



Contractor



**Forth Crossing** Bridge Constructors

HOCHTIEF Solutions  
American Bridge International  
DRAGADOS  
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT  
SEPTEMBER 2013**

00	14/09/2013	First Revision	MWN	NAM	NAM
<b>Rev</b>	<b>Rev. Date</b>	<b>Purpose of revision</b>	<b>Made</b>	<b>Checked</b>	<b>Reviewed</b>

Document status

**FOR APPROVAL**

Made by Martin Wilson	Checked By: Neil Abraham
Initials: MWN	Initials: NAM

Document number	Rev
<b>REP-00141</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.

## **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 September 2013. 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 have risk assessed noise & vibration resulting from all construction activities through the production of Plans for Control of Noise & Vibration (PCNVs). During the preparation of the PCNVs, the assessment/prediction of vibration levels has illustrated that no construction plant, equipment or methodology to be utilised by FCBC during the period in question, was envisaged to induce any levels of vibration at 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**

**September 2013**

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	2	0	0	0
Clufflat Brae	5	2	0	0
Dundas Home Farm	0	1	0	0
Echline	0	0	0	0
Inchgarvie Lodge	0	0	0	0
Scotstoun	0	0	0	0
Springfield	2	0	0	0
Tigh-Na-Grian	0	1	0	0
Whinnyhill	9	7	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 and piling. 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 m.s<sup>-2</sup> and the time period over which the VDV is measured is in seconds. This yields V DVs in m.s<sup>-1.75</sup>.

- 2.10.** The vibration dose value (VDV), a cumulative measurement of the vibration level received over an 8-hour or 16-hour period, is recommended in BS 6472 as the appropriate measure to evaluate human exposure to vibration in buildings in residential and other uses.
- 2.11.** During the monitoring period, vibratory rollers and whacker plates were used intermittently at several locations around the site. Due to the distances between the work areas and any sensitive receptors, none of the exceedances in VDV levels can be associated with the use of vibratory rollers or whacker plates.
- 2.12.** In addition, detailed investigation of all exceedances (i.e. review of PPV levels over 30 seconds periods) has shown that each resulted from isolated, non-construction related events, which likely occurred close to the monitoring station.
- 2.13.** Within the Appendix B, there are short gaps of missing data in the PPV and VDV graphs. These occurred as a result of monitoring device errors.

### **3. CONCLUSION**

- 3.1.** Considering the distance between FCBC construction works and sensitive receptors, and the methods of working utilised, the risk of damage to structures or nuisance to residents resulting from vibration is highly unlikely.
  
- 3.2.** Due to the location and sensitivity of vibration monitoring equipment, the exceedances presented in the graphs included in the appendices of this report do not represent levels generated by construction, but rather show local interference around the monitoring equipment.



**Forth Crossing** Bridge Constructors

HOCHTIEF Solutions  
American Bridge International  
DRAGADOS  
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 September 2013
M1	Whinny Hill	Network	Excavation and breaking rock at Castlandhill Road.  N.B. No evening, night time or Sunday daytime construction in vicinity.
M3	Tigh-Na-Grian	Crossing	Central Tower rebar, formwork & concreting works North Tower rebar, formwork & concreting works North Tower crane platform piling
M7	Butlaw Fisheries	Crossing	Central Tower rebar, formwork & concreting works South Tower underwater concrete, dewatering & blinding, rebar & formwork Pier S1 final caisson excavation & airlifting Pier S4 airlifting Pier S5 rebar & formwork Demobilisation of Trial Pit Society Road works
M10	Inchgarvie Lodge	Crossing	South Tower excavation & airlifting Pier S1 jet grouting works Pier S4 airlifting Pier S5 airlifting & concrete works Launch – assembly of stillages, delivery and assembly of structural steel sections Installation of rebar and formwork and preparation of construction joints at S7/S8 Works at pier trials area works Society Road works
M11	Linn Mill	Network	Launch – assembly of stillages, delivery and assembly of structural steel sections Installation of rebar and formwork and preparation of construction joints at S7/S8 Works at pier trials area works Society Road works  N.B. No evening, night time or Sunday daytime construction in vicinity.
M13	Clufflat Brae	Network	Launch – assembly of stillages, delivery and assembly of structural steel sections Installation of rebar and formwork and preparation of construction joints at S7/S8 Works at pier trials area works Society Road works Echline field – excavation of mainline

			N.B. No evening, night time or Sunday daytime construction in vicinity.
M14	Springfield	Network	<p>Launch – assembly of stillages, delivery and assembly of structural steel sections          Installation of rebar and formwork and preparation of construction joints at S7/S8          Works at pier trials area works          Echline field – excavation of mainline          Gyratory – structures</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M15	Echline Field	Network	<p>Launch – assembly of stillages, delivery and assembly of structural steel sections          Installation of rebar and formwork and preparation of construction joints at S7/S8          Works at pier trials area works          Echline field – excavation of mainline          Gyratory – structures</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M16	Scotstoun	Network	<p>Bus link works.</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M17	Dundas Home Farm	Network	<p>Backfilling of utility works          Environmental bund</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>

Table 2 lists the main construction activities undertaken in the locality of each of the vibration monitors during the period of September 2013.

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

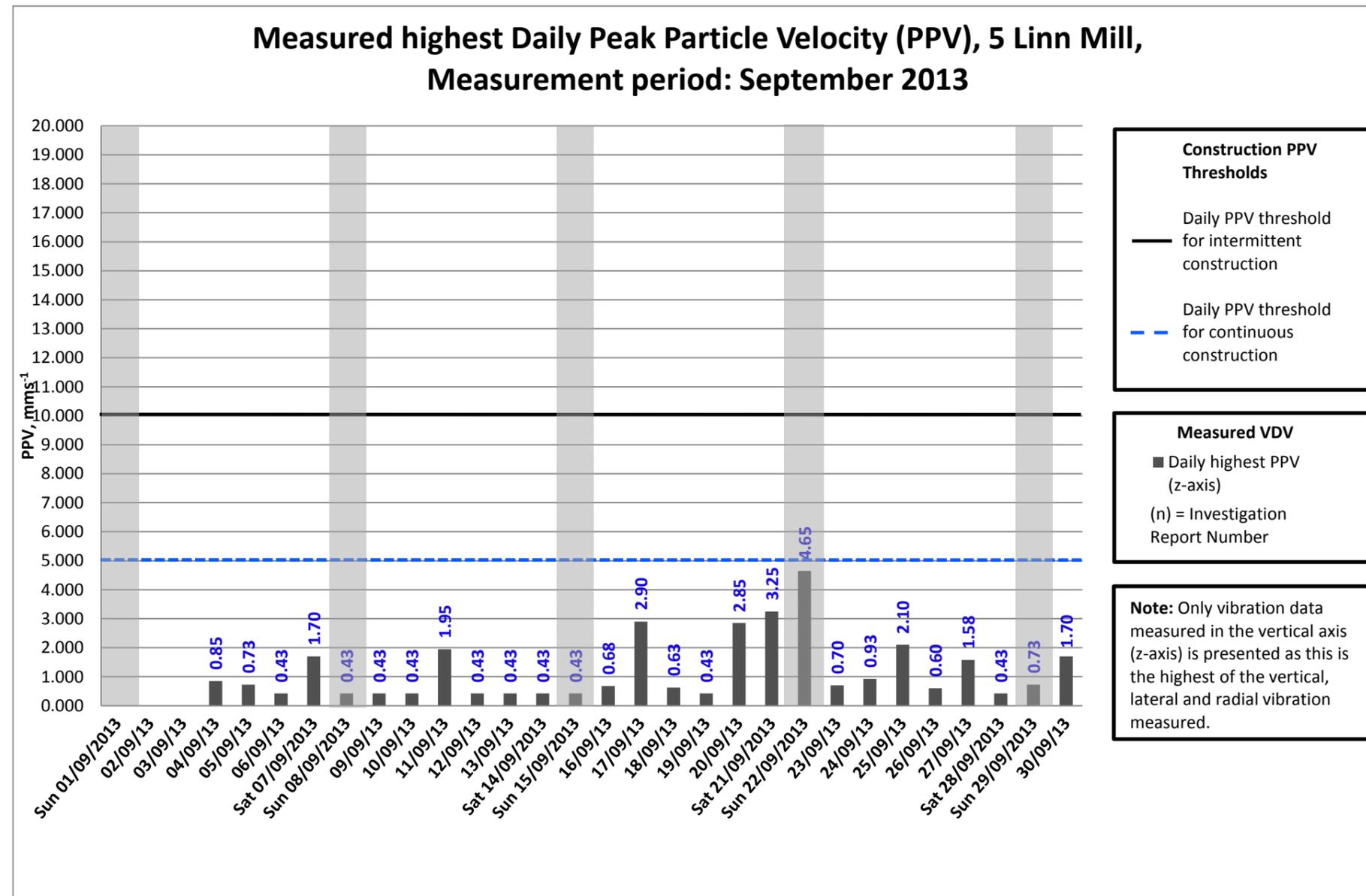
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	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	270	1800	N/A	-	-

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

**Notes on Table 3**

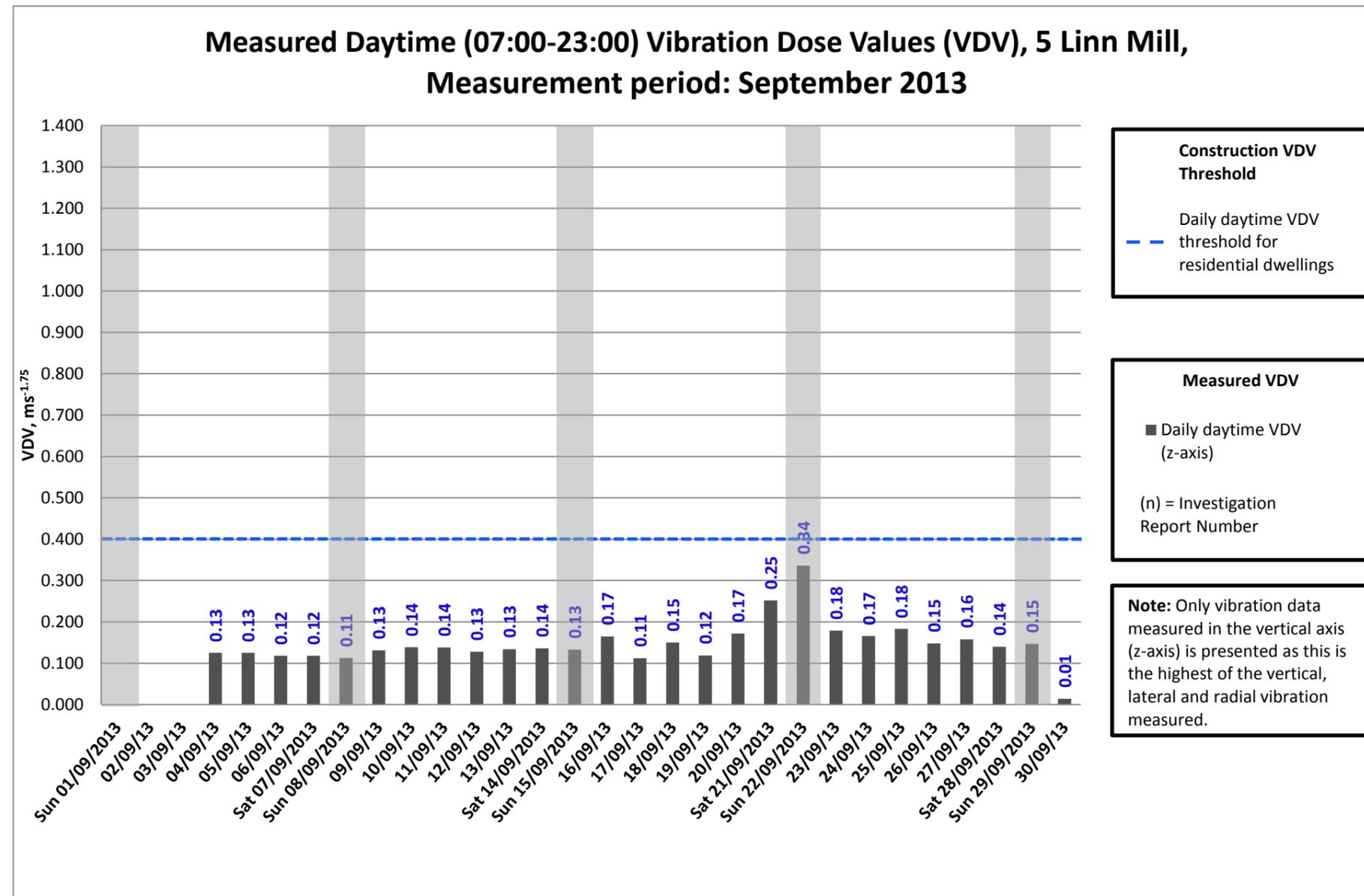
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s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

## APPENDIX B – VIBRATION GRAPHS



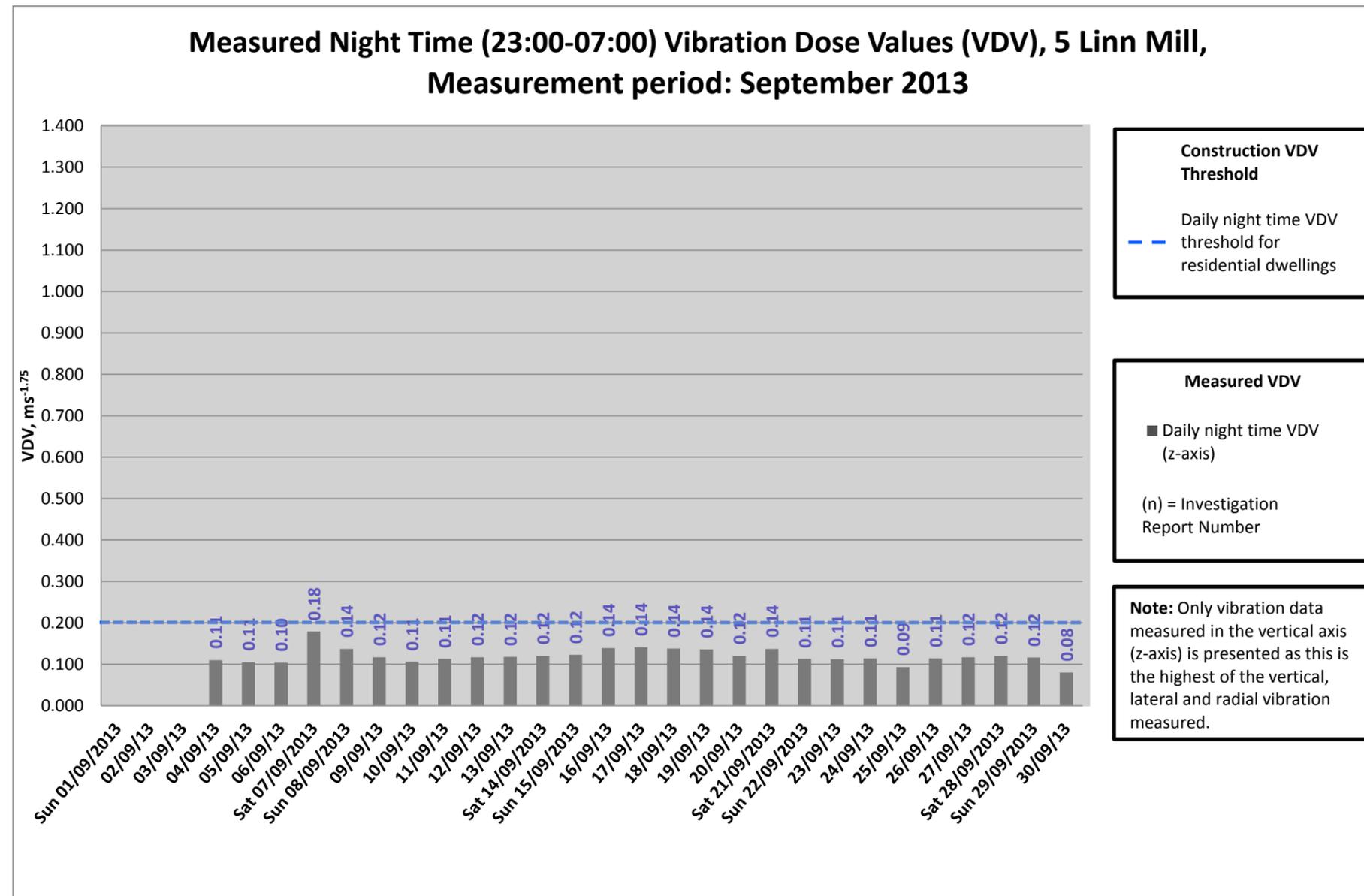
**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 01/09/13 to 03/09/13 due to device power error (faulty connector lead).

