

2 D I P Documentation

Zonge Data Processing

Two-dimensional Resistivity and IP Modeling

Version 5.00

Scott MacInnes
September 2003

Zonge International

3322 E. Fort Lowell Road, Tucson, AZ 85716, USA
Tel: (520) 327-5501 Fax: (520) 325-1588 Email: zonge@zonge.com

This page intentionally left blank

2 D I P

Table of Contents

Introduction	5
Installation	6
Minimum Hardware Configuration	6
Installation Procedure	6
Installing program and sample data files	6
Moving key-disk software to your hard drive	7
Installing a hardware lock	7
SETUP32	8
Graphics Configuration	9
Recall Procedure.....	9
Program Use	10
Model Creation.....	10
Model Editing	13
Model Evaluation.....	17
Review Data.....	19
References	20
Appendix A: File Format Documentation	21
*.2DM file (model parameters)	21
*.IPD file (res/IP data)	23
CFTABLE.CRL (color fill table)	24
*.STN file (station location coordinates).....	24
*.MDE file (Zonge data processing control)	25
*.Z2D file (Zonge plotting program ZPLOT *.Z file format)	26

This page intentionally left blank

Introduction

2DIP is a finite element program that computes the resistivity and IP responses of two-dimensional models. Models may include both subsurface structure and surface topography on cross sections up to one hundred dipole lengths long. Default electrode configurations for dipole-dipole, pole-dipole, or gradient arrays are available, or electrode positions may be specified in an input file for arbitrary surface or downhole in-line array geometry's. Apparent resistivity and IP phase or chargeability model responses for up to 800 data points may be calculated. Calculated data are stored in a tabular, comma-separated-value file format that allows plotting by generic contouring programs.

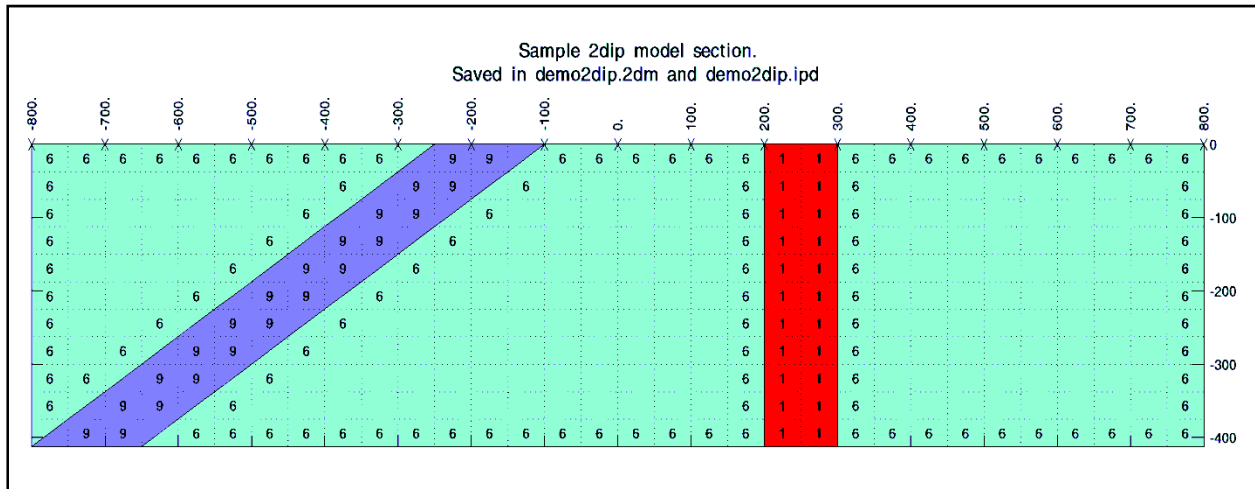


Figure 1: Cross-section of arbitrary two-dimensional geologic model. Up to nine resistivity and IP values may be specified on a cross section up to one hundred dipole lengths long and nine or more dipole lengths deep. Model responses are calculated as apparent resistivity and phase for dipole-dipole, pole-dipole, pole-pole, gradient or arbitrary four-electrode surface/downhole arrays. Topography may be modeled by importing topographic profile data to shape the model-section mesh while building a new model.

Information about 2DIP may be obtained by writing or calling:

Zonge International
3322 East Fort Lowell Road
Tucson, Arizona 85716

Phone (520) 327-5501
FAX (520) 325-1588
Email zonge@zonge.com

Installation

Minimum Hardware Configuration

The minimum hardware configuration needed to operate 2DIP v5.00 is a personal computer running MS-Windows with screen graphics set to "true" or "high" (16, 24 or 32-bit) color mode

Installation Procedure

2DIP refers to the two related programs, 2DIP.EXE and R2DIP.EXE, that provide model editing and modeling calculations respectively. Each distribution copy of 2DIP may be installed on more than one computer, but comes with either a key-disk software registration system compatible with Windows 95/98 or a parallel port hardware-lock or "dongle" compatible with new versions of MS Windows. Backup copies of installed files may be made freely, but they will function only with valid software registration.

Key-disk software registration can be moved from the distribution disk to a hard-drive for extensive use on one computer. Key-disk registration may later be moved back to the distribution disk for installation on another computer. Once 2DIP and hardware lock software is installed, dongles may be moved from one computer to another, but should only be removed or added with computer and printer power off.

Installing program and sample data files

A SETUP program is provided to install 2DIP programs to your hard drive. SETUP copies files to your hard drive and unzips them, but does not make any changes to operating system files.

To install 2DIP program files from a 3.5" disk, place the distribution disk in a floppy disk drive and log-on to that drive. Then type "SETUP" and press Enter. You will see a screen title showing the program's name and version number. Below the title block a set of highlighted fields specify the source drive you are installing 2DIP from, usually floppy drive A: or B:, and the target hard drive letter and path in which 2DIP should be installed. It is usually easiest to put 2DIP programs in a directory that is already on your computer's MS-DOS path. You can move from field to field in the SETUP program's screen by pressing the Tab key to move forward and Shift+Tab to move backward. To cycle through disk drive letters, press the space bar or left and right arrow keys. Select drive letters and edit the target path to suit your computer's configuration. When you press F10, SETUP will verify your edited changes and will place files in your target directory.

If you are installing programs from a CD, SETUP allows you to move groups of program files from the distribution CD to a target hard-drive directory. As with floppy-disk installation, it is usually easiest to put modeling programs from a CD into a single directory on your computer's path (such as c:\datpro). Using a single directory reduces the length of the operating-system path string.

SETUP does not alter any of your computer's system configuration files. After installation, 2DIP may be run from the command line, from the start menu or from a Windows desktop shortcut.

After installation, the target installation directory should have the following files:

2DIP program files:

2DIP.EXE	- model input and editing program.
R2DIP.EXE	- model evaluation program.
R2DIPREG.EXE	- registration program.
SETUP32.EXE	- installs drivers for hardware lock
CFTABLE.CLR	- color fill table in Surfer color spectrum file format
2DIP_UPDATE.NTS	- notes on 2dip version updates

Sample data files:

DEMO2DIP.2DM	- model-parameter file.
DEMO2DIP.IPD	- model-data file.
DEMO2DIP.MDE	- data processing annotation and control file.
DEMO2DIP.STN	- station location and topography file.
DEMO2DIP.Z2D	- Zonge ZPLOT-format plot-data file.

Note that sample data files must be read/writeable for use with 2DIP. Test data files distributed from a CD-ROM may need their attributes modified from read only to read and write. An easy way to change file attributes is to right-click on a file name in Windows Explorer, select Properties and uncheck the Read Only check box.

Moving key-disk software registration to your hard drive.

Key-disk software registration may be left on the distribution disk. R2DIP will then run only when the distribution disk is present in your floppy-disk drive. For more convenience, you can move key-disk registration to your hard-drive. When this is done, the 3.5" key-disk will not be required to operate the program. However, if the hard disk is transferred to another person, reformatted or corrupted, that copy of the protection is lost. One spare copy of the software registration is included on each distribution disk.

IF your software was provided for demonstration purposes, then software registration may NOT be moved to a hard disk. Typically, the registration is set to expire 30 days after you first use the program. Registration may be reset by purchasing 2DIP and obtaining a reset code by fax or email.

