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FCBC

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Project FORTH REPLACEMENT CROSSING

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VIBRATION MONITORING REPORT

JULY 2016

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## INTRODUCTION

- 1.1. Monitoring of construction vibration is being undertaken by FCBC during the construction of the new Forth Crossing and associated road network. This report covers the month of July 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, footsteps or 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 vibration, and damage resulting solely from well-controlled construction and demolition vibration is rare. There are many other mechanisms that 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 of FCBC construction-related vibration is highly unlikely.
- 2.5.** The number of threshold exceedances at the various vibration monitoring stations during the relevant period are shown in Table 1 below.

**Table 1: Number of exceedances of thresholds set out in the CoCP**

*July 2016*

Location	PPV Exceedance		VDV Exceedance	
	<i>Continuous</i> (5 mm.s <sup>-1</sup> )	<i>Intermittent</i> (10 mm.s <sup>-1</sup> )	<i>Day</i> (0.4 m.s <sup>-1.75</sup> )	<i>Night</i> (0.2 m.s <sup>-1.75</sup> )
Linn Mill	0	0	0	0
Butlaw Fisheries	1	1	0	0
Clufflat Brae	16	4	0	0
Dundas Home Farm	0	2	0	0
Echline	0	0	0	0
Inchgarvie Lodge	3	3	0	0
Scotstoun	0	0	0	0
Springfield	12	3	0	0
Tigh-Na-Grian	0	0	0	0
Whinnyhill	11	4	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 of the 3 axis that are 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 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 (night time) or 16-hour (day time) 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 however no exceedances were recorded as a result of the use of this equipment.
- 2.12.** Detailed investigation of all other exceedances (i.e. review of PPV levels over 30 seconds periods) has suggested that each resulted from isolated, non-construction related events, which occurred close to the monitoring station.
- 2.13.** Within the Appendix B, there are gaps of missing data in the PPV and VDV of Butlaw and Inchgarvie graphs. These occurred due to a power supply issue that was quickly resolved by the environmental department.



### **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.



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

**Table 2: Monitoring Locations**

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During July 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>• FT19 Works</li> <li>• FT10 Bridge Demolition</li> <li>• Main carriageway Roadworks</li> <li>• Rock breaking / 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>• AVN Rebar and concrete works</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 works</li> <li>• Pier S2 works</li> <li>• Pier S3 Hydro-demolition</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 works</li> <li>• Pier S2 works</li> <li>• Pier S3 Hydro-demolition</li> <li>• AVS rebar &amp; concrete deck works</li> <li>• South Abutment 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>• South Abutment works</li> <li>• Excavation and breaking of SuDS detention basin</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>• South Abutment works</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>• South abutment works</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• South abutment works</li> <li>• Main carriageway roadworks</li> </ul>
M16	Scotstoun	Network	<ul style="list-style-type: none"> <li>• Footpath works</li> <li>• Utility works</li> </ul>



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			<ul style="list-style-type: none"> <li>• B800 North and South road works including bridge works</li> <li>• ESQ11 works</li> <li>• Mainline roadworks</li> </ul>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> <li>• Utility works</li> <li>• B800 North and South roadworks including bridge works</li> <li>• Mainline roadworks</li> </ul>

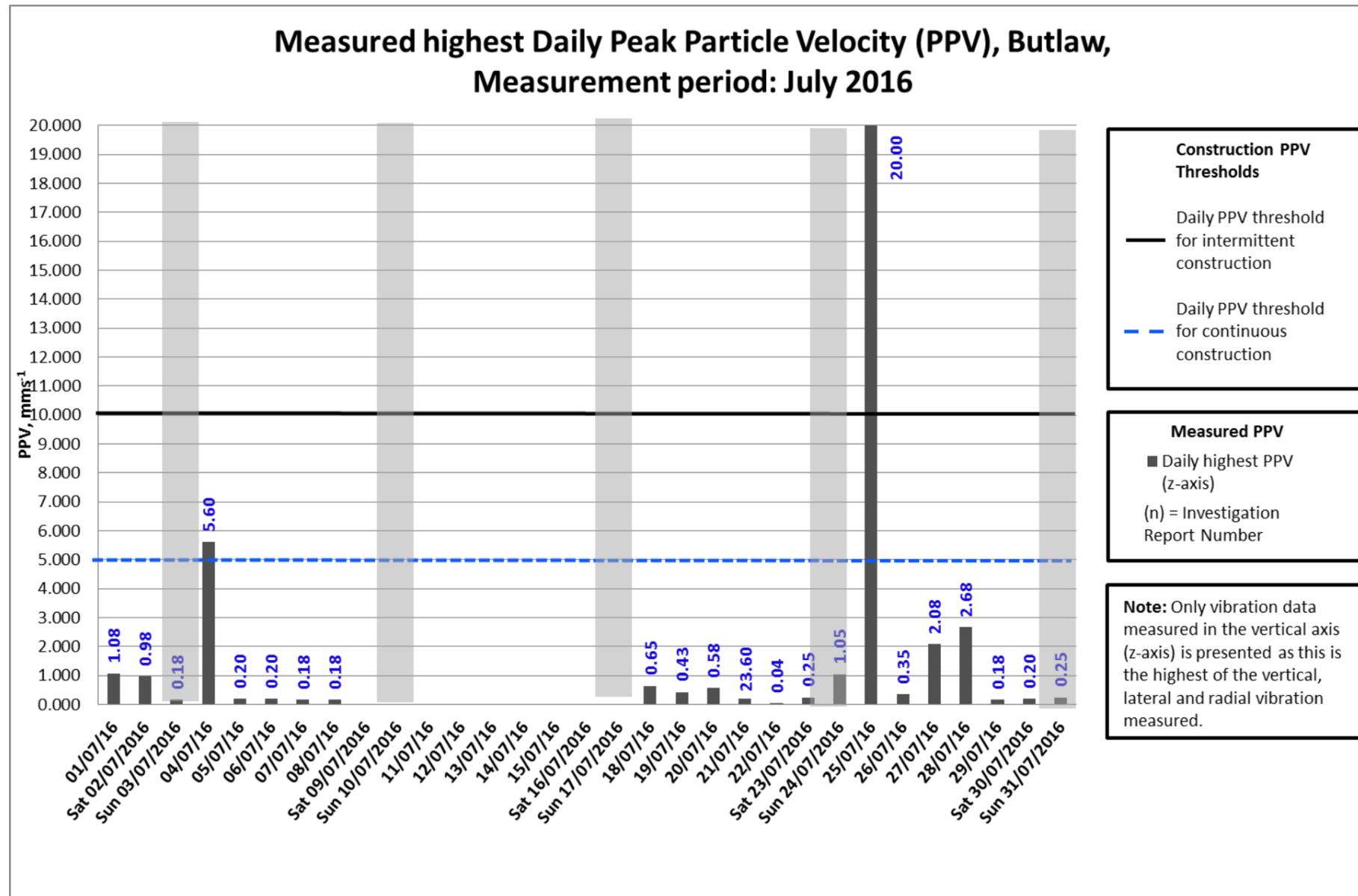
**Table 3: PCNV Predicted PPV & VDV Levels**

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	Roller/Whacker	0.383	0.04

**Notes on Table 3**

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

## APPENDIX B – VIBRATION GRAPHS

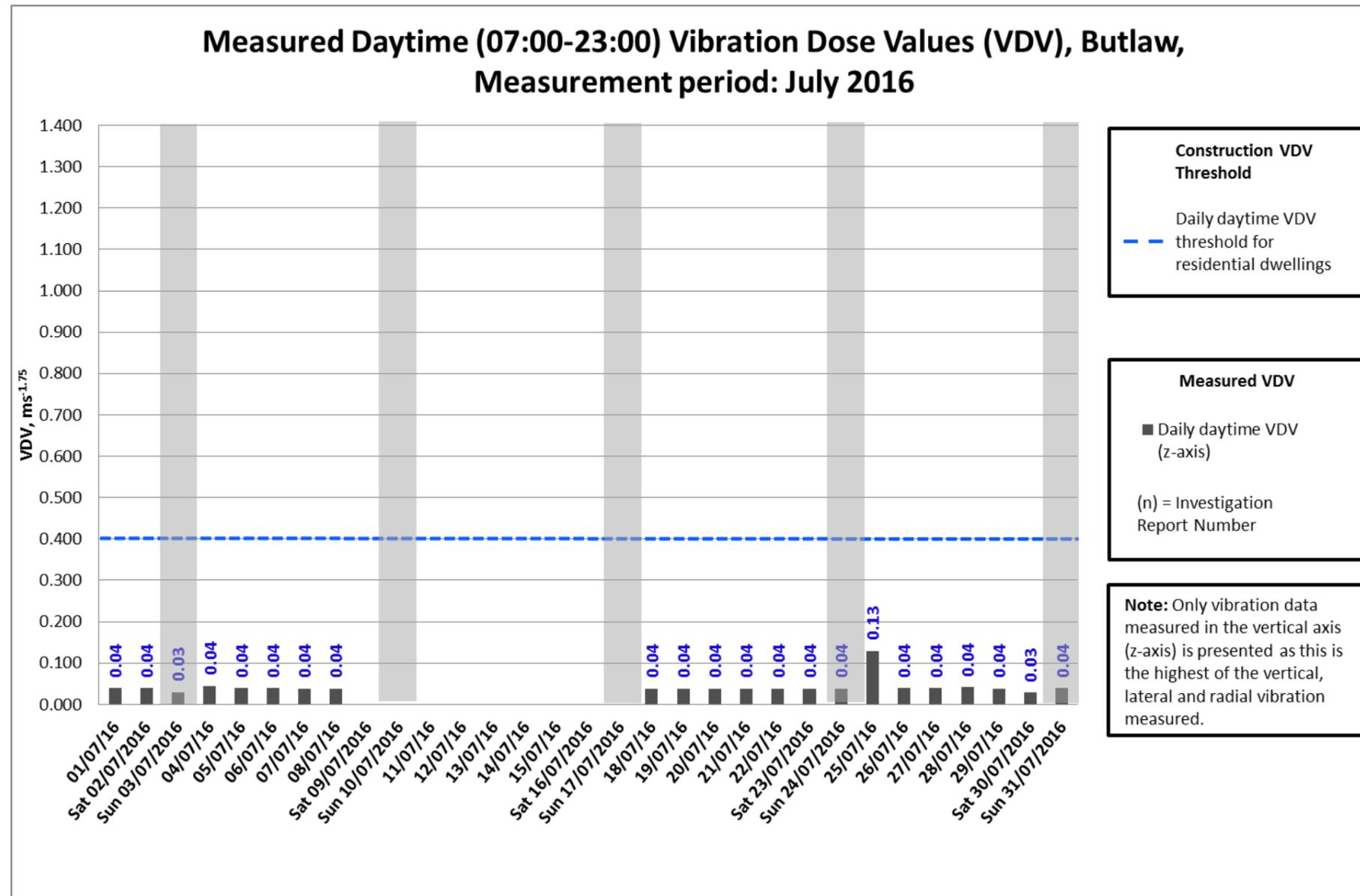


Exceedance on the 4<sup>th</sup> of July has been investigated and found to be caused by the environmental department carrying out monitor maintenance on the noise monitor. Due to the proximity of the noise monitor to the transducers (part of the device that picks up the vibration) movement made by the environmental department was picked up (graph above from the 04/07/2016).

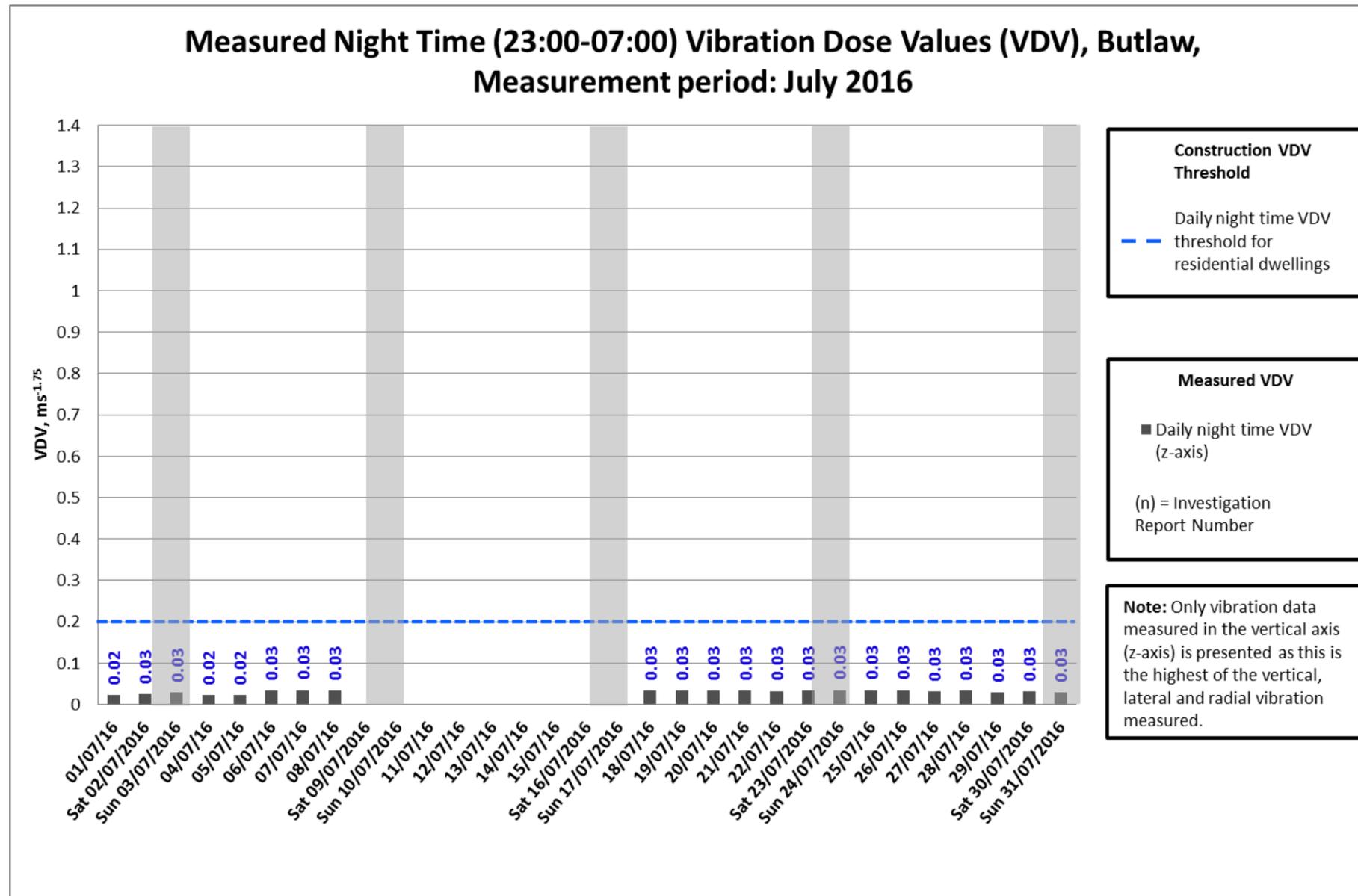


Exceedance on the 25<sup>th</sup> of July has been investigated and found to be caused by the residential gardener cutting the grass where the vibration monitor is located.

Data missing from the 9<sup>th</sup> to the 17<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 18<sup>th</sup> of July.

