TUTORIAL

on

Multichannel Analysis of Surface Wave (MASW) in the *RadExPro* Software

(Revision of 08.07.2011)

DECO Geophysical SC
Moscow State University Science Park
1-77 Leninskie Gory
Moscow 119992, Russia
Tel.: (+7 495) 930 84 14
E-mail: support@radexpro.com
Website: www.radexpro.com

Table of contents

Introduction

This manual is intended for users who begin to process data acquired using the method of multichannel analysis of surface wave in the RadExPro program. It covers all standard stages of creation of shear wave velocity profile – data loading, geometry input, calculation of dispersion images, inversion of dispersion curves.

Theoretical basics of the multichannel analysis of surface wave method can be found in the sources below:

Park, C.B., Miller, R.D., and Xia, J., 1999, Multichannel analysis of surface waves: Geophysics, v. 64, n. 3, pp. 800-808

Lai, G., Rix, J., 1998, Simultaneous inversion of Rayleigh phase velocity and attenuation for near-surface site characterization, National Science Foundation and U.S. Geological Survey

Haskell, N. A. 1953, The dispersion of surface waves on multilayered media, Bull. Seismological Soc. of Am., v. 43, n. 1, p. 17-34.

Dal Moro, G., Pipan, M., Forte, E., Finetti, I., 2003, Determination of Rayleigh wave dispersion curves for near surface applications in unconsolidated sediments, Expanded Abstract, Society of Exploration Geophysicists, p. 1247-1250.

Foti, S., 2000, Multistation methods for geotechnical characterization using surface waves: PhD thesis, Politecnico di Torino, Italy.

All processing is executed on an example of the real data which can be downloaded from our website: http://radexpro.com/site/files/tutorials/MASWInpData.zip

The archive contains the initial data for the survey: 6 seismic records in SEG-Y format.

Additionally, you can download the existing project resulting from execution of all steps described in this guidance: http://radexpro.com/site/files/tutorials/MASW_project.zip

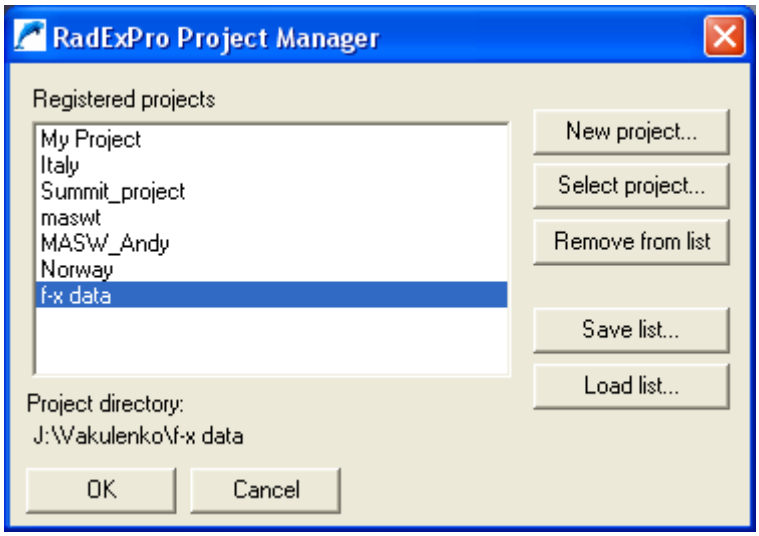
Data input, geometry assignment

Create project in RadExPro

All processing of data acquired from the method of surface waves in RadExPro program is carried out within the frames of projects. A project is a set of the initial data, intermediate and final results of processing, process flows organized in a uniform database used by the seismic data processing package RadExPro. The projects are stored in separate folders on a disk, the folder for the project appears automatically with the project creation.

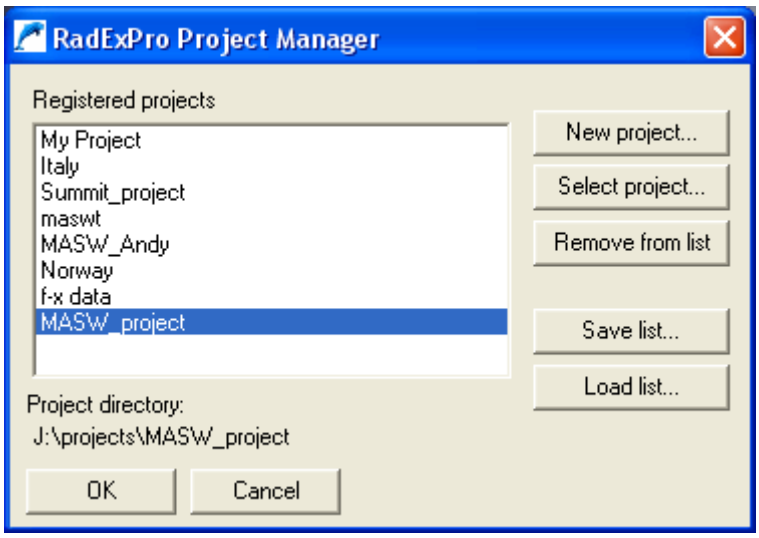
The project can be transferred from one PC to another simply by copying a folder (provided that all data used is stored in this folder). Let us create a new processing project. Launch the program using the Start menu or the icon on the desktop:

The project manager will appear. Together with this, the dialog box containing the list of the registered projects will open.

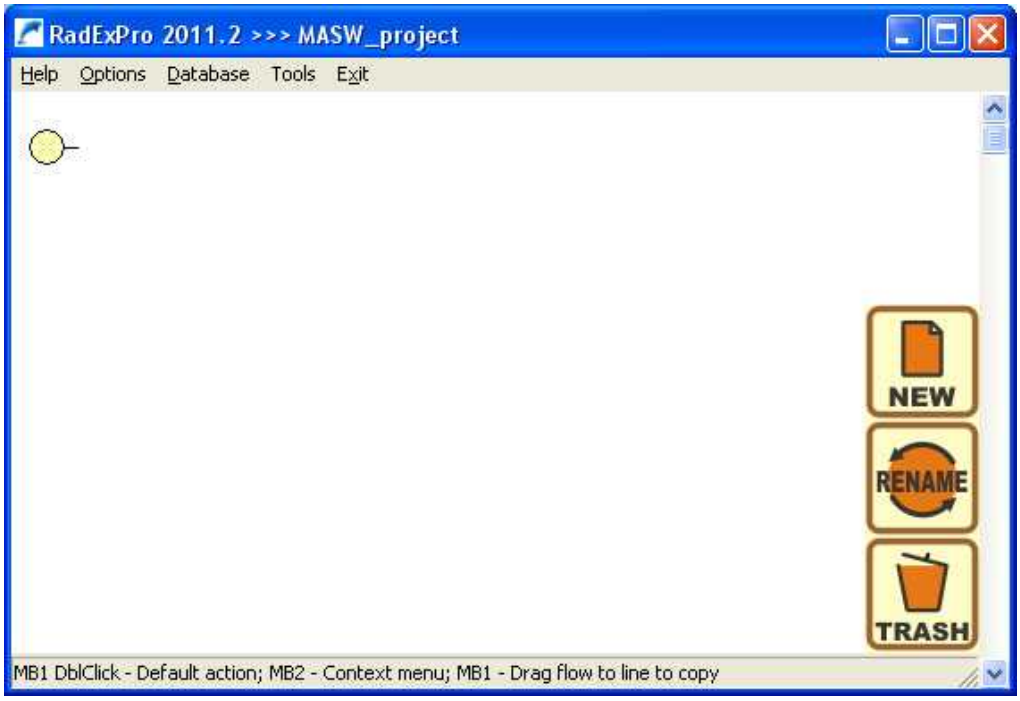


Press “New Project” button and select the parent directory on the disk where the subfolder with the project will be created. After that, enter your project name in the window that appeared.

Make sure that option Create subfolder is marked and press OK. The subfolder with the project name will appear in the selected directory. Also, the project will appear in the list of the available (registered) projects. Select it and press OK.

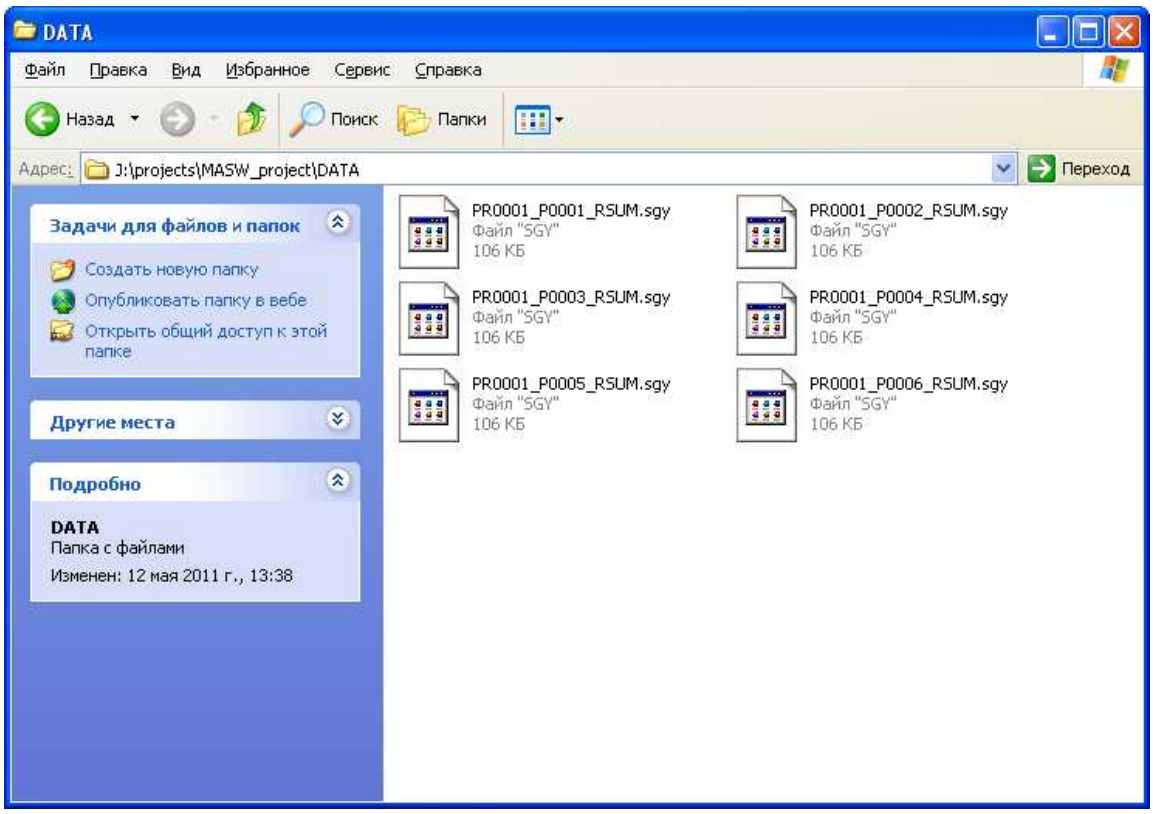


The home base window of RadExPro program containing the project tree will appear. Now the tree is empty.

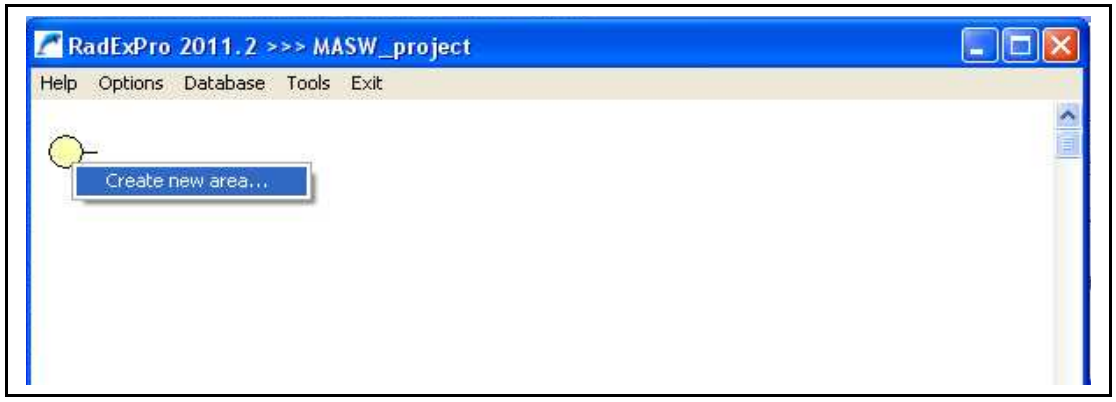


Initial data loading into the project

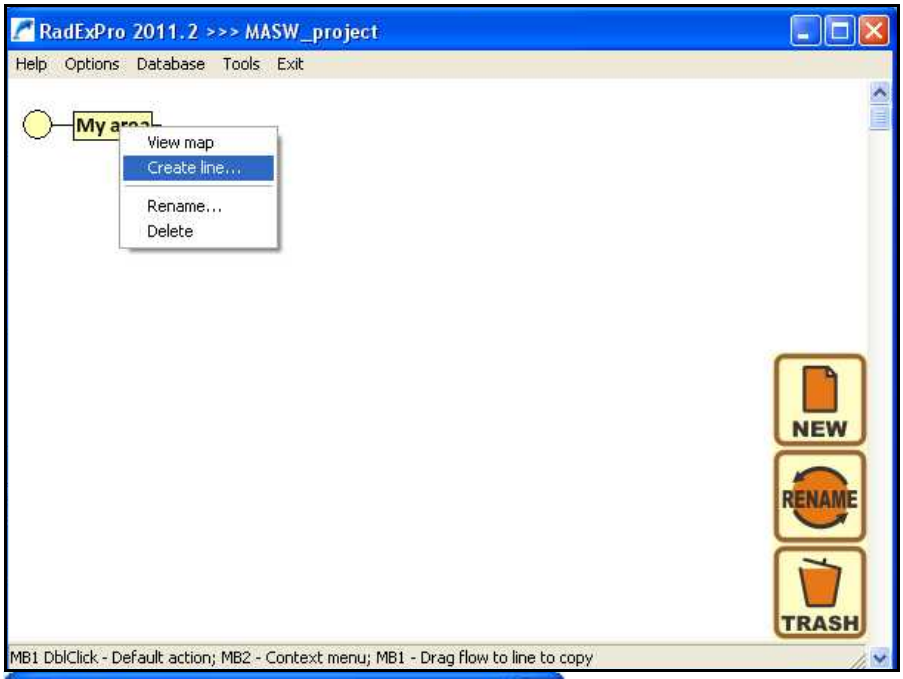
Using Windows explorer browse the project folder, create subfolder Data and copy the initial data there:

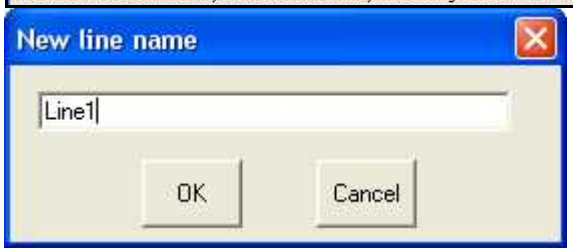


Storage of the data in this folder enables the package to use relative paths to the data files instead of the absolute ones, which simplifies projects transfer from one PC to another.
Return to the home base of RadExPro. RadExPro database consists of 3 structural levels. The upper level corresponds to the area where the works were carried out, the medium level – to the line, the lower one – to the processing flow. Click the right mouse button on the yellow circle, select the option Create new area and enter the name of the area where the works were conducted.



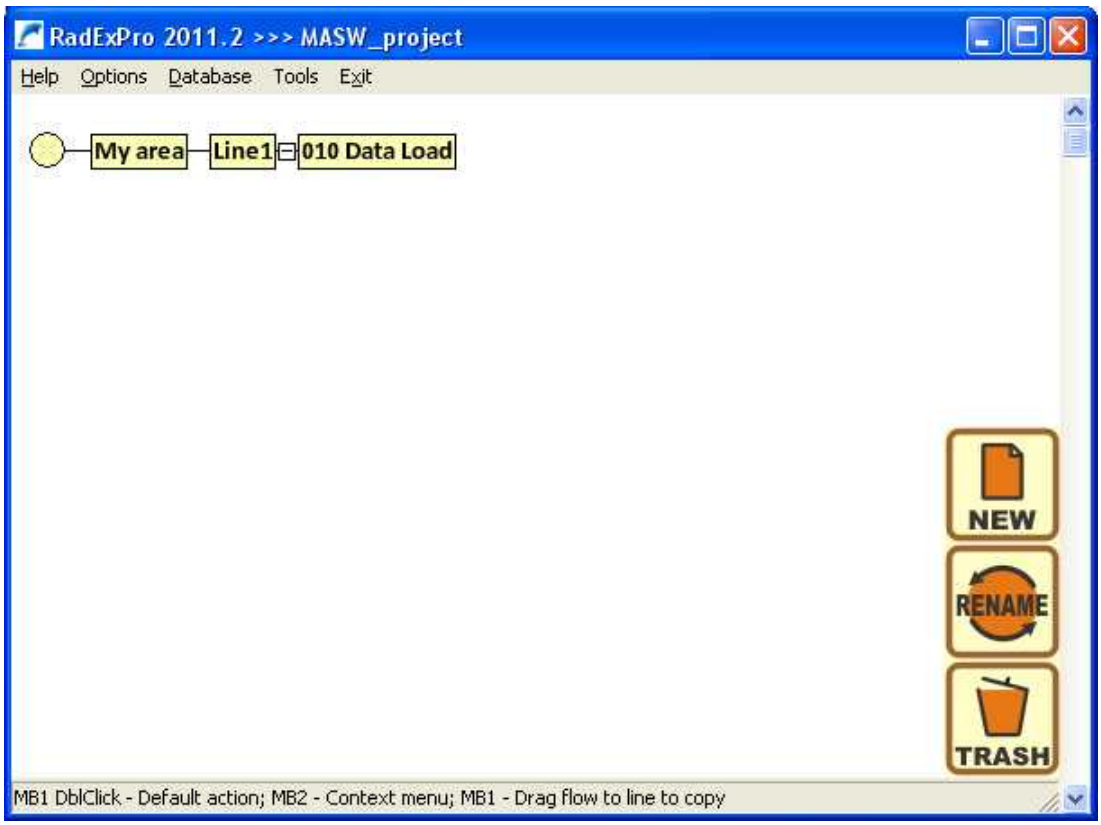
Similarly, after clicking the right mouse button on the yellow rectangle with the area name, select Create line and create a new line.



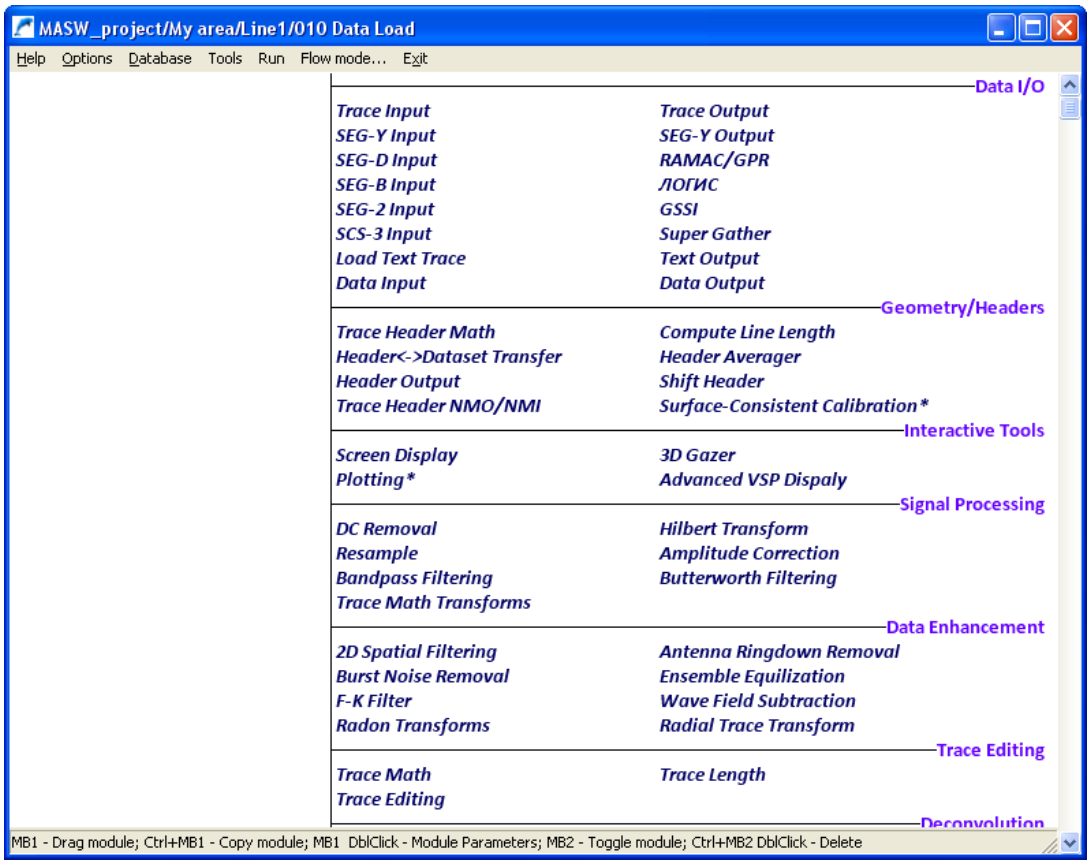


The database enables to keep several areas within the framework of one project, each area may contain several lines, each line is processed in several flows. In the same manner as we created area and line let us create the processing flow 010 – Data Load.

At the beginning of each flow name it is recommended to use its number. The procedure of seismic data processing consists of several stages executed consecutively. RadExPro program arranges the names of the database structural elements in alphabetical order, so it is reasonable to enumerate the flows for their displaying in correct logical order.



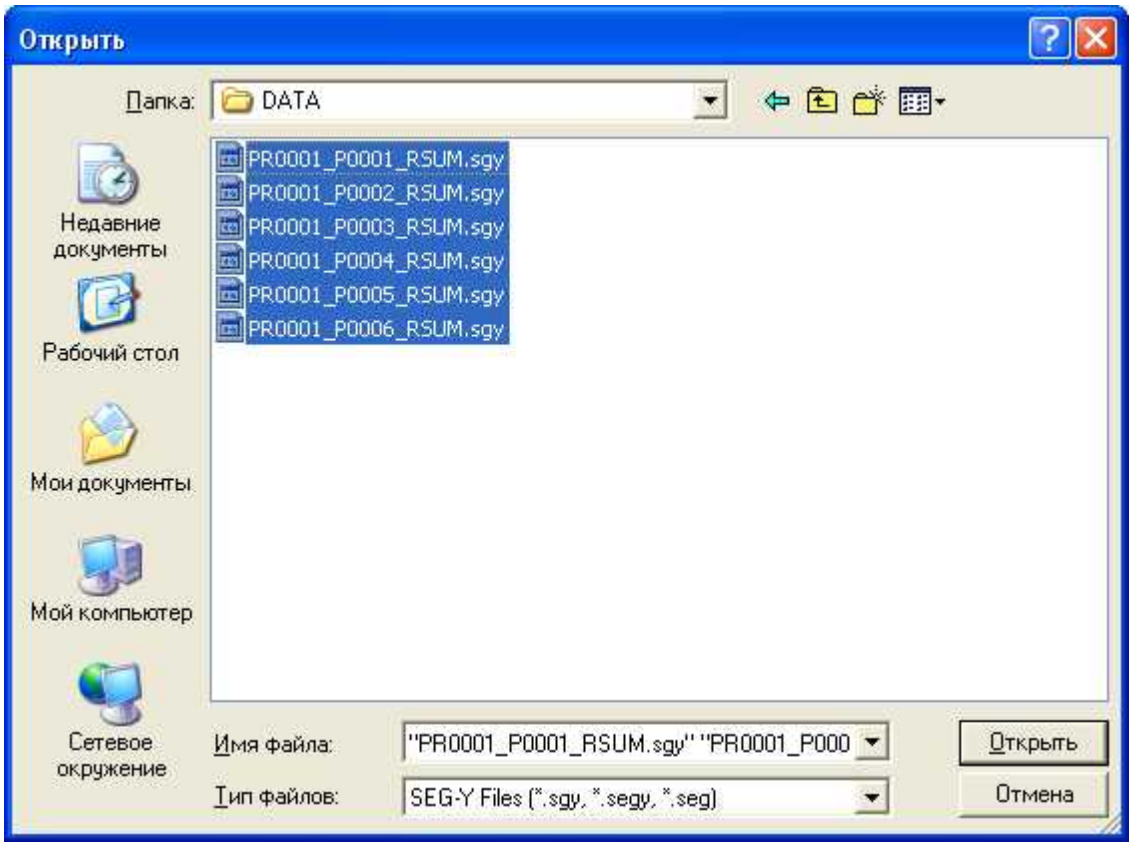
Proceed to the flow edit mode by double clicking on the flow name with the left mouse button. The flow edit window will open. The left part of the window shows the flow itself (it is empty now), the right part shows the library of available processes (modules) divided into sense-groups.