The utility EVMOVE.COM is provided on the distribution key disk. Assuming that the 3.5" distribution disk is in drive A: and that your hard drive is labeled C:, type

"EVMOVE A: C:" to move a copy of software registration from drive A: to drive C:

"EVMOVE C: A:" to recall a copy of software registration from drive C: to drive A:

Installing a hardware lock

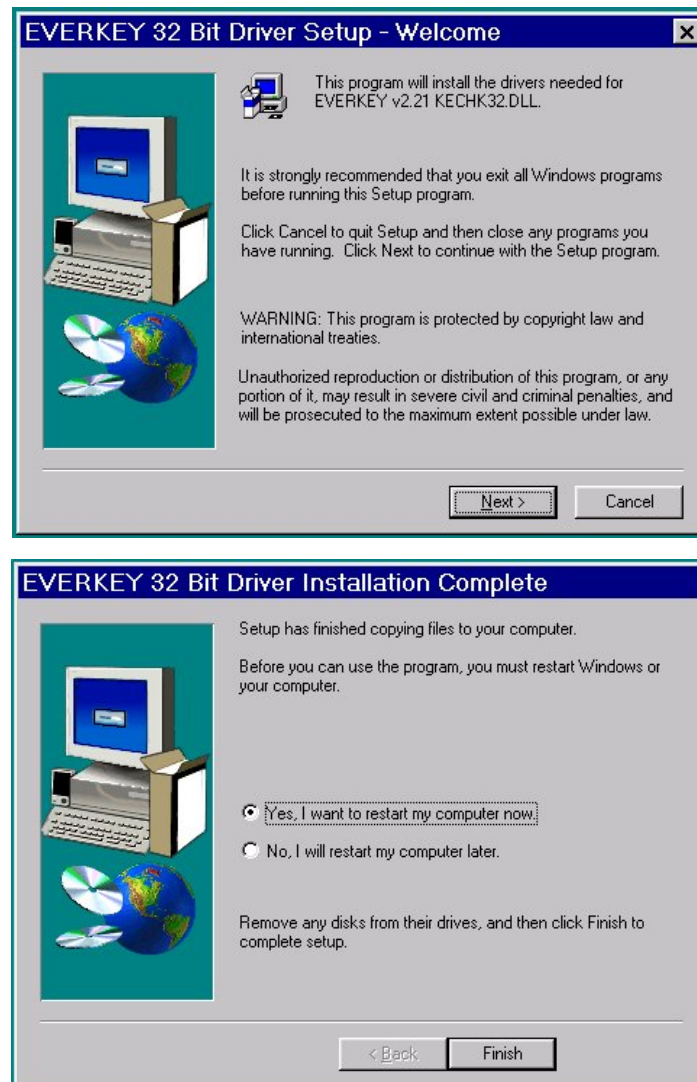
A parallel-port hardware lock or dongle is required for computers running Windows NT, 2000 or XP. Using 2DIP's hardware-lock registration system requires additional configuration steps. If your program comes with a parallel-port hardware lock, install it by turning off power to your computer and printer. Unplug the parallel-port printer cable from the back of your computer and plug the hardware lock into your computer's 25-pin parallel port. Then plug the parallel printer cable into the hardware lock, piggyback fashion.

You do not have to have a printer physically installed for the hardware lock to function. If you do have a printer connected, it must be turned on and on-line when you run 2DIP. If you have more than one parallel port, it makes no difference which one you use.

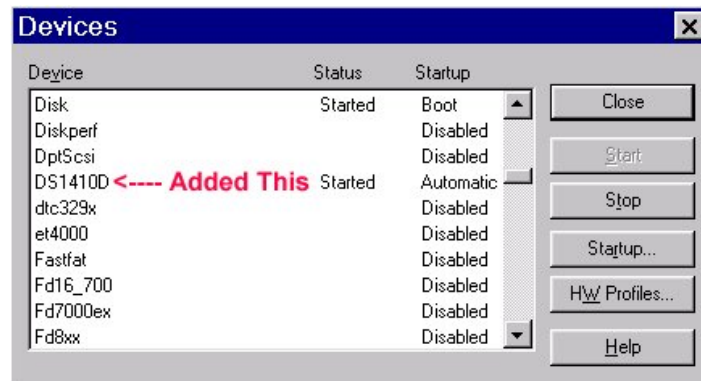
Note: You must ensure that the end of the hardware lock labeled “Computer” is connected to your computer’s parallel port. It is possible to plug the hardware lock in backwards, which may damage the hardware lock, the parallel port or both.

SETUP32

This file needs to be executed once to install a driver that allows the hardware-lock software to access the parallel port. The driver file is DS1410D.SYS, which is put into your computer’s driver directory. After rebooting PCs running Windows NT, 2000 or XP, you will see this driver listed in the ‘Devices’. (START / Settings / Control Panel / Devices). This driver is automatically started when your computer boots up.



Execute the program SETUP32, then reboot your PC. After re-booting a PC running Windows NT, 2000 or XP, the list of ‘Devices’ should include a new driver, DS1410D



Test the software registration by executing R2DIPREG from the 2DIP hard-disk directory. You should see text like:

Registered to: Alaska Earth Sciences Serial # 1099
Copyright 1999 Zonge Engineering
All Rights Reserved.

A software registration check is done every time R2DIP is initiated. R2DIP calls R2DIPREG to check for valid software registration. Key-disk systems make a software check, while hardware-lock systems look for an appropriate hardware key or “dongle” in the parallel port.

Graphics Configuration

2DIP expects VGA, SVGA or XVGA graphics set to high color (16, 24 or 32-bit) mode. Model sections may be plotted on your printer, exported to a “Windows MetaFile” (wmf) for pasting into MS-Word documents or exported to a “Portable Network Graphics” (png) 300 ppi raster image for editing with generic graphics programs.

Color-fill colors are controlled by the resistivity and IP color ranges specified within 2DIP and by red, green, blue colors specified in cftable.clr. cftable.clr is an ASCII text file in the Golden Software Surfer, color spectrum format. It has records with a percentage (0 to 100) followed by an associated red, green and blue color level (0 to 255) (See the clr file format description in Appendix A). The supplied cftable.clr file specifies partially saturated rainbow colors that are light enough to keep overprinted text visible. File cftable.clr may be edited to generate custom colors. 2DIP first looks for cftable.clr in the current working directory, then in the directory holding 2dip.exe, and if still not found, in directories on the operating system path. 2DIP uses internal default color-fill values if it cannot find a copy of cftable.clr. cftable.clr is also used by the Zonge plotting programs s2dplot and modsect.

Recall Procedure

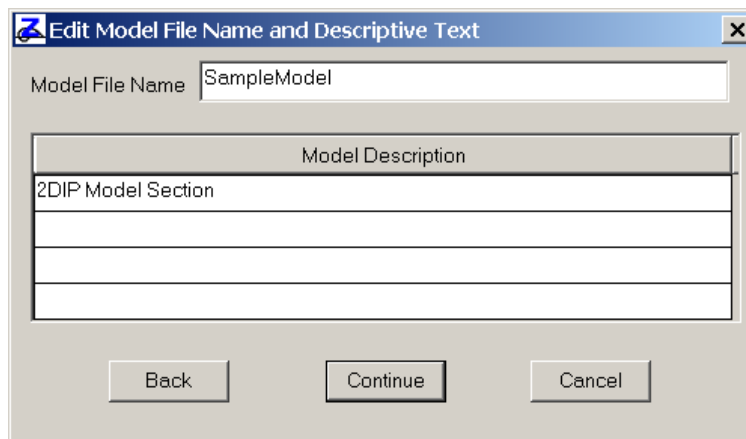
To recall 2DIP back to the distribution disk, place the distribution disk in a floppy-disk drive and log on to that drive, then type "RECALL" and press Enter. RECALL displays a screen with fields for the drive and directory where 2DIP is installed and for the letter of the floppy drive holding the distribution disk. Edit the source drive and path to match your computer's configuration and then press F10 to start the RECALL procedure. RECALL erases 2DIP.EXE, R2DIP.EXE and DEMO2DIP.* from the “recall from” directory.

Program Use

The two main programs in the 2DIP modeling package are 2DIP.exe for generating and editing model files and R2DIP.exe for evaluating model files and calculating apparent resistivity and IP values. 2DIP.exe must be used first to create a geologic model section. Model files DEMO2DIP.2DM and DEMO2DIP.IPD have been provided as an example of program use.

Model Creation

Model files are generated using 2DIP.EXE. Typing "2DIP" on the command line, or running 2DIP.exe from the Start menu or a short cut brings up a window with an initial menu allowing **New** model creation, **Open** an existing model file, or **Exit** the program. Selecting New starts the process of creating a new model section. 2DIP.exe first shows a dialog with fields for the model file name and descriptive annotation text.



The screenshot shows a Windows-style dialog box titled "Edit Model File Name and Descriptive Text". It features a "Model File Name" input field containing the text "SampleModel". Below this is a "Model Description" section, which is a multi-line text area containing the text "2DIP Model Section" followed by three empty lines. At the bottom of the dialog are three buttons: "Back", "Continue", and "Cancel".

Given the **Model File Name** SampleModel, 2DIP will create files SampleModel.2dm and SampleModel.ipd in the current working directory. Up to four lines of **Model Description** text will be displayed above the model section in 2dip plots. Each line may be up to 80 characters long. Selecting the **Back** button by moving the mouse cursor to it and pressing the left mouse button will move you to the previous menu or dialog. Selecting **Cancel** will abort the New Model build. Select **Continue** to continue on to the next step.

2DIP next shows a dialog with fields that control model section dimensions.

Set Model Section and Finite-Element Mesh Parameters

Survey Type: IP Units:

Stn Number Scaling: Dipole Length:

Model Width: First Station: Last Station:

Model Height: Model Section Thickness:

Row Thickness Multiplier:

model pixel columns per dipole. => 32 by 11 pixel model section
 finite elements per model pixel => 168 by 69 finite element mesh

No topography data loaded.

Survey Type may be DipoleDipole, PoleDipole, PolePole, Gradient or Downhole. For DipoleDipole, PoleDipole, PolePole, and Gradient arrays, 2DIP automatically specifies appropriate electrode positions sufficient to span the width of the model section. If a Downhole survey type is selected, 2DIP will show a spreadsheet-like grid field with columns for transmitter and receiver station numbers and depths. Electrodes must land on finite element nodes, so electrode coordinates should be rounded to even increments of

$\text{dipole_length}/(\text{model_pixel_columns_per_dipole} * \text{finite_elements_per_model_pixel})$.