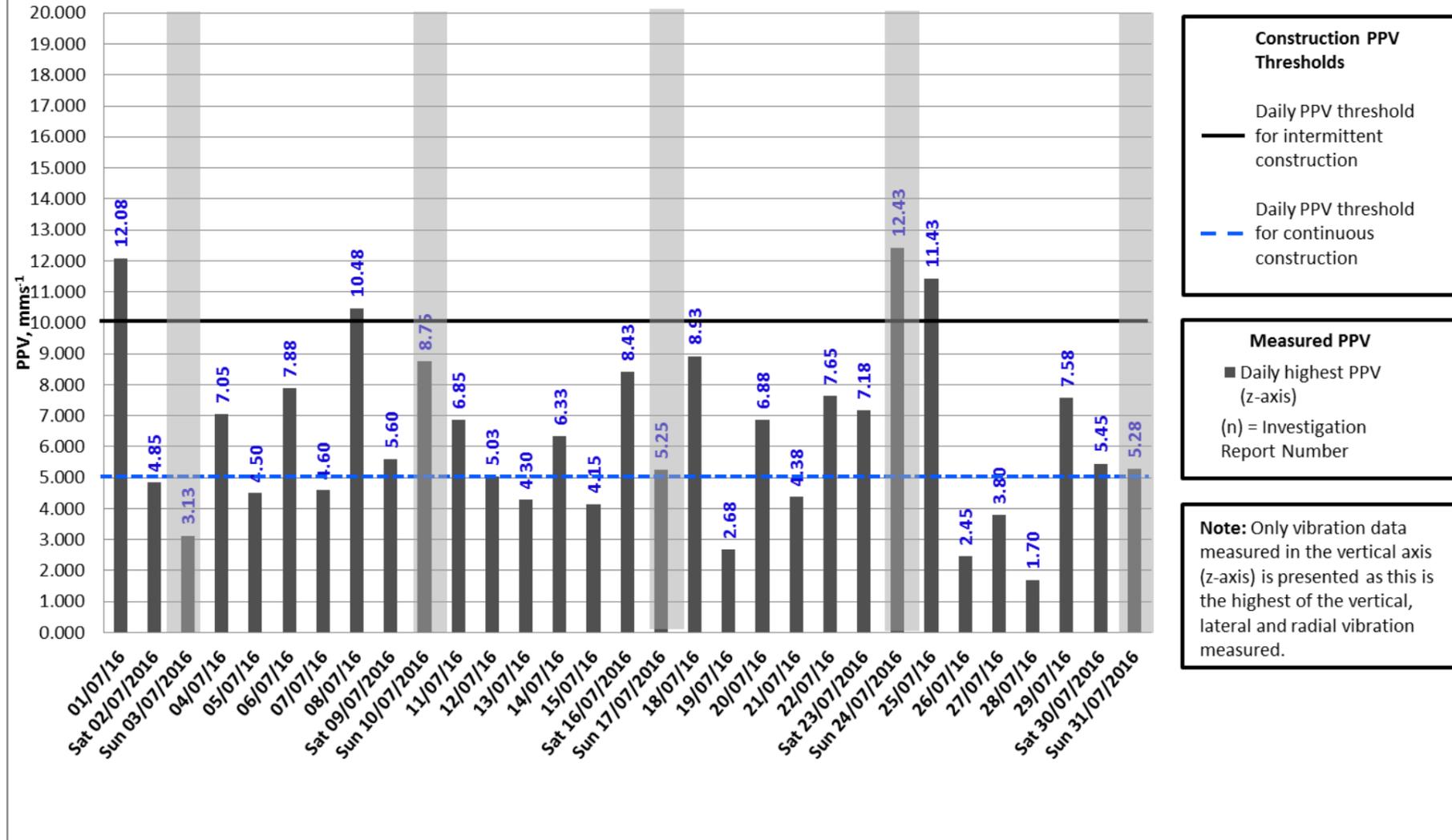


Data missing from the 9<sup>th</sup> to the 17<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 18<sup>th</sup> of July.



Data missing from the 9<sup>th</sup> to the 17<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 18<sup>th</sup> of July.

### Measured highest Daily Peak Particle Velocity (PPV), Clufflat Brae, Measurement period: July 2016



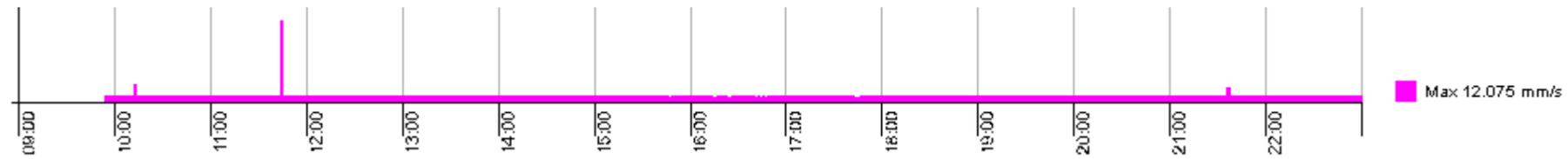
**Construction PPV Thresholds**

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

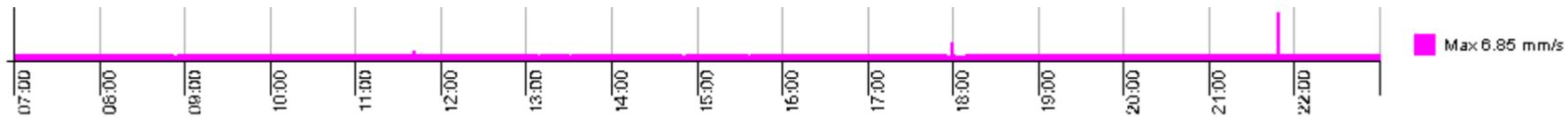
**Measured PPV**

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

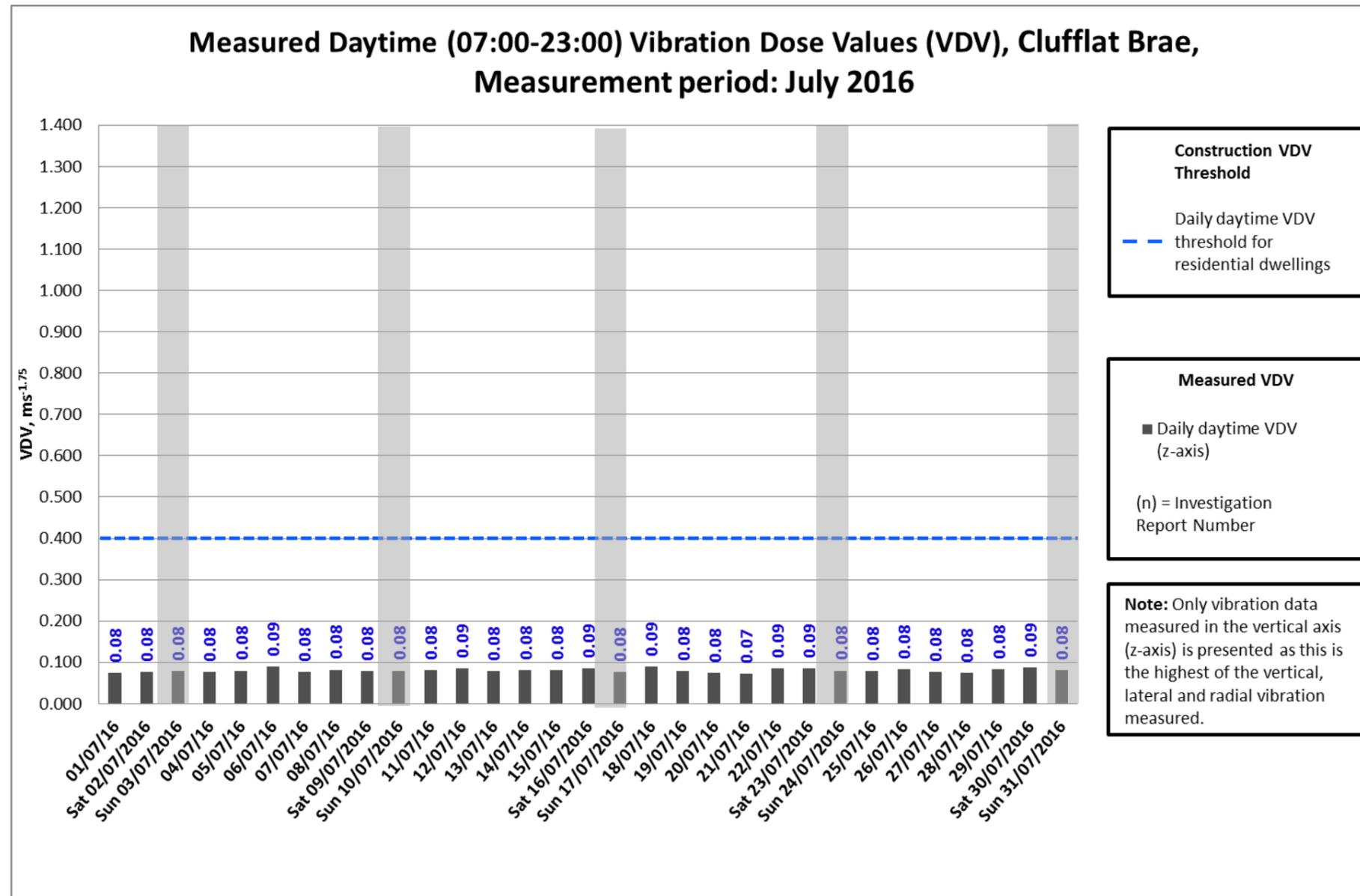
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

