Inversion of Dispersion Curves

— For 2-D Shear-Wave Velocity (Vs) Cross Section —

Prepared By

Choon B. Park, Ph.D.

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1. Overview

This module generates a shear-wave velocity (Vs) profile (1-D or 2-D) from input dispersion curve(s). It will be a 1-D (depth) profile if only one dispersion-curve file (*.DC) is imported, whereas a 2-D (depth and surface distance) Vs cross section will be produced if multiple files are imported. Each dispersion curve will be analyzed (i.e., inverted) to find a 1-D Vs profile whose "theoretical" (or "modeled") fundamental-mode (M0) dispersion curve fits the input "measured" curve most closely through a generic searching algorithm. In this sense, all input dispersion curves to produce the 2-D Vs cross section are inverted "almost" independently to produce individual 1-D Vs profiles that will then be used to construct the final Vs cross section through an appropriate spatial interpolation scheme (e.g., bilinear scheme). The reason we say "almost" is due to a slight interaction between adjacent dispersion curves during the initial velocity (Vs) model creation that is executed at the beginning of the inversion process. This interaction occurs if the option "Detect Bedrock" is selected (default) that will first analyze all input dispersion curves only to find the simplest velocity model consisting of overburden/bedrock (i.e., 2-layer model). Then, based on this 2-D velocity model, preliminary bedrock topography is constructed with a proper lateral continuity applied, and the corresponding velocities are assigned for the overburden and bedrock. This 2-D information will then serve as a global initial model to which, at the beginning of the searching process, the inversion of each dispersion curve will refer at the corresponding surface location for the starting (initial) (1-D) velocity model.

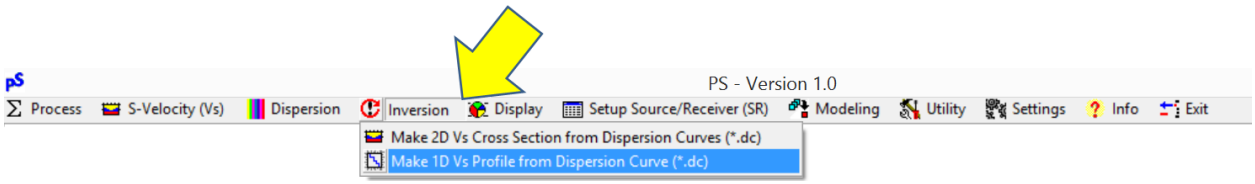
The searching algorithm is based on the sensitivity matrix (called a "Jacobian" matrix) that depicts the relative change in phase velocity of the theoretical (modeled) dispersion curve for a unit change in velocity of a particular layer in the model. Although this fundamental philosophy seems straightforward, there are a significant number of empirical parameters introduced in the algorithm that are necessary to make the searching process more accurate, stable, and faster. Some of these parameters are included in the "Options..." section in the main dialog so that they can be adjusted whenever necessary. Otherwise, the program will automatically assign the most optimum values based on the examination results of input dispersion curve(s) in some key acquisition and processing attributes such as offset range used during data acquisition, frequency (wavelength) range in measured dispersion curve(s), etc.

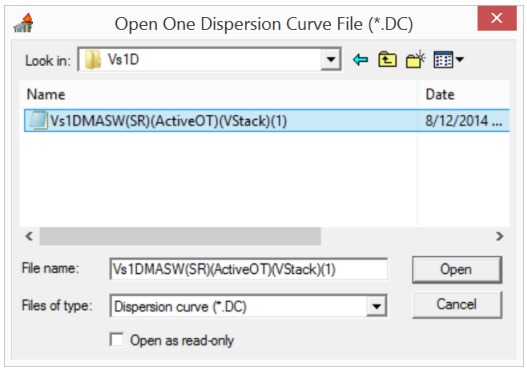
P-wave velocity (Vp) of each layer is determined by the Poisson's ratio (POS) during the inversion process. The POS is dynamically assigned based on the searched value of Vs; for example, POS = 0.45 for Vs = 150 m/sec, and POS = 0.33 for Vs = 1500 m/sec. Although the influence of POS is usually minimal, this dynamic estimation of POS has been proven more effective through extensive modeling experiments. The default value of density is 2.0 gram/cc for all layers.

Demonstration of the complete procedure by using a sample data set is provided in the PS User Guide "Generating 2-D Cross Section (Working with Sample Data)."

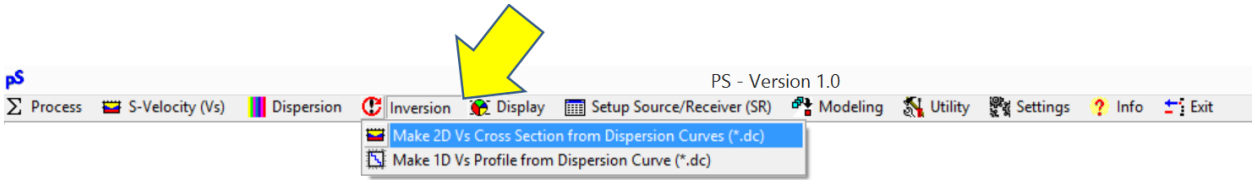
2. Importing Input Data

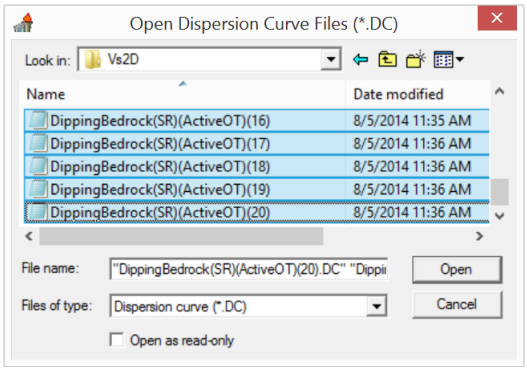
To generate a 1-D (depth) shear-wave velocity (Vs) profile, go to "Inversion" → "Make 1D Vs Profile from Dispersion Curve" and select one dispersion-curve file (*.DC).