Another easy way to handle arbitrary in-line arrays is to build a new model section with default DipoleDipole or Downhole electrode positions, then edit and extend the resulting ipd file to suit your needs. Ipd files have a csv format suitable for spreadsheet manipulation (see Appendix A, IPD File Format).

IP Units may be either mrad, msec or PFE. R2DIP calculates IP effects by making small perturbations to model section resistivity and the IP calculations are not affected by the choice of IP Units.

Station Numbers per Dipole is the station number increment for each dipole length or, equivalently, the dipole length in station numbers. Station numbers are usually, but not always, scaled to be distance along line. Keeping Station Numbers per Dipole equal to Dipole Length is simpler, but is not required. **Dipole Length** is the dipole length in length units. If you are specifying a completely arbitrary array that does not have a single dipole length, use a length that is close to the smallest transmitter-receiver electrode separation. **Length Units** are specified in the field immediately to the right of Dipole Length. Length units may be m, km, ft, or kft.

Model Width is controlled by the station number values specified in **First Station** and **Last Station**. 2DIP enforces its built in limit of model sections no more than 100 dipole lengths long by changing the value of the Last Station field.

Model Height fields control the model's depth extent. **Element_Height / Element_Width** adjusts the shape of model pixels and finite elements along the top of the model section. The default Element_Height / Element_Width value of 0.75 is appropriate for surface surveys. A value of 1 is appropriate for downhole modeling. The ratio of element height over element width should not be too far from 1. **Depth Extent** controls the model section's cumulative thickness. 2DIP first tries to reach the specified depth extent with model pixel rows of uniform height, up to a limit of 50 rows. If it is unable to reach the specified depth, it introduces a row to row height multiplier so that deeper rows are thicker.

The size of model section pixels and finite elements is controlled by model pixel columns per dipole and finite elements per model pixel. **Model pixel columns per dipole** may vary from 1 to 6. It should be set no higher than necessary to provide the needed detail in the model section. R2DIP subdivides each model pixel into smaller finite elements to compute the model section's resistivity/IP response. **Finite elements per model pixel** may vary from 1 to 4. Model_pixels_per_dipole times finite_elements_per_model_pixel gives the number of finite element columns per dipole length. There should be six to eight finite element columns per dipole length. Using fewer elements per dipole degrades the model's accuracy and using more than eight or ten finite elements per dipole length creates large finite element systems that take much longer to evaluate.

2DIP includes an option for reading topographic data from a tabular stn file. STN files have columns of station number, easting, northing and elevation (see stn file format description in Appendix A). 2DIP will read topographic profile data from a stn file if you click on the **Get Topography from *.STN File** button. 2DIP assumes that you will adjust the First Station and Last Station fields to correspond to the range of stations present in the stn file. It also assumes that the stn file station-number scaling corresponds to Stations per Dipole and that stn file coordinates are in the length units selected in the 2DIP dialog. 2DIP distorts the new model section to fit the topographic profile, so it can be used to model topographic effects for real terrain.

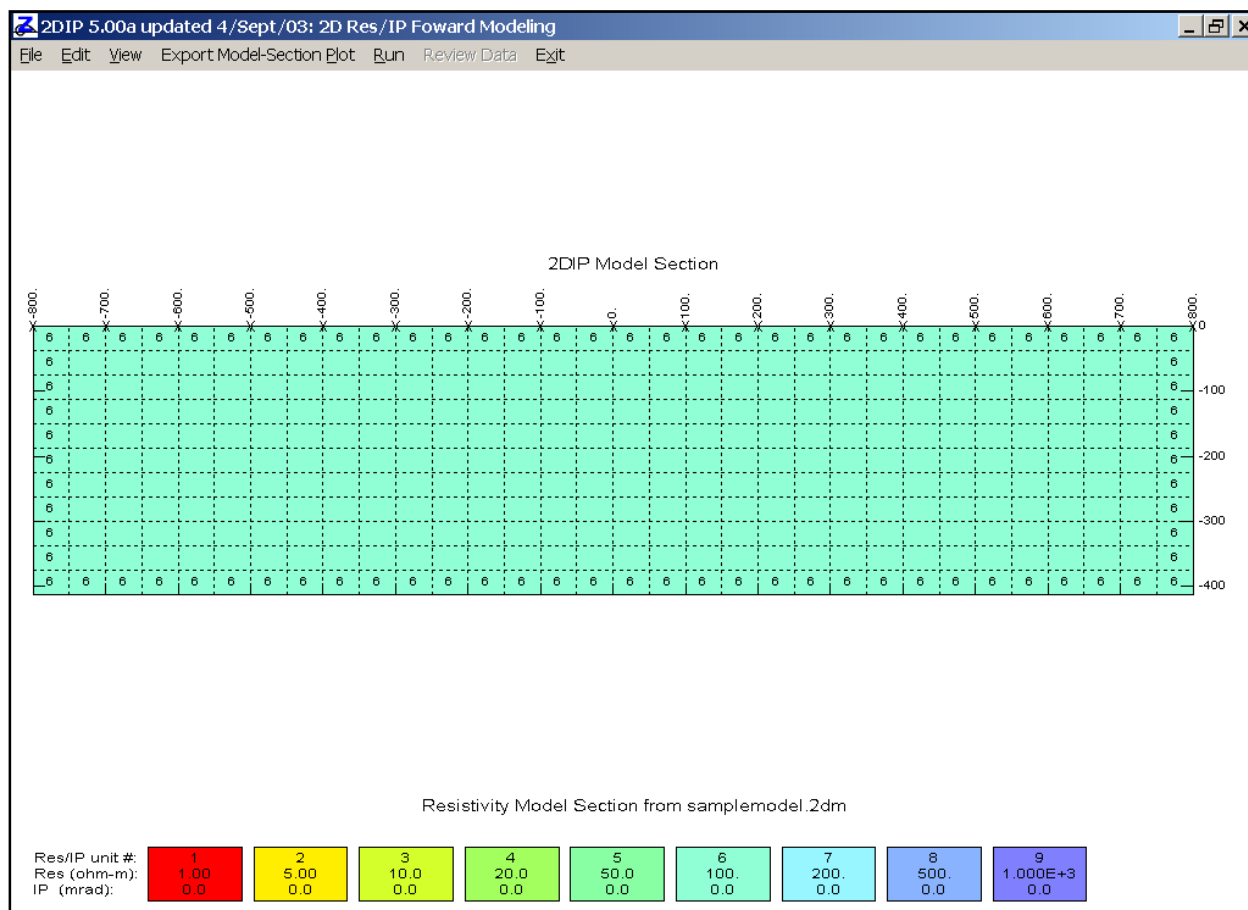
Select **Continue** to go on with the new model build, select **Back** to return to the Edit Model File Name and Descriptive Text dialog or **Cancel** to abort the new model build. Selecting Continue brings up a dialog for editing the model's resistivity and IP properties.

	Resistivity	IP (mrad)	Unit Label
1	1.000	0.0	
2	5.000	0.0	
3	10.00	0.0	
4	20.00	0.0	
5	50.00	0.0	
6	100.0	0.0	
7	200.0	0.0	
8	500.0	0.0	
9	1000.	0.0	

Back Continue Cancel

2DIP model sections may have up to nine distinct units. The Edit Resistivity and IP properties dialog allows you to set the electrical properties of each unit and give it an optional name. **Resistivity** values are given in ohm-m and may vary from 10^{-3} to 10^6 ohm-m. **IP** values are given in mrad, msec or PFE (as selected in the previous dialog) and can vary from 0 to 3140. **Unit Labels** can be any alphanumeric string up to 32 characters long.

Select **Continue** to finish the new model build, select **Back** to return to the Edit Model Section and Finite Element Mesh Parameters dialog or **Cancel** to abort the new model build. Selecting Continue completes the construction of a new model section. After default model section values are initialized, 2DIP draws the section and waits for your next menu selection.

