THE EFFECTS OF FIRING PATTERNS, METEOROLOGY AND TERRAIN ON COMMUNITY NOISE EXPOSURES FROM A MILITARY RIFLE RANGE

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BACKGROUND

Heals Range in Central Saanich, B.C., has been an active military small arms range since before WWI. Semi-rural residential development has gradually encroached on the range and this, combined with its then upcoming use during the 1994 Commonwealth Games, led to calls from some elements of the community for restriction or termination of its use, due to excessive noise impacts. In response, the DND retained ***Wakefield Acoustics Ltd.*** to study the shooting noise and how it was influenced by firing patterns/positions, meteorology and terrain features.

SHOOTING NOISE MEASUREMENTS

Heals Range is located in a semi-agricultural valley bounded by forested hillsides. On several occasions during 1992-93, C7 rifle noise measurements (A-weighted Impulse levels - dBAI) were made at ten mostly residential locations around the range (source-receiver distances varied from 150 to 1650 m) under a variety of light-wind and windless conditions. Both normal multiple-shooter military practices or "serials" (at 25 to 300 m firing ranges) and controlled individual-round shooting (at 25 to 1000 m firing ranges) were measured.

At distant valley floor receivers, single C7 round noise levels varied by up to 30 dBAI (e.g. 45 to 75 dBAI) depending largely on meteorological conditions. Nearer the range along the valley sides, this variation was more like 10 to 15 dBAI (e.g. 65 to 80 dBAI).

SINGLE-ROUND NOISE MODEL

An empirical model was developed to predict single-round noise levels as a function of firing range and firing posture (prone, kneeling, standing) and to define the probable limits of shooting noise at the various receiver locations. The model generated three separate results: 1. upper-limit or "worst-case" noise levels accompanying either a significant "source-to-receiver" wind or a strong temperature inversion, 2. "with excess attenuation" noise levels (one for each firing posture) occurring under near-neutral atmospheric conditions when ground effect attenuation and/or terrain/forest shielding are fully active, 3. lower-limit "near maximum sound shadow" values accompanying either a "receiver to source" wind or a strong temperature lapse condition. The single-round model (derived from components of U.S. CERL, Swiss and Swedish military rifle noise models) was as follows:

$$L_{AI} = 141 + 7(1+\cos\theta) - (24 + \cos\theta)\log_{10}D - 40\,(1-e^{-D/400})/(h_{av} + 0.5) - 10\log_{10}(3+59\Delta PL) - 5(W_F/100) \quad \text{(dBAI)} \qquad \text{(Eqtn.1)}$$

where:

- L_{AI} = A-weighted impulse response sound level,
- 141 = reference impulse sound level at 1 m,
- θ = source to receiver bearing angle (degrees),
- D = source to receiver distance (m),
- h_{av} = aver. height sound path above ground (m),
- ΔPL = increase in sound path length due to terrain shielding,
- W_F = width of forest belt(s) encountered along sound path (m), to maximum of 200 m.

Under "worst-case" conditions (only geometric spreading and atmospheric absorption present), just the first three terms of Eqtn. 1 were used. However, where terrain features and/or forest belts were so close to the source and/or receiver that their shielding would not likely be fully overridden by down-wind or thermal inversion effects, extra shielding effects of from -1 to -10 dBAI were applied to the "worst case" shooting noise levels. Under "with excess attenuation" conditions all six terms were used. Under "near maximum sound shadow" conditions, a sound shadow attenuation term (-30 to -35 dBAI depending on source-to-receiver distance) was applied to the worst case noise levels.

