Developed by NITEC LLC under a Federal Assistance Agreement with the U.S. Department of Energy/National Energy Technology Laboratory

COZVIEW/COZSIM USER MANUAL

COZView/COZSim integrates an easy to use user interface for pre and post processing of the reservoir simulation results, a technically rigorous 3D, 3-phase, 4-component, extended black oil simulator, and a net present value (NPV) optimization functionality for evaluation of CO2-EOR in oil reservoirs.

Last Update 02/22/2013

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1 COZView/COZSim Introduction

COZView/COZSim was developed by NITEC LLC under a Federal Assistance Agreement with the U.S. Department of Energy/National Energy Technology Laboratory. The software was developed during 2011 and 2012.

COZView/COZSim was developed with the goal that

1) a technically respectable field-wide CO2-EOR feasibility analysis can be accomplished in less than one month, and
2) such an analysis can be affordable to small and mid-size companies.

From a technical perspective, the objective was to develop a credible CO2-EOR software solution that includes:

1) the necessary physics that is lacking in simplistic solutions,
2) ease of use through present-day graphical user interface technologies,
3) sophisticated numerical algorithms and procedures for field development planning, and
4) global optimization technology to maximize the net present value of the CO2-EOR application.

The software integrates an easy to use user interface for pre and post processing of the reservoir simulation results, a technically rigorous 3D, 3-phase, 4-component, extended black oil simulator, and a net present value (NPV) optimization functionality for evaluation of CO2-EOR in oil reservoirs.

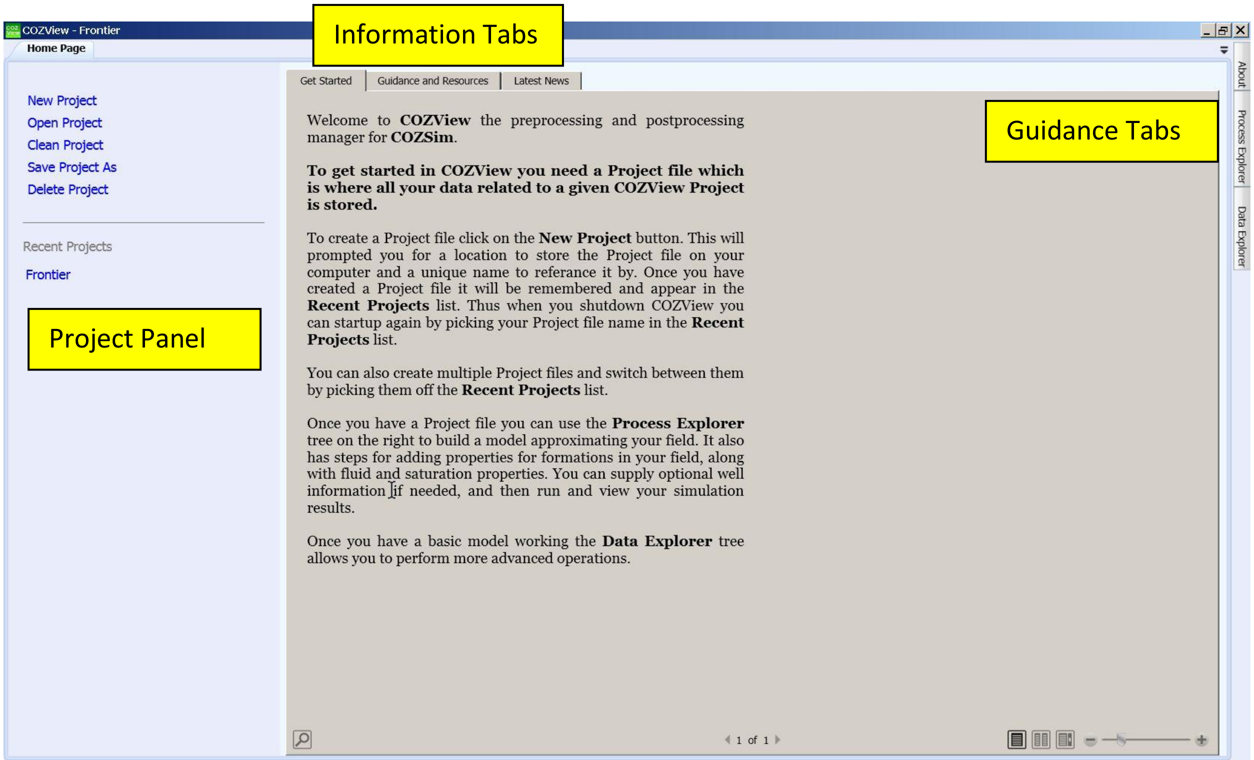
COZView attempts to simplify the simulation model development process while emulating the actual reservoir under evaluation as closely as possible. A white paper will be available on numerical aspects of COZSim.

1.1 Home Page

The Home page consists of a Project panel on the left, Information Tabs at the top and Guidance Tabs on the right.

The Information Tabs – *Get Started, Guidance and Resources* and *Latest News* provide useful information to the user.

The Guidance Tabs – *Data Explorer, Process Explorer,* and *About* are the key operational tabs for the software. A Single-click on these tabs will display a menu of operations.



The Project panel provides the user the opportunity to manage old and new projects. Old projects may be archived in the COZView project folder and/or identified under **Recent Projects**. A Single-click will activate any of the items in the Project Panel.

The user should select *New Project* upon first use of COZView. The user will be asked to enter a project name. A Project Name cannot contain any blank spaces. The name of the new active project will appear in the upper left as **COZView-*Project Name.***

The user will not be allowed to enter COZView without an activated project.

1.2 Project Management

Project management for **COZView** is handled from the Home Page. A number of options are available to the user.

- New Project

  Allows the user to initiate a new project from scratch.

- Open Project

  Allows the user to open a previously created project that is in the **COZView** project directory, but is not in the Recent Project list.

- Clean Project

Allows the user to retain all project input data, but remove all simulation result files from the current project.

- Save Project As

  Allows the user to create a duplicate of the active project under a new project name.

- Delete Project

  Allows the user to remove all input and simulation result files associated with the project from the COZView directory.

- Recent Projects

  Allows the user to select a recent project as the active project. A right-click on the project name will allow the user to remove the project from the Recent Projects list. This does not impact any of the input or simulation result files in the COZView directory.

1.3 Guidance Tabs

The Guidance Tabs are the *Process Explorer* and *Data Explorer*. The *Process Explorer* is intended as the primary guidance tool for most users. It will systematically guide the user through the required steps to build a simulation model that is representative of the actual reservoir to be investigated and to make a simulation prediction run or optimization runs.

The *Data Explorer* tab provides additional functionalities for the simulation model run submission and data loading which are typically not needed by the user.

1.4 About

The *About* Tab provides version numbers and release dates for **COZView** and the integrated simulator **COZSim**. These are important should the need arise to communicate with the software developers concerning apparent software bugs of the software version being used.

2 Guidance and Resources

The software has been designed to make the building of the representative simulation model and viewing the simulation results as easy as possible. Parameter default values and internal correlation to develop certain data will be used when appropriate.

The user is encouraged to utilize the Process Explorer menus whenever possible as these have been designed to streamline the process.

2.1 Data Requirements

The software has been designed with the primary intent that the user will build a representative simulation model of their reservoir and run user designed CO2-EOR prediction cases.

A list of required and optional data that the user will need to supply during the model building process is provided in the Data List chart at the end of this document. The user may find it useful to print this list and gather the relevant data before starting the data input process in **COZView**.

2.2 Mouse Operations

A number of unique, user friendly features have been incorporated in **COZView** which are controlled by the mouse. These mouse operations are documented below as a guide to the user.

Left-Click

Single – selects

Right-Click

Displays a menu

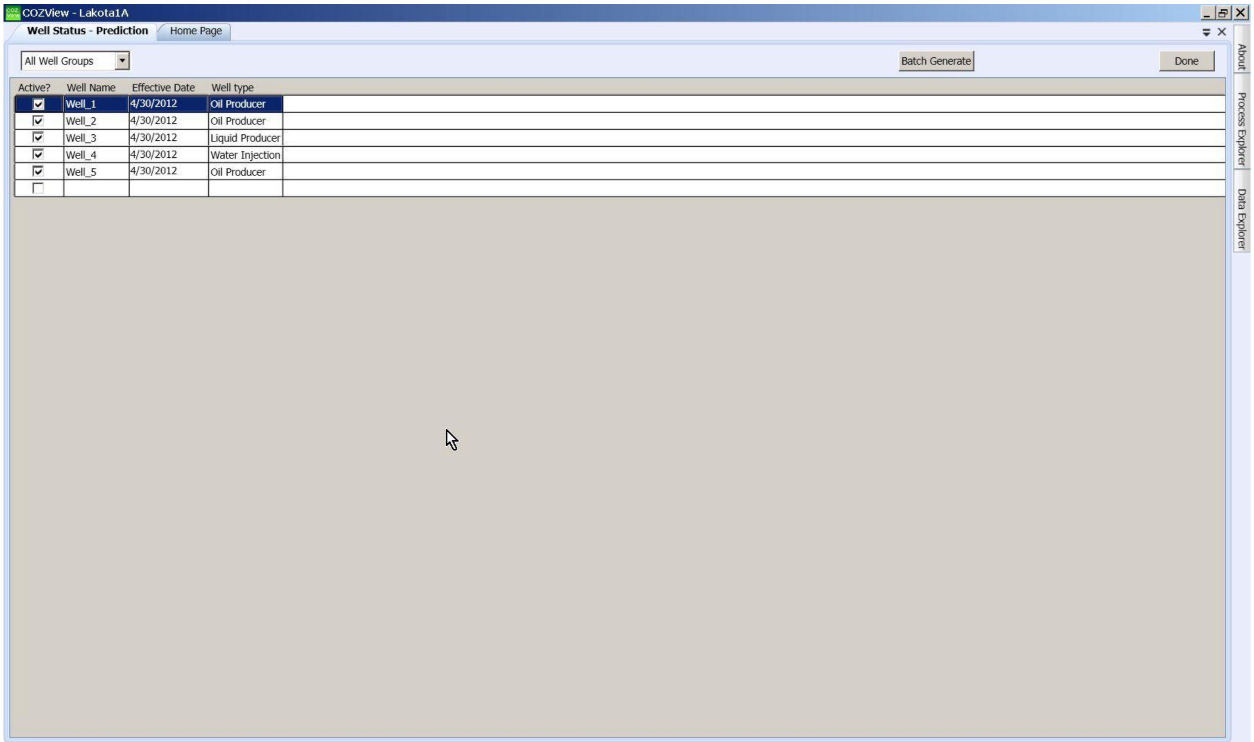
Lists /Tables

Highlight a range of items

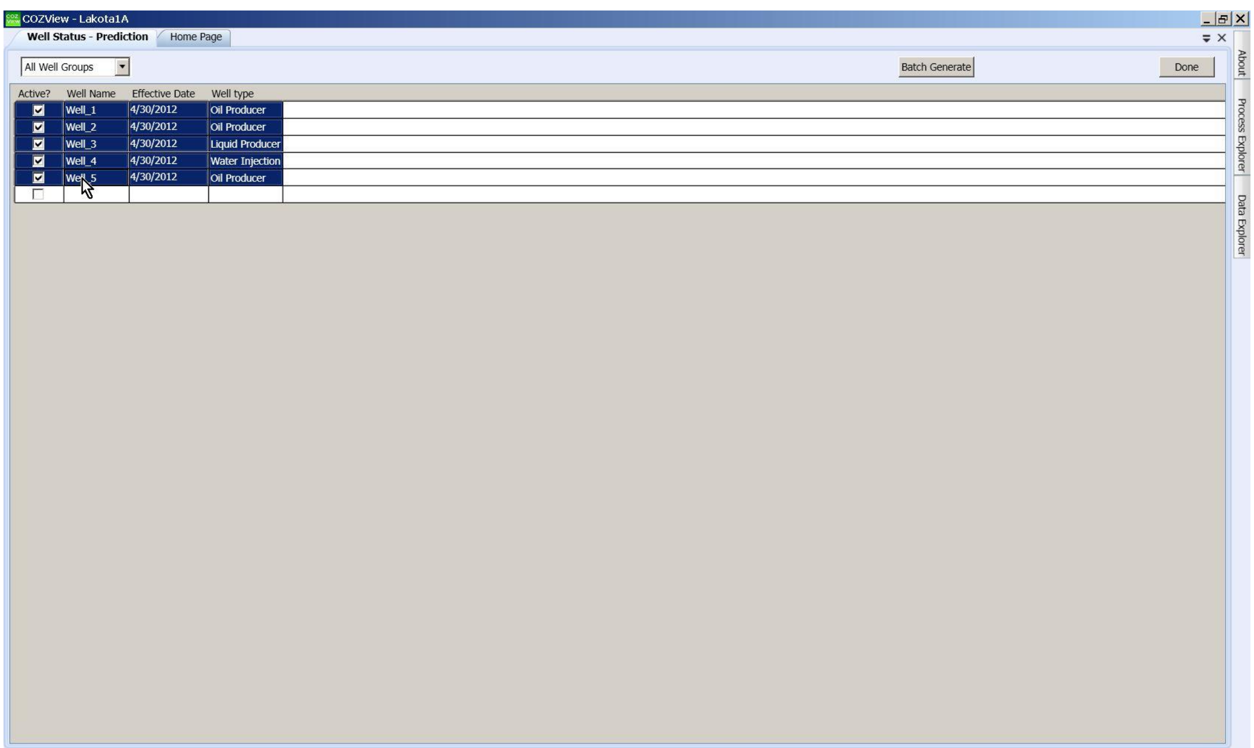
Select and highlight (left-click) followed by SHIFT+ select and highlight (left-click) further down the list of items. This will highlight the range selected.

EXAMPLE:

Select and highlight (left-click)



SHIFT+ select and highlight (left-click)



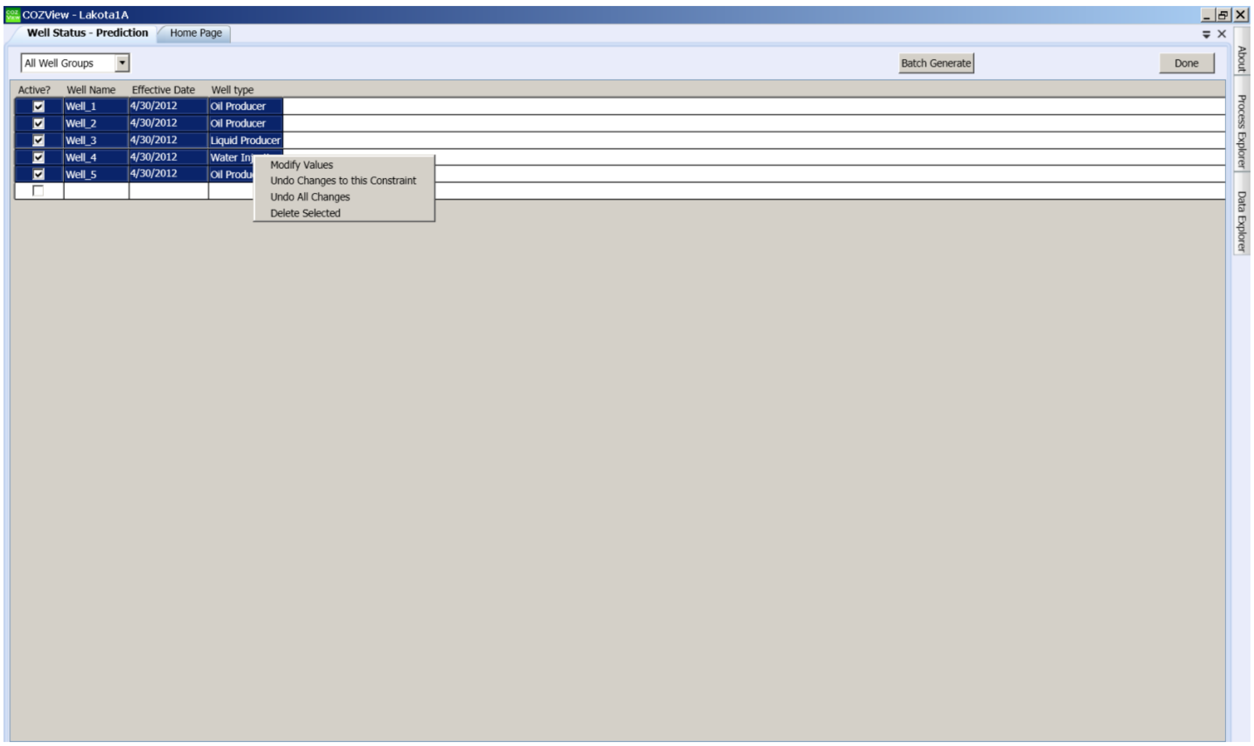
A right-click in a column of the highlighted data will display a menu

Modify Values – provides a menu of choices for the selected column; all rows changed to the selected choice

Undo Changes to this constraint - cancels changes made to the selected column for all rows

Undo All Changes – cancels all changes since last Save

Delete Selected – deletes all highlighted rows



Highlighting

CTRL + Select and drag will highlight the "drag" range. CTRL also allows multiple selection of individual items. Each CTRL click adds to the current selection,

Delete a range of items

Highlight as noted above and right-click for menu to delete or select Delete key

Tabs

Left-click to select.

