



Contractor

**FCBC**  
Queensferry  
Crossing

DRAGADOS | AMERICAN BRIDGE INTERNATIONAL  
HOCHTIEF | MORRISON CONSTRUCTION

Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT**  
**MARCH 2016**

00	11/04/16	First draft	MRN	SWR	SWR
<b>Rev</b>	<b>Rev. Date</b>	<b>Purpose of revision</b>	<b>Made</b>	<b>Reviewed</b>	<b>Approved</b>

Document status

**FOR REVIEW**

Made by Michael Richardson	Checked By: Steven Westwater
Initials: MRN	Initials: SWR

Document number	Rev
<b>REP-00273</b>	<b>00</b>

This document is intellectual property of FCBC Construction JV. Copying, distribution, usage, and information on contents of this are forbidden unless explicitly authorized.



DRAGADOS | AMERICAN BRIDGE INTERNATIONAL  
HOCHTIEF | MORRISON CONSTRUCTION

## **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 March 2016. 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**

**March 2016**

Location	PPV Exceedance		VDV Exceedance	
	Continuous ( $5 \text{ mm.s}^{-1}$ )	Intermittent ( $10 \text{ mm.s}^{-1}$ )	Day ( $0.4 \text{ m.s}^{-1.75}$ )	Night ( $0.2 \text{ m.s}^{-1.75}$ )
Linn Mill	2	0	0	0
Butlaw Fisheries	2	0	0	0
Clufflat Brae	12	3	0	0
Dundas Home Farm	3	1	0	0
Echline	0	0	0	0
Inchgarvie Lodge	0	5	0	0
Scotstoun	0	1	0	0
Springfield	4	3	0	0
Tigh-Na-Grian	0	0	0	0
Whinnyhill	7	0	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  $5 \text{ mm.s}^{-1}$  for continuous construction (e.g. piling), and  $10 \text{ mm.s}^{-1}$  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  $\text{m.s}^{-2}$  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 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 and monitor problems.



### **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 are unlikely to be generated by construction, but rather show local interference around the monitoring equipment.



DRAGADOS | AMERICAN BRIDGE INTERNATIONAL  
HOCHTIEF | MORRISON CONSTRUCTION

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

**Table 2: Monitoring Locations**

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During March 2016
M1	Whinny Hill	Network	<ul style="list-style-type: none"> <li>• Earthworks/Fill placement</li> <li>• Hope Street roadworks</li> <li>• FT03 &amp; FT04 works</li> <li>• Demolition Works FT07</li> <li>• FT09 works</li> <li>• FT19 Works</li> <li>• Main carriageway Roadworks</li> <li>• Rock crushing</li> </ul>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• North Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• Pier N1 &amp; N2 bearing works</li> <li>• AVN Launch</li> </ul>
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• South Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• Pier S1 rebar, formwork &amp; concrete works</li> <li>• Pier S2 rebar, formwork &amp; concrete works</li> <li>• AVS rebar &amp; concrete deck works</li> </ul>
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation</li> <li>• South Tower rebar, formwork, concreting works deck section lifts and stay cable installation</li> <li>• Pier S1 rebar, formwork &amp; concrete works</li> <li>• Pier S2 rebar, formwork &amp; concrete works</li> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> </ul>
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• No night time or Sunday construction in the vicinity</li> </ul>
M13	Clufflat Brae	Crossing	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• No night time or Sunday daytime construction in the vicinity</li> </ul>
M14	Springfield	Network	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• Earthworks south abutment area</li> <li>• No night time or Sunday daytime construction in the vicinity</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Earthworks south abutment area</li> <li>• Main carriageway roadworks</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> </ul>



DRAGADOS | AMERICAN BRIDGE INTERNATIONAL  
HOCHTIEF | MORRISON CONSTRUCTION

			<ul style="list-style-type: none"> <li>• ESQ11 rebar works</li> <li>• Mainline roadworks</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>• ESQ11 rebar works</li> <li>• Mainline roadworks</li> </ul>

Table 2: The main construction activities undertaken in the locality of each of the vibration monitors during the period of March 2016.

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

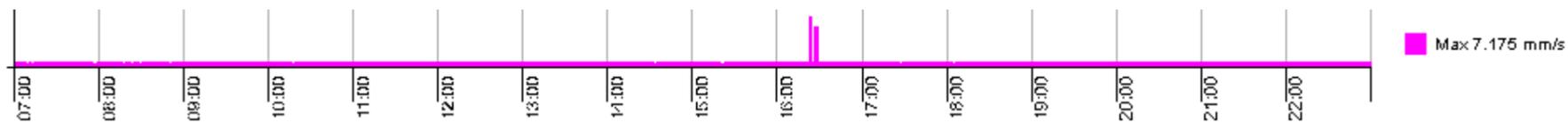
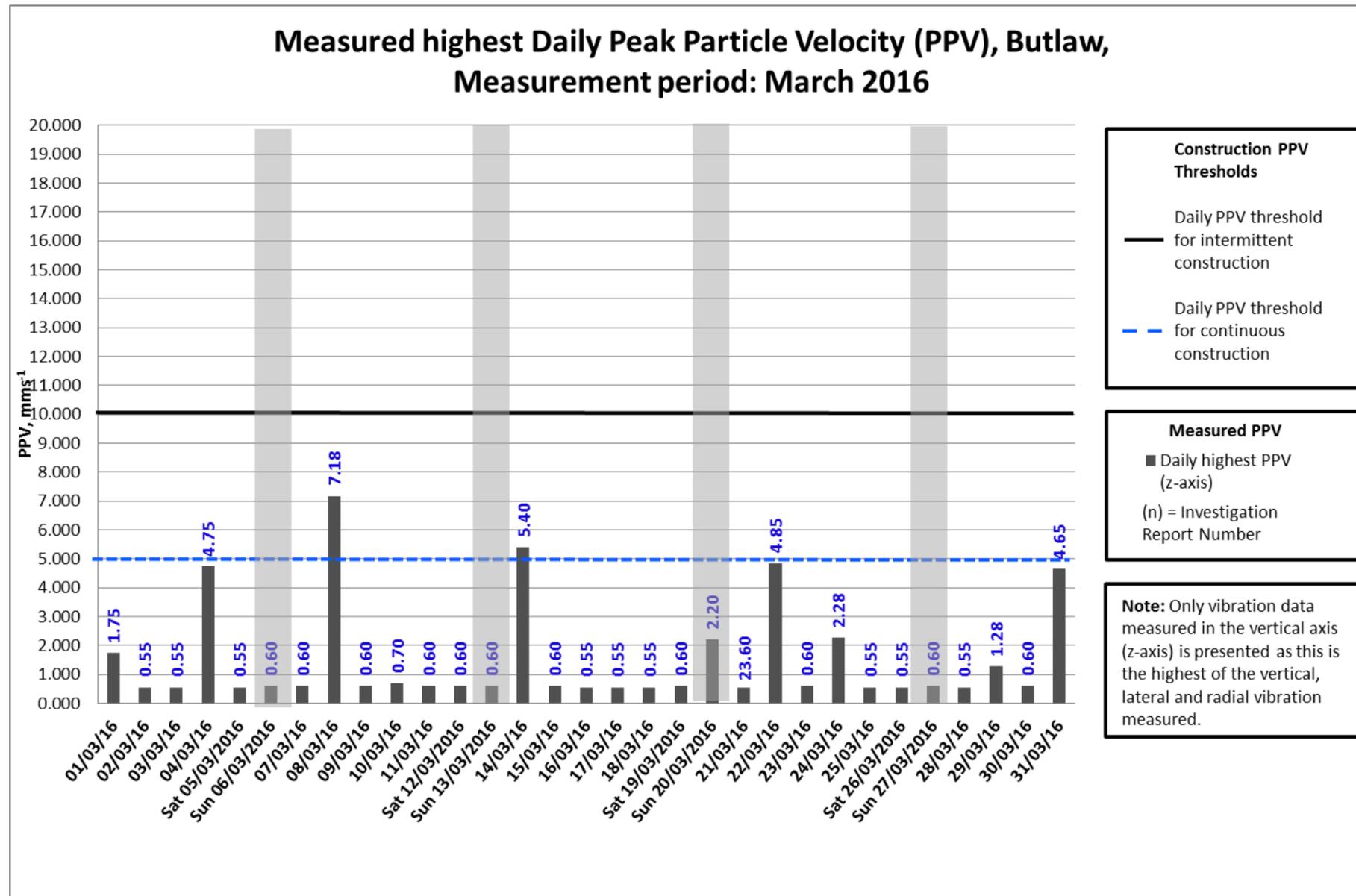
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	2.44	0.37
Dundas	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.

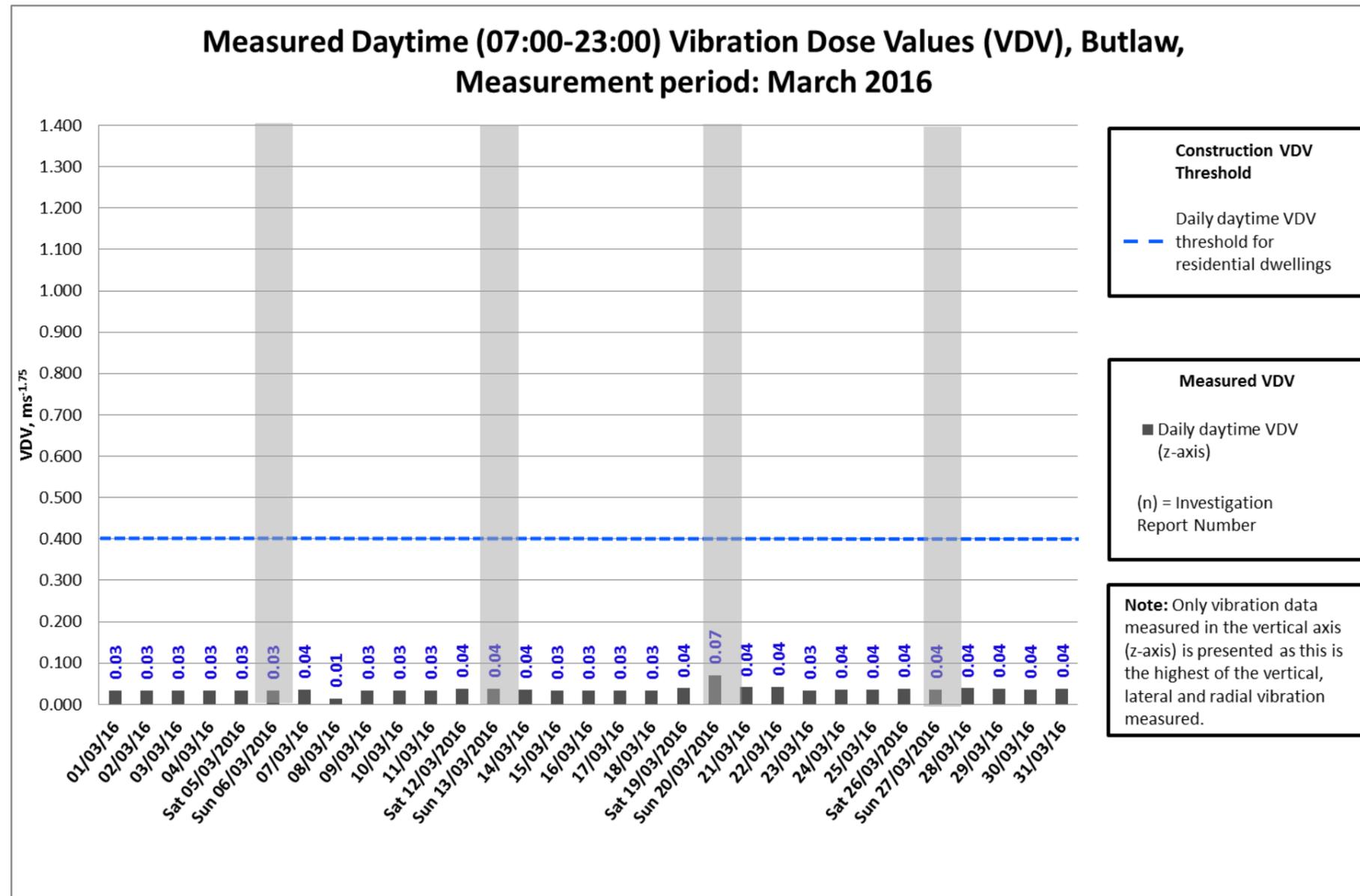
**Notes on Table 3**

- 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.

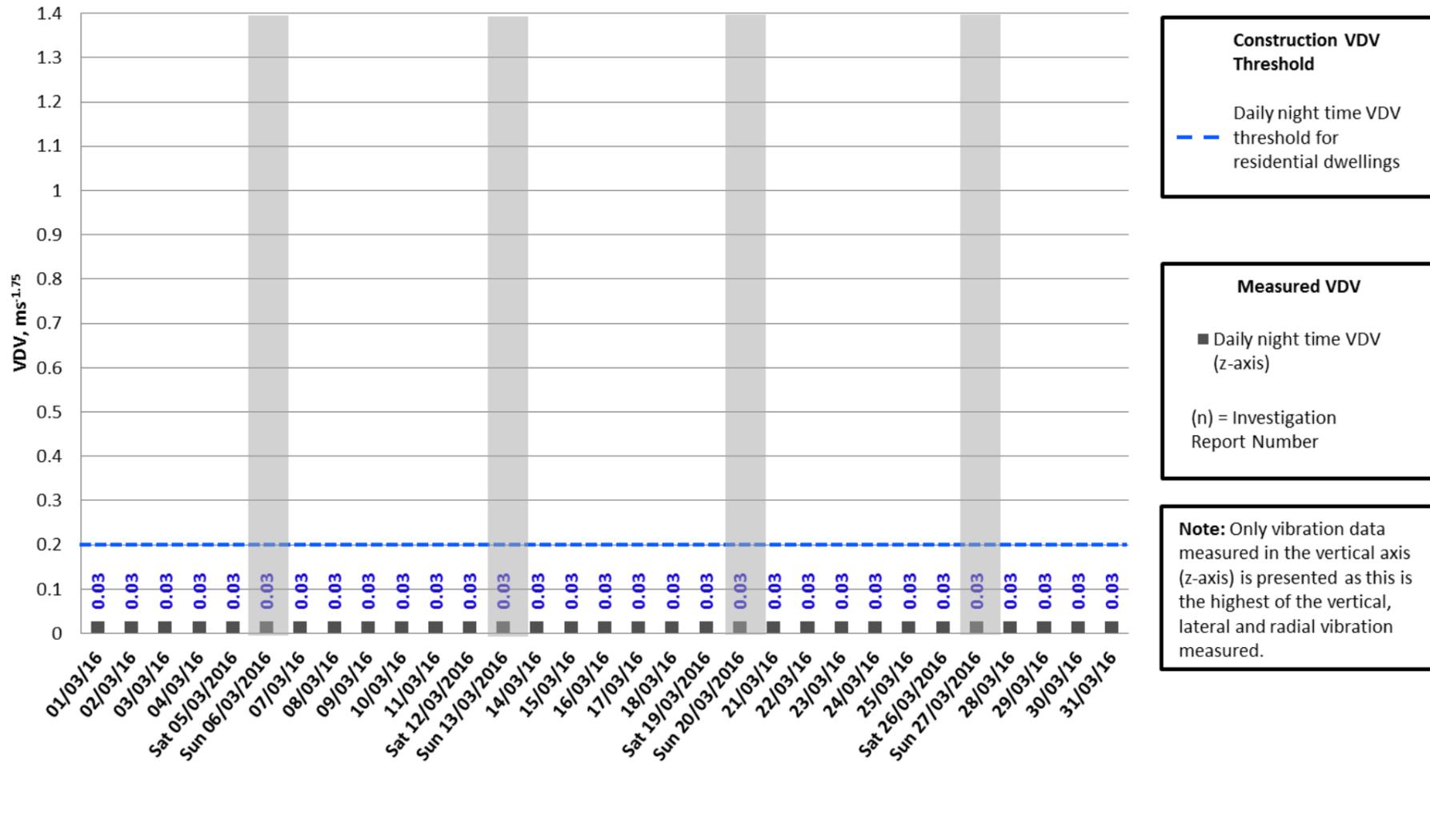
## APPENDIX B – VIBRATION GRAPHS



Exceedances on the 8<sup>th</sup> and 14<sup>th</sup> of March have been investigated and found to be caused by the environmental department carrying out maintenance to monitoring equipment in this location.