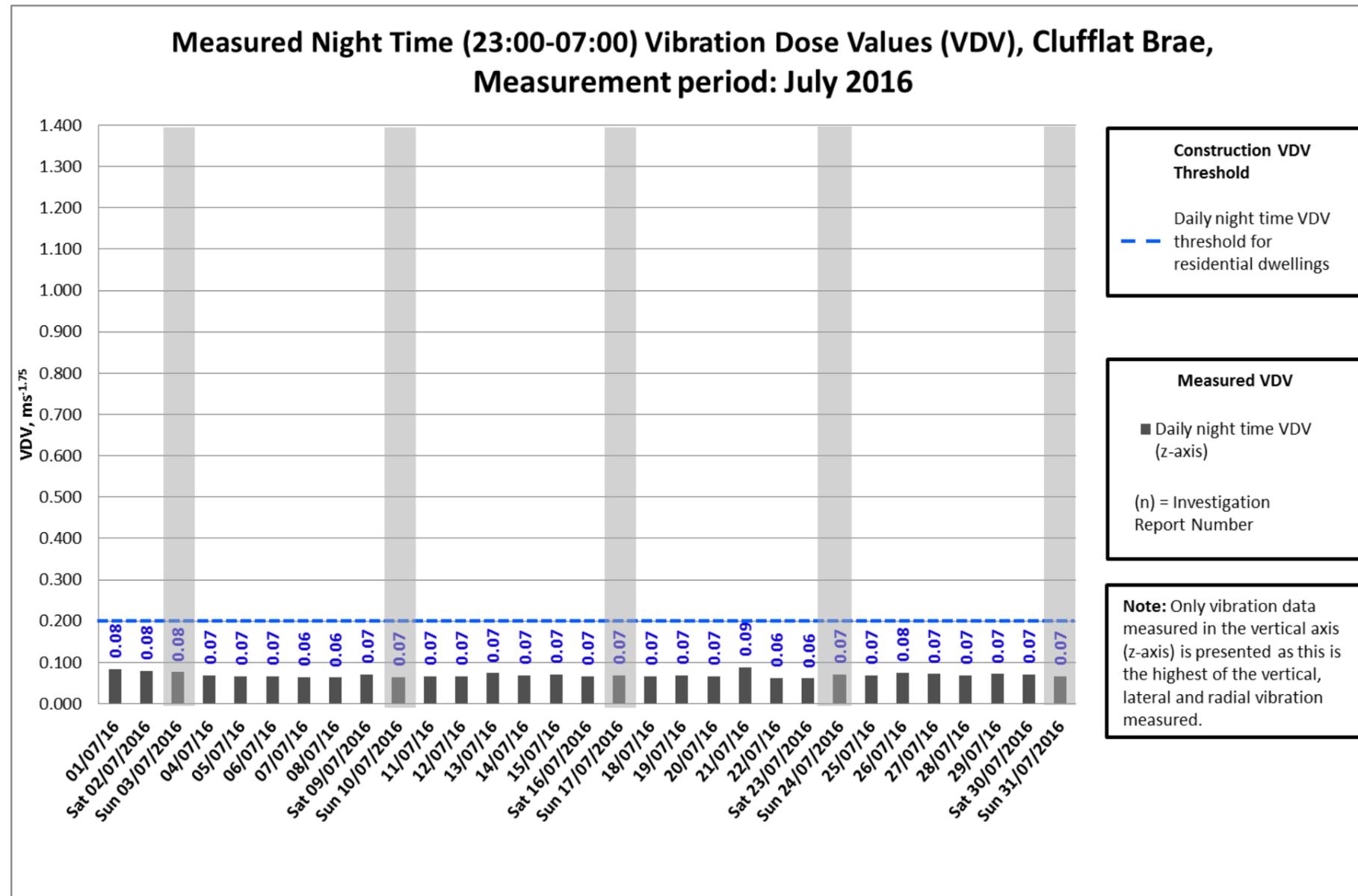


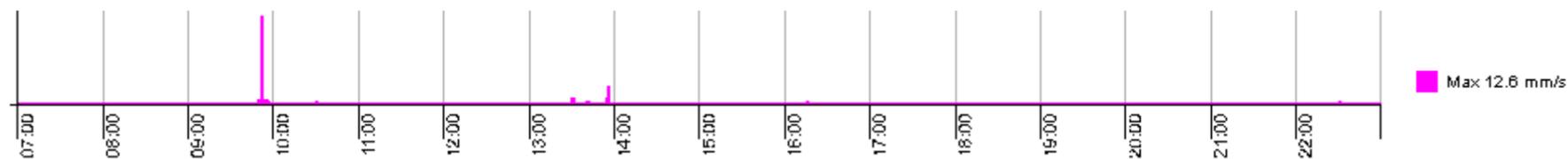
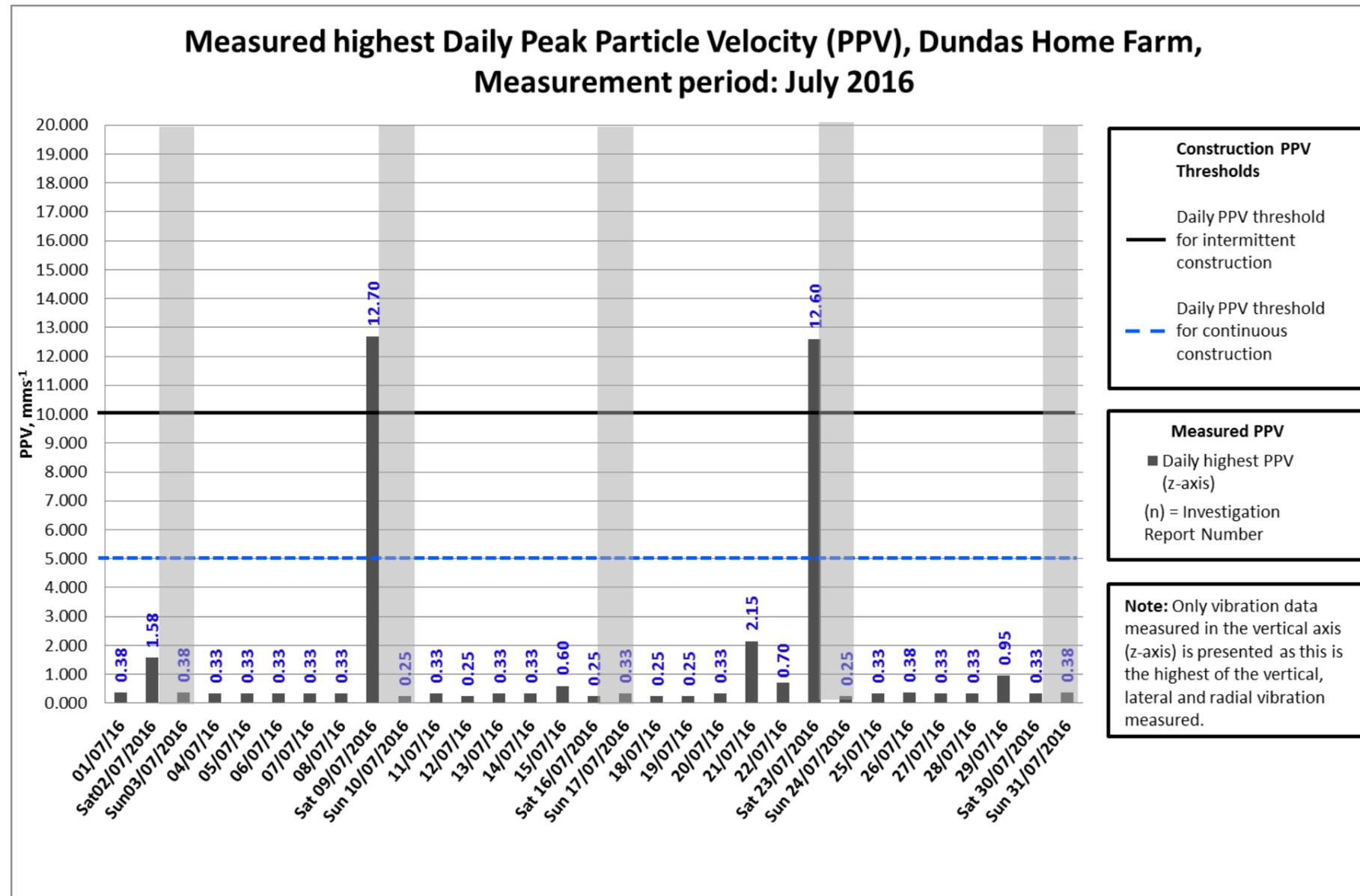
Exceedances on the 1<sup>st</sup>, 4<sup>th</sup>, 6<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup>, 11<sup>th</sup>, 12<sup>th</sup>, 14<sup>th</sup>, 16<sup>th</sup>, 18<sup>th</sup>, 22<sup>nd</sup>, 23<sup>rd</sup>, 29<sup>th</sup> and 30<sup>th</sup> of July have been investigated and found to be caused by individual isolated events (graph above from the 01/07/2016). Due to the closest works being approximately 220m away with minimal plant with the potential for generating vibration. With the monitor being located in a public amenity area there is a likelihood that the exceedances seen above have been caused by pedestrian use of this area.



Exceedances on the 2<sup>nd</sup>, 10<sup>th</sup>, 17<sup>th</sup>, 20<sup>th</sup>, 25<sup>th</sup>, 24<sup>th</sup> and 31<sup>st</sup> of July have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these events (graph above from the 02/07/2016).

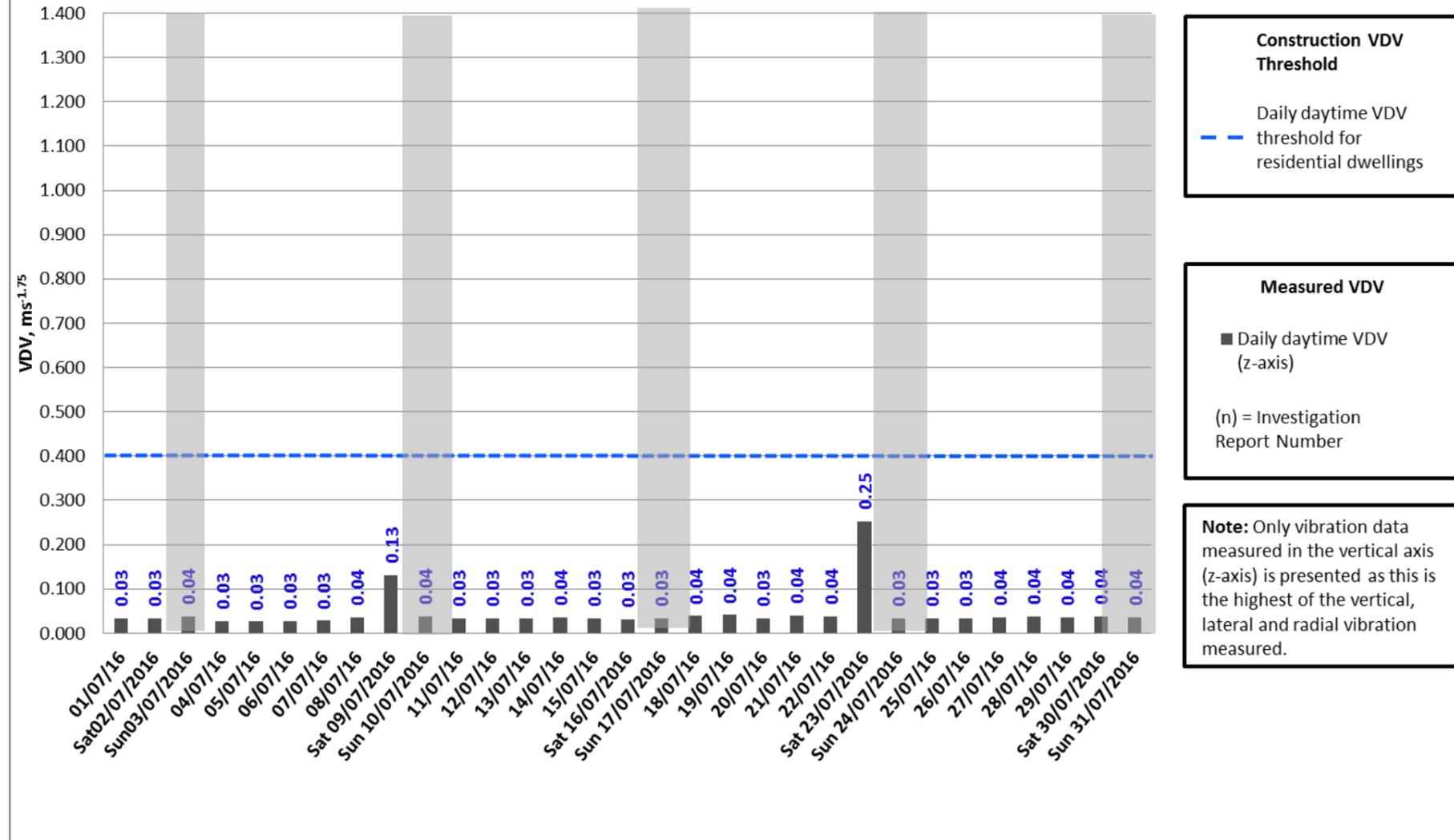






Exceedances on the 9<sup>th</sup> and 23<sup>rd</sup> of July have been investigated and found to be caused by individual isolated events (graph above from the 23/07/2016). During this period the nearest works to the monitor was 115m away. These works consisted of installation of the crash barrier, line marking and road surfacing, of these works only one had plant likely to cause threshold exceedances seen above. However if this was the case then there would be threshold exceedances consistent throughout the month rather than only being on the two days stated above. Due to this the likely cause of these exceedances may be from localised activity nearby the monitor (an example being the grass getting cut nearby the monitor).

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



**Construction VDV Threshold**

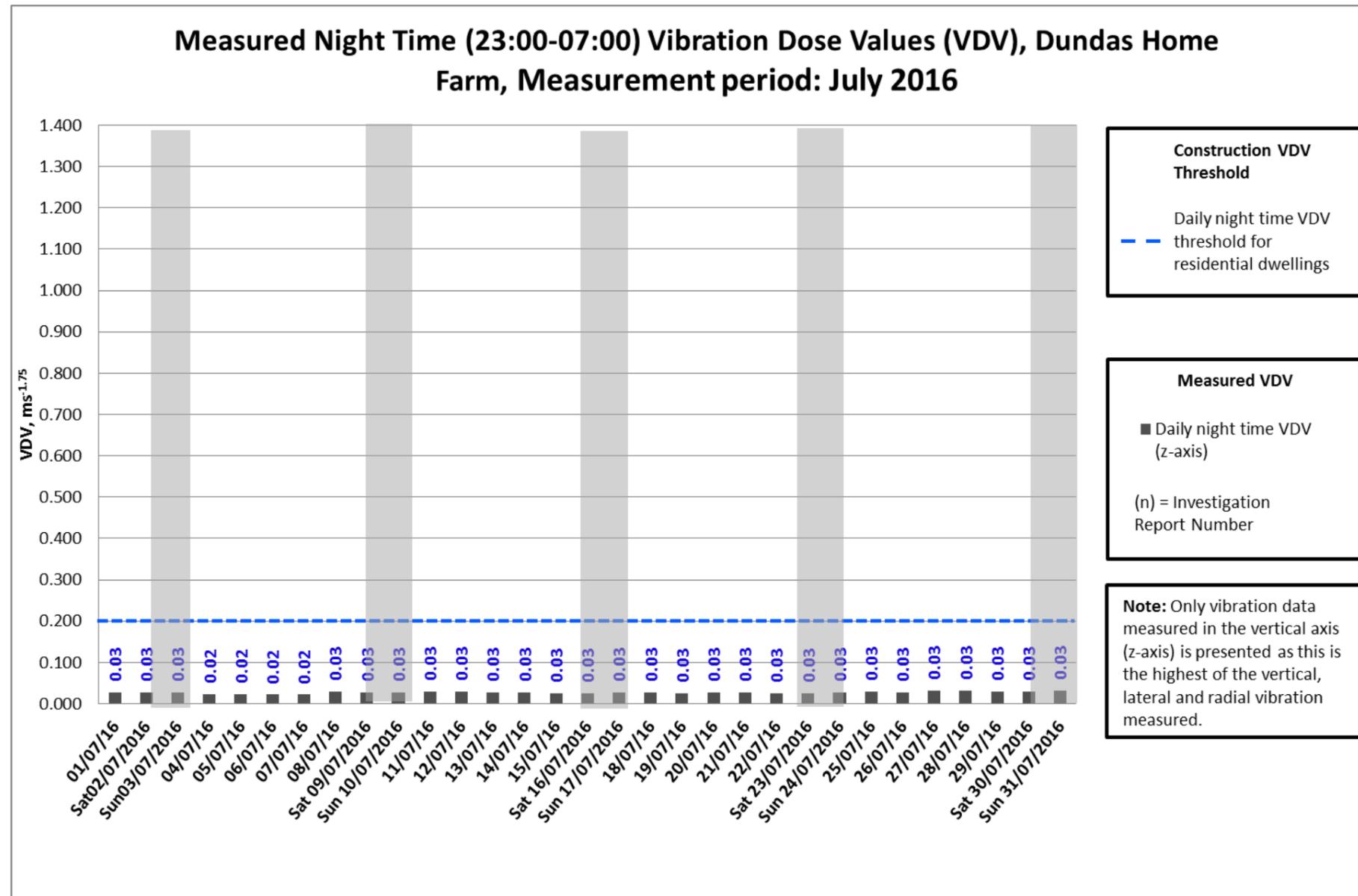
Daily daytime VDV threshold for residential dwellings

**Measured VDV**

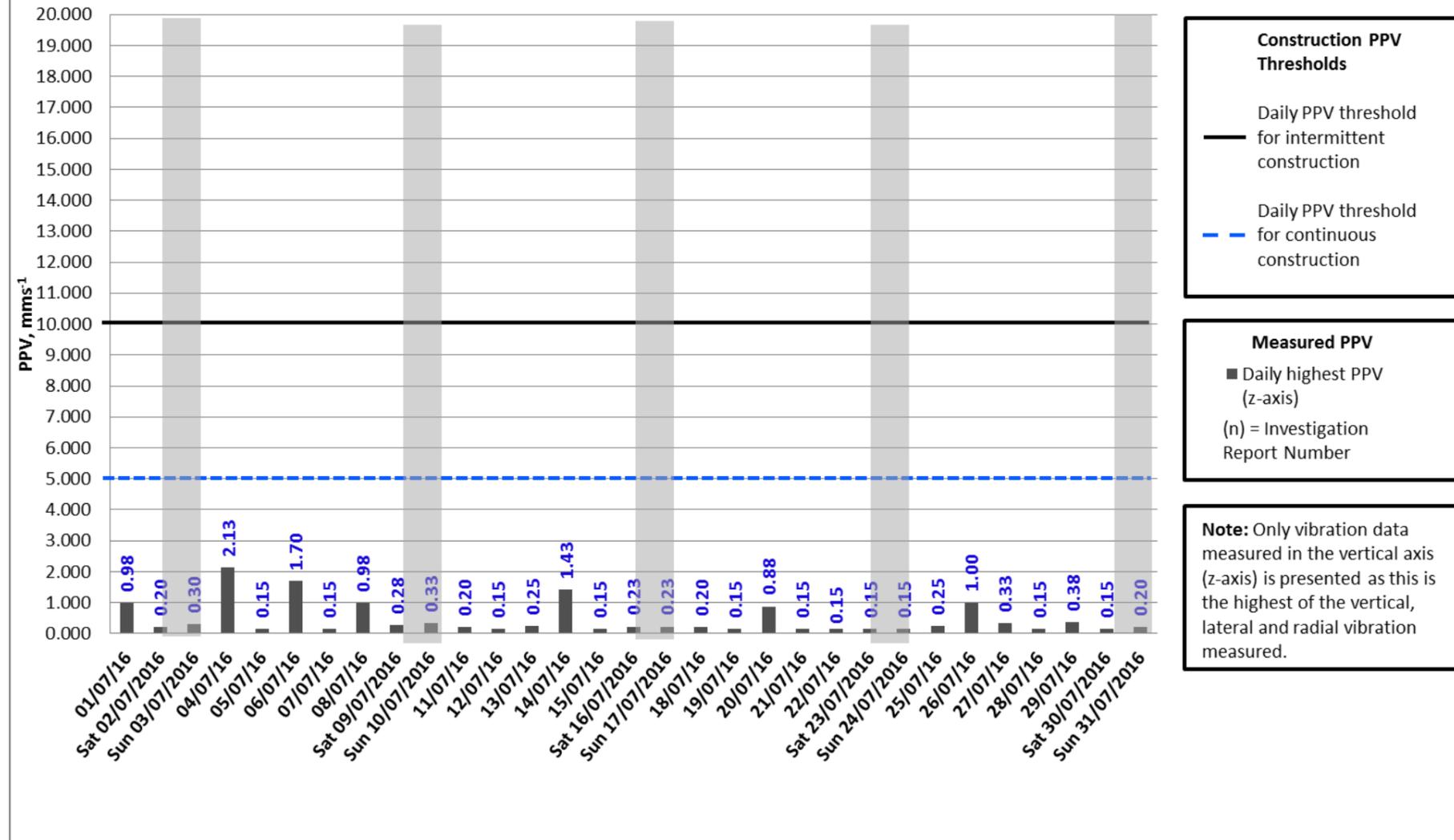
■ Daily daytime VDV (z-axis)

(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 highest Daily Peak Particle Velocity (PPV), Echline, Measurement period: July 2016