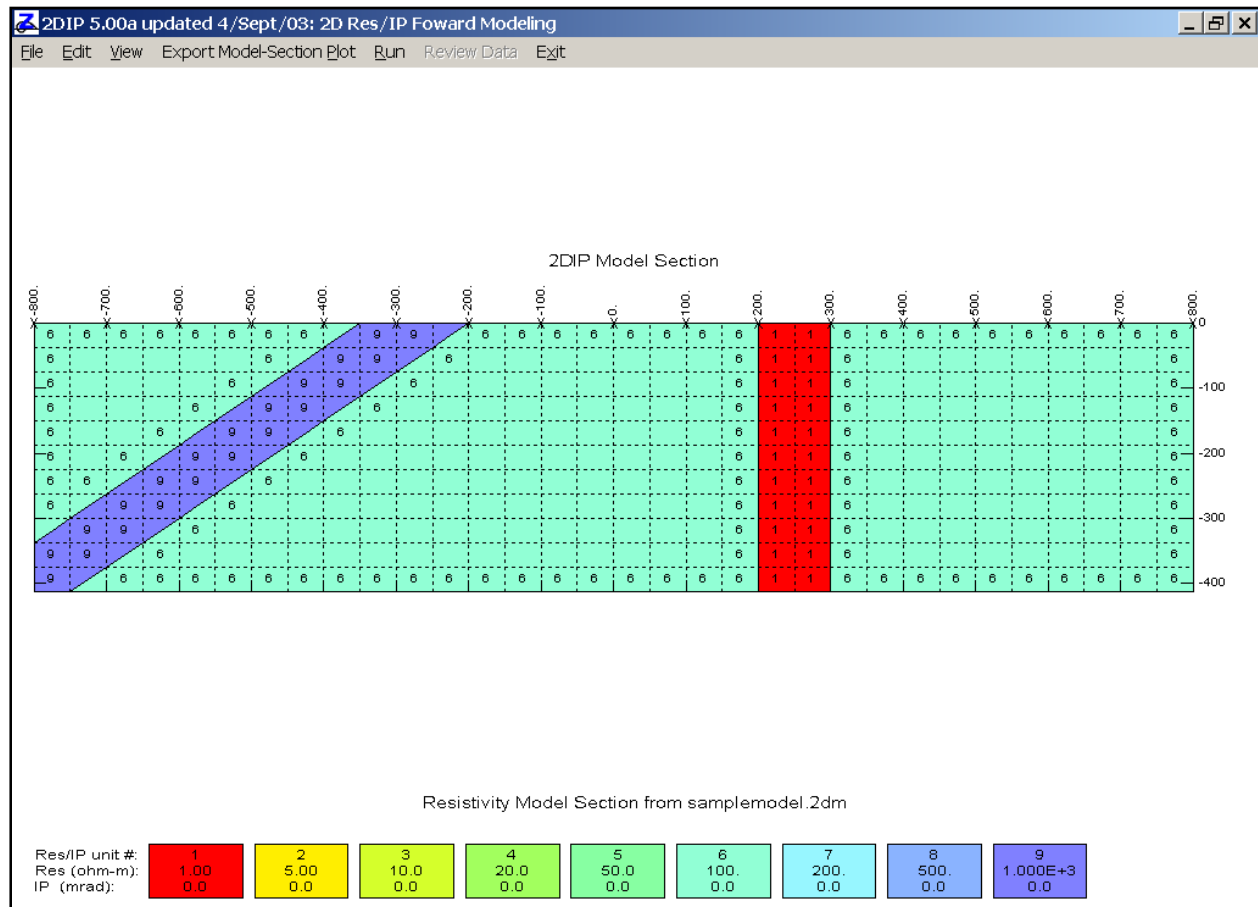


Model Editing

After building a new model or after the name of an existing model is entered, 2DIP draws a cross section of the current model. Each resistivity/IP geologic unit is given a color proportional to its resistivity and is labeled with an integer index. 0 indicates air and units 1 through 9 can be assigned arbitrary resistivity and IP values. Contacts between geologic units are outlined by solid lines. At a sufficiently detailed scale, dotted lines indicate the size and location of pixels in the model section. Transmitter and receiver electrode locations are marked by small crosses.

A menu across the top of the window presents an array of choices. Selecting **Edit** pops up a submenu with Draw Geology, Edit Res/IP and Model Description. Select **Edit | Draw Geology** to add geologic structure to the model section. 2DIP will show a submenu with a list of possible geologic units, air and geologic units 1 to 9. Select the unit for which you wish to add to the model section, then move the

mouse cursor to the first corner of the geologic structure and press the left mouse button. Move the cursor to the next corner and click again, working your way around the outline of a polygonal shape. When you close the curve on the first corner, 2DIP will fill the polygon with the geologic unit's color. You can press the ESC key to abort input of a geologic structure during the Draw Geology action.



In this section I have added a vertical conductive dike = unit 1 and a dipping resistive dike = unit 9 with two invocations of Draw Geology.

Geologic properties can be changed by selecting **Edit | Edit Res/IP** on the main menu.

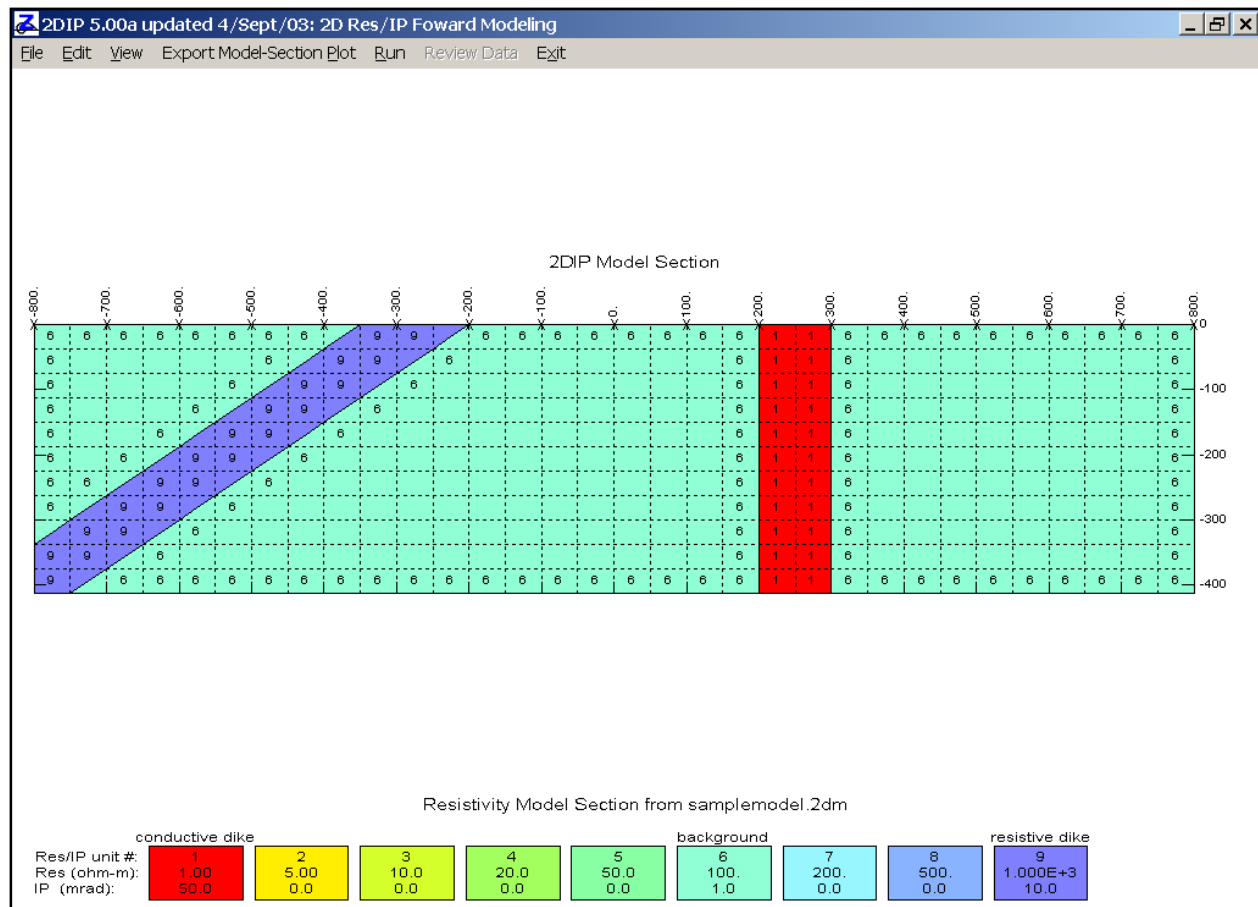
Edit Resistivity/IP Properties

Resistivity and IP Parameters

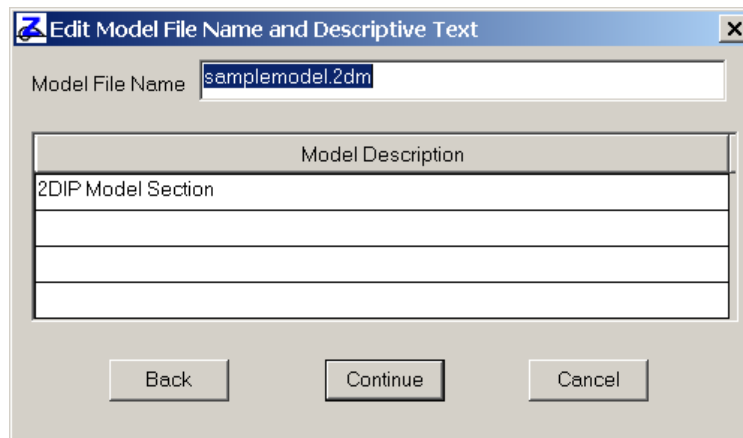
	Resistivity	IP (mrad)	Unit Label
1	1.000	50.000	conductive dike
2	5.000	0.0	
3	10.00	0.0	
4	20.00	0.0	
5	50.00	0.0	
6	100.0	1.0000	background
7	200.0	0.0	
8	500.0	0.0	
9	1000.	10.000	resistive dike

Back Continue Cancel

In this illustration, I have modified default values to give unit 1 a polarizability of 50 mrad and a unit label of “conductive dike”. I have added a polarizability of 1 and the label “background” to unit 6, and unit 9 has a polarizability of 10 and the label “resistive dike”. Selecting the Continue button stores the changes and returns you to the window with a model-section plot and main menu. Note that the legend across the bottom of the plot now shows the new geologic unit labels and the IP annotation shows the new polarizability values given to units 1, 6 and 9.