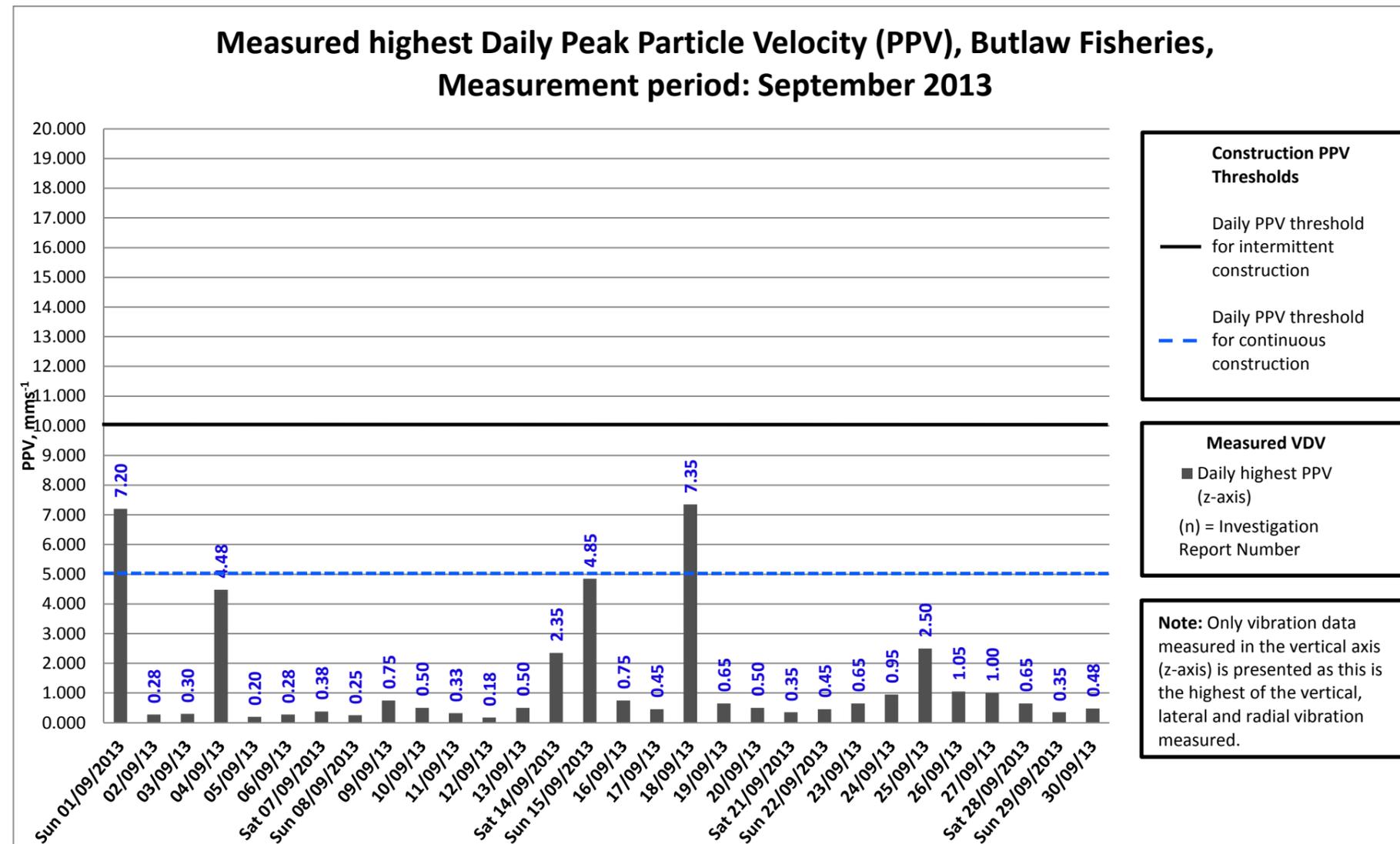


**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 01/09/13 to 03/09/13 due to device power error (faulty connector lead).

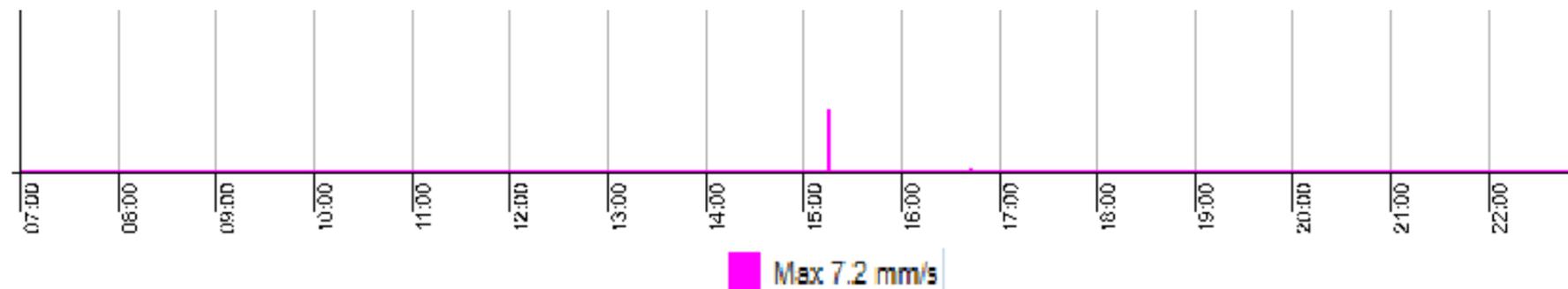


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Linn Mill vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.
  - Data is missing from 01/09/13 to 03/09/13 due to device power error (faulty connector lead).

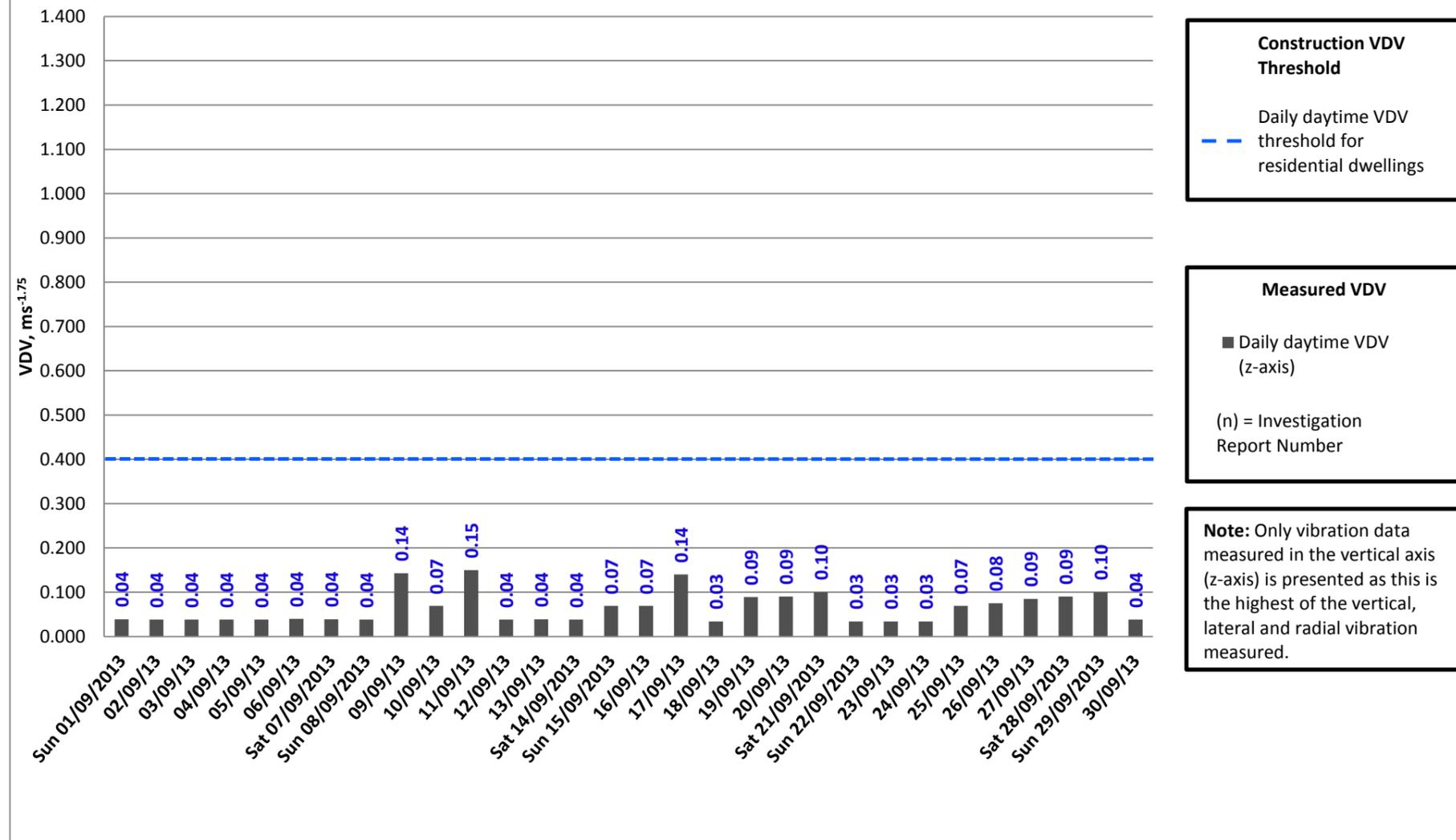


**Notes:**

- The PPV values on 01/09/13 and 18/09/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 01/09/13). Both of these PPV values are within the intermittent threshold of 10mm/s



### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: September 2013



**Construction VDV Threshold**

— Daily daytime VDV threshold for residential dwellings

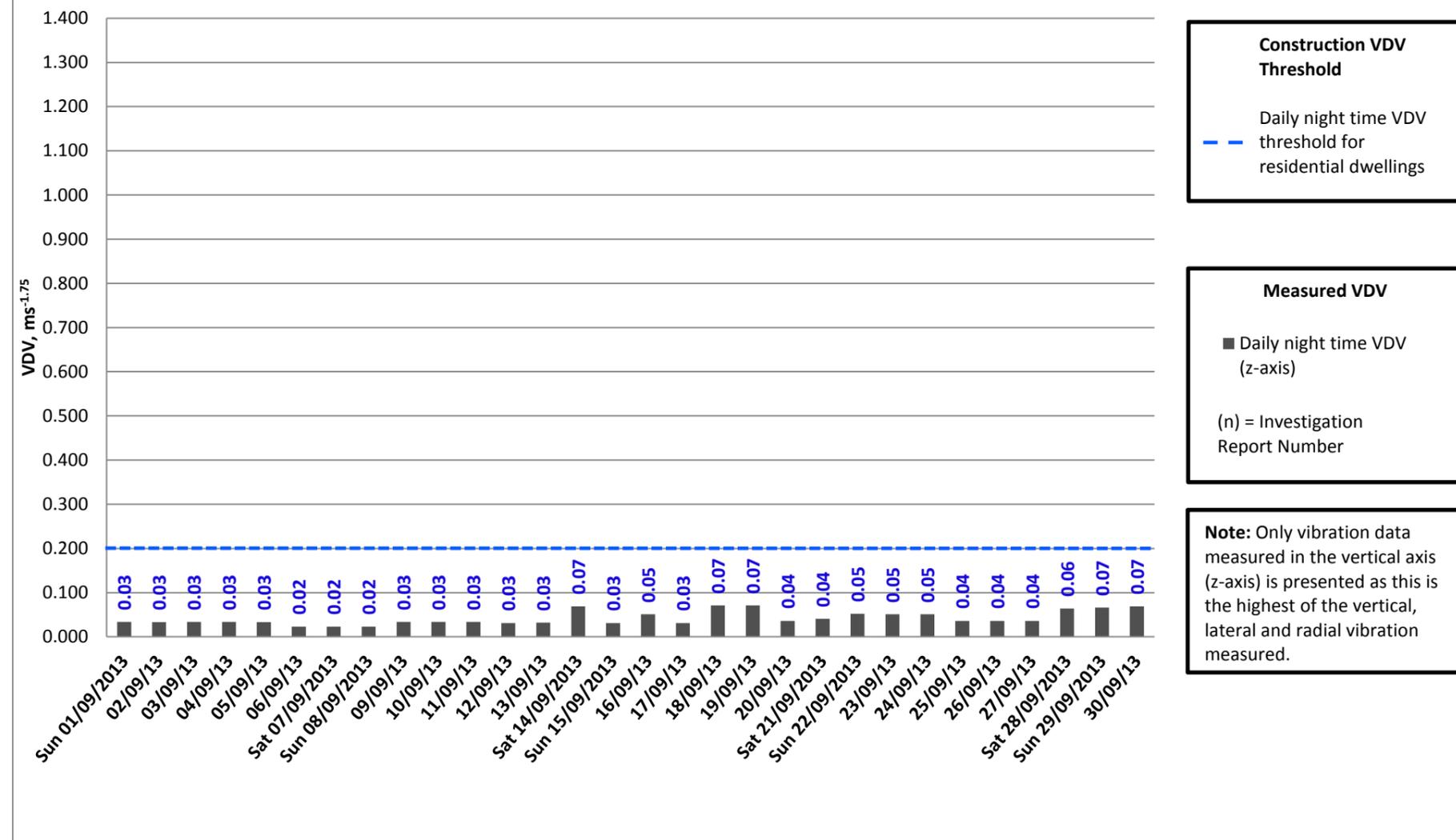
**Measured VDV**

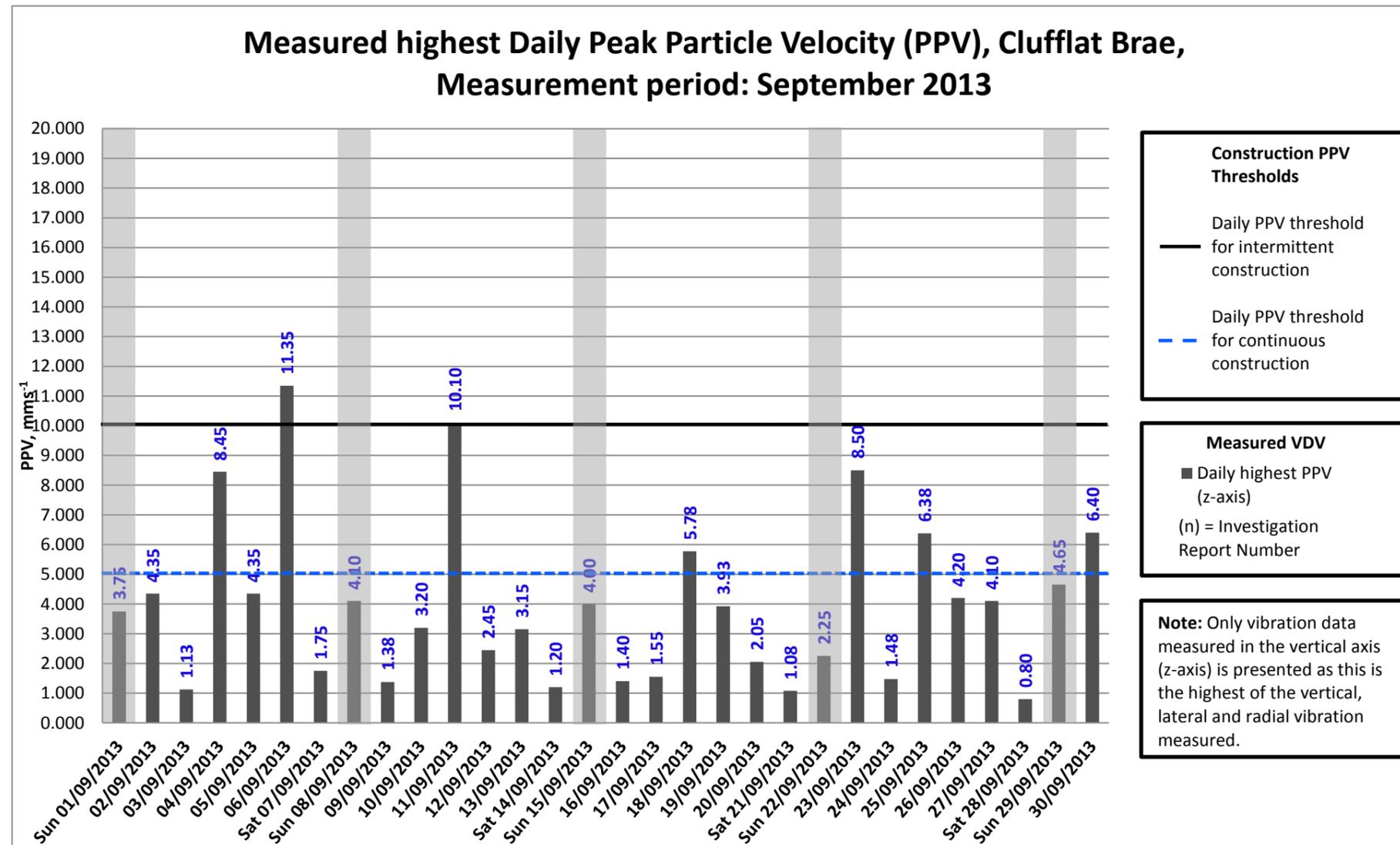
■ Daily daytime VDV (z-axis)

(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.