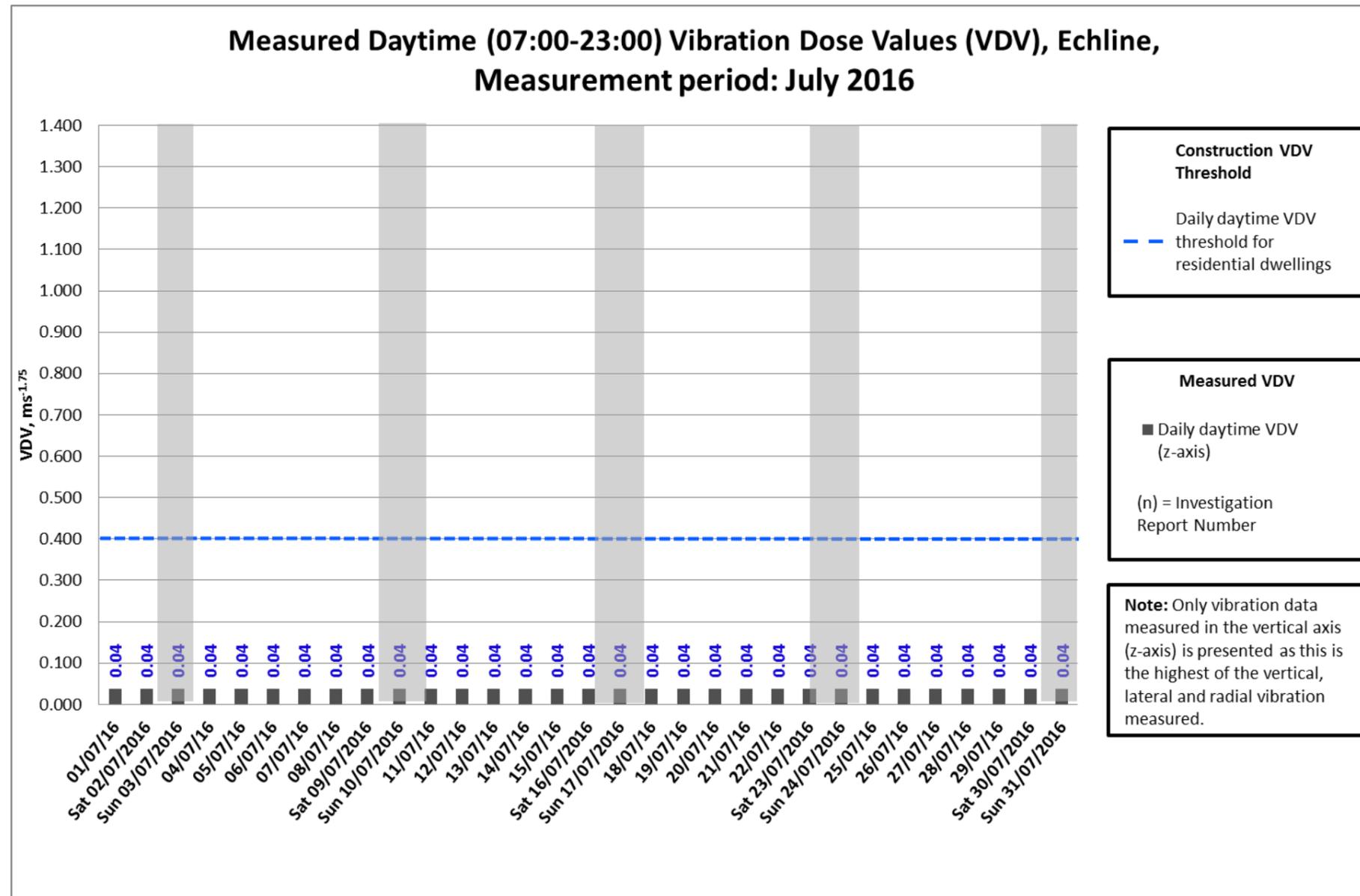
**Construction PPV Thresholds**

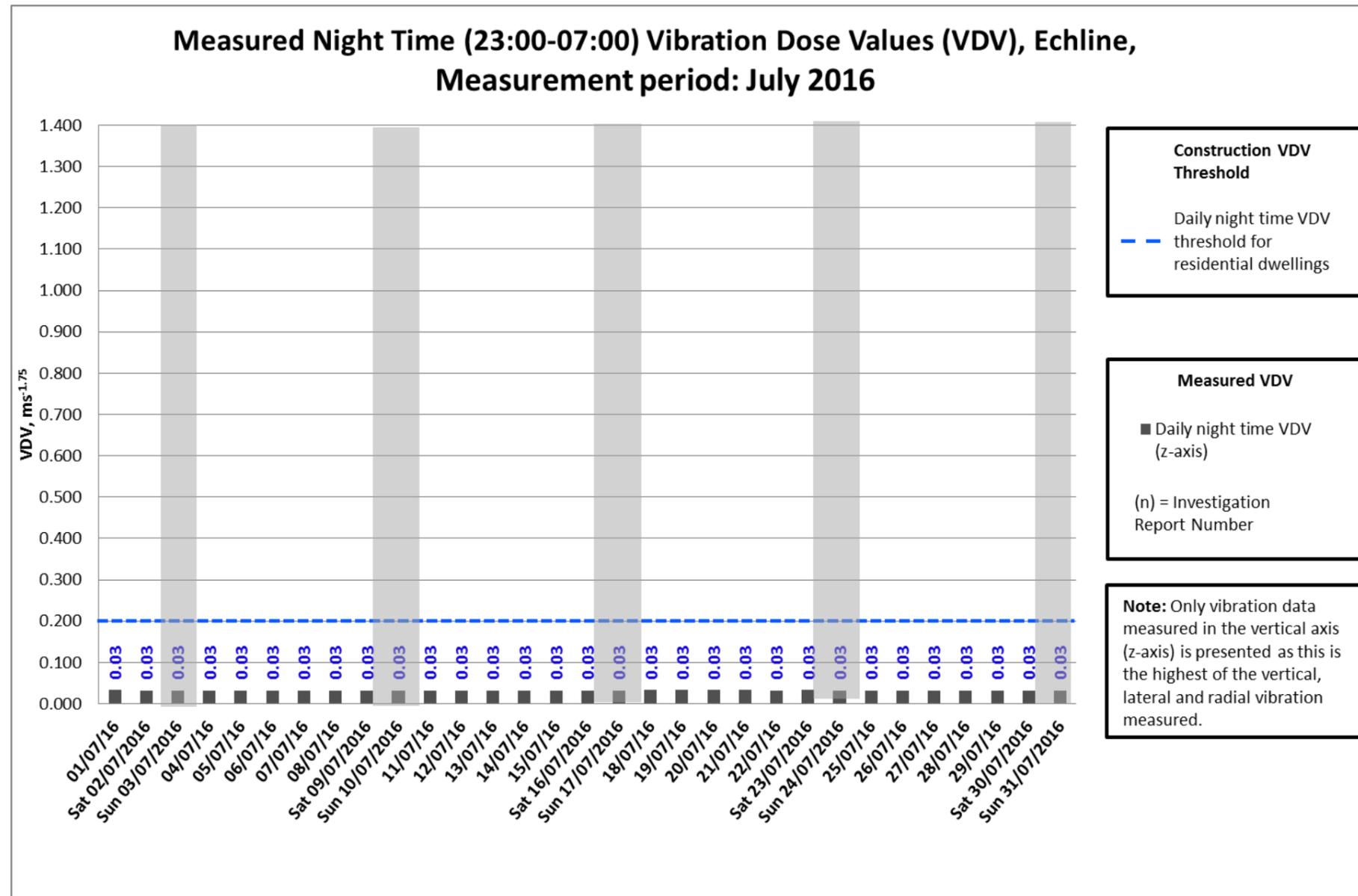
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

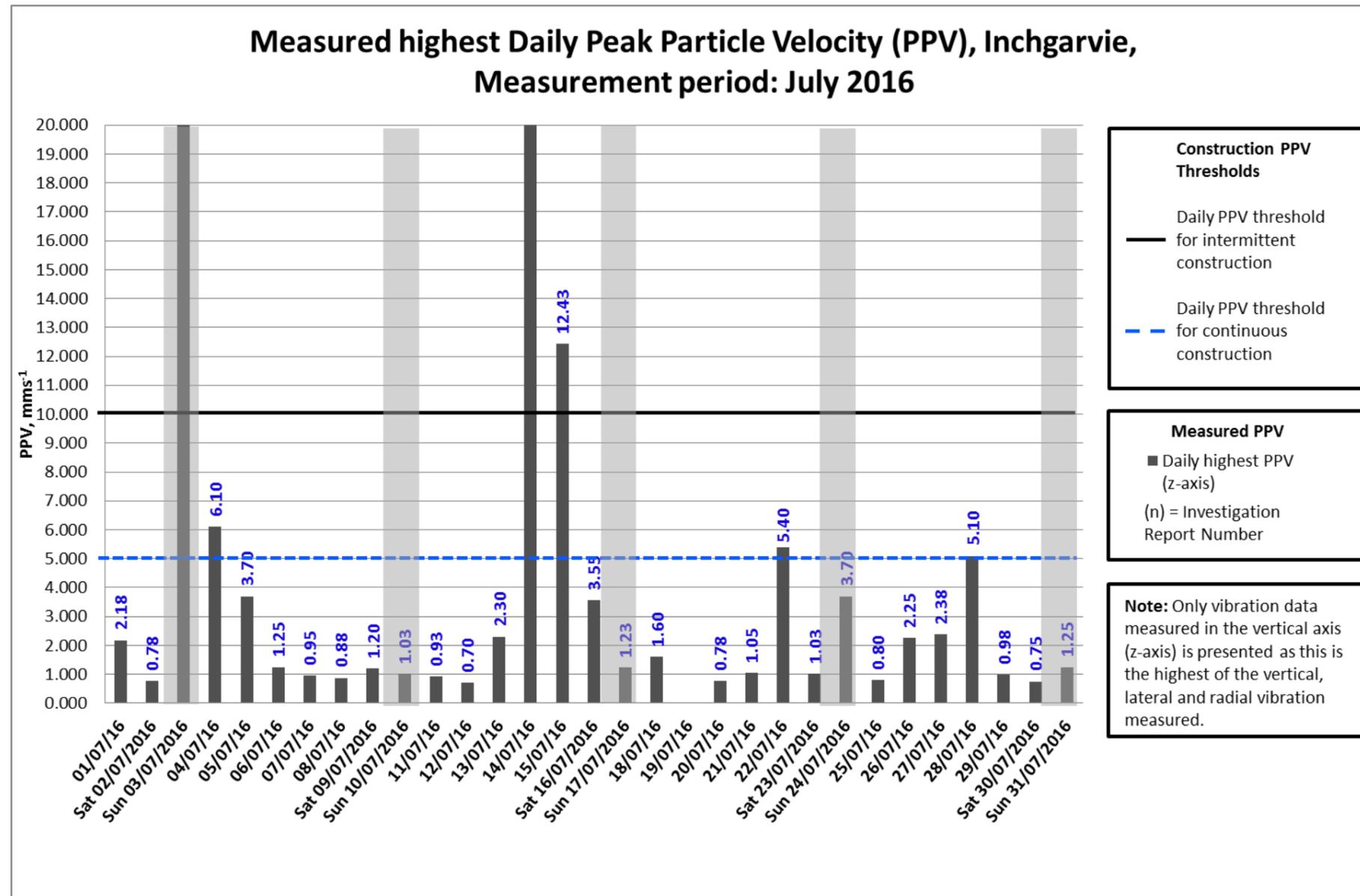
**Measured PPV**

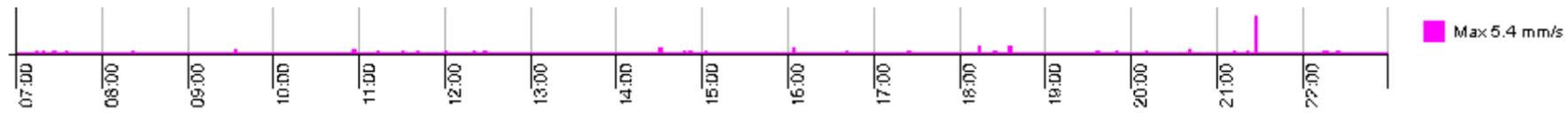
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

**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.

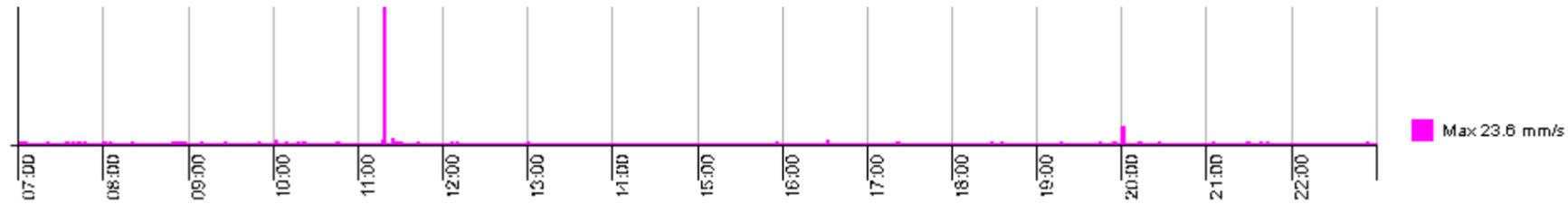








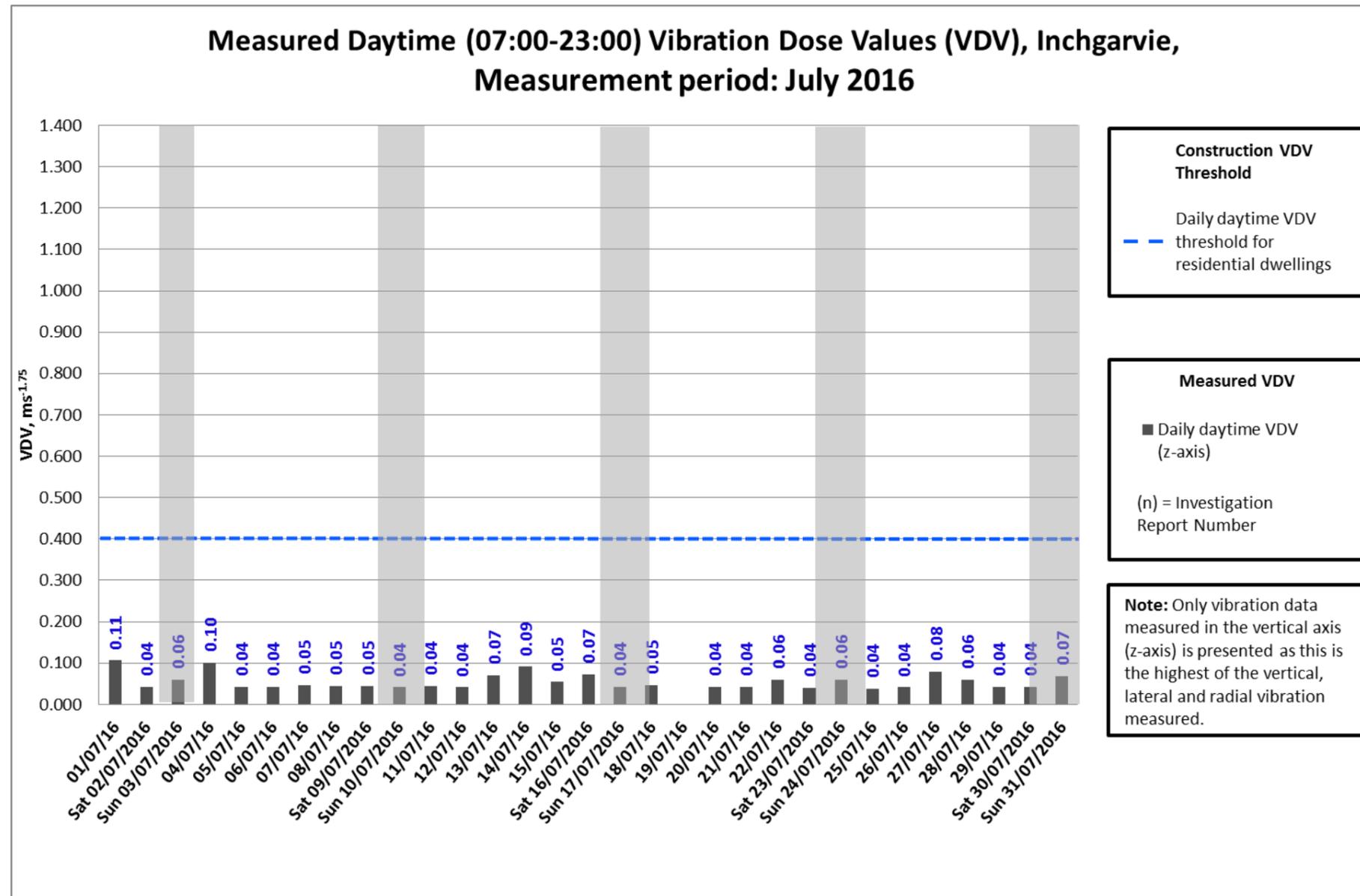
Exceedances on the 3<sup>rd</sup>, 4<sup>th</sup>, 22<sup>nd</sup> and 28<sup>th</sup> of July have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these events (graph above from the 22/07/2016).



