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MINISTRY OF DEFENCE LAND RANGES – NOISE AND VIBRATION STUDY

REVIEW OF PREVIOUS SHOEBURYNESS NOISE AND VIBRATION STUDY

FINAL REPORT
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REVIEW AND AUTHORISATION			
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1. INTRODUCTION

1.1.1 To fulfil the requirements of the 2015 independent monitoring study, Southdowns has undertaken a review of the Vibrock Study methodology and findings as presented in the Vibrock report entitled '*An Assessment of Environmental Vibration Produced During Explosive Activities at Shoeburyness, Essex from January 2003 to March 2004*' (Ref: R04.3760/2/DJ) [1].

1.1.2 The requirements for the Vibrock review, as presented in the Shoeburyness Noise and Vibration Monitoring Study (NVMS) System Requirements Document (SRD) [2] are as follows:

- the study shall identify if the approach taken by the Vibrock Study remains valid (SRD_012);
- the study shall identify if the conclusions of the Vibrock Study remain valid (SRD_13); and
- the study shall identify if the effects of *Range Activities* as described in the Vibrock Report remain valid (SRD_14).

1.1.3 The review requirements are discussed in the following Section of this document and the summary conclusions are presented in Section 3.

1.1.4 This report is not intended to provide a detailed critique of the Vibrock study and is limited to a review of those requirements of the SRD specifications only.

2. REVIEW OF VIBROCK STUDY

2.1 Approach

2.1.1 There are notable differences between the approaches adopted in the current study and those adopted for the Vibrock study. These differences can be classified as follows:

- survey design and specification;
- available technology for monitoring;
- scale and specification of data capture;
- management of data integrity and quality;
- assessment thresholds; and
- presentation and reporting detail.

2.1.2 One of the aims of the current study was to undertake a review of these aspects and to implement a study with a contemporary and optimised approach maximising the opportunities to deploy highly functional equipment and data processing techniques.

2.1.3 Whereas the basic measurement metrics adopted are similar, and the primary references for deriving the assessment criteria are also similar, the scope of the current study is considered to be more extensive than the Vibrock study.

2.1.4 The following specific requirements were included into the scope for the current study, and which were not required to be addressed in the Vibrock study:

- review of contemporary research material to define appropriate assessment criteria;
- investigation into a causal link between Range Activities and measured sound and vibration effects in the community;
- maximising the quantity of measured data over the survey period;
- use of high sensitivity and remotely operated equipment;
- capture and off-site storage of high quality digital signals for future reference;
- networked and synchronised triggering systems across all monitoring stations to manage the data associated with Range activity;
- improved confidence in the identification of Range Activities and corresponding measurement data;
- monitoring of meteorological conditions during survey; and
- presentation and assessment of all data.

2.1.5 Whilst the scale, complexity and specification requirements of the current study are considered to be far greater than that of the Vibrock study, the basic principles of applying triggered measurements for both air overpressure (L_{Zpeak}) and groundborne vibration (PPV), remain unchanged.

2.2 Assessment Criteria

2.2.1 Southdowns has undertaken a contemporary review of published guidance and other research findings to enable the assessment criteria to be verified for the current study.

2.2.2 The Vibrock study included both vibration and air overpressure effect thresholds in a similar fashion to the current study. It also drew upon the same technical references that Southdowns has in part relied upon in determining its own thresholds.

2.2.3 However, since the Vibrock study was completed, several relevant British Standards which Vibrock rely upon in deriving their air overpressure damage thresholds have been revised as follows:

- BS 6472-2: 2008 *Guide to Evaluation of Human Exposure to Vibration in Buildings. Part 2: Blast-Induced Vibration*
- BS 5228-2: 2009+A1:2014 *Code of practice for noise and vibration control on construction and open sites. Vibration*
- BS EN ISO 4866: 2010 *Mechanical Vibration and Shock – Vibration of Buildings – Guidelines for the Measurement of Vibration and Evaluation of their Effects on Structures*

2.2.4 Whilst there is no explicit narrative on the criteria applied to any assessment in the Vibrock study, Table 2.1 and Table 2.2 shows the assessment criteria that are referred to in the Vibrock Study report.

