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ABSTRACT

This report gives a brief overview of typical background noise levels in Europe, and suggests a procedure for the prediction of background noise levels based on population density. A proposal for the production of background noise maps for Europe is included.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	acoustics	akustikk
GROUP 2	noise	støy
SELECTED BY AUTHOR	background	bakgrunn

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Summary

The background noise throughout Europe varies substantially. In remote wilderness areas the background noise is dominated by natural sounds, and determined in particular by the wind speed. The wind generated A-weighted broadband sound is approximately proportional to the logarithm (base 10) of the wind speed.

In populated areas the background noise is determined by human activity, in particular road traffic noise. The overall background noise level in areas not directly exposed to a major noise source seems to be proportional to the logarithm (base 10) of the population density. The daily variations follow closely the distribution of road traffic. Similarly the spectrum of the background noise resembles that of road traffic noise, but high frequency components are less prominent due to frequency dependent propagation attenuation.

An accurate description of the background noise is important for discussing the audibility of other sources, e.g. en route aircraft noise. A certain percentile level seems to be the best descriptor. The noise metrics, L_{den} and L_{night}, defined by the EU noise directive, are not ideal for describing the background noise situation. However, it is recommended that a general description of background noise levels in Europe is based on these metrics since they will become readily available for large areas as a result of the ongoing noise mapping. As a first approximation the appropriate percentile levels can be predicted on the basis of L_{den}.

1 Background

The development in aviation industry indicates that the noise produced by new aircraft may be different from the current situation, both with respect to noise spectrum and the actual noise levels on the ground.

Detailed information on the background noise levels in different areas is necessary in order to assess the possibility that the sound from new aircraft will be audible, and hence possibly annoying to the people in these areas.

This report discusses the background noise situation in Europe. Background noise in this context is also referred to as *ambient noise* or *residual noise*. This is the sound at a location from a number of more or less identifiable sound sources when the direct sound from prominent sources is excluded. The background noise can also be considered as the threshold below which, the time varying community noise level seldom drops.

Information on the background noise levels in various regions in Europe is not readily available. The results of the ongoing noise mapping process will provide some information, but the mapping will be focused mainly on densely populated areas in order to identify *black spots* where environmental noise may be a health hazard. According to reports so far less effort has been assigned to identifying and characterizing quiet areas.

The information currently available may be sufficient to provide a first estimate of the general background noise situation. This estimation can be based on census data for population density.

2 Basic concepts

The two words *sound* and *noise* are used in this report with the following meaning: *sound* is the physical phenomenon; small pressure variations in the air that can be picked up by a microphone or directly by the human ear. *Noise* is per definition *unwanted sound.* It may be debated if the correct term to describe the key issue in this report is *background noise* or *background sound.* The sound from distant traffic is probably not something desirable, and therefore qualifies to the definition *background noise.* The sound from leaves rustling in the wind or the sound from a waterfall, however, is likely to be characterized as natural sounds. The term *background sound* will therefore be more appropriate. The term *background noise* is used in this report without the distinction whether the sound is wanted or not.

Land use varies quite substantially through out Europe, and the background noise will vary accordingly. It is therefore necessary to define different types of areas or zones for assessing the background noise levels.

Wilderness areas are areas with little or no human activity. The background noise level is largely determined by natural sounds.

Rural areas have some human activity such as traffic, residences, etc. There is a continuous increase in activity, and hence in background noise levels, as the rural area changes character to suburban, urban and metropolitan. Various areas need to be classified and assessed differently.

2.1 Soundscapes

Soundscape is a relatively newly invented word that can be defined as the acoustic equivalent of a landscape. A soundscape is an area with specific sound qualities. The soundscape is characterized by the activity in the area and the presence of various sound sources. Distant sound sources outside the immediate surroundings may also be important for the character of the soundscape.

The EU Noise Directive, END, [1] defines an area of relative quiet in the countryside as *being undisturbed by traffic, industry or recreational activities.* This is a rather subjective definition as it is impossible to define the intrusive noise level above which the area is no longer undisturbed.

The Symonds Group Ltd. in a report to the EU [2] has arrived at the following definition of relative quiet in the countryside as being *an acoustic soundscape where the benign natural sounds dominate over man made and other unwanted sounds.*

A *quiet rural area* is a soundscape characterized by a very low level of background noise from man-made sources, and by a small number of (slightly) higher level noise intrusions. A noise intrusion is an event that can be clearly distinguished, due to special acoustic features. The instantaneous noise level may exceed a specific limit, or the spectral content of the noise event may be clearly different from the general background, for instance with pure tonal components.

The noise intrusions in a quiet area, may be clearly distinguishable, but still the instantaneous sound level will generally be just slightly above the background. If the intruding noise events are characterized by high maximum levels, the area may not qualify to be labeled *quiet* even if the number of such intruding noise events are small.

Quiet rural areas may be still further differentiated depending on the number of noise intrusions per unit time.

Areas far away from any man made installation or human activity, can be classified as *wilderness*. In a wilderness the soundscape is characterized by natural sounds only: wind blowing in the threes, running water, occasional sounds from birds, etc. Sounds from man made activities are noticed less often than once per day.

Closer to cities or agglomerations one may define *tranquil areas*. In England, a tranquil area is defined as a place sufficiently far away from the visual or noise intrusion to be considered unspoilt by urban influences. A tranquil area is thus determined by distances from disturbing factors [3]:

- at least 3 km from major motorways, from larger towns, and from major industrial areas
- at least 2 km from minor motorways and major trunk roads and from the edge of smaller towns
- at least 1 km from medium disturbance roads (typically more than 10,000 vehicles per day)

In Sweden such areas are characterized as *quiet recreational areas*, [4]. The number of noise intrusions (distinguishable noise events) are typically 60-120 events per day (0600-2200).

Sweden also defines *recreational areas close to a city*. Such areas should be located at least 500 m from medium sized roads and rail roads. A similar distance is needed to industrial plants, harbors, goods terminals, etc. Number of noise intrusions are typically 120-240 per day (0600-2200).

By just looking at the number of intrusions, one may consider the surroundings of a small airport as a quiet area. However, the dynamic range of the noise events: typically high peaks above the background level, will disqualify the use of the term *quiet area*.

Within the context of urban areas, END describes a *relatively quiet area in an agglomeration* as *an area, delimited by the competent local authority, which is not exposed to a value of L_{den} greater than a certain value, to be declared by the Member State.*

This is a straightforward definition but of little use for our purpose. We will define a relatively quiet urban area as a soundscape where one is not openly exposed to major noise sources. In general this will mean that one is sheltered from major transportation noise sources. Such quiet areas may be inside large city parks, inside sheltered court yards, etc.

3 Noise levels in rural soundscapes

In remote areas far away from any human activities the sound level is determined by natural sources such as water (rain, rivers and water falls), and wind making waves and blowing through the vegetation. On rare occasions there are also sounds from geothermal activities such as hot springs and volcanoes. In addition there are single noise events such as falling rocks, the breaking of ice, etc.

Depending on location and seasonal variations there are also sounds from wildlife.

The sound generated by wind in foliage has been studied quite extensively in connection with wind power projects. It has been shown that the wind generated A-weighted broadband sound is approximately proportional to the logarithm of the wind speed (log base 10).