Right-click on Menu tabs across top of screen for menu to close tab or float tab

3D Operations

Pan

Right-click and drag

Zoom

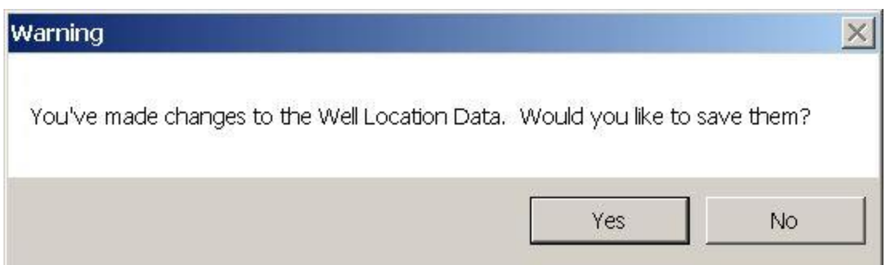
Left-click and drag

Rotate

Center-click and drag

2.3 Saving Data

The saving of data input by the user does not occur automatically in **COZView**. There are three buttons used in the various windows that cause the data to be saved. These are **Save and Continue**, **Save and Quit** and **Done**. **Save and Continue** saves the data and does not close the window that is in use. **Save and Quit** saves the data and returns to the prior window. **Done** saves the data and returns to the prior window also. Any of these selections should result in a message similar to the one below. The user should respond accordingly.



In some cases the user my wish to make a copy of the current project, such that the duplicate project can be altered in some minor manner. The user should use **Save Project As** on the **Home Page** window.

2.4 Screen Refreshing

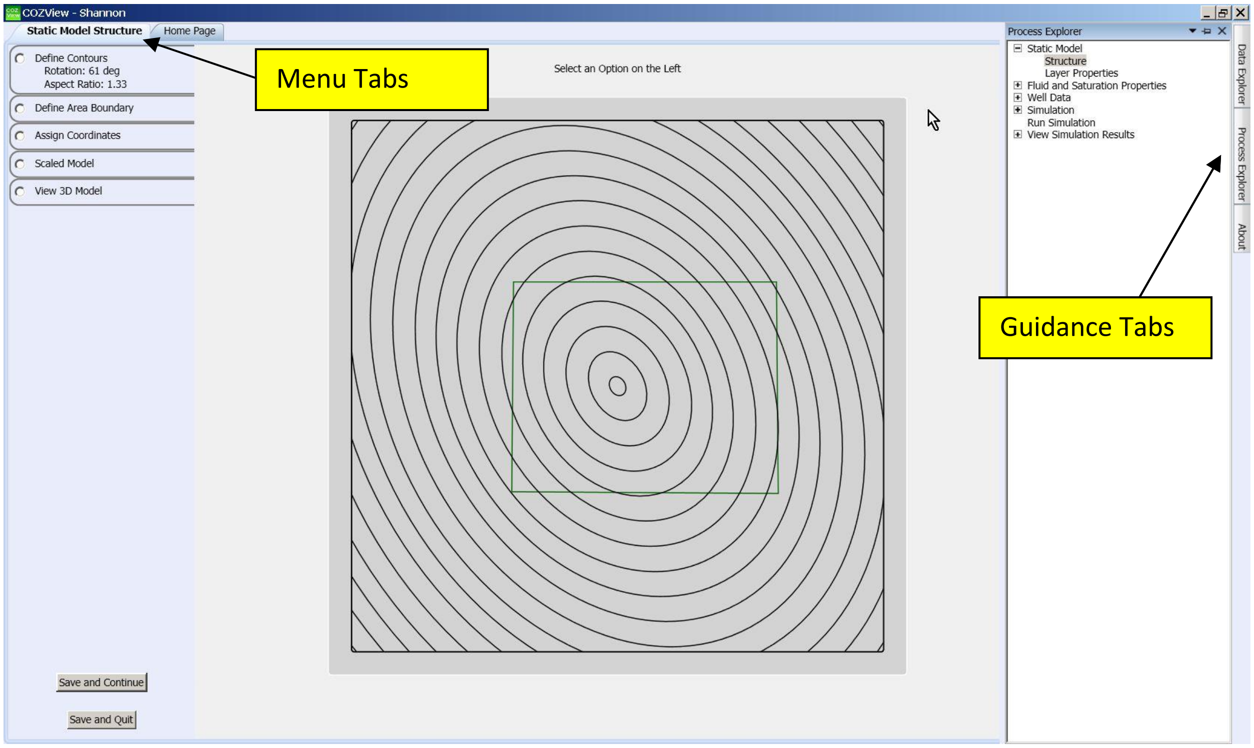
Throughout **COZView** data provided in one screen may be related to data on another screen. In many cases a particular menu tab may not be automatically refreshed when a data change impacting that screen is made elsewhere even though the data has been saved by the user using the **Save** or **Done** buttons.

To refresh an affected screen, close the menu tab at the top of the window for that screen and reopen the screen from the *Process Explorer* menu area.

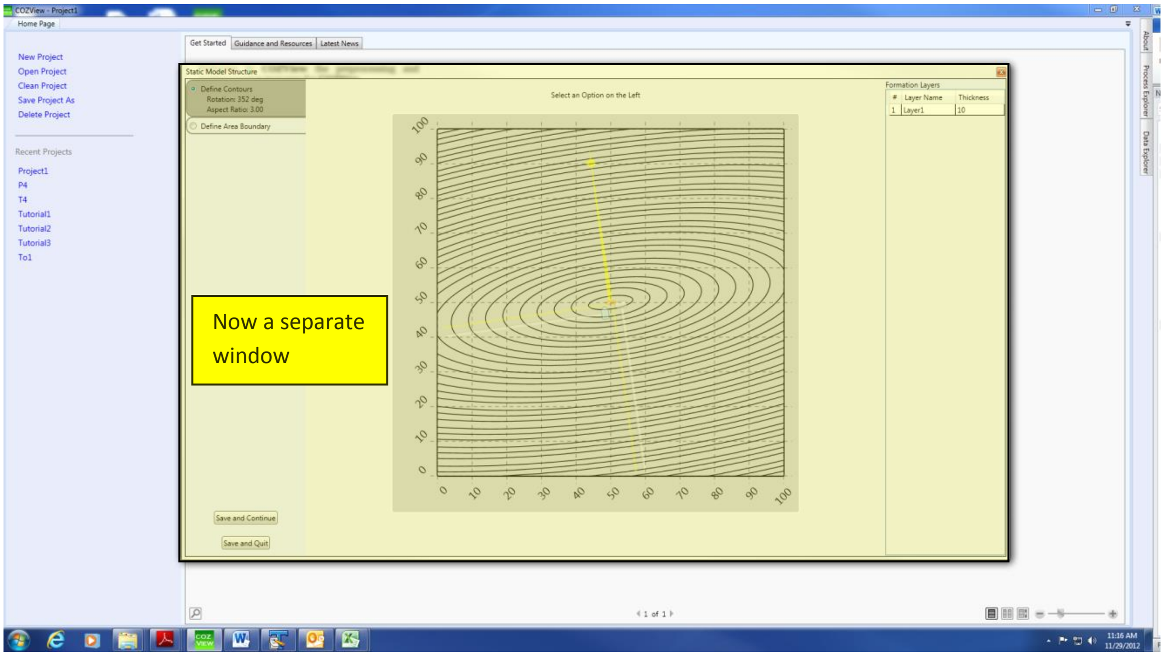
2.5 Guidance and Menu Tabs

The Guidance tabs are the vertical tabs on the right side of the **COZView** window. The Menu tabs are the horizontal tabs across the top of the **COZView** window.

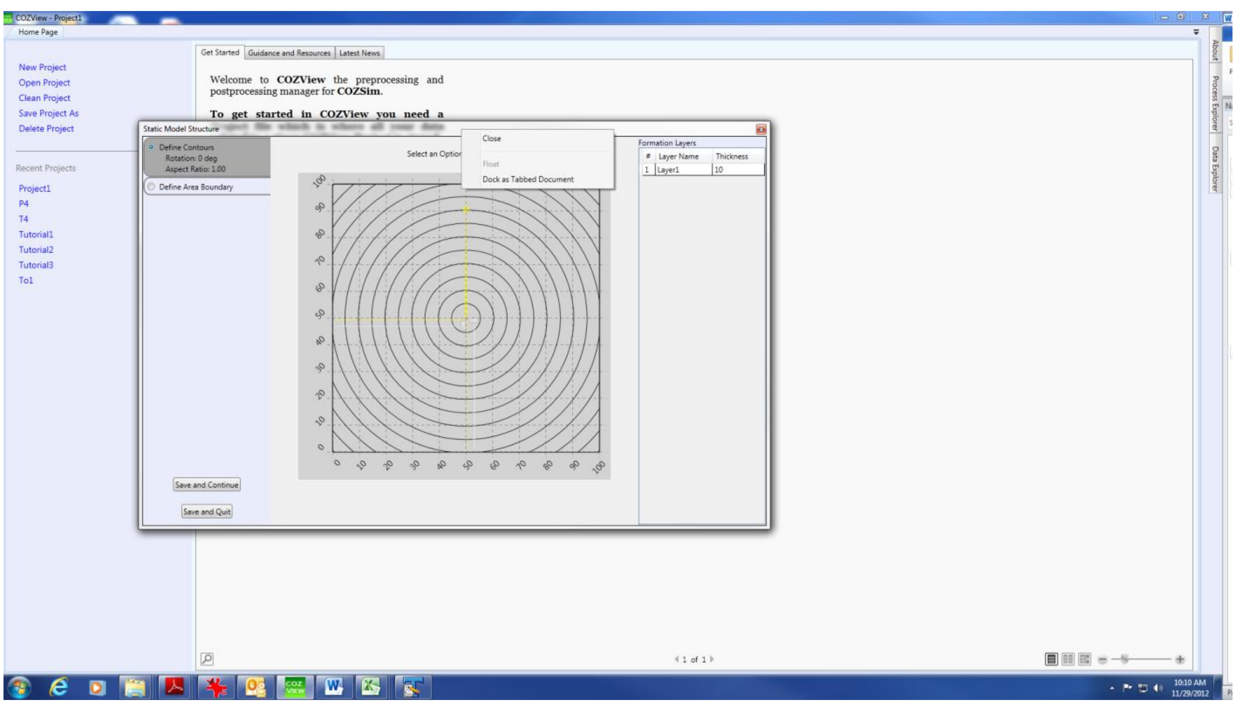
The Menu tabs appear when a specific menu item is selected from within one of the Guidance tabs. The picture below shows the Static Model Structure Menu tab alongside the Home Page tab. This was the result of single-clicking on the Structure Menu under the Static Model in the Process Explorer Guidance tab.



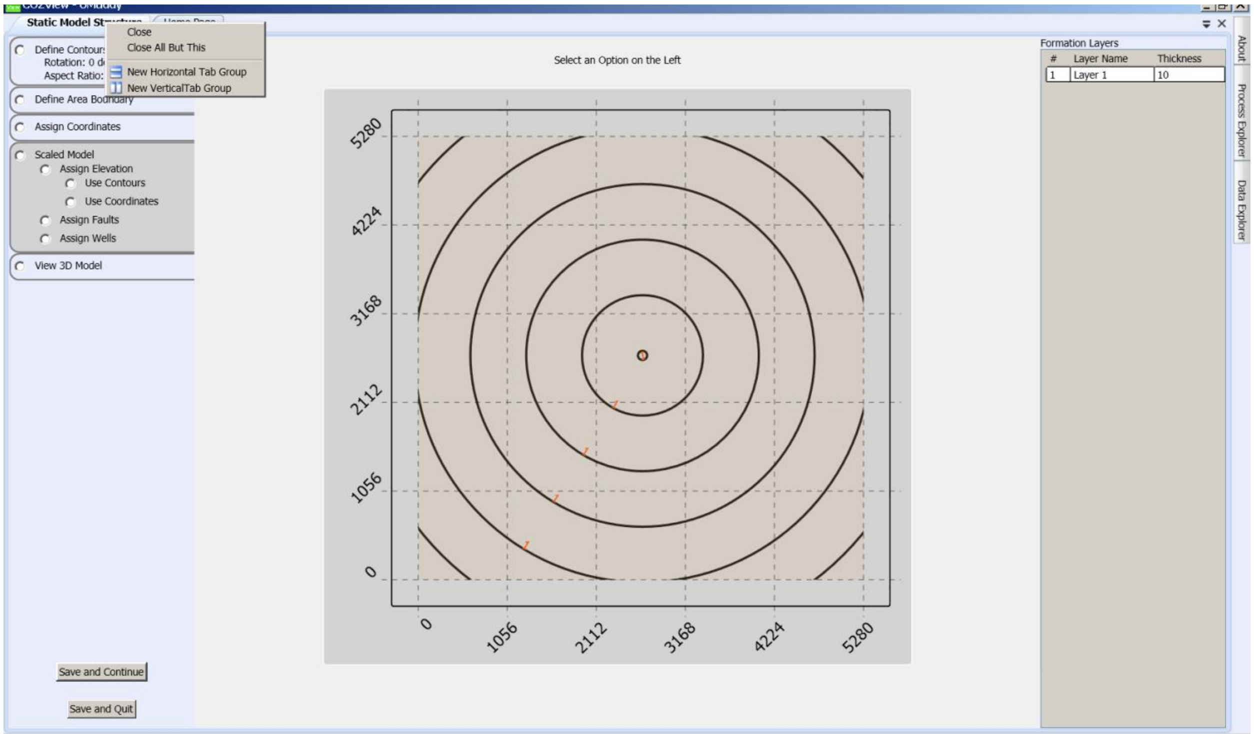
Any menu tab can be transferred to a separate window by selecting and dragging the tab to another area of the screen as shown below. This can be very useful when multiple monitors are available. This allows multiple **COZView** menus to be viewed at the same time.



A menu tab window can be returned to the horizontal tab area by right-clicking the Title bar and selecting *Dock as Tabbed document*. The menu window and the tab can be closed by right-clicking the Title bar and selecting *Close*.



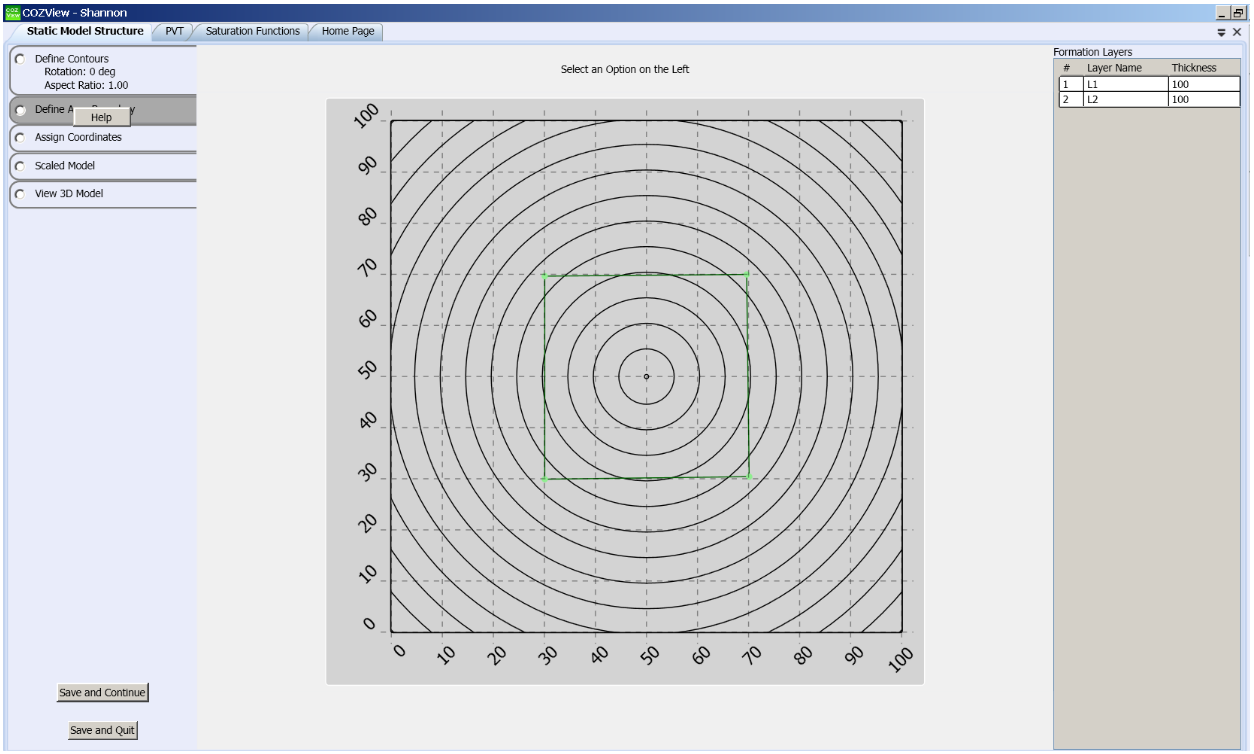
Right-clicking on a menu tab, while in the horizontal tab area, allows the user to select *Close* or *Close All But This* in order to reduce the number of tabs in the horizontal tab area.