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Butlaw, Measurement period: March 2016



**Construction VDV Threshold**

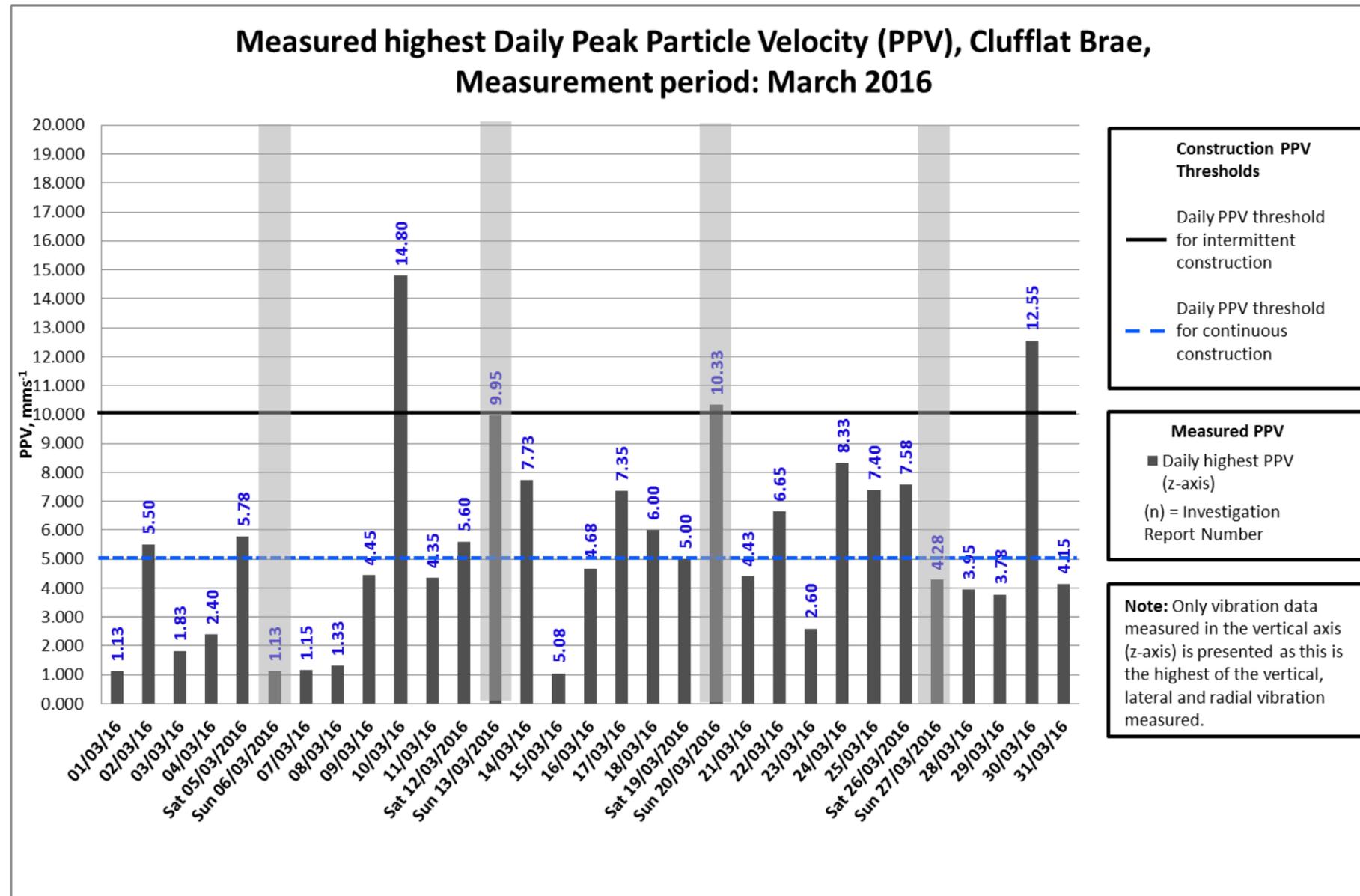
Daily night time VDV threshold for residential dwellings

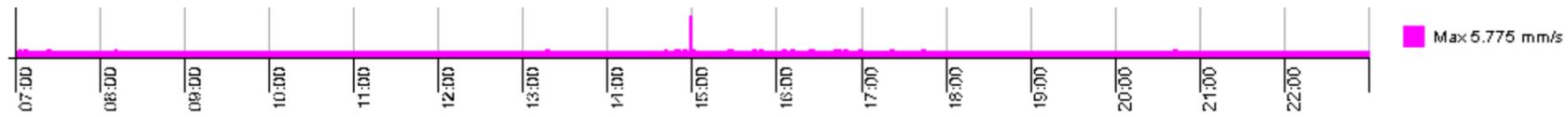
**Measured VDV**

■ Daily night time VDV (z-axis)

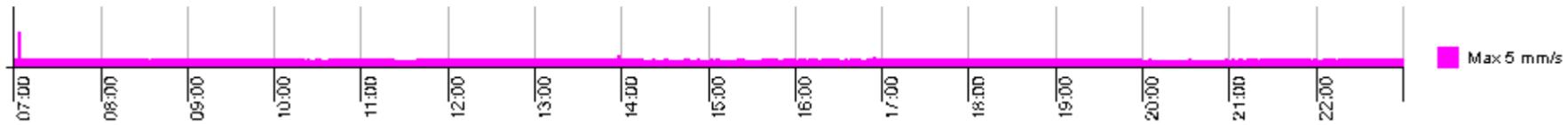
(n) = Investigation Report Number

**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.

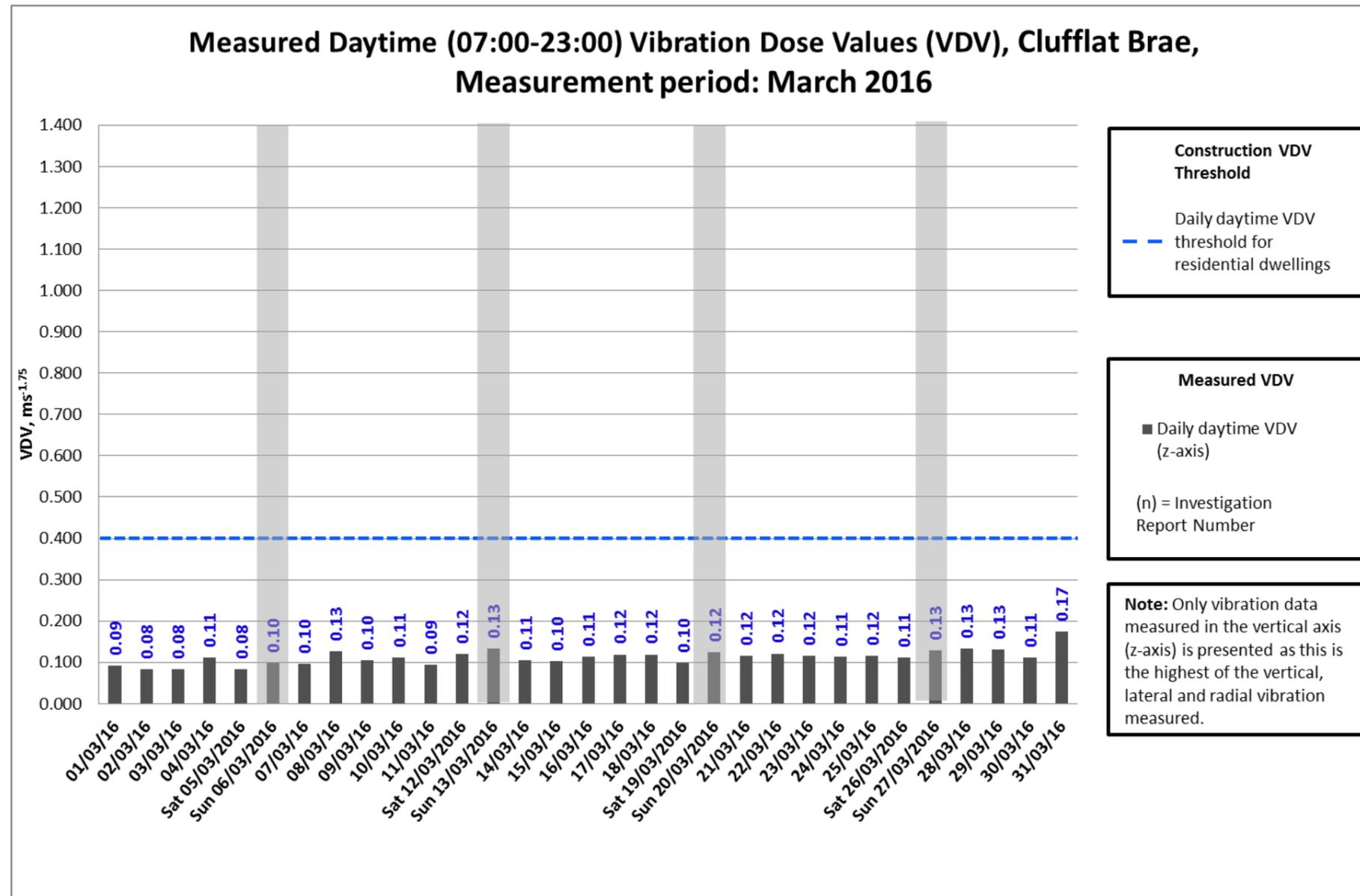


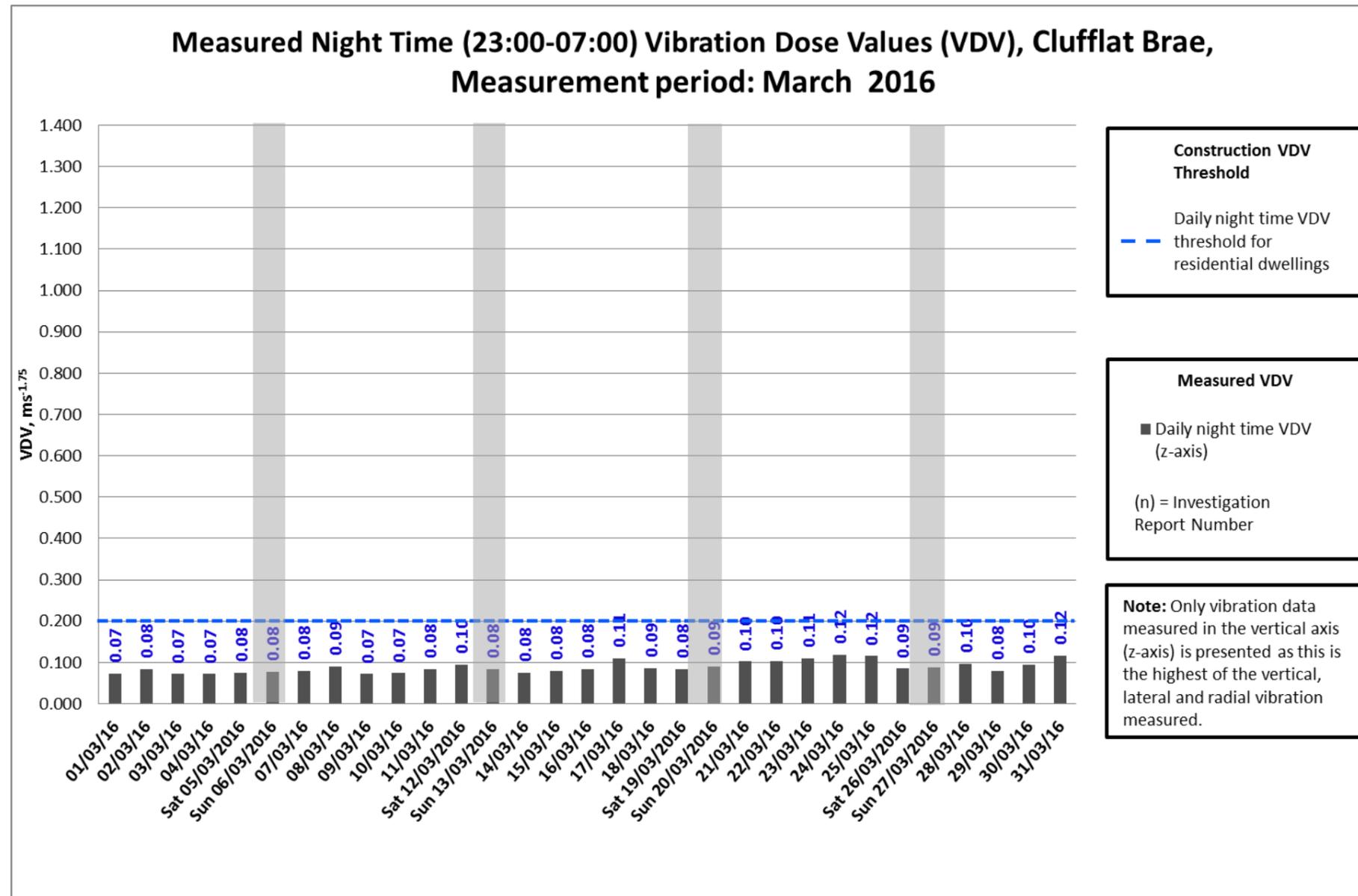


Exceedances on the 2<sup>nd</sup>, 5<sup>th</sup>, 10<sup>th</sup>, 12<sup>th</sup>, 14<sup>th</sup>, 17<sup>th</sup>, 18<sup>th</sup>, 22<sup>nd</sup>, 24<sup>th</sup>, 25<sup>th</sup>, and 26<sup>th</sup> of March have been investigated and found to be caused by individual isolated events that are unlikely to have been caused by construction related activities (graph above from the 05/03/2016).

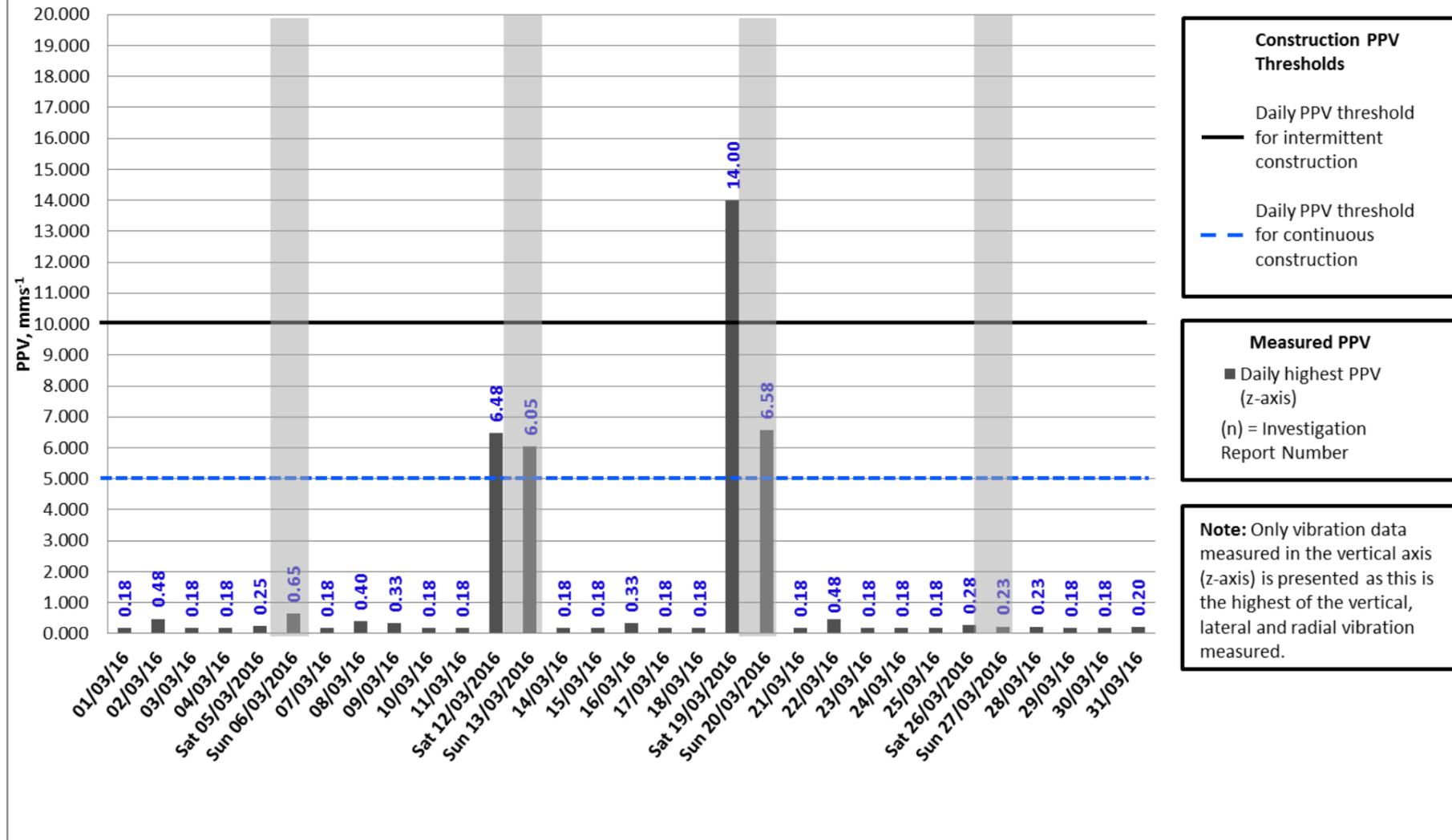


Exceedances on the 13<sup>th</sup>, 19<sup>th</sup>, 20<sup>th</sup> and 30<sup>th</sup> of March have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction relate activities was the cause of these (graph above from the 19/03/2016).