The absolute level, however, will vary quite a lot depending on the type of vegetation, distance to the source, etc. Figure 3.1 shows the results from two series of measurements.
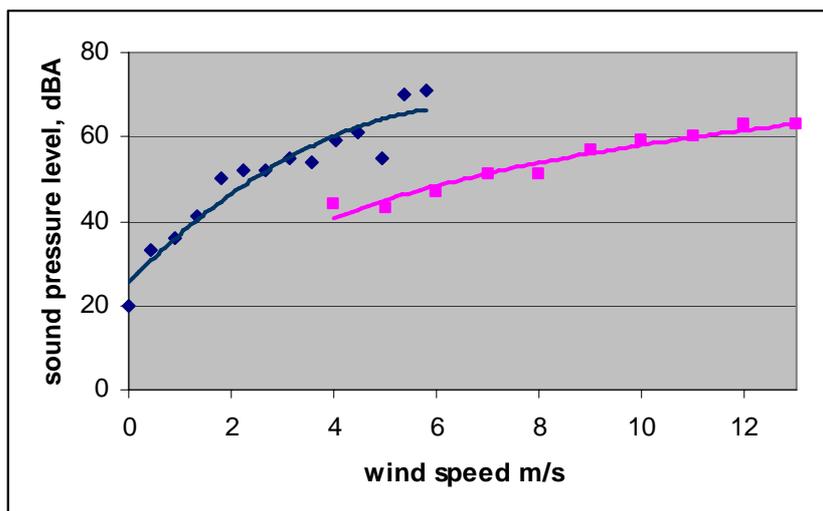
Figure 3.1. Noise generated by wind in foliage [6] [7]

At moderate wind speeds, 5 m/s, there is a difference of about 20 dB, 45 dBA vs. 65 dBA.

In remote rural areas (wilderness) the instantaneous sound level is found seldom to drop below L_A 25-30 dBA [8] [9], even without any anthropogenic sources. The authors of an Irish study on noise in quiet areas, however, propose that the sound level should not exceed $L_{A10,1h}$ of 30 dB (day) and 27 dB (night) [10]. This means that the instantaneous sound level exceeds 30 dBA for only 6 minutes per hour during the day. The corresponding threshold at night is 27 dBA.

(Note: the meaning of percentile levels is sometimes reversed in the literature. L_{yy} may mean the level exceed or <u>not</u> exceeded yy percent of the time. In this report L_{yy} means the level that is exceeded yy percent of the time. Percentile levels are also referred to as centile levels.)

As an example we will assume a noise situation with a steady background sound level and occasional emerging noise events. A background level of 25 dBA and 6 minutes per hour of noise at 35 dBA will yield an equivalent level $L_{Aeq, 24 h}$ of about 28 dB, or a day-evening-night level L_{den} of about 34 dB. If the background level is increased to 30 dBA (day) and 27 dBA (night) and the

emerging noise events remain the same, the corresponding equivalent levels will be: $L_{Aeq, 24 h}$ about 31 dB and L_{den} about 35 dB.

Pesonen [11] reports background noise levels in northern Scandinavia. In sparsely populated areas the noise level is in the range L_{dn} 30 – 33 dBA.

Conclusion: The time weighted equivalent sound level, L_{den} , in wilderness areas and sparsely populated areas seldom drops below 30-35 dB, and most of the time the instantaneous sound level stays below 30 dBA.

A very simple way of estimating the background noise level in a certain area is based on the population density. The basic premise is that everyday human activity will generate sound, and where there are more people, more activity will generate more sound. The concept was initially developed by the US EPA in 1974 [12], and the results were validated and confirmed by Cathrine Stewart et al in 1999 [12]. Expressed in SI units they report the following relationship:

$$L_{dn} = 17.9 + 10 \log (\rho)$$

where ρ is the population density in persons per square kilometer. The relationship is valid for areas not directly exposed to a major sound source (away from major roads, rail roads, airports, industrial plants, etc.). For the purpose of this study, and with the accuracy that could be expected, the equation can be re-written:

$$L_{dn} = 18 + 10 \log (\rho) \qquad\qquad \text{[Equ.1]}$$

It is unclear across which range the formula is valid. For the validation in 1999 the population density varied between 600 and 13,000 persons per square mile ($230 – 5,000$ persons/km^2). In a report on the *value of natural quiet* Miller applies the formula to areas with a density as low as 50 persons/km^2 [14], and in their report [2] the Symonds Group applies the formula down to "1-10 persons/km^2" .

Equation 1 was developed and validated in the US. Studies from many developed countries show that road traffic is the main contributor to the general background noise level. Due to differences in the amount of traffic in Europe and the US (kilometers driven per person per day) it is likely that Equ.1 will overestimate the noise for Europe. However, a difference in traffic volume 2:1 between the US and Europe, will only yield a difference in noise levels of 3 dB.

A large study on children's mental health was conducted in Austria in 1998 [15]. More than 1300 children in the Tyrol area participated. The noise levels at the children's residences were reported to be in the range L_{dn} 31 – 81 dBA with 95 % of the residences within 40 – 60 dBA. According to official Austrian statistics, the population density of the villages in the lower Inntal, where the study was conducted, varies typically in the range 20 – 100 persons/km^2. Using Equ. 1 this will yield noise levels in the range L_{dn} 31 – 38 dBA for residences not exposed directly to major noise sources.

Noise monitoring has been carried out in the city of Kaunas. This is the second largest city of Lithuania, with a population of about 366.000, and a population density of 87 people per km^2. The sound level in the quiet areas of this town (away from direct exposure to traffic) is reported to be in the range L_{den} 36 – 40 dBA [16]. A prediction based on Equ.1 yields as a result L_{dn} 37 dBA.

(Note: For these noise situations the metrics L_{den} and L_{dn} can be considered equal, see chapter 7.)

Naturvårdsverket, Sweden, has reported extensively on the sound levels in quiet areas within the city of Stockholm [4]. In recreational areas in the outskirts of town the instantaneous sound level seldom drops below 35 – 38 dBA (L_{A95}), and the daytime (06-22) equivalent level is in the range 40 – 46 dBA. The equivalent diurnal level ($L_{Aeq,\ 24\ h}$) is only 1 -3 dBA lower. The corresponding L_{dn} level is in the range 46 - 50 dBA. The population density of "urban Stockholm" as opposed to "metro Stockholm" is about 2,000/6,500 persons/km^2. The sound level for urban areas according to Equ. 1 should be L_{dn} 51 dBA.

Average sound levels in "highly urbanized" and "less urbanized" areas of Amsterdam have been reported to be $L_{Aeq,\ 24\ h}$ 53 dBA and 50 dBA (L_{A95} 41 - 35 dBA, L_{dn} 57 – 54 dBA) [17]. The population density of Amsterdam is about 4,500 people/km^2. According to Equ.1 this corresponds to L_{dn} 54 dBA.

Conclusion: The population density is a good predictor for the noise level in urban areas. Equation 1 is valid for locations in urban areas not directly exposed to a major noise sources.

Inner city noise levels are remarkable similar through out Europe. The sound levels are generally dominated by road traffic. Acoustically, a street with high buildings on both sides will "lift" the sound sources to the top of the buildings, and they will blend together in an "energy blanket" that will radiate down into areas not directly exposed to road traffic such as city parks, shielded back yards etc.