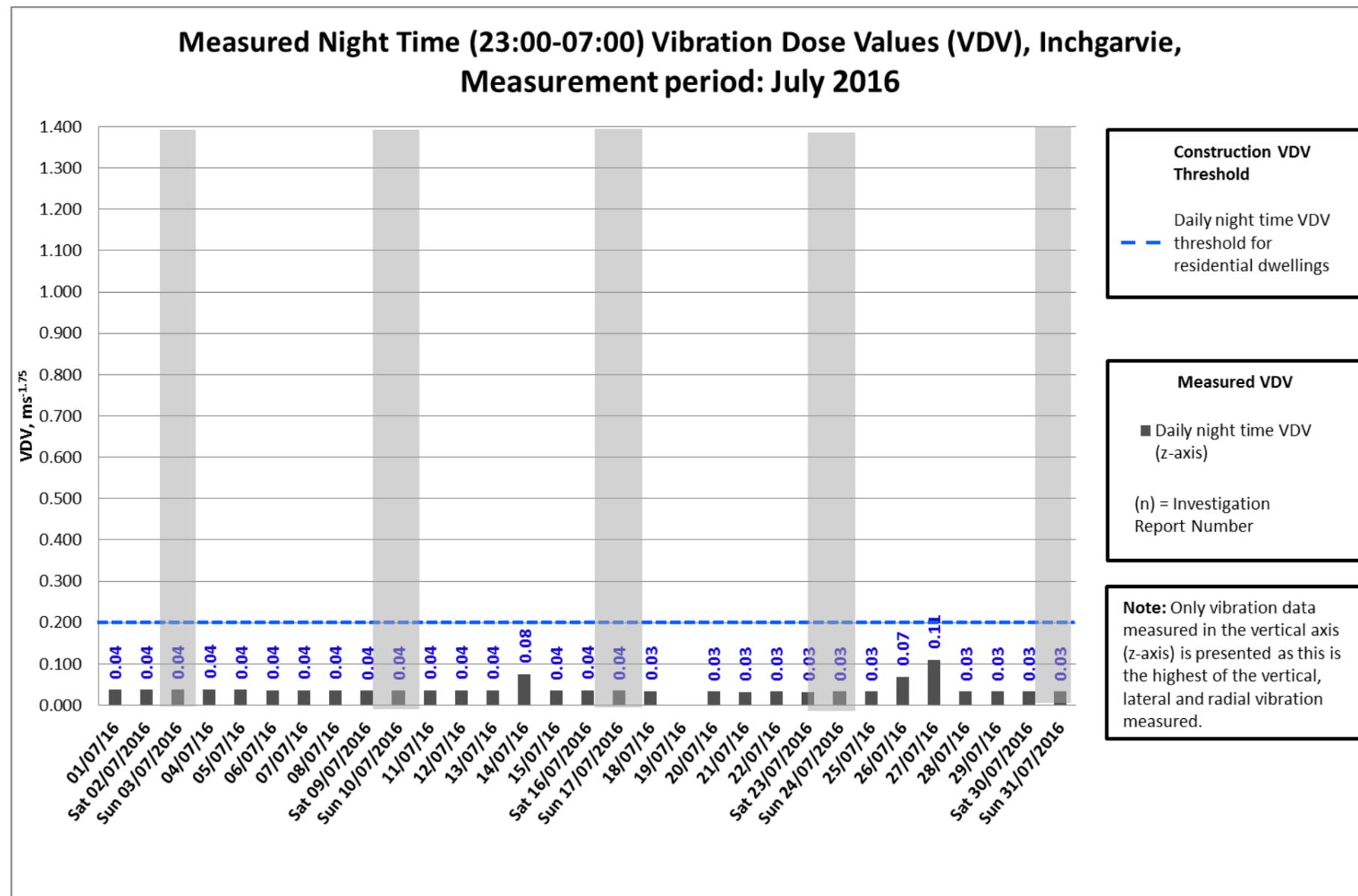
Exceedances on the 14<sup>th</sup> and 15<sup>th</sup> of July have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 14/07/2016).

During this period, the resident at the property where the monitor is situated had ongoing private construction works. It is likely that exceedances within the graph above were caused by the works at the property rather than the construction of the new crossing and supporting infrastructure.

Data missing on the 19<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 20<sup>th</sup> of July.

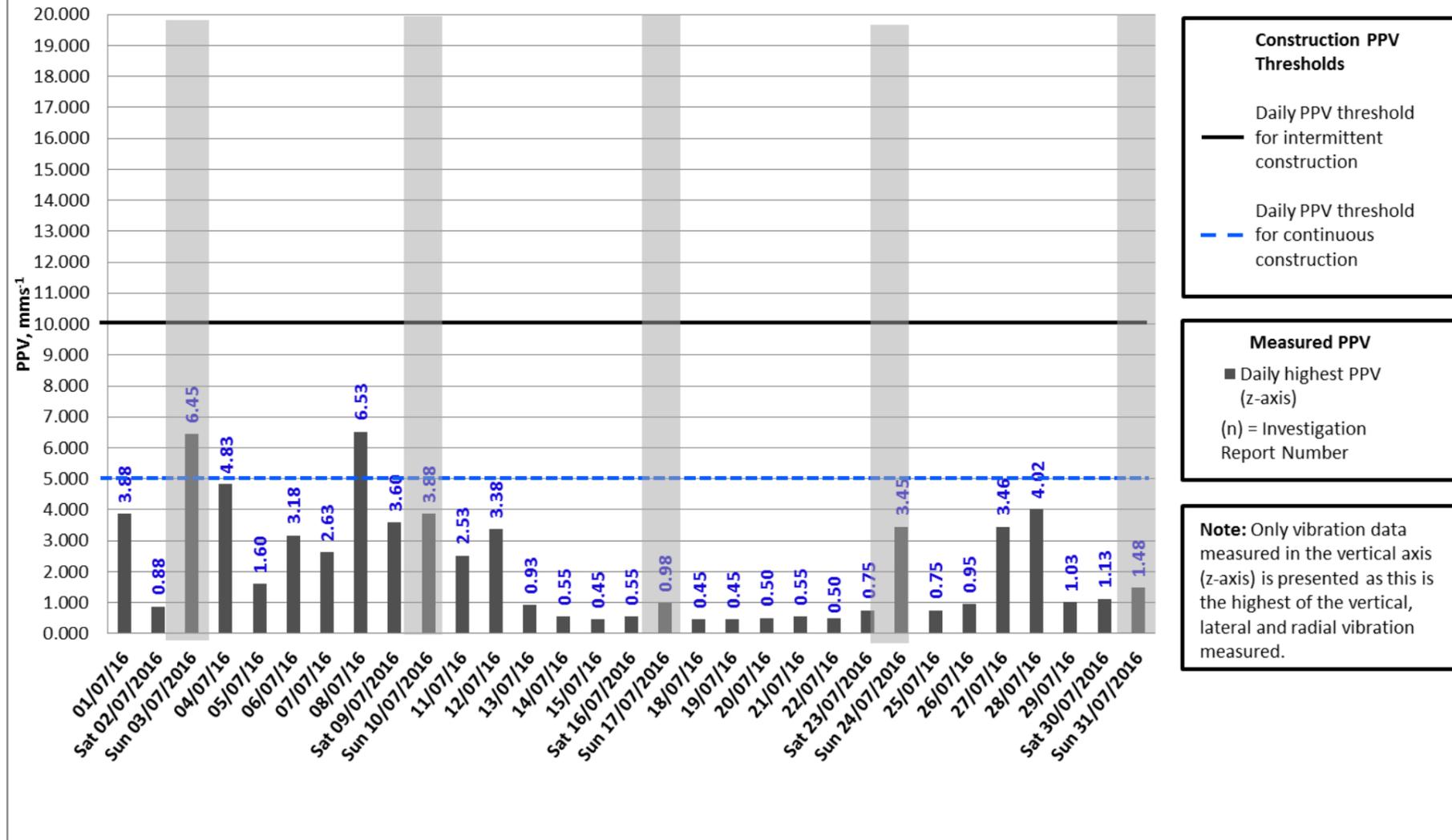


Data missing on the 19<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 20<sup>th</sup> of July.



Data missing on the 19<sup>th</sup> of July was caused by a power issue at the monitor location. This was resolved by a member of the environmental department on the 20<sup>th</sup> of July.

### Measured highest Daily Peak Particle Velocity (PPV), Linn Mill, Measurement period: July 2016



**Construction PPV Thresholds**

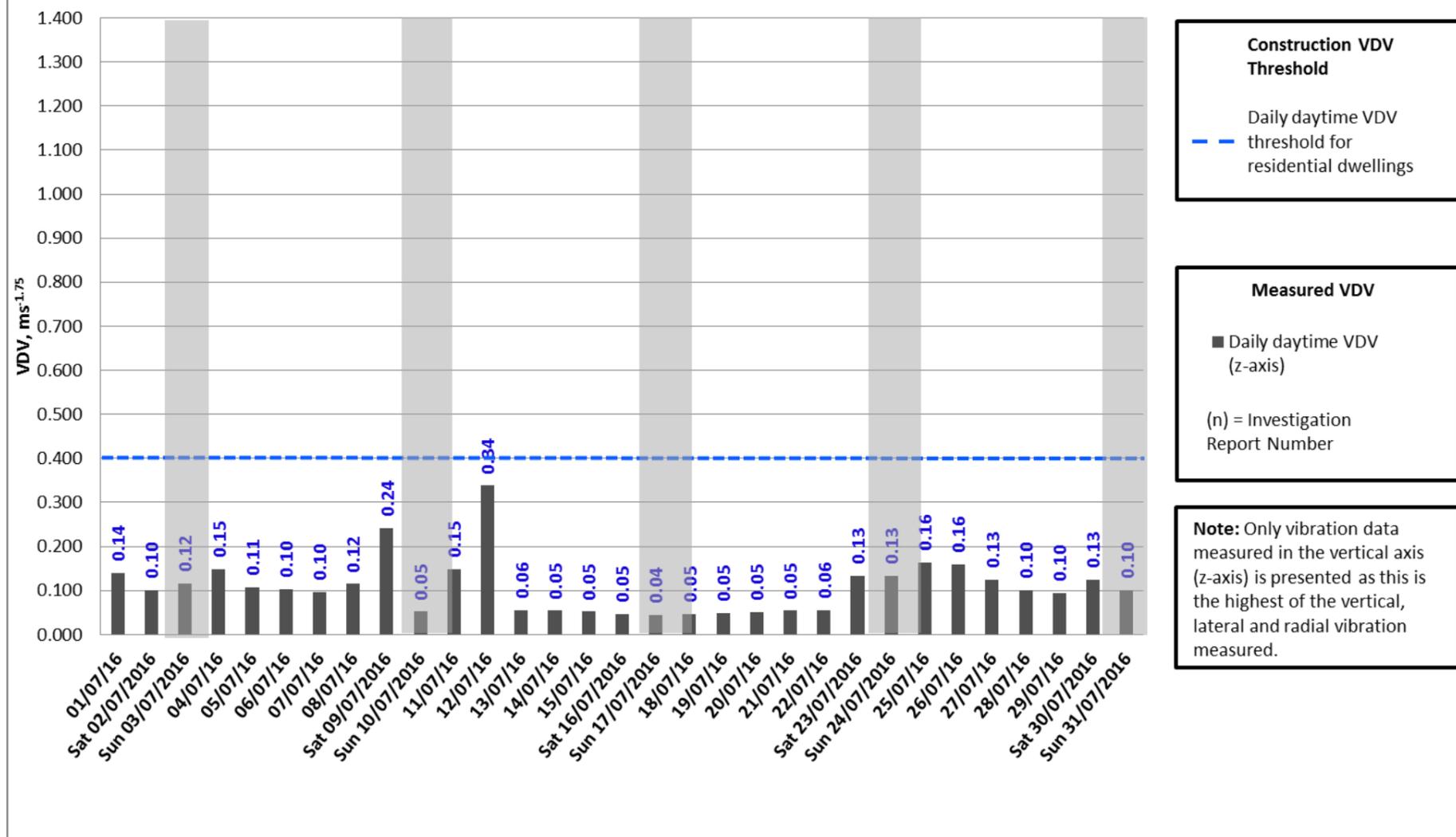
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

**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), Linn Mill, Measurement period: July 2016



**Construction VDV Threshold**

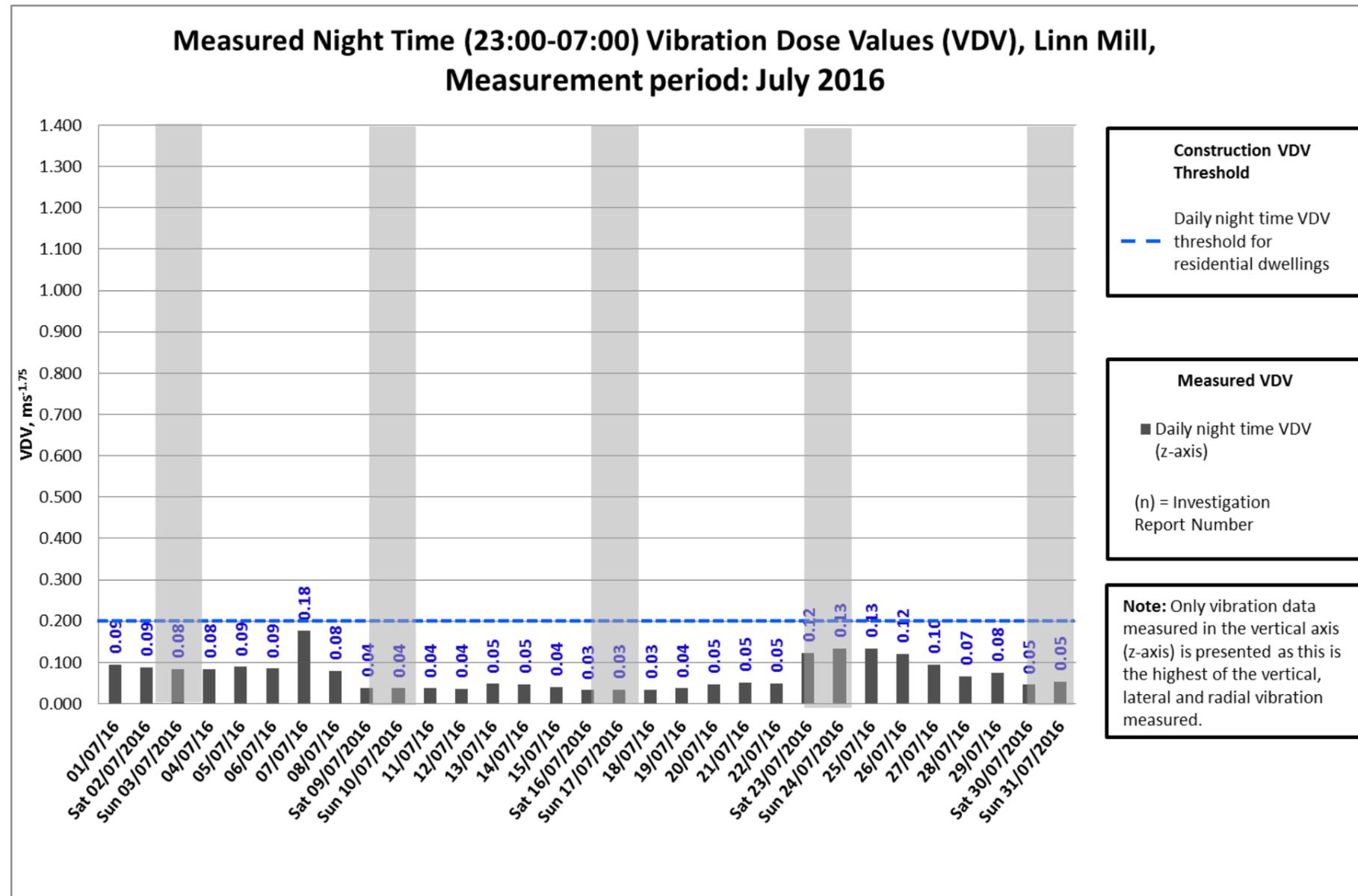
Daily daytime VDV threshold for residential dwellings