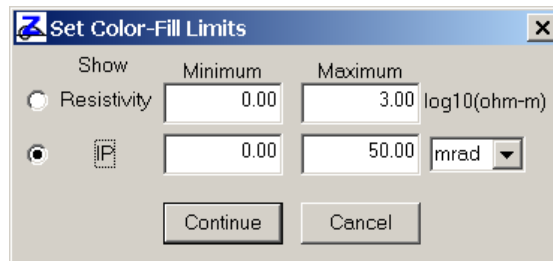
Selecting main menu option **Edit | Model Description** brings up a dialog with the model file name and fields for descriptive text.



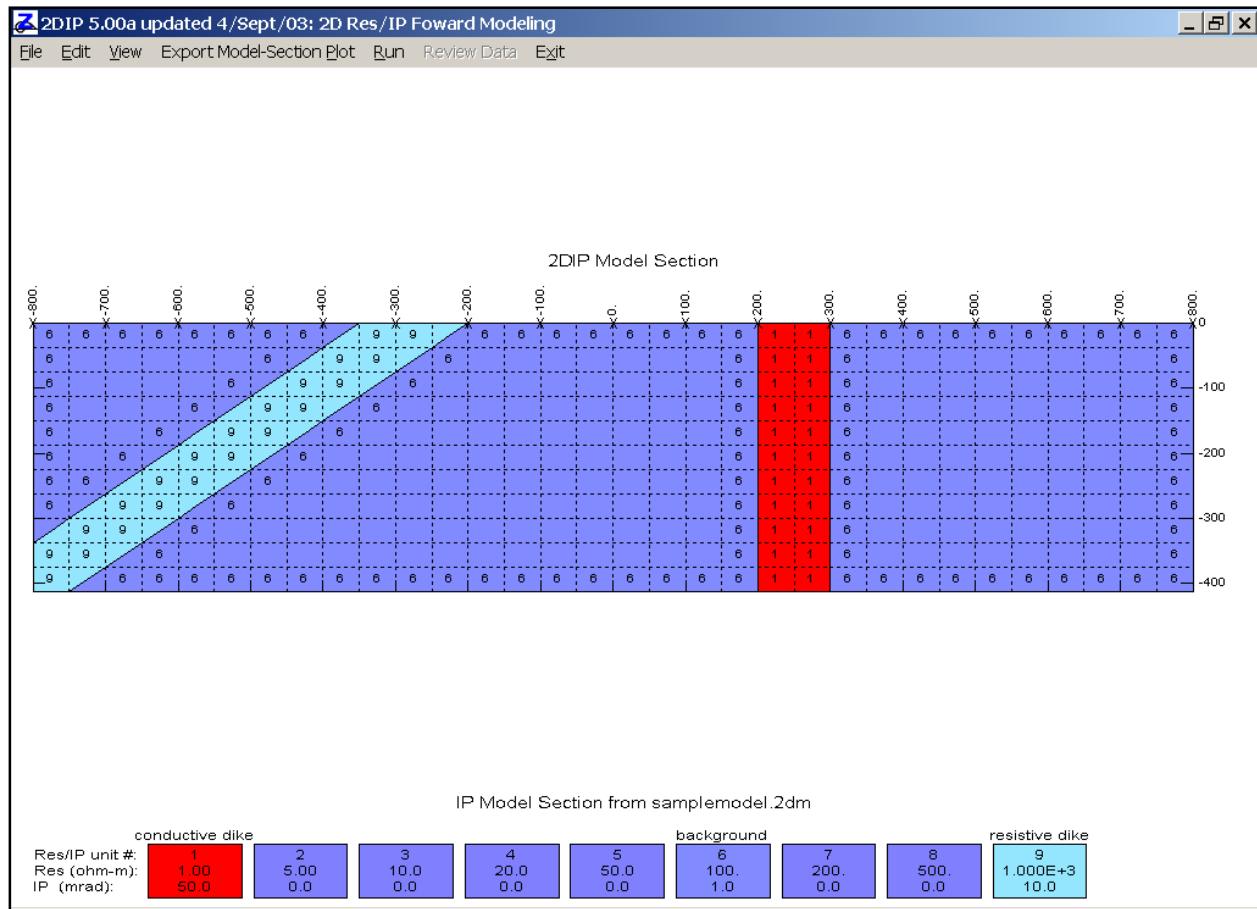
The Edit Model File Name and Descriptive Text dialog may look familiar from the New model build.

Select **Continue** to save any changes or select **Back** or **Cancel** to return to the main menu and model section plot without saving any changes made to dialog field values.

Selecting **View | Color Fill** from the main menu brings up a dialog with fields for controlling color fill in the model section and data pseudosection plots and for showing either resistivity or IP model sections.

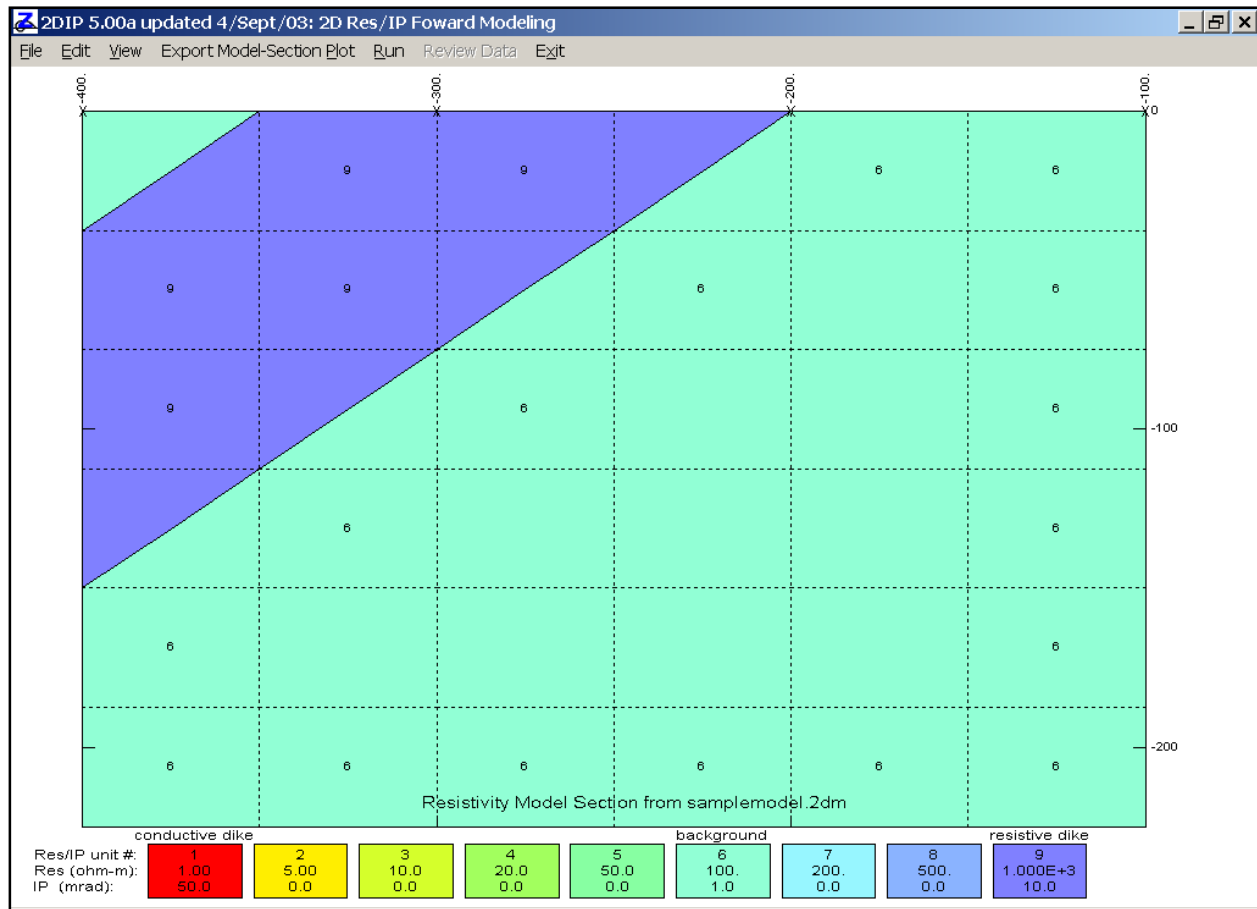


Two radio buttons on the left side of the dialog, Show **Resistivity** or **IP** control whether 2DIP plots a resistivity or IP model section. Minimum and Maximum fields in the middle of the dialog control color-fill endpoint levels. Resistivity color levels are based on $\log_{10}(\text{ohm-m})$, while IP color fills use IP values as is. A menu field on the right side of the Set Color-Fill Limits dialog allows selection of IP units, mrad, msec or PFE. Since R2DIP calculates frequency and time-domain IP responses in the same way, IP units are used to label plots but have no effect on numeric results.



2DIP shows an IP cross section after selecting Show IP in the Set Color-Fill Limits dialog and then clicking on the Continue button.

The remaining View menu sub-options control the extent of the model section display. Zoom Rectangle is probably one of the most useful zoom controls. After selecting **View | Zoom Rectangle**, move the mouse cursor to one corner of a new, more detailed view area and press the left mouse button, then move the mouse cursor to a second corner, defining a rectangular box, and press the left mouse button again. 2DIP will then redraw a magnified view of the model sub-section that you have just outlined.

