NATIONAL
ACOUSTIC
LABORATORIES
COMMONWEALTH
DEPARTMENT
OF HEALTH

Community reaction to noise from Colston Hill AFV Range, Puckapunyal

NAL Internal Report
No. 40
March 1983

NATIONAL ACOUSTIC LABORATORIES

COMMONWEALTH DEPARTMENT OF HEALTH

INTERNAL REPORT NO 40

MARCH 1983

COMMUNITY REACTION TO NOISE FROM COLSTON HILL AFV RANGE, PUCKAPUNYAL

T.J. SMITH

ADVANCED ACOUSTICAL TECHNOLOGY SECTION

Australian Government Publishing Service

Canberra 1983

ISBN 0 644 01238 2

Printed by Canberra Reprographics Pty Limited,
119 Wollongong St, Fyshwick, A.C.T. 2609

CONTENTS

ABSTRACT

Results are presented of measurements of the noise produced by the 105mm gun fitted to the Leopard tank while using the proposed AFV range at Colston Hill, Puckapunyal. The measurements were taken on the northern boundary of three rural properties adjacent to the range over a period of three days. The results are compared to the relevant criteria for hearing and structural damage, and community annoyance. The effectiveness of certain noise control measures proposed by the Department of Defence are also examined.

INTRODUCTION

The acquisition of land adjacent to the Puckapunyal Range East has meant that local residents will be exposed to noise levels resulting from Army training activities. The purpose in acquiring the land, known as Range West, was, in part, to establish an AFV (Armoured Fighting Vehicle) static live firing site for the Leopard tank. The site will be located on the northern side of Colston Hill approximately two kilometres from the southern boundary of Range West. Three rural properties, Coffey, Anderson, and Love, adjacent to the Tooborac Road which runs along the Range West Southern boundary, form the main area of concern.

At the request of the Environment Section, Defence Facilities Division of the Department of Defence the Applied Noise Research Section of the National Acoustic Laboratories undertook to determine if the noise would exceed the appropriate community standards, and in the event of it doing so, the effectiveness of proposed noise control measures in reducing the noise level. As part of this study noise measurements were taken over a period of three days at three sites in December 1981. The aim of this report is to present the data collected over the three day period, determine whether or not the noise level is in excess of the appropriate criterion for hearing conservation, structural damage and community reaction, and examine the specific noise control measures proposed by the Department of Defence.

MEASUREMENT PROCEDURE AND INSTRUMENTATION

Two Leopard tanks were positioned on the northern side of Colston Hill, below the crest. They fired alternatively at any one of ten targets ranging over a distance of 750 to 2500 metres away, and within a 30 degree arc; see figure 1. The ammunition consisted of practice HEAT (High Explosive Anti-Tank), practice APDS (Anti-Personnel Discarding Sabot) and HESH (High Explosive Squash Head), of which mainly HEAT and APDS was used during the exercise. A total of only ten rounds of HESH were fired.[1] For each round of HESH, which explodes on impact, the firing and impact noise were measured separately. Muzzle velocity, propellant type and charge size data on the three types of ammunition are given in Table 1.

The three measurement sites were situated on the northern boundary of each of the three properties adjacent to the range; see figure 1. Site 1 was 2.2 kilometres from the firing point, site 2 was 1.8 kilometres, and site 3 was 2 kilometres. It was expected that the noise levels at the selected measurement sites would be typical levels at the boundary though they would be marginally higher than those at the residence on the property. After representations from the owners measurements were also taken at the residence on each property (see Appendix A). Some measurements were also taken at the firing point so as to monitor the variation in level at the source.

---

1. The HESH ammunition was only made available during the exercise not having originally been proposed for use.

Measurements were taken over a period of three days, at three times each day (early morning, early afternoon, and evening).[2] At each time a minimum of ten rounds were fired, to allow for short term variations in noise level. Longer term variations caused by changing meteorological conditions would be partly accounted for in taking measurements over three days. With a wide variation in noise level the data would be more likely to be representative of what the residents would be exposed to during future use of the range, though the number of rounds fired during the three days would not necessarily be representative of future range activities.

The instantaneous peak linear sound pressure level (SPL) in decibels (dB lin) relative to 20 micro Pa, of each round was measured using a Bruel and Kjaer Impulse Precision Sound Level Meter Type 2209 fitted with a Bruel and Kjaer half inch Condenser Microphone Type 4134. The Sound Level Meters were mounted on tripods which were adjusted so that the microphones were 1.2 metres above ground level. They were calibrated at the beginning of each measurement session with a Bruel and Kjaer Pistonphone Type 4220. Each measurement was recorded along with the time, ammunition type, and any relevant comments regarding the meteorological conditions. Two way radio was used to co-ordinate between the firing point and measurement sites, as well as to provide information on the ammunition type.

There was no monitoring of meteorological conditions. Notes regarding general wind direction, qualitative assessment of wind speed (eg. calm, slight, gusty, etc.) temperature, and cloud cover were made at each site. Data, wind speed and direction for the three days, was later

2. No measurements were taken in the evening of the last day.

obtained from the Bureau of Meteorology which has a station at Mangalore Airfield some 32 kilometres to the east of Colston Hill. It provides a general guide to the wind conditions in the area and their probable effect on noise levels. This data and the observations made at the measurement sites were found to be in general agreement.

EXAMINATION OF NOISE DATA

The sound level data for the HEAT and APDS type ammunition for the three days are shown in figures 2 to 4. Data for the HESH from the evening of the 9.12.81 and morning of the 10.12.81 is shown in figure 5. The mean levels for HEAT and APDS at each time and for the three days is shown in Table 2. No distinction has been made between HEAT and APDS. In the only session in which a similar number of rounds of APDS and HEAT were fired the difference between their mean levels was only 1 or 2dB, depending on the measurement site. This is small in comparison to a range in level of up to 8dB for each type, and therefore is not considered significant.

Only ten rounds of HESH were fired, and not all rounds could be measured at each site largely because of wind interference with the instrumentation. Therefore statistically significant mean levels could not be determined at each site. Nevertheless, the data collected does indicate that the firing sound levels are significantly lower, in the order of 13dB, than for both HEAT and APDS. The HESH impact levels were of the same order as the firing noise. At the time the measurements were taken there was a southerly wind which may have affected the impact levels more than the firing levels. The low HESH firing sound levels cannot be fully explained by the muzzle velocity and charge size, see Table 1, being considerably lower than for HEAT and APDS.

