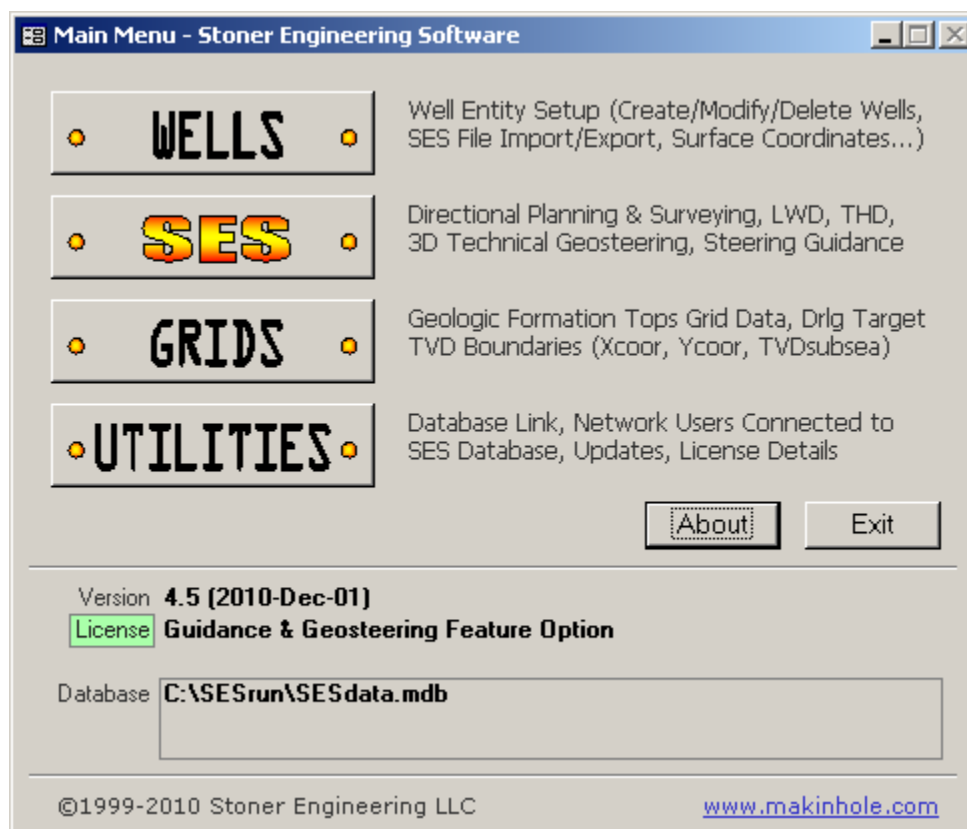


# Stoner Engineering Software

## SES USER MANUAL

Version 4.5

December 1, 2010



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12/3/2010 Compilation

## INTRODUCTION to SES

The surge of oil/gas/CBM horizontal drilling operations that emerged mid-2000's created a demand for software technology that could simplify the process of tracking and managing such operations from a geologic perspective. Stoner Engineering Software (**SES**) is a full-suite solution to this demand. SES continues to evolve to the changing and refined needs of industry participants that choose SES.

SES is horizontal/directional well planning and execution software, including 3D technical geosteering and directional steering guidance from patented Fuzzy Logic control technology<sup>1</sup>.

Key features of SES include:

- Technical Geosteering with 3DStratBlocks (3DSB) and Relative Stratigraphic Depth concepts (no distortion like vertical section projection)
- Extreme data loading/updating/editing ease and flexibility and management (enter/edit data by hand/keyboard, clipboard copy/paste, LAS format file import, or all of the above)
- Supports multiple working hypotheses/interpretations while Geosteering; allows for interpretation gaps and or overlaps while Geosteering
- Supports simultaneous graphing of multiple LWD data curves while actively Geosteering, with user control of line colors, min/max scale limits, log/linear scale format, and constant-value lines...per LWD curve and stored per 3DSB
- Single 3DSB-level control of payzone and  $\pm 5$  offset beds thickness & color & names, with easy property settings-transfer between wells for visual consistency & fast setup
- Directional steering control guidance, whether drilling geometric path or Geosteering
- Full and or partial-well cross-sections with zoom control of TVD versus MD (no distortion from vertical section projection) or Vertical Section of well paths, stratigraphic beds, and multiple tracks of LWD data with user control of track placement & track size & track content (up to 8 curves total)
- Easily setup a new center-line plan and post its definition on cross-section display
- Displays multiple offset/stacked zones on TVD versus MD|VS cross-sections for enhanced zone visualization and communication, with optional zone labeling
- Supports simultaneous use of multiple Type Logs for Geosteering correlation and Type Logs may contain up to 4 data curves (e.g., gamma ray, resistivity, porosity)
- Easily transfers type logs between wells for re-use (e.g., pad drilling)
- Easily creates "Derived" Type Logs from the landing or anywhere where signal calibration confidence exists
- Allows for a statistically-smoothed EVOLVING type log (derived from 3DStratBlock calibrations) to be posted while Geosteering progresses
- Allows for all traces of 3DStratBlock calibrations to be posted while Geosteering progresses

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<sup>1</sup> Stoner, Michael S. 2000 (8 August). Numerical control unit for wellbore drilling. United States Patent #6,101,444.

- View geologic model from grid data 3D interpolation during well planning, surveying, and on cross-sections
- Exports Geosteered Marker Bed 3D control points along entire well path in global coordinates for input to revise 3<sup>rd</sup> party software geologic models or analyses (also helpful for reservoir simulation preparation)
- Interactive 3D graphics of survey data with rotate/zoom/pan
- Graphs and easily zooms all data sources, including survey data, well plan data, type log data, LWD data, and cross-sections
- Internally performs all directional survey calculations and related minimum-curvature interpolations for Geosteering and graphing
- Supports network server hard drive for database location and simultaneous multi-user database access
- Easily transfers all well data between SES users or databases using a single XML format file and export/import
- Supports multiple methods of licensing (flash-drive, floating-network, machine-specific, & magic-password)
- Minimum curvature interpolates surveys at any user-specified MD; labels plots and reports with MD-tagged annotations
- Creates professional directional survey/plan reports applicable to regulatory filings
- Vertical Section Azimuth associated with each individual survey or plan...easily handles multi-laterals in opposite/different directions
- Backwards compatible...v4 can read and write v3 SES xml files
- Computes Technical Hole Deviation (THD) whether drilling geometric path or Geosteering
- Creates THD well logs with THD projections whether drilling geometric path or Geosteering
- Computes/designs general 3D/2D directional/horizontal well plans with unlimited targets
- Computes directional wellbore surveys (minimum curvature method)
- Creates vertical section and plan/map view plots
- USA (ft, °/100ft) & metric (m, °/30m) units supported

## **System Requirements**

SES requires Microsoft Access and Microsoft Excel. These products ship with Professional editions of Microsoft Office. Microsoft Office 2000, XP (2002), 2003, 2007, and 2010 are supported. The latest service packs are required (see <http://office.microsoft.com/en-us/downloads/default.aspx>).

## **Installation**

SES installer may be downloaded from [SES Download.htm](#). It is named something like "SES\_4\_50\_Setup.exe." With SES *not* running (i.e., from a prior installation), run SES installer and follow the on-screen instructions. After installing SES, an SES icon will be present on your desktop.

## **How to start/run SES**

SES installer adds a 'Stoner Engineering' directory to your Windows Start—Programs menu. Under 'Stoner Engineering' is an icon entry named 'SES 4' that when clicked will launch SES, assuming Microsoft Office Professional has been installed. The SES icon on your desktop may

also be used to run SES. Yet another alternative method to launch SES is to open SES.mde, which is the SES run-time file, directly from/using Microsoft Access.

With some versions of Microsoft Access, you may be prompted with warning messages upon running SES. Select 'Open' or otherwise navigate through the dialog boxes to get SES opened without restrictions. **To change Microsoft Access settings so you never have to click 'Open'**, simply open Microsoft Access stand-alone and change the security settings to 'Low' using the menu Tools...Macro...Security.

A security installation of SES occurs upon first use of SES. You may need access to a valid License Code to authorize your copy of SES to use most features of SES. Please contact Stoner Engineering LLC to acquire a valid license code if applicable.

## License Logistics and Pricing

SES supports multiple methods of licensing, including machine-specific, flash-drive, floating-network, and magic-password. Please contact Stoner Engineering LLC or view [SES Licensing.htm](#) for the most recent information about licensing and pricing.

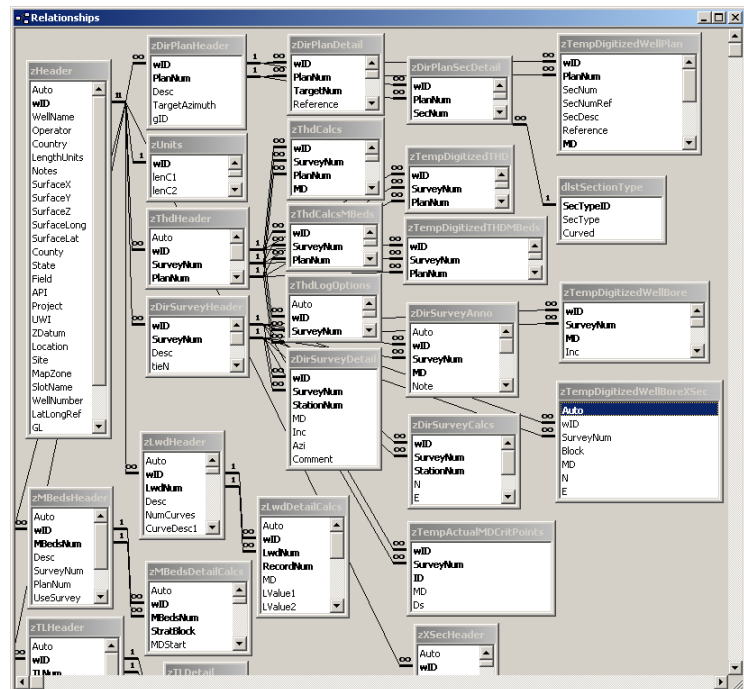
### License Code (Machine-Specific)

From UTILITIES screen, License tab, you may copy your “Current License Code” *text* and send it to Stoner Engineering LLC to acquire a valid updated License Code if applicable. With a revised License Code, use this same screen to enter a new license code if you’re not using one of the other licensing methods.

## SES Data (SESdata.mdb)

SES data (e.g., directional surveys, surface coordinates, offset type log data, LWD data, well plans, geologic grids, marker bed 3DStratBlock parameters, THD, etc.) are stored in a Microsoft Access relational database in a particular format. A fresh SES installation will include a default database named “SESdata.mdb.” Installing an SES version upgrade *or* uninstalling SES will *not* delete or overwrite or change your existing SES\_Database(s)!

An SES v4.x *default* SESdata.mdb database, which contains multiple technical geosteering, grid use, THD, and well plan examples, may be downloaded from the SES technical support web page. Also, an *empty* SESdata.mdb database may be downloaded. The SES technical support web page is located at [SES\\_TechSupport.htm](http://www.ses.com/Support/SES_TechSupport.htm).



SES formatted databases from SES version 2.1 forward may be converted into the current format using UTILITIES screen. SES allows SES formatted databases (SESdata.mdb) to have *any* file name with an “mdb” extension, and it may be located on any type of drive (network server, fixed media, removable media, etc.).

SESdata.mdb can contain data from multiple different wells. Eventually its file size may grow (e.g., in excess of 100MB) and general SES performance may be affected. It is perfectly acceptable to create multiple copies of SESdata.mdb and place them strategically in a file directory structure that inherently groups information with applicable subsets of your company's wells (e.g., field 'A' or division 'B' or client 'C', etc.). Another popular practice is to manage a “working” version of SESdata.mdb for active wells and use an “archive” version of SESdata.mdb to save final version data, where SESdata.mdb exists in two or more different directories. This archive database for example can safely be as large as 2GB. WELLS screen is used to add and delete wells in a particular SES\_Database, and UTILITIES screen can be used to compact fragmented SES\_Database files to conveniently minimize their file sizes.

MAIN MENU screen shows the database to which SES is currently attached. You may attach to a different SES\_Database (e.g., corporate SES\_Database located on a network server hard drive) using UTILITIES screen, SES Database tab.

## ***Technical Support***

The website contact form is the most reliable method of contacting Stoner Engineering LLC. The email submitted to us via the contact form is monitored “24/7/365.”

Please contact Stoner Engineering LLC ([contactSE.htm](#)) for technical support or send email directly to techsupport at makinhole dot com. A variety of other technical discussions and resources may also be found online at:

- [SES TechSupport.htm](#) and
- [Technical Discussions](#)

## GENERAL Microsoft Office HOW TO...

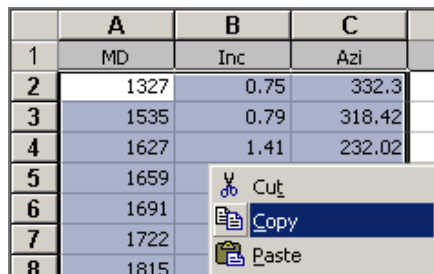
### How To Paste Data From Excel

Only select and copy *data values* with columns in the proper order (i.e., do *not* copy column heading labels). SES automatically handles row numbering when applicable. Each Excel cell should contain one value or no value (i.e., not two or more values). In some cases, data may first need to be parsed into one-value-per-cell using Excel's Text-to-Columns feature.

Any copied data, which are tab-delimited, may be pasted directly into SES. Excel automatically tab-delimits data when cells are copied to the clipboard for pasting elsewhere. However, data may also manually be made tab-delimited using a text editor such as UltraEdit.

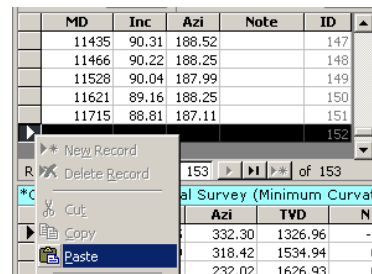
To paste data into an SES data table after copying, *right-click* on the bottom row selector (asterisk or triangle) and select Paste from the shortcut menu; or left-click on the bottom row selector (asterisk or triangle) and press CTRL-V.

Sorting and/or calculating (using a toolbar button) *may* be necessary after pasting data.



	A	B	C
1	MD	Inc	Azi
2	1327	0.75	332.3
3	1535	0.79	318.42
4	1627	1.41	232.02
5	1659		
6	1691		
7	1722		
8	1815		

COPY DATA (without column labels)



MD	Inc	Azi	Note	ID
11435	90.31	188.52		147
11466	90.22	188.25		148
11528	90.04	187.99		149
11621	89.16	188.25		150
11715	88.81	187.11		151
				152

PASTE onto last row in table

### How To Insert Data Between Existing Data

All data is added at the bottom of a table. In some cases, sorting may be necessary after adding and or deleting data. Click the 'A to Z' toolbar button to sort data when applicable.

### How To Delete A Row

Click the row selector at the far left side of a table to select a row (or rows) to delete. Right-click over the selection and click 'Delete Record' from the shortcut menu, or press the 'Delete' key.

### How To Undo Data Changes \*While\* In Edit Mode

Press 'Esc' key *WHILE* in edit mode to undo a cell/record data change. A "pencil...icon" may appear at the left side of the row on some screens *WHILE* SES is in edit mode.

## PROGRAM/DATA FLOW for GEOSTEERING


General SES data flow to perform typical technical geosteering is as follows:

- ↓ (optional) Grid data ([GRIDS Screen](#))
- ↓ (optional) Well plan ([SES Screen – PLANNER](#))
- ↓ (**required**) Type log data from offset penetration ([SES Screen – TYPE LOG](#))
- ↓ (**required**) Directional survey data ([SES Screen – SURVEYS](#))
- ↓ (optional) THD calcs and related logs ([SES Screen – THD TECHNOLOGY](#))
- ↓ (**required**) LWD data ([SES Screen – LWD](#))
- ↓ (**required**) Geosteer ([SES Screen – GEOSTEER](#) and [SES Screen – GEOSTEER – ParamTuner](#))
- ↓ (**required**) Cross-Sections ([SES Screen – CROSS-SECTIONS](#))

If your sole interest in SES is 'raw' technical geosteering, please review the hyperlinked screen discussions above marked with "**required**."

Grid data, which would source from Surfer or Petra or Geographix or Petrel or the like, is great if you want to see the geo model in SES vertical section or cross-section views.

Grid data may also be used to display “hard” TVD drilling window targets in a cross-section.

Please see GRIDS screen  Tips for a full example.

For live operations, LAS format files for directional survey and LWD data produce the quickest (fewest clicks) means of SES data updating. However, key-punch and copy/paste (e.g., from Excel) are also fully supported. Key-punch can be handy when a survey station estimate at TD is necessary in order to use gamma data beyond/deeper-than the survey tool. Key-punch is also (at times) paramount to correcting or removing erroneous data, which is very simple with SES.

## ONLINE TRAINING VIDEOS

There are at least two general levels of training associated with SES technical geosteering. First, there is the learning curve to SES logistics...knowing which button clicks and screens do the task at hand. Second, there is the developed skill that comes from analyzing data with SES and extracting value based on what is discovered from knowing how to 'read' the results. As might be expected, the latter takes much more time (relatively) to acquire and requires the user to 'think like a geologist' for best results. See [GEOSTEERING ANALYST'S TRADE SECRETS](#) for more information.

Fortunately, climbing the SES logistics learning curve can be done reasonably quickly. This user manual is one resource to help accomplish the task, but equally important—if not more important—are the online training videos published at [SES\\_ScreenShots.htm](#). Approximately 70+ minutes have been created to help new users get acquainted with SES. The next critical component to learning is doing (free trials are always available).



## WELLS Screen

WELLS: SE Demo v4 #1 (Grid)

Selected Well  
**SE Demo v4 #1 (Grid)**

Click to Select Well

WellName	Field
SE Demo (Plan) Horizontal	Stone
SE Demo (Plan) S-Type	Stone
SE Demo (Survey)	Stone
SE Demo (THD) 3D	Stone
SE Demo (THD) Mostly Vertical	Stone
SE Demo (THD) Multi-Plan	Stone
SE Demo (THD) Sidetrack	Stone
SE Demo (THD) Slant	Stone
<b>SE Demo v4 #1 (Grid)</b>	<b>Stone</b>
SE Demo v4 #2 (Geosteer)	Stone
SE Demo v4 #3 (Geosteer)	Stone
SE Demo v4 #4 (Geosteer)	Stone
SE Demo v4 #5 (Geosteer)	Stone

Edit Well Header  
Add New Well  
Delete this Well

**Well Header**

General | Surface | Data Units | Other

**A "Well" has a common surface location and may have multiple well paths, sidetracks, laterals, plans, surveys, etc.**

Well Name: SE Demo v4 #1 (Grid)  
Field: Stoneman  
OPERATOR:  
Analyst:  
Analyst Company:  
Drilling Rig:  
UWI:  
API:  
Well Number:  
Slot Name:

? Close

### General

A "Well" has a common surface location and will have multiple data sets associated to it, such as directional Surveys, Type Logs, LWD, Marker Beds (Interpretations), THD, and Cross-Sections.

WELL SETUP tab can be used to:

- 1.) Add a new well to SES\_Database.
- 2.) Delete the selected existing well and all associated data from SES\_Database.
- 3.) Modify/edit numerous well properties.
- 4.) Navigate to Wells in SES\_Database and see their properties.

EXPORT tab can be used to:

Create a 'flat' file in XML format containing all SES well-related data, which may be used to transfer well data to other SES users and/or to other SES\_Database(s).

IMPORT tab can be used to:

Import an SES XML file created with SES using the Export feature.

RECORD COUNTS tab can be used to:

Quickly return a table listing of data record counts in various SES\_Database data tables for the selected existing well.

## Critical

- 1.) If a new well has been added while SES screen is open, simply close SES screen and re-load it from Main Menu to have the new well available to select from SES screen.
- 2.) If well data units are changed after (e.g., directional survey) data have been added to SES, re-calculate ALL survey-related data using SES screens.
- 3.) If the geologic model via grid data will be displayed in Surveys, Planner, and or Cross-Sections, then the well's surface coordinates (Surface X, Surface Y, Surface Z) must be entered in the same coordinate system (e.g., UTM13, Colorado State Plane, etc.) as the grid data.

## Important

The status bar at the far bottom of the window is used extensively to inform you of various information. If SES is working OR if the mouse cursor shows 'busy', *please let processing complete before clicking or typing.*

There are several screen tips throughout SES. Just place your mouse over a control and if available the tip will appear. Clicking into a text box usually provides more information in the status bar.

Several example wells accompany SES. In some cases after example inspection, you may easily answer your question!



## Tips

- To create a full copy of a well and all of its data within SES, export it and then import it with 'Create Copy...' checked on the IMPORT tab.
- SES xml files may be exported in the current version format or in the prior version format for full backwards compatibility.

The screenshot shows the 'Import' tab of the SES software. At the top, there are four tabs: 'Well Setup', 'Export', 'Import', and 'Record Counts'. Below the tabs, on the left, is a button labeled 'Create SES File...'. To the right of this button is the 'Export Format' section, which contains two radio buttons: 'SES XML (text)' (which is selected) and 'SES V3.x'. Below the 'Export Format' section is the 'Export Options (may cause the SES file to become significantly large)' section, which contains two checkboxes: 'Include Associated Grid Data if applicable' and 'Include ALL wells (not just the selected well)'. Both checkboxes are currently unchecked.

- SES will import SES xml files created in the current version format or in the prior version format for full backwards compatibility.

## GRIDS Screen

**GRIDS: SE Demo1 20 Zones**

Selected Grid: **SE Demo1 20 Zones**

Click to Select

- Grid Name
- SE Demo1 1 Zone
- SE Demo1 20 Zones**
- SE Demo2
- SE Demo3

Grid Data Setup | Quick Plot

**Grid Header**

Grid Name: SE Demo1 20 Zones | Grid ID: 999999999

Marker Beds in Grid: 20 | Grid Info: meters

Z Datum: Sea Level | File:

Map Zone: UTM

**MARKER BED NAMES**

#1	F34	#11	F44
#2	F35	#12	F45
#3	F36	#13	F47
#4	F37	#14	F48
#5	F38	#15	F50
#6	F39	#16	F51
#7	F40	#17	F52
#8	F41	#18	F53
#9	F42	#19	F54
#10	F43	#20	F56

**Grid Detail**

	EASTING	NORTHING	F34	F35	F36	F37	F38	F39	F40	F41
▶	318300	6380850	-96.75	-98.04	-99.23	-100.54	-120.07	-120.95	-122.69	-123.85
	318300	6380875	-96.19	-97.49	-98.68	-100.00	-119.15	-120.04	-121.81	-122.98
	318300	6380900	-95.61	-96.91	-98.12	-99.42	-118.20	-119.10	-120.90	-122.06
	318300	6380925	-94.99	-96.30	-97.50	-98.81	-117.25	-118.15	-119.96	-121.12

Record: 1 of 4270

Close

### General

A "Grid" is a triplet (X, Y, Z coordinate) dataset from 3<sup>rd</sup> party software that represents the 'digitized' 3D location of a geologic horizon, or a group of multiple geologic horizons (X, Y, Z1, Z2, Z3, etc.). The X-Y spacing may be arbitrary and null/missing Z values may exist, however equal X-Y spacing is recommended. GRIDS may also be used to setup drilling target TVD windows (e.g., Top, Target, Base) with as few as three coordinates.

GRID DATA SETUP tab can be used to:

- 1.) Add a new Grid to SES\_Database by first naming and setting-up the Grid and its zone names and then pasting the actual grid data into the grid detail section of the screen.
- 2.) Delete the selected existing Grid and all associated data from SES\_Database.
- 3.) Modify/edit numerous Grid properties.

4.) Navigate to Grids in SES\_Database and see their properties and how many wells are associated to them.

QUICK PLOT tab can be used to:

- 1.) Plot the X-Y locations where data exists for the selected Grid.
- 2.) Print the graph to any system printer or copy the graph to the clipboard for paste into 3<sup>rd</sup> party software.

## Critical

- 1.) TVDsubsea 'Z' depths are assumed to be positive above sea level and negative below sea level.
- 2.) A Grid may be associated to a well's Survey or Plan using SES screen. For proper grid interpolation, the X-Y-Z coordinate system must be the same as the well's Surface X-Y-Z coordinate system.
- 3.) While not required, equidistant-spaced grid data is recommended for optimum grid interpolation (e.g., if grid data spacing is 200 ft in the X-direction, it should also be 200 ft in the Y-direction as opposed to 50 ft for example).



## Tips

- Grid data must be tab-delimited to paste into SES. Data copied from Excel for example is tab-delimited. Data may be made tab-delimited manually using a text editor.
- To view the X-Y extent of your grid data, use the 'Quick Plot' tab of the GRIDS screen.
- Multiple wells may independently use the same Grid.
- Typically, grid data is created in 3<sup>rd</sup> party engineering/geologic software. However, results from SES geosteering are by design setup to help update such geologic models after or during drilling. Control points of geosteered beds may be exported from SES Cross-Sections and used in the gridding process that creates Grid data.
- GRID DATA AS DRILLING TARGET WINDOW
  - In some cases it may be desirable to display "hard" TVD drilling window targets in select graphs. This may easily be handled in SES by using Grid Data to define such drilling boundary limits. The *minimum* requirement is three such coordinates that in-turn define a plane or multiple planes in the case of top/base/target. An example follows whereby the Grid dataset is comprised of nine coordinates to define three planes.