### Measured highest Daily Peak Particle Velocity (PPV), Dundas Home Farm, Measurement period: March 2016



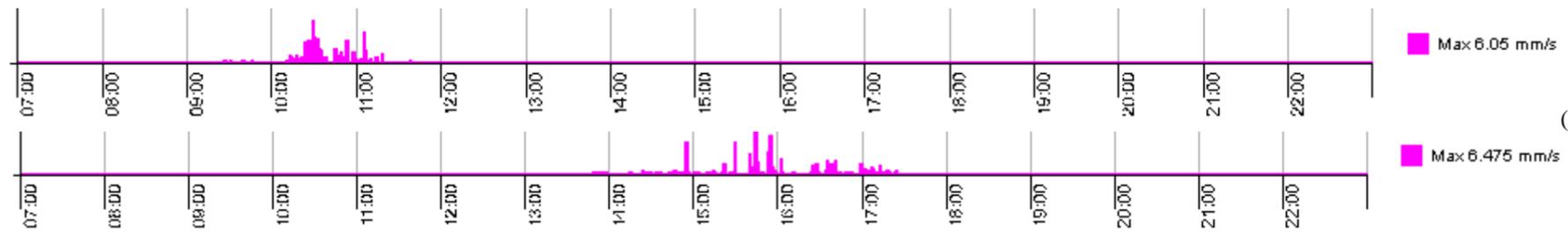
**Construction PPV Thresholds**

- Daily PPV threshold for intermittent construction (solid black line)
- Daily PPV threshold for continuous construction (dashed blue line)

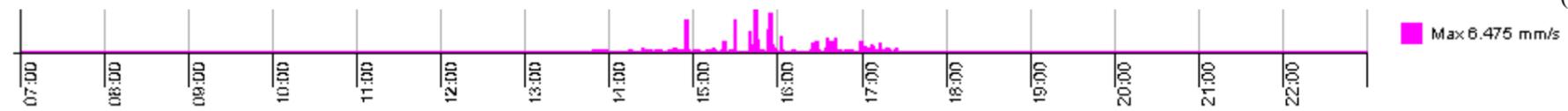
**Measured PPV**

- Daily highest PPV (z-axis) (dark grey bar)
- (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.

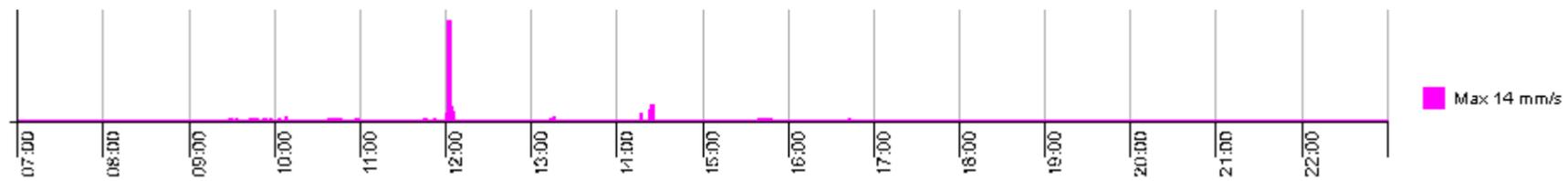


(figure 1)

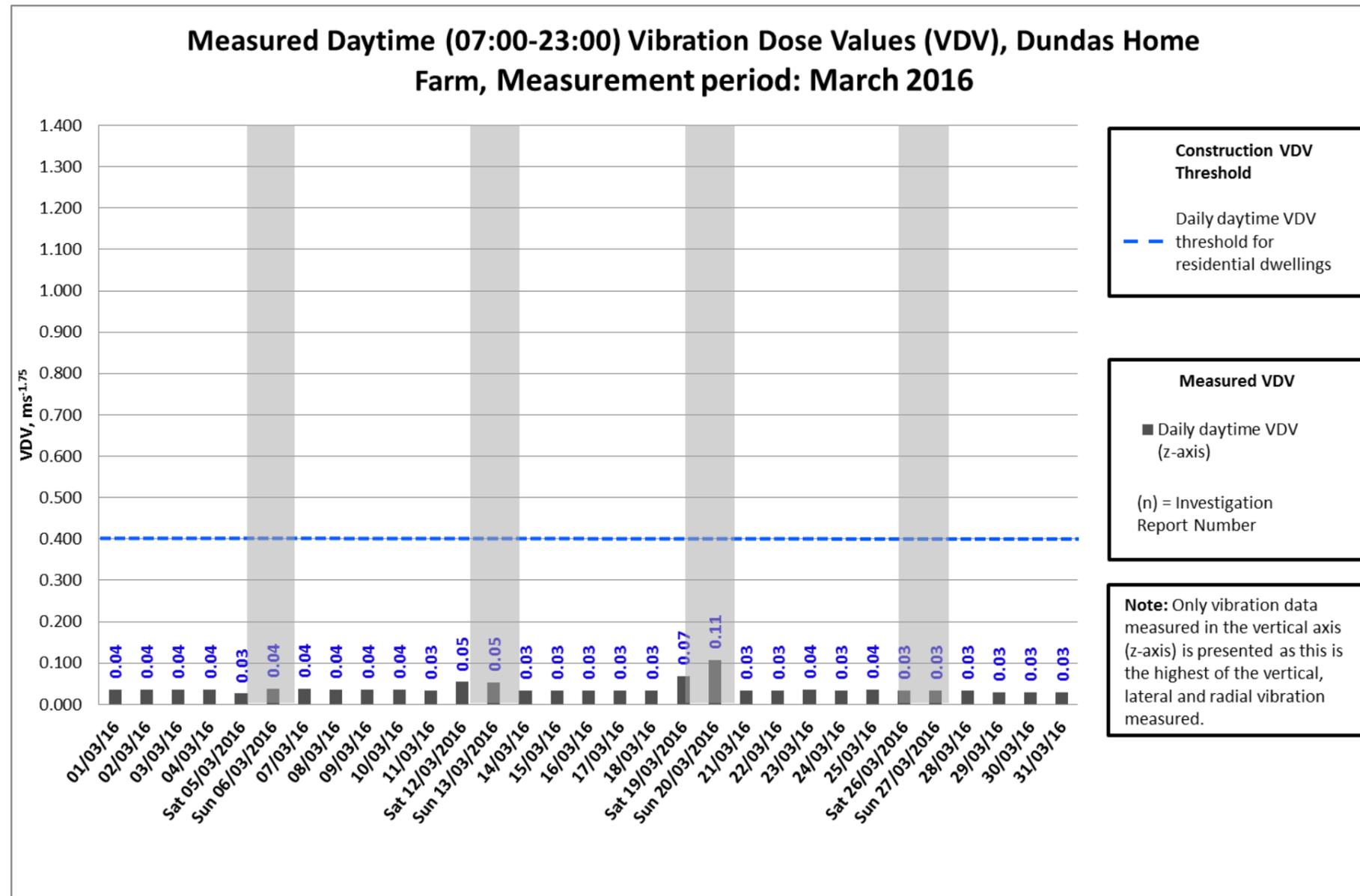


(figure 2)

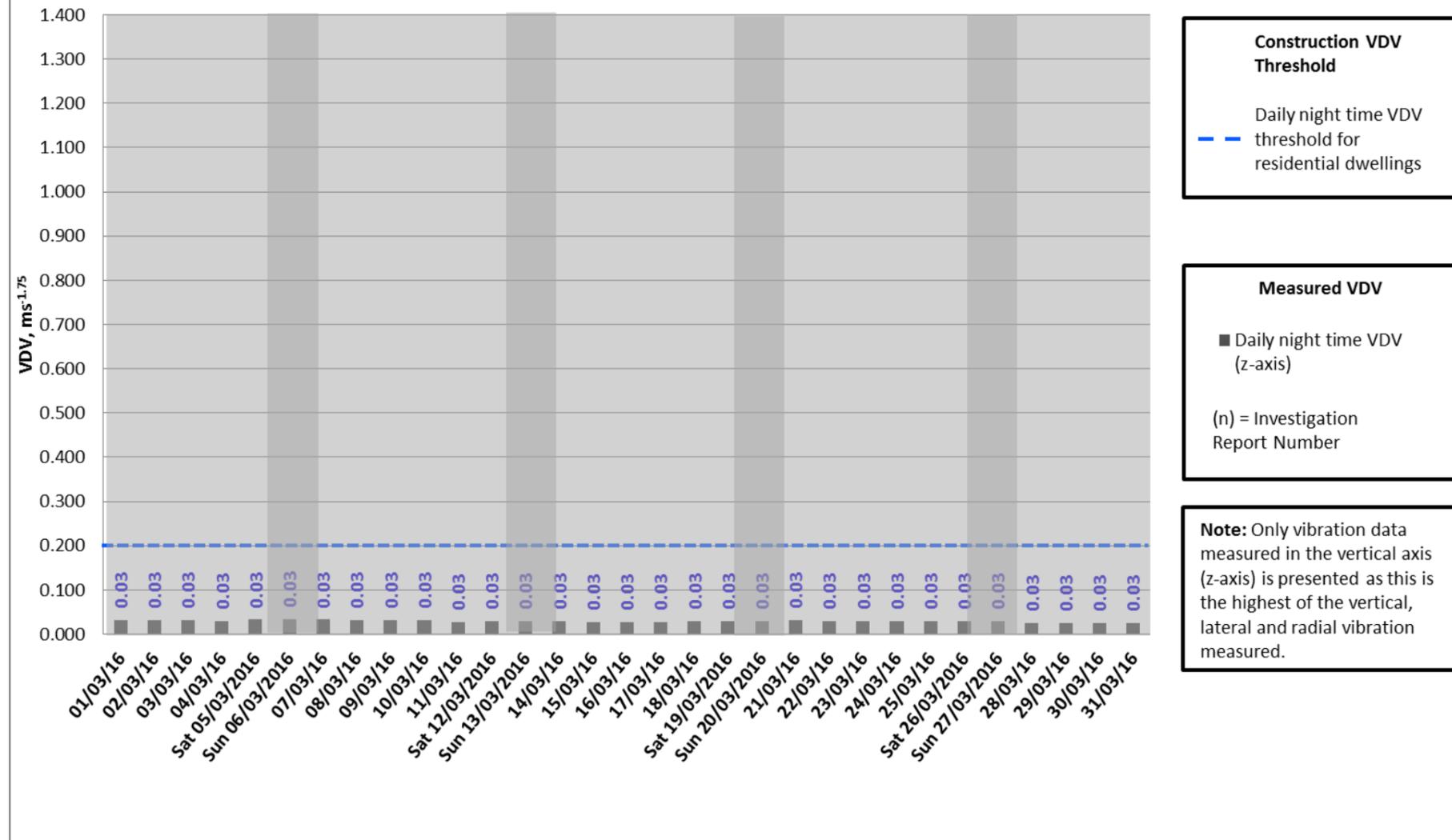
Exceedances on the 12<sup>th</sup>, 13<sup>th</sup> and 20<sup>th</sup> of March have been investigated with the source of the vibration to be unknown. During inspection of the monitor location there was large quantities of wood left nearby the monitor location which when being placed in this location may have resulted in the continuous vibration levels seen above (Figure 1 from 12/03/2016, figure 2 from 13/03/2016). During these periods of sustained vibration levels exceedances on the 13<sup>th</sup> of March (as seen above) was during a Sunday which is out of normal working hours which supports the following conclusion that there vibration levels may have been caused by localised movement rather than construction related activities.

