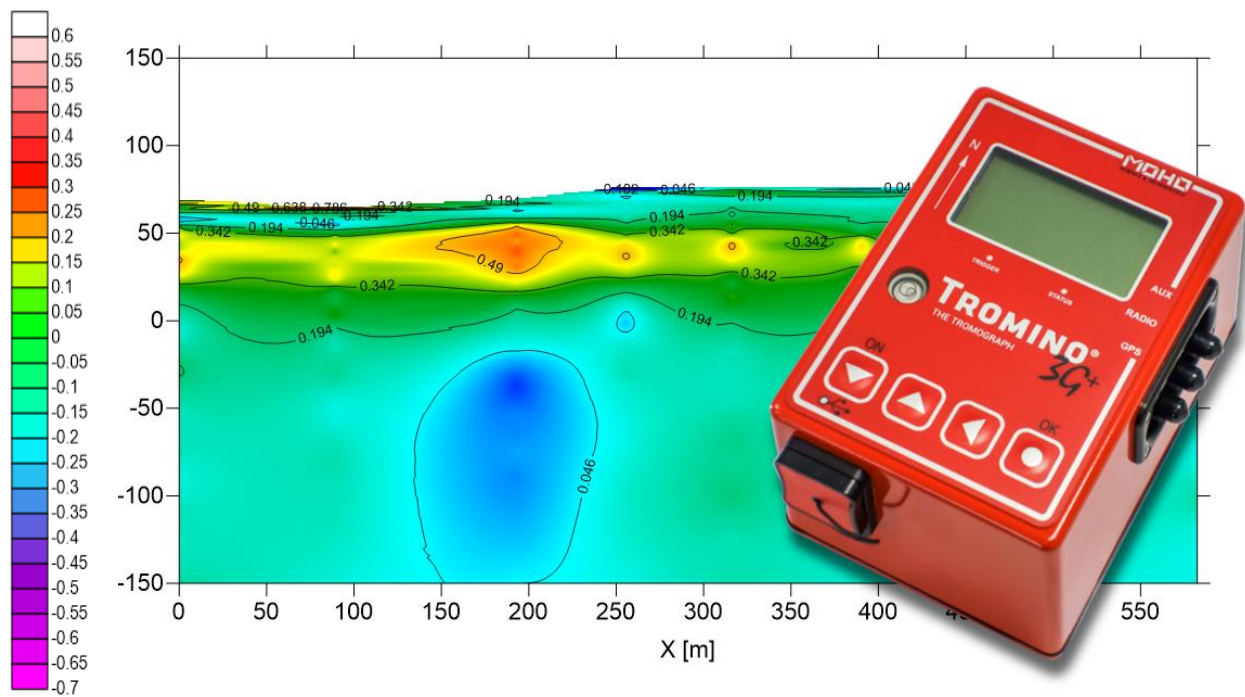


2D-3D VISUALIZATION OF H/V CURVES ACQUIRED WITH TROMINO®

$\log_{10} H/V$



2017

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Introduction

The H/V curves acquired along 2D (or 3D) profiles can be synthetically reproduced as contour plots, where the same color shades indicate the same H/V amplitude or as isoline plots, where the isolines have the same meaning (Figure 1). Since high amplitude values of the H/V ratios (the so-called peaks) indicate high impedance contrasts in the subsoil (reflectors), a contour plot imaging can help identifying the lateral continuity of the seismic reflectors.

In this type of plots, the horizontal axis usually indicates the distance between the measurement points while the vertical axis indicates 1) frequency or 2) depth.

In the first case, the H/V curve is represented exactly as processed from the spectral analysis. In the second case, the shift from the H/V-frequency domain to the H/V-depth domain is achieved on the basis of the user's defined assumptions about the V_S profile with depth.

In the simplest cases, the V_S profiles with depth have the shape illustrated in Figure 6, that is an exponential law with different V_S gradients (α exponent). This is clearly a simplification but still useful to get a clearer *ensemble* view of a set of H/V curves.



Remind that the seismic stratigraphy obtained from the procedure described in this report depends on the user's V_S assumptions. Large deviations from reality can occur in presence of deep reflectors, since the deviation of the real from the assumed V_S can sum up over the layers with the same sign. Results in absolute terms are a function of the specific V_S assumptions performed by the user.