The range in sound levels during a measurement session varied from 3dB to 13dB over the three day period. There was a tendency for it to be greater when there was a southerly wind. These short term variations are mainly due to the effect atmospheric turbulence has on sound propagation. In two sessions (viz. morning of 9.12.81 and 10.12.81) there was a shift in the range of levels due to a change in meteorological conditions (eg. change in wind direction and/or speed). There were quite marked shifts in the overall levels from day to day. For example, it can be seen by comparing figures 2 and 3 that the levels were generally higher for the 8.12.81 than for the 9.12.81. There was also a quite large change in levels between the morning and afternoon sessions of day 3 which can be related to a change in wind direction from south-west to north.

The data also shows that the noise levels at site 1 were generally higher than at site 2 which in turn was marginally higher than those at site 3. This can be seen in figures 2 to 4 and in the mean levels in Table 2. It is postulated that this is due to the "pear" shaped directivity pattern typical of artillery weapons where the level at the front is highest and decreases towards the rear. The three sites 1, 2 and 3 were oriented at approximately 110°, 150° and 165°, respectively, to the gun axis, indicating that the expected levels at sites 2 and 3 would be similar and at site 1 would be somewhat higher again.

EFFECTS OF NOISE

Hearing Damage

For evaluating the risk of hearing damage from exposure to gunfire noise the National Acoustic Laboratories use the CHABA criterion (1). This criterion relates the duration and peak level of the impulse to the permissible number of exposures per day. The criterion "floor" occurs at 138dB for a duration of 200ms to 1s and 100 exposures per day; for a ten fold change in the number of exposures the peak level is adjusted by 5dB. Over the three days of measurements the highest level measured was 123dB. Typically the duration of the impulse would be hundreds of milliseconds which is in the range specified above. The permissible number of exposures would be 1600 per day assuming a peak level of 123dB. Since projected usage of the range, shown in Table 3, indicates an average of twenty rounds will be fired per day there is no likelihood of the residents incurring any hearing damage.

Structural Damage

Airblast from explosions can cause structural damage if the level is sufficiently high, the damage manifesting itself initially in the form of broken or cracked windows, and cracked plaster when it is on a flexible backing. Such damage is likely to occur in structures in poor or aged condition before affecting those in good condition. A recent report (2) on the possibility of structural damage caused by noise from a 500 lb bomb explosion indicated that at levels below 140dB peak linear sound pressure level damage is extremely unlikely. Airblast from the 105mm gun mounted in the Leopard tank would not contain the same amount of extremely low frequency energy (i.e. below 20Hz) that is produced by large quantities of explosives. This implies that the 140dB damage limit will be even more conservative when applied to noise from artillery of this size.

This criterion is well above the maximum measured level of 123dB. Assuming that this is a representative maximum sound level then there would be no likelihood of structural damage resulting from future range activities.

Community Annoyance

In previous studies (3, (4), (5) of noise from army firing ranges the Composite Noise Rating (CNR) has been used for assessing community response to impulse noise. The CNR as applied to gunfire noise was derived empirically from aircraft noise and sonic boom data (6). A recent study of noise around Holsworthy Army Firing Range by A. Hede and R. Bullen, of these laboratories, aims at establishing a relationship between annoyance and sound level for artillery. Though a report has not been published, a preliminary examination of the data has provided a usable experimentally based criterion to replace the modified CNR.

The criterion represents a level at which 10% of the exposed population are "seriously affected"; the 90 CNR criterion previously used assumed that 10% would be "highly annoyed". For Holsworthy preliminary analysis shows that this occurs when the long term average peak SPL is approximately 95dB. Analysis of the data has not so far helped to reveal whether or not a relation exists between annoyance and number of rounds. The CNR also uses an "equal energy" relation between SPL,number of rounds and annoyance. The "equal energy" principle will be applied here so as to adjust the 95dB criterion for the difference in rounds fired at Holsworthy and Puckapunyal. For Holsworthy the average number of rounds fired per day was probably in the range 40 to 60. For Puckapunyal the average number of rounds of HEAT and APDS per day will be 13. The correction Δ to be added to 95dB is given by,

$$\Delta = 10 \log 40/13 \text{ to } 10 \log 60/13$$

$$= 5 \text{ to } 7 \text{ dB}$$

Therefore the 10% seriously affected level for a community adjacent to the Puckapunyal Range West would be 100 to 102 dB peak SPL. For convenience only the higher figure will be used as the annoyance criterion. This being a long term average peak SPL it can be directly compared with the average peak levels in Table 2, which exceed the criterion by 15dB, 11dB and 10dB at sites 1, 2 and 3, respectively.

Noise from the HESH ammunition was not considered in this analysis since there was not enough data to estimate long term mean levels. However, the data gathered was considerably lower than that for HEAT and APDS and would not appreciably affect the above result.

It is clear the area that will be affected by excessive sound levels extends considerably beyond the three properties considered in this report. An accurate estimate of the area in which the sound level will exceed 102dB is outside the scope of this report, requiring more sound level data gathered over a longer period of time.

NOISE CONTROL

As part of the study the Department of Defence requested that should the sound level be found to be excessive two proposals for noise control be examined. The proposals were,

a) to resite the firing point, but within the vicinity of Colston Hill, presumably further down the northern side, and/or

b) construct an earth mound, approximately ten metres high, behind the tanks.

The proposals to be effective would have to achieve a noise reduction of 15 dB at the southern boundary.

a) An acceptable noise level cannot be achieved by resiting the firing point elsewhere within the vicinity of Colston Hill as the required noise reduction is too high. The extra shielding gained by moving the tanks further down the northern side would only be slight (see below). If a simple spherical spreading model for sound propagation is assumed, to attain 15dB of noise reduction the firing point would need to be resited nine kilometres north of Colston Hill.

b) The effect of a ten metre high earth mound behind the tanks was examined in detail (see Appendix B). It is clear that such a mound could not achieve the required noise reduction, at best providing about 3dB under neutral meteorological conditions. It would be unlikely that such a mound would have any significant effect on the mean noise level at the southern boundary.

Recently Driscoll and Sneck showed that reductions of this order are attainable with muzzle suppressors. A suppressor of size 3.05 metres in diameter by 21.3 metres in length was designed for a fixed cannon test facility using a stop butt. It would have no application in the type of live firing to be conducted at Colston Hill. The required noise reduction may be attained in a facility housing the tanks, and acoustically designed to disipate the energy or a proportion of it. As it is not within the scope of this report to treat in detail the requirements for such a facility it is recommended that its feasibility be examined.

CONCLUSION

The future use of Colston Hill for AFV static live firing is likely to produce sound levels at the Coffey, Anderson and Love properties which would be unacceptable by community standards. Noise measurements taken over a period of three days indicate that the noise level will considerably exceed the criterion used for community annoyance, though there is no risk of hearing or structural damage. It is also clear that the area in which the noise will be excessive encompasses considerably more than the three properties considered in this report. Since this finding is based not only on measured sound levels but also on information regarding number of rounds fired and days per year the range will be used, any variation in these will affect the noise exposure.

