014
M1	Whinny Hill	Network	<ul style="list-style-type: none"> • Excavation for working platform • Rock breaking • Temporary casting yard <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • North Tower rebar, formwork & concreting works • Pier N1 de-stressing wells, cleaning of cofferdam & Blinding
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • South Tower rebar, formwork & concreting works • Pier S1 de-stressing wells work • Pier S2 cofferdam excavation • Pier S3 cofferdam excavation • Pier S4 rebar, formwork & concreting works • Pier S5 rebar, formwork & concreting works • Pier S6 rebar, formwork & concreting works
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • South Tower rebar, formwork & concreting works • Pier S1 de-stressing wells work • Pier S2 cofferdam construction • Pier S3 cofferdam excavation • Pier S4 rebar, formwork & concreting works • Pier S5 rebar, formwork & concreting works • Launch - Install plates and strands to props, king post works and
M11	Linn Mill	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Launch operations • Pier S5 rebar, formwork & concreting works <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M13	Clufflat Brae	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Launch operations <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M14	Springfield	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Launch operations <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M15	Echline Field	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works

			<p>and structural steel works</p> <ul style="list-style-type: none"> • Launch operations • Gyrotory – concrete finishing, formwork, parapet concrete pours and associated work • New A904 construction • Scottish Gas diversion work and pipe laying <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M16	Scotstoun	Network	<ul style="list-style-type: none"> • Utilities works • Brash removal <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> • ESQ04 BP protection works and gantry installation/removal of cofferdam sheets <p>N.B. No night time or Sunday daytime construction in vicinity.</p>

Table 2 lists the main construction activities undertaken in the locality of each of the vibration monitors during the period of August 2014.

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	-	-

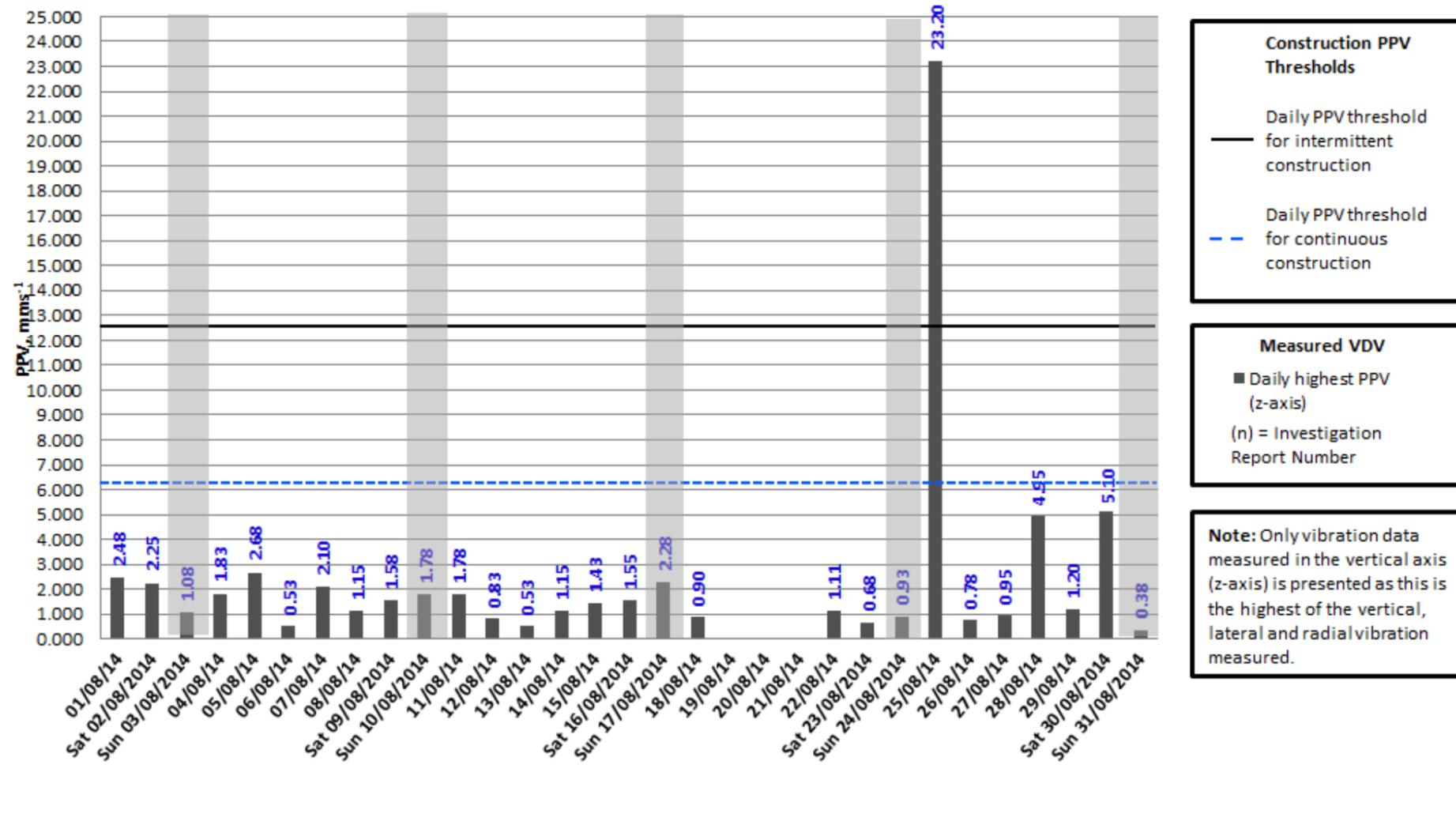
Table 3 lists the distances from vibration monitors to the closest work areas for both day and night time periods. It also lists worst case PPV and eVDV calculations exhibited at the vibration monitors, resulting from the maximum vibration inducing plant operated at the nearest work areas.

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

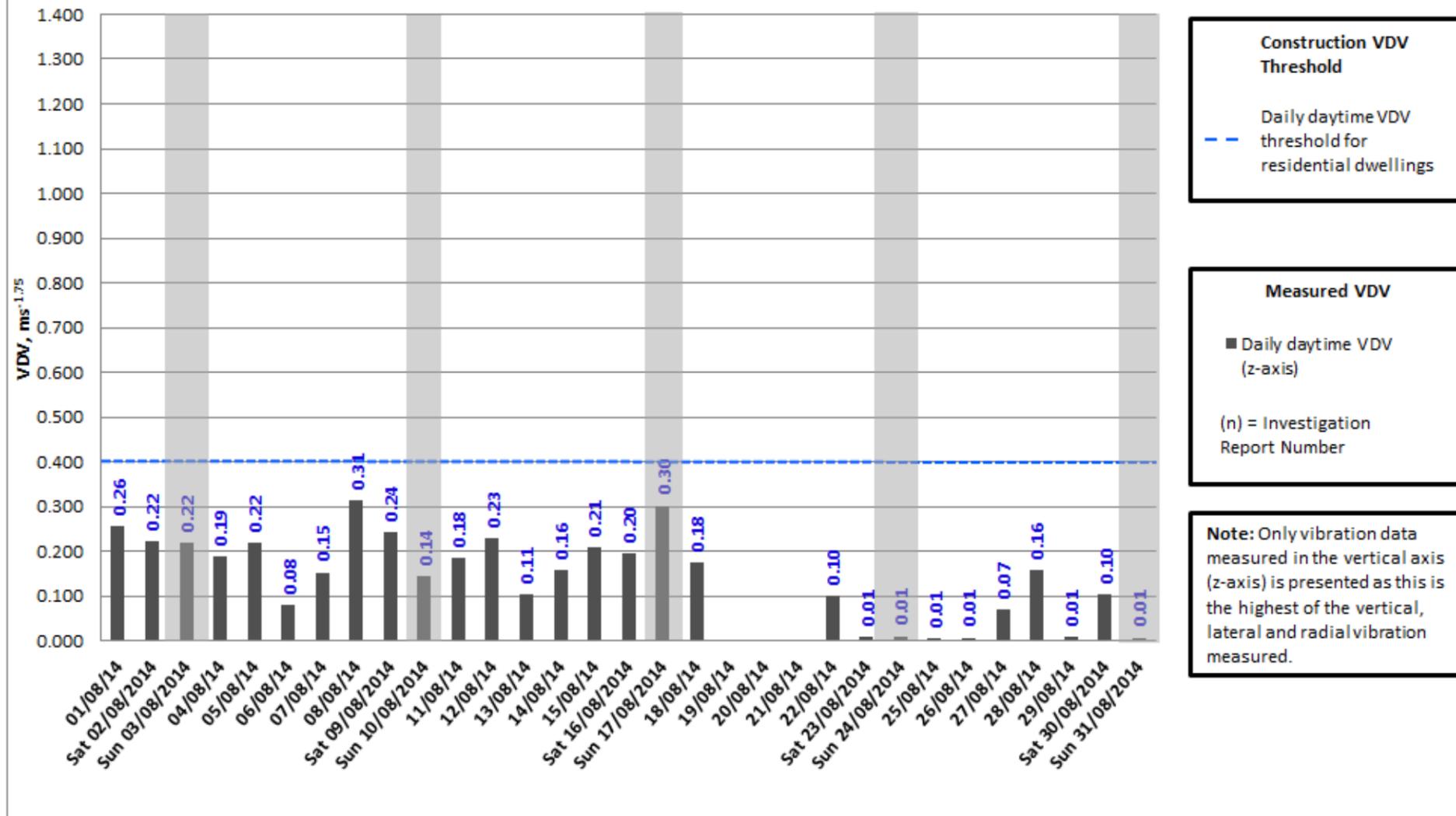
Measured highest Daily Peak Particle Velocity (PPV), 5 Linn Mill, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Linn Mill monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedance on the 25/08/2014 has been investigated, and has been seen to be an individual, isolated event within the period. It is considered to be highly unlikely to be caused by FCBC activity.

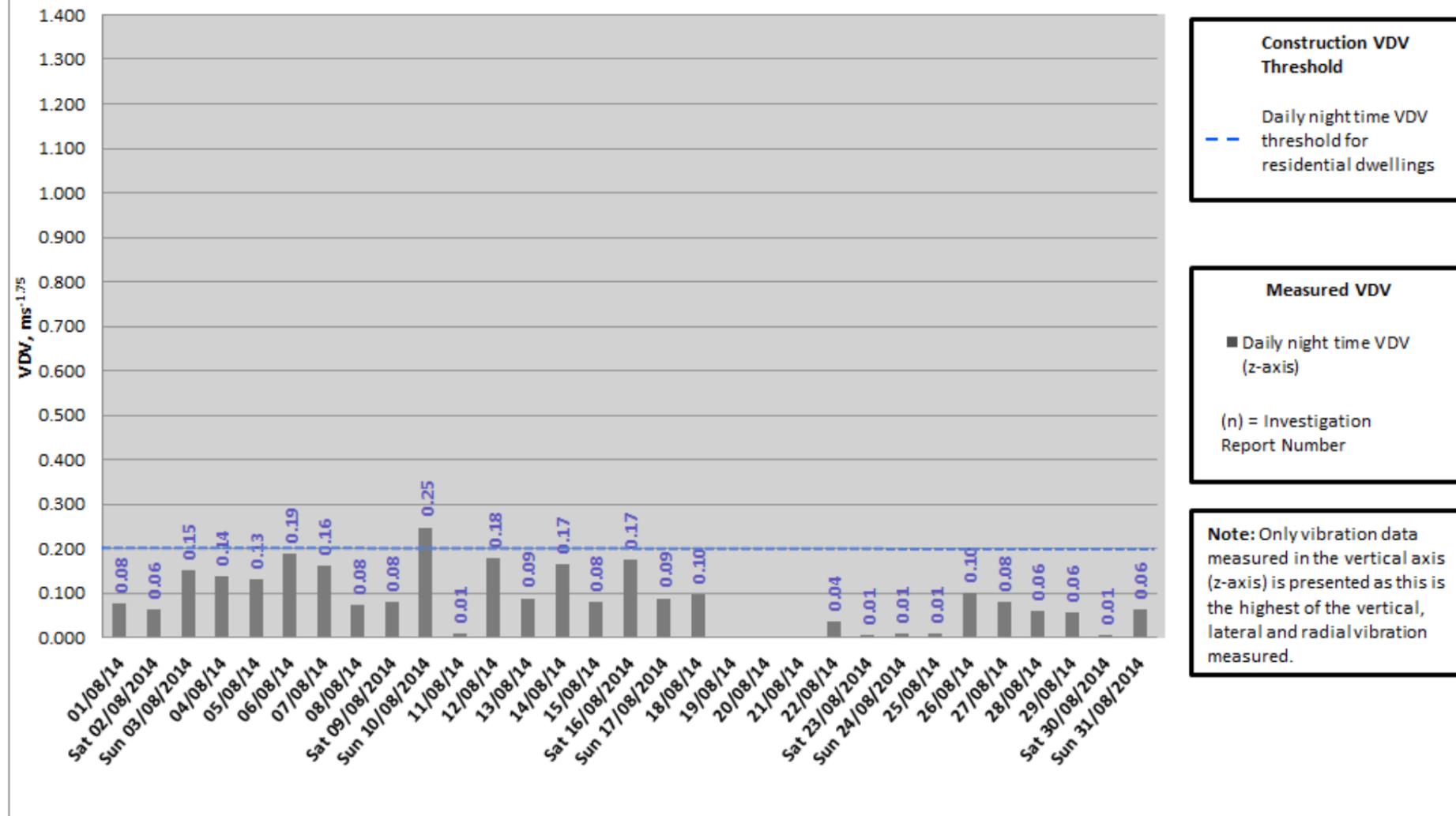
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), 5 Linn Mill, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Linn Mill monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