Typical noise levels in shielded inner city locations are in the range 45-50 dBA. Detailed noise measurements have been found for these cities: Stockholm [18], Gothenburg [19], Trondheim [20], and Berlin [21].

Examples of reported measurements:

Norra Djurgården, (park) Stockholm: $L_{Aeq,24\ h}$ 46 dBA, $L_{Aeq,day}$ 47 dBA, L_{A95} 39 dBA
Partille, Gothenburg, (back yard): $L_{Aeq,day}$ 47 dBA
City park, Trondheim,(1 hour during day): L_{Aeq} 49.3 dBA, L_{A90} 46.9 dBA, L_{A10} 51.1 dBA
Tiergarten, Berlin, (1 hour during the day): L_{Aeq} 49 dBA, L_{A90} 47.4 dBA, L_{A10} 50.2 dBA

These levels are in good agreement with equation 1.

4 Time of day

Road traffic is the main source for noise annoyance in most areas. In most countries in Europe about 75 percent of the noise annoyance represents contributions from road traffic noise. Also in locations not too far from a populated area, the background noise will be dependent on the sound from distant road traffic.

As a first approximation the road traffic distribution can be used to estimate the variation in the background noise levels. The noise from a heavy vehicle is typically 8-10 dBA higher than that of a passenger car. In a traffic mix with 10-15 percent heavy vehicles, the two categories "light" and "heavy" vehicles will contribute equally much to the total noise level.
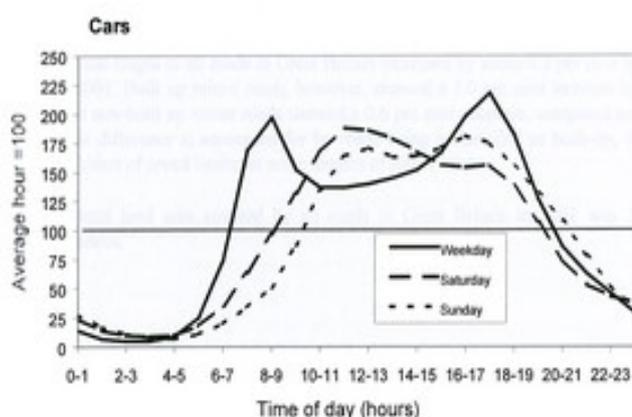
Figure 4.1. Time of day/week distribution for light vehicles in the UK [22]
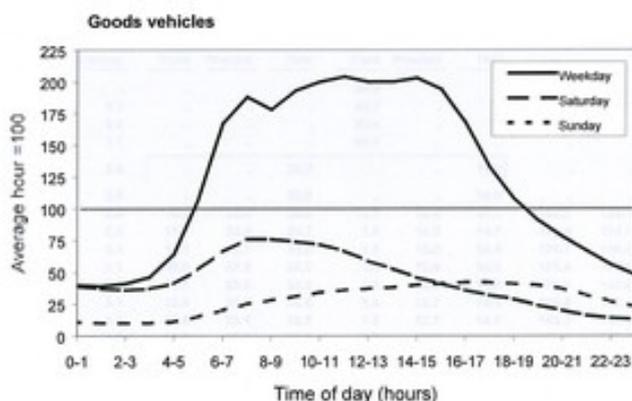
Figure 4.2. Time of day/week distribution for heavy vehicles in the UK [22]

The two figures, 4.1 and 4.2 shows the relative distribution of vehicles as a function of time of day. The figures are based on statistics from the UK, but similar distribution can be found in most European countries [22].

For light vehicles the traffic in the quiet night period is about 1/10 of that during the rush hours. This difference is equal to about 10 dB in the noise level. In other words: the noise level in the middle of the night is about 10 dB below the noise during peak hours. On an hourly basis the noise at night is about 7 dB below the hourly average, and the peak hour noise level is about 3 dB above the average.

For heavy vehicles the ratio between night-time and daytime traffic is about one-to-five, equal to 7 dB. The night-time level is about 4 dB below the hourly average and the levels during the day is about 3 dB above the hourly average.

Assuming that light and heavy vehicles contribute equally, the difference in the noise level from the most quiet hour at night and the most busy hour during the day will be 9 dB, and compared to the hourly average the noise level will vary between -6 dB and + 3 dB.

A similar difference, 9-10 dB between high and low hourly noise level, has been reported for instance for the city of Prague [23], a large European capital, and the city of Point Arena in California [24], characterized as a "small town with rural character". This difference can probably be considered fairly constant for areas where road traffic is the main noise source.
Typical 24-hour distribution for the noise level in a Norwegian city is shown in figure 4.3 [25].
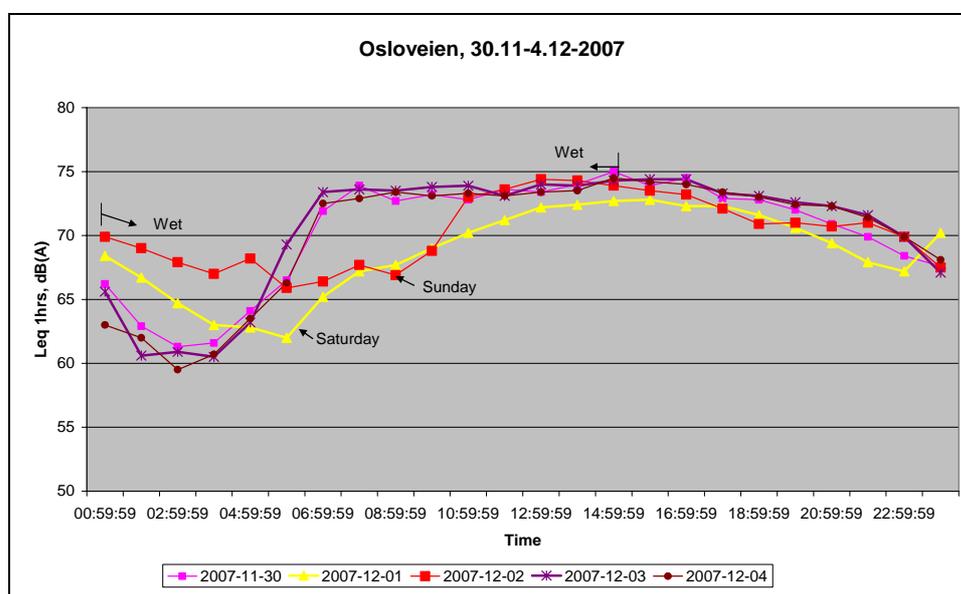
Figure 4.3. Typical hourly L_{Aeq} for traffic noise in a Norwegian city [25]