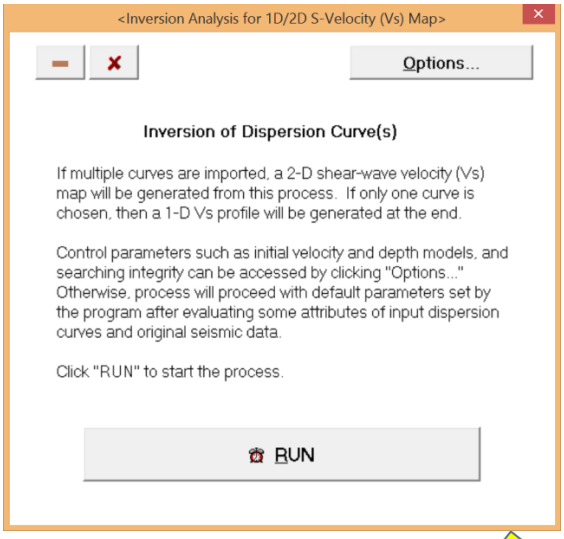


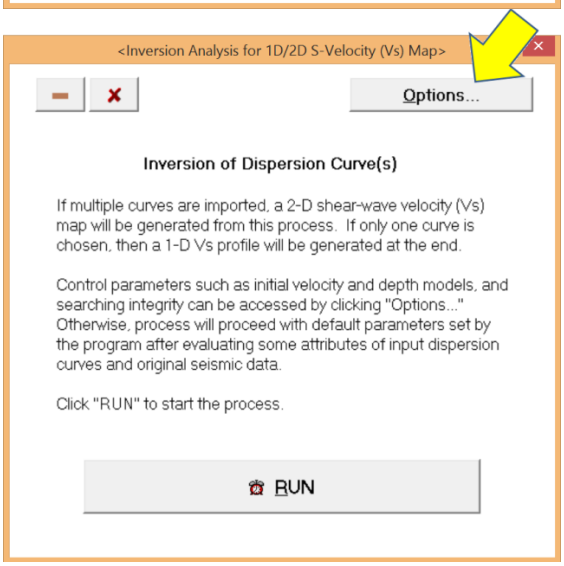
To generate a 2-D (depth and surface distance) shear-wave velocity (Vs) cross section, go to "Inversion" → "Make 2D Vs Cross Section from Dispersion Curves" and select multiple dispersion-curve (*.DC) files at the same time that were previously prepared by analyzing a data set from the same (one) survey line.