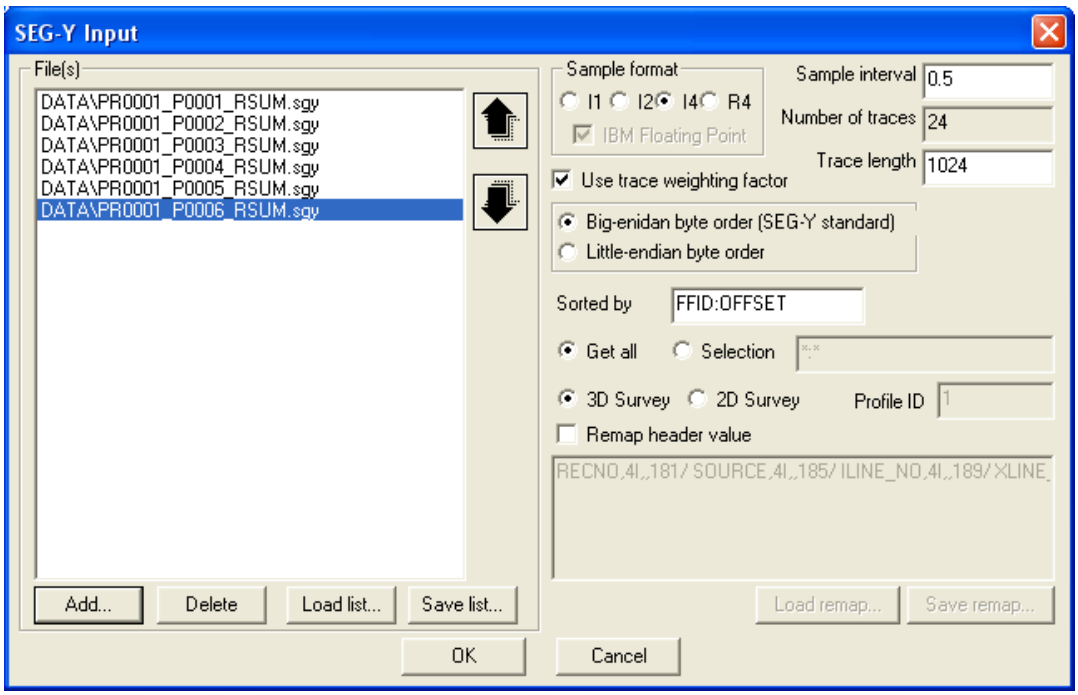
Let us create a flow consisting of modules SEG-Y Input and Trace Output (both the modules are located in Data I/O – data input-output group). This flow will read the data from SEG-Y file on the disk and write it to the project database as the base object - "dataset".
The modules are added to the flow one by one. In order to add a module to the flow, just drag it from the library on the right side to the flow area on the left side. After doing this, the module parameters edit dialog window will open. (Further on, this module parameters dialog window in the flow can be activated with double click on the module name). The modules already in the flow can be dragged upwards and downwards relative to each other using a mouse.

Let us add SEG-Y Input module from Data I/O group to the flow.

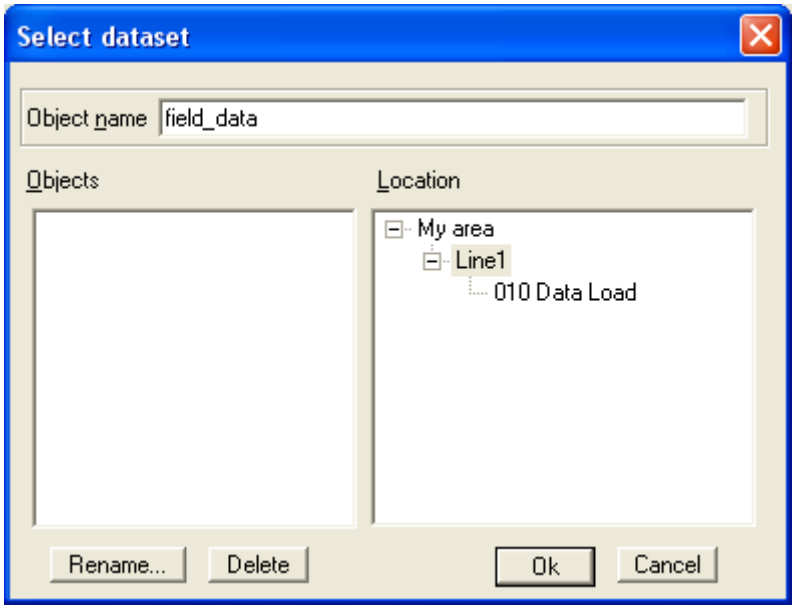
We add the acquired data by pressing Add button and browsing the files location (they were copied to folder DATA of the current project). Each *.sgy file corresponds to one SP on the line. For the sake of convenience we shall load all SPs to one dataset in further processing. To do this, we shall select all the files in the folder and press "Open".



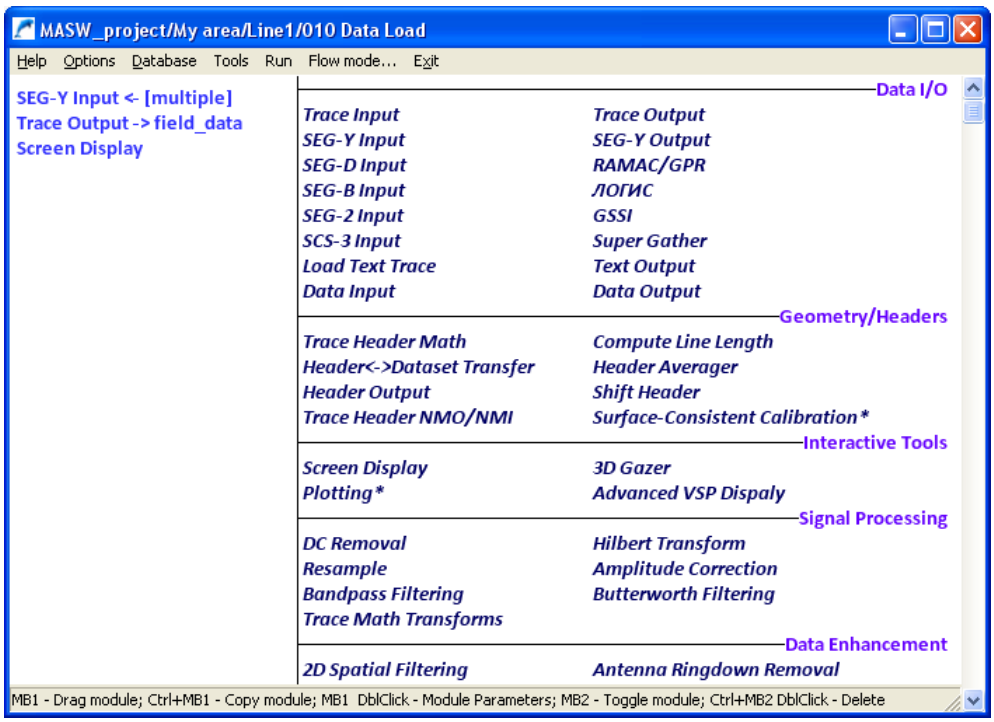
The list of the added files will appear in the left part of the module. The parameters and files record format are set in the right part (they are defined automatically, but they can always be changed in case of incorrect definition by the program). In this specific case the parameters defined automatically are correct.
After pressing the OK button, the window with module parameters will close and the module will appear in the flow.



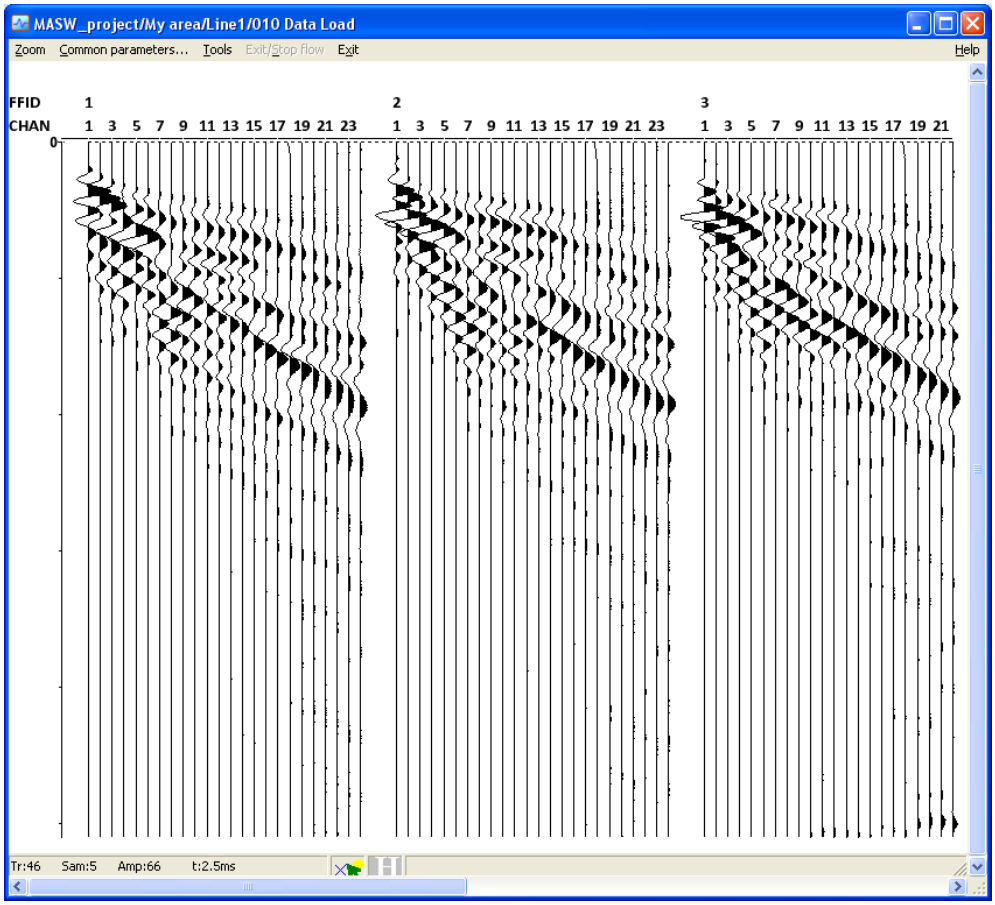
After SEG-Y Input module we will add Trace Output module to the flow which is to save the read data in the database. We name the object containing this data as field_data and we will allocate it at the second level of the database in line called Line1:



Also, to control the loaded data, after Trace Output module add Screen Display module to the flow. The flow should look as follows:



To run the flow, select Run menu command. As a result the Screen Display window displaying the input data will appear, and the data will be read from the file on the disk and written into the database. The Screen Display window that should appear on the screen is shown below.



Field operations execution technique using the method of multichannel analysis of surface waves

The selection of arrangement parameters while carrying out observations using the MASW method is directly related to the desirable lateral and vertical resolution. The length of the detector line (D) is related to the maximum wavelength (λmax): D ≈ λmax, while the maximum depth for which transverse waves velocity can be recovered is defined as half of the greatest wavelength: Zmax ≈ λmax/2.
On the other hand, the distance between receivers (dx) is related to the minimum wavelength (λmin) and, accordingly, with the minimum survey depth (Zmin): dx ≈ λmin, Zmin ≈ λmin/2. In practice, however, the crucial factor defining the maximum wavelength is the source. Normally, it is initial tens of meters.
It is recommended to use low-frequency (4.5 Hz) vertical receivers for this purpose. Low-frequency receivers help to achieve registration of waves with greater length, which, in turn, increases depth of the method. Application of receivers with higher frequency is also admissible.
The offset between the source and the first receiver is usually selected from 1 to 4 dx distances.
The most frequently used type of observations when executing the works using this method is "profiling", i.e. the source is moved together with the receiving arrangement for a certain step which is selected in accordance with the lateral resolution of the method.

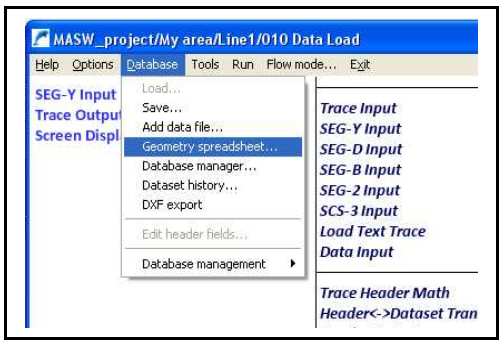
Geometry assignment

Acquisition parameters:
The data used was the information acquired by the following technique:
Reception line – 24 channels, distance between channels – 1 m (vertical geophones). Offset between the source and the first receiver – 5 m. All arrangement moved through 1 m.