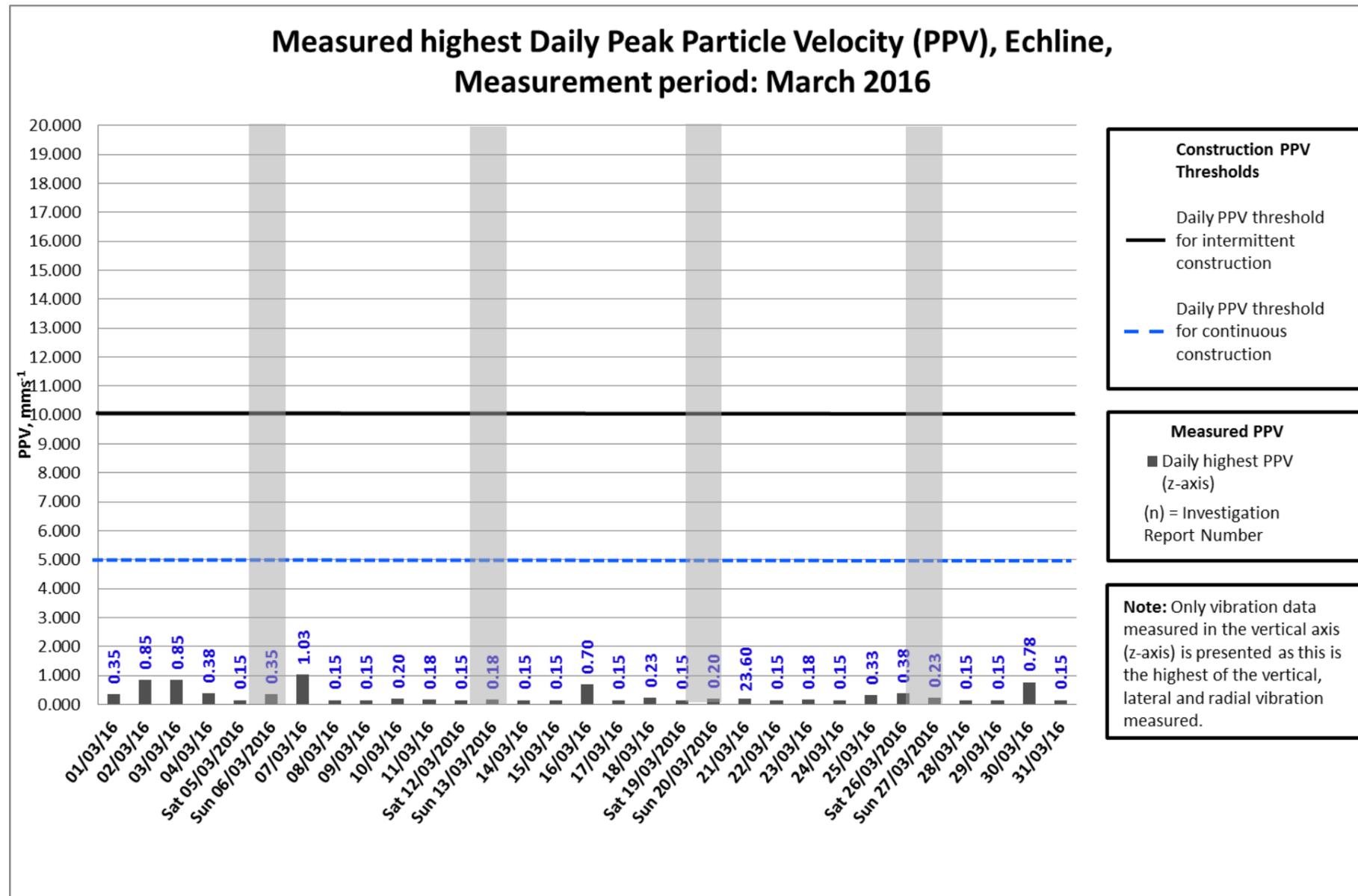


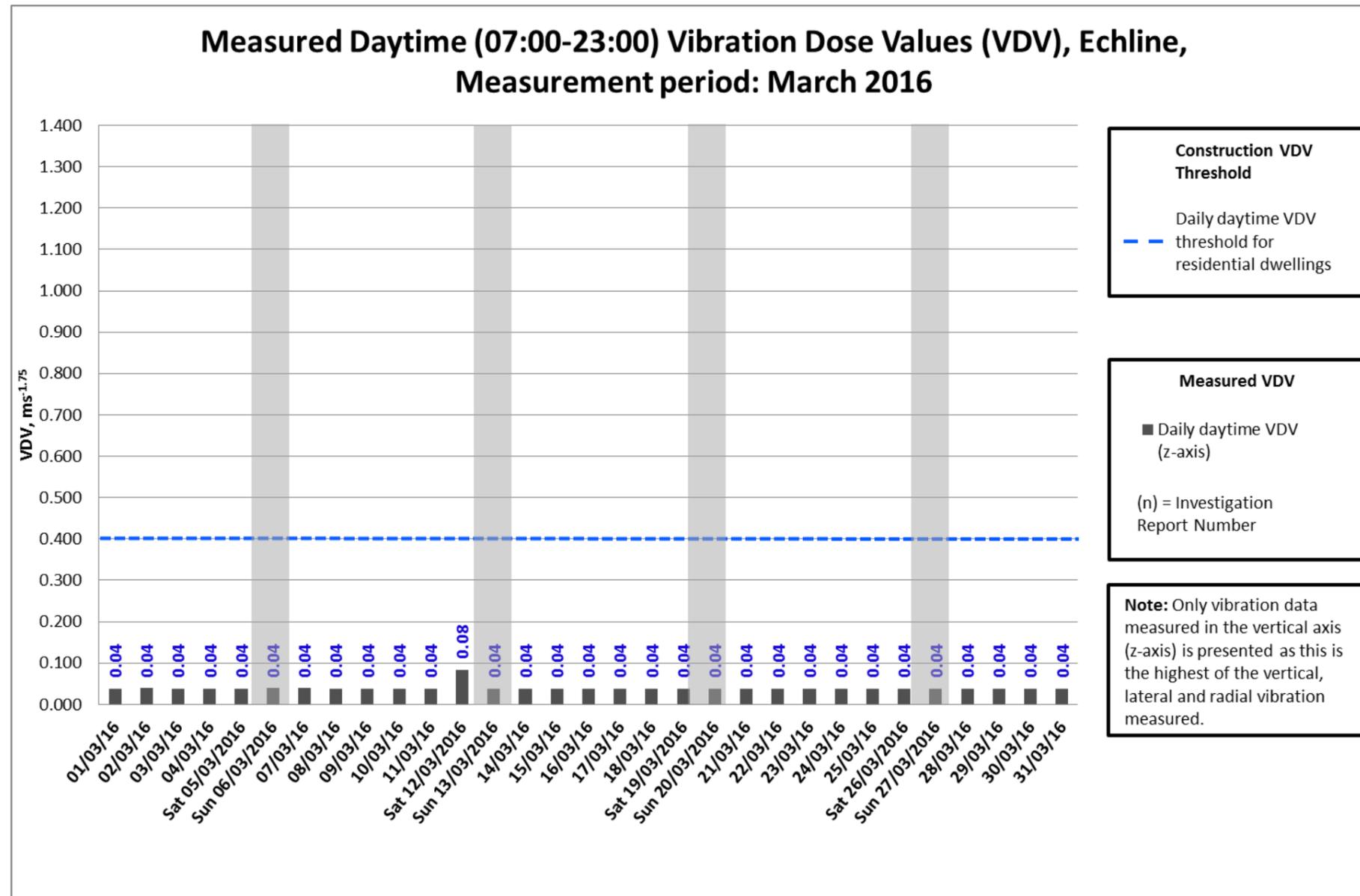
Exceedance on the 19<sup>th</sup> of March has been investigated and found to be an isolated event that is unlikely to have been caused by construction related activities (graph above from the 19/03/2016).

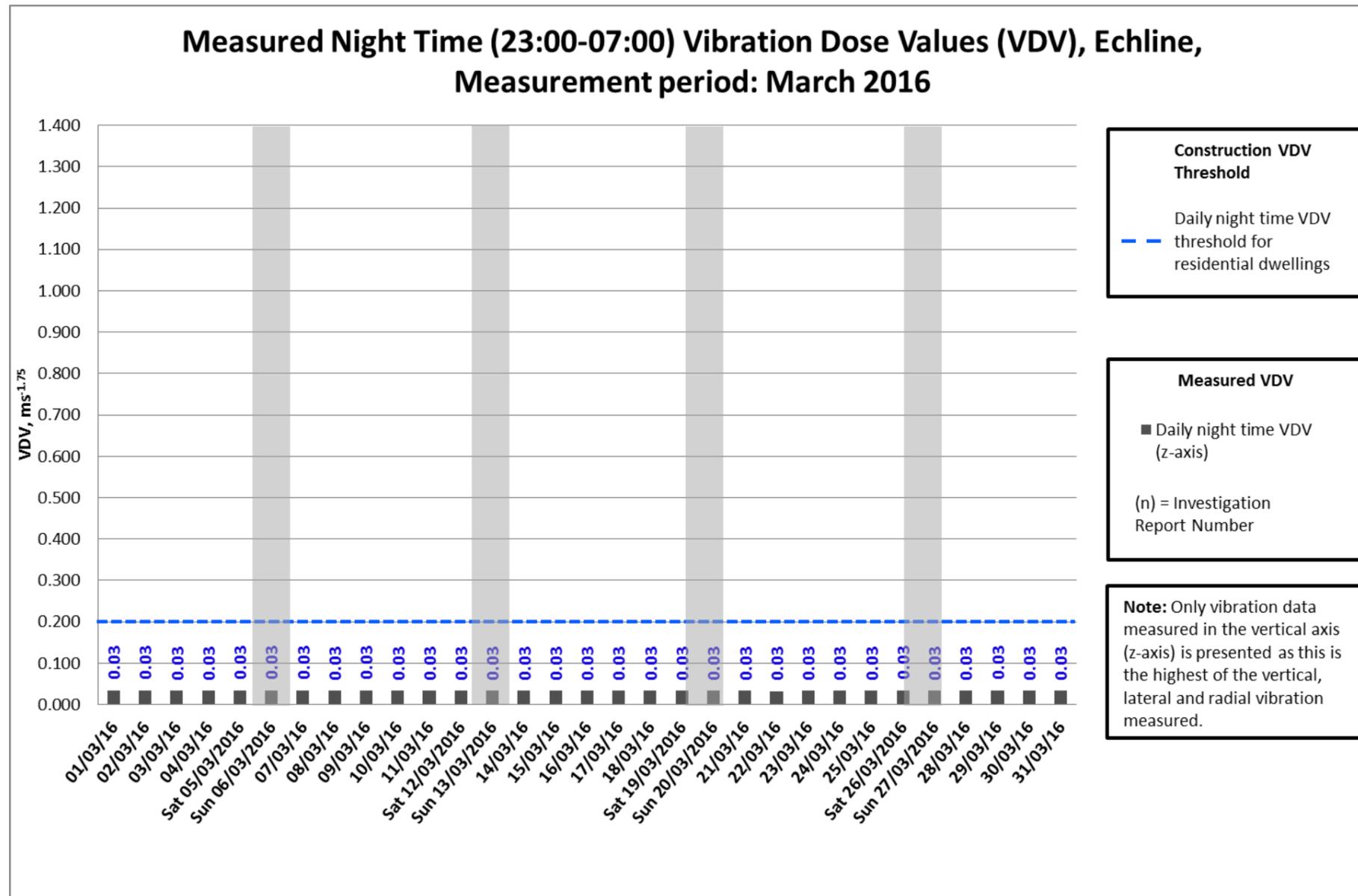


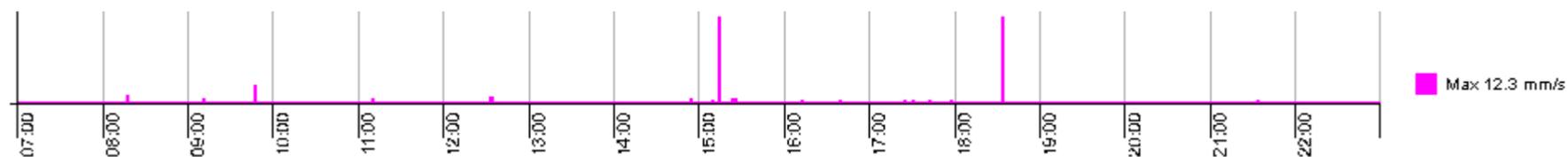
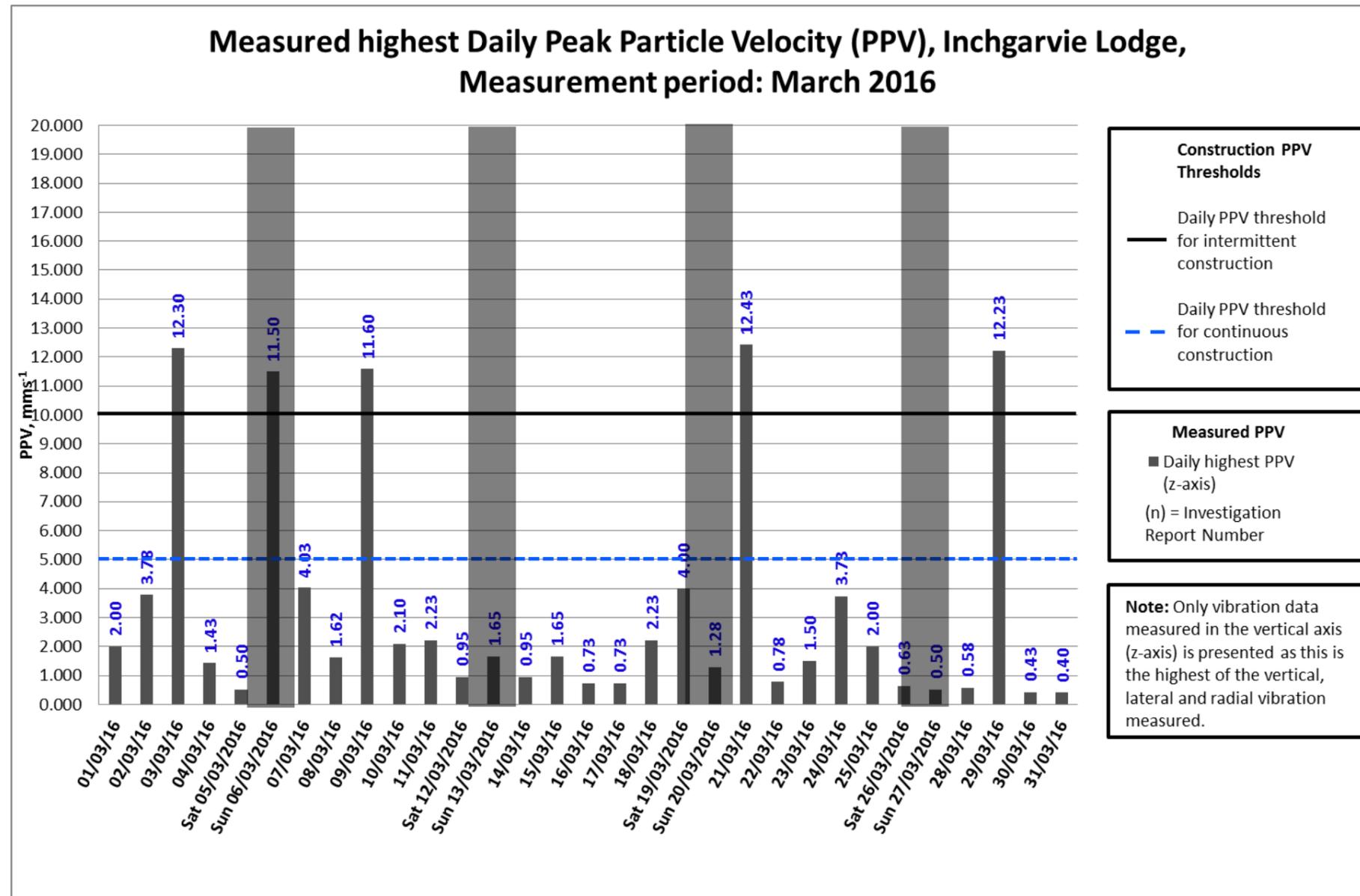
### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: March 2016