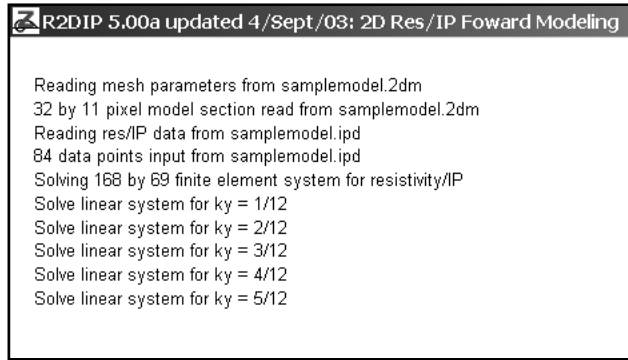


You can get back to a plot of the entire model section by selecting **View | Zoom All**. Zoom In will create a new view with 2 times magnification. After clicking on menu choice **View | Zoom In** move the mouse to the center of the new view and press the left mouse button. 2DIP will then draw a magnified model subsection. Selecting **View | Zoom Out** is similar, except that the new view is less detailed by a factor of two. **View | Zoom Pan** retains the same plot scale, but re-centers the plot on the point specified by positioning the mouse and left clicking.

Model section plots may be exported for hard copy with Export Model Section Plot suboptions. **Export Model Section Plot | To *.wmf** exports a model section plot to a vector-based "Windows MetaFile", which is suitable for pasting into MS-Word documents. **Export Model Section Plot | To *.png** exports a plot to a raster based, "Portable Network Graphics" file with a resolution of 300 pixels per inch. *.png files can be manipulated in generic graphics programs, pasted into MS-Word documents or transferred over the Internet. **Export Model Section Plot | To Printer** uses the Windows Print Manager to make a hard copy of the model section plot on any printer attached to your computer system.

Model Evaluation

2DIP calls R2DIP to calculate the model response when you select the main menu choice **Run**. 2DIP writes the current model section to a 2dm file and electrode positions to a ipd file, then calls R2DIP.exe with a command line system call and waits for R2DIP to finish.



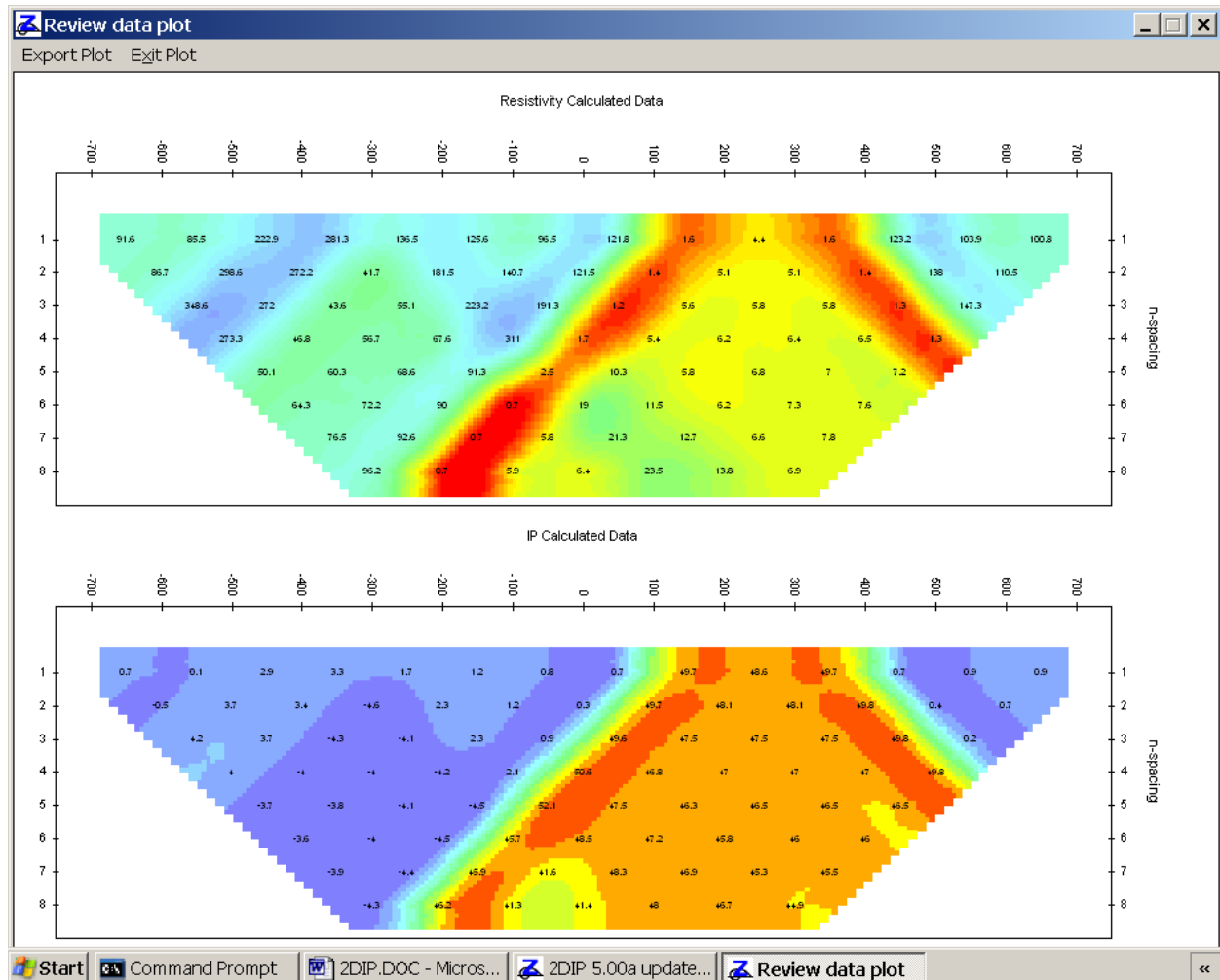
R2DIP.exe opens a new window and reports on its progress as it is calculating the resistivity and IP response of the model section. R2DIP adds wide margins to the sides and bottom of the model section, moving finite-element mesh boundaries well away from geologic structure in the model section. Each model pixel is subdivided into NSPLIT by NSPLIT finite elements for increased numerical accuracy. Comparisons of R2DIP 100 m dipole-dipole results with data calculated using an image solution over a 200 m wide vertical dike differ by an average of 0.6 percent with 4 cells per dipole length and better than 0.1 percent with 8 cells per dipole length. Pole-dipole, pole-pole and gradient test results using a vertical dike model indicate an average error of about 1 percent. After it has finished its calculations, R2DIP updates the ipd file and returns control to 2DIP.exe.

Modeling results are also written into a Zonge z-format file with the extension *.Z2D. The Zonge pseudosection contouring program ZPLOT can be used to create black and white plots of modeling results. For the example files, typing "ZPLOT DEMO2DIP.Z2D" produces two HPGL plot files, DEMO2DIP.X01 and DEMO2DIP.X02. *.X01 holds a calculated apparent resistivity pseudosection plot and *.X02 holds a calculated IP phase pseudosection plot.

Once 2DIP model and data files (*.2dm and *.ipd) have been created, R2DIP may be run from the command line, i.e. "r2dip samplemodel", and it will calculate the model response as a stand-alone program. Calls to R2DIP can be made from a batch file, which can be handy for evaluating the response of a group of models during lunch hour.

Review Data

After R2DIP has been run to calculate apparent resistivity and IP values, and the data have been read back into 2DIP, 2DIP activates the Review Data main menu option. Selecting Review Data brings up a new window with color-filled apparent resistivity and IP pseudosections.



Review Data pseudosection plots include posted data values. Color fill levels may be adjusted by selecting **Exit Plot** from Review Data menu, then using View | Set Color Fill to adjust the color fill range. In the above plot, I have extended the IP color fill maximum from 50 to 60, so that the IP response isn't completely saturated with red near the conductive polarizable dike.

Review Data plots may be exported for hard copy with Export Plot menu choice. **Export Plot | To *.wmf** writes a vector-based "Windows MetaFile", which may inserted into MS-Word documents. **Export Plot | To *.png** writes a 300 ppi raster image file in "Portable Network Graphics" format, which is handy for use in generic graphics programs or transfer via the Internet. **Export Plot | To Printer** uses the Windows Print Manager to make a plot hard copy on your computer system's printer.

You can exit 2DIP from the model-section window by selecting **Exit** on the main menu or by pressing the ESC key. If you have made any changes to the model section, it is good idea to use **File | Save** or **File | Save As** to save a copy of the model before exiting 2DIP.

References

Coggon, J.H., 1971, Electromagnetic and electrical modeling by the finite element method: *Geophysics*, v36, p132-155.

Dey, A., and Morrison, H.F., 1979, Resistivity modeling for arbitrarily shaped two-dimensional structures, *Geophysical Prospecting*, v27, p106-136.

Huebner, K.H., and Thorton, E.A., 1982, *The finite element method for engineers*, John Wiley and Sons, New York.

Rijo, L., 1977, Modeling of electric and electromagnetic data: unpublished PhD dissertation, Dept. of Geology and Geophysics, University of Utah.

Wannamaker, P.E., 1992, Documentation for IP2DI-v1.00, Finite element program for dipole-dipole resistivity/IP forward modeling and parameterized inversion of two-dimensional earth resistivity structure, Univ. of Utah Research Inst, Earth Science Lab Report, ESL-92002-TR.