2.6 Help

A **COZView/COZSim** User Manual is available for access by the user. This manual can be downloaded and printed as a pdf file from the area where installation materials were provided. The manual can also be accessed from any **COZView** window.

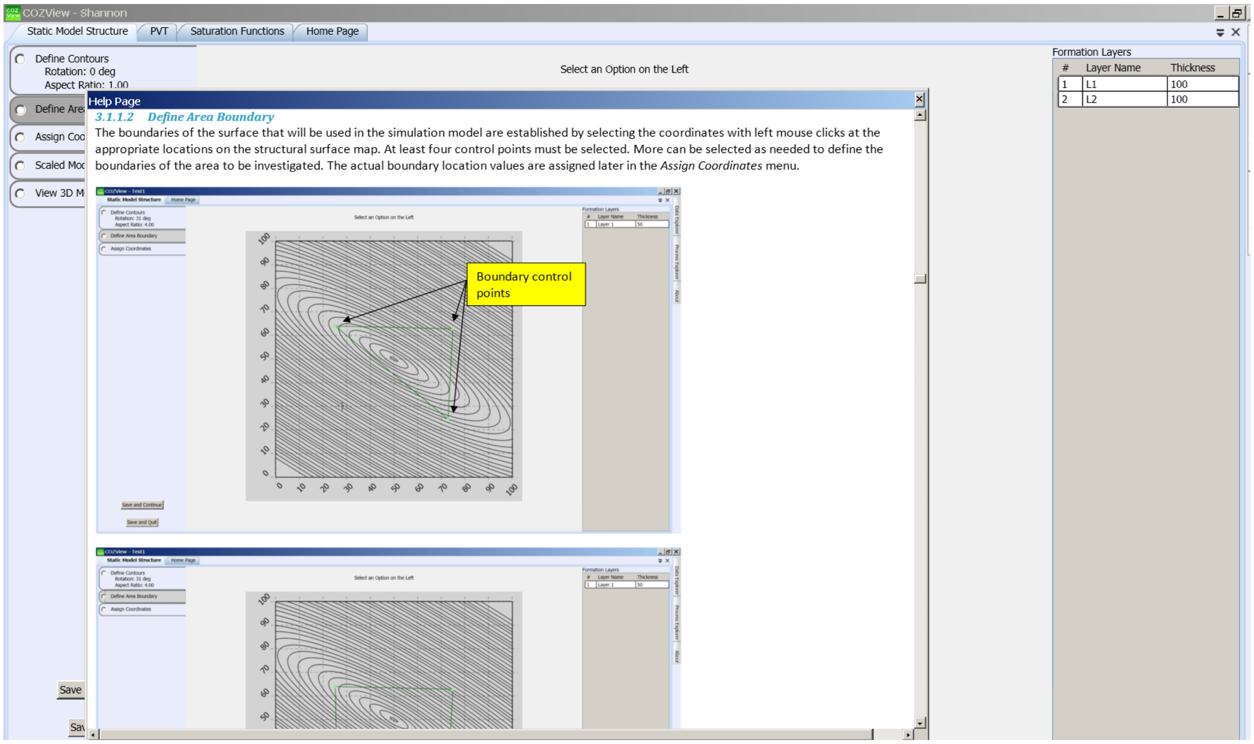
To activate *Help* for a specific topic, the topic must be active. In the Static Model Structure window below, the topic *Define Area Boundary* was selected. A right-click on the topic displays a Help box. Help may be accessed on some screens by a right-click on the screen itself.



Selection of *Help* accesses the related topic in the User Manual and displays it as a separate window. This window can be dragged to a different location by the user if desired. The window can be closed by selecting the X in the upper right corner of the Help window.

The user can view multiple *Help* windows by selecting a different topic on a COZView window and activating *HELP*.

In addition, the scroll bar on the right of any HELP window can be used to move forward or backward in the documentation.


COZView - Shannon
Static Model Structure
PVT
Saturation Functions
Home Page
Define Contours
Rotation: 0 deg
Aspect Ratio: 1.00
Select an Option on the Left
Formation Layers
Layer Name Thickness
1 L1 100
2 L2 100
Help Page
3.1.1.2 Define Area Boundary
The boundaries of the surface that will be used in the simulation model are established by selecting the coordinates with left mouse clicks at the appropriate locations on the structural surface map. At least four control points must be selected. More can be selected as needed to define the boundaries of the area to be investigated. The actual boundary location values are assigned later in the Assign Coordinates menu.
Boundary control points
Save

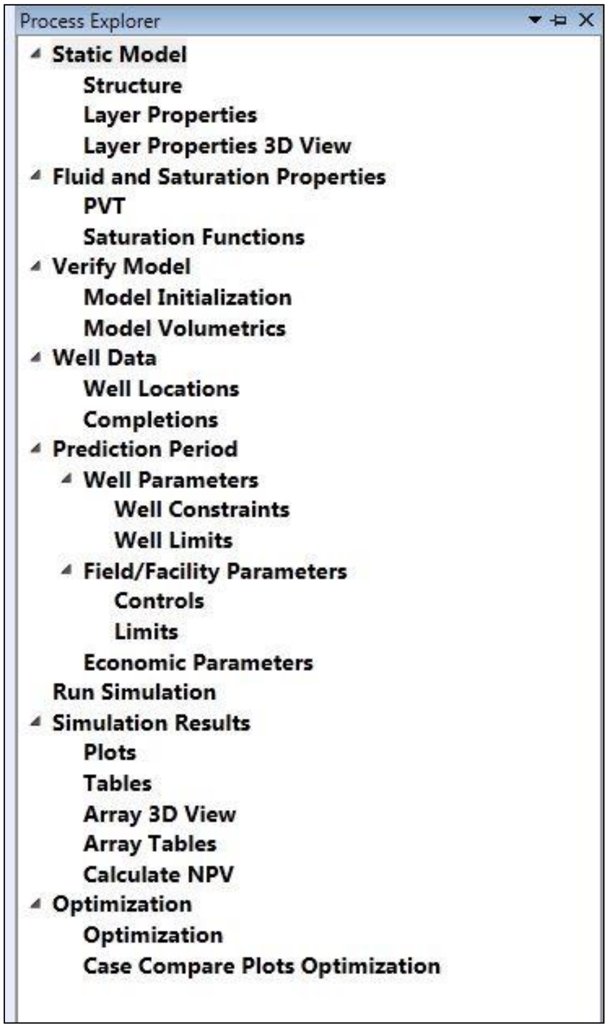
3 Process Explorer

The *Process Explorer* is designed to aid the user in quickly creating a representative simulation model of the reservoir to be investigated. The necessary steps to

- Create a *static model;*
- Define appropriate *PVT* and *Saturation Functions* (*relative permeability* and *capillary pressure*);
- Identify *well locations* and *completions;*
- Establish field and well simulation model *operating controls* and *limits;*
- Define *economic parameters;*
- Launch a *simulation run;*
- Review the *simulation results;* and
- Make *optimization* runs

are provided in the *Process Explorer* area. **We strongly advise initial users to develop their model by systematically moving step by step through the Process Explorer menus.**

Other less frequently needed functionality is provided in the *Data Explorer* area.

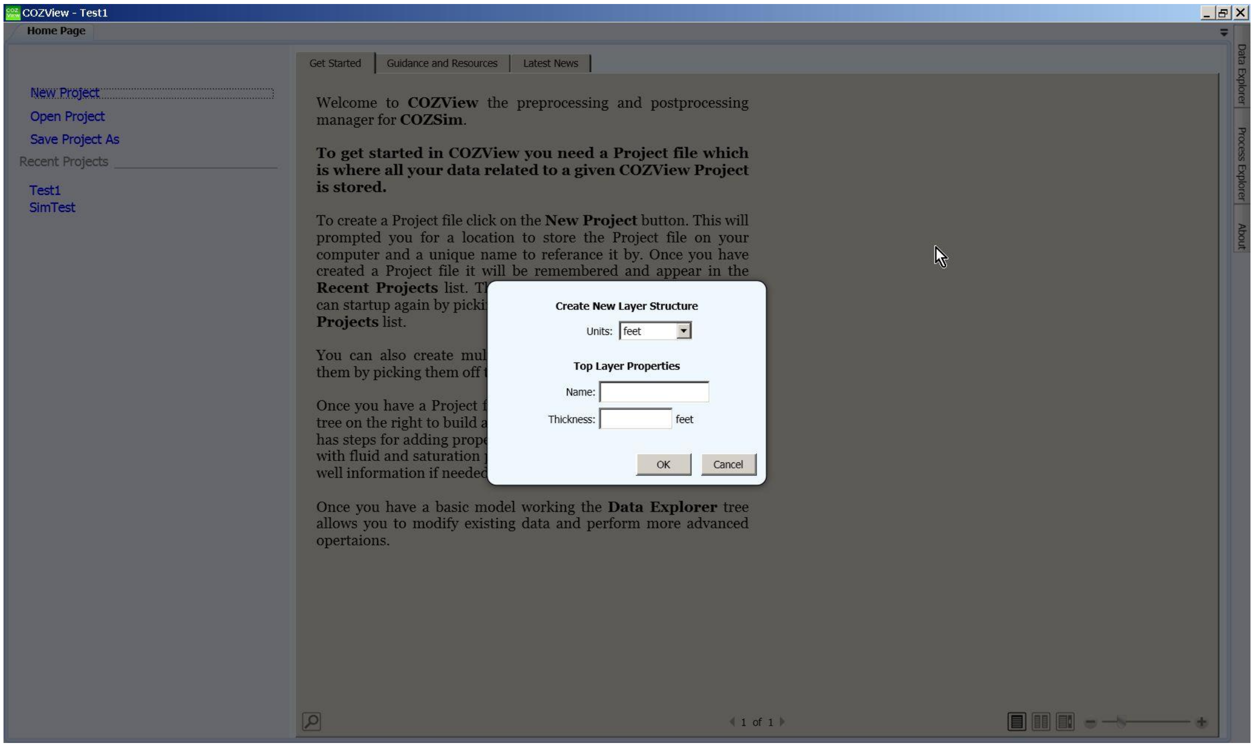


3.1 Static Model

The static model defines the geologic properties of the reservoir to be investigated which do not change with time, pressure or saturation. These are the

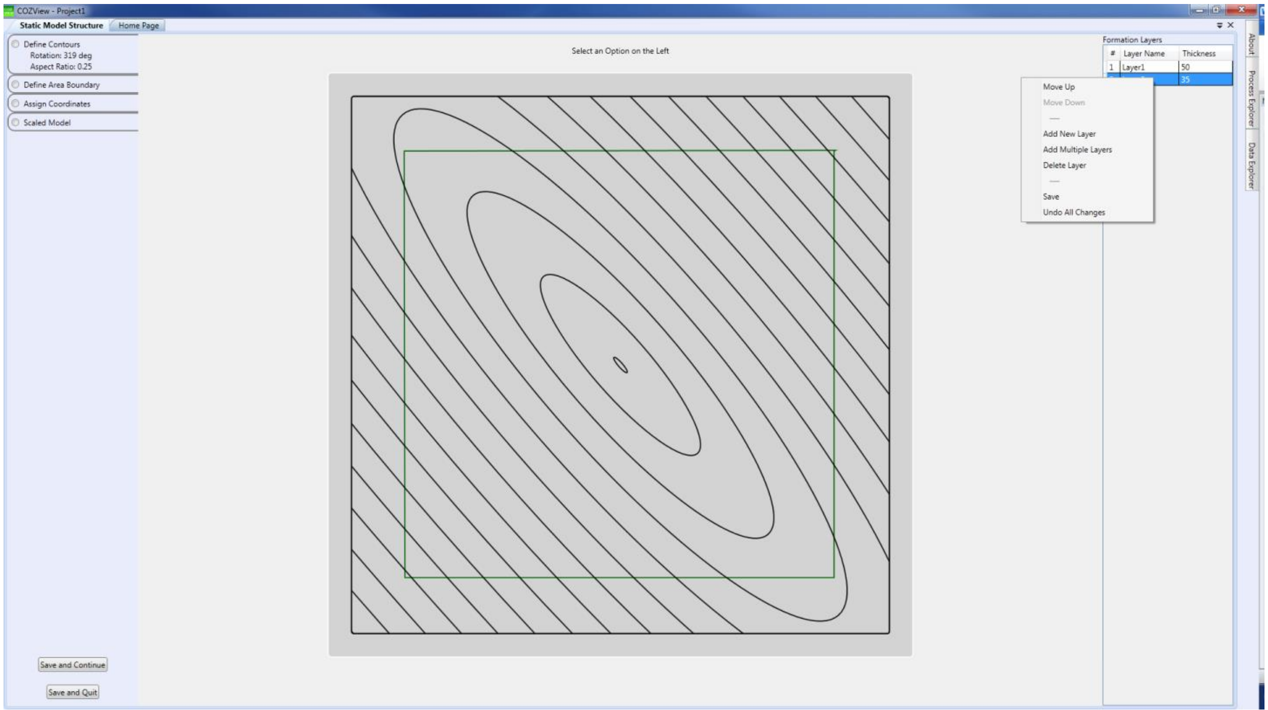
- Structural surface
- Formation thicknesses (net and gross)
- Porosity
- Absolute permeability
- Rock compressibility
- Irreducible water saturation

First time selection of the *Static Model* results in a request for a *Top Layer Name* and gross *Thickness* along with identification of the thickness units. The *Top Layer Name* can be any alpha numeric description. This starts the definition process of the model in **COZView**.



At any time after defining the *Top Layer Properties*, the user can save the model by clicking the **Save and Continue** button or the **Save and Quit** button. Periodic saving is suggested as the model is built. Leaving the *Static Model* area without saving may result in a loss of data.

Once a new model has been created or when an existing model has been selected, the Layer Name(s) and gross thickness will appear in the upper right corner of the *Static Model* screen. New layers can be created with a right-click on the last layer name and selection of Add New Layer. Multiple layers can also be added by selecting Add Multiple Layers. The Layers are assumed to be ordered from top to bottom – 1, 2, 3, etc.