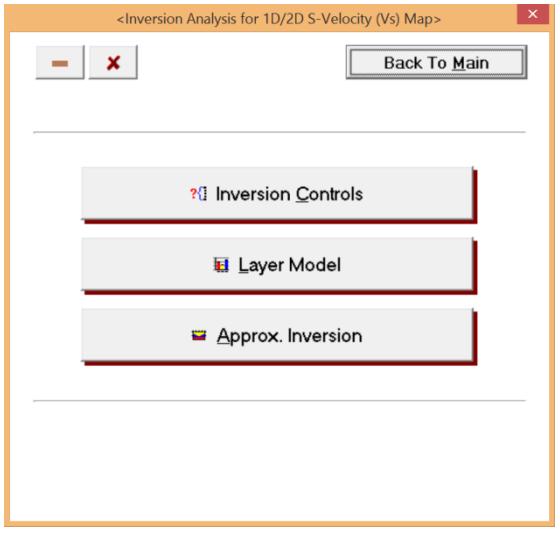




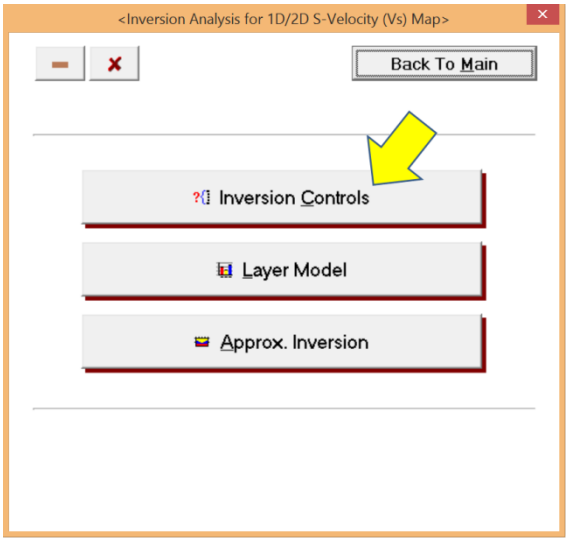
3. Main Dialog





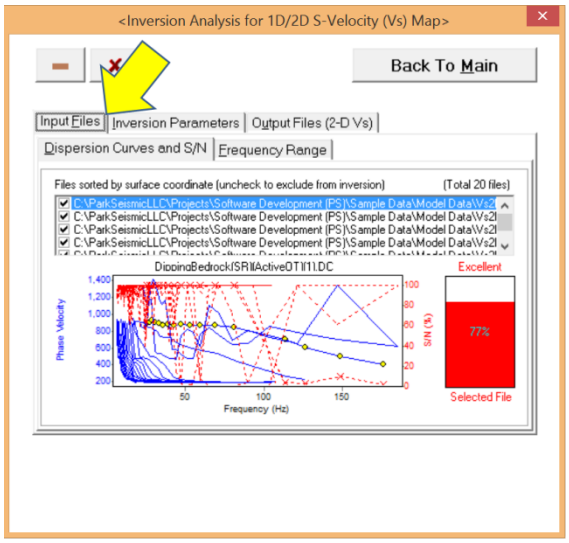


4. Inversion Controls

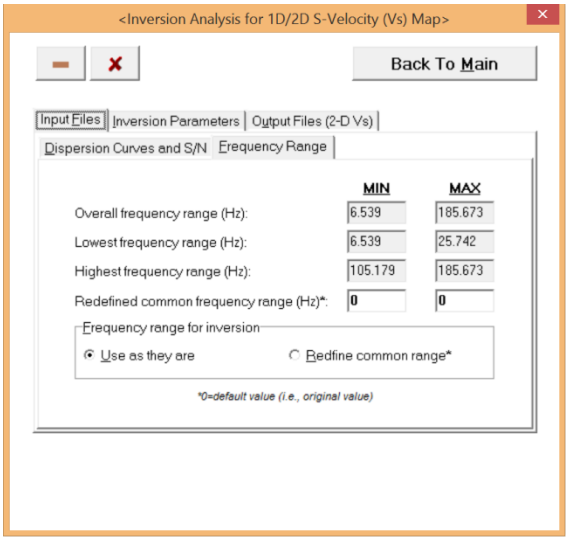


4.1 Input Files

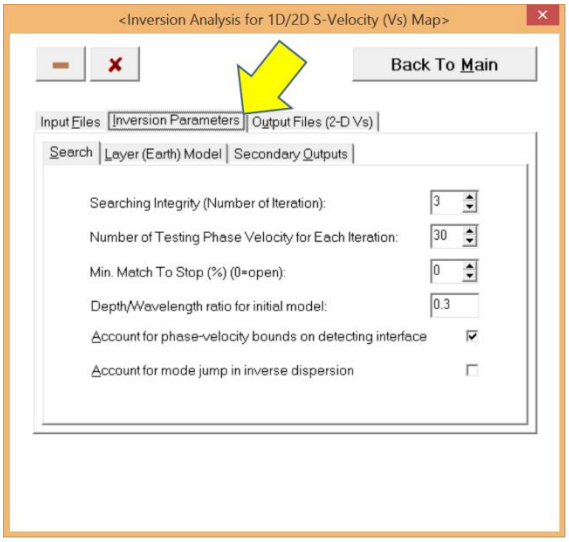
In the "Dispersion Curves and S/N" tab, all input dispersion curves are displayed in a chart to allow for visual inspection. A specific curve can be marked by selecting the corresponding item in the file name list box. Any curve can be "unchecked" to be excluded from the inversion analysis.



In the "Frequency Range" tab, the frequency of input dispersion curves used for inversion can be redefined (if necessary) to a narrower range by entering (non-zero) values in the "MIN" and "MAX" boxes.



4.2 Inversion Parameters



4.2.1 Search

Search Integrity (Number of Iteration): This specifies the total number of searching processes, each of which will use the output from the previous search as the initial (starting) model.

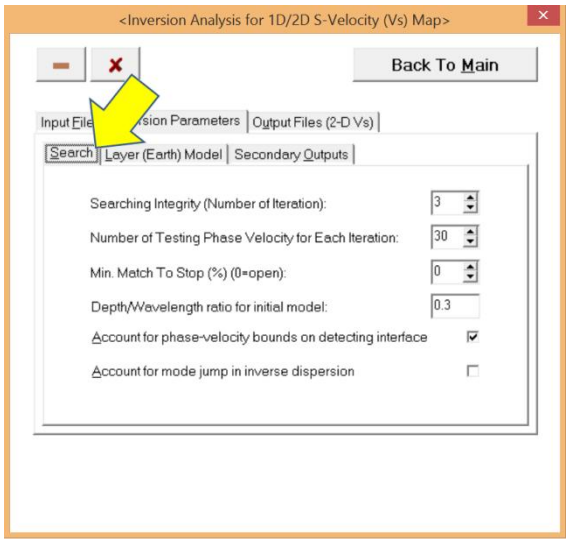
Number of Testing Phase Velocity for Each Iteration: This is related to the total number of examining velocities (Vs's) at a certain stage of the searching process. This is directly related to the resolution in testing velocities.

Min. Match To Stop (%) (0=open): This criterion will stop the searching process if met before the number of iterations is reached.

Depth/Wavelength ratio for initial model: This is the ratio used during initial velocity model creation.

Account for phase-velocity bounds on detecting interface: If checked, this will account for the minimum and maximum phase velocities in the input dispersion curve to estimate initial velocities of overburden and bedrock during the "Detect Bedrock" process (if this option is also checked).

Account for mode jump in inverse dispersion: If checked, this will generate apparent dispersion curves instead of the fundamental-mode (M0) curves by accounting for the mode jump during the theoretical dispersion curve generation. This can significantly prolong the process time.



4.2.2 Layer (Earth) Model

Number of Layer: Total number of layers (including the last half space) used in the velocity model.

Max. depth (Zmax)*: Depth to top of the deepest (last) layer (i.e., half space) in the velocity model.

Zmax Bound*: A non-zero value will limit Zmax smaller than this value. This option will be active only when the "Variable max. depths" has been checked.

Variable max. depths: If checked, Zmax will become another searching variable during the inversion. The initial velocity model will be scaled according to the new examining Zmax for each inversion for a given maximum depth (Zmax). The "Depths Model" tab on the right side will be enabled only when this option is checked.