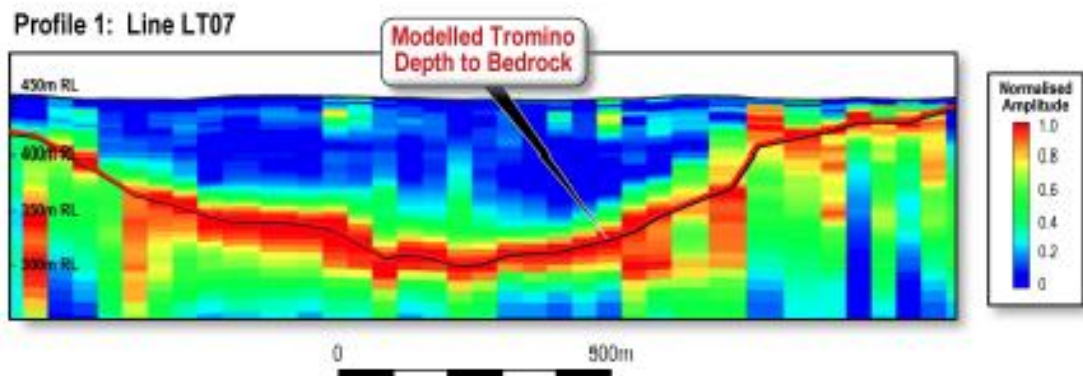


Figure 1. Example of synthetic visualization of H/V curves along a section. The color shades are proportional to the amplitude of the H/V ratio according to the color scale to the right. The red band marks the frequency shift of the H/V peak along the section. Frequency was converted to depth according to the specific V_S assumptions performed by the operator.

Preliminary procedures

In the field:

- Perform the recordings along the desired direction (Figure 2). The distance between the measurement points determines the horizontal resolution of the final contour plot: the model between two measurement points is interpolated and therefore not necessarily real,
- Keep the same sampling rate for each acquisition. Should this not be the case, use the *File > Desampling* function of *Grilla* to reset the traces to the same sampling rate.

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In the office:

- Download the recordings from Tromino® and name them with progressive numbers (e.g., TR_01, TR_02, TR_03, TR_04, as in Figure 4).
The file names can be modified also from *Grilla*.

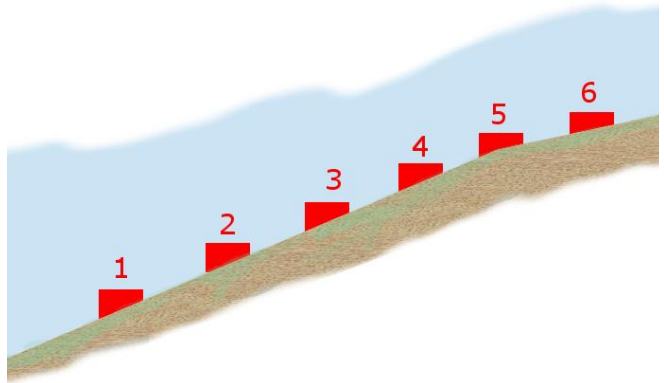


Figure 2. Example of alignment of recordings (left) and progressive numbering (right).

H/V data analysis

- In *Grilla*, analyze the data individually or in *batch mode*. Keep the same analysis parameters for all the recordings. Enable the SAVE OUTPUT IN ASCII option as shown in Figure 3 and assign the file name and destination path (e.g. C:\ASCII).

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Note: all the files to be used to produce the 2D-3D contour plots must be identified by a unique number, progressive along the alignment (e.g., TR_01, TR_02, TR_03 etc.).

Note: in the batch mode analysis, a box to set the file name and initial number will appear (Figure 4). In this case the files will be numbered in the same order in which they appear in the *Grilla* database. Should this be not the desired order, modify it directly in the *Grilla* database before proceeding.

It is very important that after the analysis each H/V curve has a narrow standard deviation around the mean. To this aim, it should be cleaned by removing transients. Do not proceed until the H/V curves have a good quality.

- Press *Ok* and proceed with the analysis of all the recordings.