For a typical "city mix", 10-15 %, heavy vehicles, the two types of vehicles will contribute equally (energy wise) to the equivalent level. The level for any hour during the day can be estimated from the 24-hour levels (L_{eq} or L_{den}) by using the data in figure 4.4. Vice versa, the 24-hour L_{eq} or L_{den} can be estimated by measuring the equivalent level for one hour during the day.
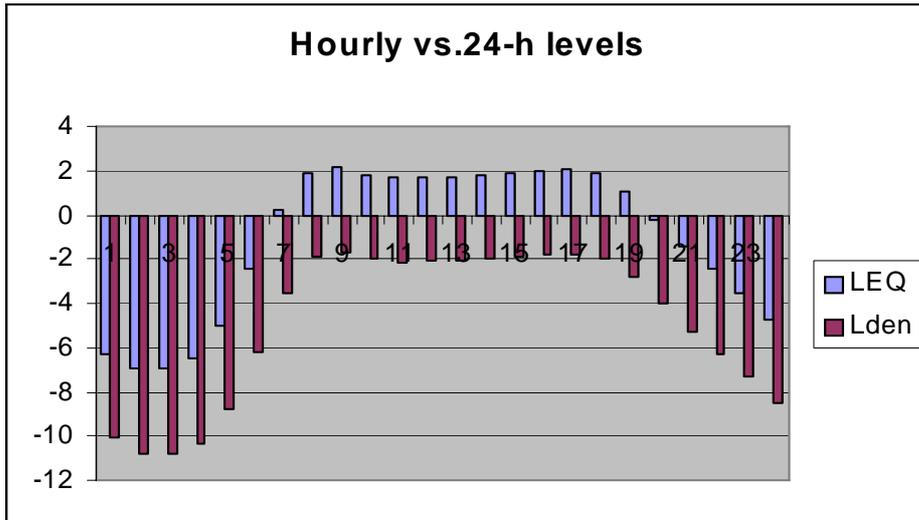
Figure 4.4. The relationship between 1-hour equivalent levels and the corresponding 24-hour Leq or Lden for a typical mix of light and heavy vehicles. The figure is based on British traffic statistics [22].

It can be concluded from figure 4.4 that the sound level during the day is about 2 dBA higher than the 24-hour equivalent level, or about 2 dBA below the day-evening-night level.

Detailed noise measurements have been carried out in the city of Klagenfurt, Austria [26]. The diurnal level variation is shown in figure 4.5. The noise level follows the same time pattern as is shown in figures 4.3 and 4.4. The difference between night time low L_{Aeq} and day time high L_{Aeq} (half hour periods) is around 10 dB.
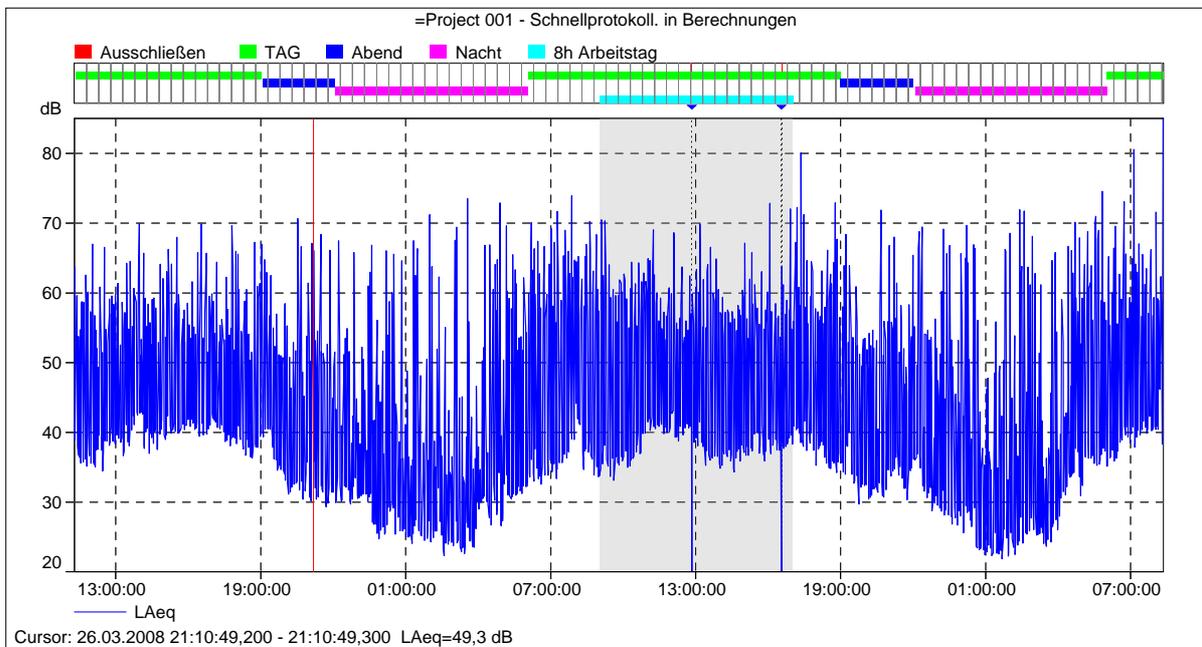
Figure 4.5 Background noise levels in the Austrian city Klagenfurt [26]

5 Spectrum and amplitude distribution

The noise from road traffic originates from two main sources: engine/propulsion and tyre-road interaction. The engine noise is dominated by low frequency components with a maximum in the range 50 – 100 Hz. Rolling noise has a maximum around 1 kHz. There is a cross-over between the two components around 500 Hz. A typical spectrum for light vehicles is shown in figure 5.1.
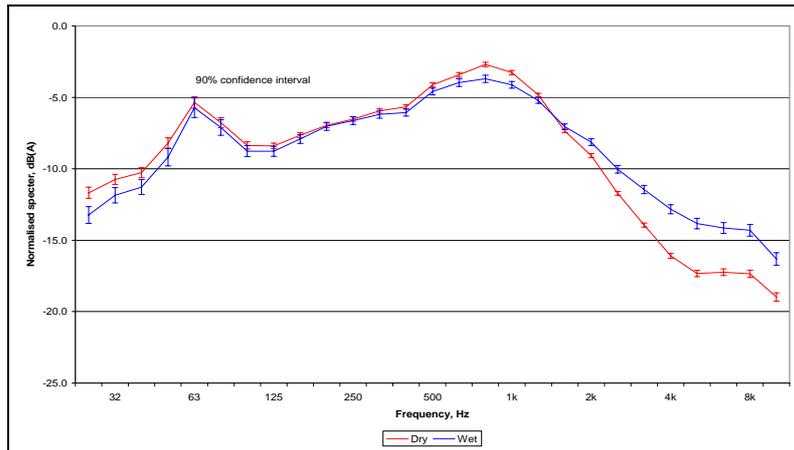
Figure 5.1. Typical spectrum for road traffic noise [25]

The spectrum in figure 5.1 is measured relatively close to the source. As the distance increases the low frequency components will be more dominating due to a frequency dependent propagation attenuation. At very large distances (kilometers) the influence of rolling noise will be small, and the peak in the spectrum around 1 kHz (figure 5.1) will gradually disappear.