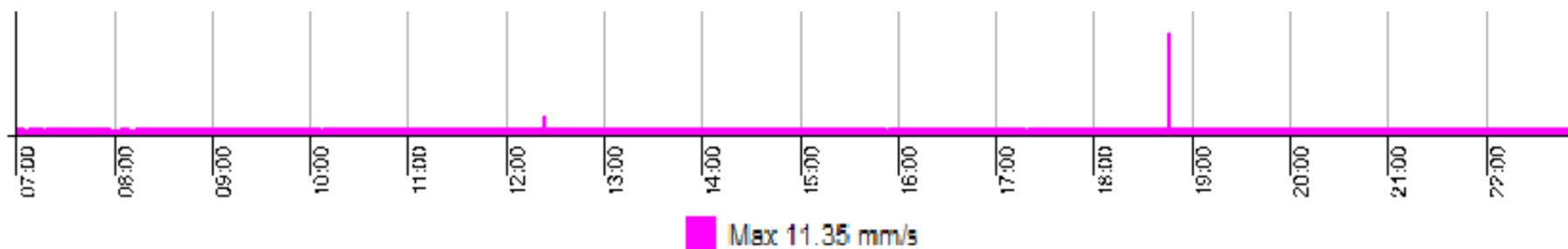
### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: September 2013

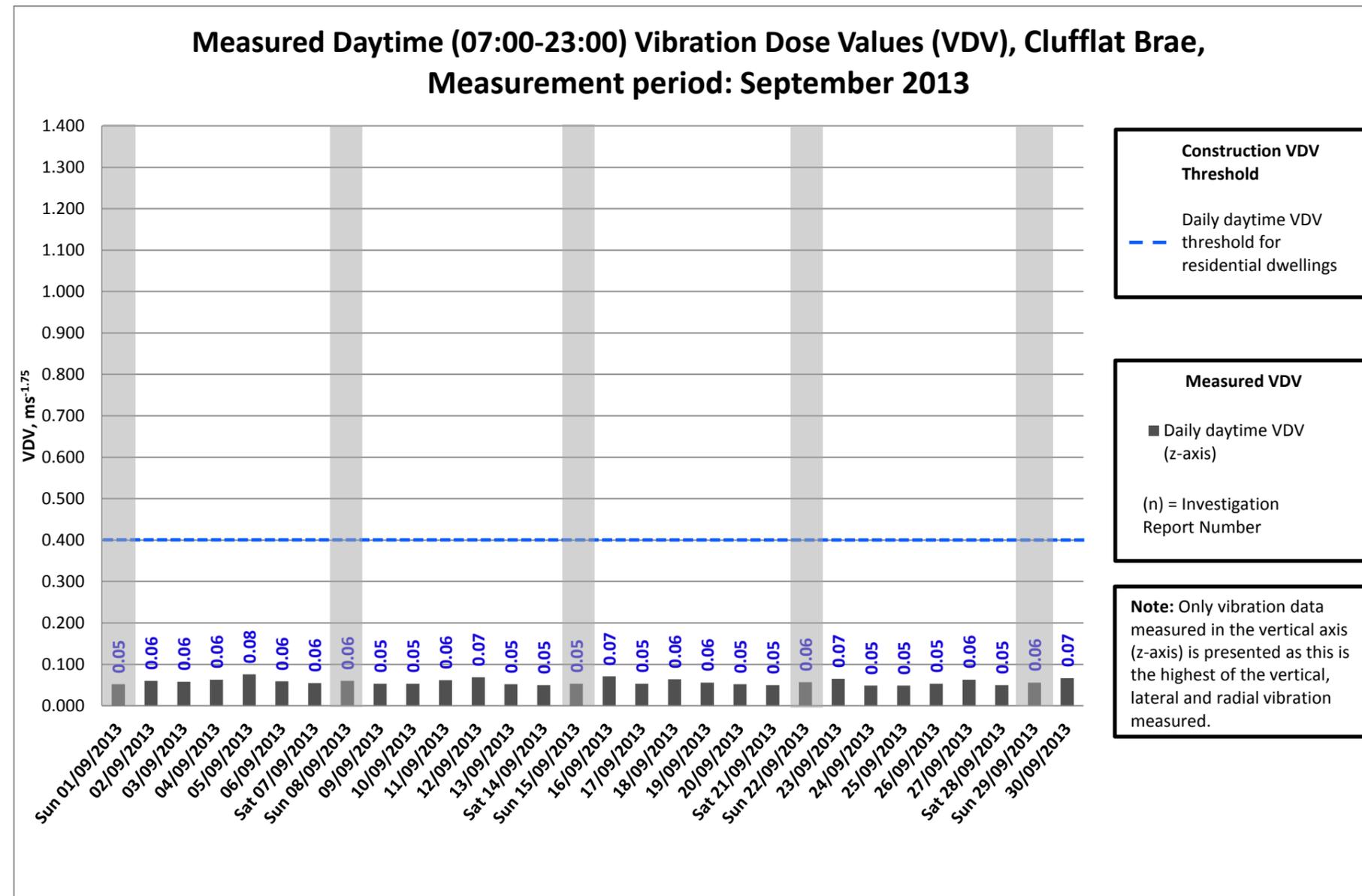




**Notes:**

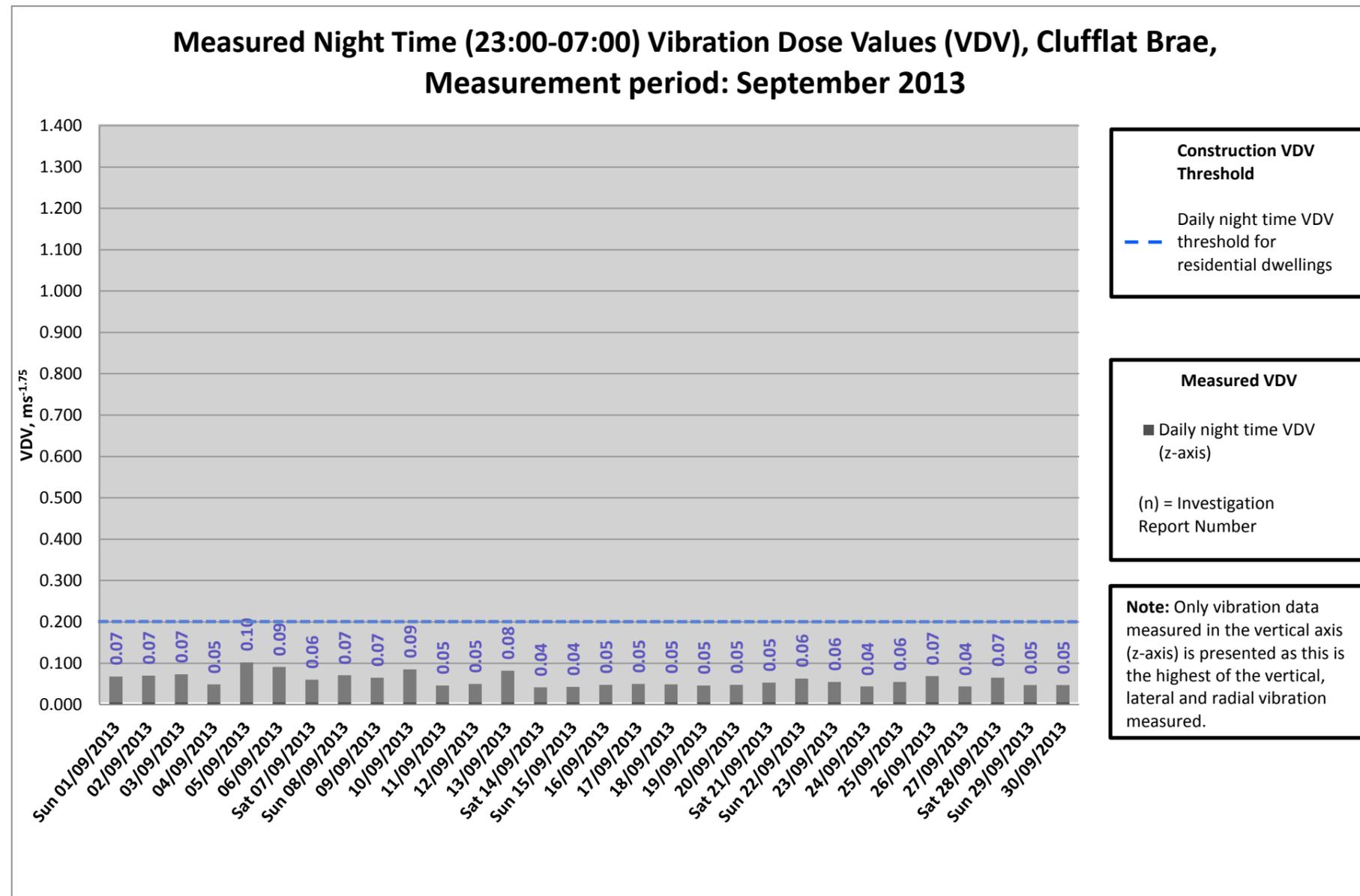
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 04/09/13, 06/09/13, 11/09/13, 18/09/13, 23/09/13, 25/09/13 & 30/09/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 06/09/13), the majority of which are within the intermittent threshold of 10mm/s. Furthermore, it is extremely unlikely that these particular levels were generated as a result of FCBC construction, as the only works to be conducted in the vicinity of the monitor on any of these dates in question, involving vibration inducing plant, were the Society Road works & excavation of mainline in Echline Field, which involved the use of a vibratory roller for certain periods. A vibratory roller exhibits continuous levels vibration over the period of use, not intermittent, isolated levels as displayed in the above exceedances. In addition (as stated in Table 3), a vibratory roller was not operated within 40m of the monitor.





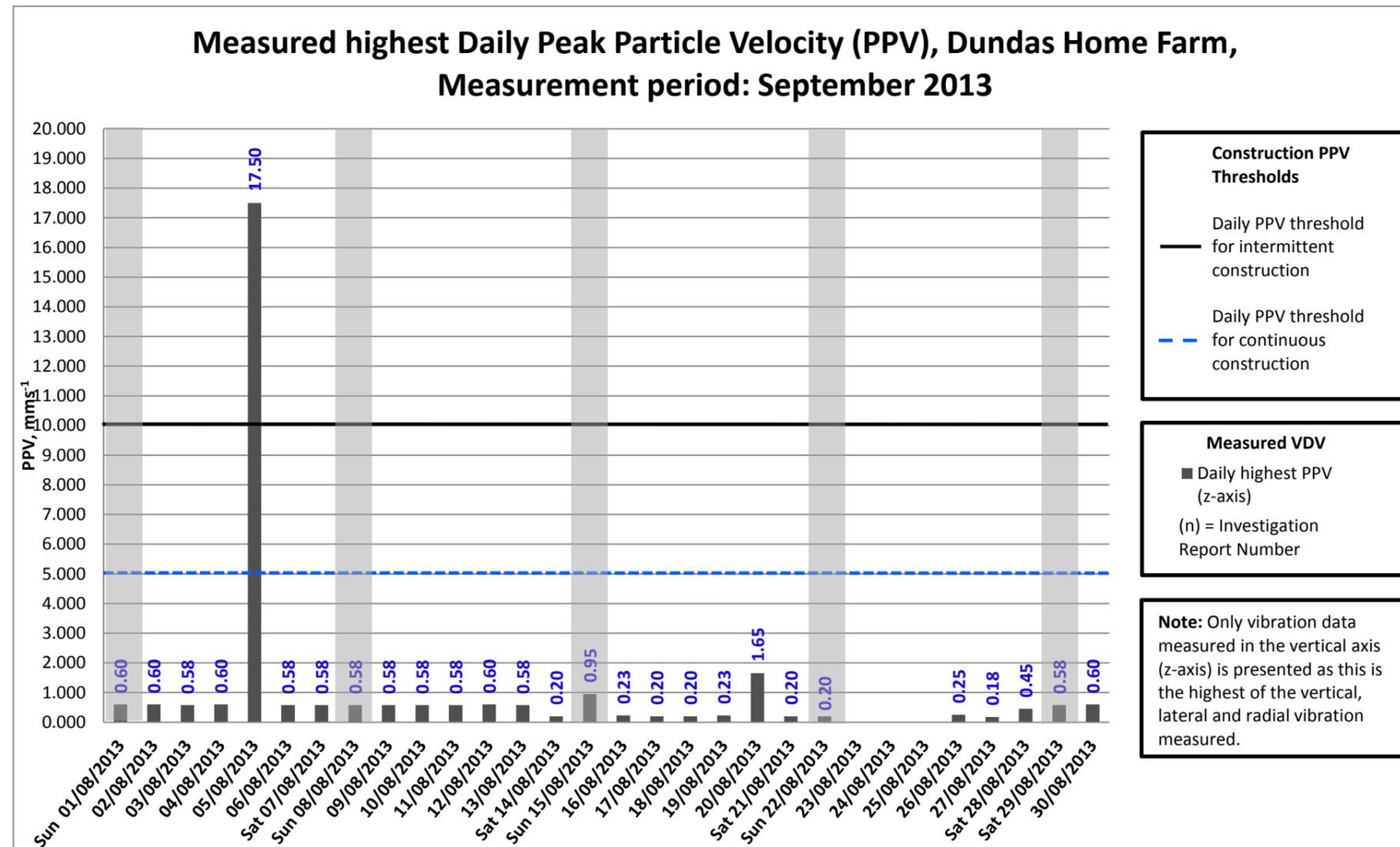
**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.