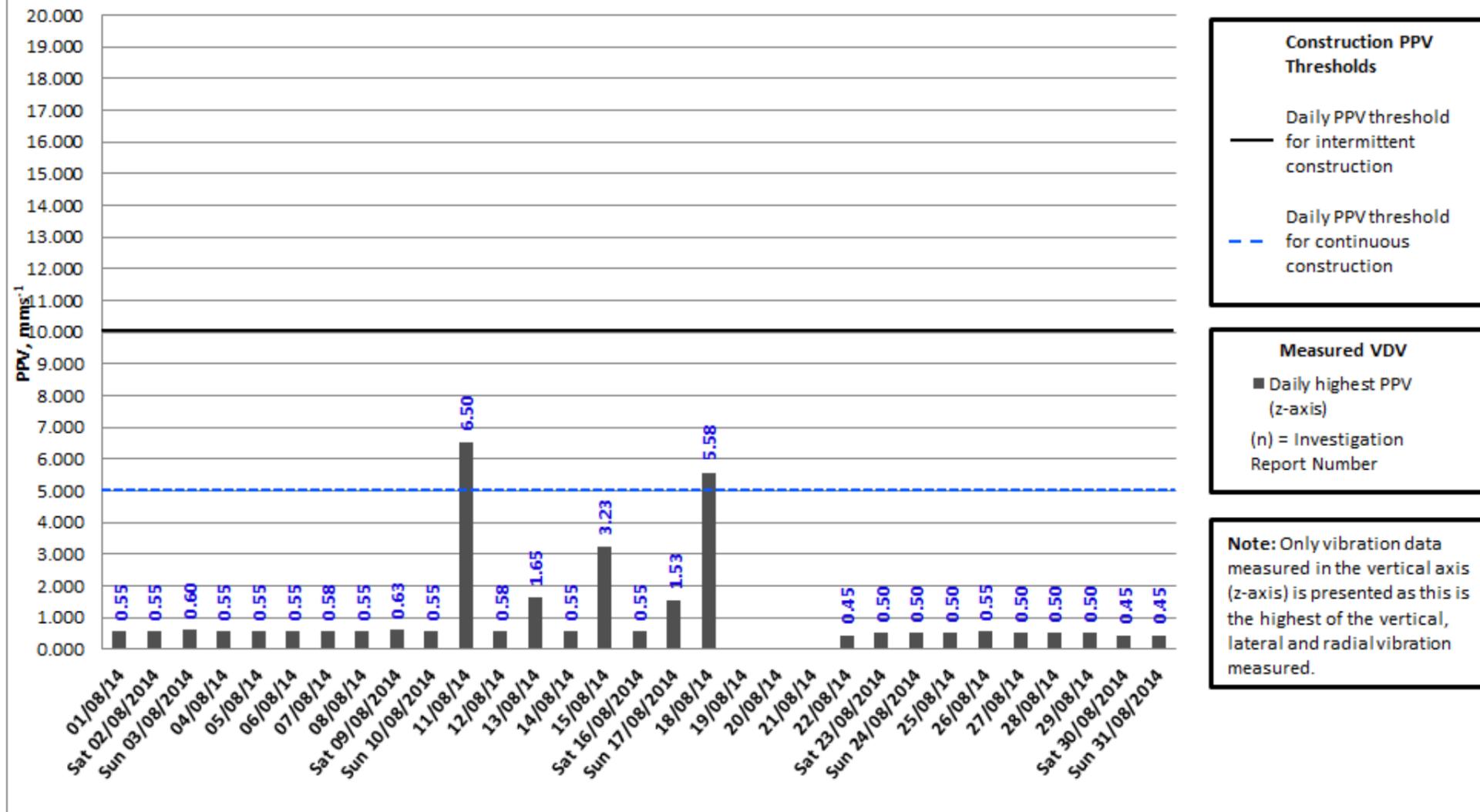
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), 5 Linn Mill, Measurement period: August 2014



Notes:

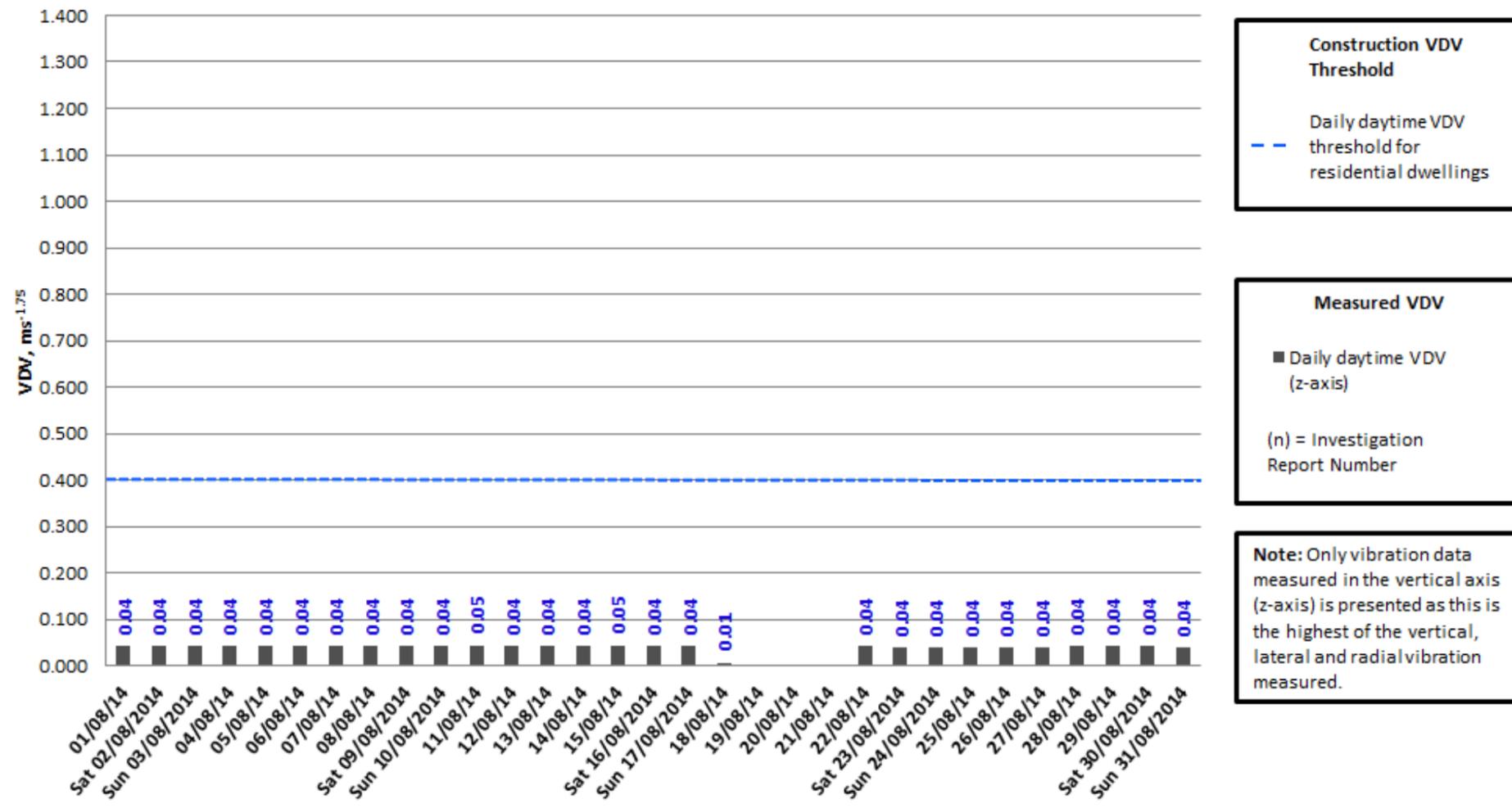
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Linn Mill vibration monitor throughout the month of June 2014. This graph is included for illustrative purposes only.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedance on the 10/08/2014 has been investigated, and has been seen to be an individual, isolated event within the period.

Measured highest Daily Peak Particle Velocity (PPV), Butlaw Fisheries, Measurement period: August 2014



- Notes:**
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
 - The exceedances on the 11/08/2014 and 18/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. They are considered to be highly unlikely to be caused by FCBC activity.

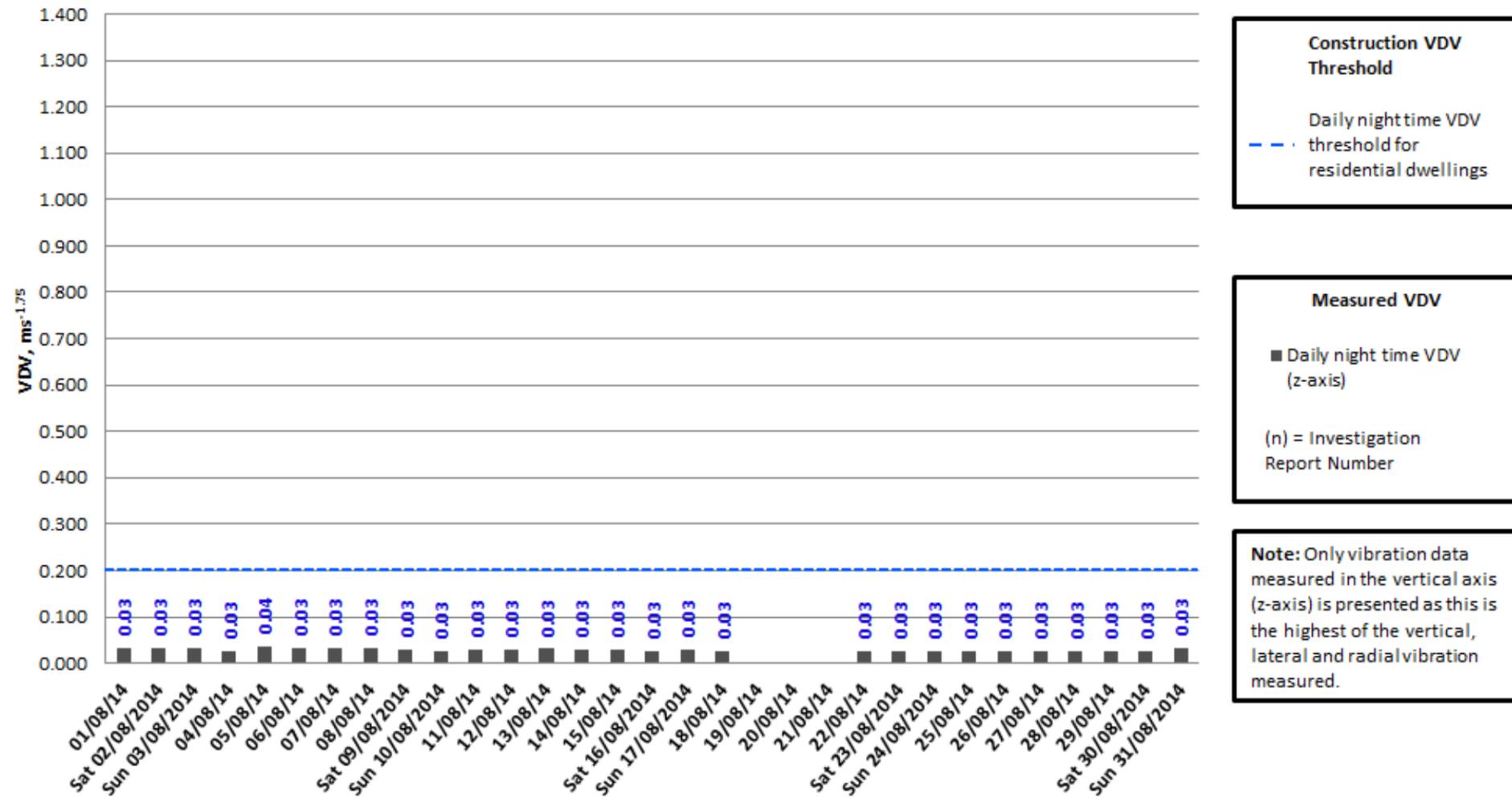
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: August 2014



Notes:

- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

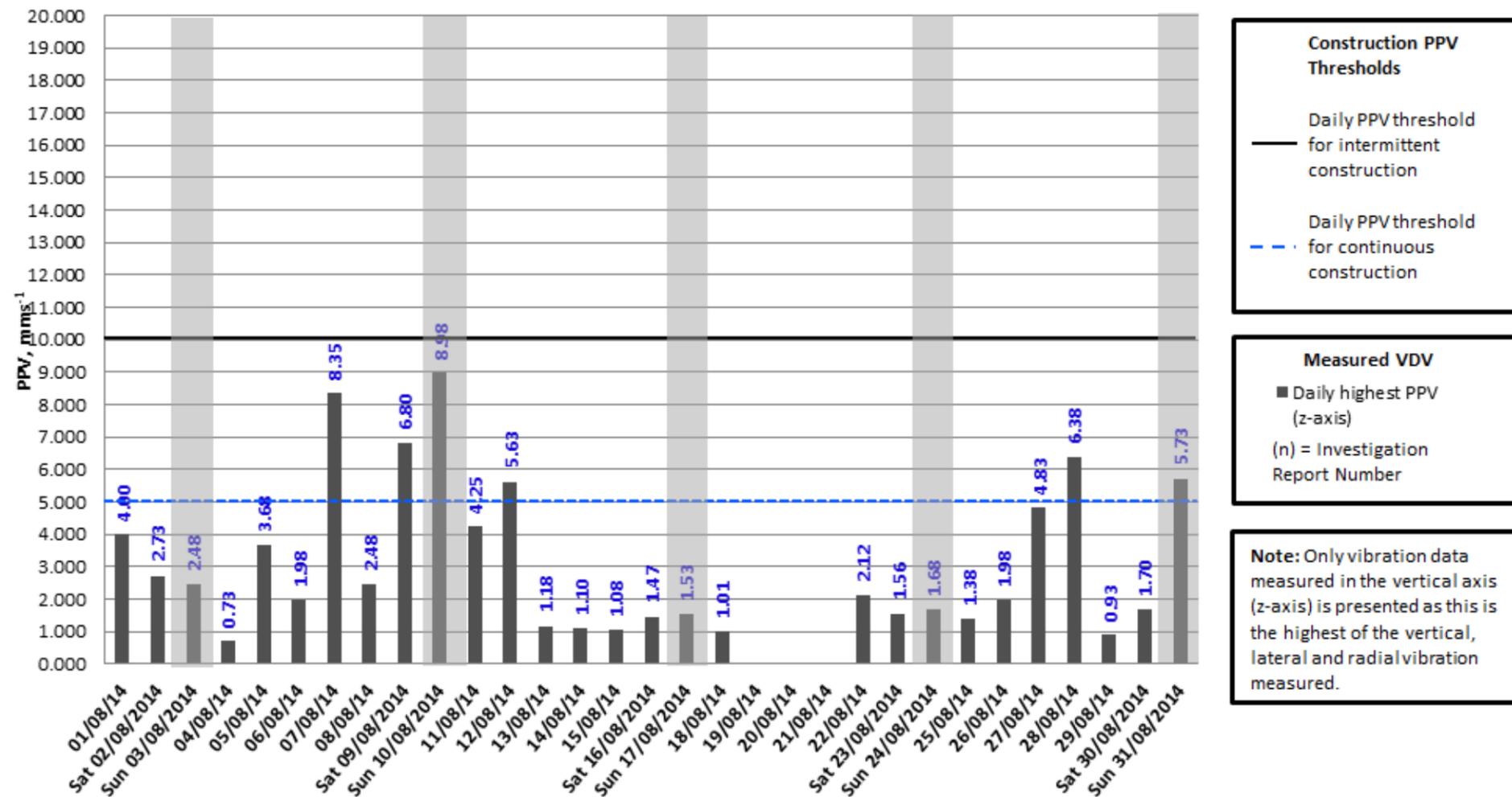
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: August 2014



Notes:

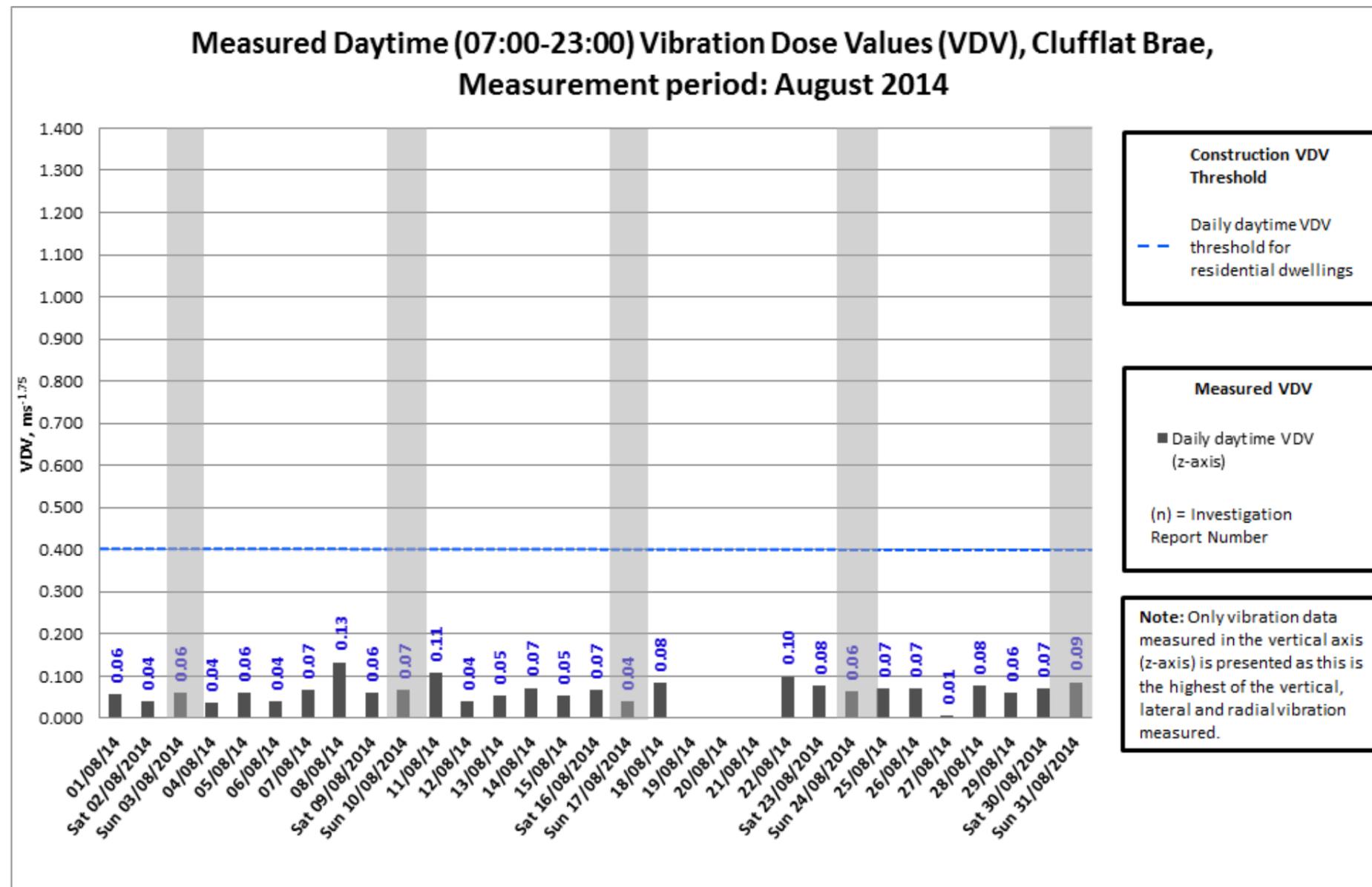
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured highest Daily Peak Particle Velocity (PPV), Clufflat Brae, Measurement period: August 2014



Notes:

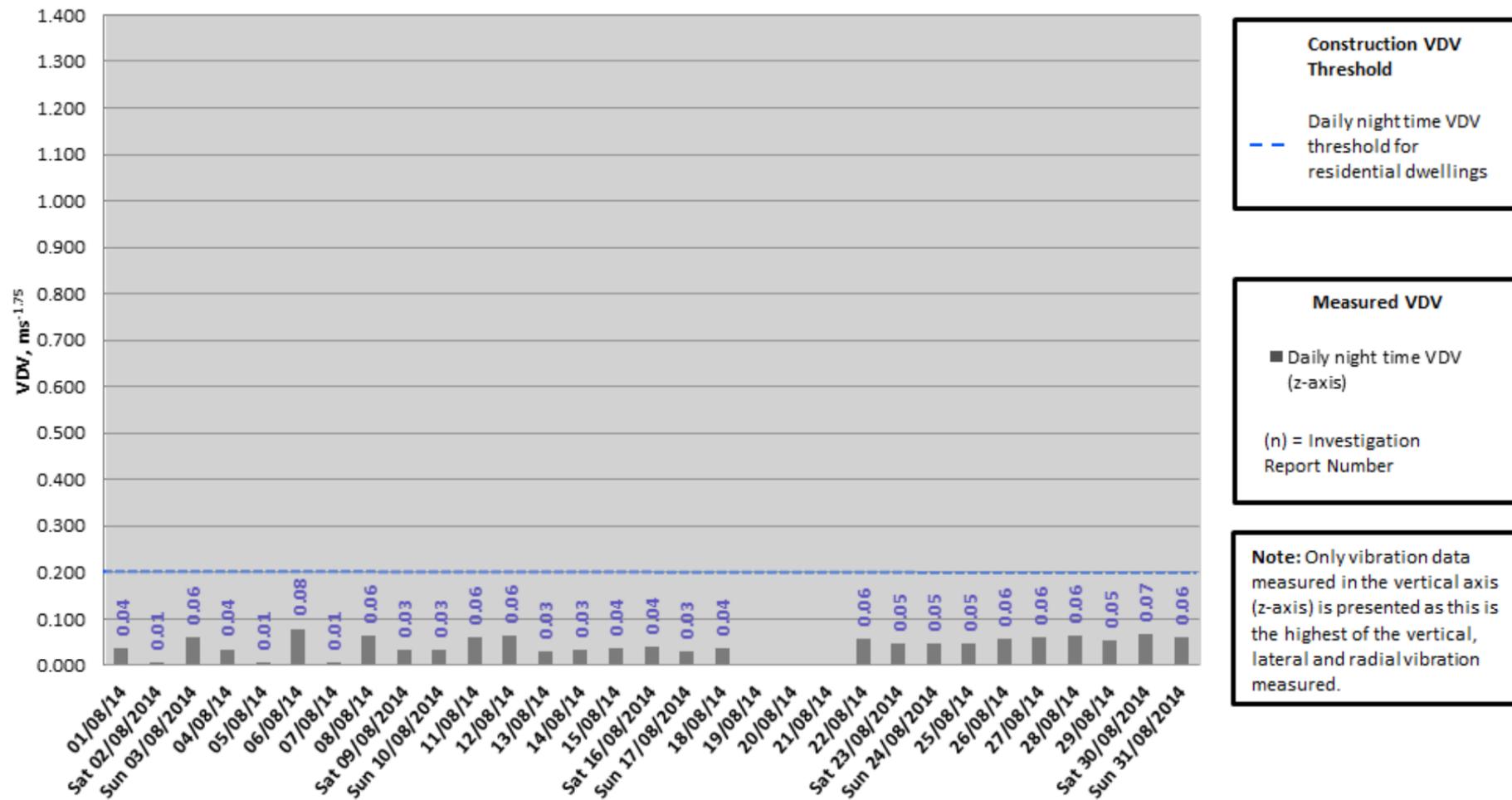
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Clufflat Brae monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedances on the 07/08/2014, 09/08/2014, 10/08/2014, 12/08/2014, 28/08/2014 and 31/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. They are considered to be highly unlikely to be caused by FCBC activity.



Notes:

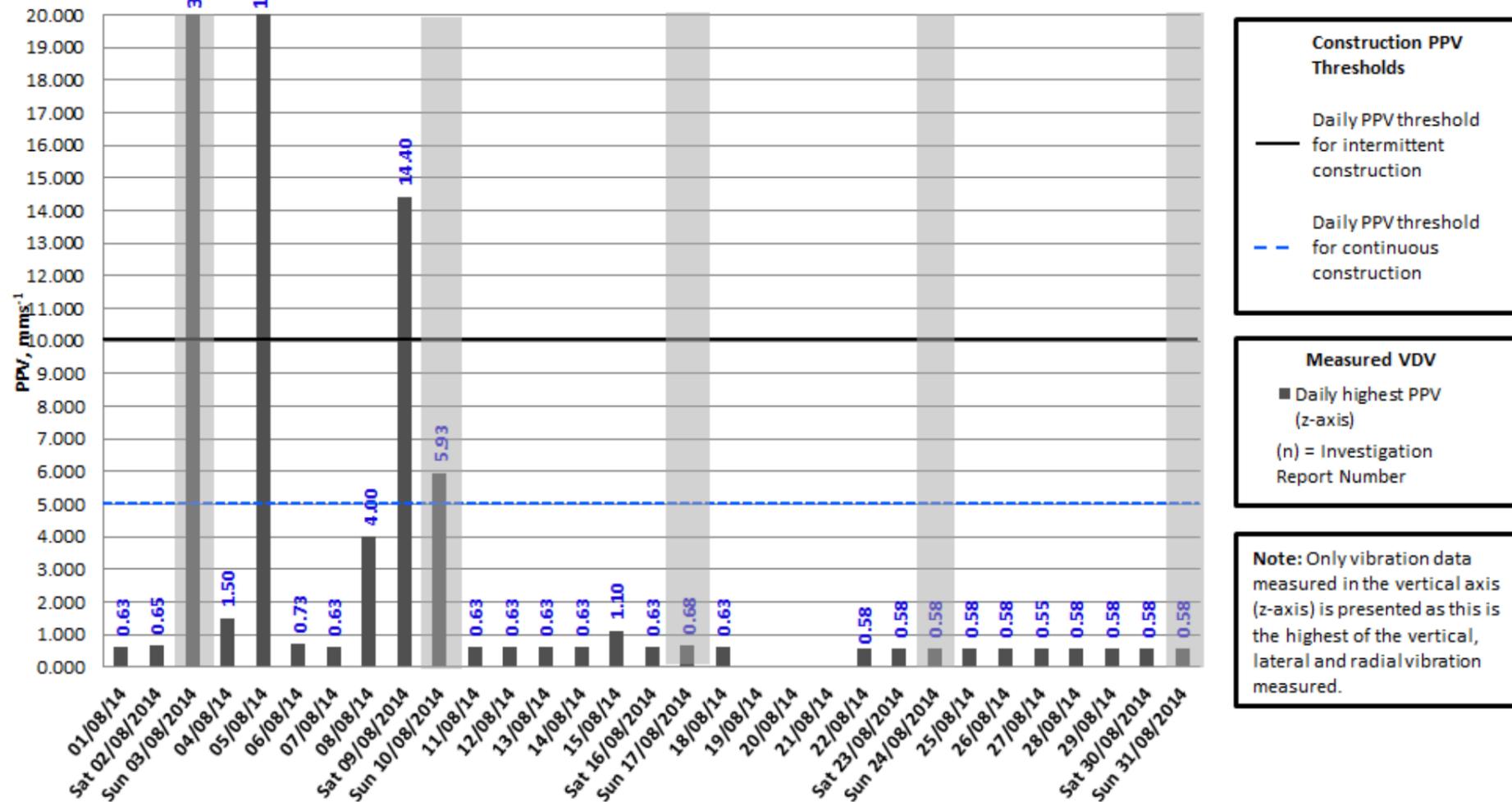
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Clufflat Brae monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Clufflat Brae, Measurement period: August 2014



- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Clufflat Brae vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
 - The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

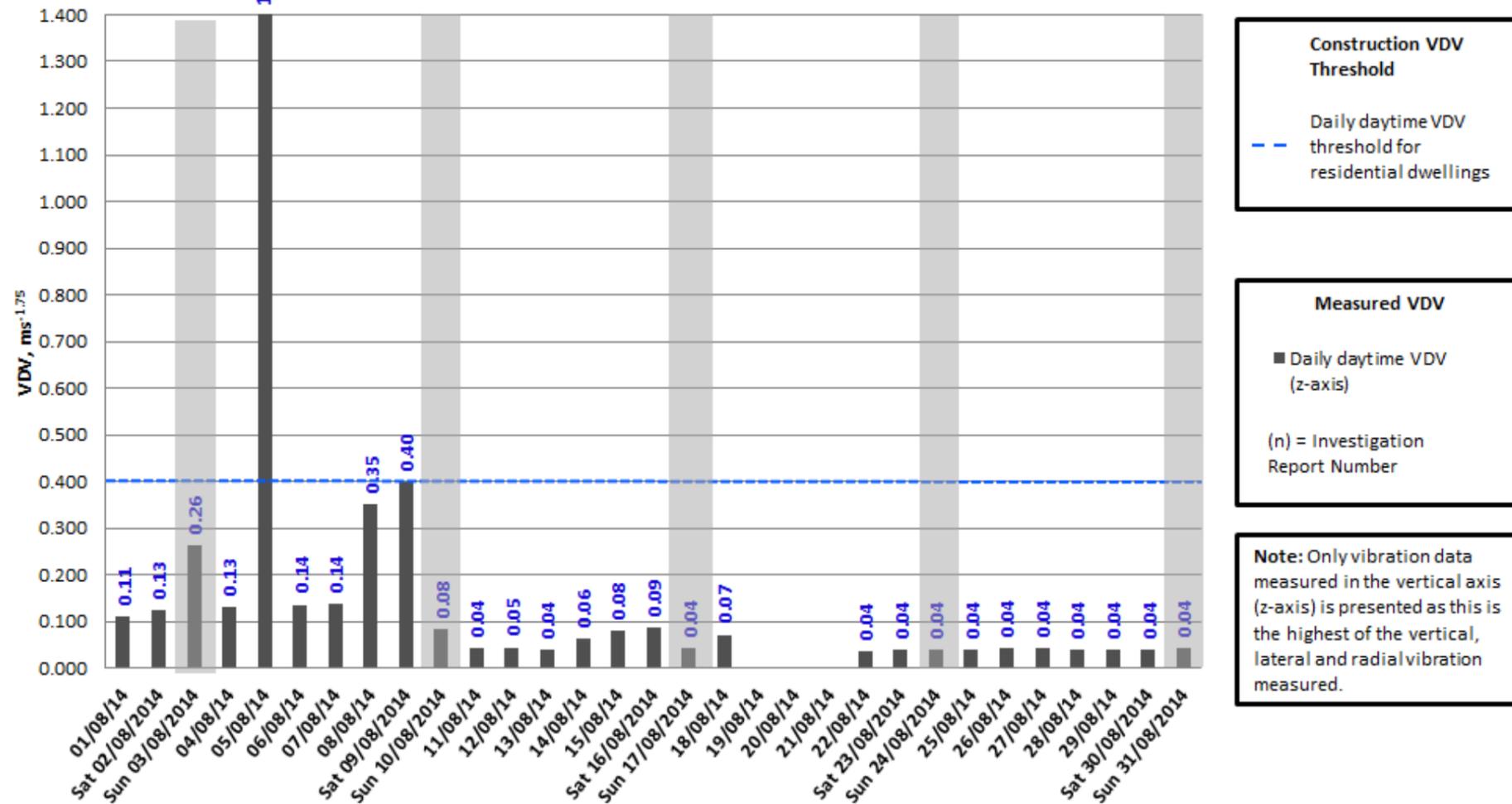
Measured highest Daily Peak Particle Velocity (PPV), Dundas Home Farm, Measurement period: August 2014



Notes:

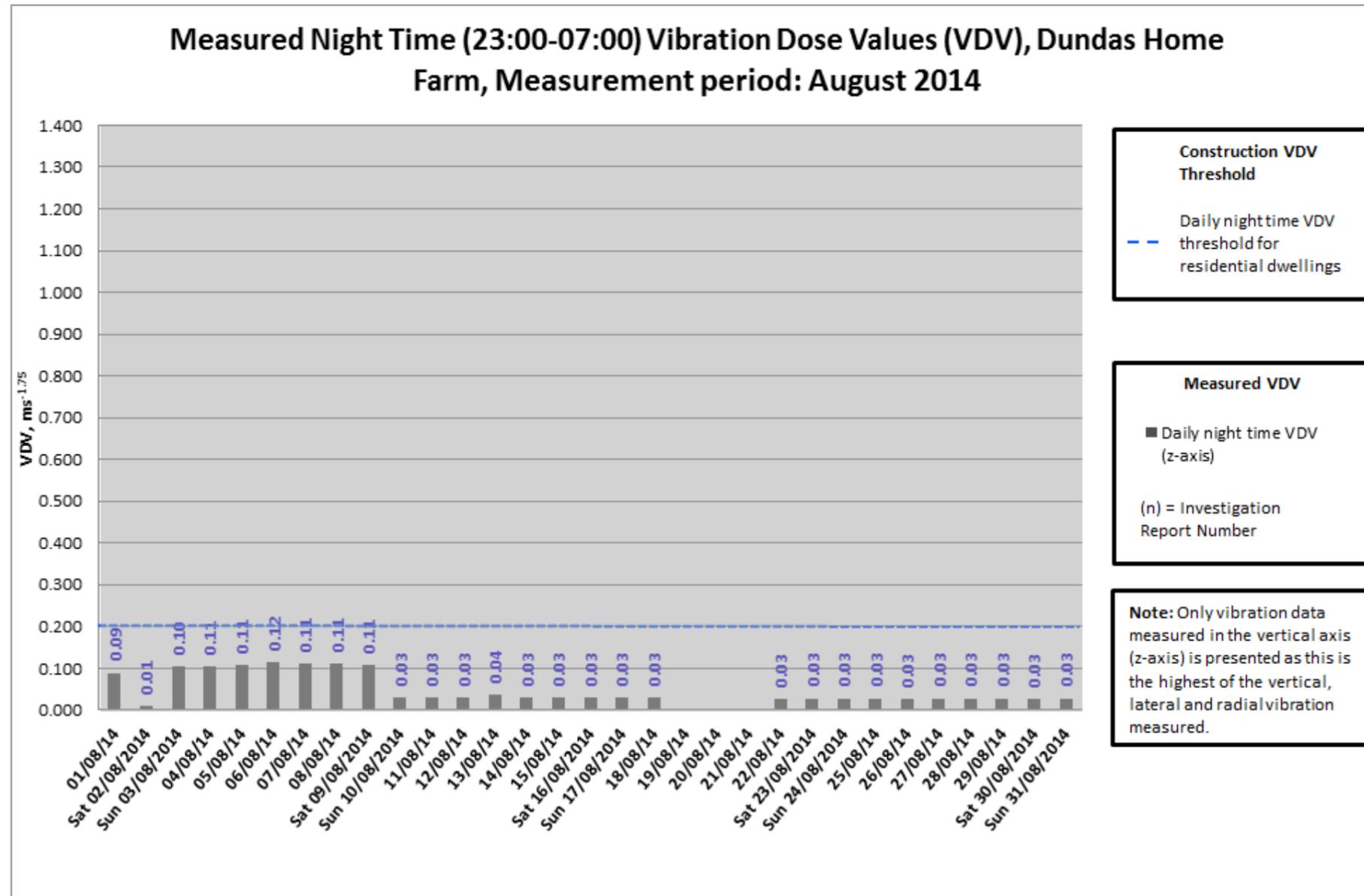
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Dundas monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedances on the 03/08/2014, 05/08/2014, 09/08/2014 and 10/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. More specifically there was landscaping works by residents and the transducers were moved causing an exceedance of 148.40 on 05/08/14.

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: August 2014



Notes:

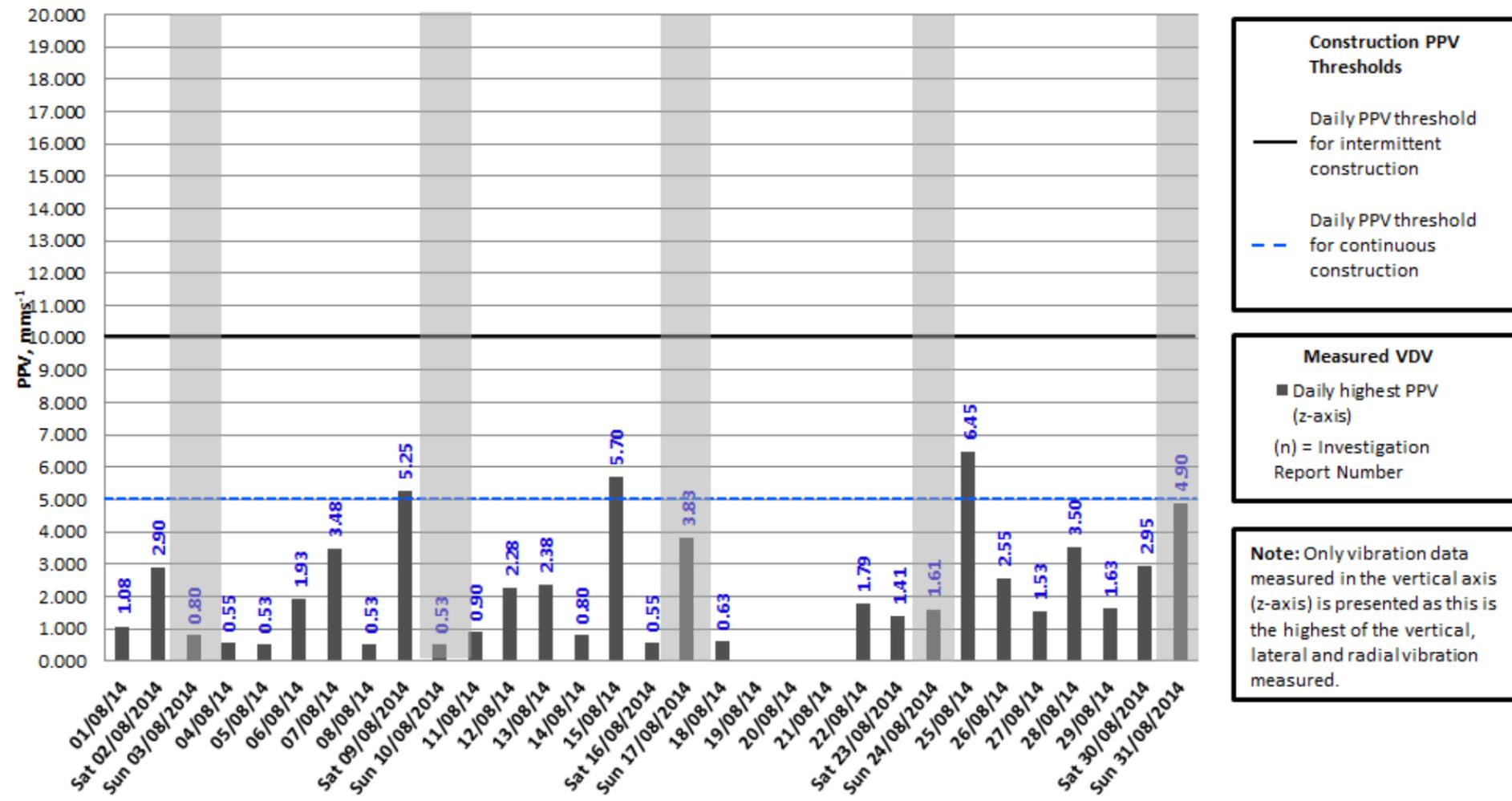
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Dundas monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedance on the 05/08/2014 has been investigated, and has been seen to be an individual, isolated event within the period.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas Home Farm vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

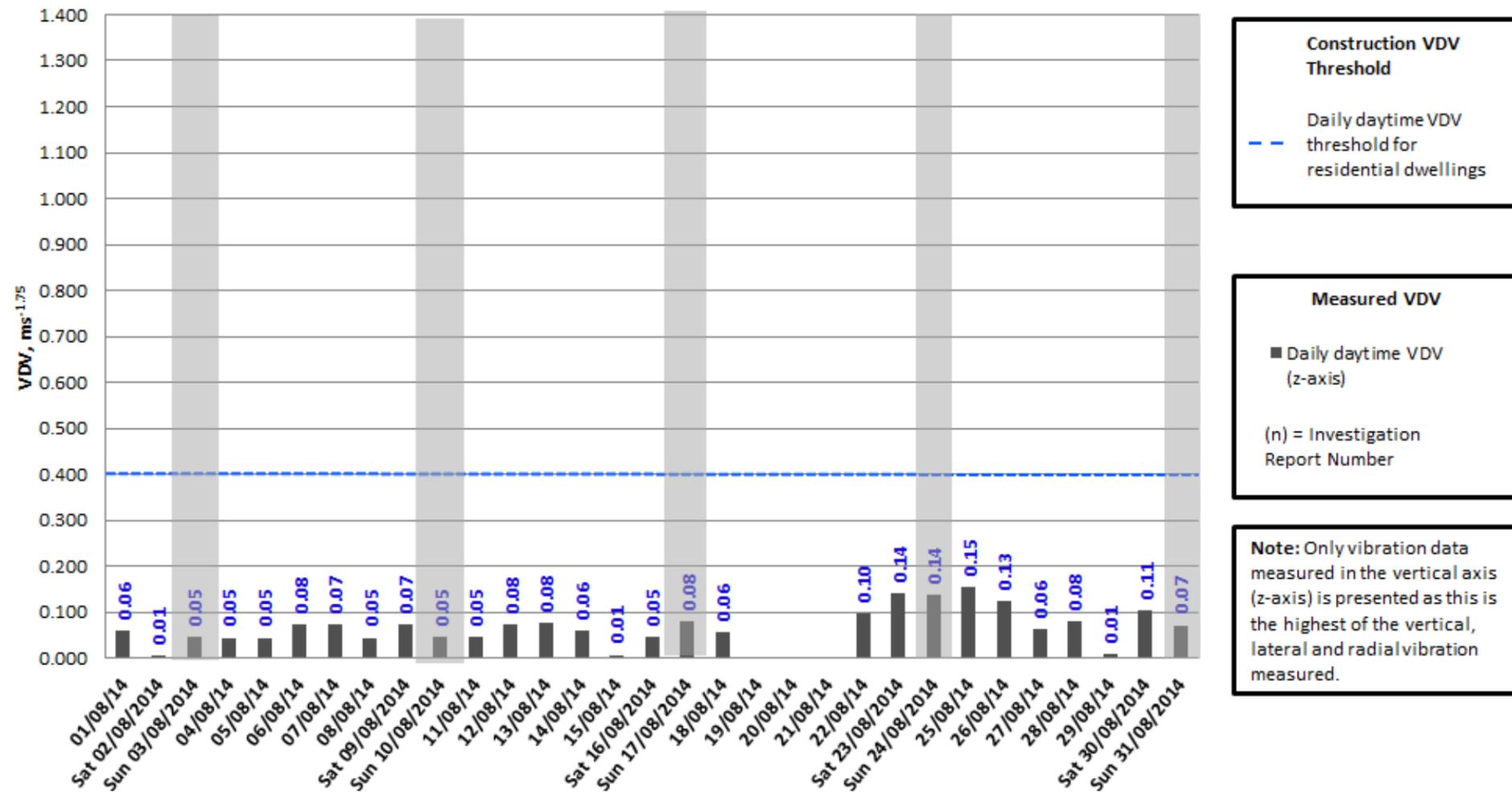
Measured highest Daily Peak Particle Velocity (PPV), Echline, Measurement period: August 2014



Notes

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Echline monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedances on the 08/08/2014, 15/08/2014 and 25/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. They are considered to be highly unlikely to be caused by FCBC activity.

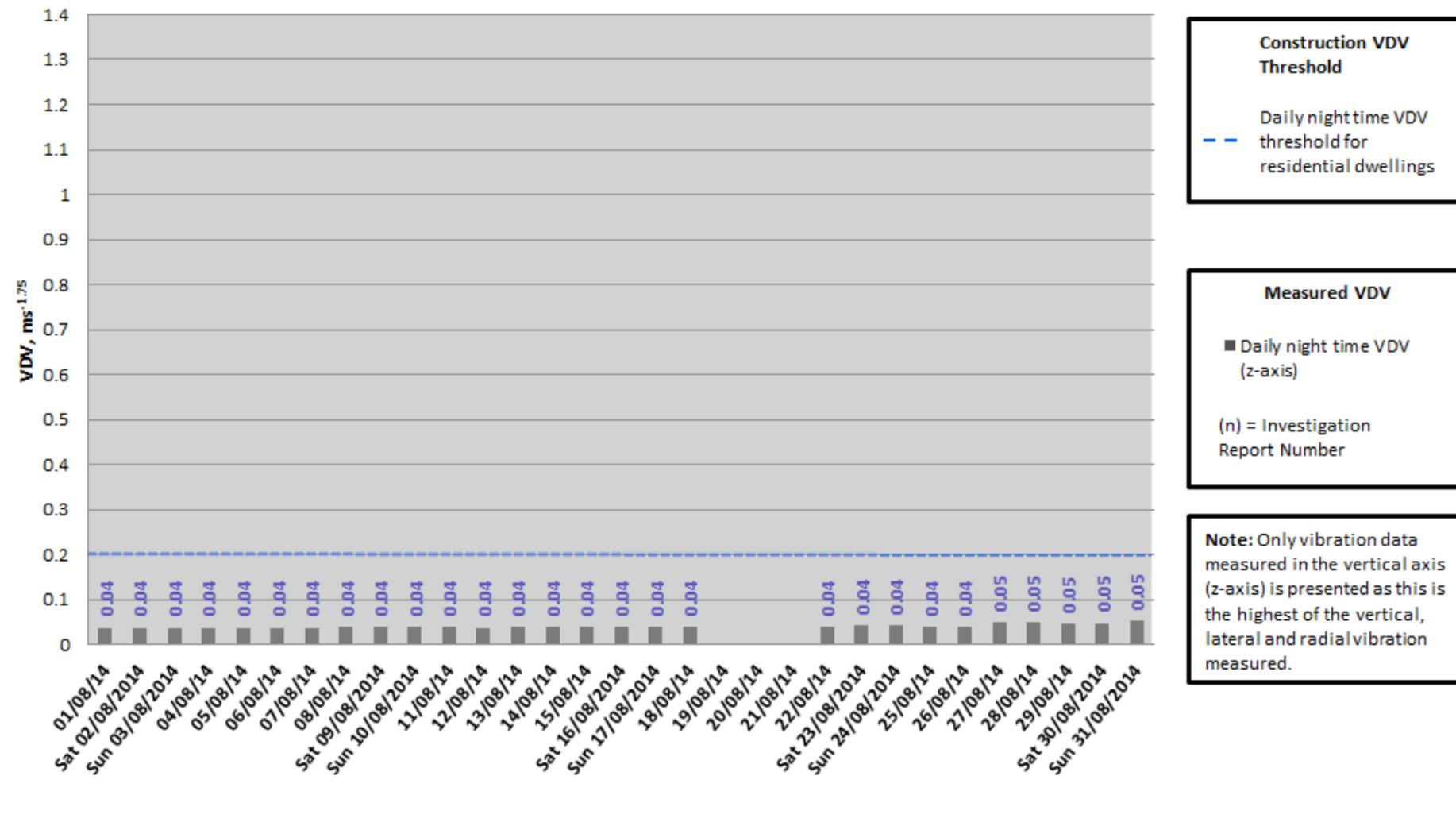
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Echline, Measurement period: August 2014