Grid Data Setup Quick Plot

**Grid Header**

Grid Name: JBD23: Target Window Grid ID: 468621212

Marker Beds in Grid: 3 Grid Info:

Z Datum: Sea Level File:

Map Zone: UTM15N FT NAD27

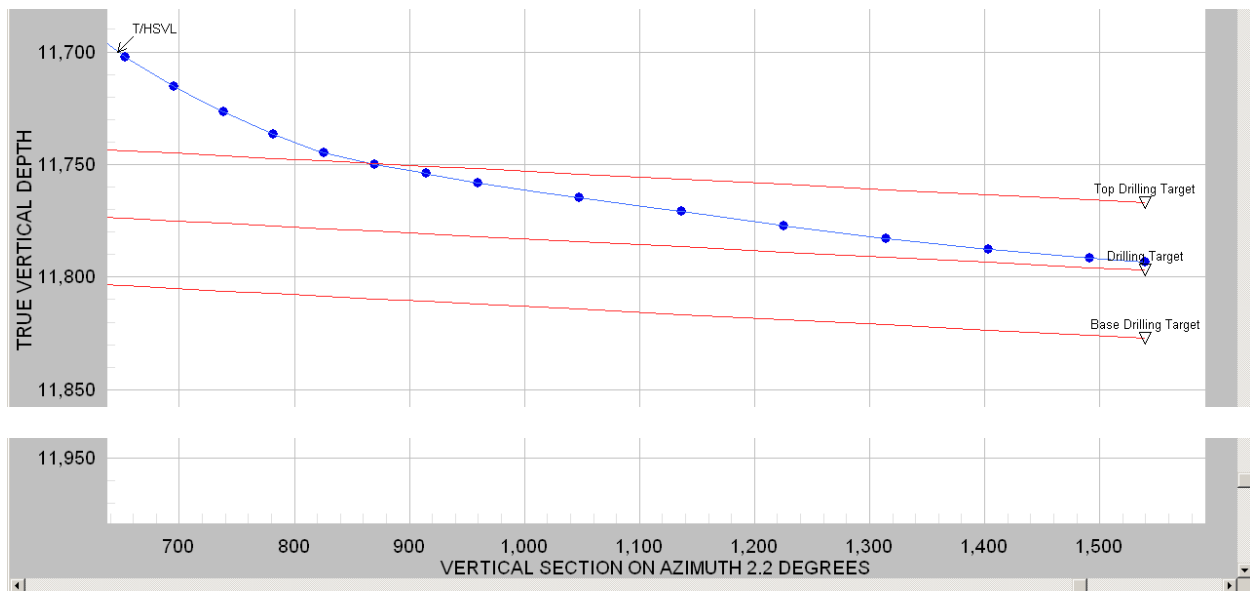
**MARKER BED NAMES**

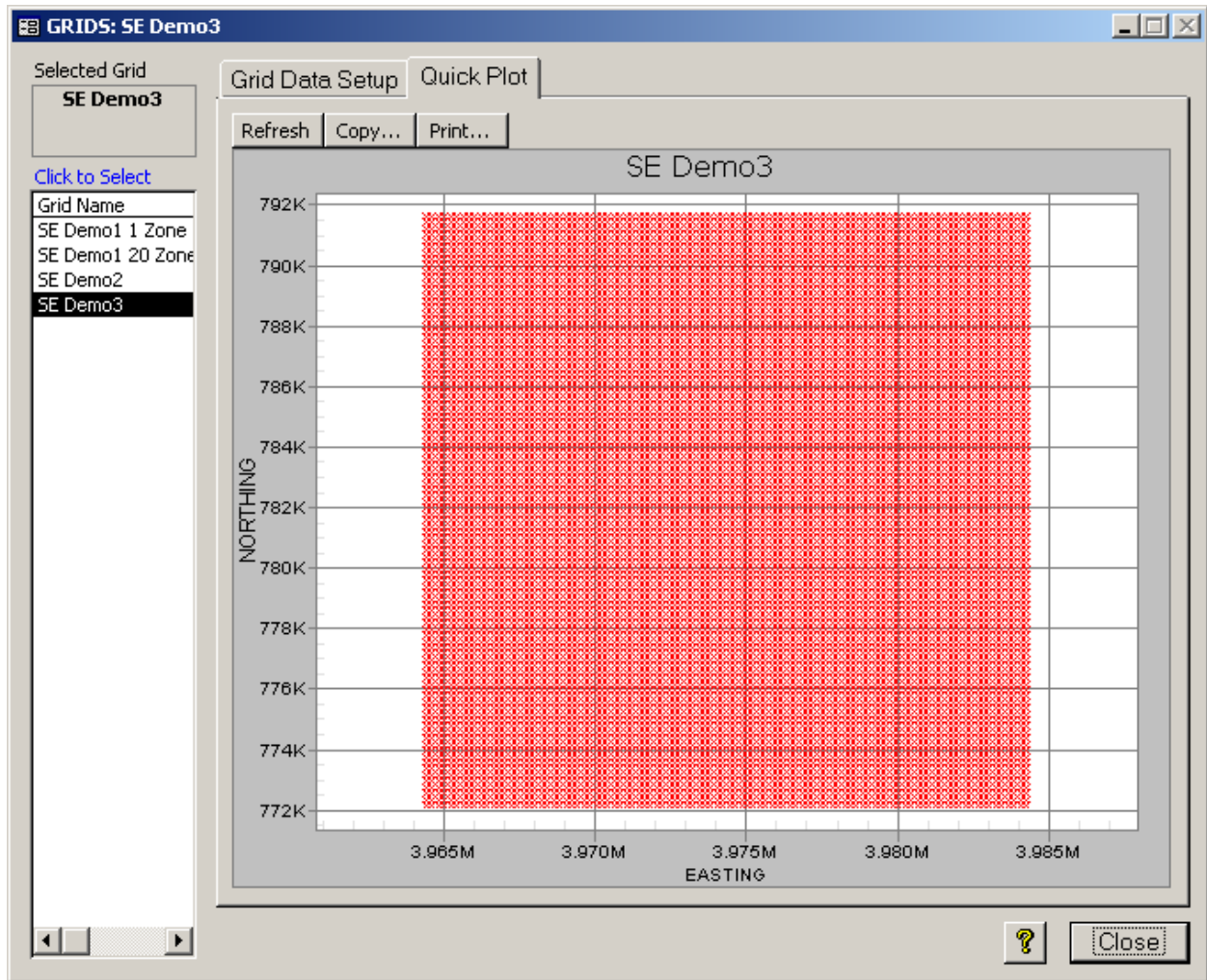
#1	Top Drilling Target	#11	
#2	Drilling Target	#12	
#3	Base Drilling Target	#13	
#4		#14	
#5		#15	
#6		#16	
#7		#17	
#8		#18	
#9		#19	
#10		#20	

**Grid Detail**

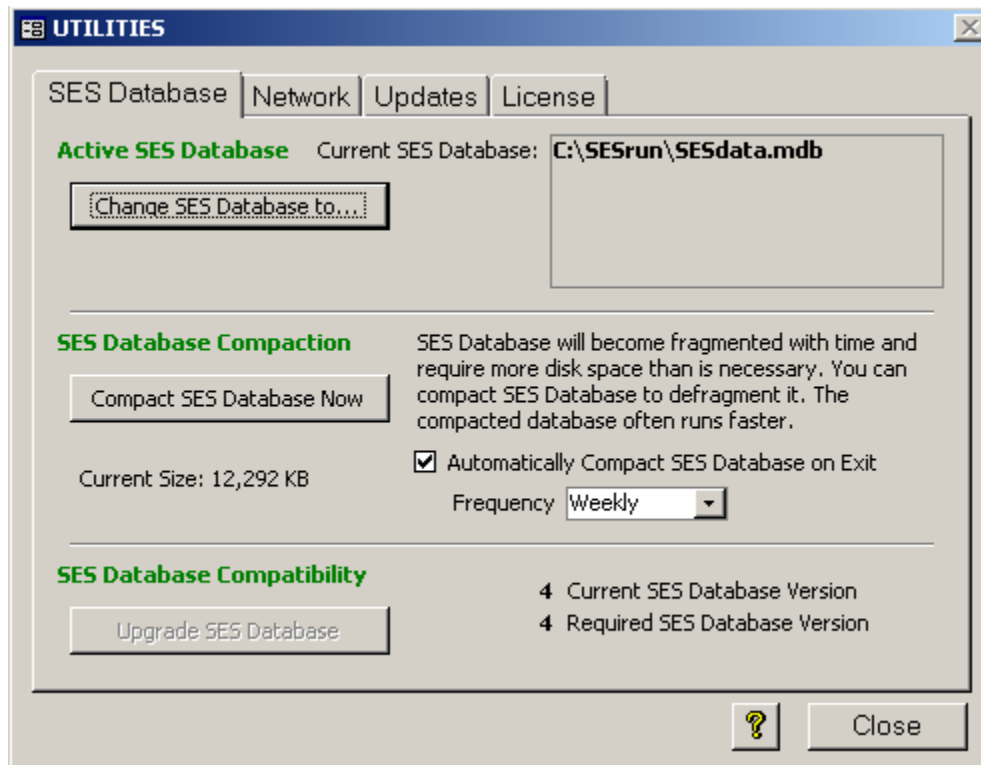
	EASTING	NORTHING	Top Drilling Target	Drilling Target	Base Drilling Target
▶	1403969	11712734	-11451.00	-11481.00	-11511.00
	1404077	11714271	-11491.00	-11521.00	-11551.00
	1404144	11717900	-11586.00	-11616.00	-11646.00
*					

Record: 1 of 3





## UTILITIES Screen



### General

UTILITIES is used to manage data connectivity, to monitor database network-use status, to check for software updates, and to enter or check License information.

SES DATABASE tab can be used to:

- 1.) Connect SES to an SES\_Database, which is a Microsoft Access database (mdb) file in a special format.
- 2.) Compact SES\_Database to minimize its file size and enhance general SES performance.
- 3.) Determine the format version of connected SES\_Database.
- 4.) Upgrade connected SES\_Database to be compliant with the respective SES run-time version.

NETWORK tab can be used to:

Determine computer names currently using SES\_Database to which SES is configured to connect to, and computer name of user running the run-time file (SES.MDE). The directory containing the run-time file is also presented.

UPDATES tab can be used to:

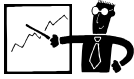
Query [www.makinhole.com](http://www.makinhole.com) to check for SES upgrade availability. Your version is compared to the most current release.

LICENSE tab can be used to:

Determine current in-use License type and its expiration date, and enter License code information. Information about floating-network license administration may be queried.

## Critical

1.) To release a floating-network license seat immediately, click the Exit button from the License tab or from Main Menu screen.

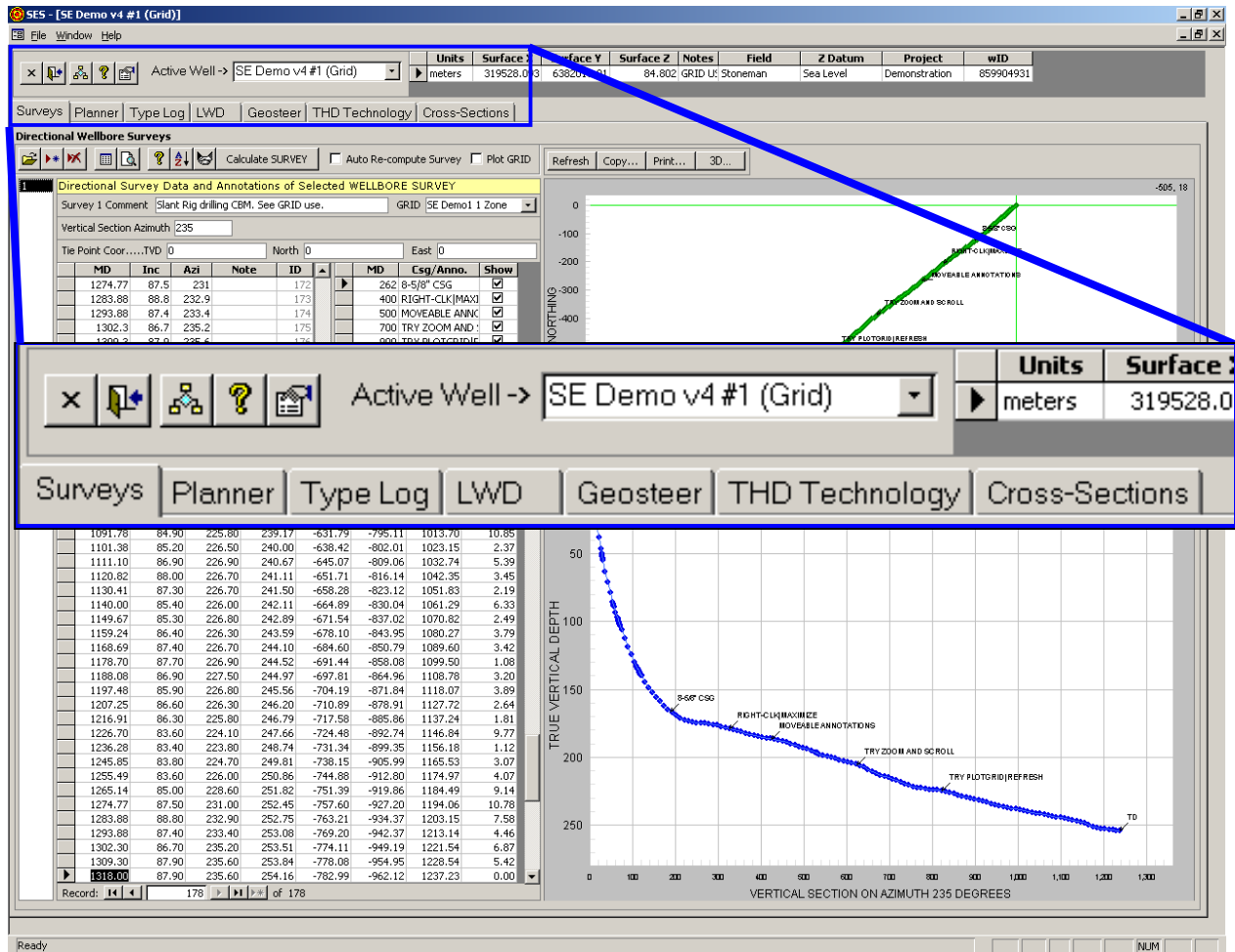
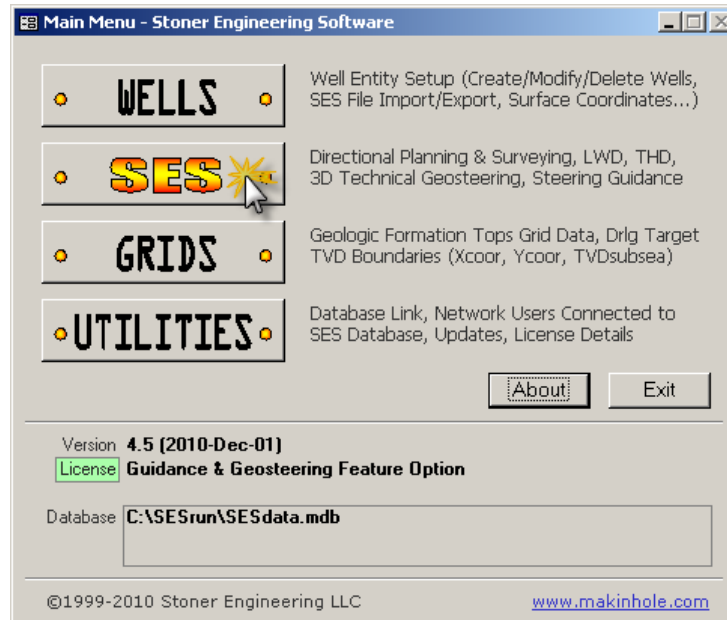


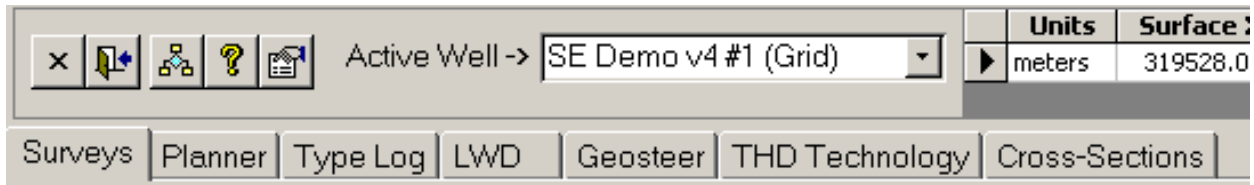
## Tips

- External from SES (for example, with Windows Explorer), SESdata.mdb may be copied and or moved to reside (for example) on a network server hard drive and be strategically placed into directories/folders that are relevantly named (by field, division, client, archive, etc.) and regularly backed-up. An empty SES\_Database may be downloaded from the SES online technical support page.
- Multiple users can simultaneously access the same SES\_Database with SES being run on multiple computers.
- Compacting SES\_Database also performs a database repair.
- It is possible to create and use a 'working' version of SES\_Database for active wells and an 'archive' version of SES\_Database for general storage/preservation. The archive version may be as large as 2GB. WELLS screen can be used to transfer entire well data in and out of SES\_Database.
- SESdata.mdb should regularly be backed-up as a safe-computing precautionary measure.
- To immediately release a floating-network license seat, click 'Exit' button from Main Menu or click the exit icon from the License tab of UTILITIES. Such seats *automatically* expire in roughly one hour of non-use.



# SES





## General

SES screen is the 'command center' of SES and contains multiple other screens. Each tab or 'screen' addresses a unique aspect of SES including smart data integration by design.

SES screen can be used to:

- 1.) Navigate to well-specific data by selecting a well from the drop-down box.
- 2.) Create and navigate to multiple data sets regarding directional surveys, well plans, type logs, LWD data, marker beds from geosteering, THD technology, and cross-sections.
- 3.) Get more information by clicking the Help icon ("??") on any screen.

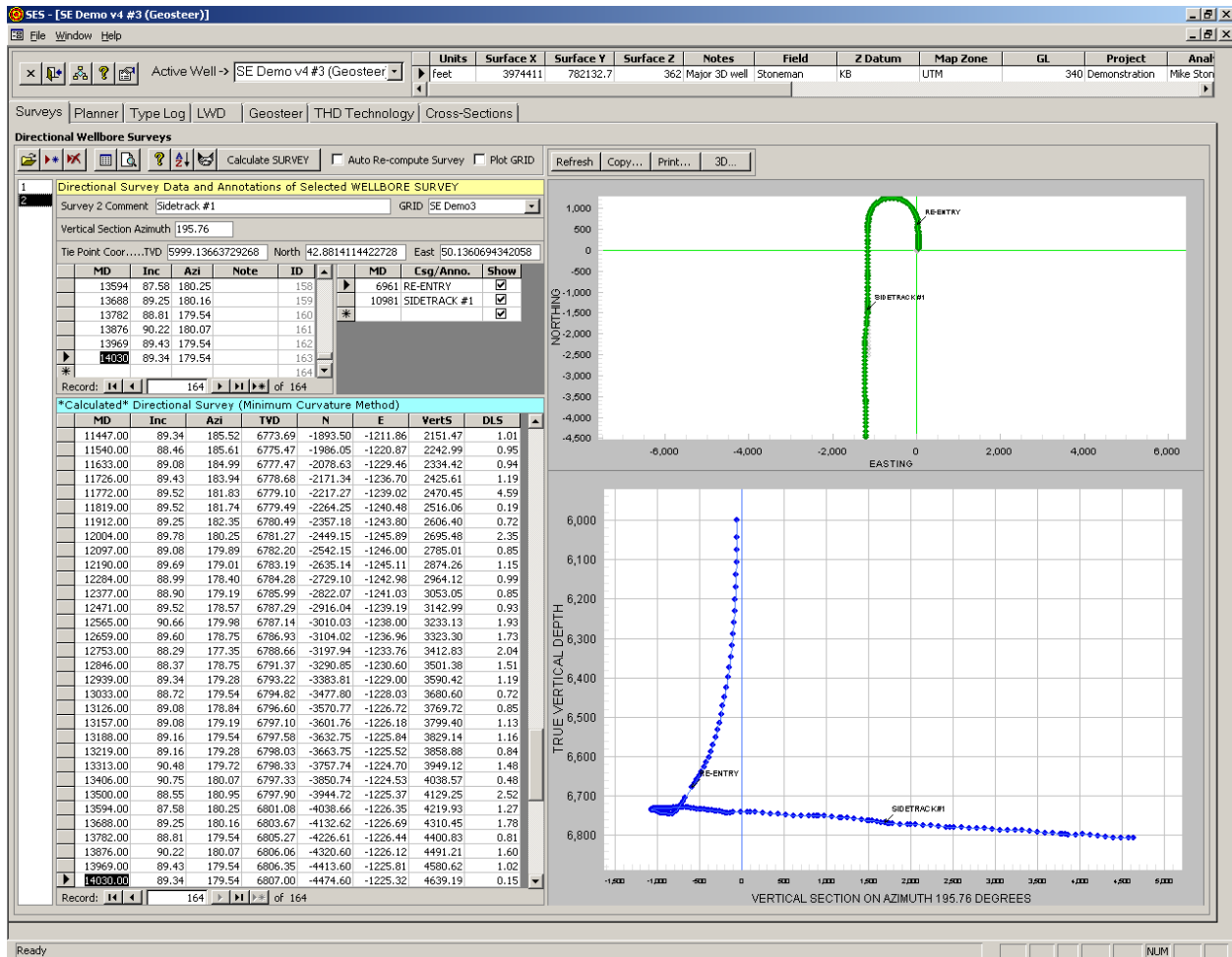
## Critical

- 1.) Wells are added to SES using WELLS screen from Main Menu. If a well has been added but is not a selection in the drop-down box here, simply close SES screen and re-load it from Main Menu.
- 2.) When closing SES, it is recommended to USE THE PROVIDED BUTTONS (e.g., 'Exit' from Main Menu) instead of the 'X' in the upper-right corner of the window. This method saves the last loaded well for subsequent initial load if possible.

## HOT KEYS

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)

# SES Screen – SURVEYS



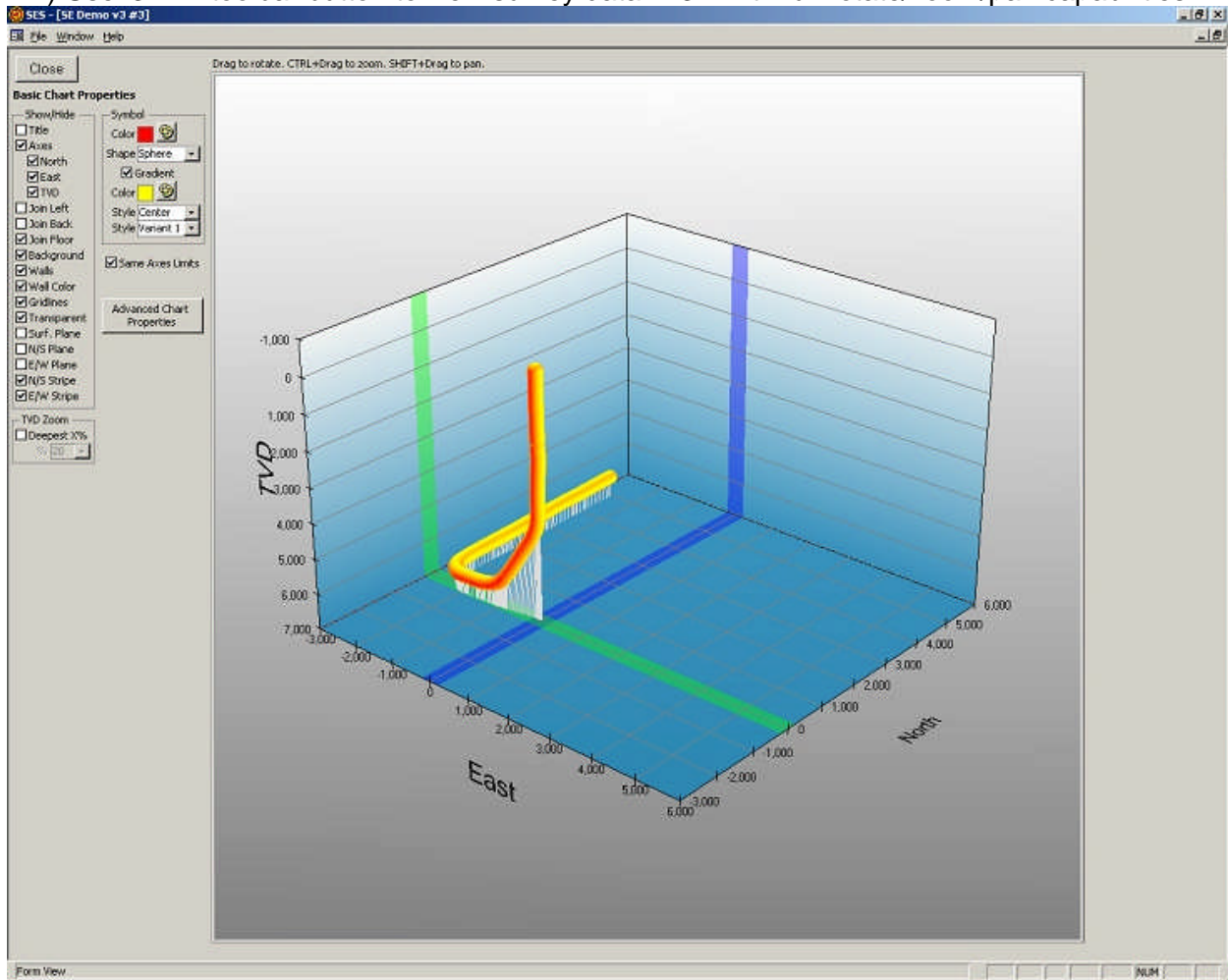
## General

The survey calculational method is minimum curvature, including interpolation between stations.