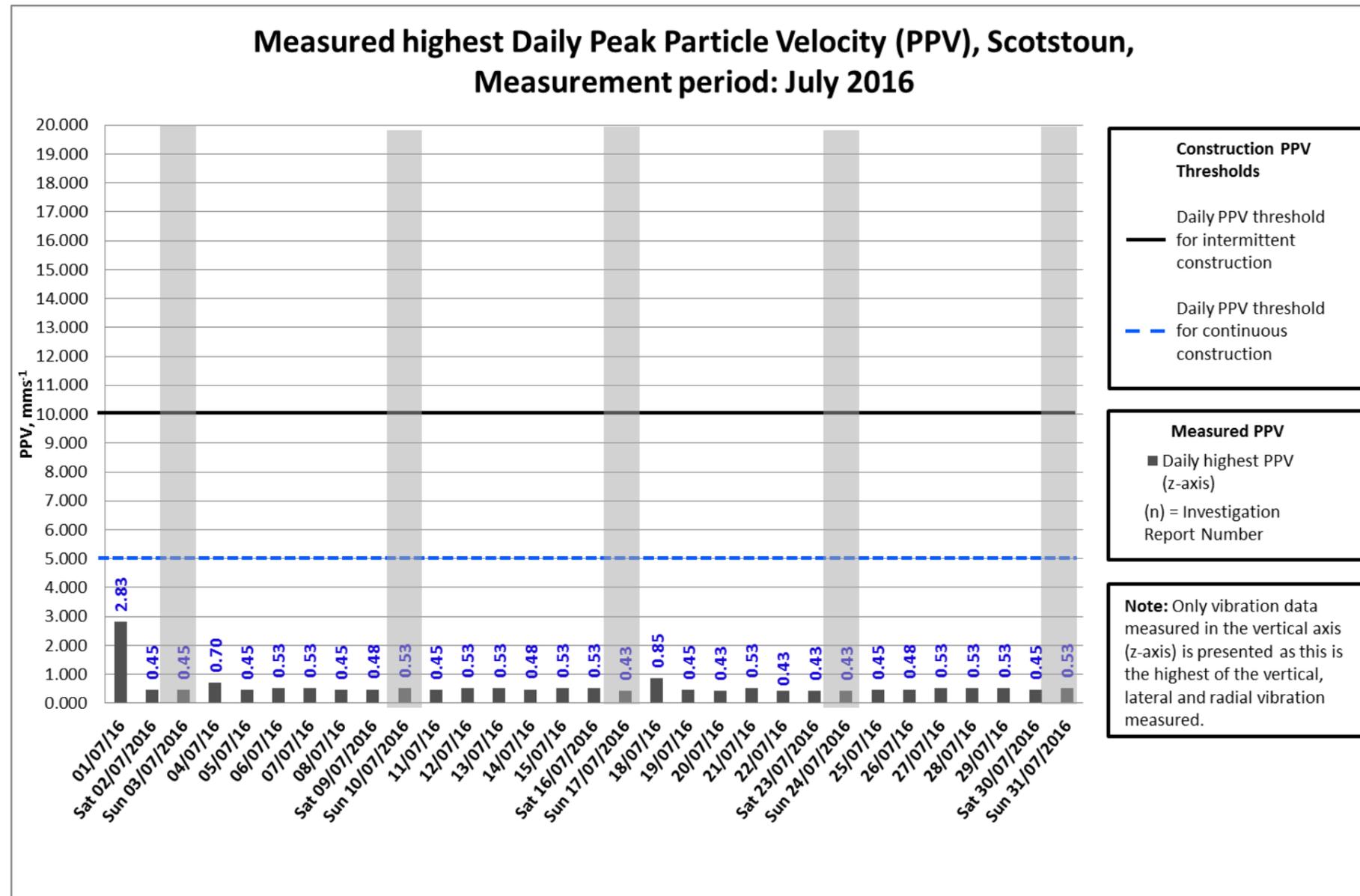
**Measured VDV**

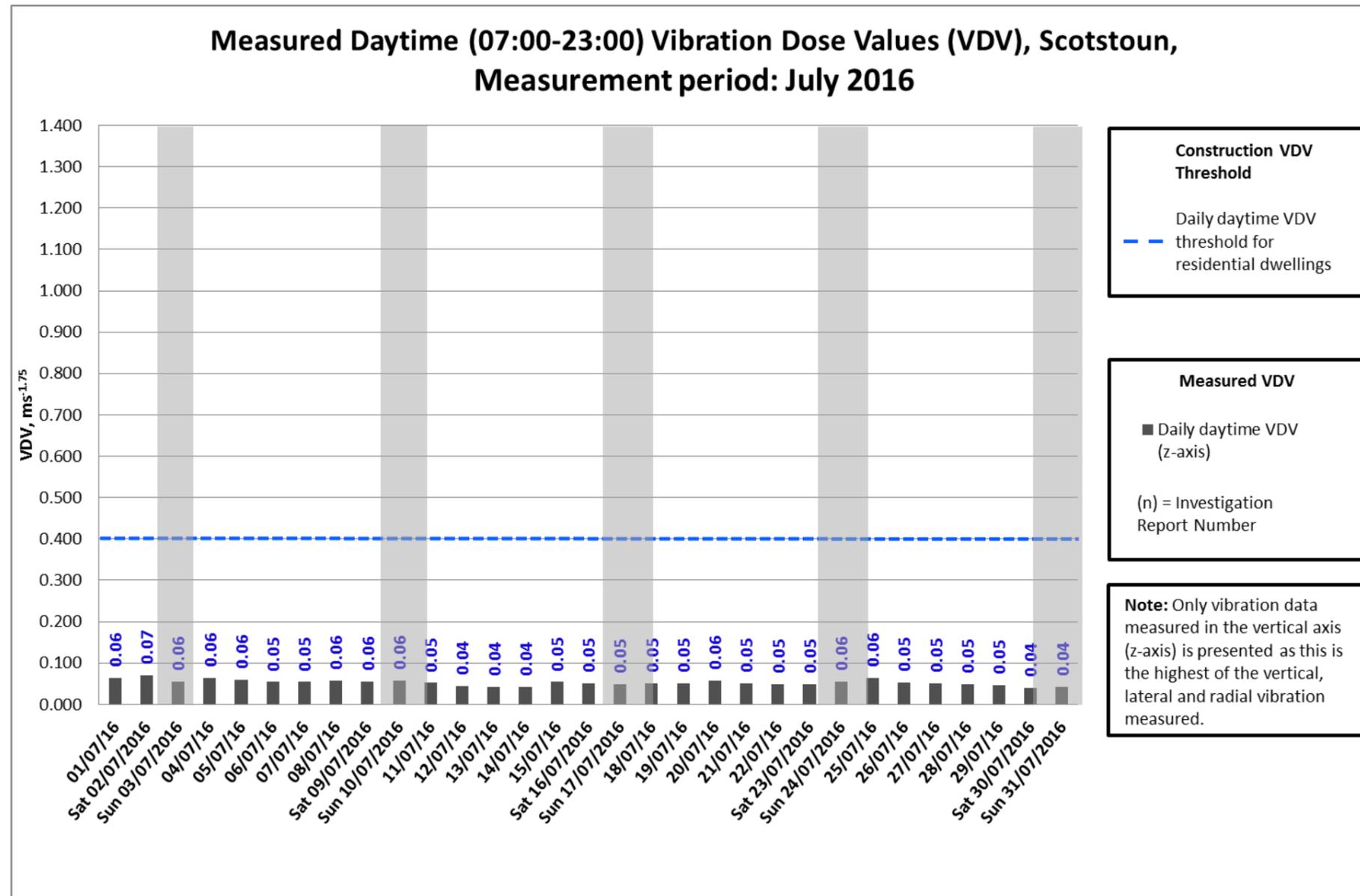
■ Daily daytime VDV (z-axis)

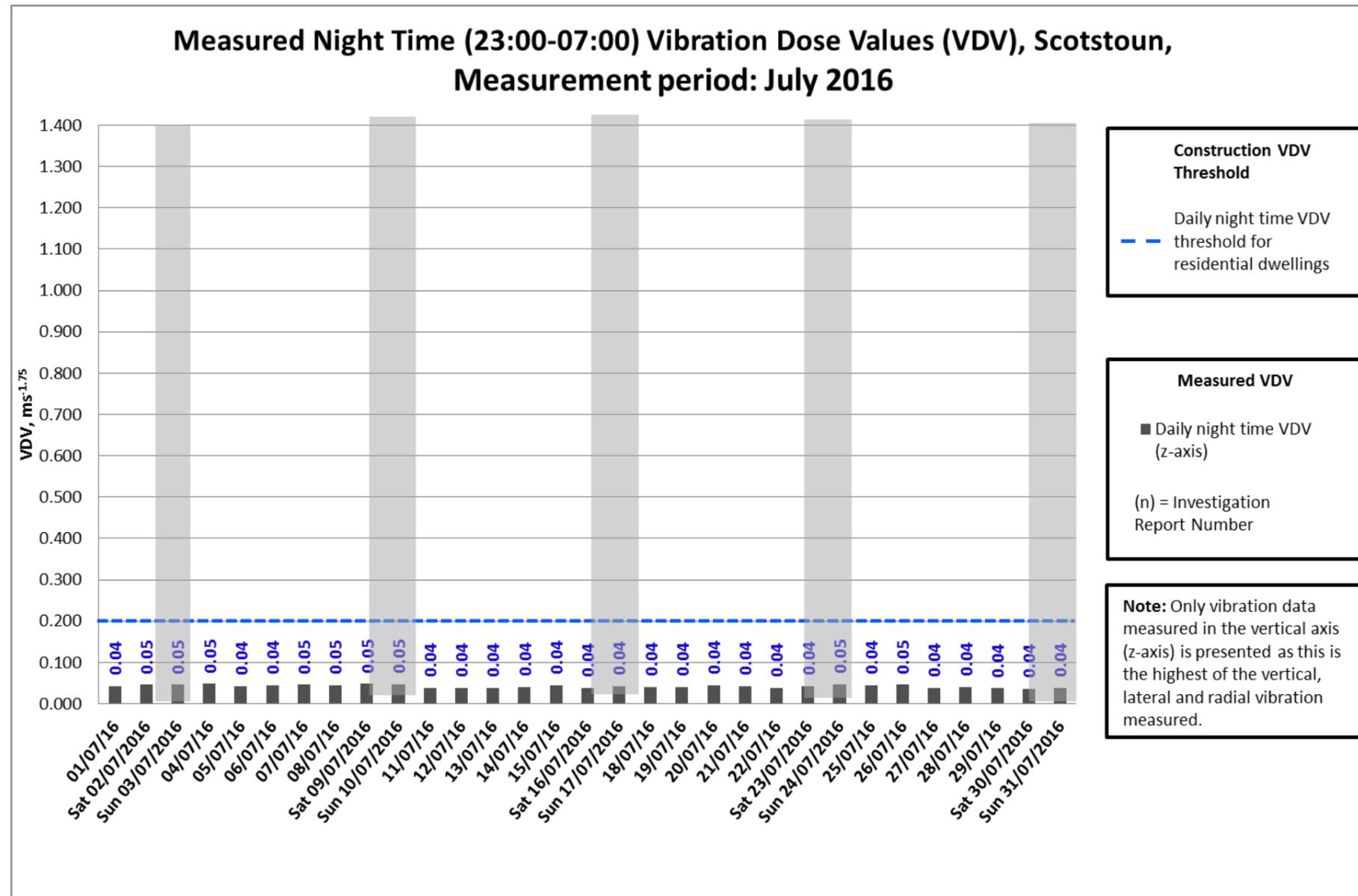
(n) = Investigation Report Number

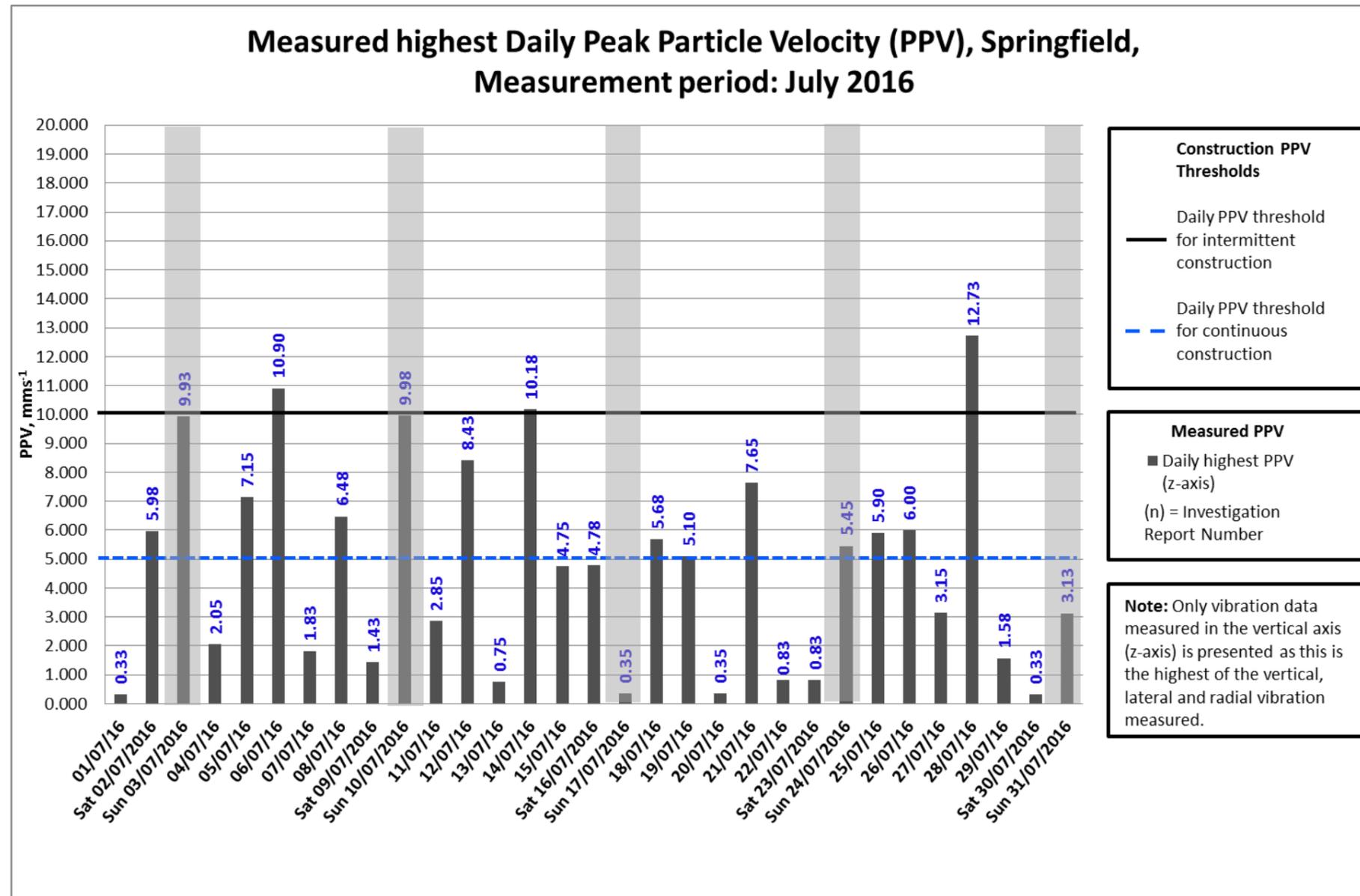
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.









