Contractor

Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project

FORTH REPLACEMENT CROSSING

Document title

VIBRATION MONITORING REPORT

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Contents

Appendices:

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 January 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

January 2013

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s^{-1})	*Intermittent (10 mm.s^{-1})*	*Day (0.4 m.s$^{-1.75}$)*	*Night (0.2 m.s$^{-1.75}$)*
Butlaw Fisheries	0	0	0	0
Clufflat Brae	2	0	0	0
Dundas Home Farm	0	0	0	10
Echline	9	0	0	0
Inchgarvie Lodge	0	0	0	0
Linn Mill	5	1	10	13
Scotstoun	2	0	0	0
Springfield	1	2	0	0
Tigh-Na-Grian	5	5	0	0
Whinnyhill	6	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 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^{-1} for continuous construction (e.g. piling), and 10 mm.s^{-1} for intermittent construction (e.g. blasting).

2.8. These thresholds are set to protect against building damage. For this monitoring period, all the exceedances have been investigated thoroughly and appear to have been generated as a result of standalone, instantaneous events arising from local interferences, the exact source of which remains unknown.

2.9. Vibration Dose Value (VDV) is a metric used in vibration monitoring. It is calculated by taking the fourth root of the integral of the fourth power of acceleration after it has been frequency-weighted. The frequency-weighted

acceleration is measured in $m.s^{-2}$ and the time period over which the VDV is measured is in seconds. This yields VDVs in $m.s^{-1.75}$.

2.10. 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.

2.11. 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.

2.12. 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.

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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 January 2013
M1	Whinny Hill	Network	Breaking of rock Loading of rock Drilling and Blast 13 (conducted 19/01/13) N.B. No evening, night time or Sunday daytime construction in vicinity.
M3	Tigh-Na-Grian	Crossing	Placement of Central Tower cofferdam North Tower caisson excavation North Tower jet grouting Installation of pier N1 cofferdam
M7	Butlaw Fisheries	Crossing	Placement of Central Tower cofferdam South Tower jet grouting Pier S1 caisson excavation Pier S4 excavation Installation of pier S5 cofferdam Pier S6 Piling and excavation works Installation of rebar & concrete pour at pier S7 Grit blasting at pier S8
M10	Inchgarvie Lodge	Crossing	Placement of Central Tower cofferdam South Tower jet grouting Pier S1 caisson excavation Pier S4 excavation Installation of pier S5 cofferdam Pier S6 Piling and excavation works Installation of rebar & concrete pour at pier S7 Grit blasting at pier S8 Break out rock from launch Works at South Abutment including concrete pour
M11	Linn Mill	Network	Break out rock from launch Works at South Abutment including concrete pour N.B. No evening, night time or Sunday daytime construction in vicinity.
M13	Clufflat Brae	Network	Break out rock from launch Works at South Abutment including concrete pour N.B. No evening, night time or Sunday daytime construction in vicinity.

M14	Springfield	Network	Break out rock from launch Generate rock at Queensferry gyratory N.B. No evening, night time or Sunday daytime construction in vicinity.
M15	Echline Field	Network	Generate rock at Queensferry gyratory Backfill of A904 verges Hedge removal at U221 N.B. No evening, night time or Sunday daytime construction in vicinity.
M16	Scotstoun	Network	Drainage works N.B. No evening, night time or Sunday daytime construction in vicinity.
M17	Dundas Home Farm	Network	Utilities works Export of rock to Dundas Badger fence installation N.B. No evening, night time or Sunday daytime construction in vicinity.

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

Table 3: PCNV Predicted PPV & VDV Levels

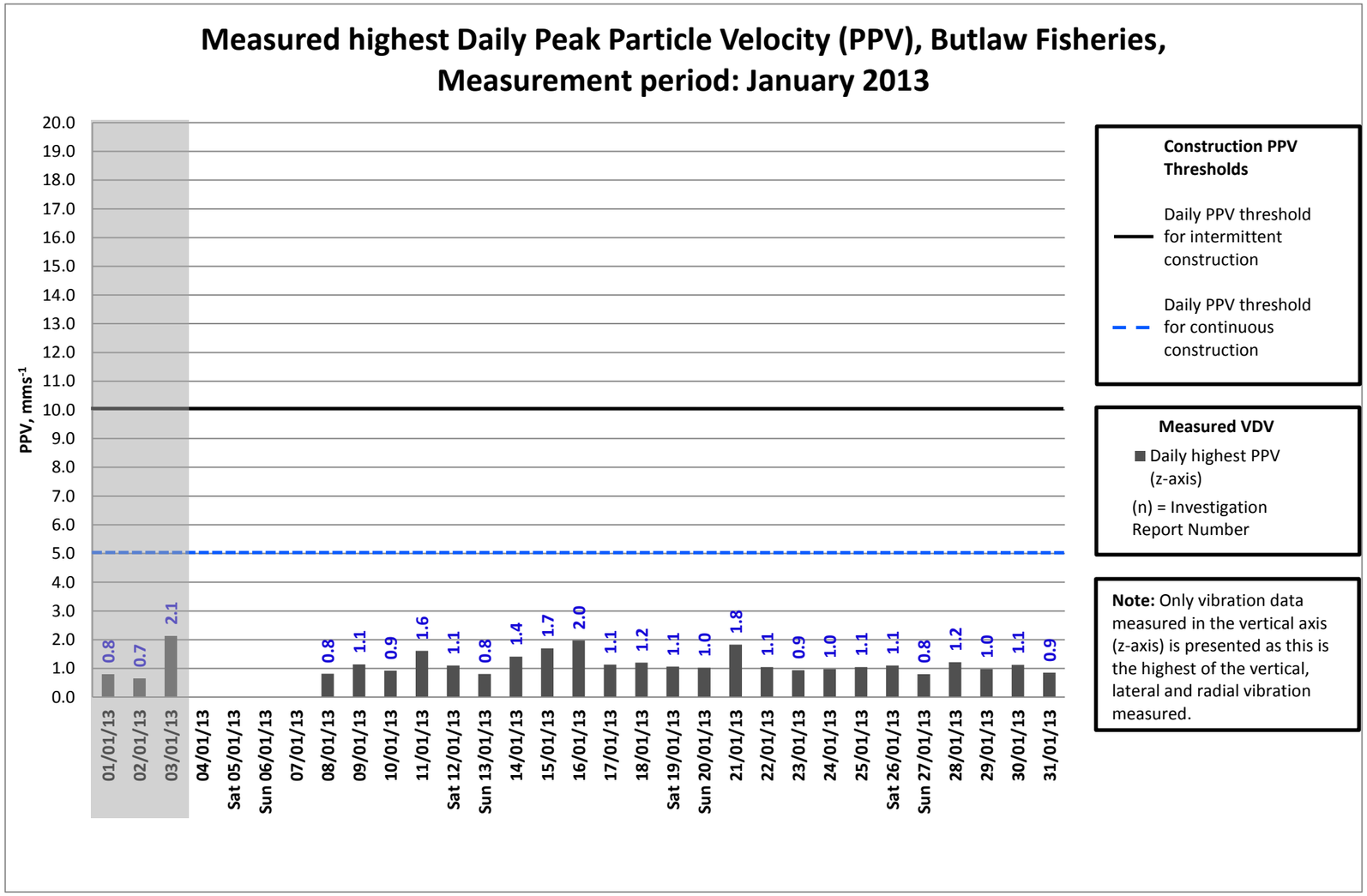
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV ($m.s^{-1.75}$)
Butlaw Fisheries	150	230	Roller/Piling	0.39	0.23
Clufflat Brae	40	350	Roller/Whacker	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	250	Roller/Whacker/Piling	1.77	0.33
Linn Mill	60	500	Roller/Whacker/Piling	1.36	0.33
Scotstoun	50	2000	Roller/Whacker	1.77	0.33
Springfield	50	600	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	270	1800	Blast 13	-	-

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

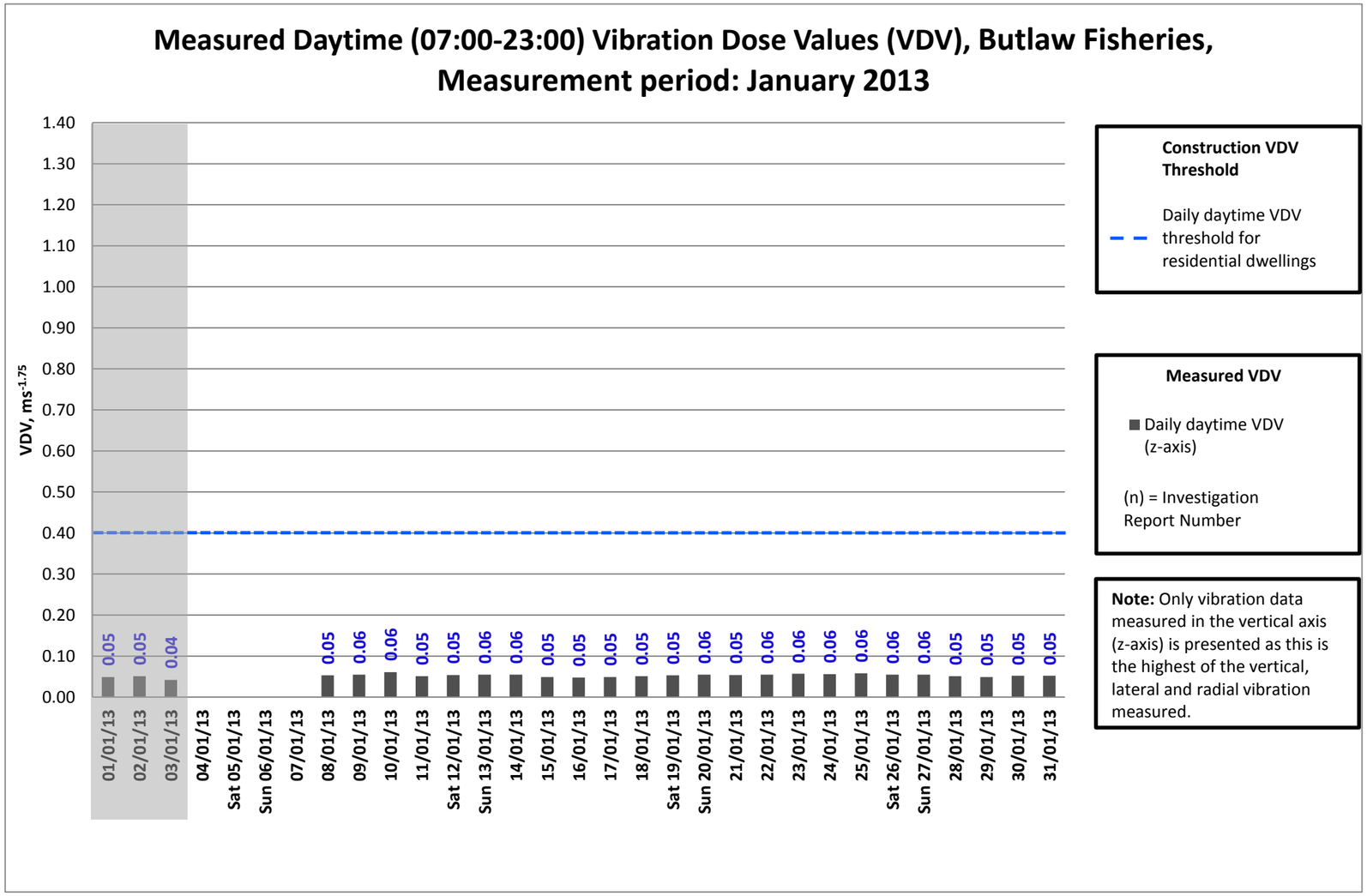
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller, whacker plate and vibro-piling rig (NOTE: Hydraulic rock breakers which typically 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 80m of any occupied sensitive receptors & were not operated within 25m of any sensitive receptor.
- Whacker plates were not utilised within 40m of any occupied sensitive receptor.
- The vibro piling rig was only in operation at Pier S6 which is 150m (worst case) from the nearest sensitive receptor (Butlaw Fisheries).
- All blasts were monitored on an individual basis using a number of monitoring devices at the nearest receptors. There has been no damage to any receptor due to blasting activities. None of the blasts conducted during the period in question registered a PPV on any of the permanent vibration monitors.
- All roller eVDV values in the table above are based on the worst case scenario of a vibratory roller remaining in continuous operation for 4 hours a minimum 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 over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 04/01/13 to 07/01/13 due to device error.