Notes

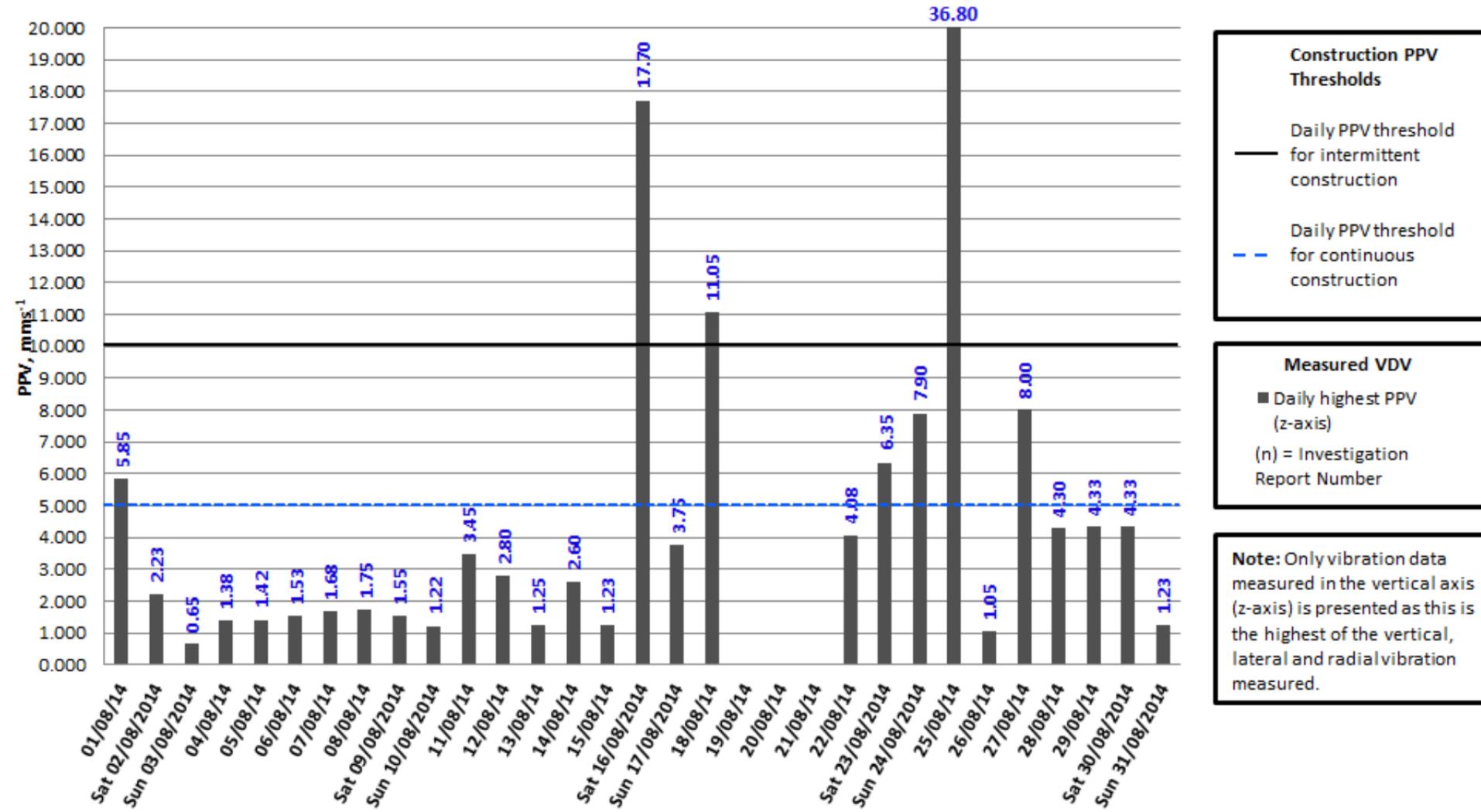
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Echline monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Echline, Measurement period: August 2014



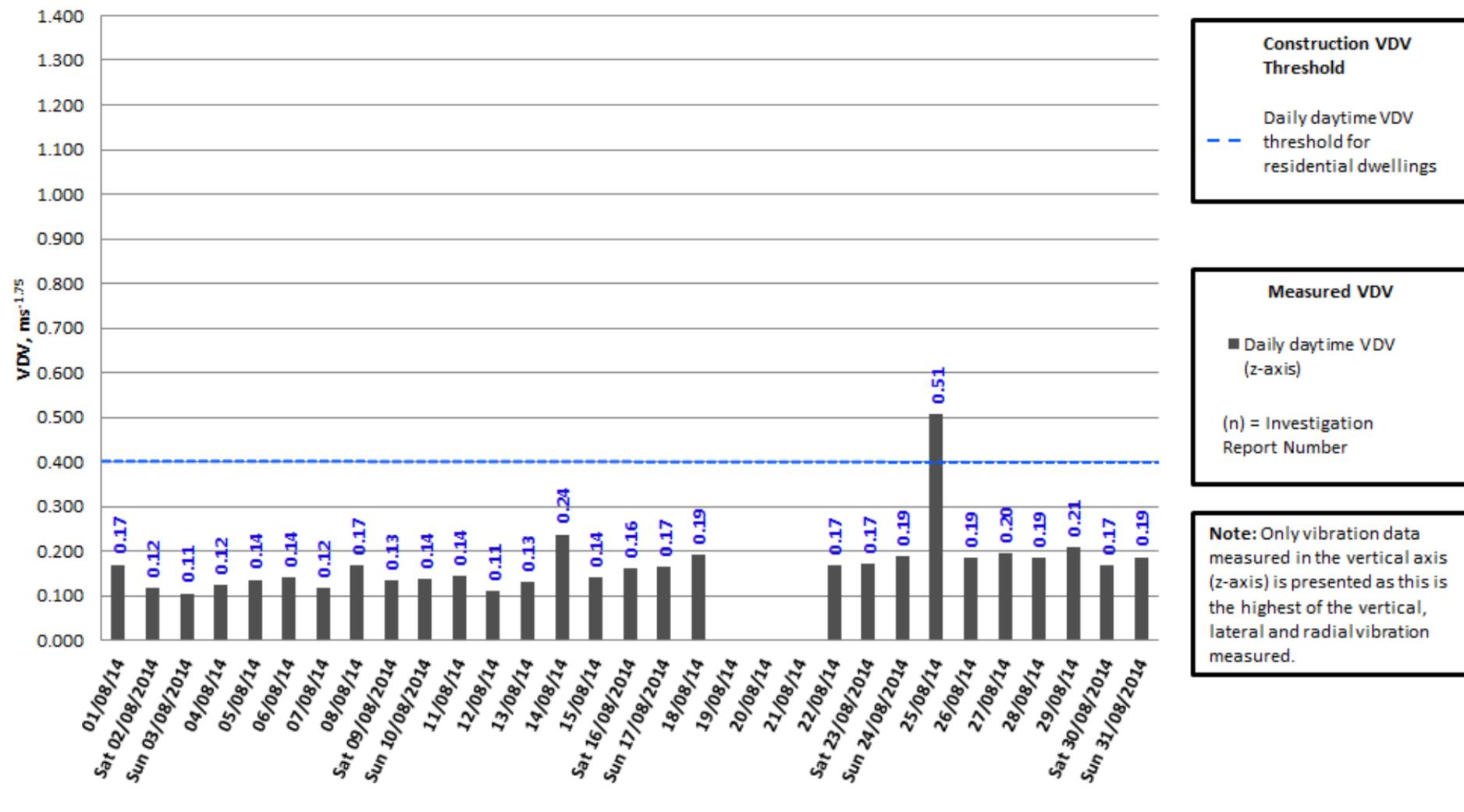
- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Echline vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
 - The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured highest Daily Peak Particle Velocity (PPV), Inchgarvie Lodge, Measurement period: August 2014



- Notes:**
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
 - The exceedances on the 01/08/2014, 16/08/2014, 18/08/2014, 23/08/2014, 24/08/2014, 25/08/2014 and 27/08/2014 have been investigated, and have been seen to be individual, isolated events within the period.

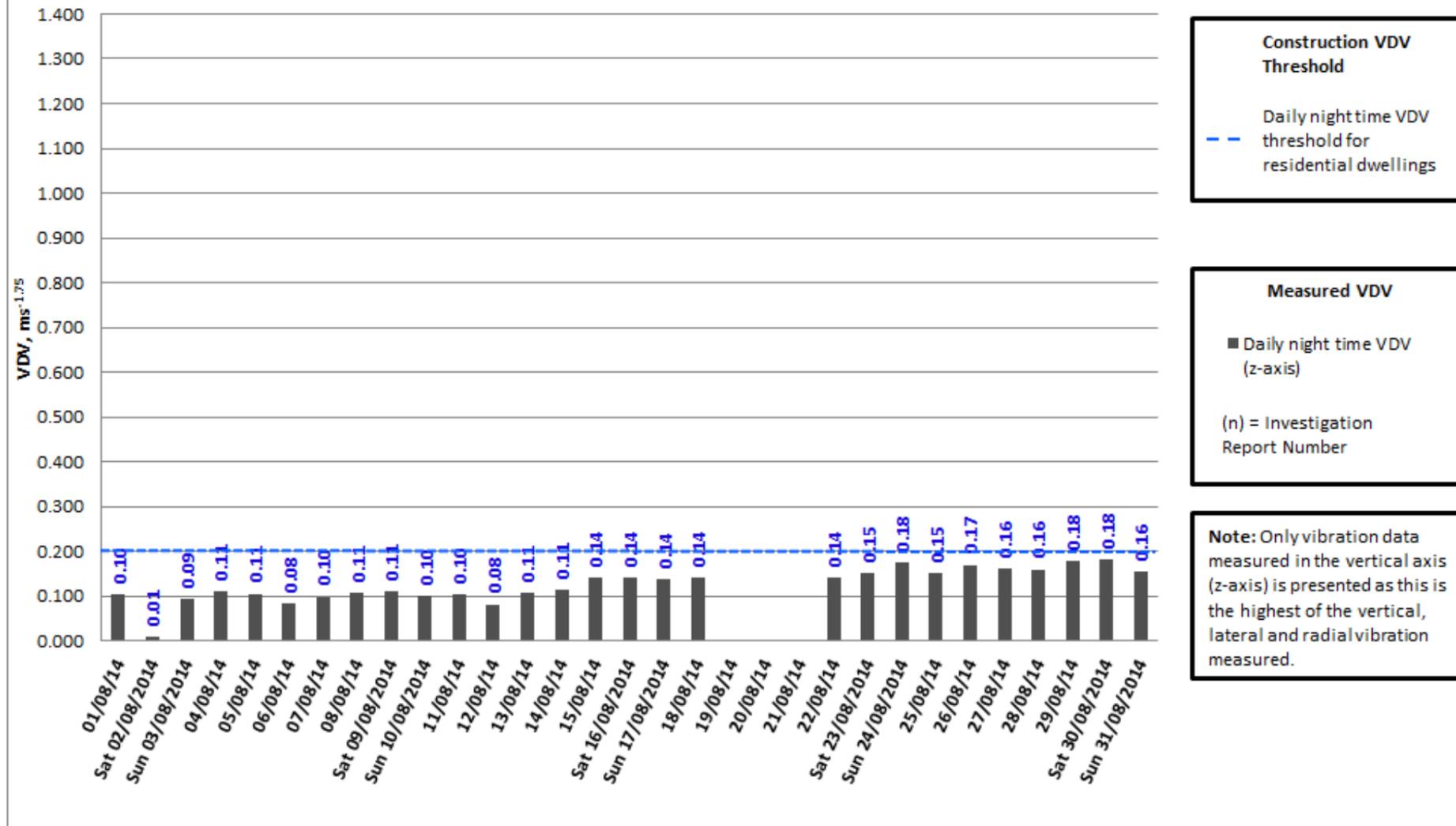
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: August 2014



Notes:

- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedance on the 25/08/2014 has been investigated, and has been seen to be an individual, isolated event within the period.

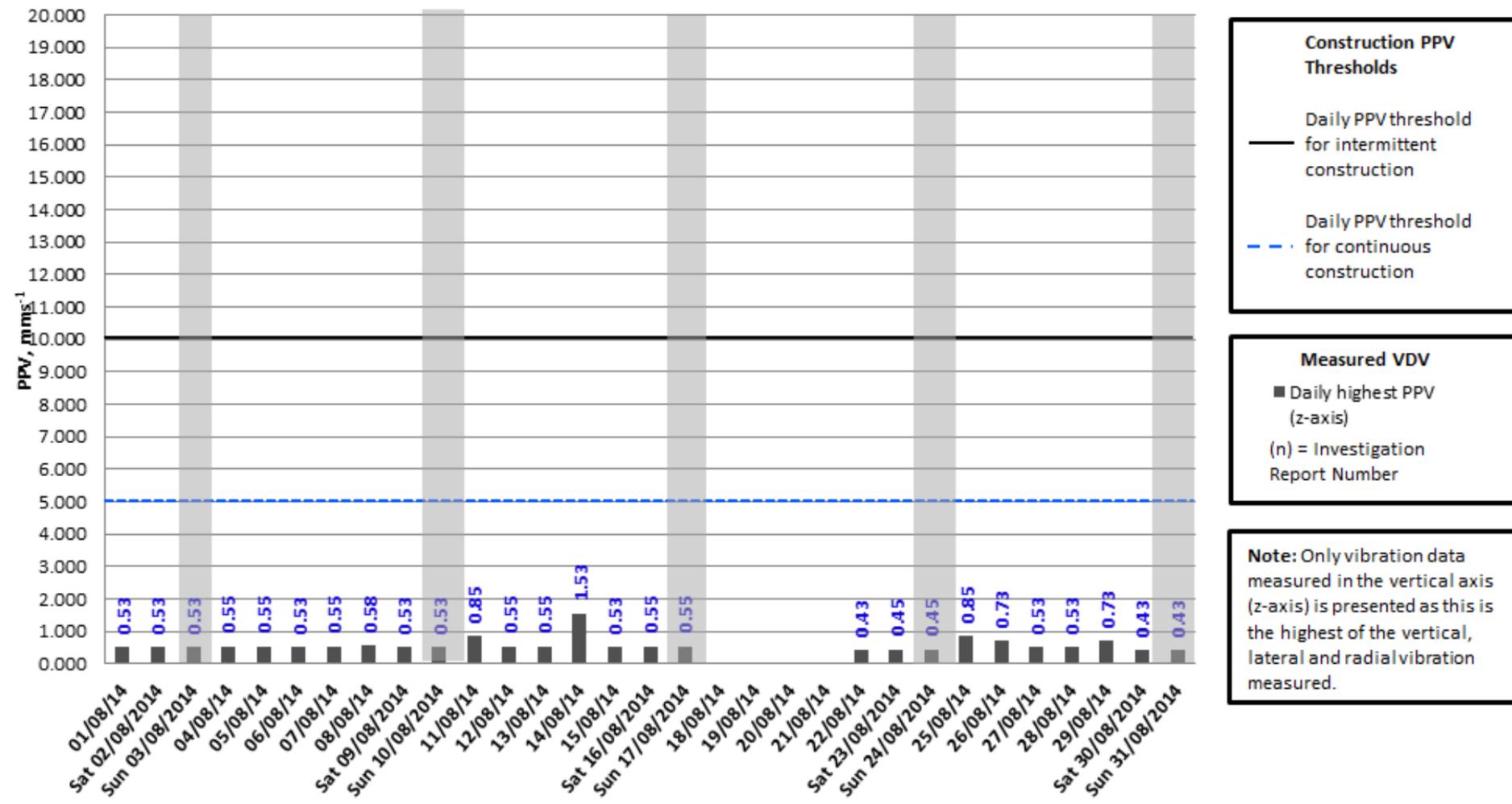
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: August 2014



