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MINISTRY OF DEFENCE LAND RANGES - NOISE AND VIBRATION STUDY

MOD PENDINE RANGE

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VOLUME 1: FINAL REPORT

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MOD PENDINE RANGE

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This is Volume 1 of 3 of the MOD Pendine Range Final Report. This volume should be read in conjunction with Volumes 2 and 3.

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1. INTRODUCTION

1.1 Background

1.1.1 There is a public perception that Test, Evaluation, Demilitarisation, and Training support activities (the Range Activities) at the Ministry of Defence (MOD) Land Ranges operated by QinetiQ can produce noise and vibration that may be damaging to property through airborne or seismic shock waves.

1.1.2 Southdowns Environmental Consultants Ltd (Southdowns) has been appointed by QinetiQ, on behalf of the MOD, to undertake an independent investigation into whether, and to what extent, Range Activities result in potentially damaging effects to building structures at locations surrounding the Land Ranges.

1.1.3 QinetiQ provides Test and Evaluation (T&E) and Training Support services to MOD under a 25-year contract – the Long Term Partnering Agreement (LTPA).

1.1.4 The initial requirements for the monitoring study were presented in 'Pendine Noise and Vibration Monitoring Study (NVMS) - System Requirements Document (SRD) [1] produced on behalf of the MOD by QinetiQ.

1.1.5 The Single Statement of User Need, set out in the SRD states:

'The User requires a competent independent study to ascertain whether Test, Evaluation, Demilitarisation, and Training support activities (the Range activities) cause excessive noise or vibration that could possibly cause damage or exceed legal limits and their effect on local communities and at specific locations through airborne or seismic shock waves'

1.1.6 Further consideration was given to the main study aims, the associated risks and study limitations and, following further communication with QinetiQ, the final study scope and key objectives were agreed. These are set out in Section 1.2 below.

1.2 Scope

1.2.1 The study comprised the long-term continuous measurement of airborne sound pressure levels, air over pressure and ground-borne vibration caused by Range Activities at a series of locations within and around the LTPA Land Ranges. The resulting measurement dataset has been analysed and where possible, a causal link between on-Range Activities and measured magnitudes of sound and vibration at surrounding off-Range locations determined.

1.2.2 Where a causal link has been determined from the analysis, then the magnitudes of measured sound / air overpressure and ground-borne vibration have been assessed against appropriate criteria to establish the likely risk of: potential building damage.

1.2.3 The following key objectives have been identified to achieve the overarching aims of the study:

- Establishment of relevant metrics, criteria and thresholds for building damage, through the review of contemporary research and published literature;
- Selection of appropriate monitoring equipment and systems;
- Development of a detailed methodology for the undertaking of a large scale monitoring programme;

- Selection of suitable monitoring locations;
- Design and implementation of data management procedures to maintain data quality;
- Collation and analysis of large quantities of data;
- Determination of the magnitude of sound pressure and vibration exposures from Range Activities;
- Development of a robust technique for defining causal link; and
- Reporting of suitable information to the client and other external parties.

1.2.4 The monitoring commenced in the vicinity of the Pendine Range on 3rd November 2014 for a period of six months at 10 off-Range monitoring locations. In addition, two monitoring systems were installed within the confines of the MOD Pendine Land Range. The monitoring equipment was set-up with a synchronous trigger system which allowed for simultaneous triggering between the on-Range and off-Range monitoring locations, allowing data capture at the off-Range monitoring locations at the precise time of an activity on the Range.

1.2.5 The assessment criteria and thresholds adopted for this study are summarised in Section 2 of this report. The monitoring study methodology is presented in Section 3. Details of the Range Activities and the data captured are presented in Section 4. The results of the monitoring study are presented and discussed in Section 5 and finally, the study conclusions are presented in Section 6.

2. ASSESSMENT CRITERIA

2.1 Introduction

2.1.1 An independent review of published available contemporary research and guidance has been undertaken to ensure that appropriate assessment indicators and effect thresholds were identified and adopted for the interpretation and assessment of the collated dataset.

2.1.2 The following series of review objectives were established to achieve the overall aim:

- develop an understanding of the acoustic effects of activities which are undertaken on MOD Land Ranges;
- identify the acoustic characteristics which may cause adverse effects leading to structural damage;
- provide best practice guidance for the measurement of acoustic effects from military Land Range Activities at receptor locations distant from Range operations; and
- develop an understanding of the magnitudes at which such acoustic related effects are likely to cause structural damage to property and potential damage to hearing.

2.1.3 The review drew on previous similar studies undertaken in the UK and overseas, as well as relevant British Standards and academic literature, to provide context and technical commentary on the key considerations for the monitoring study.

2.1.4 The primary focus of the review was associated with potential building damage associated with sound pressure, air overpressure and ground-borne vibration generated by Range Activities. Human responses associated with the non-auditory adverse effects of noise and vibration including disturbance, annoyance and sleep disturbance fall outside the scope of the review.

2.1.5 The findings of the research are presented in full in Southdowns report 'Criteria for the Assessment of Potential Building Damage Effects from Military Test Activities' - reference [2].

2.2 Building Damage Thresholds

2.2.1 The findings of the independent review have been used to establish relevant thresholds for the onset of building damage for ground-borne vibration and air overpressure. The thresholds, presented in Table 2.1 and Table 2.2 for ground-borne vibration and air overpressure respectively, have been adopted for the main study, to assess the potential effects from Range Activities, on properties and their occupants in the vicinity of Pendine Range.

TRANSIENT VIBRATION THRESHOLDS FOR THE ON-SET OF COSMETIC DAMAGE					
TYPE OF BUILDING		**MAXIMUM DISPLACEMENT**	**PEAK COMPONENT PARTICLE VELOCITY IN FREQUENCY RANGE OF PREDOMINANT PULSE**		
		Less than 4 Hz	Less than 4Hz	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures Industrial and heavy commercial buildings		-	-	50 mms^{-1} at 4 Hz and above	
Unreinforced or light framed structures. Residential or light commercial type		0.6 mm zero to peak	-	15 mms^{-1} at 4 Hz increasing to 20 mms^{-1} at 15 Hz	20 mms^{-1} at 15 Hz increasing to 50 mms^{-1} at 40 Hz and above
Precautionary Thresholds Adopted	**Any building**	**0.6 mm zero to peak**	**12.5 mms^{-1}**		
	Vulnerable Structures		**6 mms^{-1}**		

TABLE 2.1: GROUND-BORNE VIBRATION THRESHOLDS FOR ON-SET OF COSMETIC DAMAGE TO BUILDINGS

Notes:
[1] – further information on the derivation of these values is provided in Reference [2].

Air Overpressure Threshold Scale	
dB L_{Zpeak}	**Categorisation**
180	Onset of structural damage
171	General window breakage
151	Some window breakage
140	Reasonable threshold to prevent glass and plaster damage
134	USBM 'Safe' maximum
120	Secondary vibration effects including rattling windows and objects

TABLE 2.2: AIR OVERPRESSURE THRESHOLDS FOR DAMAGE AND OTHER EFFECTS ON BUILDING STRUCTURES

Notes:
[1] – further information on the derivation of these values is provided in Reference [2].

2.3 The Control of Noise at Work Regulations 2005

2.3.1 In addition to the consideration of potential damage to building structures, the study has also considered the potential for Range Activities to exceed statutory limits, which include the

thresholds set out in the Control of Noise at Work Regulations 2005, as referenced in the Pendine SRD [1].

2.3.2 The Control of Noise at Work Regulations 2005 (CNWR) [3] came into effect on the 6th April 2006 and describe the various obligations on employers and employees to ensure that the risk of hearing damage in the workplace is minimised. The Regulations are based around two action levels and an exposure limit value, which are reproduced in Table 2.3.

Lower exposure action values	daily or weekly personal exposure of 80 dB(A)[1]
	peak sound pressure of 135 dB(C)[2]
Upper exposure action values	daily or weekly personal exposure of 85 dB(A) [1]
	peak sound pressure of 137 dB(C) [2]
Exposure limit values	daily or weekly personal exposure of 87 dB(A) [1]
	peak sound pressure of 140 dB(C) [2]

TABLE 2.3: SUMMARY OF ACTION AND EXPOSURE LIMIT VALUES FROM THE CNWR 2005

Notes:
[1] - The daily or weekly personal exposure is the level of exposure to noise of a person, averaged over a working day or week; and
[2] - The peak sound pressure is the maximum value of the C-weighted sound pressure, to which a person is exposed during the working day.

2.3.3 The above action values and exposure limits are used to determine the risk to hearing and when action should be taken to reduce an employee's exposure to noise.

3. MONITORING METHODOLOGY

3.1 Study Location

3.1.1 The MOD Pendine Land Range is located on the southwest coast of Wales, approximately 12 miles southwest of the town of Carmarthen. It provides the MOD with a key facility for test, evaluation and training support activities and is the UK and NATO European Regional Test Centre (ERTC) and is a recognised facility for the accreditation of small arms and cannon ammunition.

3.1.2 The Range covers a land area of approximately 20 km^2 which includes a 9 km section of shoreline with the sea danger area stretching over approximately 18 km^2. It also includes an Air Danger Area which extends up to 23,000 ft.

3.1.3 The Pendine Land Range is divided into three areas; West, Central and East. The separate areas have different facilities, sub divided into smaller individual test site areas, providing a total of 18 available Ranges.

3.1.4 The central section of the Range features a 1500m Long Test Track (LTT) facility which allows for high-speed dynamic trials.

3.1.5 The eastern end of the Range consists of long range small arms and static trial ranges, including a smaller test track, although it is understood to be rarely utilised.

3.2 Site Selection Process

3.2.1 Locations for the monitoring study were selected on the basis of both acoustic and non-acoustic considerations, having regard to appropriate published guidance documents. The practicalities of installing, securing and maintaining the monitoring equipment were also key considerations.

3.2.2 Following the completion of the site selection process, 10 off-Range locations and 2 on-Range locations were selected. The monitoring locations are presented in Table 3.1 overleaf and Figure A1 of Appendix A.

3.2.3 Full details of the site selection process for the monitoring locations are provided in Volume 2 – Technical Appendices: Detailed Methodology [4].

Monitoring Location Identification Code	Area /Region	Approximate Distance to Range (PEN_R1) (km)
PEN_R1	On-Range	N/A
PEN_R2	On-Range	N/A
PEN_OS1	Laugharne	3.7
PEN_OS2	Laugharne	0.6
PEN_OS3	Laugharne	3.1
PEN_OS4	Laugharne	4.0
PEN_OS5	Llanstephan	6.2
PEN_OS6	Ferryside	8.0
PEN_OS7	Kidwelly	7.8
PEN_OS8	Ferryside	11.8
PEN_OS9	Plashett	1.9
PEN_OS10	Pendine	5.6

TABLE 3.1: MONITORING LOCATIONS

3.3 Selected Monitoring Equipment

3.3.1 The selected monitoring equipment deployed for the main study was based on the SINUS Samurai monitoring system. The system comprises an industrial PC running Windows 7 and features a synchronous triggering function which has allowed for simultaneous triggering between separate monitoring locations. Data collected during the monitoring study was stored locally on Solid State Drives (SSD) installed within each of the monitoring stations, and then uploaded to a dedicated secure central data server on a daily basis via a File Transfer Protocol (FTP).

3.3.2 Each monitoring station comprised of:

- SINUS Swing 4-channel noise and vibration monitoring station; and
- Uninterruptible Power Supply (UPS) system (up to 48 hours of power backup).

3.3.3 Connected accessories to each of the SINUS noise and vibration monitoring station include:

- G.R.A.S. 41CN Outdoor Microphone System;
- SINUS tri-axial geophone;
- Garmin Global Positioning System (GPS) receiver; and
- Thies Clima Sensor (at selected monitoring locations).

3.4 Synchronous Detection Technique

3.4.1 A feature of the monitoring system deployed was the use of a GPS clock to synchronise the time base across all monitoring systems at both on-Range and off-Range locations. Combined with this was the use of a networked synchronous triggering system which allowed for simultaneous triggering between on-Range, and all off-Range monitoring locations. To ensure data capture, the trigger threshold for all three on-Range monitors was set at 75 dB L_{pAF}. When this trigger level, at one of the on-Range monitors was exceeded, a trigger command was transmitted to the off-Range monitoring systems via the internet,

which allowed for data to be captured at the monitoring locations at the precise time of an on-Range Activity occurrence. In addition to the main triggering system, each off-Range monitor was also configured to trigger following a localised (non Range related) noise event.

3.4.2 A 5 second pre-trigger audio capture, followed by a post trigger audio capture of 30 seconds was set up for the on-Range systems. The off-Range monitors were set with a 5 second pre-trigger capture, followed by a post-trigger capture of audio for up to 120 seconds, which allowed for small delays implicit in the triggering system and also delays expected due to the propagation of air overpressure and/or ground-borne vibration over the longer distances involved. The hardware was programmed to ensure that any trigger activity was captured from both the microphone and geophone sensors simultaneously, to allow side by side comparison of sound pressure and ground-borne vibration in the time domain.

3.4.3 The introduction of a synchronised time base and networked triggering system allowed for a clear link to be established between on-Range Activities and magnitudes of sound / air overpressure and vibration at off-Range locations, which is a principle aim of the monitoring study. An overview of the synchronous trigger system process is displayed graphically in Figure A2 of Appendix A.

3.4.4 Full details of the monitoring equipment and data management systems are provided in Volume 2 – Technical Appendices: Detailed Methodology [4].

4. MONITORING SUMMARY

4.1 Summary of Range Activities and Data Capture

4.1.1 The full Pendine Range firing records, as provided by QinetiQ Ltd between 3rd November 2014 and 3rd May 2015 are presented in Volume 3: Technical Appendices – Results [5].

4.1.2 During the monitoring study, there were a total of 3,282 events which triggered the on-Range monitors (1,719 captured by PEN_R1 and 1,563 captured by PEN_R2).

4.1.3 Of the 3,282 triggered events, 3,149 were attributable to non-firing activities on the Range including local vehicle movements, wind noise on the microphone, local maintenance works, Range alarms and vehicle sirens.

4.1.4 Of the 133 (3,282 – 3,149) Range triggered events, 30 triggered more than one of the on-Range monitors, capturing a total of 103 individual Range Activities.

4.1.5 The trials undertaken on the Range during the monitoring period were categorised as Static activities, Dynamic activities, Small Arms & Cannon Fire and 'Military' training.

4.1.6 The 'Small Arms & Cannon Fire' and 'Military' training activities were considered unlikely to trigger the on-Range monitoring systems. Playback of the audio waveform indicated that triggered activities which occurred during notified 'Small Arms & Cannons Trials' and 'Military' training activities were in fact attributable to extraneous activities (including vehicle movements and wind noise on the microphone) and therefore these activities have been excluded from further consideration in this study accordingly.

4.1.7 During the monitoring study, the Range logs recorded a total of 149 Static and Dynamic Activities were expected to trigger the on-Range monitoring systems, with 149 individual activities recorded, of these, 46 (149 – 103) were not captured by Range monitors.

4.1.8 Of the 46 Range Activities not captured by the on-Range monitors, 42 were not captured because they did not exceed the trigger threshold level (TNE), whilst 4 were not captured due to equipment outages.

4.1.9 Of the 103 individual triggered Range Activities, the number captured at an individual off-Range monitor ranged between 89 and 66, as displayed in Table 5.1 below. The number of Range Activities not captured at an off-Range location was influenced by a variety of reasons including: unforeseen delays in installing the ADSL services at off-Range locations, previously agreed hosts deciding to withdraw from the monitoring study, ADSL outages and on-Range network outages.

4.1.10 The on-Range network outages were responsible for 13 Range Activities not being captured at off-Range locations between 13th and 15th January 2016. Following a review of the Range firing logs as presented in Volume 3: Technical Appendices – Results, it is noted that the type and size of the 13 Range Activities not captured are considered to be typical Range Activities, and are therefore represented by other activities captured during the study.

4.1.11 Where the on-Range monitors were not triggered it was found that the off-Range monitors were also not triggered locally by sound / air overpressure from the Range Activity.

4.1.12 A summary of the quantities of captured on-Range and off-Range Activities during the monitoring study is presented in Table B1 of Appendix B.

4.2 Summary of Data Capture

4.2.1 Full details of scheduled equipment maintenance works (including telecommunications and data management system maintenance) and known system outages experienced during the monitoring study are presented in Volume 2- Technical Appendices – Detailed Methodology [4], whilst Tables B2 to B7 of Appendix B provide summarised schedules of Range Activities captured at each of the individual off-Range monitoring locations respectively.

5. RESULTS AND DISCUSSION

5.1 Introduction

5.1.1 The dataset collected during the monitoring study has been processed, using appropriate methodologies and statistical techniques, to determine causal links and to assess the magnitude of the measured values. These methodologies and techniques are described in full in Volume 2 – Technical Appendices – Detailed Methodology [4], which includes worked examples of a selection of confirmed Range Activities captured during the monitoring study. In addition, examples of non-Range (or 'extraneous') activities are presented to enable a direct comparison with those known to be associated with Range Activities.

5.1.2 Section 5.2 below presents a summary of the testing undertaken to test for any causal link between on-Range and off-Range triggered activities, while Section 5.3 presents a summary of the results for the on-Range and off-Range triggered activities and a summary of activities concluded not to be associated with the Range.

5.1.3 The full study results for sound pressure / air overpressure and vibration including time histories, sound spectrograms and calculated statistical results are presented in Volume 3 –Technical Appendices – Results [5].

5.2 Test for Causal Link

5.2.1 The classification of the test for a causal link used herein provides a measure of the probability that an activity at a primary location has given rise to a measured response at a secondary location.

5.2.2 Automated signal processing techniques were used to determine an initial indication of causality at all monitoring locations for all captured Range Activities. The magnitude of causality presented in the results has been categorised accordingly:

- positive causality (PC) – statistical evidence indicates a reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. probable causality);
- uncertain causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. possible causality);
- no causality (NC) – little or no statistical evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. unlikely causality).

5.2.3 Activities which fall into positive causality (PC) have been included in the data set for assessing magnitudes of sound / air overpressure at off-Range locations, as it is accepted that the measured effect is most likely to be due to Range Activities.

5.2.4 Activities which fall into the uncertain causality (UC) category have also been included in the assessment nevertheless, as it is accepted that the measured effect could be due to Range Activities.

5.2.5 For activities which identified no causality (NC) following the initial application of the signal processing techniques, further manual analytical interrogation of the data set was applied in each case to determine whether a causal link could be established.

5.2.6 Where causality was subsequently established, the individual Range Activities were included in the assessment of sound / air overpressure magnitudes from Range Activities.

5.2.7 A summary of the distribution of confirmed Range Activities detected at the off-Range monitoring locations is presented graphically in Figure A3 in Appendix A, which identifies the proportion of the activities that have been assessed to have: positive, uncertain or no causality. These results are also tabulated in Table 5.1.

Off-Range Location	Total On-Range Activities[1] Captured	Total Off-Range Activities[1] Captured	No. of Activities Captured			% Activities Captured		
			No Causality	Uncertain Causality	Positive Causality	No Causality	Uncertain Causality	Positive Causality
PEN_OS1	103	88	10	18	60	11%	20%	69%
PEN_OS2	103	89	9	17	63	10%	19%	71%
PEN_OS3	103	81	7	10	64	9%	12%	79%
PEN_OS4	103	74	10	15	49	14%	20%	66%
PEN_OS5	103	89	8	13	68	9%	15%	76%
PEN_OS6	103	87	7	15	65	8%	17%	75%
PEN_OS7	103	80	10	22	48	13%	28%	59%
PEN_OS8	103	87	9	14	64	10%	16%	74%
PEN_OS9	103	69	12	17	40	17%	25%	57%
PEN_OS10	103	78	12	32	34	15%	41%	44%

TABLE 5.1: DISTRIBUTION OF ACTIVITIES INTO CAUSAL CATEGORIES

Notes:
[1] number of individual static and dynamic activities captured.

5.2.8 The results indicate that Range Activities which showed 'No-Causality' varied between 8% (PEN_OS6) and 17% (PEN_OS9) across the individual off-Range monitoring locations, when using a combination of signal processing techniques and manual interrogation of the data set.

5.2.9 Between 44% (PEN_OS10) and 79% (PEN_OS3) of the confirmed on-Range Activities have been classified as 'Positive Causality' across all of the off-Range monitoring locations.

5.2.10 The off-Range monitoring location where the highest number of activities were categorised as 'Uncertain Causality' was at PEN_OS10.

5.2.11 The lower confirmed causality at PEN_OS10 is most likely to be due to a combination of meteorological effects (including the effects of the prevailing wind direction) as it is the only monitoring location to the west of the Range.

5.2.12 PEN_OS3 is shown to exhibit the lowest proportion of 'Uncertain Causality' whilst the number of 'No Causality' activities is similar to a number of other off Range locations.

5.2.13 The study has therefore identified a confirmed causal link between Range Activities and measured effects at off-Range monitoring locations, for up to 79% of the triggered Range Activities. So this means if those activities falling into the 'Uncertain Causality' category are included for a cautious assessment then up to 91% (PEN_OS3) of the on-Range Activities show a causal link at off-Range monitoring locations. Activities falling into the 'No Causality' category have not been included in the assessment.

5.3 Sound / Air Overpressure and Vibration Magnitudes

5.3.1 The dataset (Positive and Uncertain Causality) has been processed to calculate absolute sound / air overpressure and vibration values both on-Range and off-Range monitoring locations.

5.3.2 The sound / air overpressure and vibration levels measured at PEN_OS1 to PEN_OS10, which are directly attributable to on-Range Activities are presented fully in Volume 3: Technical Appendices – Results [5].

5.3.3 Sound / air overpressure levels are presented graphically in Figures A4 to A33 of Appendix A and summarised in Tables B2 to B7 of Appendix B

Summary of Range Activity Results

5.3.4 The results indicate that the highest Z-weighted (or linear) sound pressure level resulting from a static Range Activity, measured at an off-Range location during the monitoring study was 134 dB L_{Zpeak}, which was measured at the PEN_OS3. This falls below the adopted study threshold to prevent glass and plaster damage of 140 dB L_{Zpeak}, by approximately 6 dB.

5.3.5 The highest c-weighted sound pressure level from a static Range Activity, measured at an off-Range location was 127dB L_{Cpeak}, which falls below the CNWR lower exposure action value of 135 dB $L_{Cpeak.}$

5.3.6 The results also indicate that the highest sound pressure level from a dynamic Range Activity, measured at an off-Range location during the monitoring study was 124 dB L_{Zpeak}, which was measured at PEN_OS2. This is above the threshold at which secondary vibration effects may occur but falls below all the building damage thresholds presented in Table 2.2.

5.3.7 Detailed analysis of the results has shown that the vibration signals captured at off-Range locations arrived at a similar time to the sound pressure waves, indicating that the vibration generated by Range Activities at off-Range locations was a result of a coupling effect between the sound / air overpressure wave and the ground at the point of measurement, rather than from direct ground-borne propagation of vibration from the source of Range Activity. An example of this is shown graphically in Figure A36 of Appendix A for PEN_OS2 with the signal arriving around 7 seconds after the on-Range event was triggered. If the measured vibration was associated with ground-borne propagation then a pronounced difference in arrival times would be observed with the vibration signal arriving in advance of the sound pressure signal. Further details are provided in Volume 2 – Technical Appendices – Detailed Methodology, Chapter 4 [4].

5.3.8 Notwithstanding that the vibration measured is considered to be attributable to the air overpressure coupling (as opposed to ground-borne vibration), the highest component

velocity level measured at an off-Range location during the static Range Activities was 0.87 mms^{-1}, which was measured on the z-axis at PEN_OS3. This falls considerably below the ground-borne vibration thresholds for the on-set of cosmetic damage as set out in Table 2.1.