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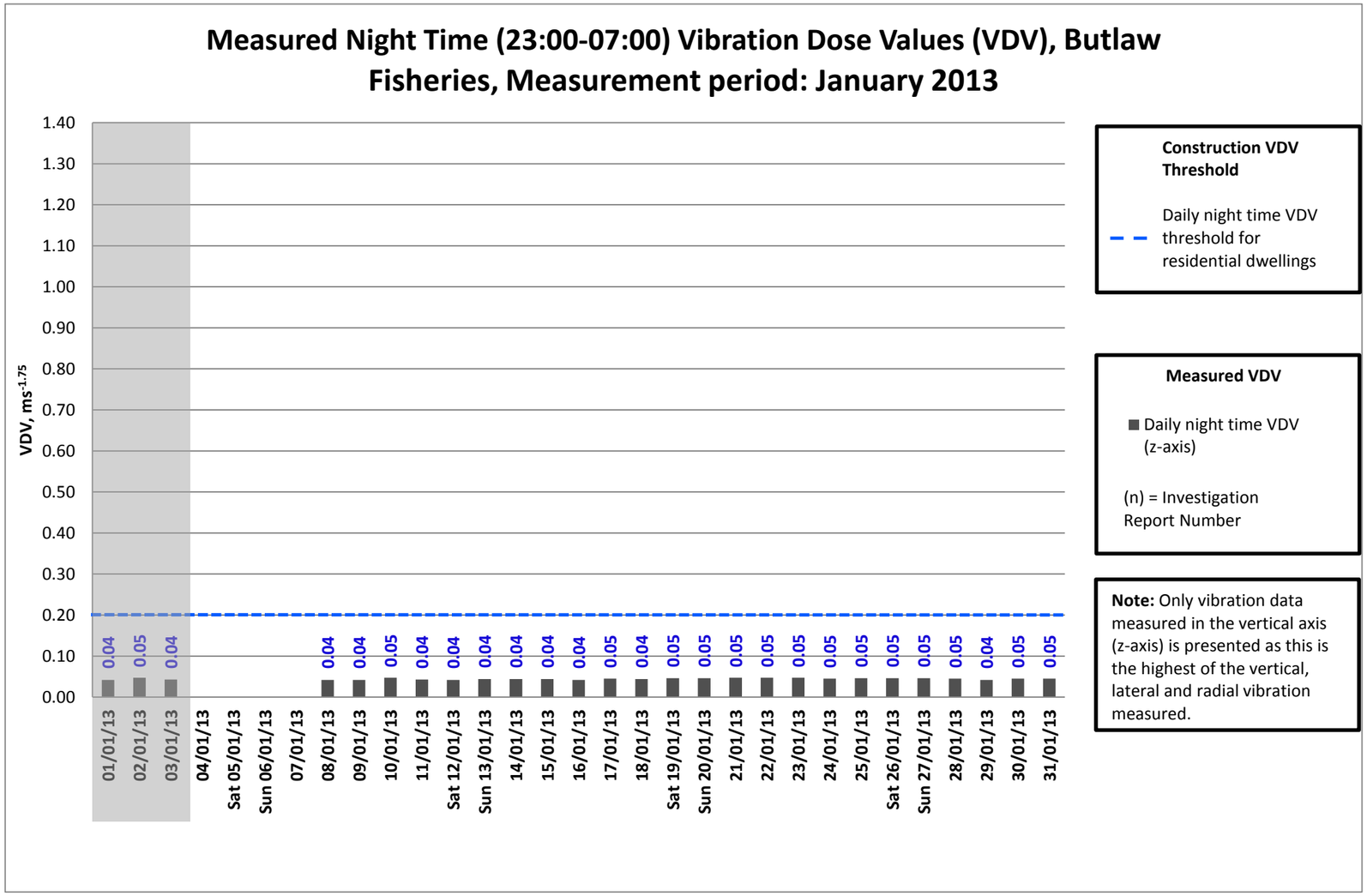
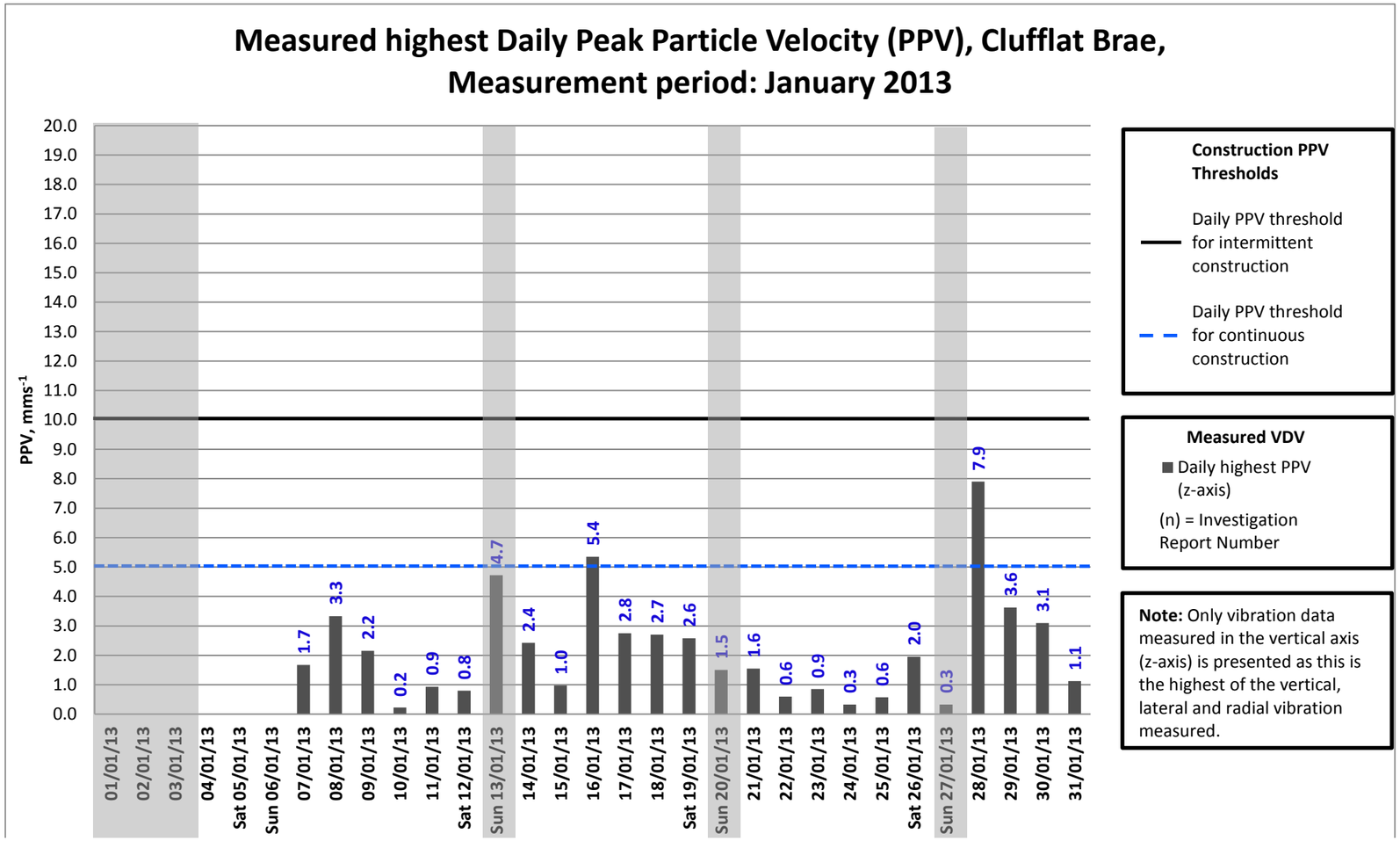
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 04/01/13 to 07/01/13 due to device error.



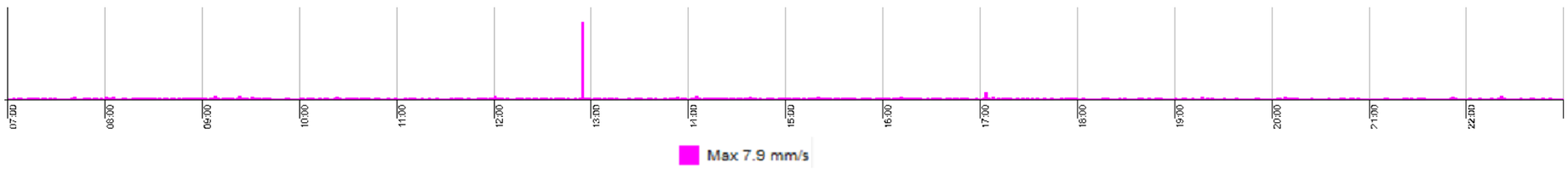
Notes:

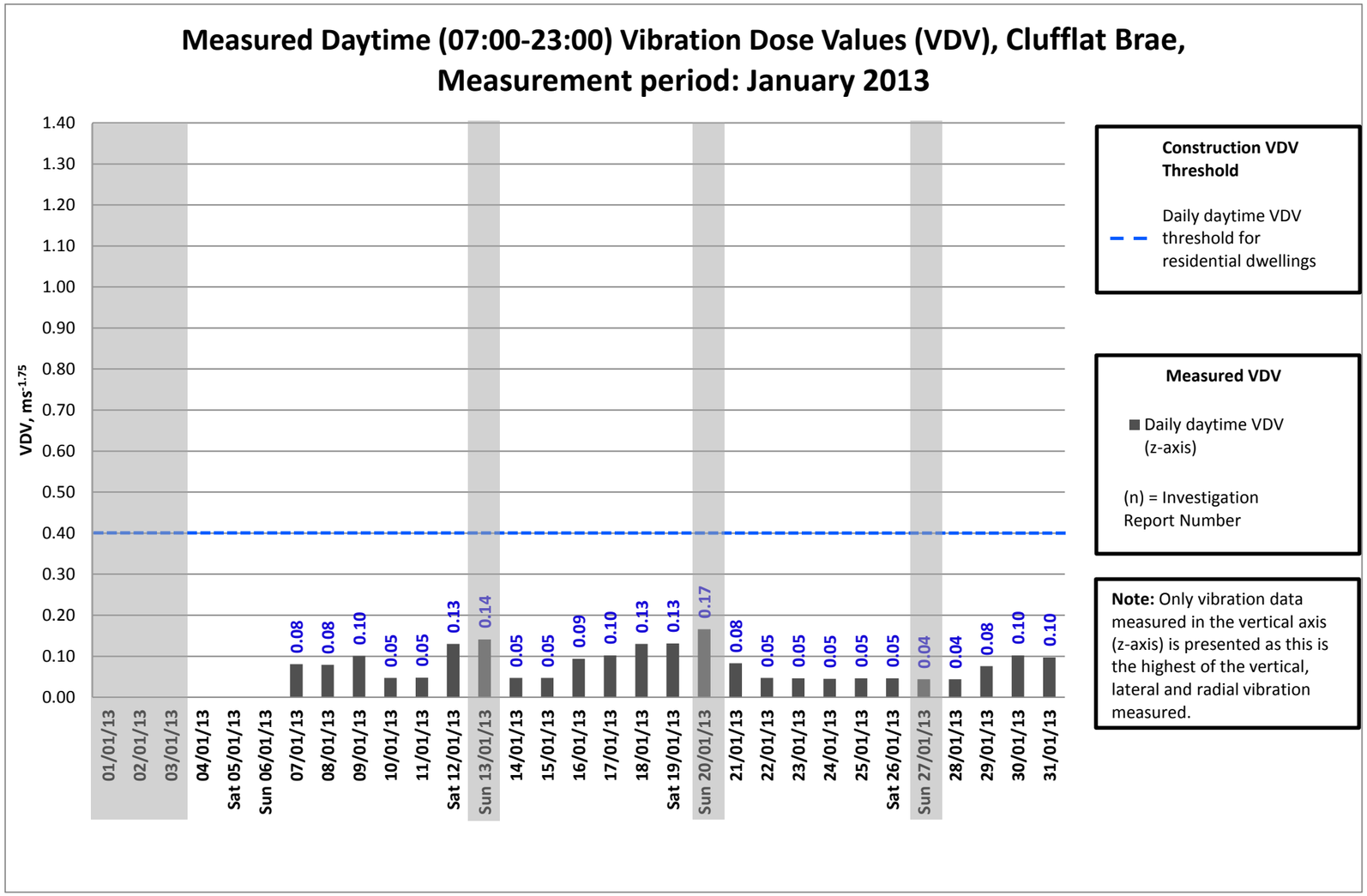
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 04/01/13 to 07/01/13 due to device error.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 01/01/13 to 06/01/13 due to device error.
- The PPV values on 16/01/13 & 28/01/13 have both been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 28/01/13), and are both within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were concreting and backfill works at the South Abutment, which did not involve any vibration inducing plant or equipment.





Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
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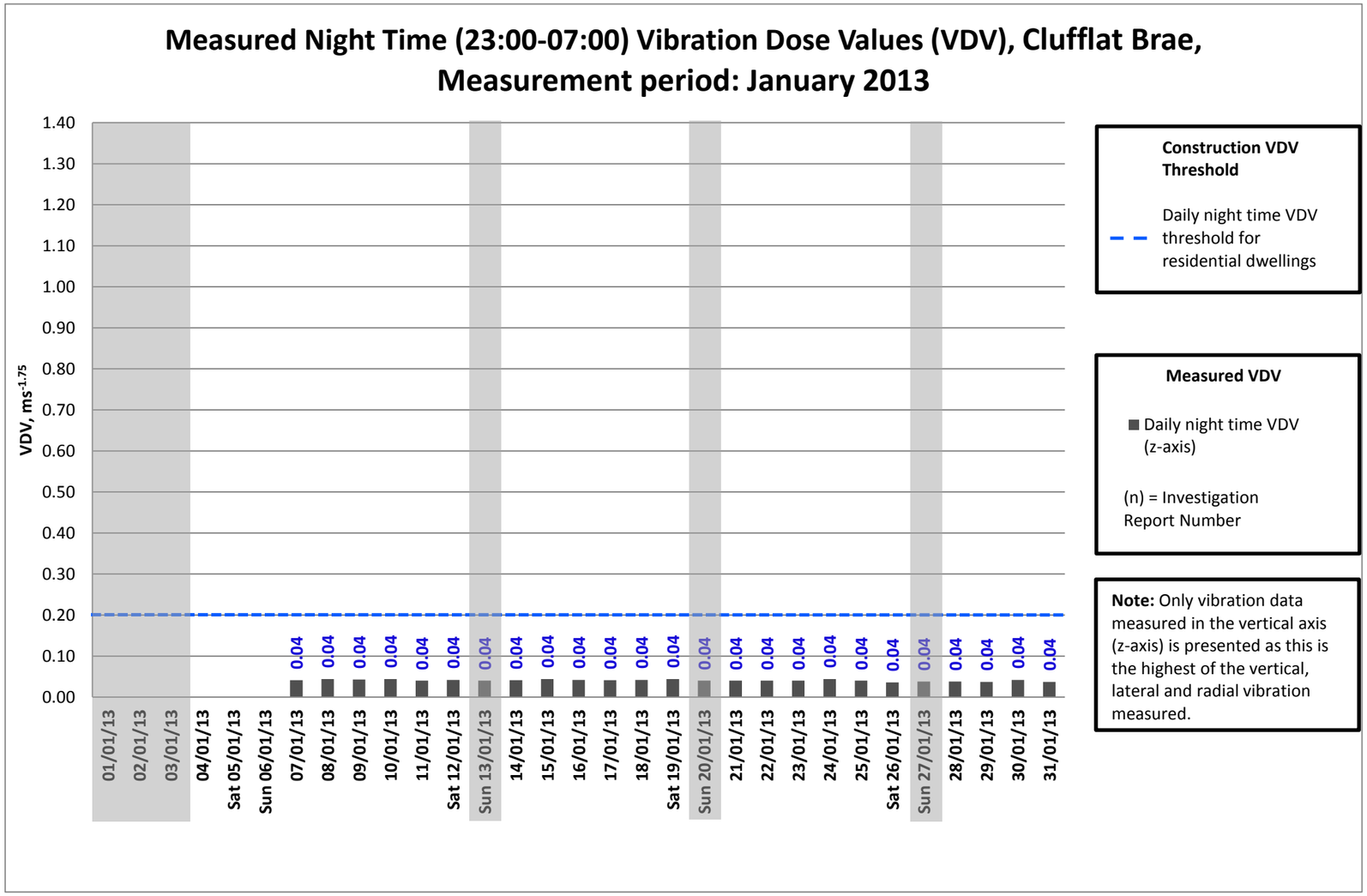
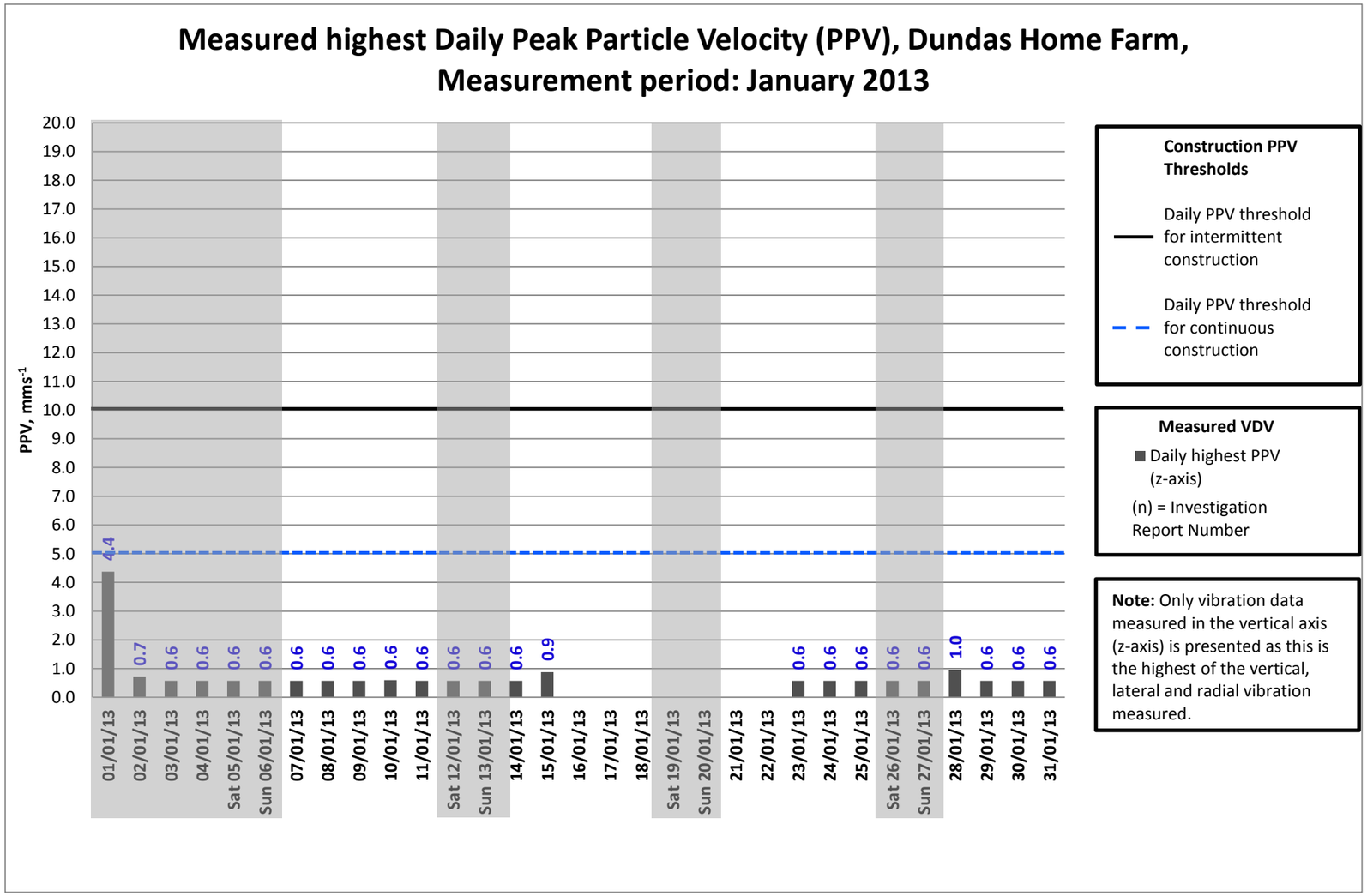


Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 01/01/13 to 06/01/13 due to device error.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
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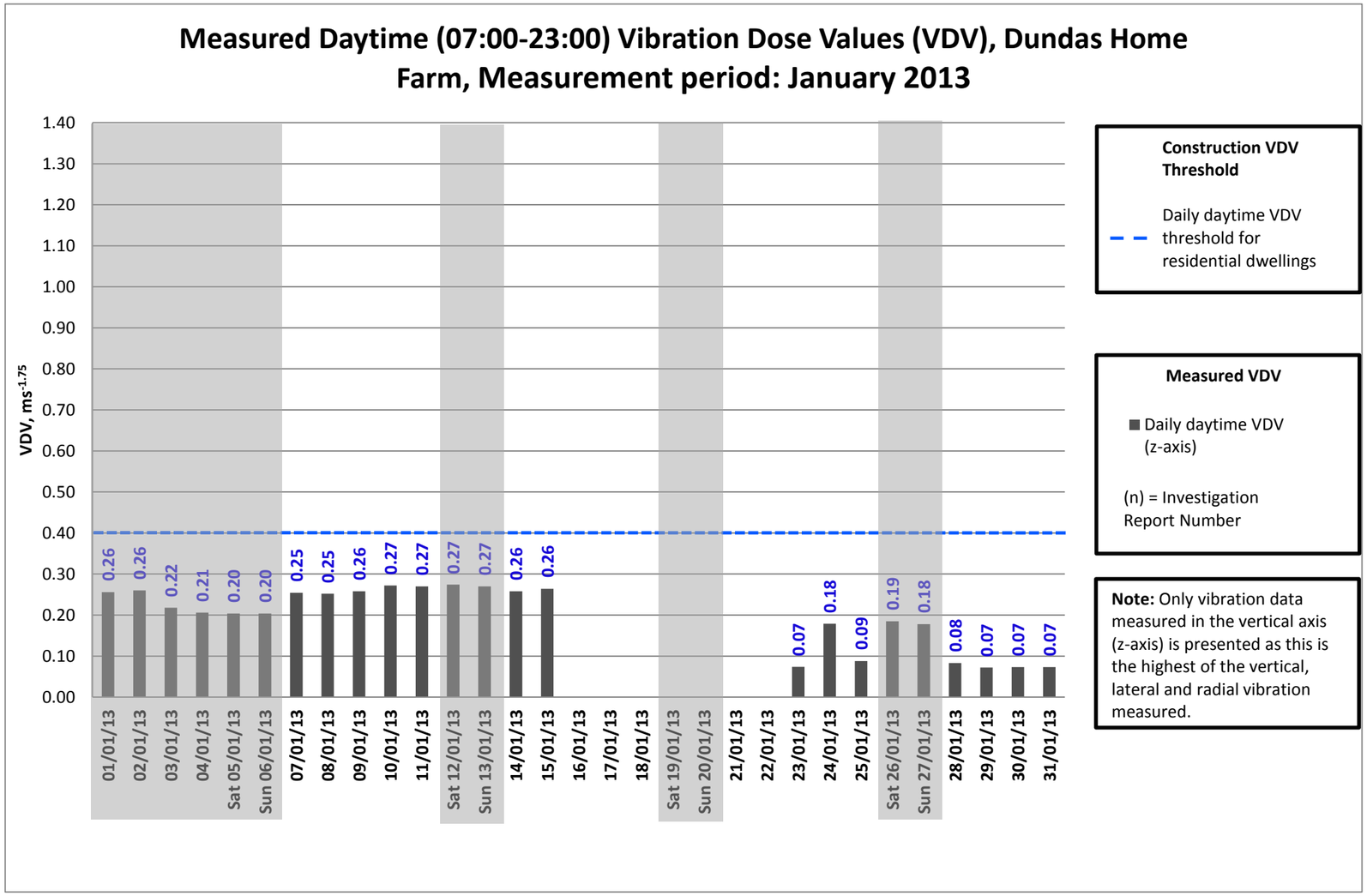
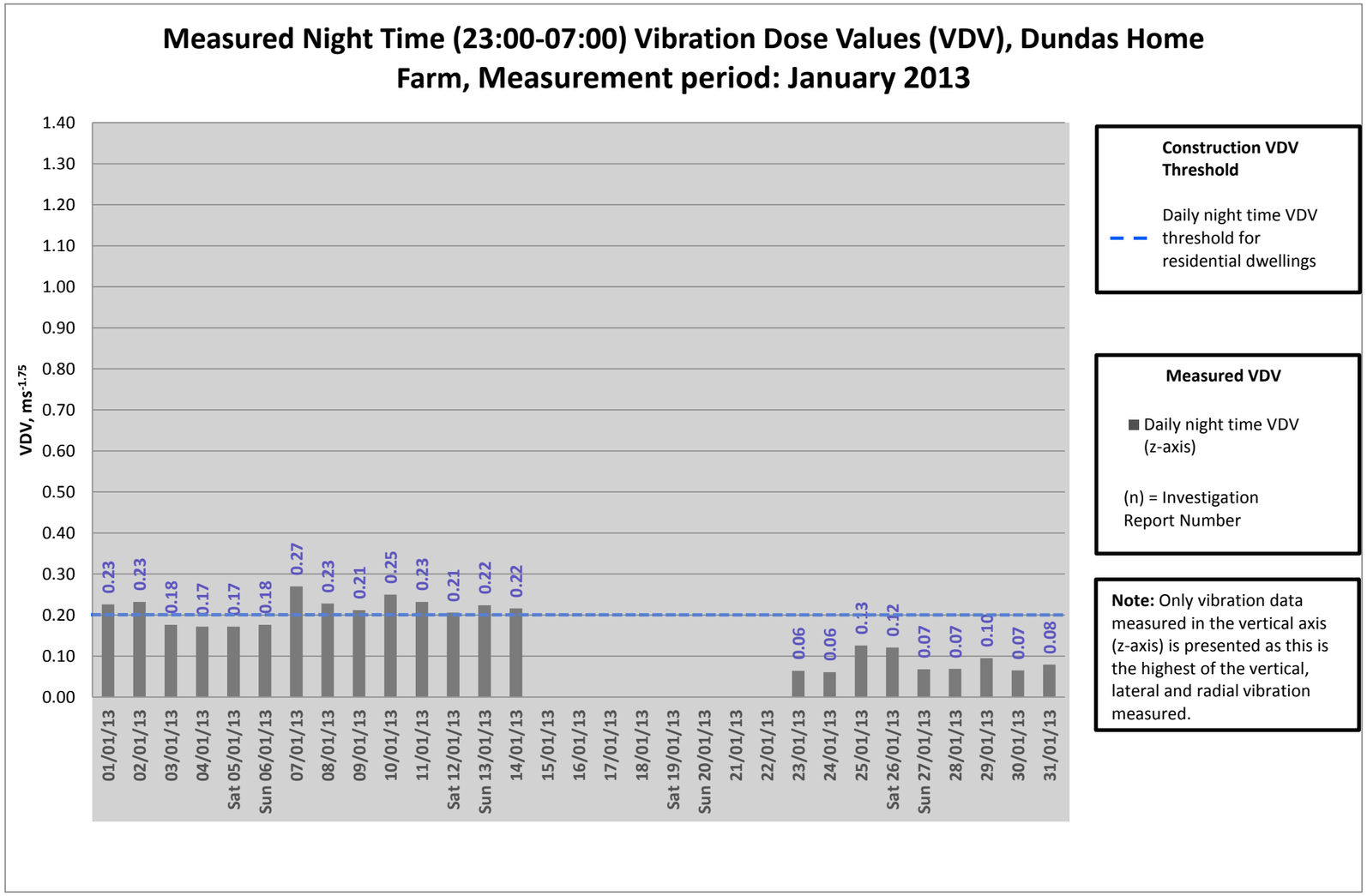


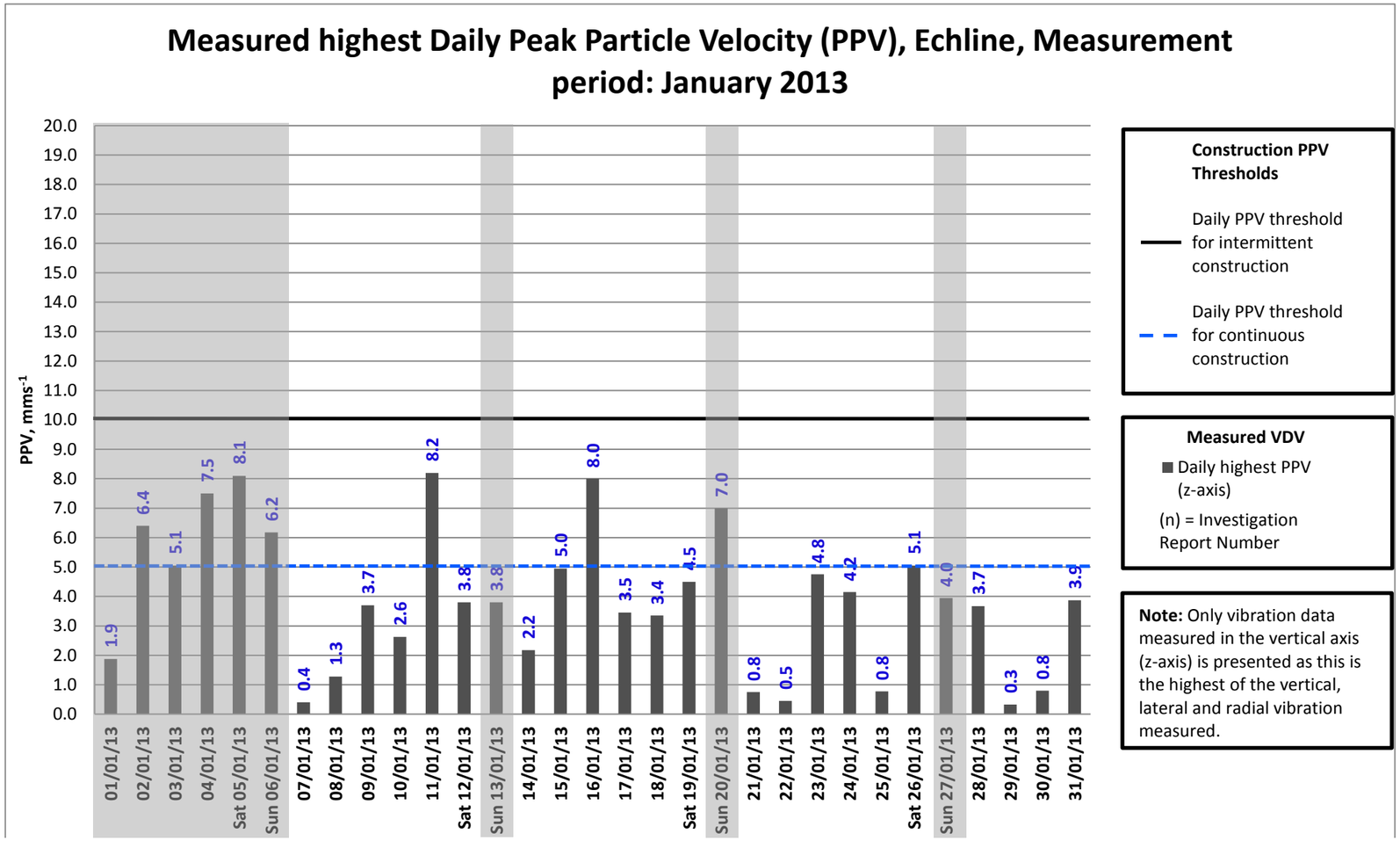
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 16/01/13 to 22/01/13 due to device error.



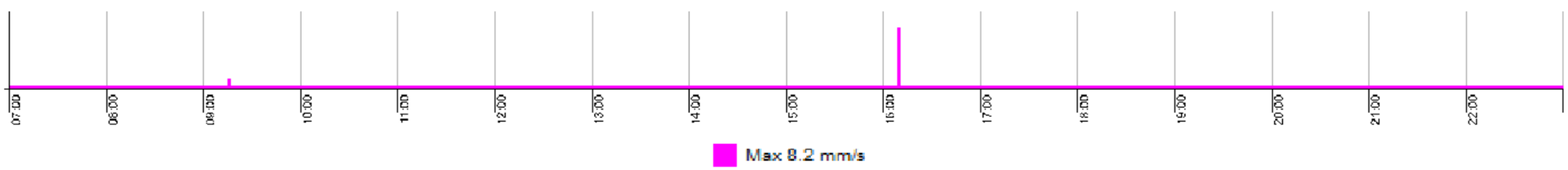
Notes:

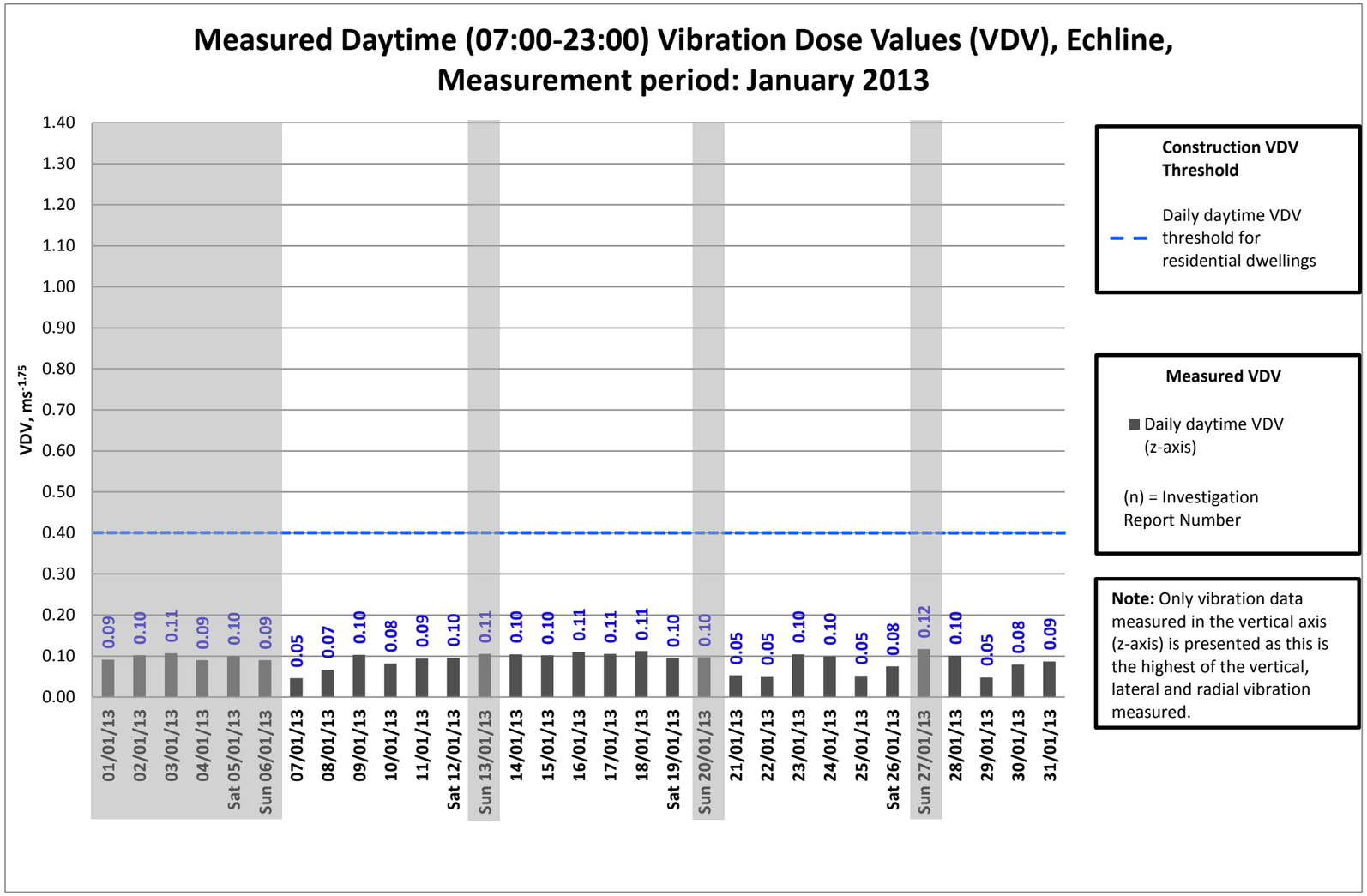
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas vibration monitor throughout the month of January 2013. This graph is included for illustrative purposes only.
- Data is missing for 16/01/13 to 22/01/13 due to device error.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- The PPV values on 11/01/13, 16/01/13 & 26/01/13 have all been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 11/01/13), and are all within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were rock generation and backfill operations at the Queensferry gyratory and A904 verges respectively. The only vibration inducing plant or equipment involved in these activities were rock breakers, which were operated a minimum distance of 40m from the monitor (and nearest receptors), and can thus be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels are likely due to road traffic (e.g. occasional HGVs passing by).





