



Contractor



**Forth Crossing** Bridge Constructors

HOCHTIEF Solutions  
American Bridge International  
DRAGADOS  
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT  
OCTOBER 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 October 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 necessarily represent levels only generated by construction, but rather show all 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**

**October 2015**

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s <sup>-1</sup> )	Intermittent (10 mm.s <sup>-1</sup> )	Day (0.4 m.s <sup>-1.75</sup> )	Night (0.2 m.s <sup>-1.75</sup> )
Linn Mill	9	6	2	0
Butlaw Fisheries	1	1	0	0
Clufflat Brae	12	1	0	0
Dundas Home Farm	0	0	0	0
Echline	1	0	0	0
Inchgarvie Lodge	4	9	0	0
Scotstoun	0	0	0	0
Springfield	3	2	0	0
Tigh-Na-Grian	0	0	0	0
Whinnyhill	6	3	0	0

- 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<sup>-1</sup> for continuous construction (e.g. piling), and 10 mm.s<sup>-1</sup> 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 mostly 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  $\text{m.s}^{-2}$  and the time period over which the VDV is measured is in seconds. This yields V DVs 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. Landscaping works at Echline Corner did however trigger an exceedance on the adjacent monitor.
- 2.12.** In addition, detailed investigation of all exceedances (i.e. review of PPV levels over 30 seconds periods) with exception from Echline Corner it has shown that each resulted from isolated, non-construction related events.

### **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. The exceedance at Echline corner that can be found in appendix B was only caused by localised works nearby the monitor with no use of vibration emitting plant.



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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 October 2015
M1	Whinny Hill	Network	<ul style="list-style-type: none"> <li>• Earthworks/Fill placement</li> <li>• New Ferrytoll Road</li> <li>• FT03&amp;FT04 deck works</li> <li>• FT09 works</li> <li>• FT19 Works</li> <li>• Roadworks</li> </ul>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works Deck section lifts</li> <li>• North Tower rebar, formwork, concreting works , deck section lifts</li> <li>• Pier N1 rebar formwork &amp; concrete works</li> <li>• AVN works</li> </ul>
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> <li>• Pier S1 rebar, formwork &amp; concrete works</li> <li>• Cleaning, Blinding pour and Rebar installations at Pier S2</li> <li>• Central Tower rebar, formwork, concreting works deck section lifts</li> <li>• South Tower rebar, formwork, concreting works, deck section lifts</li> </ul>
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> <li>• AVS – Rebar works and concrete works</li> <li>• Pier S1 rebar, formwork &amp; concrete works Cleaning,</li> <li>• Pier S2 rebar, formwork &amp; concrete works</li> <li>• Central Tower rebar, formwork, concreting works deck section lifts</li> <li>• South Tower rebar, formwork, concreting works, deck section lifts</li> <li>• Main Carriageway earthworks</li> </ul>
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> <li>• AVS – Rebar works and concrete works</li> <li>• No night time or Sunday construction in the</li> </ul>



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			<p>vicinity</p> <ul style="list-style-type: none"> <li>• Main carriageway works</li> </ul>
M13	Clufflat Brae	Crossing / Network	<ul style="list-style-type: none"> <li>• AVS – Rebar works and concrete works</li> <li>• No night time or Sunday daytime construction in vicinity.</li> <li>• Main Carriageway works</li> </ul>
M14	Springfield	Network	<ul style="list-style-type: none"> <li>• AVS –Rebar works and concrete works N.B. No night time or Sunday daytime construction in vicinity.</li> <li>• Earthworks South Abutment area</li> <li>• Main carriageway works</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• AVS – Rebar works and concrete works</li> <li>• No night time or Sunday construction in the vicinity</li> <li>• Earthworks South Abutment area</li> <li>• Main Carriageway works</li> </ul>
M16	Scotstoun	Network	<ul style="list-style-type: none"> <li>• Footpath works</li> <li>• Utility works</li> <li>• B800 North road works including bridge works</li> <li>• B800 bridge demolition</li> <li>• B800 piling works</li> <li>• SB Bus link barrier works</li> </ul>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> <li>• Utility works</li> <li>• B800 South roadworks including bridge works</li> <li>• B800 bridge demolition</li> <li>• B800 piling works</li> <li>• SB bus link</li> <li>• Main carriageway works</li> </ul>

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

**Table 3: PCNV Predicted PPV & VDV Levels**

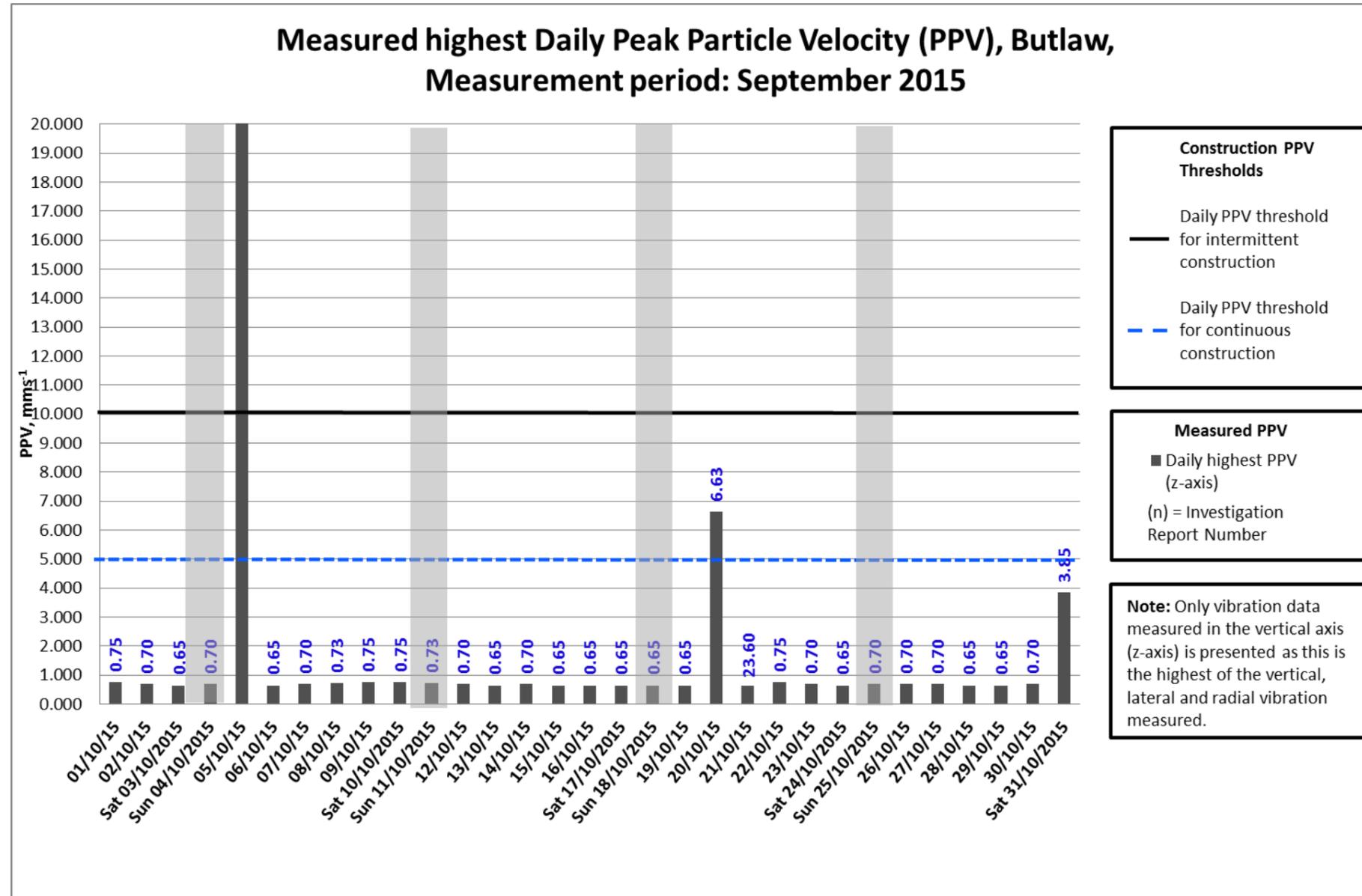
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	2.44	0.37
Dundas	325	325	Piling	0.28	0.15
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	110	110	Piling	0.82	0.45
Springfield	50	300	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	108	1800	Roller/Whacker	0.19	0.1

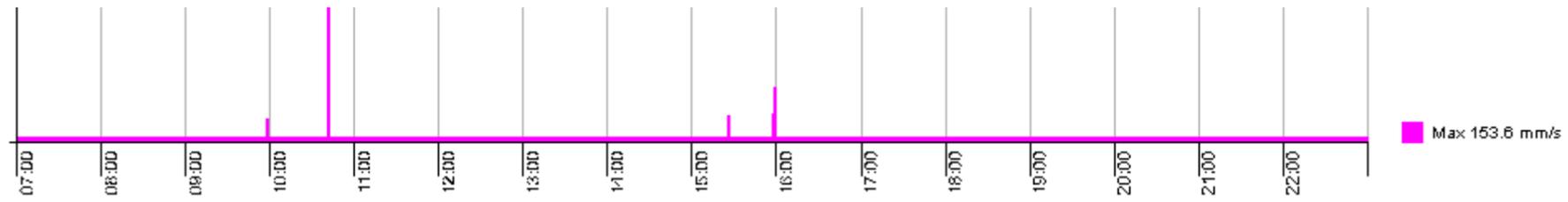
Table 3: The distances from vibration monitors to the closest work areas for both day and night time periods. It also lists worst case PPV and eVDV calculations exhibited at the vibration monitors, resulting from the maximum vibration inducing plant operated at the nearest work areas.

**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 at an average distance of 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, at a minimum distance (40m) from the nearest receptor.

## APPENDIX B – VIBRATION GRAPHS

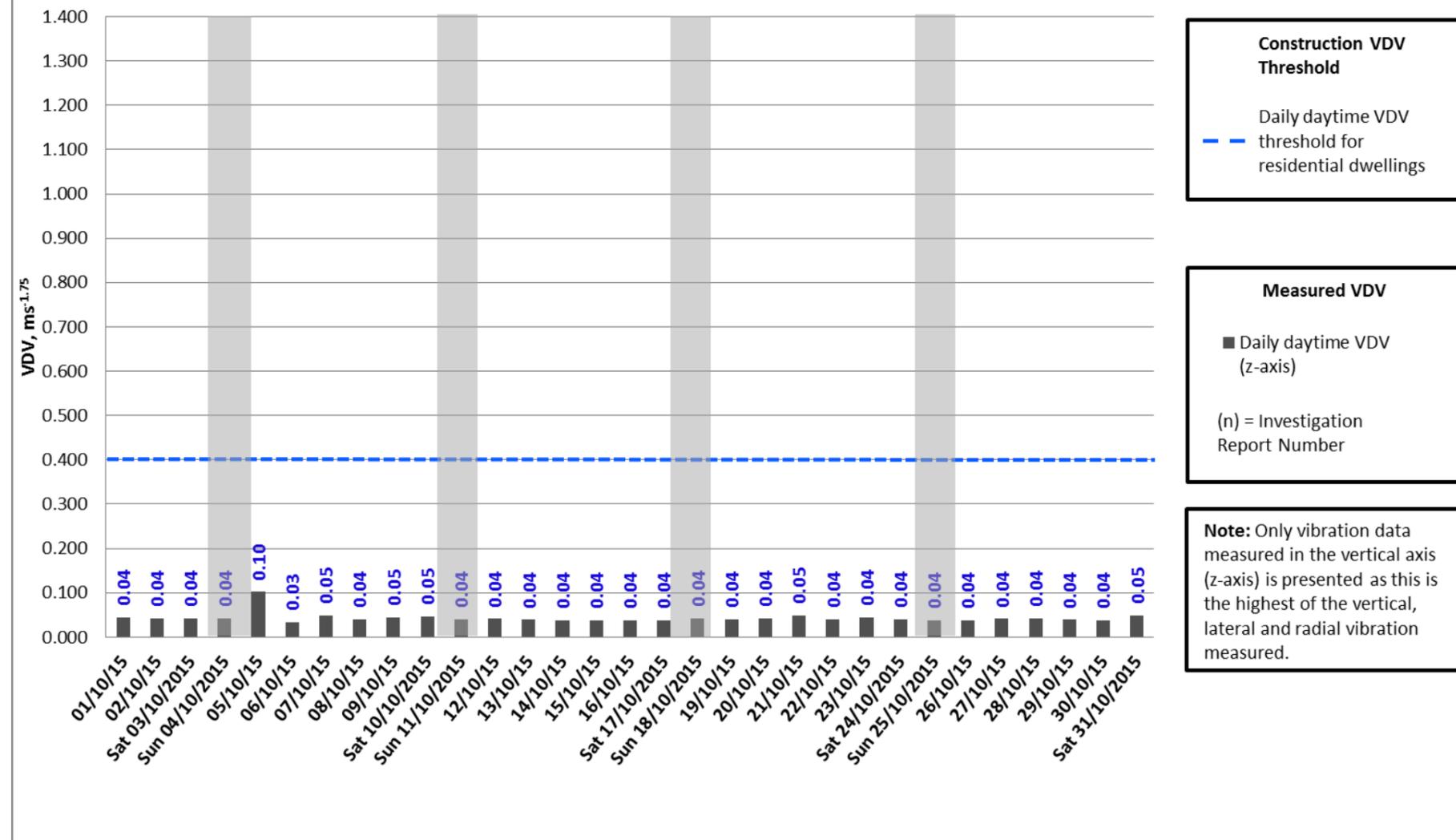




Exceedance on the 05/10/2015 has been investigated and found to be activity nearby the vibration monitor. Levels found later that day at approximately 15:30 were due to monitor maintenance ongoing on the noise monitor. Due to the noise monitor being in close proximity to the vibration transducer, movement was picked up on the vibration monitor (graph above from the 05/10/2015).

Exceedance on the 20/10/2015 has been investigated and found to be caused by monitor maintenance undertaken on the noise monitor. Due to the noise monitor being in close proximity to the vibration transducer, movement was picked up on the vibration monitor.

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw, Measurement period: October 2015



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

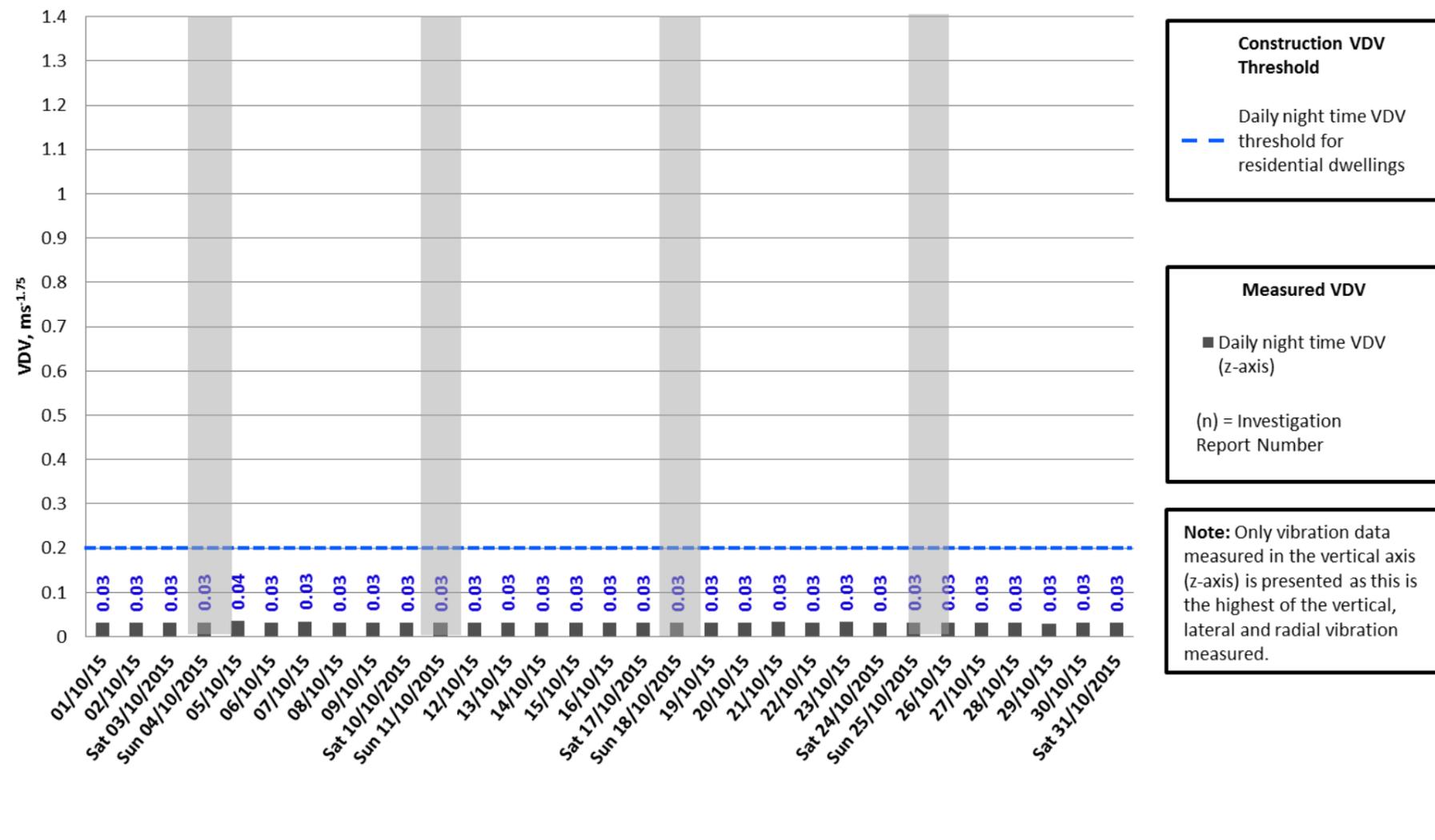
**Measured VDV**

■ 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), Butlaw, Measurement period: October 2015