The Department of Defence noise control proposals will not be effective in reducing the noise to an acceptable level. If resiting the AFV range at a suitable distance from the boundary is not viable than other proposals need to be examined.

REFERENCES

1. WARD, W.D., et al., "Proposed Damage Risk Criterion for Impulsive Noise (Gunfire)", Report of Working Group 57. National Academy of Sciences - National Research Council, Committee on Hearing, Bio-acoustics, and Biomechanics (CHABA).

2. SMITH, T.J. "Structural Damage Resulting Form Airblast Produced by MK82 Bombs - Puckapunyal Army Firing Range", NAL Report No. 94, May 1982.

3. KENNA, L.C. "Noise Trials - Kingswood", NAL Report 230/2/4 (1976).

4. BULLEN, R., PEPLOE, P. ROSE, J.A. and Noise Services Section," Noise Levels Resulting from Artillery Firing at Holsworthy Army Range", NAL Internal Report No. 11 (1979).

5. BULLEN, R., KENNA, L.C. and NAL Noise Section," Propagation of Sound from Blasting at Singleton Army Range", NAL Report No. 71 (1978).

6. CARTER, N. "A Method of Evaluating Community Response to Noise from Military Firing Ranges", NAL Report No. 67, February 1977.

7. DRISCOLL, D.A., and SNECK, H.J. "Cannon Muzzle Noise Suppression Facility Analysis and Tests", Noise Control Engineering, Vol. 6, no. 2, March-April 1981.

8. "Puckapunyal Range Development Plan". Army Office, Department of Defence. April 1981.

TABLE 1

TYPE	MUZZLE VEL. (M/Sec)	PROPELLANT/CHARGE SIZE (KG)
HESH L35	731	NH-033/2.87
HEAT M490	1174	M30/5.1255
APDS L52	1478	NQ/M-047/5.598

TABLE 2

MEAN PEAK SPL

DATE	SESSION	SITE 1	SITE 2	SITE 3
	1	120 N = 18	116 N = 19	115 N = 19
8.12	2	120 N = 12	114 N = 8	107 N = 7
	3	118 N = 10	110 N = 8	107 N = 7
	1	112 N = 35	107 N = 31	106 N = 33
9.12	2	110 N = 10	105 N = 10	106 N = 11
	3	106 N= 19	106 N = 17	108 N = 19
	1	110 N = 20	107 N = 19	109 N = 18
10.12	2	121 N = 10	119 N = 10	117 N = 9
	3	-	-	-
	MEAN	117	113	112

N = number of rounds measured.

TABLE 3

PUCKAPUNYAL RANGE - PROJECTED USAGE

No. of days/year Colston Hill AFV Range used for live firing (8)	225 static
Total rounds per year of HEAT, HESH and APDS	4518 *

* This figure is based on 105mm ammunition issued to the ARMOURED CENTRE, and can be assumed to be divided equally between the three types.

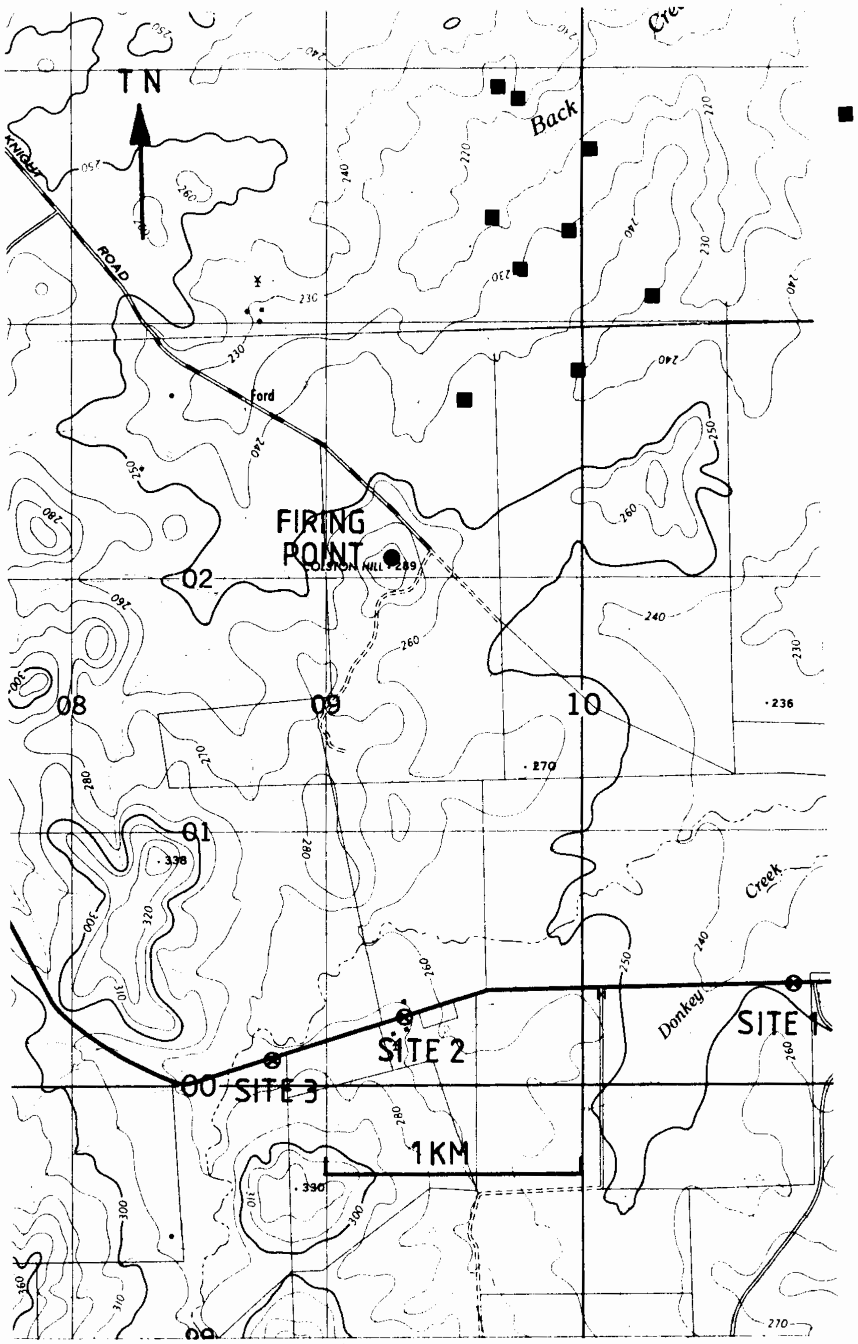

Figure 1. The location of measurement sites and, the firing point; ■ indicates the position of the targets used during the exercise.