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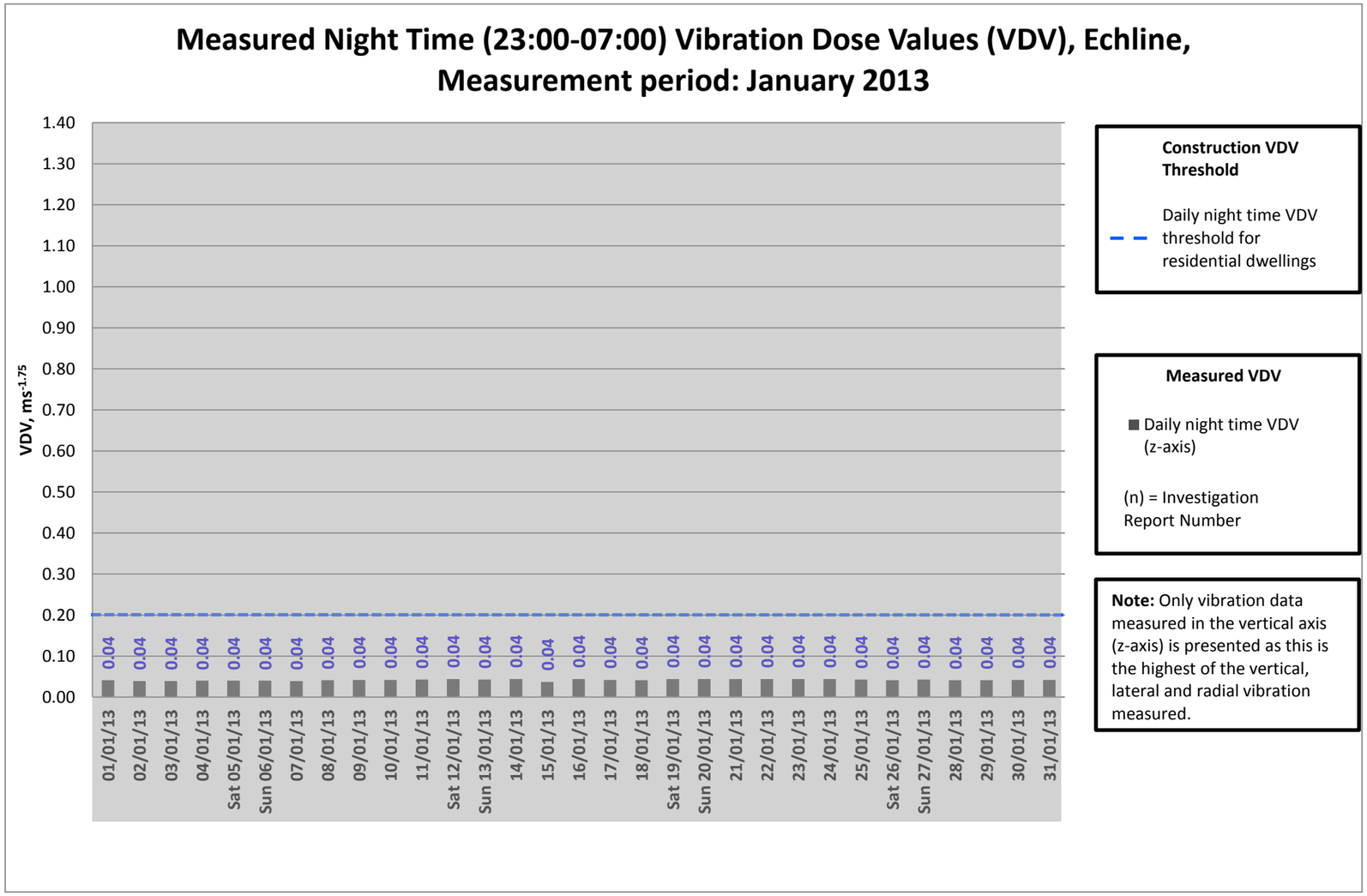
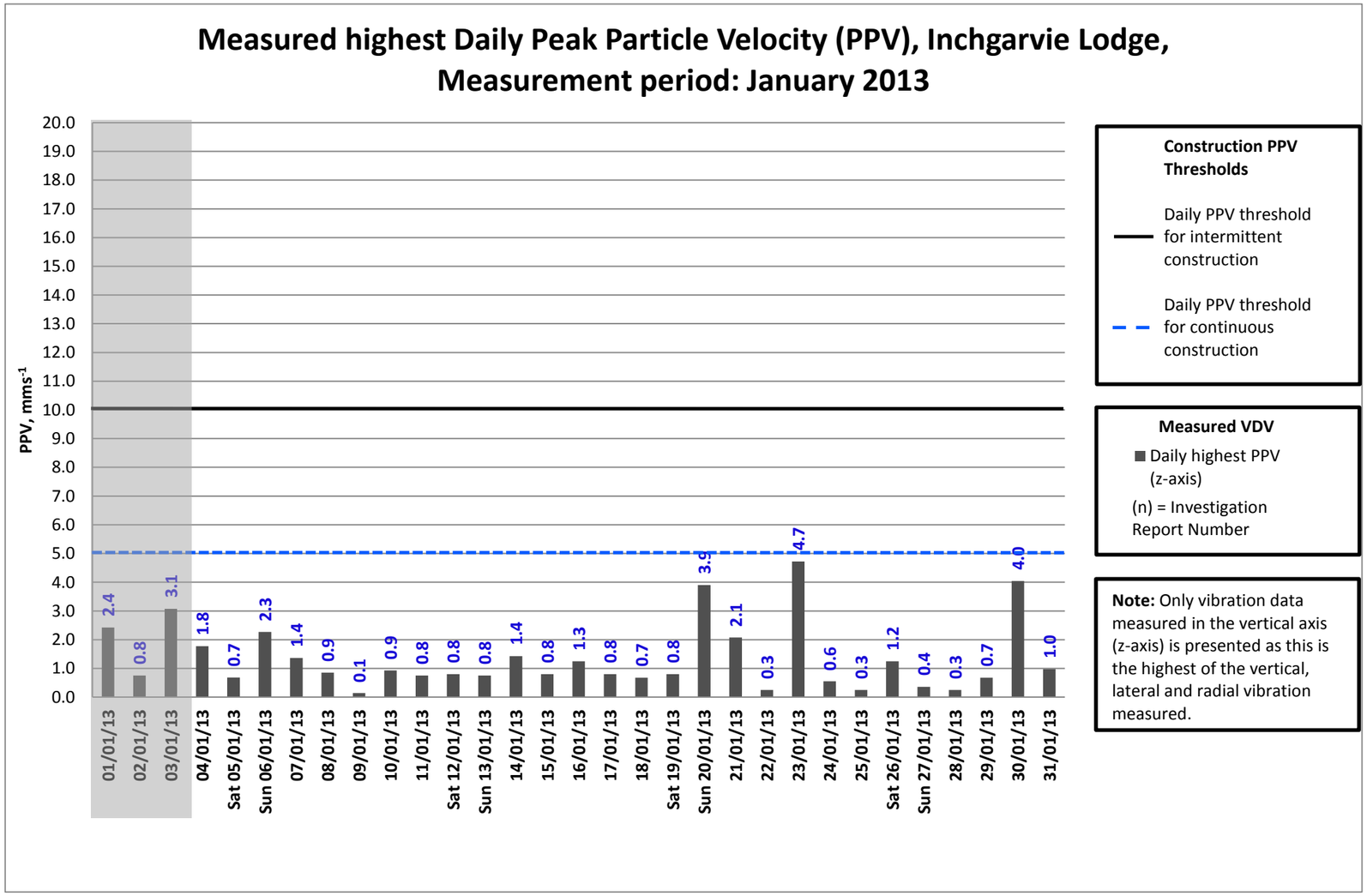
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.



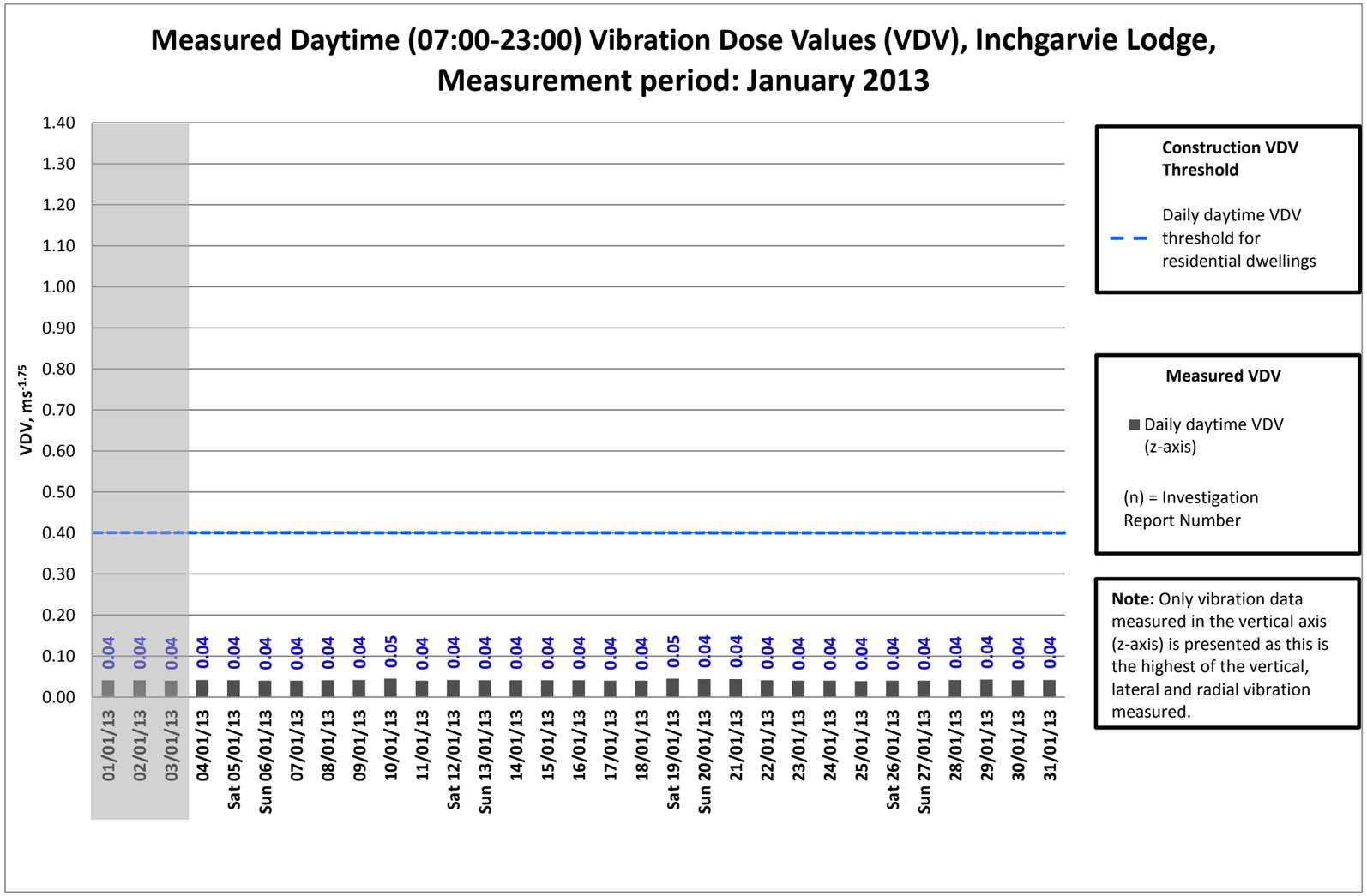
Notes:

- 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 January 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 over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.



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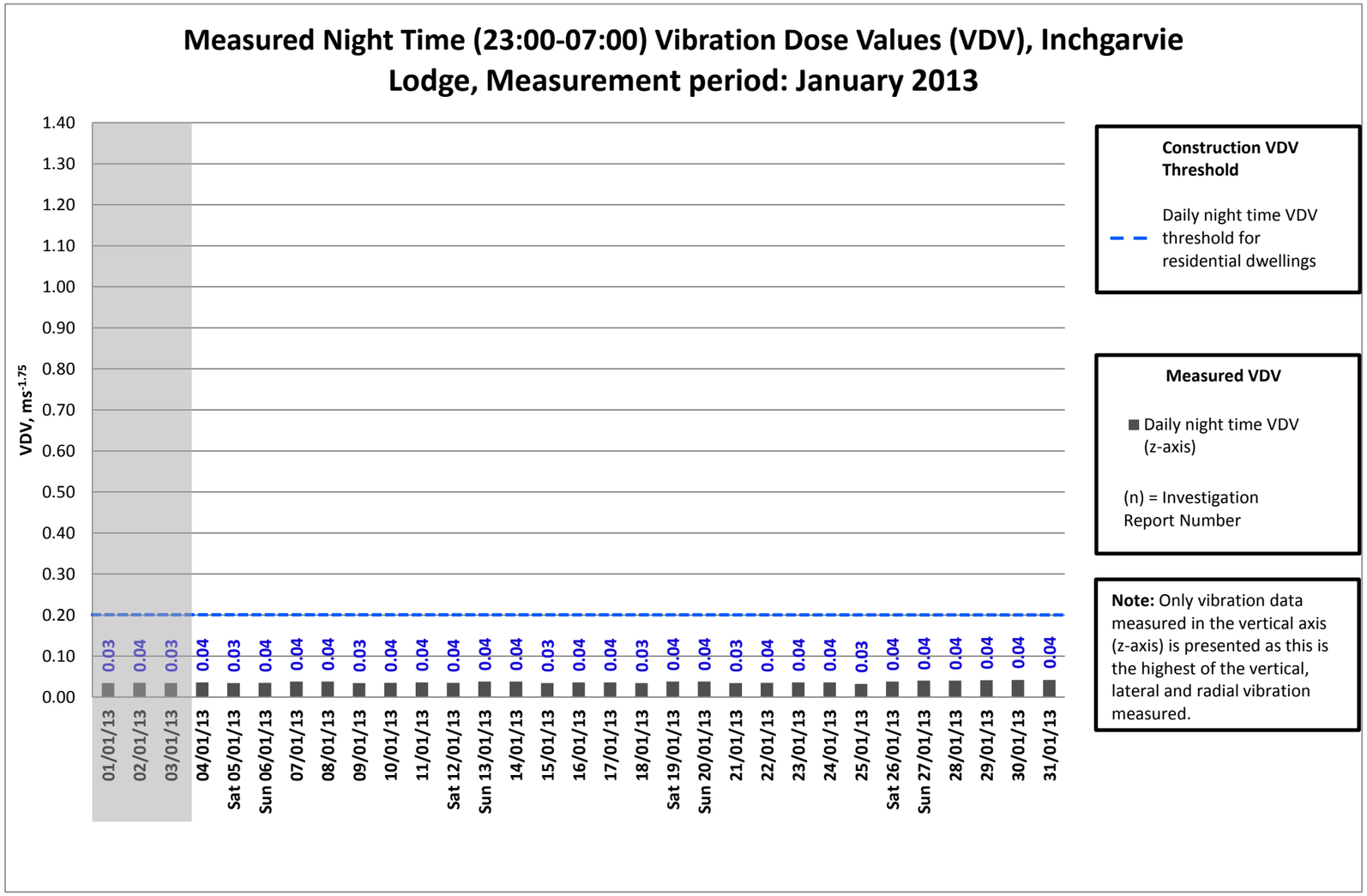