AIR OVERPRESSURE EFFECT THRESHOLD		
LEVEL	**EFFECT**	**SOURCE**
180 dB (20 kPa)	Structural damage can be expected	not cited
170 dB (6300 Pa)	window cracking	not cited
150 dB (630 Pa)	poorly mounted, and hence prestressed windows might crack	not cited
134 dB	USBM Maximum Recommended Level (0.1 Hz high pass)	USBM
133 dB	USBM Maximum Recommended Level (2.0 Hz high pass)	USBM
129 dB	USBM Maximum Recommended Level (5.0 or 6.0 Hz high pass)	USBM
105 dB(C)	USBM Maximum Recommended Level	USBM

TABLE 2.1: ASSESSMENT CRITERIA INCLUDED IN THE 2004 VIBROCK REPORT

VIBRATION LEVELS NECESSARY FOR THE POSSIBLE ONSET DAMAGE TO PROPERTY		
50 mms^{-1}	Produce structural damage to residential type structures	USBM
50 mms^{-1} at 40 Hz	Guide value to prevent cosmetic damage to property	BS 7385
15 – 20 mms^{-1} at 4 Hz and 15 Hz	Guide value to prevent cosmetic damage to property	BS 7385
12.7 mms^{-1}	Onset of cosmetic damage (USBM recommended for such relatively unusual vibration)	USBM

TABLE 2.2: ASSESSMENT CRITERIA INCLUDED IN THE 2004 VIBROCK REPORT

2.2.5 By comparison, a summary of the thresholds for the onset of building damage for ground-borne vibration and air overpressure as presented in Southdowns report 'Criteria for the assessment of potential building damage effects from Range Activities' which were adopted for the 2015 Southdowns noise and vibration study, are presented in Tables 2.3 and 2.4 for vibration and air overpressure respectively.

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[1]		[2]	[3]	50 mms^{-1} at 4 Hz and above	
Unreinforced or light framed structures. Residential or light commercial type[1]		0.6 mm zero to peak[1]	[3]	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[4]	**Any building[5]**	**0.6 mm zero to peak[1]**	**12.5 mms^{-1}**		
	Vulnerable Structures[6]		**6 mms^{-1}**		

TABLE 2.3: SOUTHDOWNS ADOPTED ASSESSMENT CRITERIA FOR GROUND-BORNE VIBRATION THRESHOLDS FOR ON-SET OF COSMETIC DAMAGE TO BUILDINGS

Notes:
[1] – Following guidance from BS 7385-2
[2] – damage thresholds for maximum displacement below 4 Hz for reinforced or framed structures and heavy commercial buildings are not defined in BS 7385-2.
[3] – damage thresholds for PPV below 4 Hz for any building type are not defined in BS 7385-2
[4] – Cautious thresholds adopted for this study which do not indicate a level above which damage will occur, rather they offer a precautionary level at which further consideration may be required.
[5] - probability of damage tends towards zero at 12.5 $mrns^{-1}$ peak component particle velocity (BS7385-2).
[6] – reduction in PPV threshold levels for vulnerable structures based on precautionary principles applied on recent major UK infrastructure projects.

AIR OVERPRESSURE THRESHOLD SCALE [1]		
dB (lin)	**Categorisation**	**Source**
180	Onset of structural damage	BS 6472, BS 5228
171	General window breakage	USBM
151	Some window breakage	USBM
140	Reasonable threshold to prevent glass and plaster damage	USBM
134	USBM 'Safe' maximum	USBM
120	Secondary vibration effects including rattling windows and objects	BS 6472, BS 5228, USBM

TABLE 2.4: SOUTHDOWNS ADOPTED ASSESSMENT CRITERIA FOR AIR OVERPRESSURE THRESHOLDS FOR DAMAGE EFFECTS ON BUILDING STRUCTURE

Notes:
[1] – Compendium of advised thresholds from BSi and USBM sources.