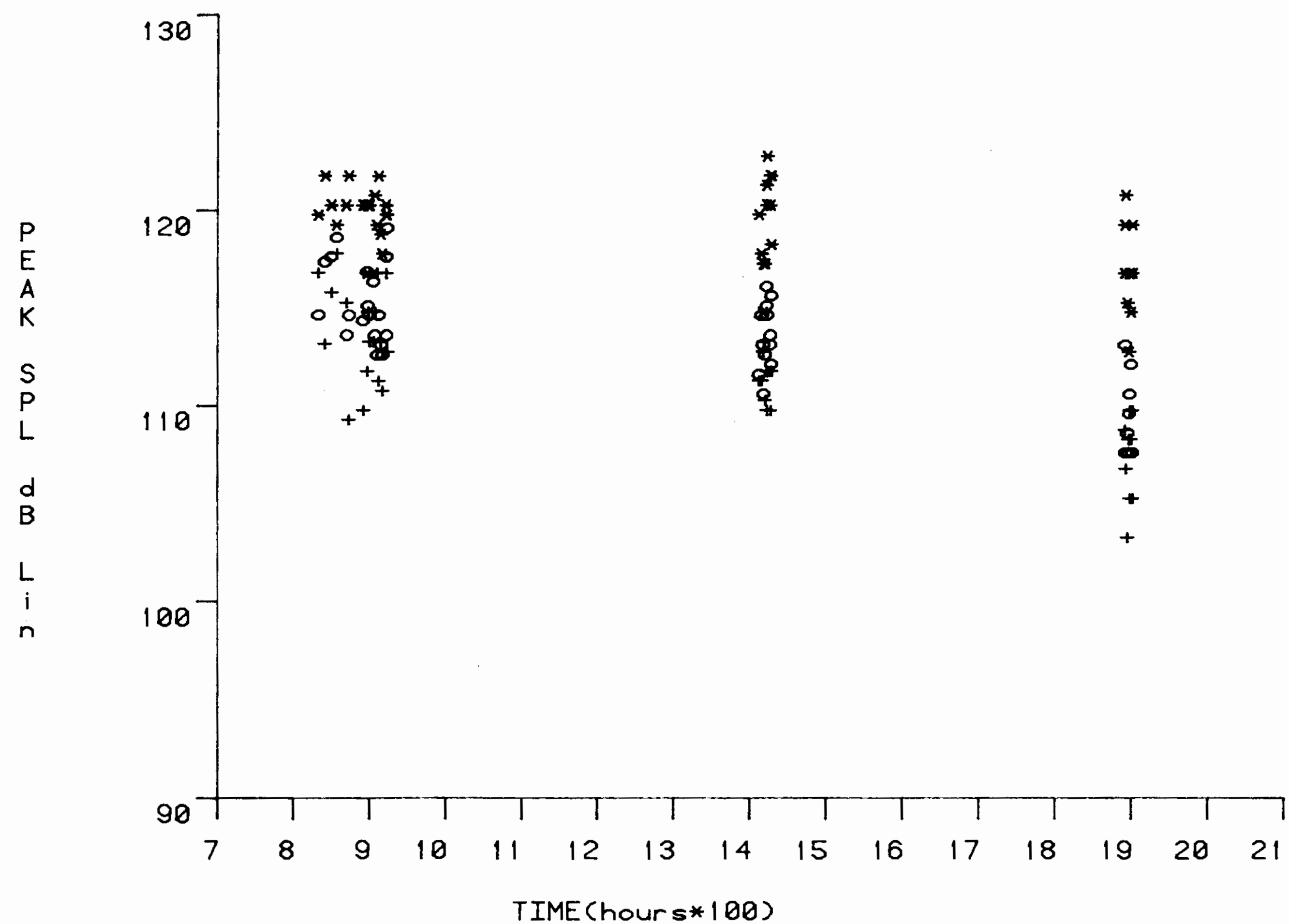

Figure 2. Sound levels for 8.12.81 (*..site 1; o..site 2;+..site 3).