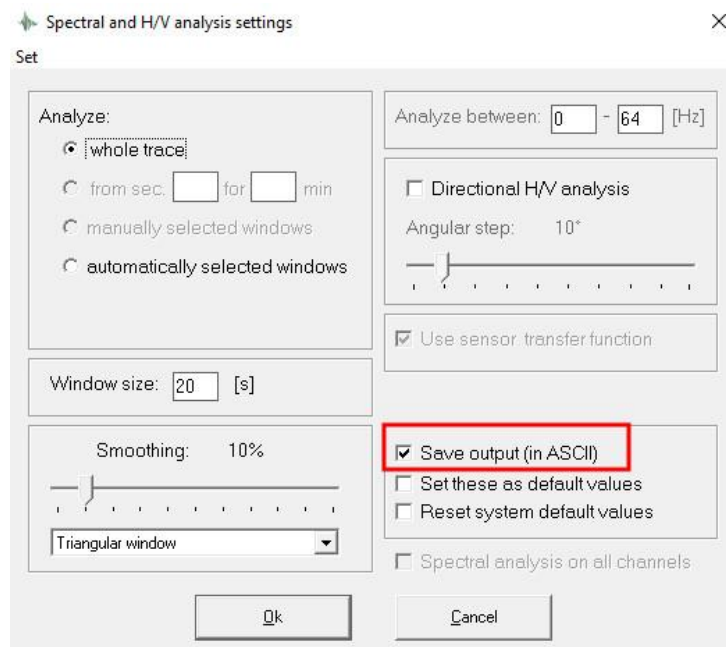


Figure 3. H/V analysis window. Enable the SAVE OUTPUT IN ASCII option.

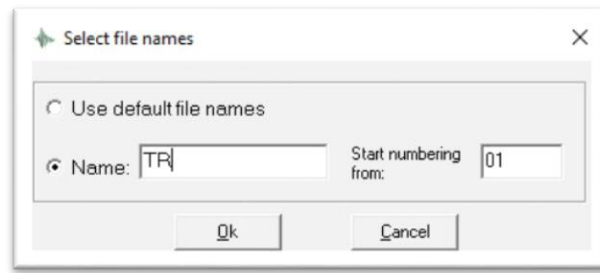


Figure 4. Assign a name and the initial number to the files to be analyzed in batch mode.

Generation of the contour plot files

From the *Grilla* menu, select *Analysis tools >> H/V >> Contouring*.

The software converts the processed H/V curves from the frequency domain to the depth domain by using a V_s model selected by the user. The files resulting from this operation can be input in software like Matlab® or Surfer® (Figure 5) or similar.

- 1) In the box *Path to .asc file* write the path of the folder containing the ASCII files. The path must include also the file name, excluding the progressive number (if you followed the example provided so far, type C:\ASCII\TR_).
- 2) In the box *Number of files*, type the number of the files of the section.
- 3) 4) Insert the coordinates (progressive distance, elevation) of each measurement point. This operation can be done:
 - a. Manually (typing the values for each point or copying them from other files)
 - b. Loading the coordinates from a text file (*Browse* button in the box *Load from file*) formatted with 2 columns:

<i>progressive distance [m]</i>	<i>elevation a.s.l. [m]</i>
00	210
30	250
68	222
85	180

The elevation can be left 0 if the study area is flat or if the altimetric profile is not relevant.

Note: the decimal separator is the point “.”.

Note: Distance can be written in any preferred measurement unit. The contour plot will be produced with the same unit.

- 5) To convert the H/V data from the frequency to the depth domain, it is mandatory to assume:
 - a. a near surface V_s value (200 m/s in the example of Figure 5),

- b. a V_S gradient with depth. For a detailed discussion on the gradient, refer to Ibs Von Seht and Woholenberg (*Bull. Seism. Soc. Am.*, 89, 250-259, 1999).

Some possible gradients are illustrated in Figure 6. At sites characterized by a slow V_S increase with depth (e.g., fine grained alluvial plains), use low α values (0.05, 0.1). At sites characterized by a large V_S increase with depth (e.g., coarse grained alluvial plains), use large α values (0.2, 0.3).

- 6) Select H/V amplitude or $\log_{10} H/V$. The logarithmic scale tends to smooth the amplitude differences but usually provides plots easier to be read in terms of lateral extension of the seismic reflectors.
- 7) Click Go.

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The software generates 4 files (x.dat, height.dat, logHV.dat e FileSurfer.dat) to be used to plot the contour maps.

Path to .asc file

Path to .asc files: C:\ASCII\TR_ 1

Number of files: 4 2

Coordinates (insert manually):

x [m]: 0 30 68 85

Elevation [m]: 210 250 222 180 3

Read 4 x-coordinates. Read 4 elevation values.