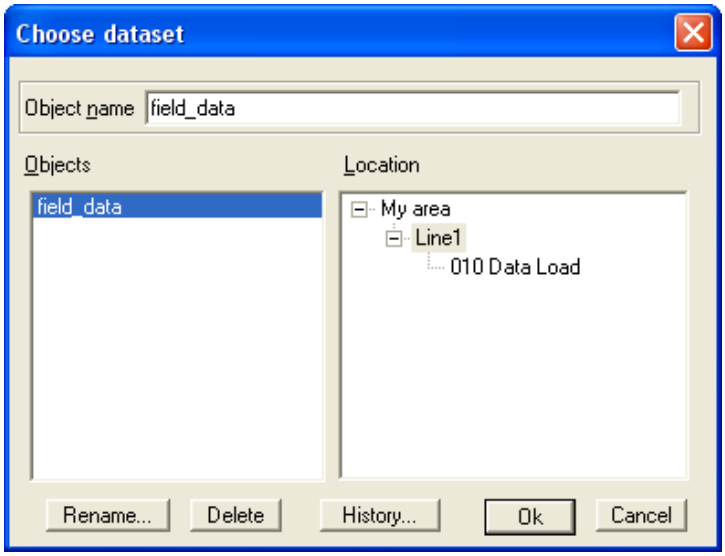
Geometry assignment to the seismic data means that each trace is given a number of values which are, consequently, saved in the specified header fields of the dataset in the project database.
In case of multichannel analysis of surface waves, for proper module operation the following headers are to be defined:

1. Source position number (FFID)
2. Channel number (CHAN)
3. Source axis (SOU_X)
4. Receiver axis (REC_X)
5. Offset between the source and the receiver (OFFSET)

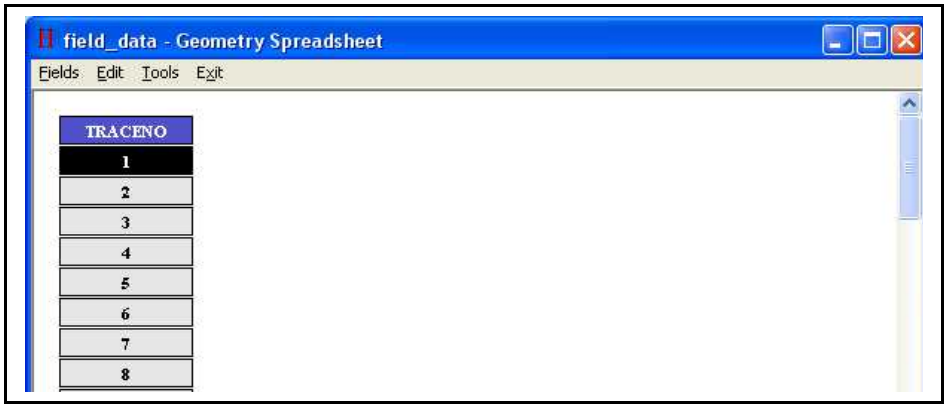
In practice, there can be any combination of the filled trace headers. For example, data can be transferred for processing even with empty headers. In this case they will have to be formed using the tools offered by the processing package.
For manipulations with the seismic data header fields, the RadExPro package applies Geometry Spreadsheet tool. Select menu item Database/Geometry Spreadsheet...



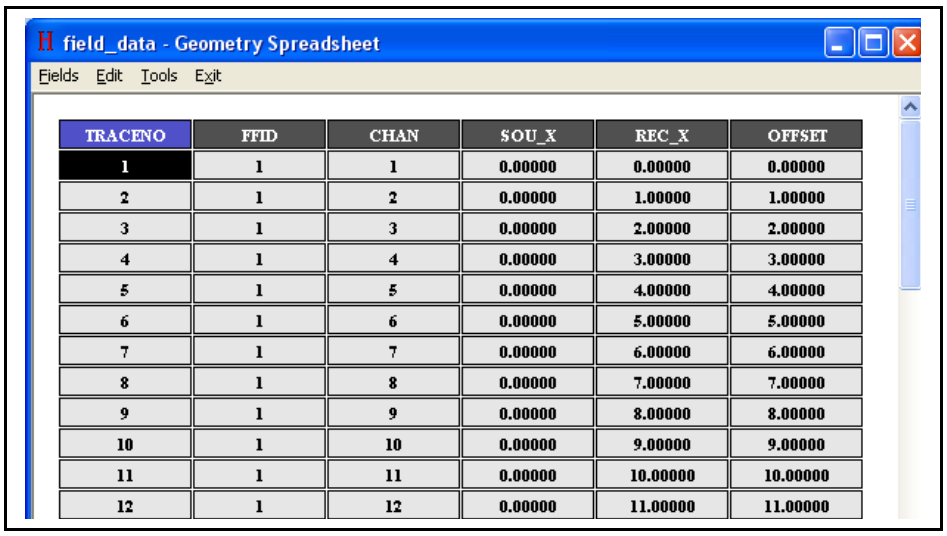
Then select the set of the seismic data the geometry of which is to be edited.



As a result the header edit window will appear:

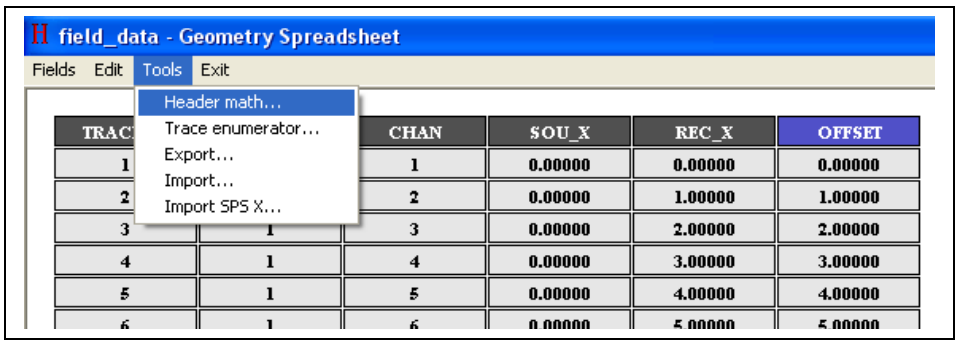


To display the required header fields (all header fields registered in the database already exist, but they are not displayed) select the menu option Fields / Add fields... In the open dialog box keeping the Ctrl button pressed select the following header fields: FFID, CHAN, SOU_X, REC_X, OFFSET.
As a result the header edit window should look as follows:

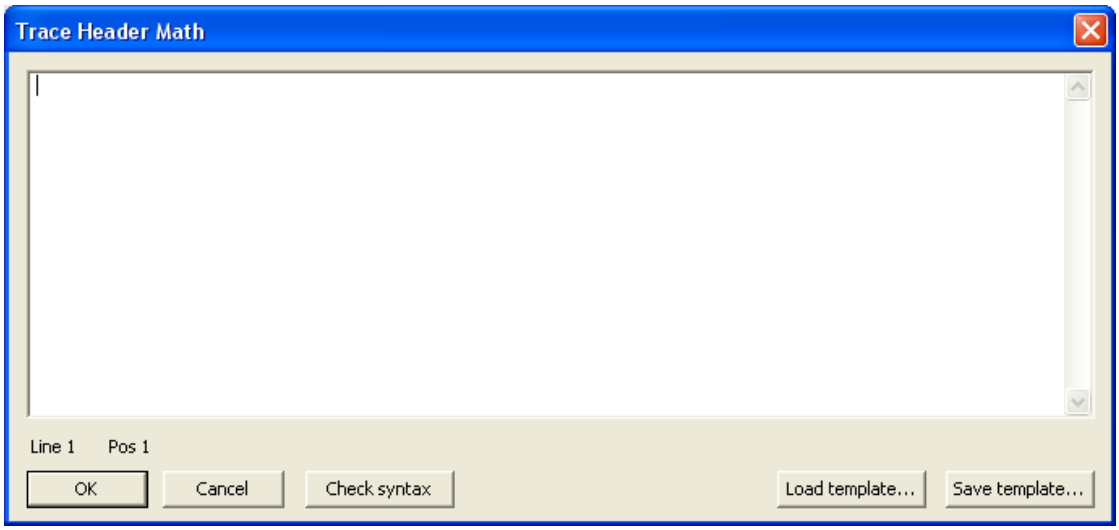


TRACENO	FFID	CHAN	SOU_X	REC_X	OFFSET
1	1	1	0.00000	0.00000	0.00000
2	1	2	0.00000	1.00000	1.00000
3	1	3	0.00000	2.00000	2.00000
4	1	4	0.00000	3.00000	3.00000
5	1	5	0.00000	4.00000	4.00000
6	1	6	0.00000	5.00000	5.00000
7	1	7	0.00000	6.00000	6.00000
8	1	8	0.00000	7.00000	7.00000
9	1	9	0.00000	8.00000	8.00000
10	1	10	0.00000	9.00000	9.00000
11	1	11	0.00000	10.00000	10.00000
12	1	12	0.00000	11.00000	11.00000

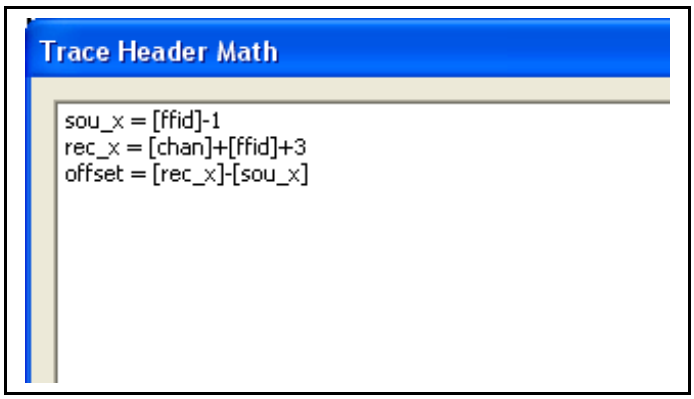
In this example headers FFID, CHAN are filled correctly, while headers SOU_X, REC_X, OFFSET are incorrect. In order to edit the headers we will use a standard package tool – Trace header math.



Trace header math enables to execute various mathematical procedures with header fields. The detailed description of all available procedures can be found in the User's Guide.

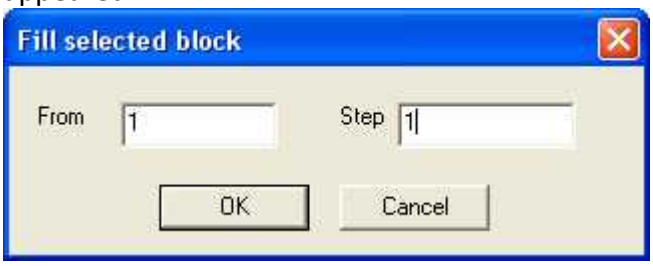


On the basis of the values of headers FFID, CHAN which are filled in the correct manner, we will use the following formulae to fill the remaining ones:



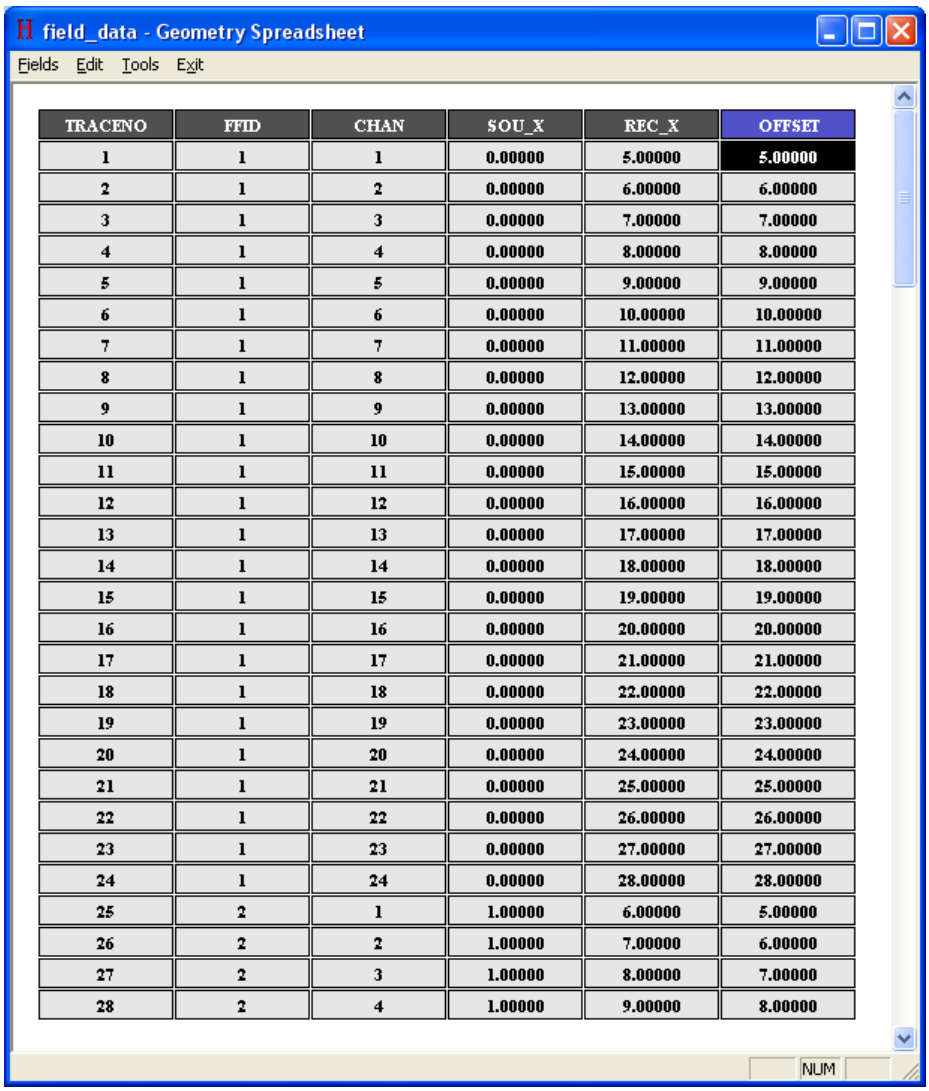
Note: it is common for fields FFID and CHAN to be not filled or filled incorrectly. To assign their values according to the parameters of our observations we can do as follows:

1. To renumber field TRACENO with values beginning from 1 with step 1. For this purpose one is to click the left mouse button on header TRACENO in Geometry Spreadsheet (blue rectangle) – as a result the whole column of values will be selected, to push button Insert on the keypad, and to specify the initial value and step in the dialogue that appeared:



2. To use the following formulae:
   ffid = trunc (([traceno]-1)/24) + 1
   chan = fmod ([traceno]-1, 24) + 1

The result should look as follows:



TRACENO	FFID	CHAN	SOU_X	REC_X	OFFSET
1	1	1	0.00000	5.00000	5.00000
2	1	2	0.00000	6.00000	6.00000
3	1	3	0.00000	7.00000	7.00000
4	1	4	0.00000	8.00000	8.00000
5	1	5	0.00000	9.00000	9.00000
6	1	6	0.00000	10.00000	10.00000
7	1	7	0.00000	11.00000	11.00000
8	1	8	0.00000	12.00000	12.00000
9	1	9	0.00000	13.00000	13.00000
10	1	10	0.00000	14.00000	14.00000
11	1	11	0.00000	15.00000	15.00000
12	1	12	0.00000	16.00000	16.00000
13	1	13	0.00000	17.00000	17.00000
14	1	14	0.00000	18.00000	18.00000
15	1	15	0.00000	19.00000	19.00000
16	1	16	0.00000	20.00000	20.00000
17	1	17	0.00000	21.00000	21.00000
18	1	18	0.00000	22.00000	22.00000
19	1	19	0.00000	23.00000	23.00000
20	1	20	0.00000	24.00000	24.00000
21	1	21	0.00000	25.00000	25.00000
22	1	22	0.00000	26.00000	26.00000
23	1	23	0.00000	27.00000	27.00000
24	1	24	0.00000	28.00000	28.00000
25	2	1	1.00000	6.00000	5.00000
26	2	2	1.00000	7.00000	6.00000
27	2	3	1.00000	8.00000	7.00000
28	2	4	1.00000	9.00000	8.00000

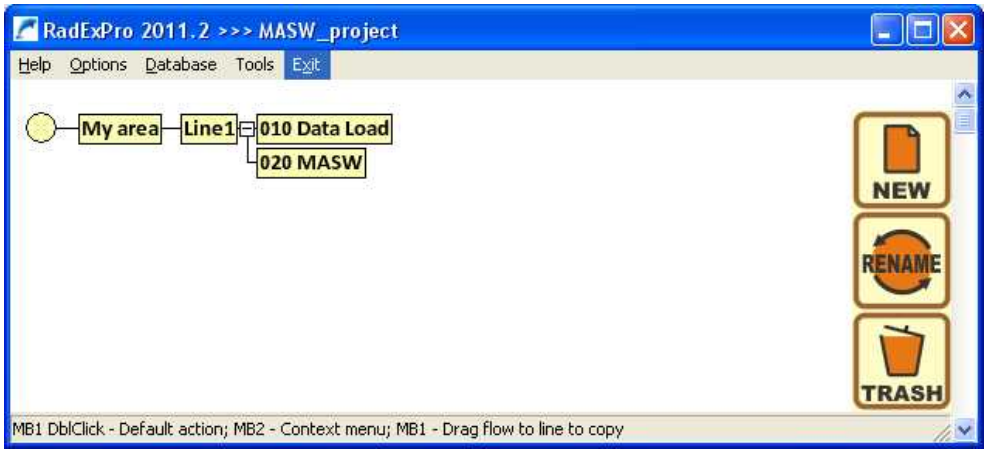
Save the acquired result with menu item Edit-> Save changes and quit the geometry editor by pushing Exit.

After assigning geometry of observations, one can immediately proceed to work with the multichannel analysis of surface waves module.

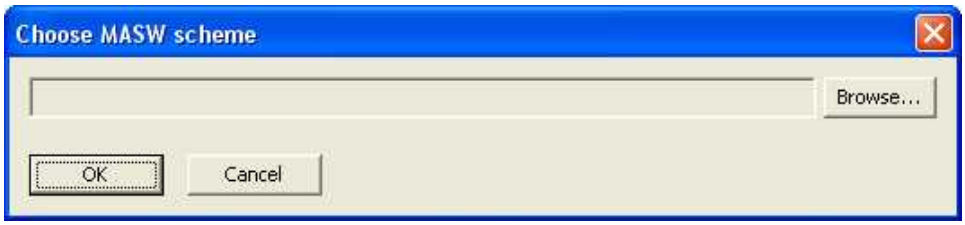
Work with MASW module

Processing scheme setting

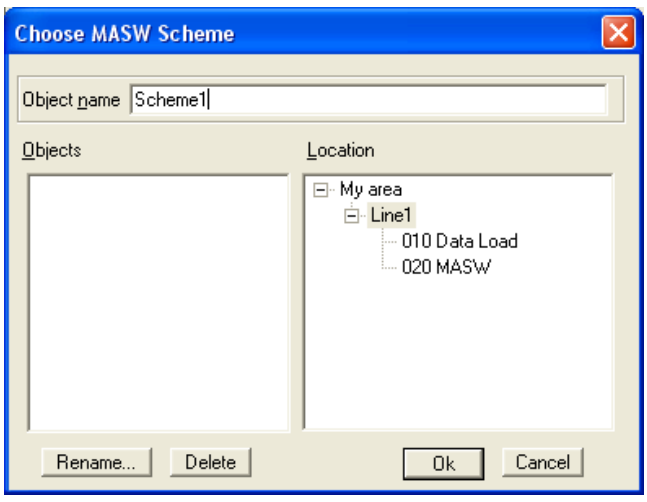
Create new flow “020 – MASW”:

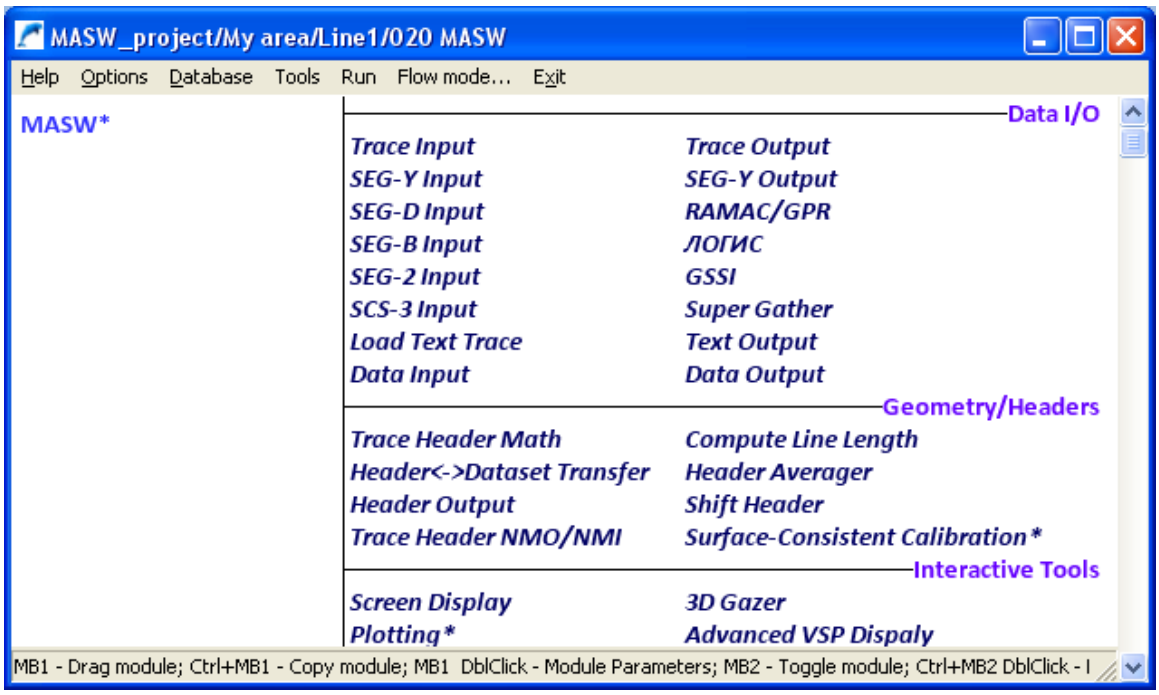


Enter the flow and add MASW module located in group Surface Wave Analysis.
Data processing is executed within the framework of a particular processing scheme. A scheme is a set of dispersion images, associated curves, resulting model, and calculation parameters and images and model visualization. Each scheme is stored in a separate directory “MASW” of the project.
When a module is added to a flow, a scheme selection dialogue appears – create new scheme by pushing button “Browse …”.

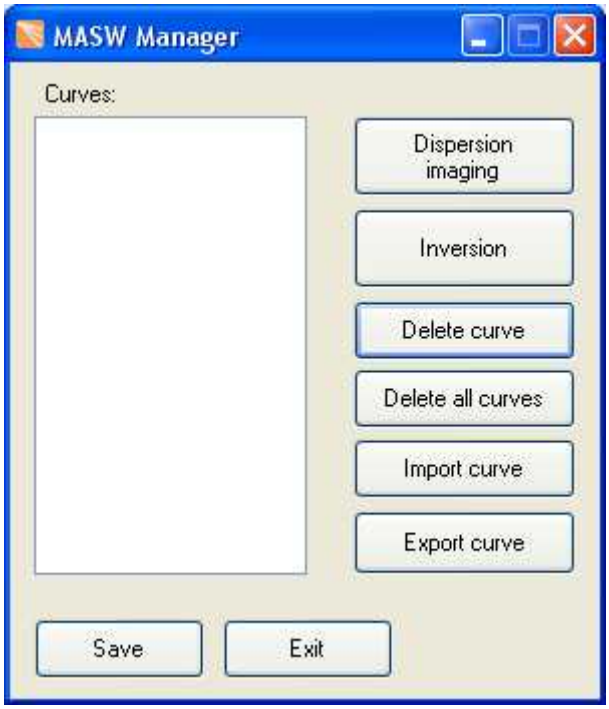


We will name the scheme as Scheme1 and save it at the level of the current line. After pushing OK the module will appear in the list.



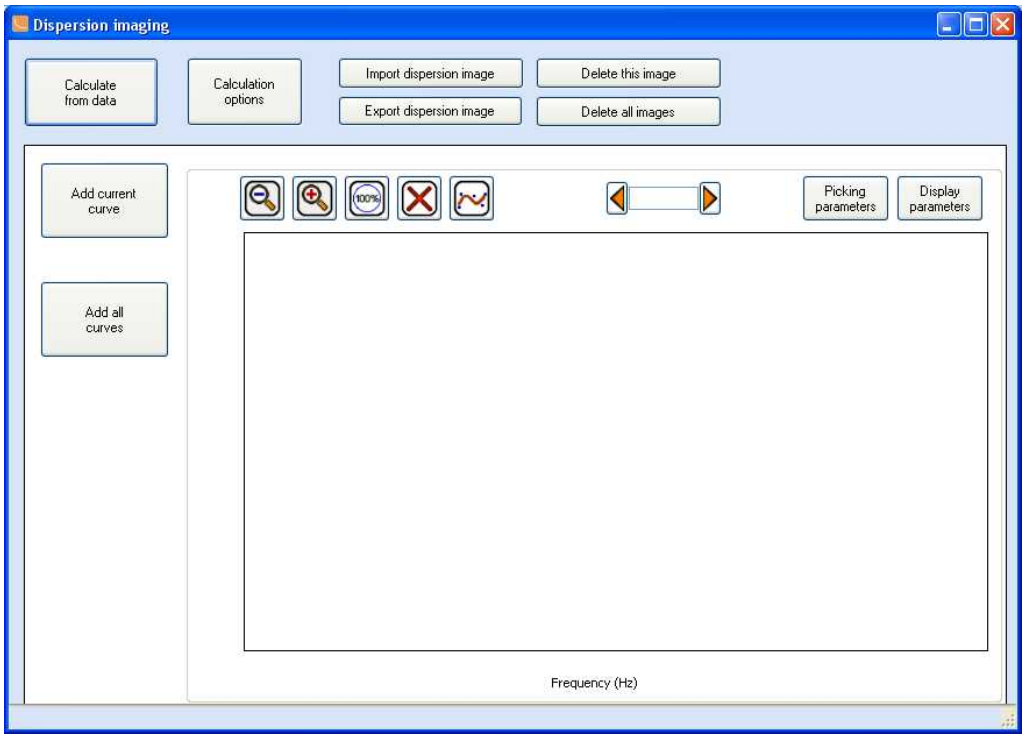


Launch the module by pushing button Run. As a result the project control home base window will appear – “MASW Manager”. The left part of the window shows the list of all the dispersion curves added in the scheme. The curves are sorted by header SOU_X in ascending order. The “MASW Manager” project control window will remain empty until an image has been processed and added.

