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Evaluation of Reflection Plane in GPM **SP Net info 70**

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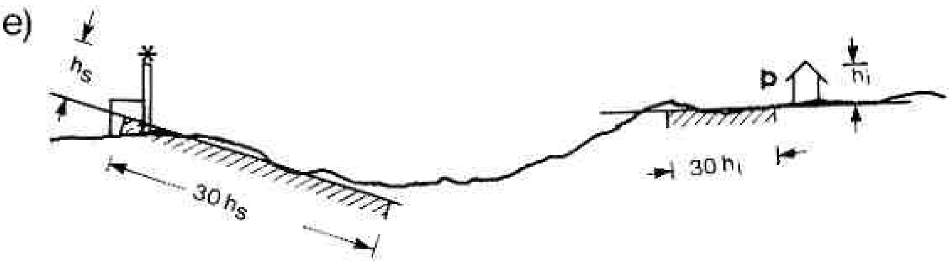
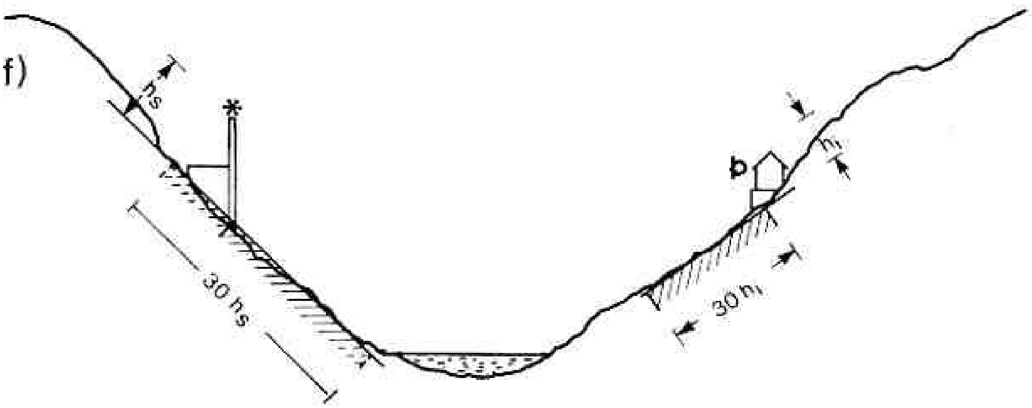
Background.
General Prediction Method (GPM) – our common Nordic standard for prediction of environmental noise from industrial plants – was developed in the late 70ies and published in 1982. The method was to a wide extent based on an existing Dutch method derived for a flat terrain. The basic algorithms in GPM were never meant to be used in a hilly terrain. Especially the algorithms to estimate the ground effect assumed a flat terrain.

To compensate for this, an appendix in the report recommended how to define the height of the source and immission points to be used for the calculation of the ground effect in case of an undulating terrain; this recommendation was stated by means of sketches and a few accompanying words, but no algorithms. Two of those sketches are shown below.