Notes:

- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

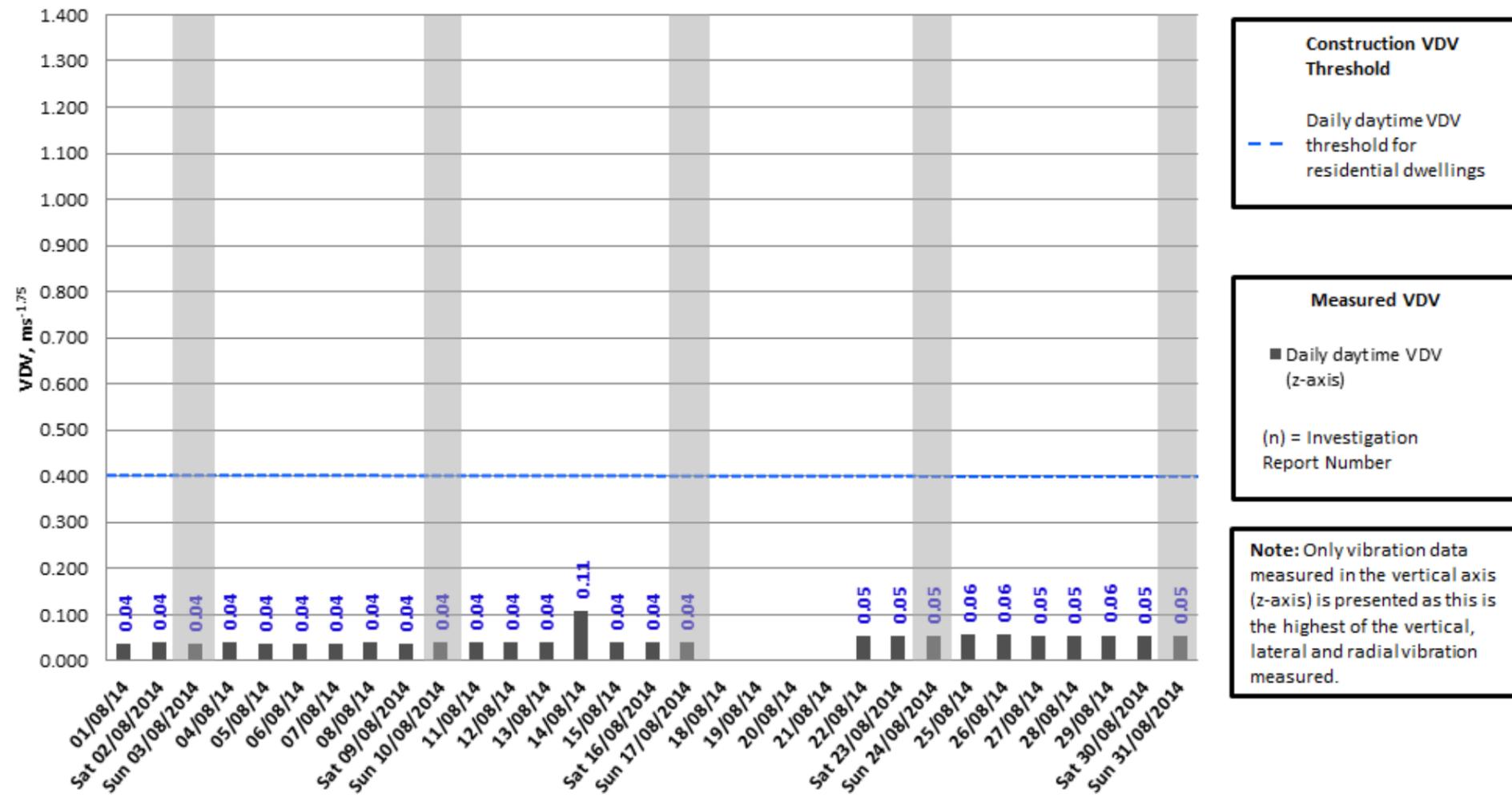
Measured highest Daily Peak Particle Velocity (PPV), Scotstoun, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Scotstoun monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

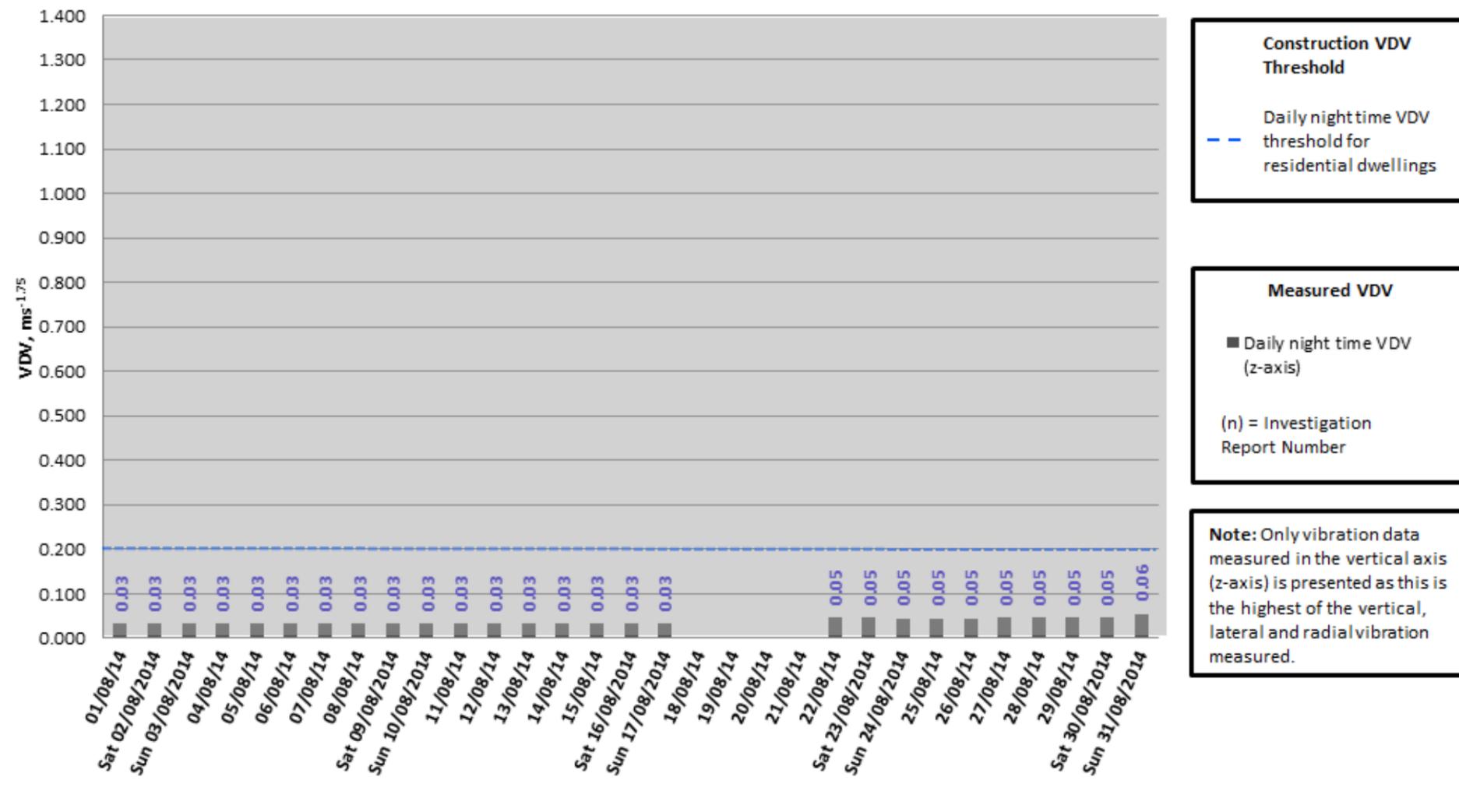
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Scotstoun monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

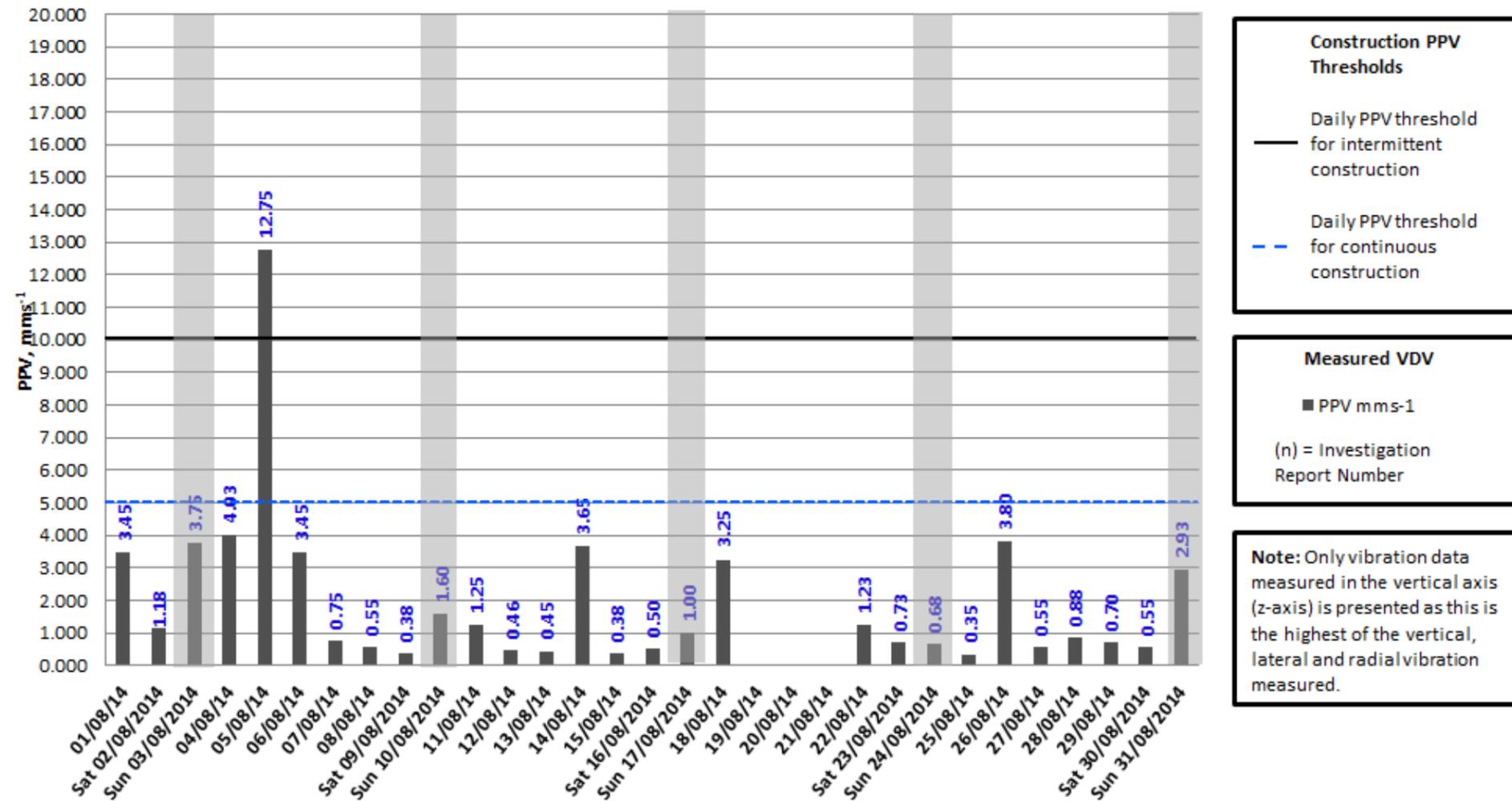
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Scotstoun vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

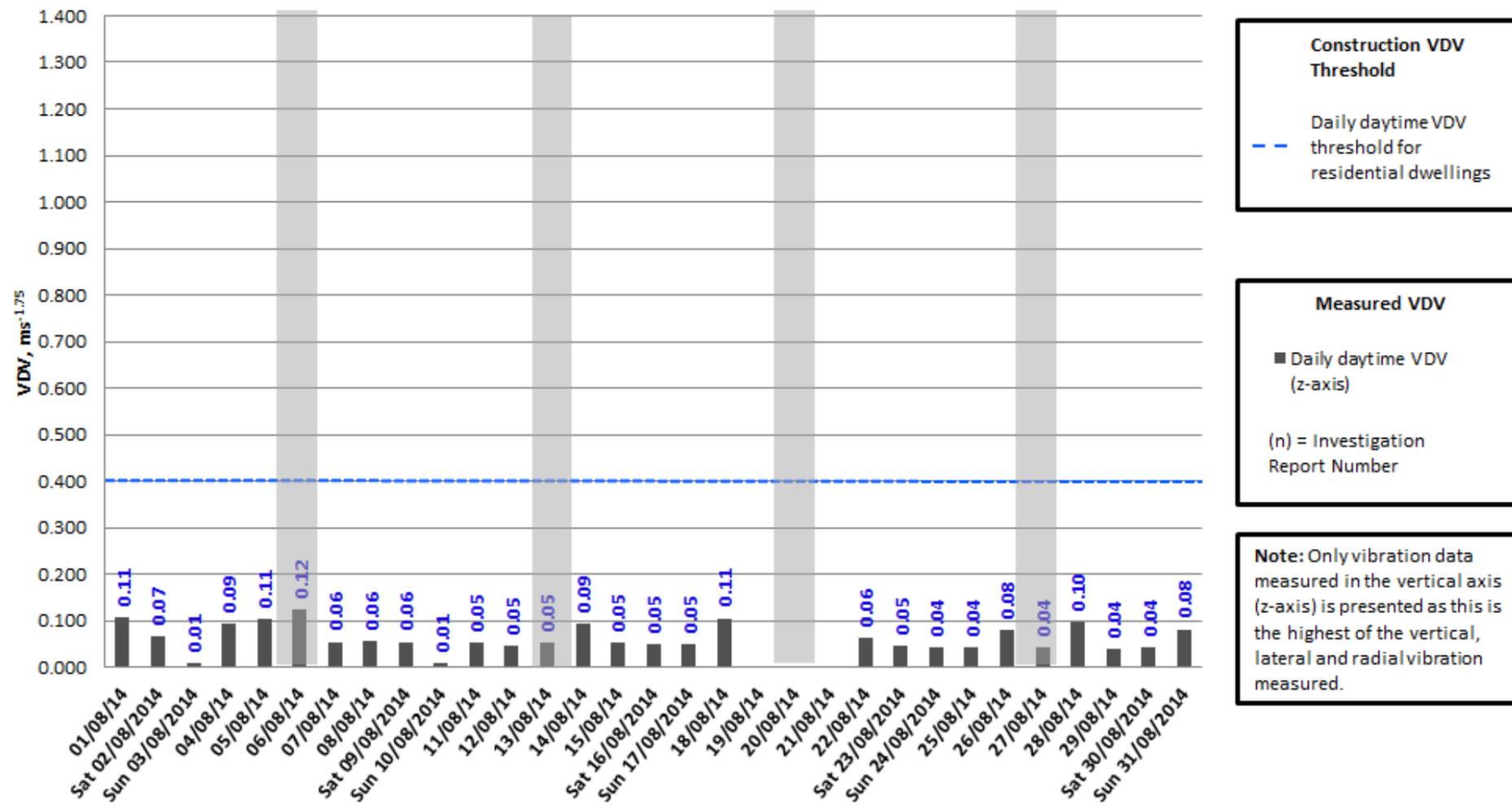
Measured highest Daily Peak Particle Velocity (PPV), Springfield, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Springfield monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedance on the 05/08/2014 has been investigated, and has been seen to be an individual, isolated event within the period.