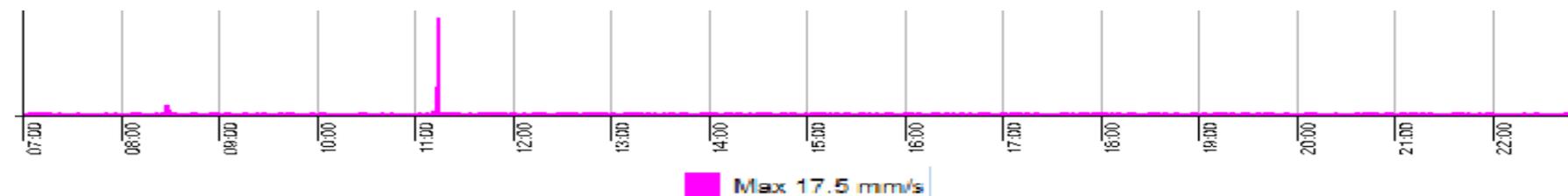
**Notes:**

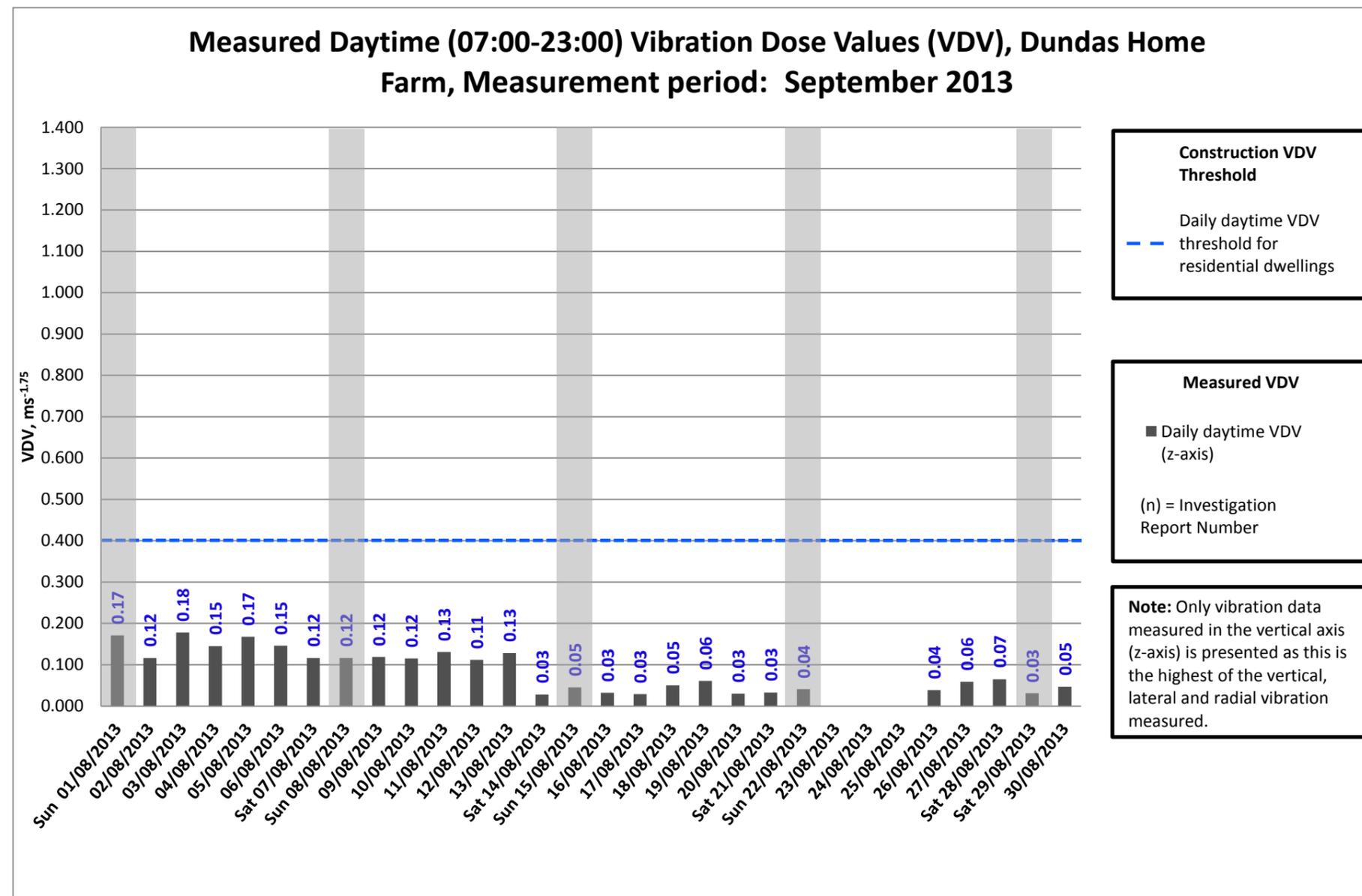
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Clufflat Brae vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.



**Notes:**

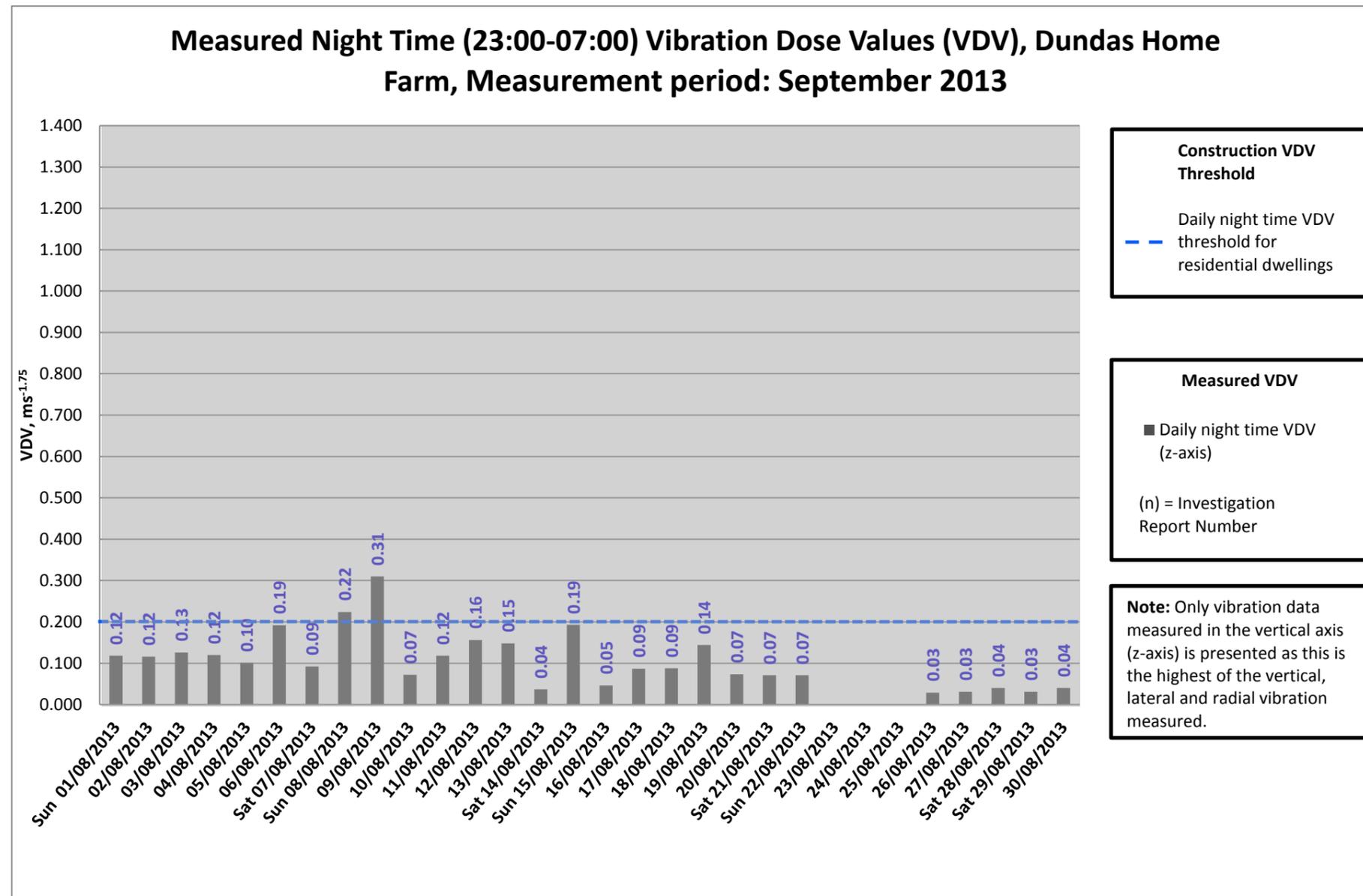
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 23/09/13 and 25/09/13 due to a machine power source issue (power cable accidentally cut during private works at host property).
- The PPV value on 05/09/13 has been investigated, and has been seen to be an individual, isolated event within the period (see Vibrock PPV graph below from 05/09/13). Furthermore, it is extremely unlikely that this particular level was generated as a result of FCBC construction, as the only works to be conducted in the vicinity of the monitor on this date, involving vibration inducing plant, was the generation of the Dundas Environmental Bund, which involved the use of a vibratory roller for certain periods. A vibratory roller exhibits continuous levels of vibration over the period of use, not intermittent, isolated levels as displayed in the above exceedance. In addition (as stated in Table 3), a vibratory roller was not operated within 75m of the monitor.





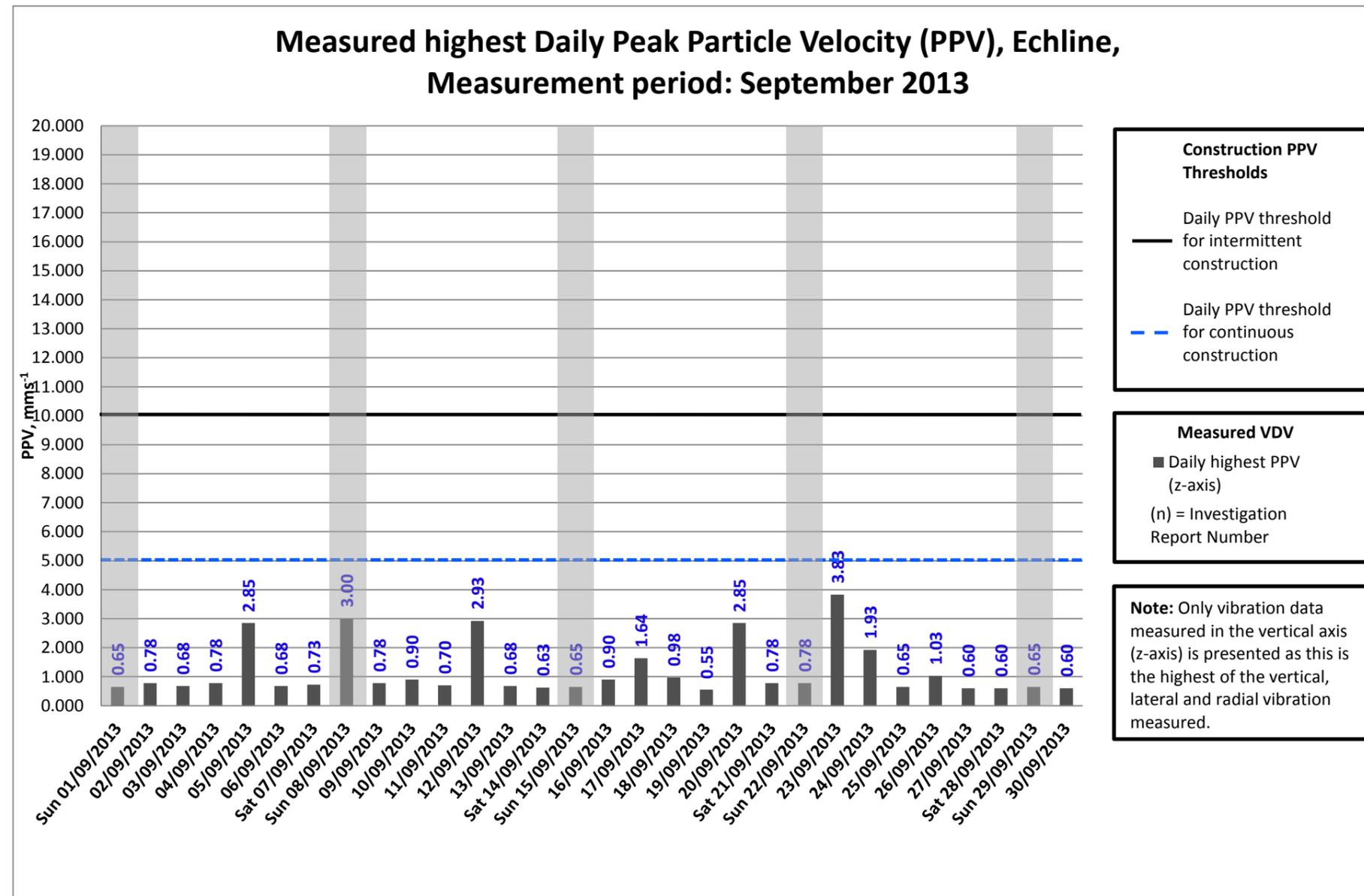
**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 23/09/13 and 25/09/13 due to a machine power source issue (power cable accidentally cut during private works at host property).



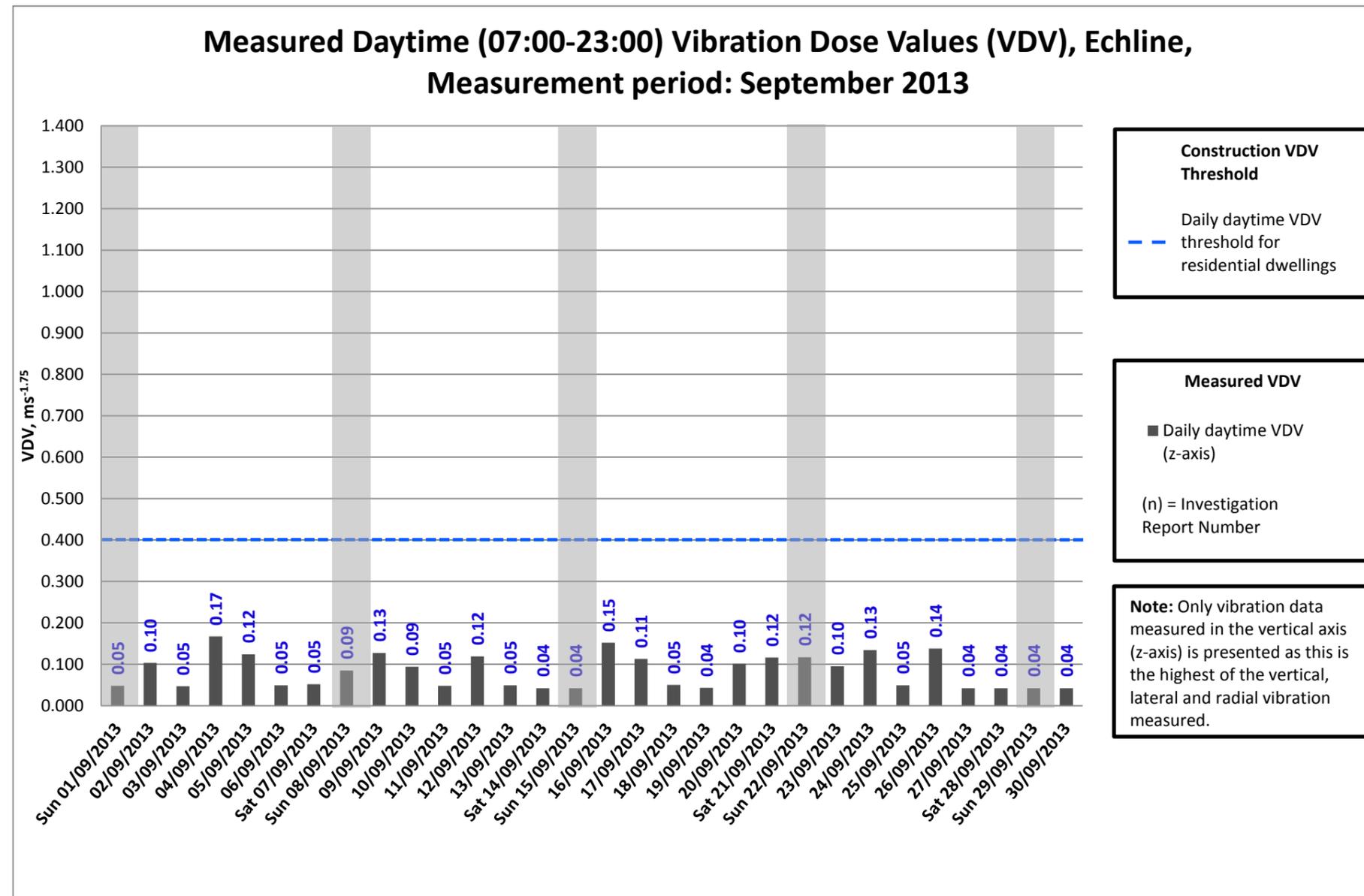
**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.