3.1.1 Structure

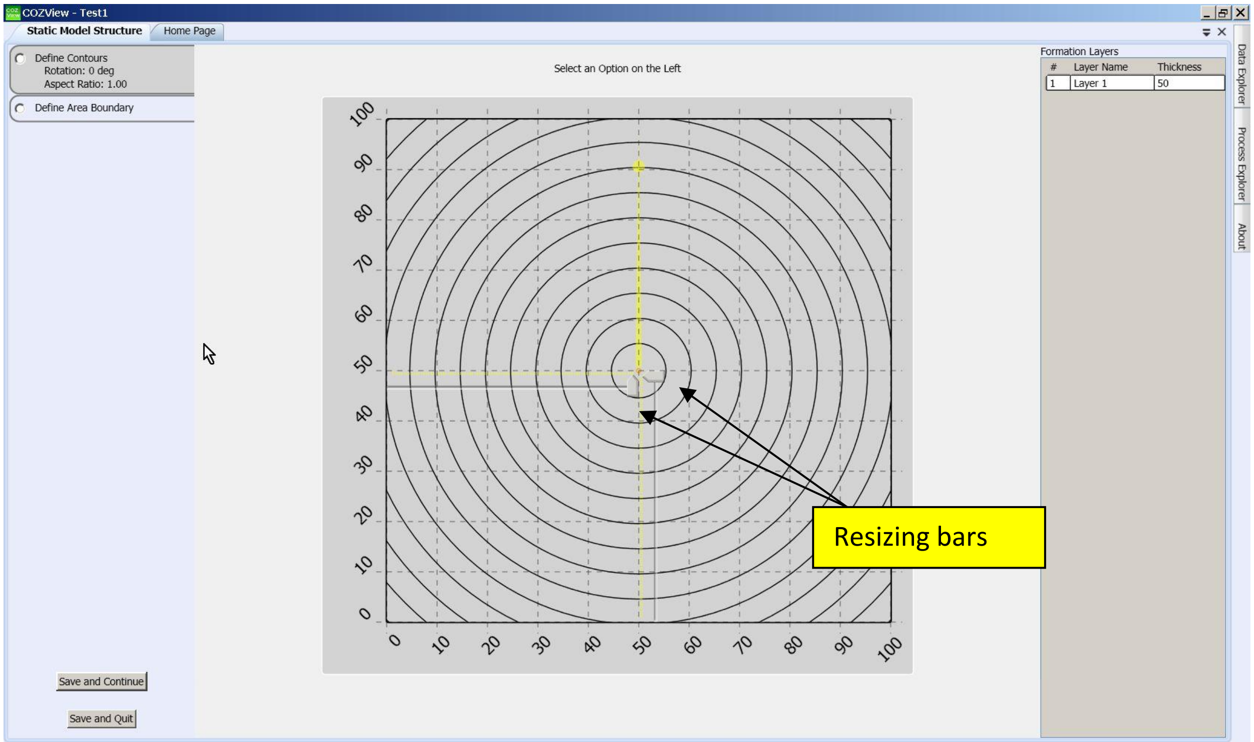
The *Structure* section of the *Static Model* allows the user to define a structural surface and adjust it to approximate the reservoir to be investigated. In the *Static Model Structure* menu

- boundaries for the simulation model are established,
- faults are located and
- well locations can be defined.

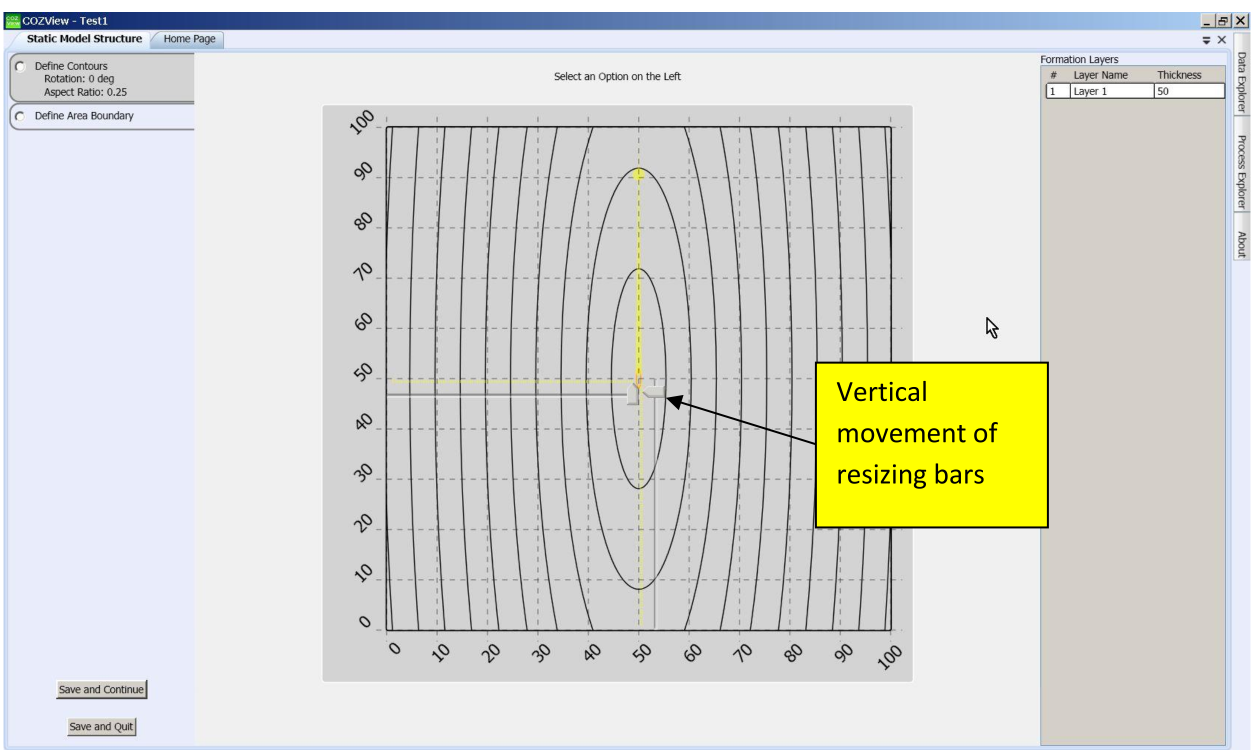
3.1.1.1 Define Contours

COZView allows the user to develop a structural surface for the simulation model that approximates the user's top structure map of the reservoir to be investigated. If available, the user should have their top structure map for reference when creating the structural surface for the simulation model.

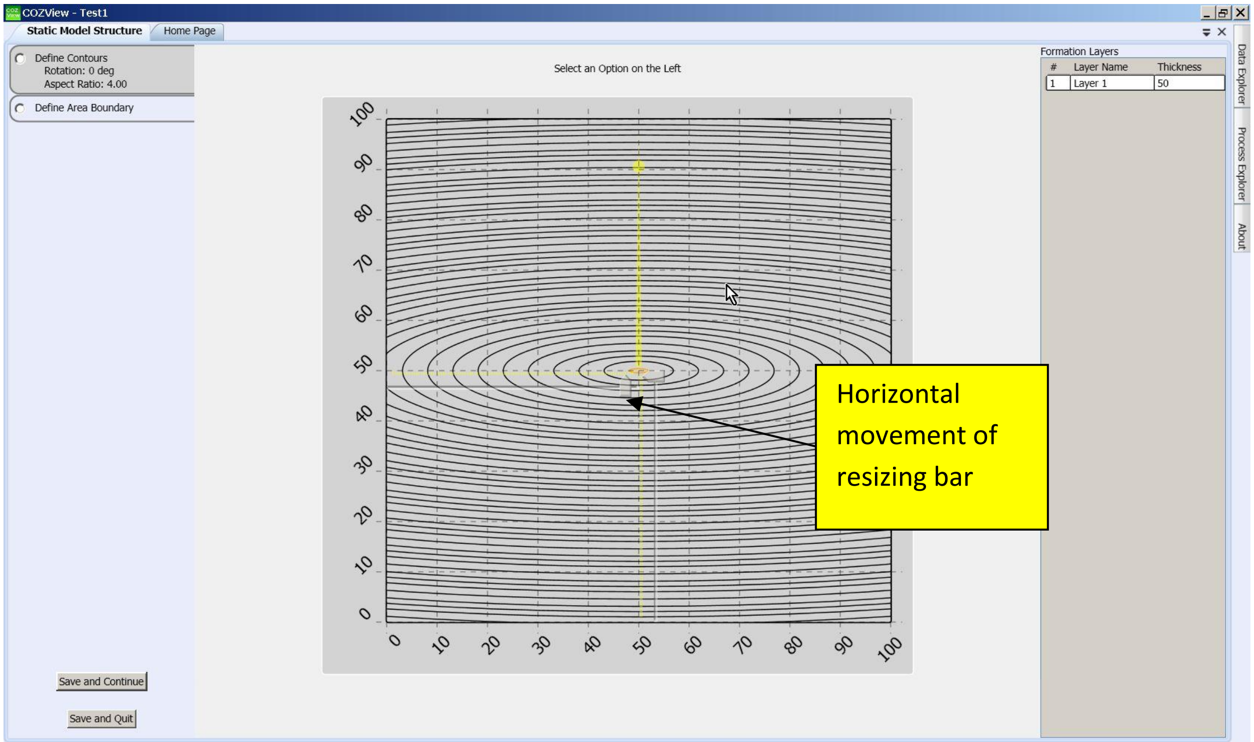
Select *Define Contours*. The default screen shows a circular set of evenly spaced contours. Layer 1, defined earlier, is shown in the upper right panel along with the gross thickness.



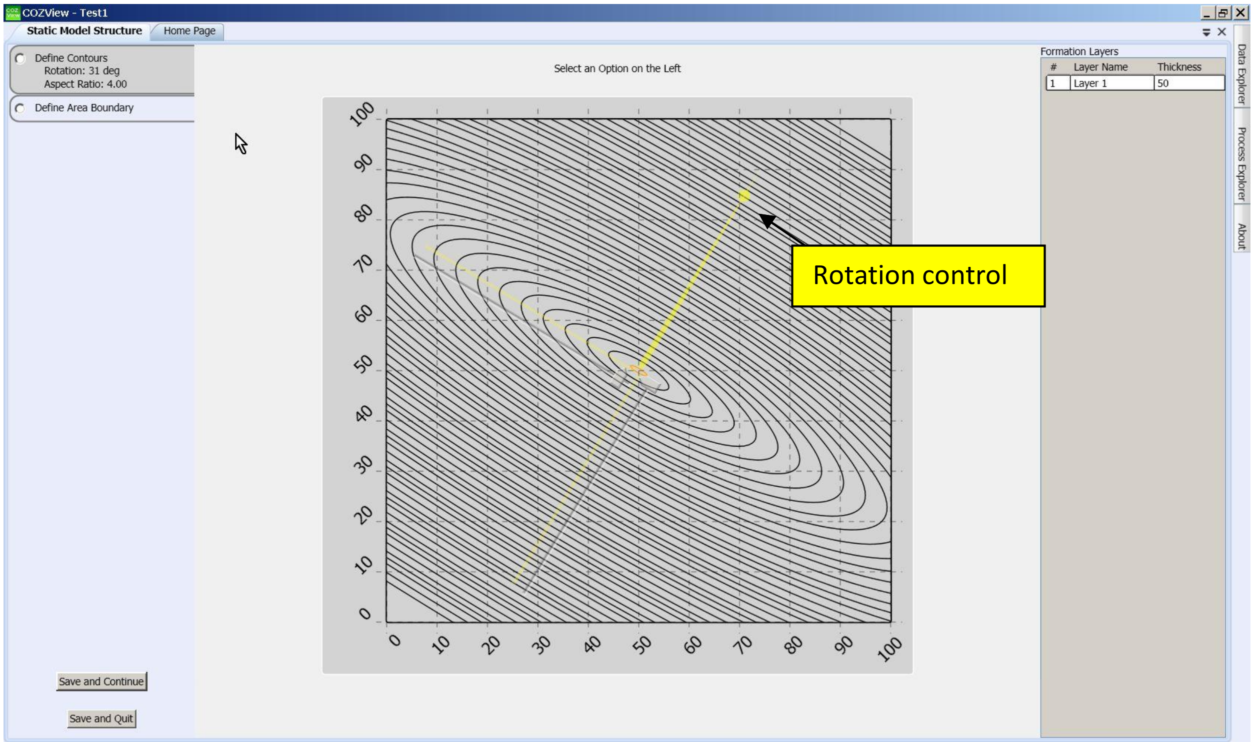
To the right and below the center of the interior circle are two *resizing bars* which allow the user to alter the shape of the contour surface. Movement of the *resizing bar* vertically with a left *click and drag* mouse operation, results in the figure below.



Movement of *the resizing bar* horizontally results in the figure below.



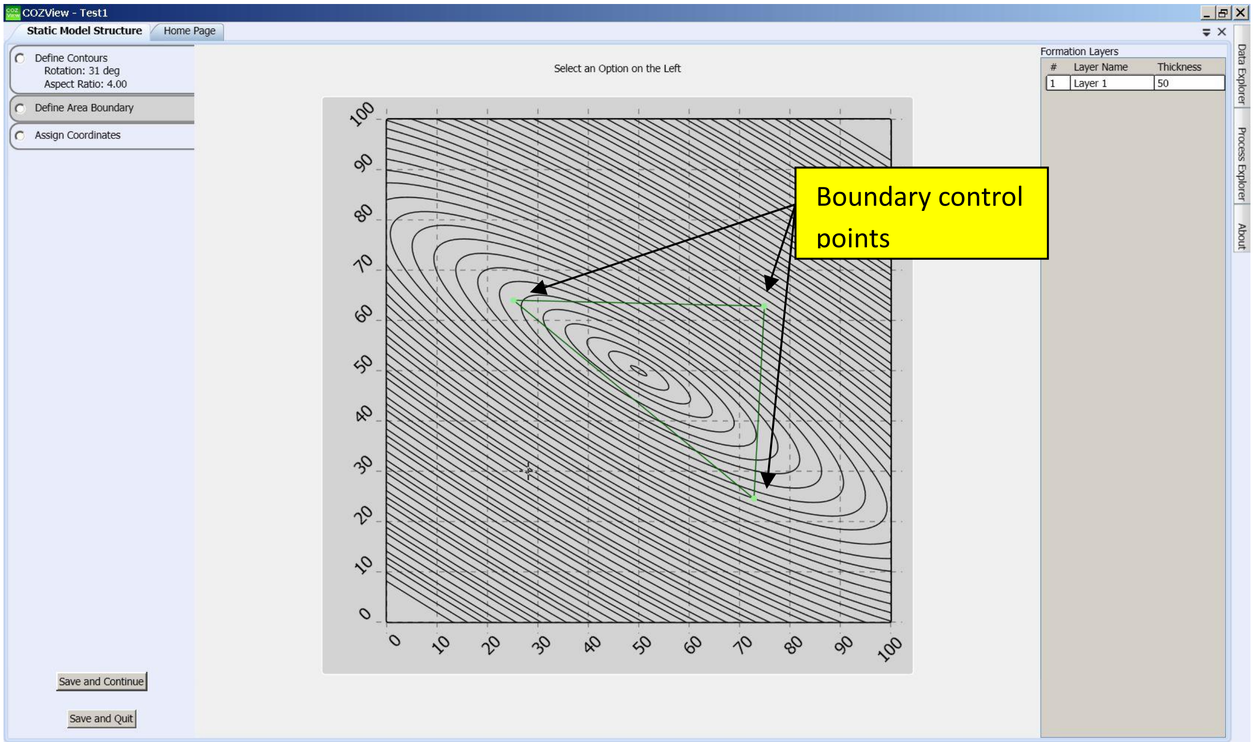
The yellow ball (*rotation control*) at the end of the yellow pillar can be used to rotate the surface clockwise or counterclockwise with a left *click and drag* mouse operation.