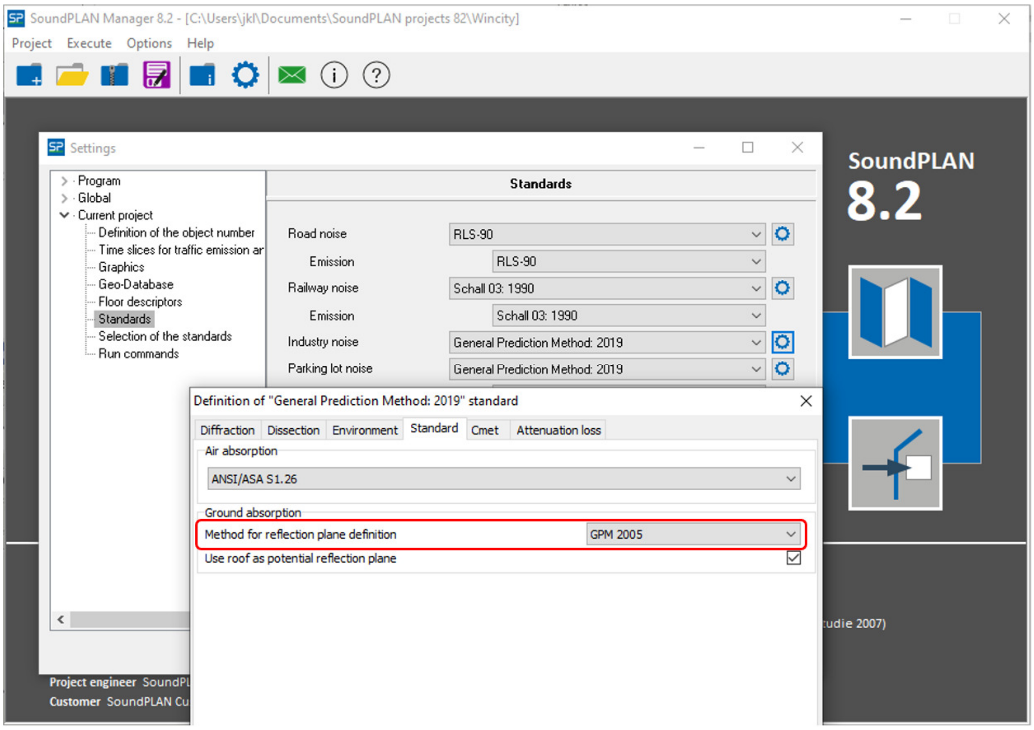
How can the idea behind these sketches be implemented in a sound mapping software? Naturally, each programmer has his own answer to that question. In SoundPLAN the height of the source and receiver has for years been evaluated by simplifying the cut between source and receiver into (a maximum of) 5 straight lines using linear regression. A detailed description of this can be found at the end of this Net Info.

However, this evaluation has a drawback in some situations: by changing the terrain profile between source and receiver 'just a little bit', the source and receiver height might change considerably and thus the ground effect.

This was discussed at the user group meeting in Copenhagen in June 2005. It was also announced at the meeting that a solution to the problem would be worked out in collaboration with some of the developers behind GPM in order not to violate the basic idea of the method.

Since then a couple of meetings have been arranged in which a programmer from SoundPLAN head office and two people from DELTA - Jørgen Kragh and Birger Plovsing - participated. This group agreed upon a new algorithm to evaluate the source and receiver height to be used when calculating the ground effect according to GPM. With the release of SoundPLAN 6.4 (August 2006) this new algorithm became available for SoundPLAN users.

The new algorithm
You can activate the new algorithm – named GPM 2005 (see foot note page 5) – from the SoundPLAN Manager > Options > Settings > Standards > click the button next to General Prediction Method > index card Standard. Hint: If you select GPM 2005 in your global settings (Global > Standards), all new projects will automatically be done with the new algorithm.



The definition of the ground effect in the original GPM-report is so 'flexible' that most likely multiple algorithms will fall inside its basic idea. The advantage about the new algorithm GPM 2005 is that it is more robust compared to the old one. The ground effect will not change significantly if the terrain is changed a little. A detailed description of the new algorithm can be found later in this Net Info.

Deviations between GPM 1982 and GPM 2005
If you rerun an old project with the new GPM 2005 you might end up with different results. The risk for discrepancies between the two sets of results depends on a lot of parameters. The hillier the terrain, the greater the risk for differences (in this sense it is important to remember that a totally flat terrain with sources above flat roofs is a 'hilly' terrain). In projects where the entire area is hard, the discrepancies tend to be smaller than with soft terrain or a mix between hard and soft areas. Another parameter that might have an influence on the difference between the two results is the density of elevation information between source and receiver.

We did several full-scale tests of this. In the first test project the terrain was fairly flat – within 4 m – and the ground was a mix of hard and soft areas. 294 sources (of all three types, point, line and area sources) were defined, several of these were located above flat roofs; 5 receivers were defined at distances from 70 m to 770 m from the sources. We did calculations with both GPM 1982 and GPM 2005 and compared the total level as well as the contribution level from each of the 294 source in each of the 5 receivers; the results – stated as result with GPM 2005 minus result with GPM 1982 - came out as follows:

Rec. 1. Total A-weighted level: no chance. 194 levels unchanged, 100 levels changed within the range [-2,2; +1,6]