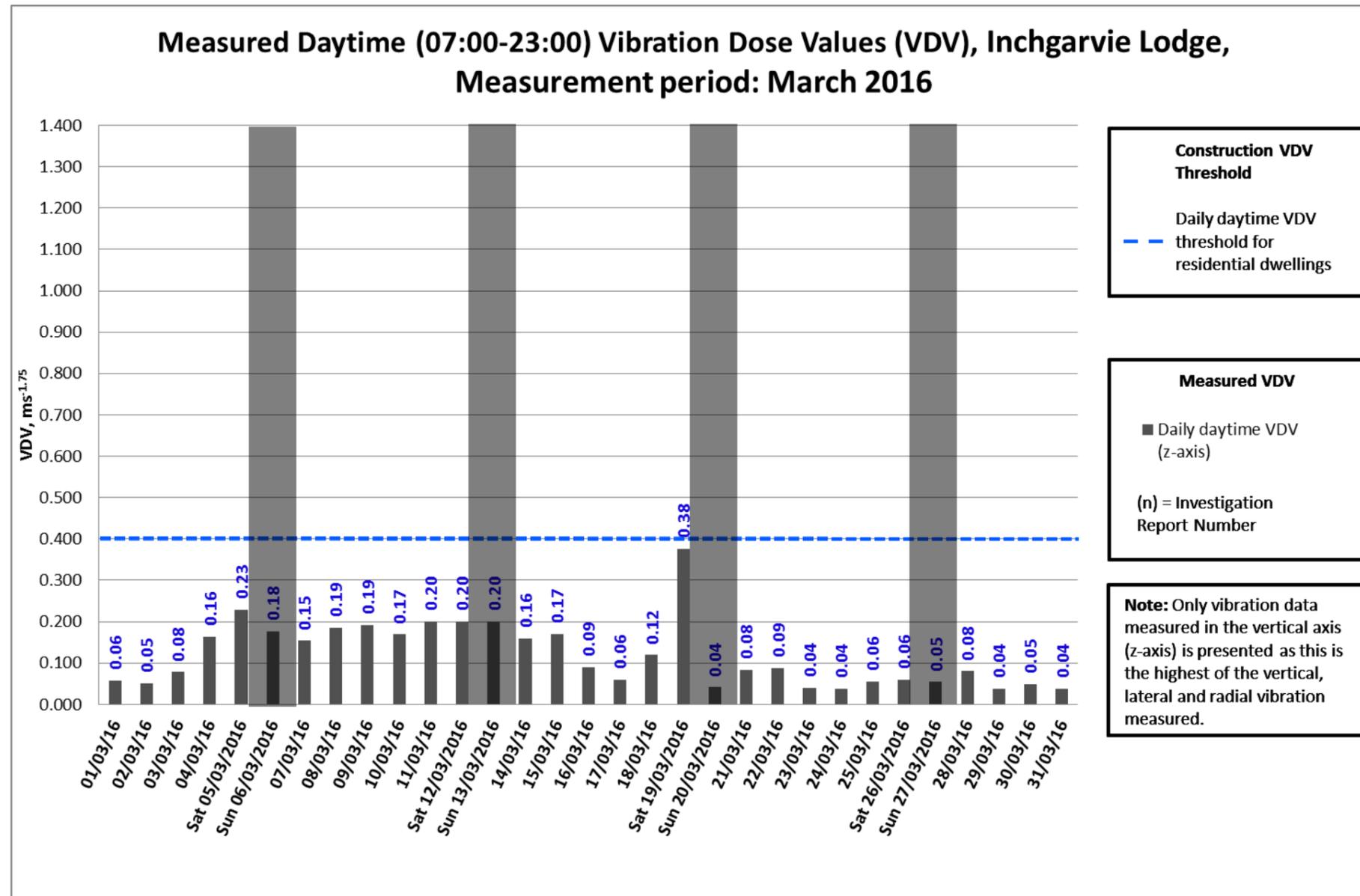


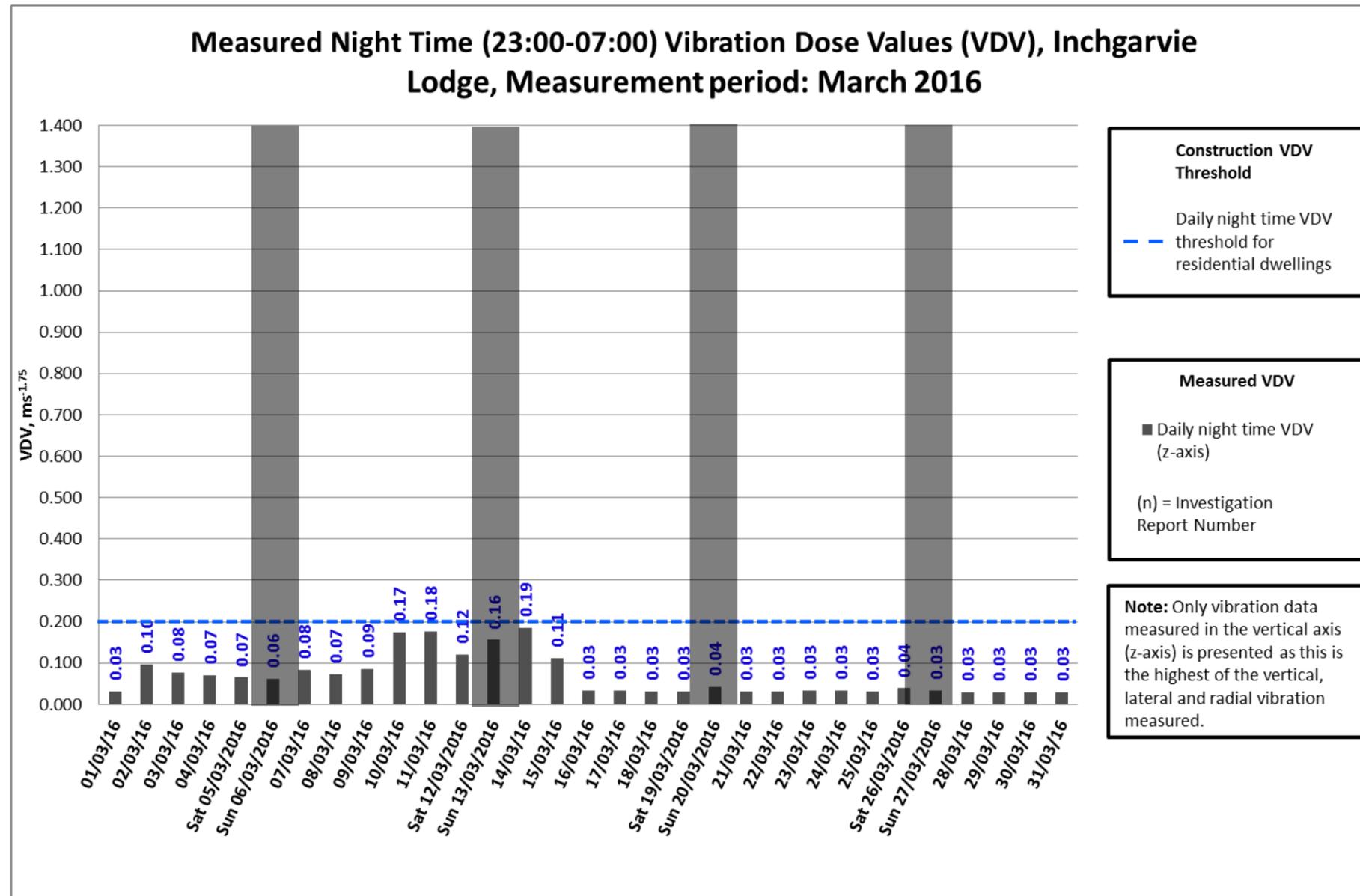


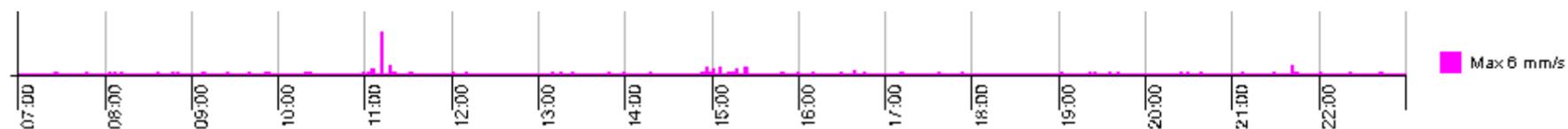
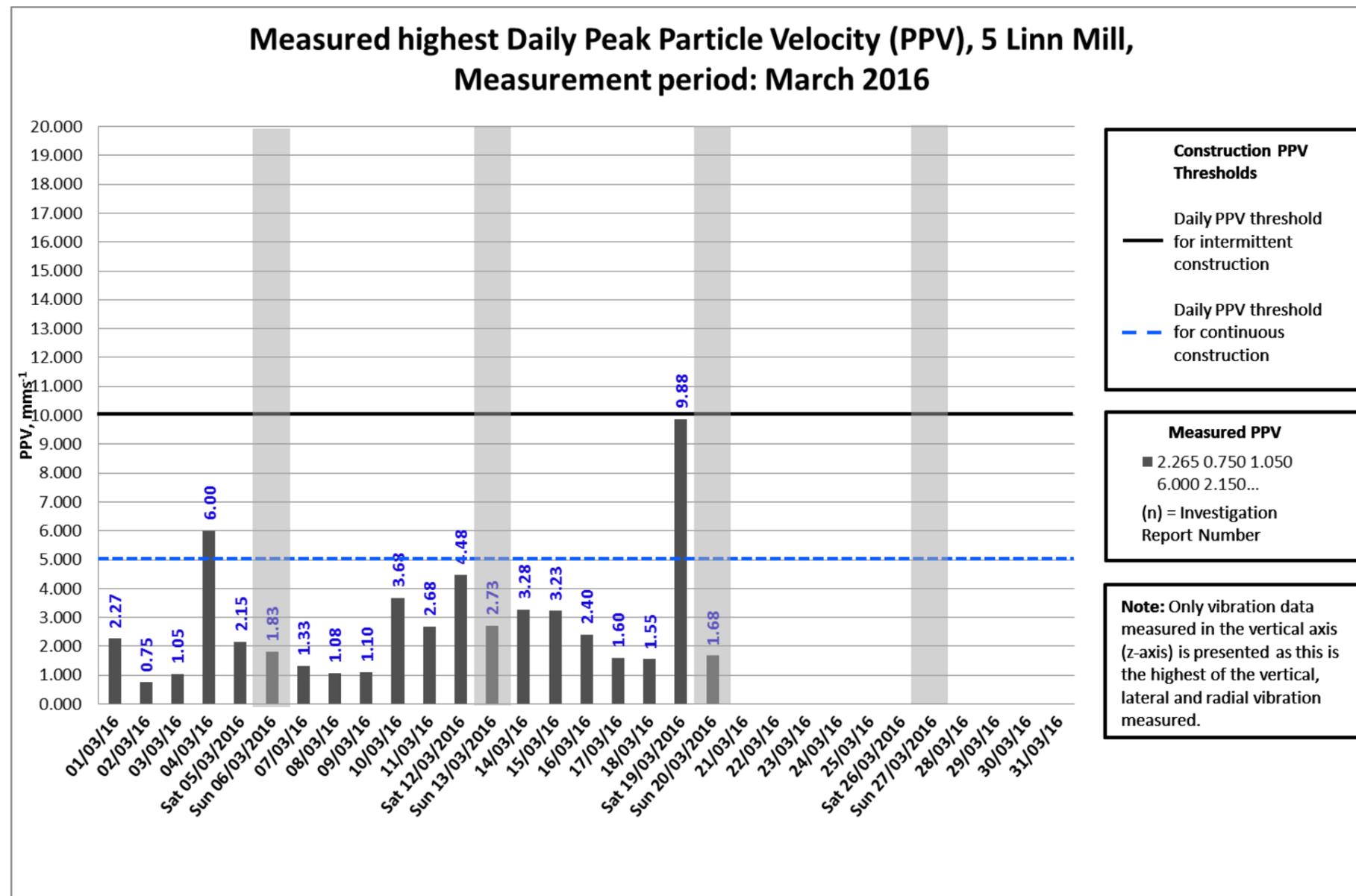




Exceedances on the 3<sup>rd</sup>, 6<sup>th</sup>, 9<sup>th</sup>, 21<sup>st</sup> and 29<sup>th</sup> have been investigated and found to be one off isolated events. During this period the closest works to the vibration monitor was approximately 160m away with minimal vibration emitting equipment used (rebar and concrete works). The vibration monitor is situated at a resident's house in which there was ongoing private construction works on the property which are likely to have been the cause of the vibration levels. On this basis it is highly unlikely that the vibration levels seen above have been caused by construction related activities (graph above from the 12/03/2016).

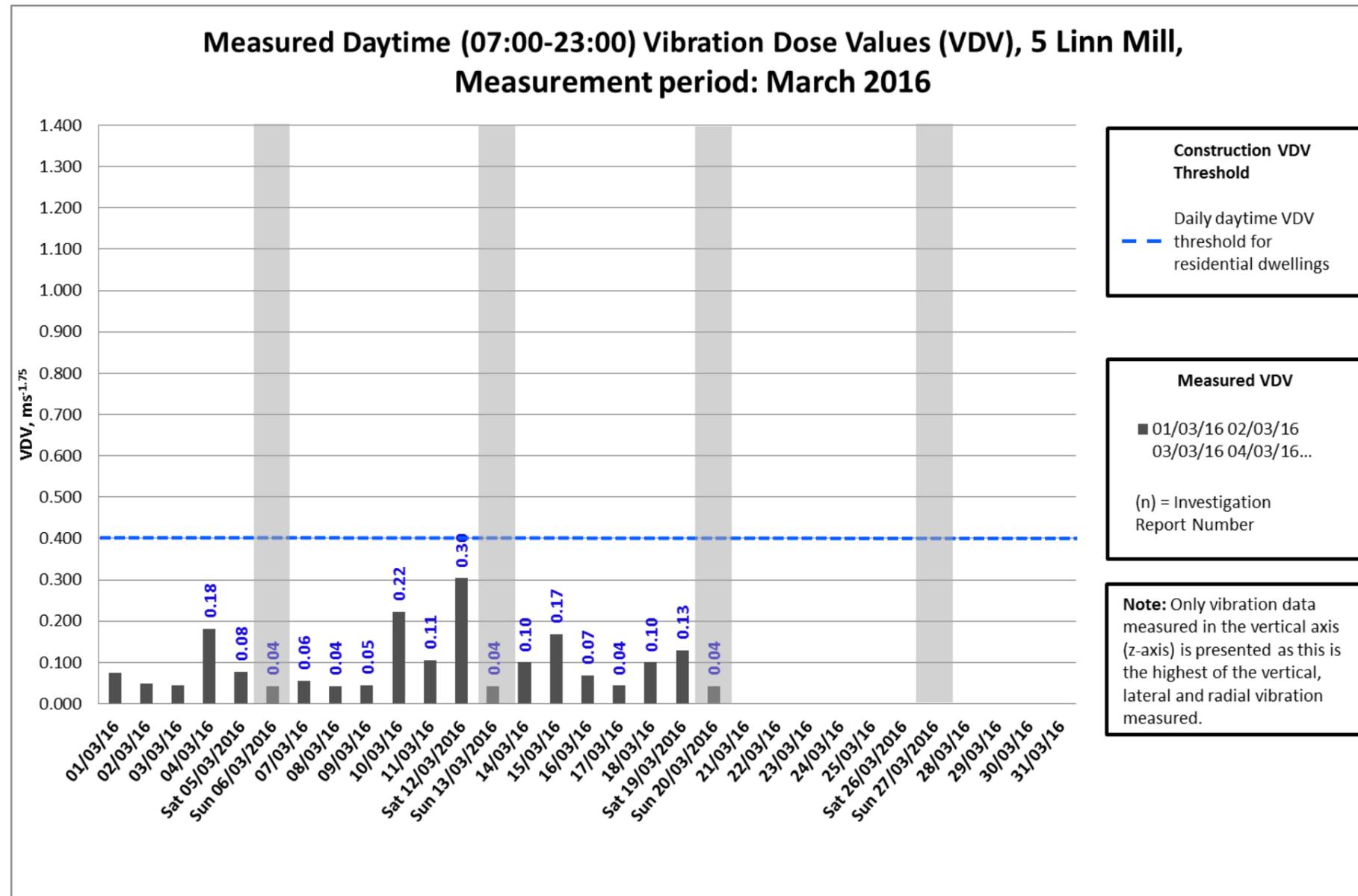




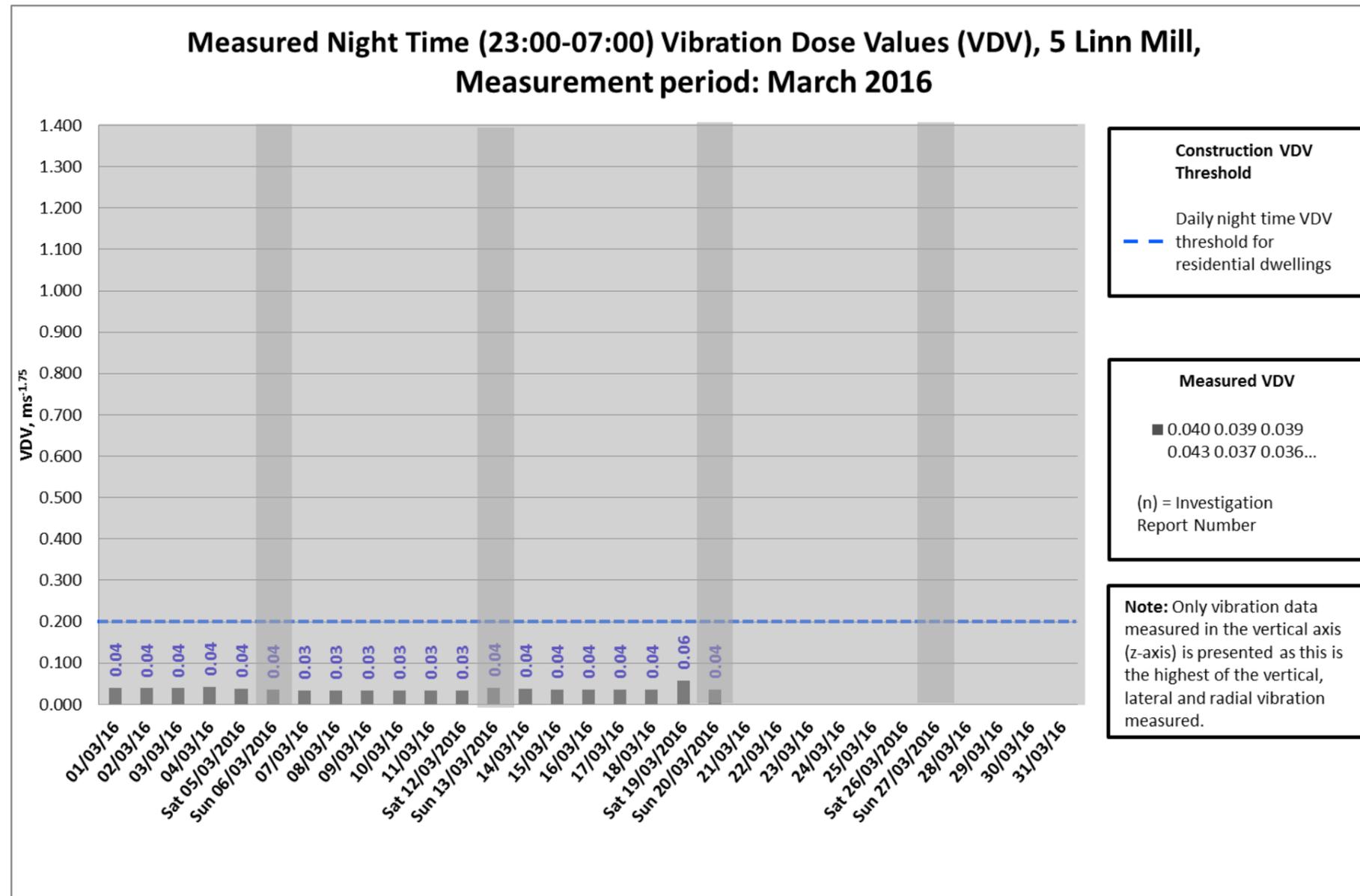


Exceedances on the 4<sup>th</sup> and 19<sup>th</sup> of March have been investigated and found to be individual isolated events. It is highly unlikely that these events were caused by construction related activities (graph above from the 04/03/2016). The monitor is situated in close proximity to the residents outdoor log store situated in the back garden. It is envisaged that these high readings were in fact due to the residents fetching logs from this store area.