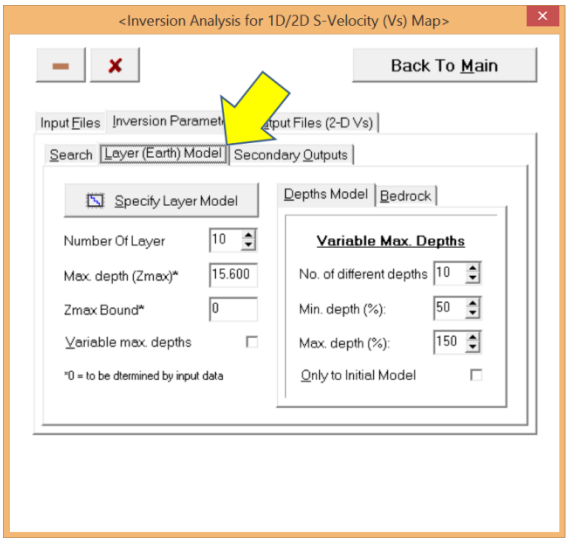
No. of different depths: Total number of different Zmax that will be examined at each iteration.

Min. depth (%): Minimum Zmax considered as percent of the specified maximum depth (Zmax).

Max. depth (%): Maximum Zmax considered as percent of the specified maximum depth (Zmax).

Only to Initial Model: The "Variable max. depths" will be applied only during the initial model creation.

*A zero value (0) indicates an optimum value will be determined by the program.



Detect Bedrock: If checked, the initial model creation will search for the simplest velocity model of overburden/bedrock first. Then, the actual multi-layered (e.g., 10-layer) initial model will be created based on results from this process.

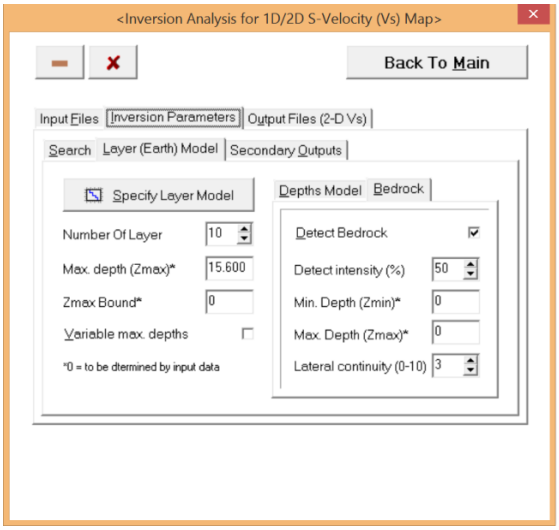
Detect intensity (%): This determines the number of different depths that will be searched; the higher this number, the more depths that will be examined.

Min. Depth (Zmin)*: Minimum Zmax to be examined.

Max. Depth (Zmax)*: Maximum Zmax to be examined.

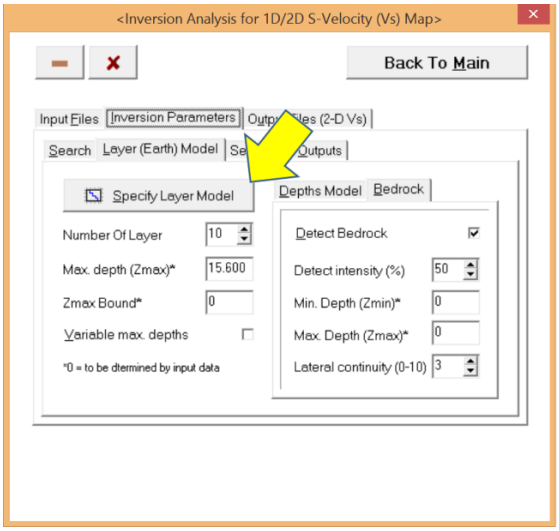
Lateral continuity (0-10): If a non-zero value is entered, this will apply the lateral averaging (smoothing) of the created 2-D overburden/bedrock model in velocity and bedrock topography.

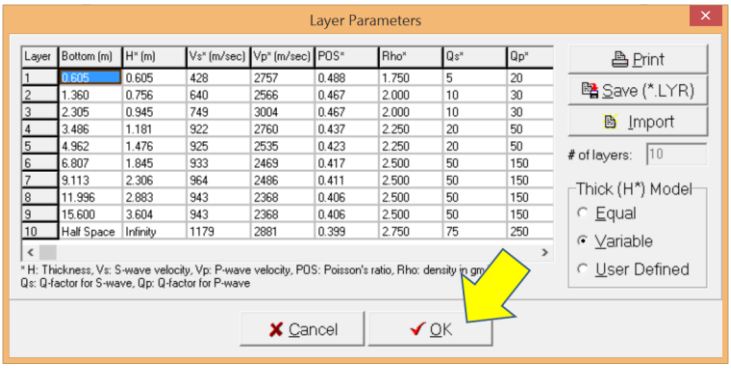
*A zero value (0) indicates the optimum value will be determined by the program.



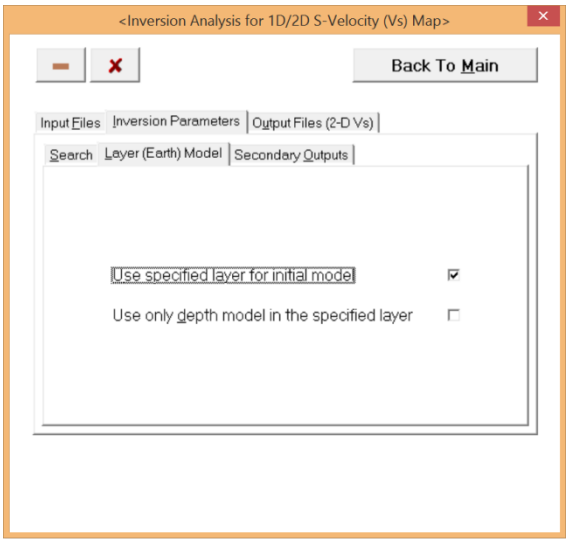
If the "**Specify Layer Model**" button is clicked, then the following table will be displayed showing numerical values of all parameters in the velocity (or "layered-earth") model. Individual values can be viewed and manually edited. (Note Q values, Qs and Qp, are not used during the inversion.) If this

display is closed by clicking the "OK" button, then this layer model will become the initial velocity model common to all input dispersion curves.