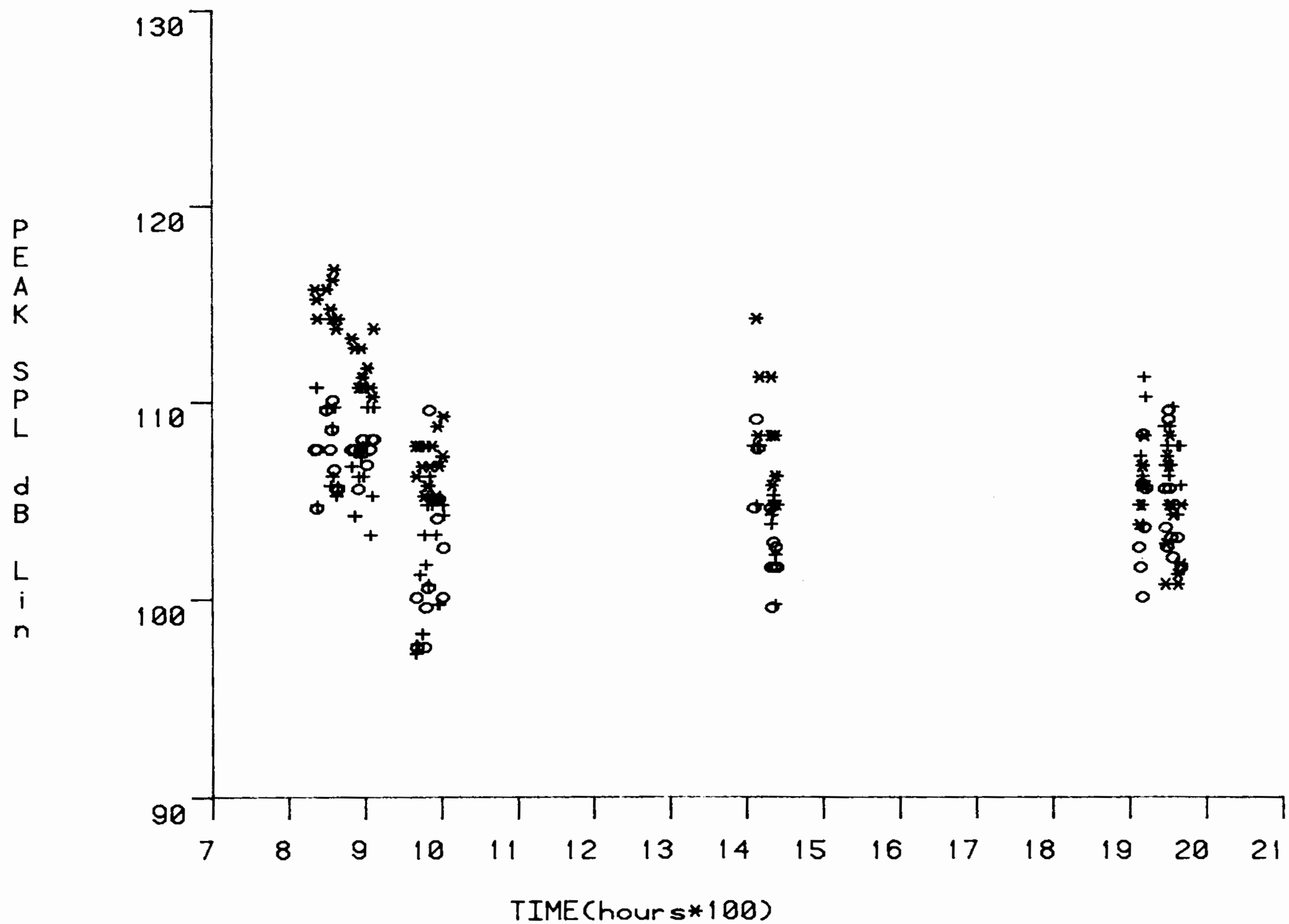

Figure 3. Sound levels (excl. HESH) for 9.12.81
(*..site 1;o..site 2;+..site 3).

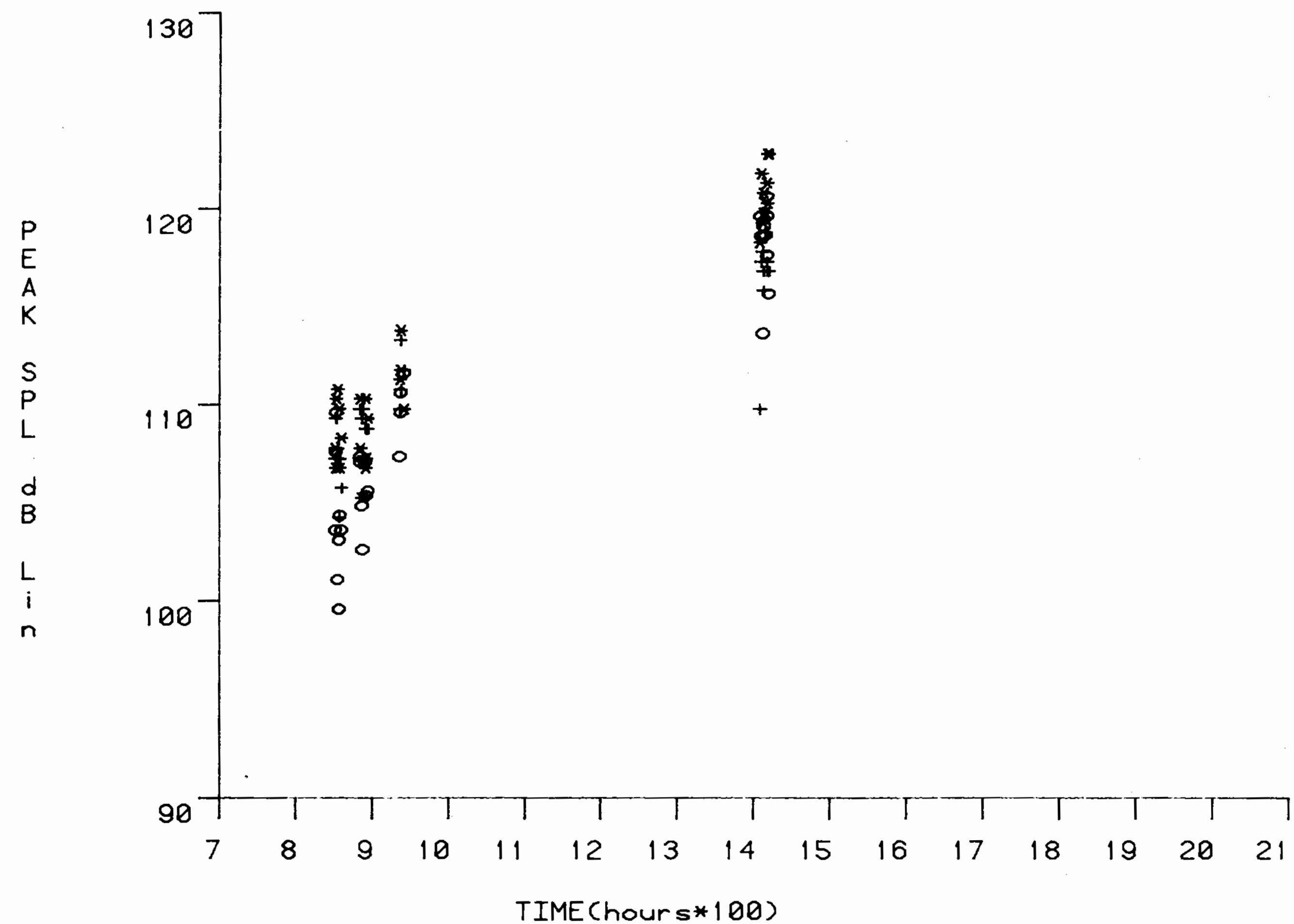

Figure 4. Sound levels (excl. HESH) for 10.12.81
(*..site 1;o..site 2;+..site 3).