**Construction VDV Threshold**

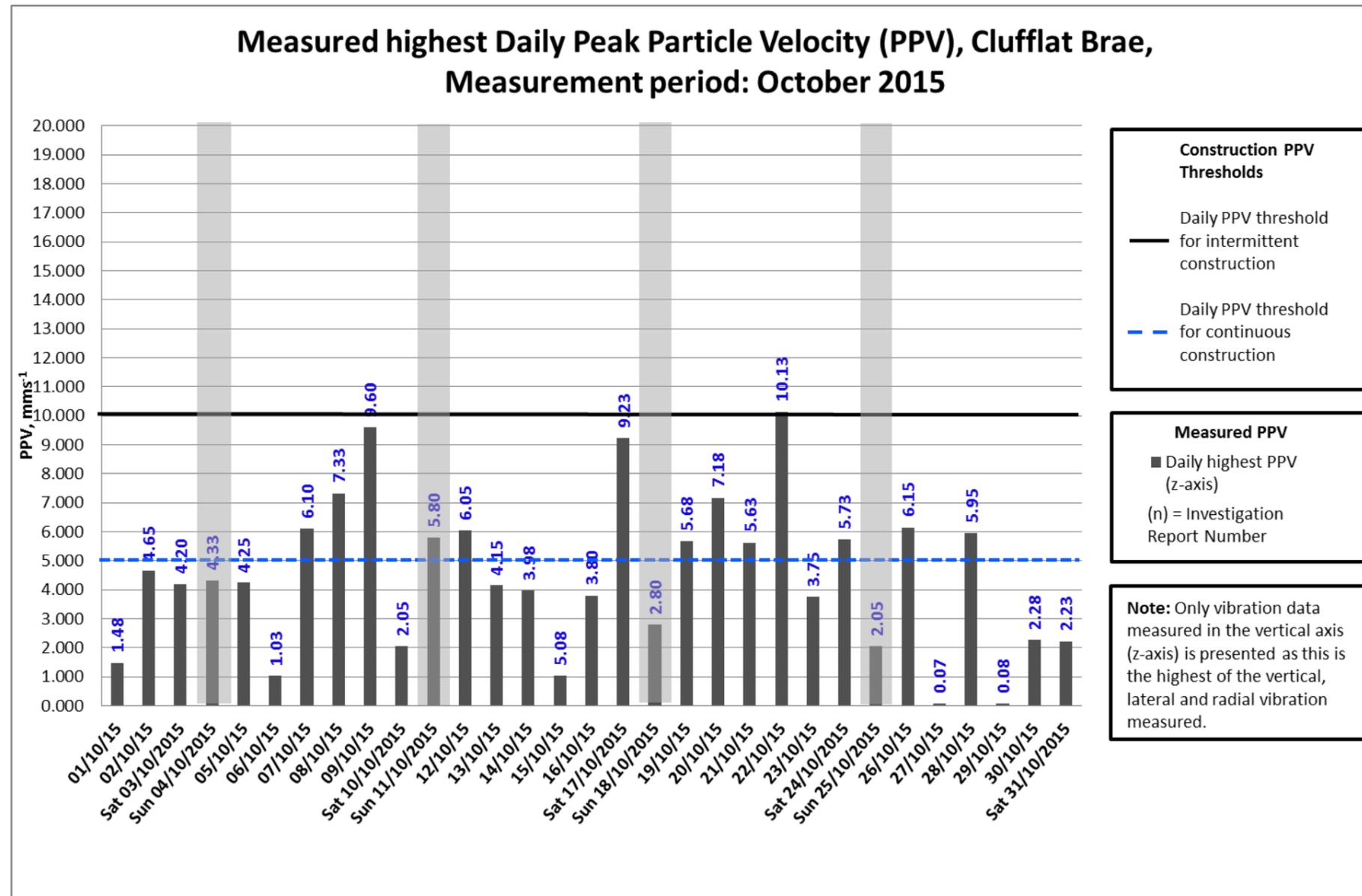
Daily night time VDV threshold for residential dwellings

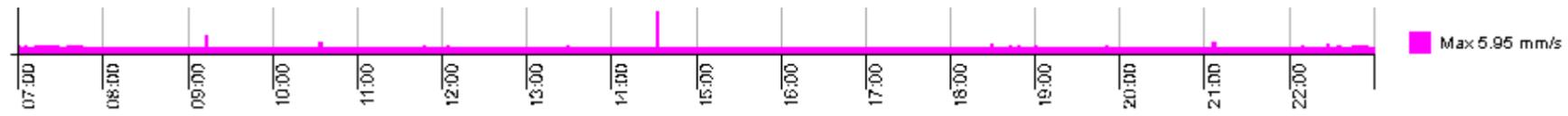
**Measured VDV**

■ Daily night time VDV (z-axis)

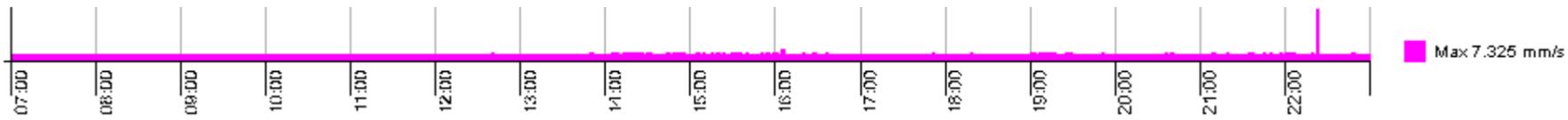
(n) = Investigation Report Number

**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.

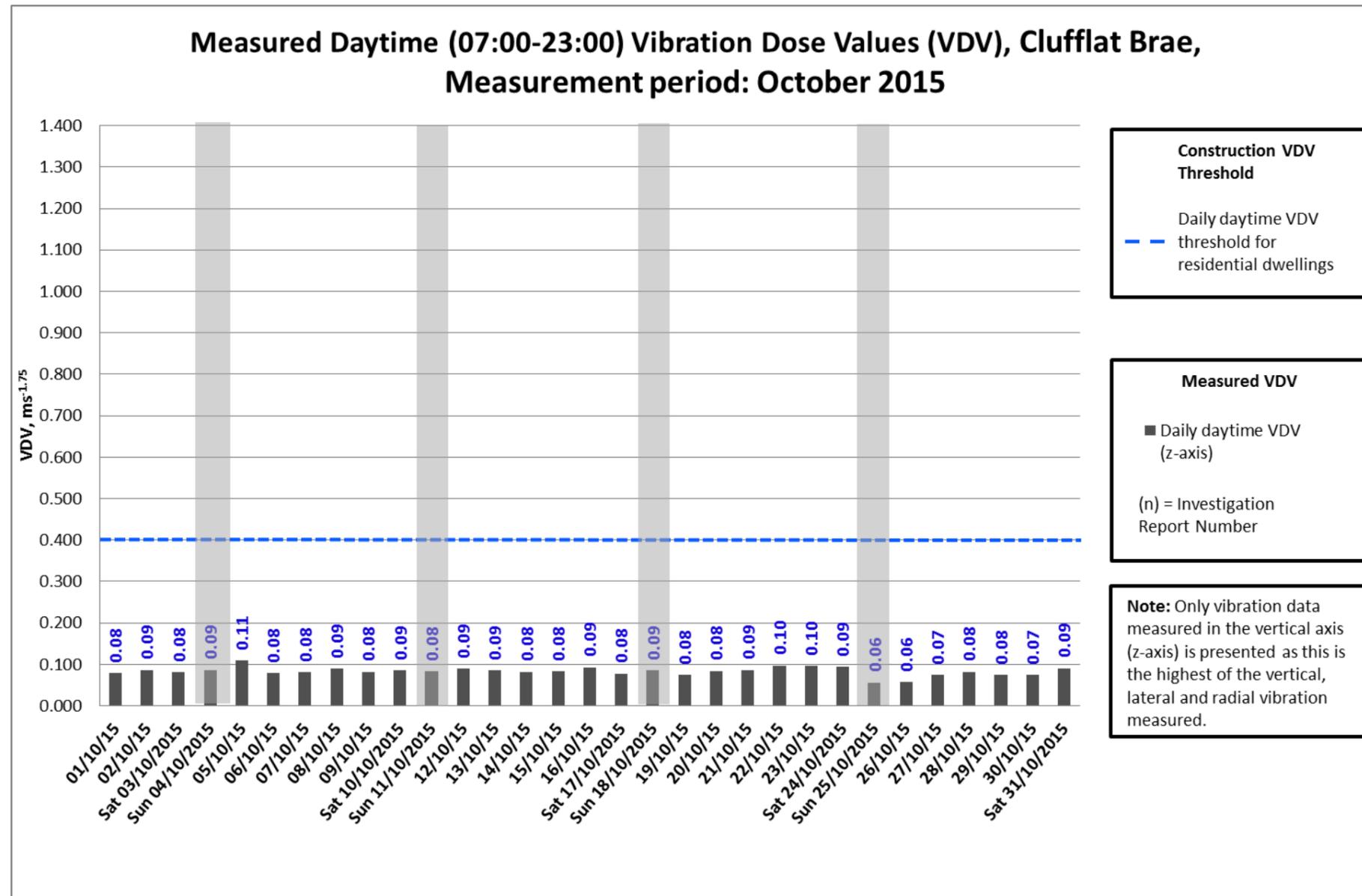




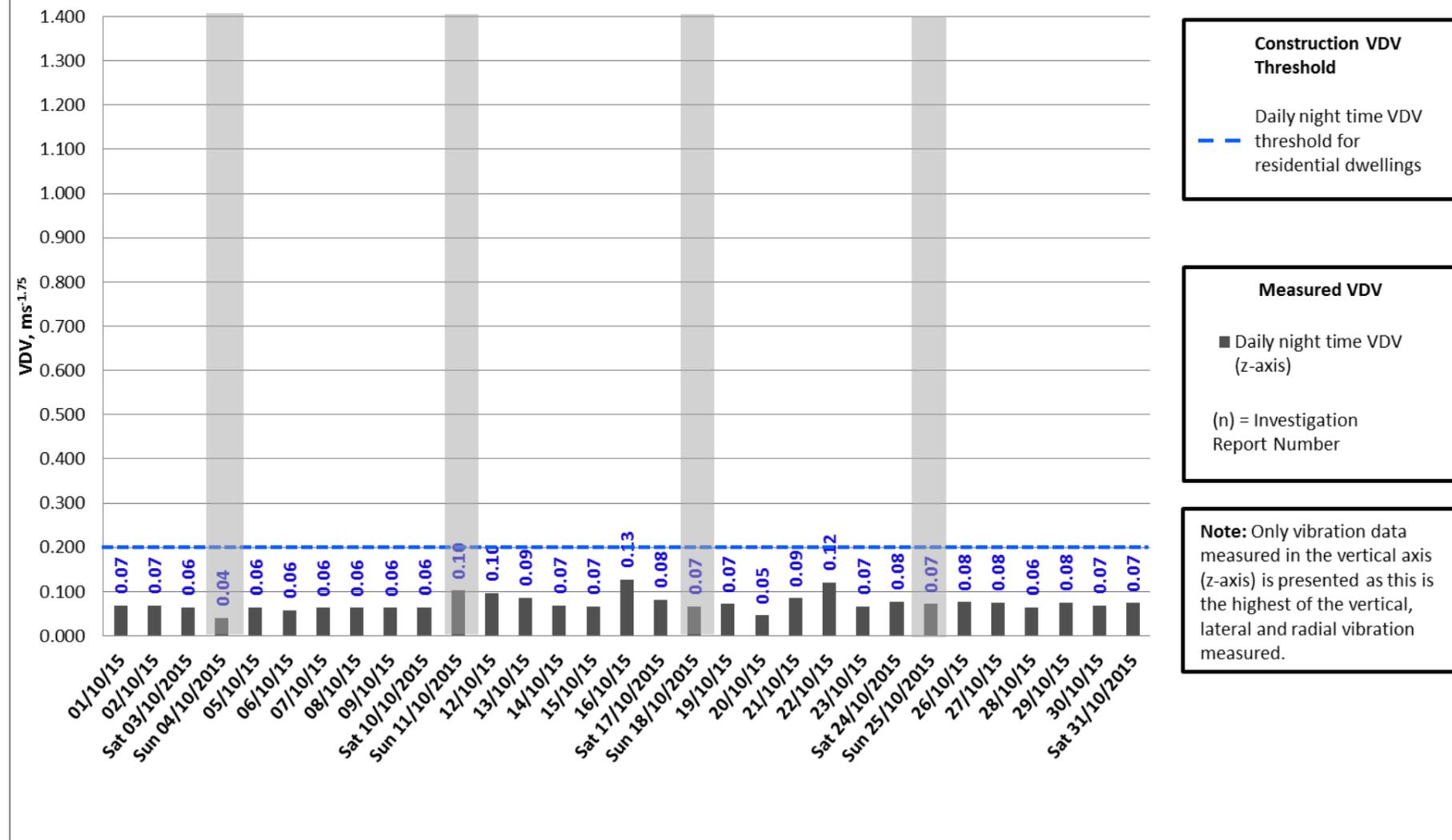
Exceedances on the 7<sup>th</sup>, 9<sup>th</sup>, 12<sup>th</sup>, 17<sup>th</sup>, 19<sup>th</sup>, 24<sup>th</sup>, 26<sup>th</sup> and 28<sup>th</sup> of October have been investigated and found to be one off isolated events which are highly unlikely to be caused by construction related activities (graph above from the 28/10/2015)



Exceedances on the 8<sup>th</sup>, 11<sup>th</sup>, 20<sup>th</sup>, 21<sup>st</sup>, and 22<sup>nd</sup> of October have been investigated and found to be one off isolated events that were found out with working hours and are highly unlikely to be caused by construction related activities (graph above from the 08/10/2015).



**Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Clufflat Brae,  
 Measurement period: October 2015**



**Construction VDV Threshold**

Daily night time VDV threshold for residential dwellings

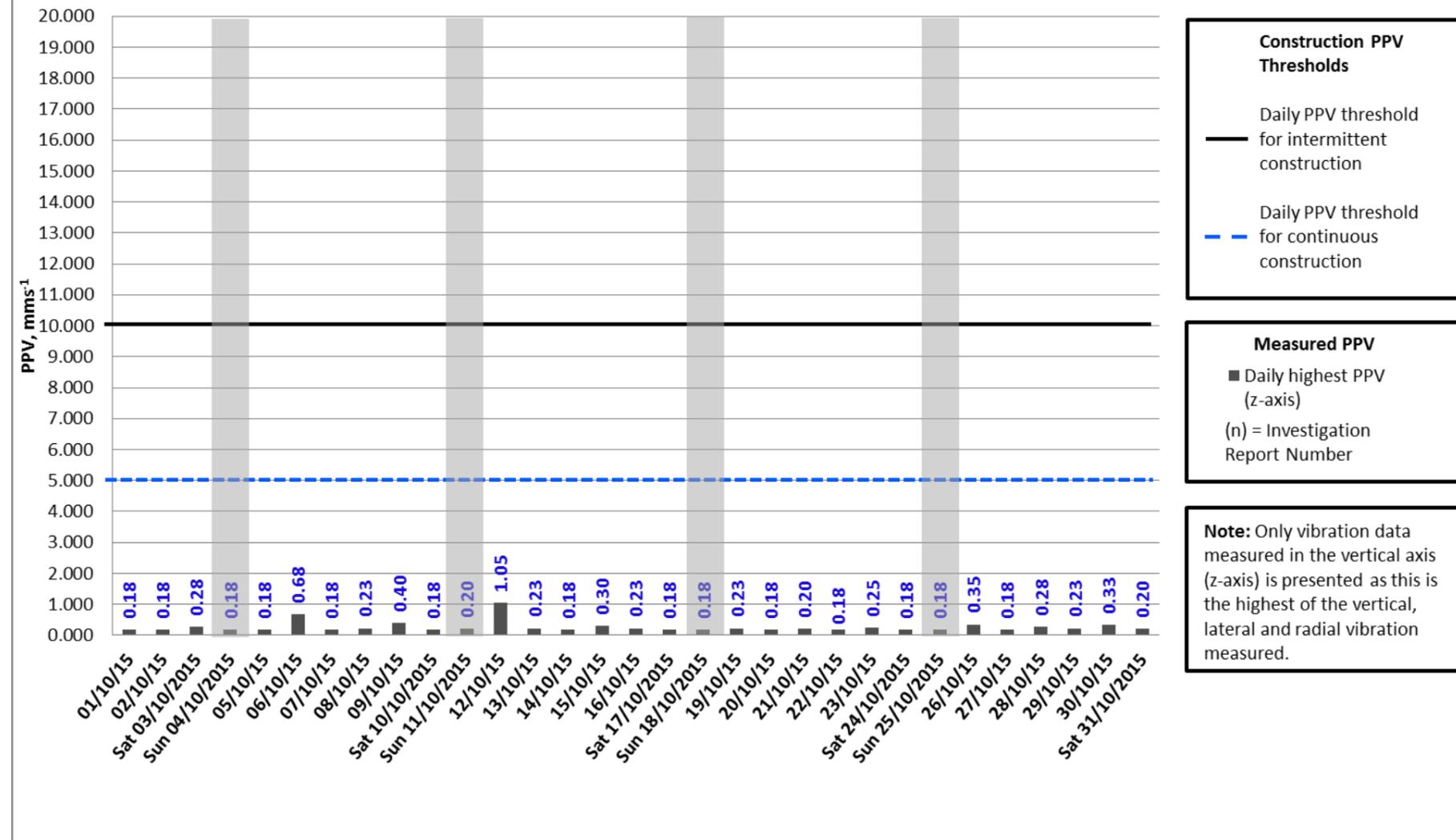
**Measured VDV**

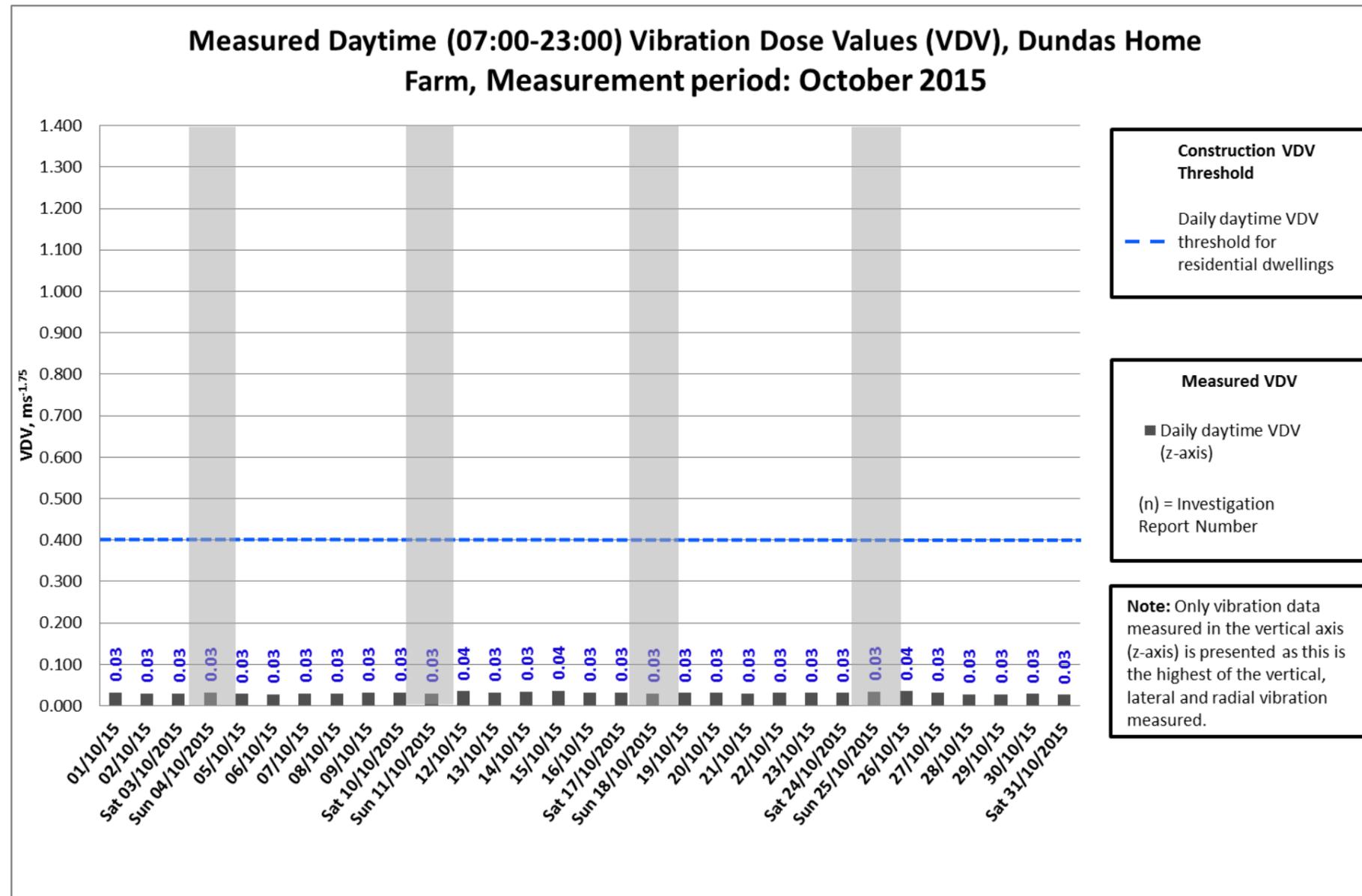
■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

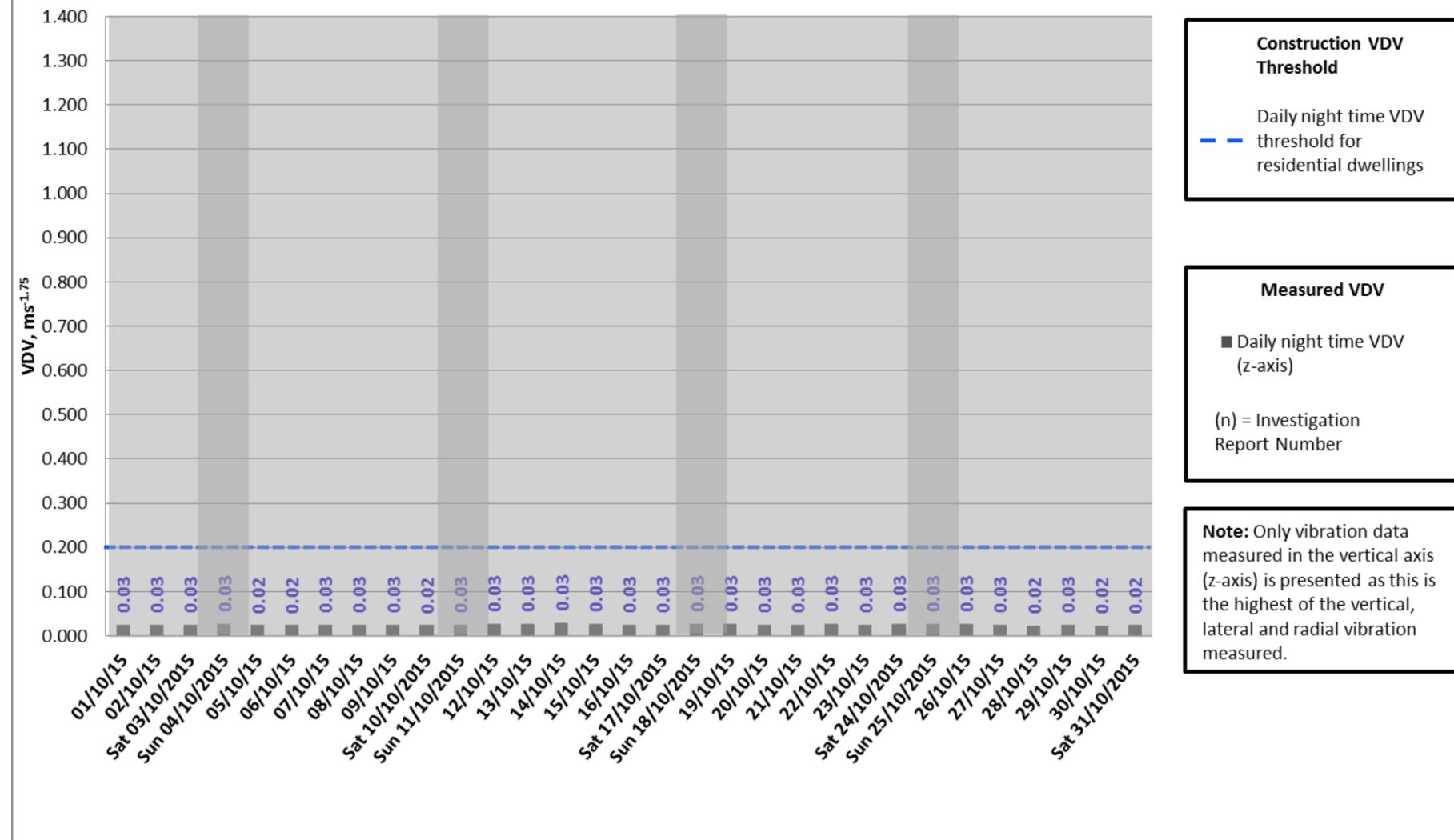
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

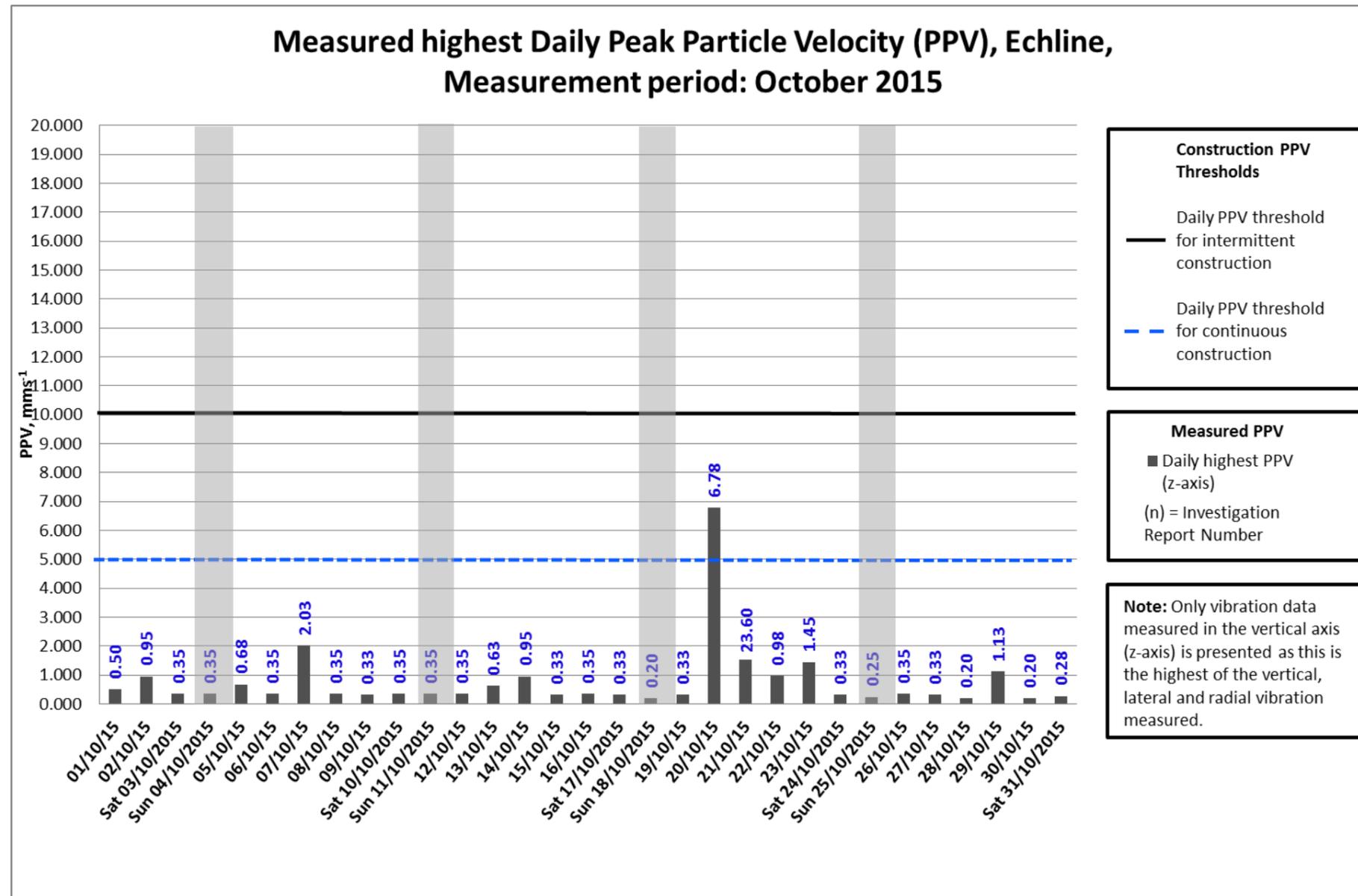
### Measured highest Daily Peak Particle Velocity (PPV), Dundas Home Farm, Measurement period: October 2015





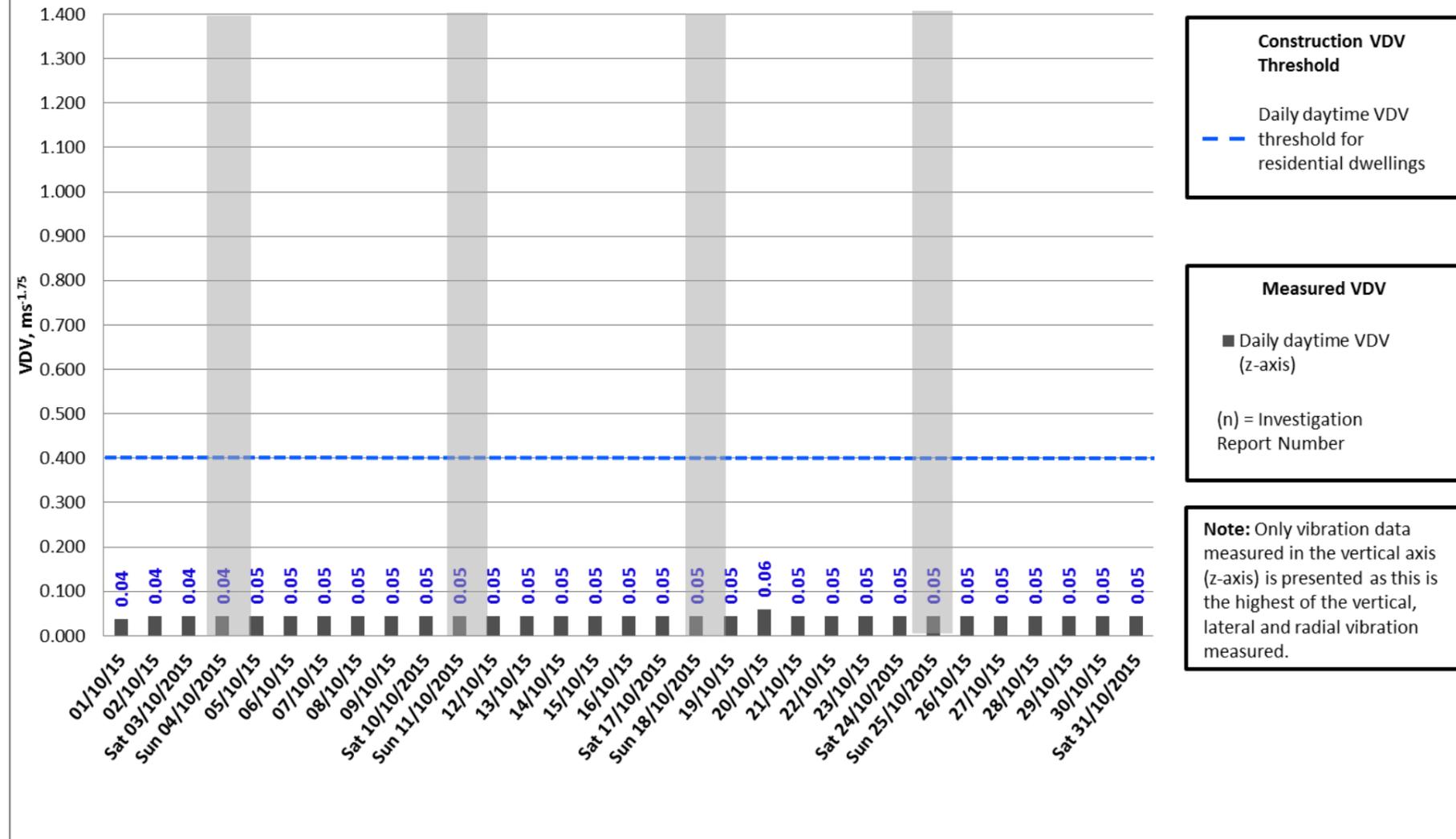
### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: October 2015





Exceedance on the 20/10/2015 has been investigated and it was found to be caused by landscape gardeners working at Echline corner within close proximity of the vibration monitor (graph above from the 20/10/2015).