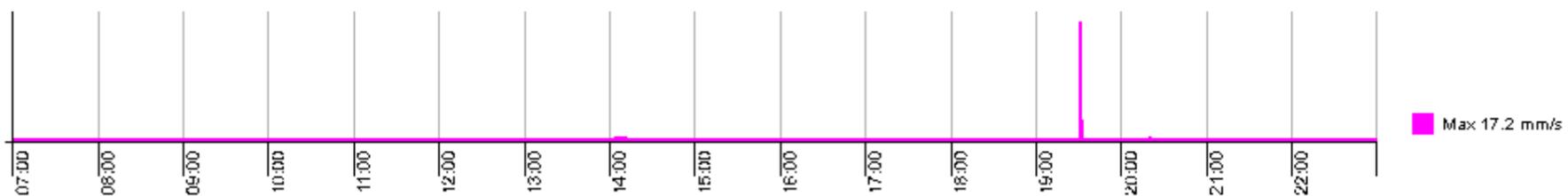
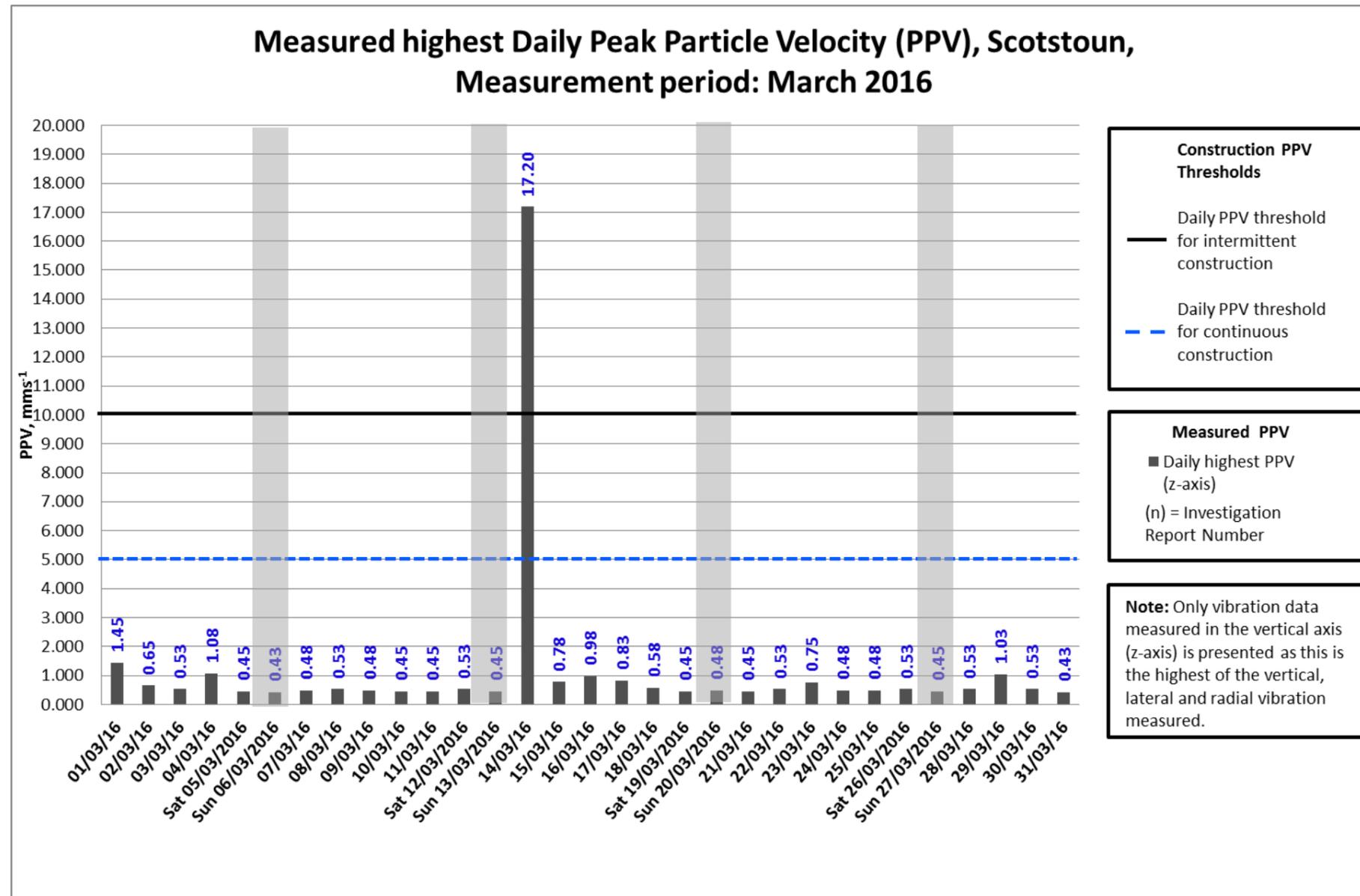
Data is missing during the period from 21<sup>st</sup> to the 31<sup>st</sup> of March due to a power fault to the monitor. This has since been resolved on the 1<sup>st</sup> of April.



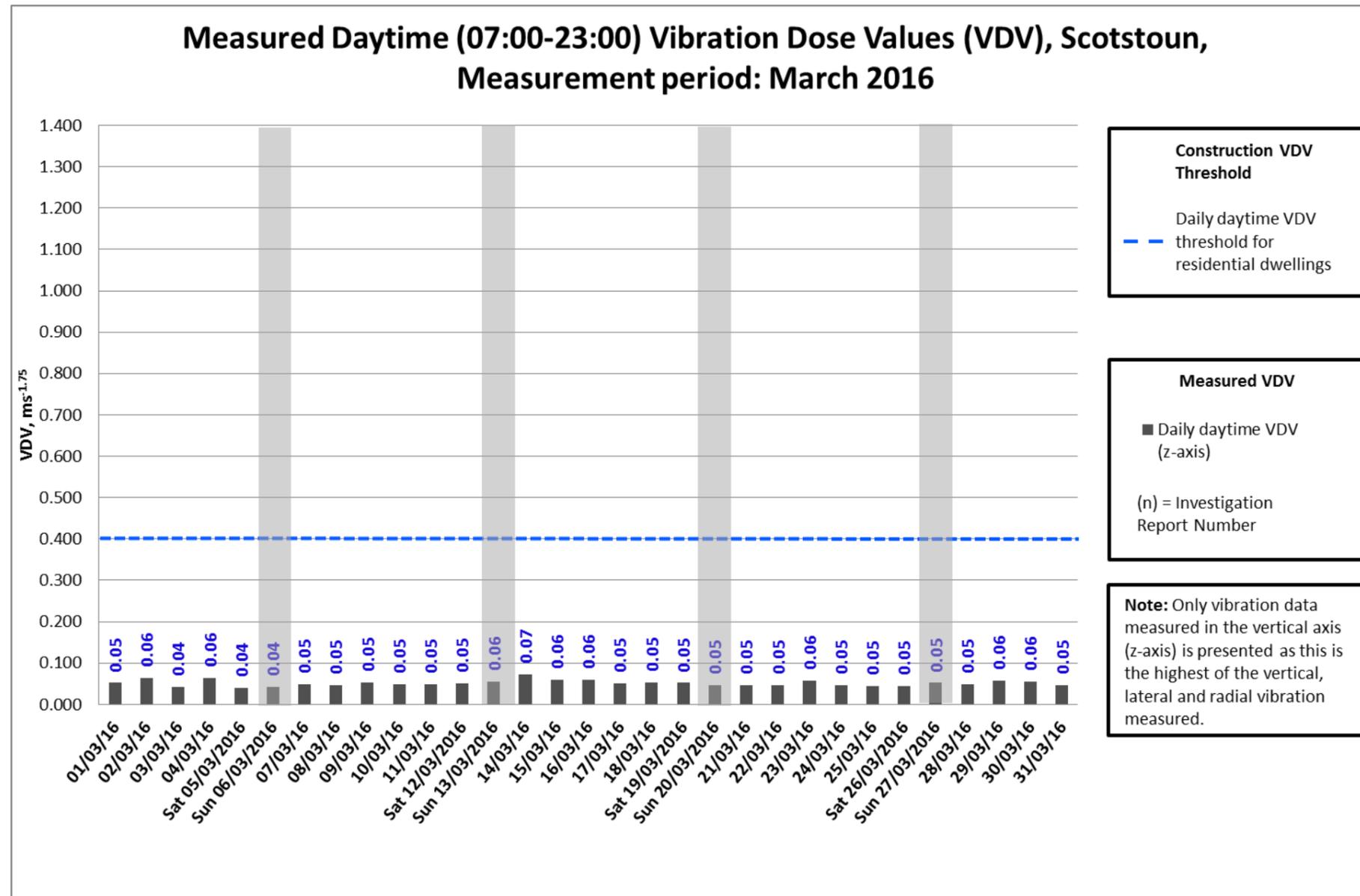
Data is missing during the period from 21<sup>st</sup> to the 31<sup>st</sup> of March due to a power fault to the monitor. This has since been resolved on the 1<sup>st</sup> of April.



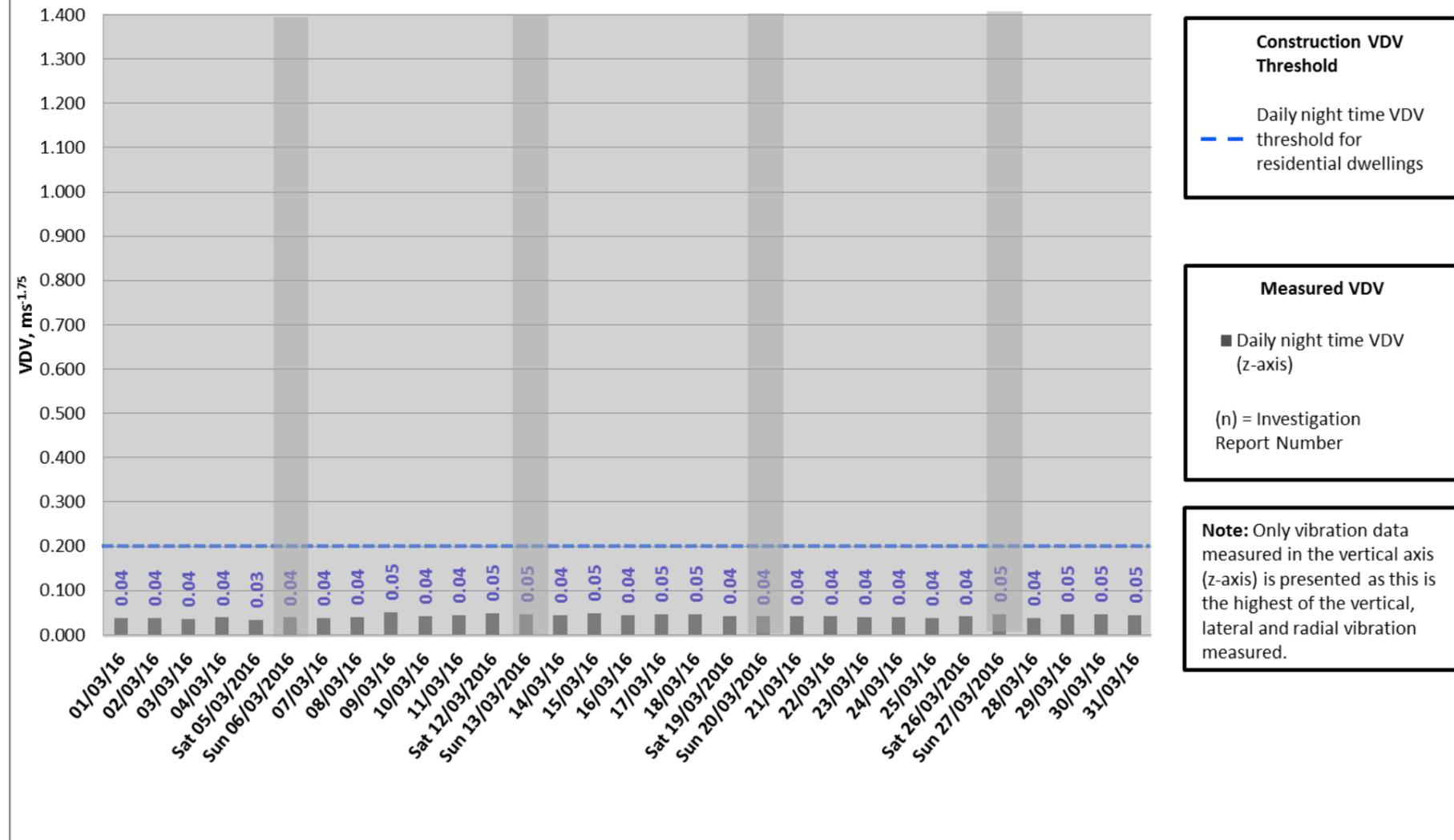
Data is missing during the period from 21st to the 31st of March due to a power fault to the monitor. This has since been resolved on the 1st of April.



Exceedance on the 14<sup>th</sup> of March has been investigated and found to be out with normal working hours and is unlikely to have been caused by construction related activities (graph above from the 14/03/2016).



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: March 2016



**Construction VDV Threshold**

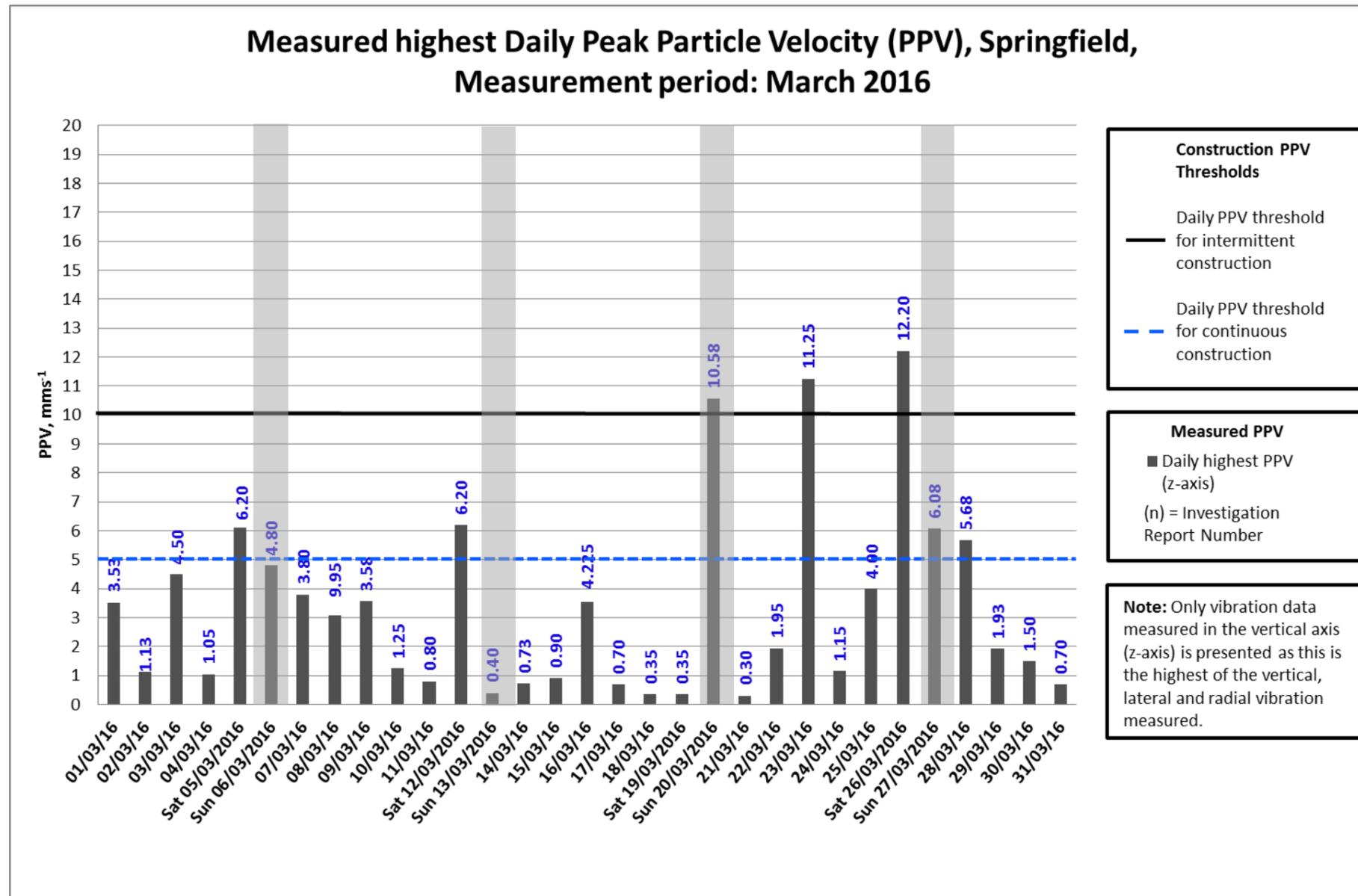
Daily night time VDV threshold for residential dwellings

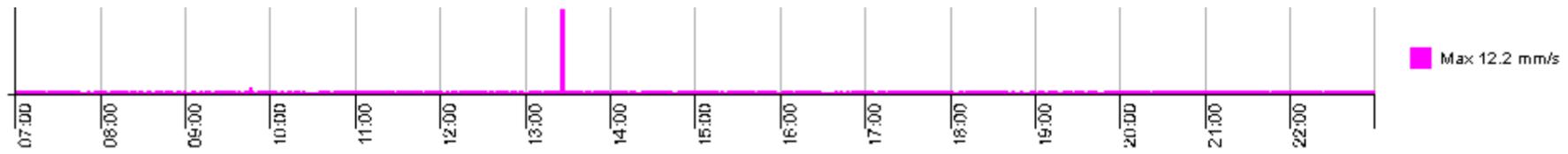
**Measured VDV**

■ 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.