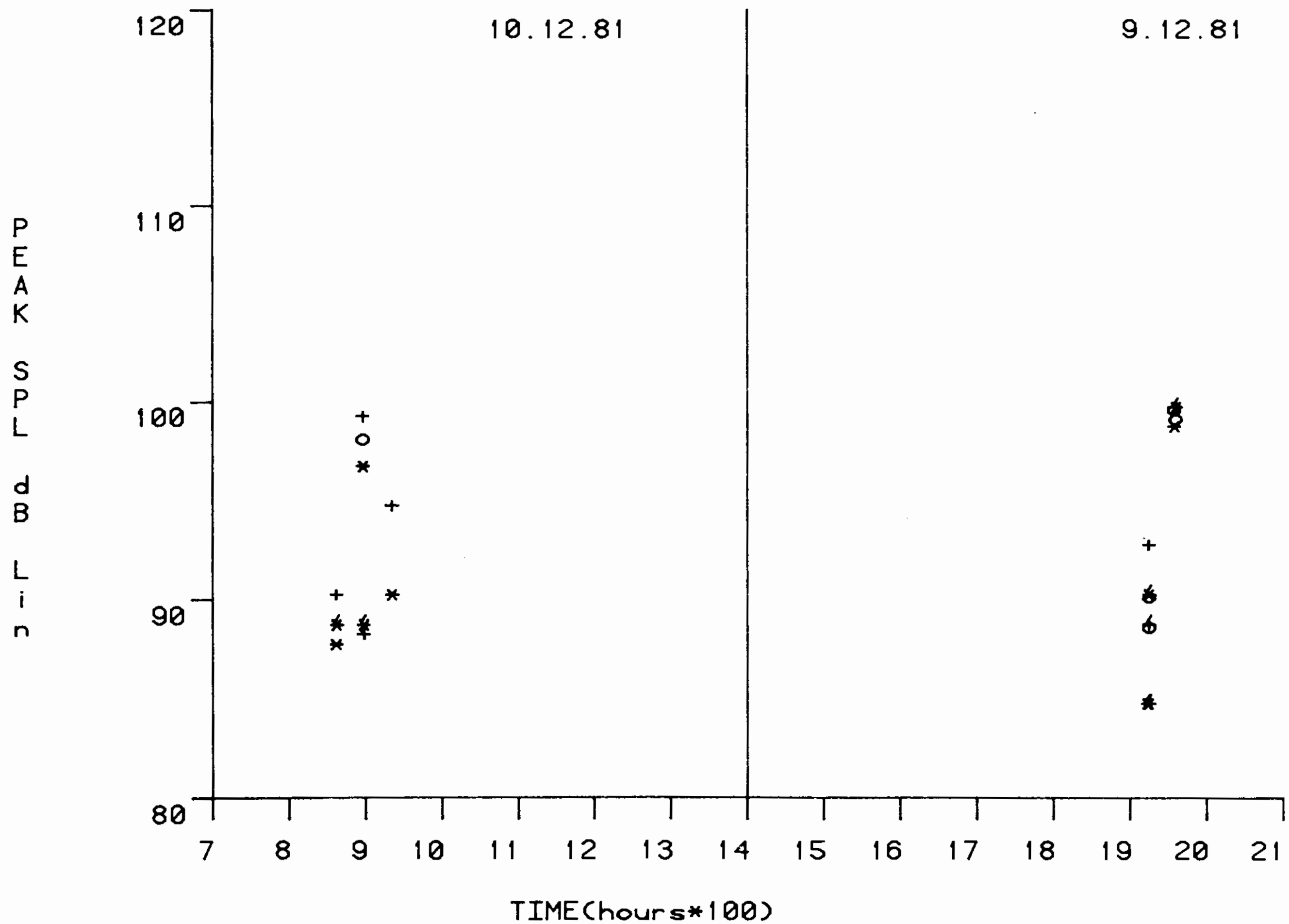

Figure 5. Sound levels for HESH ammunition on 9.12.81 and 10.12.81 (*..site 1;o..site 2;+..site 3 and ' indicates impact).

APPENDIX A

The mean noise levels measured at the owner's residence on each property are shown in Table A1. Measurements were taken at the Coffey and Love properties over three sessions, and at the Anderson property for one session only. As with the three sites on the boundary the noise measurements were predominately of HEAT and APDS type ammunition though some HESH was included but not enough to be statistically significant. Included in Table A1 are the mean levels at the boundary for the same rounds as measured at the residence, and the overall mean for the three sessions.

At the Coffey property the instantaneous differences between the boundary and residence varied from -4 to +6 over the three sessions. At the Anderson property the variation was only -1 to +2 during the one session. The variation at the Love property was +2 to +7. (A positive difference indicates that the level at the boundary, (i.e. the previously selected measurement sites, is higher). The total number of rounds measured were 25, 28 and 11 for the Coffey, Love and Anderson properties respectively. The difference between the mean levels at the boundary and residence was +2, +1, and +4 for the Coffey, Anderson and Love property. Using a simple spherical spreading model for sound propagation it would be expected that the differences would be at most one dB for the three properties. The large instantaneous differences are probably due to atmospheric turbulence and other meteorological irregularities which can vary from site to site and produce significant variations in sound level. Though the Coffey and Anderson residences were at a higher altitude than the boundaries, more so for the Coffey property, this difference would not have a significant effect on sound levels. The data clearly shows that the mean sound level at the boundary is higher than at the residence. For the Coffey and Anderson properties the difference was small and close to what would be expected from the inverse square law for sound propagation. In the case of the Love property the difference was higher than expected.

TABLE A1

MEAN NOISE LEVELS AT BOUNDARY AND RESIDENCE

DATE	SESSION	BOUNDARY			RESIDENCE		
		COFFEY	ANDERSON	LOVE	COFFEY	ANDERSON	LOVE
9.12	1	115	103	107	114	102	103
	3	106	-	108	107	-	104
10.12	1	109	-	109	108	-	106
MEAN		113	103	108	111	102	104

APPENDIX B

EXPECTED NOISE REDUCTION FROM EARTH MOUND

The method for determining the noise reduction provided by an earth mound is that developed by Kurze and Anderson (1). This method applies to a "thin" barrier so that the calculated insertion losses[1] will differ slightly from that obtained with an earth mound. The calculated insertion losses are for a ten metre high barrier at the top of Colston Hill and the tank muzzle fifty metres from the barrier. It was considered that this would be close to an optimum configuration. If the tank muzzle is brought closer to the barrier the insertion loss increases, by 1dB if the distance is halved.

To calculate the insertion loss the wavelength of the sound, which was not available from the measurements, has to be known. Measurements taken at Holsworthy indicate that the spectrum of the noise from 105mm artillery has a peak at approximately thirty hertz. This agrees with data gathered by Driscoll and Sneck on a 105mm M68 tank cannon (2). Therefore, the wavelength at thirty hertz (11.5 metres) has been used.

The relative heights of the source (the tank cannon muzzle) and receiver (a microphone 1.2 metres above the ground) were obtained from drawings made of the cross sectional topography between the firing point and each measurement site.

---

1. Insertion loss is the difference in noise level at a receiver with and without a barrier installed.

The insertion loss (I.L.) due to a "thin" barrier is given by, (3)

$$\text{I.L.} = 20 \log \left(\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}} \right)$$

where $N = 2\delta/\lambda$

δ = path difference (metres)

λ = wavelength (metres)

Figures B2-B4 show the source-barrier-receiver configuration for each site. For sites 2 and 3 there is already a degree of shielding provided by the hill. The insertion loss in these cases has been calculated with and without the earth mound; the difference between the two is the nett insertion loss provided by the mound. The hill insertion loss is so low, 0.2dB, that it could be neglected. Table B1 summarises the calculations and gives the insertion loss of the mound for each site.