Then, the following two options will be available. The "**Use specified layer for initial model**" will use, if checked, all parameters specified in the layer model [i.e., Vs, Vp (or POS), depths, and density], whereas the "**Use only depth model in the specified layer**" will use only the depth model (i.e., a series of different thicknesses) during the initial model creation. To go back to the original default options for the "Layer (Earth) Model" tab, uncheck "Use specified layer for initial model" option.



4.2.3 Secondary Outputs

Map of output (Vs) confidence (%) [...(2DConf).TXT]: This will generate, if checked, the 2-D confidence (%) map in association with the 2-D velocity (Vs) cross section that will show relative distribution of reliability in the corresponding part of the velocity section. This "reliability" concept is directly linked to the sensitivity of velocity (Vs) change to the modeled dispersion curve; the higher sensitivity corresponds to the more reliable inversion result.

Modeled layer [*(Model).LYR]*: If checked, the final 1-D Vs profile (*.LYR) inverted from each input dispersion curve will be saved.

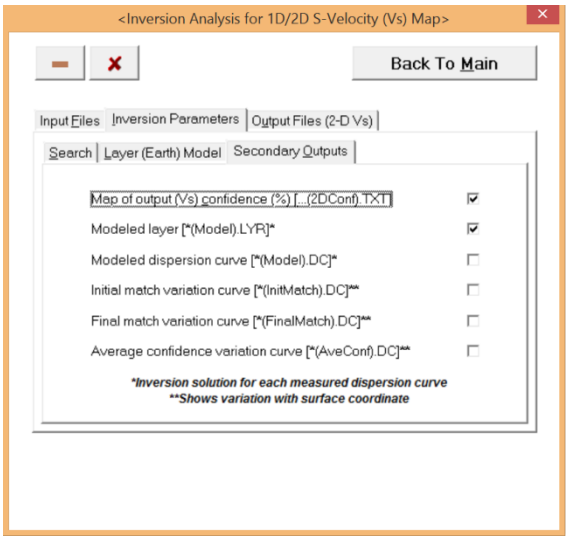
Modeled dispersion curve [*(Model).DC]*: If checked, the theoretical (i.e., modeled) fundamental-mode (M0) dispersion curve will be saved for each input (measured) dispersion curve.

Initial match variation curve [*(InitMatch).DC]:** If checked, the match between the M0 curve modeled from the initial velocity model and the input curve will be saved in a file (*.DC) so that the variation (from one surface location to another) can be displayed at the end of inversion for 2-D Vs cross section.

Final match variation curve [*(FinalMatch).DC]:** If checked, the match between the M0 curve modeled from the final velocity model and the input curve will be saved in a file (*.DC) so that the variation (from one surface location to another) can be displayed at the end of inversion for 2-D Vs cross section.

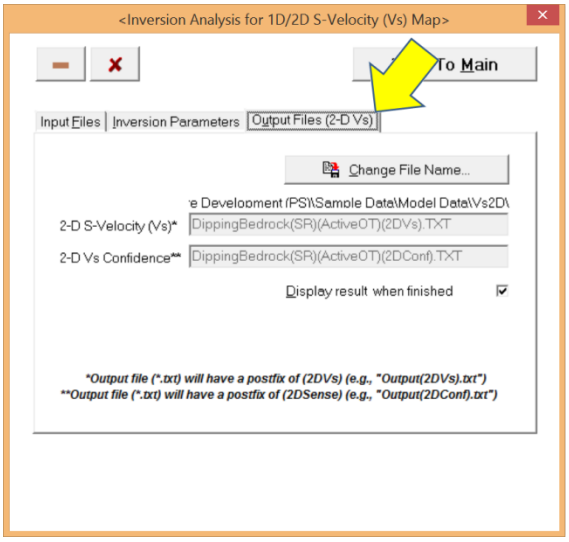
Average confidence variation curve [*(AveConf).DC]:** If checked, the overall confidence for one input dispersion curve is saved in a file (*.DC) so that the variation (from one surface location to another) can be displayed at the end of inversion for 2-D Vs cross section.

*This type will show the inversion solution for each measured dispersion curve
**This type will show variation with surface coordinates.



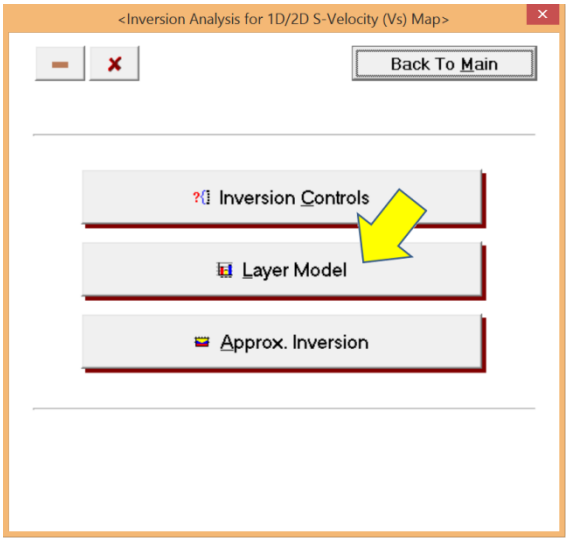
4.3 Output Files (2-D Vs)

The name of the output 2-D velocity (Vs) cross section can be changed. The default name will have "(Vs2D)" appended at the end of the common name of the input dispersion curve files. The 2-D confidence file will have "(2DConf)" appended. Both types of output will be text files (*.TXT).