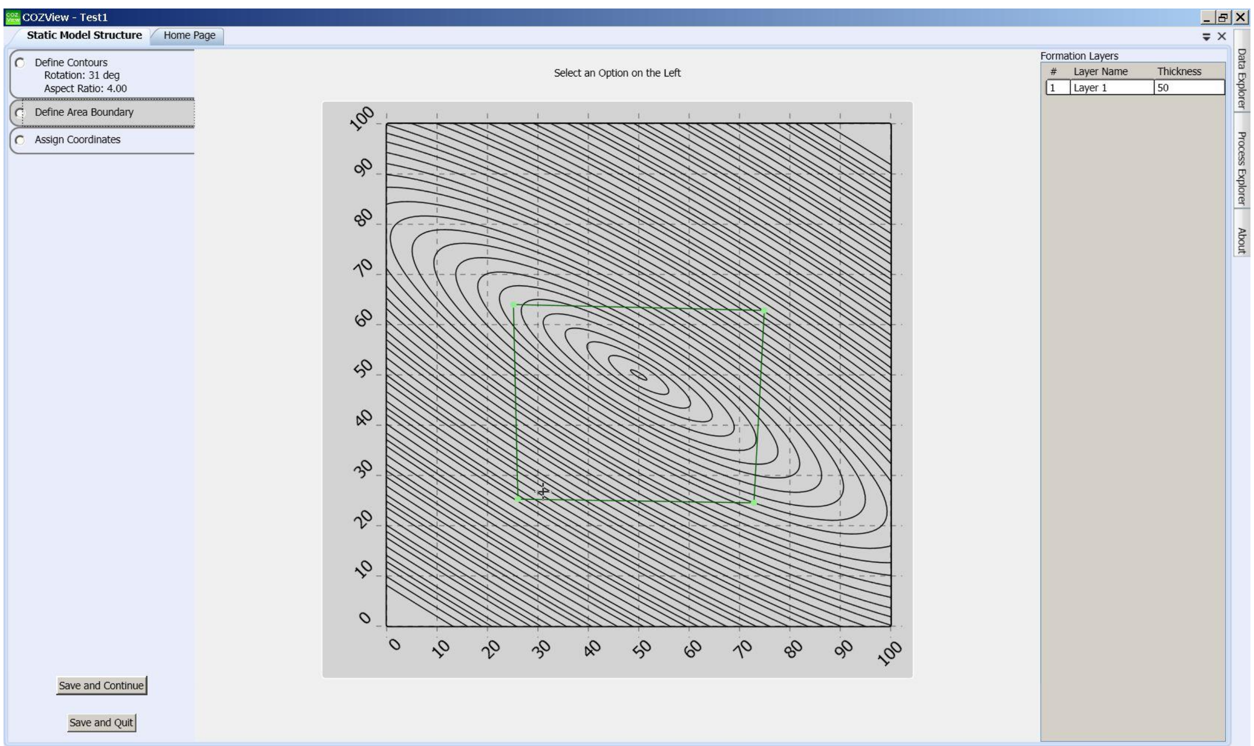


These controls can be used to create a surface that replicates the actual structure top map as closely as possible.

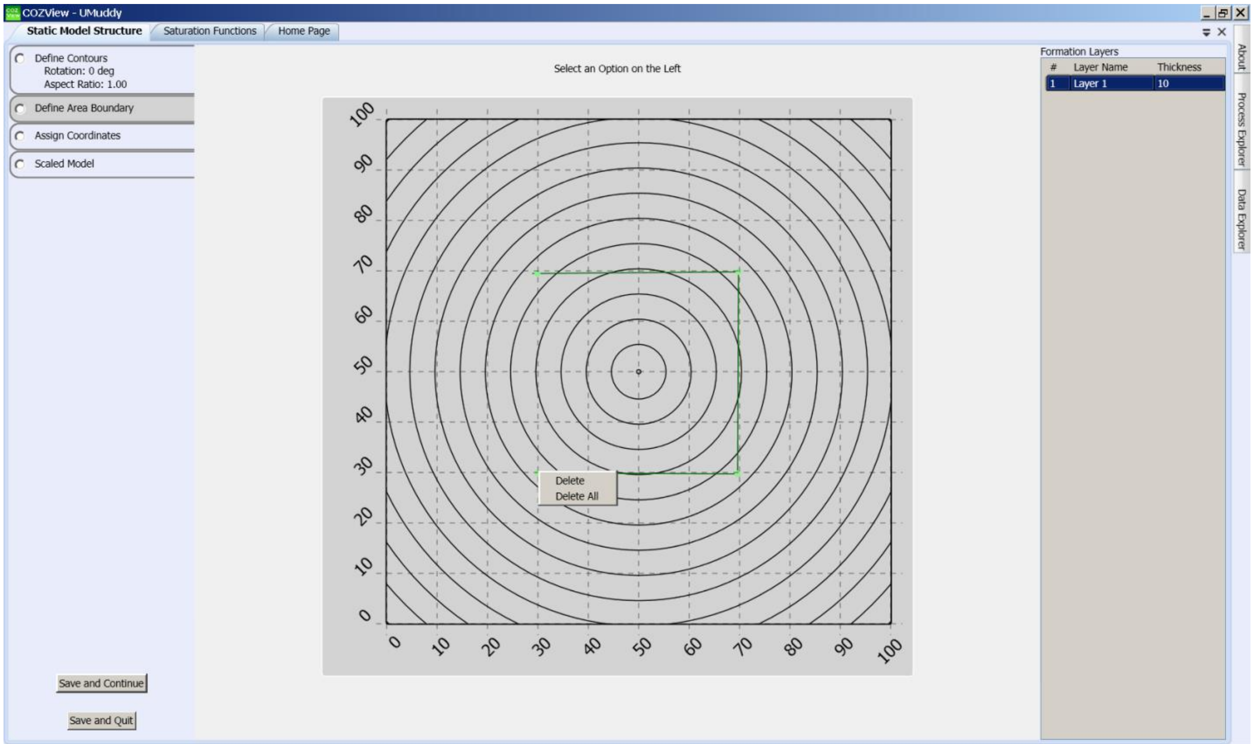
3.1.1.2 Define Area Boundary

Select *Define Area Boundary*. The boundaries of the surface that will be used in the simulation model are established by selecting the coordinates with left mouse clicks at the appropriate locations on the structural surface map. At least four control points must be selected. More can be selected as needed to define the boundaries of the area to be investigated. The actual boundary location values are assigned later in the *Assign Coordinates* menu.





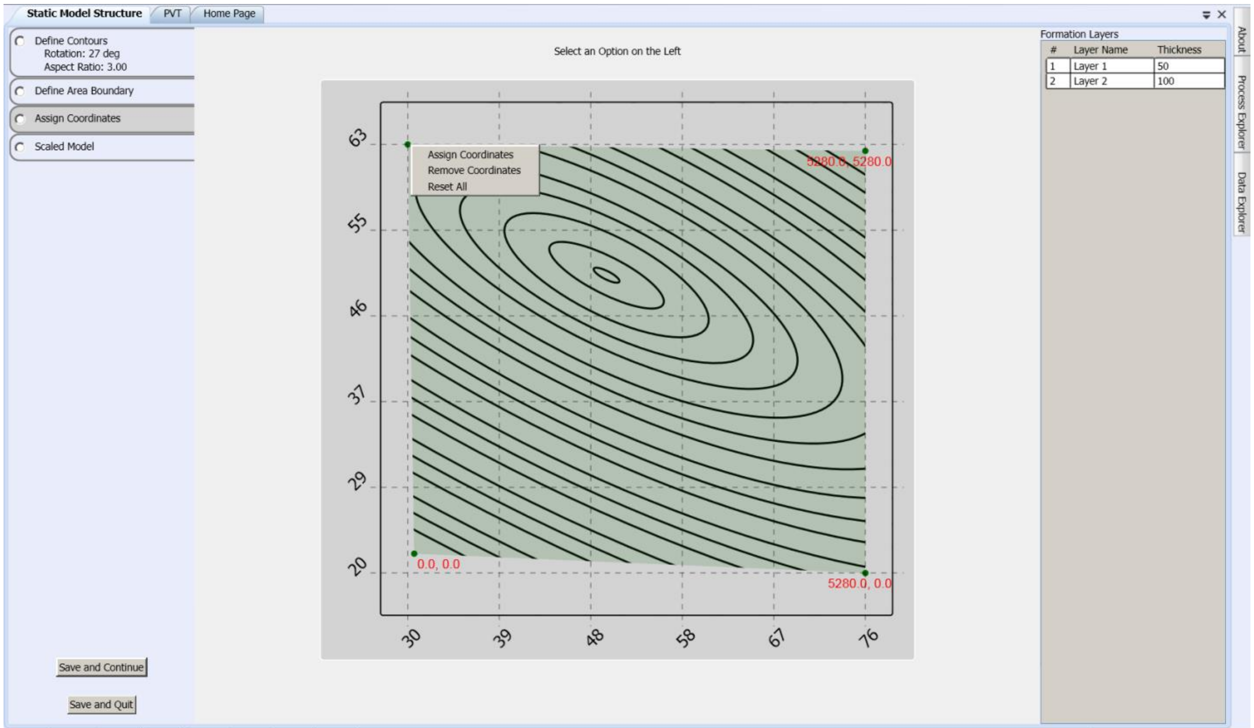
Should the user wish to change a boundary control point, a right-click on the control point will allow that point to be deleted or all points to be deleted. The user can reset the desired control points with appropriate left mouse clicks.

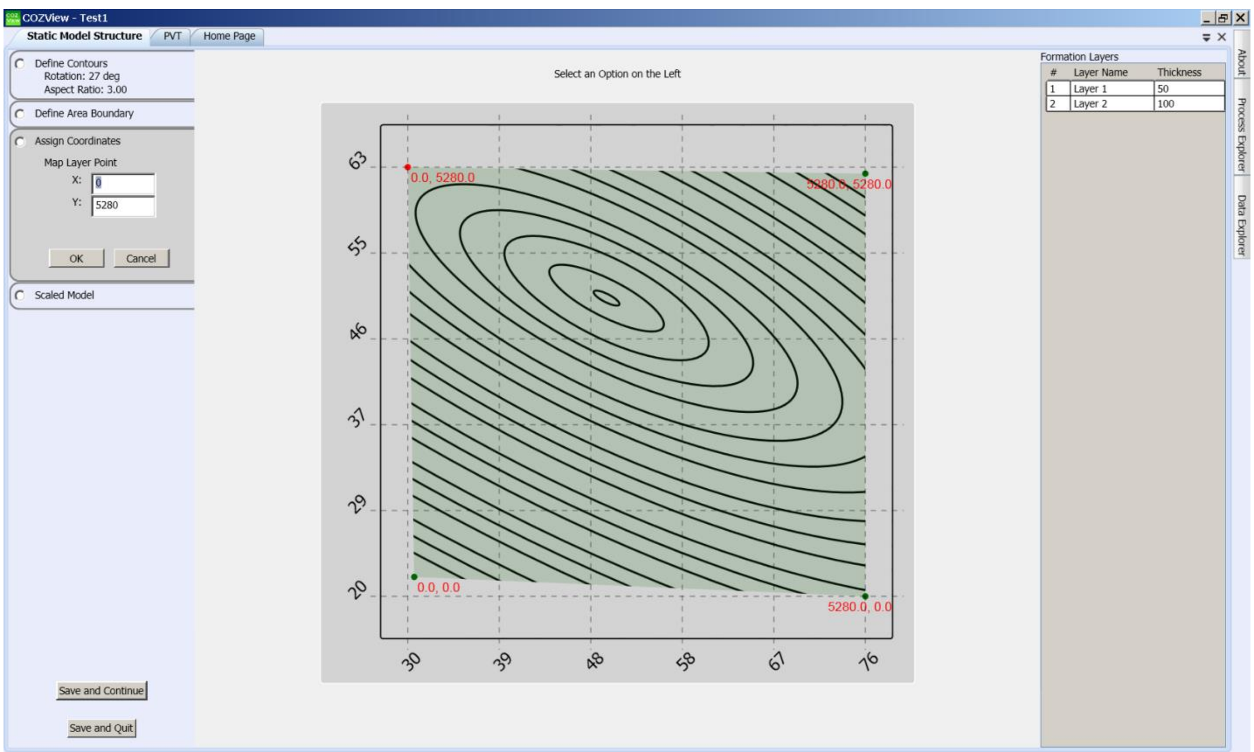


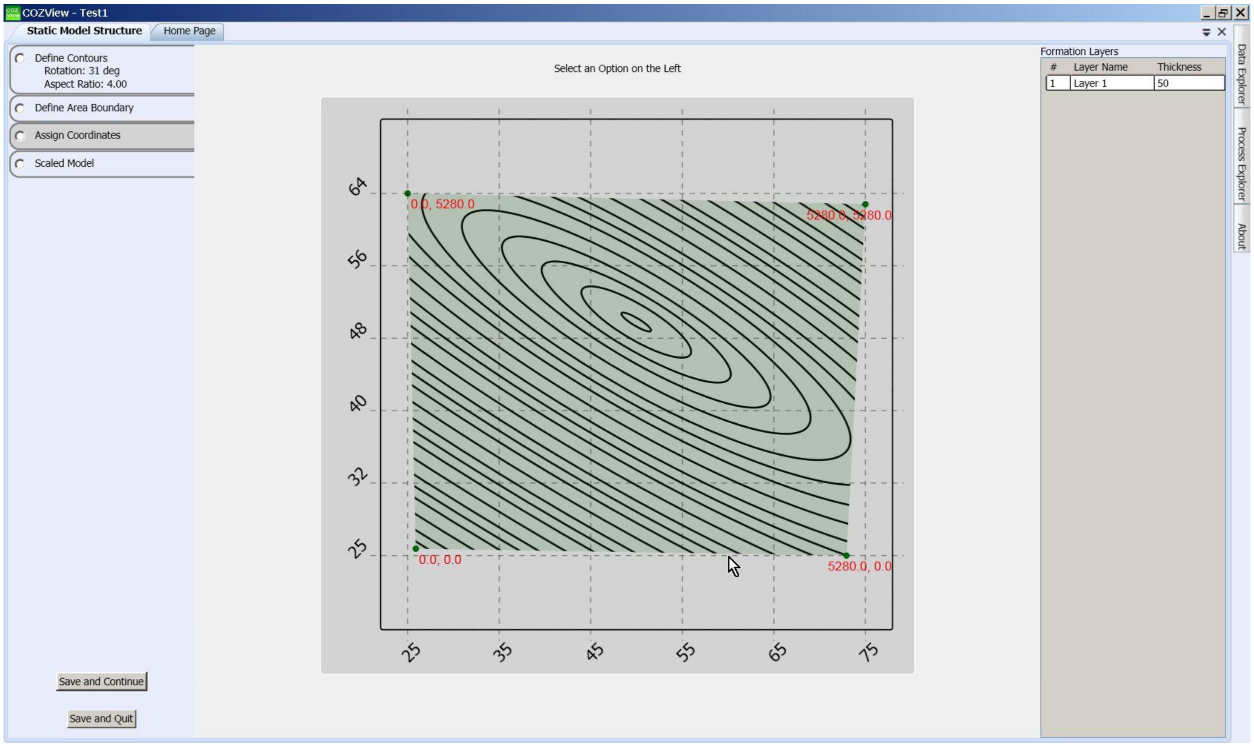
Individual boundary control points can be moved by a left-click and drag to a new location. If this is done after the coordinates of the boundary control point have been set, the coordinates for the moved-points must be re-defined.

3.1.1.3 Assign Coordinates

Selection of *Assign Coordinates* and a right-click on each boundary control point will prompt the user to input the X and Y coordinates for that control point. These coordinate values can be determined from the actual structure top map or approximated by the user.


Static Model Structure
PVT
Home Page
Define Contours
Rotation: 27 deg
Aspect Ratio: 3.00
Define Area Boundary
Assign Coordinates
Scaled Model
Select an Option on the Left
Assign Coordinates
Remove Coordinates
Reset All
5280.0, 5280.0
0.0, 0.0
5280.0, 0.0
Save and Continue
Save and Quit
Formation Layers
Layer Name Thickness
1 Layer 1 50
2 Layer 2 100
About
Process Explorer
Data Explorer


COZView - Test1
Static Model Structure
PVT
Home Page
Define Contours
Rotation: 27 deg
Aspect Ratio: 3.00
Define Area Boundary
Assign Coordinates
Map Layer Point
X: 0
Y: 5280
OK
Cancel
Scaled Model
Select an Option on the Left
0.0, 5280.0
5280.0, 5280.0
0.0, 0.0
5280.0, 0.0
Save and Continue
Save and Quit
Formation Layers
Layer Name Thickness
1 Layer 1 50
2 Layer 2 100
About
Process Explorer
Data Explorer



3.1.1.4 Scaled Model

Selection of *Scaled Model* results in display of the structure surface developed by the user and the model boundaries on the map. The user must provide

- contour elevations.