5.3.9 Table B11 of Appendix B presents the distribution of maximum component velocities per each orthogonal axis. A total of 51% of events across all monitoring stations (Range and Off-Range) observed a maximum velocity level on the z-axis (vertical) compared to 33% on the y-axis and 16% on the x-axis.

5.3.10 A vibration level of 3.65 mms^{-1} was measured at PEN_OS7 during a static Range Activity, however, further interrogation of the data set revealed that this was due to localised activity which occurred during the same time period.

5.3.11 The highest vibration level measured at an off-Range location during the dynamic Range Activities was 0.29 mms^{-1}, which was measured at PEN_OS2. This falls considerably below the ground-borne vibration thresholds for the on-set of cosmetic damage as set out in Table 2.1.

5.3.12 The maximum displacement levels for both static and dynamic activities fell below the threshold of 0.6 mm zero to peak at frequencies below 4 Hz, with the highest measured level being 0.01 mm. A displacement level of 0.06 mm was measured at PEN_OS7, however this was not found to be as a consequence of a Range Activity.

Summary of Off-Range Locally Triggered Activities

5.3.13 A summary of locally triggered measurements (triggered activities not associated with Range Activities e.g. birdsong, aircraft, road traffic) are presented in Volume 3: Technical Appendices – Results [5]. The table presents the highest $L_{Cpeak,}$ L_{Zpeak} and PPV values measured at each off-Range monitoring location between 3rd November 2014 and 31st May 2015.

5.3.14 The results indicate that the highest number of off-Range triggered activity caused by local activities was 1,121, at PEN_OS8. These were mainly attributable to the close proximity of the property to the West Wales railway line, confirmed by audio playback of the triggered activities.

5.3.15 The lowest number of off-Range triggered activities which were caused by local activity was 11, at PEN_OS9.

5.3.16 The highest level measured at any off-Range location, which occurred as a result of localised activity was 135.7 dB $L_{Zpeak,}$ which was measured at PEN_OS1 and was confirmed to be attributable to local fireworks.

5.3.17 Fireworks were also responsible for the highest measured levels at PEN_OS4, PEN_OS7, PEN_OS8 and PEN_OS 10.

5.3.18 The highest vibration levels measured as a result of off-Range local activity ranged from 0.00034 mms^{-1} at PEN_OS6 to 0.90 mms^{-1}, at PEN_OS10.

5.4 Meteorological Data

5.4.1 Meteorological monitoring data was collated at the following five monitoring locations during the monitoring study:

- PEN_R1, On-Range;
- PEN_OS4, Laugharne;
- PEN_OS6, Ferryside;
- PEN_OS7, Kidwelly; and
- PEN_OS10, Pendine.

5.4.2 The results of the meteorological monitoring data including wind speed (ms^{-1}), wind direction, air temperature (°C), relative humidity (%), atmospheric pressure (mBar) and rain rate (mm/h) for each of the five locations gathered during the monitoring study are presented fully in Volume 3 -Technical Appendices – Results [5].

5.4.3 The results of the meteorological data collated at the On-Range location (PEN_R1) during the monitoring study are summarised in Table B8 of Appendix B and discussed in the following sub-sections.

5.4.4 Wind speeds measured On-Range during the Range Activities presented in this report were found to average 3.7 ms^{-1} with maximum and minimum levels of 14.8 ms^{-1} and 0.2 ms^{-1} respectively.

5.4.5 The average air temperature measured on-Range during the Range Activities presented in this report was 7.3°C with maximum and minimum levels of 14.7 °C and 0.9°C respectively.

5.4.6 The average relative humidity measured on-Range during the Range Activities presented in this report was 83.9% with maximum and minimum levels of 100 % and 59.6 % respectively.

5.4.7 The average rain rate measured on-Range during the Range Activities presented in this report was 0.3 mm/h with maximum and minimum levels of 10.9 mm/h and 0.0 mm/h respectively.

5.4.8 A review of the meteorological data presented in Volume 3 -Technical Appendices – Results [5] indicates Range Activity data capture has occurred under a range of meteorological conditions over a six month period, including conditions which are likely to have enhanced sound pressure propagation over large distances.

6. CONCLUSIONS

6.1.1 The sound pressure level and vibration monitoring commenced in the vicinity of the Pendine Range on 3rd November 2014 for a period of 6 months at 10 no. off-Range monitoring locations. In addition, 2 no. on-Range monitoring systems were installed within the confines of the MOD Pendine Land Range. The monitoring equipment was set-up with a synchronised triggering system which enabled simultaneous triggering between the on-Range and off-Range monitoring locations, allowing data capture at the off-Range monitoring locations at the precise time of an activity at the Range.

6.1.2 Activity data capture has occurred under a range of meteorological conditions over a six month period, including conditions which are likely to have enhanced sound pressure propagation over large distances.

6.1.3 In total, 103 individual static and dynamic Range Activities were captured by the on-Range monitors. Of these, the maximum number of activities captured at a single off-Range location was 89, whilst the minimum was 66 at another.

6.1.4 Analytical and statistical functions were developed to analyse the recorded signals captured to determine whether a causal link exists between activities occurring on-Range and the signals captured at off-Range locations.

6.1.5 The study has tested and confirmed a 'probable' causal link between Range Activities and measured effects at off-Range monitoring locations, for up to 79% of the triggered activities. If those activities also falling into the 'possible' causal link category are included, then up to 91% (PEN_OS3) of the Range Activities would confirm a causal link at off-Range monitoring locations.

6.1.6 The results of the study indicate, 96 % (N = 822) of the Range Activity data points captured at off-Range monitoring locations remained below the adopted study threshold for secondary vibration effects including ratting of objects of 120 dB $L_{Zpeak.}$

6.1.7 Of the remaining 4% (N = 33), the highest measured sound pressure level at an off-Range location which was attributable to a Range Activity was 134 dB L_{Zpeak}. This falls below the adopted study threshold to prevent glass and plaster damage of 140 dB L_{Zpeak}.

6.1.8 There is no evidence of appreciable ground-borne vibration (propagation of vibration through the ground) being received at any of the off-Range monitoring locations.

6.1.9 Vibration measured as a result of the coupling between the air overpressure and the ground did not exceeded the ground-borne vibration thresholds adopted for this study for the on-set of cosmetic damage at any off-Range locations.

6.1.10 Whilst not considered to be directly relevant in cases where vibration propagated through the ground is minimal or absent, nor when building damage risk is the sole consideration, the maximum level at any location also does not exceed the threshold of 134 dB L_{Zpeak} recommended by the USBM for blasting regime design purposes as a 'safe' maximum.

6.1.11 None of the measurements that relate to confirmed Range Activity at off-Range locations exceeded the lower action value of 135 dB L_{Cpeak}, set out in The Control of Noise at Work Regulations 2005.

6.1.12 The magnitudes of sound / air overpressure and vibration resulting from the on-Range Activities catalogued during the monitoring period are unlikely to have resulted in damage to building structures at locations surrounding the Range when compared to the thresholds derived and adopted for this study.

6.1.13 The Range Activities observed during the study period have been described by QinetiQ as being representative of typical activities undertaken on the Pendine Range, relating to scheduling, type, size and frequency of firing.

6.1.14 As such, based upon consideration of the data gathered and assessment thresholds derived, the continuation of Range Activities under the same conditions of operation and management by QinetiQ, would lead to the conclusion that any building damage as a result of activities at the Pendine Range is improbable.

7. REFERENCES

1. A.K. Waters. 2012 Pendine Noise & Vibration Monitoring Study (NVMS), System Requirements Document. QINETIQ/12/02298/1.0/ 2012.

2. Southdowns Environmental Consultants Ltd. 2016. *Criteria for the Assessment of Potential Building Damage Effects from Range Activities.* 1897m-SEC-00151-03.

3. Controlling Noise at Work (2005). The Control of Noise at Work Regulations 2005. Guidance on Regulations

4. Southdowns Environmental Consultants Ltd. 2016. *Volume 2 – Technical Appendices: Detailed Methodology*. 1897m-SEC-00168-04.

5. Southdowns Environmental Consultants Ltd. 2016. Volume 3: Technical Appendices – Results. 1897m-SEC-00168-04.

APPENDIX A: FIGURES

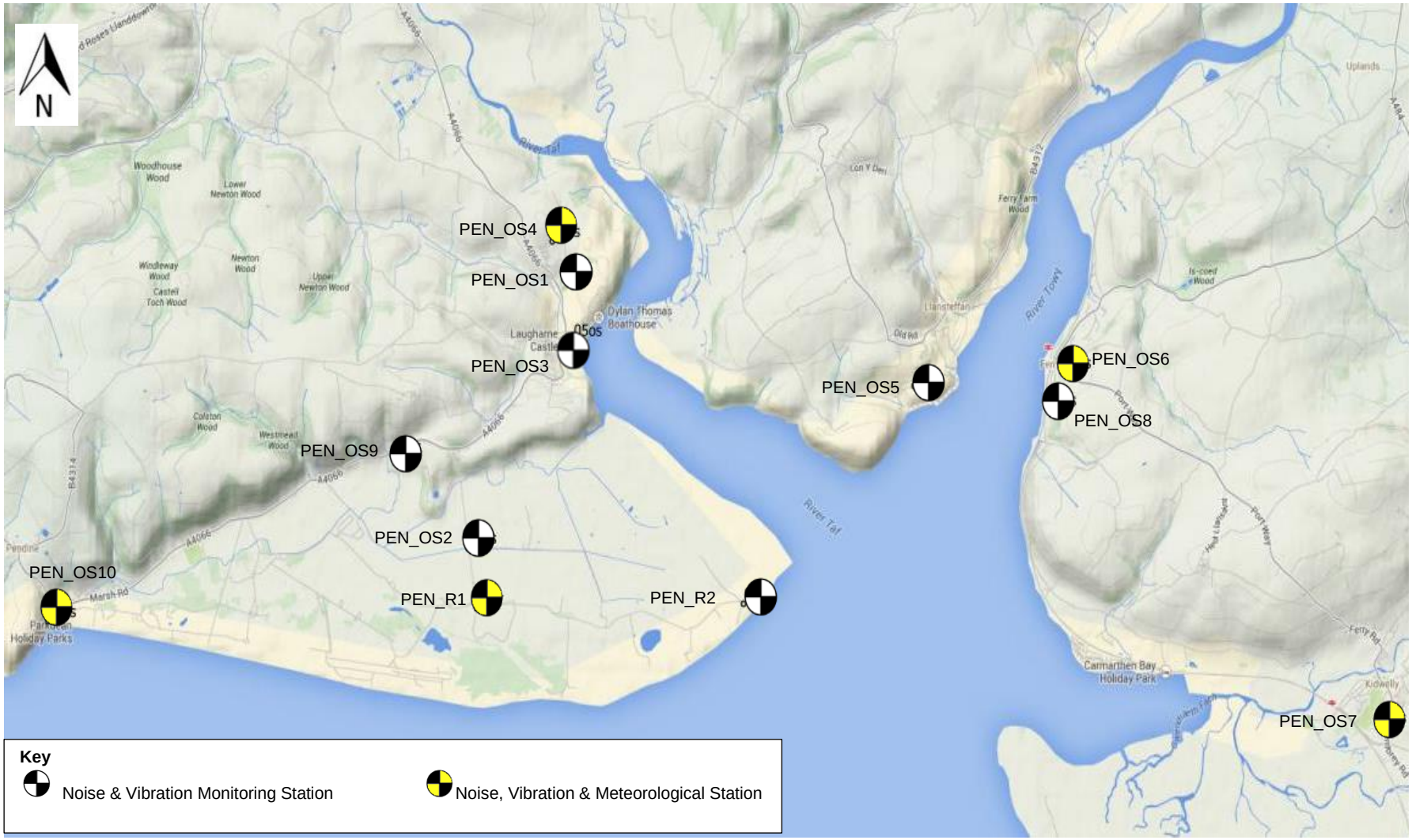

FIGURE A1: MONITORING LOCATIONS

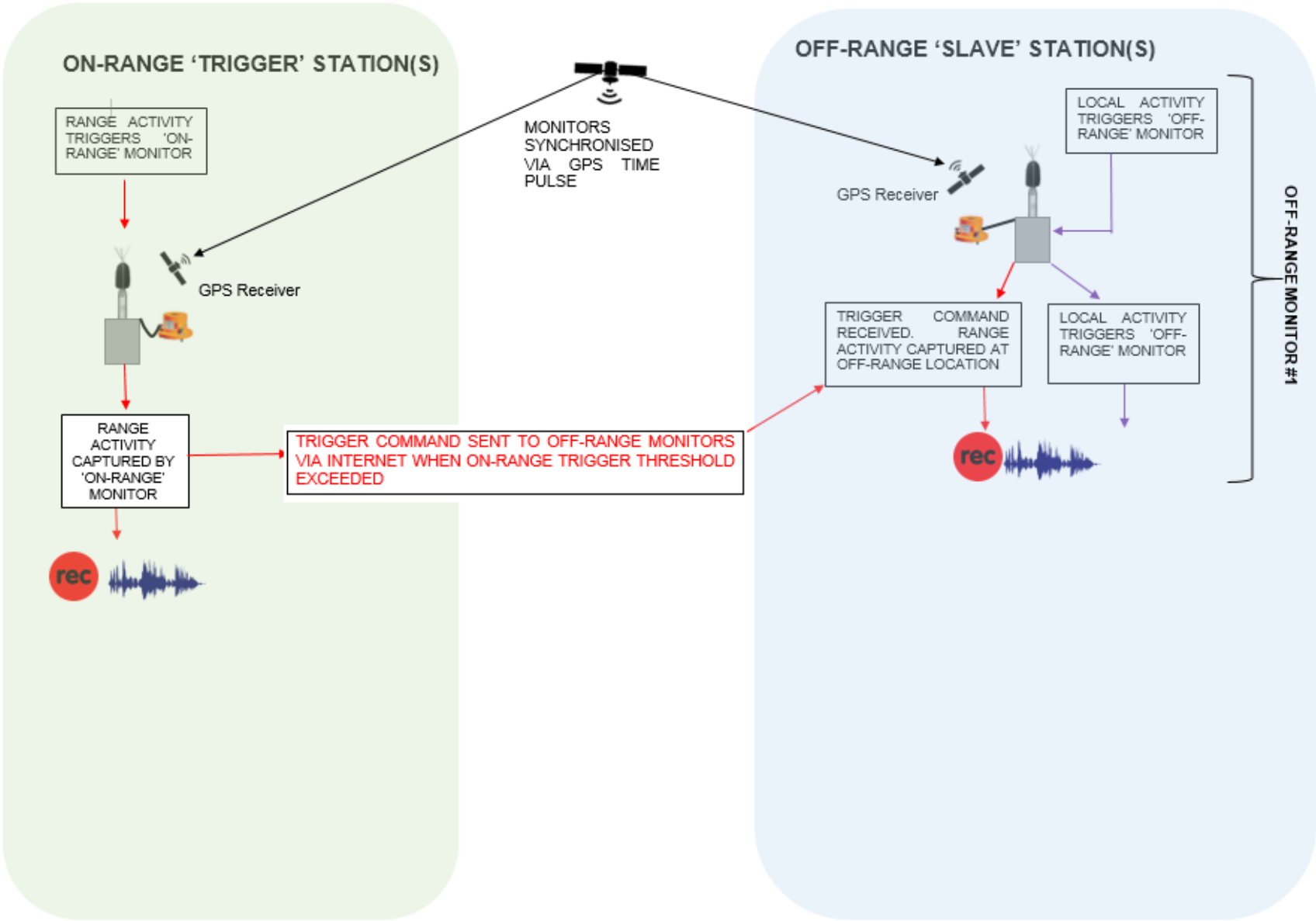

FIGURE A2: SYNCHRONOUS TRIGGER SYSTEM PROCESS

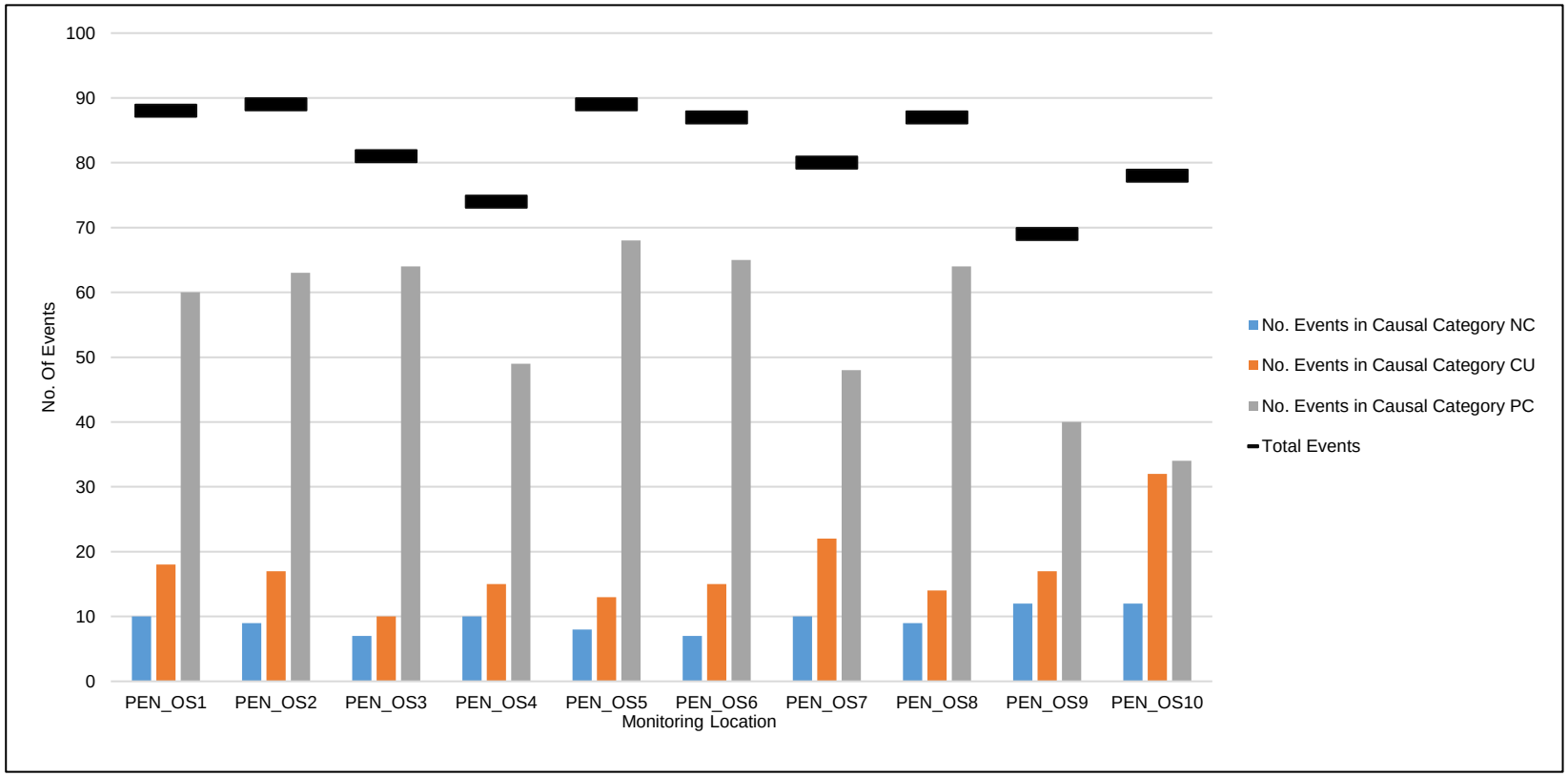

FIGURE A3: **DISTRIBUTION OF ACTIVITIES INTO CAUSAL CATEGORIES**

Notes:
[1] total number of Range Activities captured at each off-Range monitoring location represented by black markers;
[2] 'No Causality' or NC represented by blue bars
[3] 'Uncertain Causality' or UC represented by orange bars;
[4] 'Positive Causality' or PC represented by grey bars.

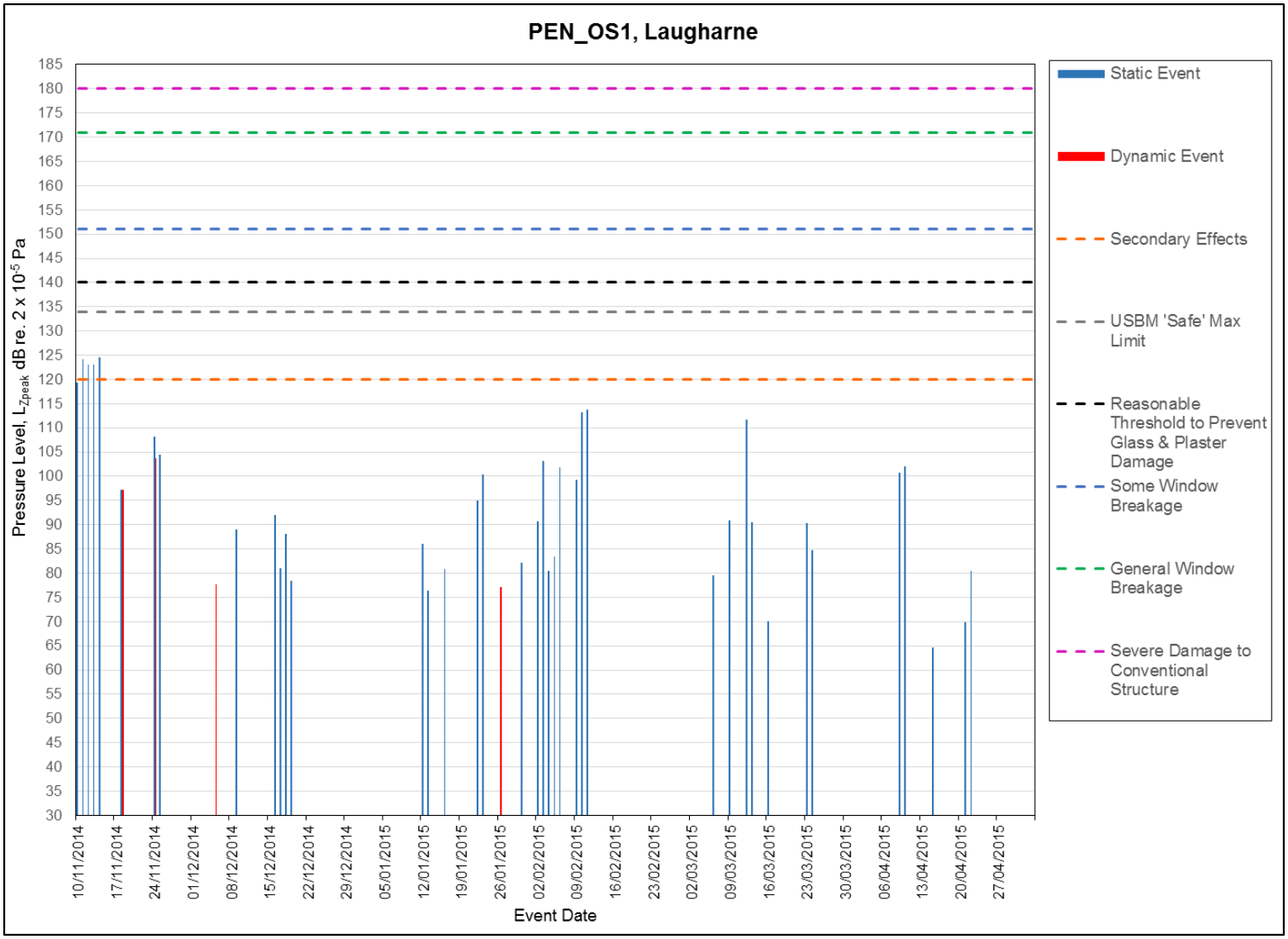

FIGURE A4: SUMMARY OF LZPEAK VALUES, PEN_OS1, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