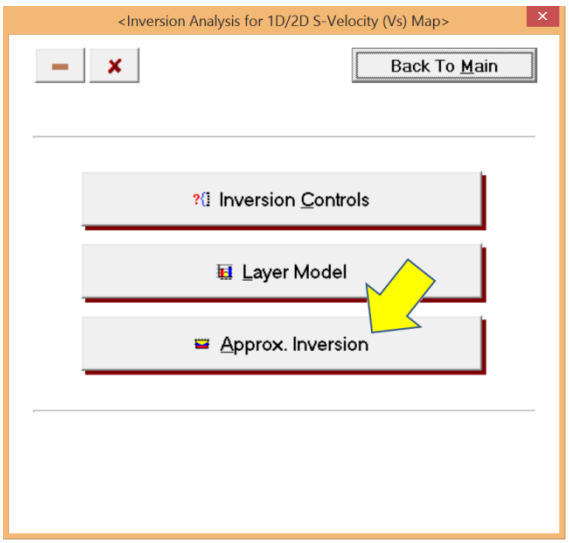
5. Layer Model

This button will display a table of all numerical values for the velocity (or "layered-earth") model in which individual values can be viewed and edited. This model can then be used as a common initial model during the inversion. This button works the same way as the "Specify Layer Model" button does as explained in section 4.2.2 [Layer (Earth) Model].



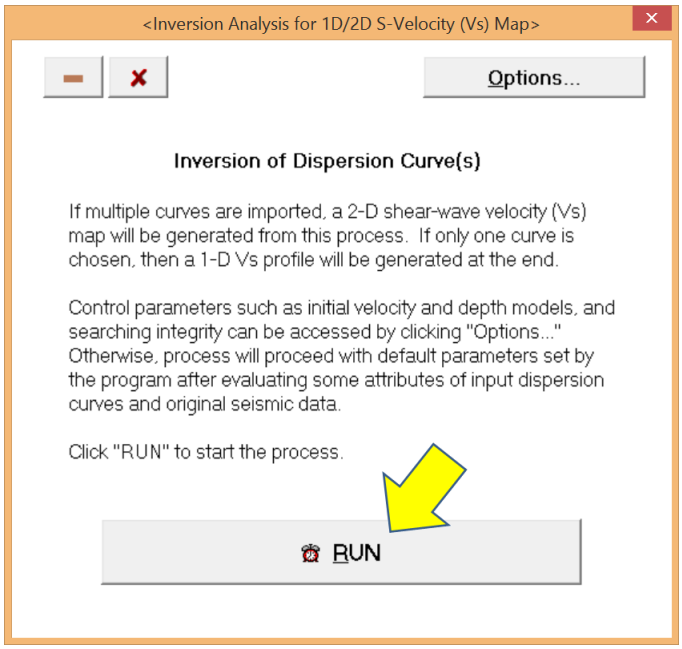
6. Approx. Inversion

This button performs an inversion based on the input dispersion curves simply by remapping wavelengths to depths according to a constant ratio (0.333). This will be a fast process that can be used as a "quick" check-up process.

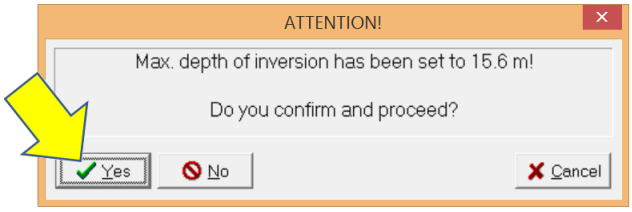


7. Run (2-D Vs Cross Section)

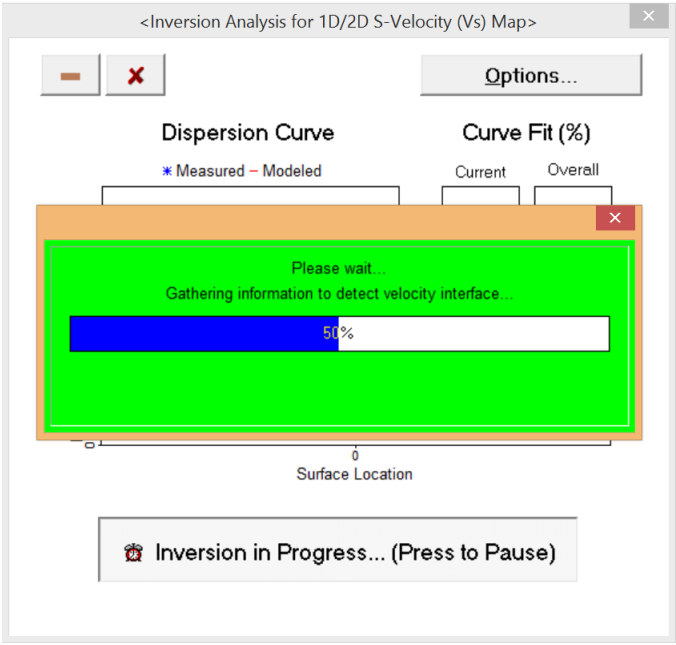
Click "Run" to launch the process.