The spectrum in figure 5.2 is based on measurements of actual highway traffic at 10 m distance. The percentage of heavy vehicles is between 15 and 20 %, hence the higher level at low frequencies (engine noise). The level difference between 63 Hz and 1000 Hz is about 12 dB. The corresponding spectra at various distances have been calculated using the NORD2000 propagation model, (propagation across flat, soft ground). As the distance increases the components at high frequencies are attenuated more than the low frequency components due to atmospheric absorption. At 1 km the above mentioned difference has increased to about 23 dB, and at 10 km the difference is about 36 dB. The dip in the mid-frequency range is mainly due to ground absorption.
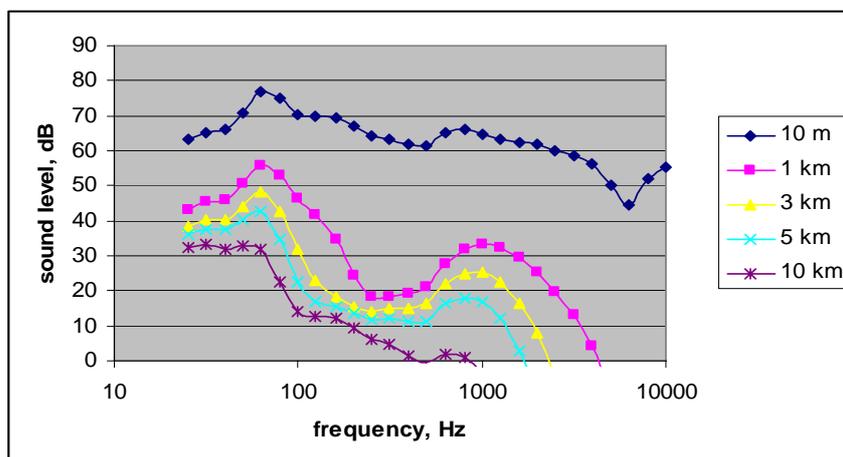
Figure 5.2 Typical spectrum of road traffic noise calculated at different distances from the source

Miller has carried out extensive background noise measurements in national parks in the US [27]. Figure 5.2 shows the results from about four months of recordings. Each line represents the average 1-hour spectrum for one day. The sharp rise in the noise level below 100 Hz is due to wind blowing across the microphone and do not represent acoustic sound. The noise in the intermediate frequency range is largely caused by distant traffic sound. The slope for the middle-high frequency range is about -3 dB/octave except for the peak around 6 kHz. This is produced locally by insects(!). Measured in dBA values the day-to-day dynamic range would be about 35 dB. This shows that the noise can vary quite substantially on a daily basis.
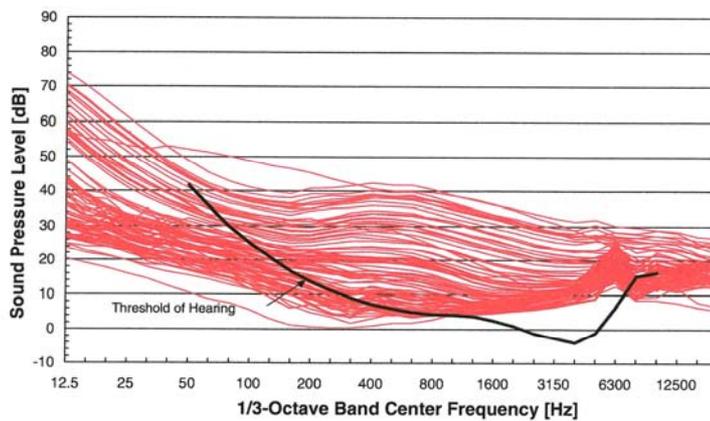
Figure 5.2. Background noise levels and spectra for open woodland [27]

6 Low frequency noise – infrasound

Annoyance caused by low frequency noise, LFN, has become more pronounced in later years. LFN is reported to cause annoyance especially indoors. There may be several reasons for this. Normal buildings have very little attenuation in the low end of the frequency spectrum, but good attenuation at middle and high frequencies. Results from practical experiments and surveys indicate that the annoying effect of LFN is more prominent in the absence of other middle and high frequency sounds. Therefore modern houses with good facade attenuation for "normal community noise sources" (for instance road traffic) may actually cause increased annoyance at low frequencies. Annoyance caused by LFN is seldom reported outdoors.

Many countries have introduced special noise regulation at low frequencies. The acceptable threshold levels are usually very similar to the normal hearing threshold. This means that LFN is considered annoying as soon as it can be detected. Threshold values for LFN in different European countries are shown in figure 6.1 [29].

Unless there are specific low frequency sources present (heavy machinery, gas flows, gas torches, etc.) the time pattern for LFN follows the general trend for ordinary audible environmental noise with a maximum during the day period and minimum levels during the night [29]. This is shown in figure 6.2.

Outdoor measurement of low frequency noise is difficult due to wind conditions. Wind blowing across the microphone (even at very low speeds) will generate noise. Measurements must therefore be restricted to periods with very low wind speeds, and the microphone must be equipped with a large wind screen. Under normal conditions the spectrum level will increase towards lower frequencies. The 1/3 octave level at 10 Hz will typically be 20-30 dB higher than the level at 100 Hz.
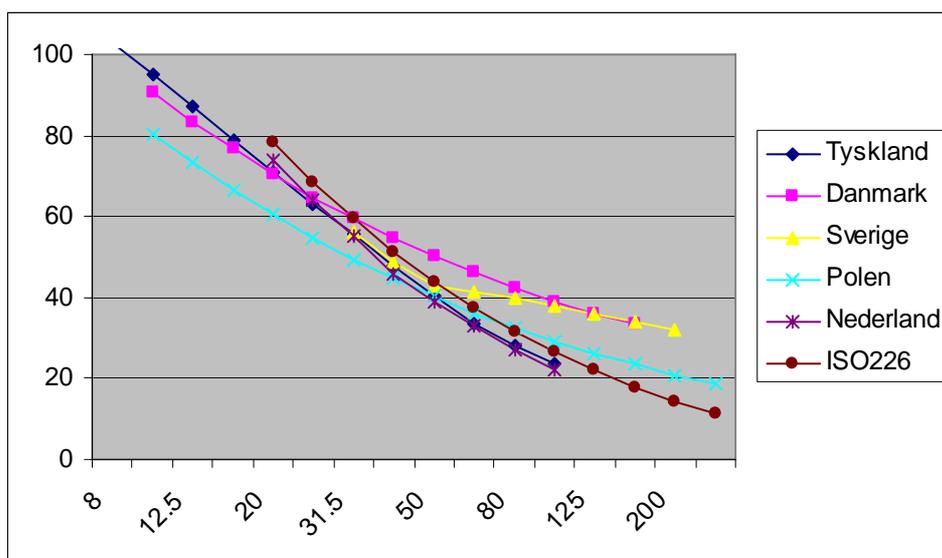
Figure 6.1. Threshold levels for acceptable LFN in some European countries
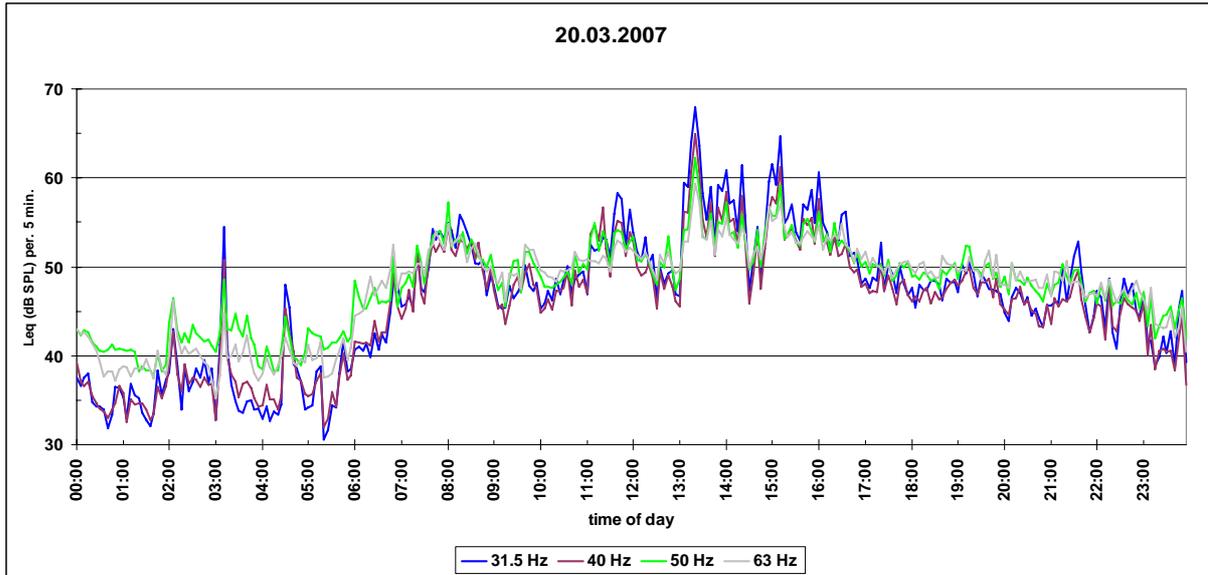
Figure 6.2. Typical 1/3 octave LFN levels in a Norwegian city