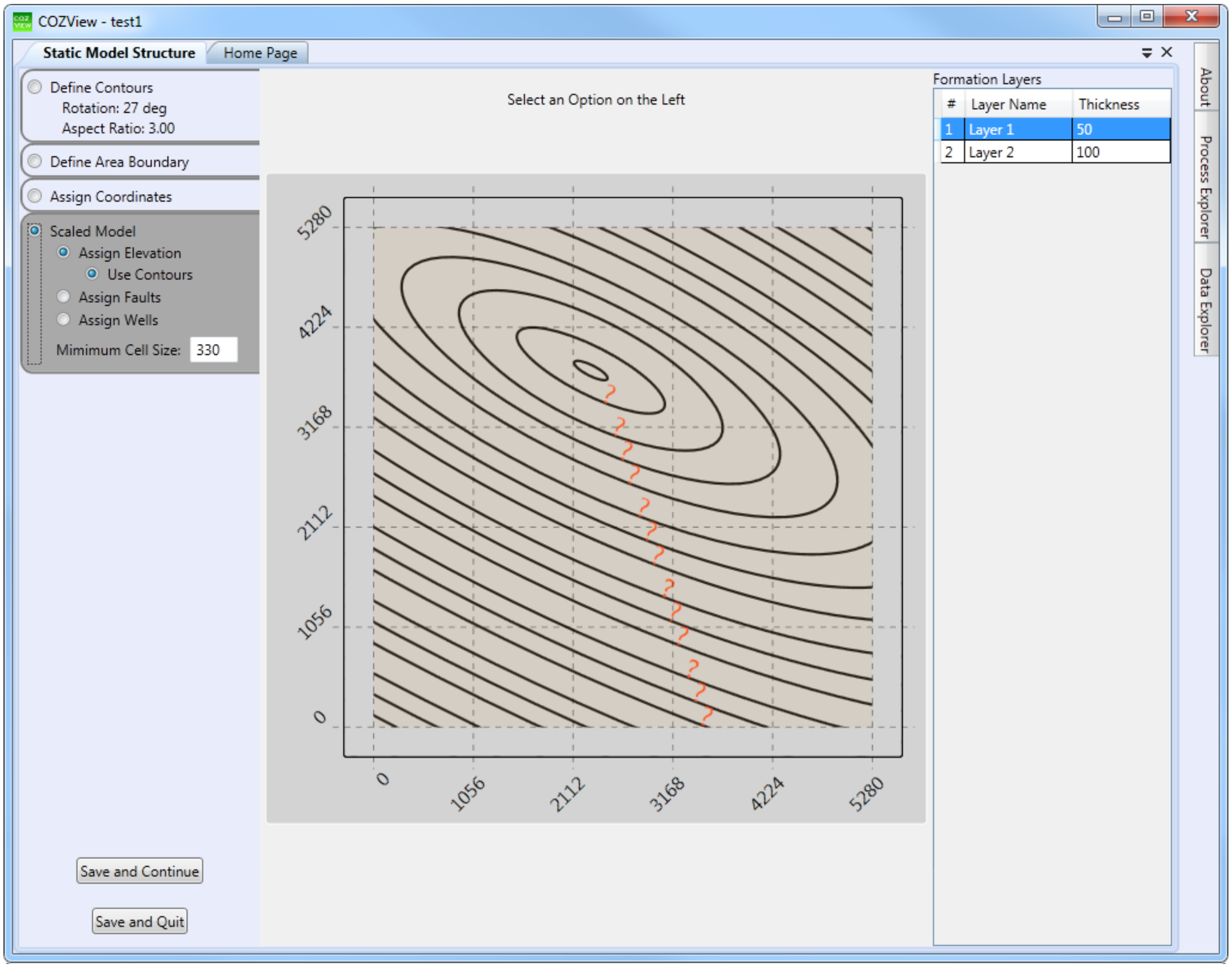
The user can also

- locate faults and
- locate wells in this area.

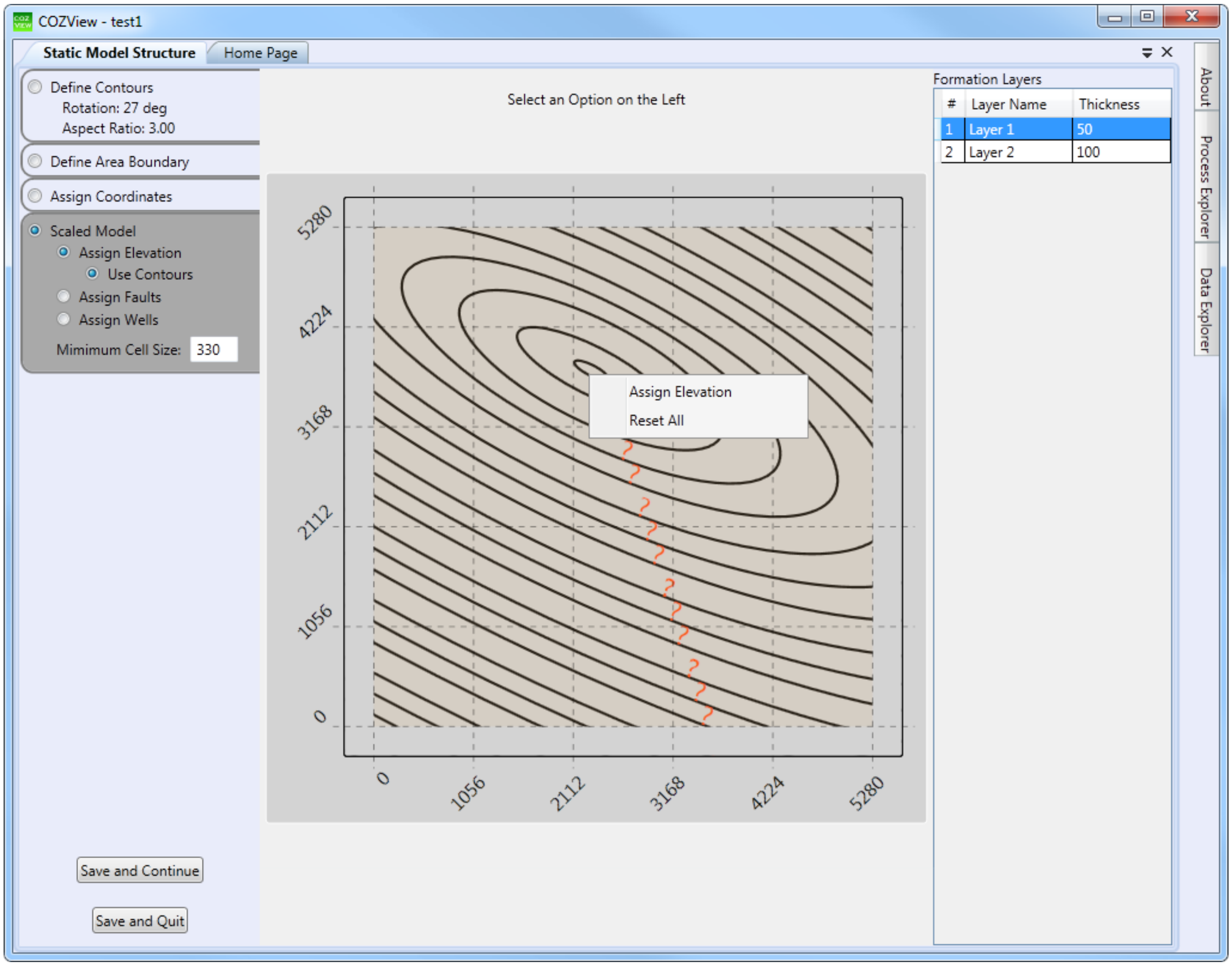
Behind the scenes, the model uses kriging technology to create information needed for the simulation grid cells.

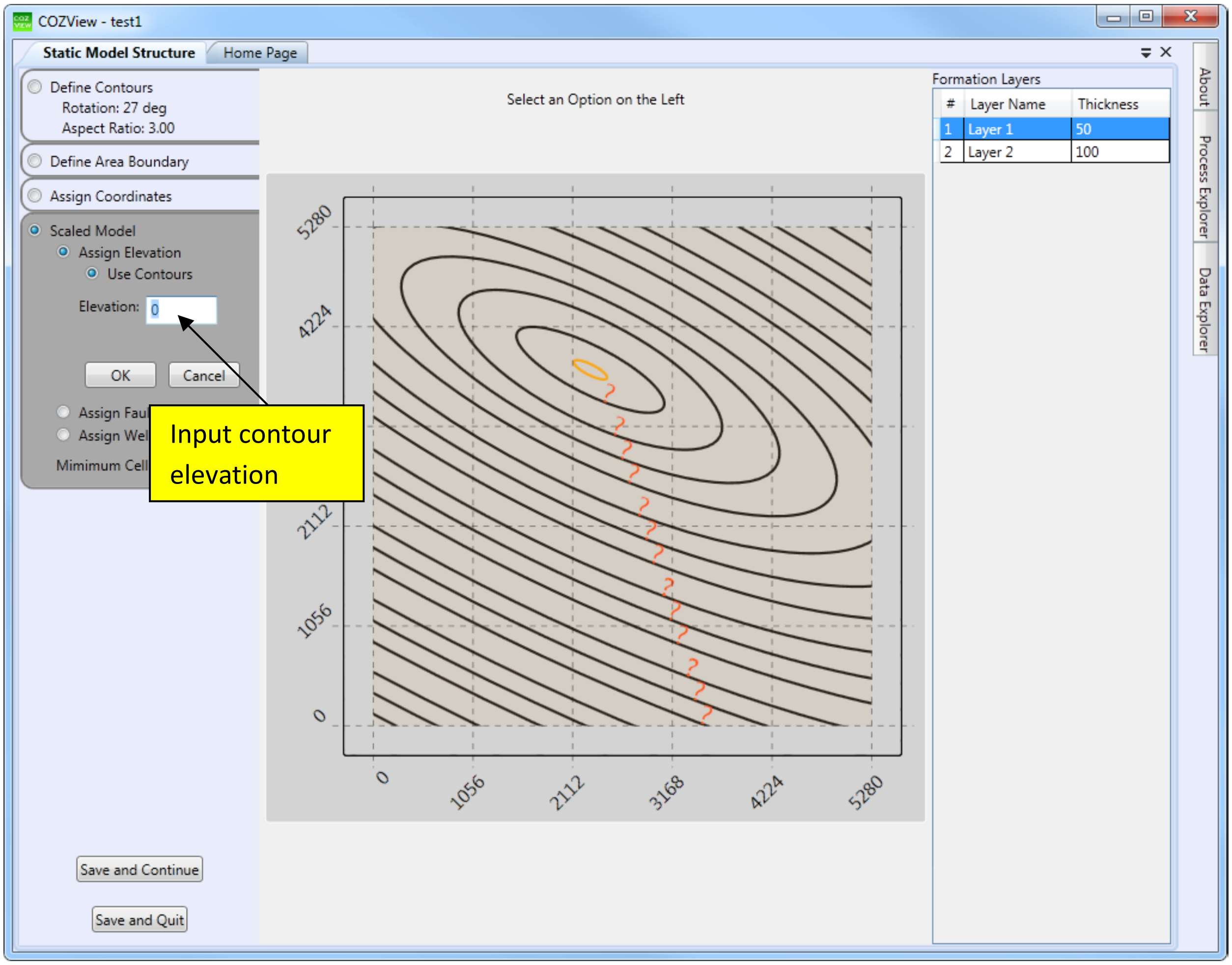
3.1.1.4.1 Assign Elevations

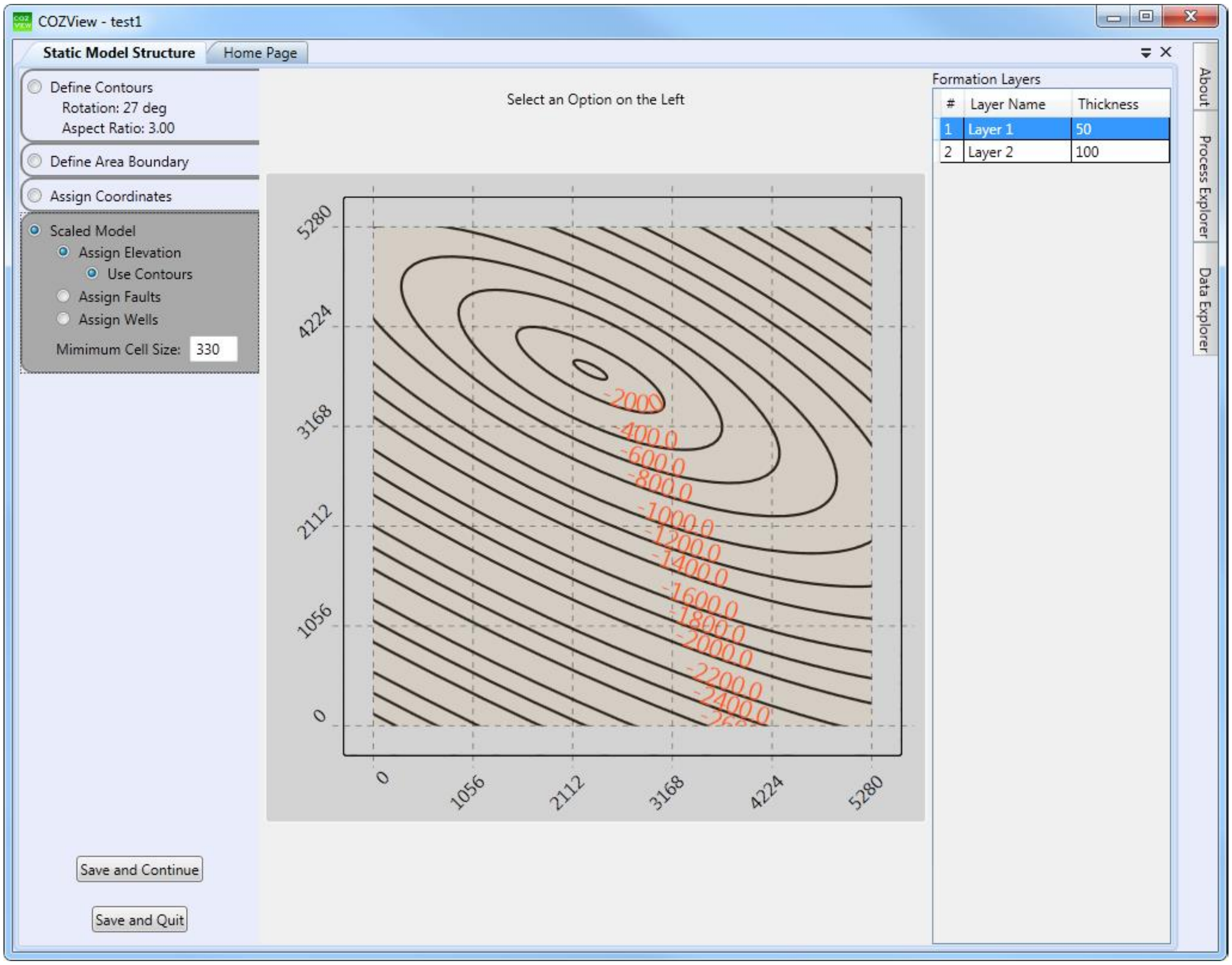
Selection of Assign *Elevations* results in the following display.



A right-click on a contour allows the user to assign a value to that contour. The user can assign contour values to any **two** contours. The implied contour interval calculated by the software will be used to assign values to the rest of the contours. Should the user wish to start over with the contour value assignment, a right-click on the contour and selection of *Reset All* is available.