Appendix A: File Format Documentation

*.2DM File (model parameters)

2DIP produces model-parameter and res/IP data files to save modeling results and to move information between 2DIP and R2DIP. Model parameters are stored in a ASCII text file with the extension .2dm. Model-parameter values can be edited directly with a text editor although most changes are done with 2DIP's editing features. A partial listing of the file DEMO2DIP.2DM and an explanation of model parameters follows.

```
"Model from 2DIP v5.00a  Date:05/09/03  Time:16:26:36"
&R2DIP
  Header(1)='2DIP Model Section',
  Array='DipoleDipole',LengthUnits='m',IPUnits='mrad'/
&MESH2D
  DipoleLength=100.,StnPerDipole=100.,StnBeg=-800.,StnEnd=800.,
  CRMIN=.00,CRMAX=3.00,CRINC=.10,CPMIN=.00,CPMAX=50.00,CPINC=5.00,
  RES(1)=1.0000E+0,RERR(1)=1.00,PHZ(1)=50.00,PERR(1)=.10,CRLABEL(1)="conductive dike",
  RES(2)=5.0000E+0,RERR(2)=1.00,PHZ(2)=.00,PERR(2)=.10,CRLABEL(2)="",
  RES(3)=1.0000E+1,RERR(3)=1.00,PHZ(3)=.00,PERR(3)=.10,CRLABEL(3)="",
  RES(4)=2.0000E+1,RERR(4)=1.00,PHZ(4)=.00,PERR(4)=.10,CRLABEL(4)="",
  RES(5)=5.0000E+1,RERR(5)=1.00,PHZ(5)=.00,PERR(5)=.10,CRLABEL(5)="",
  RES(6)=1.0000E+2,RERR(6)=1.00,PHZ(6)=1.00,PERR(6)=.10,CRLABEL(6)="background",
  RES(7)=2.0000E+2,RERR(7)=1.00,PHZ(7)=.00,PERR(7)=.10,CRLABEL(7)="",
  RES(8)=5.0000E+2,RERR(8)=1.00,PHZ(8)=.00,PERR(8)=.10,CRLABEL(8)="",
  RES(9)=1.0000E+3,RERR(9)=1.00,PHZ(9)=10.00,PERR(9)=.10,CRLABEL(9)="resistive dike",
  NXNODE=33,NZNODE=12,NSPLIT=3 /
  -800., -800., 0.,
  0.0,-37.5,-75.0,-112.5,-150.0,-187.5,-225.0,-262.5,-300.0,-337.5,
  -375.0,-412.5,
  '66666666699'
  '66666666699'
  '66666666999'
  '66666666999'
  -750., -750., 0.,
  0.0,-37.5,-75.0,-112.5,-150.0,-187.5,-225.0,-262.5,-300.0,-337.5,
  -375.0,-412.5,
  '66666666999'
  '66666666999'
  '66666666996'
  '66666666996'
  . . . . .
  . . . . .
  . . . . .
```

Two Fortran namelist blocks occupy the first section of *.2DM files. Namelist parameters can be given in any order between the character strings "&R2DIP" or "&MESH2D" which mark the beginning of the two namelist blocks and "/" which mark their ends.

R2DIP Namelist parameters:

Header - free-format describing model.
Array - survey array type (DipoleDipole, PoleDipole, Gradient, General).
LengthUnits - length units (m, km, ft or kft).
IPUnits - IP-response units (mrad, msec or PFE).

MESH2D Namelist parameters:

DipoleLength - dipole length (LengthUnits).
StnPerDipole - dipole length (station numbers).
StnBeg - first station in model.
StnEnd - last station in model.
CRMIN - resistivity color fill minimum (log10(ohm-m))

CRMAX	- resistivity color fill maximum (log10(ohm-m))
CPMIN	- IP color fill minimum (IPUnits)
CPMAX	- IP color fill maximum (IPUnits)
Res(*)	- model resistivities (ohm-m).
Rerr(*)	- a priori model resistivity error (used by inversion programs) (percent).
Phz(*)	- model IP (IPUnits).
Perr(*)	- a priori model IP error (used by inversion programs) (IPUnits).
NXNODE	- number of model section node columns.
NZNODE	- number of model-section node rows.
NSPLIT	- number of finite element rows and columns per model pixel.

The second section of *.2DM files contains two types of records in an alternating sequence. Records specifying coordinates for a vertical column of model-section nodes sandwich record blocks defining model pixel properties.

Vertical columns of model nodes are first located horizontally by three values: station number, grid east, and grid north. Station numbers are proportional to distance along line, although variation due to surveying error or slope correction can be accommodated. Grid east and grid north values should be accurate and are given in the same LengthUnits used to specify elevation and DipoleLength. The three horizontal-location values are followed by NZNODE elevation values, one elevation value for every node in the vertical column. 2DIP's finite element mesh allows vertical displacement of mesh nodes, primarily for more accurate modeling of topography. All 3+NZNODE node-location values are read free-format, so spacing and line breaks are not important. Values must be in order and separated by spaces or commas.

Numbers specifying node locations sandwich record blocks specifying model pixel properties. A group of four lines, each line NZNODE-1 characters long, defines the physical properties of a column of pixels. The first line indicates the properties of triangular subcell 1, the second triangular subcell 2, etc (see figure A1).

The last record in a *.2DM files should be a list of node locations along the edge of the model section. There should be a total of NXNODE node-location record blocks and NXNODE-1 pixel property blocks.

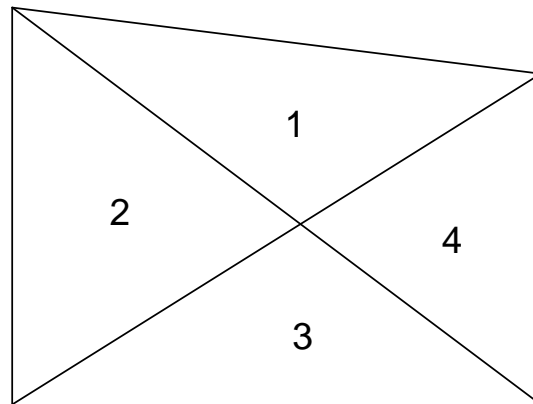


Figure A1: Groups of four triangular subpixel cells, indexed 1 to 4, are combined into trapezoidal model pixels with vertical sides and possibly sloping top or bottom edges. Individual resistivity and IP properties may be specified for each triangular subpixel cells. R2DIP divides each model pixel into NSPLIT by NSPLIT finite elements with the same topology. Four triangular subelements make up each trapezoidal finite element.

*.IPD File (res/IP data)

*.IPD files hold electrode locations, observed data and calculated resistivity and IP data in a tabular, comma-separated-value format. There is one numeric record per data point. The first line should hold column labels. Comment lines for annotation beginning with a "!", "\", "/", or "" can be included anywhere in the file and are ignored. 2DIP and R2DIP attempt to read numeric values from all other records. The *.ipd file format lends itself to manipulation by a spreadsheet. It is fairly straightforward to create a file with electrode locations for an arbitrary in-line or downhole survey configuration in Excel, then save the file in csv format and paste in 2DIP *.ipd header lines.

Partial *.IPD-file listing:

```
"SPltH", "SPltV", "SRxH1", "SRxH2", "STxH1", "STxH2", "ARobs", "ARerr", "APobs", "APerr", "ARmod", "APmod"
"Data from 2DIP v5.00a Date:05/09/03 Time:16:27:14"
"Array=DipoleDipole, DipoleLength=100.00, StnPerDipole=100.00, LengthUnits=m, IPUnits=mrads"
-650,-100,-800,-700,-600,-500,91.60,1.0,0.7,0.1,91.60,0.7,
-550,-100,-700,-600,-500,-400,85.49,1.0,0.1,0.1,85.49,0.1,
-600,-150,-800,-700,-500,-400,86.71,1.0,-0.5,0.1,86.71,-0.5,
-450,-100,-600,-500,-400,-300,222.9,1.0,2.9,0.1,222.9,2.9,
-500,-150,-700,-600,-400,-300,298.6,1.0,3.7,0.1,298.6,3.7,
-550,-200,-800,-700,-400,-300,348.6,1.0,4.2,0.1,348.6,4.2,
-350,-100,-500,-400,-300,-200,281.3,1.0,3.3,0.1,281.3,3.3,
-400,-150,-600,-500,-300,-200,272.2,1.0,3.4,0.1,272.2,3.4,
-450,-200,-700,-600,-300,-200,272.0,1.0,3.7,0.1,272.0,3.7,
-500,-250,-800,-700,-300,-200,273.3,1.0,4.0,0.1,273.3,4.0,
-250,-100,-400,-300,-200,-100,136.5,1.0,1.7,0.1,136.5,1.7,
-300,-150,-500,-400,-200,-100,41.74,1.0,-4.6,0.1,41.74,-4.6,
-350,-200,-600,-500,-200,-100,43.58,1.0,-4.3,0.1,43.58,-4.3,
-400,-250,-700,-600,-200,-100,46.81,1.0,-4.0,0.1,46.81,-4.0,
-450,-300,-800,-700,-200,-100,50.11,1.0,-3.7,0.1,50.11,-3.7,
-150,-100,-300,-200,-100,0,125.6,1.0,1.2,0.1,125.6,1.2,
-200,-150,-400,-300,-100,0,181.5,1.0,2.3,0.1,181.5,2.3,
-250,-200,-500,-400,-100,0,55.10,1.0,-4.1,0.1,55.10,-4.1,
. . . . .
. . . . .
. . . . .
```

Record 1 is a list of column labels indicating the data type in each column. Record 2 is a comment line showing the program name and version along with the date and time when the file was updated.