The degree of insertion loss is affected by the length of the barrier. The figures in Table B1 apply to a "long" barrier which is approximately ten times the wavelength. Therefore the length of the earth mound would have to be of the order of 100 metres.

The insertion loss also depends on meteorological conditions. The Kurze and Anderson model assumes the sound rays travel in straight lines. When the rays are bent by the prevailing meteorological conditions the barrier insertion loss is affected. If the temperature gradient is positive or the wind direction is from the source to receiver the apparent barrier insertion loss is lower than that calculated. This indicates that the high sound levels would tend not to be affected by the barrier but low sound levels would tend to be lower. The mean sound level, therefore, would be virtually unaffected by the earth mound.

The calculated insertion losses are only an indication of the degree of reduction that can be expected from an earth mound. To obtain a more accurate figure would require knowing the frequency spectrum of the actual impulse, and complex signal processing.

REFERENCES

1. ANDERSON, G.S., and KURZE, U.J., "Sound Attenuation by Barriers", Applied Acoustics, Vol. 4 no. 1, January 1971.

2. DRISCOLL, D.A., and SNECK, H.J. "Cannon Muzzle Noise Suppression Facility Analysis and Tests", Noise Control Engineering, Vol. 6, no. 2, March - April 1981.

TABLE B1

	SITE 1	SITE 2		SITE 3		
	Barrier	Existing	Barrier	Existing	Barrier	
A (m)	50.64	50.04	51.42	50.04	51.42	
B (m)	2200.66	1750.09	1750.22	1950.08	1950.20	
d(m)	2050.47	1800.07	1800.07	2000.06	2000.06	
S(m)	0.83	0.06	1.57	0.06	1.56	
N	0.14	0.01	0.27	0.01	0.27	I.L.
I.L. (dB)	2.2	0.19	3.61	0.19	3.59	
Nett Insertion Loss (dB)	2.2	3.4		3.4		

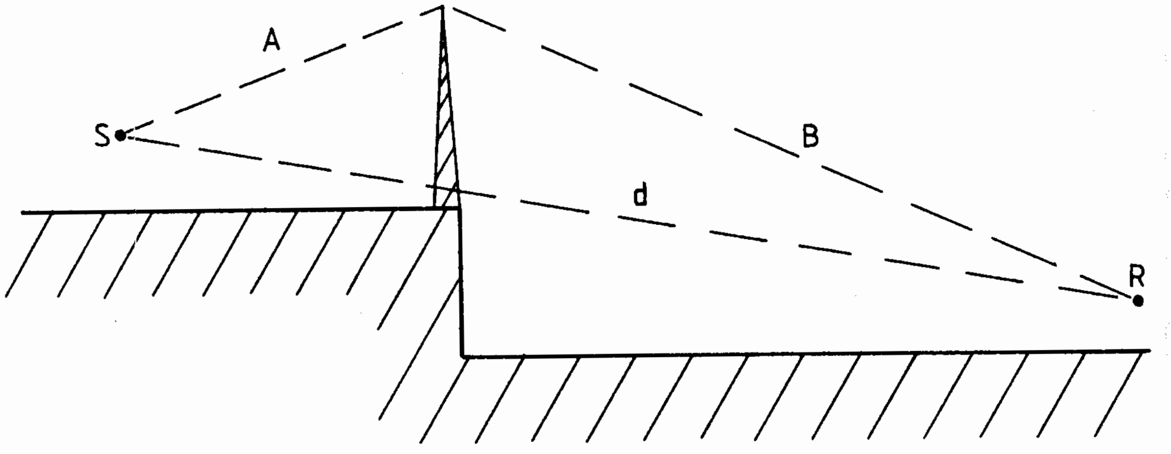

Figure B1. This is the basic comfiguration of source-barrier-receiver for Colston Hill. The path difference, S = A + B - d.

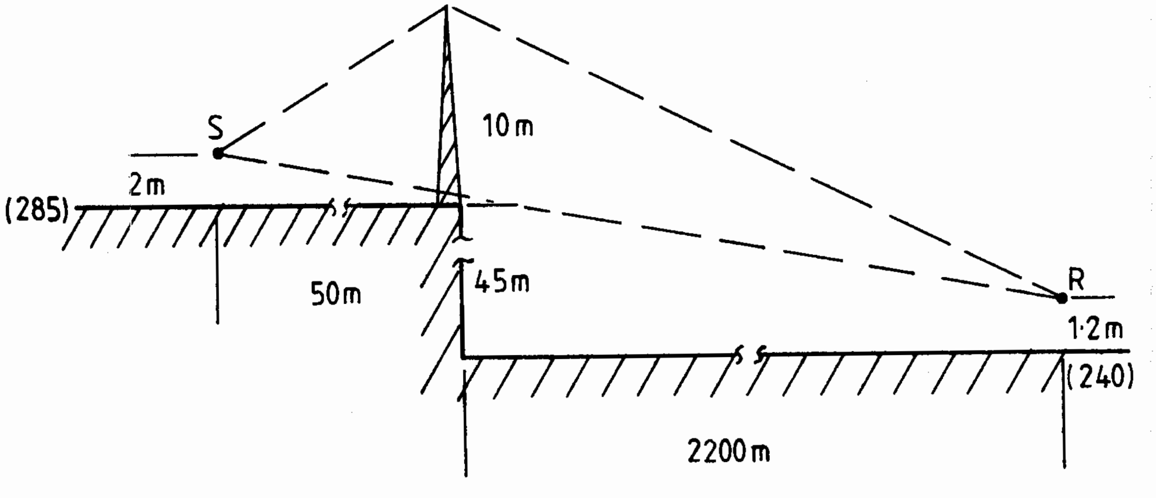

Figure B2. Schematic showing source-barrier-receiver configuration for site 1.