2.2.6 In general the air overpressure assessment criteria are comparable (to within 1 dB) between the current and Vibrock studies with the following notable inclusions in the Southdowns study:

- 140 dB (lin) reasonable thresholds to prevent glass and plaster damage; and
- 120 dB (lin) secondary effects, including rattling objects.

2.2.7 The 120 dB threshold included in the current study is not associated with building damage per se but has been included to enable an appreciation of the possible reasoning behind any reported adverse comment at or above this level. The omission of this threshold will not have affected the key conclusions in the Vibrock report.

2.2.8 Vibrock chose to rely upon a 150 dB threshold as the basis for its damage criteria whereas the current study has presented a more cautious level of 140 dB, below which USBM indicates that damage is improbable.

2.2.9 The difference between these thresholds would only be of consequence for the occasions where measured levels approach or exceed either the 140 or 150 dB mark. This has not been the case at Shoeburyness, where measured levels from both studies have fallen below 140 dB at all off-Range monitoring locations and thus the conclusions relating to building damage should not be affected by the difference in this threshold.

2.2.10 The Vibrock study adopted a PPV assessment criteria of 12.7mms^{-1} for ground-borne vibration based upon USBM guidance, with the following notable differences applied by Southdowns:

- 12.5 mms^{-1} PPV threshold for unreinforced or light framed structures. Residential or light commercial type;

- 6 mms^{-1} PPV threshold for the eventuality that some buildings may be classified as vulnerable structures warranting further caution as recommended in BS 7385-2; and

- In addition to PPV, consideration of maximum displacement of 0.6 mm (zero to peak) where the dominant vibration frequency lies below 4 Hz.

2.3 Results

2.3.1 QinetiQ has advised that there have been no major changes to the scope of activities conducted at MOD Shoeburyness during the period 2004 to 2015, with the overall utilisation of the Range fluctuating by about ±20% over the period 2004 to 2015 when compared with 2004 as a baseline. A copy of the statement provided by QinetiQ is included in Appendix B.

2.3.2 Figure A1 of Appendix A shows a distribution of all the measured off-Range levels recorded during the Southdowns study which were identified as being attributable to Range activity (by satisfying the causality test conditions stipulated). The events catalogued during the Vibrock study are also shown.

2.3.3 The distribution shows that in the current study, 90% of events were at, or below, the 110 – 115 dB L_{Zpeak} range. The Vibrock study shows that 90% of events were at or below the range 130 – 135 dB L_{Zpeak} range. This is explained due to the different triggering system for the two studies, with the current system enabling positive identification of range related events at lower magnitudes. This results in a greater number of the lower level (<100 dB L_{Zpeak}) events having been catalogued in the current study.

2.3.4 Figure A2 shows a comparison of the data points catalogued during both the Vibrock and Southdowns noise and vibration studies presented against distance from the Range. The graph shows that the highest air overpressure levels catalogued during the 2015 Southdowns study at off-site locations (marked in bold symbols), and confirmed to be attributable to Range Activity, are lower than the highest air overpressure levels presented in the Vibrock report at comparable distances from the range.

2.3.5 It can be seen that all air overpressure levels recorded during the Vibrock and current studies remained below the air overpressure thresholds for damage effect on building structures (whether the 150 dB or the more cautious 140 dB threshold is applied).

2.3.6 Detailed analysis of the Southdowns study results has shown that the vibration signals captured at off-Range locations arrived at a similar time to the sound pressure waves. This indicates that the vibration measured at off-Range locations, arising from Range Activities 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 the activity. This is a similar observation to the one reported in the Vibrock study.

2.3.7 This observation confirms that it is not appropriate to rely solely on threshold values which are predicated on the concurrent presence of appreciable ground-borne vibration (in addition to air overpressure) for assessing building damage. For this

reason, and other factors, the USBM recommended maximum 'safe' limit of 134 dB (cited by both Vibrock and Southdowns), which is based upon statistical analyses of such situations, has not been considered the most reliable threshold for assessing the potential for building damage.

2.3.8 During the Southdowns study, no ground vibration readings attributable to Range Activity exceeded the ground-borne vibration thresholds adopted for the study for the on-set of cosmetic damage at any off-Range location.