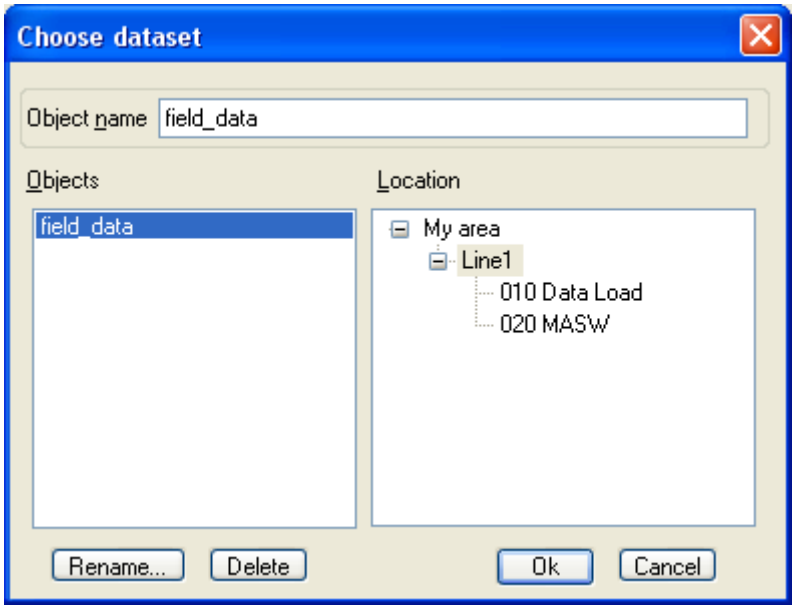


Dispersion images calculation

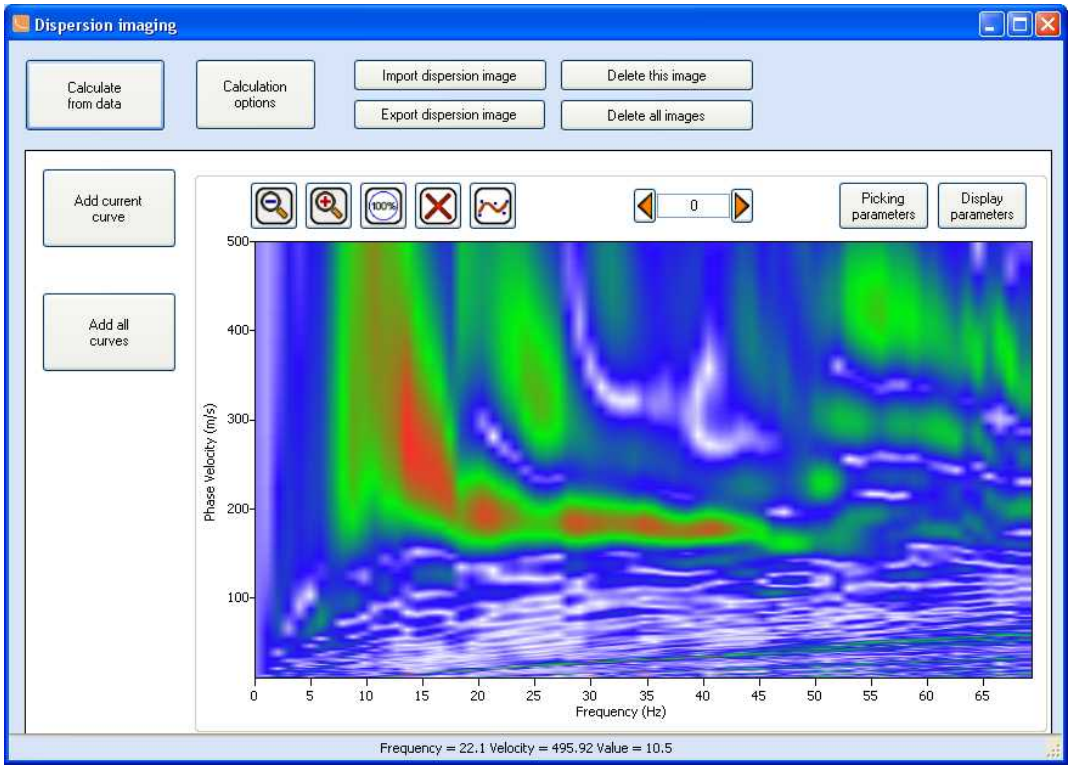
Press Dispersion Imaging button – dispersion images calculation and processing window will appear:



To calculate a dispersion image push Calculate from data, specify the path in the database to the field_data dataset saved earlier and push OK.



Wait till calculation of dispersion images is completed ("Calculating dispersion images" indicator will disappear). Upon completion, a dispersion image for the first SP in the dataset will appear on the screen:



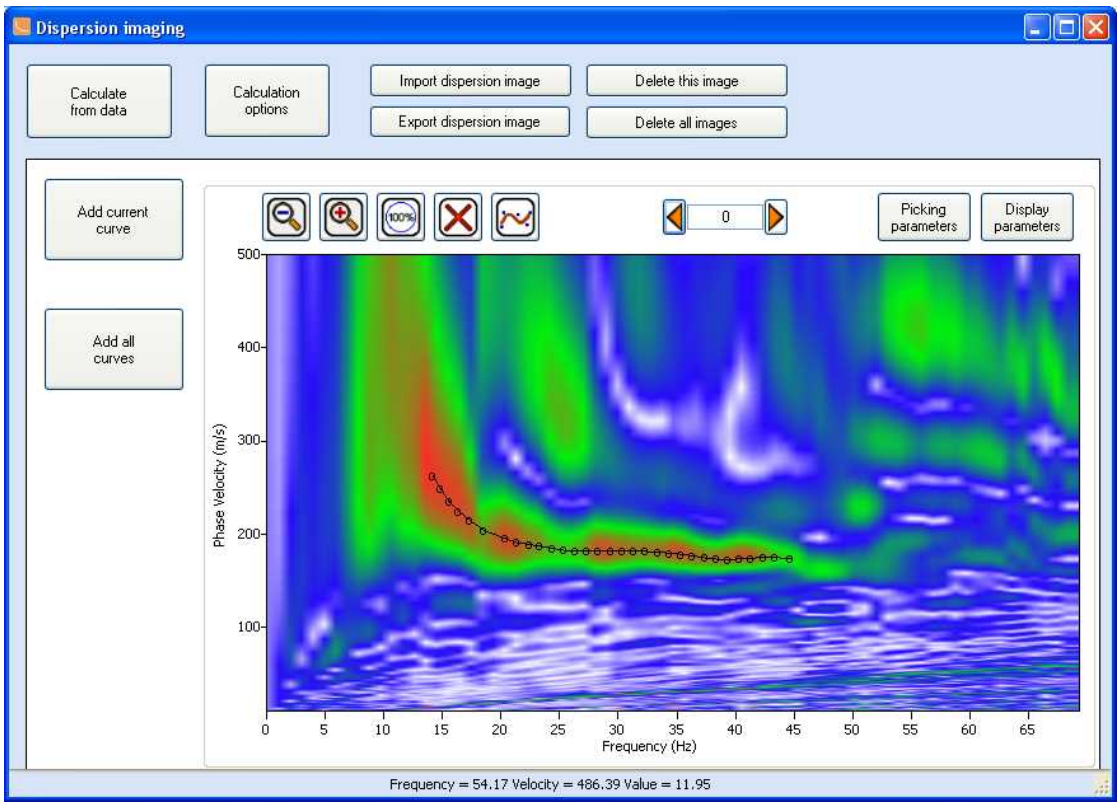
Dispersion images are calculated automatically for all SPs in the current dataset (in this case, 6 dispersion images will be calculated).

By default, an image is calculated in the range of phase velocities 0 to 500 ms with the step of 1 ms and the range of frequencies 0 to 70 Hz. If the image exceeds frequency or velocity limits, calculation parameters can be changed by pushing button "**Calculation options**" and repeating the process starting from the dataset selection. In our example the specified calculation parameters enable us to receive sufficient informative dispersion image, no change of ranges is required.

After the dispersion image appears on the screen it is necessary to extract the dispersion curve by image picking on a maximum of amplitudes. By default, the mode of automatic picking is activated – the points are automatically placed between the first and the last amplitudes on a maximum in the specified window with the assigned step, the parameters are set by **Picking parameters** option.

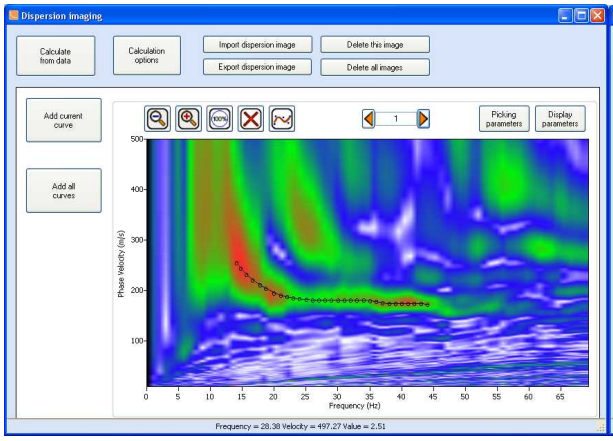
Click once on the left mouse button on a maximum in the left part of the dispersion image and once on a maximum in the right part of the image (as shown in the figure below). As a result the dispersion image will be picked on all the maxima of amplitudes with the assigned step between these two points. The points position can be changed by holding the right mouse button on this point and moving it to the required place. The point is deleted with double click of the right mouse button on the point.

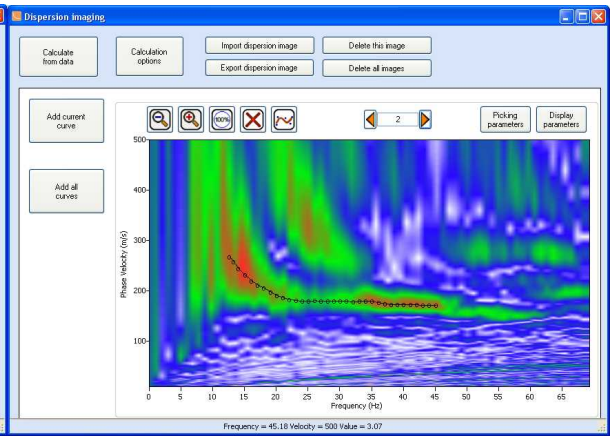
Picking smoothing is executed upon pushing the smoothing button  in the toolbar. Achieve picking similar to the picture:

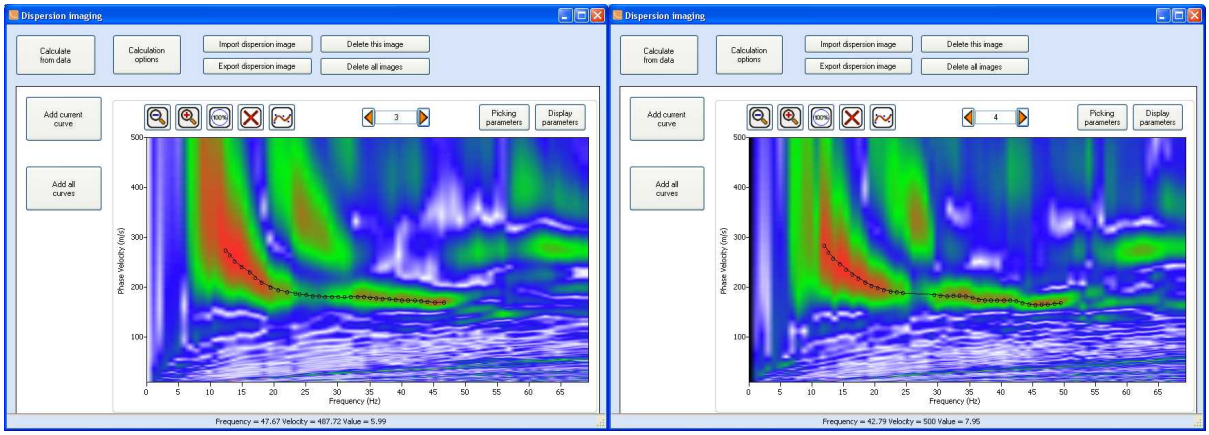


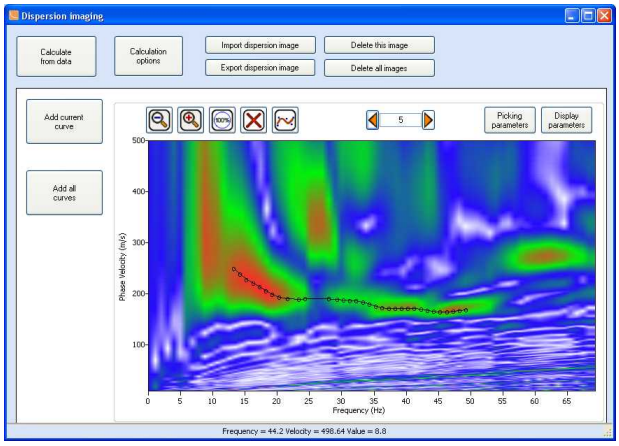
! Selection of the principal mode on the dispersion image is not always simple and unambiguous procedure. It can be complicated both by dominance of higher modes and a wide maximum in the lower frequencies.
It is well to bear in mind that change of picking in relatively small limits can cause a significant deviation of velocities in the resultant model.