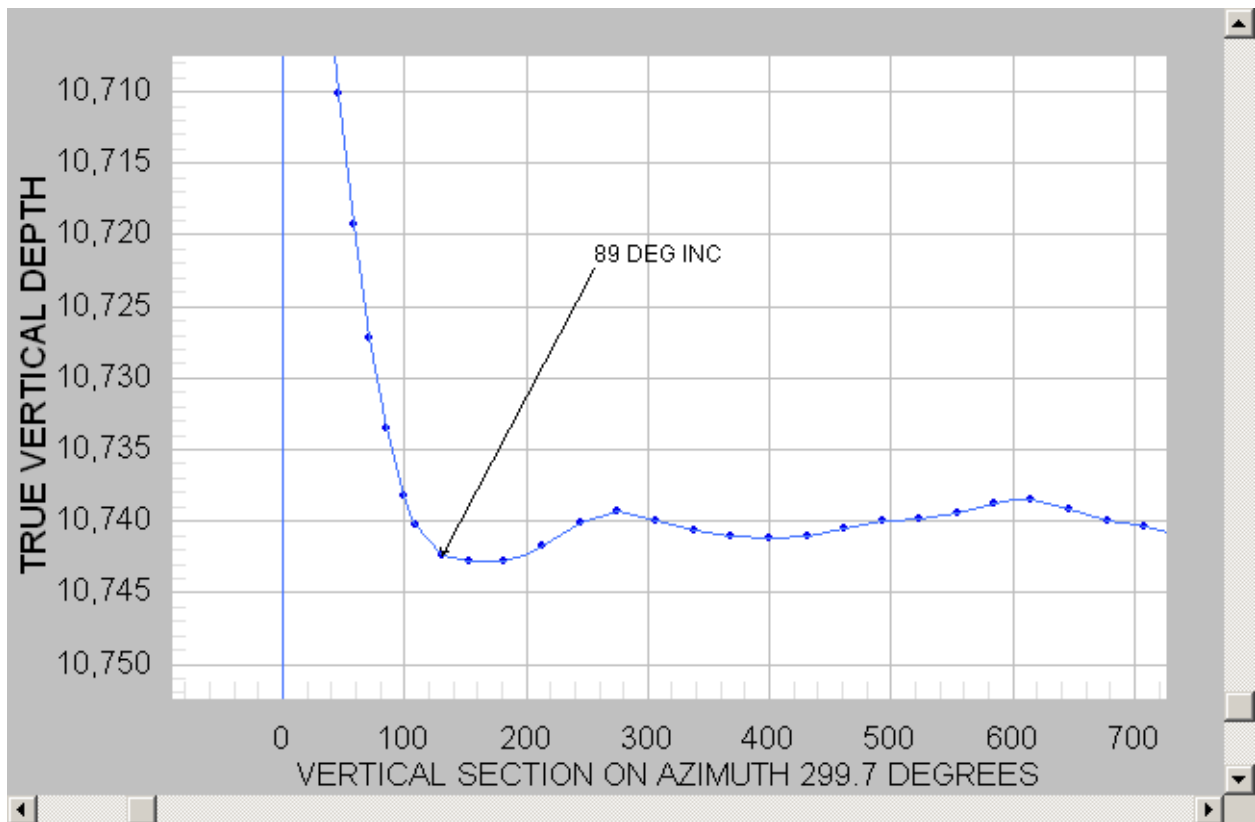
SURVEYS screen can be used to:

- 1.) Input 'raw' wellbore directional survey data (MD, Inc., Azi.) using keypunch, pasting from Excel, or by import from a LAS format file; MANUALLY enter tie-point coordinates and Vertical Section Azimuth.
- 2.) Calculate the Cartesian coordinates (True Vertical Depth, North, East) and Vertical Section of a wellbore.
- 3.) Set each directional survey Vertical Section Azimuth independent of other surveys.
- 4.) Create Vertical Section View and Plan View standard directional plots of a wellbore.
- 5.) 3D plane-interpolate associated geologic Grid and display the formations/boundaries on the Vertical Section View.

- 6.) Interpolate the calculated survey at arbitrary Measured Depths for (TVD,N,E,Inc.,Azi.).
- 7.) Create a 'digitized' wellbore survey table with extra interpolated values for smoother graphing.
- 8.) Print/Preview a professional directional survey report for regulatory reporting or otherwise.
- 9.) Print the standard directional plots on any system printer (including Adobe/PDF).
- 10.) Copy the standard directional plots for paste into another application.
- 11.) Use '3D...' toolbar button to view survey data in 3D with full rotate/zoom/pan capabilities.



- 12.) Zoom the 2D graphs by dragging a window with the mouse; then pan by clicking the scroll bars.
- 13.) Change a variety of graph properties (including full screen mode / maximize) by right-clicking over the graph and using the shortcut menu.
- 14.) Move graph annotations by simply dragging the text to a new location.



## Critical

- 1.) The Tie Point coordinates (TVD, North, East) in the header section of the screen are the Cartesian Coordinates of the first station (at ID=0) and must be manually entered if non-zero.
- 2.) If directional data, Tie Point data, or Vertical Section Azimuth are changed in any way, click 'Calculate Survey' or press F6 to refresh the survey calculation.
- 3.) From Well Properties, coordinates SurfaceX, SurfaceY, SurfaceZ must equal local coordinates at (TVD,N,E)=(0,0,0) for proper geologic grid display.
- 4.) For proper geologic grid display, coordinates SurfaceX and SurfaceY must be in the same coordinate system as the associated grid.
- 5.) If well units are changed (e.g., from ft to m), re-calculate all surveys.
- 6.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## HOT KEYS

F6 - same as clicking Surveys toolbar button 'Calculate Survey'

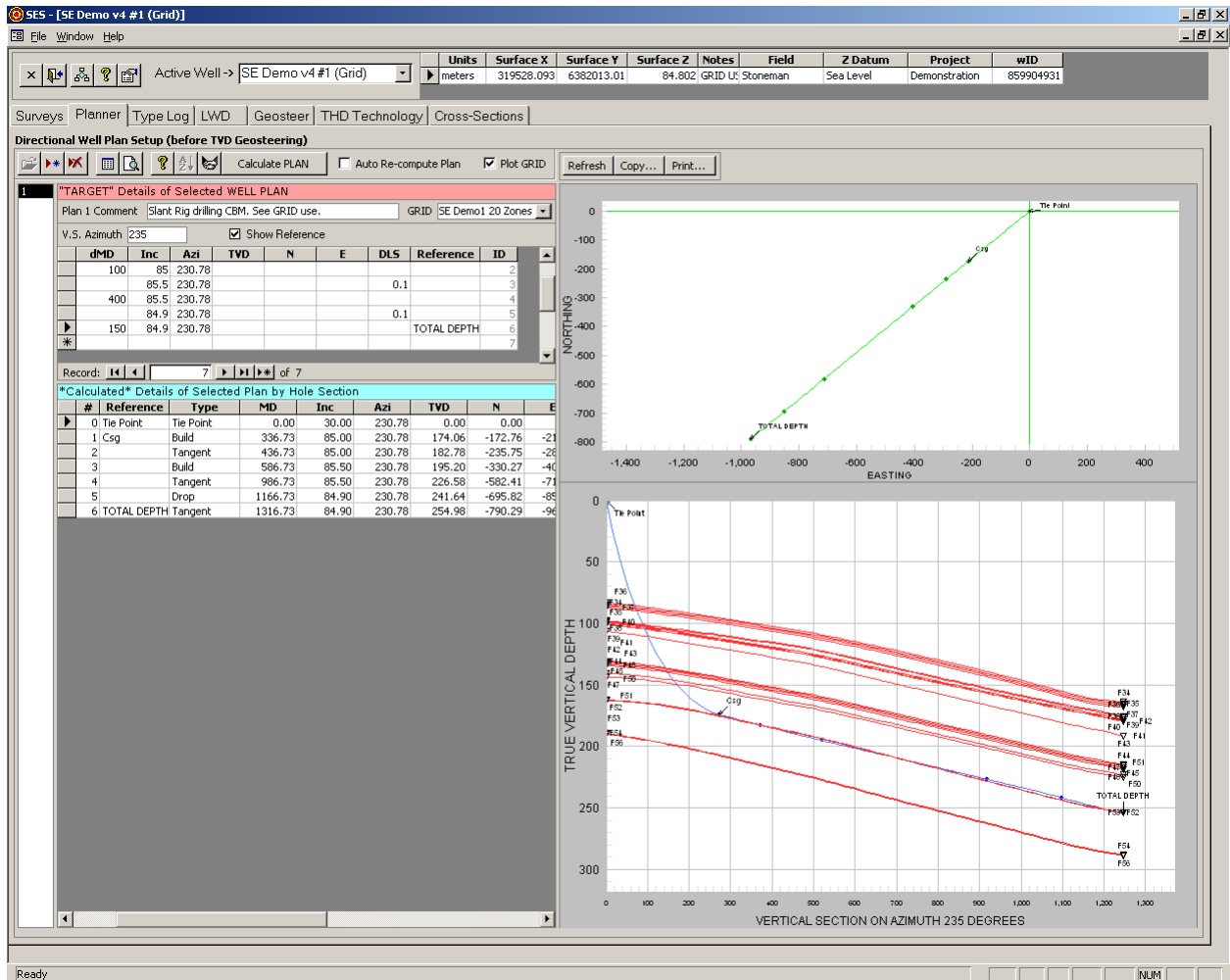
CTRL - hold down Control key while clicking a different Survey # in the list box and the graphics WILL be updated (navigation/dataload is faster without updating graphics; click 'Refresh' to update graphics)

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)



- Step one for any SES technical geosteering operation is to **ensure the SES calculated directional survey matches 'exactly' with the service company** supplying the source directional survey data. If they don't match, **resolve the difference before proceeding** (*most likely cause is tie-point difference...see Critical point #1*). The calculated digits should match because most drilling service companies employ the minimum curvature survey calculational method, as does SES.
- Let us repeat! Step one for any SES technical geosteering operation is to ensure the SES calculated directional survey matches 'exactly' with the service company supplying the source directional survey data. It is critical to operations that everyone be on the same page. Resolve any differences before proceeding with LWD data loading or any analyses.
- If SES calculated vertical section does not match the field but north/south and east/west coordinates do match, then the vertical section azimuth (VSA) within SES and the value in use by the field are not the same. VSA is entered into SES in the header portion of SURVEYS screen.

## SES Screen – PLANNER



### General

Any type of directional well plan comprised of linear and circular-arc hole sections can be designed, including a circular arc in an oblique plane in any octant(s).

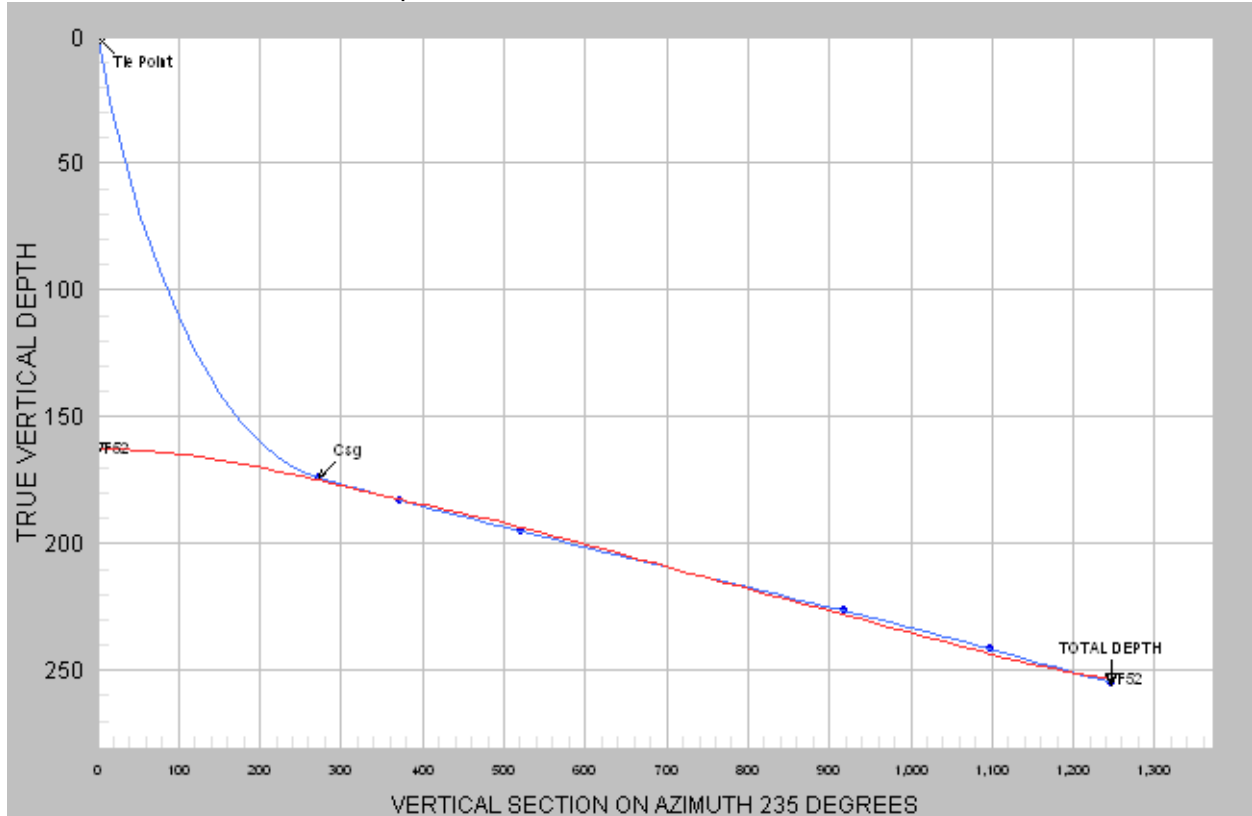
PLANNER screen can be used to:

- 1.) Design and calculate the critical point values of any 3D or 2D well plan by combining multiple successive "Targets" as needed.
- 2.) Determine the minimum curvature necessary to intersect a specified 3D coordinate (target).
- 3.) Implement a "Target" that extends a straight 3D or 2D line by a specified length.
- 4.) Implement a "Target" that extends a 3D or 2D curved line by specifying dogleg-severity and ending inclination and azimuth.

5.) Associate each well plan with the same or different Vertical Section Azimuth as other well plans.

6.) Create Vertical Section View and Plan View standard directional plots of a well plan.

7.) 3D plane-interpolate associated geologic Grid and display the formations/boundaries on the Vertical Section View with the plan.



8.) Create a 'digitized' well plan survey table with extra interpolated values for smoother graphing.

9.) Print/Preview a professional well plan survey report for regulatory reporting or otherwise.

10.) Print the standard directional plots on any system printer (including Adobe/PDF).

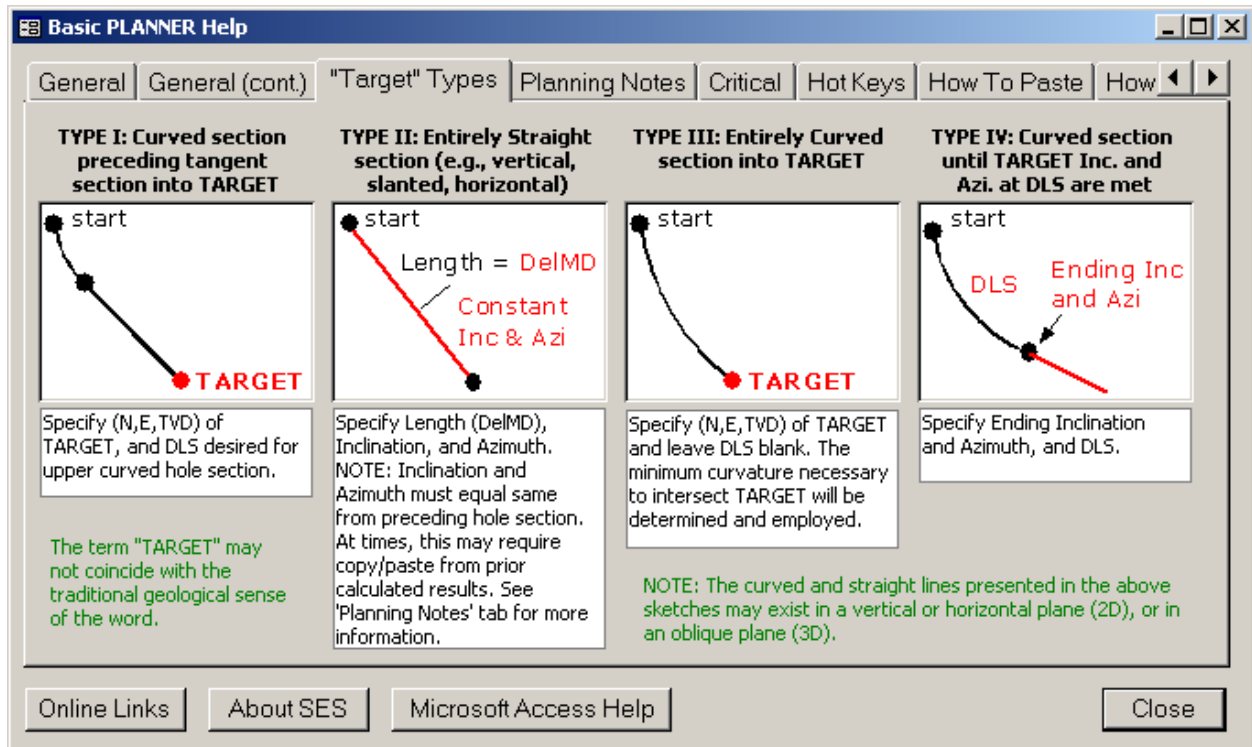
11.) Copy the standard directional plots for paste into another application.

12.) Zoom a graph by dragging a window with the mouse; then pan by clicking the scroll bars.

13.) Change a variety of graph properties (including full screen mode / maximize) by right-clicking over the graph and using the shortcut menu.

14.) Move graph annotations by simply dragging the text to a new location.





## PLANNING NOTES

When designing or specifying a well plan, consider calculating the PLAN after the addition of EACH new target. This helps to ensure that the well plan parameters are valid and within accordance to what SES expects. The results are presented in the lower part of PLANNER screen.

It is **HIGHLY RECOMMENDED** to follow the preceding suggestion when using Type II or Type IV Target Types, especially if Inclination and/or Azimuth are not "simple" numbers. Copy and Paste of non-simple numbers (e.g., 23.435980298 degrees) is **HIGHLY RECOMMENDED** in cases that require calculating the plan to determine the numbers to feed into the next "Target".

For 2D wells, the following may assist in the respective design. In each case, it is assumed that Target ID=0 is the tie point and Target ID=1 is Type II to Kick-Off point, both of which have already been specified.

**SLANT (BUILD-AND-HOLD or DROP-AND-HOLD):** Type I to well bore Total Depth.

**DOUBLE BUILD:** Type I to start of lower build section, Type I to well bore Total Depth.

-OR-

**DOUBLE BUILD:** Type I to start of lower build section, Type IV to final Inclination and Azimuth, Type II to well bore Total Depth.

**S-TYPE:** Type I to start of drop section, Type I to well bore Total Depth.

-OR-

**S-TYPE:** Type I to start of drop section, Type IV to final Inclination and Azimuth, Type II to well bore Total Depth.

The foregoing are only suggestions. Given the four "Target" types allowed, there are multiple ways to create an identical well plan.

## Critical

- 1.) The Tie Point coordinates (TVD, North, East) and angles (Inc., Azi.) are entered on the first row of the table (at ID=0).
- 2.) If well plan data or Vertical Section Azimuth are changed in any way, click 'Calculate PLAN' or press F6 to refresh the well plan calculation.
- 3.) From Well Properties, coordinates SurfaceX, SurfaceY, SurfaceZ must equal local coordinates at (TVD,N,E)=(0,0,0) for proper geologic grid display.
- 4.) For proper geologic grid display, coordinates SurfaceX and SurfaceY must be in the same coordinate system as the associated grid.
- 5.) If well units are changed, re-calculate all plans.
- 6.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## HOT KEYS

F6 - same as clicking Planner toolbar button 'Calculate PLAN'

CTRL - hold down Control key while clicking a different Plan # in the list box and the graphics WILL be updated (navigation/dataload is faster without updating graphics; click 'Refresh' to update graphics)

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)

## HOW TO INSERT TARGETS BETWEEN EXISTING TARGETS...

All new data is added at the bottom of a table. Combine row Cutting and Pasting to essentially insert. For example, assume you have 4 targets (rows) and now you want to insert a New Target between row 2 and 3. Enter the New Target data as a new record at the bottom. Then select rows 3 and 4 and Cut by right-clicking over the selection and clicking Cut. Then right-click on the asterisk at the bottom left part of the table and click Paste on the shortcut menu. See "Planning Notes" tab for recommendations.



## Tips

- To "transfer" an already-designed well plan from a service company into SES Planner, there are two common methods:
  1. Use dogleg-severity (DLS...value of zero means the hole section is linear; value of non-zero means the hole section is curved) to manually by inspection

transform the plan into a finite number of either Type II or Type IV 'target' types after fully defining the tie point (first station/row, ID=0), OR

2. Fully specify the properties at the tie point (first row, ID=0), and then simply paste the Cartesian coordinates of the well plan into SES. This method ONLY works "perfect" if the source data are full precision (i.e., NOT formatted; for example the number 23.435980298 is formatted if it is reported as 23.44)

Method 1 example...(formatted) well plan from a service company...

MD*	INC*	AZI*	TVD*	N*	E*	VertS*	DLS*	Reference
5936.00	0.00	0.00	5936.00	0.00	0.00	0.00	0.00	KOP
6000.00	4.68	188.73	5999.93	-2.58	-0.40	2.61	7.31	
6100.00	11.99	188.73	6098.81	-16.90	-2.59	17.09	7.31	
6200.00	19.30	188.73	6195.04	-43.53	-6.68	44.04	7.31	
6300.00	26.61	188.73	6287.06	-82.05	-12.60	83.01	7.31	
6400.00	33.92	188.73	6373.37	-131.83	-20.24	133.38	7.31	
6500.00	41.23	188.73	6452.57	-192.06	-29.49	194.31	7.31	
6600.00	48.54	188.73	6523.38	-261.76	-40.20	264.83	7.31	
6700.00	55.85	188.73	6584.64	-339.80	-52.18	343.79	7.31	
6800.00	63.16	188.73	6635.35	-424.91	-65.25	429.89	7.31	
6900.00	70.47	188.73	6674.70	-515.71	-79.19	521.75	7.31	
6920.95	72.00	188.73	6681.44	-535.32	-82.20	541.59	7.31	P.P. /CSNG PNT
7000.00	76.58	188.73	6702.83	-610.51	-93.75	617.67	5.80	
7100.00	82.38	188.73	6721.07	-707.65	-108.67	715.95	5.80	
7200.00	88.18	188.73	6729.29	-806.12	-123.79	815.57	5.80	
7216.64	89.15	188.73	6729.68	-822.56	-126.31	832.20	5.80	
7300.00	89.15	188.73	6730.92	-904.94	-138.96	915.55	0.00	
7400.00	89.15	188.73	6732.40	-1003.78	-154.14	1015.54	0.00	
7500.00	89.15	188.73	6733.88	-1102.61	-169.31	1115.53	0.00	
7600.00	89.15	188.73	6735.37	-1201.44	-184.49	1215.52	0.00	
7700.00	89.15	188.73	6736.85	-1300.27	-199.67	1315.51	0.00	
7800.00	89.15	188.73	6738.33	-1399.10	-214.84	1415.50	0.00	
7900.00	89.15	188.73	6739.82	-1497.93	-230.02	1515.49	0.00	
8000.00	89.15	188.73	6741.30	-1596.76	-245.19	1615.47	0.00	
8100.00	89.15	188.73	6742.78	-1695.59	-260.37	1715.46	0.00	
8200.00	89.15	188.73	6744.27	-1794.42	-275.55	1815.45	0.00	
8300.00	89.15	188.73	6745.75	-1893.25	-290.72	1915.44	0.00	
8400.00	89.15	188.73	6747.23	-1992.08	-305.90	2015.43	0.00	
8500.00	89.15	188.73	6748.72	-2090.91	-321.07	2115.42	0.00	
8600.00	89.15	188.73	6750.20	-2189.74	-336.25	2215.41	0.00	
8700.00	89.15	188.73	6751.68	-2288.57	-351.43	2315.40	0.00	
8800.00	89.15	188.73	6753.17	-2387.40	-366.60	2415.39	0.00	
8900.00	89.15	188.73	6754.65	-2486.23	-381.78	2515.38	0.00	
9000.00	89.15	188.73	6756.13	-2585.06	-396.96	2615.36	0.00	
9100.00	89.15	188.73	6757.62	-2683.90	-412.13	2715.35	0.00	
9200.00	89.15	188.73	6759.10	-2782.73	-427.31	2815.34	0.00	
9300.00	89.15	188.73	6760.58	-2881.56	-442.48	2915.33	0.00	
9400.00	89.15	188.73	6762.07	-2980.39	-457.66	3015.32	0.00	
9500.00	89.15	188.73	6763.55	-3079.22	-472.84	3115.31	0.00	
9600.00	89.15	188.73	6765.04	-3178.05	-488.01	3215.30	0.00	
9700.00	89.15	188.73	6766.52	-3276.88	-503.19	3315.29	0.00	
9800.00	89.15	188.73	6768.00	-3375.71	-518.37	3415.28	0.00	

9900.00	89.15	188.73	6769.49	-3474.54	-533.54	3515.27	0.00
10000.00	89.15	188.73	6770.97	-3573.37	-548.72	3615.25	0.00
10100.00	89.15	188.73	6772.45	-3672.20	-563.89	3715.24	0.00
10200.00	89.15	188.73	6773.94	-3771.03	-579.07	3815.23	0.00
10300.00	89.15	188.73	6775.42	-3869.86	-594.25	3915.22	0.00
10400.00	89.15	188.73	6776.90	-3968.69	-609.42	4015.21	0.00
10500.00	89.15	188.73	6778.39	-4067.52	-624.60	4115.20	0.00
10600.00	89.15	188.73	6779.87	-4166.35	-639.77	4215.19	0.00
10700.00	89.15	188.73	6781.35	-4265.18	-654.95	4315.18	0.00
10800.00	89.15	188.73	6782.84	-4364.02	-670.13	4415.17	0.00
10900.00	89.15	188.73	6784.32	-4462.85	-685.30	4515.16	0.00
11000.00	89.15	188.73	6785.80	-4561.68	-700.48	4615.14	0.00
12000.00	89.15	188.73	6800.64	-5549.98	-852.24	5615.03	0.00
13000.00	89.15	188.73	6815.47	-6538.29	-1004.00	6614.92	0.00
13100.00	89.15	188.73	6816.96	-6637.12	-1019.18	6714.91	0.00
13200.00	89.15	188.73	6818.44	-6735.95	-1034.35	6814.90	0.00
13300.00	89.15	188.73	6819.92	-6834.78	-1049.53	6914.89	0.00
13400.00	89.15	188.73	6821.41	-6933.61	-1064.71	7014.88	0.00
13500.00	89.15	188.73	6822.89	-7032.44	-1079.88	7114.87	0.00
13600.00	89.15	188.73	6824.37	-7131.27	-1095.06	7214.86	0.00
13700.00	89.15	188.73	6825.86	-7230.10	-1110.24	7314.85	0.00
13800.00	89.15	188.73	6827.34	-7328.93	-1125.41	7414.84	0.00
13900.00	89.15	188.73	6828.82	-7427.76	-1140.59	7514.83	0.00
14000.00	89.15	188.73	6830.31	-7526.59	-1155.76	7614.81	0.00
14100.00	89.15	188.73	6831.79	-7625.42	-1170.94	7714.80	0.00
14200.00	89.15	188.73	6833.28	-7724.25	-1186.12	7814.79	0.00
14300.00	89.15	188.73	6834.76	-7823.09	-1201.29	7914.78	0.00
14400.00	89.15	188.73	6836.24	-7921.92	-1216.47	8014.77	0.00
14438.64	89.15	188.73	6836.82	-7960.11	-1222.33	8053.41	0.00

...can be transferred into the following equivalent SES well plan INPUT...