Coord. (load from file):

Browse 4

Top Vs [m/s]: 200

Exponent (alpha in Ibs V. S. Wholenberg 1999): 0.25 5

☒ Log10 H/V 6

☐ H/V

Go

Figure 5. Parameter window of the H/V contouring tool.

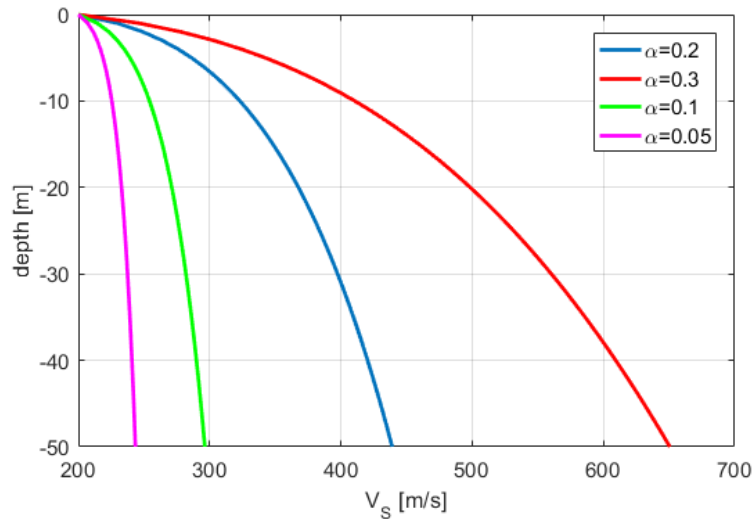


Figure 6. V_s function with depth for different values of the α parameter. The gradients for the fine alluvial plains are better represented by small α values. The initial V_s for all the illustrated case is 200 m/s on the surface. This assumption must be tuned according to the site under study.

Contour plots

Let us now describe how to create contour plots with 2 common software.

In Matlab®

To create a contour map in Matlab®, move to the folder where the output data are saved and type the following commands:

```
load x.dat
load height.dat
load loghv.dat
contourf(x, height, loghv)
```

A contour plot as Figure 7 will be displayed. Since the H/V curves span a range from a few cm (100 Hz) to hundred meters (0.1 Hz), it might be recommended to limit the scale view to the upper tens of meters.

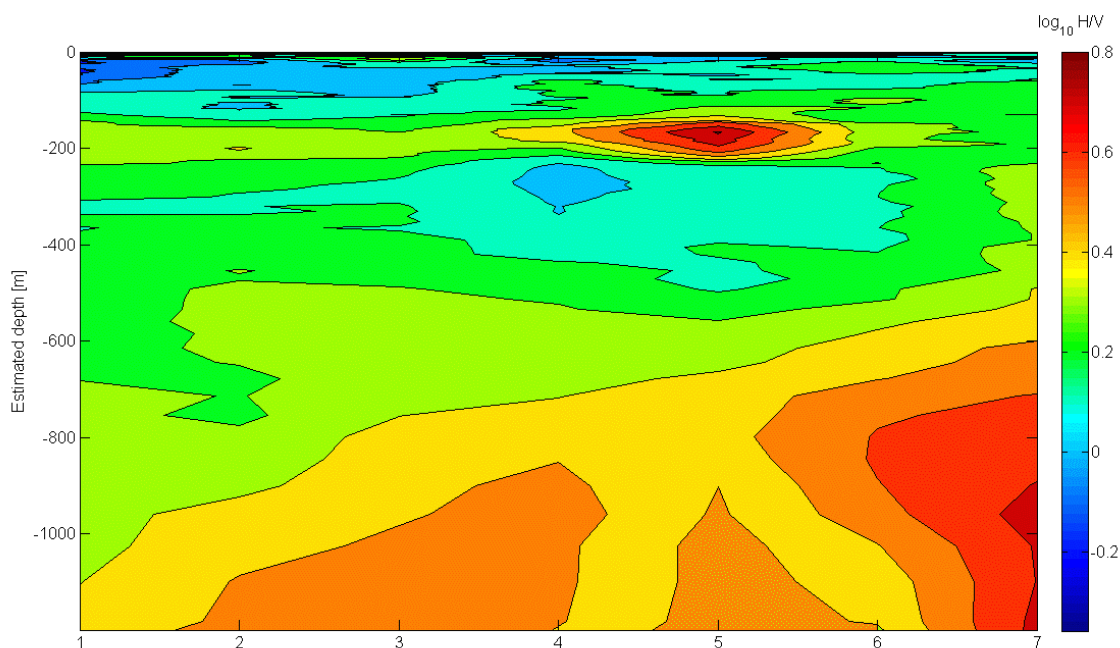


Figure 7. Example of contour map created with Matlab®.