7 Metrics to describe background noise levels

Various metrics have been used in this report to describe the background noise situation. These metrics reflect the quantities and indices being used in the reports and articles that have been cited.

The European Noise Directive, END, introduces the two noise metrics L_{den} and L_{night}. These are probably not the best indicators for background noise with respect to audibility/detectability of specific sources. However, these indicators have the advantages of simplicity and conformity, and, as the member countries start producing noise maps and making action plans, these indicators will be readily available for communities all over Europe. It is therefore recommended that the background noise levels are defined, if feasible, using one or both of these noise metrics.

In this report three different indices have been used to characterize the "average" noise level of a 24-hour period: L_{Aeq}, L_{dn}, and L_{den}, depending on which one was used in the original report. As a general rule one can assume that L_{Aeq} values are taken from older studies, L_{dn} values come from studies in the US, and L_{den} values are fairly new European studies.

Road traffic is the dominating source for background noise. Miedema et al have found that for road traffic noise the difference $L_{den} - L_{dn}$ varies between 0.1 dB and 0.3 dB. Their conclusion is based on studies in Europe, Japan and the United States [30]. For practical purposes L_{den} and L_{dn} can therefore be interchanged when describing the background noise using the results from existing studies. The difference between $L_{Aeq,24 h}$ and L_{den} is typically 4 dB (L_{den} being the larger quantity).

Note: Results from road traffic noise measurements along city streets have traditionally been presented as *facade levels.* This implies that the reflection from the house facade has been included. Similar results without the facade reflection, so called *free field conditions,* will be 3 dB lower. L_{den} values are per definition always referred to *free field conditions.* It is therefore important to verify the measuring conditions when comparing results from different studies.

Miller has studied how people visiting national parks react to disturbing sounds, for instance from aircraft [27]. He concludes that audibility is closely related to spectral differences between the background noise and the disturbing sound, and also the instantaneous level. Percentile levels, i.e. the level that is exceeded a certain percentage of the time, may be a better indicator than an energy integrated index.

Miller has concluded that the best representation of a "baseline" level to assess audibility of intruding sounds is the daytime median sound level, L_{50} [14]. L_{50} represents the sound level that is exceeded 50 percent of the time. The "baseline level" should be measured/predicted without the presence of the intruding sound. The criterion level for audibility should be chosen a fixed number of dB below L_{50} (typically 3-5 dB) depending on the degree of audibility that can be tolerated.

The best representation of a "baseline" sound level to assess audibility is assumed to be the daytime median sound level [14]. Wyle Laboratories has derived at the following approximate relationship [31]:

$$L_{50} = L_{dn} - 5 \text{ dB} \qquad \text{(Equ. 2)}$$

Similar relationships can be found for other percentile levels, as well, but for percentiles other than L_{50} the approximations will depend heavily on the dynamic range of the sound signal. L_{95} is often used to characterize the most quiet periods. The sound drops below this level only five percent of the time. In locations at some distance from dominating sources, L_{95} is typically 2-6 dB below L_{50} [4]. Minimum and maximum levels are poor descriptors for the background sound level. The dynamic range for the instantaneous sound level can vary from about 15 dBA to more than 40 dBA depending on the distance from dominating sources [26] [32].

As an example: the city of Klagenfurt (see page 12) has a population density of 769 persons/km^2. According to equ.1 and equ.2 this corresponds to $L_{den} \approx 47$ dB and $L_{50} \approx 42$ dBA, and the most quiet period, characterized by L_{95} should be in the range 36 – 40 dBA.

The cumulative level distribution of the background noise measurements in Klagenfurt, re figure 4.5, is shown in figure 7.1. The actual measurement results are slightly higher than the predictions.
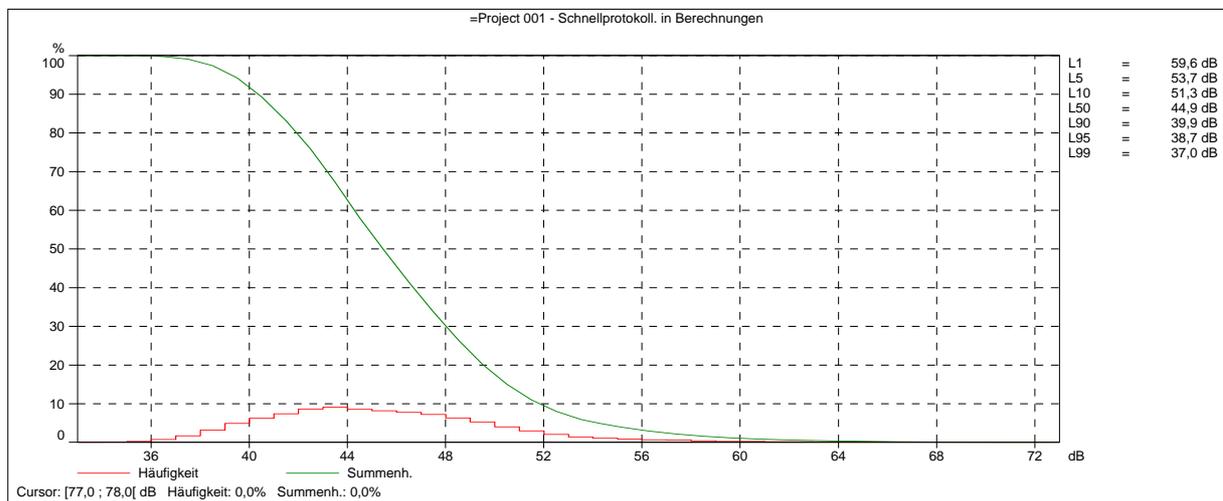
Figure 7.1 Background noise levels in Klagenfurt, Austria. Cumulative distribution [26]
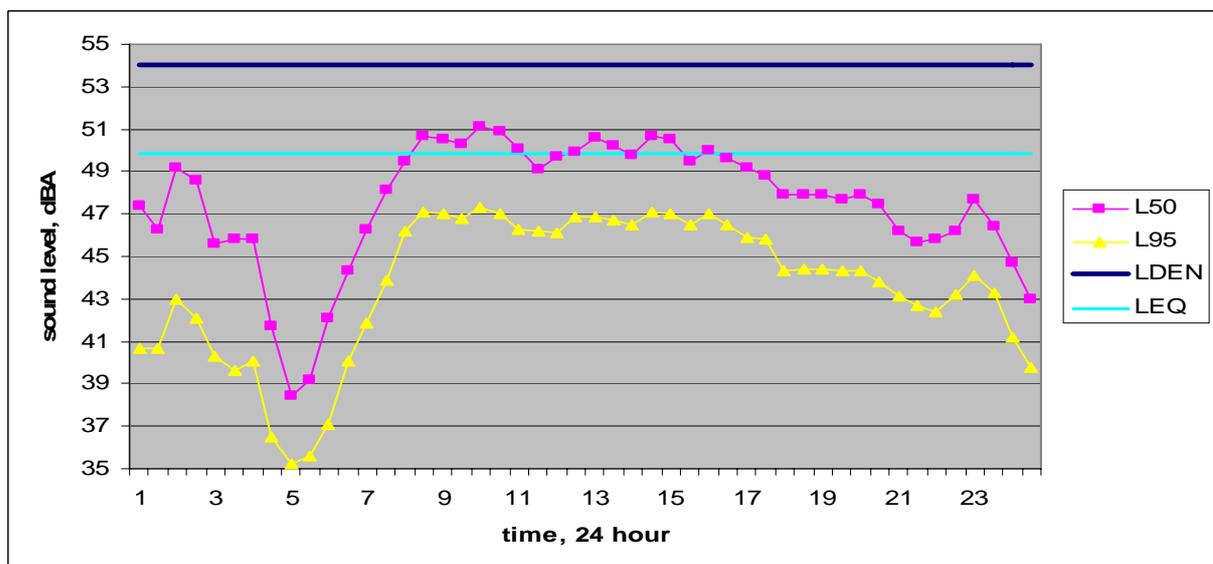
Figure 7.2 Background noise levels in Trondheim, Norway. Time series for a 24 hour period [20]