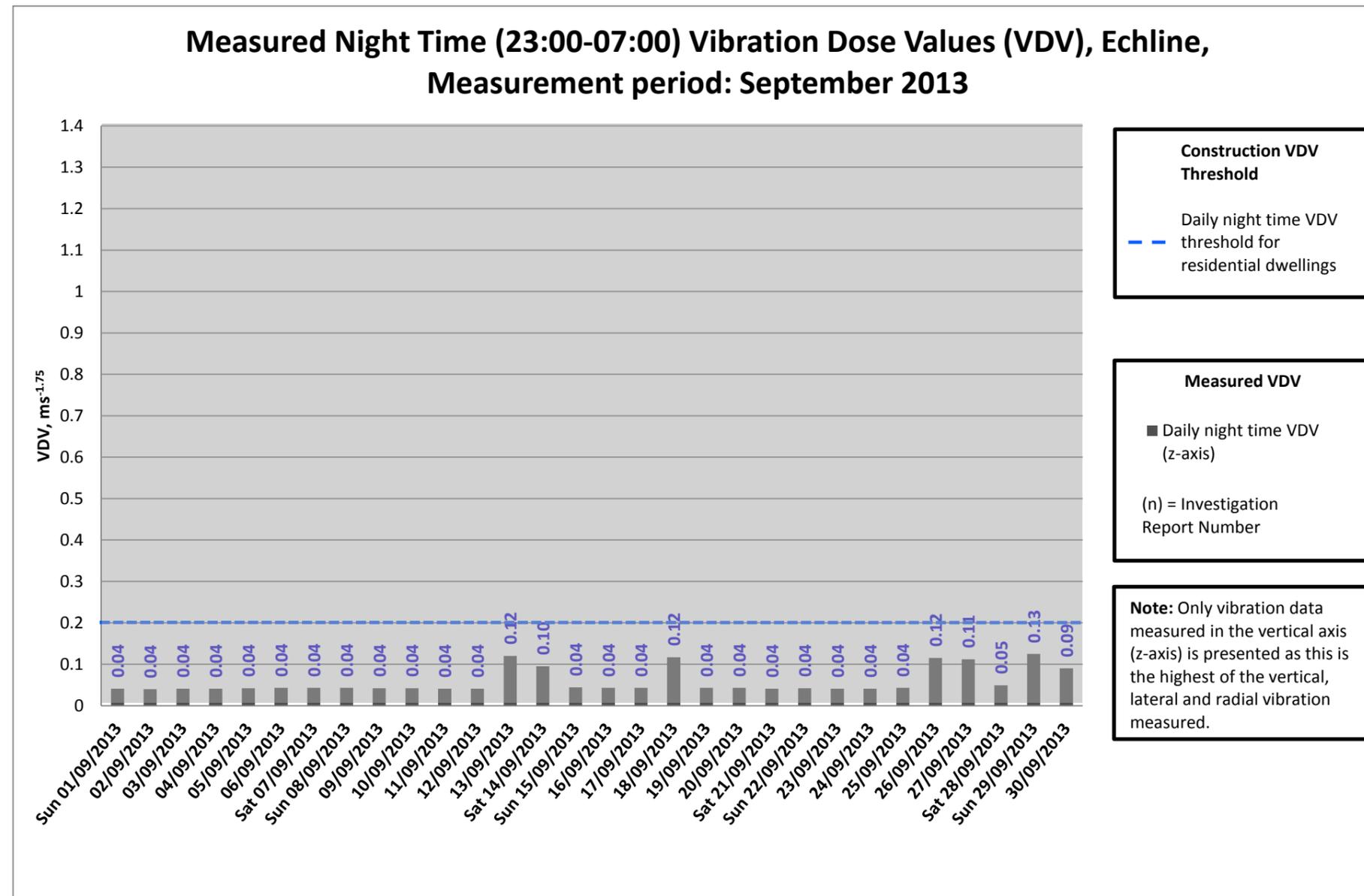
**Notes**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.

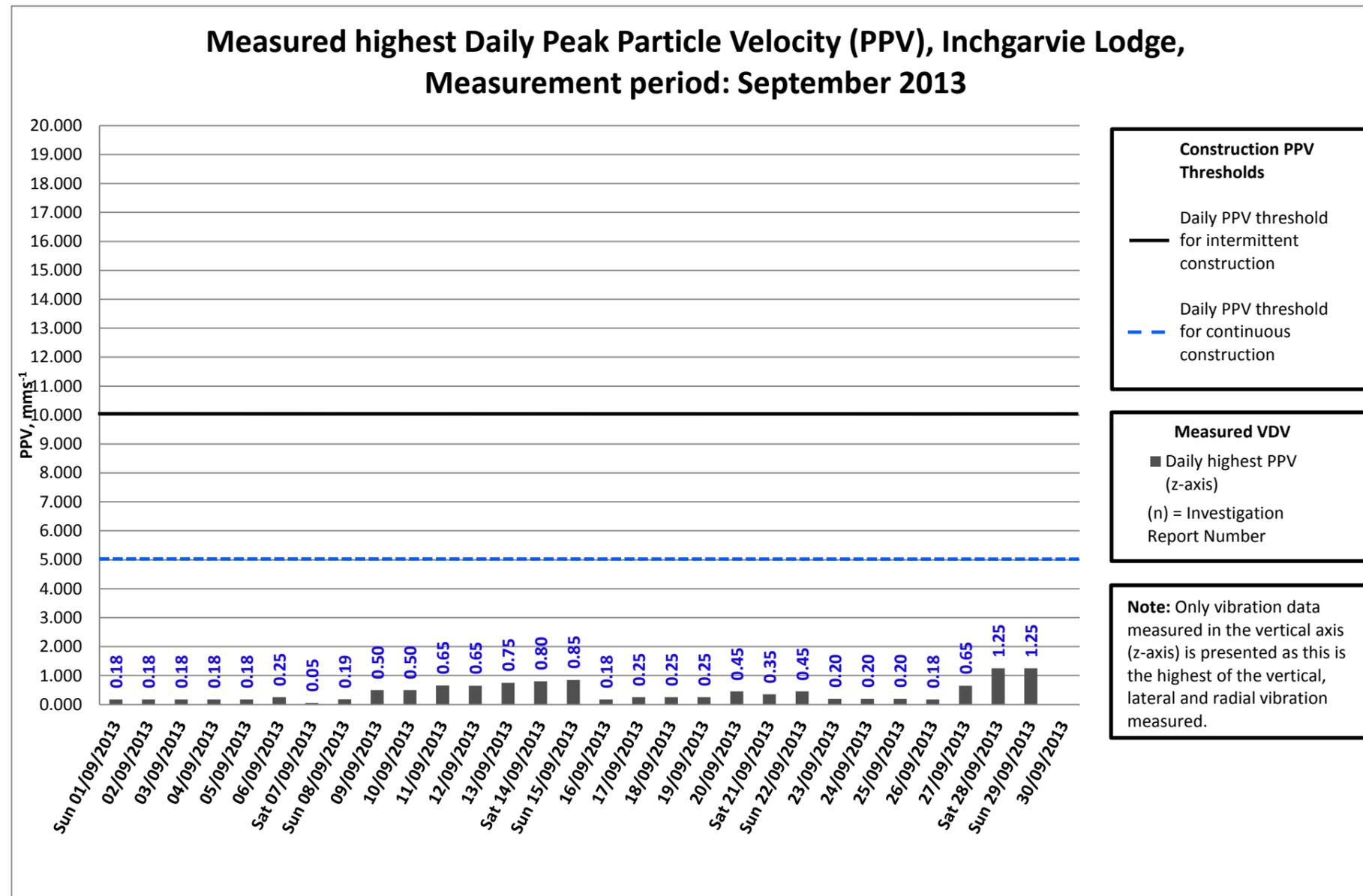


**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.

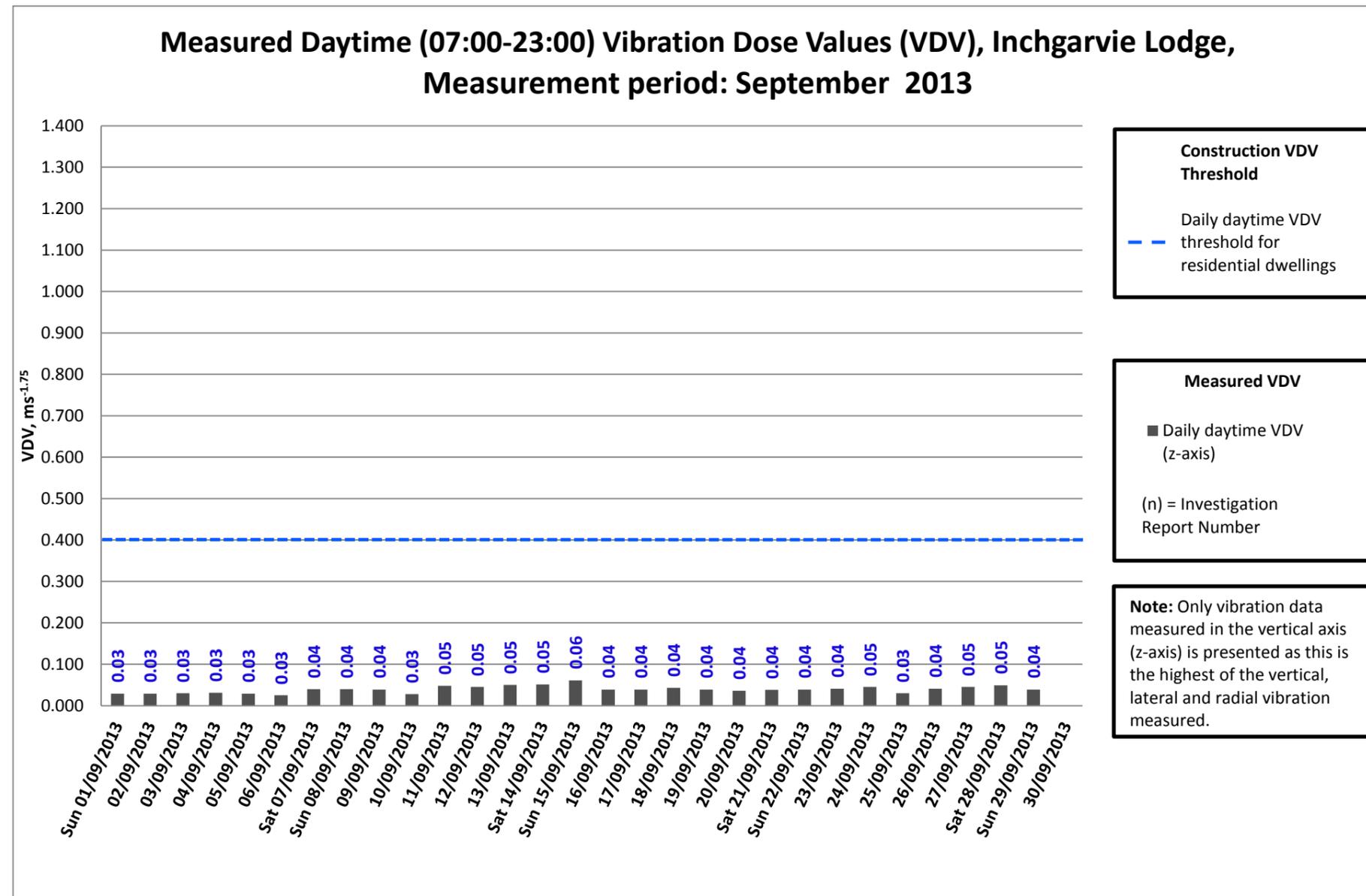


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Echline vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.



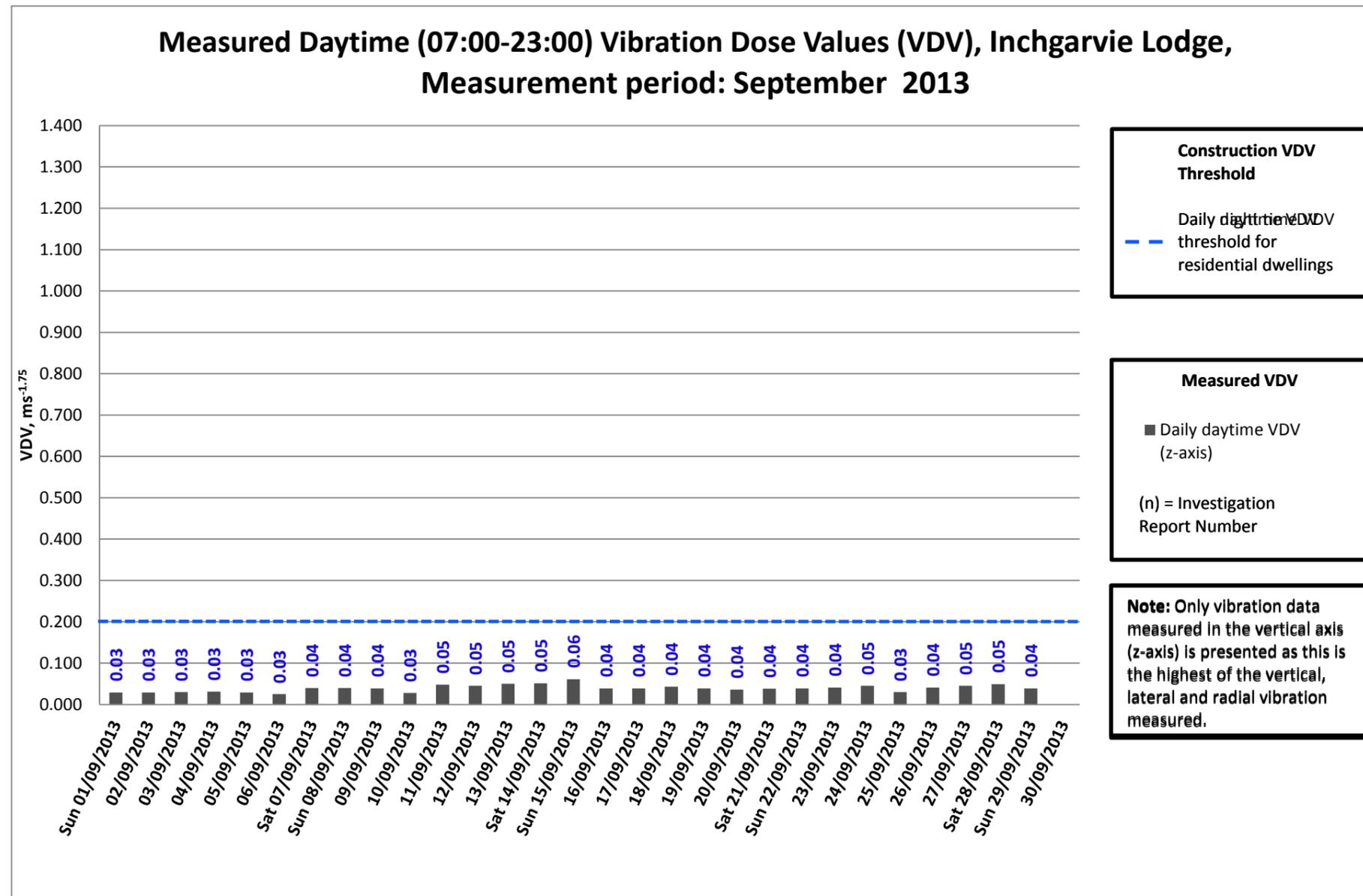
**Notes:**

- Data is missing from 30/09/13 due to a machine power source issue (removal of additional monitoring device for repair (air quality monitor) triggered an electrical mains fault).



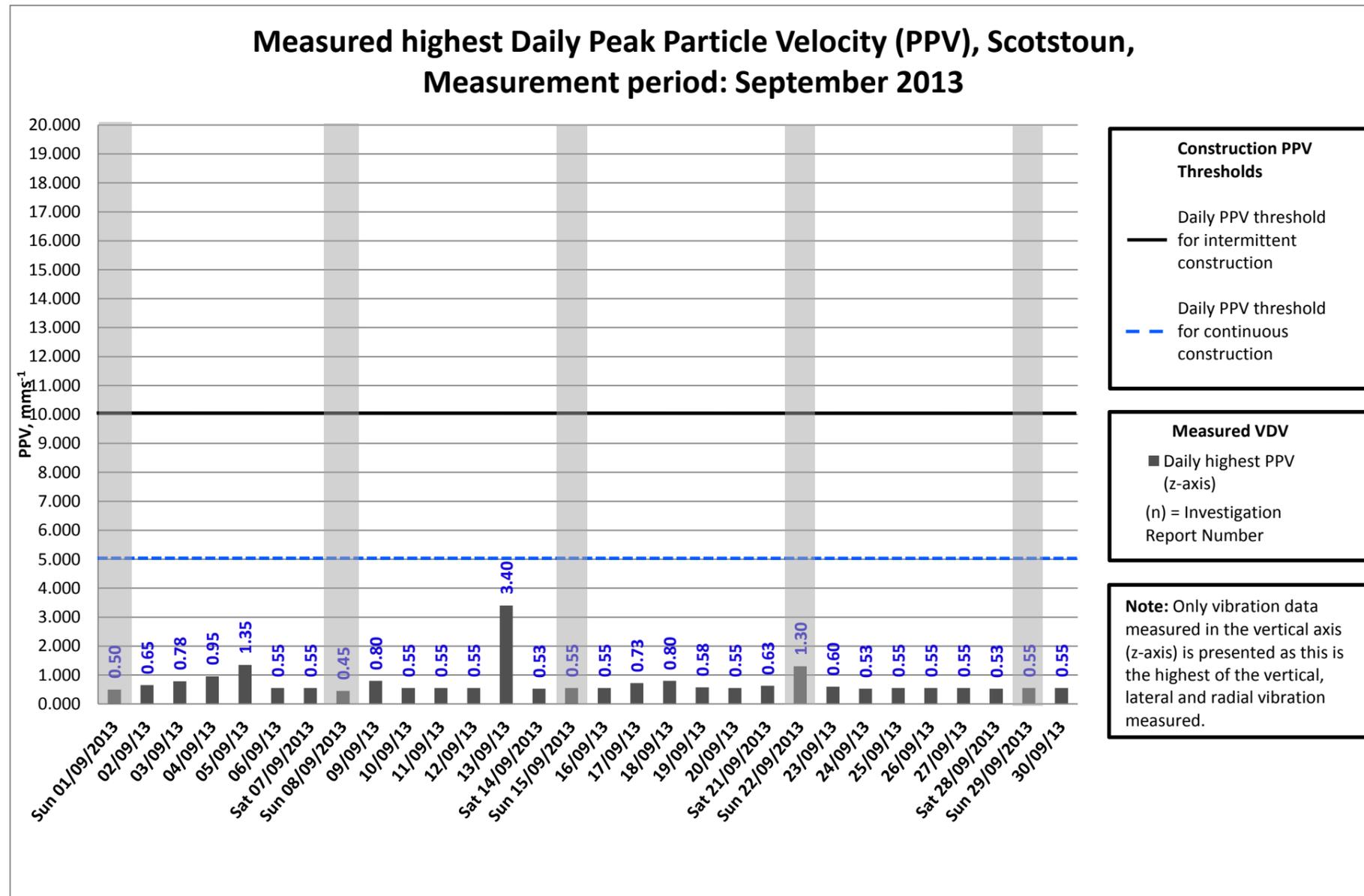
**Notes:**

- Data is missing from 30/09/13 due to a machine power source issue (removal of additional monitoring device for repair (air quality monitor) triggered an electrical mains fault).