2.3.9 The Vibrock study identified some vibration magnitudes as high as 12.7 mms^{-1} on two occasions at one location.

2.3.10 Whilst the Vibrock study identified some measured vibration magnitudes as high as 12.7 mms^{-1}, it is reported that the Range was 'inactive'† and as such the data was discarded. The inclusion of the more cautious PPV thresholds above, and the maximum displacement metric as applied by Southdowns would not have materially affected the assessment in the Vibrock report.

2.3.11 Vibrock concluded that:

'In conclusion we would stress that at no time throughout this survey did any events even approach those levels considered necessary for the possible onset of the most cosmetic of damage whether the vibration was ground or airborne.'

'All interested parties should be totally reassured that all vibration, albeit perceptible on occasion, was safe.'

2.3.12 It is assumed that the above conclusion has been made on the basis of an assessment against the presented thresholds in the Vibrock report. Whilst the conclusions of the current study rely upon a different and more cautious damage on-set threshold, and hence inevitably attract different use of terminology by the relevant researchers, the maximum magnitudes of both air pressure and groundborne vibration measured in the current study fall below those measured by Vibrock and either damage threshold (140 or 150 dB) by a considerable margin.

2.3.13 The scientific evidence on which the conclusions are based is therefore no worse in the current study than in the 2004 Vibrock study.

† 'Inactive' defined at the time of the issue of the Vibrock report as the following: "*You will see that, for the majority of the events recorded by Vibrock, the range was not engaged in any activity which could have led to the recorded vibration effect. In such cases, Vibrock has commented that the site was 'Inactive'. To avoid any further possible misunderstanding, I should point out that that does not mean that the Range was closed on that day, but that an analysis of the nature and timing of the recorded event (taking into account the time taken for ground and airborne vibration to travel from the range to the monitors) could not be attributed to any activity on the site at that time.*"

3. CONCLUSIONS

3.1.1 A review of the 2004 Vibrock Limited report titled *'An Assessment of Environmental Vibration Produced During Explosive Activities at Shoeburyness, Essex from January 2003 to March 2004'* has been undertaken with reference to the requirements of the SRD specifications.

3.1.2 QinetiQ advised that there have been no major changes to the scope of activities conducted at MOD Shoeburyness during the period 2004 to 2015, with the overall utilisation of the Range fluctuating by about ±20% over the period 2004 to 2015 when compared with 2004 as a baseline.

Vibrock Study Approach

3.1.3 There are notable differences in the approaches adopted in the Vibrock study and the current Southdowns study, with the latter incorporating a greater scope, complexity and specification than the former.

3.1.4 The improvements in technology, data capture and processing techniques between the studies have led to a much larger dataset being acquired (2015) with a higher degree of certainty attached to the causality between Range Activities and measured magnitudes.

3.1.5 The general approach adopted in the Vibrock Study with regards to: the deployment of monitoring equipment at on-Range and off-Range locations; the measurement of air overpressure and groundborne vibration magnitudes; and the assessment of measured magnitudes against published effect thresholds remains a valid approach.

Vibrock Study Effects

3.1.6 Southdowns has undertaken a contemporary review of published guidance and other research findings to determine appropriate assessment criteria for the assessment of potential building damage effects from Range Activities. The findings of this review have been compared with the assessment criteria presented in the 2004 Vibrock report and the primary sources of guidance relied upon in the Vibrock study remain valid in relation to the risk of potential building damage.

3.1.7 The absence of appreciable vibration propagating through the ground during both the current and previous studies, as well as other factors, has precluded the reliable application of the 134 dB 'safe' maximum limit recommended by the USBM for the onset of building damage on this occasion. Notwithstanding this, all measured levels from both studies would fall below the threshold in any case.

3.1.8 Southdowns has chosen a more cautious air overpressure threshold for indicating the potential onset of damage, below which damage is described as improbable. The difference in threshold is of little consequence to the findings of either study as off-Range measured values from both studies fall considerably below either of the threshold values.