In Surfer®

A free version of Surfer® can be downloaded from this [link](#).

Grid creation

Let us start by creating a grid with the software tool Grid Data (Figure 8). Select the file FileSurfer.dat containing the data to contour (e.g., C:\ASCII\FileSurfer.dat).

Surfer® reads automatically the three data columns of the FileSurfer.dat file: the first contains the x coordinates (horizontal), the second the y coordinates (vertical), the third the H/V (or $\log_{10} H/V$) amplitude for each couple of points (x, y) .

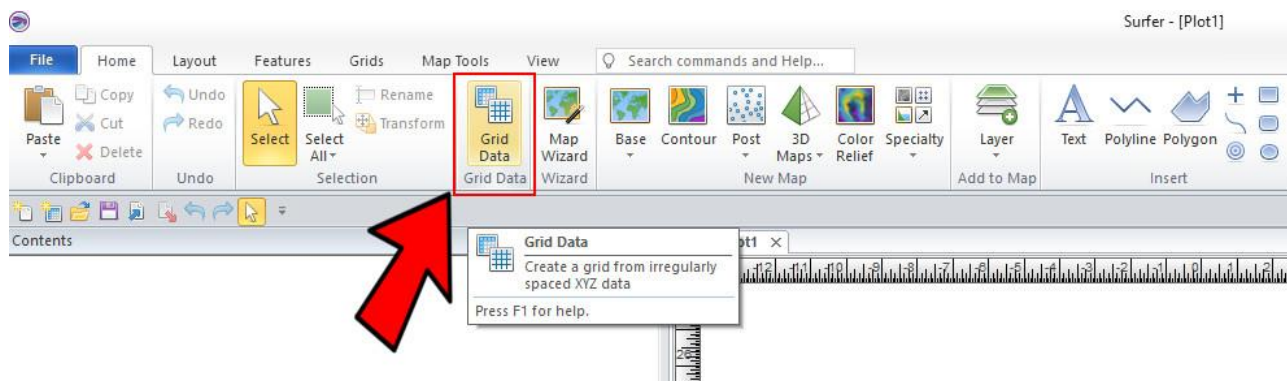


Figure 8. Click the Grid Data icon to create the grid.

We shortly describe the main settings of the Grid Data menu (Figure 9).

- 1) Select the interpolation model (*kriging* is a common choice, further details in the related [manual](#)),
- 2) Choose the maximum depth to be displayed in the contour plot. A 0.1 Hz peak in a H/V curve may indicate a seismic reflector at depth larger than 1000 m. If the target of the survey is the shallow subsoil, it is convenient to set the maximum desired depth at this stage. Depths are negative numbers (*Y Direction: Minimum*).
- 3) Set the spacing parameter that is the distance between two isolines. Even though this value can be as low as desired, note that this can become just a graphical effect and does not correspond to an increase of information at will. Do not confuse chromatic details with the real resolution of the investigation technique.
- 4) Do not tick the box marked with number 4 in Figure 9. If the topography is not flat, follow the instruction in the next section.

Press OK. Surfer® saves the output files in the same folder as the input files.