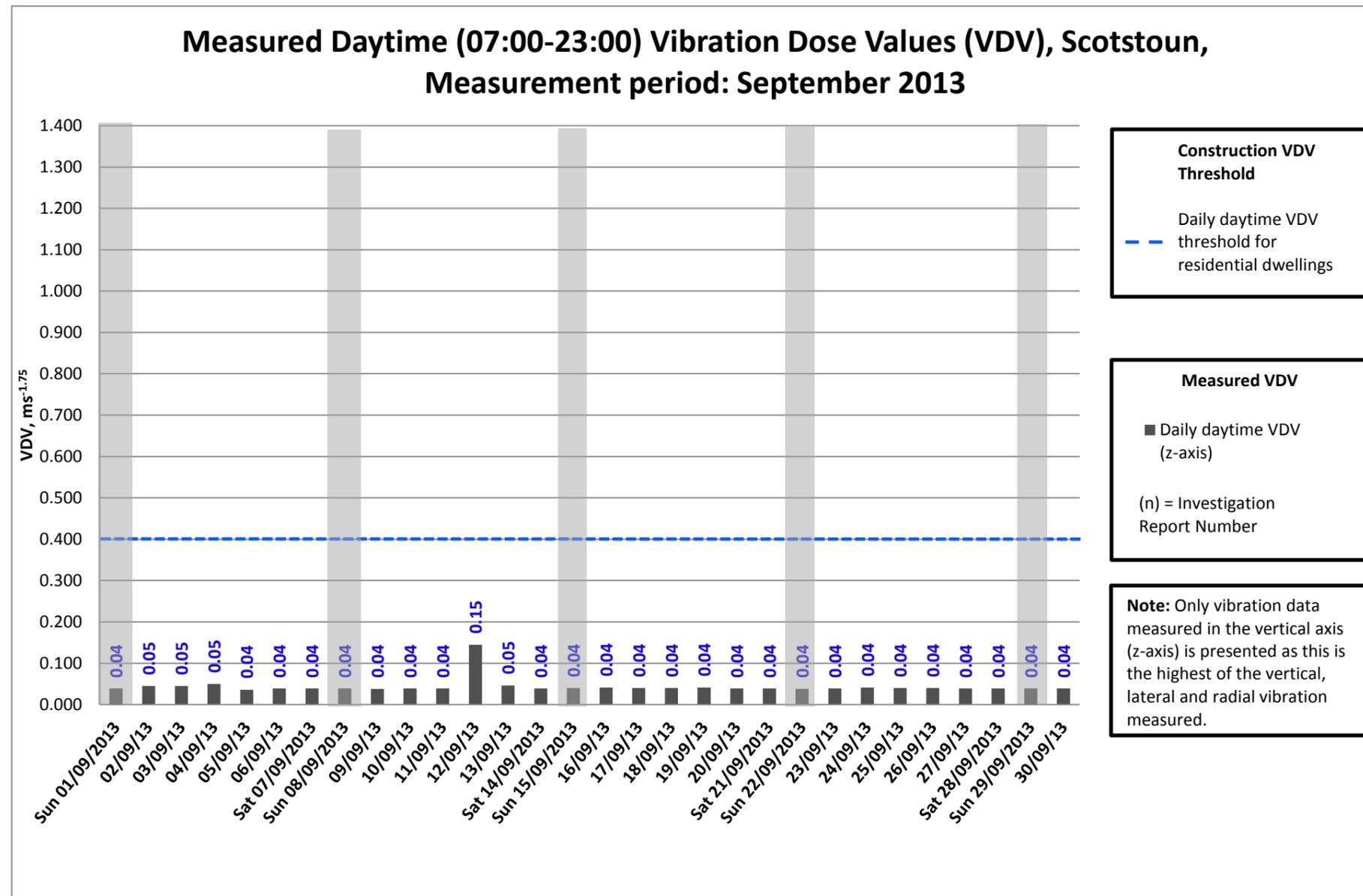
**Notes:**

- Data is missing from 30/09/13 due to a machine power source issue (removal of additional monitoring device for repair (air quality monitor) triggered an electrical mains fault).



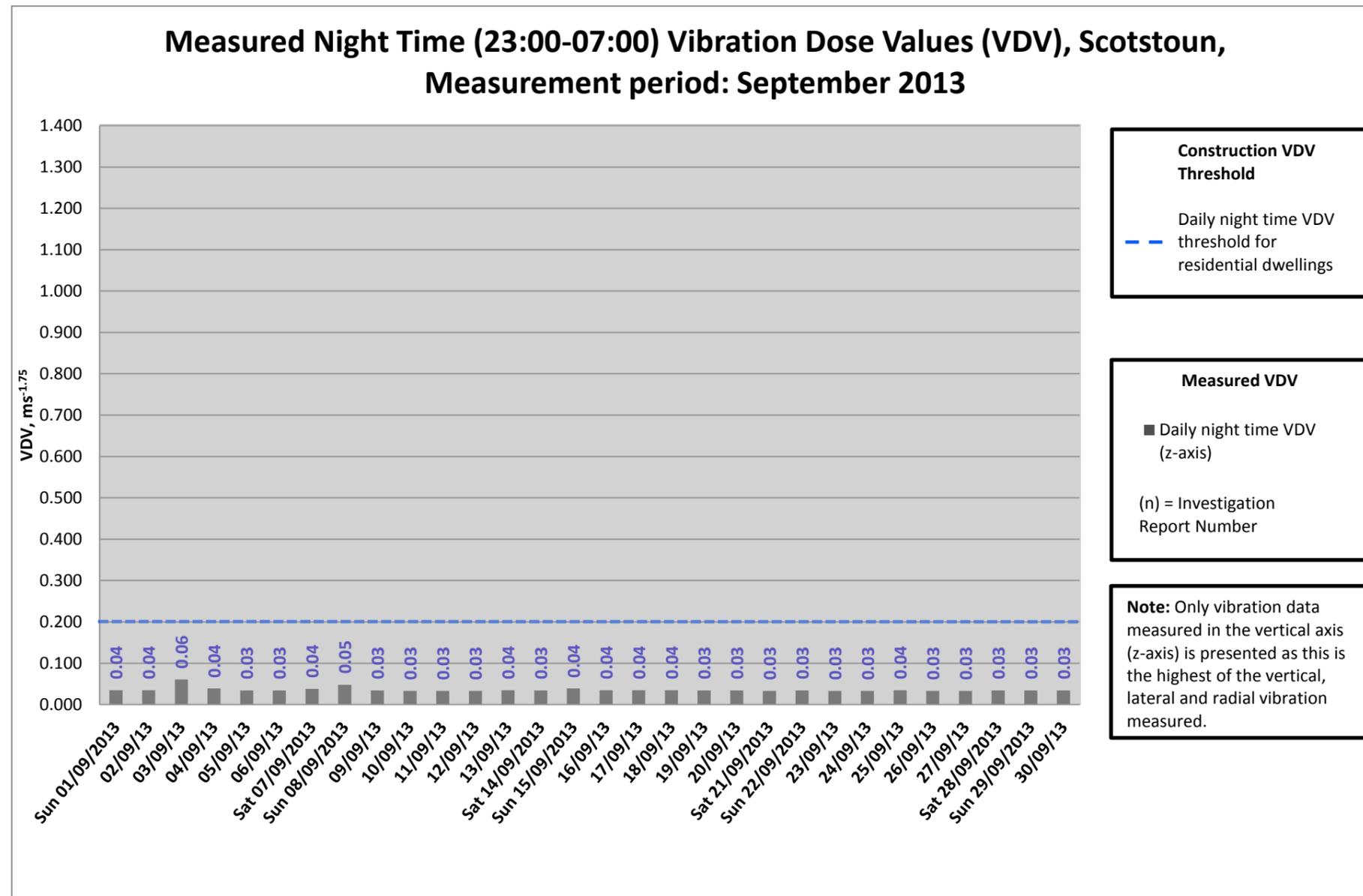
**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.

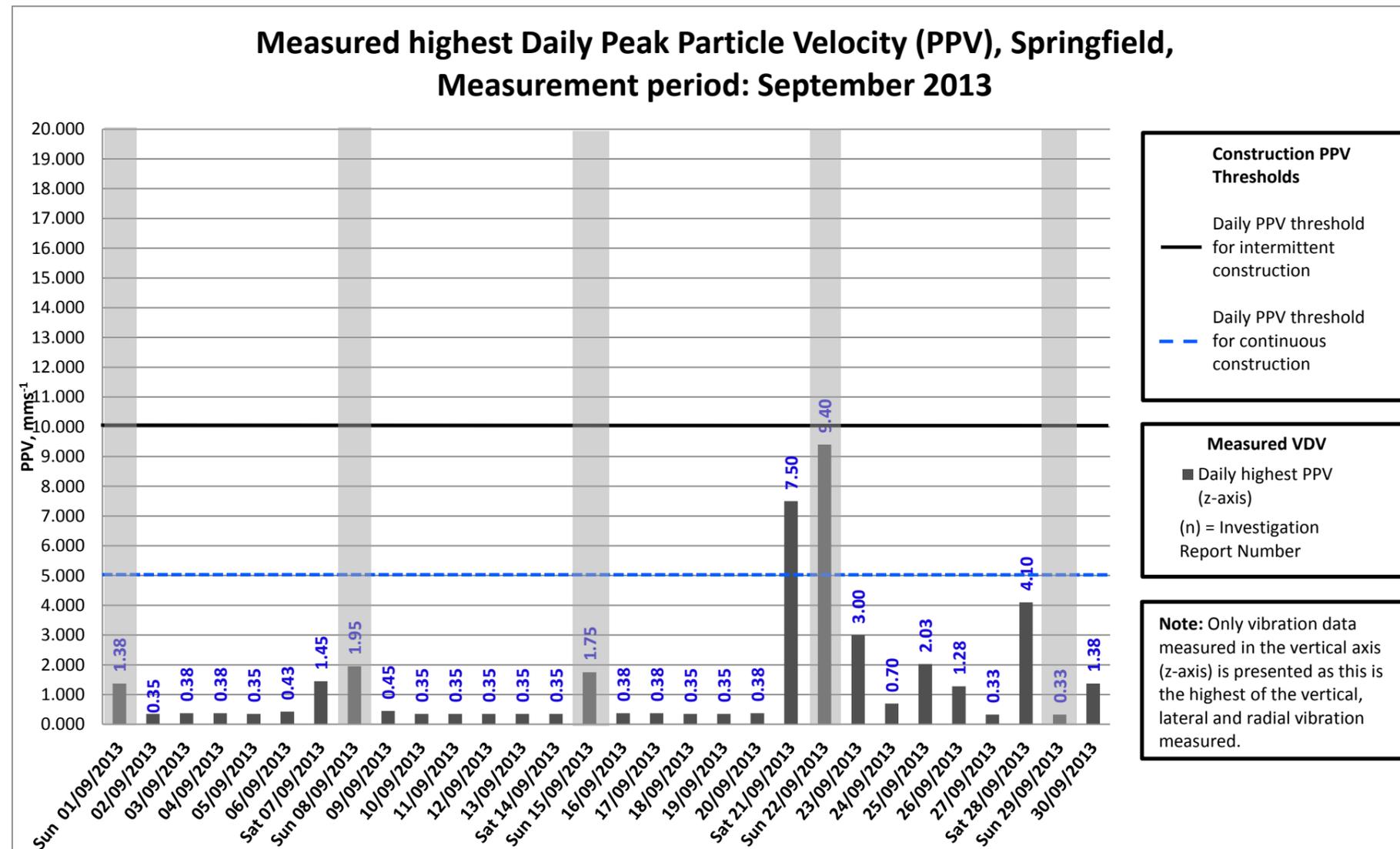


**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.

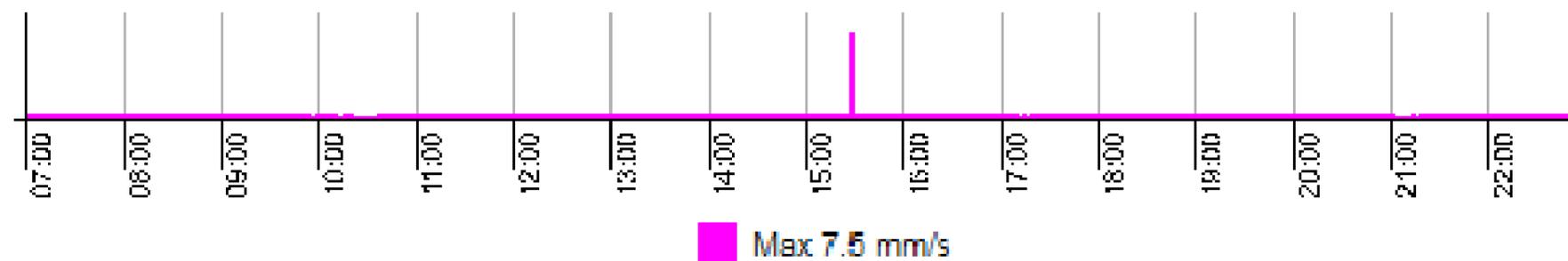


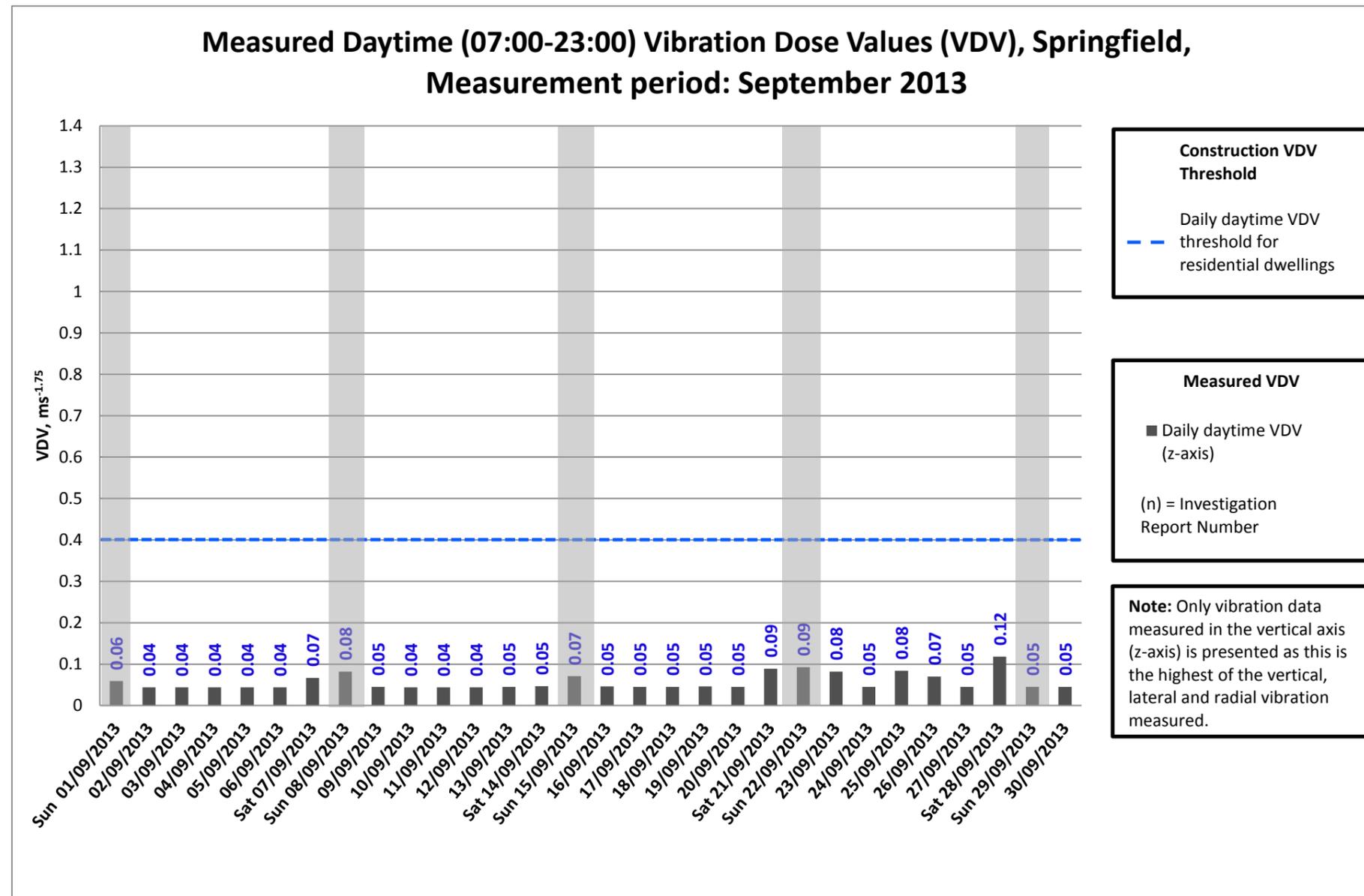
- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Scotstoun vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.