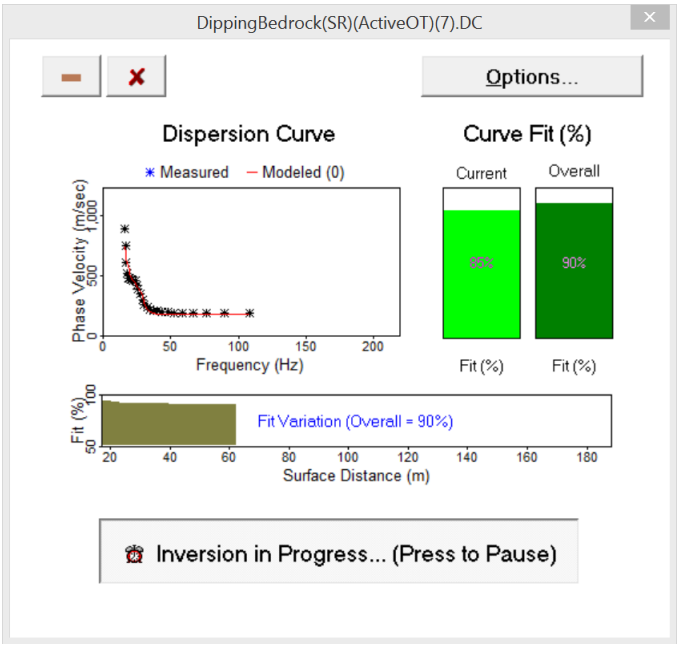
The following dialog will be displayed to confirm the maximum depth (Zmax) of the inversion that is originally determined by the program based on the average offset range used during data acquisition. This is one of the most important parameters in the inversion process that is directly related to the resolution of the final 2-D shear-wave velocity (Vs) map. If you click "No", then the program will show the relevant tab where you can adjust Zmax as well as other parameters. Otherwise, click "Yes."



First, the process to determine the depth to the velocity (Vs) interface (i.e., bedrock depth) will take place. This is the depth where the most abrupt change in velocity occurs. This process is termed in the control diagram as "Bedrock Detection."

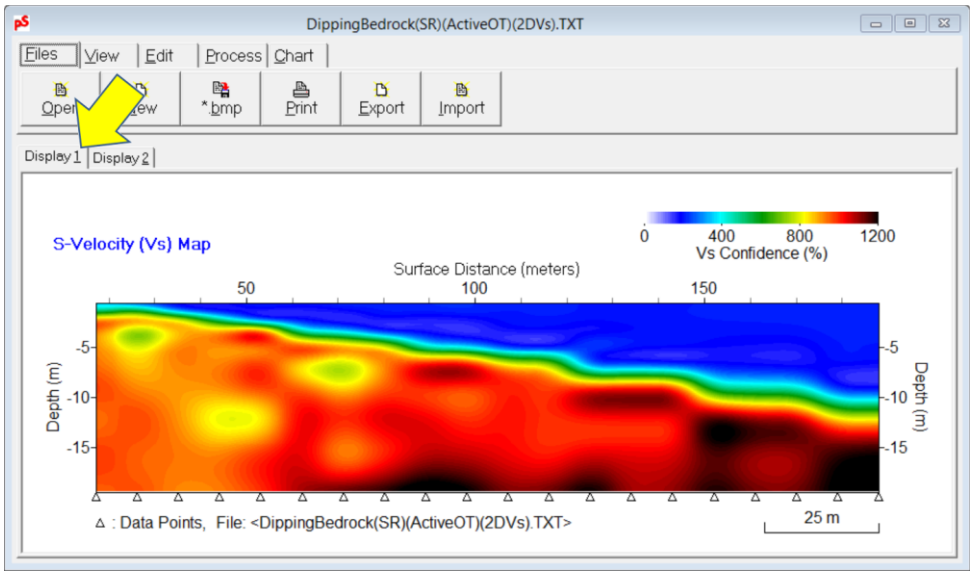


Then, the next processing step to find the velocity (Vs) model whose theoretical (i.e., modeled) dispersion curve best matches the measured curve will take place. This is accomplished through an iterative process during which intermediate dispersion curves will be displayed to show the corresponding match. The overall match will also be displayed in a single-column graph as well as a 2-D chart form showing its variation with surface location.

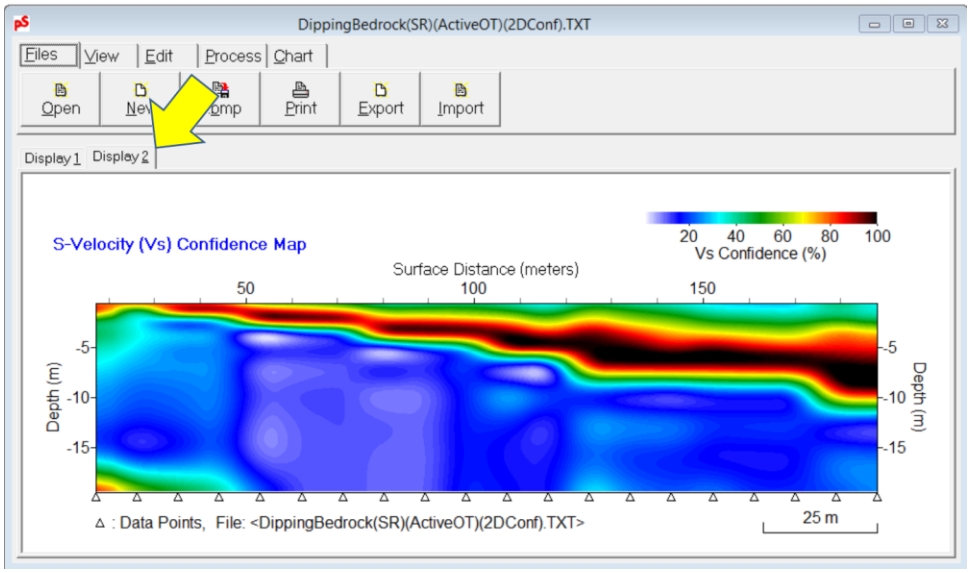


At the end of the inversion process, the following two types of output will be saved and then automatically displayed within the same form (under "Display 1" and "Display 2" tabs); a 2-D shear-wave velocity (Vs) cross section map [*(2DVs).TXT], and the corresponding 2-D Vs confidence map [*(2DConf).TXT], respectively, as shown below. The velocity color scheme in the 2-D Vs cross section is automatically determined by the program based on the velocity value distribution in the input file [*(2DVs).TXT]; this can be changed through a control dialog explained below. Notice that the cross section map shown below used the color scheme displayed at the top that is matched within the Vs range of 0-1200 m/sec. The confidence map shows the distribution of relative reliability in inversion results (Vs values) so that it can be used to judge credibility of velocity values in the cross section map that may change from one place to another.