Vibrock Study Findings

3.1.9 The results presented in the 2004 Vibrock report have been compared against the 2015 Southdowns noise and vibration study results.

3.1.10 When the magnitudes of air overpressure values presented in the Vibrock report are compared against the results of the 2015 Southdowns noise and vibration study, they are observed to be of a similar or lower magnitude, with none exceeding the onset of building damage thresholds (either 140 or 150 dB) at off-Range locations.

3.1.11 When the magnitudes of vibration values presented in the Vibrock report are compared against the results of the 2015 Southdowns noise and vibration study, they are observed to be of a similar magnitude. On some occasions the Vibrock study identified magnitudes as high as 12.7 mms^{-1}, however, it is noted the Range is reported as being 'inactive' and these data have been discarded accordingly.

3.1.12 The Vibrock Study report concluded that during the survey, events did not even approach those levels considered necessary for the possible onset of the most cosmetic of damage. Similarly, the current study has found that all measured air overpressure and vibration magnitudes fall considerably below the adopted assessment criteria.

REFERENCES

1. Hogg, D.J. 2004. *An Assessment of Environmental Vibration Produced During Explosive Activities at Shoeburyness, Essex From January 2003 to March 2004*. Vibrock RO4.3760/2/DJH

2. A.K. Waters. 2012 Shoeburyness Noise & Vibration Monitoring Study (NVMS), System Requirements Document. QINETIQ/12/02300/1.0/ 2012

3. Southdowns Environmental Consultants Ltd. 2015. *Criteria for the assessment of potential building damage effects from Range Activities 1897m-SEC-00151-04.*