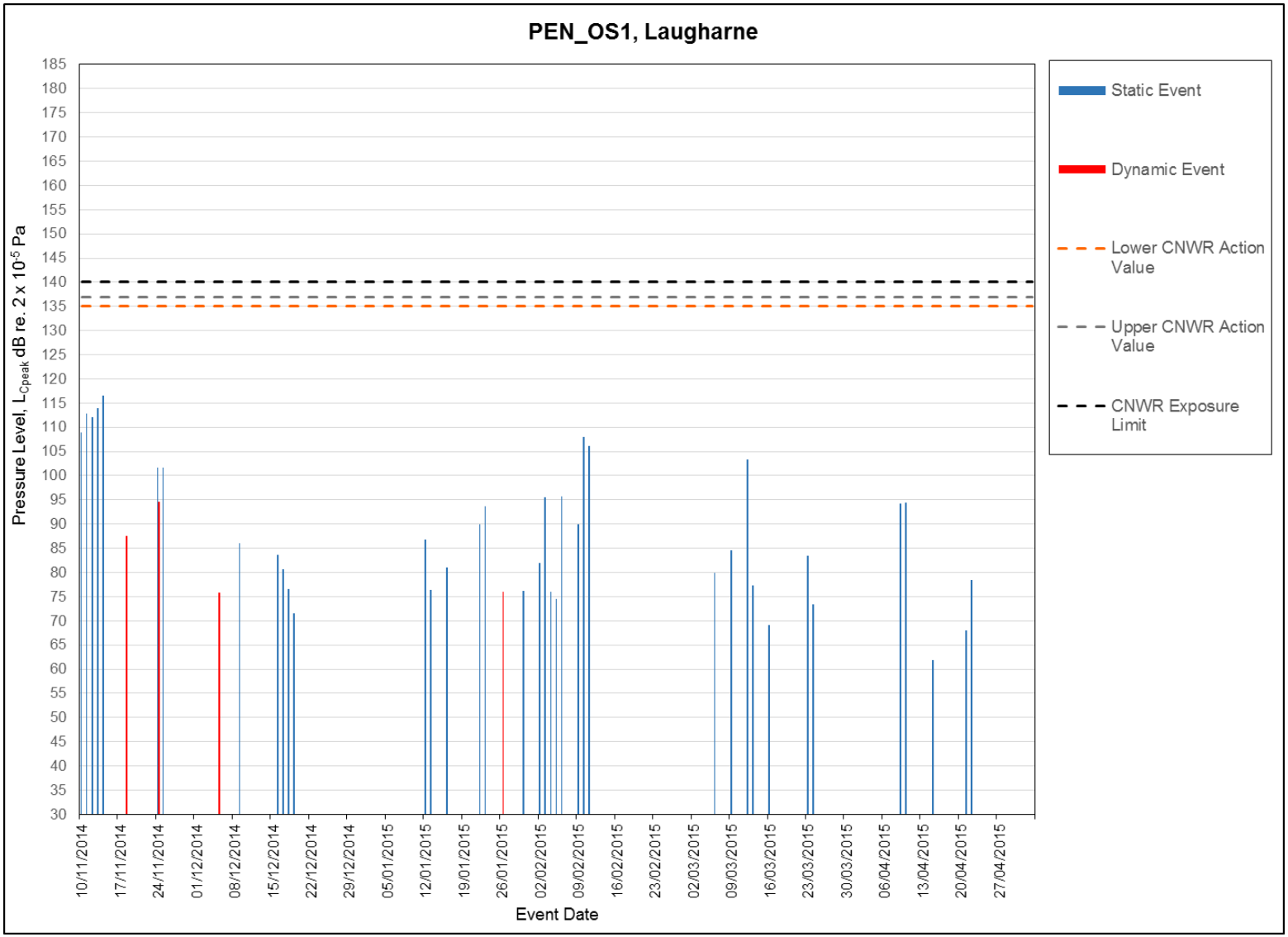

FIGURE A5 : SUMMARY OF LCPEAK VALUES, PEN_OS1, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

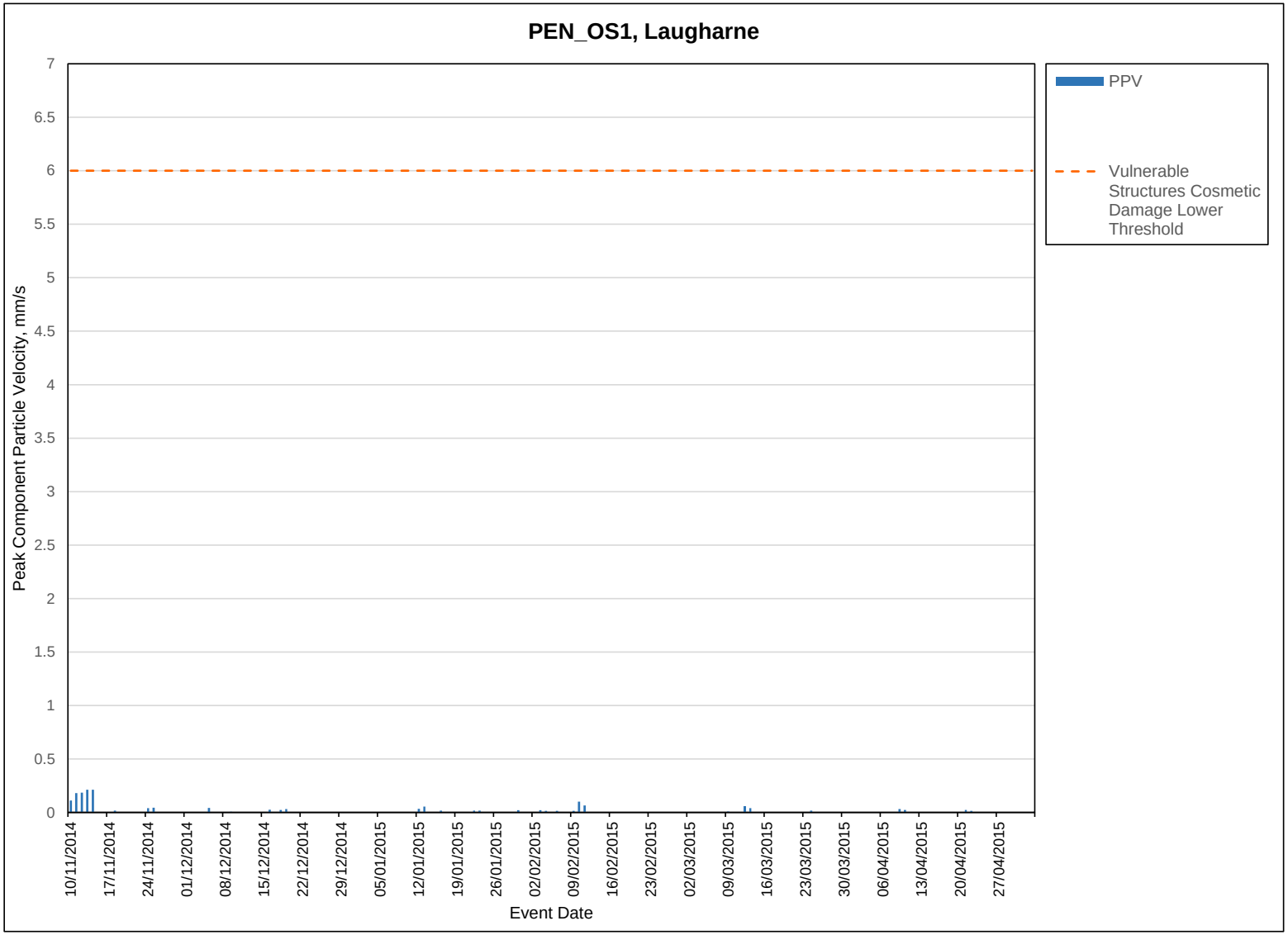

FIGURE A6: SUMMARY PPV VALUES, PEN_OS1, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

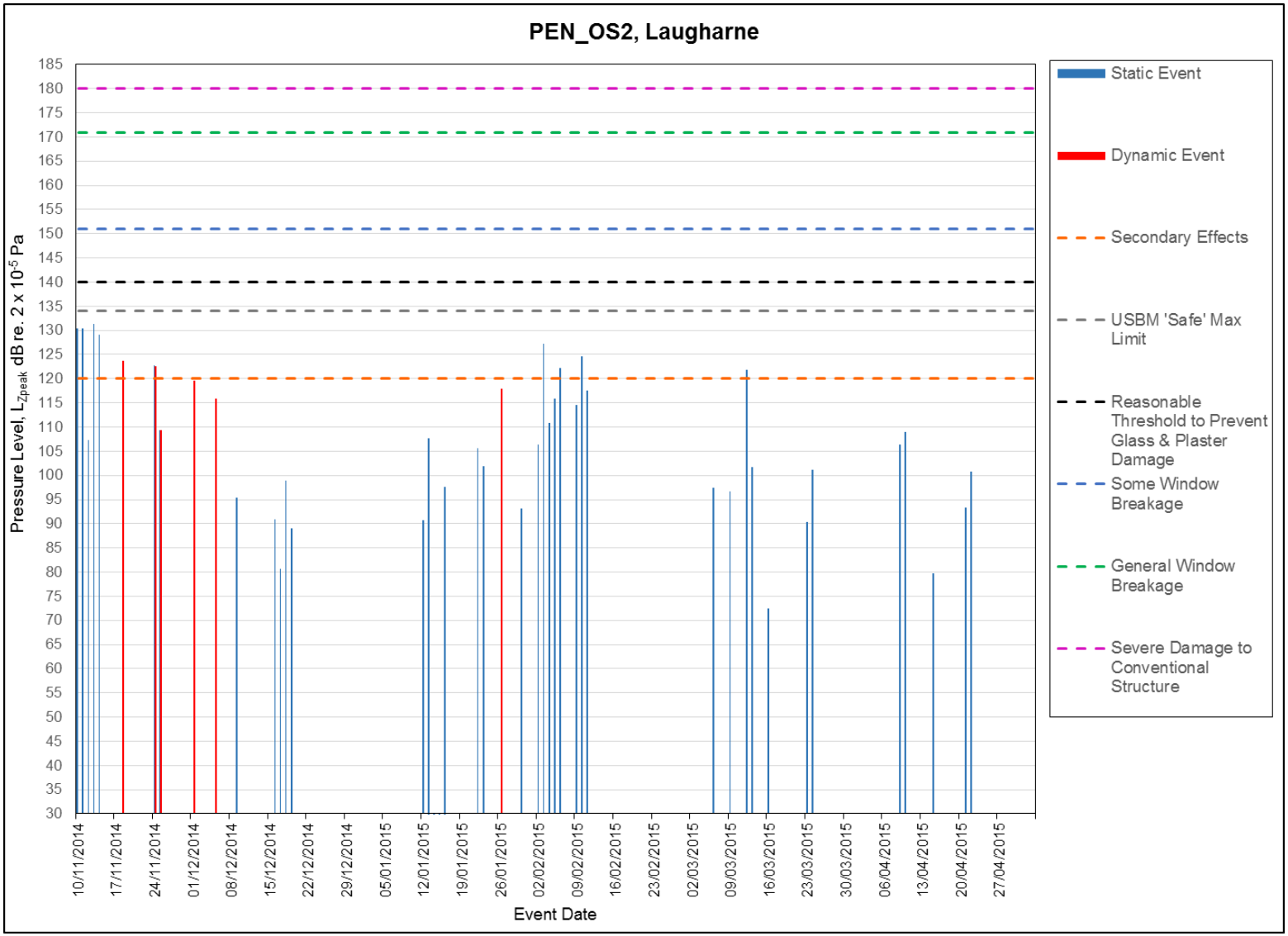

FIGURE A7 : SUMMARY OF LZPEAK VALUES, PEN_OS2, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

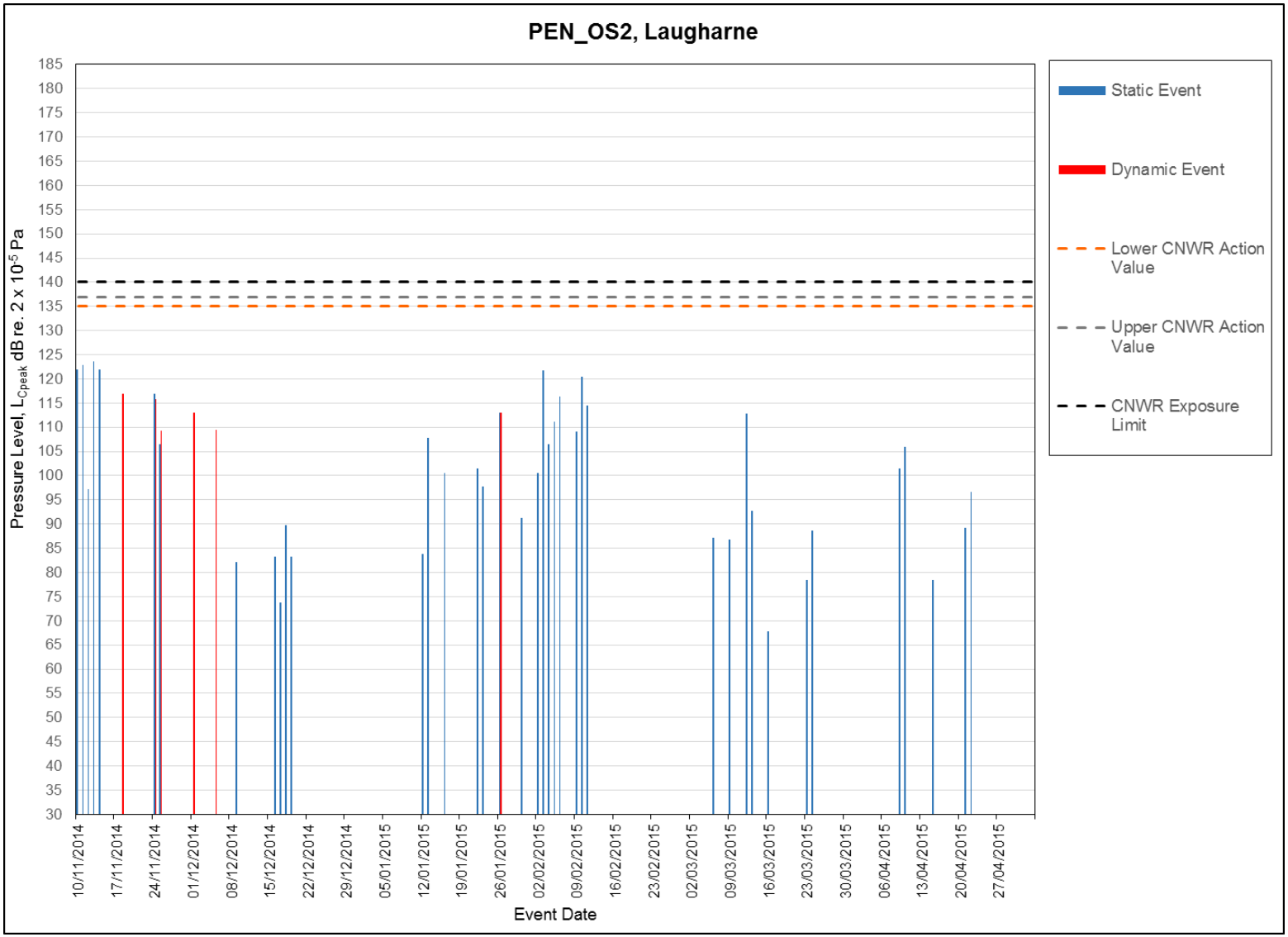

FIGURE A8 : SUMMARY OF LCPEAK VALUES, PEN_OS2, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

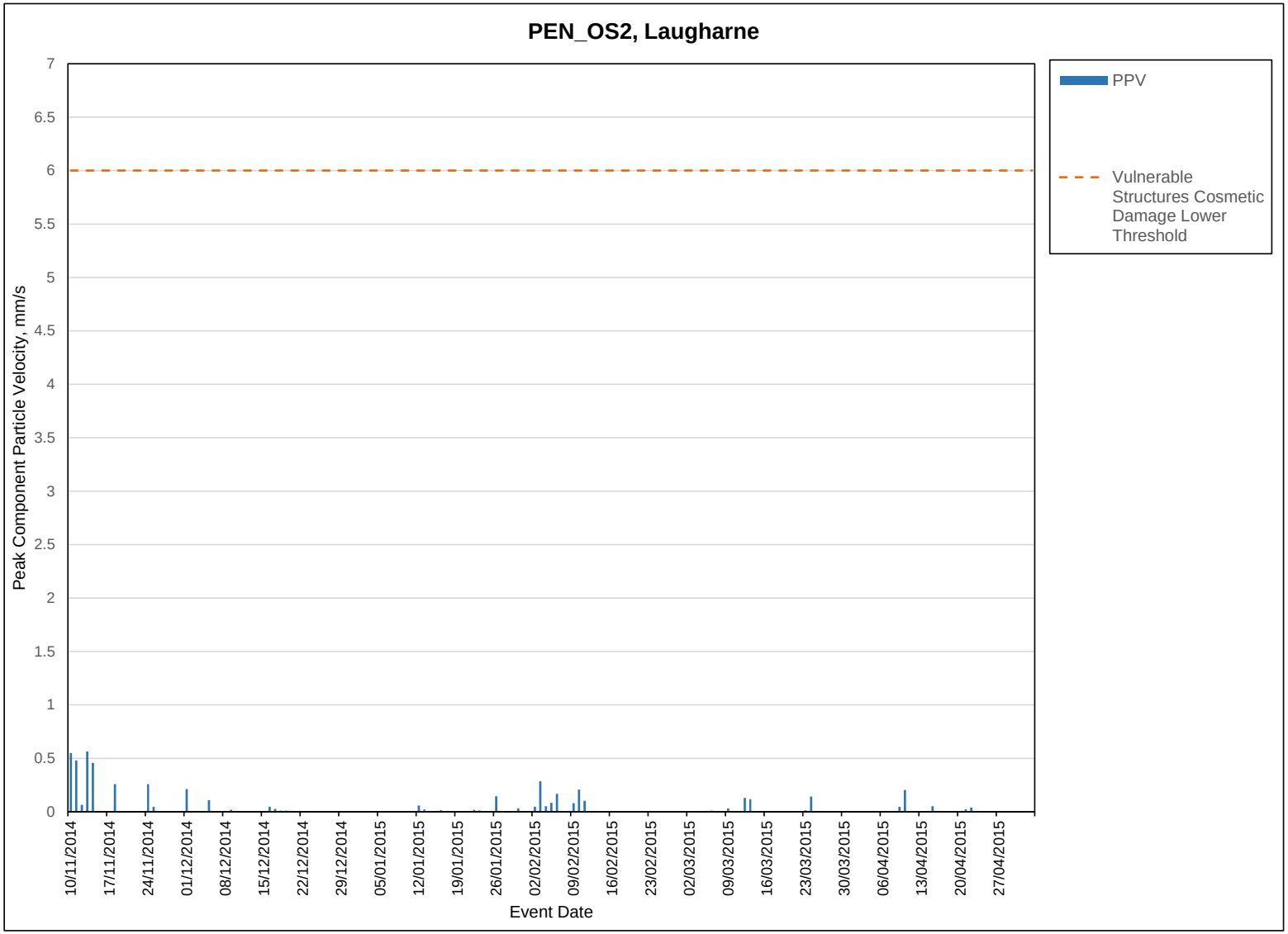

FIGURE A9 : SUMMARY PPV VALUES, PEN_OS2, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