<2-D Vs Cross Section Map>

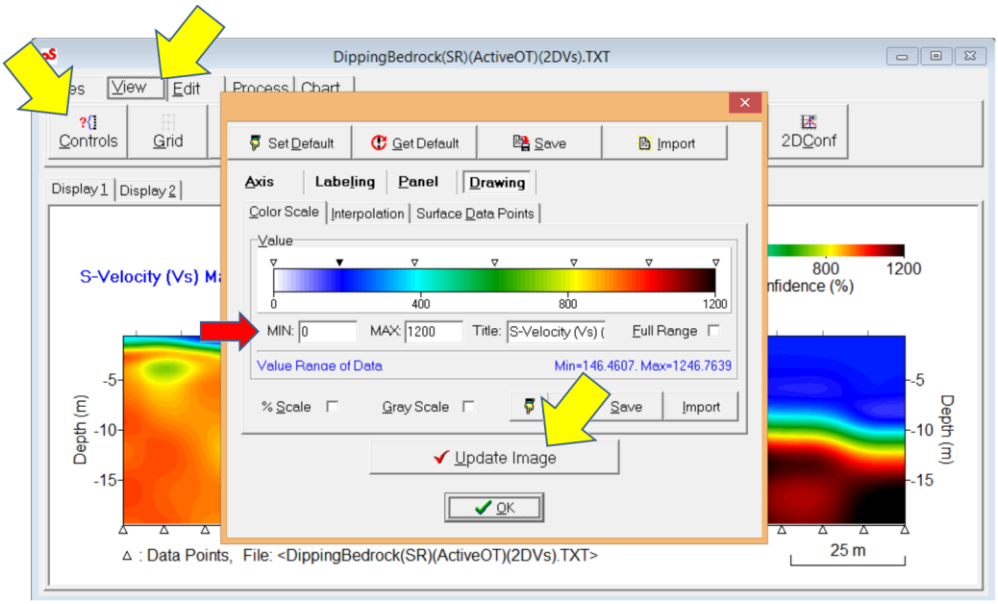


<2-D Vs Confidence Map>

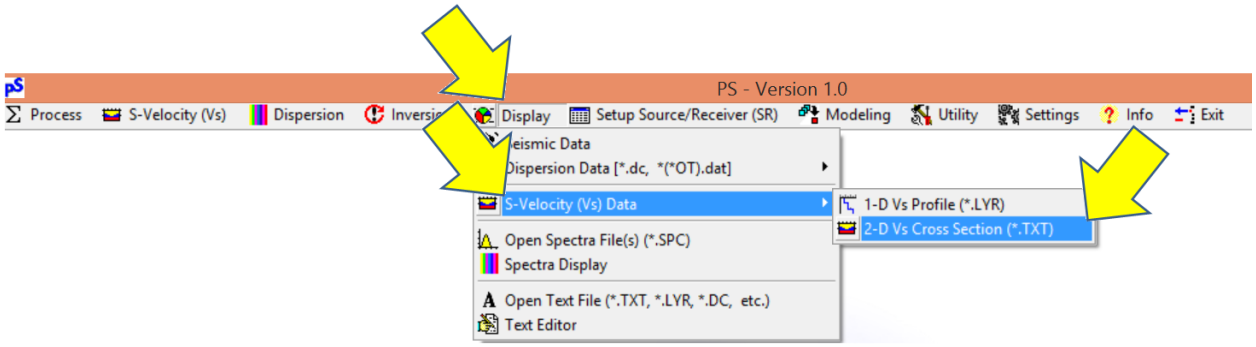
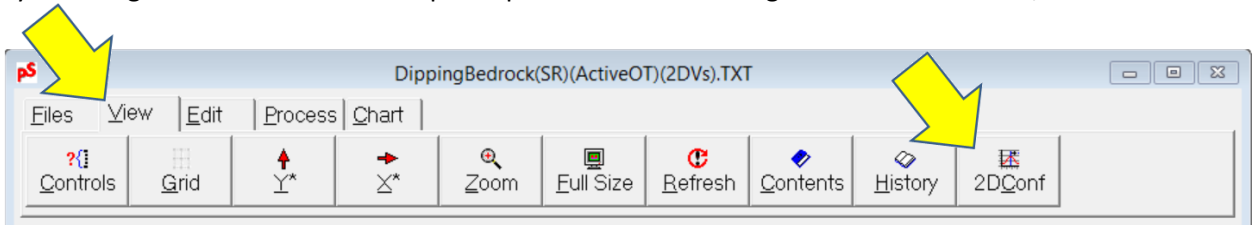


<To Change Velocity (Vs) Color Scale>

Select the "View" tab in the top tool panel. Then, click the "Controls" button to display the control dialog. Enter values for "MIN" and "MAX" to specify the range of velocity and then click "Update Image" button at the bottom. Many parameters related to the 2-D interpolation (e.g., interpolation schemes) and display (e.g., changing axis scale, labeling, etc.) of the input text file (*.TXT) in the usual three-column format (i.e., X, Depth, Value) can be accessed through this dialog.



In case you need to manually open the 2D Vs cross section file, you can do so by going to "Display" in the main menu, and then "S-Velocity (Vs) Data" → "2-D Vs Cross Section (*.TXT)", as shown below.



The corresponding confidence map can be automatically imported within the cross section display form by selecting the "View" tab in the top tool panel and then clicking the "2DConf" button, as shown below.