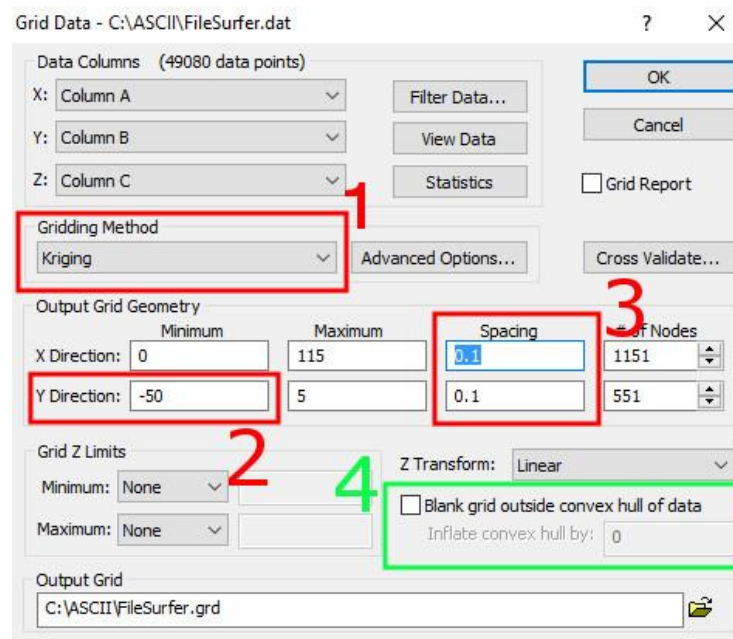


Figure 9. Parameters to be set to create a grid in Surfer®.

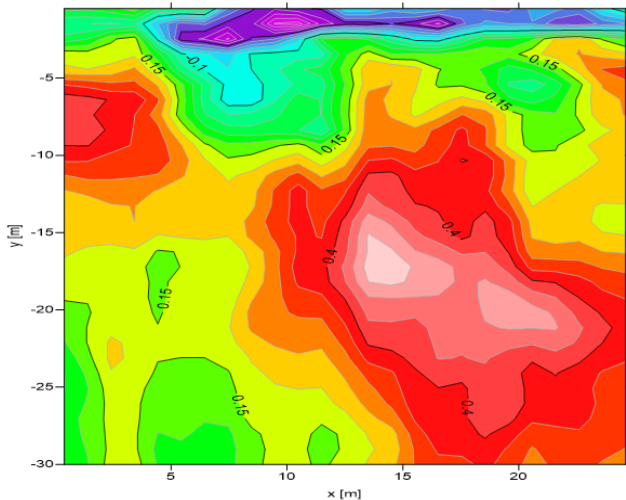


Figure 10. Contour with large spacing values.

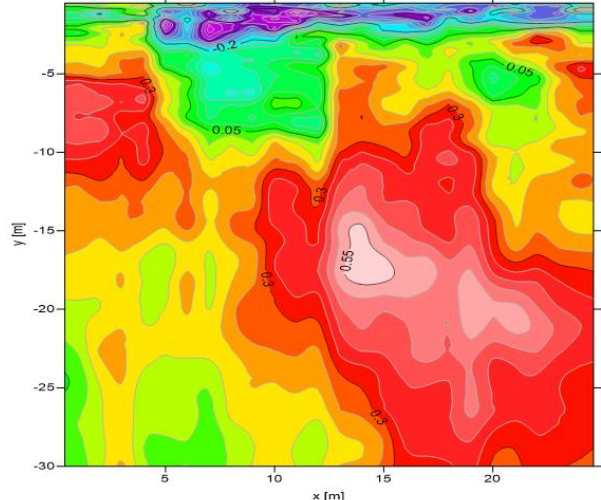


Figure 11. Contour with narrow spacing values.

Contour plot

Click the *Contour* icon (Figure 14) and open the .grd file created previously.

The H/V isoline plot will be created and this can be customized by using the menu that appears by clicking the image.

The *Fill contours* option and the chromatic scale set to *Gravity* usually provide good graphical results (Figure 14, Figure 15).

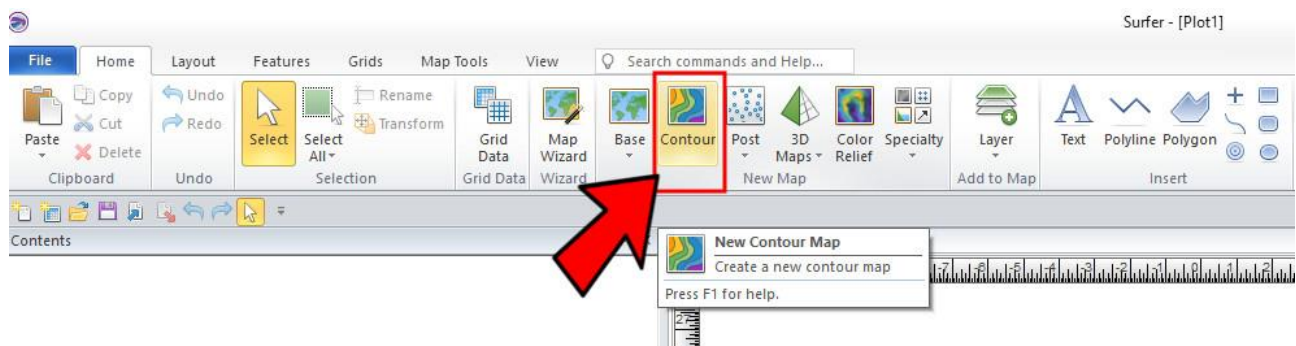


Figure 12. Select Contour to create the H/V color map.