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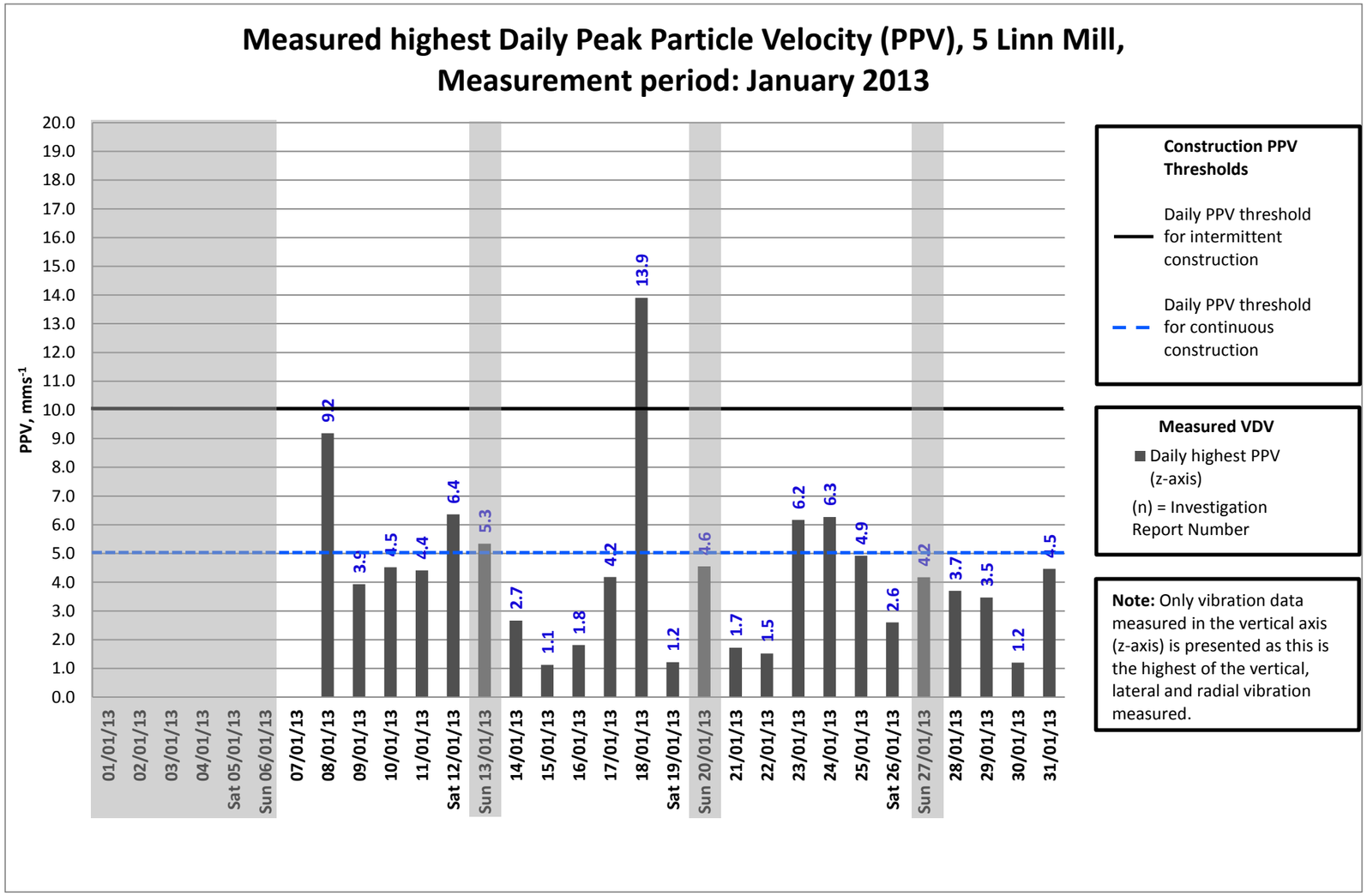
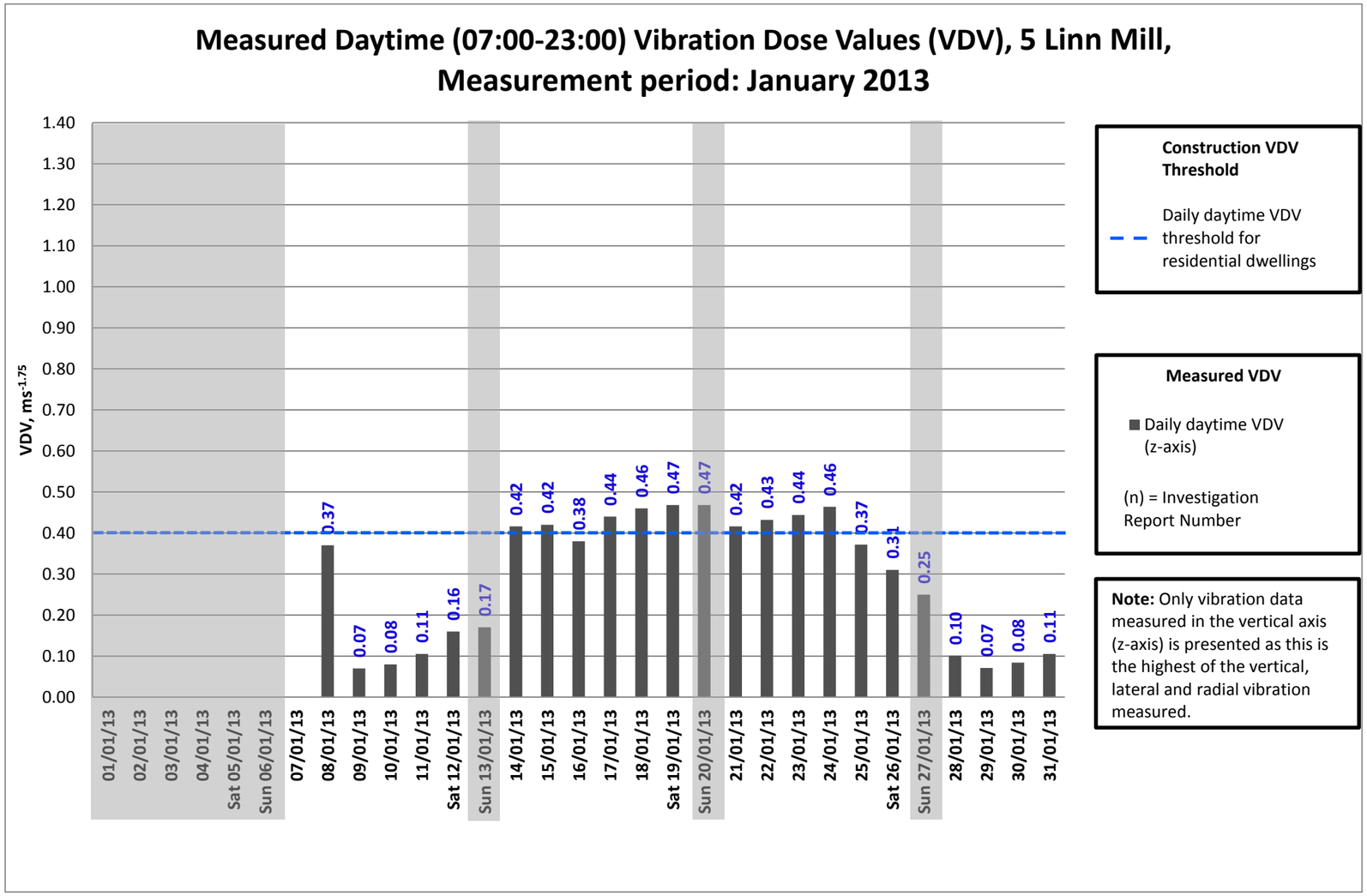


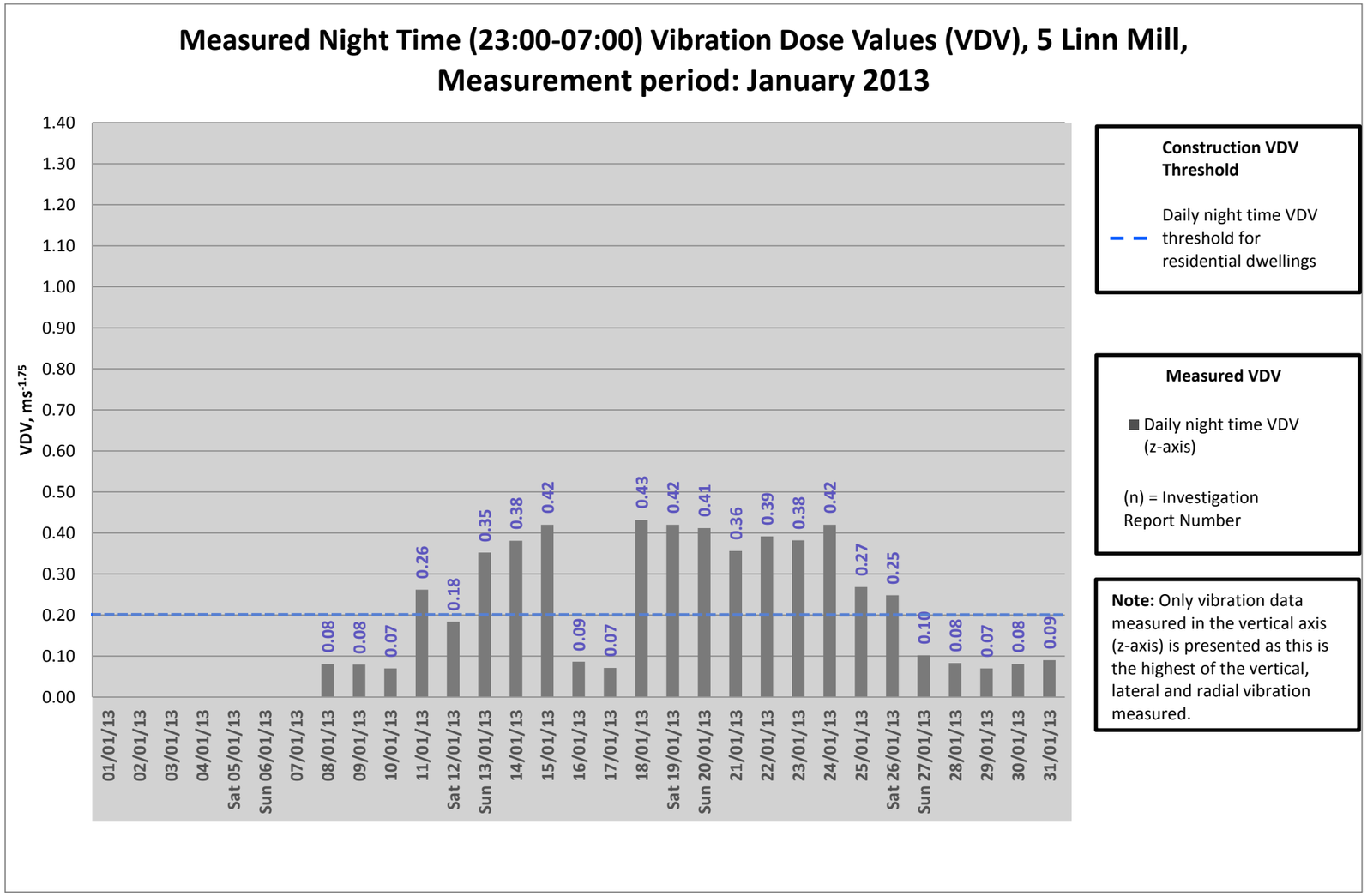
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 01/01/13 to 07/01/13 due to device error.
- When analysed the data downloaded from this monitor was found to be corrupted, however, the levels displayed on this graph were obtained directly from the monitor at the time of download.
- These particular exceedances cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were concreting and backfill works at the South Abutment, which did not involve any vibration inducing plant or equipment. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).



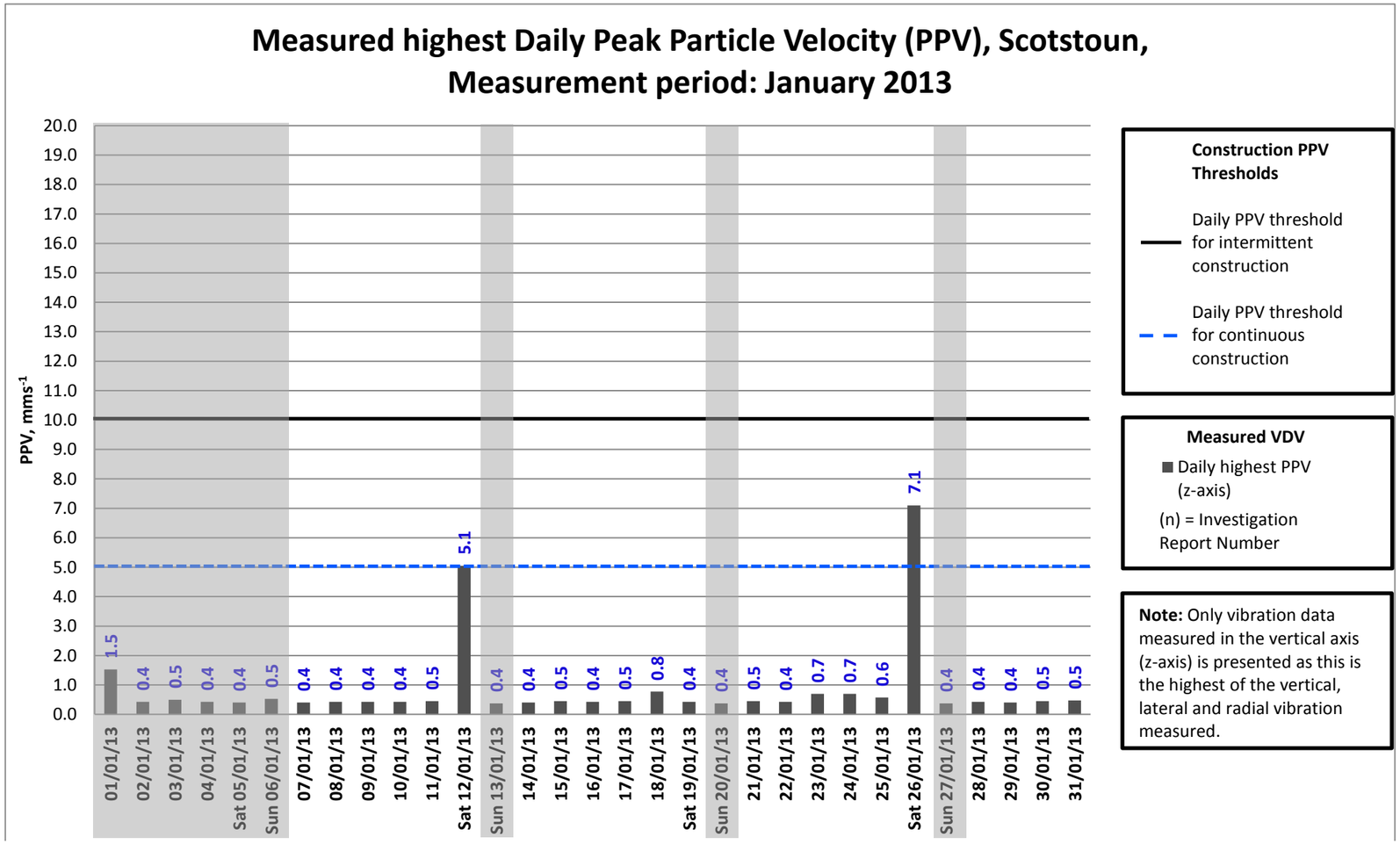
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 01/01/13 to 07/01/13 due to device error.
- When analysed the data downloaded from this monitor was found to be corrupted, however, the levels displayed on this graph were obtained directly from the monitor at the time of download.
- These particular exceedances cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were concreting and backfill works at the South Abutment, which did not involve any vibration inducing plant or equipment. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).