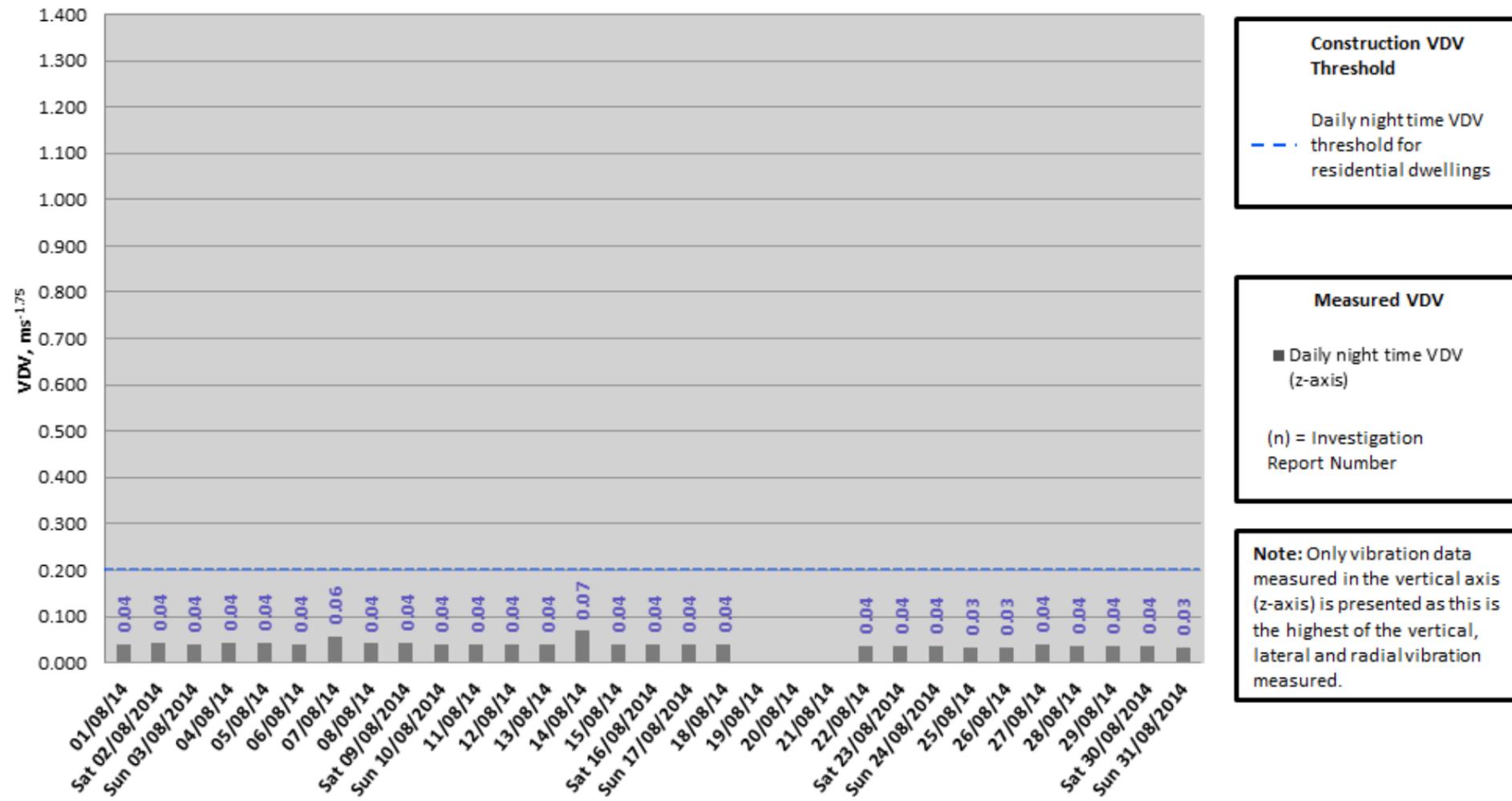
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield, Measurement period: August 2014



Notes:

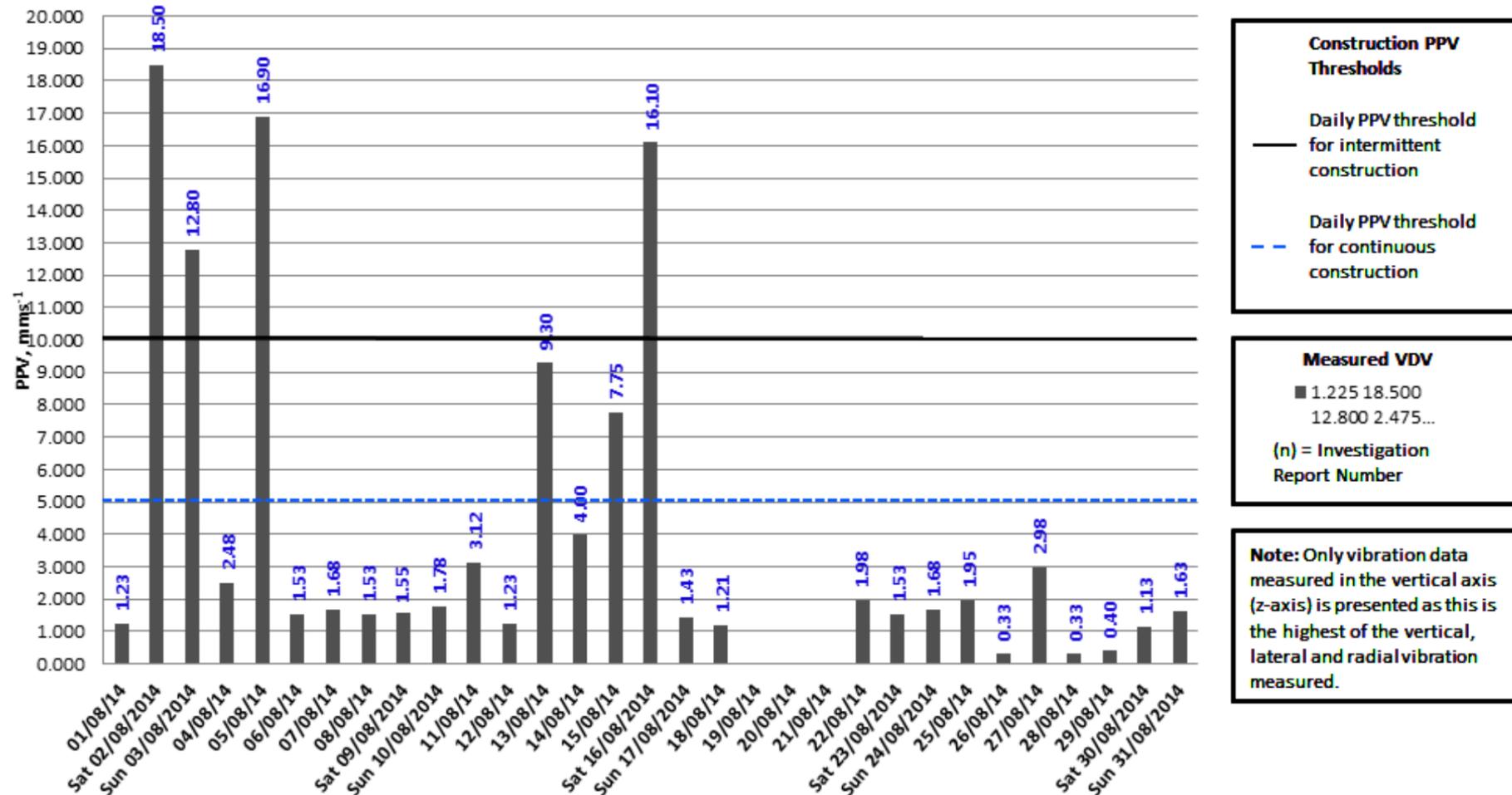
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Springfield monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Springfield, Measurement period: August 2014



- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
 - The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na Grian, Measurement period: August 2014



Construction PPV Thresholds

— Daily PPV threshold for intermittent construction

- - - Daily PPV threshold for continuous construction

Measured VDV

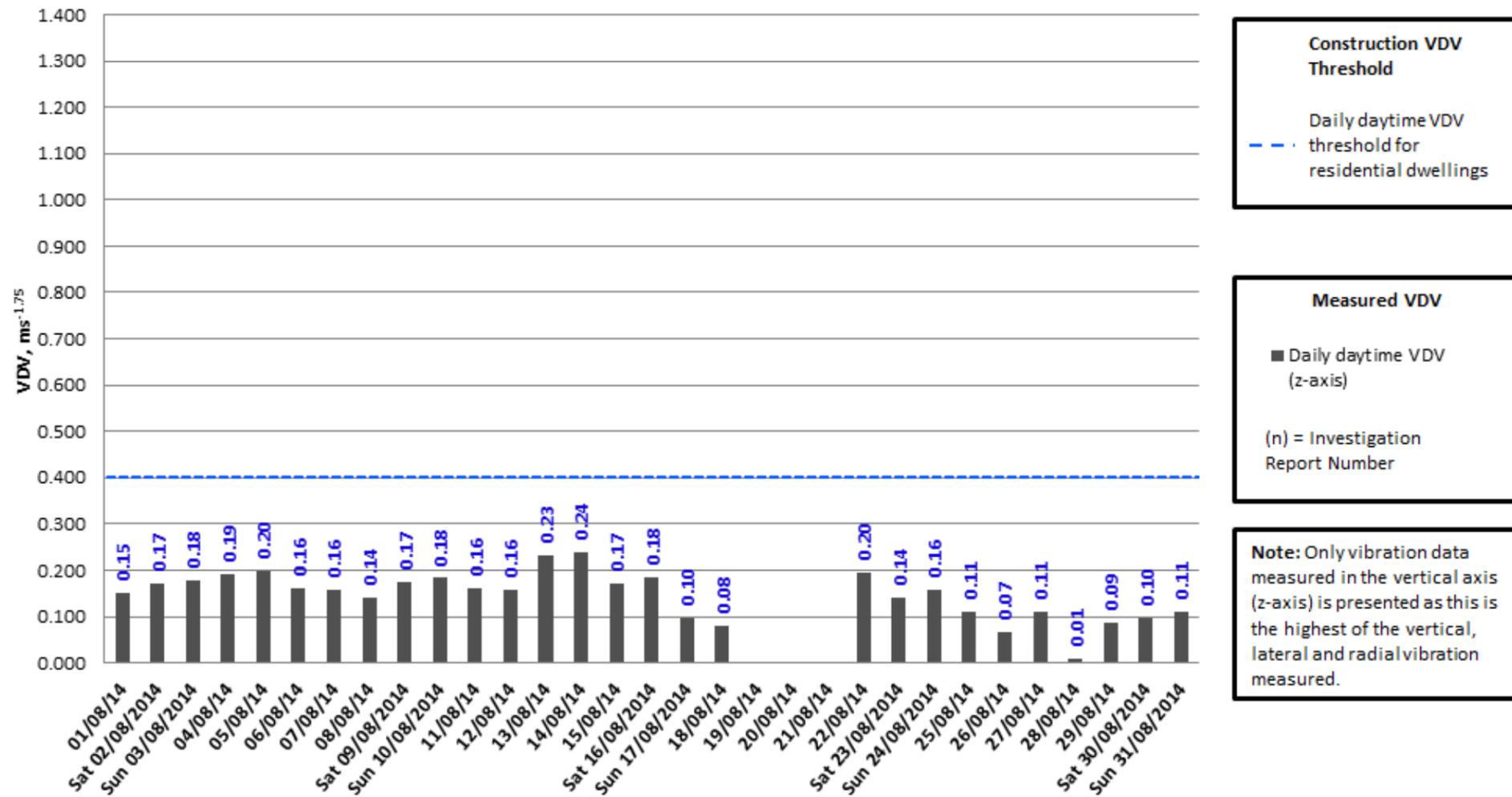
■ 1.225 18.500
 ■ 12.800 2.475...

(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.

- Notes:**
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
 - The exceedances on the 02/08/2014, 03/08/2014, 05/08/2014, 13/08/2014, 15/08/2014 and 16/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. It is highly unlikely to be attributed to FCBC works as the only works within the distant proximity of Tigh-Na Grian are works on approach pier N1 and North Tower. These works include rebar/formwork and concrete pours only which are very unlikely to produce vibration levels of this magnitude. They are considered to be highly unlikely to be caused by FCBC activity.