COZView - test1
Static Model Structure
Home Page
Define Contours
Rotation: 27 deg
Aspect Ratio: 3.00
Define Area Boundary
Assign Coordinates
Scaled Model
Assign Elevation
Use Contours
Assign Faults
Assign Wells
Mimimum Cell Size: 330
Save and Continue
Save and Quit
Select an Option on the Left
Assign Elevation
Reset All
0
1056
2112
3168
4224
5280
Formation Layers
Layer Name Thickness
1 Layer 1 50
2 Layer 2 100
About
Process Explorer
Data Explorer


COZView - test1
Static Model Structure
Home Page
Define Contours
Rotation: 27 deg
Aspect Ratio: 3.00
Define Area Boundary
Assign Coordinates
Scaled Model
Assign Elevation
Use Contours
Elevation:
OK
Cancel
Input contour elevation
Save and Continue
Save and Quit
Select an Option on the Left
Formation Layers
Layer Name Thickness
1 Layer 1 50
2 Layer 2 100
About
Process Explorer
Data Explorer
0
1056
2112
3168
4224
5280

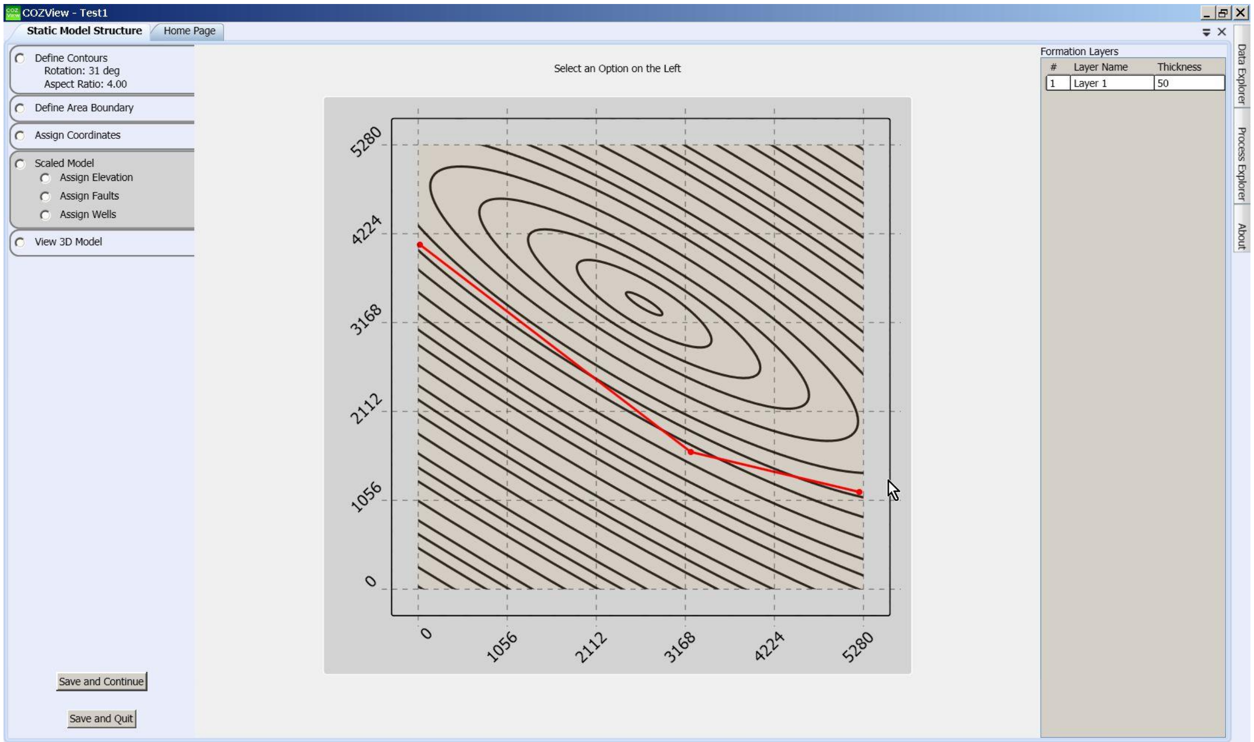


Be sure to click the **Save and Continue** button before leaving the *Assign Elevations* area.

Additionally, if the elevation contour values are changed at a later time, they must be saved or the model is not updated and the 3D View will be incorrect.

3.1.1.4.2 Assign Faults

Selection of *Assign Faults* allows the user to define a vertical fault with left mouse clicks at the appropriate locations. The *vertical fault* will penetrate all layers in the model and will act as a barrier to flow. Partial communication across a fault is not allowed.



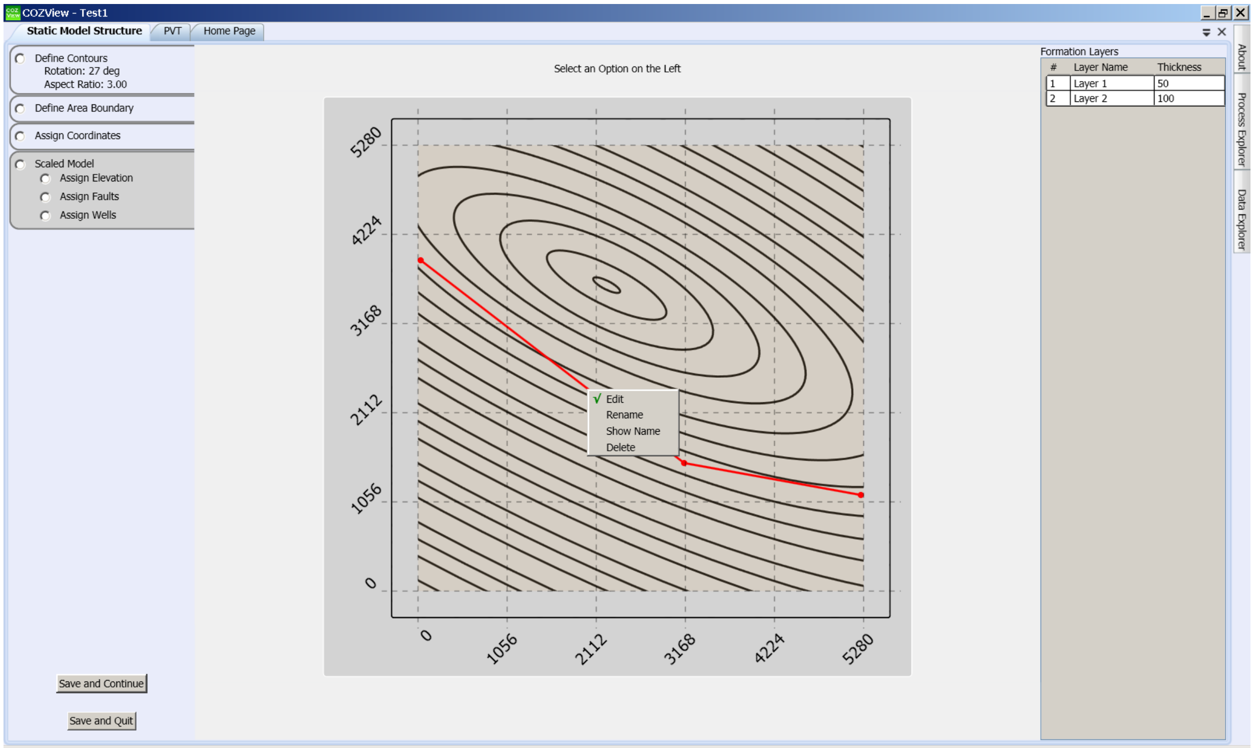
Changes to a fault which has been created can be done as follows:

Delete a fault control point: a right-click on the control point allows the user to delete that control point;

Delete a fault trace: a right-click on a segment of the fault allows the user to delete the entire fault trace.

Display or change fault name: A Fault name is assigned at the time of fault creation; this can be displayed and changed by the user with a right-click on a segment of the fault trace.

If the user wishes to input *multiple faults*, a right-click on a segment of the most recently defined fault allows the user to select **√Edit**. This selection stops (unchecks) further editing of the current fault trace and allows the user to start input of a new fault trace.



Be sure to click the **Save and Continue** button before leaving *Assign Faults*.

3.1.1.4.3 Assign Wells

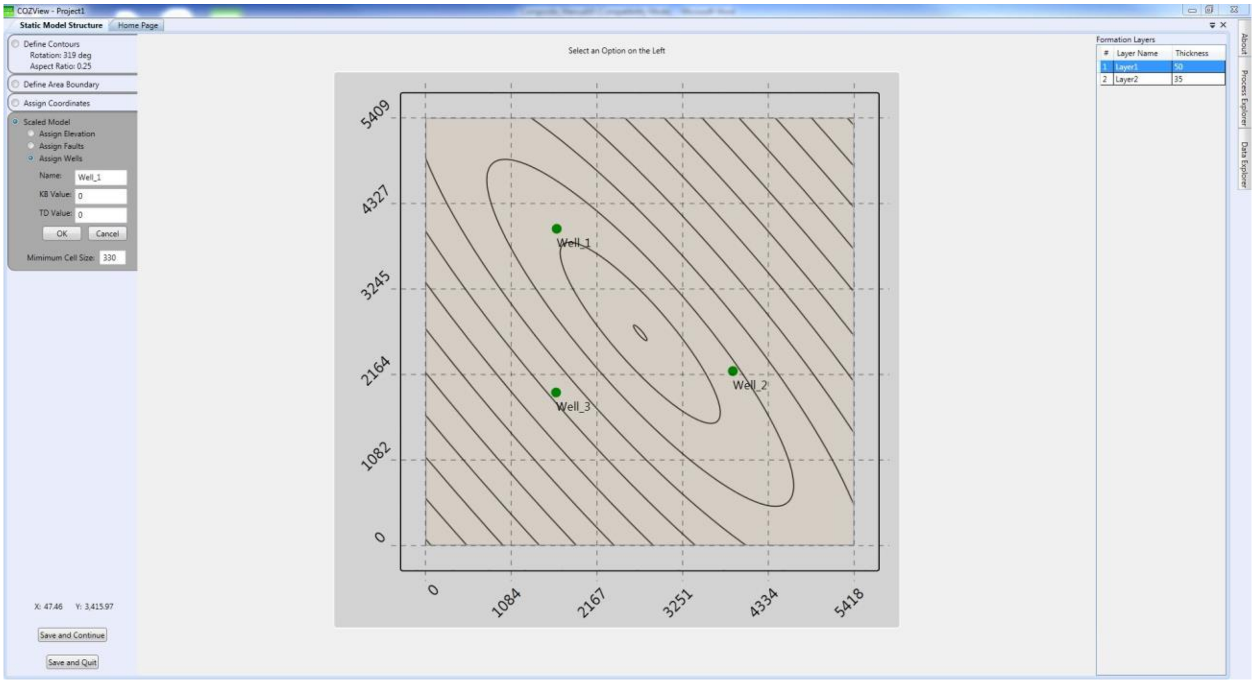
Selection of *Assign Wells* allows the user to locate wells on the structure surface map previously created.

Placement of well on the map: a left-click with the cursor at the desired location will result in placement of a well. The default name is Well #. The well # defaults to 1 and each new well is incremented to the next number.

Change well name: a right-click on the well symbol displays a well panel for changing or inputting the well name.

Input well KB and TD: KB elevation and TD values for the well are input in the well panel. Click OK to close the well panel. These parameters are for reference only; they are not used in COZView or COZSim.

The x, y coordinate location of the <u>cursor</u> is displayed in the lower left of the window. This may assist the user in locating wells in the model when the actual well coordinates are known.



Be sure to click **Save and Continue** or **Save and Quit** before leaving *Assign Wells*.

If the user has the actual well locations and there are a number of wells to identify in the model, this manual location of each well may be too time consuming. The user may wish to load the well locations using the Import functionality in the *Well Data, Well Location Data* section 3.4.1.

If the active screen is in the Static Model window, any Save operation after assignment of elevations will result in a "Loading" message next to *View 3D Model*. **Wait until the Loading message has disappeared before proceeding.**

3.1.1.4.4 Simulation Grid

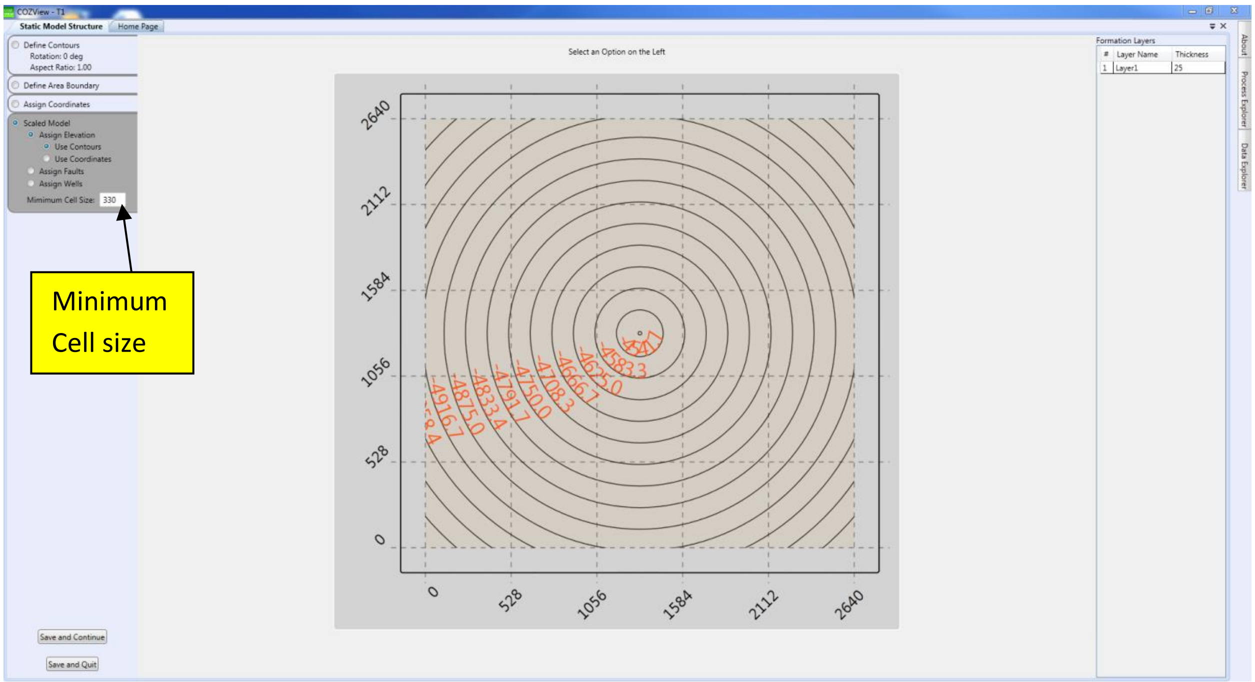
COZView will create the simulation grid automatically during the *Scaled Model* process. The grid can be viewed in the 3D displays. The number of cells in the simulation grid is based on the areal boundaries and the shape of the area to be modeled. There are two overriding principles in creating the grid – 1) a grid cell's dimensions will not be less than 330 ft by 330 ft and 2) all grid cells will be square.

The maximum number of grid cells in either the X- or Y-direction will be 100. If the model area is square and the model area exceeds 33,300 ft on each side, the grid will be 100 by 100 (10,000 total cells per layer).

If the square model area is less than 33,300 ft on each side, say 10,000 ft, the grid will be 30 by 30 (900 total cells per layer). Each grid cell will be 333 ft by 333 ft.

If the model area is rectangular in shape, the longest dimension of the rectangular area will determine the cell dimensions. For a model area with rectangular dimensions (X and Y) of 25,000 ft by 15,000 ft, the grid will 75 cells in the X-direction and 45 cells in the Y-direction (3375 total cells per layer). The cell size will be 333 ft by 333 ft.

When modeling areas of small dimensions, like a small acreage pattern or element of symmetry, the default minimum cell dimensions may result in too few cells in the model. Hence, the user may wish to override the default minimum cell dimensions of 330 in the minimum Cell Size box at the bottom of the Scaled Model area.

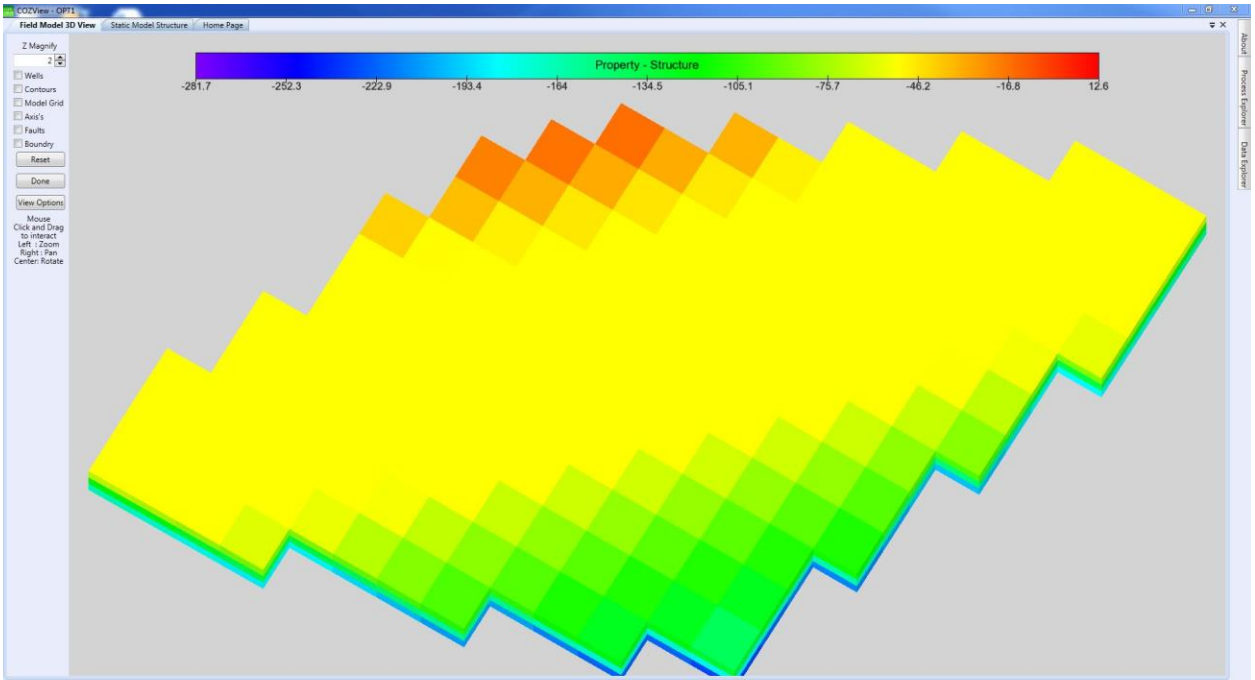


This should be done with caution. Reducing the minimum cell size will increase the number of total cells in the model, which will increase the simulation run time. This should only be done for the noted "small acreage" models. The minimum cell size is 220 ft. The maximum number of cells in the X- and Y-directions will not be allowed to exceed 100.