After picking of one image is completed proceed to the dispersion image related to the next SP by pushing the right arrow on the toolbar  . Execute the picking of the remaining images in a similar manner:

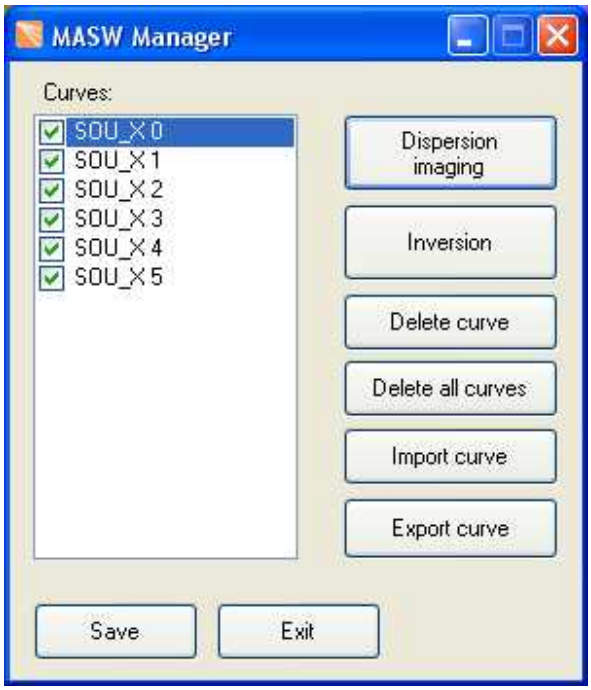








After all curves are received, they are to be added to the list of curves that will undergo the processing procedure (they will be submitted to the input of the inversion procedure). To achieve this, push **Add all curves** on the left in the dispersion images calculation window. As a result the curves will appear in the list of the project home base window:



Inversion procedure

Before starting curve fitting process it is necessary to set the initial environment model.
Push Inversion button – the initial model filling type selection dialogue window will appear.

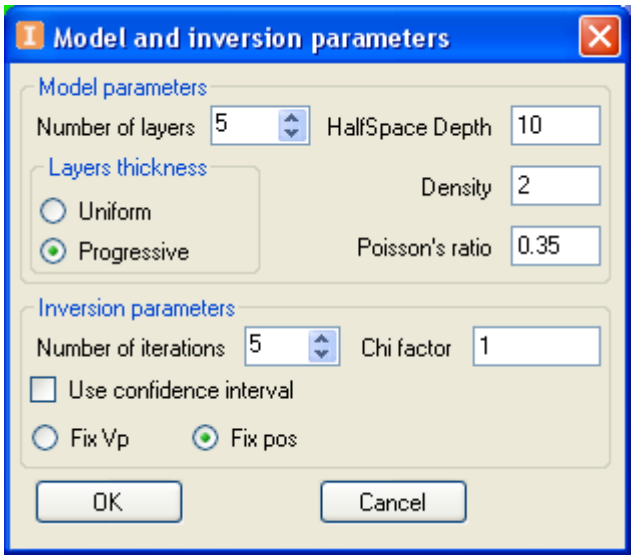
Let us select automatic filling by pushing button "Yes". As a result the initial model parameters setting window will appear.

Selection of the initial model parameters:

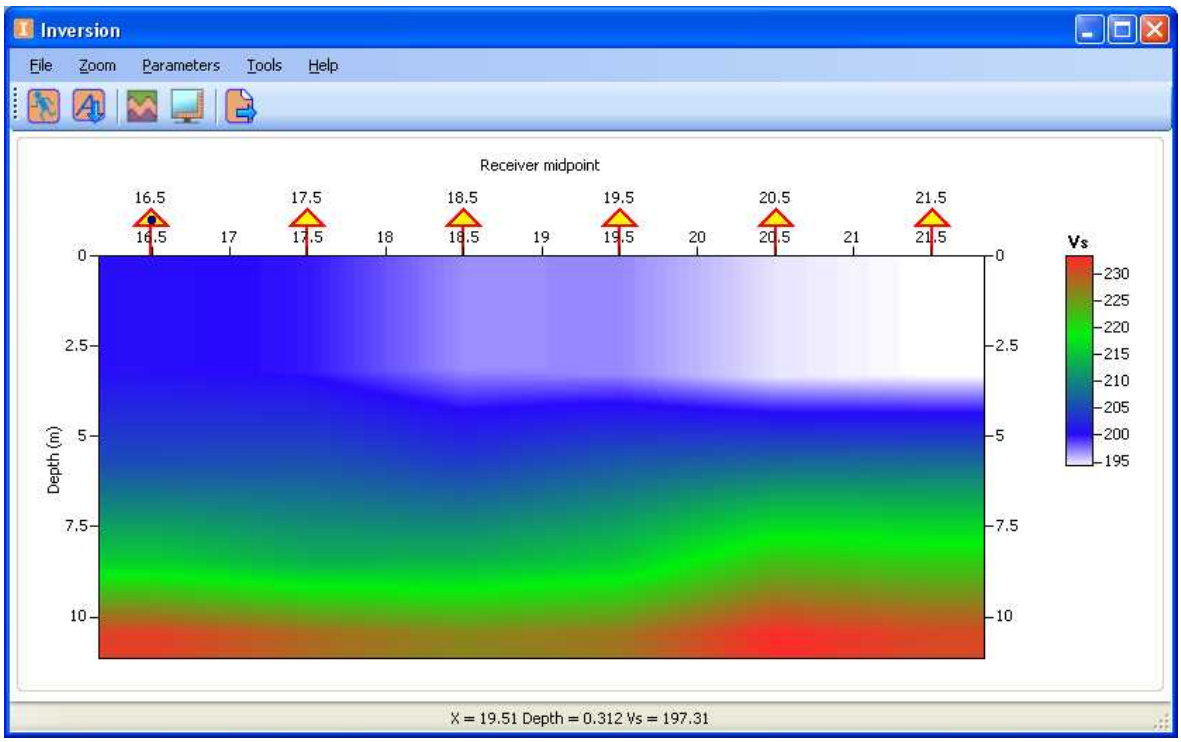
1. Half space depth. An approximate half space depth estimate is to be selected in accordance with the maximum wavelength divided in two. We will define the maximum wavelength on the basis of the dispersion image related to the first SP. The extreme point has the frequency of ~ 13 Hz and the phase velocity of ~ 265 km/s, which corresponds to a wavelength of approximately 20 m.
Let us set half space depth equal half of this wavelength, i.e. 10 m.

2. Now we set the number of layers – 5 with their thickness progressing with depth.
Number of layers – 5, Layer thickness – Progressive.

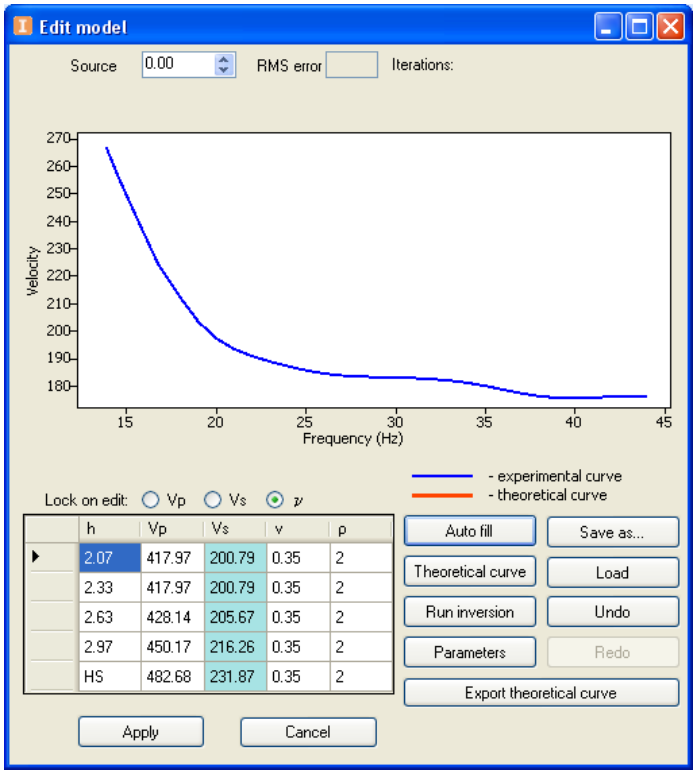
3. We will leave the remaining parameters setting by default having changed only the value to be fixed during the inversion: **Fix Pos** – Poisson's ratio is fixed to changing Vp (the detailed description of parameters is given in the User's Guide).



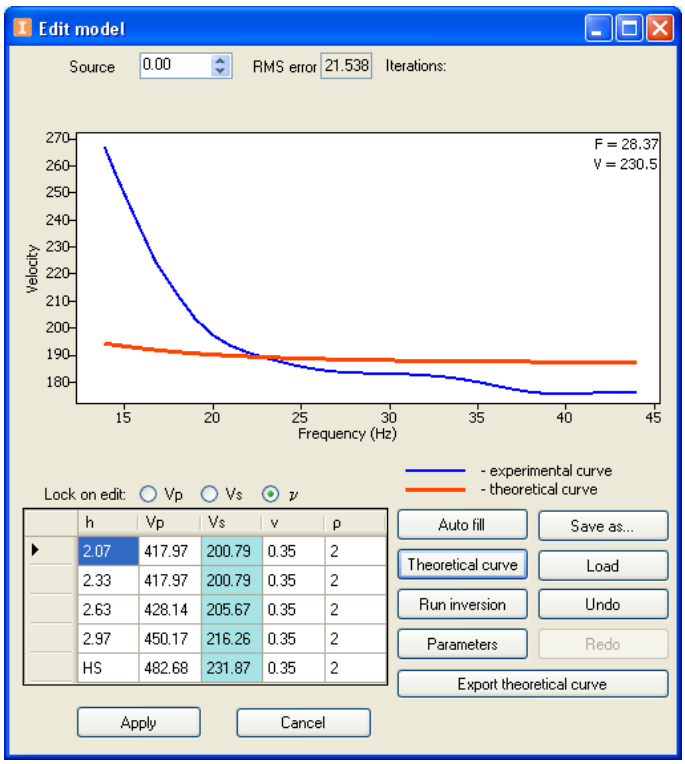
Push OK, a window displaying the automatically received initial model will appear:



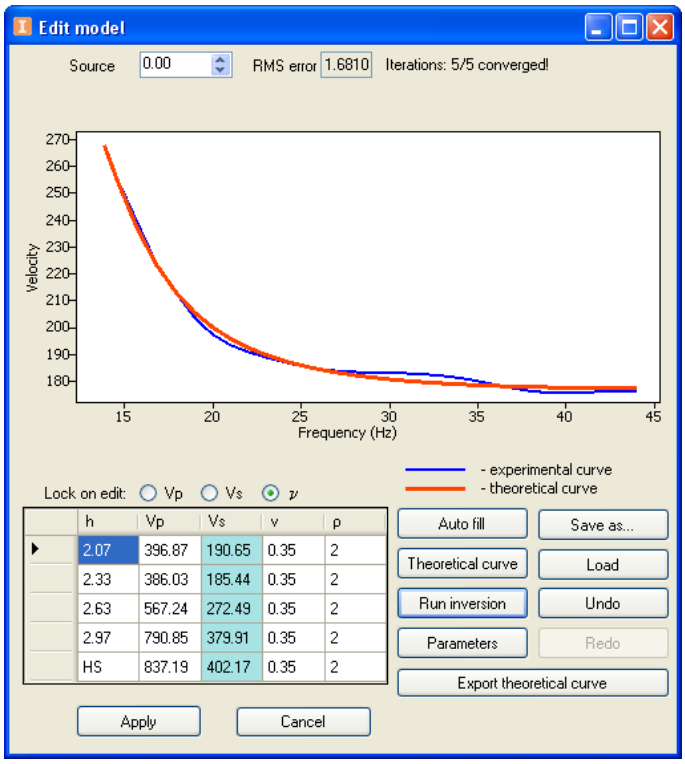
Triangles designate midpoints of the arrangement to which curves and, accordingly, transverse velocity lines are anchored. Proceed to the curve fitting mode by double clicking on the left mouse button on the triangle of the first SP.
The curve fitting window will appear. By default, blue color points at the picked curve related to the SP specified in the Source field:



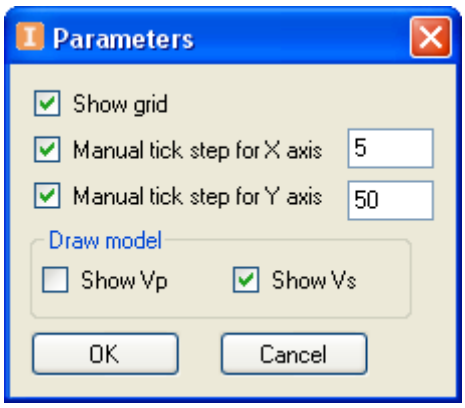
The lower part of the window contains the initial model of the environment based on the parameters set by us earlier. To display the theoretical curve for this model push **Theoretical Curve** – it is highlighted in red color:

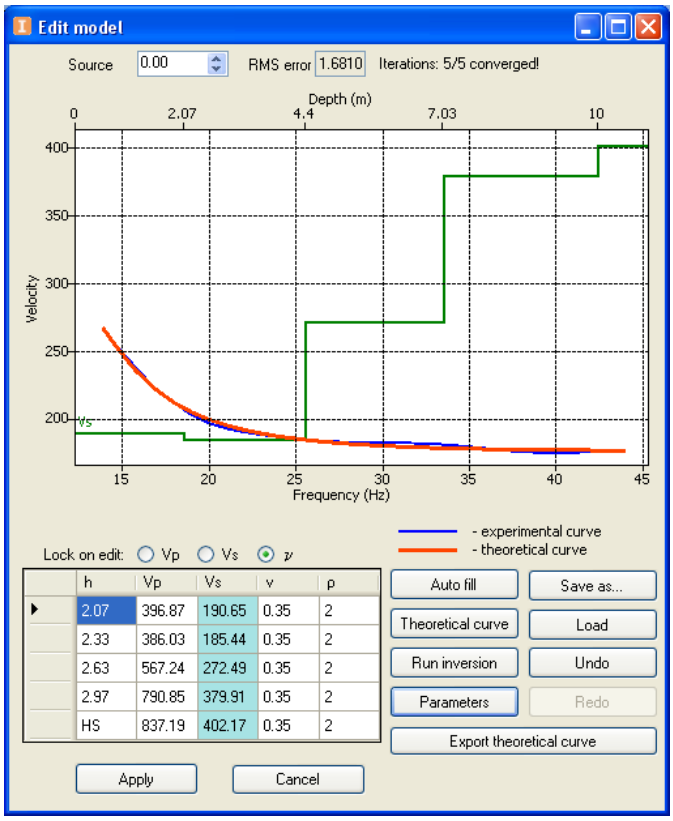


Launch the theoretical curve fitting process by pushing button **Run Inversion**. The current environment model and the associated curve are updated on each iteration. The process stops when of the specified root-mean-square error is achieved. The result of curve fitting for this SP:



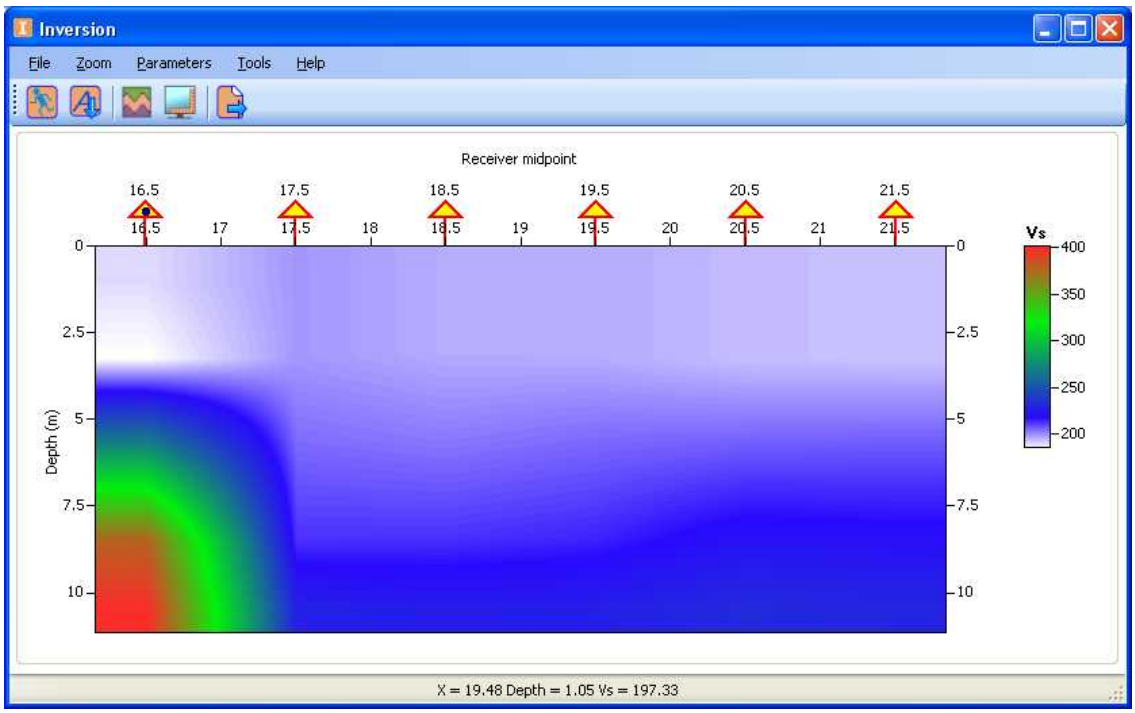
To display transverse velocity lines over the dispersion curve push Parameters and mark the “Show Vs” field. Also this tab provides possibility to display grid parameters setting:





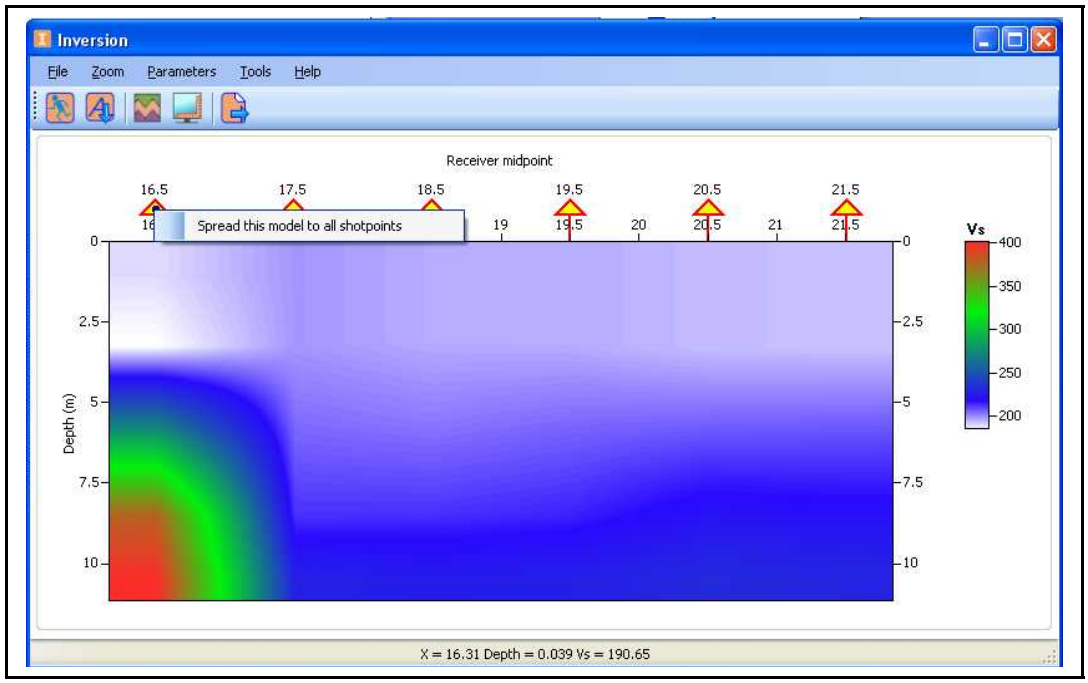
The curve fitting option **Edit model** gives the user wide range of opportunities to learn influence of various environment parameters on changes of the dispersion curve form.

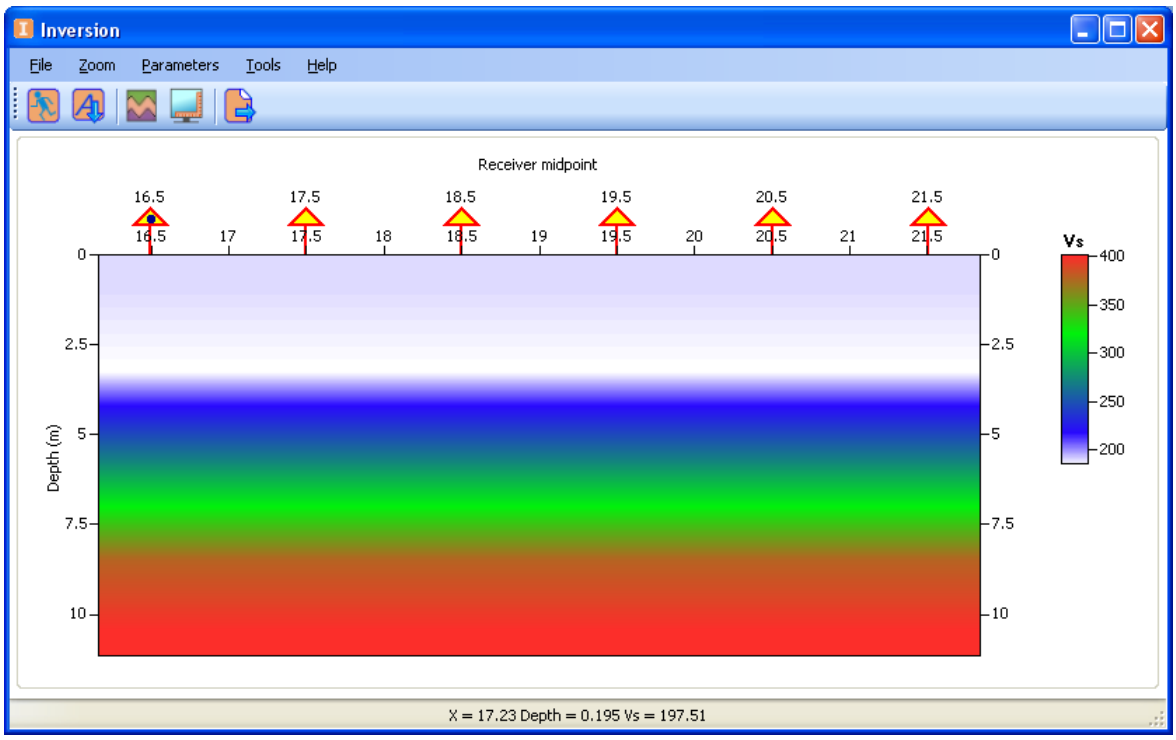
Push button Apply – the current model for SP 0 will be displayed in the **Inversion** final model window:



Curve fitting for remaining SPs can be executed in a similar manner.

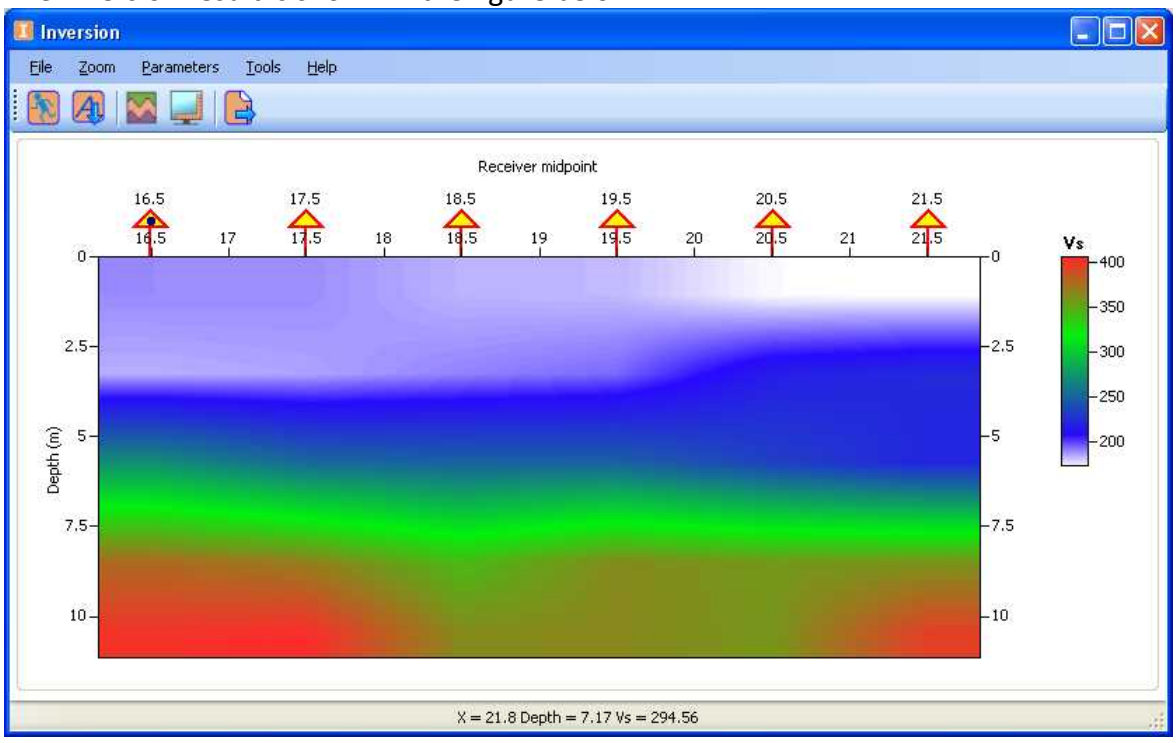
As the inversion process is ambiguous and much depends on the initial model, we will do as follows – we will set the fitted model on the zero SP as the initial model for the remaining SPs. For this purpose in **Inversion** window we push the right mouse button on this SP triangle and select option **Spread this model to all shot points**.





Now, having a realistic initial model for all SPs, we launch inversion for the whole line by pushing button Run Inversion  on the taskbar.

The inversion result is shown in the figure below:



To test curve fitting quality on any SP one has to double click on the SP triangle – a fitting window for this particular curve will appear.
This image gives allocation of transverse waves velocities and is an aggregate result that can be uploaded to a grid file (*.grd) for further operations.