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Echline, Measurement period: October 2015



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

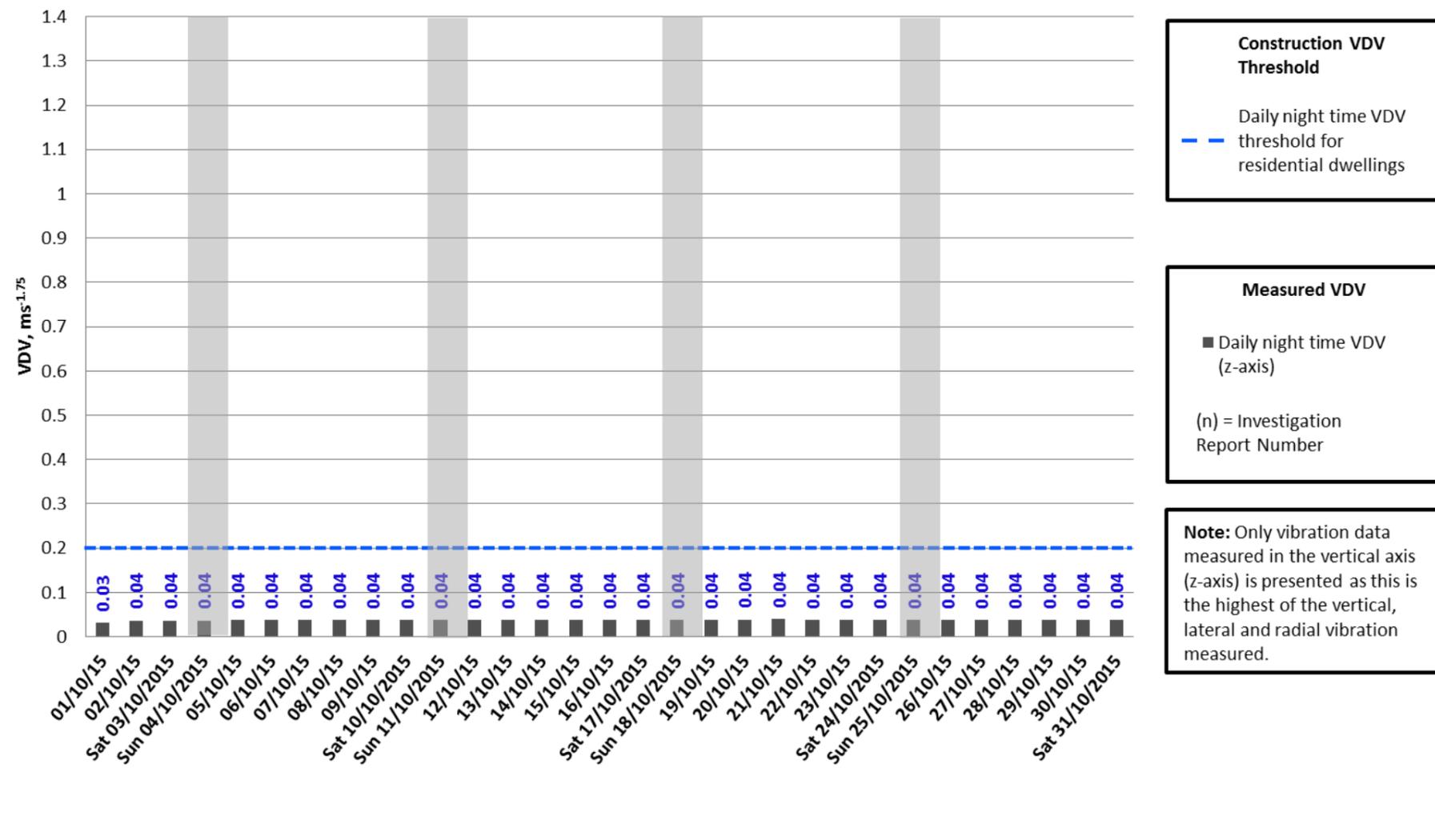
**Measured VDV**

■ 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), Echline, Measurement period: October 2015



**Construction VDV Threshold**

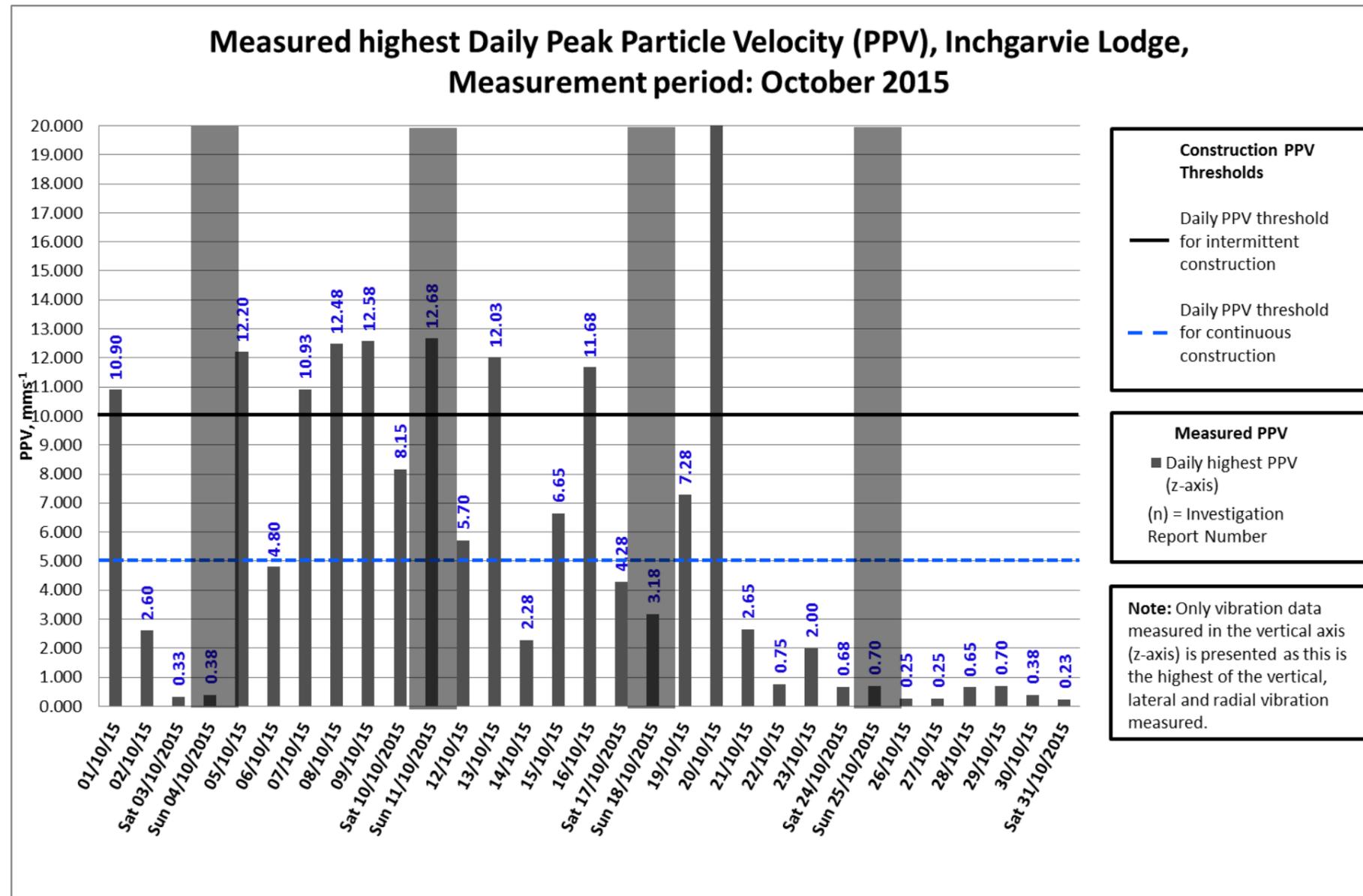
Daily night time VDV threshold for residential dwellings

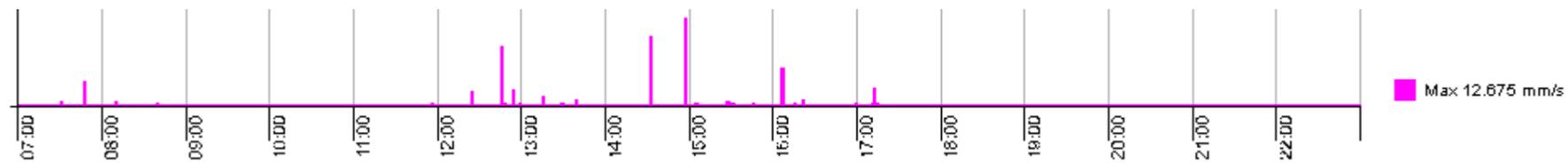
**Measured VDV**

■ Daily night time VDV (z-axis)

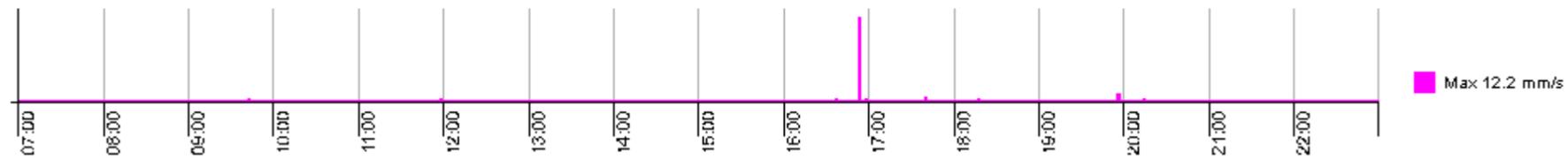
(n) = Investigation Report Number

**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.

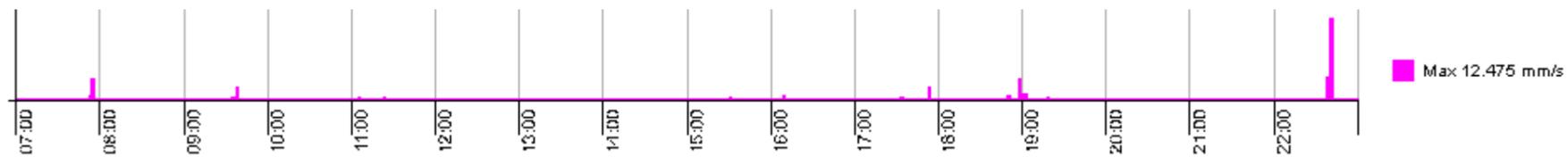




Exceedances on the 1<sup>st</sup>, 11<sup>th</sup>, 17<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> of October have been investigated and were found to be caused by domestic construction works at the property. (graph above from the 11/10/2015).

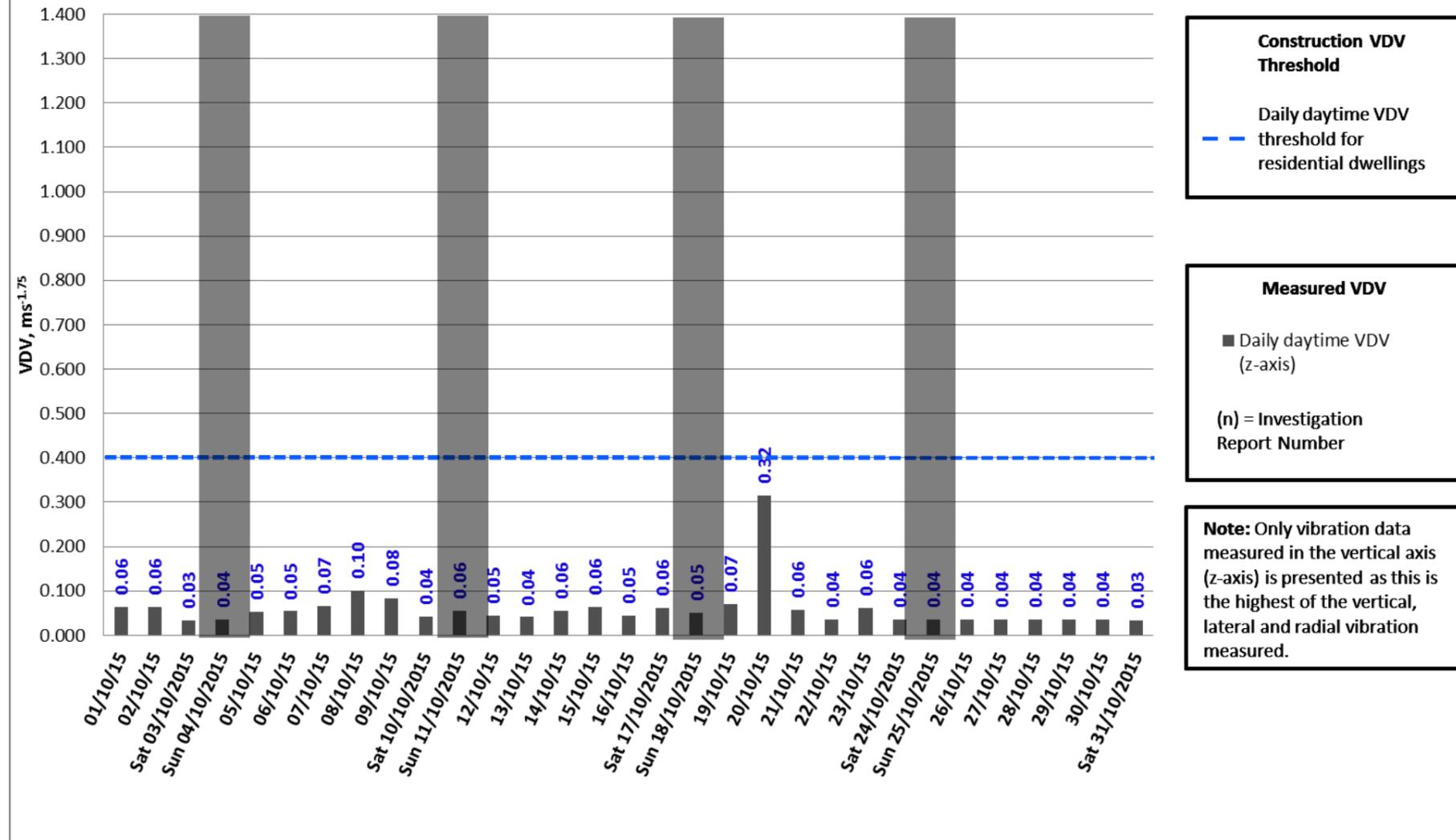


Exceedances on the 5<sup>th</sup>, 7<sup>th</sup>, 10<sup>th</sup>, 12<sup>th</sup>, 13<sup>th</sup>, 15<sup>th</sup> and the 16<sup>th</sup> of October have been investigated and found to be one off isolated events that are unlikely to be caused by FRC construction related activities. These exceedances may or may not have been caused by the localised construction activities at the this property, but no evidence was found to back this up (graph above from the 05/10/2015).



Exceedance on the 8<sup>th</sup> and 9<sup>th</sup> of October have been investigated and found to be isolated events that were out with working hours and are highly unlikely to have been caused by FRC construction related activities (graph above from the 08/10/2015).