Record 3 is a comment line containing survey configuration information that is used when TS2DIP reads *.ipd files while building a new inversion model section. All remaining records in DEMO2DIP.IPD specify individual four-electrode resistivity/IP data points.

Column Number: Associated variable

- 1: horizontal plot-point coordinate (station number).
- 2: vertical plot-point coordinate (station number).
- 3: location of receiver electrode 1 (station number).
- 4: location of receiver electrode 2 (station number).
- 5: location of transmitter electrode 1 (station number).
- 6: location of transmitter electrode 2 (station number).
- 7: observed apparent resistivity (ohm-m).
- 8: observed apparent resistivity error (percent).
- 9: observed apparent IP (IP Units).
- 10: observed apparent IP error (IP Units).
- 11: calculated apparent resistivity (ohm-m).
- 12: calculated apparent IP (IP Units).

*.IPD files holding downhole survey data add four additional columns with electrode depths in vertical stations numbers, STxV1, STxV1, SRxV1, SRxV1. It is easier to keep track of electrode locations, particularly for downhole data, if station numbers equal distance along line and distance down hole.

CFTABLE.CLR (color fill table)

CFTABLE.CLR specifies the colors used for plot color fills. The cftable.clr file supplied with 2DIP holds a rainbow spectrum with partially saturated colors that don't hide overprinted annotation text. Clrtable.clr is in the Golden Software, Surfer "color spectrum" file format. The first line holds an ID string, "ColorMap", followed by a version number and interpolation method between color control points. Both values should be 1. Subsequent records hold space separated control point, red, green and blue values. Control points are a percentage that can vary from 0, equal to the color fill minimum, to 100, equal to the color fill maximum. *.clr file records should be ordered from low to high by control point value. Red, green and blue values are integers that can vary from 0 to 255 (low to high color saturation). Cftable.clr colors can be customized to suit your needs. Zonge plotting programs s2dplot and modsect also use cftable.clr to set contour fill colors.

CFTABLE.CLR listing:

```
ColorMap 1 1
    0      128      128      255
   25      153      255      255
   50      128      255      128
   75      255      255       0
  100      255       0       0
```

*.STN File (station location coordinates)

*.STN files hold information about station locations in a simple tabular format. 2DIP uses them to import topographic profile data. A *.stn file should have at least two records, corresponding to the first and last stations in a survey line. Additional records may be necessary to trace out topographic changes or curved survey lines. Modeling programs assume that station numbers are closely related to distance along line. Location coordinates for stations which are not explicitly listed in the *.stn file are calculated by linear interpolation between station numbers. Comment lines preceded by a "!", "\", "/" or "" in column 1 may be inserted anywhere in the file and are skipped. The first record in a *.stn file should be a column label line beginning with an alphabetic character. 2DIP assumes that *.stn files will have four columns with station, easting, northing, and elevation. Column labels and numeric records may be either space or comma separated, but comma separated values are preferred.

Column 1: client station numbers. Station numbers may not be in an official length unit, such as m or ft, but should be proportional to distance along line.

Column 2: x coordinate = easting in LengthUnits (m,km,ft,kft).

Column 3: y coordinate = northing in LengthUnits (m,km,ft,kft).

Column 4: z coordinate = elevation in LengthUnits (m,km,ft,kft).

*.STN file listing:

```
Station,GridEast,GridNorth,Elevation
"Sample station file for 2DIP."
-1000,-1000,1000,500
 -300, -300,1000,500
  000,  000,1000,350
  300,  300,1000,500
1000, 1000,1000,500
```

***.MDE File (Zonge data processing control file)**

*.MDE files hold annotation and Zonge data-processing-control information and are necessary for plotting with the Zonge ZPLOT pseudosection contouring program. A *.MDE-file consists of one or more MODE LINES, each of which begins with a "\$" in the first column, optionally followed by a program name and colon ":". The name of the mode is followed by an equal sign "=", then the value to assign to the variable. Spaces may be included between elements of the mode line. Spaces in values defined as text will be included as part of the value.

***.MDE-file listing:**

```
$ CLIENT=Zonge International
$ PROJECT=2DIP Modeling
$ JOBNUMB=9500
$ JOBDATE=April 96
$ JOBLINE=DEMO2DIP
$ BRGLINE=East
$ BRGBACK=West
$ STNLO= -800.0
$ STNHI= 800.0
$ LBLDELT= 100.0
$ STNDELT= 100.0
$ ASPACE= 100m
$ UNITS= m
$ auto=yes
$ zplot:sizeX=1.5
$ zplot:sizeY=0.75
$ zplot:view=y
```

***.MDE-file variables:**

CLIENT - Name of company running survey (text).
PROJECT - Project name (text).
JOBNUMB - Job number.
JOBDATE - Date when survey was conducted.
JOBLINE - Line number.
BRGLINE - Forward line bearing (in direction of increasing station numbers).
BRGBACK - Line back bearing (in direction of decreasing station numbers).
STNLO - First GDP station number shown on pseudosection.
STNHI - Last GDP station number shown on pseudosection.
STNDELT - GDP station-number increment. Default: STNDELT=1.0
LBLFRST - Client station number corresponding to STNLO GDP station number.
Default: LBLFRST=STNLO
LBLDELT - Client station number increment along axis. Default: LBLDELT=STNDELT
ASPACE - Dipole length (length units).
UNITS - Length units (m, km, ft, kft).
AUTO - yes = batch file processing mode.
ZPLOT: SIZEX - horizontal ZPLOT plot scale (LBLDELT/cm).
ZPLOT: SIZEY - vertical ZPLOT plot scale (data points/cm).
ZPLOT: VIEW - yes = preview ZPLOT plots on screen.

*.Z2D File (Zonge plotting program ZPLOT *.Z file)

*.Z files hold data in an (x,y,z) format specialized for the Zonge plotting program ZPLOT.

Partial *.Z2D-file listing: ! Modeling results from R2DIP v5.00a

```
$ DATE= 05/09/03
$ ASPACE= 100.m
$ ZPLOT: DATA= N-SP
R2DIP v5.00a Contour file.
Cl Cn Ce Ns Nd Yl Plot file 1
1 10 0 3 1 0
Dipole-Dipole IP Data
Calculated App Resistivity
values in ohm-m
IIxxxxxxxxxYYYYYYYzzzzzzzzzzzz AAA
2 -650. 1. 9.160E+01
2 -550. 1. 8.549E+01
2 -600. 2. 8.671E+01
2 -450. 1. 2.229E+02
2 -500. 2. 2.986E+02
2 -550. 3. 3.486E+02
2 -350. 1. 2.813E+02
2 -400. 2. 2.722E+02
: : : :
: : : :
99: 9999.00
```

Description of values in sample *.Z file:

Line # Explanation:

2: \$ ASPACE= 100.m Keyword specifying dipole length

3: \$ ZPLOT: DATA= N-SP Keyword specifying vertical plot axis type

4: R2DIP v3.00d Program name and version that generated this file.

5: Cl Label for contour type: 0 = linear
1 = logarithmic
2 = pseudo-log

For pseudo-log contours, positive and negative values are contoured separately, using $\log_{10}(\text{abs}(\text{value}))$, plus a zero contour.

Cn Label for number of contours per interval.

Ce Label for exponent of the contour interval.
The "interval" is an integer power of ten: 10^{Ce}

Ns Label for number of significant digits when posting values.
Values: -1, 3, 4, 5. (-1 = free format for small values)

Nd Label for the number of digits after the decimal.

YI Label for vertical axis: 0 = none
1 = linear frequency
2 = log frequency
3 = linear depth

6: 1 Value of CI: logarithmic contours

5 Value of Cn: 5 contours per "interval"

0 Value of Ce: interval = 100 = 1

3 Value of Ns: use 3 significant digits for contouring

1 Value of Nd: plot 1 digit after the decimal

1 Value of YI: linear frequency axis

7-9: Data description for this Plot File. Two to six lines are available, NOT including the first column.
Plot programs may plot these lines as title information.

10: Header line for the data that follows:

II - Command flag:

0 = Skip this line of data.

1 = Omit for contouring, but post the bracketed value.

2 = Use for contouring and post the value (most common).

3 = Label a point or station by plotting a symbol under the X-axis at the X-coordinate.

4 = Use for contouring, post the symbol and not the value.
Used for depth plots where values are interpolated for the bottom of the plot to improve the gridding.

5 = Use to set plot limits, do not contour or post.
Used for depth plots to set zero depth. Used to provide a margin around the data, as for plan maps.

xxxxxxx - X-coordinate, usually station coordinate.

YYYYYYYY - Y-coordinate, not used for Flag = 3

zzzzzzzz - Value to be plotted at X-Y for Flags 1, 2, 4.

AAA - For Flag 1 or 2, ZPLOT posts any characters in the AAA column instead of the value in the zzzzzzzz column.

For Flag 3, ZPLOT plots a symbol below the X-axis at the x-value according to an integer in column AAA. A zero or positive integer refers to symbols in TABLE 1 of the PLOT Manual. A negative integer refers to topographic symbols in the CTOPO Manual.

99: 9999.0 - End-Of-Plot indicator.