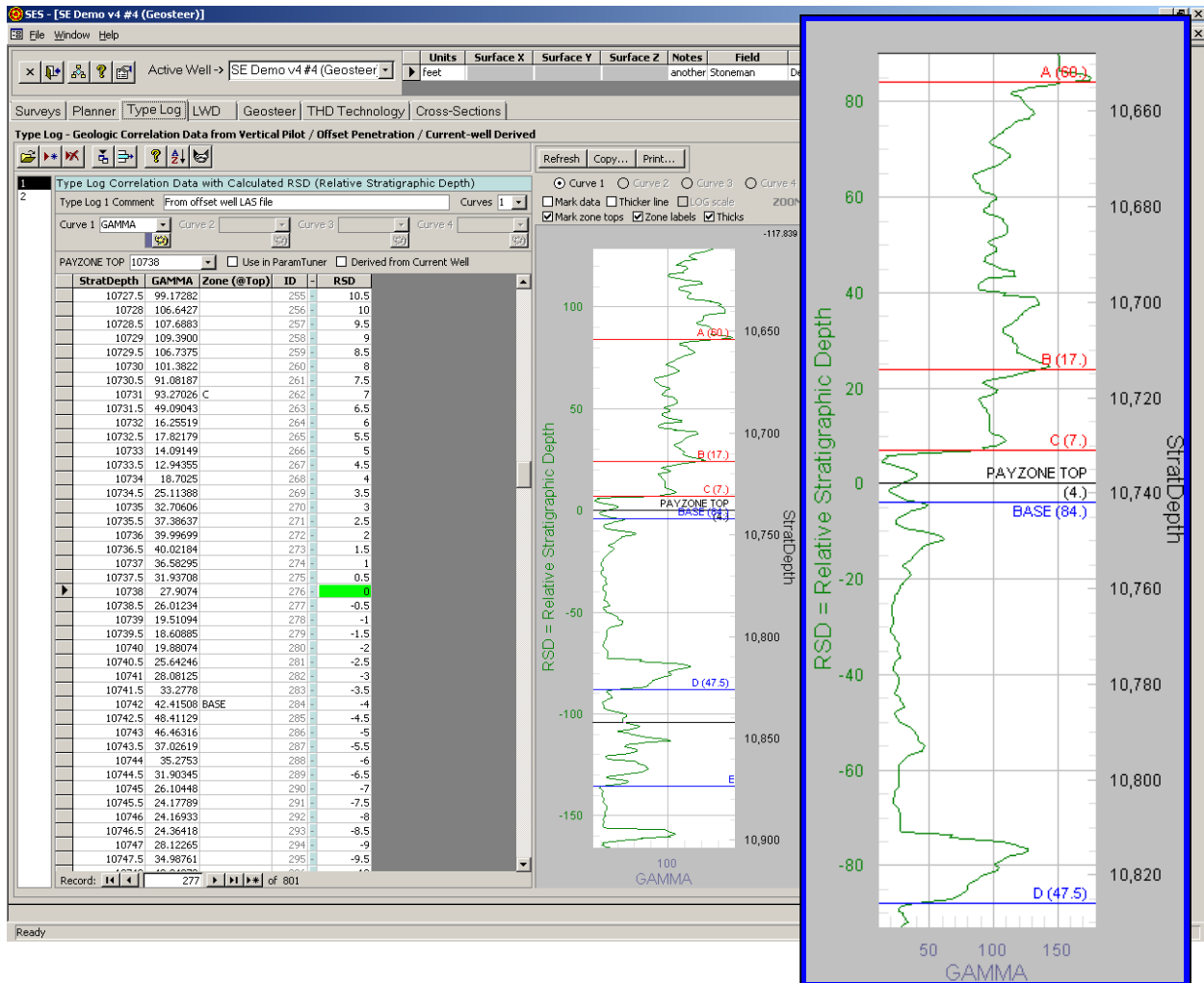
dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
0	0	0	5936	0	0		KOP	0
	72	188.73				7.31	P.P./Csng Pnt	1
	89.15	188.73				5.8	LANDED	2
7222	89.15	188.73					TD	3

...with SES well plan calculated OUTPUT...

#	Reference	Type	MD	Inc	Azi	TVD	N	E	DLS	VertS
0	KOP	Vertical	5936.00	0.00	0.00	5936.00	0.00	0.00		0.00
1	P.P./Csng Pnt	Build	6920.95	72.00	188.73	6681.44	-535.32	-82.20	7.31	541.59
2	LANDED	Build	7216.64	89.15	188.73	6729.68	-822.56	-126.31	5.80	832.20
3	TD	Horizontal	14438.64	89.15	188.73	6836.82	-7960.11	-1222.33	0.00	8053.41

- A well plan defined in Planner may be available for use in multiple other SES screens, including THD Technology, Geosteer/ParamTuner, and Cross-Sections.
- A well plan is not required to use SES to perform technical geosteering.

## SES Screen – TYPE LOG



### General

A Type Log provides guidance for signal expectations while landing and drilling a horizontal well. Each Type Log may include from one to four curves of MD-tagged information and each may individually (and simultaneously) be used when Geosteering.

TYPE LOG screen can be used to:

- 1.) Input geologic correlation "Type Log" data (e.g., Gamma, High-Side Gamma, Resistivity, Porosity, etc.) using keypunch, pasting from Excel, or by import from a file in LAS format.
- 2.) Manage and navigate Type Log data from multiple vertical offset wells, vertical pilot holes, dip-corrected calculated logs, AND/OR derived type logs from the current horizontal well.
- 3.) Designate each curve name and curve color (color is applied in ParamTuner).

4.) Convert 'Stratigraphic Depth' (which in most cases is MD from a vertical well with beds of low dip) to 'Relative Stratigraphic Depth' (RSD) by simply entering the depth of the PAYZONE TOP. RSD is needed for geosteering and is automatically calculated in the table.

5.) Designate/check which Type Log(s) should currently be displayed in ParamTuner when Geosteering (multiple Type Logs can be displayed simultaneously).

6.) Recall if a Type Log was derived from the current well (e.g., during the landing and/or subsequently; see ParamTuner from Geosteer screen).

7.) Graph a Type Log data curve, including linear or LOG10 scale format (see adjacent picture).

8.) Print the graph on any system printer (including Adobe/PDF).

9.) Copy the graph for paste into another application.

10.) Zoom a section of graph by dragging a window with the mouse within the graph; then pan by clicking the scroll bars.

11.) Change a variety of graph properties (including full screen mode / maximize) by right-clicking over the graph and using the shortcut menu.

12.) Display horizontal lines on the graph by simply entering text into the 'Zone (@Top)' column at a particular depth.

13.) Set 'PAYZONE TOP' by double-clicking a data point while the graph is zoomed.

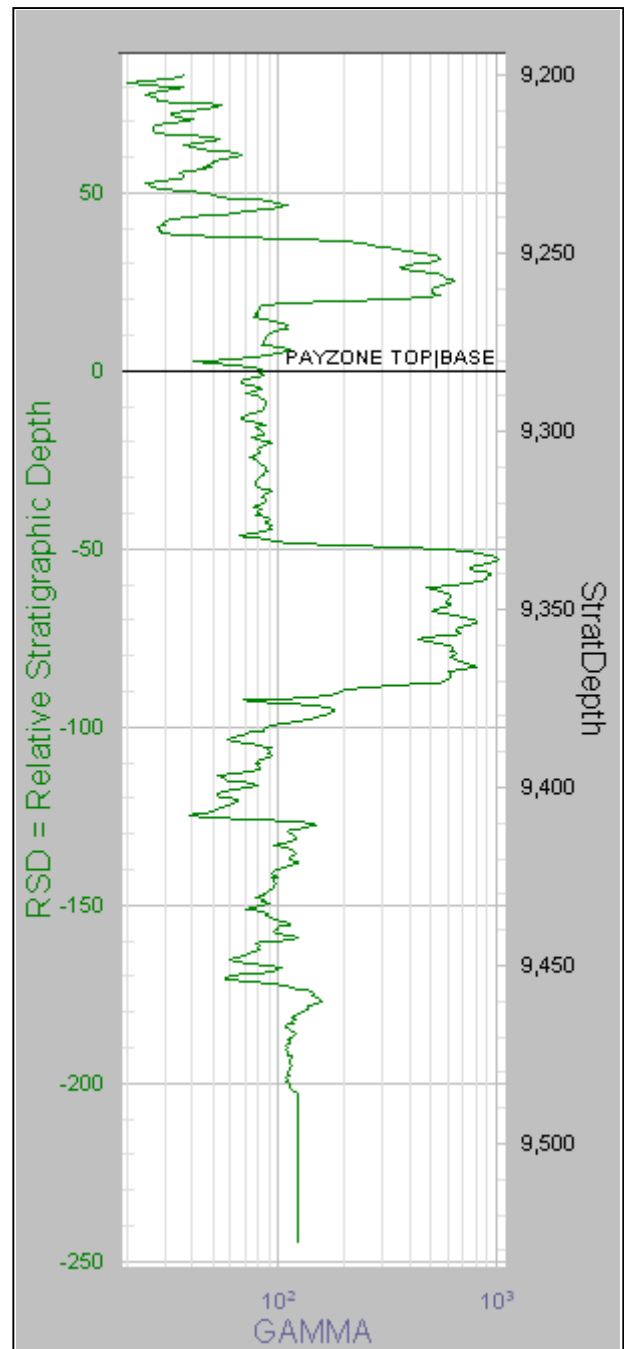
14.) Delete an exterior range of data (e.g., shallow-depth data) far from the payzone.

15.) Import/copy/transfer type log data from another well.

16.) Reset 'PAYZONE TOP' in middle of interpretation, with automatic correction to all existing interpretations and 3DSB stored views.

## Critical

1.) PAYZONE TOP, which defines where Relative Stratigraphic Depth (RSD) equals zero and graphically in cross-sections will be seen as the



primary marker bed boundary (either bed top or bed base), must be specified in the header portion of Type Log screen.

2.) PAYZONE TOP must have an exact corresponding depth and curve value in the data details/table in order to use Ratio Normalization when Geosteering. At PAYZONE TOP, RSD equals zero and the table cell shows a green background.

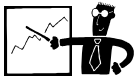
3.) Type Log and LWD Curves are coupled. For use geosteering with ParamTuner, if Type Log Curve 1 contains gamma, then associated LWD Curve 1 should also contain gamma.

4.) Exported SES XML files will be smaller if unnecessary Type Log data have been deleted from the respective dataset. For example, if 1000 to 7000 ft of Type Log data exist but the payzone top is located at 6800 ft, then consider deleting the unneeded data from 1000 to 6300 ft for smaller related files AND FASTER PARAMTUNER PERFORMANCE.

5.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## HOT KEYS

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)



## Tips

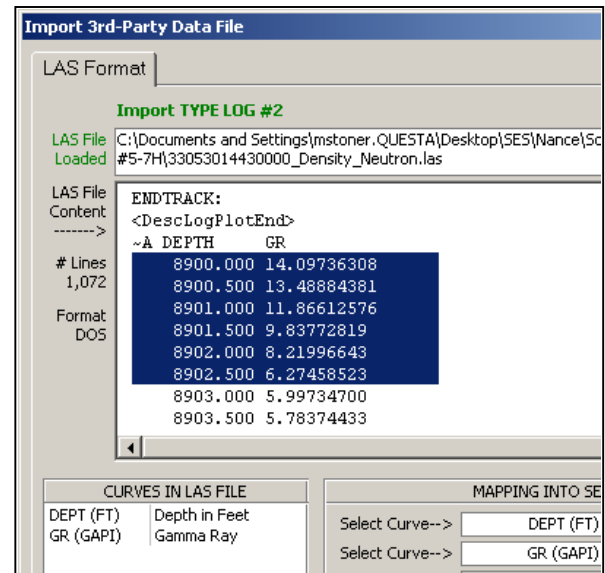
- ParamTuner is the interactive geosteering screen in SES where Type Log data is displayed with other data from the horizontal well being drilled. Frequently, initial Type Log (e.g., Gamma) data come from a vertical well in the vicinity of the horizontal well and the data are imported from an LAS format file that contains data for the entire vertical well. In many cases the depth range covered is far more than what is needed for technical geosteering and as a result the “shallow” data creates unneeded overhead through larger-than-necessary array sizes. ParamTuner performance may be enhanced if such non-needed data are deleted from SES or never imported in the first place. Three common methods to address this concept are discussed below:
  1. After loading (e.g., LAS file importing) the full Type Log dataset into Type Log screen of SES, use 'delete unneeded Type Log data...' toolbar button to open a wizard to help remove unnecessary data.
  2. After loading the full Type Log dataset into Type Log screen of SES, manually select and then delete the non-needed (e.g., shallow) depth data. In some cases clicking to a different Type Log # and then back—or selecting a different well and then returning—may be required to “clean-up” or otherwise Refresh the screen/table.

3. If using the LAS file importer, non-needed rows of data can be selected and deleted from within the viewer window (see adjacent picture showing data selection just prior to pressing delete key) prior to importing the data. This action will *not* affect the source LAS file data.

- Cross-sections in SES can include up to five stacked beds above and five stacked beds below the primary payzone. Type Log screen is often helpful to determine what those offset beds thicknesses should be if the color scheme also has some sort of stratigraphic reference.

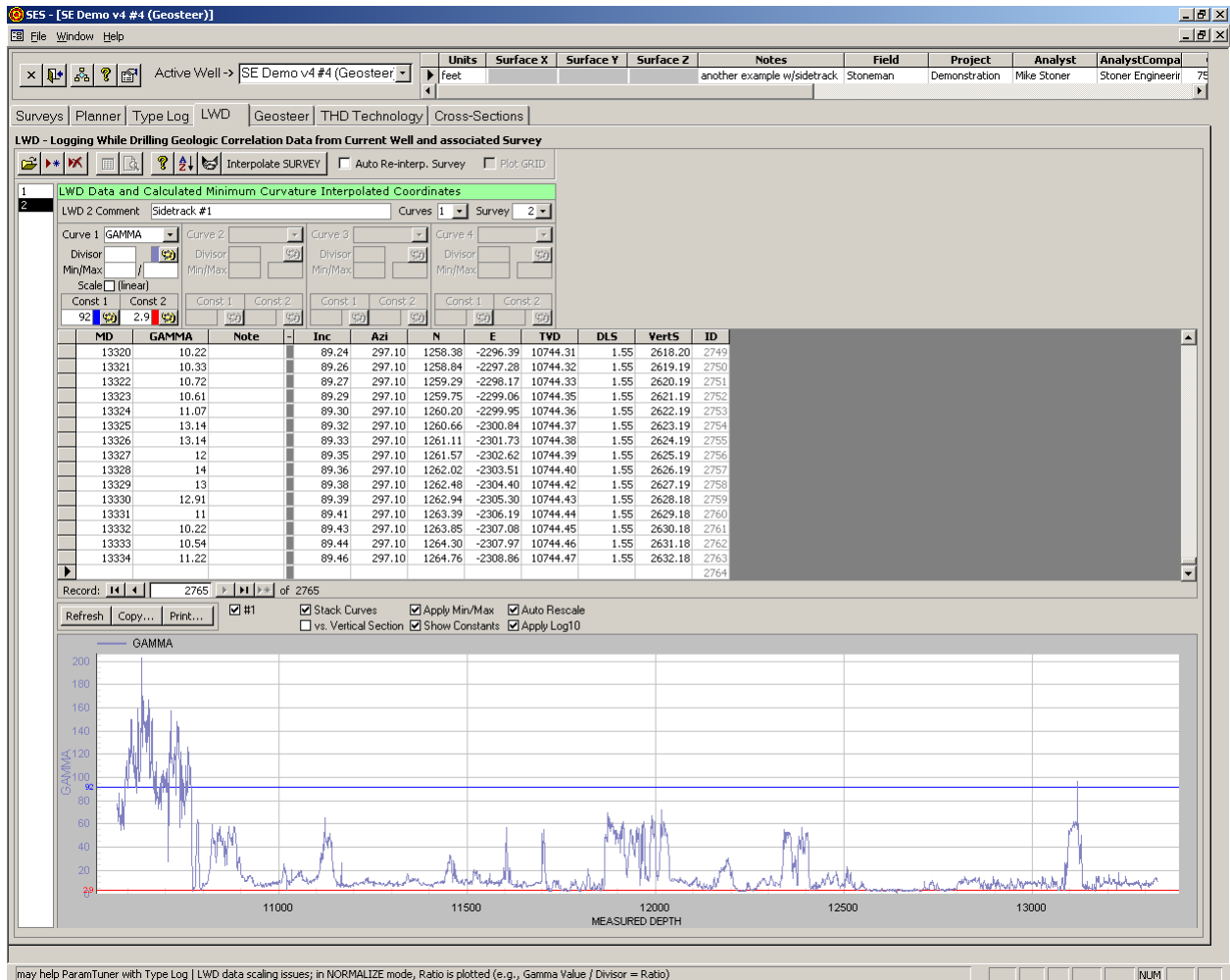
Entering a comment in the 'Note/Zone' column at a particular depth will produce an annotated horizontal line on Type Log graph. Moving the mouse over the graph and observing the cursor tracking coordinates may further assist with determining desired stacked bed thicknesses for input on Geosteer screen (Tab View - Bed Thickness & Color tab).

- ParamTuner screen ('Camera' toolbar button) may be used to create a Type Log derived from select 3DSBs of an analyst's interpretation. If performed, the derived type log dataset will appear on Type Log screen with the next incremental type log ID number.





## SES Screen – LWD



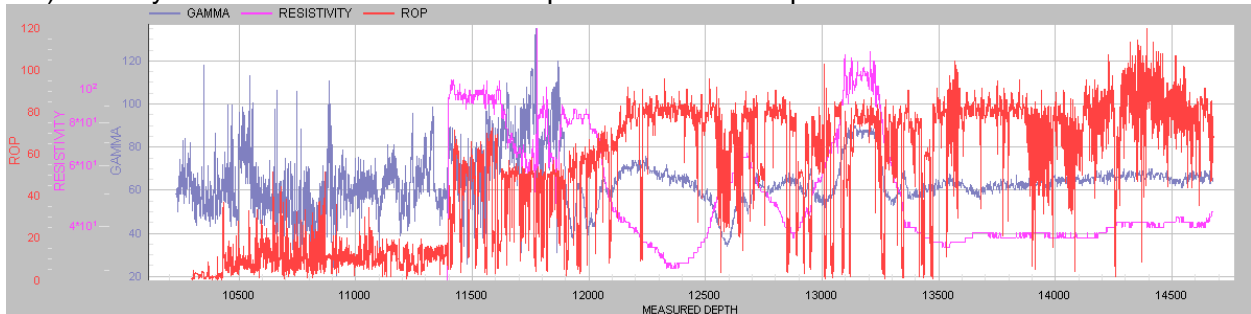
### General

Any MD-tagged data used to Geosteer or to be viewed on Cross-Sections constitute "Logging While Drilling" (LWD) data. The survey interpolation method is minimum curvature.

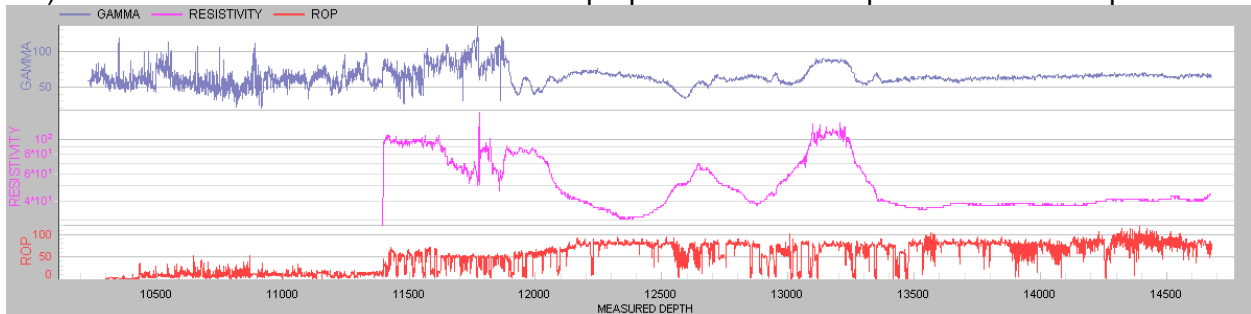
LWD screen can be used to:

- 1.) Input LWD data (e.g., Gamma, High-Side Gamma, Total Gas, ROP, Casing Pressure, etc.) using keypunch, pasting from Excel, or by import from a file in LAS format.
- 2.) Associate an LWD data set to a directional survey.
- 3.) Interpolate associated directional survey at LWD MDs for Cartesian coordinates and wellbore angles, for use when Geosteering.
- 4.) Manage and navigate multiple LWD data sets from the current well (e.g., multiple wellbores/sidetracks).

- 5.) Designate each curve name of each LWD data set (up to four curves per data set).
- 6.) Designate a 'Divisor' value for each curve (used with Ratio-Normalization when Geosteering).
- 7.) Plot LWD curve data versus MD or Vertical Section.
- 8.) Print the graph on any system printer (including Adobe/PDF).
- 9.) Copy the graph for paste into another application.
- 10.) Zoom a section of graph by dragging a window with the mouse within the graph; then pan by clicking the scroll bars or zoom again.
- 11.) Change a variety of graph properties (including full screen mode / maximize) by right-clicking over the graph and using the shortcut menu.
- 12.) Overlay LWD data curves when multiple curve data are present.



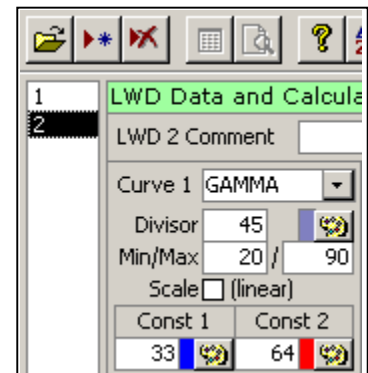
- 13.) Stack LWD data curves and set relative proportion when multiple curve data are present.

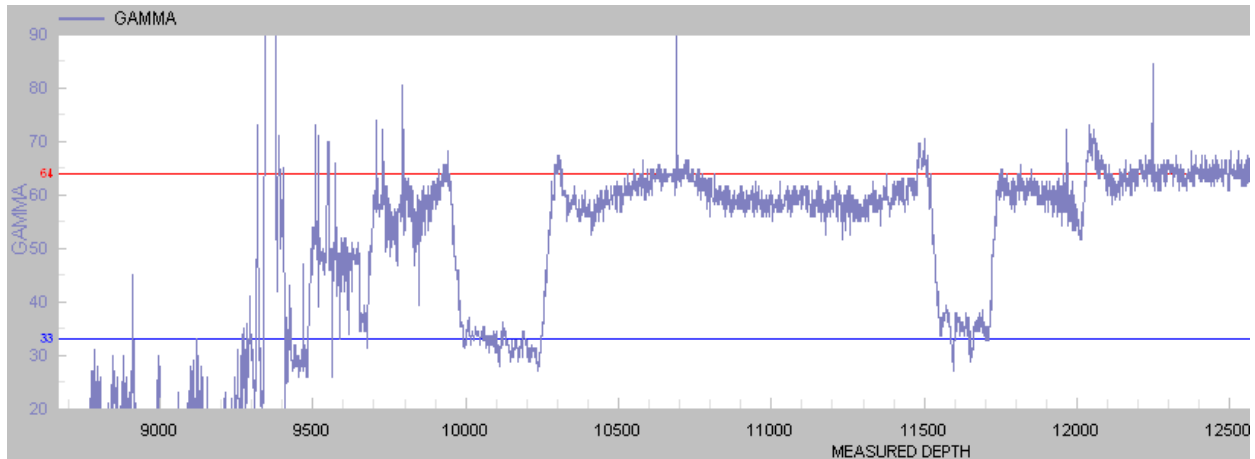


- 14.) Navigate to a data point in the table by clicking a graph data point while the graph is zoomed.

- 15.) Set LWD curve Min, Max, Color, and linear/log scale format. (See adjacent picture)

- 16.) Set up to two constant values and their colors, for graphing in LWD, ParamTuner, and Cross-Sections. (See next picture)





17.) Select which available data curve(s) to graph.

## Critical

- 1.) Each LWD data set must be correctly associated with a directional survey in the header portion of LWD screen.
- 2.) If directional data are changed, click 'Interpolate Survey' or press F6 to refresh the survey interpolation at LWD MDs.
- 3.) If well units are changed, re-calculate.
- 4.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## HOT KEYS

F6 - same as clicking LWD toolbar button 'Interpolate Survey'

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)



## Tips

- During live geosteering operations, typical bottom-hole assembly configurations are such that (for example) the gamma tool is closer to the drill bit than is the survey tool, and thus, gamma data will lead survey data. In order to use gamma data while geosteering with SES, a spatial location from where the gamma signal was measured is required. Therefore, in some cases, it might be necessary to first provide a directional survey station *estimate* (e.g., at current TD) in order to fully use all available gamma data. Such estimate could be quite different during the landing than during the horizontal section, to account for significantly different/intentional anticipated build and or turn gradients. Consulting with the directional driller is recommended for angle estimations at TD.