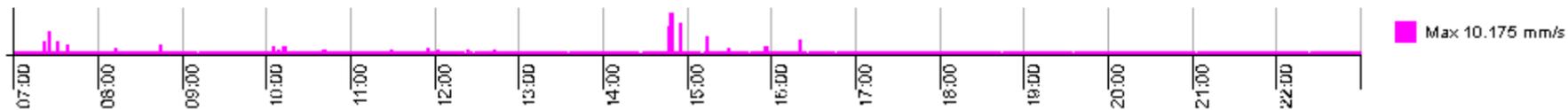




Exceedances on the 8<sup>th</sup>, 15<sup>th</sup>, 25<sup>th</sup> and 28<sup>th</sup> of July have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 25/07/2016).

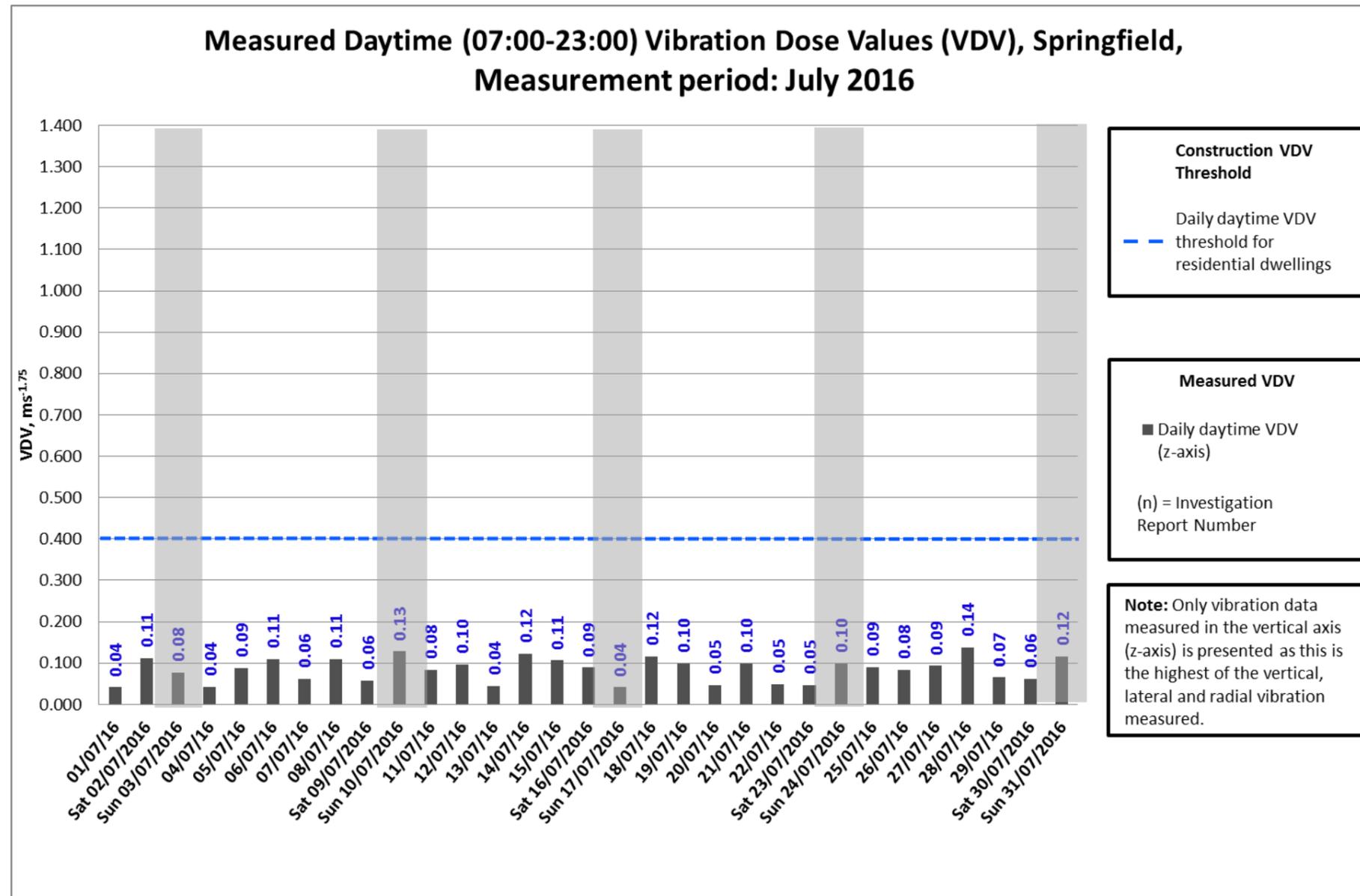


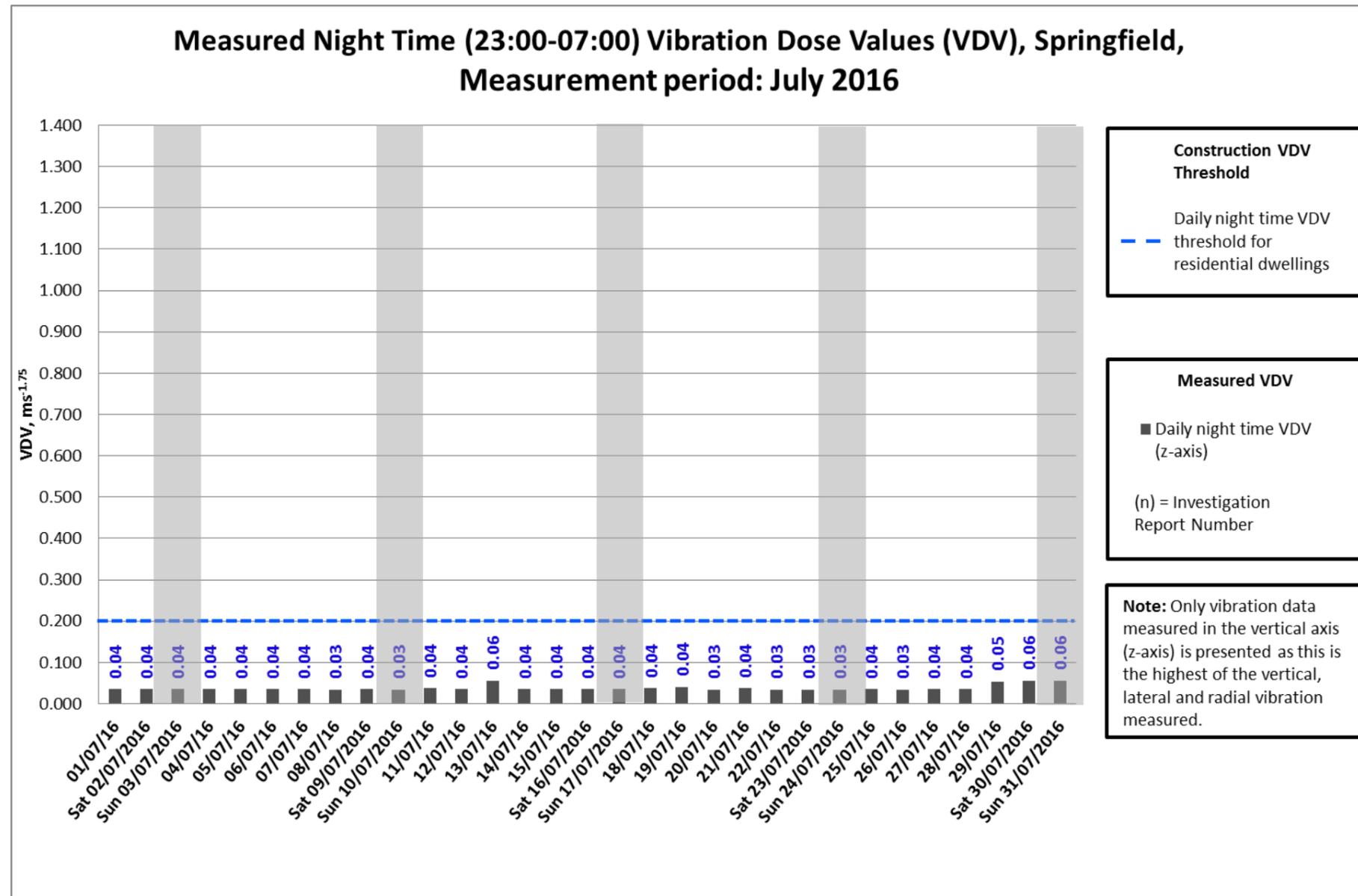
Exceedances on the 3<sup>rd</sup>, 10<sup>th</sup>, 12<sup>th</sup>, 19<sup>th</sup>, 21<sup>st</sup>, 24<sup>th</sup> and 26<sup>th</sup> of July have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 12/07/2016).