**Notes:**

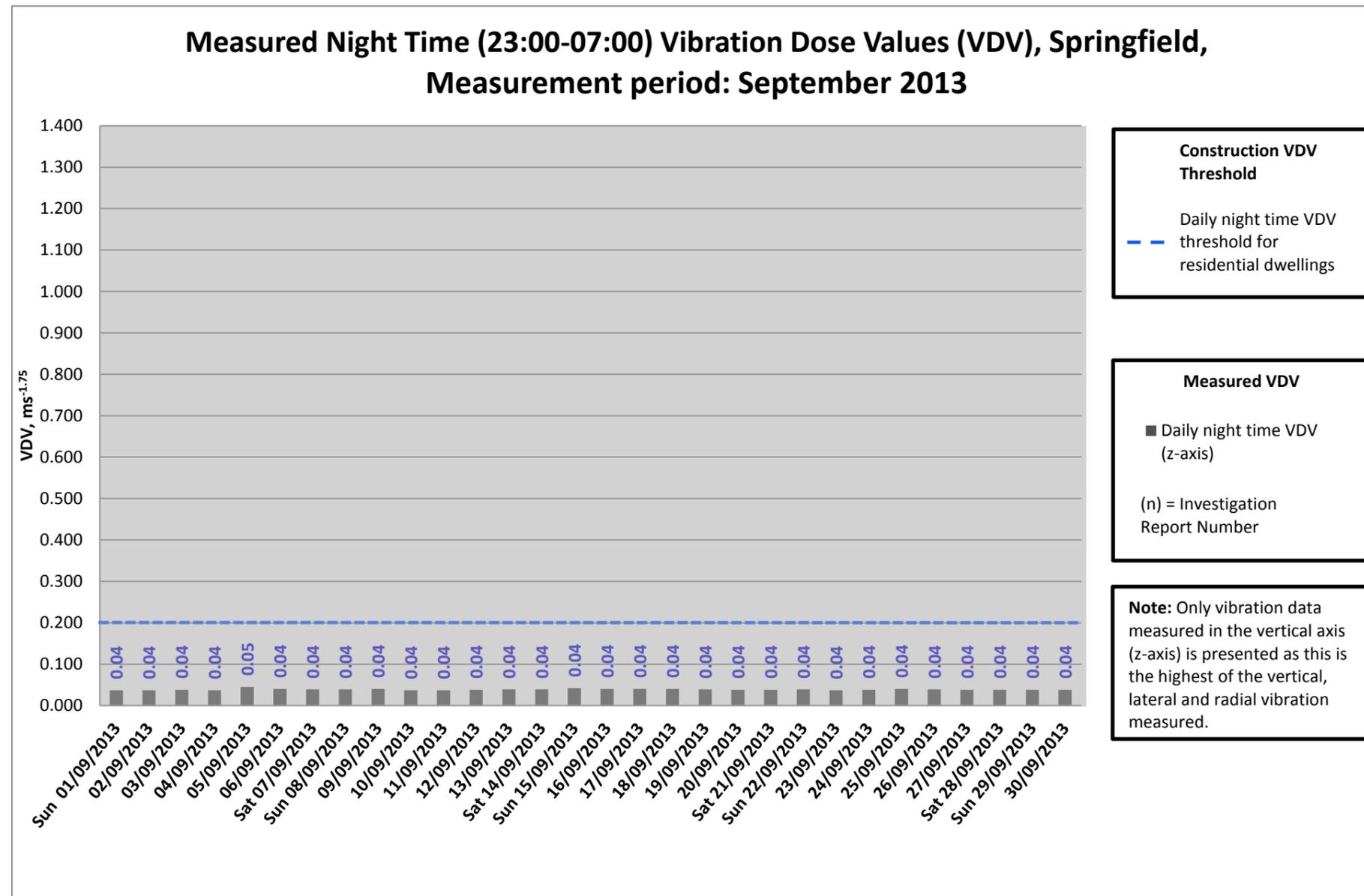
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV value on 21/09/13 has been investigated, and has been seen to be an individual, isolated event within the period (see Vibrock PPV graph below from 21/09/13). This PPV value is within the intermittent threshold of 10mm/s.



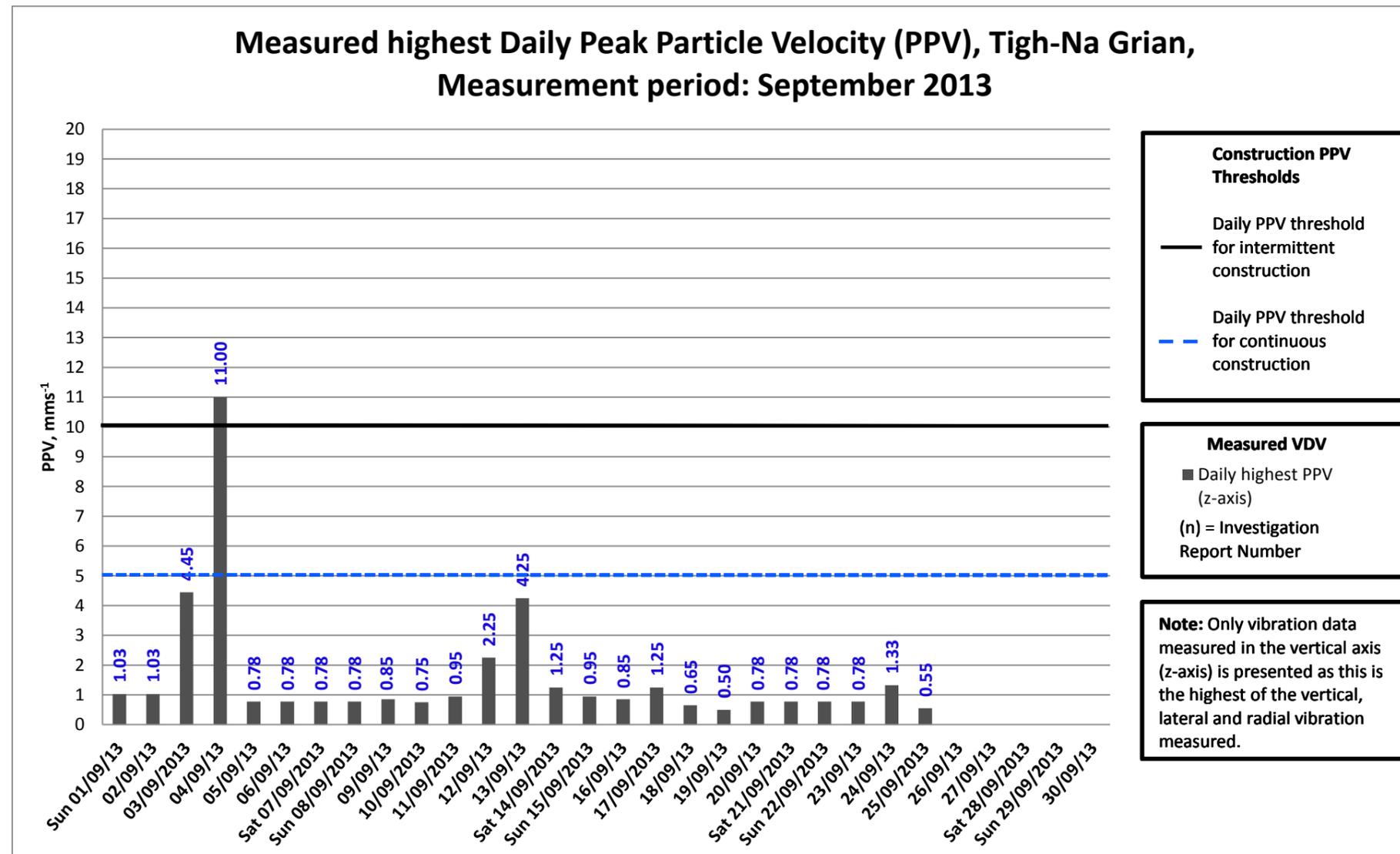


**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sunday.

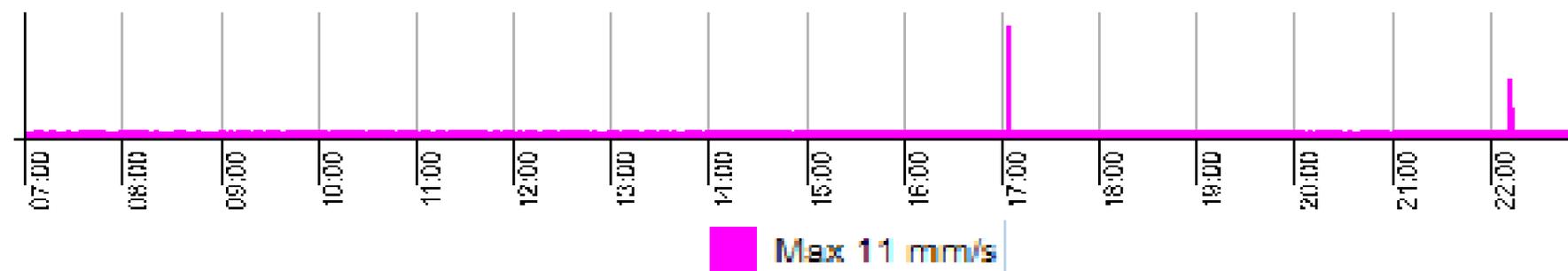


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.

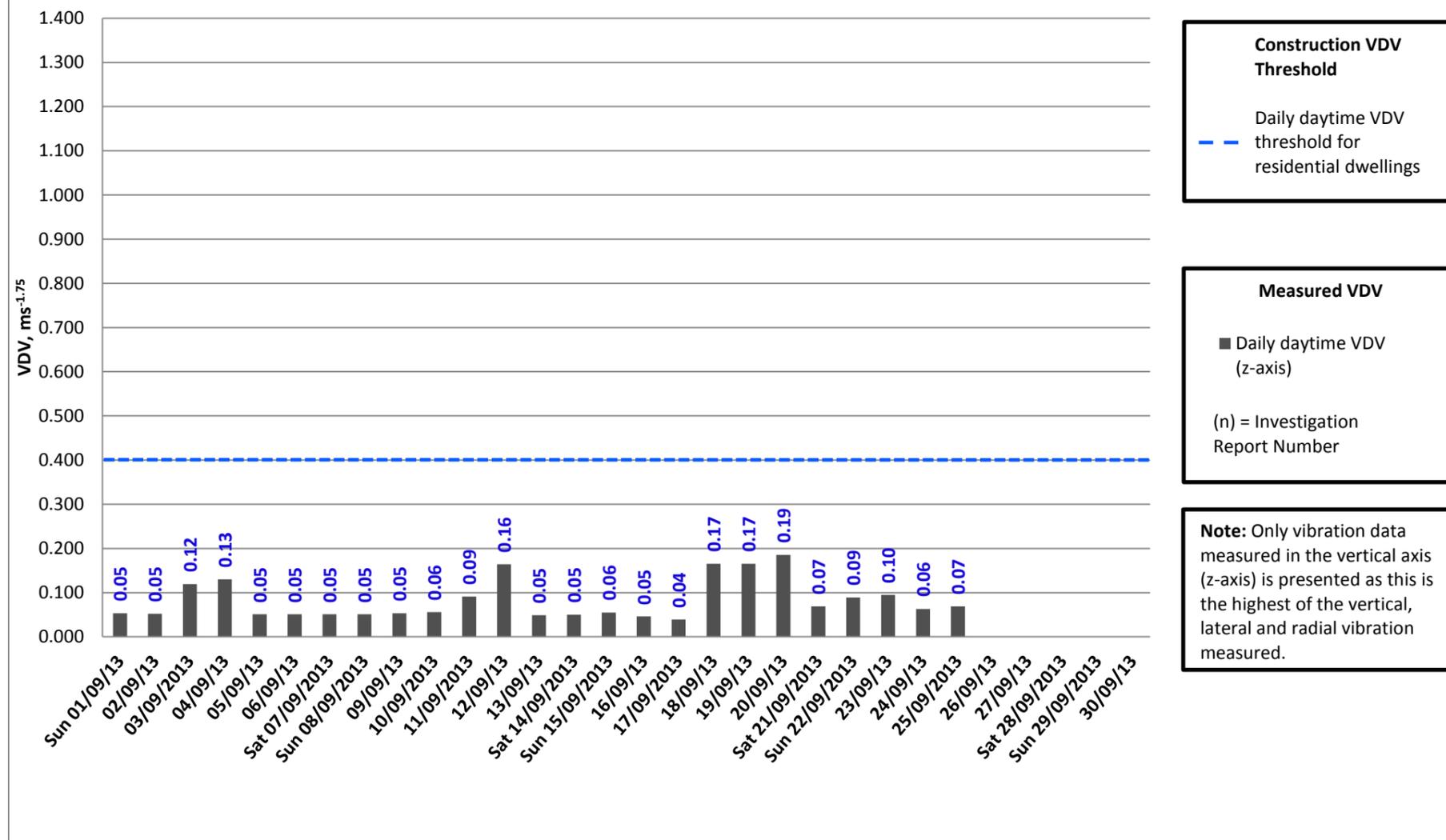


**Notes:**

- Data is missing from 26/09/13 to 30/09/13 due to device power error (faulty connector lead).
- The PPV value on the 04/09/13 has been investigated, and has been seen to be an individual, isolated event within the period (see Vibrock PPV graph below from 04/09/13). Furthermore, this particular level cannot have been generated as a result of FCBC construction, as the only the works to be conducted throughout the month of September in vicinity of the monitor, were works at the North Tower (rebar, formwork & concreting works and crane platform piling works), which is over 250m from the receptor.