- LWD screen can easily be used to *create* Type Log data from a *directional* offset well or pilot hole. The first steps would be to load the directional survey and LWD data and interpolate the directional survey from LWD screen. Then simply copy the appropriate LWD TVD column and treat it as StratDepth with respect to an SES Type Log and paste it. Next, the LWD formation evaluation signal—gamma ray for example—would be copied from LWD screen and pasted onto an appropriate data column (Curve) on Type Log screen. This method is acceptable in a geologic area with low regional bed dip ( $<10^\circ$ ). If significant regional bed dip occurs in the offset or pilot well, an additional geometric correction may be necessary.
- Navigating in order to “clean” erroneous data from LWD is easy. Simply click and drag a window near the suspect data to “zoom” and then click a data point and the table selection will automatically move to the clicked data point. Manual data editing may then commence. An alternative method to manage suspect data is to enter LWD curve minimum and maximum values, for select application in ParamTuner and Cross-sections.
- LWD curve color and properties (e.g., min, max, scale format) that are set from LWD screen are also applied in ParamTuner and Cross-sections if applicable.

## SES Screen – GEOSTEER

The screenshot displays the SES - [SE Demo v4 #3 (Geosteer)] application window. The main menu includes File, Window, and Help. The active well is SE Demo v4 #3 (Geosteer). The interface is divided into several sections:

- Top Bar:** Units (feet), Surface X (3974411), Surface Y (782132.7), Surface Z (362), Major 3D well (Stoneman), Z Datum (KB), Map Zone (UTM), GL (340), Project (Demonstration), and Anal (Mike Ston).
- Surveys | Planner | Type Log | LWD | Geosteer | THD Technology | Cross-Sections |**
- Geologic Stratigraphy Interpretation (TVD Geosteering):**
  - Interpolate SURVEY:** ☐ Auto Re-interp. Survey ☐ Plot GRID
  - Marker Bed 2 Comment:** ST#1, Interp. #1
  - LWD:** 2 **Survey:** 2
  - Tab View:** ☒ **Table View:** ☐ **Type:** Top **SD to Target:** 1 **Plan:** 1
  - 3DStratBlock #:** 74
  - Parameters:**
    - Curve # Others:**

1	1
2	2
3	3
4	4
    - Fast Load:** ☐ **1000**
    - SES-determined 3DStratBlock Parameters:**

EASTING	NORTHING	Strike
-1226.21	-4263.60	270.00
    - Default length of new 3DStratBlock:** 100

A yellow box labeled **TAB VIEW** points to the **Tab View** radio button. A blue box highlights the **Parameters** tab. A green box highlights the **ParamTuner** button at the bottom of the **Parameters** tab.

## SES Screen – GEOSTEER (continued)

SES - [SE Demo v4 #3 (Geosteer)]

File Window Help

Units Surface X Surface Y Surface Z Notes Field Z Datum Map Zone GL Project Analyst

feet 3974411 782132.7 362 Major St Stoneman KB UTM 340 Demonstration Mike Stoner

Surveys | Planner | Type Log | LWD | Geosteer | THD Technology | Cross-Sections

Geologic Stratigraphy Interpretation (TVD Geosteering)

Interpolate SURVEY Auto Re-Interp. Survey Plot GRID

**TABLE VIEW**

A Marker Bed is comprised of multiple 3DStratBlocks and represents an Interpretation

Marker Bed 2 Comment ST#1, Interp. #1 LWD 2 Survey 2

Tab View Table View Type Top SD to Target 1 Plan 1

Block	MDStart	MDEnd	MD	TVD	Dip	Dip Azi	EASTING	NORTHING
35	9486	9519	9486	6743.35	1.98	180	-1178.84	65
36	9519	9529	9519	6744.49	5.88	180	-1178.55	32
37	9529	9579	9529	6745.52	2.55	180	-1178.44	22
38	9579	9837	9579	6747.4	1.2	180	-1177.87	-27
39	9837	10059	9837	6752.8	0.3	0	-1175.12	-285
40	10059	10194	10059	6751.64	0.19	180	-1172.53	-507
41	10194	10216	10194	6752.09	2.23	180	-1168.83	-642
42	10216	10267	10216	6752.95	0.84	180	-1168.58	-664
43	10267	10298	10267	6754.15	0.83	0	-1168.68	-715
44	10298	10356	10298	6754.15	2.35	180	-1168.71	-746
45	10356	10501	10356	6756.53	1.04	180	-1168.65	-804
46	10501	10707	10501	6759.15	0.04	180	-1169.27	-949
47	10707	10866	10707	6764.35	0.13	180	-1171.86	-1155
48	10866	10874	10866	6759.65	0.13	180	-1172.24	-1314
49	10874	10948	10874	6759.65	4.96	180	-1172.25	-1322
50	10948	10996	10948	6766.05	3.79	180	-1172.43	-1396
51	10996	11146	10996	6769.23	0.83	180	-1172.64	-1444
52	11146	11236	11146	6771.4	0.28	180	-1182.33	-1593
53	11236	11292	11236	6771.84	1.19	180	-1190.67	-1683
54	11292	11380	11292	6773	0	180	-1196.14	-1739
55	11380	11607	11380	6769.95	1.65	180	-1205.19	-1826
56	11607	11686	11607	6776.45	1.37	180	-1227.16	-2052
57	11686	11899	11686	6778.33	0.2	180	-1233.80	-2131
58	11899	12129	11899	6780.05	0.13	180	-1243.28	-2344
59	12129	12456	12129	6780.57	0.29	180	-1245.85	-2574
60	12456	12656	12456	6780.2	1.74	180	-1239.55	-2901
61	12656	12808	12656	6786.27	0.75	180	-1237.02	-3101
62	12808	12910	12808	6790.15	0.4	180	-1231.62	-3252
63	12910	13037	12910	6792.6	0.07	180	-1229.41	-3354
64	13037	13111	13037	6794.45	0.07	180	-1228.00	-3481
65	13111	13155	13111	6795.95	5.21	0	-1227.01	-3555
66	13155	13227	13155	6787.4	1.18	0	-1226.21	-3599
67	13227	13264	13227	6792.1	4.9	0	-1225.42	-3671
68	13264	13277	13264	6788.93	2.83	0	-1225.04	-3708
69	13277	13322	13277	6788.3	1.1	0	-1224.93	-3721
70	13322	13434	13322	6799.1	0.83	0	-1224.66	-3766
71	13434	13489	13434	6797.83	0.15	180	-1224.63	-3878
72	13489	13679	13489	6797.4	1.55	180	-1225.19	-3933
73	13679	13819	13679	6802.54	0.66	180	-1226.66	-4123
74	13819	13987	13819	6804.15	0.32	0	-1226.21	-4263
75	13987			6804.15	0.32	0		

Record: 75 of 75

Starting MD of 3DStratBlock

## General

A "Marker Bed" data set is a collection of 3DStratBlocks and collectively defines one interpretation. Each 3DStratBlock is a planar surface that defines the geologic marker top (or base) over a finite MD range of the associated survey. "Geosteering" involves determining the 3DStratBlock extents and orientation, such that LWD data is sufficiently mapped onto the type log using Relative Stratigraphic Depth (RSD). RSD is the minimum distance to the 3DStratBlock from the wellbore location and then also RSD is given in the form of a type log and thus calibration resolves the differences.

GEOSTEER screen can be used to:

- 1.) Manage and navigate multiple "Marker Bed" data sets (interpretations) of the current well. Supports multiple geologic interpretations and/or multiple wellbores/sidetracks.
- 2.) Load ParamTuner screen, which is used to visually calibrate/tune the parameters of a 3DStratBlock of the selected 'Marker Bed'...THIS IS GEOSTEERING!
- 3.) Select an LWD data set and associated directional survey to geosteer using ParamTuner.
- 4.) Designate whether the 'Marker Bed' is a formation top or a formation base.
- 5.) Designate the stratigraphic depth difference from the marker (i.e., where RSD=0) to the TARGET location of the actual wellbore (positive value is deeper/below; negative value is shallower/above).
- 6.) Designate an associated well plan that may optionally be displayed in ParamTuner.
- 7.) Enter individual 3DStratBlock parameter values, such as MD ranges and control point properties including MD, TVD, True Dip, and True Dip Direction Azimuth.
- 8.) Navigate and or set 3DStratBlock parameter values using Tab View or Table View display format.
- 9.) Set which primary Type Log & LWD curve to load in ParamTuner (Curve 1 is most common and the default). OTHER curves may be posted in-addition (set in Tab View).
- 10.) Interpolate the associated directional survey at the Marker Bed control point MD to thereby determine the control point Northing and Easting coordinate values.
- 11.) Set the name, thickness, and color of the 'PAYZONE Marker Bed' and same for up to +/-5 offset layers, for full-well cross-section generation using 'Cross-Sections' screen and for RSD log strip display in ParamTuner.
- 12.) Import/copy/transfer 3DSB properties (thicknesses, colors, names of payzone and offset layers) from any other Marker Bed in SESdata to current Marker Bed.
- 13.) Create the next 3DStratBlock at the end of the last 3DStratBlock by double-clicking MD\_End of the 'new record' row (last row in table; row with asterisk if row not selected).

14.) Automatically search for and insert 3DStratBlocks into MD 'gaps' using the insert button in the header portion of Geosteer screen.

15.) Set the DEFAULT length of new 3DStratBlocks.

16.) Set ParamTuner to operate in FastLoad mode, where user-set-depth range of 3DSB/LWD data relative to the active 3DSB MD are loaded instead of all such data (helpful for interpretations with many 3DSBs).

17.) Let SES try to guess the parameters of the first 3DSB (#0) of a new interpretation, in order to get ParamTuner opened for initial/first-3DSB calibration. (Simply click 'ParamTuner' for a Marker Bed with no 3DSBs yet defined.)

## **Critical**

1.) LWD and Survey data sets must be associated to a "Marker Bed" by making the designation in the header portion of Geosteer screen.

2.) From Geosteer tab view click 'ParamTuner' with a brand new (i.e., empty) interpretation (Marker Bed) and SES will try to guess the parameters of the first 3DSB in order to GET STARTED geosteering with ParamTuner.

3.) It is recommended practice to make the control point MD equal to MDstart.

4.) A control point appears on the TVD vs. MD plot on ParamTuner screen as a black dot symbol and LWD data that fall within the current 3DStratBlock MD range is colored **magenta**.

5.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## **HOT KEYS**

Dbl-Click MD - interpolates survey at MD to get control point Easting and Northing coordinates

Dbl-Click TVD - determines control point TVD, to start exactly at end of prior 3DStratBlock

Dbl-Click MDend - creates new/next 3DStratBlock by adding default length to MDstart, using MDstart as control point MD, interpolates survey, determines control point TVD from end of prior 3DStratBlock, and loads new 3DStratBlock in ParamTuner

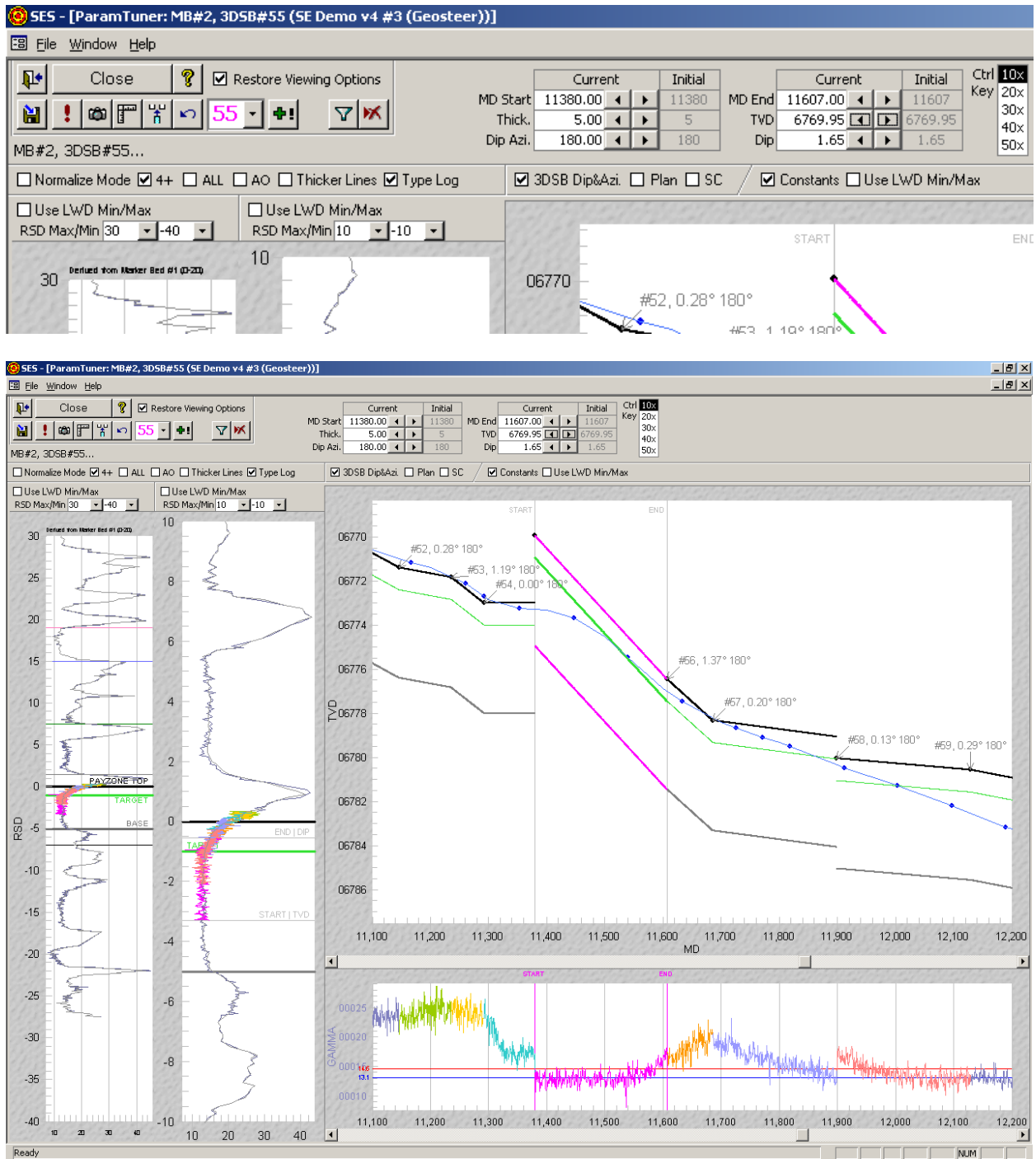
Dbl-Click Block#, MDstart, Dip, or Dip Azimuth - loads respective 3DStratBlock as ACTIVE in ParamTuner

F6 - same as clicking Geosteer toolbar button 'Interpolate Survey'

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)



## SES Screen – GEOSTEER – ParamTuner



### General

**Parameter Tuner** (ParamTuner) is used to "Land" and Geosteer a horizontal well by 3DStratBlock (3DSB) calibration/tuning. LWD data from the horizontal well are mapped onto a Type Log "expected" profile from offset penetration. ALSO see Geosteer screen help for more information as these screens are coupled. ParamTuner is opened from Geosteer screen.

ParamTuner screen can be used to:

- 1.) Calibrate the mathematical parameters that define each 3DStratBlock within an interpretation.
- 2.) Observe relative stratigraphic progression into and within the geologic Type Log sequence.
- 3.) Define 3DStratBlock MD extents (well path interval over which beds are acting with associated planar properties).
- 4.) Change 3DSB parameter values by clicking or clicking and holding associated spin buttons (amplification applied if CTRL key also simultaneously pressed).
- 5.) Instantaneously observe how 3DSB parameters True Dip, True Dip Direction Azimuth, and control point TVD alter the mapping of LWD data onto a Type Curve using Relative Stratigraphic Depth (RSD). RSD is the minimum 3D distance from the location of LWD signal along the well path to the 3DStratBlock.
- 6.) Change MD\_Start by dragging vertical line labeled 'START' on the cross-section to a new location (control point MD/Northing/Easting is also automatically changed).
- 7.) Change MD\_End by dragging vertical line labeled 'END' on the cross-section to a new location.
- 8.) Change TVD by dragging horizontal line labeled 'START | TVD' on inner/right RSD track to a new location.
- 9.) Change Dip/DipAzi by dragging horizontal line labeled 'END | DIP' on inner RSD track to a new location.
- 10.) Experiment with changing 3DSB parameter values and then restore the original/last-saved values by clicking 'Undo' toolbar button.
- 11.) Set the 'PAYZONE Marker Bed' thickness (i.e., the 3DStratBlock thickness); stored by 3DSB.
- 12.) Plot LWD data on RSD tracks in Normalize Mode (ratios are plotted, i.e.,  $LWD\_Value/LWD\_Divisor$  and  $TypeLog\_Value/TypeLog\_Value@RSD=0$ ); stored by 3DSB.
- 13.) Modify LWD\_Divisor by clicking 'Filter' toolbar button and entering new value.
- 14.) Observe color-coded LWD signal / RSD mapping for ACTIVE and nearby 3DStratBlocks.
- 15.) Set RSD track min/max axes limits using respective drop-down boxes or by dragging/panning tracks directly, to preserve by 3DSB the data view at time of calibration.
- 16.) Override auto LWD\_Value axes limits and force each respective track to inherit LWD-configured min/max/log settings; stored by 3DSB.
- 17.) Post LWD-configured constant value lines on LWD\_Value vs. MD track; stored by 3DSB.

- 18.) Re-Load ParamTuner screen, which resets/recalculates default view properties and manifests changes made from other SES screens, by clicking 'Exclamation Point' toolbar button.
- 19.) Add/append a new 3DStratBlock by clicking 'Append' toolbar button.
- 20.) Post offset 3DStratBlock parameters True Dip and True Dip Direction Azimuth as annotation labels in TVD vs. MD cross-section; stored by 3DSB.
- 21.) Set which 3DStratBlock is ACTIVE by toolbar drop-down box selection OR by double-clicking 3DSB# annotation label in TVD vs. MD cross-section.
- 22.) Delete the ACTIVE 3DStratBlock (existing 3DSBs are automatically renumbered).
- 23.) Insert a 3DStratBlock between existing 3DSBs to fill 'gaps' by clicking 'Insert' toolbar button (existing 3DSBs are automatically renumbered).
- 24.) Create a "Derived" Type Log (typically after coming-into and through the landing) based on select 3DStratBlocks (click 'Camera' toolbar button to load wizard).
- 25.) Disable display of the type log(s) set to 'Use in ParamTuner' (Type Log screen); stored by 3DSB.
- 26.) Scroll back-and-forth through TVD|LWD vs. MD graphs by using mouse wheel or scroll bars.
- 27.) Isolate RSD signal mapping from active 3DSB only ('AO' checkbox); no offset colored data.
- 28.) Post RSD signal mapping from ALL 3DSBs ('ALL' checkbox).
- 29.) Add curve called '4+', which statistically smoothes ALL prior RSD-mapped data and posts a single curve on RSD tracks; essentially an evolving derived type log; stored by 3DSB.
- 30.) Set general line thicknesses; stored by 3DSB.
- 31.) Post the associated well plan on TVD vs. MD cross-section (requires calculated THD); stored by 3DSB.
- 32.) Post survey callouts (MD/Inc/Azi/DLS/TVD/VS) at survey stations ('SC' checkbox).
- 33.) Set a custom zoom size by dragging a horizontal window over the TVD vs. MD cross-section graph. Repeated zooming is supported.
- 34.) Zoom-out completely or Restore Initial Zoom from last load by right-clicking the TVD vs. MD cross-section and using the short-cut menu.
- 35.) Change a variety of graph properties (including full screen mode / maximize) by right-clicking over the graph and using the shortcut menu.
- 36.) Right-click a graph and Export to Print or Copy.

37.) Plot multiple secondary LWD\_Value curves (e.g., resistivity, TG, ROP, casing pressure, flare height, high-side gamma, low-side gamma, etc.) in lower track graph by selecting such 'Other' curves from Geosteer screen, Tab View.

## Critical

1.) ParamTuner is used in conjunction with Geosteer screen and is opened from Geosteer by double-clicking a 3DSB# or by clicking ParamTuner button in tab view.

2.) Unlike elsewhere in SES, with ParamTuner you must click the 'Save' toolbar button in order to save changes to the database. This facilitates experimentation, which frequently is needed during calibration.

3.) A control point appears on the TVD vs. MD plot as a black dot and LWD data that fall within the ACTIVE/current 3DStratBlock MD range are colored **magenta**.

## HOT KEYS

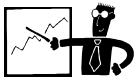
Dip Direction Azimuth – double-click and its value will 'flip' 180 degrees. For example, if its value is 45 degrees, double-clicking would change its value to 225. This dip-direction-reversal need will naturally occur when the Dip is tuned to zero and “more” is needed.

TVD – double-click to change its value to 'snap' to the end of the prior 3DSB.

MD\_End – double-click to change its value to 'snap' to current TD.

CTRL – all spin buttons operate at 10x to 50x while the CTRL button is held down. You may click and hold the spin button down with the mouse while simultaneously you may also toggle holding down the CTRL button.

ALT+TAB – is a convenient Windows keystroke combination to quickly toggle between open windows, e.g., Geosteer and ParamTuner. Press ALT key, then TAB key, and then release these keys to return to the respective window. (NOTE: In some versions of Microsoft Office, ALT+TAB behavior has been changed to CTRL+F6, unfortunately)



## Tips

- If technical geosteering is new for you, it is recommended to first analyze an historical horizontal well or multiple such wells before applying SES geosteering to live horizontal drilling operations. In addition to climbing the software learning curve and not being burdened with data lag issues inherent to live operations, 'practicing' will introduce you to the geologic features that are present in your field that without technical geosteering software analysis were likely not fully appreciated.
- The typical *minimum* data required to apply SES technical geosteering are the directional survey, the type log gamma signal from an offset/pilot vertical well, and the gamma signal from the horizontal well.
- The horizontal wellbore (including the build section) penetrates the reservoir in a unique location that is different than the type log location! As a result, bed thicknesses and

dependable geologic marker depths may vary and in some cases 'fake faults' and or non-realistic dips may be necessary to process the signal coming into the landing. After landing, a constant payzone thickness is most commonly assumed.

- SES technical geosteering does not have variable-dip-calibration application until the wellbore at the start of the 3DSB is significantly inclined (e.g., in excess of 30 degrees). Before significant wellbore inclination is attained, TVD should be adjusted to map signal onto the type log and dip should be left at zero or regional average.
- It is possible while geosteering to reach data analysis conditions where multiple different interpretations are equally likely; at least (perhaps) until some other signal signature is evidenced later in the wellbore. SES by design is setup to easily handle management of multiple simultaneous interpretations (Marker Beds). The Geosteer 'Add' (asterisk) toolbar button allows an existing interpretation to be copied for subsequent alternative tuning/calibration.
- ParamTuner displays RSD and cross-section geosteering domains.
- See
- 
- 
- 
- [GEOSTEERING ANALYST'S](#) TRADE SECRETS for more important information.