The model was applied to each of the nine residential measurement locations around the range. As an example, Figure 1. below illustrates the model's output, with

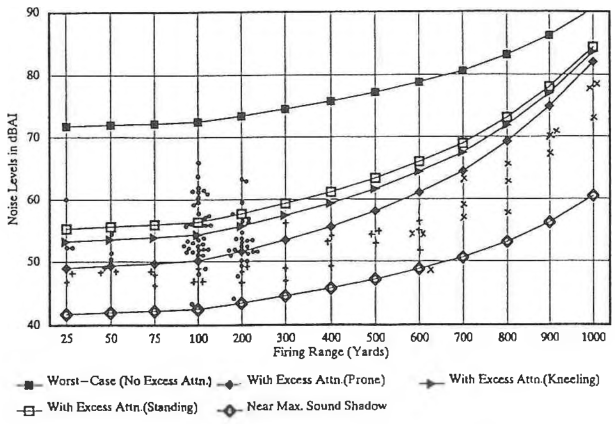

Figure 1: Single-Round C7 Rifle Noise Levels (dBAI) at Foxtrot Site as a Function of Firing Range

measured single round data plotted, for "Foxtrot Site" (located on the eastern edge of the valley floor about 150 m southeast of the 1000 m firing position and about 1125 m from the 25 m firing position). Typically during the noise measurements, "Foxtrot" site was upwind of the range and therefore appears to have generally benefited from ground effect attenuation as well as some sound shadow attenuation.

Heals Range is surrounded on three sides by residences so that certain firing positions are favourable for certain residences and unfavourable for others. To indicate which firing ranges could be expected to produce the least overall noise impact, community average "worst case" single round noise levels were computed for each firing range. The shortest ranges (from 25 to 200 m) were projected to create average community noise exposures from 4 to 5 dBAI lower than the longest ranges (700 to 1000 m). This was fortunate since most military rifle practices are from ranges of 200 m or less.

EFFECTS OF FIRING PATTERNS

During a given military practice serial, up to 20 shooters may fire more or less concurrently. The firing rate (rounds/sec) varies considerably with type of serial. With 20 shooters, the total firing rate of the group can range from about 1 rnd/s for the more deliberate serials (zeroing, application and grouping) to 20 rnd/s for the "snap" and "rapid" serials. Sustained firing within the semi-reverberant environment of Heals Range (decay rates induced by the surrounding forested hillsides were measured at 15 to 60 dB/s), can produce substantial amplification of shooting noise levels. Differences of 5 to 7 dBA were observed between 20-shooter "rapid" and 20-shooter "application" serial).

The following expression was developed to predict this sustained fire, reverberant build-up effect:

$$L_{sust} = 10\log \sum_{n=1}^{N} 10^{[L_0-(n-1)D_R/F_R]/10} - L_0 \quad \text{(dBAI)} \qquad \text{(Eqtn. 2)}$$

where:

L_{sust} = sustained-fire reverberant noise level build-up (dBAI),
L_0 = single round impulse noise level (dBAI),
D_R = reverberant decay rate (dB/s),
F_R = total firing rate (rnds/s),
$N = tF_R$ = total number rounds fired in time "t".

For conditions at Heal Range, this expression predicted reverberant build-up effects of between 0 to 7 dBAI.

LOCAL METEROLOGICAL PATTERNS

A meteorological station (Davis Weather Monitor II) was set up at Heals range to monitor the wind velocity, relative humidity and temperature at two heights (0.9 and 7.25 m) above ground allowing temperature inversion or lapse conditions to be detected. Data was continuously sampled and stored in the system's digital memory and periodically down-loaded via modem. Data acquired from summer 1993 to early 1994 was used to generate monthly summary plots of wind velocity and temperature gradient versus time of day. These could be used to select practice times which, on a statistical basis, would minimize the potential for disturbance in the surrounding community by avoiding periods of likely temperature lapse or of downwind propagation towards residential areas of greatest concern.

CONCLUSIONS

Through a combination of noise measurement, empirical propagation model development and monitoring of local meteorology, it has been found that appreciable variations in community noise exposures around Heals Range can result from the selection of firing range, firing patterns and firing postures. However, much more significant fluctuations can be attributed to local meteorology, which, at least during the more critical warm weather months, exhibits fairly consistent diurnal patterns.

These investigations have then provided the DND with the information necessary to permit, over time, minimization of community noise exposures from Heals Range primarily through the selection of practice times and firing ranges that take best advantage of natural sound attenuating mechanisms available in the range's valley bottom setting.