Background noise measurements in a Norwegian city [20] is shown in figure 7.2. L_{Aeq} and L_{den} are calculated for the whole 24 hour period. The two plots, L_{50} and L_{95}, are percentile levels for 30 minutes periods. For the daytime period L_{50} is about 4 dB below L_{den}, and L_{95} is about 7.5 dB below L_{den} or 3.5 dB below L_{50}. Except for the midnight hours, the difference between L_{50} and L_{95} is fairly constant.

These examples indicate that the criterion level for detection/audibility of intruding noises, can be estimated on the basis of L_{Aeq} or L_{den}, provided that road traffic noise is the main contributing source.

8 Further research

Background noise levels for Europe are not readily available. As a first approximation it is recommended to use the population density and predict the background noise levels using Equ. 1 (chapter 3). The area of Europe is slightly more than 10 million km^2. The grid size would have to be chosen depending on local conditions. A grid of 10 km x 10 km would mean that about 100,000 cells would have to be completed. However, large areas could probably be combined.

The population density varies quite a lot. It is "very low", say less than 10 persons/ km^2, in Northern Scandinavia. In central Europe the average density is about 100 – 400 persons/ km^2 , and in densely populated metropolitan areas it may be as high as 4,000 – 25,000 persons/ km^2 (see table 8.1). The actual population densities of various areas can be found from official census registers.

Location	persons/km^2
France	115
Switzerland	180
Germany	230
Netherlands	400
Berlin	3,800
Amsterdam	4,500
London	4,700
Madrid	5,500
Paris	25,000

Table 8.1
Population density in some countries and metropolitan areas

This background noise study has been prompted by possible new developments regarding aircraft noise. The grid size should therefore also be chosen to reflect the expected variation in this noise. If we assume a typical cruising altitude of 10,000 meters (33,000 ft), a grid of 10 km^2 right underneath the aircraft will have a level variation of about 1 dB. A level variation of 3 dB within the grid will correspond to about 100 km^2. Similarly a variation of 5 dB corresponds to a grid size of about 1,000 km^2.

For a refinement of the predicted background noise levels, it may be possible to utilize the results from the ongoing EU noise mapping. This mapping is focused on large agglomerations and highly noise exposed areas. The proposed equation, however, estimates the background noise level in areas *not directly exposed to major noise sources.* If the EU noise maps have been produced with good quality prediction tools, there should be data for shielded areas within these agglomerations, that could be used to verify and/or correct the estimations based on population density.

For a still further refinement actual noise measurements like those presented in figure 5.2, may be considered.

It is suggested that the background noise data is presented as a color coded map of Europe with a grid size of 1,000 km^2, and L_{50} or L_{95} as the noise metric. The resolution could be typically 5 dB. Major European cities have an area that varies with a factor of about 10, from 6-800 km^2 to 6-8,000 km^2 depending on how the metropolitan area is defined. This means that the large cities will be represented by somewhere between one and six to eight grids.

With this grid size the noise levels in smaller cities will be underestimated. The map will therefore be conservative with respect to audibility of special noise sources such as aircraft. If a certain level is chosen as a threshold for audibility, the noise source in question will be heard less frequently in smaller cities than indicated by the background noise map that is produced according to the proposed procedure.

8.1 Detailed project proposal: Background noise maps for Europe

The client has requested a proposal for a research project with options of the order of magnitude of 10-, 40-,and 90,000 €. Based on standard rates for EU projects, these sums amount to about 2, 8, and 18 man/weeks of work.

The background noise estimates will initially be based on a simple relationship between noise and population density:

$$L_{50} \; = \; 13 + 10 * \log(\rho) \quad \text{[dBA]} \quad\quad\quad \text{(Equ.3)}$$

where ρ is the population density: persons per square kilometers, (re Equ.1 and Equ .2).

Option 1:

Calculation of background noise levels based on regional data from each European country. Most European countries have different levels of public administration, and are thus sub-divided in different administrative units. Census data for these units are readily available from national databases. A typical example is shown in figure 8.1 [33].

Estimated effort equivalent to 10,000 €.

Option 2:

Calculation of background noise levels based on available GIS data. The grid size should be 10x10 kilometers or smaller. A typical example of gridded population data is shown in figure 8.2. Data is available for most European countries, but there is a need for verification in some areas [34].

The calculated levels should be checked and verified against data from the END noise mapping where such data is available

Estimated effort equivalent to 40,000 €.

Option 3:

Calculation of background noise levels similar to "option 2". Additional data from actual noise measurements in selected locations in co-operation with JRC and with local authorities. These measurements can be used to verify/correct Equ. 3, and, if appropriate, also be used to make calculations of an alternative noise descriptor, for instance L_{95}.