**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Inchgarvie Lodge,  
 Measurement period: October 2015**



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

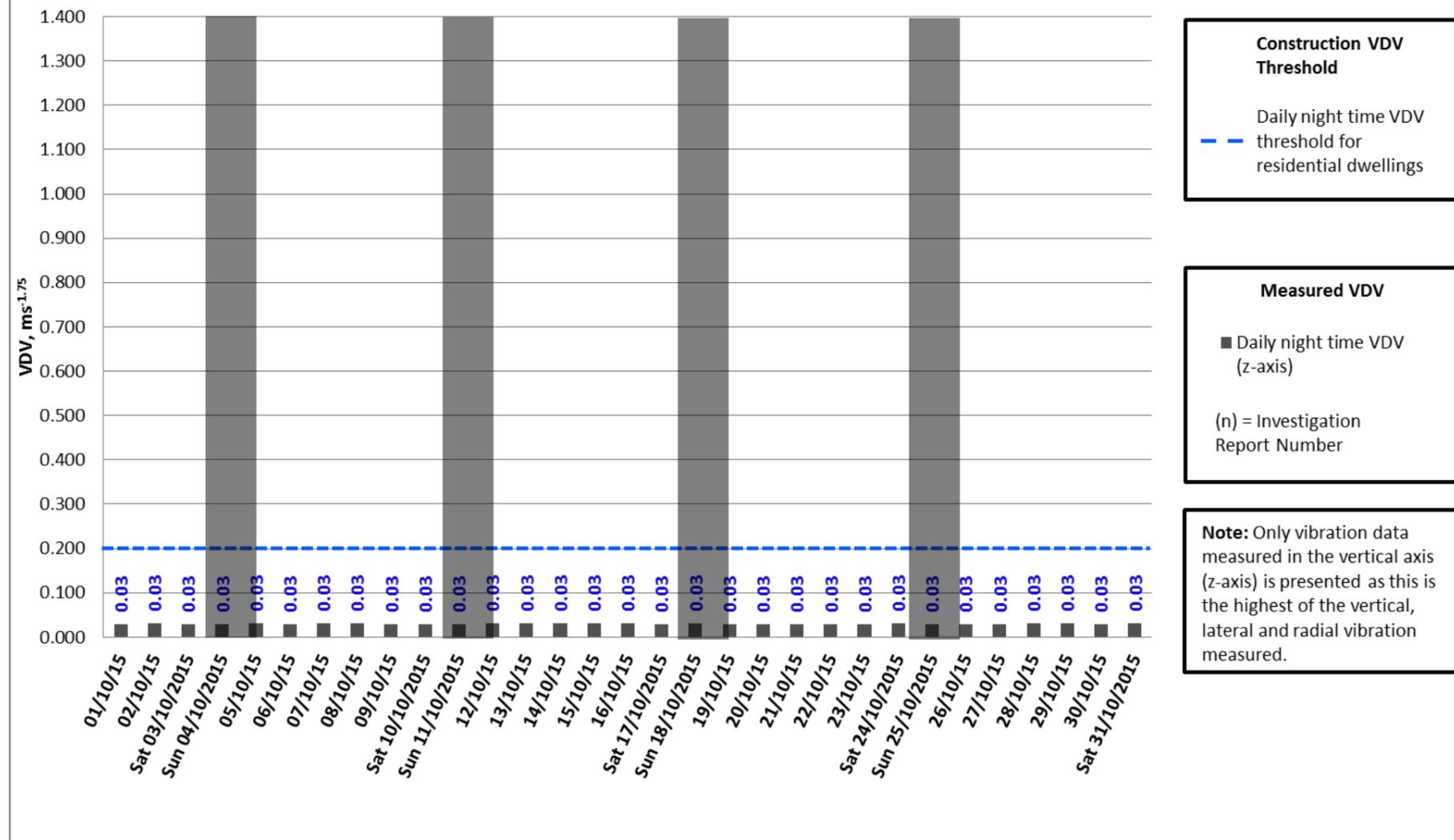
**Measured VDV**

■ 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), Inchgarvie Lodge, Measurement period: October 2015



**Construction VDV Threshold**

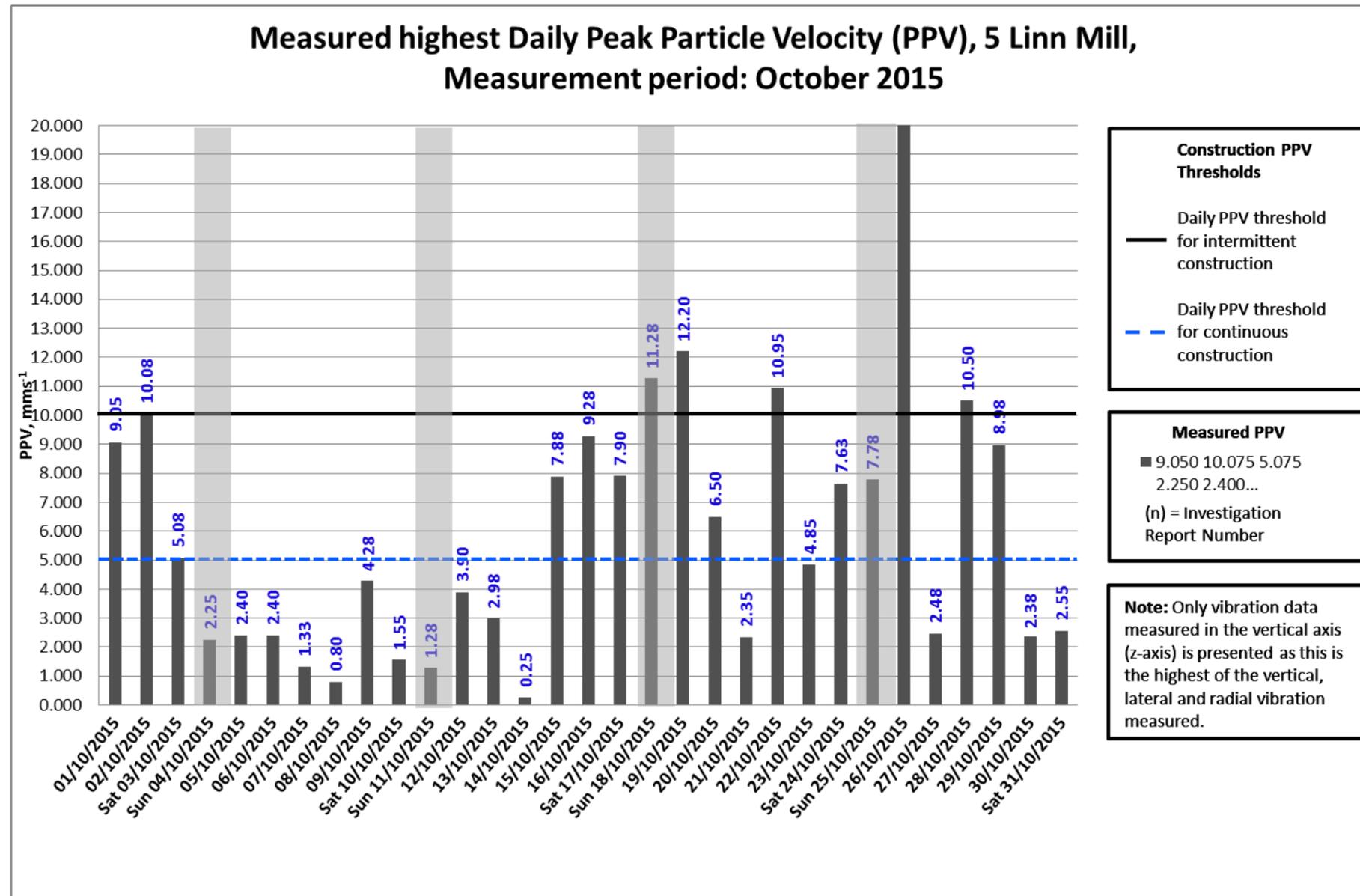
Daily night time VDV threshold for residential dwellings

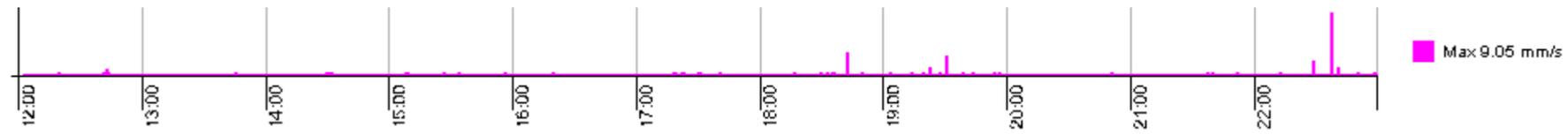
**Measured VDV**

■ Daily night time VDV (z-axis)

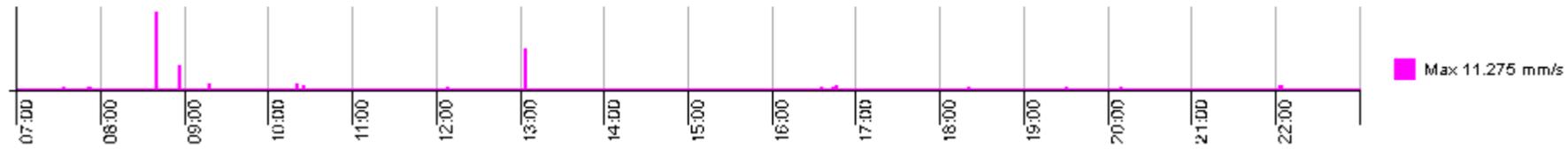
(n) = Investigation Report Number

**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.

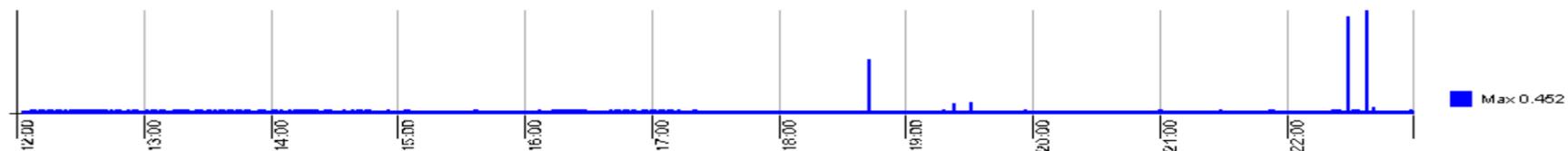
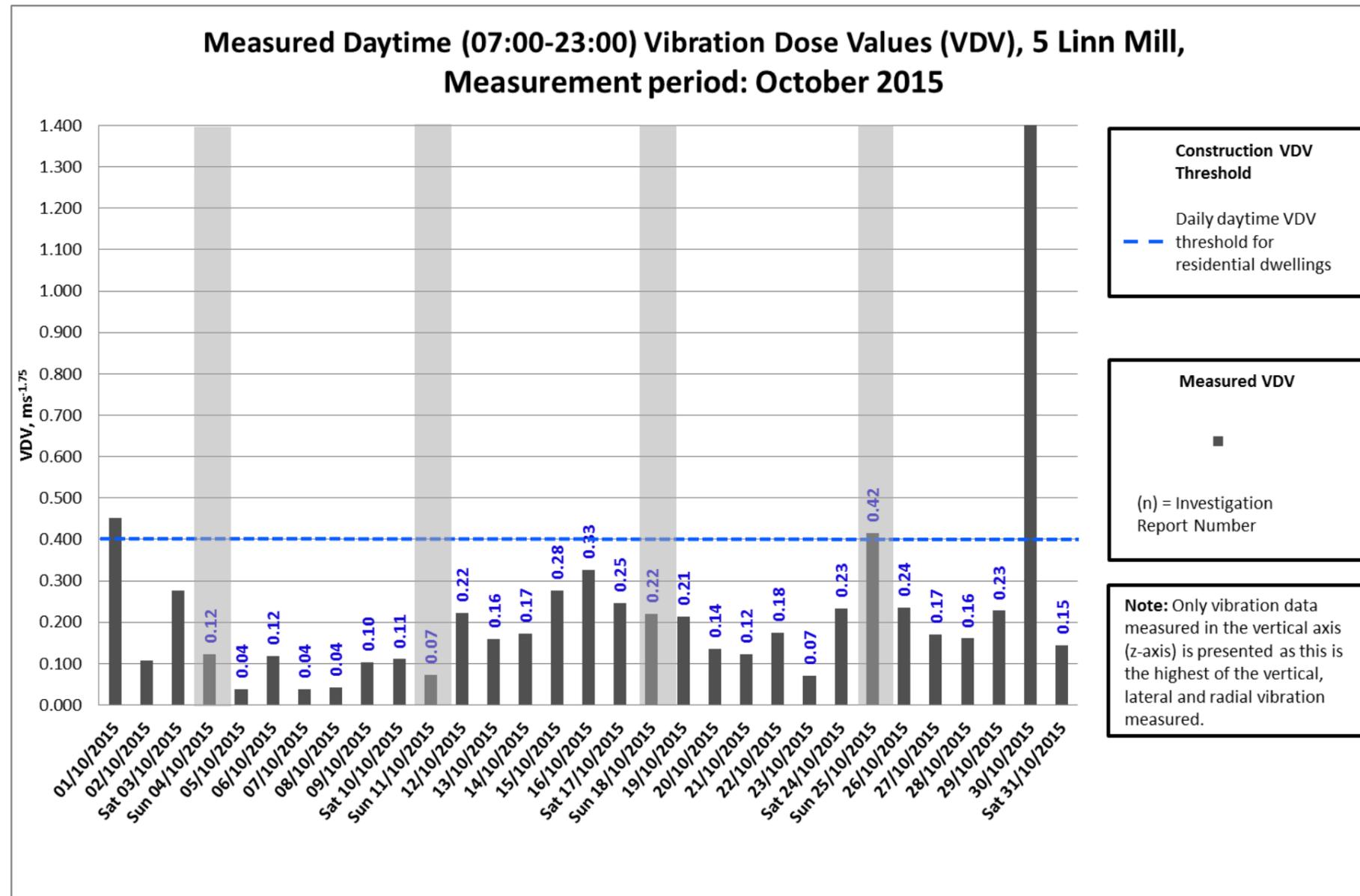




Exceedances on the 1<sup>st</sup>, 16<sup>th</sup>, 17<sup>th</sup> and 28<sup>th</sup> of October have been investigated and have been found to be out with construction working hours and thus are highly unlikely to be construction related (graph above from the 01/10/2015).