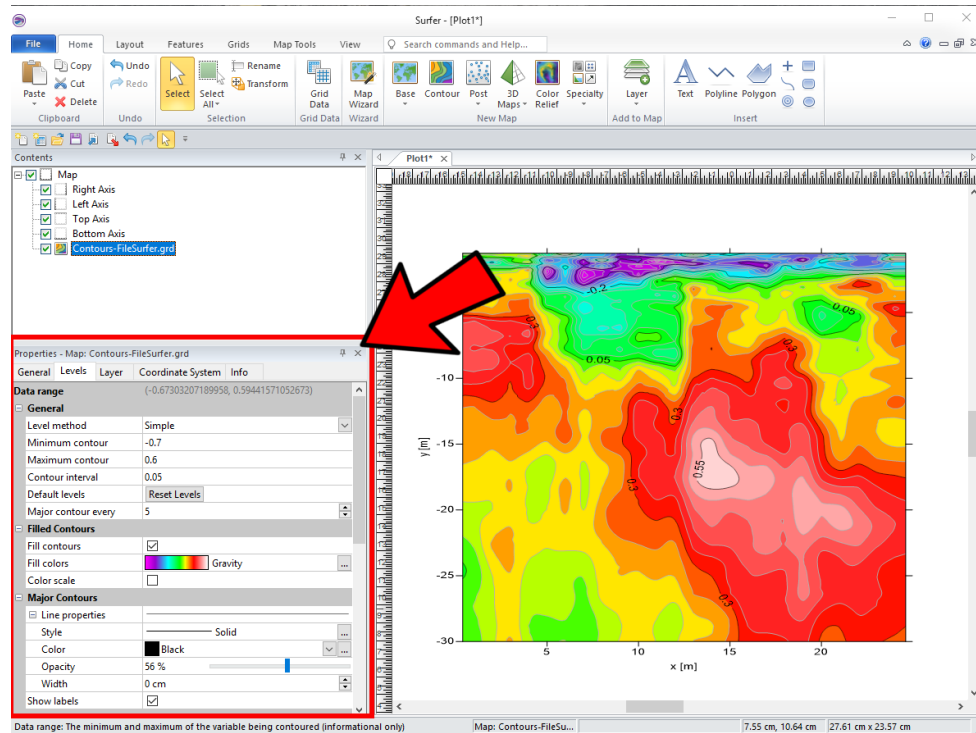


Figure 13. Menu to customize the contour plot.

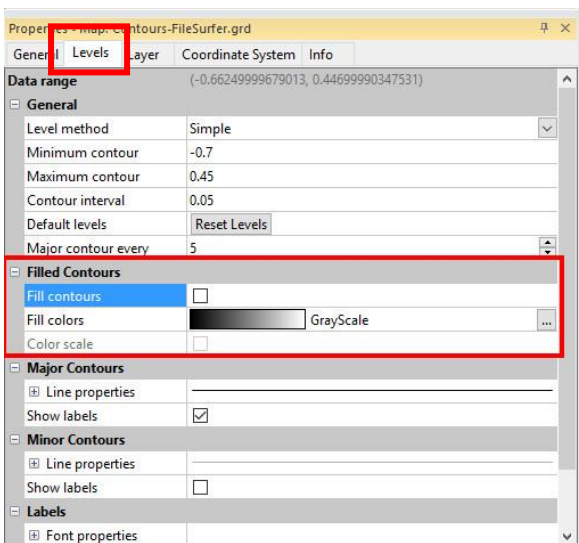


Figure 14. Menu Levels.