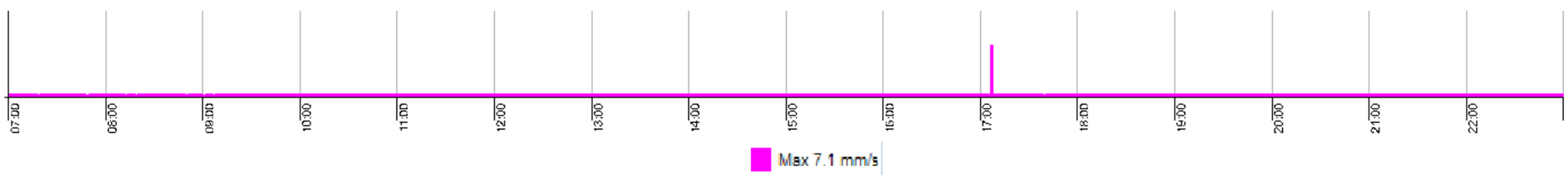
Notes:

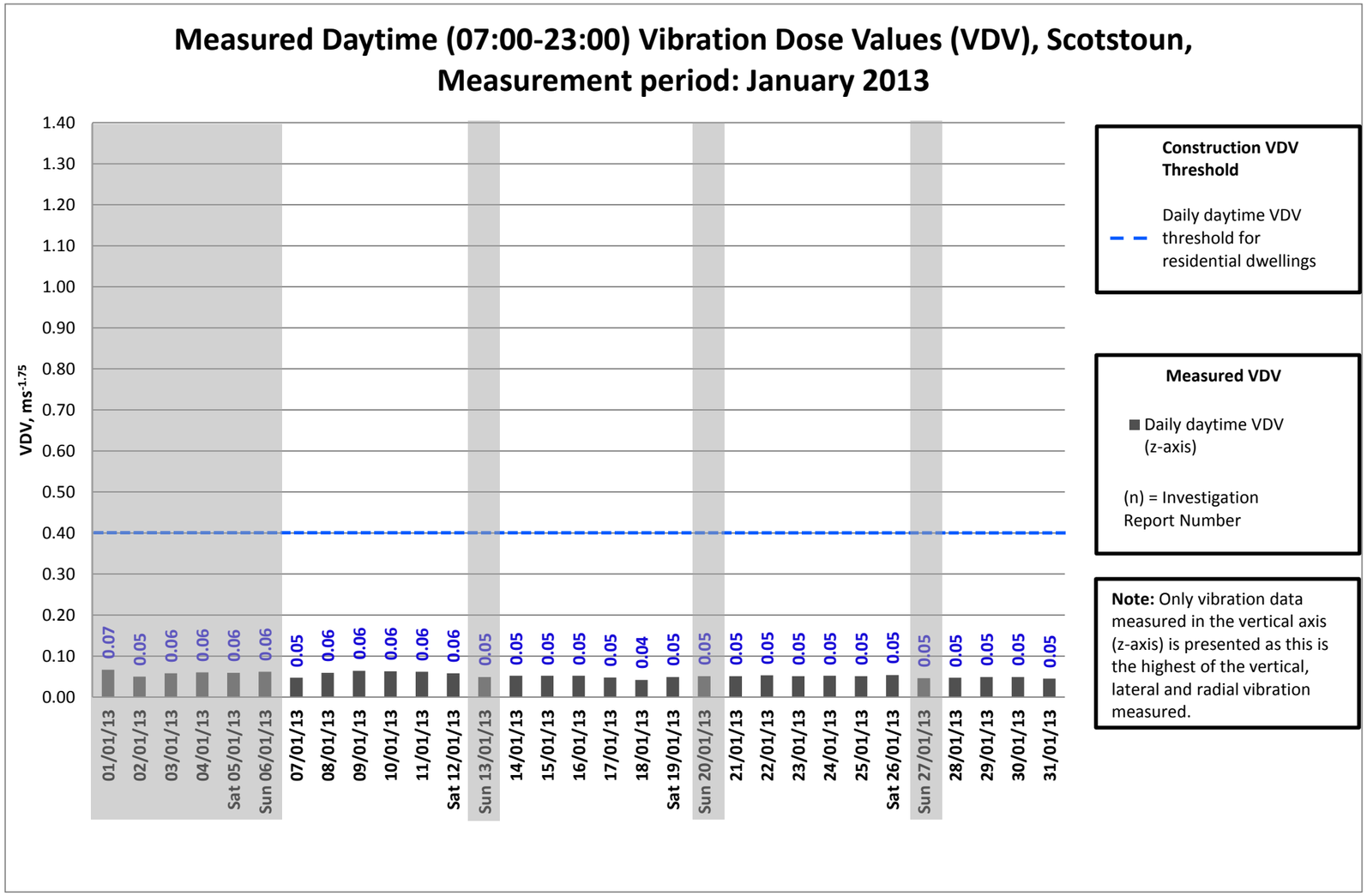
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Linn Mill vibration monitor throughout the month of January 2013. This graph is included for illustrative purposes only.
- Data is missing for 01/01/13 to 07/01/13 due to device error.
- When analysed the data downloaded from this monitor was found to be corrupted, however, the levels displayed on this graph were obtained directly from the monitor at the time of download.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- The PPV values on 12/01/13 & 26/01/13 have both been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 26/01/13), and are both within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor were drainage works, and did not involve any vibration inducing plant. Considering the location of the monitor, these levels are likely due to road traffic (e.g. occasional HGVs passing by).





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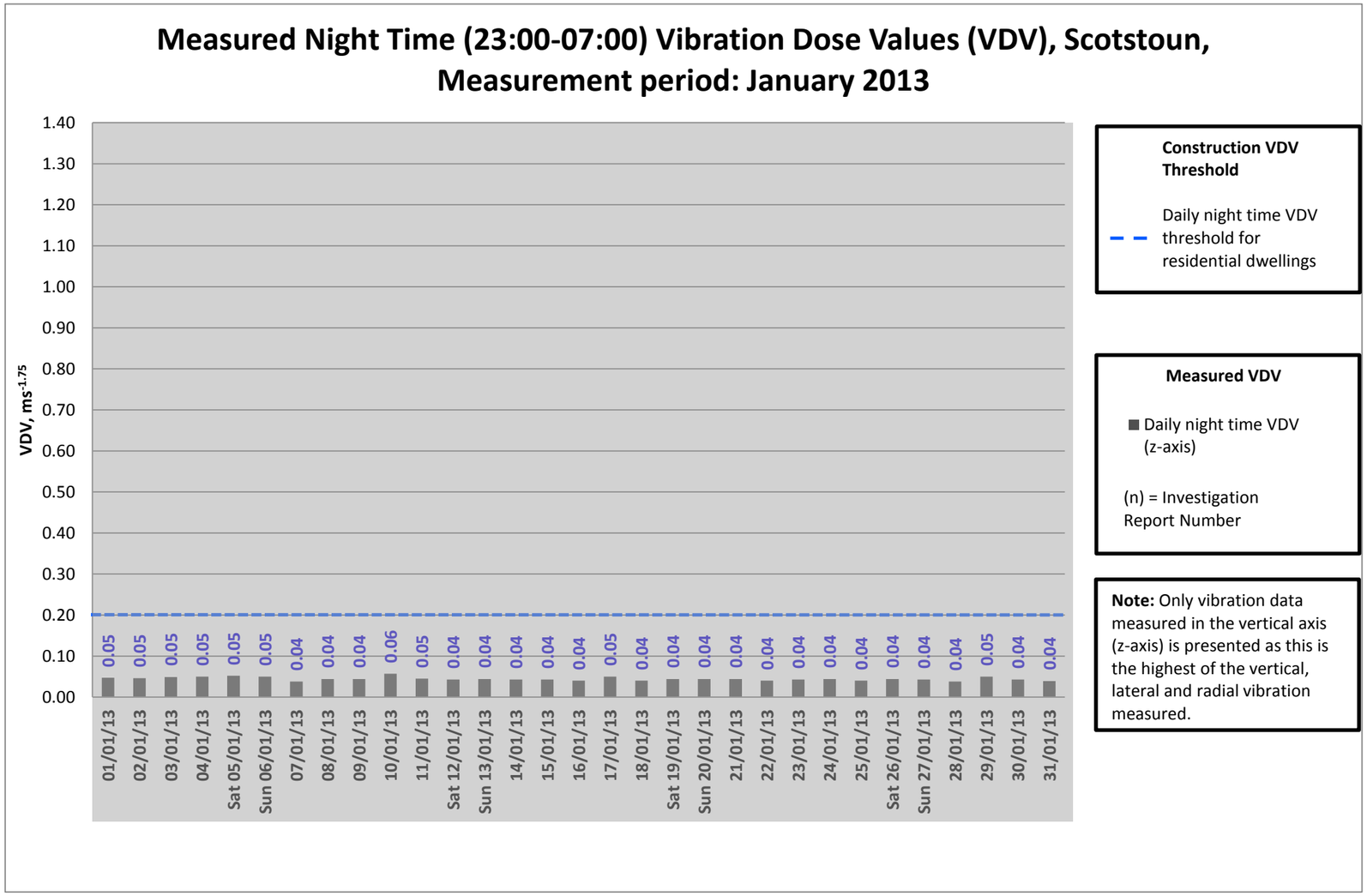
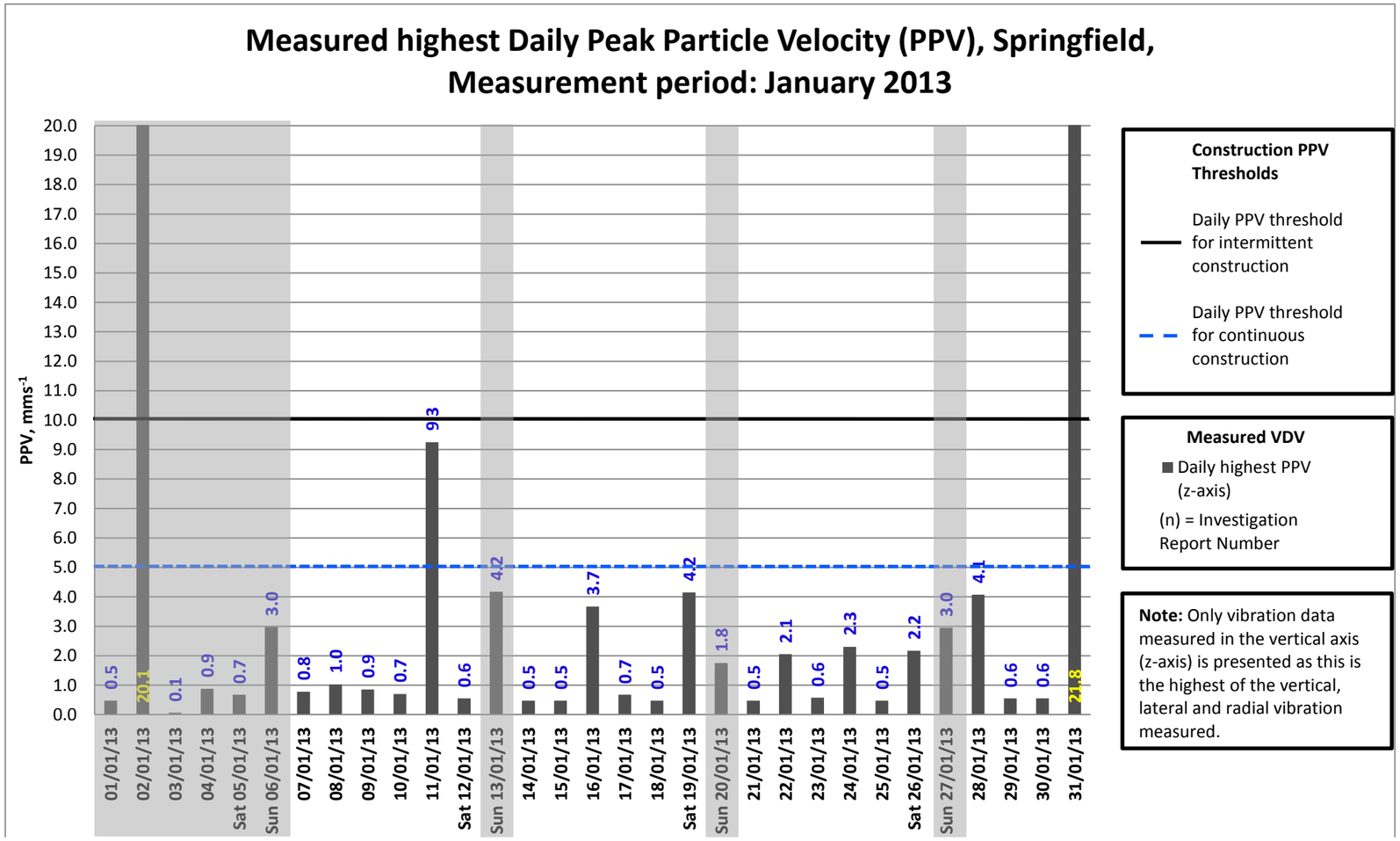


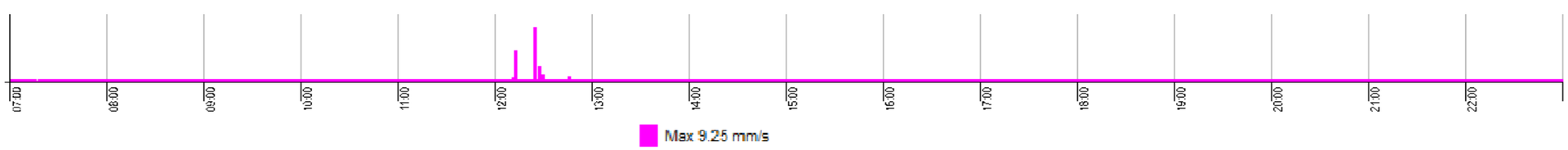
Notes:

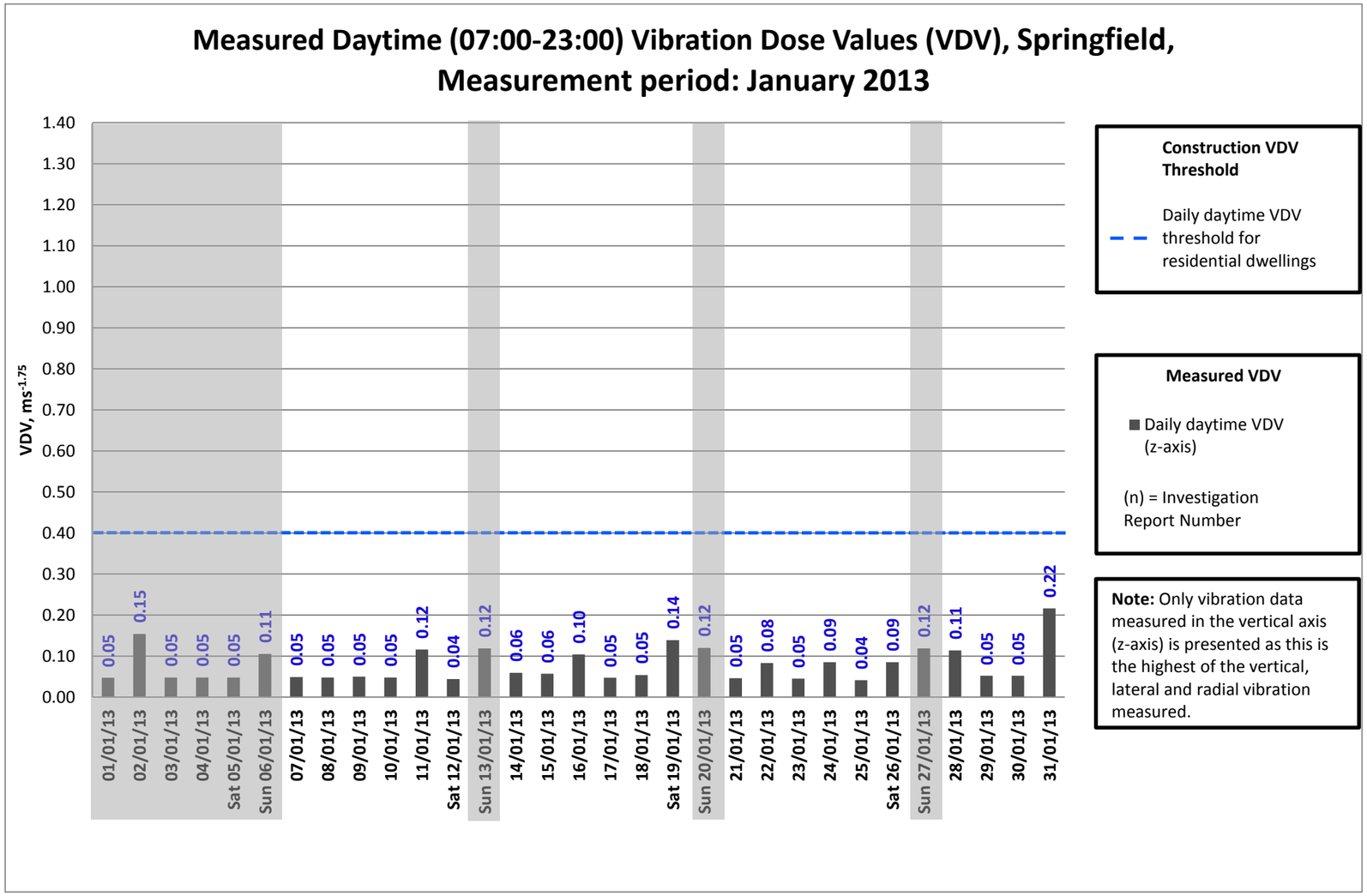
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Scotstoun vibration monitor throughout the month of January 2013. This graph is included for illustrative purposes only.