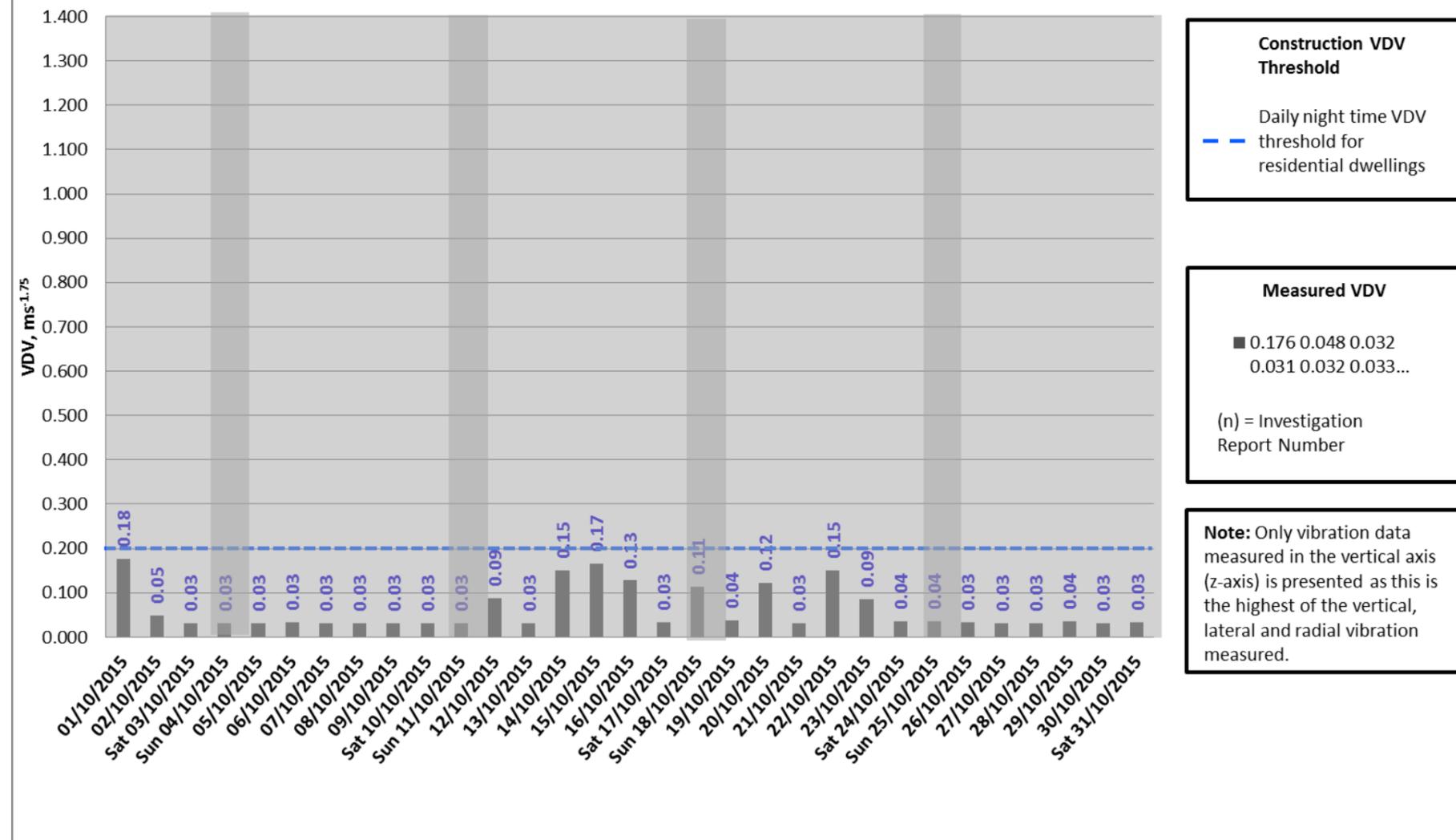


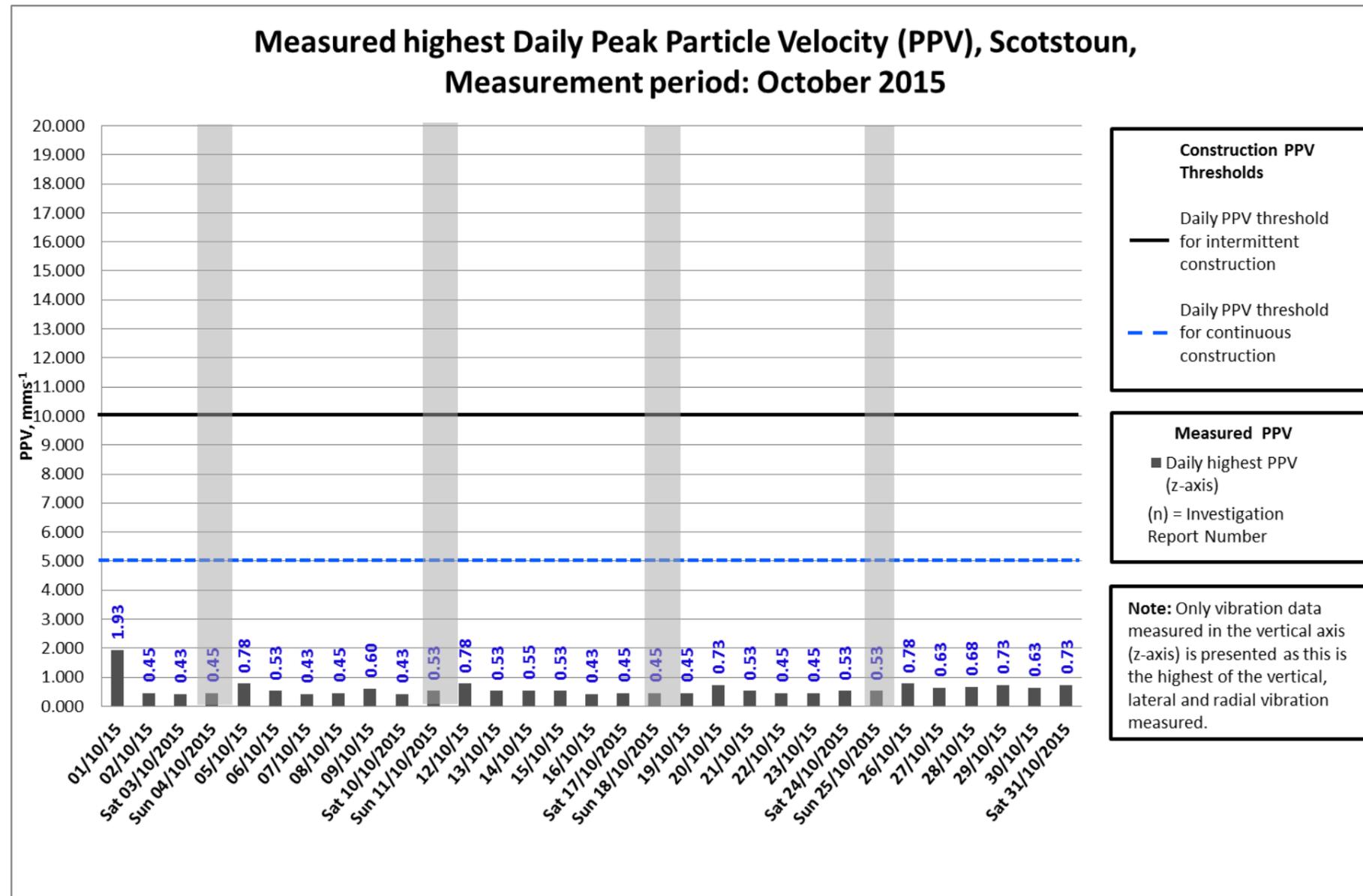
Exceedances on the 2<sup>nd</sup>, 3<sup>rd</sup>, 15<sup>th</sup>, 18<sup>th</sup>, 19<sup>th</sup>, 20<sup>th</sup>, 22<sup>nd</sup>, 24<sup>th</sup>, 25<sup>th</sup>, 26<sup>th</sup> and 29<sup>th</sup> of October have been investigated and found to be one off isolated events that are unlikely to be caused by construction related activities (graph above from the 18/10/2015).

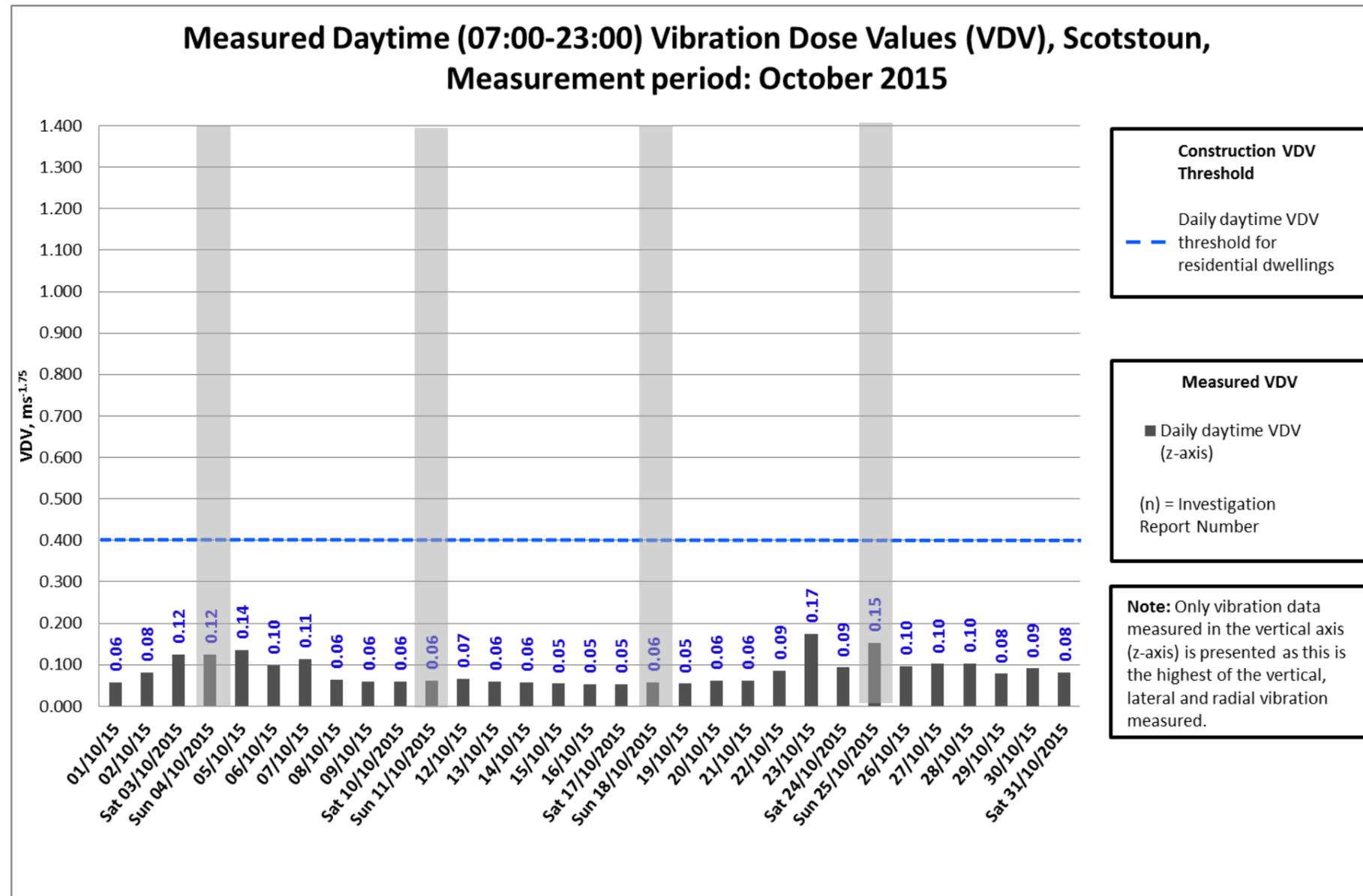


Exceedances on the 1<sup>st</sup> and 25<sup>th</sup> of October have been investigated and found to be one off isolated events that are unlikely to be caused by construction related activities (graph above from the 01/10/2015).

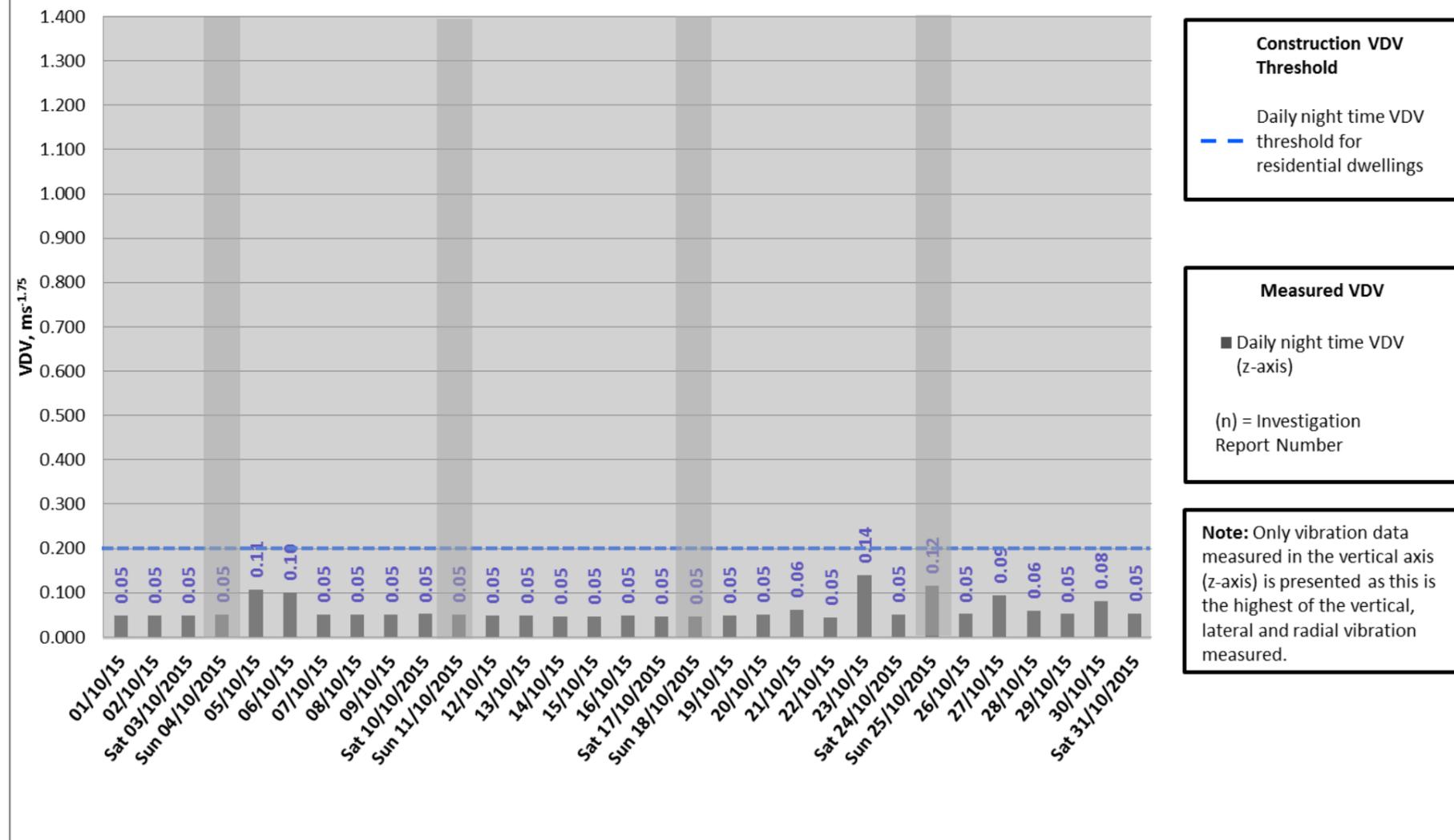
### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), 5 Linn Mill, Measurement period: October 2015







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



**Construction VDV Threshold**

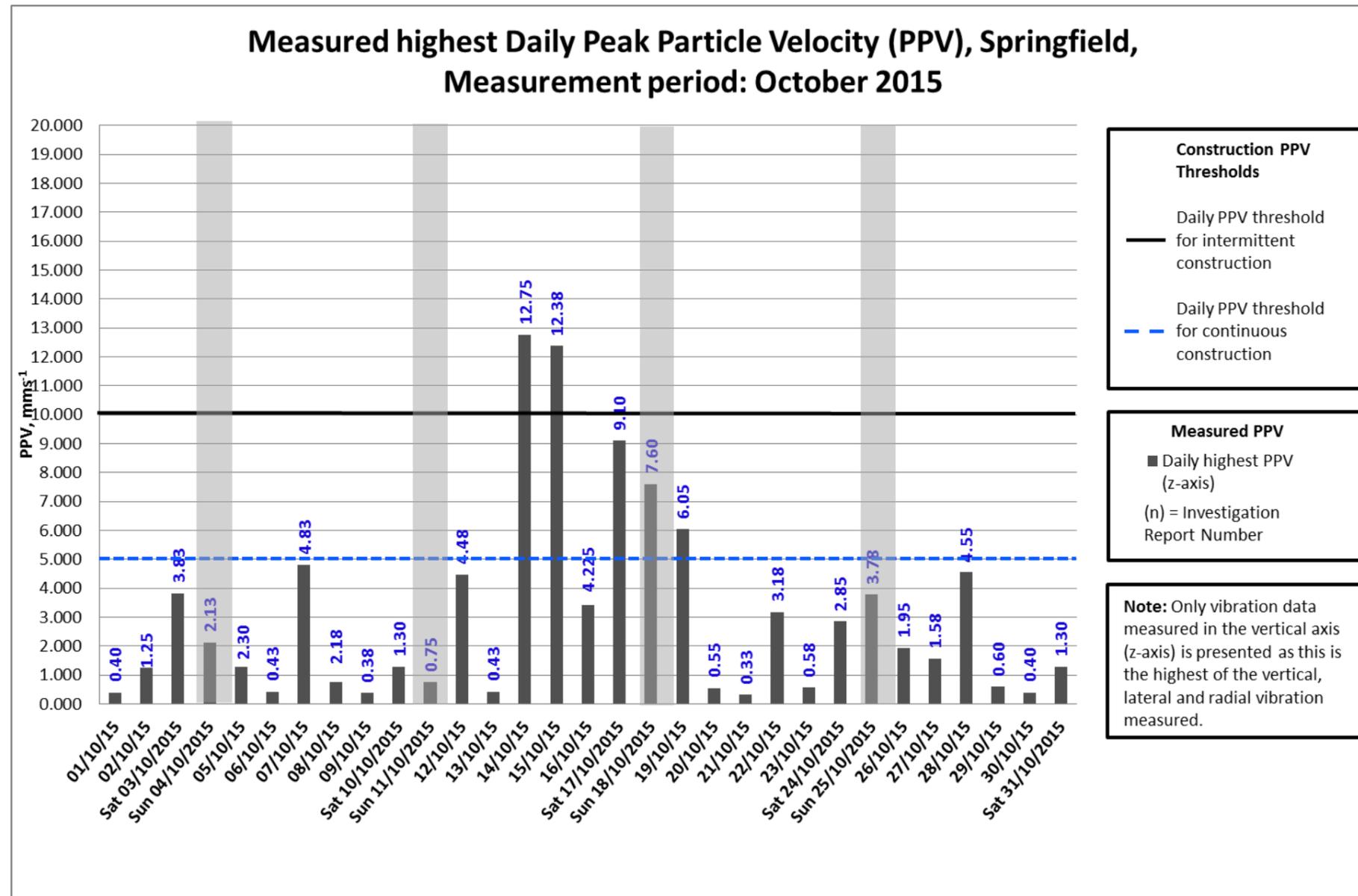
Daily night time VDV threshold for residential dwellings