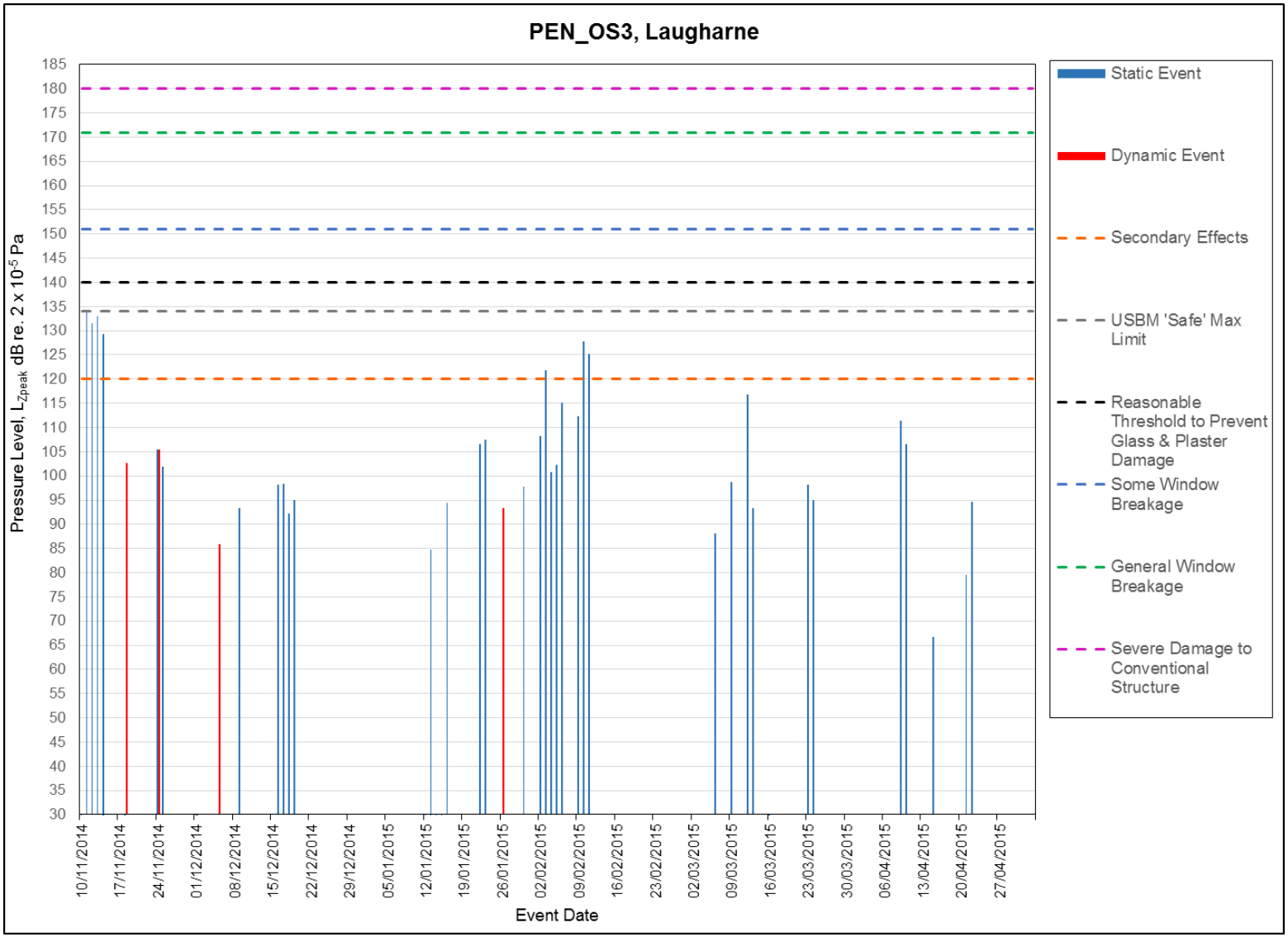

FIGURE A10 : SUMMARY OF LZPEAK VALUES, PEN_OS3, LAUGHARNE, 3RD NOVEMBER 2014 TO 3RD MAY 2015

Note: Highest daily levels presented

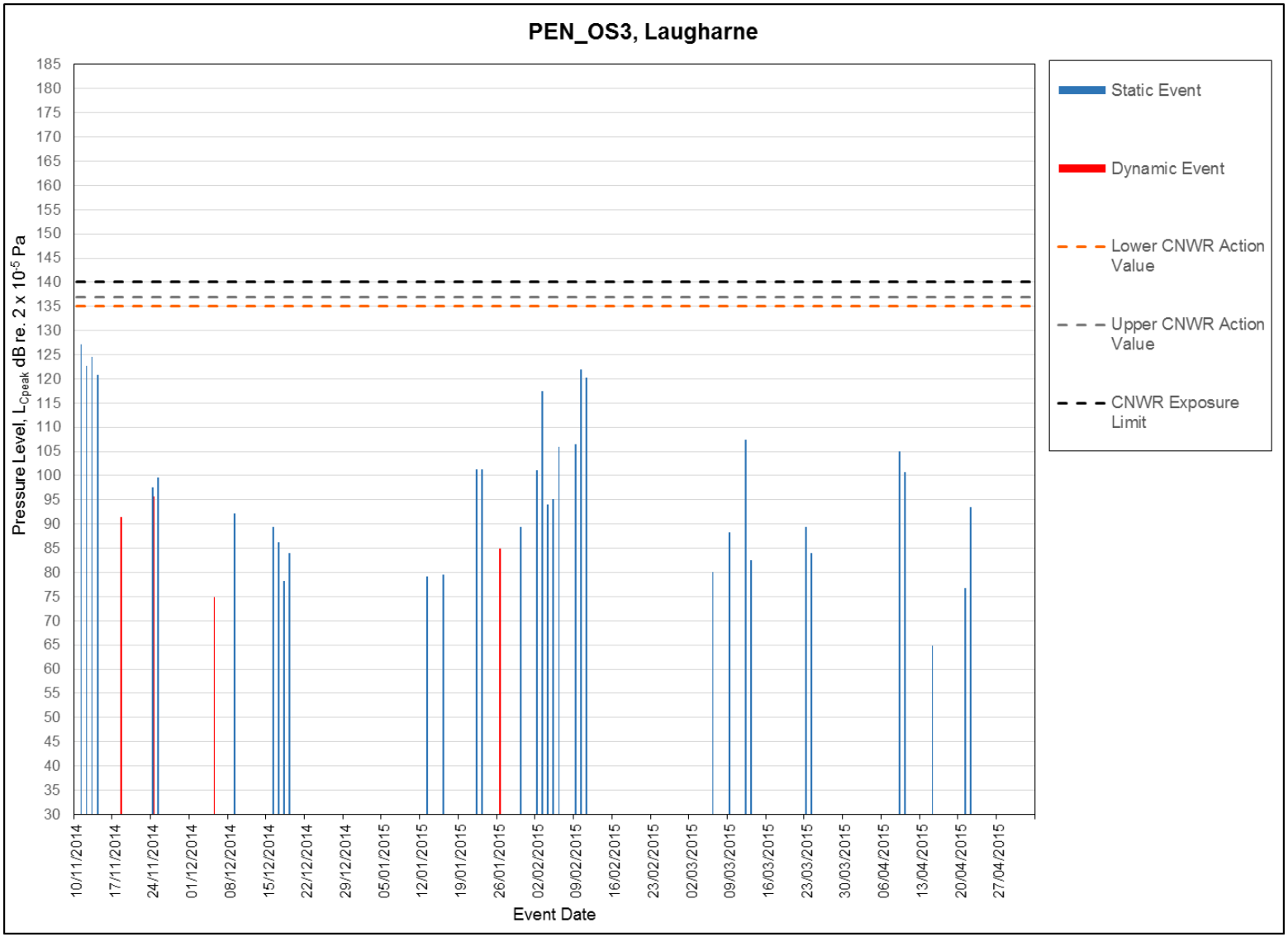

FIGURE A11 : SUMMARY OF LCPEAK VALUES, PEN_OS3, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

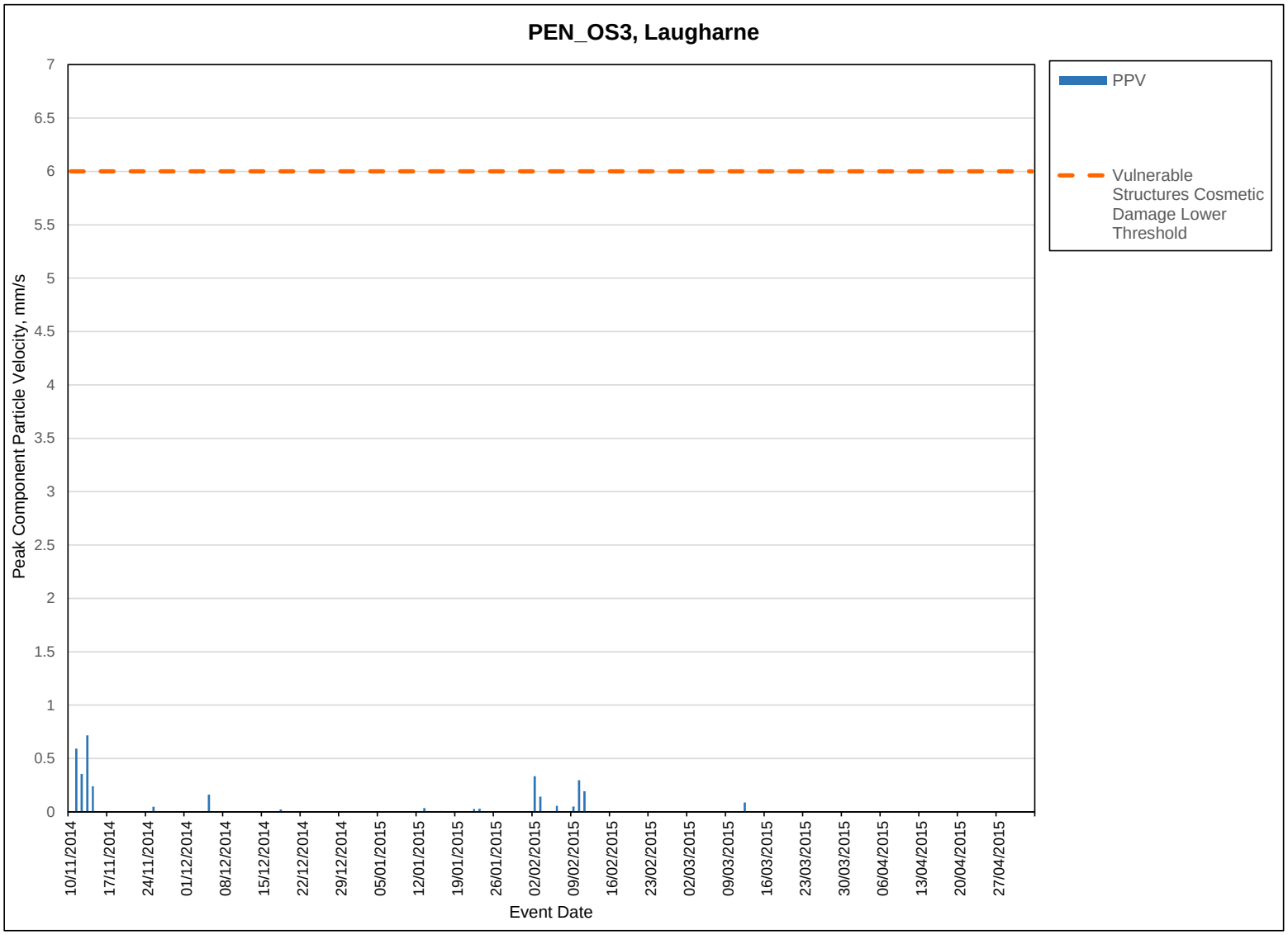

FIGURE A12 SUMMARY PPV VALUES, PEN_OS3, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

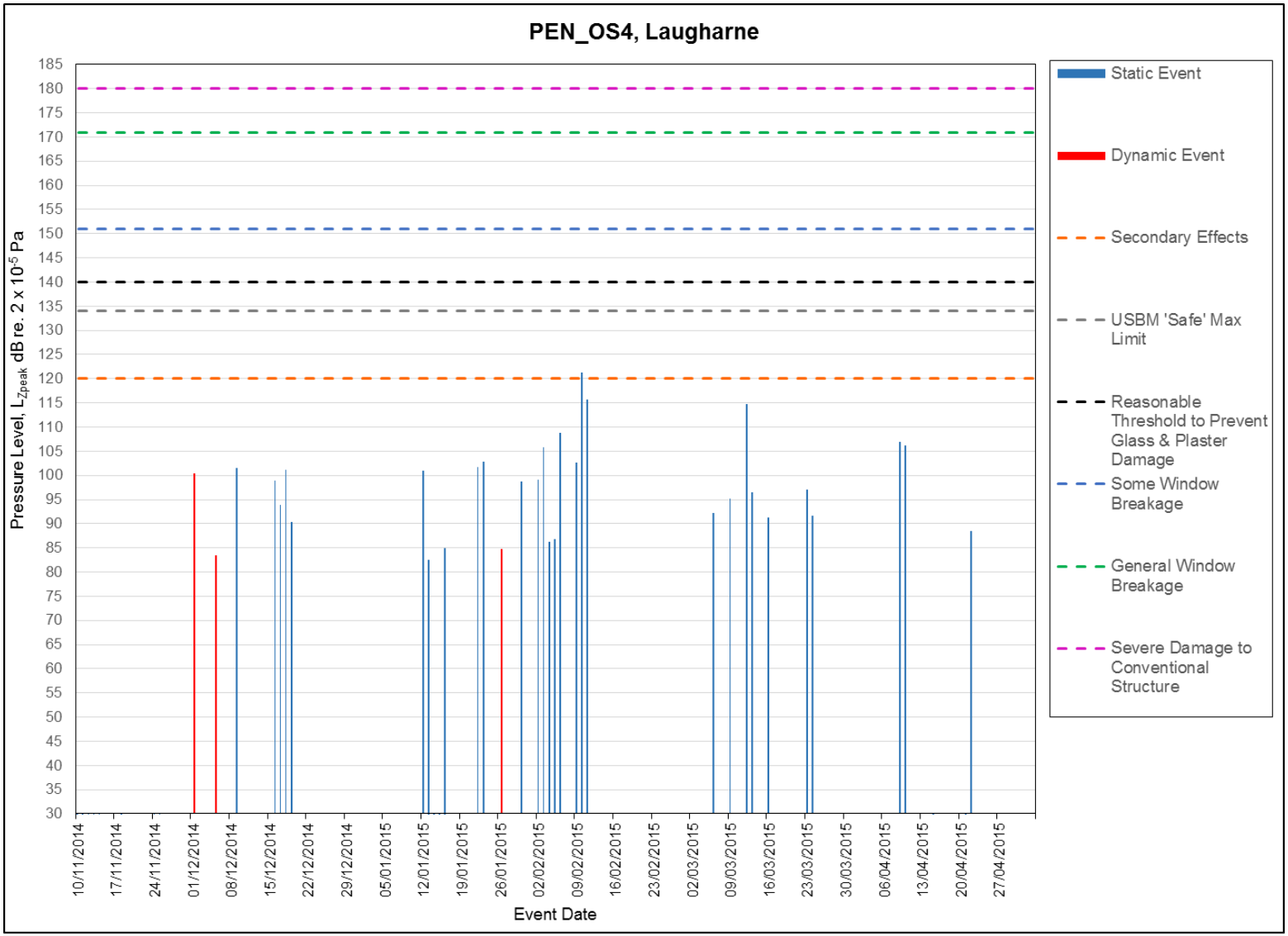

FIGURE A13 : SUMMARY OF LZPEAK VALUES, PEN_OS4, LAUGHARNE, 3RD NOVEMBER 2014 TO 3RD MAY 2015

Note: Highest daily levels presented

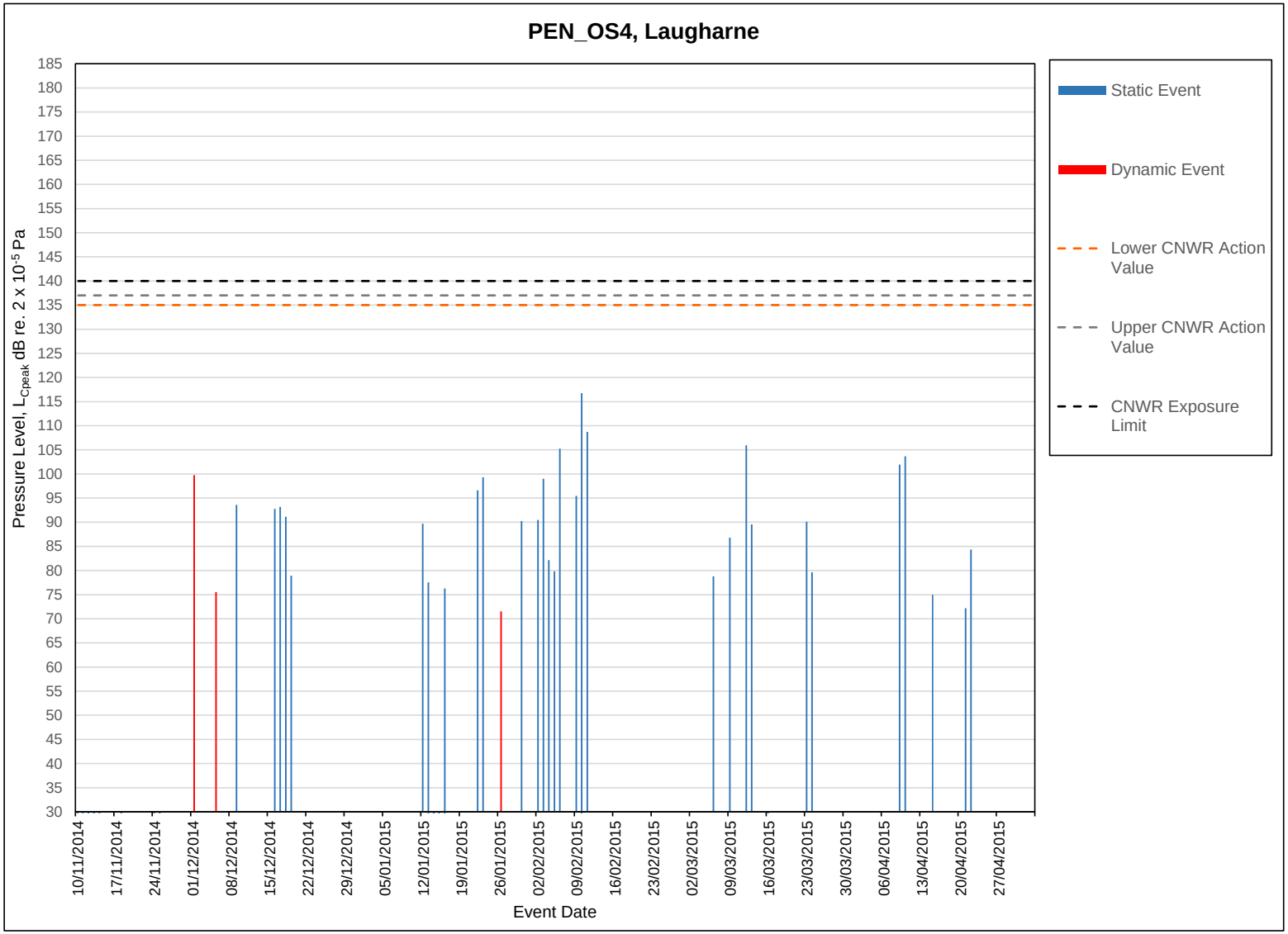

FIGURE A14 : SUMMARY OF LCPEAK VALUES, PEN_OS4, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