Notes:

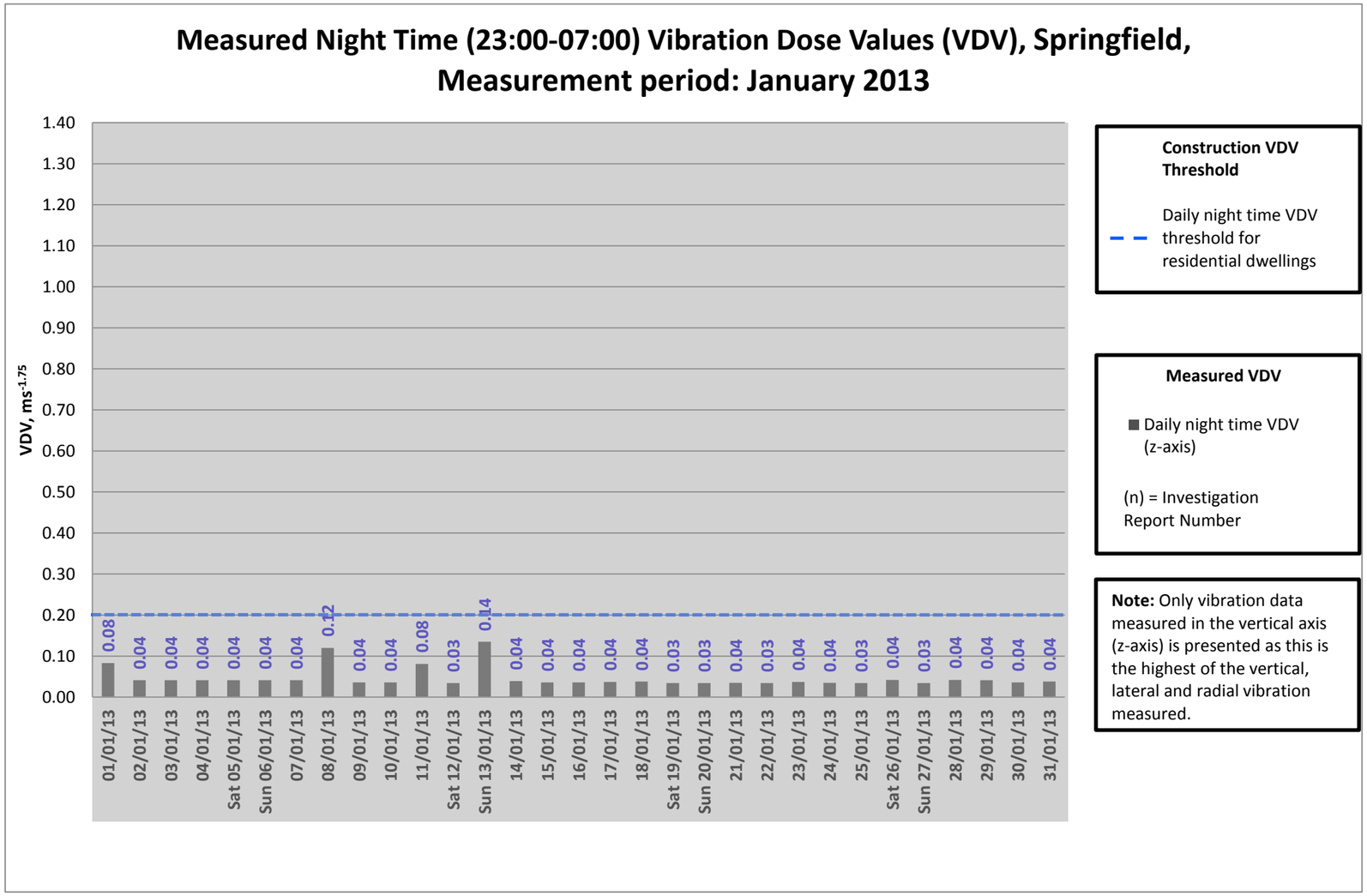
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- The PPV values on 11/01/13 & 31/01/13 have both been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 11/01/13). The level recorded on 11/01/13 is within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were rock generation and break out operations at the Queensferry gyratory and Echline Field respectively. The only vibration inducing plant or equipment involved in these activities were rock breakers, which were operated a minimum distance of 50m from the monitor (and nearest receptors), and can thus be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).





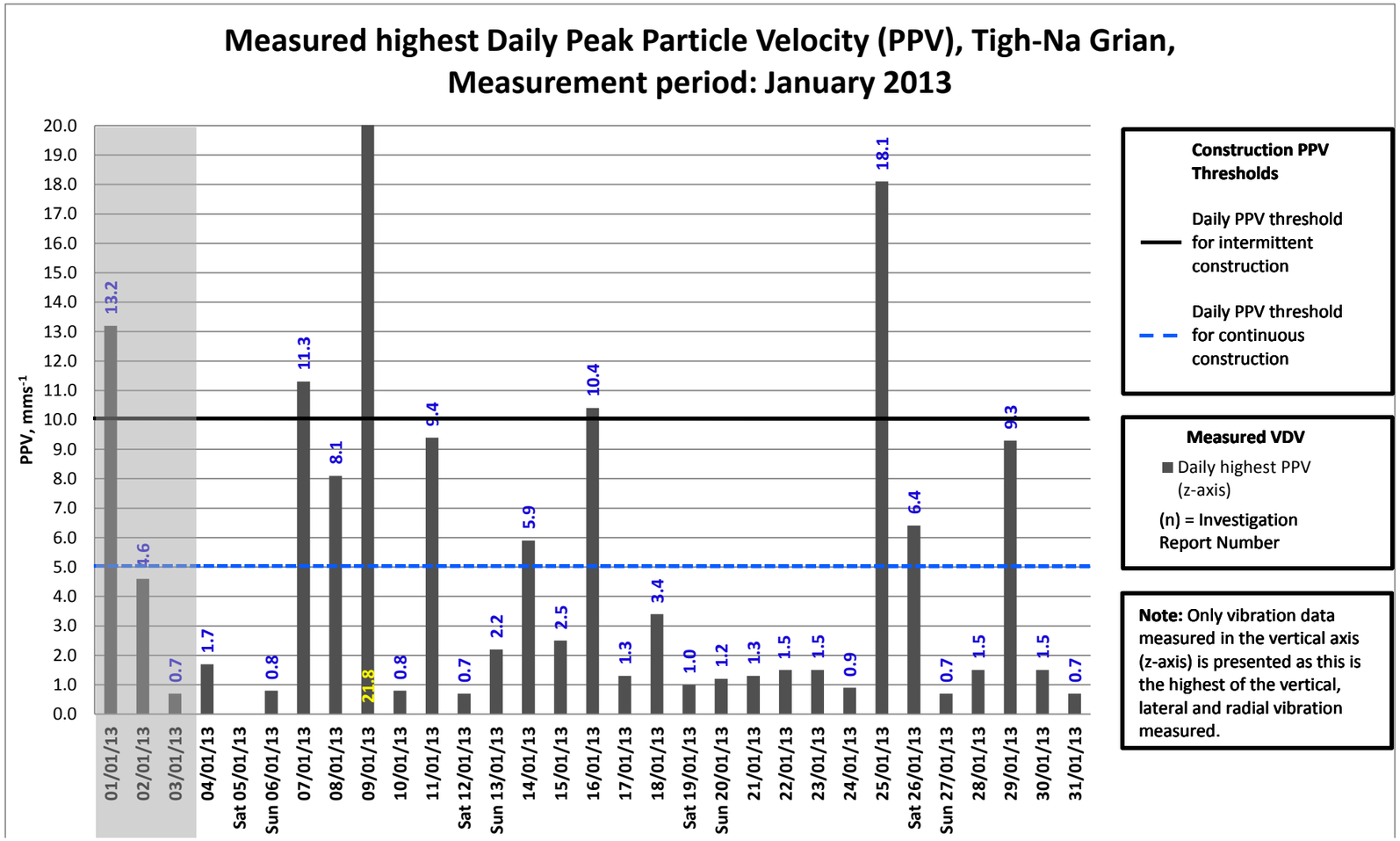
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.



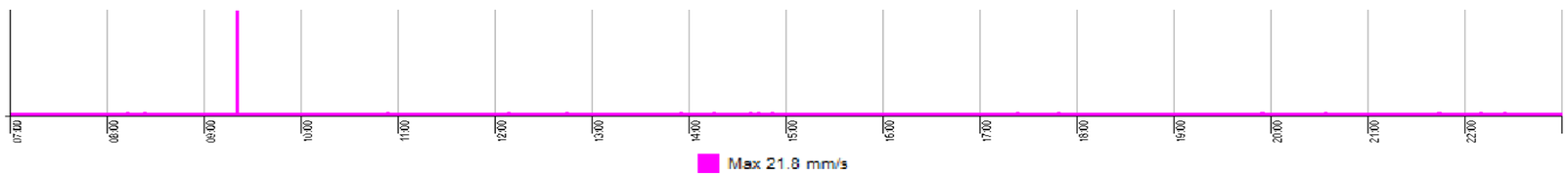
Notes:

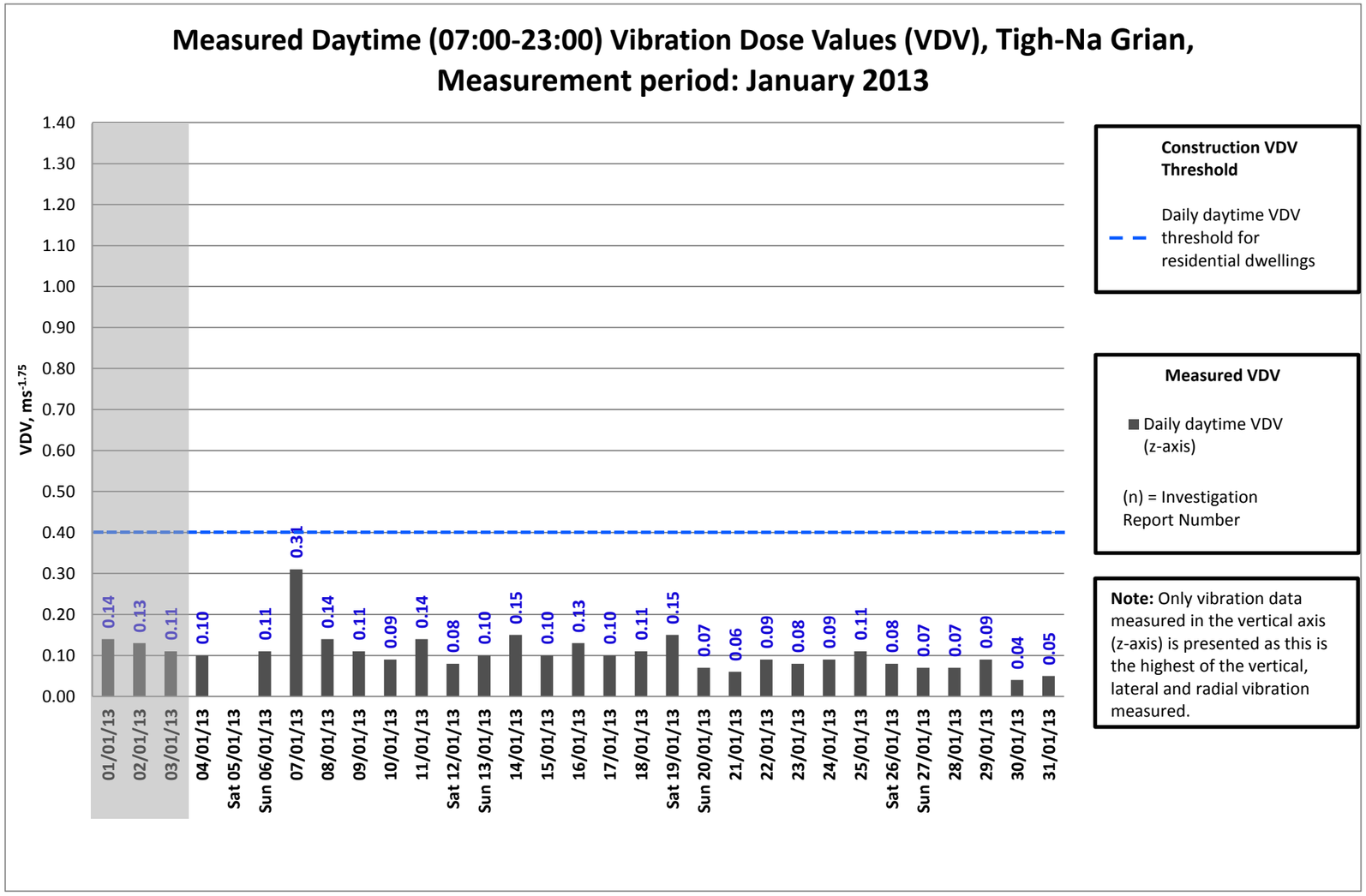
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of January 2013. This graph is included for illustrative purposes only.