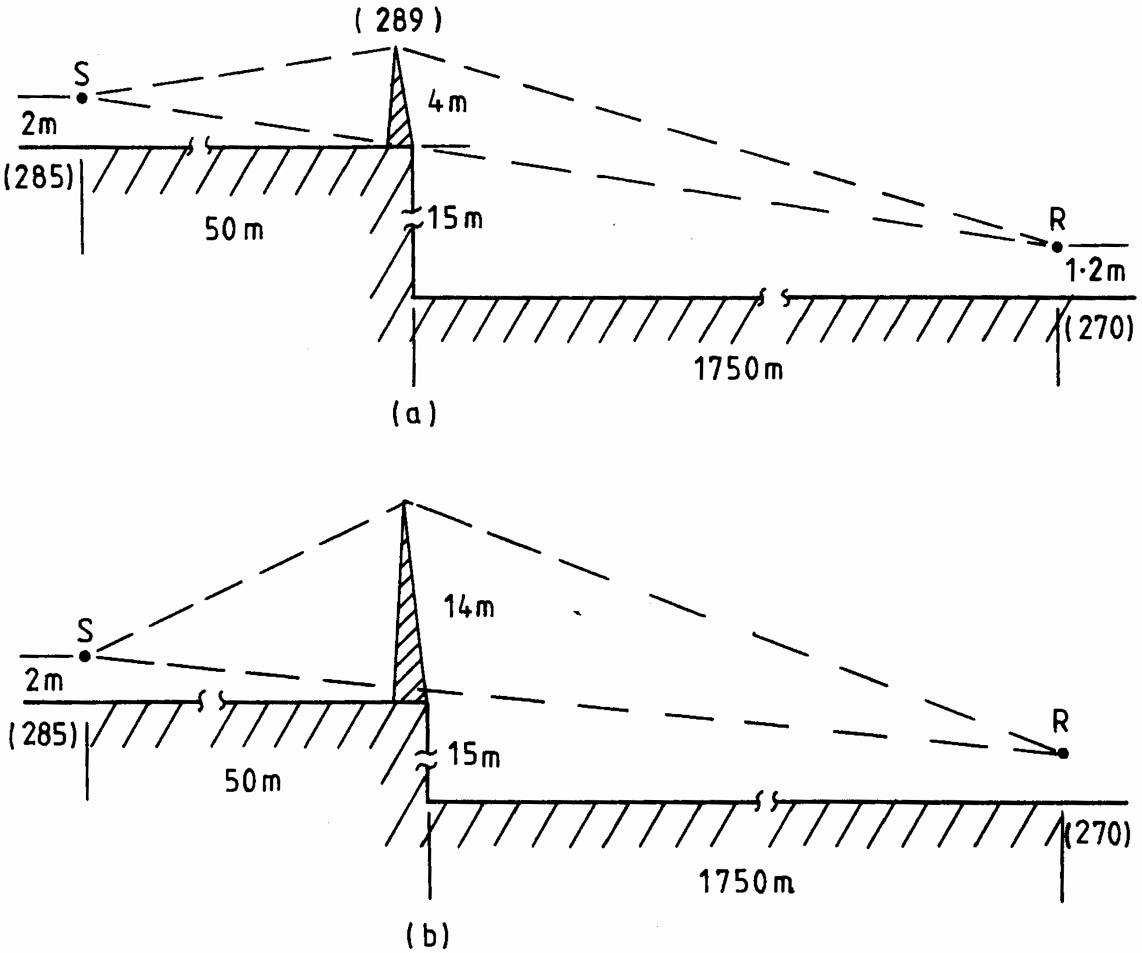

Figure B3. The configuration for site 2 that would exist without the 10 metre high earth mound is shown in (a). The addition of the earth mound is shown in (b). The figures in brackets are the heights above sea level.

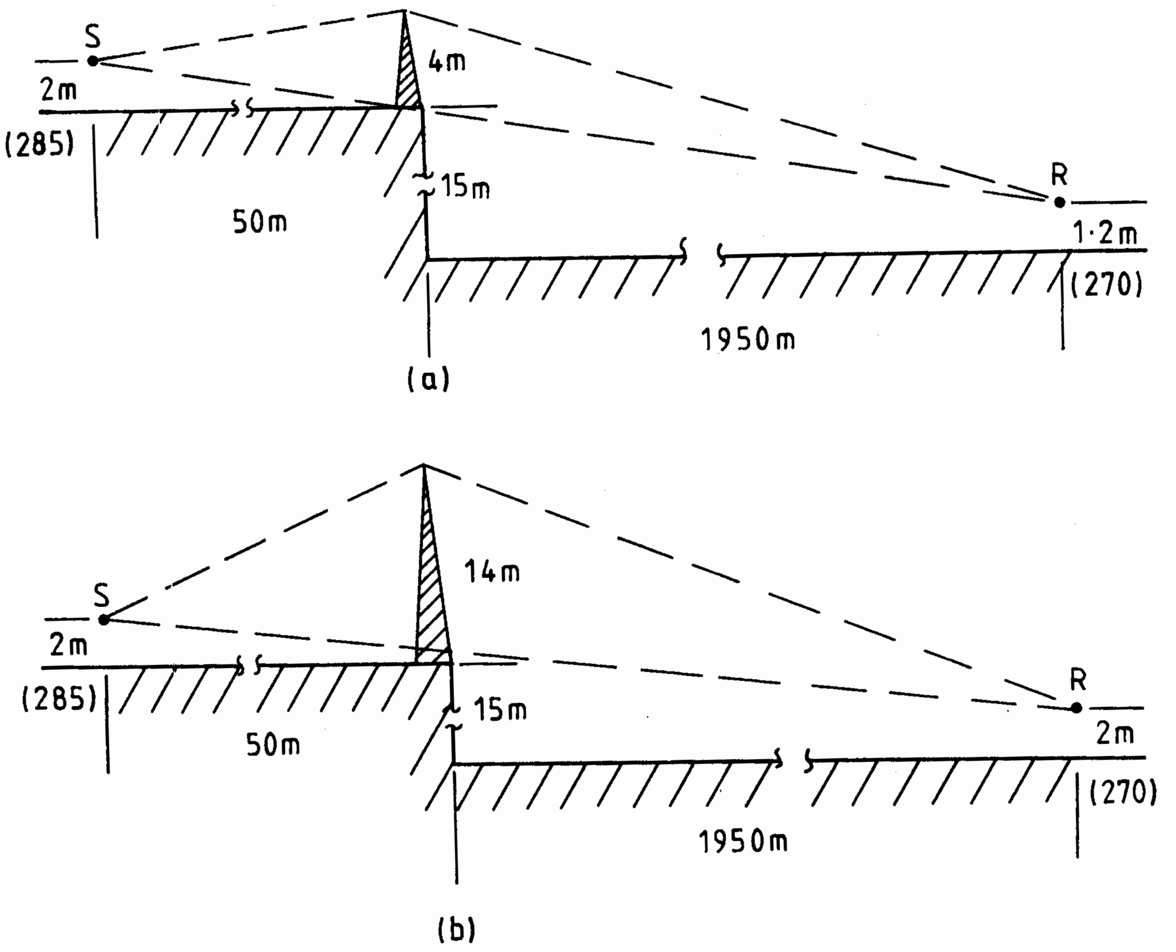

Figure B4 The configuration for site 3 is similarly to site 2 except that the source to receiver distance is greater, (a) without earth mound, (b) with mound.