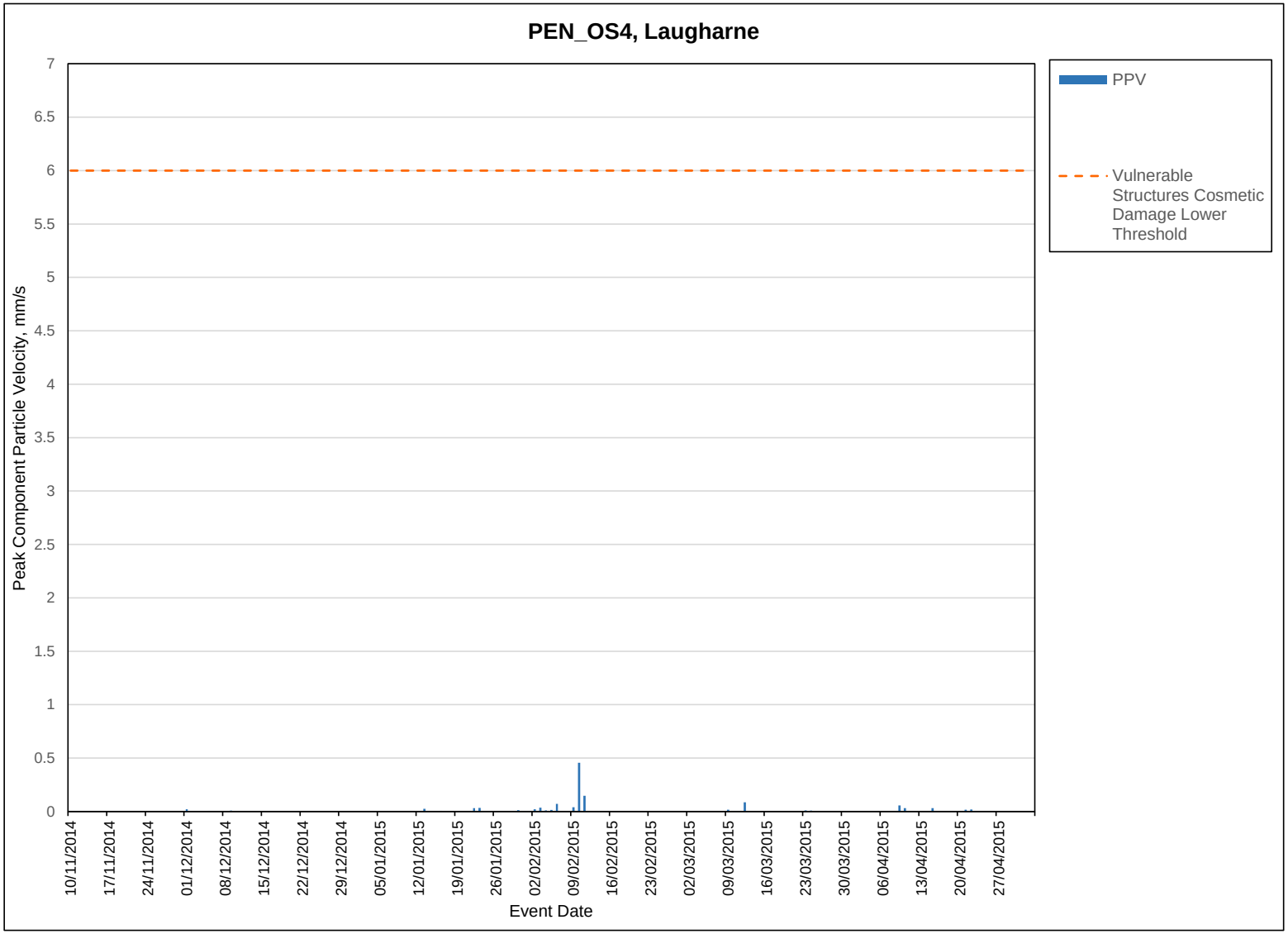

FIGURE A15 : SUMMARY PPV VALUES, PEN_OS4, LAUGHARNE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

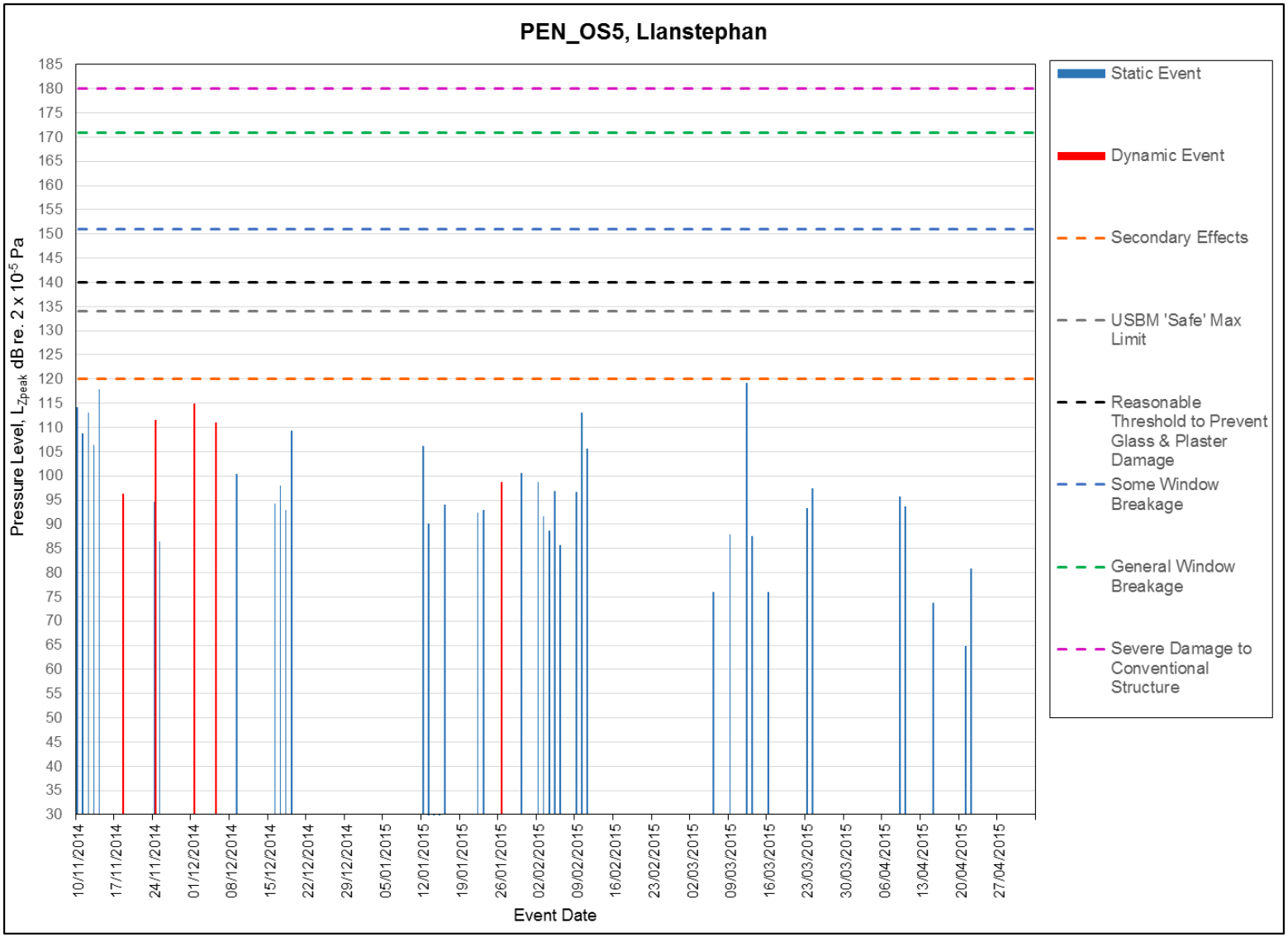

FIGURE A16: SUMMARY OF LZPEAK VALUES, PEN_OS5, LLANSTEPHAN, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

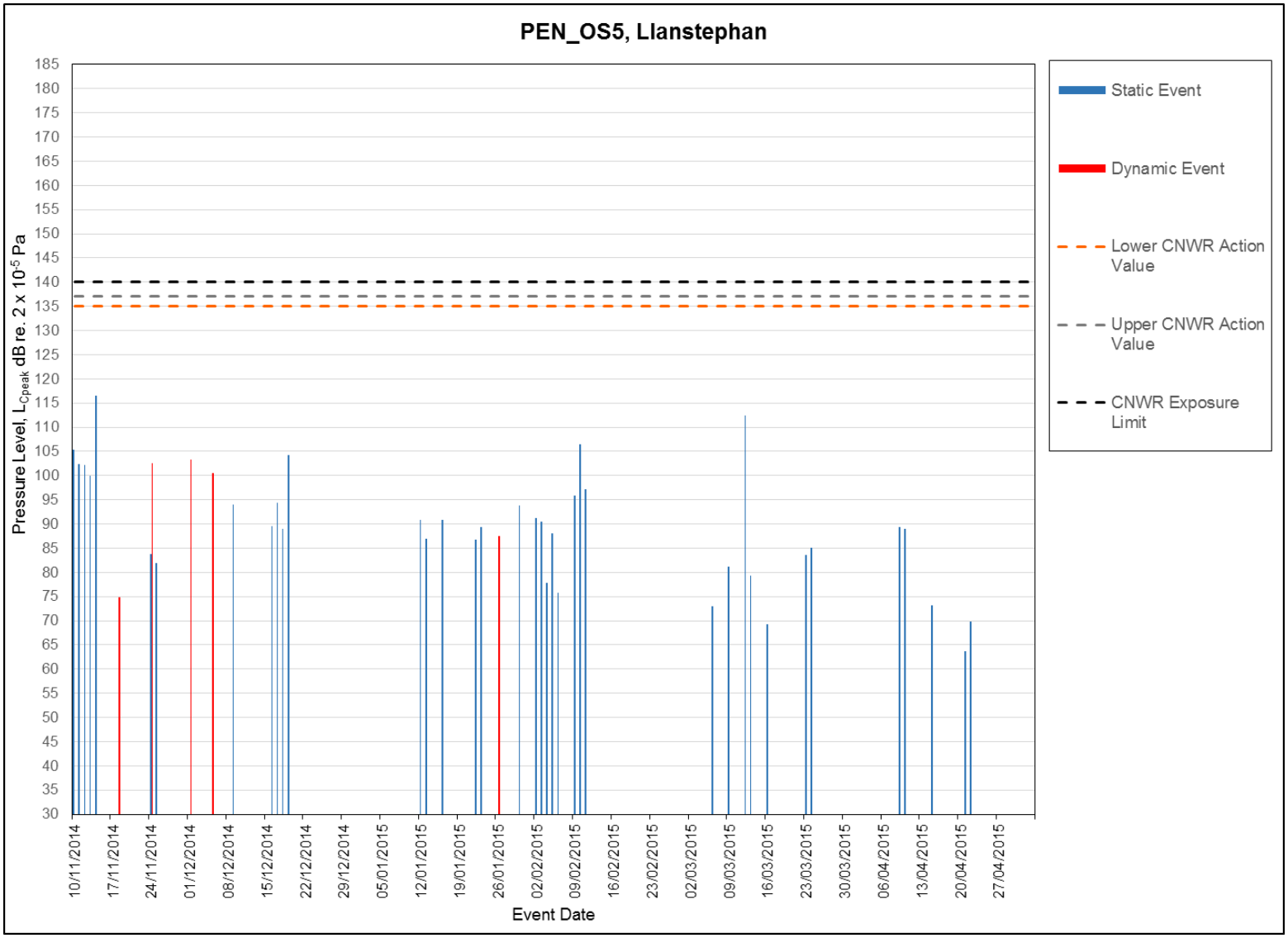

FIGURE A17 : SUMMARY OF LCPEAK VALUES, PEN_OS5, LLANSTEPHAN, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

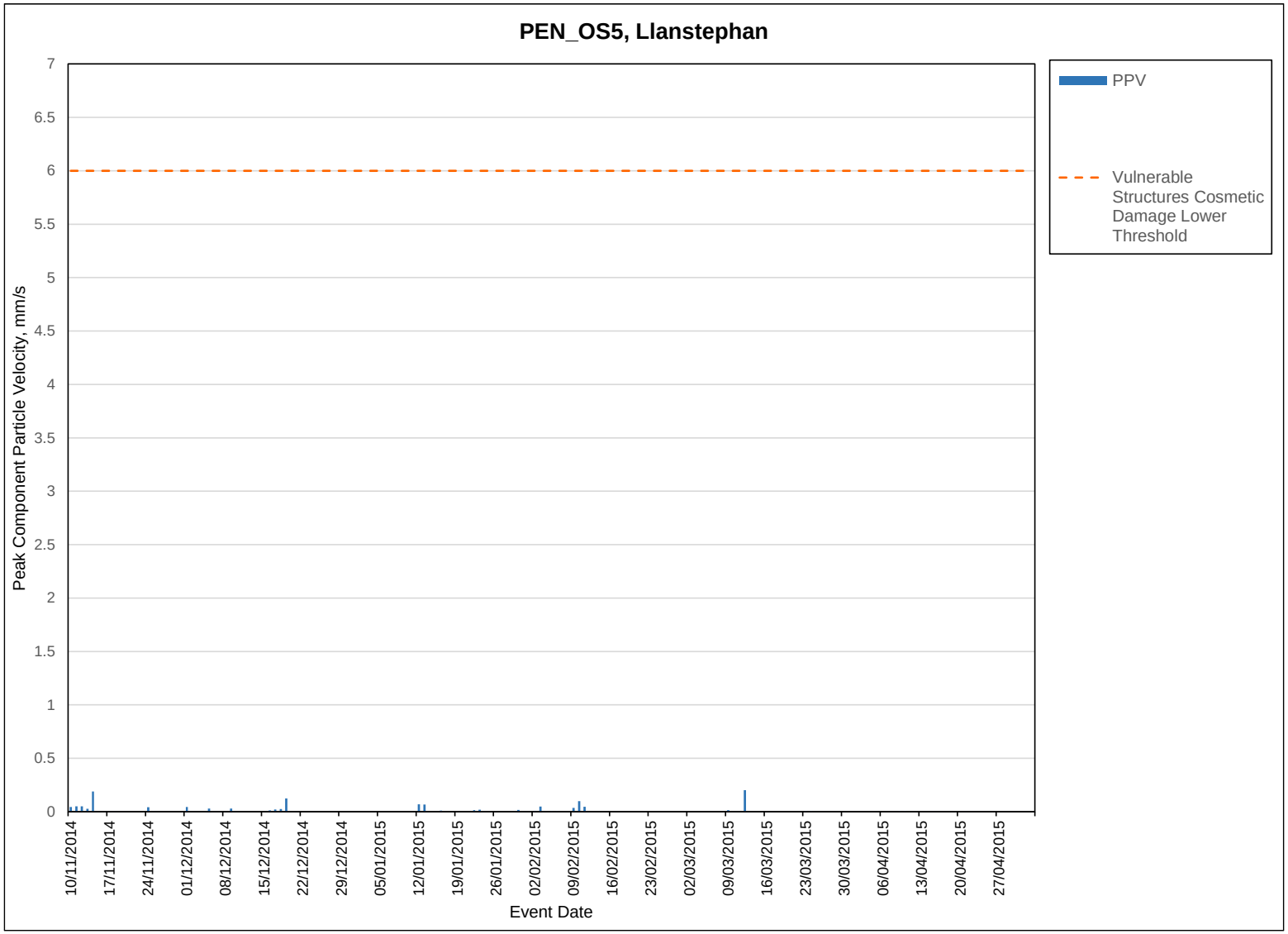

FIGURE A18 : SUMMARY PPV VALUES, PEN_OS5, LLANSTEPHAN, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

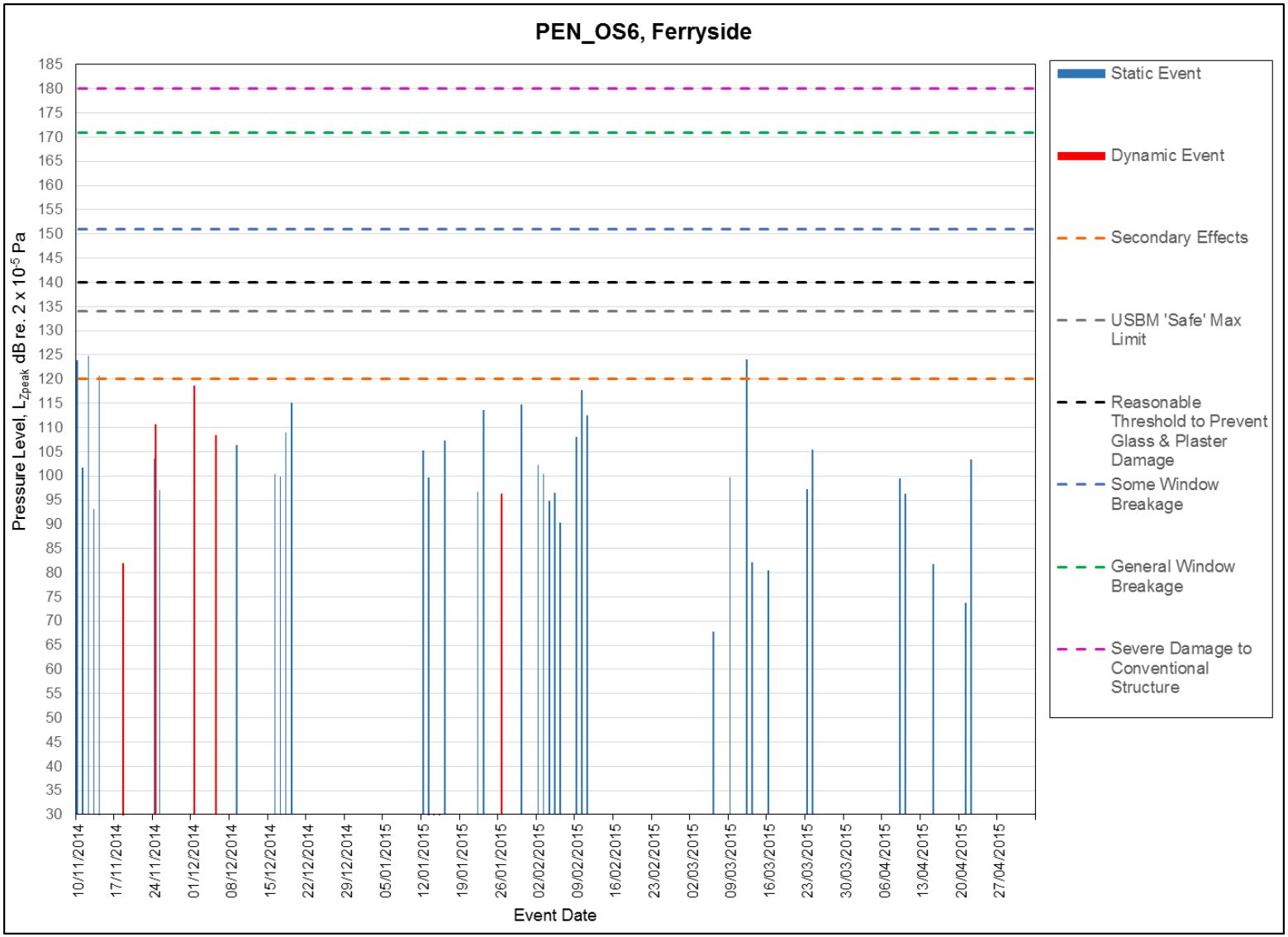

FIGURE A19 : SUMMARY OF LZPEAK VALUES, PEN_OS6, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

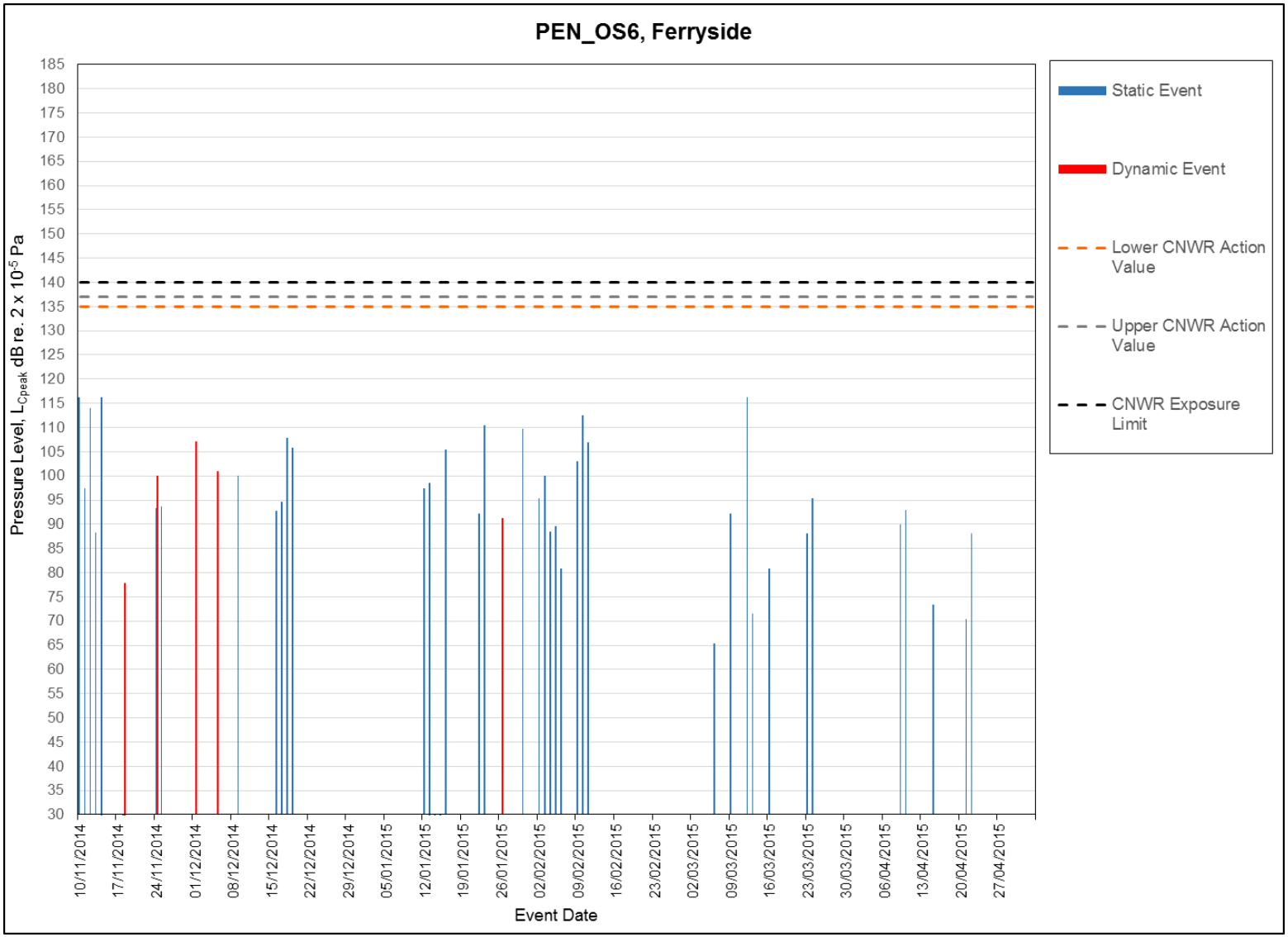

FIGURE A20 SUMMARY OF LCPEAK VALUES, PEN_OS6, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

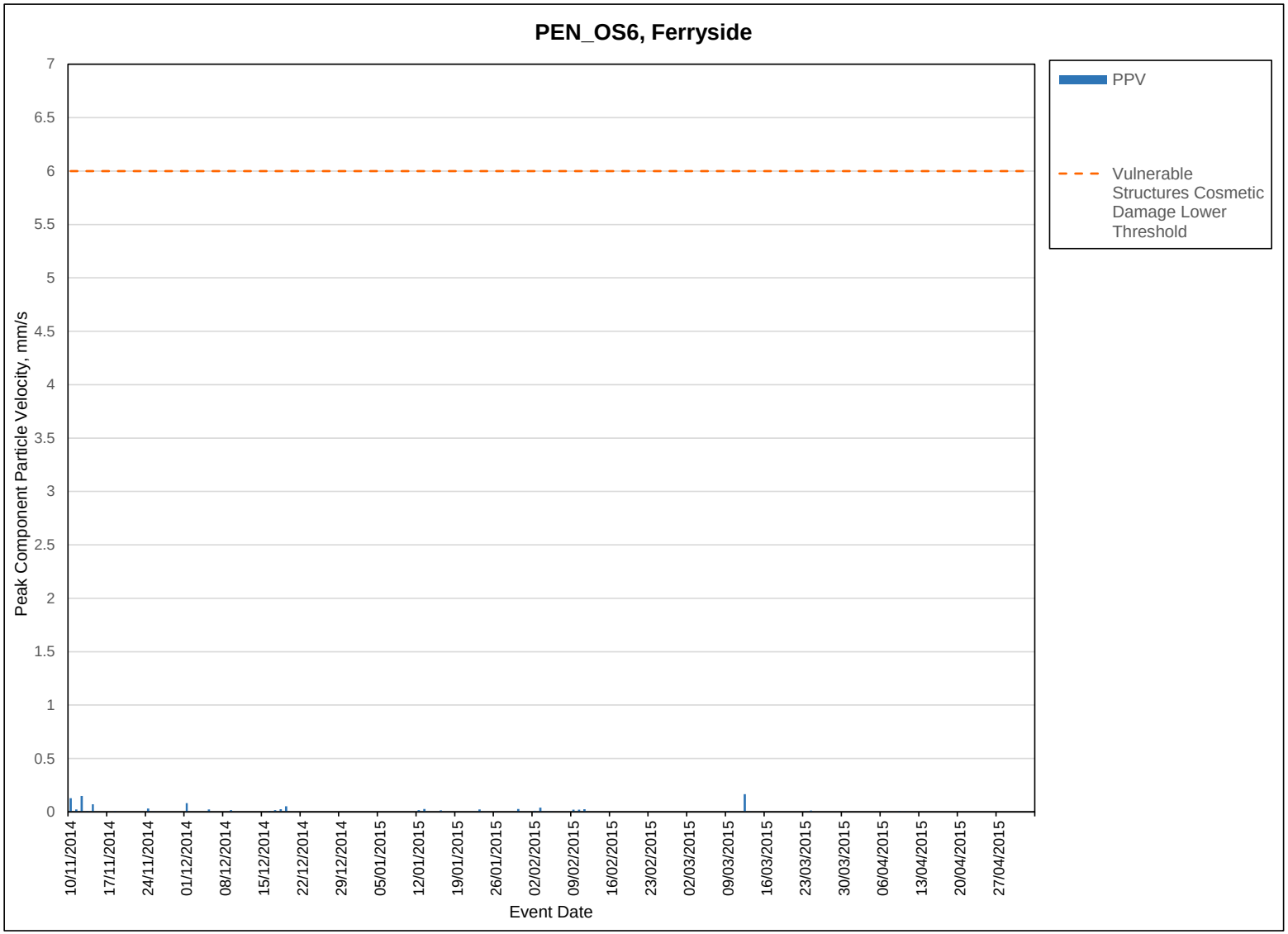

FIGURE A21 : SUMMARY PPV VALUES PEN_OS6, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY