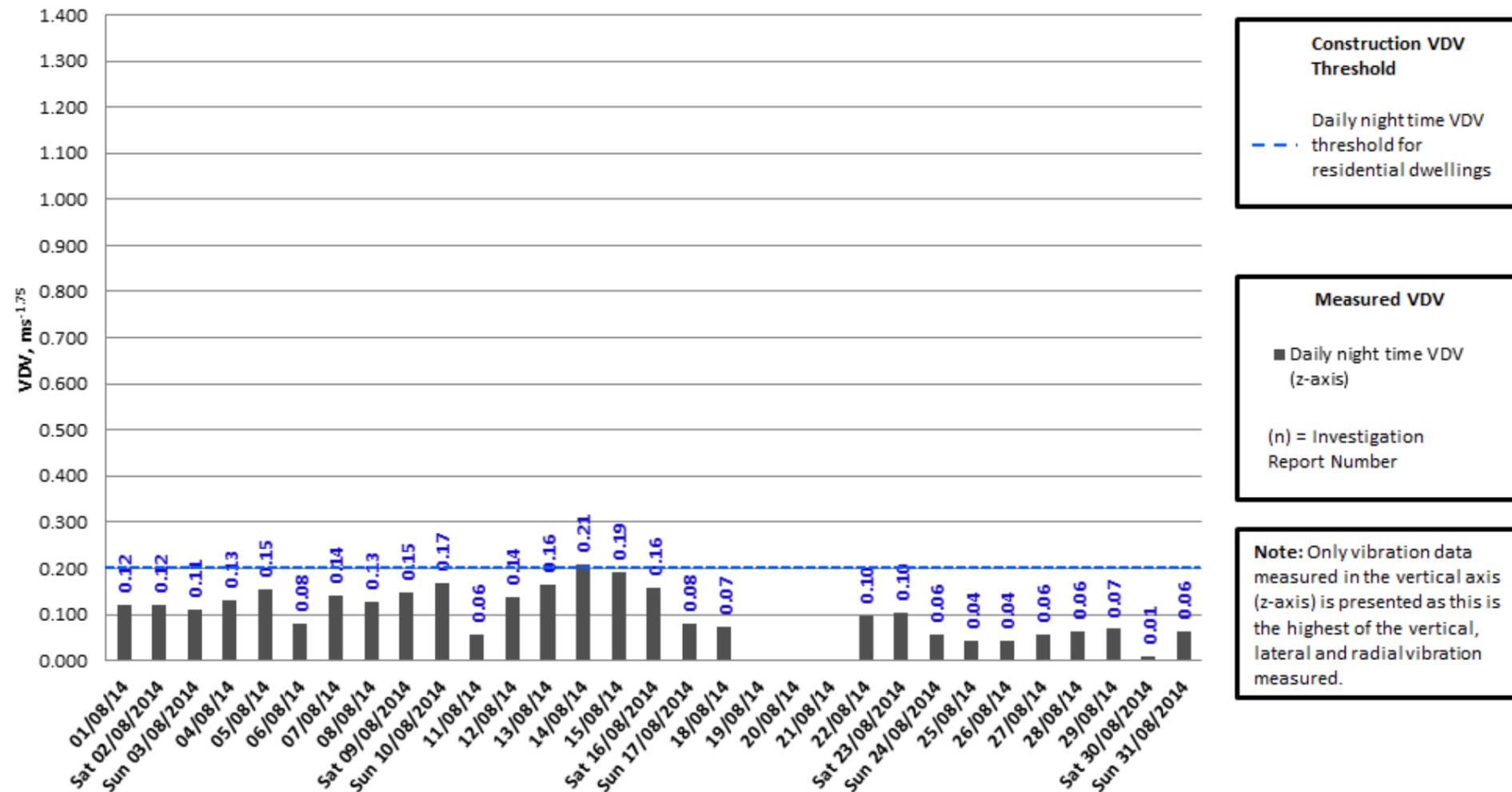
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: August 2014



Notes:

- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

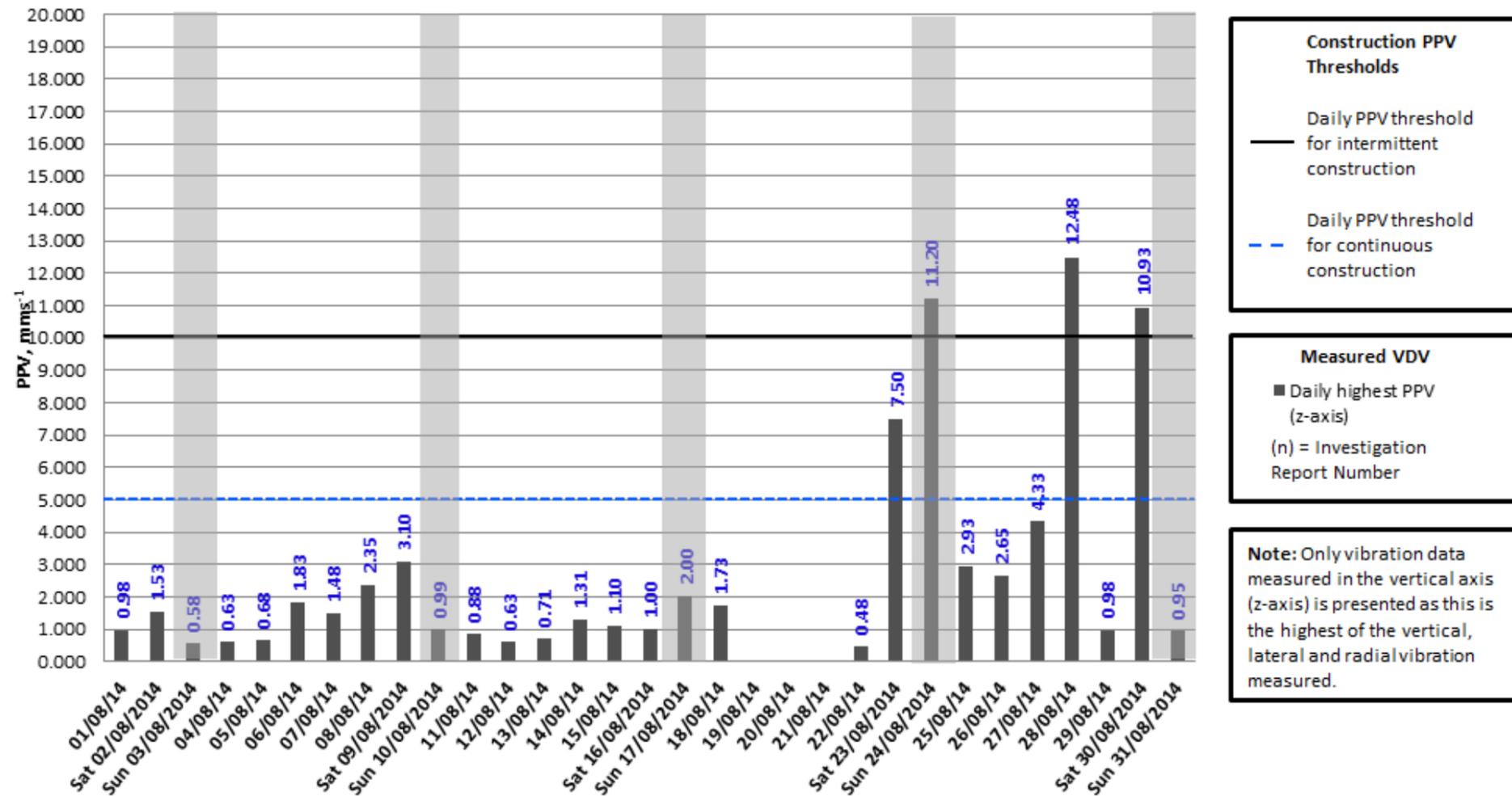
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: August 2014



Notes:

- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The slight exceedance on the 14/08/14 is highly unlikely to be attributed to FCBC works as the only works within the distant proximity of Tigh-Na Grian are works on approach pier N1 and North Tower. These works include rebar/formwork and concrete pours only which are very unlikely to produce vibration levels of this magnitude. They are considered to be highly unlikely to be caused by FCBC activity.

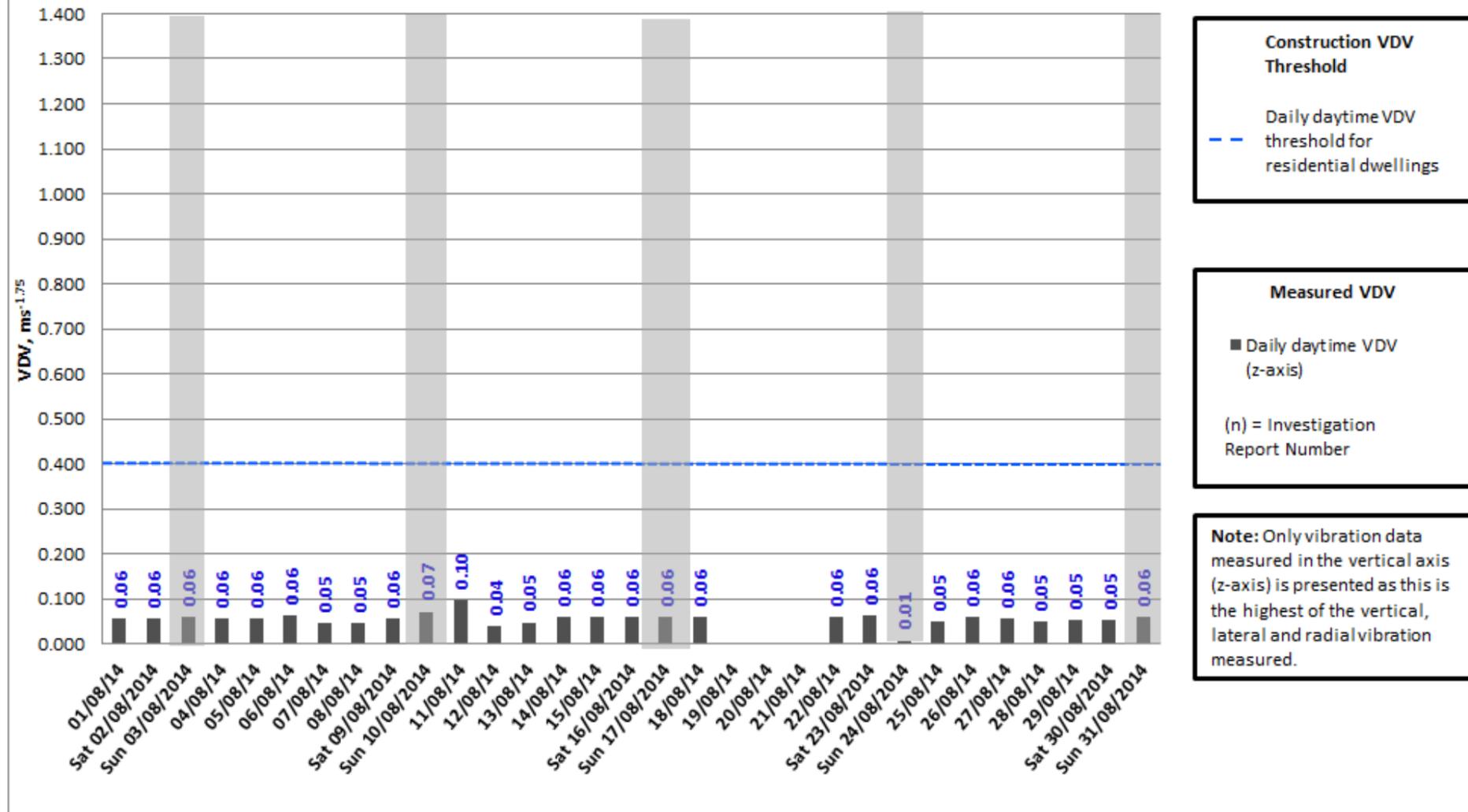
Measured highest Daily Peak Particle Velocity (PPV), Whinnyhill, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Whinnyhill monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.
- The exceedances on the 23/08/2014, 24/08/2014, 28/08/2014 and 30/08/2014 have been investigated, and have been seen to be individual, isolated events within the period. They are considered to be highly unlikely to be caused by FCBC activity.

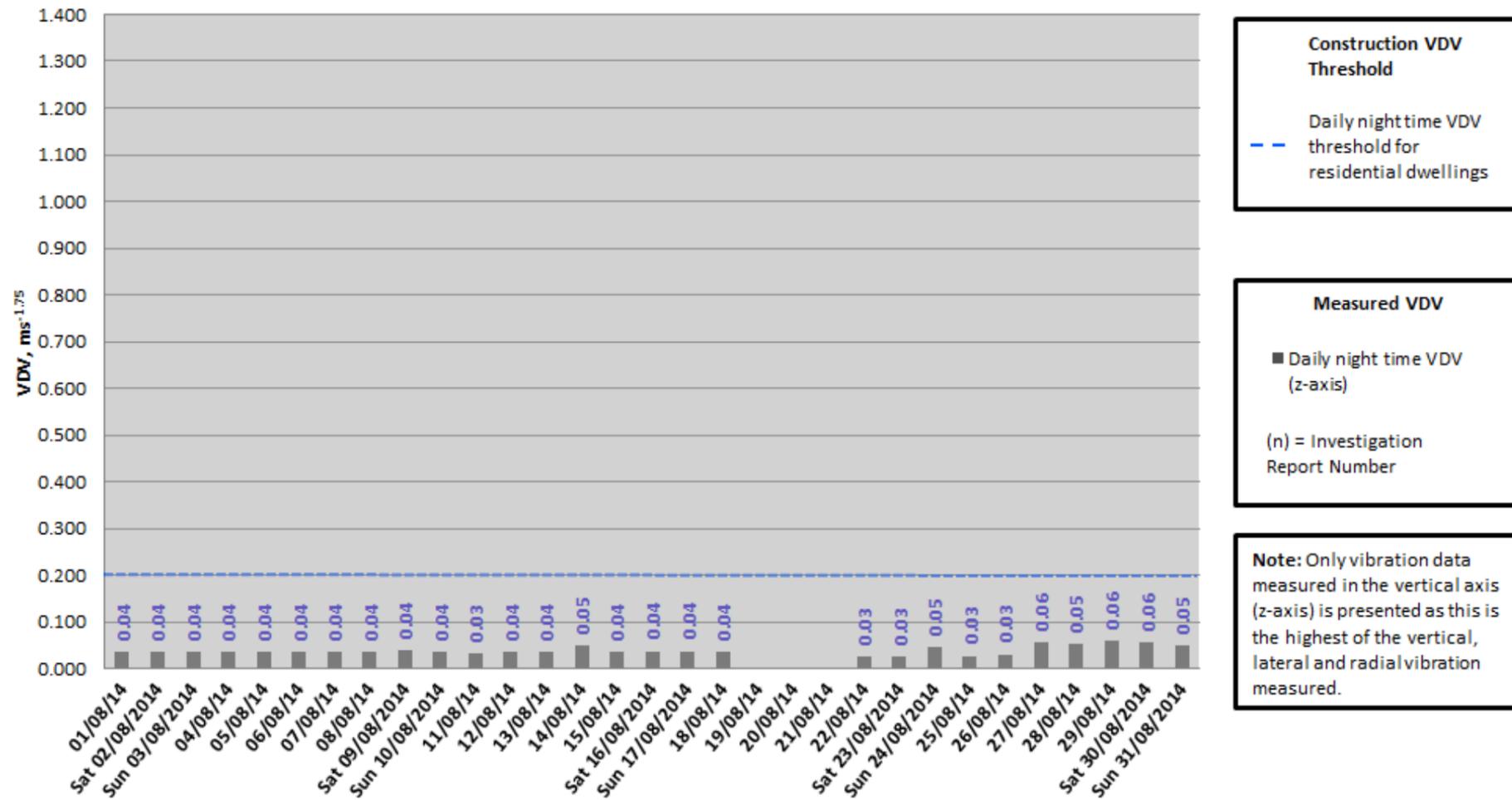
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Whinnyhill monitor on Sundays.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: August 2014



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Whinnyhill vibration monitor throughout the month of August 2014. This graph is included for illustrative purposes only.
- The data missing from the 19/08/2014, 20/08/2014 and 21/08/2014 is due to the monitor being calibrated.