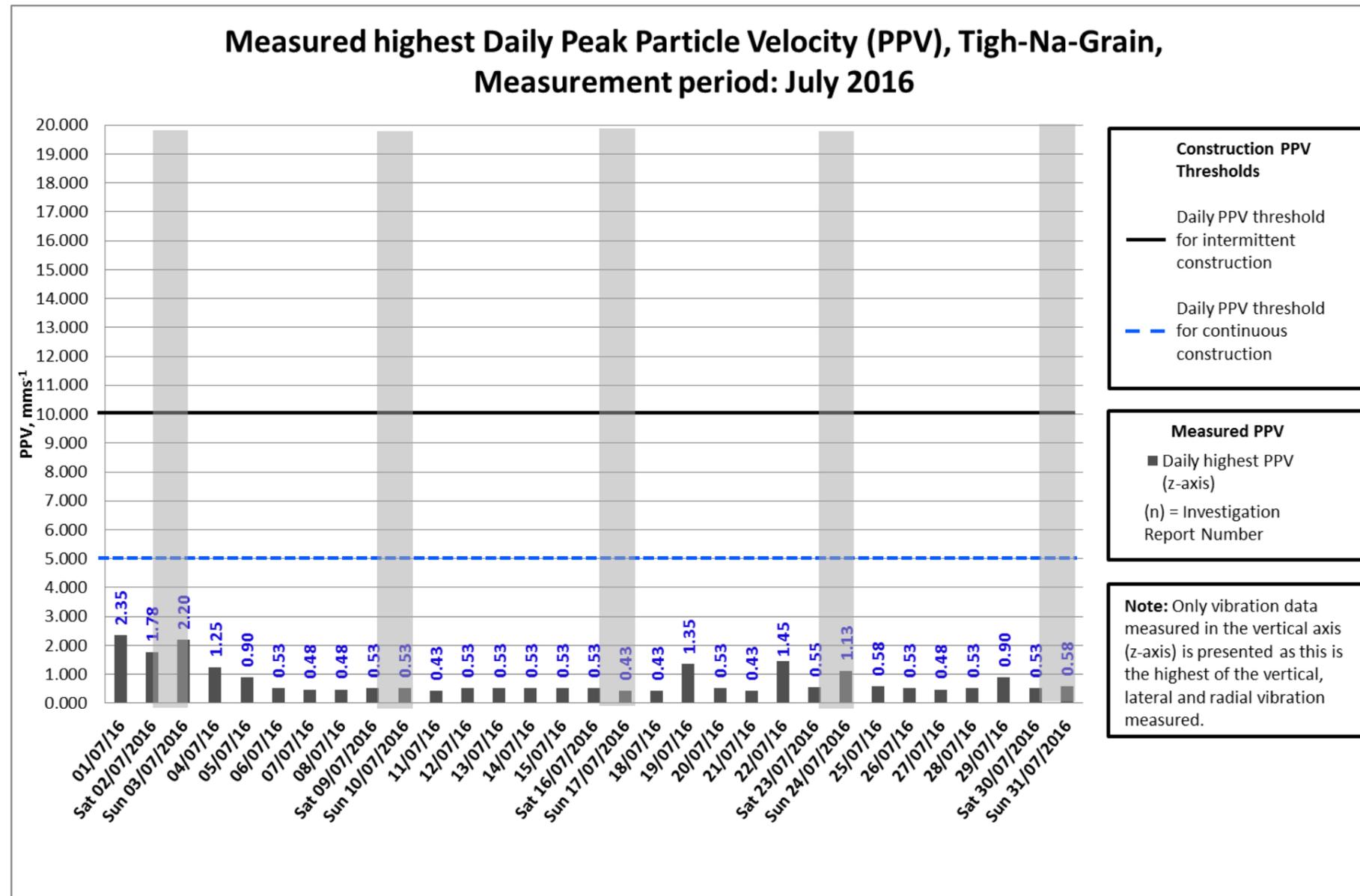


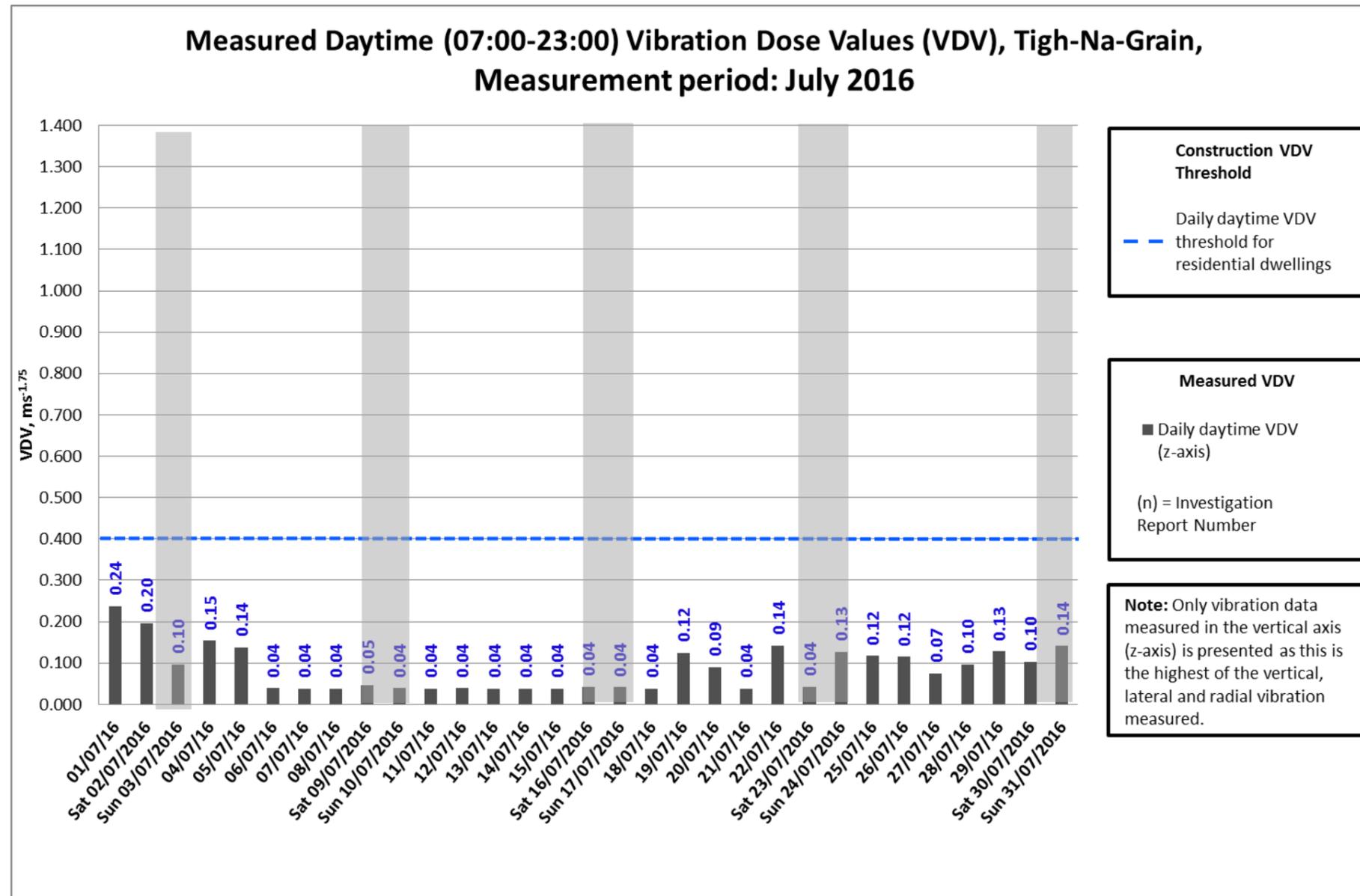
Exceedances on the 2<sup>nd</sup>, 5<sup>th</sup>, 14<sup>th</sup> and 18<sup>th</sup> of July have been investigated and found to be caused by residential activity within the vicinity of the monitor (graph above from the 14/07/2016).

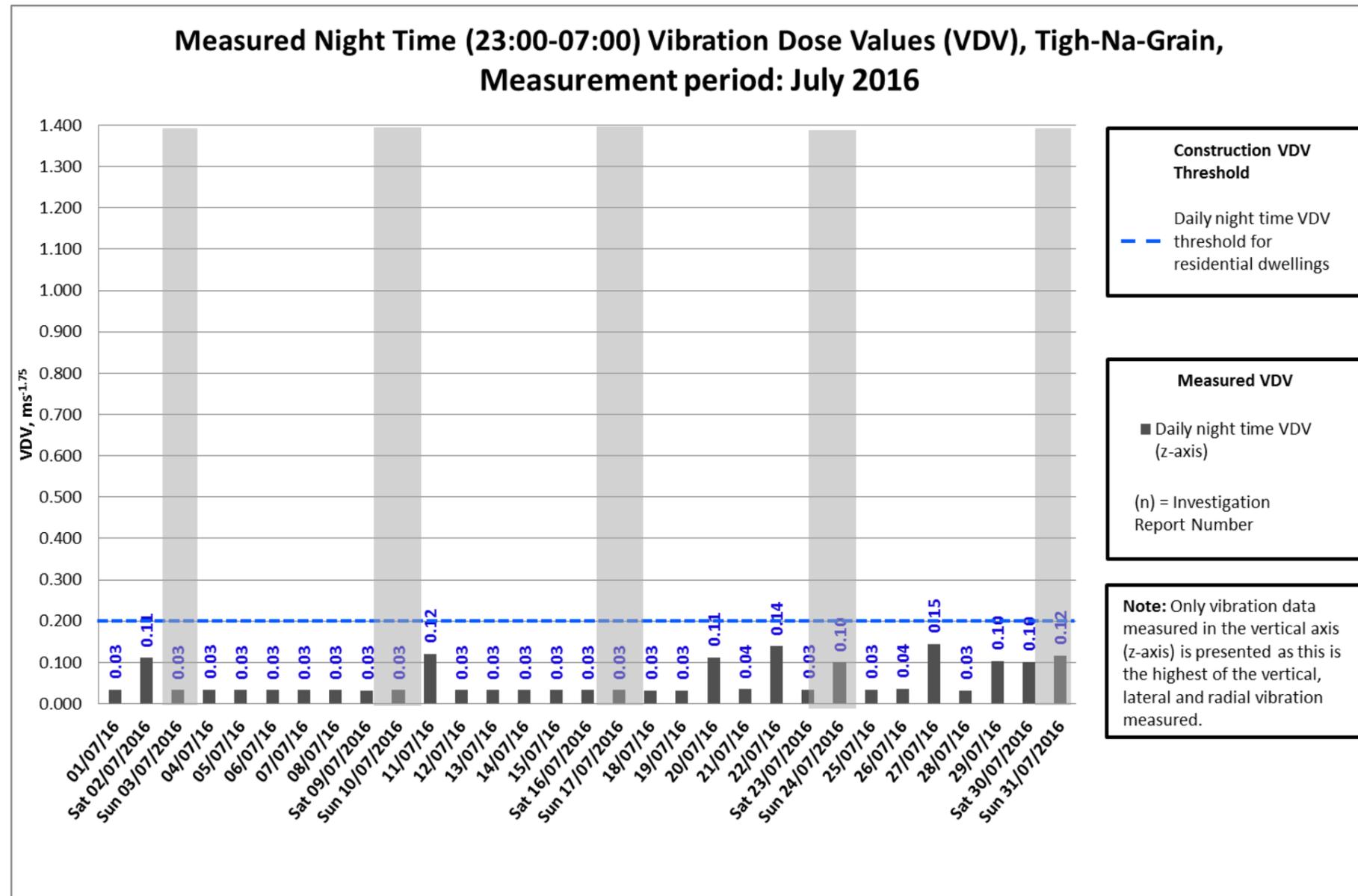
During the reported period there were a number of days where the resident of the property the monitor is situated at was backfilling with gravel nearby monitor, which has had an impact on this month's readings.

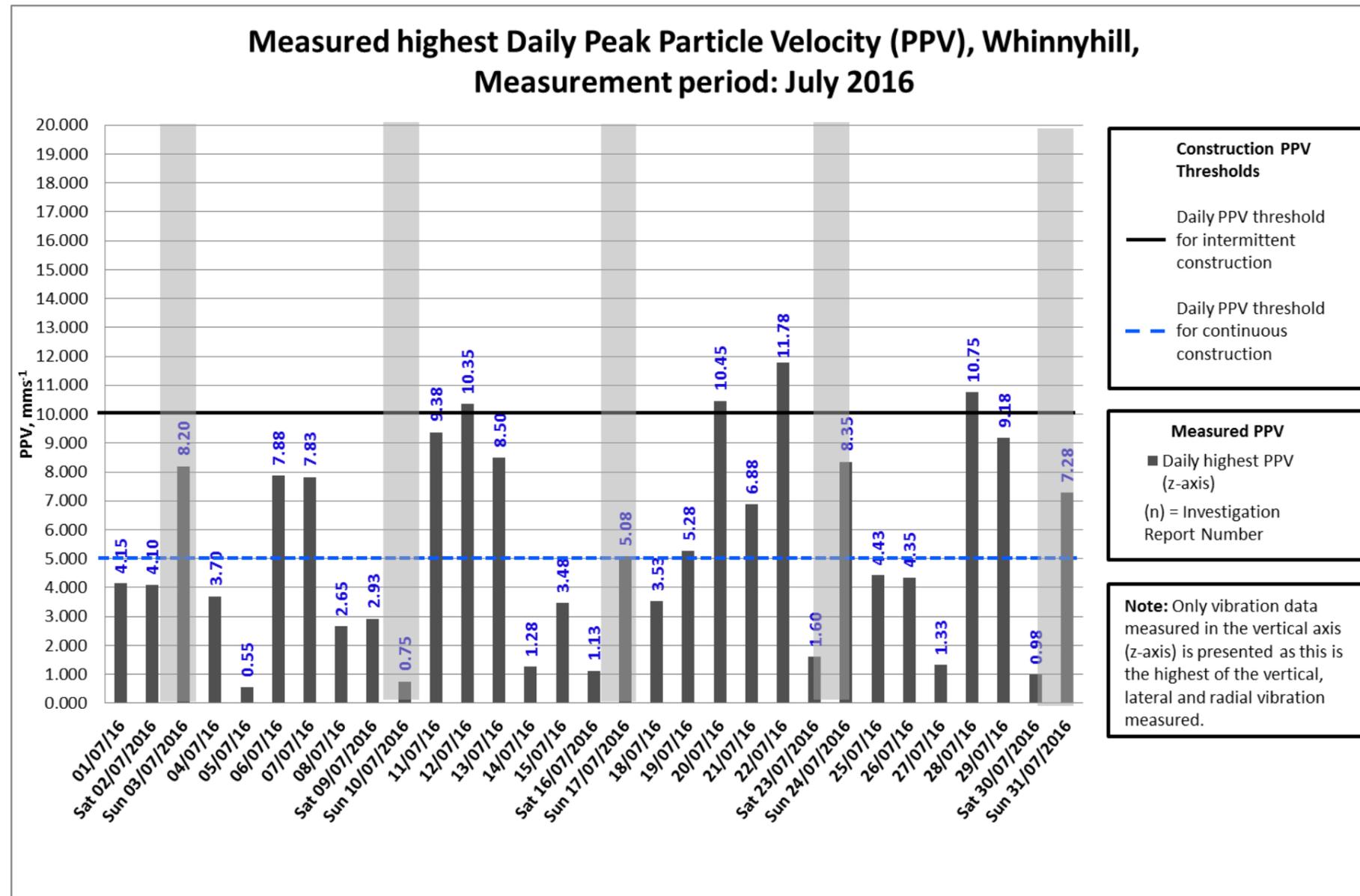






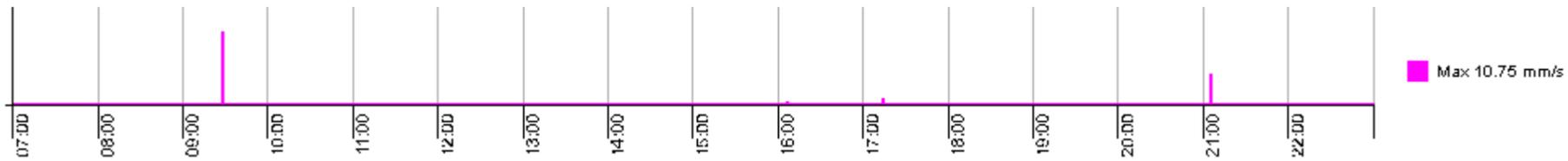






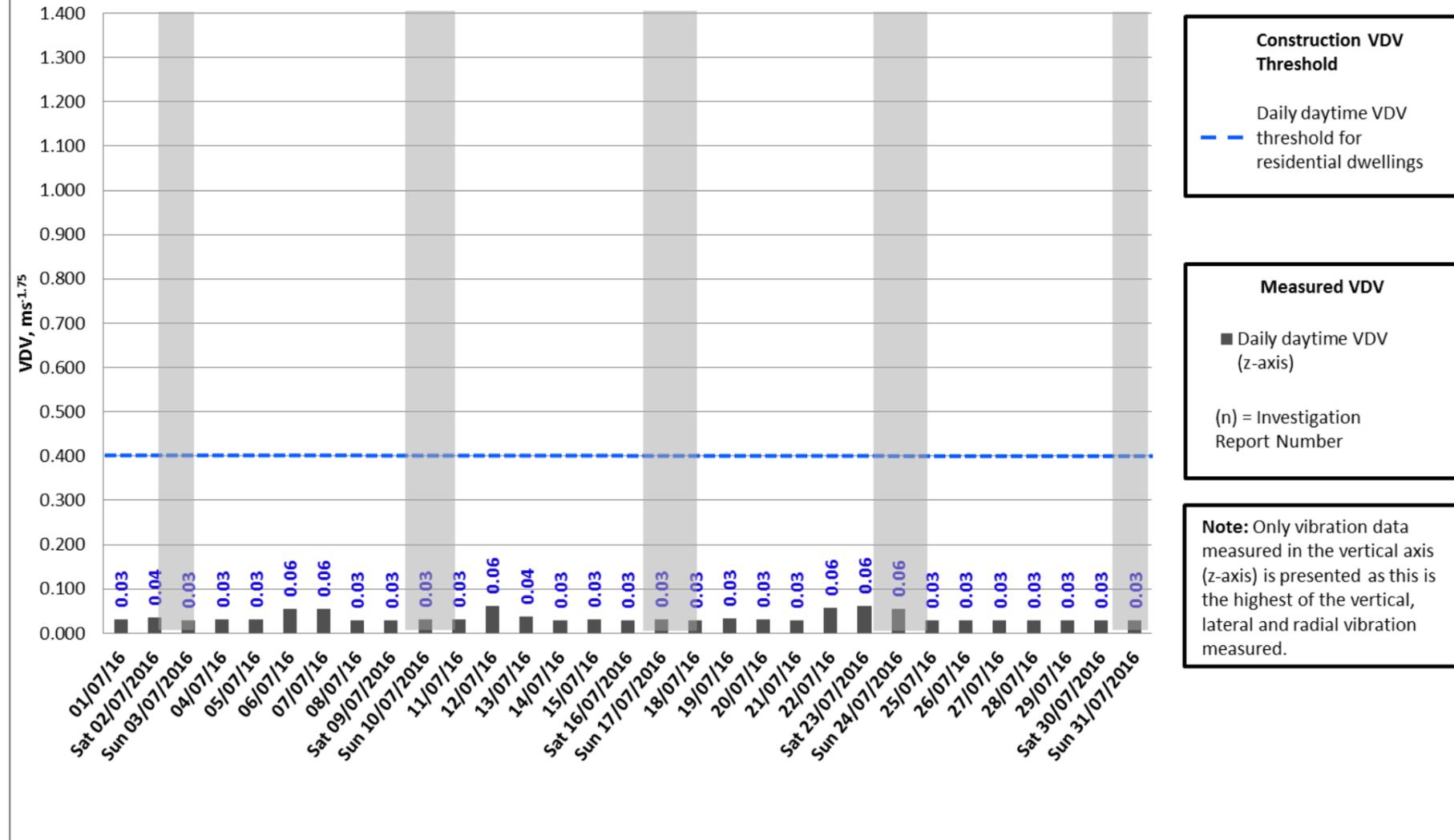


Exceedances on the 3<sup>rd</sup>, 11<sup>th</sup>, 17<sup>th</sup>, 21<sup>st</sup>, 24<sup>th</sup> and 31<sup>st</sup> of July have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these events (graph above from the 11/07/2016).



Exceedances on the 6<sup>th</sup>, 7<sup>th</sup>, 12<sup>th</sup>, 13<sup>th</sup>, 19<sup>th</sup>, 20<sup>th</sup>, 22<sup>nd</sup>, 28<sup>th</sup> and 29<sup>th</sup> of July have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 28/07/2016).

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