Note: Highest daily levels presented

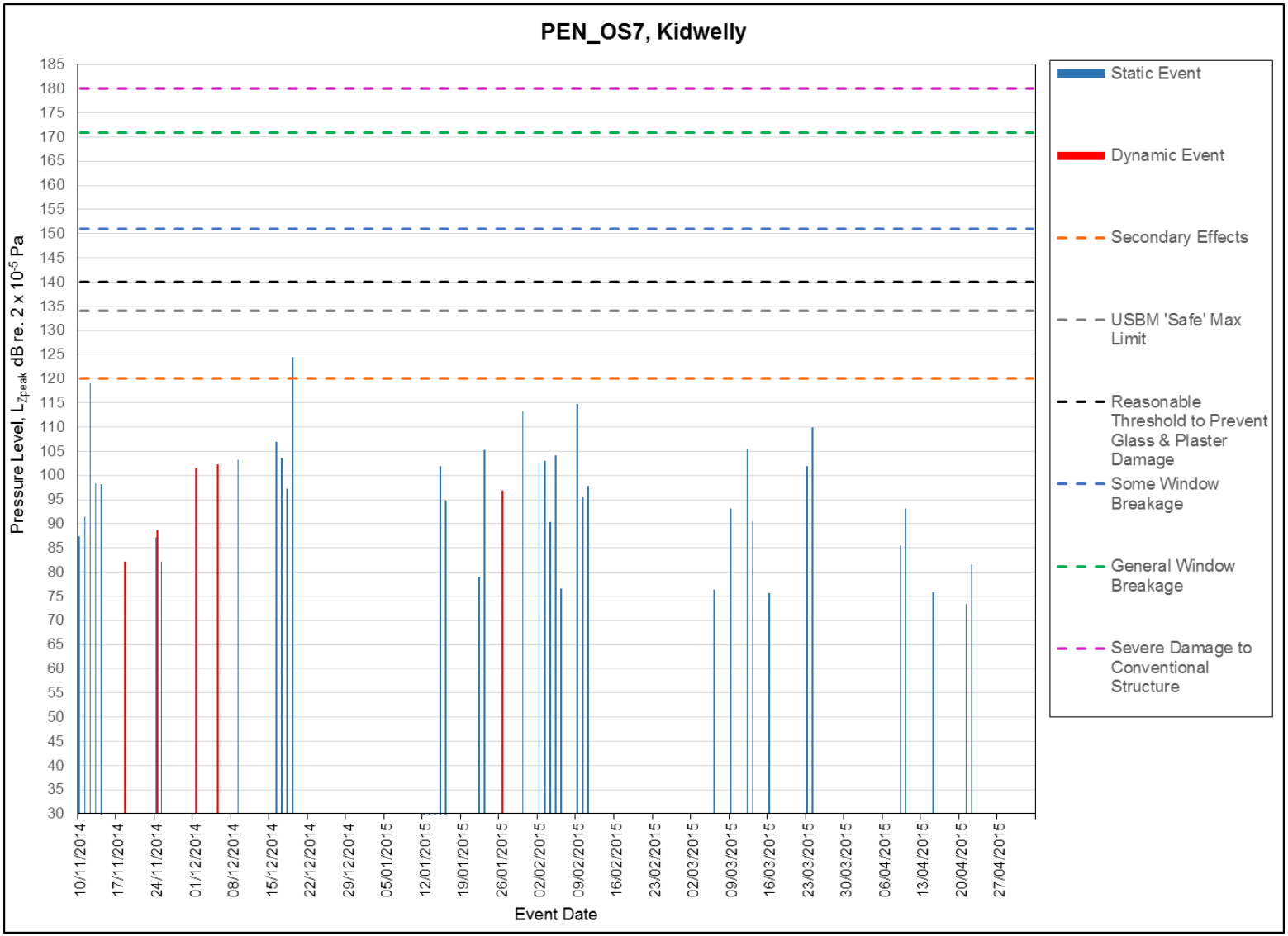

FIGURE A22 SUMMARY OF LZPEAK VALUES, PEN_OS7, KIDWELLY, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

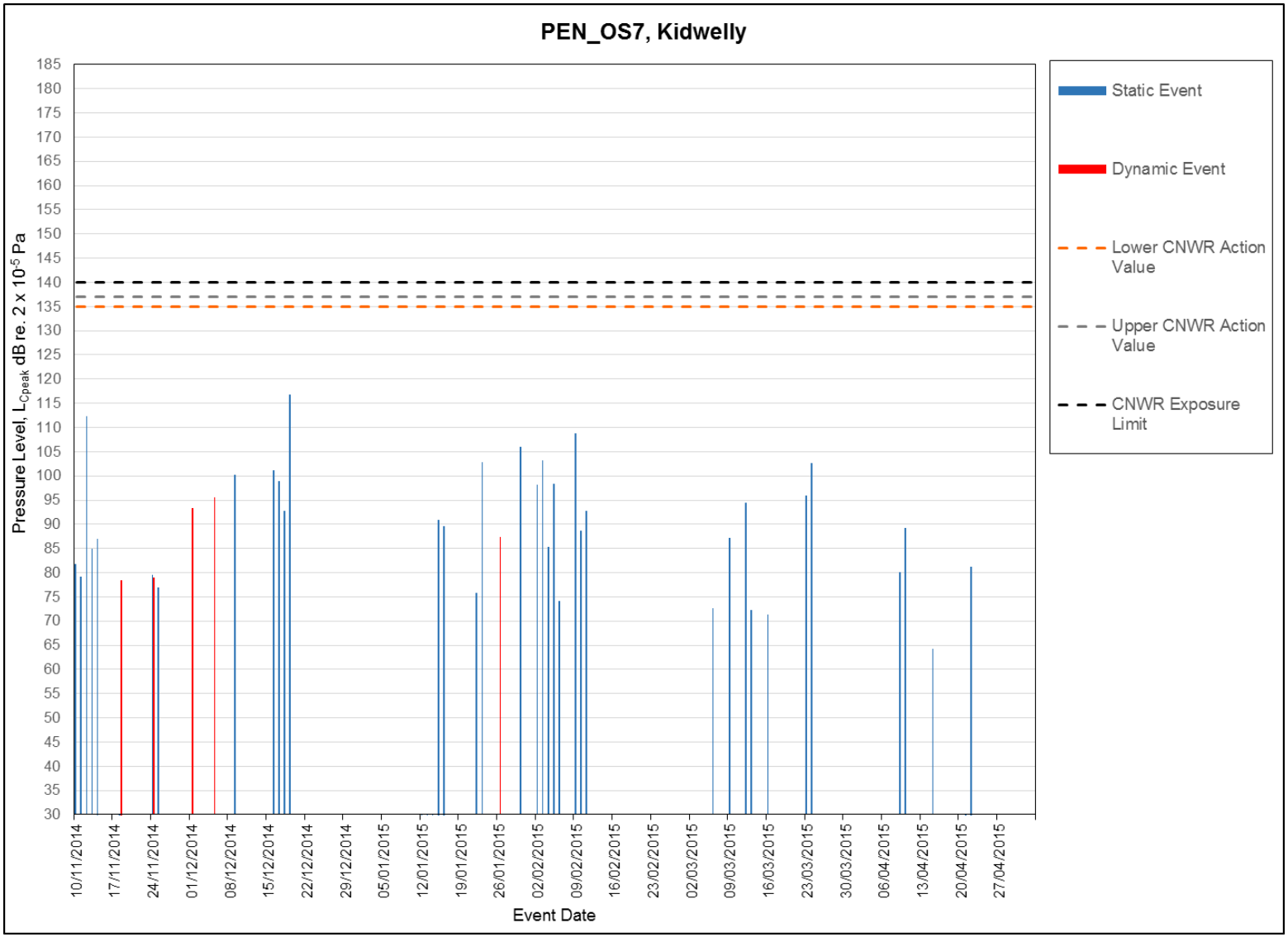

FIGURE A23 : SUMMARY OF LCPEAK VALUES, PEN_OS7, KIDWELLY, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

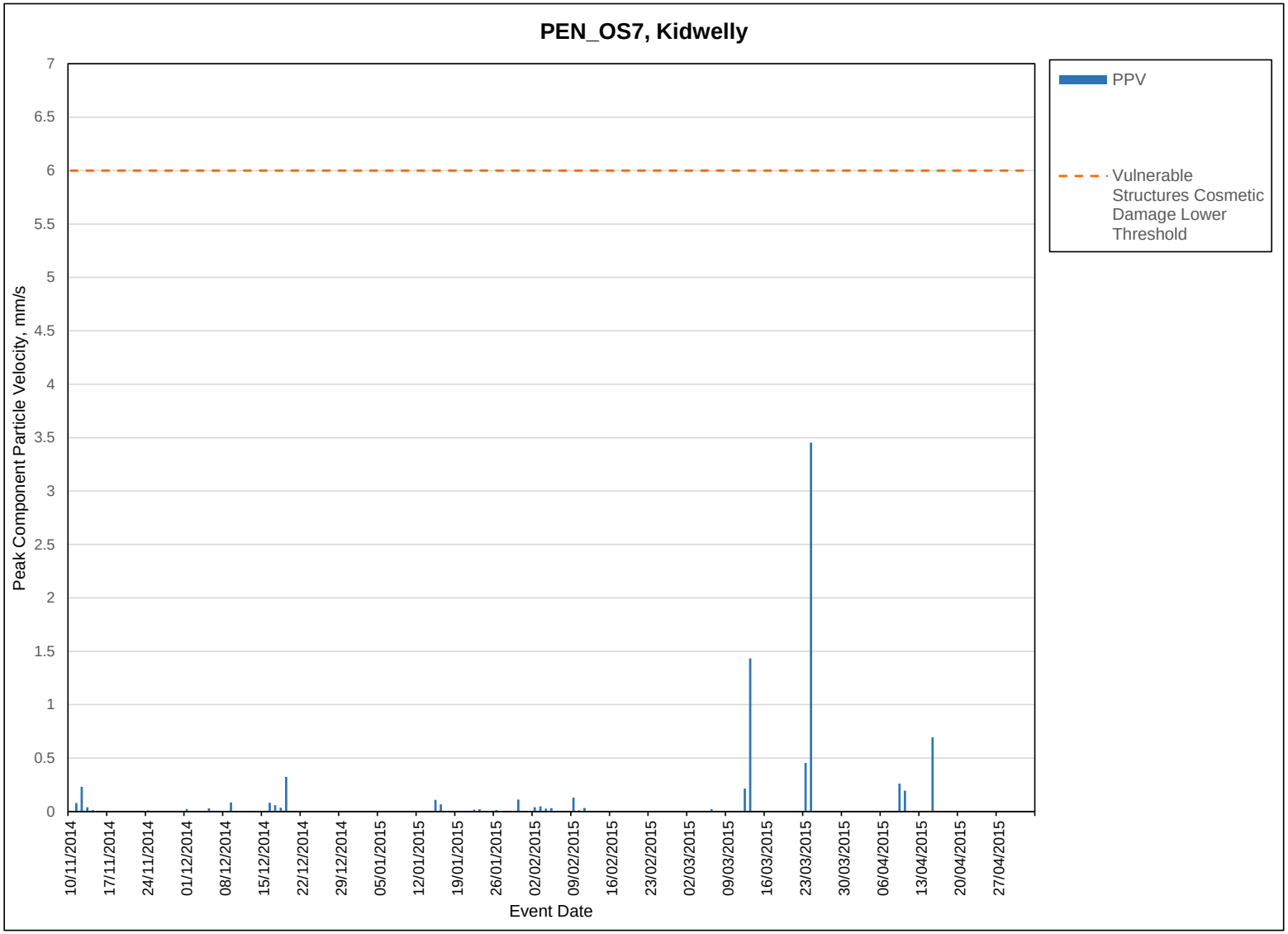

FIGURE A24 SUMMARY PPV VALUES PEN_OS7, KIDWELLY, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

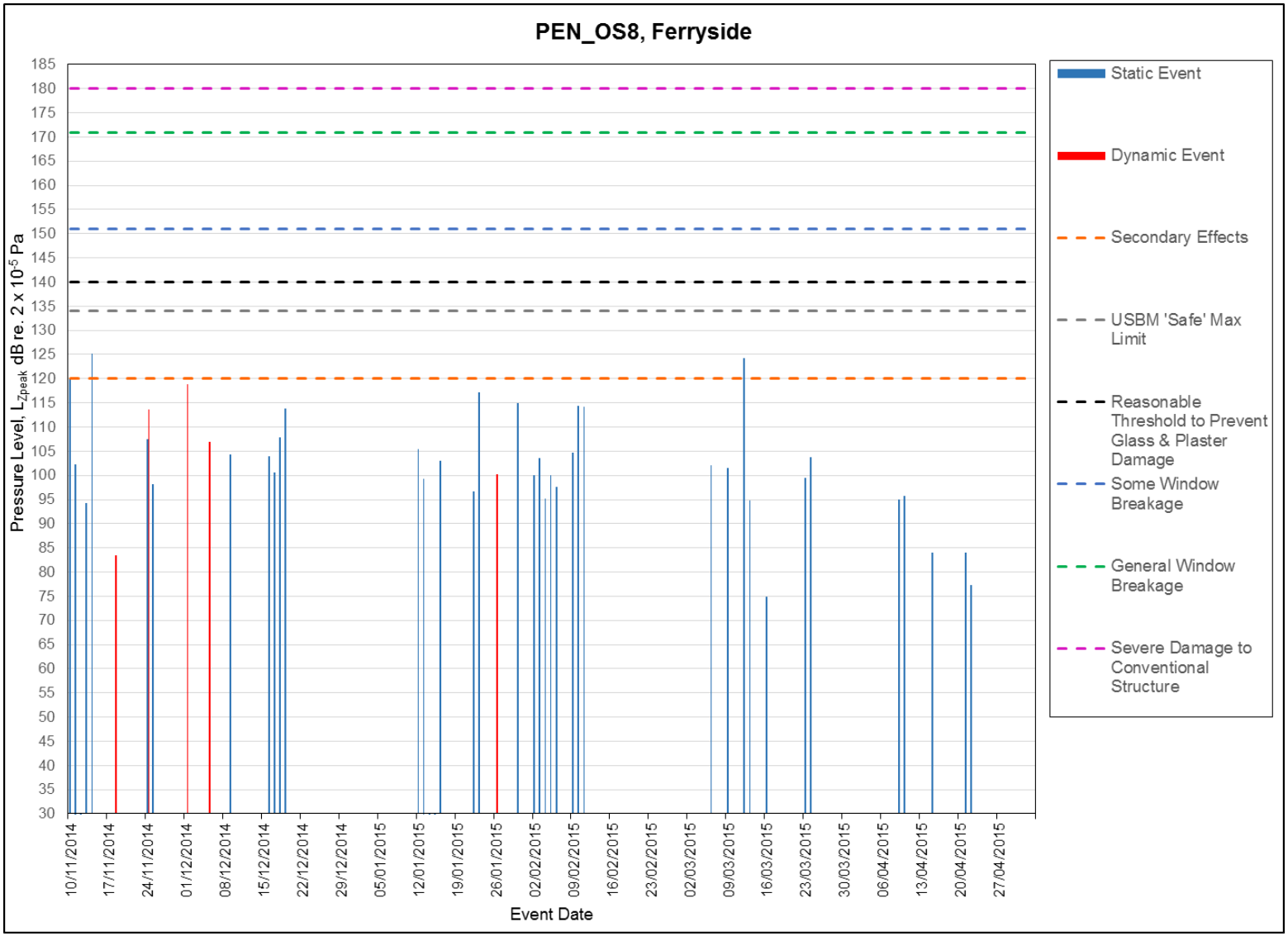

FIGURE A25 : SUMMARY OF LZPEAK VALUES, PEN_OS8, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

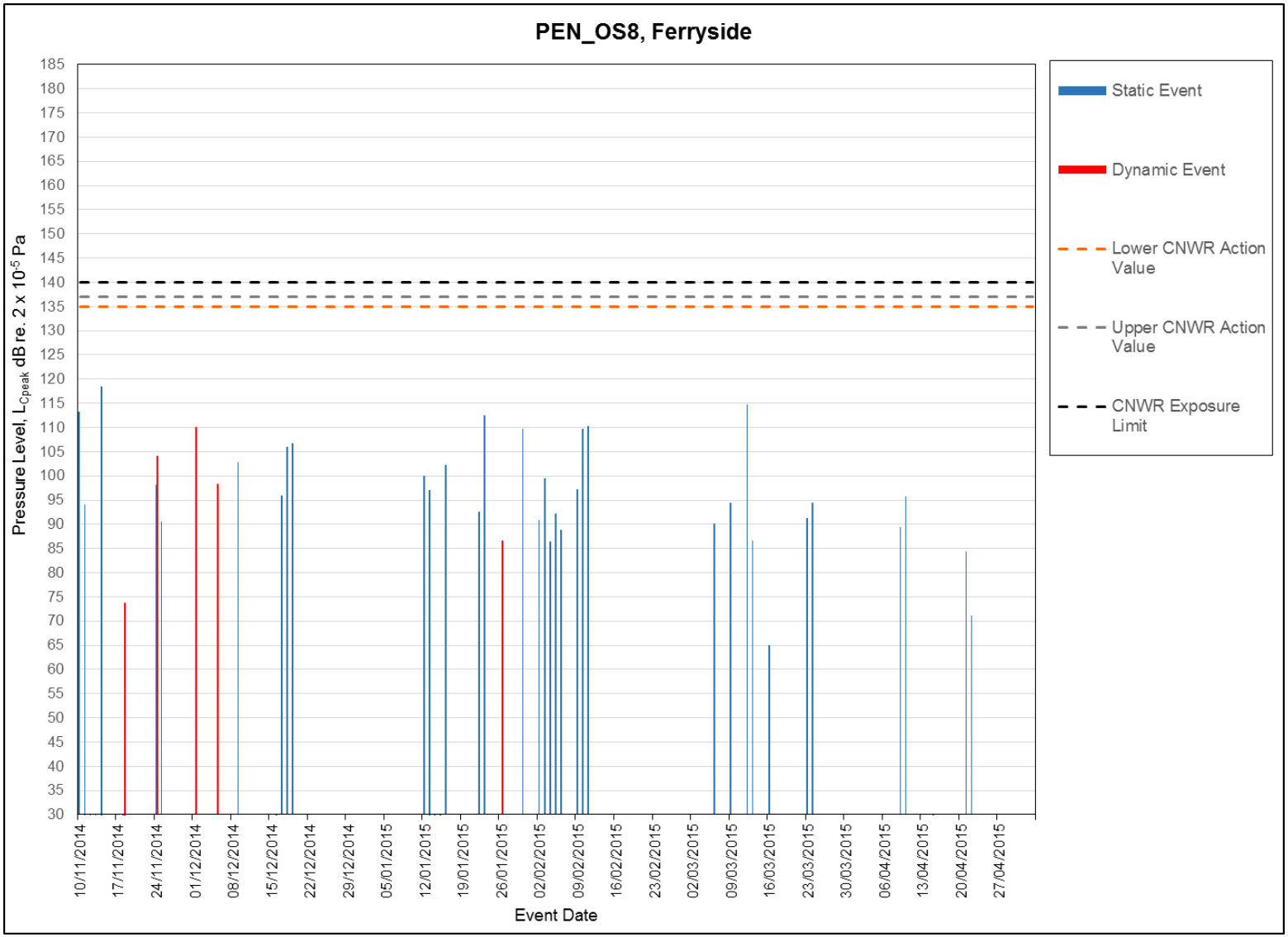

FIGURE A26 : SUMMARY OF LCPEAK VALUES, PEN_OS8, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