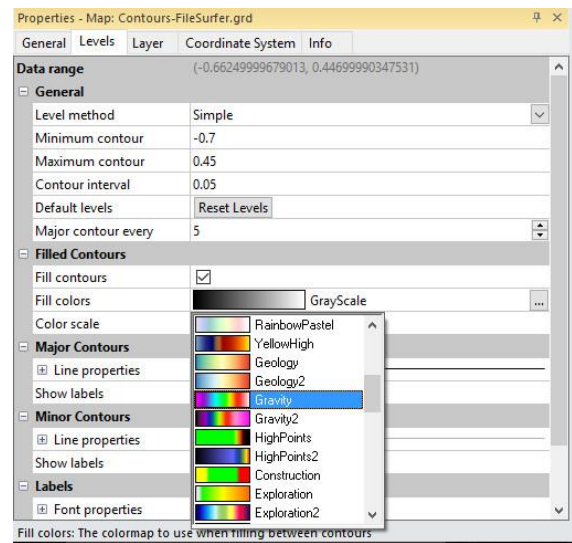


Figure 15. Color scale settings.

Non-flat topography

In case of non-flat topography, operate as it follows:

- 1) Create a grid as described on page 9. In absence of alternative information, Surfer® creates a rectangular grid. In case of a non-flat topography, the ground profile must be included in a polygon, so that the part outside the polygon can be deleted.
- 2) From the main menu of Surfer® select *File > New > Worksheet* and insert the coordinates of the points of the surface (the same coordinated inserted on item 2 and 3 of Figure 5).
 Cell A1: type the number of the vertices that compose the polygon.
 Cell B1: type zero.
 Cell C1: give a name to the polygon.
 In column A, type the *x* coordinates. In column B, type the *y* coordinates. In column C, type all zeroes (Figure 17).
 Complete the procedure by clicking *File > Save As*, and save the file with the extension .bln, (*Save as type: BLN Golden Software Blanking (*.bln)*).
- 3) Select *Grids* from the main menu and click *Blank*.
 A window opens. Select:
 - a. the .grd file created in the previous step
 - b. the .bln file
 - c. the layer type to export (e.g., *Contour*).

Press *Ok* and move to the *Home* window where the contour map can be created with the *New Contour Map* option (Figure 12).

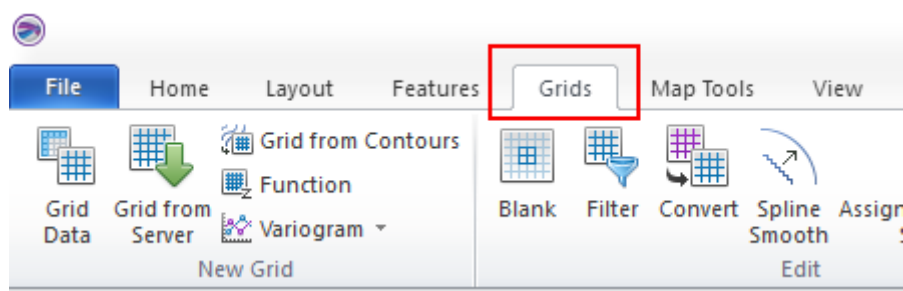


Figure 16. The *Blank* command can be entered from the *Grids* menu.

	A	x	B	y	C	z
1	16		0	sky		
2	0		444.9		0	
3	34.3		299.7		0	
4	958.8		432.6		0	
5	1791.8		243.9		0	
6	1903		461.1		0	
7	3050.1		458.8		0	
8	3583.3		450.7		0	
9	3586.5		449.6		0	
10	4030.1		425.2		0	
11	4037.1		434.6		0	
12	4452		448.6		0	
13	4476.5		409.7		0	
14	4920		452.7		0	
15	4928.7		447.6		0	
16	5272.4		445.6		0	
17	0		444.9		0	
18						

Figure 17. Example of polygon coordinates.

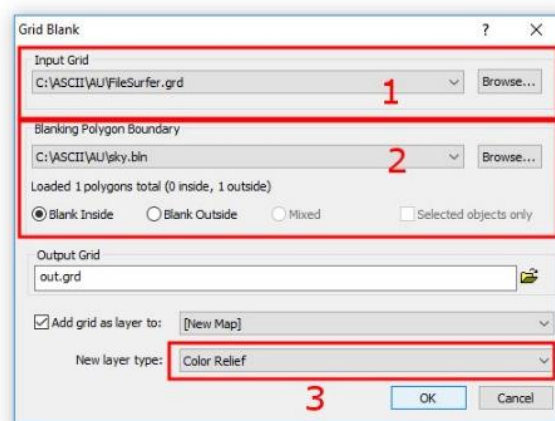


Figure 18. Grid blank window.