Rec. 2. Total A-weighted level: + 0,1 dB(A). 216 levels unchanged, 78 levels changed within the range [-2,0; +2,6]

Rec. 3. Total A-weighted level: - 0,1 dB(A). 235 levels unchanged, 59 levels changed within the range [-2,2; +2,0]

Rec. 4. Total A-weighted level: + 0,1 dB(A). 212 levels unchanged, 82 levels changed within the range [-2,7; +2,5]

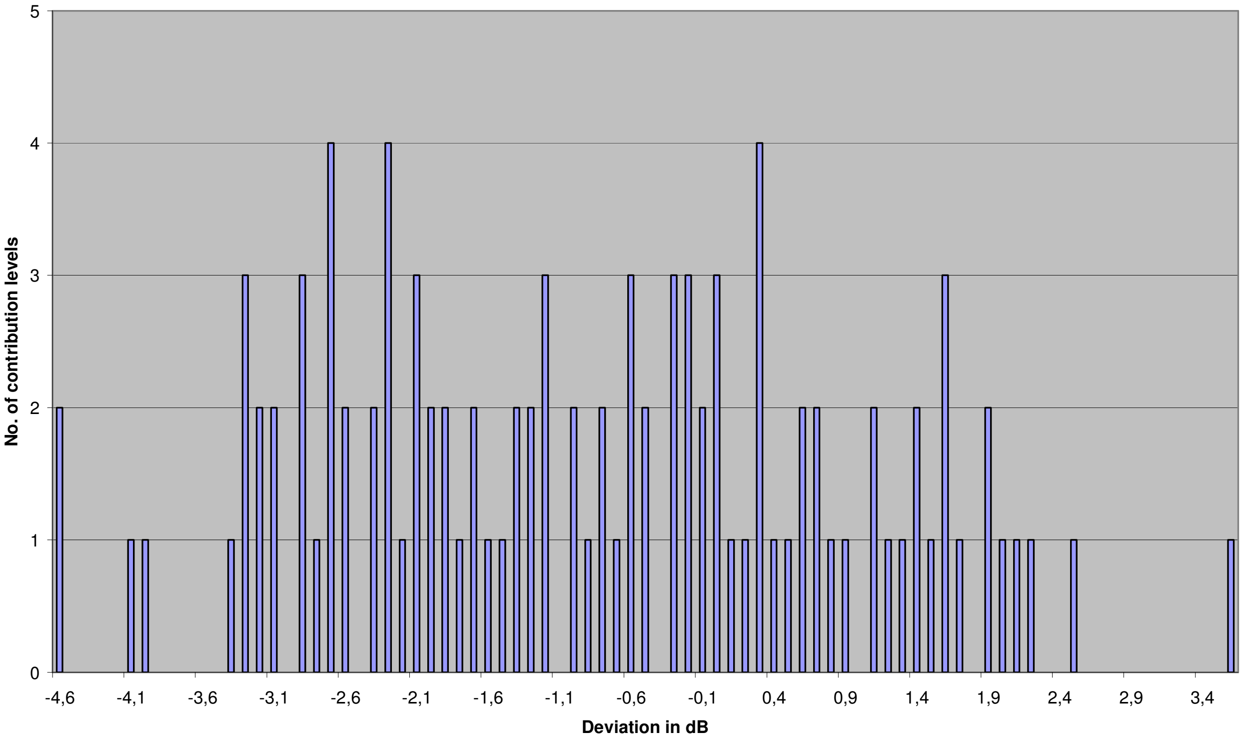
Rec. 5. Total A-weighted level: - 0,2 dB(A). 63 levels unchanged, 231 levels changed within the range [-2,9; +2,7]

A second test project dealing with a none-flat terrain was also done. In this project the elevation difference was about 15 m inside the area in question. The ground was again a mix of hard and soft areas. 102 sources (of all three types) were defined, several of these were located above flat roofs; 2 receivers were defined at distances from 50 m to 450 m from the sources. The results (GPM 2005 minus GPM 1982) were:

Rec. 1. Total A-weighted level: +0,3 dB(A). 27 levels unchanged, 75 levels changed within the range [-2,5; +2,4]