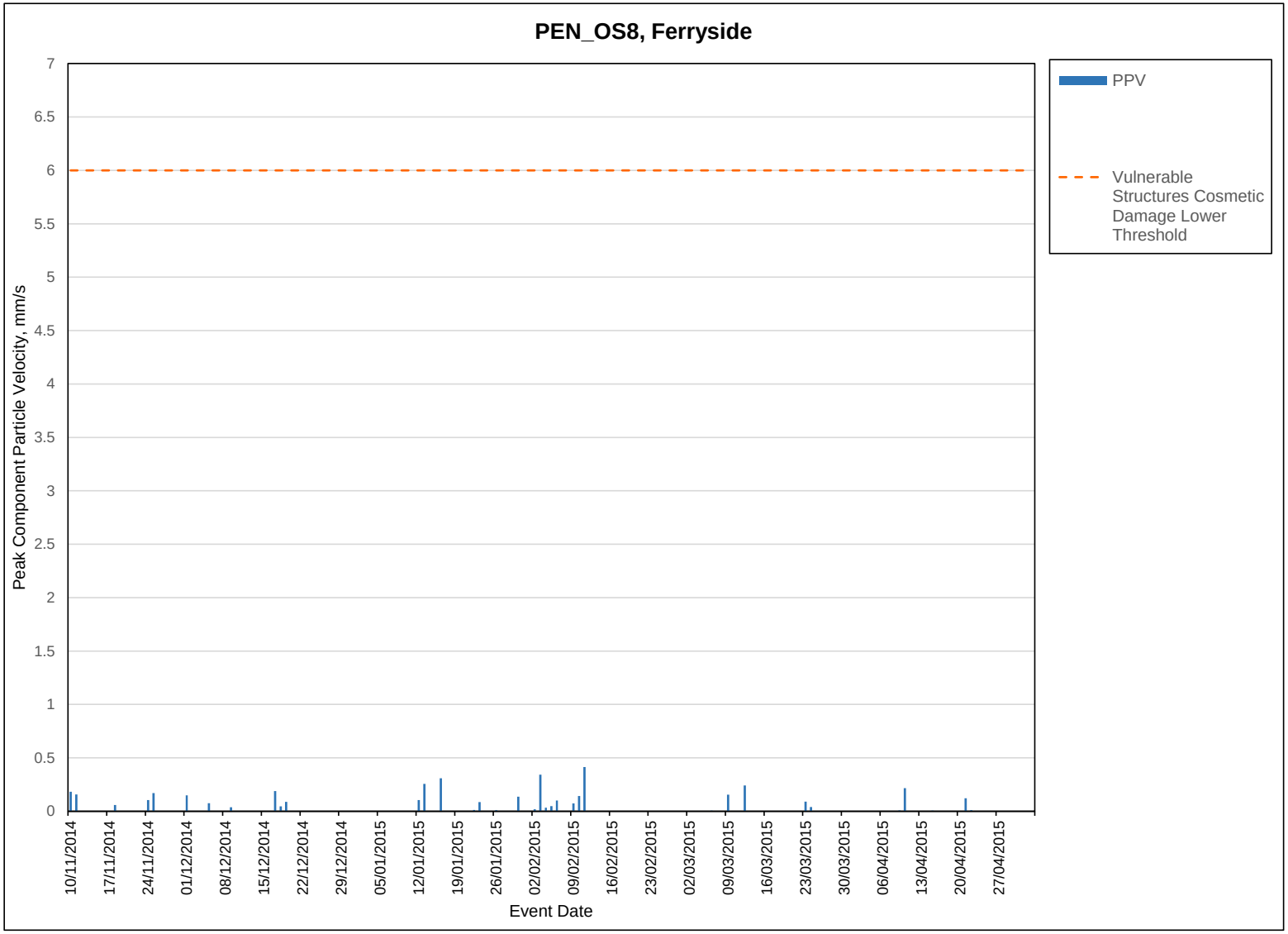

FIGURE A27 SUMMARY PPV VALUES, PEN_OS8, FERRYSIDE, 3RD NOVEMBER 2014 – 3RD MAY

Note: Highest daily levels presented

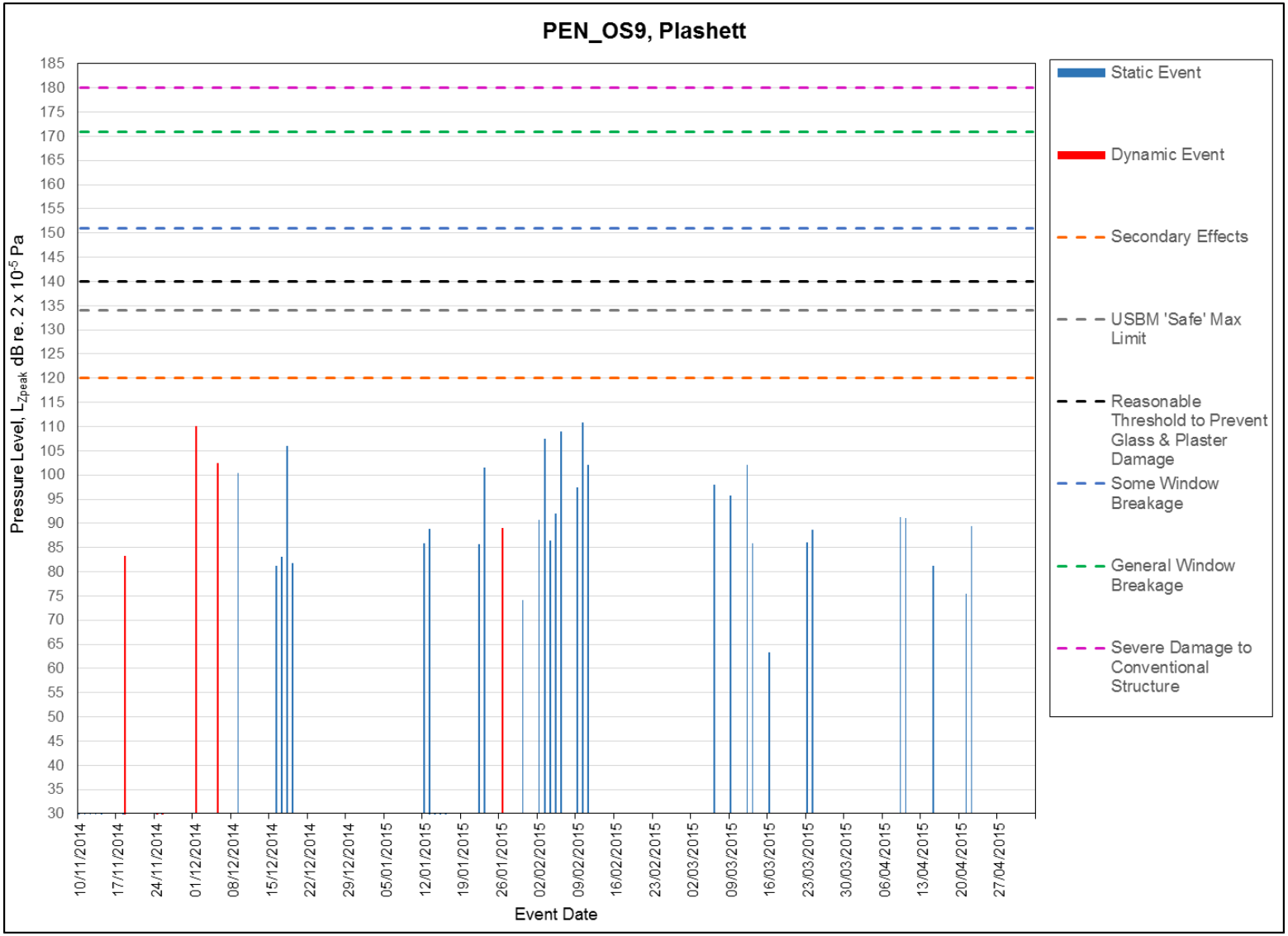

FIGURE A28 : SUMMARY OF LZPEAK VALUES, PEN_OS9, PLASHETT, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

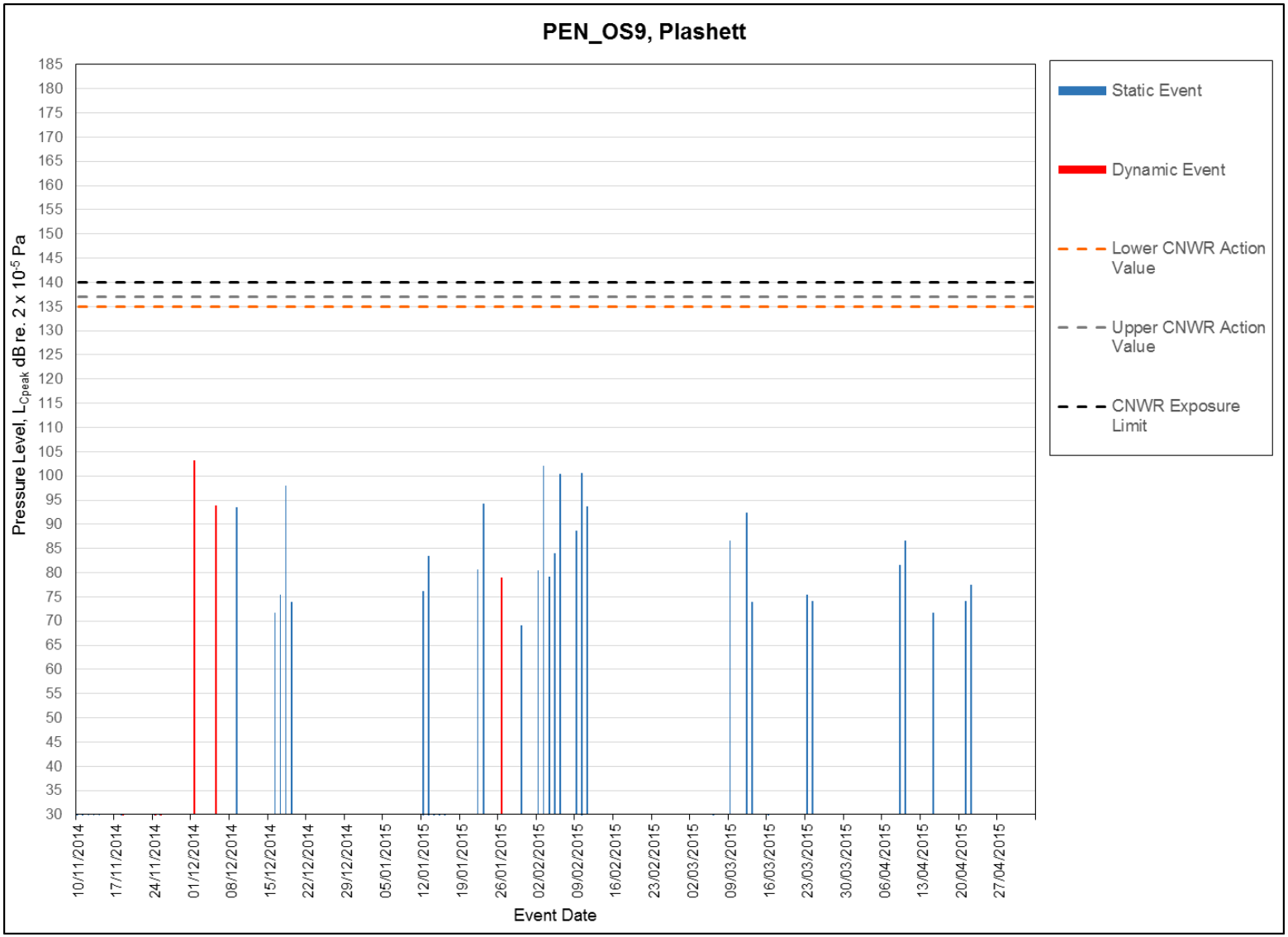

FIGURE A29 : SUMMARY OF LCPEAK VALUES, PEN_OS9, PLASHETT, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

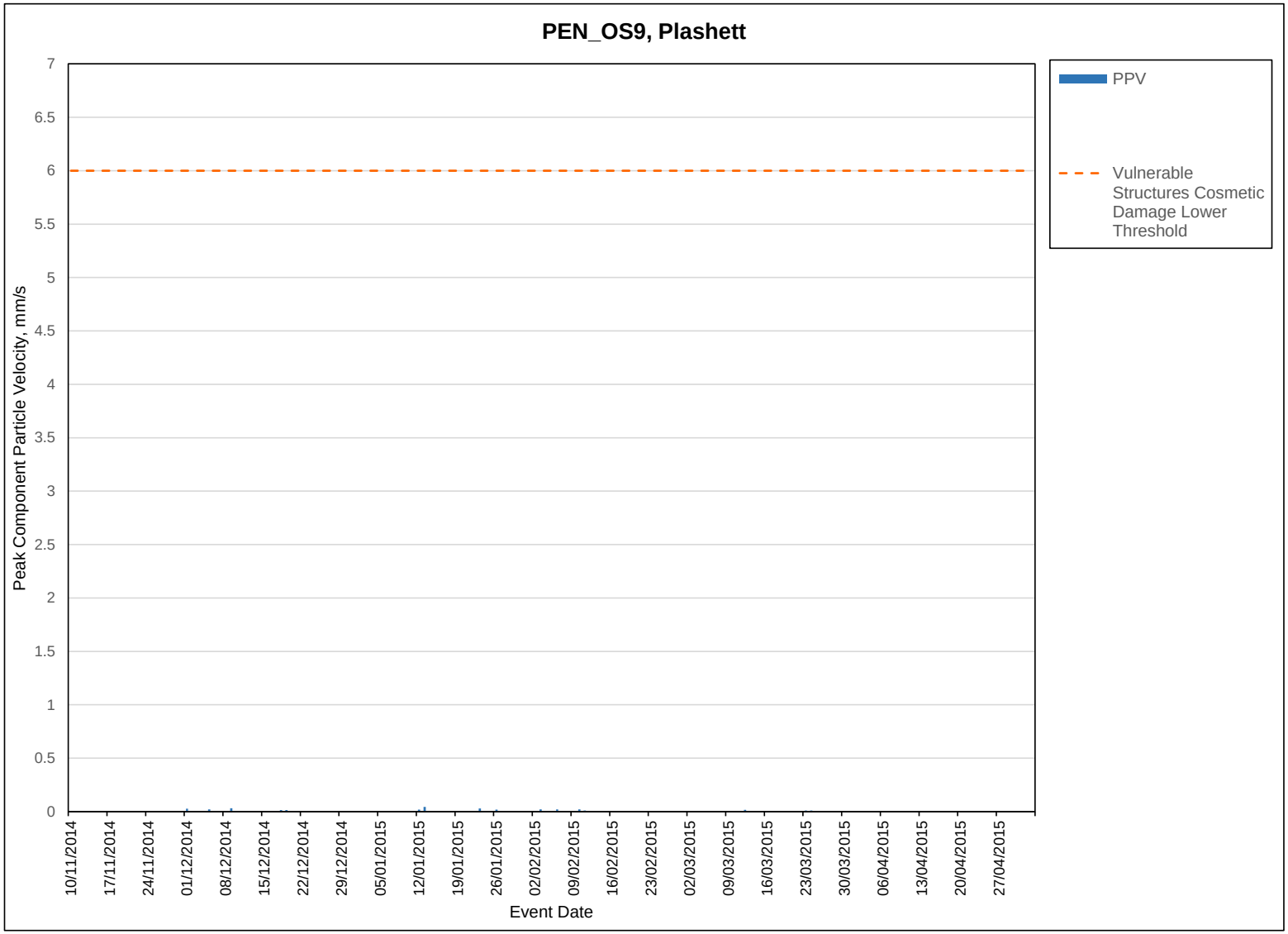

FIGURE A30 : SUMMARY PPV VALUES, PEN_OS9, PLASHETT, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

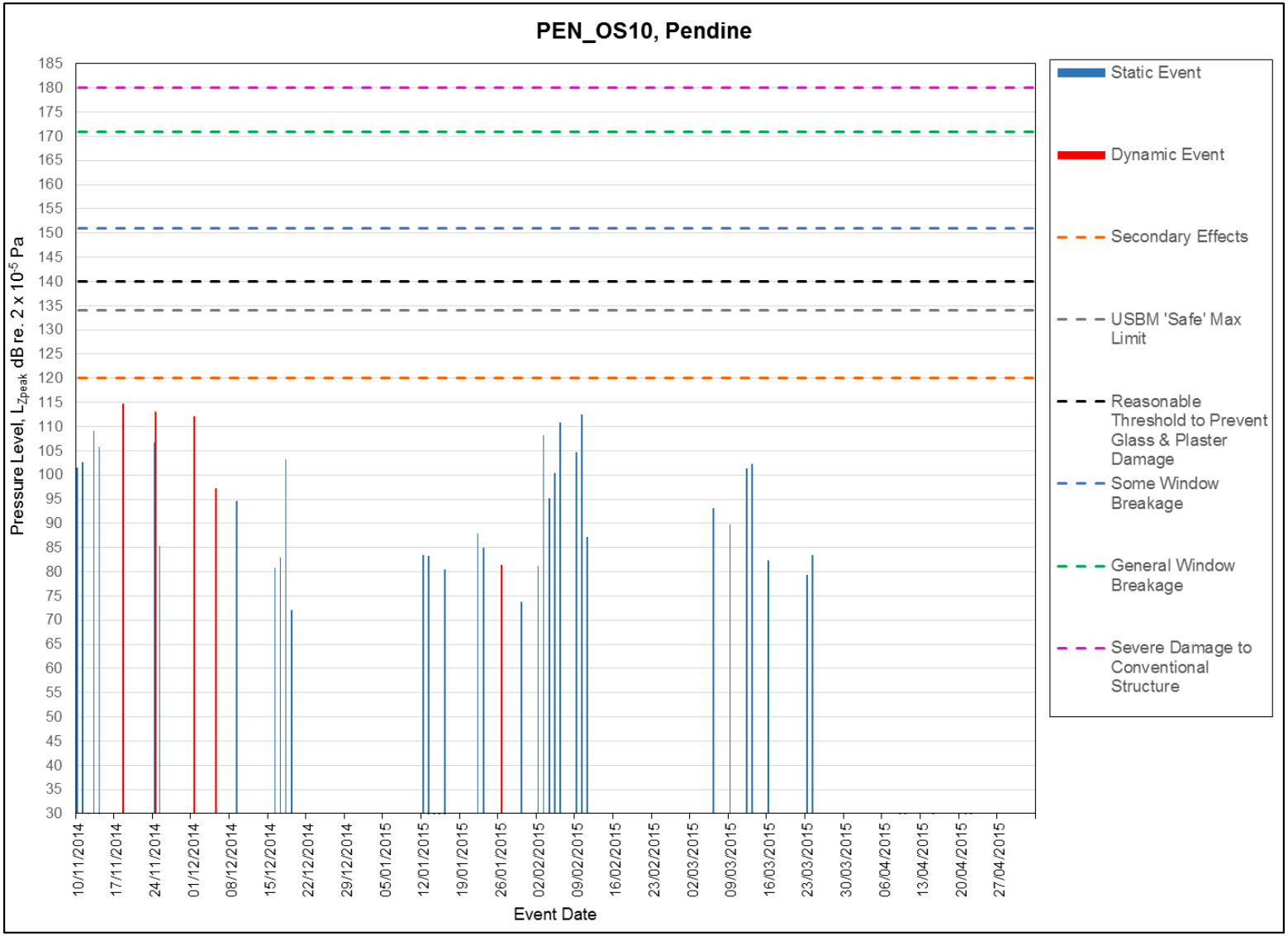

FIGURE A31: SUMMARY LZPEAK VALUES, PEN_OS10, PENDINE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

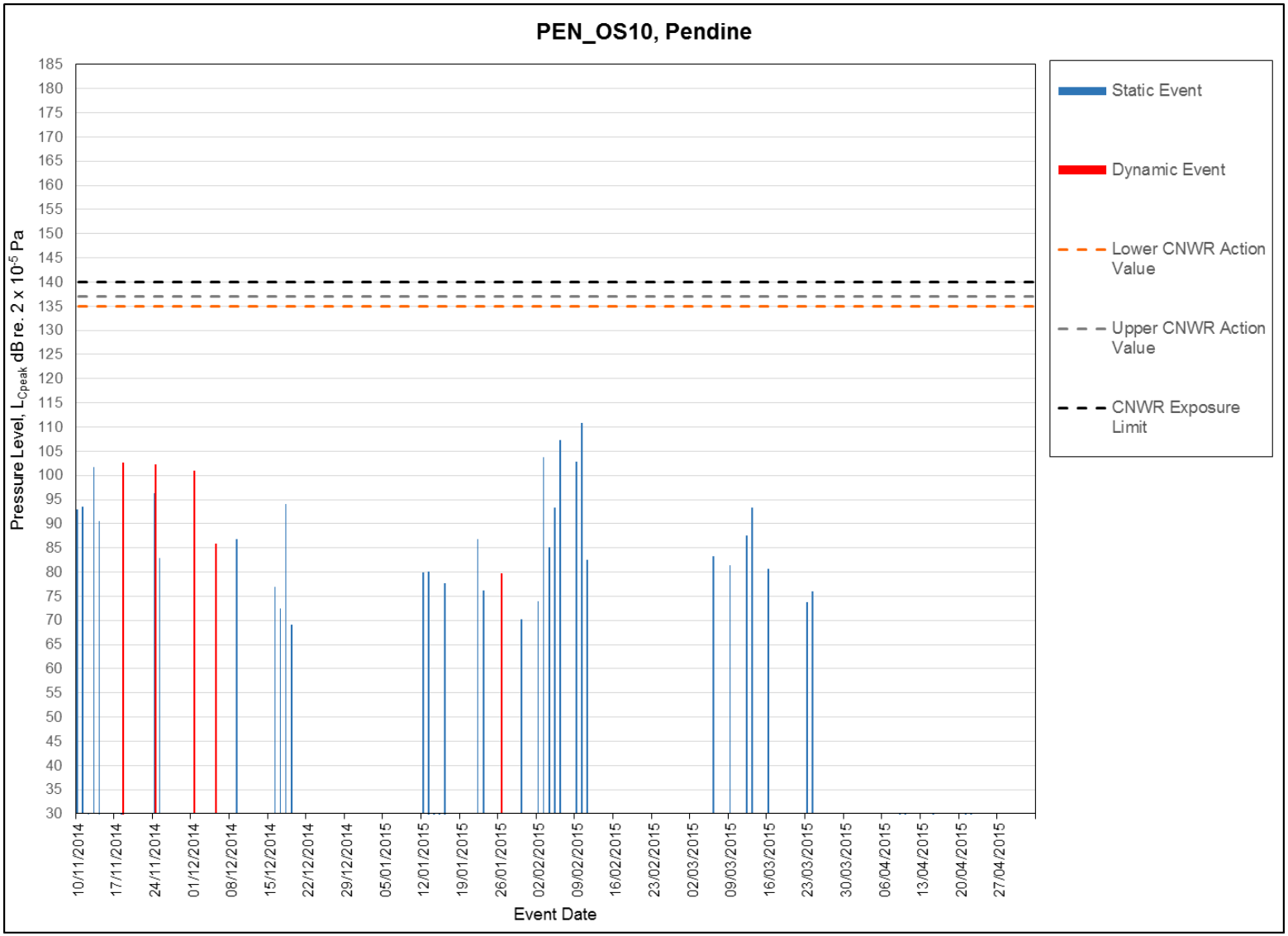

FIGURE A32 : SUMMARY LCPEAK VALUES, PEN_OS10, PENDINE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

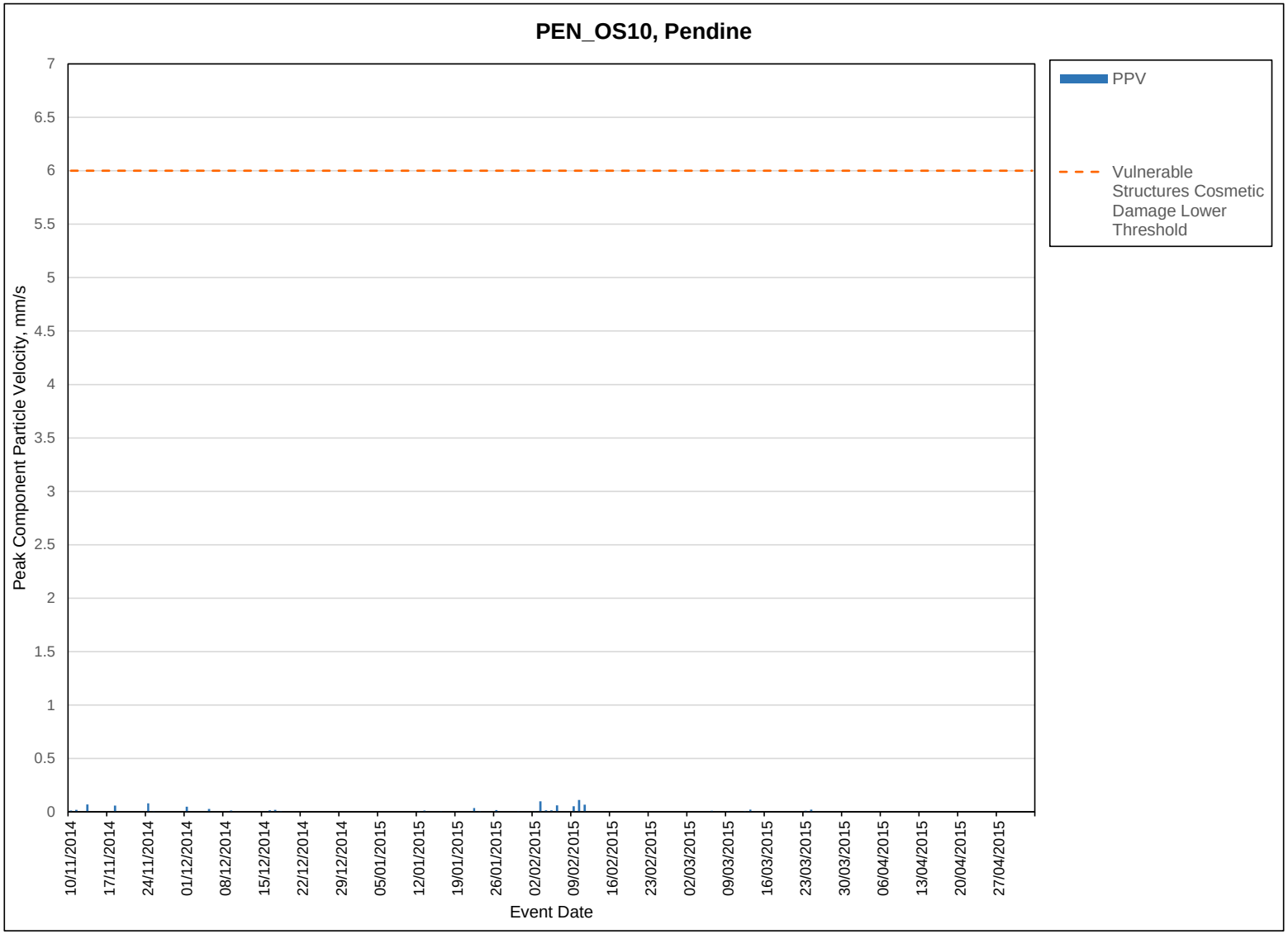

FIGURE A33 : SUMMARY PPV VALUES, PEN_OS10, PENDINE, 3RD NOVEMBER 2014 – 3RD MAY 2015

Note: Highest daily levels presented

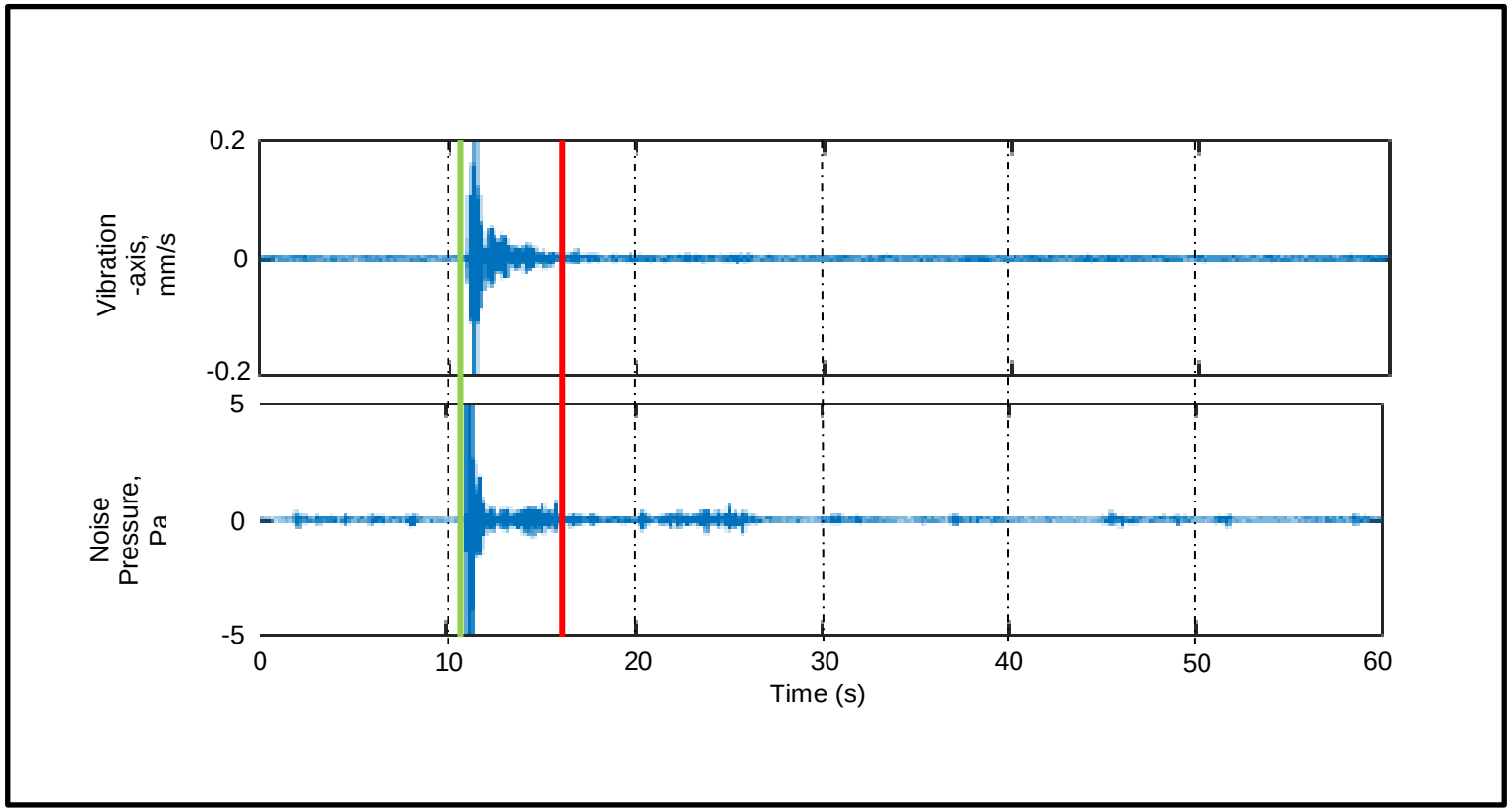

FIGURE A34: ANALYSIS OF MEASURED VIBRATION AND AIR OVERPRESSURE SIGNAL ARRIVAL TIMES AT AN OFF-RANGE LOCATION

Notes: [1] Green line indicates start of the measured events and red line indicates end of measured event

APPENDIX B: TABLES

Monitor ID	Total No. of On-Range Triggered Activities	No of Range Static and Dynamic Activities Expected to Trigger Range Monitors	No of On-Range Triggered Activities Caused by Range Static and Dynamic Activities	No of On-Range Triggered Events Caused by Non-Range Activities	No of individual Triggered Range Static and Dynamic Activities Captured by Off-Range Monitors	No of Off-Range Triggered Activities Caused by Local Activity
PEN_R1	1,719	149[3]	34	1,686	n/a	n/a
PEN_R2	1,563		99	1,474	n/a	n/a
TOTAL	3,282		103 (133)[1]	3,160[2]	n/a	n/a
PEN_OS1	n/a	n/a	n/a	n/a	85	69
PEN_OS2	n/a	n/a	n/a	n/a	86	435
PEN_OS3	n/a	n/a	n/a	n/a	79	298
PEN_OS4	n/a	n/a	n/a	n/a	73	27
PEN_OS5	n/a	n/a	n/a	n/a	89	171
PEN_OS6	n/a	n/a	n/a	n/a	87	26
PEN_OS7	n/a	n/a	n/a	n/a	76	47
PEN_OS8	n/a	n/a	n/a	n/a	77	1,121
PEN_OS9	n/a	n/a	n/a	n/a	66	17
PEN_OS10	n/a	n/a	n/a	n/a	76	61

TABLE B1: SUMMARY QUANTITIES OF TRIGGERED ACTIVITIES DURING MONITORING STUDY

Notes:

[1] Sum of the static and dynamic Range Activities captured by both Range monitors presented in brackets;

[2] Extraneous activities include those attributable to non-firing activities (i.e. local vehicle movements, wind noise on the microphone, local maintenance works, aircraft activity, alarm / sirens); and

[3] Number of individual Range Activities expected to cause a Range trigger are those associated with the quantities of reported activities in the Range logs.