# SES Screen – THD TECHNOLOGY

**SES - [SE Demo v4 #3 (Geosteer)]**

File Window Help

Active Well -> SE Demo v4 #3 (Geosteer)

Units: feet | Surface X: 3974411 | Surface Y: 782132.7 | Surface Z: 362 | Notes: Major 3D well | Field: Stoneman | Z Datum: KB | Map Zone: UTM | Project: 340 Demonstration | Anal: Mike Ston

Surveys | Planner | Type Log | LWD | Geosteer | THD Technology | Cross-Sections

Wellbore Navigation Assistance - Technical Hole Deviation (THD) & Fuzzy Drilling Direction Controller (FDDC)

Calculate THD | Auto Re-compute THD | Plot GRID

Survey Plan: 1 1 | 2 1

THD, THD Logs, & FDDC Steering Guidance

\*Denotes Planned Value

Use Marker Bed for Planned TVD | Calculate FDDC Steering Guidance | THD Logs & Directional Plots

Survey	Plan	MD	Δ High/Low Side	Δ Right/Left Side	VD	RVD	ID	RCD	HD	RHD	AD	RCD	Inc	Inc*	Azi	Azi*	TVD	TVD*	N	N*
10794.00	Towards DROP 10%	Towards LEFT 50%	2.27	-22	-0.88	2.5	9.26	-10	-0.42	0.8	88.99	89.87	89.87	89.87	180.51	180.93	6763.28	6765.55	-1242.40	-1242.55
10826.00	Towards BUILD 40%	Towards LEFT 10%	1.75	-16	-0.97	-0.3	8.81	-14	-1.21	-2.5	88.90	89.87	179.72	180.93	6763.87	6765.62	-1274.40	-1274.54		
10887.00	Towards DROP 30%	Towards LEFT 30%	-3.71	-89	2.98	6.4	7.76	-17	-0.77	0.7	88.02	85.04	180.16	180.93	6765.51	6761.82	-1335.38	-1335.82		
10929.00	Towards DROP 50%	Towards LEFT 20%	-1.59	51	2.81	-0.4	7.19	-13	-0.77	0.0	87.85	85.04	180.16	180.93	6767.02	6765.45	-1377.35	-1377.60		
10981.00	Towards BUILD 20%	Towards LEFT 10%	0.49	40	2.19	-1.2	6.41	-15	-0.95	-0.3	88.55	86.36	179.98	180.93	6768.65	6769.16	-1429.32	-1429.39		
11013.00	Towards BUILD 10%	Towards LEFT 80%	1.07	18	0.05	-6.7	6.74	10	2.13	9.6	89.16	89.11	183.06	180.93	6769.29	6770.37	-1461.30	-1461.39		
11044.00	Towards BUILD 60%	Towards LEFT 70%	0.70	-12	-0.71	-2.5	8.01	41	2.57	1.4	89.25	89.96	183.50	180.93	6769.72	6770.42	-1492.25	-1492.38		
11074.00	Towards BUILD 70%	Towards LEFT 70%	0.26	-15	-0.97	-0.9	9.40	46	2.74	0.6	88.99	89.96	183.67	180.93	6770.19	6770.44	-1522.18	-1522.34		
11167.00	NO CHANGE	Towards LEFT 90%	-0.68	-10	-0.18	0.9	15.13	62	4.33	1.7	89.78	89.96	185.26	180.93	6771.18	6770.51	-1614.89	-1615.14		
11261.00	Towards BUILD 90%	Towards LEFT 90%	-2.36	-18	-1.61	-1.5	22.52	79	4.68	0.4	89.08	90.69	185.61	180.93	6772.12	6769.75	-1708.46	-1708.80		
11292.00	Towards BUILD 100%	Towards LEFT 90%	-3.30	-31	-1.88	-0.9	25.07	83	4.76	0.3	88.81	90.69	185.69	180.93	6772.69	6769.38	-1739.51	-1739.68		
11353.00	Towards BUILD 100%	Towards LEFT 100%	-4.60	-21	-0.56	2.2	30.32	86	5.12	0.6	90.13	90.69	186.05	180.93	6773.25	6768.65	-1799.38	-1800.42		
11447.00	Towards DROP 20%	Towards LEFT 90%	-0.27	46	-0.27	0.3	38.28	85	4.59	-0.6	89.34	89.61	185.52	180.93	6773.69	6773.42	-1893.50	-1894.13		
11540.00	Towards BUILD 90%	Towards LEFT 90%	-1.43	-12	-1.15	-0.9	45.79	81	4.68	0.1	88.46	89.61	185.61	180.93	6775.47	6774.05	-1986.05	-1986.80		
11633.00	Towards BUILD 60%	Towards LEFT 80%	-2.79	-15	-0.53	0.7	52.87	76	4.06	-0.7	89.08	89.61	184.99	180.93	6777.47	6774.68	-2078.63	-2079.50		
11726.00	Towards DROP 10%	Towards LEFT 80%	-2.33	5	0.90	1.5	58.61	62	3.01	-1.1	89.43	88.53	183.94	180.93	6778.68	6776.37	-2171.34	-2172.35		
11772.00	Towards DROP 50%	Towards LEFT 40%	-1.57	16	0.99	0.2	60.18	34	0.90	-4.6	89.52	88.53	181.83	180.93	6779.10	6777.55	-2217.27	-2218.29		
11819.00	Towards DROP 50%	Towards LEFT 60%	-0.76	17	0.99	0.0	60.88	15	0.81	-0.2	89.52	88.53	181.74	180.93	6779.49	6778.76	-2264.25	-2265.26		
11912.00	Towards BUILD 60%	Towards LEFT 80%	-0.48	3	-0.32	-1.4	62.69	19	1.42	0.7	89.25	89.57	182.35	180.93	6780.49	6780.02	-2357.18	-2358.20		
12004.00	Towards DROP 60%	Towards LEFT 20%	1.42	21	0.21	0.6	63.28	6	-0.68	-2.3	89.78	89.57	180.25	180.93	6781.27	6782.69	-2449.15	-2450.17		
12097.00	Towards BUILD 20%	Towards LEFT 30%	1.19	-2	-0.49	-0.8	61.89	-15	-1.04	-0.4	89.08	89.57	179.89	180.93	6782.20	6783.39	-2542.15	-2543.14		
12190.00	Towards DROP 30%	Towards LEFT 20%	0.89	-3	0.12	0.7	59.48	-26	-1.92	-0.9	89.69	89.57	179.01	180.93	6783.19	6784.09	-2635.14	-2636.09		
12284.00	Towards BUILD 50%	Towards LEFT 10%	0.51	-4	-0.58	-0.7	55.83	-39	-2.53	-0.6	88.99	89.57	178.40	180.93	6784.28	6784.79	-2729.10	-2730.01		
12377.00	Towards BUILD 50%	Towards LEFT 20%	-0.50	-11	-0.67	-0.1	52.37	-37	-1.74	0.9	88.90	89.57	179.19	180.93	6785.99	6785.49	-2822.07	-2822.92		
12471.00	Towards BUILD 10%	Towards LEFT 10%	-1.10	-6	-0.05	0.7	49.01	-36	-2.36	-0.7	89.52	89.57	178.57	180.93	6787.29	6786.20	-2916.04	-2916.84		
12565.00	Towards DROP 70%	Towards LEFT 40%	-0.24	9	1.09	1.2	46.29	-29	-0.95	1.5	90.66	89.57	179.98	180.93	6787.14	6786.90	-3010.03	-3010.78		
12659.00	NO CHANGE	Towards LEFT 10%	0.68	10	0.03	-1.1	43.73	-27	-2.18	-1.3	89.60	89.57	178.75	180.93	6788.93	6787.61	-3104.02	-3104.72		
12753.00	Towards BUILD 80%	Towards RIGHT 20%	-0.35	-11	-1.28	-1.4	39.01	-50	-3.58	-1.5	88.29	89.57	177.35	180.93	6788.66	6788.31	-3197.94	-3198.58		
12846.00	Towards BUILD 90%	Towards LEFT 10%	-2.36	-22	-1.20	0.1	34.33	-50	-2.18	1.5	88.37	89.57	178.75	180.93	6791.37	6789.01	-3290.85	-3291.42		
12939.00	Towards BUILD 30%	Towards LEFT 20%	-3.52	-12	-0.23	1.0	31.23	-33	-1.65	0.6	89.34	89.57	179.28	180.93	6793.22	6789.71	-3383.81	-3384.35		
13033.00	Towards BUILD 90%	Towards LEFT 30%	-4.41	-9	-0.85	-0.7	28.73	-27	-1.39	0.3	88.72	89.57	179.54	180.93	6794.82	6790.41	-3477.80	-3478.29		
13126.00	Towards BUILD 60%	Towards LEFT 10%	-5.50	-12	-0.49	0.4	25.91	-30	-2.09	-0.8	89.08	89.57	178.84	180.93	6796.60	6791.11	-3570.77	-3571.23		
13157.00	Towards BUILD 70%	Towards LEFT 30%	-5.76	-9	-0.49	0.0	24.88	-33	-1.74	1.1	89.08	89.57	179.19	180.93	6797.10	6791.34	-3601.76	-3602.21		
13188.00	Towards BUILD 50%	Towards LEFT 30%	-6.01	-8	-0.41	0.3	24.03	-27	-1.39	1.1	89.16	89.57	179.54	180.93	6797.58	6791.57	-3632.75	-3633.19		
13219.00	Towards BUILD 60%	Towards LEFT 20%	-6.23	-7	-0.41	0.0	23.21	-27	-1.65	-0.8	89.16	89.57	179.28	180.93	6798.03	6791.81	-3663.75	-3664.17		
13313.00	NO CHANGE	Towards LEFT 30%	-5.82	4	0.91	1.4	20.86	-25	-1.21	0.5	90.48	89.57	179.72	180.93	6798.33	6792.51	-3757.74	-3758.12		
13406.00	Towards DROP 50%	Towards LEFT 40%	-4.12	18	1.18	0.3	19.18	-18	-0.86	0.4	90.75	89.57	180.07	180.93	6797.33	6793.21	-3850.74	-3851.08		
13500.00	Towards BUILD 80%	Towards LEFT 60%	-3.99	1	-1.02	-2.3	18.49	-7	0.02	0.9	88.55	89.57	180.95	180.93	6797.90	6793.91	-3944.72	-3945.05		
13594.00	Towards BUILD 100%	Towards LEFT 40%	-6.46	-26	-1.99	-1.0	17.95	-6	-0.68	-0.7	87.58	89.57	180.25	180.93	6801.08	6794.62	-4038.66	-4039.00		
13688.00	Towards BUILD 50%	Towards LEFT 40%	-8.35	-20	-0.32	1.8	16.76	-13	-0.77	-0.1	89.25	89.57	180.16	180.93	6803.67	6795.32	-4132.62	-4132.96		
13782.00	Towards BUILD 90%	Towards LEFT 30%	-9.24	-9	-0.76	-0.5	14.99	-19	-1.39	-0.7	88.81	89.57	179.54	180.93	6805.27	6796.03	-4226.61	-4226.92		
13876.00	Towards BUILD 20%	Towards LEFT 40%	-9.33	-1	0.65	1.5	13.15	-20	-0.86	0.6	90.22	89.57	180.07	180.93	6806.06	6796.73	-4320.60	-4320.89		
13969.00	Towards BUILD 60%	Towards LEFT 30%	-8.92	4	-0.14	-0.8	11.32	-20	-1.39	-0.6	89.43	89.57	179.54	180.93	6806.35	6797.43	-4413.60	-4413.85		
14030.00	Towards BUILD 60%	Towards LEFT 30%	-9.11	-3	-0.23	-0.1	9.84	-24	-1.39	0.0	89.34	89.57	179.54	180.93	6807.00	6797.89	-4474.60	-4474.82		

Record: 133 of 133

system units

## General

Technical Hole Deviation (THD) mathematically describes spatial differences between actual and planned well paths. Steering Guidance is calculated using THD. 'THD Logs' present THD in a log format.

THD TECHNOLOGY screen can be used to:

- 1.) Calculate THD, including for well paths where planned TVD and inclination are driven by Geosteering.
- 2.) Calculate Steering Guidance using the patented Fuzzy Logic Drilling Direction Controller (FDDC).
- 3.) Create THD Logs by opening 'THD Logs & Directional Plots' screen.
- 4.) Navigate multiple combinations of Surveys and Plans for which THD may be calculated.

5.) Designate a "Marker Bed" when THD via Geosteering is desired; here, the respective Plan governs planned North, East, and Azimuth while the geosteered 3DStratBlocks govern planned TVD and Inclination.

6.) Use THD Logs and FDDC Steering Guidance to assist rationale behind directional tool setting adjustments and frequency and duration of drilling modes.

## Critical

1.) If directional survey, plan, or Marker Bed (if applicable) data change, click 'Calculate THD' or press F6 to refresh the calculation.

2.) If creating a THD Log using a Marker Bed to determine planned TVD and Inclination, only THD at depths below the start of the first 3DStratBlock are calculated and/or graphed.

3.) If the checkbox next to 'Use Marker Bed for Planned TVD' is not checked, the THD shown represents the selected survey against the selected geometric plan.

4.) If a different Marker Bed is selected from the dropdown box, then click 'Calculate THD' or press F6 to refresh the calculation.

5.) The Printing options from the 'THD Logs & Directional Plots' screen apply to the system default printer (including Adobe/PDF). To change your system default printer, use Windows Control Panel.

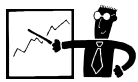
## HOT KEYS

F6 - same as clicking THD TECHNOLOGY toolbar button 'Calculate THD'

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)

## \*\*\*\*\* STEERING GUIDANCE \*\*\*\*\*

FDDC Steering Guidance is relative (how to CHANGE), NOT ABSOLUTE. For example, 'Towards DROP 40%' could mean to continue drilling high side, but less of such is advised with respect to the last survey station interval. Guidance is provided with each new survey station after sufficient inclination/azimuth is met.



## Tips

- The **most common commercial application of FDDC Steering Guidance by geologists** is to monitor its output, especially during the landing phase of a horizontal well where the geometric well plan is dominant. In general (landing or otherwise), repeated FDDC output at the 90% or 100% level should typically raise an immediate red flag and instigate communication with the directional driller for clarification about digressing from the planned path. With oversight some sidetracks can be prevented.

- FDDC Steering Guidance was calibrated to produce smooth steering adjustments (6 degrees per 100 feet or less) for minimum but realistic DLS variance.
- When using FDDC Steering Guidance with a Marker Bed (i.e., in Geosteer mode planned TVD and inclination are determined by the respective 3DSB), realize that the orientation of the leading 3DSB in real-time application is often subject to change as the interpretation is fine-tuned with additional data. In this respect, 'historical' observation of FDDC Steering Guidance and what transpired during real-time operations may be difficult to fully reproduce. This is not an issue when drilling a purely geometric plan, like some horizontal well landings or when drilling any general directional well where the target doesn't change over the course of drilling.
- In Geosteer mode (i.e., 'Use Marker Bed for Planned TVD' is checked) planned TVD and inclination are mathematically defined by the respective 3DSB. Thus, THD can easily be used to help fine-tune the horizontal landing and or to enhance communication with directional drillers. Vertical Deviation ( $\nabla D$ ) for example is the minimum 3D distance from a directional survey station to the target plane, defined by the parallel offset plane from the respective 3DSB. Based on current and target (3DSB) landing inclinations, the build gradient can be fine-tuned on the approach into the landing. For example:
  - 1) At 7050 ft MD,  $\nabla D$  is 54.46 ft and wellbore inclination is 72.63 degrees. The wellbore is already on target azimuth.
  - 2) Current planned landing inclination ( $INC^*$ ) is 91.5 degrees, i.e.,  $ID = 91.5 - 72.63 = 18.87$  degrees.
  - 3) Question: What is the current revised build gradient to hit the target zone on depth *and* on inclination?
  - 4) Answer: It's easy with THD!
    - **$11459.15590261646 * \sin^2(ID/2) / \nabla D = 5.65$  degrees/100 ft**
  - 5) Try to drill at 5.65 degrees/100 ft until the next directional survey station or 3DSB calibration change, and then respectively repeat steps 1 through 4 into the landing.



## SES Screen – THD TECHNOLOGY – THD Logs

**THD Logs & Directional Plots: SE DEMO V4 #3 (GEOSTEER), Survey #2, Plan #1**

Change Log Scale

1.0	<b>3.0</b>	5.0
1.5	3.5	5.5
2.0	4.0	Smallest
2.5	4.5	Largest

Vertical/Horizontal Deviation Projections (feet)

Project Vertical Deviation (msVD) by

Project Horizontal Deviation (msHD) by

Data Processing Progress

☐ Excel Link

☐ Real Survey Data

☐ Critical DLS\* Data

☐ Interp'd Survey Data

☐ Auto-scaling

☐ Header Info.

PRINTING

Paper Size on which to Print/Plot

☒ Emphasize deepest  when Auto-scaling THD

☒ Create Plan & Vertical Section Views to Scale

☐ Automatically Process Well Data on Open ☐ Automatically Preview after Processing

### General

THD Logs present THD and other actual/planned well path values in a log format. They may be created for geometric or geosteered well plans, dependent on how the screen was loaded.

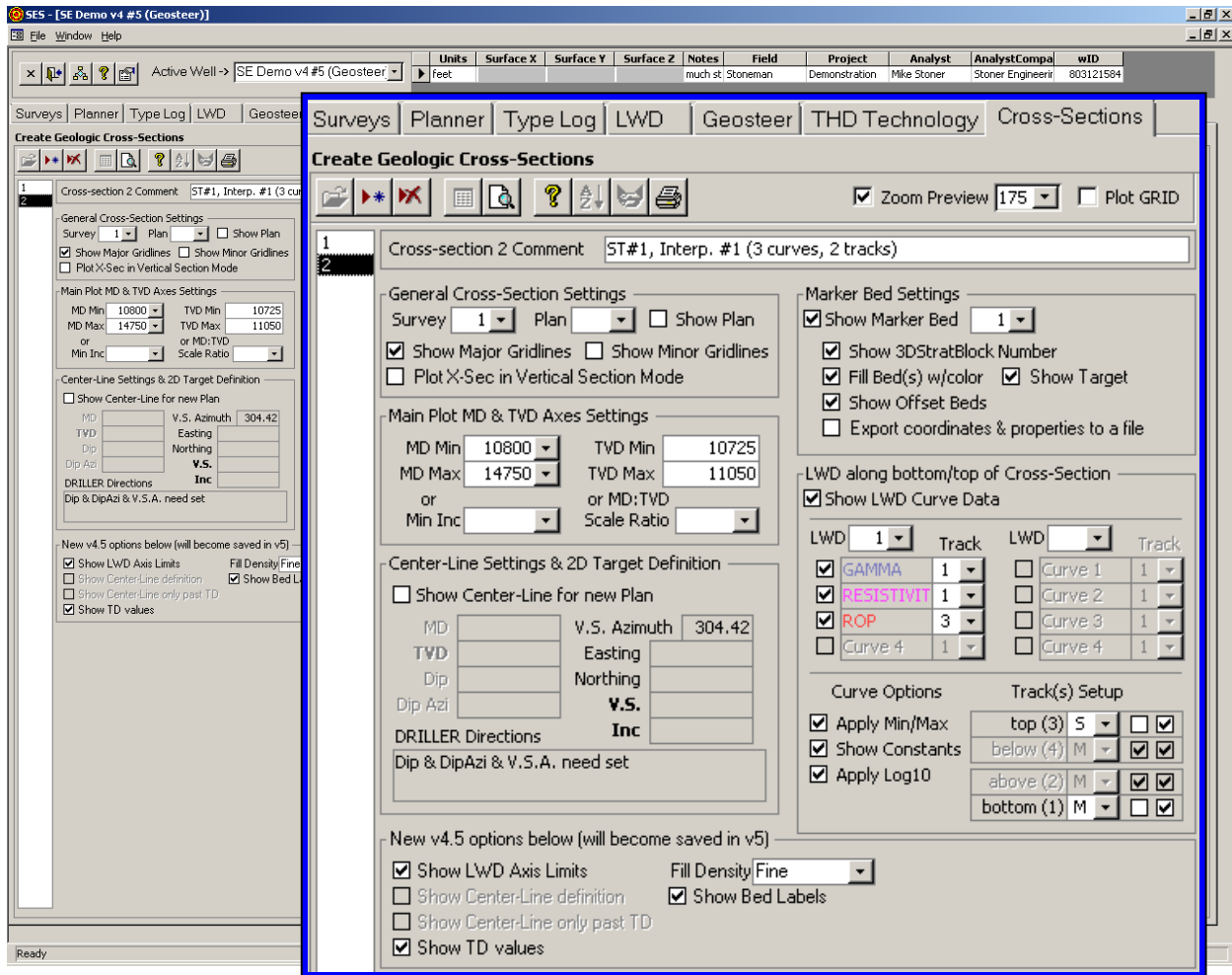
The THD LOGS & DIR. PLOTS screen can be used to:

- 1.) Create a Vertical THD Log and a Horizontal THD Log to be viewed in Excel.
- 2.) Create standard directional plots Vertical Section and Plan View, at the base of the THD Log.
- 3.) Print THD Logs or standard directional plots on the system default printer.
- 4.) Change the approximate scale of either THD Log.
- 5.) Affect the auto-scaling of THD log tracks.
- 6.) Project THD ahead of the last survey station (black line extension on THD Log).
- 7.) Assist directional tool setting adjustment decision making.

## **Critical**

If you need to preserve a THD Log for subsequent reference outside of SES, save it using Excel or print it to PDF.

## SES Screen – CROSS-SECTIONS



### General

Cross-sections plot TVD vs. MD or vs. Vertical Section and present actual well paths with multiple additional options, including 3DStratBlocks, stacked offset layers, planned well path, multiple LWD curve data, and target Center-Line for plan revision.

CROSS-SECTIONS screen can be used to:

- 1.) Configure and display full-well cross-sections for viewing/printing and screen capture for custom mark-up.
- 2.) Plot wellbore intervals of TVD vs. MD or Vertical Section with payzone marker and offset beds.
- 3.) Post payzone marker and offset bed names and control bed color shading density.
- 4.) Plot LWD data along bottom and/or top tracks of the cross-section, with optional constant-value lines and min/max/log settings inherited from LWD setup.

- 5.) Post LWD curve axes min/max limits on respective track.
- 6.) Control track position (4 options), track size (3 options), background, and gridline settings, on which up to eight LWD data curves may be plotted.
- 7.) Plot an associated well plan on the cross-section (requires plan be defined with Planner screen and calculated THD if using default MD mode).
- 8.) Plot associated Grid data (inherited from Survey).
- 9.) Create a CSV text file containing high-resolution export of coordinates and 3DSB properties of payzone top/target/base, for 3<sup>rd</sup> party software. File also includes the directional survey with a payzone in/out flag and related distance-to-boundary values.
- 10.) After clicking 'Print Preview' toolbar button, toggle zoom in/out by clicking the cross-section or change the zoom by right-clicking and changing setting.
- 11.) Manually set TVD axes range for desired data presentation, or set MD:TVD scale ratio to affect cross-section appearance.
- 12.) Define a 'dipping' plane that is plotted as a 'Center-Line' and is used to update the planned path with the directional driller. This plane, intersected by the Vertical Section Azimuth plane, is the Center-Line.
- 13.) Plot the 'Center-Line' well path, through entire interpretation or extrapolated beyond current TD (VS mode required); post 'Center-Line' mathematical definition in directional driller terms.
- 14.) Set default/initial zoom level of cross-section.
- 15.) Post survey MD/Inc/Azi/TVD/VS annotation at TD.

## **Critical**

- 1.) 'Print Preview' toolbar button draws the cross-section on the screen.
- 2.) 'Print' toolbar button prints to the system default printer (including Adobe/PDF). To change your system default printer, use Windows Control Panel.
- 3.) Right-clicking the actual cross-section also provides options such as printing, including system printer selection. If a stray line appears to connect first and last survey stations in a print-out, use 'Print' toolbar button instead.
- 4.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

## **HOT KEYS**

DBL-CLICK - double-click Center-Line Dip Azimuth to flip it 180°

ESC - press the escape key to close a cross-section preview

CTRL - hold down Control key while selecting a different Well from the dropdown box and Surveys/Planner graphics WILL NOT be updated (navigation/dataload is faster without updating Surveys/Planner graphics; click 'Refresh' respectively to update graphics)



- Even if planning to display a cross-section in vertical section mode, it is recommended to first setup the cross-section in MD mode. Typically, the cross-section starting MD will be no shallower than MD\_Start of 3DSB #0. If leading space is desired (i.e., room out-front of the bit that is yet to be drilled and interpreted), set cross-section MD max greater than current survey TD.
- To post a well plan beyond current survey TD, or to extrapolate a Center-Line beyond current survey TD, the cross-section must be generated in vertical-section mode.
- To post a well plan in MD mode, THD must have been calculated for the corresponding survey/plan pair.
- DRILLING TARGET WINDOW. It may be desirable to display “hard” TVD drilling window targets in a cross-section. This may easily be handled in SES by using Grid Data to define such vertical drilling boundary limits. Please see GRIDS screen *Tips* for a full example.
- The “Center-Line Settings & 2D Target Definition” feature of Cross-Sections provides a way to create a revised linear planned well path definition based on the analyst's interpretation that can easily be communicated to the directional drilling service company in real-time operations. The line is determined by the intersection of a 3DStratBlock-type plane and a vertical plane defined by the vertical section azimuth of the associated Survey.
- The easiest way to define and visualize a “Center-Line” is to set MD=0, DipAzi=VerticalSectionAzimuth or its 180° companion, and then calibrate TVD and Dip to get the desired well path placement on the cross-section. ‘Driller Directions’ then reports the Center-Line definition in his language (e.g., inclination). (It isn’t a requirement for the azimuths to be equal...if unequal, SES will determine the *apparent* dip and then the directional driller’s *actual* inclination given his ‘actual’ vertical section azimuth.)
- A Center-Line definition may be posted directly on a cross-section for easy, date/time-stamped communication. If multiple ‘new’ plans need preserved, simply create additional cross-sections and revise as necessary.
- To export a high-resolution (1 ft frequency) table of payzone top/target/base coordinates for general geologic model updating or other analyses (e.g., fracture stimulation response correlation), use Cross-sections ‘Export coordinates & properties to a file’ checkbox and then preview the cross-section to be prompted for a file name.
- If a Center-Line “plan” is to be available elsewhere in SES (THD Technology and or Geosteer/ParamTuner) as a bona fide well plan, then it must be fully defined and calculated using PLANNER. As an example, a Center-Line plan is displayed below,

followed by its equivalent PLANNER well plan input where total vertical section at TD was set to 4300.