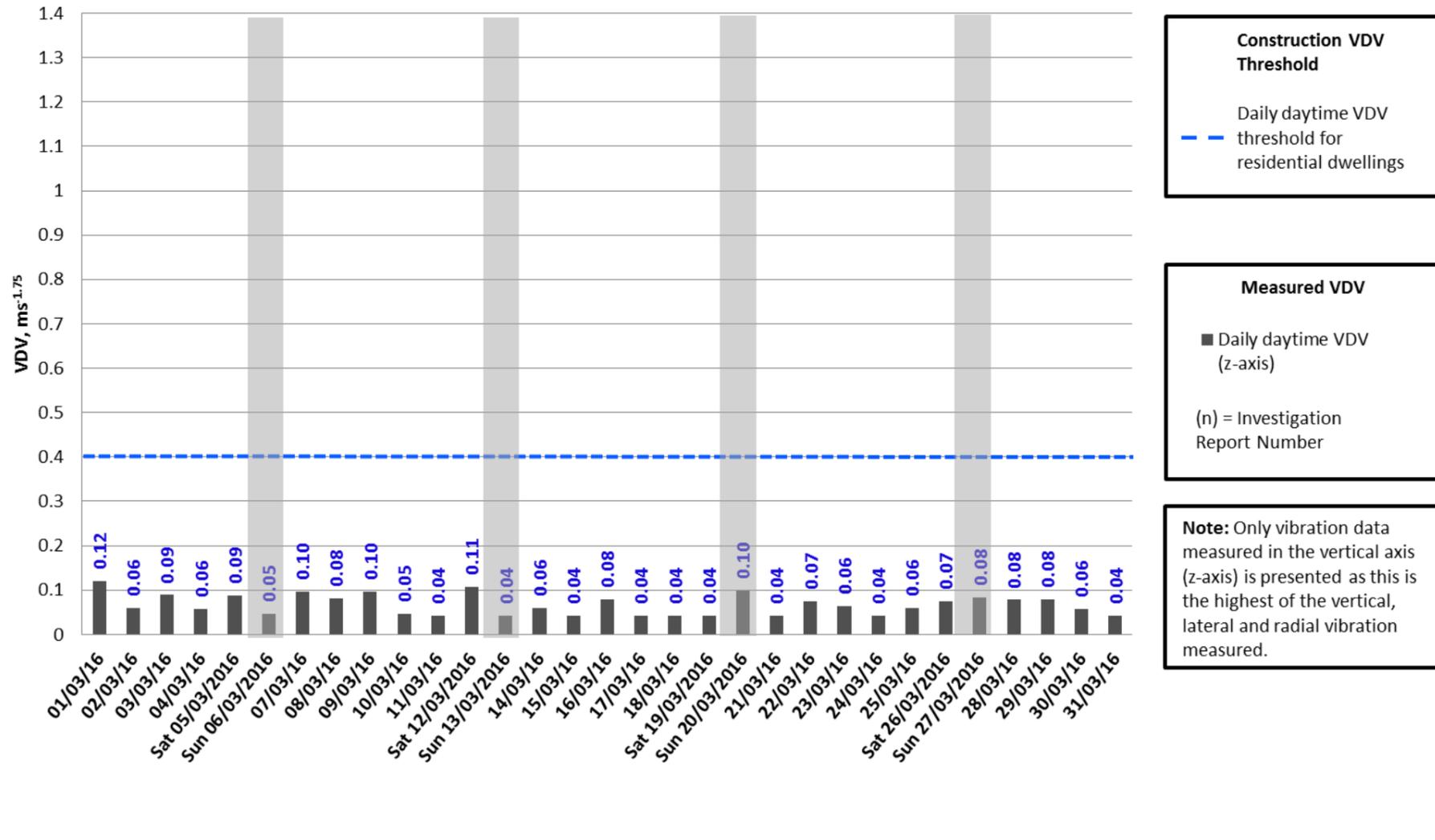




Exceedances on the 5<sup>th</sup>, 12<sup>th</sup>, 26<sup>th</sup> and 28<sup>th</sup> of March have been investigated and found to be isolated events that are unlikely to have been caused by construction related activities (graph above from the 26/03/2016)

Exceedances on the 20<sup>th</sup> and 27<sup>th</sup> of March have been investigated and found to be out with normal construction working hours of road networks with the closest works approximately 960m away it is unlikely that the exceedances were caused by construction related activities.

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield, Measurement period: March 2016



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

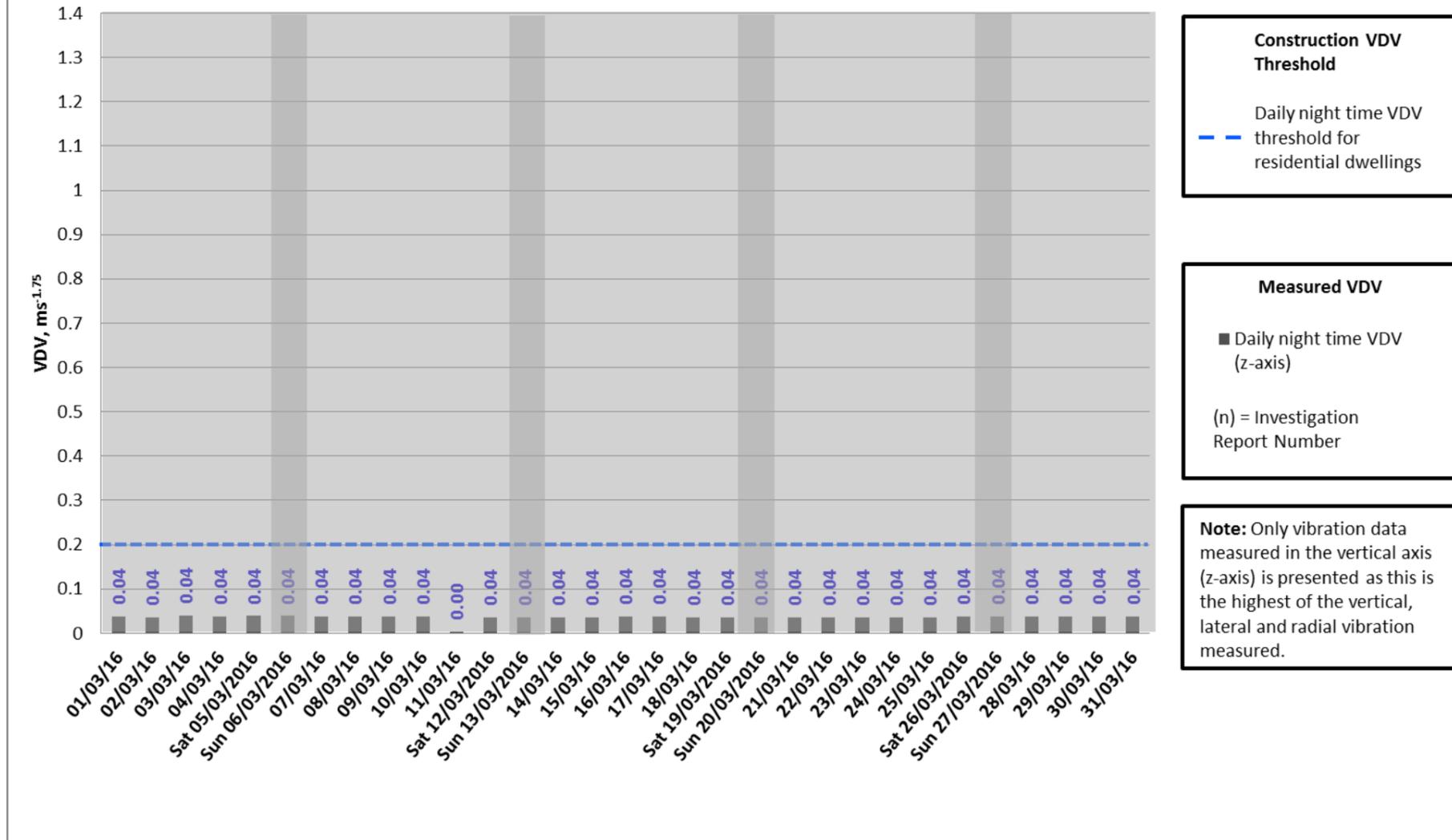
**Measured VDV**

■ Daily daytime VDV (z-axis)

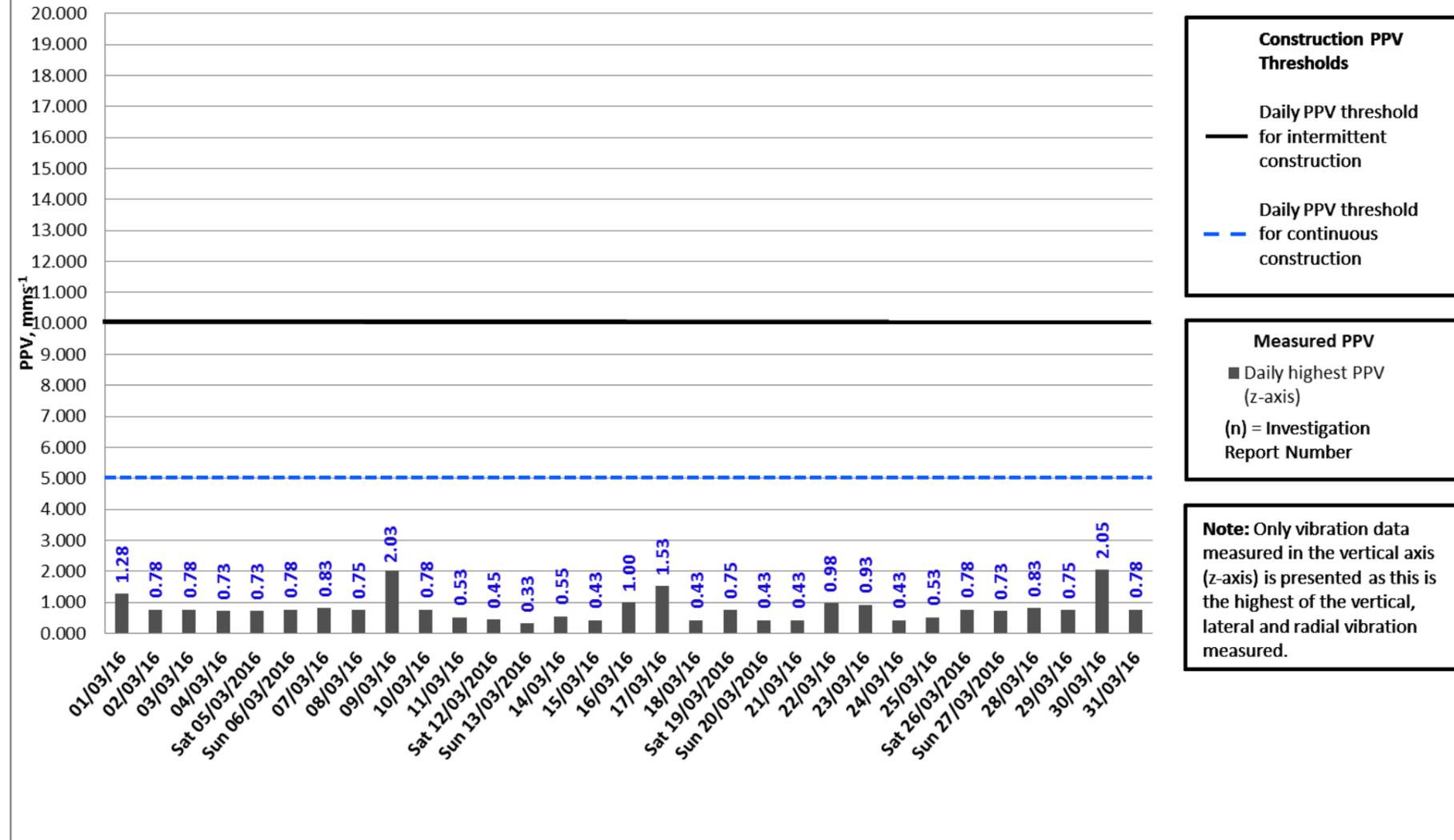
(n) = Investigation Report Number

**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: March 2016



### Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na Grian, Measurement period: March 2016



**Construction PPV Thresholds**

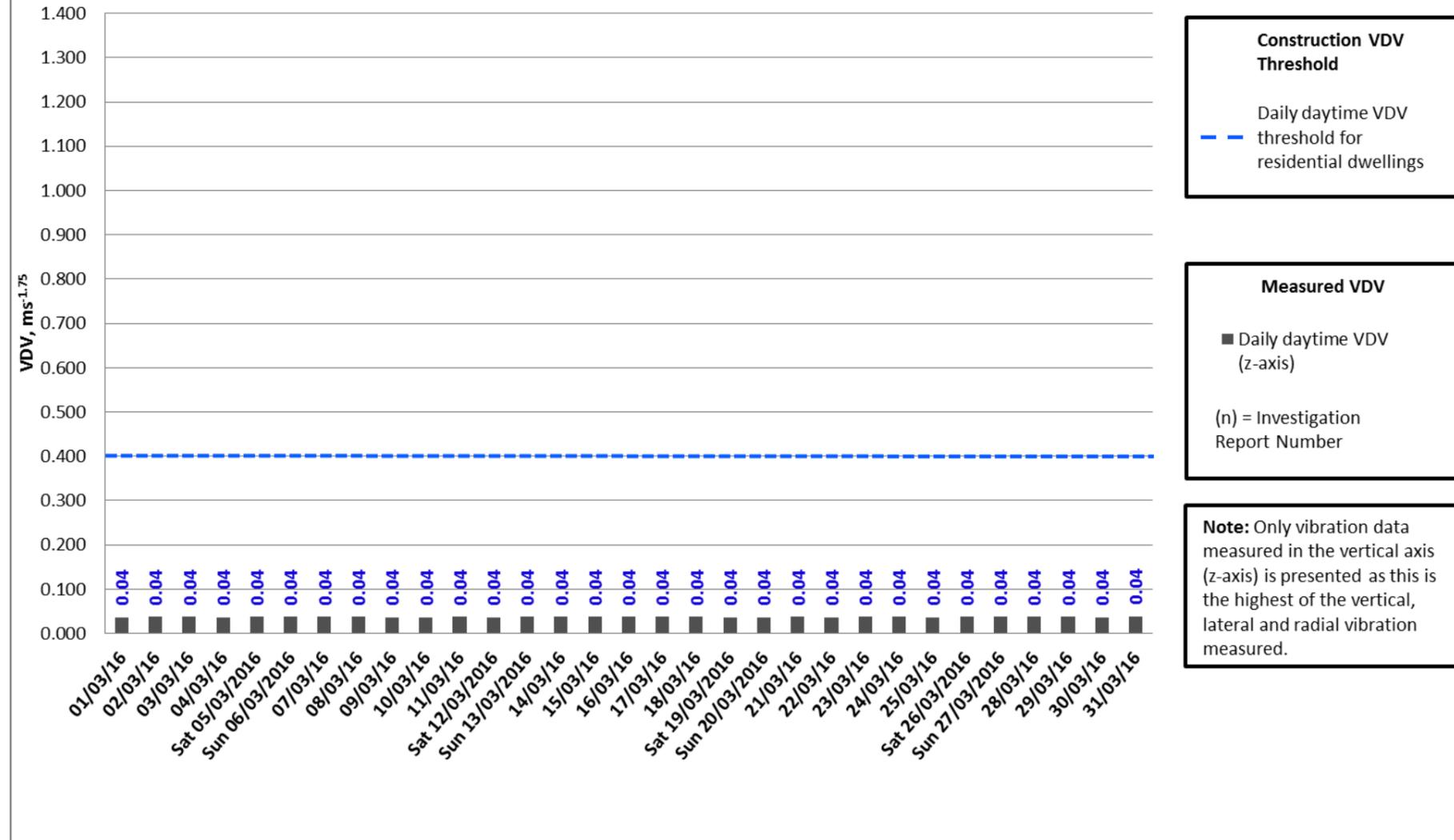
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