APPENDIX A: FIGURES

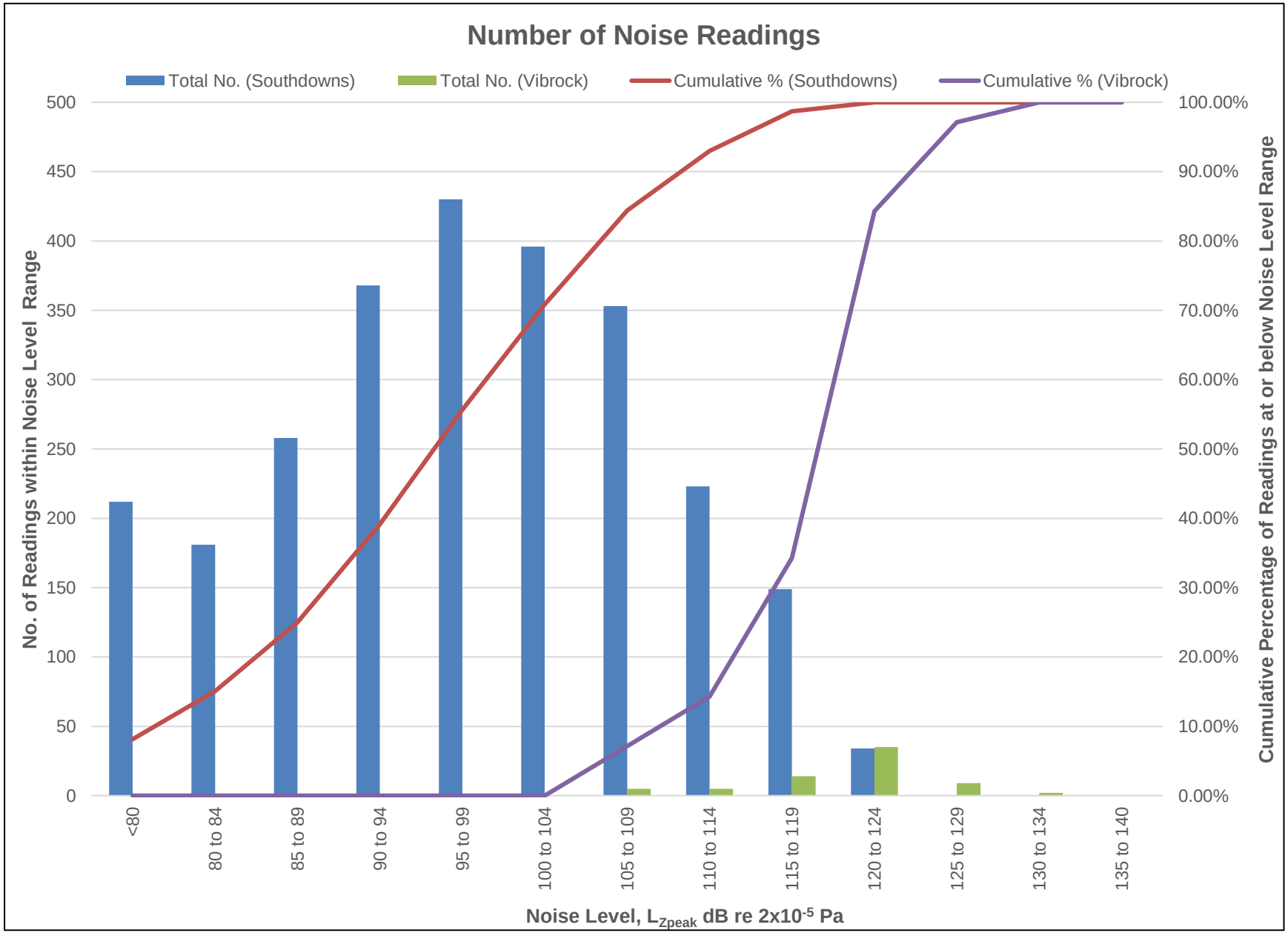

FIGURE A1: DISTRIBUTION OF OFF-RANGE READINGS CATALOGUED DURING THE VIBROCK AND SOUTHDOWNS STUDIES

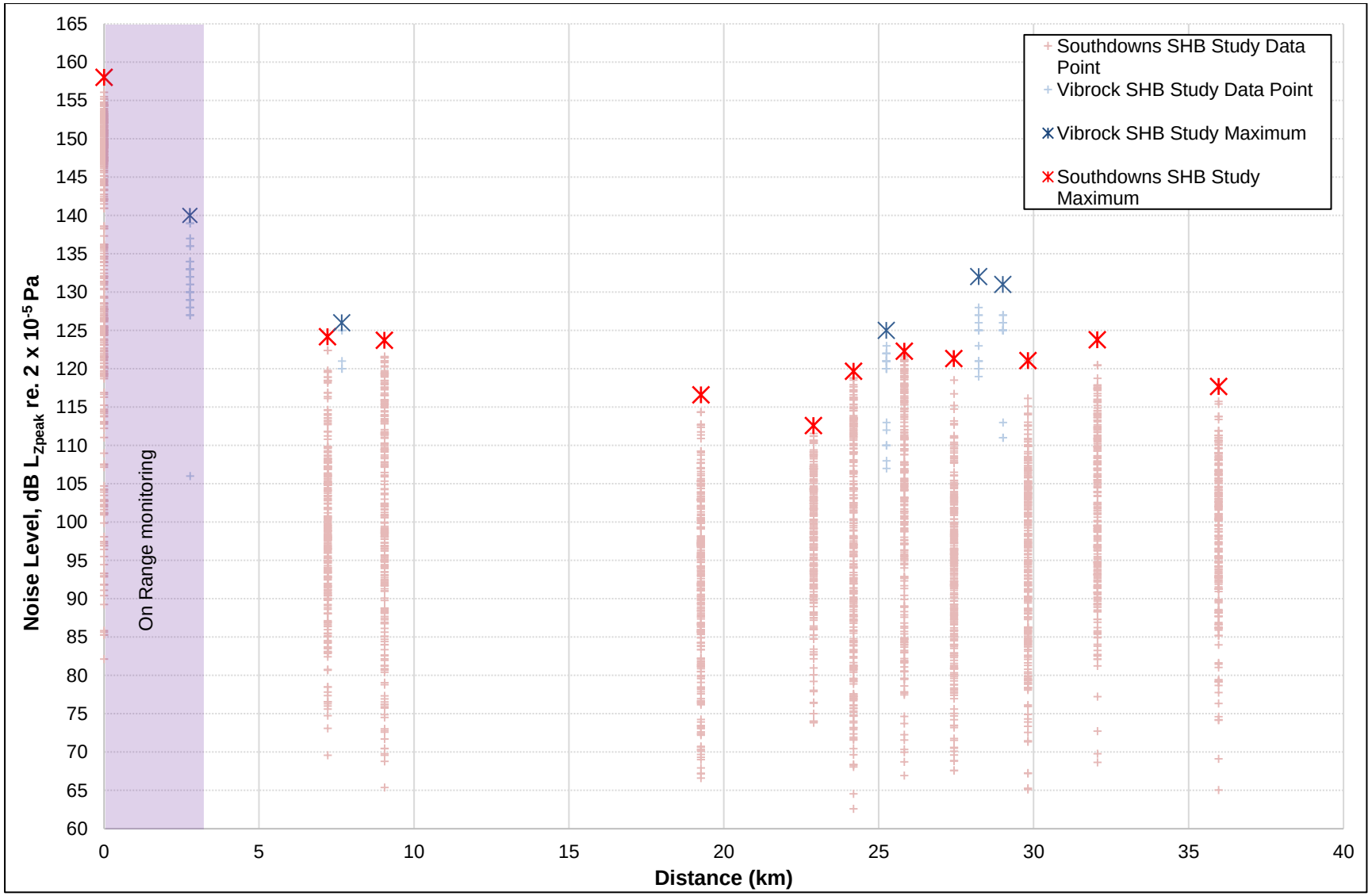

FIGURE A2: VIBROCK AND SOUTHDOWNS NOISE AND VIBRATION STUDIES, DATA COMPARISON

APPENDIX B: QINETIQ STATEMENT

"Range Activities at MoD Shoeburyness 2004 to 2015

There have been no major changes to the scope of activities conducted at MoD Shoeburyness during the period 2004 to 2015 (between the Vibrock Study and this Noise and Vibration Study), with noise generated principally by the activities of large-calibre gunfire, static detonation of munitions (mostly for disposal of life-expired items, though also for trials) and military training (Explosive Ordnance Disposal (EOD) training). There have also occasionally been static detonations arising from real (not training) EOD events. For instance, with no new large-calibre guns entering service (or on test to enter service), during the period 2004 to 2015, the noise arising from large-calibre gunfire has throughout the period been from 105mm, 120mm, 155mm and 4.5in calibre weapons.

Both the amounts of each type of activity (gunfire, static detonations and military training) and the total amount of range activity have varied year by year to meet operational requirements; the overall utilisation of the Range fluctuating by about ±20% over the period 2004 to 2015 when compared with 2004 as a baseline.