Center-Line Settings & 2D Target Definition

☒ Show Center-Line for new Plan

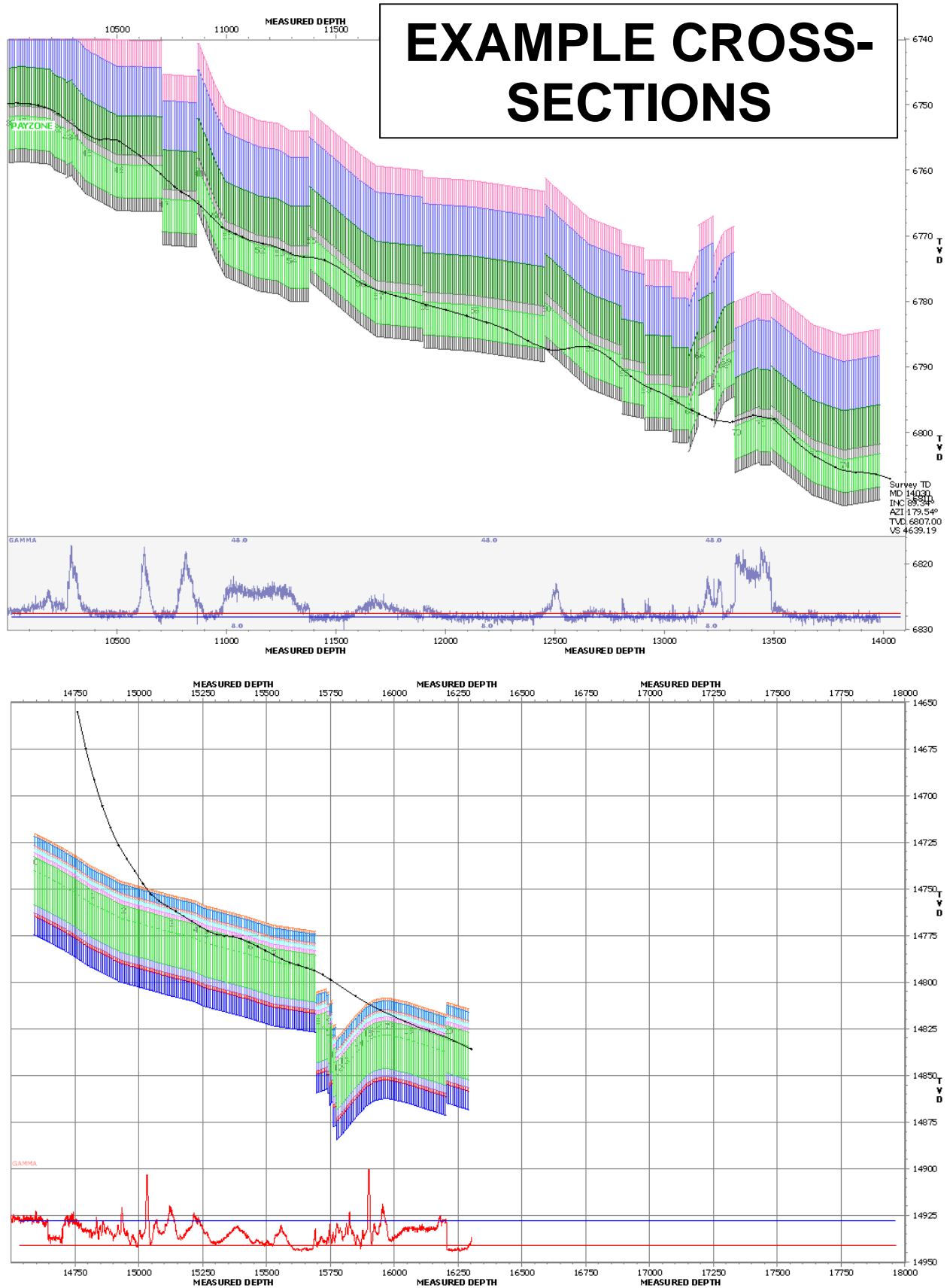
MD	0	V.S. Azimuth	154.808
<b>TVD</b>	14945	Easting	0.000
Dip	1.8	Northing	0.000
Dip Azi	154.808	<b>V.S.</b>	0.000
		<b>Inc</b>	88.200

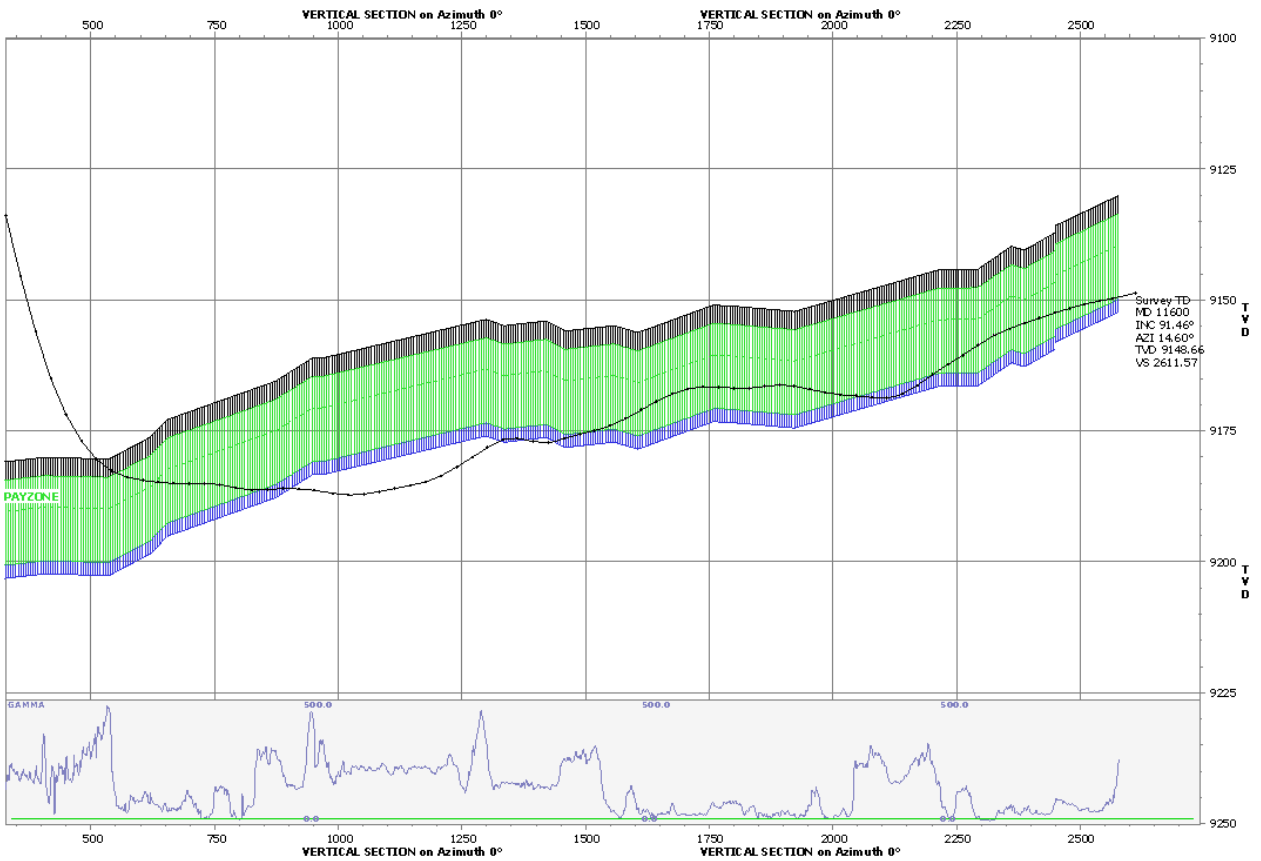
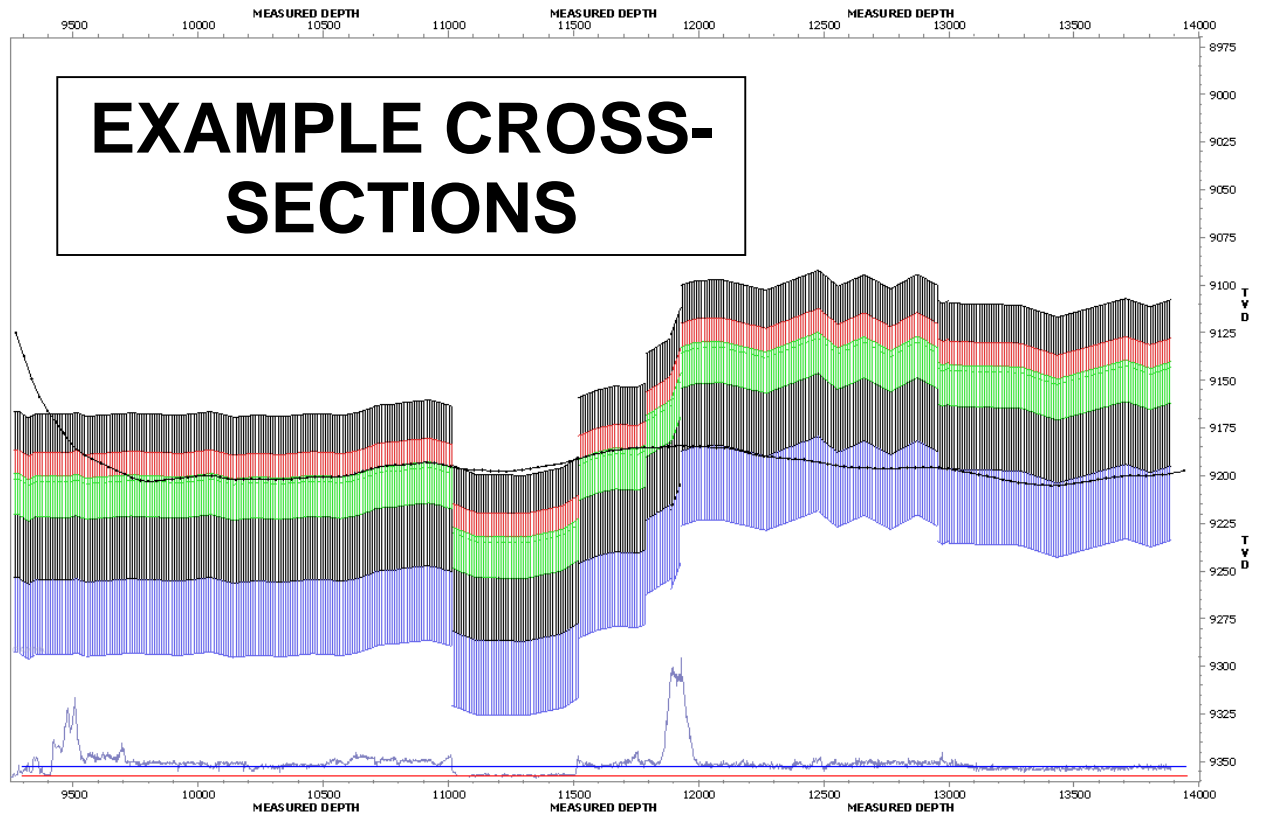
DRILLER Directions

@V.S.=0, Inc=88.20, TVD=14945.00

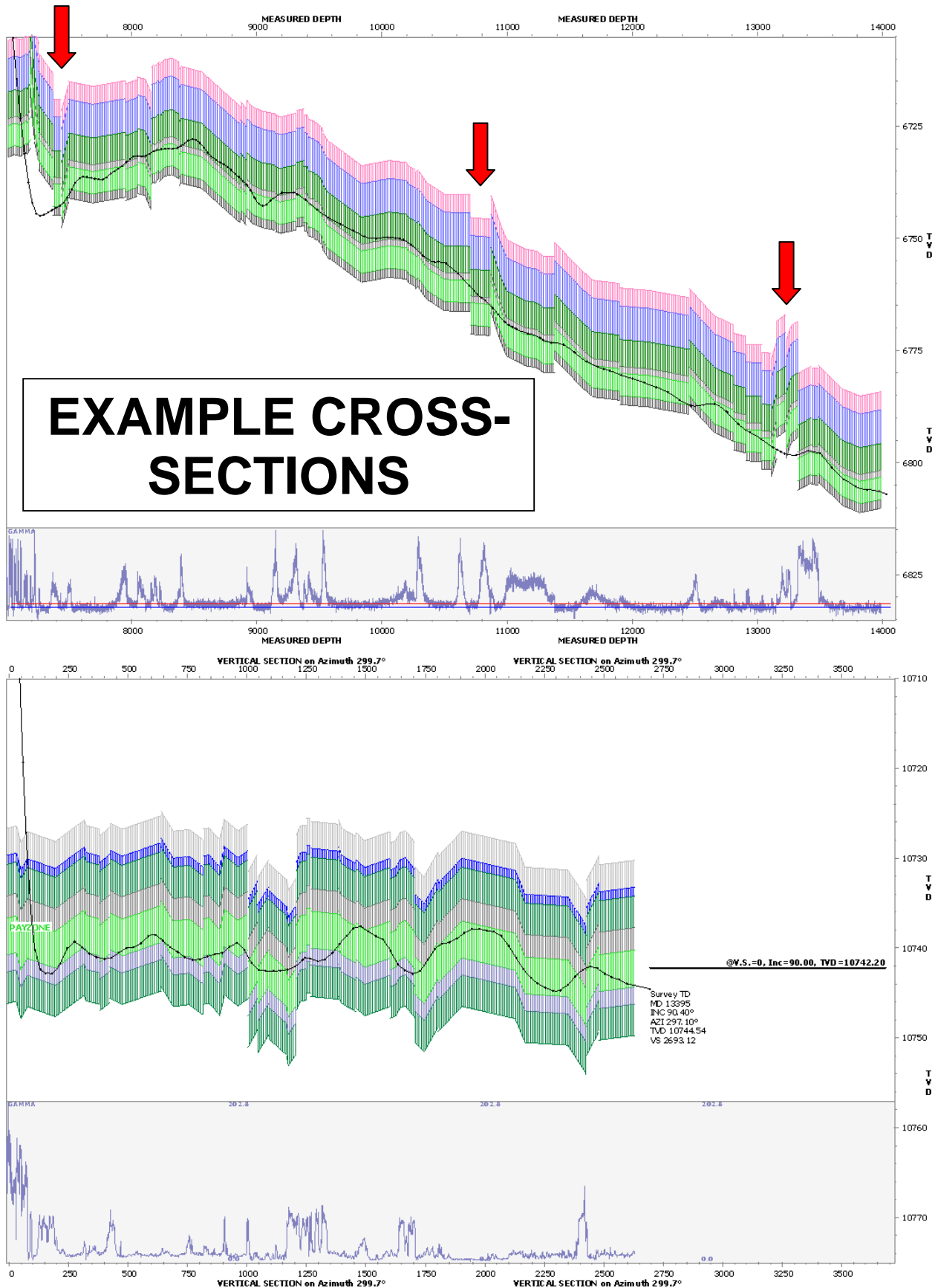
	dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
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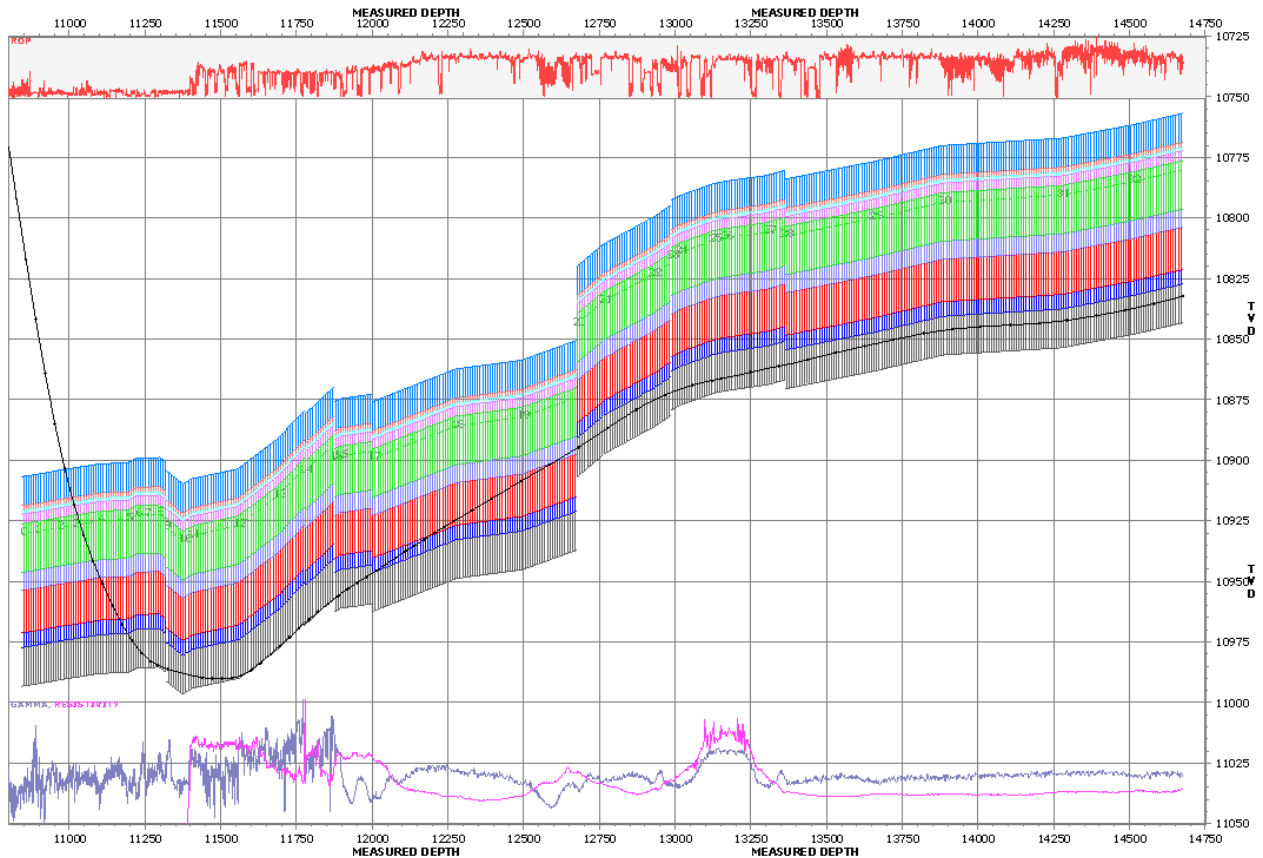
- Planned well path revisions during real-time operations based on SES technical geosteering analysis can number from very few to literally dozens, depending on circumstances and geologic arena.











## Important Final Screen Notes

If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by 'clicking-away.' This is a Microsoft bust (<http://support.microsoft.com/kb/210608/en-us>).

The status bar at the far bottom of the window is used extensively to inform you of various information. If SES is working OR if the mouse cursor shows 'busy', please let processing complete before clicking or typing.

There are several screen tips. Just place your mouse over a control and if available the tip will appear. Clicking into a text box usually provides more information in the status bar.

Several example wells accompany SES. In some cases after example inspection, you may easily answer your question!

Need a feature added to SES? Send FEEDBACK to us now using menu Help, Online/Download, and click 'Email Technical Support.'

# THANKS for using SES!

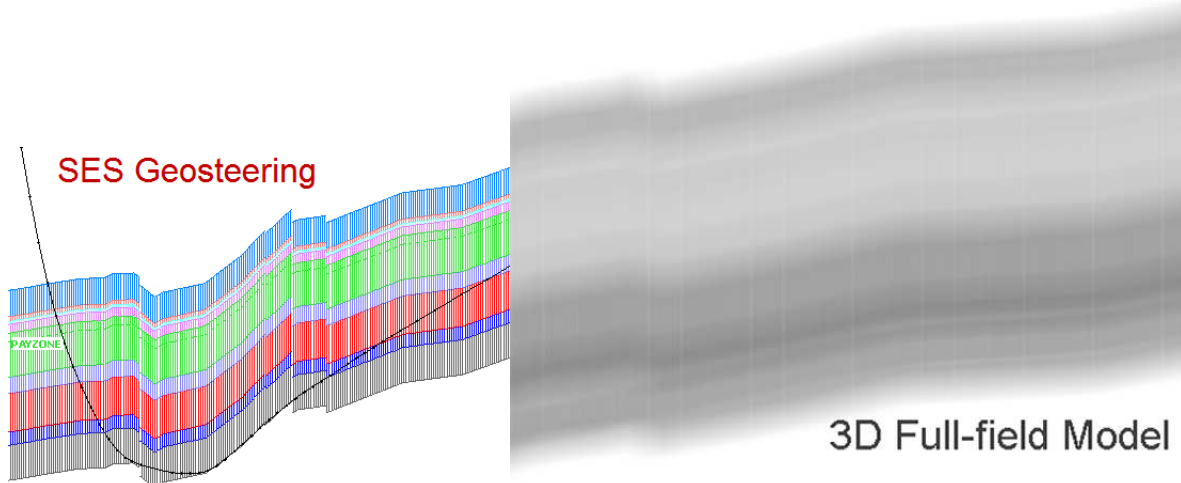
## GEOSTEERING ANALYST'S TRADE SECRETS

This ever-growing section features a variety of critically important topics related to horizontal drilling and technical geosteering. Some content is specific to SES and other is general in nature.

### ***Scale, and ellipsoids of uncertainty***

Think about scale: seismic, vertical well logs, and core. The scale of SES technical geosteering—approaching and within the lateral—is *between vertical well logs and core*. It is not surprising to repeatedly discover structural features and tendencies at near-core scale that are not observable at seismic or 3D full-field model scale.

Seismic analyses and structural contour maps are calibrated with picks from vertical/directional wells. All picks from wells are subject to ellipsoids of uncertainty regarding their true global 3D location, and these uncertainties are blended into one of innumerable gridding processes. The aerially-sparse sampling of control points (picks)—especially within an environment of low regional bed dip—clouds the certainty with which expectations about structural tendencies are true at near-core scale along a horizontal wellbore. A 1° bed dip over one *mile* is only 92 feet of elevation change. How *accurate* are TVD coordinate picks and time-depth conversions at 9000 feet, in the 3D full-field model sense? (Ask your service company's *competitor* for an answer.)



The advantage of SES technical geosteering is that the analysis is disconnected from the absolute world where true 3D accuracy is critical but inherently impractical because of relatively large ellipsoids of uncertainty. The SES ellipsoid sizes are much smaller because the interpretation is calibrated *relative* to local geologic markers deep in the landing; a bad KB or survey errors or a busted contour map from miss-spotted wells or a more complex world than seismic or contouring can honor at near-core scale, all matter not. In this "relative small-scale world" we keep our "eye on the prize" and address the modeling elegance of 3D accuracy later. There is no better estimate of lateral small-scale geologic reality—which horizontal drilling sees—than what evolves from technical geosteering.

## ***Interpreting the Early Landing***

An offset-sourced type log provides *guidance* for signal expectations when drilling into the landing and payzone portion of a horizontal well. However, as different horizons are traversed from the near-vertical to near-horizontal wellbore state, the horizontal well penetration is a unique sample of rock and measured signal. Therefore, we should 'think like a geologist' vice an engineering curve fitter, when interpreting signal coming into the landing.

Consulting/displaying multiple offset type logs may be helpful to communicate the level of thickness and signal character variability to be expected, coming into the landing and within the payzone. Quite often though, the nearest vertical reservoir penetration well log is used as the single type log to guide all expectations. With either case, differences between 'actual' and type log must be handled. In areas of low lateral geologic heterogeneity, there is no issue; but in many plays this luxury is unavailable.

How do geosteering analysts deal with thickness variability between 'evidenced' and type log when *coming into the landing*? The answer depends on multiple possible factors but the solution set of choices includes one or more combinations of the following techniques:

- **"Fake faults"** (regional or zero 3DSB dip is maintained, but what appears as a fault in RSD and cross-section domains is introduced between two adjacent 3DSBs to handle thickness variability while constraining dip variability)
- **"Unrealistic dip"** (some 3DSB dips may be exceedingly different/large in magnitude from what is most likely occurring in reality, however, the relative sense of stratigraphic depth is maintained)
- **"Tie-on"** to deepest matching signal portion at the time/depth (ignore 'poor' uphole RSD mapping differences, with final tie-on at ~100 ft RSD or wellbore inclination ~60°, using regional average dip)

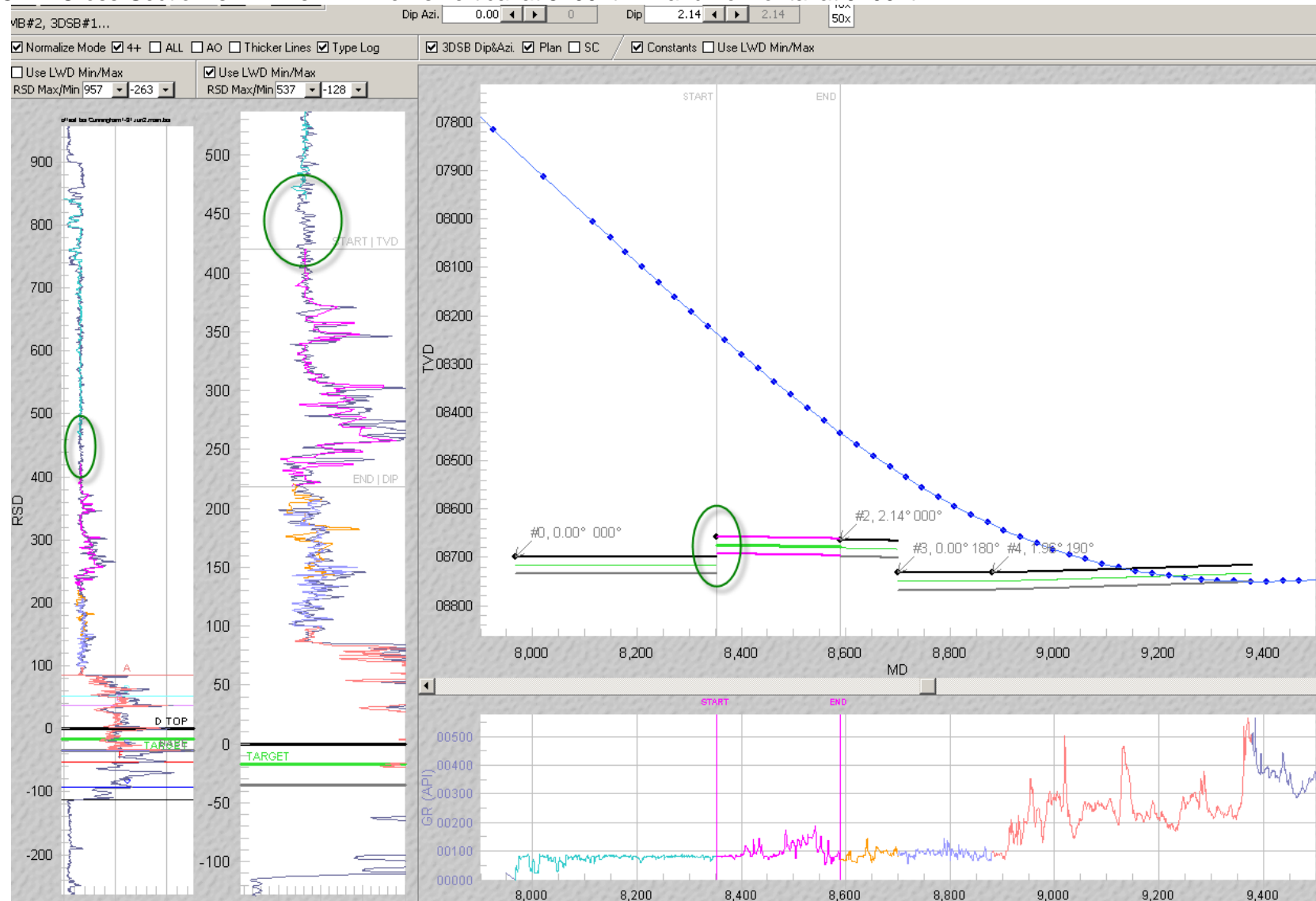
"Tie-on" method may actually be the most accurate and operationally usable technique, but it isn't necessarily the prettiest in the RSD domain. The provided ball-park numbers (~100 ft RSD or wellbore inclination ~60°) depend on wellbore build gradient and geologic variability.

Drawing a definitive conclusion too early (and acting upon it with the directional driller) regarding "where the zone is coming-in" can be counterproductive if significant thickness variability is present. Fortunately—as is often the case—as signal characteristics understanding, local/small-scale structural tendency understanding, and geosteering experience within a particular field all evolve, trained personnel know what is normal and what isn't and how best to act accordingly.

Three *early-landing* interpretation examples follow, to demonstrate the three aforementioned techniques. Please note the interpretations are identical from 8880 ft MD forward! This latter part of the landing phase is most critical and usually more stable. Fortunately, when wellbore inclination becomes significantly high, the very-early-landing estimate becomes effectively trivial and in most cases will purposefully not be displayed in distributed cross-sections.