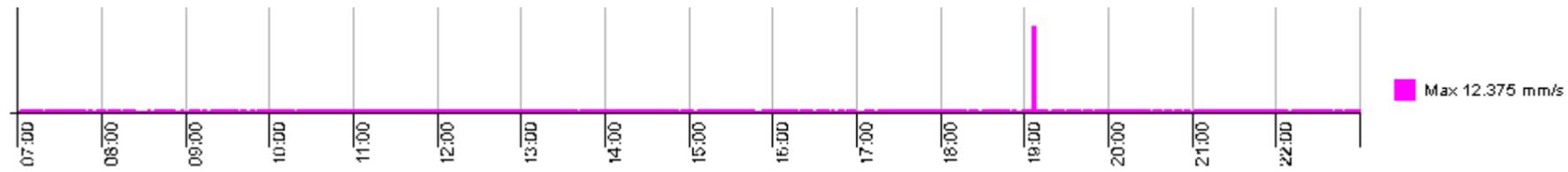
**Measured VDV**

■ Daily night time VDV (z-axis)

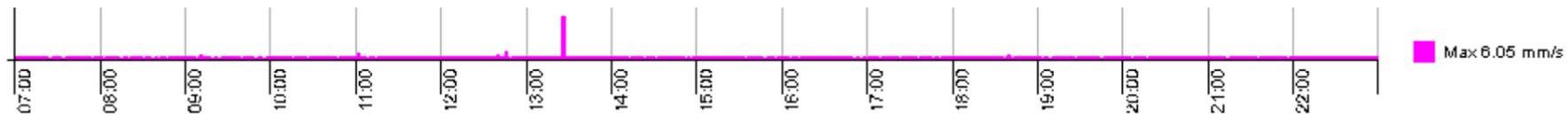
(n) = Investigation Report Number

**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.



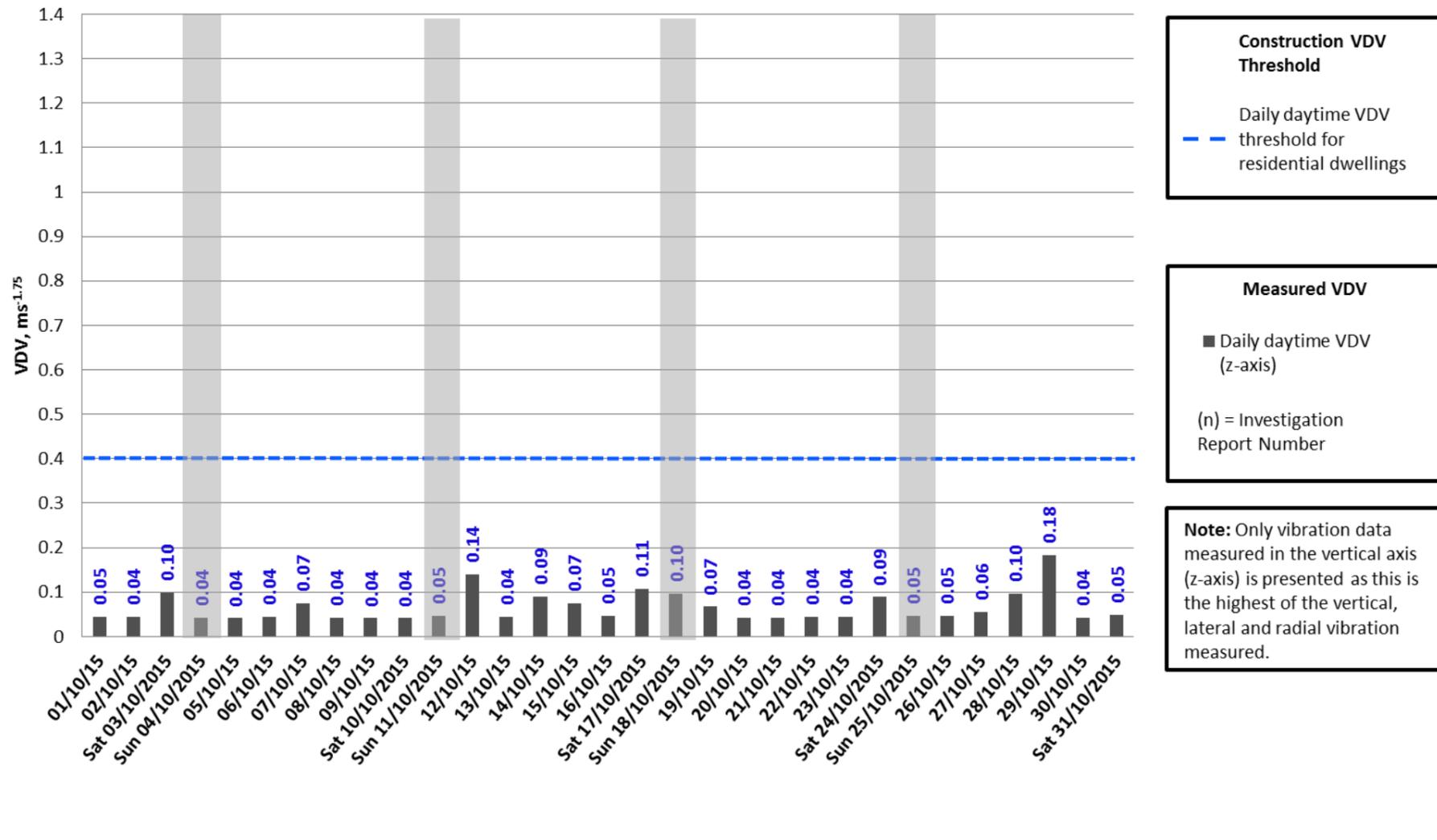


Exceedances on the 15<sup>th</sup> and 18<sup>th</sup> of October have been investigated and found to be out with construction working hours, and therefore highly unlikely to be caused by construction related activities (graph above from the 15/10/2015).

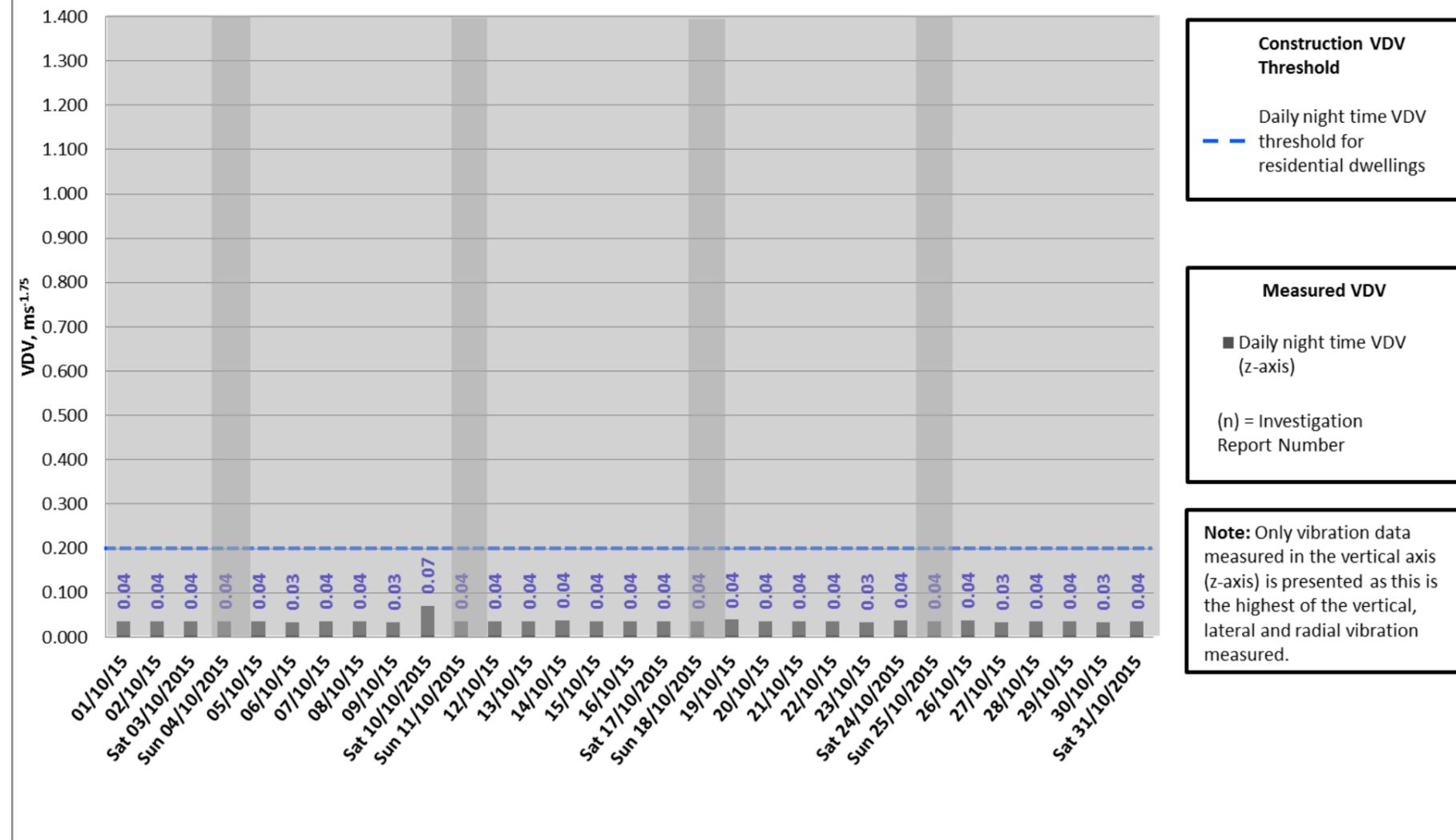


Exceedances on the 14<sup>th</sup>, 17<sup>th</sup> and 19<sup>th</sup> of October have been investigated. It has been found that the exceedance was an isolated event that is highly unlikely to have been caused by construction related activities (graph above from the 19/10/2015).

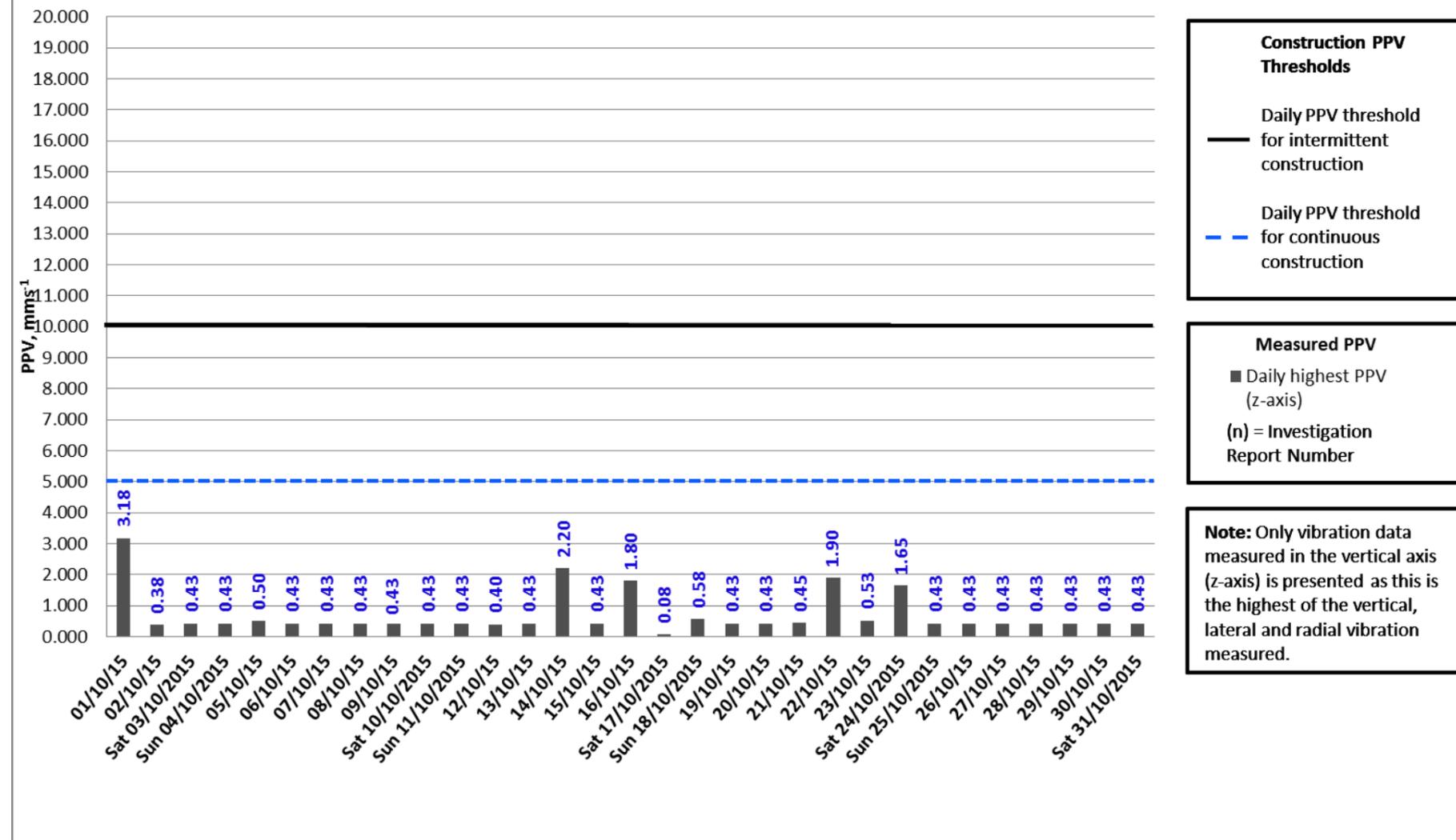
**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield,  
 Measurement period: October 2015**



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



### Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na Grian, Measurement period: October 2015



**Construction PPV Thresholds**

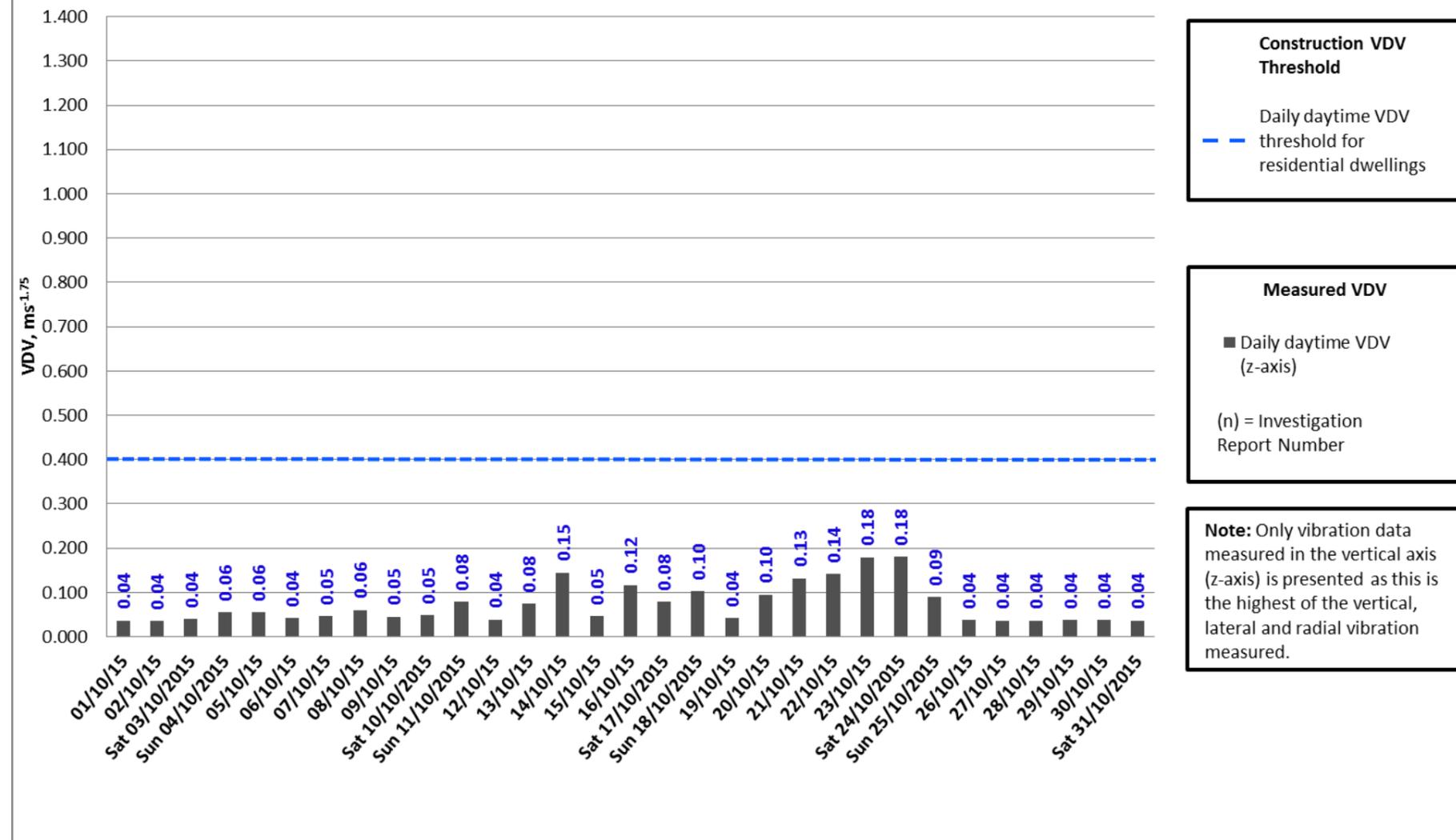
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