Nov-14		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
10	14:30	123	138	11-S1-35, S2-69	117	128	✕	Not Installed	110	117	87	115	Not Installed	95
10	15:21	127	146	11-S1-36, S2-70	109	130	✕		114	124	87	120		102
11	15:04	122	137	11-S1-41	110	127	133		104	91	85	95		96
11	15:31	126	142	11-S1-42	113	131	134		109	102	91	102		102
12	13:37	TNE	103	11-S2-111	73	94	97		100	106	95	✕		✕
12	14:08	TNE	101	11-S2-104	112	107	132		113	125	119	✕		✕
13	10:30	121	113	11-S1-49, S2-118	109	127	127		79	81	89	87		107
13	11:26	128	138	11-S1-50, S2-122	114	131	133		106	93	98	94		109
14	11:13	121	TNE	11-S1-65	112	125	129		113	121	98	120		106
14	14:39	121	TNE	11-S1-66	✕	124	✕		108	✕	✕	123		✕
14	15:12	125	TNE	11-S1-68	117	129	✕		118	82	105	125		105
18	11:56	129	TNE	11-S1-165	88	124	103		80	82	82	78		112
18	15:43	TNE	TNE	11-S1-200	97	118	✕		96	✕	82	84		115
24	13:46	127	TNE	11-S1-186	102	123	106		95	104	87	107		107
24	14:48	136	TNE	11-S1-187	95	123	106		112	111	89	114		113
25	12:07	105	TNE	11-S1-189	102	109	102		86	97	82	98		85

TABLE B2: SUMMARY OF DATA CAPTURE – NOVEMBER 2014

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details

Dec-14		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
01	15:21	95	118	12-S1-2; S2-9	76	116	86	84	111	108	102	107	103	97
05	11:39	133	120	12-S1-22; S2-45	76	116	86	84	111	108	102	107	103	97
09	12:45	TNE	112	12-S2-82	84	89	92	94	97	99	103	99	97	87
09	15:40	TNE	117	12-S2-61	86	95	93	102	100	106	99	104	101	95
16	11:12	TNE	114	12-S2-110	66	81	89	80	91	100	107	104	67	73
16	13:23	TNE	111	12-S2-111	68	88	92	81	92	97	104	101	78	78
16	15:02	TNE	110	12-S2-204	84	91	98	99	94	99	103	99	81	81
17	11:13	TNE	109	12-S2-116	65	81	98	88	92	100	101	96	83	83
17	13:41	TNE	111	12-S2-117	81	78	87	94	98	99	104	101	77	82
18	14:31	TNE	137	12-S2-124	77	99	92	101	93	109	97	108	106	103
19	10:17	TNE	124	12-S2-127	72	89	95	90	109	115	124	114	82	72

TABLE B3: SUMMARY OF DATA CAPTURE – DECEMBER 2014

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Jan-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
12	12:01	TNE	132	01-S2-80	69	91	X	101	106	105	X	105	86	84
12	12:56	TNE	128	01-S2-84	87	79	X	88	98	98	X	99	80	83
12	14:16	TNE	128	01-S2-89	66	74	X	74	96	95	X	100	78	71
13	09:50	TNE	124	01-S2-97	76	73	77	70	82	97	X	92	84	77
13	10:09	TNE	127	01-S2-99	65	73	85	83	90	100	X	99	76	81
13	10:31	TNE	126	01-S2-100	69	85	92	80	90	89	X	92	89	83
13	10:50	TNE	122	01-S2-101	X	X	X	X	X	X	X	X	X	X
13	11:11	TNE	120	01-S2-102	67	79	75	75	75	84	X	78	83	72
13	11:31	TNE	114	01-S2-103	63	108	78	65	68	85	X	71	82	80
13	13:03	TNE	138	01-S2-104	X	X	X	X	X	X	X	X	X	X
13	13:35	TNE	128	01-S2-105	X	X	X	X	X	X	X	X	X	X
14	10:44	TNE	134	01-S2-123	X	X	X	X	X	X	X	X	X	X
14	11:10	TNE	TNE	01-S2-125	X	X	X	X	X	X	X	X	X	X
14	11:37	TNE	120	01-S2-126	X	X	X	X	X	X	X	X	X	X
14	12:51	TNE	133	01-S2-127	X	X	X	X	X	X	X	X	X	X
14	13:17	TNE	138	01-S2-130	X	X	X	X	X	X	X	X	X	X
14	14:09	TNE	142	01-S2-138	X	X	X	X	X	X	X	X	X	X
14	15:07	TNE	134	01-S2-143	X	X	X	X	X	X	X	X	X	X

TABLE B4: SUMMARY OF DATA CAPTURE – JANUARY 2015

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Jan-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
14	15:30	TNE	133	01-S2-144	×	×	×	×	×	×	×	×	×	×
15	14:04	TNE	127	01-S2-214	×	×	×	×	×	×	×	×	×	×
15	14:48	TNE	133	01-S2-223	×	×	×	×	×	×	102	×	×	×
16	10:08	TNE	126	01-S2-243	81	77	74	77	78	101	94	103	×	69
16	10:39	TNE	131	01-S2-244	81	×	90	×	83	95	×	102	×	84
16	11:05	TNE	131	01-S2-246	72	86	87	76	94	107	95	103	×	76
16	11:36	TNE	133	01-S2-249	67	76	80	84	89	104	93	100	×	81
16	12:15	95	TNE	01-S1-124	67	78	95	85	86	97	×	87	×	74
22	13:50	TNE	139	01-S2-270	86	105	107	102	93	97	79	97	86	81
22	13:51	TNE	140	01-S2-271	86	105	107	102	93	97	79	97	86	81
22	14:06	TNE	133	01-S2-272	90	106	104	101	91	94	77	92	83	88
22	14:07	TNE	137	01-S2-273	90	106	104	101	91	94	77	92	83	88
23	11:20	TNE	145	01-S2-282	94	102	107	103	93	114	98	117	99	80
23	11:21	TNE	145	01-S2-283	94	102	107	103	93	114	98	117	99	80
23	11:28	TNE	140	01-S2-284	88	102	106	102	89	112	105	115	102	85
26	11:51	126	TNE	01-S1-153	76	118	93	85	99	96	97	100	89	81
30	11:42	TNE	136	01-S2-352	76	93	98	99	101	115	113	115	74	74

TABLE B4 (CTD): SUMMARY OF DATA CAPTURE – JANUARY 2015

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Feb-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
02	12:06	TNE	137	02-S2-2	82	106	108	99	99	102	103	100	91	81
03	10:42	125	135	02-S1-10 & S2-13	96	127	122	106	90	100	79	104	107	105
03	14:44	116	134	02-S1-12 & S2-19	74	106	97	83	88	96	92	94	87	108
03	15:25	98	100	02-S1-13 & S2-22	92	94	95	96	92	101	103	99	90	95
04	11:48	TNE	133	02-S1-22 & S2-32	74	102	98	84	87	91	89	94	82	95
04	15:10	TNE	133	02-S2-36	76	111	101	86	89	95	90	95	86	94
05	10:59	TNE	134	02-S2-42	73	116	97	87	97	96	104	100	92	94
05	13:17	116	135	02-S1-29 & S2-47	72	112	102	82	93	96	90	98	90	94
05	15:22	115	135	02-S1-30 & S2-50	75	107	100	83	85	97	95	94	90	100
06	10:45	123	136	02-S1-34	96	122	115	109	86	90	76	98	109	111
09	10:37	TNE	135	02-S2-71	80	106	98	94	94	108	115	104	81	102
09	12:41	TNE	134	02-S2-76	88	106	99	89	97	102	106	105	86	95
09	15:07	116	136	02-S1-92 & S2-82	90	115	112	103	95	100	113	104	98	105
10	12:22	TNE	TNE	02-S1-100 & S2-94	108	125	126	121	108	110	96	109	106	107
10	15:04	TNE	135	02-S1-103 & S2-100	107	123	128	117	102	103	82	101	106	113
11	11:44	120	135	02-S2-104	106	118	125	116	106	112	92	114	102	87
11	12:03	TNE	137	02-S2-107	85	106	96	97	91	97	87	100	90	87
11	12:04	TNE	106	02-S2-108	85	106	96	97	91	97	87	100	90	87
11	13:36	TNE	106	02-S2-111	90	105	102	98	90	103	96	104	88	84

TABLE B5: SUMMARY OF DATA CAPTURE – FEBRUARY 2015

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Feb-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
11	13:38	TNE	109	02-S2-112	89	104	98	97	92	99	84	101	88	82
11	13:40	TNE	111	02-S2-113	87	104	97	93	96	104	98	104	89	85
11	13:42	107	111	02-S1-110	87	104	97	93	96	104	98	104	89	85
11	14:14	107	111	02-S2-114	86	106	96	94	87	99	90	99	86	80
11	14:16	TNE	108	02-S2-115	90	104	95	95	86	98	89	98	89	80

TABLE B5 (CTD): SUMMARY OF DATA CAPTURE – FEBRUARY 2015

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Mar-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
06	10:48	TNE	107	03-S2-142	80	98	88	92	76	68	76	102	98	93
09	10:30	TNE	96	03-S2-168	85	97	99	95	88	100	93	102	96	90
12	10:21	TNE	109	03-S1-134	97	104	103	100	103	107	73	104	89	90
12	14:20	104	TNE	03-S2-178	103	122	117	115	119	124	106	124	102	101
13	15:02	TNE	129	03-S1-213	77	102	93	97	88	82	91	95	86	102
23	10:06	102	TNE	03-S2-198	83	90	98	97	93	97	102	99	86	79
24	12:02	TNE	TNE	03-S2-208	73	101	95	92	97	105	110	104	89	83

TABLE B6: SUMMARY OF DATA CAPTURE – MARCH 2015

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

Mar-15		Measured L_{Zpeak} Values at On-Range Locations, dB re 10^{-5} Pa		Southdowns Generated Trigger ID	Measured L_{Zpeak} Values at Off-Range Locations, dB re. 2 x 10^{-5} Pa									
Day	Time	PEN_R1	PEN_R2		PEN_OS1	PEN_OS2	PEN_OS3	PEN_OS4	PEN_OS5	PEN_OS6	PEN_OS7	PEN_OS8	PEN_OS9	PEN_OS10
09	15:33	TNE	116	04-S2-9	94	106	112	107	96	99	85	95	91	Not Installed
09	15:34	TNE	124	04-S2-11	94	106	112	107	96	99	85	95	91	
10	12:14	TNE	141	04-S2-15	95	109	107	106	94	96	93	96	91	
10	12:15	TNE	144	04-S2-15	95	109	107	106	94	96	93	96	91	
15	15:03	TNE	140	04-S2-30	62	80	67	81	74	82	76	84	81	
21	12:32	TNE	140	04-S2-58	68	93	80	72	65	74	73	84	75	
22	12:56	TNE	89	04-S2-65	74	101	95	88	81	97	78	66	90	
22	14:28	TNE	111	04-S1-136 & S2-68	78	90	92	84	72	103	78	77	78	

TABLE B7: SUMMARY OF DATA CAPTURE – APRIL / MAY 2015[2]

Notes:

TNE = *Trigger Threshold Not Exceeded;*

Green shaded cells denote Positive Causality (PC) – reasonable likelihood that an on-Range Activity has caused an off-Range effect (i.e. positive causality);

Yellow shaded cells denote Uncertain Causality (UC) – insufficient statistical evidence to confirm that the on-Range Activity has caused an off-Range effect (i.e. uncertain causality);

Blue shaded cells denote No Causality (NC) – little or no evidence to suggest that the on-Range Activity has caused an off-Range effect (i.e. no causality); and

X = Activity not captured. See Volume 2 – Technical Appendices – Detailed Methodology, Chapter 3: Equipment Outages and Scheduled Maintenance for full details.

[1] = Equipment retrieved before the end of the monitoring study at the request of resident.

[2] = Monitoring completed on 3rd May. No activities occurred between 1st and 3rd May 2015.

Month	Wind Speed (m/s)	Temperature (°C)	Relative Humidity (%)	Rain Rate (mm/h)
November	1.7 (0.2 - 3.9)	11.1 (8.7 - 13.2)	85.8 (77.0 - 99.0)	0.0 (0.0 - 0.0)
December	3.2 (0.2 - 5.6)	9.6 (7.7 - 12.4)	85.9 (66.0 - 100.0)	0.0 (0.0 - 0.0)
January	4.9 (0.5 - 14.8)	5.6 (0.9 - 10.3)	86.5 (69.0 - 100.0)	1.0 (0.3 - 10.9)
February	3.2 (1.0 - 6.7)	4.8 (1.2 - 7.0)	80.8 (62.5 - 100.0)	0.0 (0.0 - 0.0)
March	4.2 (2.5 - 6.5)	7.9 (5.3 - 9.3)	87.4 (73.0 - 97.0)	0.0 (0.0 - 0.0)
April	3.7 (2.5 - 5.2)	14.1 (12.9 - 14.7)	64.2 (59.6 - 72.6)	0.0 (0.0 - 0.0)
Summary	**3.7 (0.2 - 14.8)**	**7.3 (0.9 - 14.7)**	**83.9 (59.6 - 100.0)**	**0.3 (0.0 - 10.9)**

TABLE B8: SUMMARY OF METEOROLOGICAL DATA DURING RANGE ACTIVITIES

Notes:
[1] – average presented outside of parenthesis with the range presented within; and
[2] - based on data collated from the meteorological station installed on-Range at Brill Gate (PEN_R1). Full data presented in Volume 3 -Technical Appendices – Results.

Monitoring Location ID	NEQ / Calibre - Static Firing Events											
	<0.5kg				0.6 – 1kg				1.1 – 2.5kg			
	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]
PEN_R1	-	-	-	-	103	104	0.233	0.005	103	107	0.270	0.002
PEN_R2	135	137	0.535	0.002	141	142	0.509	0.004	144	145	1.175	0.010
PEN_OS1	68	70	0.029	0.000	85	92	0.078	0.000	102	104	0.067	0.001
PEN_OS2	90	99	0.035	0.001	108	108	0.058	0.001	107	109	0.228	0.005
PEN_OS3	77	80	0.000	0.000	94	99	0.051	0.000	105	112	0.068	0.000
PEN_OS4	72	72	0.016	0.000	93	99	0.021	0.000	104	107	0.074	0.001
PEN_OS5	89	93	0.026	0.000	94	98	0.028	0.000	94	97	0.036	0.000
PEN_OS6	108	109	0.037	0.000	105	107	0.039	0.000	110	114	0.033	0.000
PEN_OS7	93	97	0.047	0.001	101	107	0.139	0.002	103	105	0.966	0.016
PEN_OS8	106	108	0.166	0.002	102	103	0.420	0.006	113	117	0.550	0.008
PEN_OS9	74	75	0.002	0.000	87	96	0.013	0.000	94	102	0.033	0.000
PEN_OS10	94	103	0.014	0.000	83	93	0.019	0.000	83	87	0.082	0.001

TABLE B9: SUMMARY OF TRIGGERED STATIC (0.5 – 2.5KG) FIRING EVENTS, PENDINE RANGE 3RD NOVEMBER 2014 – 3RD MAY 2015

Notes:
[1] "-" indicates where no event has been recorded for the NEQ category;
[2] All events presented fall into Positive Causality or Uncertain Causality categories; and
[3] Maximum Displacement <4Hz

Monitoring Location ID	NEQ / Calibre - Static Firing Events											
	2.6 – 5kg				5.1 – 10kg				10.1 – 20kg			
	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]
PEN_R1	123	127	0.353	0.006	122	125	0.219	0.002	119	128	0.448	0.011
PEN_R2	140	146	1.449	0.027	135	137	0.584	0.008	137	142	1.379	0.032
PEN_OS1	110	119	0.178	0.004	108	114	0.137	0.001	117	125	0.314	0.007
PEN_OS2	122	130	0.631	0.010	122	127	0.368	0.003	124	131	0.785	0.020
PEN_OS3	126	133	0.708	0.004	122	128	0.465	0.005	127	134	0.886	0.006
PEN_OS4	79	90	0.000	0.000	117	121	0.565	0.004	-	-	-	-
PEN_OS5	105	114	0.137	0.001	112	119	0.252	0.001	117	118	0.219	0.001
PEN_OS6	116	124	0.182	0.001	116	124	0.208	0.001	116	125	0.190	0.001
PEN_OS7	117	124	0.444	0.003	109	115	3.646	0.058	87	98	0.089	0.001
PEN_OS8	113	120	0.251	0.003	115	124	0.439	0.006	94	102	0.028	0.000
PEN_OS9	74	82	0.016	0.000	102	109	0.032	0.000	-	-	0.000	0.000
PEN_OS10	96	107	0.047	0.000	111	113	0.151	0.001	102	109	0.099	0.001

TABLE B9 CTD: SUMMARY OF TRIGGERED STATIC (2.6 – 20KG) FIRING EVENTS, PENDINE RANGE 3RD NOVEMBER 2014 – 3RD MAY 2015

Notes:

[1] "-" indicates where no event has been recorded for the NEQ category;

[2] All events presented fall into Positive Causality or Uncertain Causality categories;

[3] Maximum Displacement <4Hz; and [4] presented level due to local activity not attributable to Range Activity

Monitoring Location ID	NEQ / Calibre - Dynamic Firing Events											
	0 – 10kg				10.1 – 20kg				Unclassified firing activity (Static/Dynamic)			
	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]	L_{Cpeak}	L_{Zpeak}	PPV mms^{-1}	Maximum Displacement mm [3]
PEN_R1	124	129	0.355	0.000	130	136	1.019	0.000	97	102	0.443	0.000
PEN_R2	109	118	0.129	0.002	118	120	0.136	0.002	130	132	0.319	0.002
PEN_OS1	88	97	0.021	0.000	95	104	0.034	0.000	87	86	0.047	0.000
PEN_OS2	117	124	0.294	0.008	116	123	0.290	0.007	84	91	0.063	0.002
PEN_OS3	92	103	0.000	0.000	96	106	0.236	0.003	0	0	0.000	0.000
PEN_OS4	100	100	0.029	0.000	76	84	0.007	0.000	90	101	0.000	0.000
PEN_OS5	103	115	0.060	0.001	103	112	0.059	0.000	91	106	0.087	0.000
PEN_OS6	107	119	0.100	0.001	101	111	0.030	0.000	97	105	0.022	0.000
PEN_OS7	93	102	0.035	0.001	96	102	0.038	0.000	-	-	-	-
PEN_OS8	110	119	0.200	0.002	104	114	0.129	0.002	100	105	0.138	0.002
PEN_OS9	103	110	0.035	0.000	94	103	0.024	0.000	75	86	0.005	0.000
PEN_OS10	103	112	0.087	0.001	102	113	0.122	0.001	67	71	0.011	0.000

TABLE B9 CTD: SUMMARY OF TRIGGERED DYNAMIC FIRING EVENTS, PENDINE RANGE 3RD NOVEMBER 2014 – 3RD MAY 2015

Notes:
[1] "-" indicates where no event has been recorded for the NEQ category;
[2] All events presented fall into Positive Causality or Uncertain Causality categories; and
[3] Maximum Displacement <4Hz

Monitoring Location ID	No of Off-Range Triggered Events Caused by Local Activity[1]	L_{Zpeak}[2]	L_{Cpeak}[3]	Max Component PPV mms^{-1}	Comments / Cause of Max Event
PEN_OS1	69	96- 136	94 - 134	0.17	Maximum event attributable to local fireworks
PEN_OS2	435	95 - 132	94 - 124	0.42	Maximum event attributable to wind & rain noise - heavy storm
PEN_OS3	298	92 - 133	92 - 125	0.54	Maximum event attributable to wind & rain noise - storm
PEN_OS4	23	98 - 125	98 - 125	0.13	Maximum event attributable to local fireworks
PEN_OS5	160	91 - 118	90 - 117	0.07	Maximum event attributable to Farming activity
PEN_OS6	26	99- 132	99 - 129	0.00	Maximum event attributable to wind & rain - storm
PEN_OS7	43	97 - 120	97 - 119	0.02	Maximum event attributable to local fireworks
PEN_OS8	1,121	97 - 132	97 - 132	0.28	Maximum event attributable to fireworks. High number of off-Range triggered event exceedances attributable to proximity to West Wales railway line
PEN_OS9	11	95 - 121	94 - 114	0.33	Maximum event attributable to wind & rain noise - heavy storm
PEN_OS10	61	94 - 131	93 - 130	0.75	Maximum event attributable to –fireworks.

TABLE B10: SUMMARY OF LOCALLY TRIGGERED EXTRANEOUS EVENTS AT OFF-RANGE LOCATIONS, 3RD NOVEMBER 2014 – 3RD MAY 2015

Notes:

[1] indicates the number of triggers attributable to events in the vicinity of individual off-Range monitoring locations (not Range firing events) e.g. wind noise, road traffic, train movements, fireworks;

[2] presents the range of L_{ZPeak} levels attributable to triggered events caused by local activity; and

[3] presents the range of L_{CPeak} levels attributable to triggered events caused by local activity.

Monitoring Location ID	No. Events Maximum in Component Axis			% Events Maximum in Component Axis		
	x	y	z	x	y	z
PEN_R1	0	11	18	0%	38%	62%
PEN_R2	2	2	83	2%	2%	95%
PEN_OS1	15	30	37	18%	37%	45%
PEN_OS2	3	0	80	4%	0%	96%
PEN_OS3	2	5	18	8%	20%	72%
PEN_OS4	1	29	18	2%	60%	38%
PEN_OS5	9	21	56	10%	24%	65%
PEN_OS6	4	35	43	5%	43%	52%
PEN_OS7	14	53	5	19%	74%	7%
PEN_OS8	5	50	20	7%	67%	27%
PEN_OS9	32	12	20	50%	19%	31%
PEN_OS10	40	14	15	58%	20%	22%
Total	**127**	**262**	**413**	**16%**	**33%**	**51%**

TABLE B11: DISTRIBUTION OF MAXIMUM COMPONENT VELOCITY PER AXIS