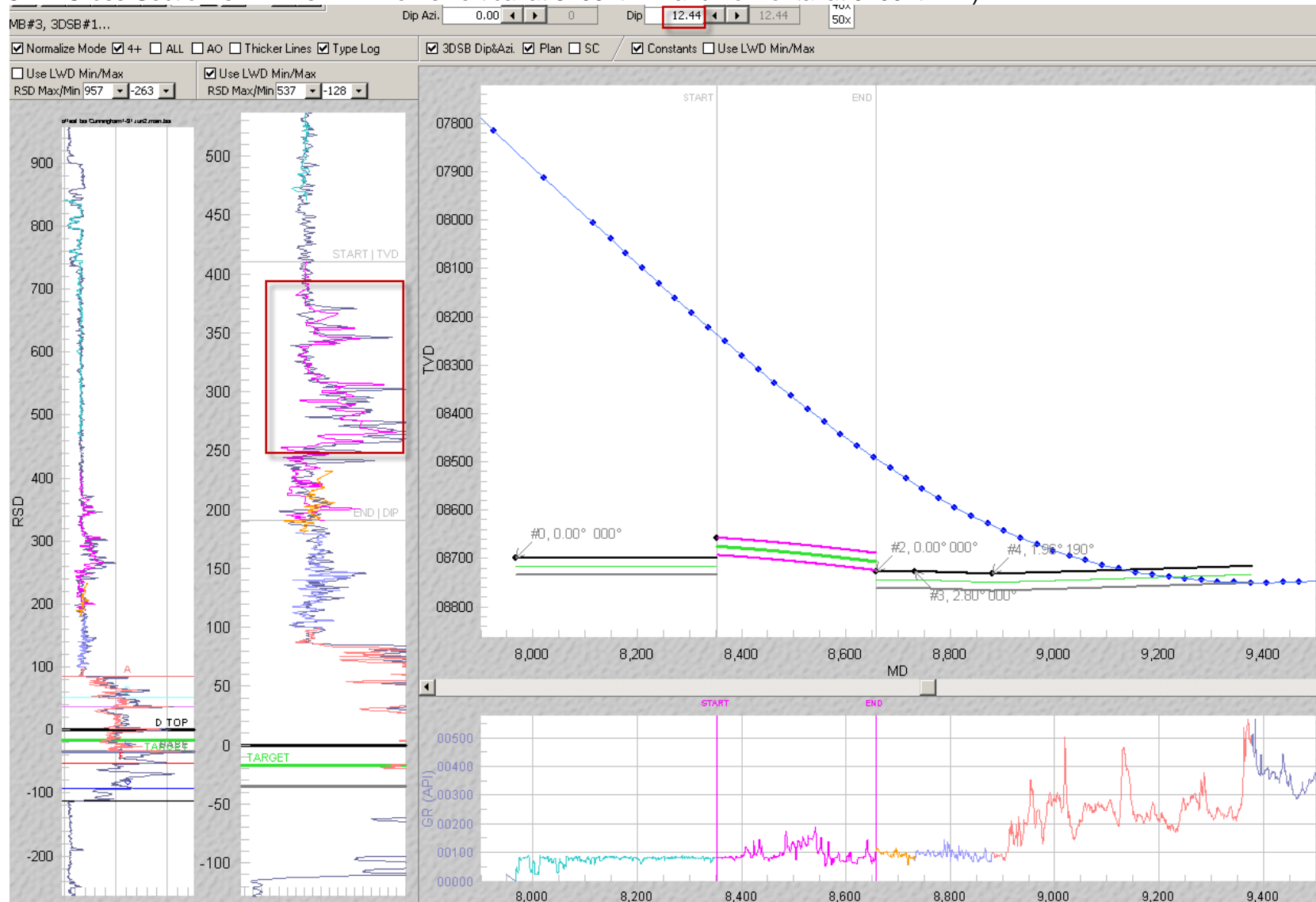
# "Fake Faults" Landing Interpretation Example

NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD.

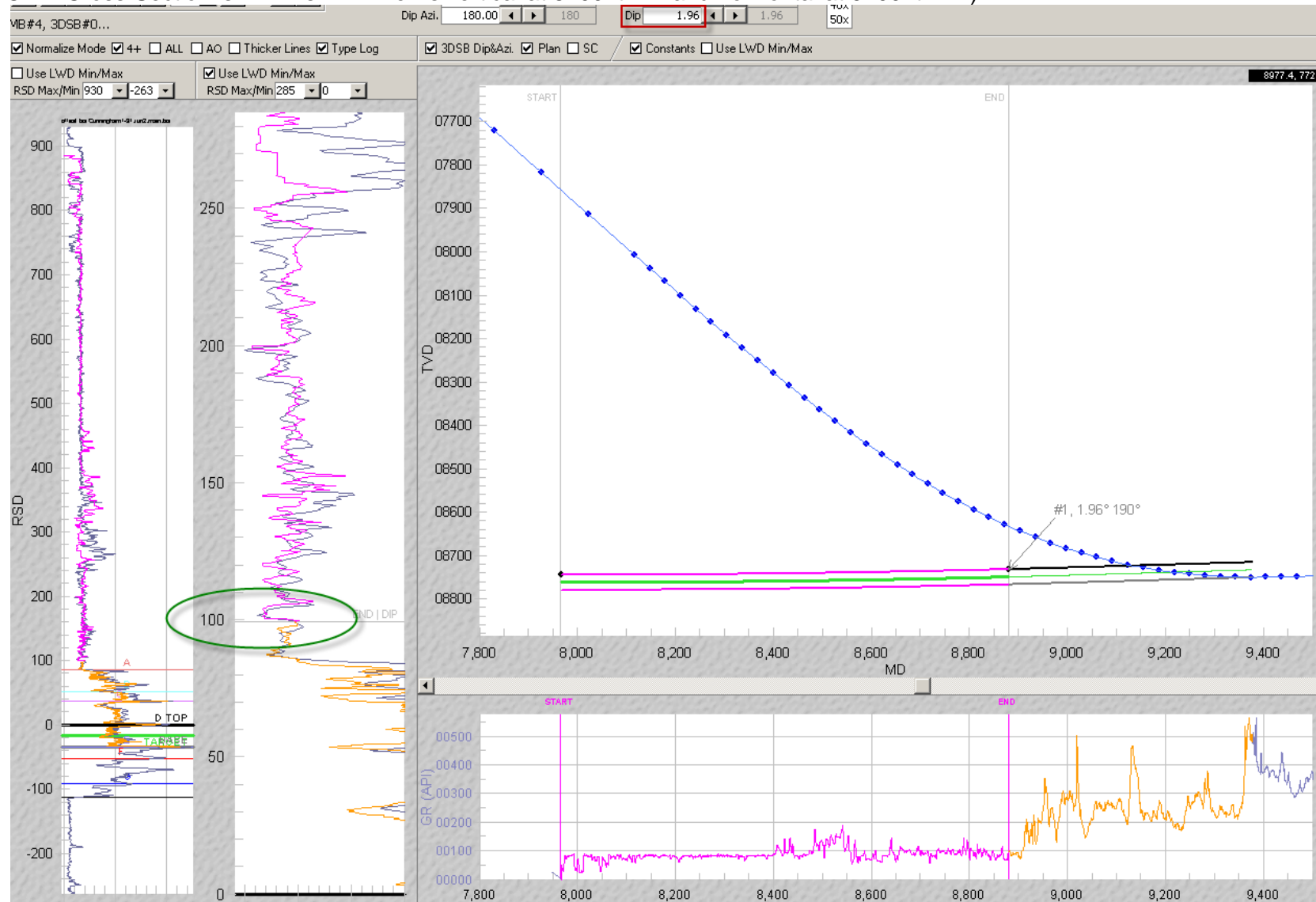


## "Unrealistic Dip" Landing Interpretation Example

(NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD.)



**"Tie-on" Landing Interpretation Example (ignore up-hole differences; tie-on about 100 ft RSD or Wellbore Inclination ~60°)**  
 (NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD.)





## ***Novice Mistakes in Lateral: Over-fitting and Under-fitting***

Making 3DSBs too short can give the analyst a *false* sense of stratigraphic location certainty *and* it can obscure the opportunity to observe the big picture, which provides the sought-after estimate of reality. At the other end of the spectrum, 3DSBs that are too long, with overly-repeated signal retracing in the RSD domain, can mask important structural information that is clearly present but hidden by the smearing of the puzzle pieces.

The rule-of-thumb is to **calibrate a 3DSB to be as long as possible, without burying important signal**. This frequently requires interpretation exploration with temporary interpretation gaps or even overlaps, and fitting 3DSBs of different sizes together. At other times during live drilling operations, complete multiple working hypotheses are necessary to be maintained, until sufficient definitive signal is acquired after drilling and analyzing such wellbore.

## ***'Block of Clarity'—the Calm Feeling of Certainty***

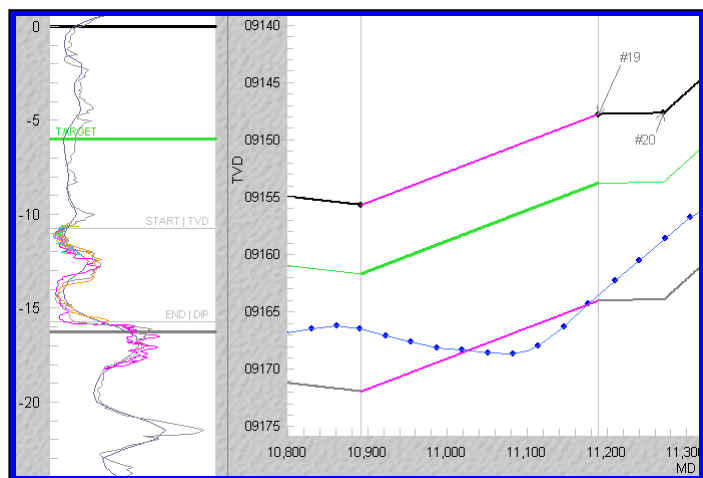
A 'block of clarity' corresponds to a finite interval of wellbore where **stratigraphic location is highly certain based on** great signal calibration matching in the RSD and cross-section domains, as well as the general **passing of all possible "sniff tests"** from all possible data sources. In many cases, a block of clarity will provide guidance to geosteer towards. *In fact, the case could be made that technical geosteering is in-effect the process of identifying as many blocks of clarity as possible, such that when fully 'connected' over the entire wellbore, a close approximation of reality is portrayed.*

Pinpointing reality well, should always precede any planned well paths changes, and **changing the planned well path always includes speculation** about payzone behavior in front of the drill bit (recall '[Scale, and ellipsoids of uncertainty](#)'). Indeed, solidifying with high certainty what has occurred behind the drill bit is step one of technical geosteering. Repeated observations of geologic reality in a given commercial play increase the speculator's odds of making good decisions because geologic reality repeats.

## ***'TraceBack'—a Steerer's Best Friend***

'Traceback' is the name given to a portion of RSD signal mapping that captures stratigraphic down-up or up-down traverse, over a wellbore interval. When correctly acquired, this observation is an excellent indicator of accurate 3DSB dip estimate. With subsequent 3DSB TVD adjustment sometimes necessary, the final result provides a "block of clarity" that serves as a local anchor about which to geosteer (towards and or from).

If true dip in reality is steady and near zero, then traceback will be evidenced with sufficient alternating TVD increase/decrease against a backdrop of sufficient signal character contrast. However, traceback need not necessarily coincide with TVD increase *and* decrease. **Traceback is evidenced by means of definitive changing wellbore stratigraphic**





**location relative to a *chance* intersection of payzone with constant dip.** Therefore, traceback may be evidenced while wellbore TVD is increasing at varying rates (or is decreasing at varying rates) relative to a portion of geologic reality that happens to truly possess constant dip over the same interval. The heart of the landing often provides an opportunity to observe traceback.

### ***Location Certainty Changes along the Wellbore***

Again, stratigraphic location certainty changes along the horizontal wellbore. In other words, the confidence in the interpretation of *some* 3DStratBlocks will be much greater than others. This is normal. For example, the signal signature when 'scraping' an offset bed may be more recognizable than drilling somewhere in the 'middle' of a clean or dirty gamma ray portion of the payzone. A wellbore interval of high confidence in stratigraphic location is called a "block of clarity."

SES by design is setup to be able to isolate/find those portions of wellbore where interpretation confidence is high. In practice, a MD 'gap' may be introduced as the user changes MD\_Start (or MD\_End of an 'internal' 3DSB) of a 3DSB and focuses on a portion of the well-recognized signal. Subsequently, the gap is typically filled-in with a 3DSB and calibrated with "Occam's razor" in mind...the simplest geologic interpretation is best.

### ***Payzone Properties: Variable Dip vs. Variable Thickness***

From drilling a *horizontal* well and analyzing LWD signal such as gamma ray data, payzone properties true stratigraphic thickness AND true bed dip (and direction) are mathematically indeterminate, i.e., their quantities are not known and cannot for which be solved. Therefore, we assume one (thickness) and calibrate/solve-for the other (dip) because this makes the most sense based on expected payzone structural variability and because this process yields a solution—albeit non-unique—sufficient to make definitive, confident, and defensible decisions.

### ***3DStratBlock Dip Direction Azimuth...What should I use?***

A set 3DSB dip and dip direction azimuth (along with control point coordinates) define a unique 3D plane that is an estimate of the payzone location and therefore technically is completely independent of wellbore azimuth. If regional dip direction azimuth is confidently known over the horizontal well area, then regional dip direction azimuth (or its 180° counterpart) may be applied while geosteering with ParamTuner.

An alternative option is to use 'current' wellbore azimuth (or its 180° counterpart). In this case, the 3DSB dip being calibrated is of an apparent nature but the resulting picture is effectively the same. In ParamTuner, the survey callout ('SC' checkbox) feature is helpful in order to quickly recall wellbore azimuth without returning to Surveys screen. This method is helpful when drilling from a pad or drilling a 3D well (significant turn) in a low regional dip environment (e.g., less than five degrees).

A third option is to strictly use *vertical section azimuth* (or its 180° counterpart). In this case, the 3DSB dip being calibrated is of an apparent (vice true) nature. This is the *most common practice* in areas of low regional dip and a 2D well (no appreciable wellbore turn).

Because of the non-unique nature of coupled dip and dip direction azimuth, and the RSD calculation, different pairs of dip/dip\_azimuth may produce an identical mapping onto the type log and thus an identical interpretation of where the payzone is located, over the respective

finite interval of wellbore. This is a "good thing" because if 3DSB dip azimuth is different than true dip direction azimuth, the same interpretation can be found as if this were not the case (obviously the calibrated dip would not equal true dip). The 3DSB concept is superior to vertical section projection analyses because in practice the ability of transforming all related data to use wellbore-interval-dependent vertical section azimuth is entirely impractical with current industry protocols.

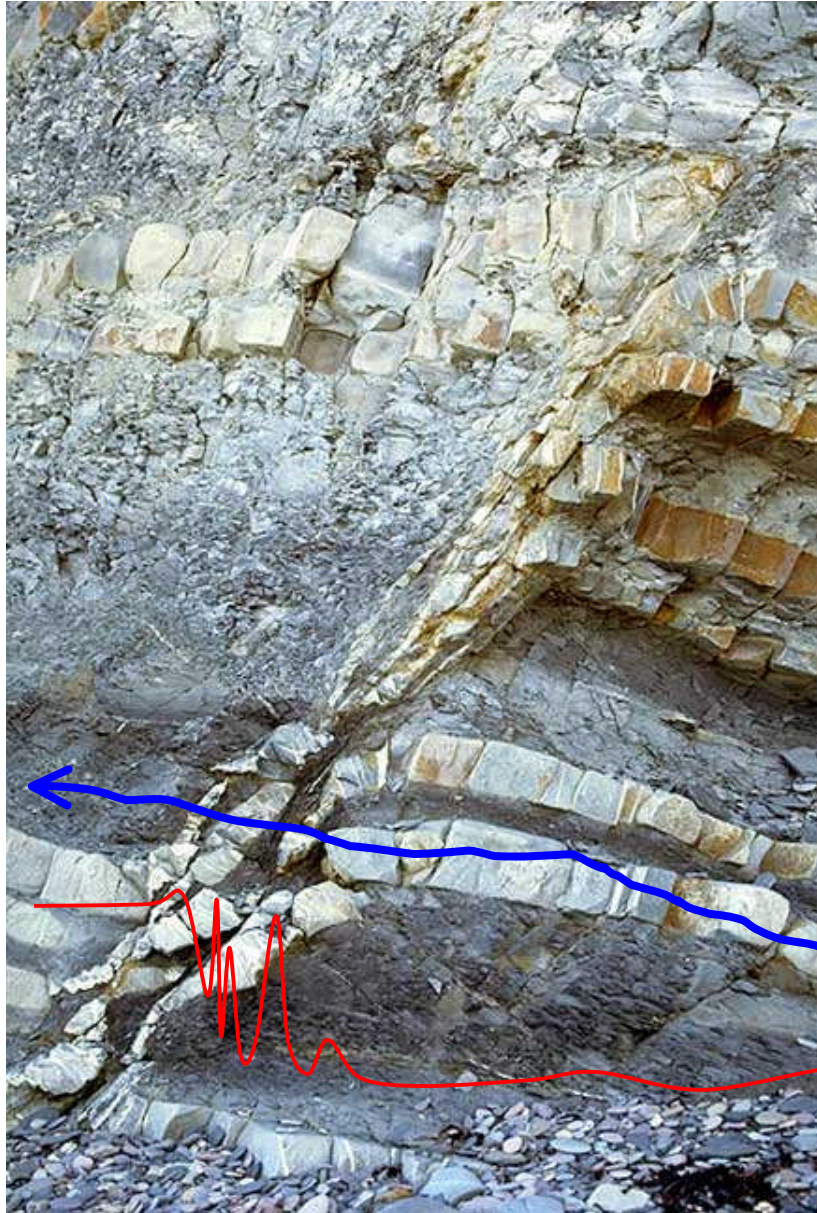
### ***Don't Get 'Crazy' with Dip too Early!***

Until significant wellbore inclination is attained (e.g., perhaps greater than 45 degrees, but there is no magic number), 3DStratBlock calibration should primarily be based on control point TVD adjustments, with 3DSB dip set to zero or some regional average value from a contour map. The *empirical manifestation of "too early" is an overly sensitive and or erratic response to dip adjustments* made via dragging the 'End | Dip' horizontal line on the inner/right RSD track on ParamTuner screen. The reason for this behavior is that the mathematics of the technology don't apply to near-vertical wellbores, and viewing the wellbore as TVD vs MD (vice vertical section) can mask the present vertical state of the wellbore. (See [Interpreting the Early Landing](#))

## FAULT OUTCROP PICTURES

We all know the cliché about pictures and words. Enough said.

### Jurassic Limestone-Shale Sequence (1)



Imagine  
the  
gamma  
signal.

Photograph by Grant M. Skerlec, <http://www.sealsinternational.com/>



## Jurassic Limestone-Shale Sequence (2)



Photograph by Grant M. Skerlec, <http://www.sealsinternational.com/>

## Faults (1)

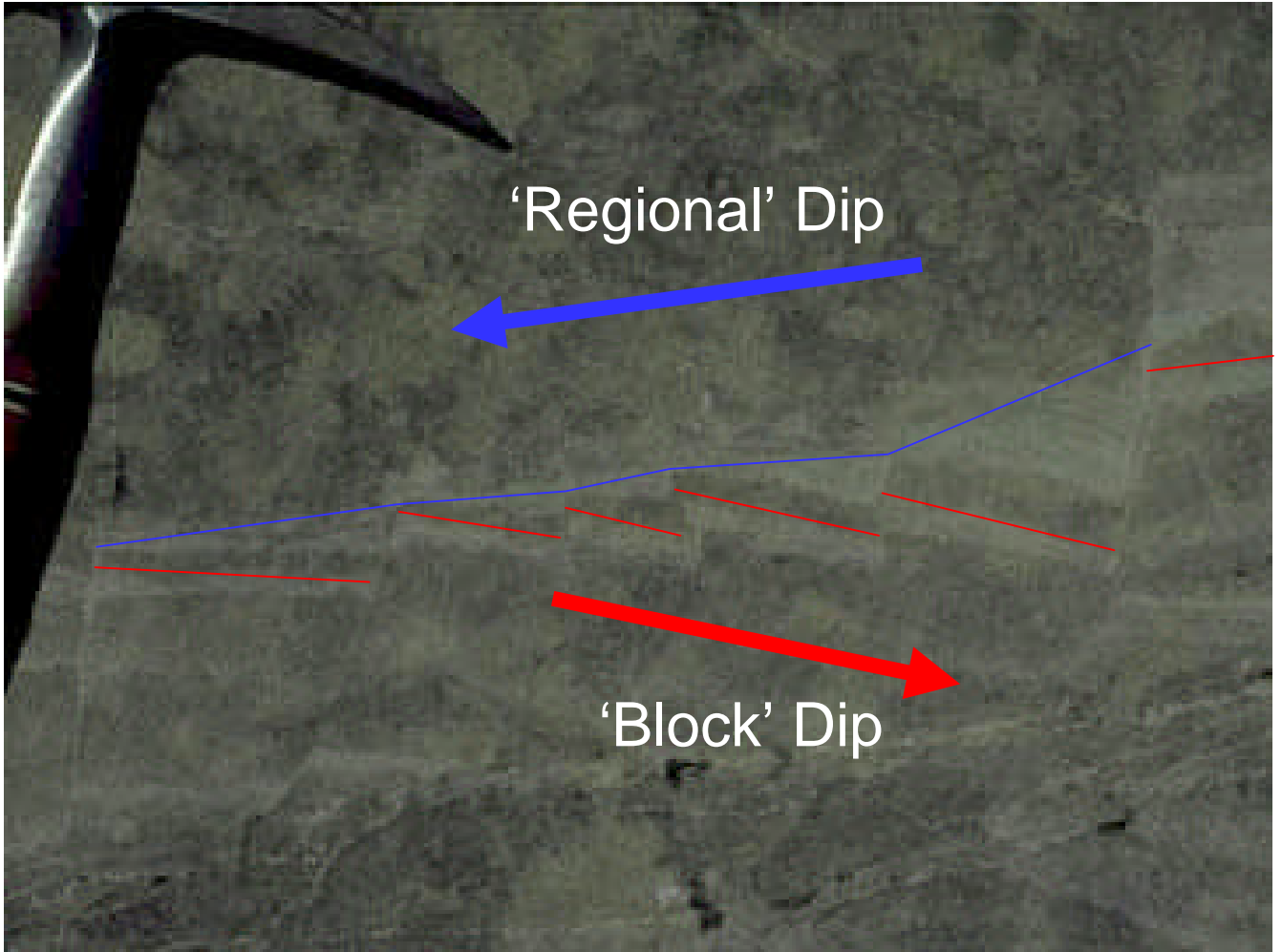
Imagine  
the  
gamma  
signal.



<http://www.northseattle.edu/>

## Faults (2)

'Local' can be opposite 'Regional.'

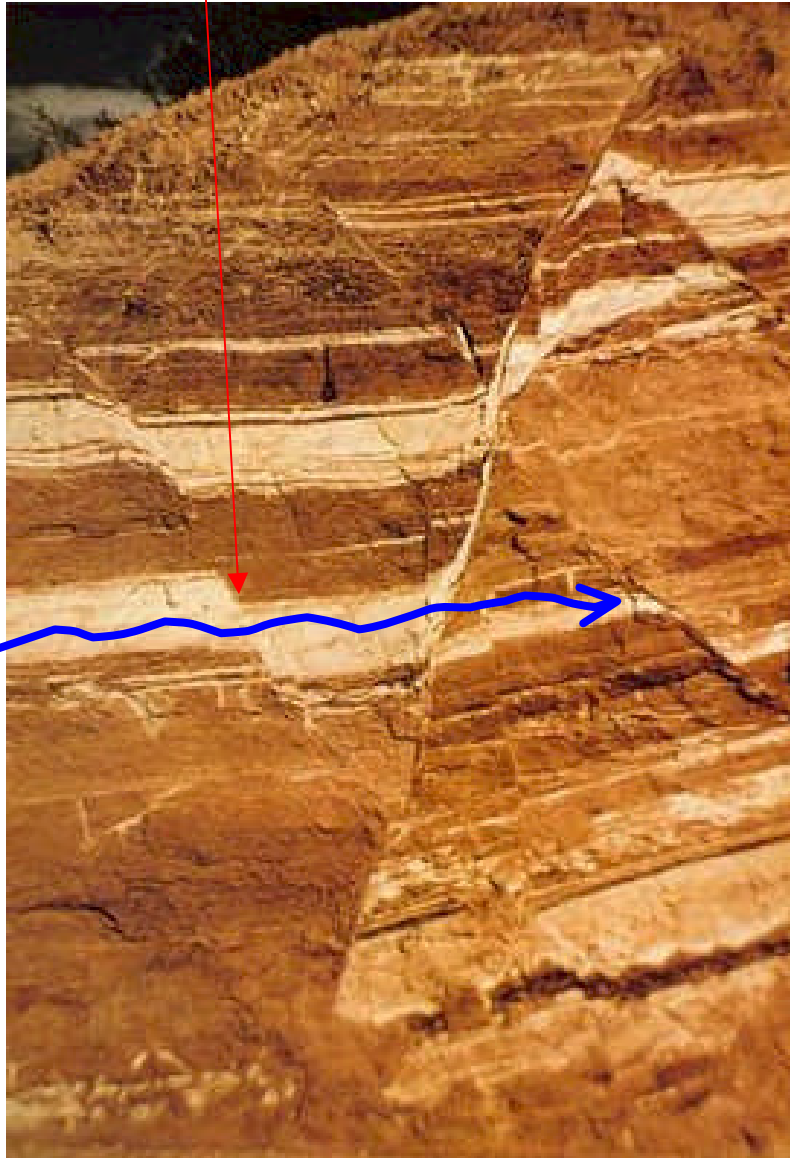


<http://www.glossary.oilfield.slb.com/DisplayImage.cfm?ID=139>

### Faults (3)

First fault would go undetected.

Imagine  
the  
gamma  
signal.



<http://www.glossary.oilfield.slb.com/DisplayImage.cfm?ID=75>



#### Faults (4)

“Photograph of faulting in Cretaceous strata southwest of Marmarth, North Dakota. Sectional view of the fault trace is exposed on the side of the bluff (between arrows).”



<http://www.state.nd.us/ndgs/Newsletter/NL01W/PDF/smlsciW01.pdf>



## Faults (5)

One "brave" geologist, or too close to the details?



<http://www.uib.no/people/nglhe/StructModulesTextbook/Faults03.swf>

**THANKS for using SES!**