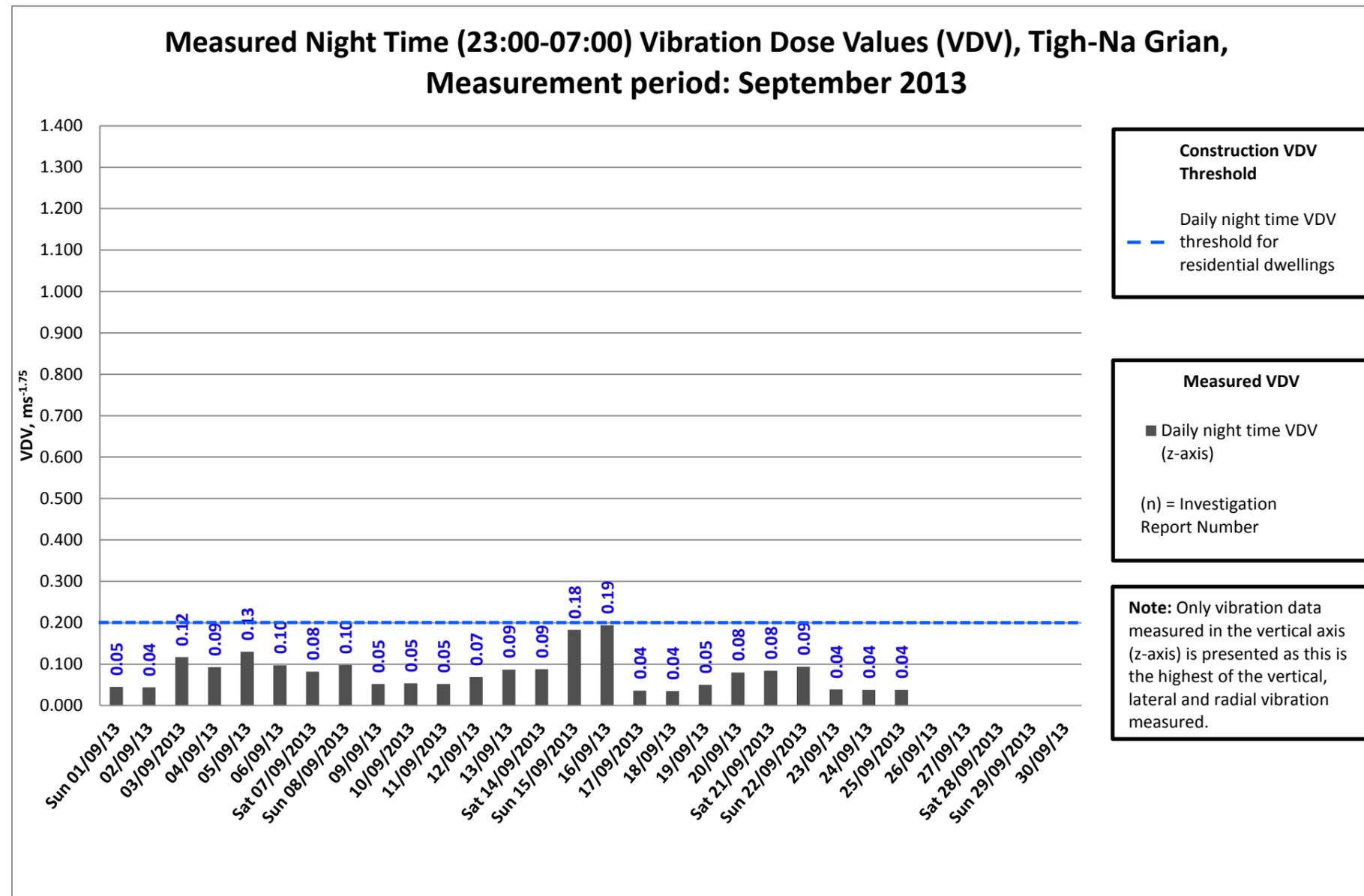


### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: September 2013



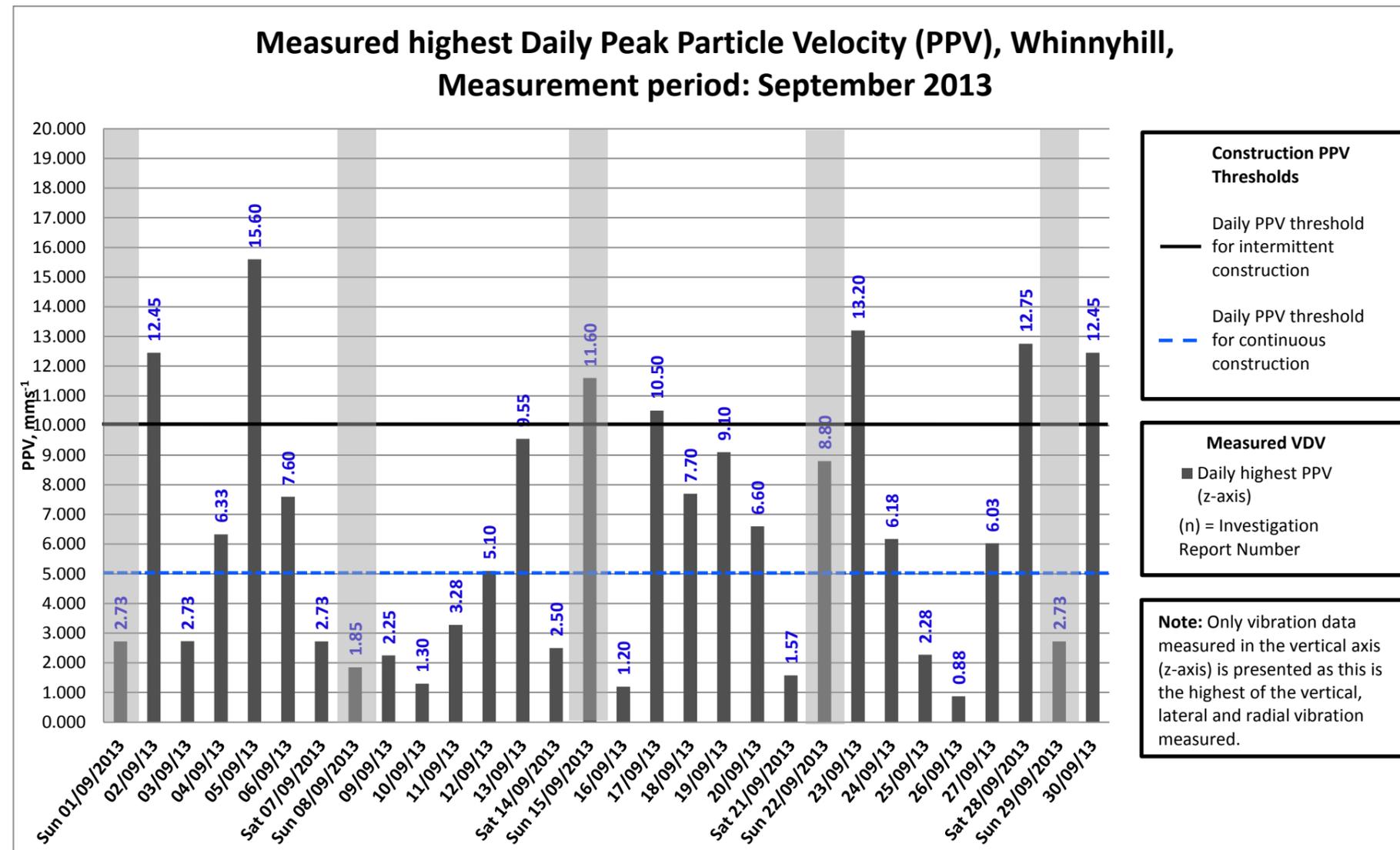
**Notes:**

- Data is missing from 26/09/13 to 30/09/13 due to device power error (faulty connector lead).



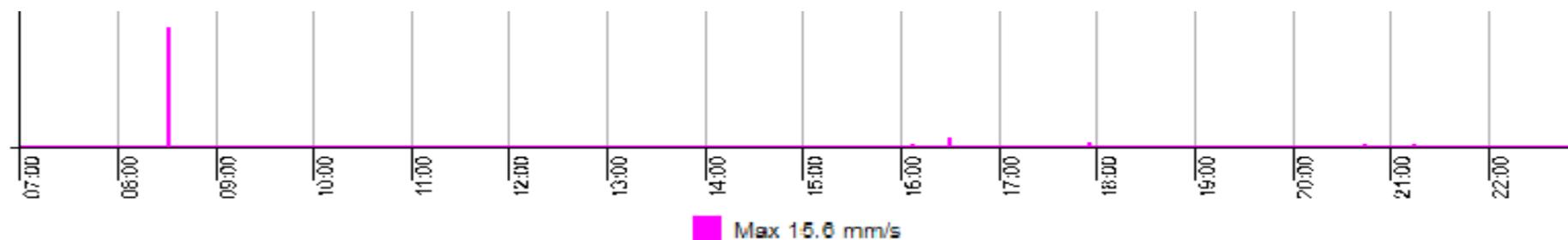
**Notes:**

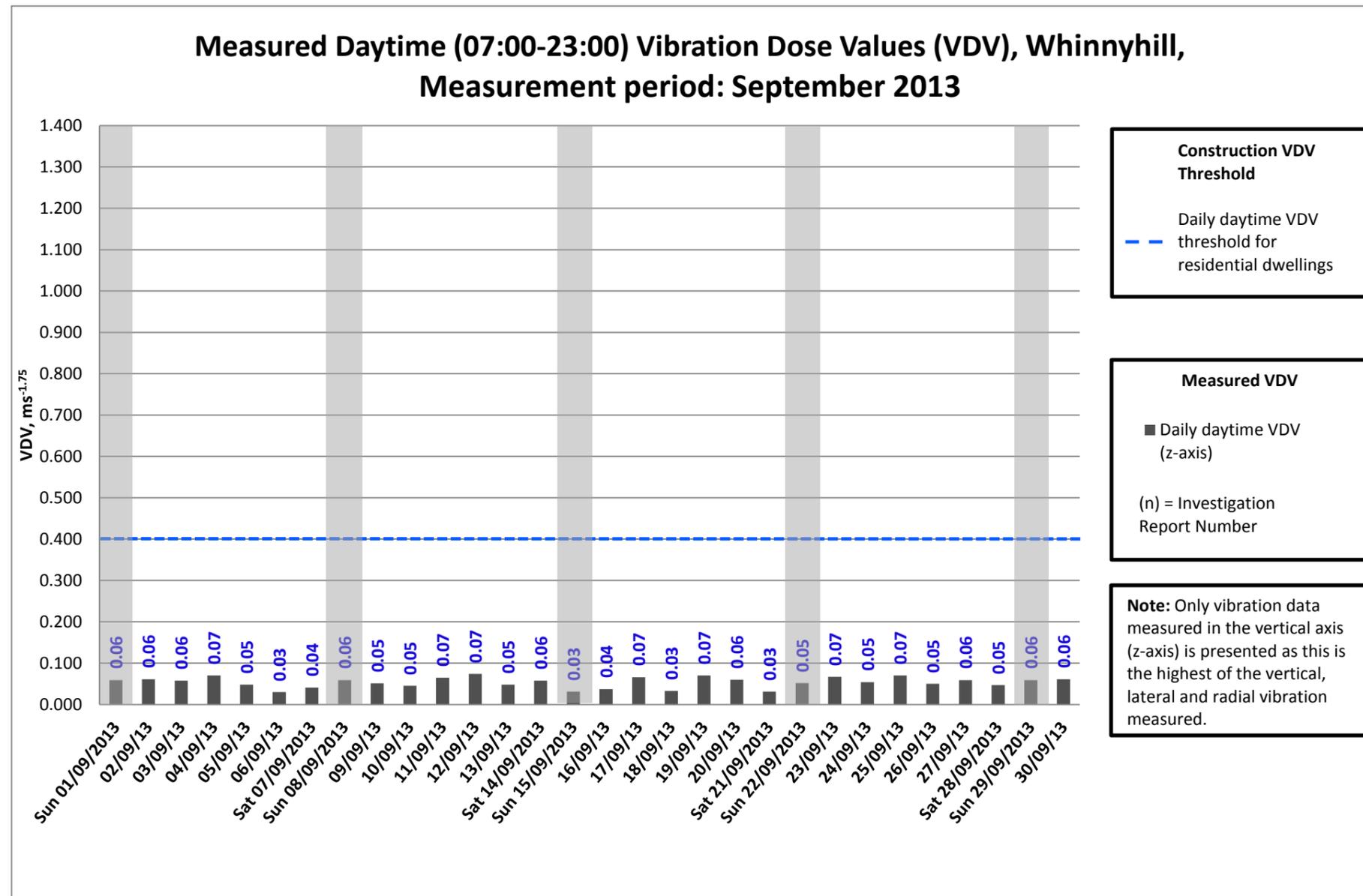
- Data is missing from 26/09/13 to 30/09/13 due to device power error (faulty connector lead).



**Notes:**

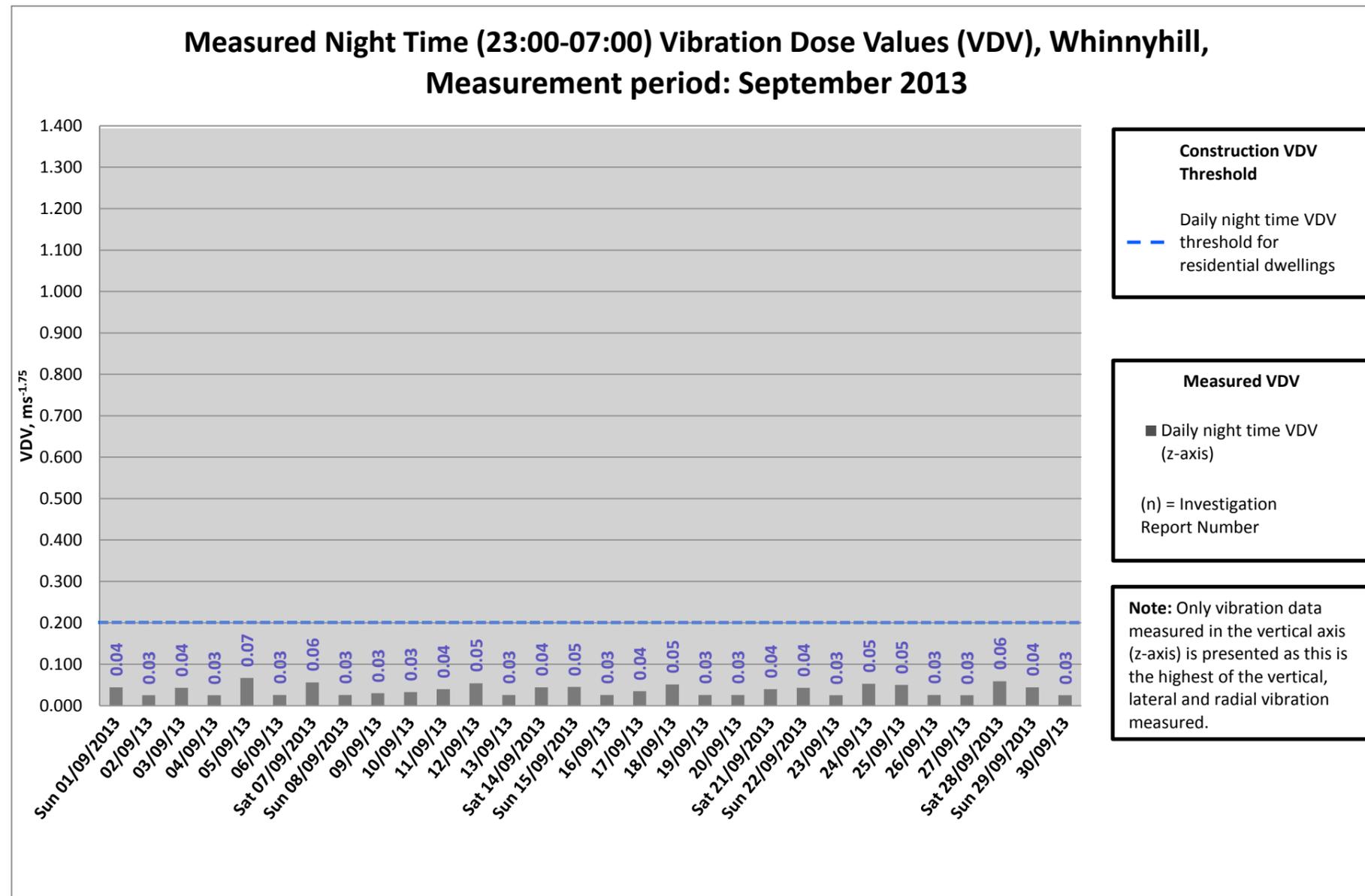
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 02/09/13, 04/09/13, 05/09/13, 06/09/13, 13/09/13, 17/09/13, 18/09/13, 19/09/13, 20/09/13, 23/09/13, 24/09/13, 27/09/13, 28/09/13 and 30/09/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 05/09/13), the majority of which are within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only work to be conducted throughout the month of September in the vicinity of the monitor, was the breaking and excavation of rock at Castlandhill Road, which is a minimum distance of 270m from the monitor, and did not involve the use of any vibration inducing plant or equipment other than a rock breakers, which (as detailed in the footnote to Table 3), generate insignificant levels of vibration at such distances.





**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.



**Notes:**

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Whinnyhill vibration monitor throughout the month of September 2013. This graph is included for illustrative purposes only.