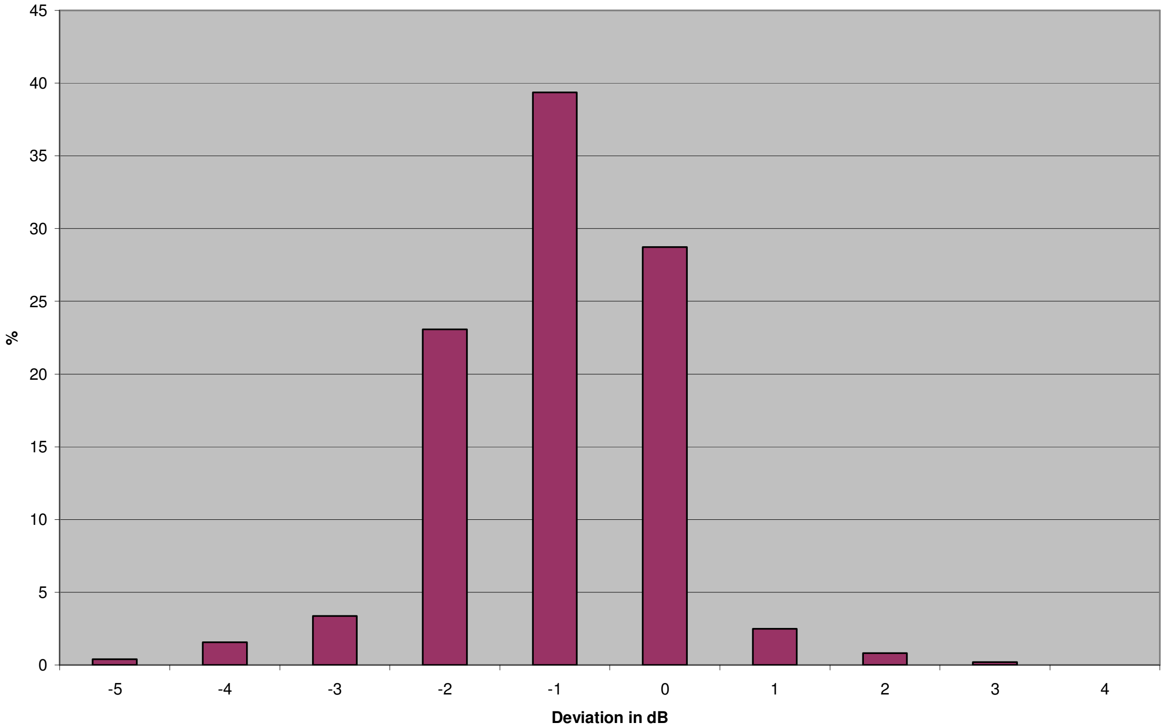
Rec. 2. Total A-weighted level: - 2,3 dB(A). 3 levels unchanged, 99 levels changed within the range [-4,6; +3,6]

The result in the last-mentioned receiver was analysed more in depth. The graph below shows how the 102 deviations were distributed.



In this specific project the majority of deviations are negative, but it cannot be concluded that GPM 2005 in general will return lower levels. However, what can be concluded in general is that in projects with several sources and receivers there will be both negative and positive deviations. Due to the accumulation of deviations, the total level in projects with only a few (dominating) sources tends to change the most, if you switch to the new algorithm.

To analyse a kind of 'worst case', we finally did a test project with only one (point) source. The terrain was rather hilly (level difference 21 m) and the ground was a mix between hard and soft areas. Grid map calculations (16500 grid receivers) were performed with both algorithms and a difference map was produced. From this difference map the graph below is produced. It shows the percentage grid cells/calculation area with a certain deviation; for instance, the deviation is -1 dB in 39 % of the calculated grid cells. In approx. 5 % of the area the deviation is bigger than 2 dB.



From these test cases we conclude that switching to GPM 2005 in old projects might in general cause the total level to change by a few 10^{th} of dB. In special situations it might change up to several dB. There is no clear tendency weather the new results will be higher or lower than the old ones.

Recommendation
As already pointed out the definition of the ground effect in GPM is rather imprecise. None of the two algorithms discussed here is more 'correct' that the other. Therefore, we will leave it up to the user to select which algorithm to use. Both GPM 1982 and GPM 2005 will be available in future versions of SoundPLAN. However, since GPM 2005 is much more stable than the old one, it can be recommended to create new projects with GPM 2005.