Notes:

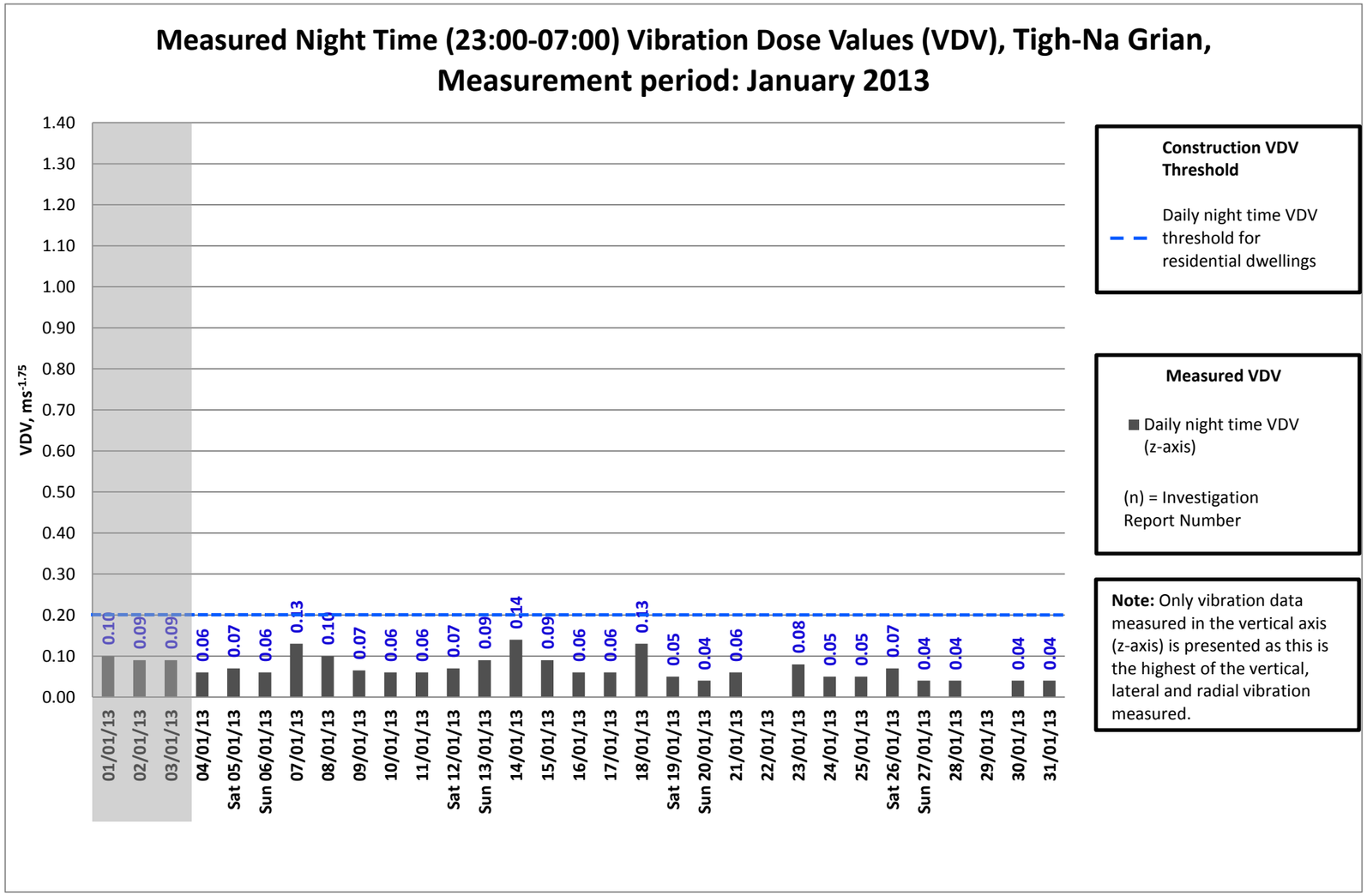
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 05/01/13 due to device error.
- All PPV exceedances have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 09/01/13). These particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were caisson excavation and jet grouting at the North Tower and the 'one-off' placement of the cofferdam at Pier N1. There was no vibration inducing plant or equipment involved in any of these activities, thus they can be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).





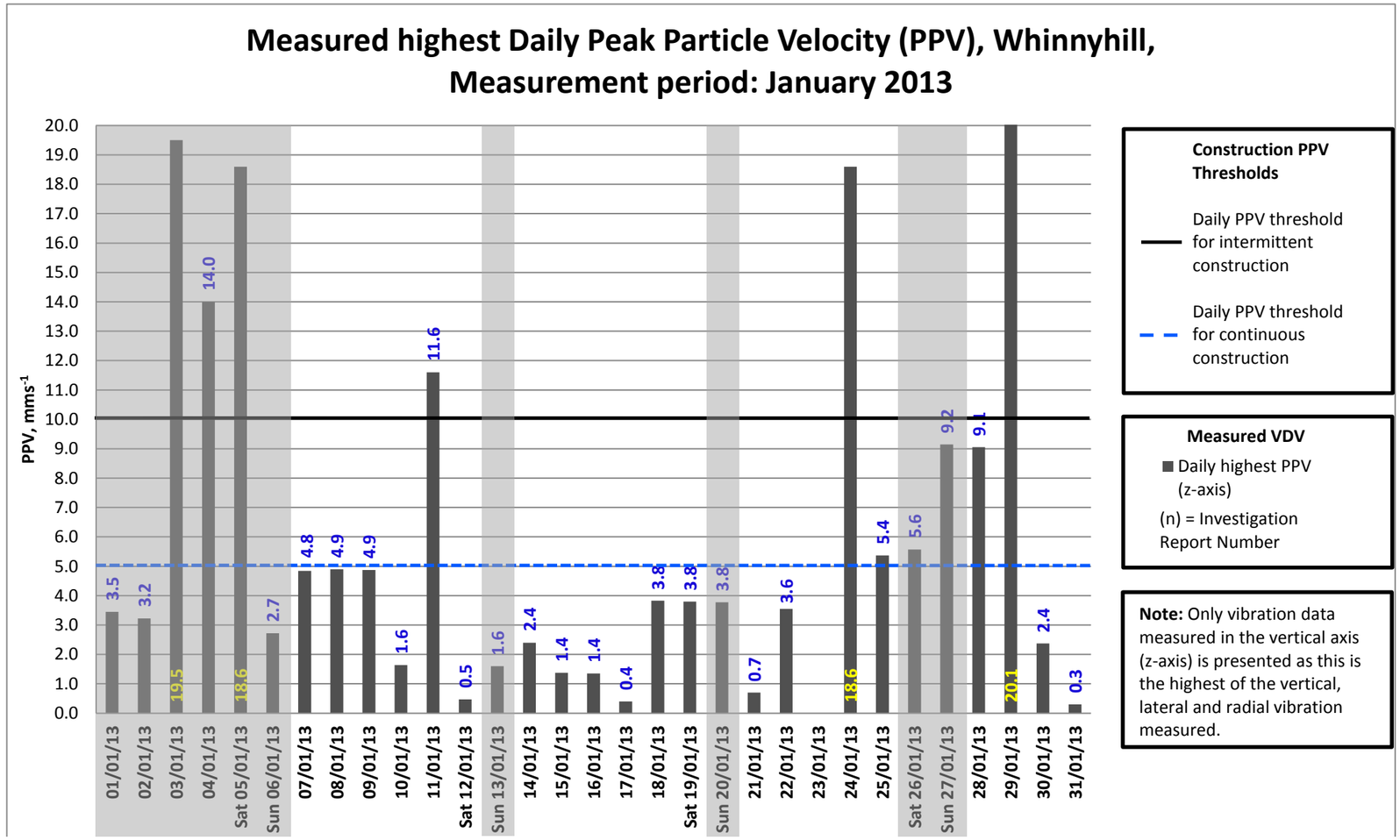
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 05/01/13 due to device error.



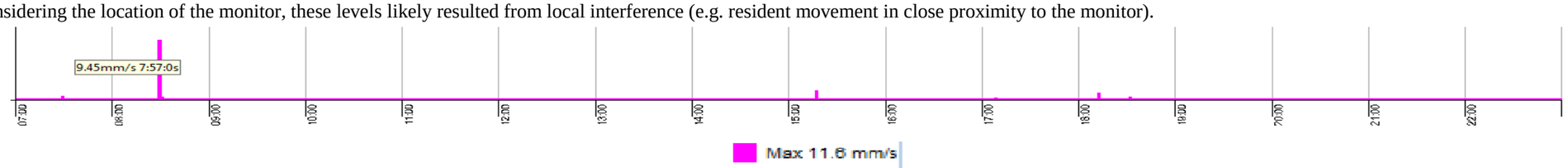
Notes:

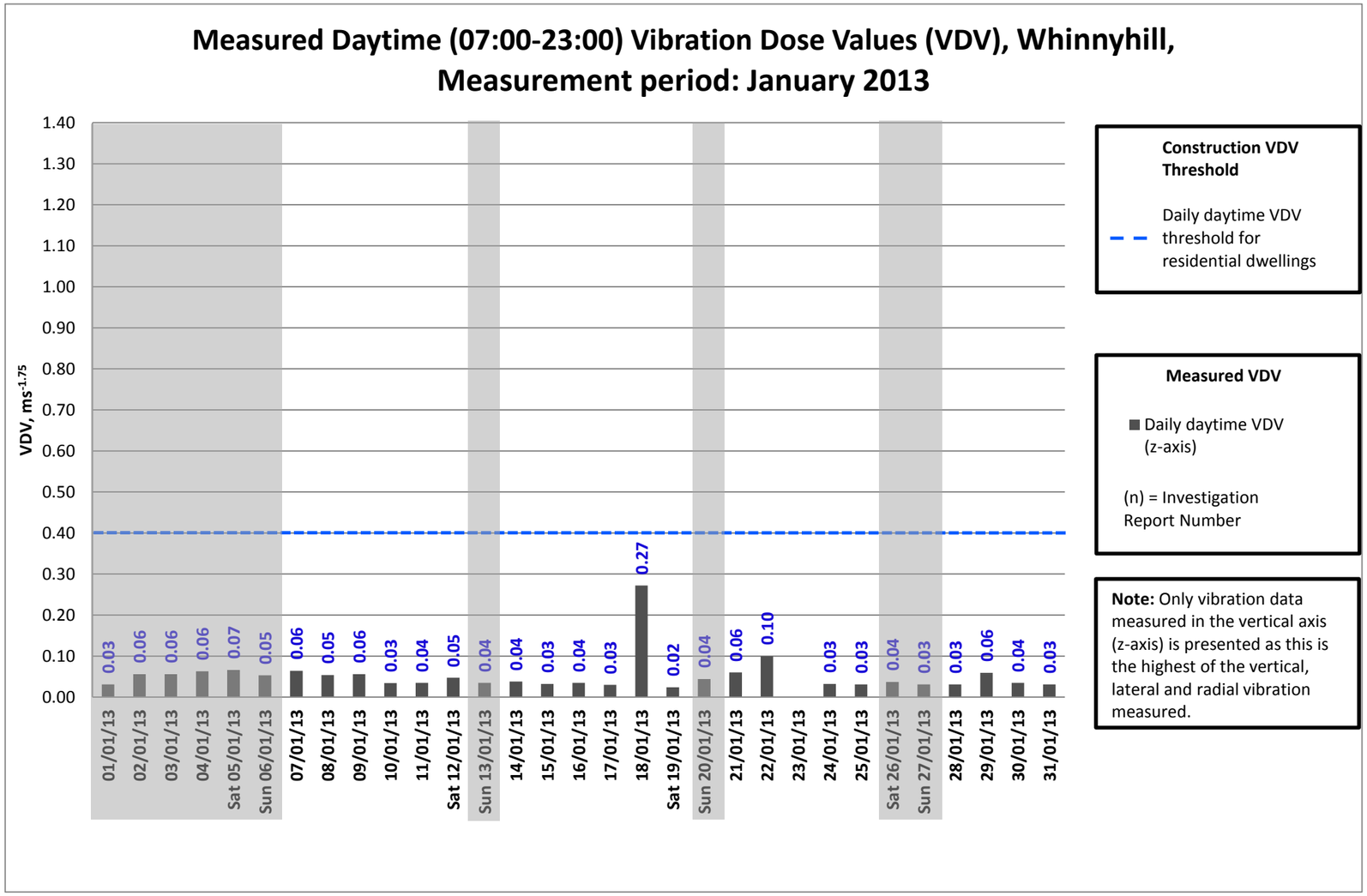
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 22/01/13 and 29/01/13 due to device error.



Notes:

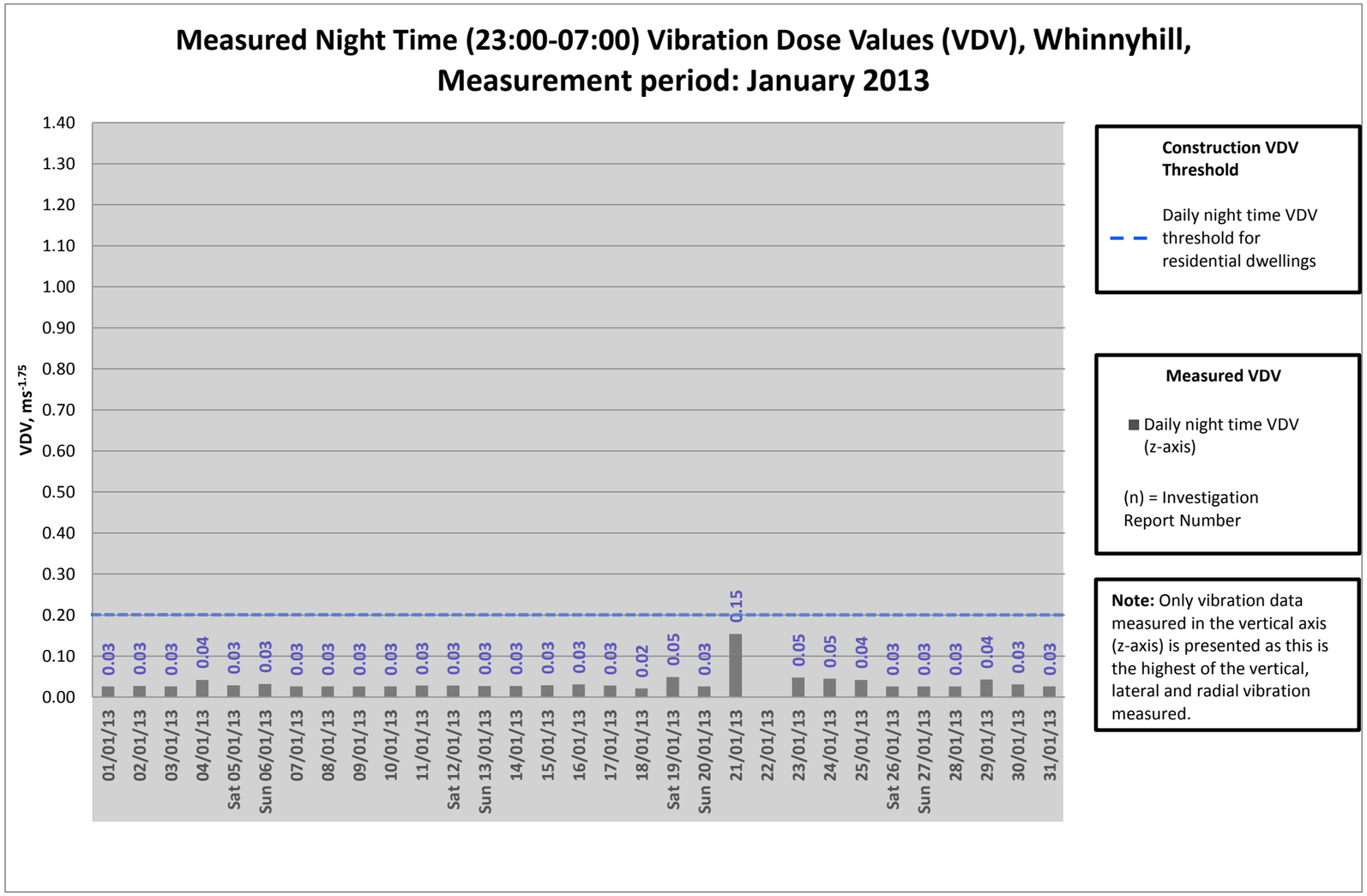
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 23/01/13 due to device error.
- All PPV exceedances have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 11/01/13). These particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor were the breaking and loading of rock at Whinnyhill and drilling in preparation for blast 13 at Whinnyhill. The only vibration inducing plant or equipment involved in these activities were rock breakers, which were operated a minimum distance of 270m from the monitor (and nearest receptors), and can thus be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).





Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted over the Christmas period - Marine: 21/12/12 to 03/01/13, Networks: 21/01/13 to 06/01/13.
- Data is missing for 23/01/13 due to device error.



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 January 2013. This graph is included for illustrative purposes only.
- Data is missing for 23/01/13 due to device error.