**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: March 2016



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

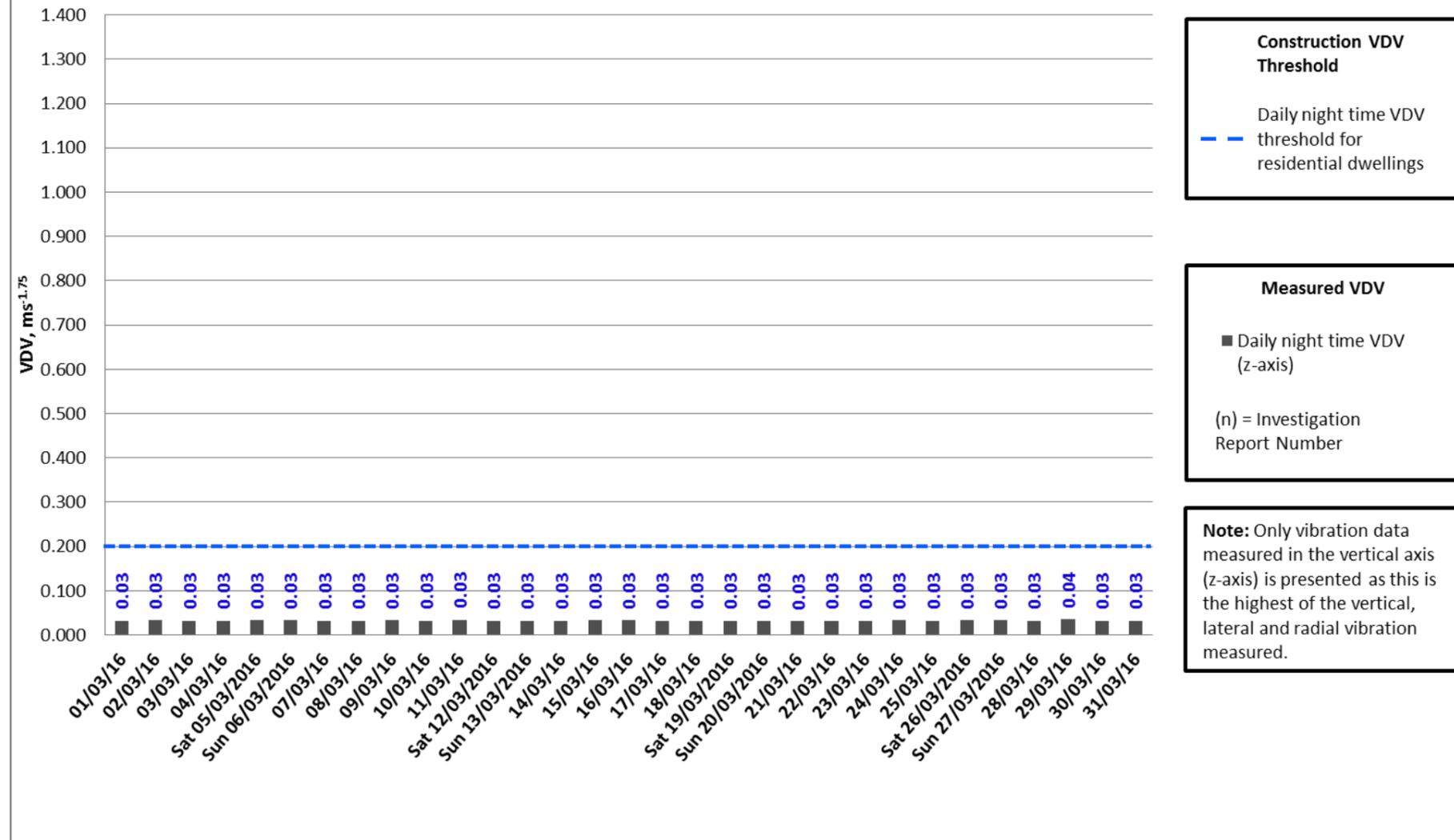
**Measured VDV**

■ 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: March 2016



**Construction VDV Threshold**

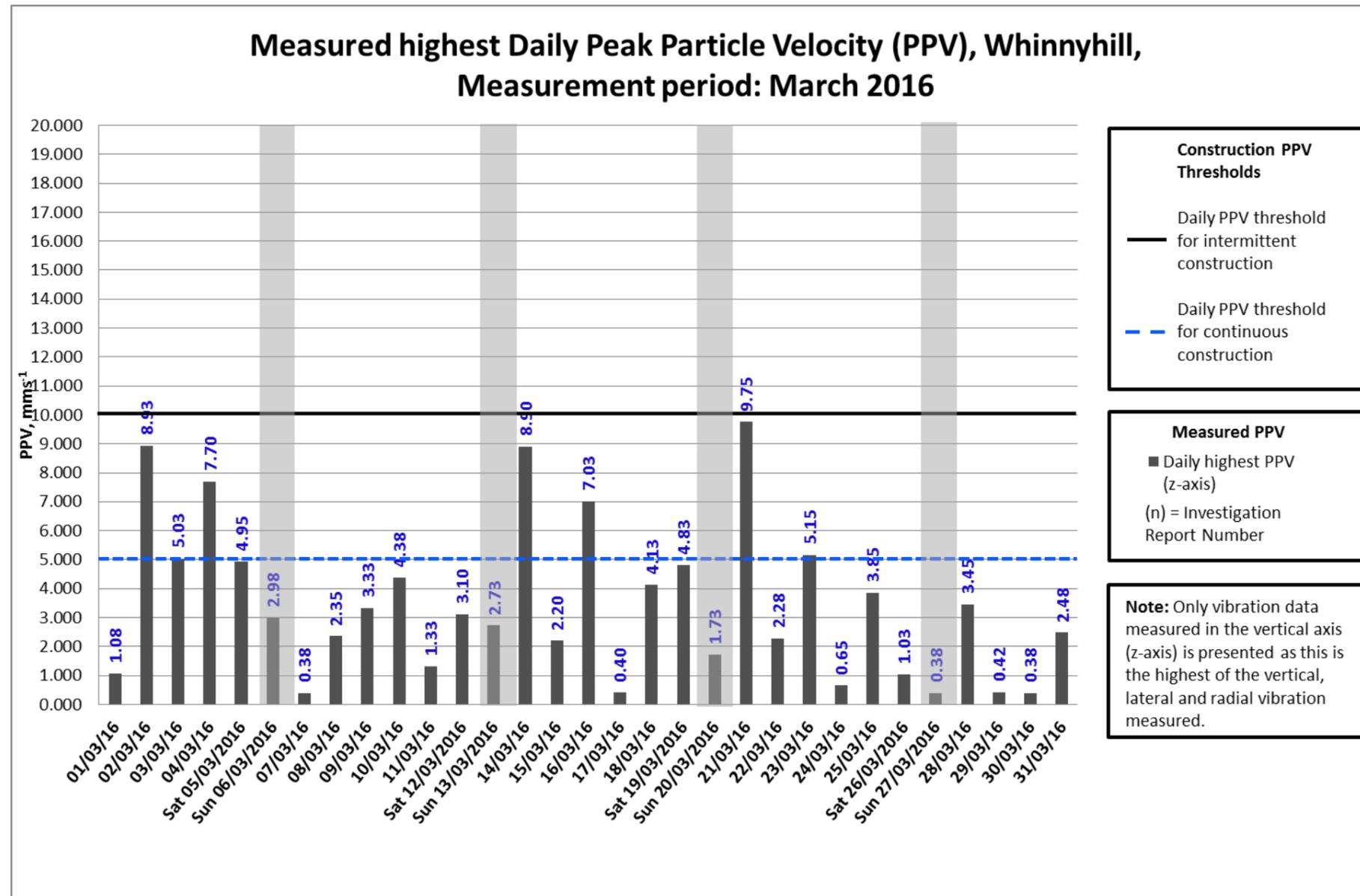
Daily night time VDV threshold for residential dwellings

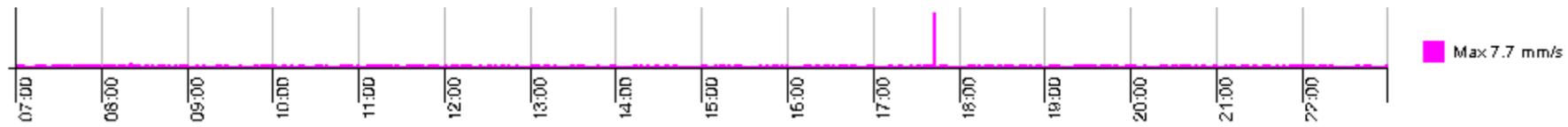
**Measured VDV**

■ Daily night time VDV (z-axis)

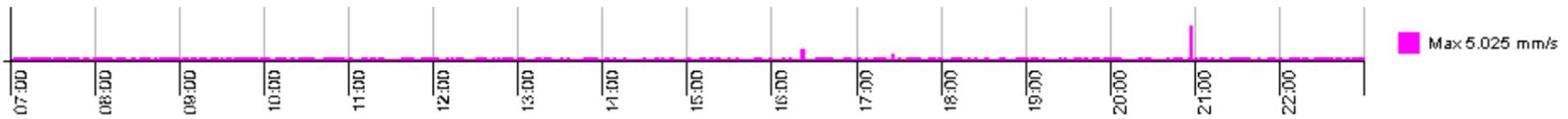
(n) = Investigation Report Number

**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.



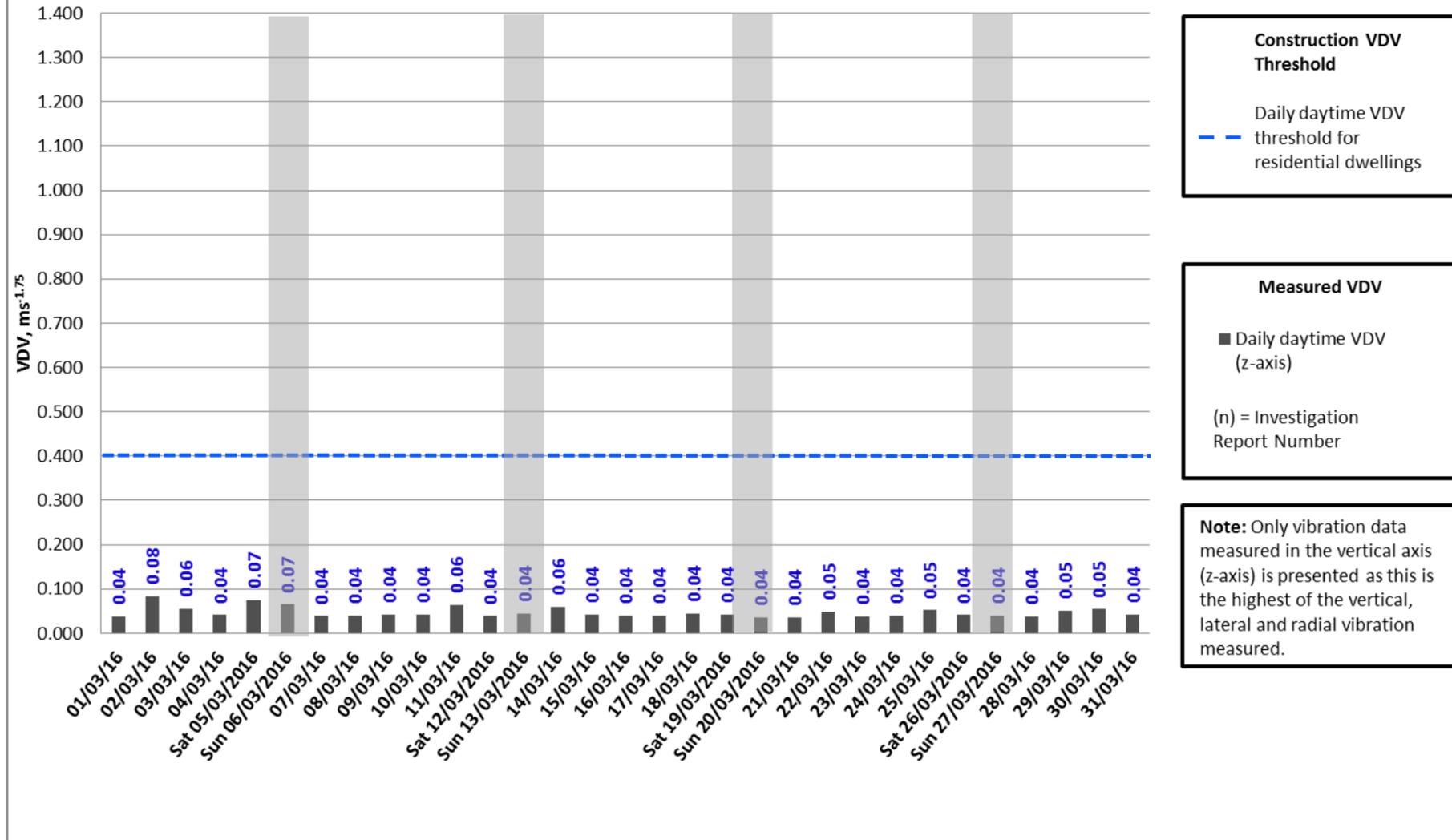


Exceedances on the 2<sup>nd</sup>, 4<sup>th</sup>, 15<sup>th</sup> and 23<sup>rd</sup> of March have been investigated and found to be caused by isolated events that are unlikely to have been caused by construction related activities (graph above from the 4/03/2016).



Exceedances on the 3<sup>rd</sup>, 14<sup>th</sup> and 21<sup>st</sup> of March have been investigated and found to be out with normal construction working hours of road networks with the closest works approximately 1700m away at north tower it is unlikely that the exceedances were caused by construction related activities.

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: March 2016



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

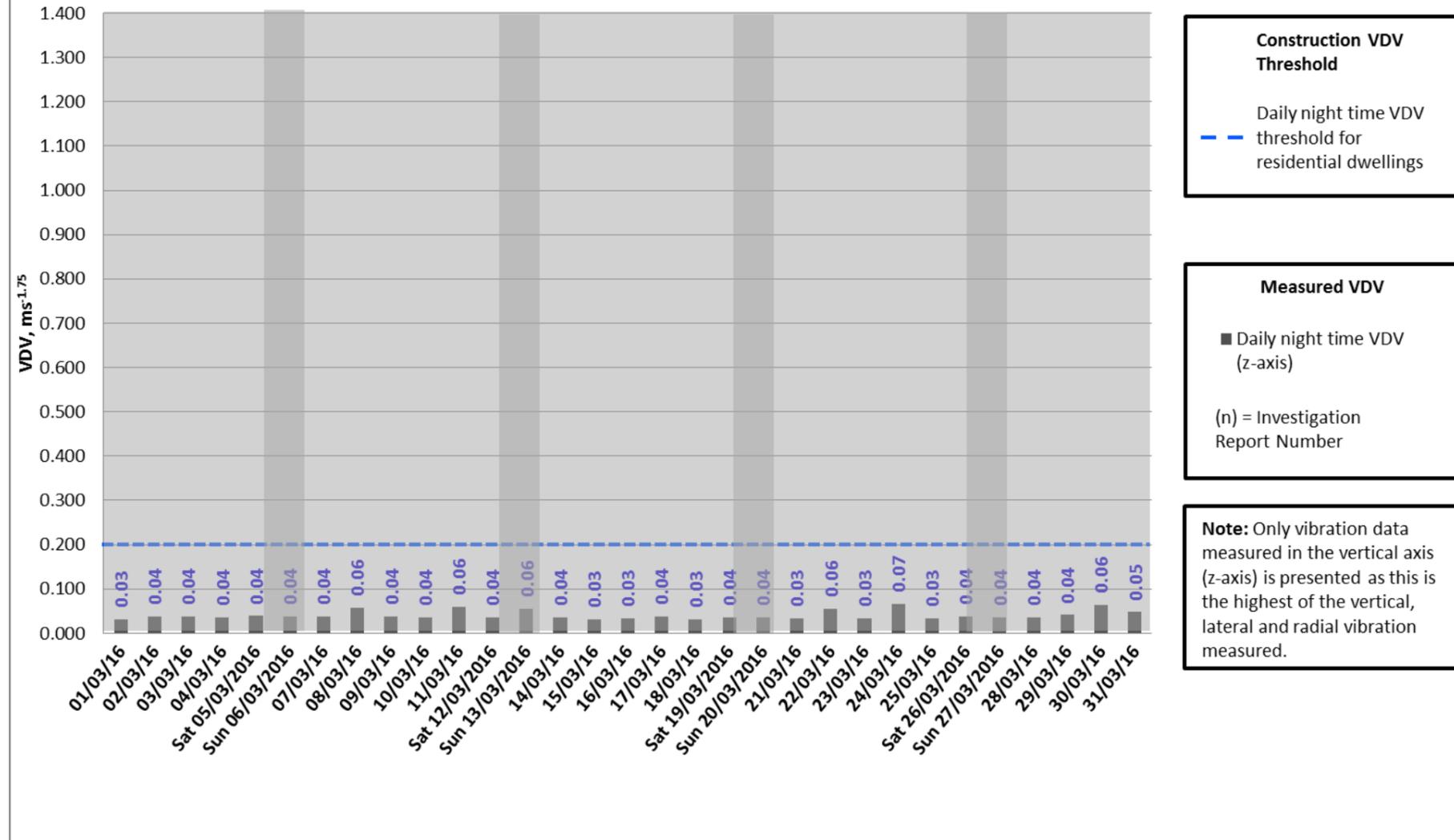
**Measured VDV**

■ 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), Whinnyhill, Measurement period: March 2016



**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.