**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.

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: October 2015



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

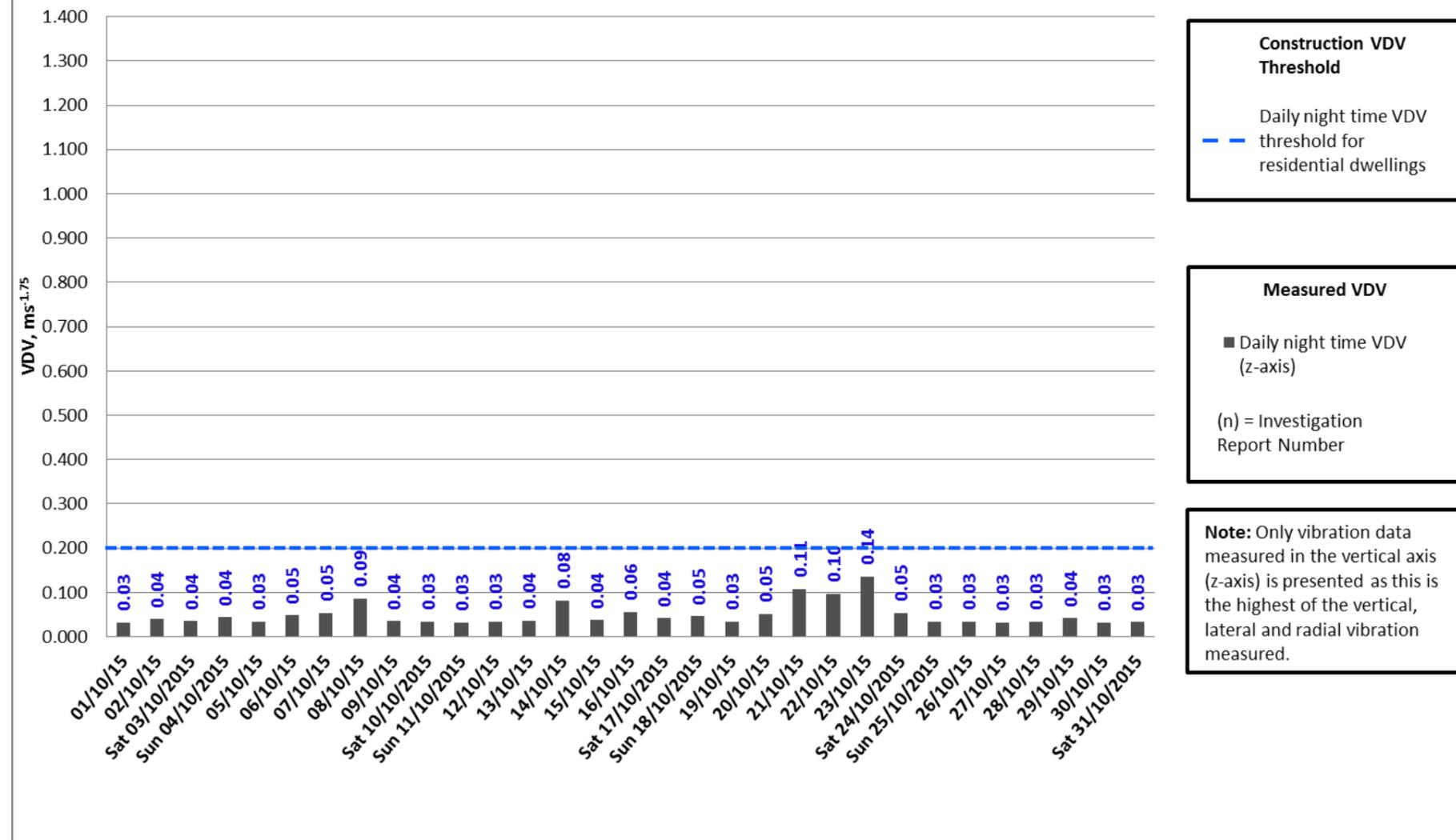
**Measured VDV**

■ 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), Tigh-Na Grian, Measurement period: October 2015



**Construction VDV Threshold**

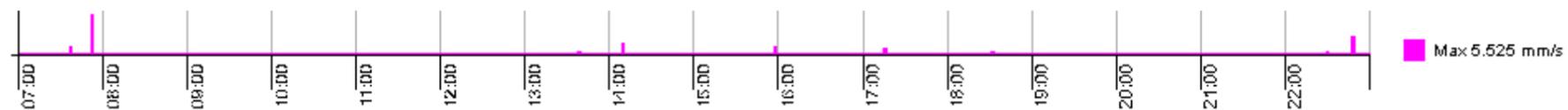
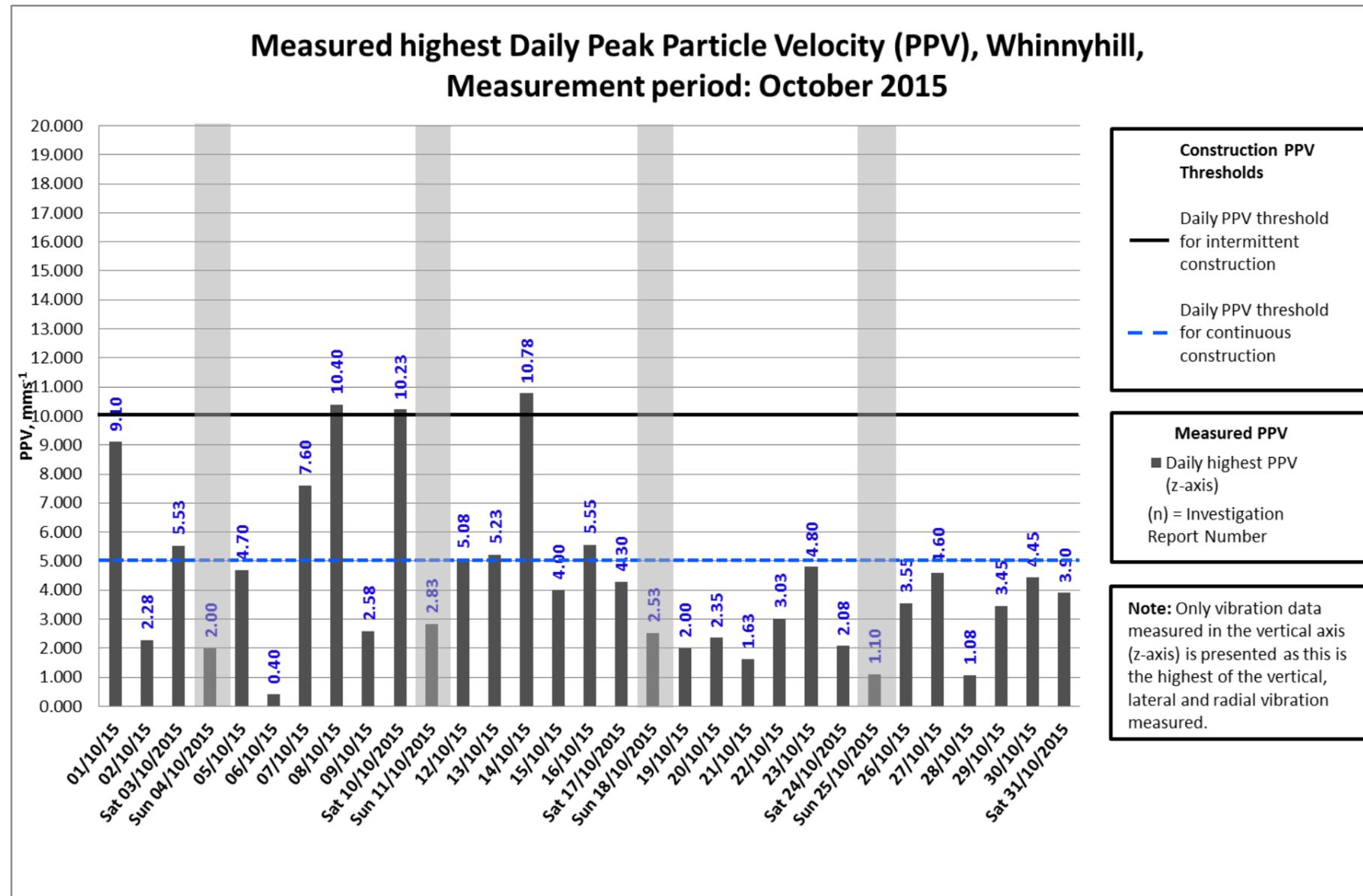
Daily night time VDV threshold for residential dwellings

**Measured VDV**

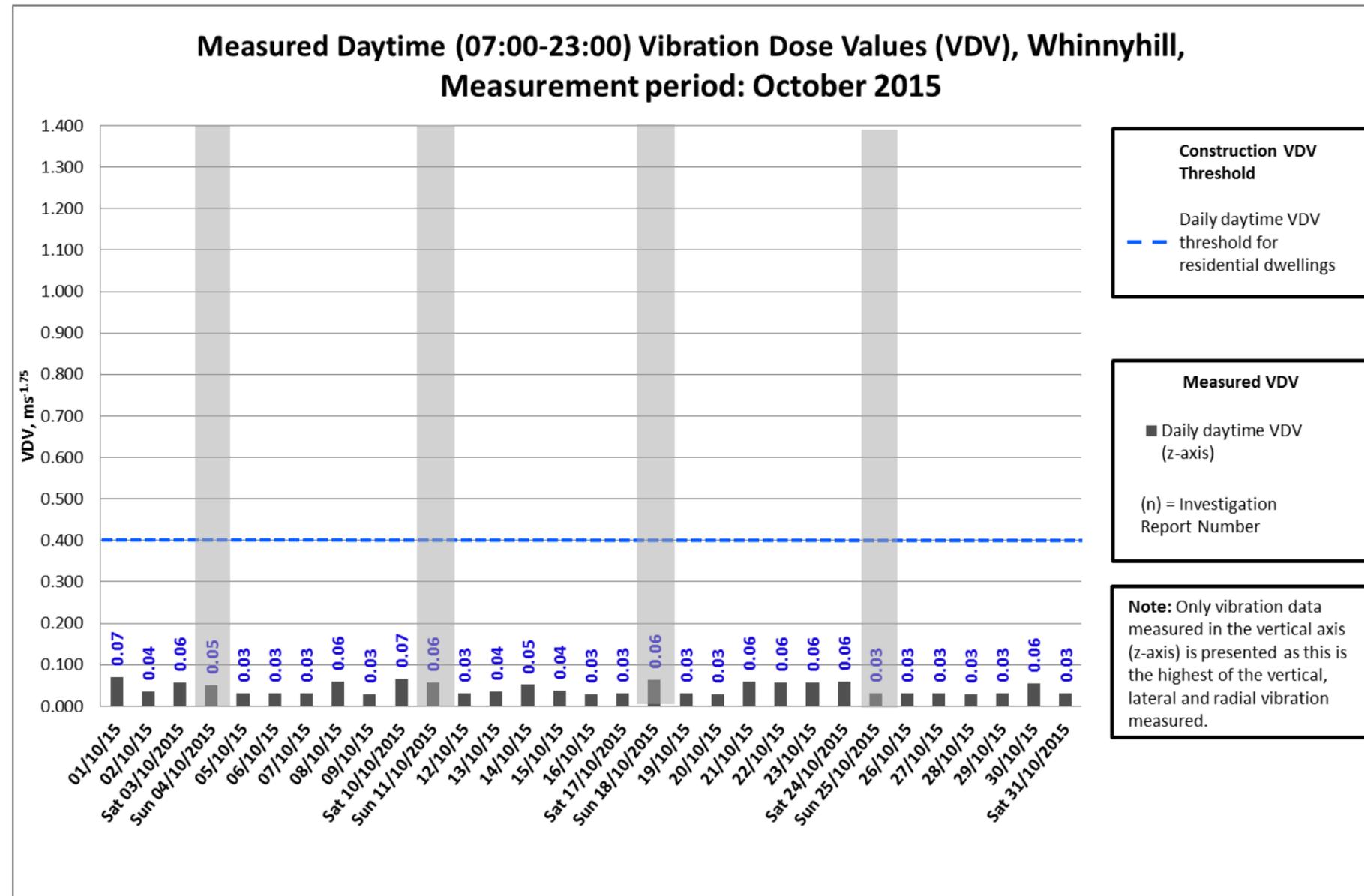
■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

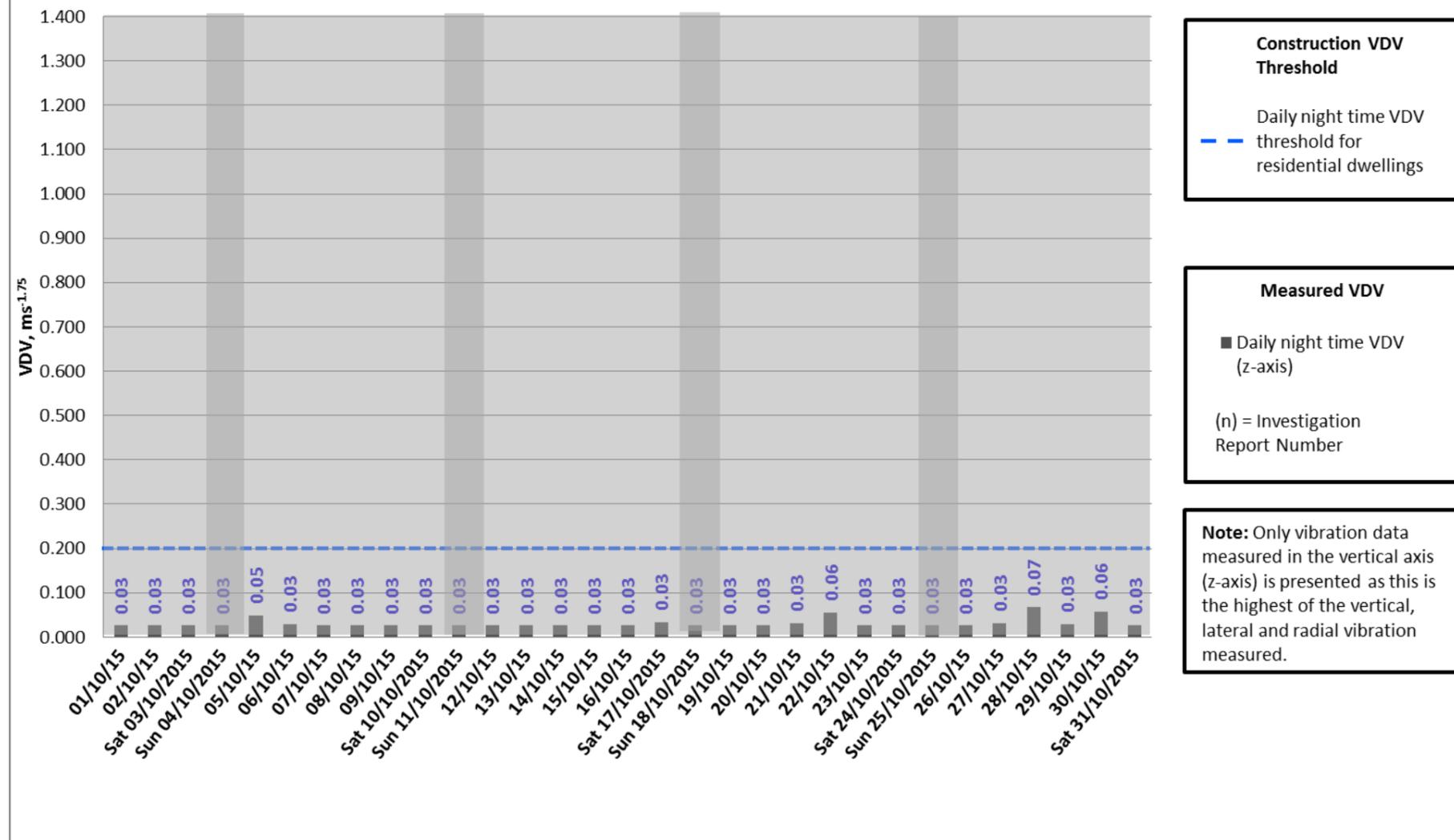
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



All exceedances within the month of October at Whinnyhill were investigated. All of these were found to be brief individual and isolated events, which are regarded as highly unlikely to have been caused by construction related activities. During this period the only potential vibration sources from plant used in this area, were from rollers working no closer than within 120m from the logger location. It is therefore considered highly unlikely to have caused these exceedances over this distance.



**Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Whinnyhill,  
 Measurement period: October 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.