Weather you should switch to GPM 2005 when updating old projects is a delicate question with ethical aspects. Considering the fact that a change in results due to a new algorithm might cause fruitless discussions between companies, authorities and consultancy, it might be a good idea to stick to the old one.

GPM 1982

1. Number of ground points between source and receiver (defined by ground height at source/ receiver and elevation lines which are cut) are estimated.
2. Segments (regression lines) are calculated which start at one point and end at another, other ground points can be in between. The regression lines must fulfil certain conditions. This will be repeatedly done by relaxing the conditions, until the number of segments is less or equal to 5.
3. The first condition is related to the angle between the segments, defined by the two neighbouring points. In the first round it must be less than 10 deg. With each round it is increased by 10 deg. A regression line ends and starts at points where this condition is not fulfilled.
4. The second condition is the regression coefficient. In the first round it must be higher than 0.975. With each round it is decreased by 0.025.
5. Now we have several segments (<=5 regression lines). For all of these, the perpendicular distance to source and receiver (can be negative!) is calculated (hiloc and hsloc), and from these the following factors are calculated:

   fi = lseg/(30*hiloc);
   if fi<0 then fi:=0;
   if fi>1 then fi:=1;

fs = lseg/(30*hsloc);
if fs<0 then fs:=0;
if fs>1 then fs:=1;
lseg: length of segment.

6. Now from all hiloc's and hsloc's those are going to be selected where the corresponding factors are highest. Those heights define the source, receiver and middle region.

GPM 2005

Variables:

dSR: horizontal source receiver distance
lhS: source height above local ground
lhR: receiver height above local ground
BF: factor to define source and receiver region (BF<=30)

1. Calculate heights above local ground lhS and lhR:
   lhR = height of receiver – ground height of receiver
   lhS = height of source – ground height of source
   limit lhR and lhS to 0.01 meter
2. Calculate maximum factor (BF) to evaluate source and receiver region:
   If 30*(lhR+lhS)>dSR then BF = dSR/(lhR+lhS) else BF = 30
3. Calculate two regression lines.
   One starting at the source in the direction of the receiver up to a distance BF*lhS (RLS).
   One starting at the receiver in the direction of the source up to a distance BF*lhR (RLR).
   The regression lines shall be calculated, so that:
   - the height of the start point is fixed
   - all intermediate points defined by a straight line between neighbouring intersections of elevation lines are taken into account. This can be done by creating a suitable number of additional elevation points.
4. Two sets of heights are calculated:
   hR1, hS1 where
   hR1 = signed vertical height above RLS
   hS1 = signed vertical height above RLS (=lhS)

   and

   hR2, hS2 where
   hR2 = signed vertical height above RLR (=lhR)
   hS2 = signed vertical height above RLR
   if hR1 is less than lhR then hR1 = lhR
   if hS2 is less than lhS then hS2 = lhS
5. If (hR1, hS1) differs from (hR2, hS2) a selection is made for which set of heights to be used to calculate the ground effect. The selection is made by calculating the ground effect at 500 Hz for both sets of heights. The calculation is done as described in the standard, considering the ground factors for the individual regions. The set of height producing the higher ground attenuation is chosen for final ground effect calculation.

Foot note: In 2019 the math for evaluating double screening according to GPM was changed radically. The new method was introduced in SoundPLAN 8.1 (April 2019) as a new standard named 'General Prediction Method 2019' and must be selected in the standard settings under Industry noise. The original method for double screening remains in SoundPLAN as the standard named 'General Prediction Method 1982'.
Despite the similar names, GPM 1982, GPM 2005, General Prediction Method 1982 and General Prediction Method 2019, we are here dealing with two completely different topics. GPM 1982 and GPM 2005 are two different ways to evaluate the reflection plane needed for calculating the ground effect. General Prediction Method 1982 and General Prediction Method 2019 comes with two different maths for estimating the screening.
In new projects it is recommended to use the reflection plane found by GPM 2005 combined with screening estimated with General Prediction Method 2019.