Estimated effort equivalent to 90,000 €.
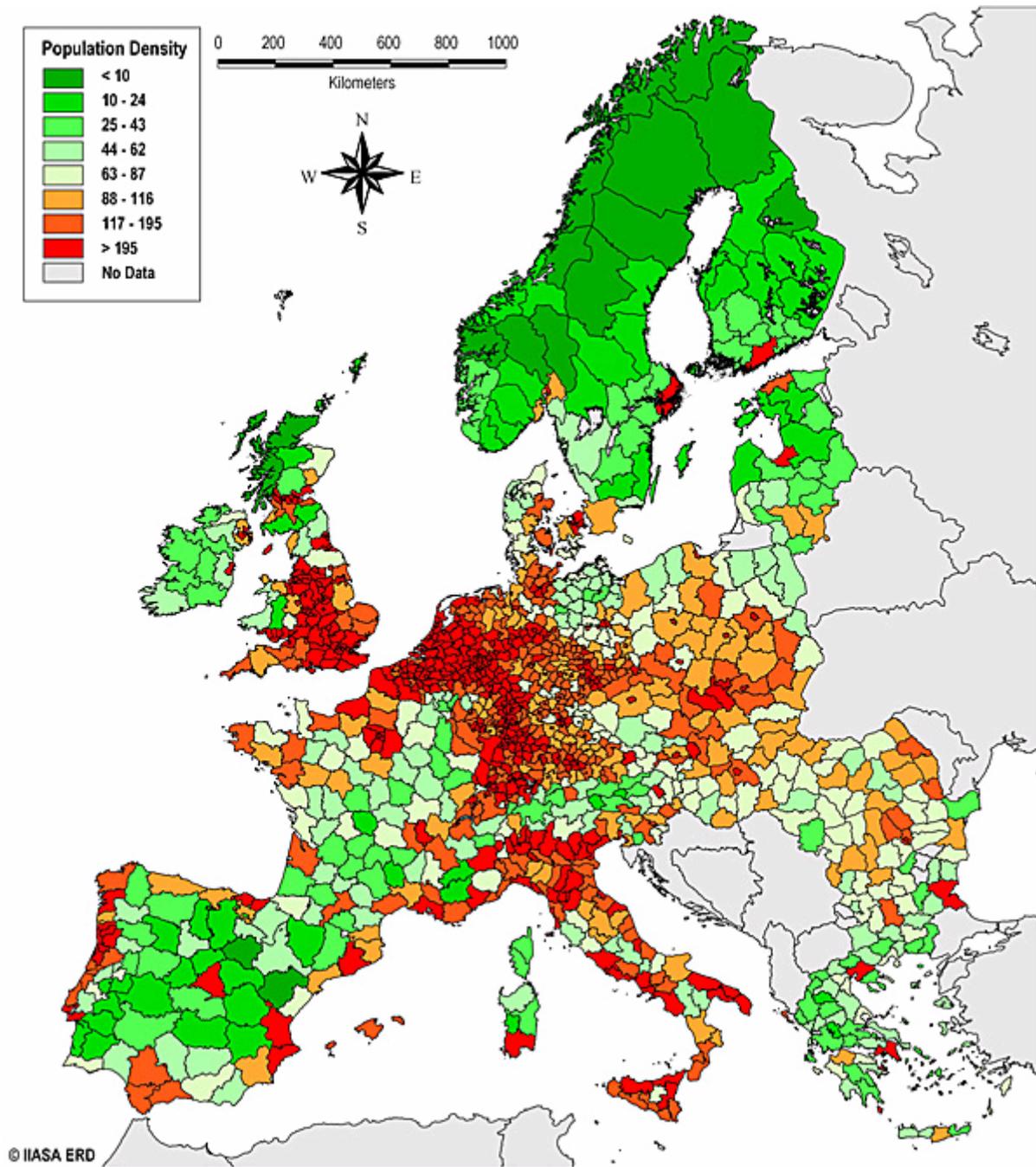
Source: IIASA ERD project

Note: This map was developed by the ERD project. We used the CISCO polygons and population data from the REGIO database of EUROSTAT, as well as data from the most recent statistical yearbooks.

Figure 8.1 Population density map for different administrative units in Europe
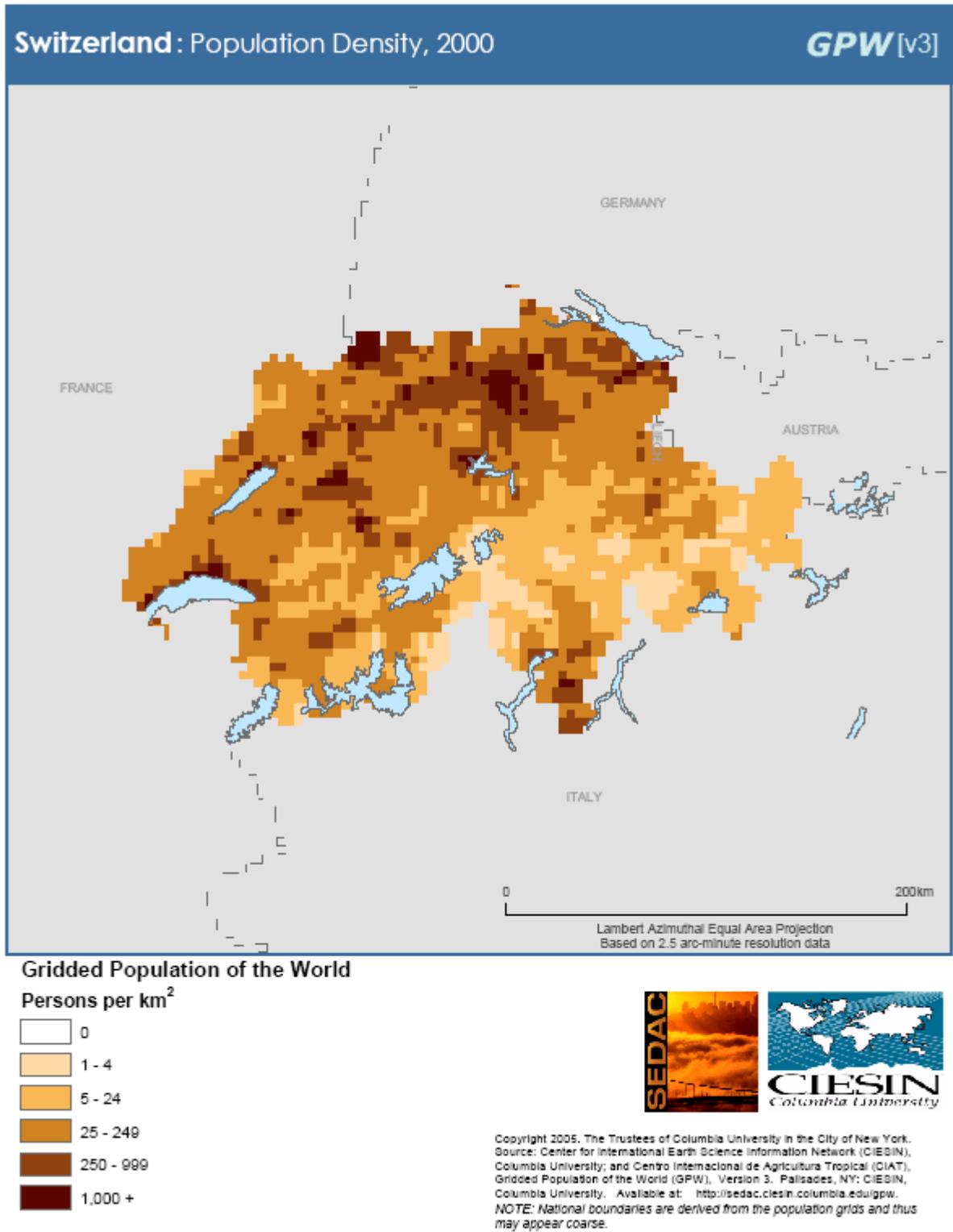
Figure 8.2 Gridded population density of Switzerland [34]

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