This period has also seen the introduction (from 2006) of test shots being fired first each day that large-calibre gunfire or static detonation range activities are planned to occur in order to validate the acoustic forecast and calculate the maximum permissible NEQ (Net Explosive Quantity) that can be detonated that day. .

This was followed by the introduction of the current Noise Monitoring System (NMS; a system of seven noise monitoring stations deployed at and around the Range) in 2010 that provides live readings at the Range of the sound pressure levels at locations in Essex and Kent some distance away from the Range.

For most Range activities, the use of test shots and deployment of the NMS described above support active management of the Range operating within the contracted noise limit through a process of predicting the likely noise level for the planned test shot, measuring the noise level at the NMS locations when the test shot is fired and then either setting a maximum size of detonation that can be fired (to stay within the noise limit) or withholding permission to fire if an individual event would clearly exceed the limits.

Throughout the day the noise level at the NMS locations is continuously displayed in Range Control and monitored for each Range event to check that the noise limit is not being exceeded and, if necessary, the maximum permissible NEQ will be adjusted in order not to exceed the noise limit.

The only exceptions to this have been specific activities (eg EOD training) or specific occasions where MoD has provided or has been granted a dispensation to potentially exceed the normal operating noise limits (usually on the basis of meeting an operational requirement where it would be unreasonable to delay the Range activity)."