Be sure to select *Save and Continue* before leaving the **Scaled Model** area to effect the change.

3.1.1.5 View 3D Model

Selection of *View 3D Model* allows the user to visualize the structure model that has been created in a three dimensional format.



The initial 3D view will be a high angle representation of the surface with a vertical Z Magnification of 2. This Z magnification can be changed by the user.

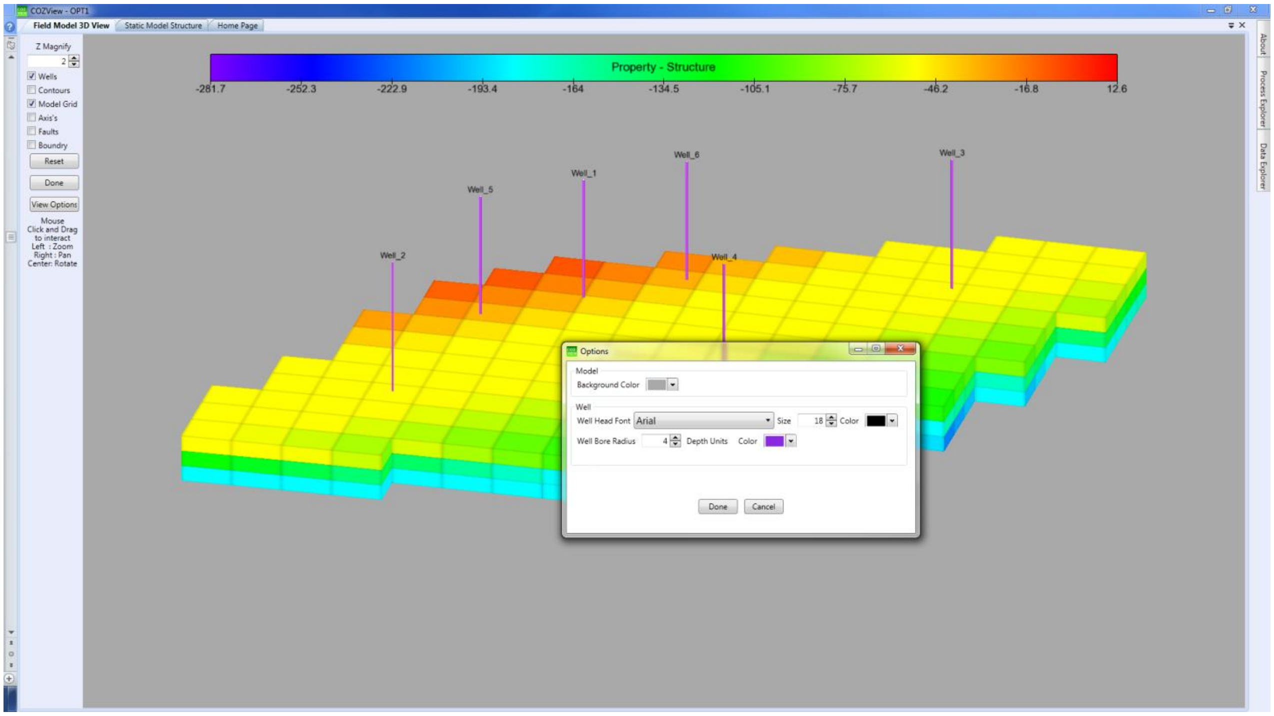
A color bar at the top of the view denotes the range of property values in the model area.

A number of views and operations can be implemented in the *3D View*. The following *click and drag* mouse operations can be used: Left – Zoom, Right – Pan, and Center – Rotate.

The display of wells, contours, (simulation) model grid, view axis's, faults and area boundaries can be activated with selection of the appropriate check boxes.

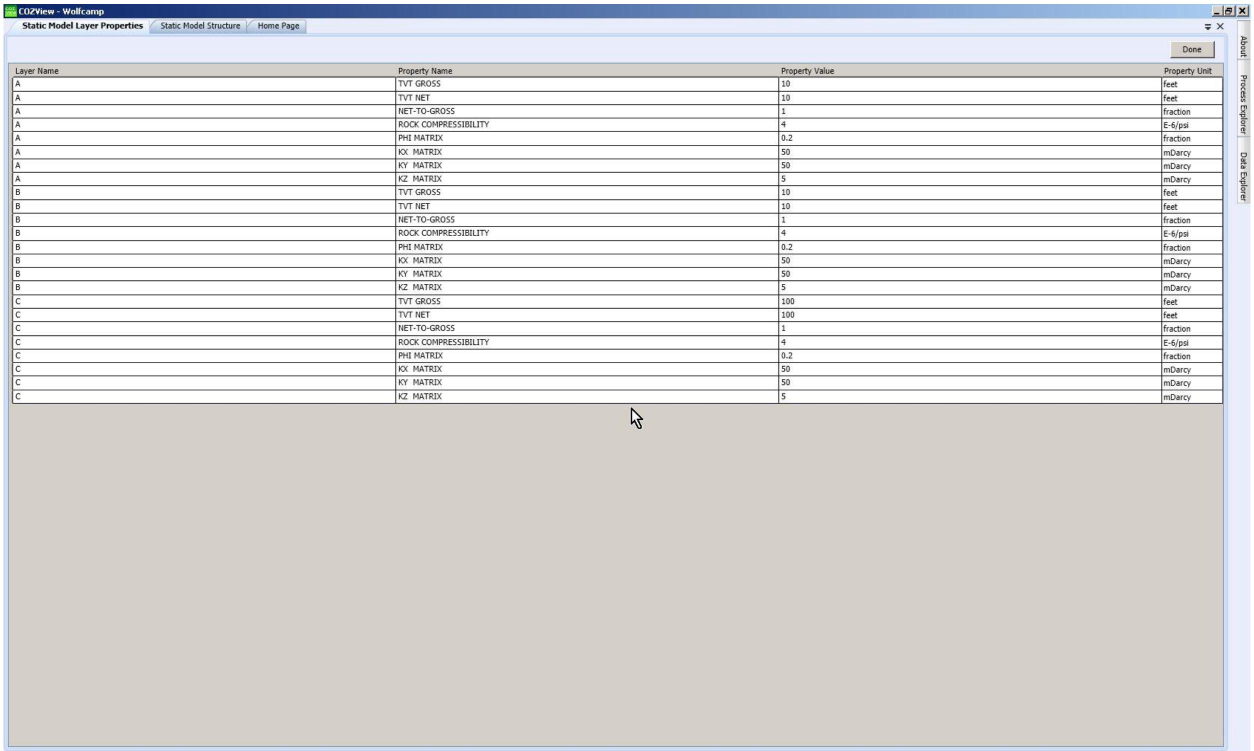
The **Reset** button allows the user to return to the initial orientation on the screen. The **Done** button exits the 3D View screen and returns the user to the prior screen view.

The **View Options** button allows the user to select the background display color (Default color is grey). The size, font, and color of the well names can be selected by the user (Default is Arial font, size 18, and color white). Users are also allowed to choose the well radius size (Default display size is 2, color is white.)



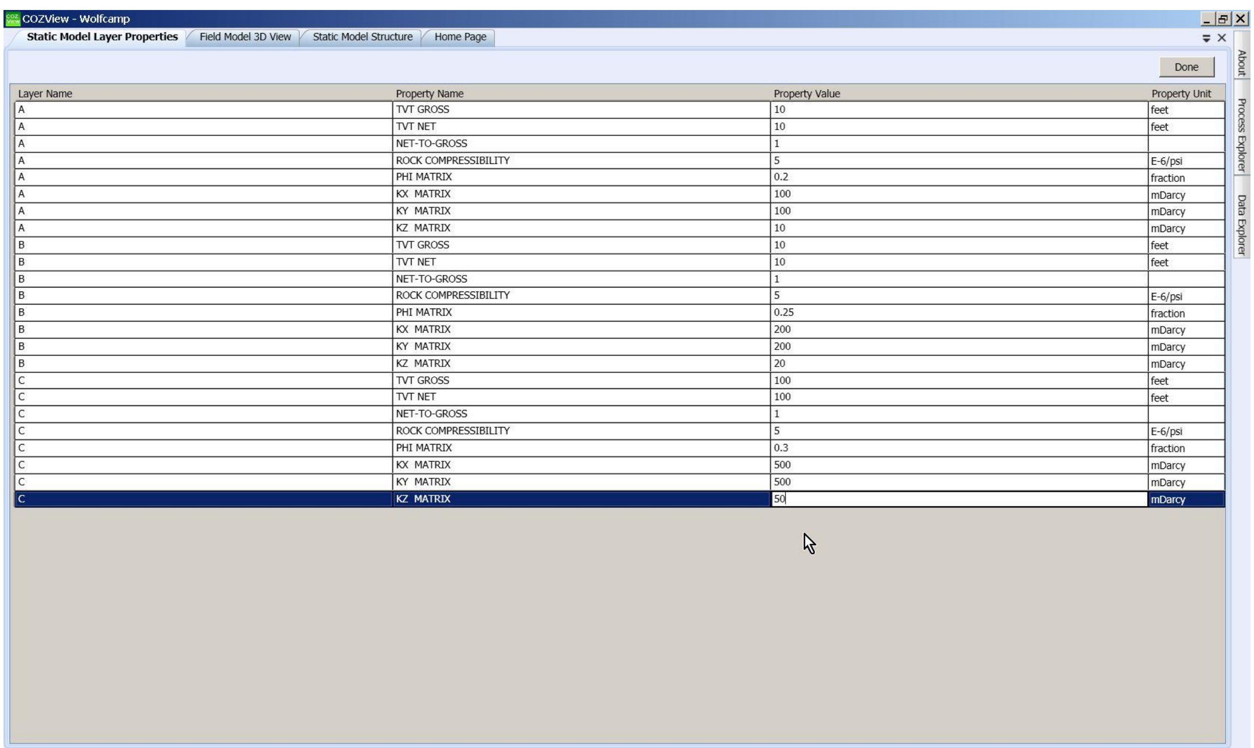
3.1.2 Layer Properties

Selection of *Layer Properties* allows the user to input various static reservoir properties required in the simulation model. A group of properties for each layer which has been previously defined is shown in the table. The properties are constant for each layer, but may be different between layers. The gross thickness previously defined for each layer and the net thickness and net-to-gross values are shown in the table. Default values are provided for all other layer properties in the table. *These default values should not be construed as acceptable values for the user's specific application.*



Layer Name	Property Name	Property Value	Property Unit
A	TVT GROSS	10	feet
A	TVT NET	10	feet
A	NET-TO-GROSS	1	fraction
A	ROCK COMPRESSIBILITY	4	E-6/psi
A	PHI MATRIX	0.2	fraction
A	KX MATRIX	50	mDarcy
A	KY MATRIX	50	mDarcy
A	KZ MATRIX	5	mDarcy
B	TVT GROSS	10	feet
B	TVT NET	10	feet
B	NET-TO-GROSS	1	fraction
B	ROCK COMPRESSIBILITY	4	E-6/psi
B	PHI MATRIX	0.2	fraction
B	KX MATRIX	50	mDarcy
B	KY MATRIX	50	mDarcy
B	KZ MATRIX	5	mDarcy
C	TVT GROSS	100	feet
C	TVT NET	100	feet
C	NET-TO-GROSS	1	fraction
C	ROCK COMPRESSIBILITY	4	E-6/psi
C	PHI MATRIX	0.2	fraction
C	KX MATRIX	50	mDarcy
C	KY MATRIX	50	mDarcy
C	KZ MATRIX	5	mDarcy

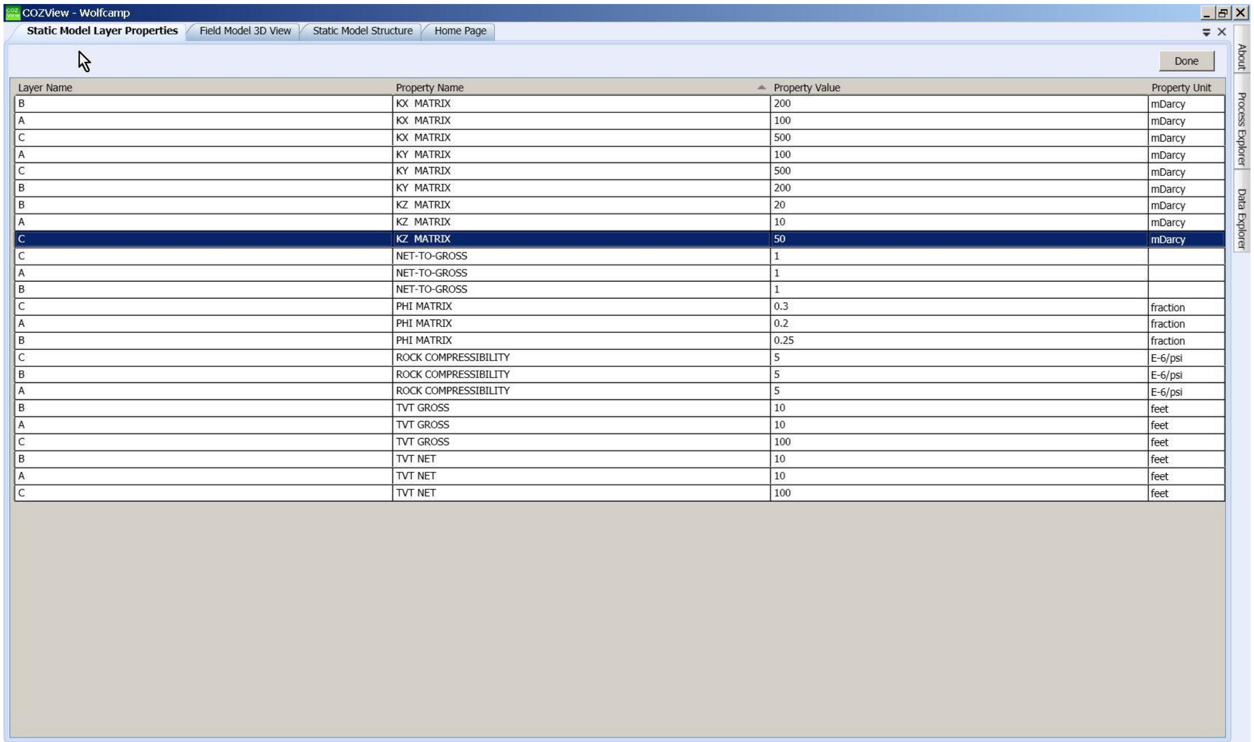
Property values are input by double clicking in the Property Value field and inputting the desired value. The property units for each property have defaulted to typical units. However, double clicking in the Property Unit field for a given property provides a dropdown menu for selection of alternative units.



Layer Name	Property Name	Property Value	Property Unit
A	TVT GROSS	10	feet
A	TVT NET	10	feet
A	NET-TO-GROSS	1	
A	ROCK COMPRESSIBILITY	5	E-6/psi
A	PHI MATRIX	0.2	fraction
A	KX MATRIX	100	mDarcy
A	KY MATRIX	100	mDarcy
A	KZ MATRIX	10	mDarcy
B	TVT GROSS	10	feet
B	TVT NET	10	feet
B	NET-TO-GROSS	1	
B	ROCK COMPRESSIBILITY	5	E-6/psi
B	PHI MATRIX	0.25	fraction
B	KX MATRIX	200	mDarcy
B	KY MATRIX	200	mDarcy
B	KZ MATRIX	20	mDarcy
C	TVT GROSS	100	feet
C	TVT NET	100	feet
C	NET-TO-GROSS	1	
C	ROCK COMPRESSIBILITY	5	E-6/psi
C	PHI MATRIX	0.3	fraction
C	KX MATRIX	500	mDarcy
C	KY MATRIX	500	mDarcy
C	KZ MATRIX	50	mDarcy

Once all values have been input select **Done** to save the values.

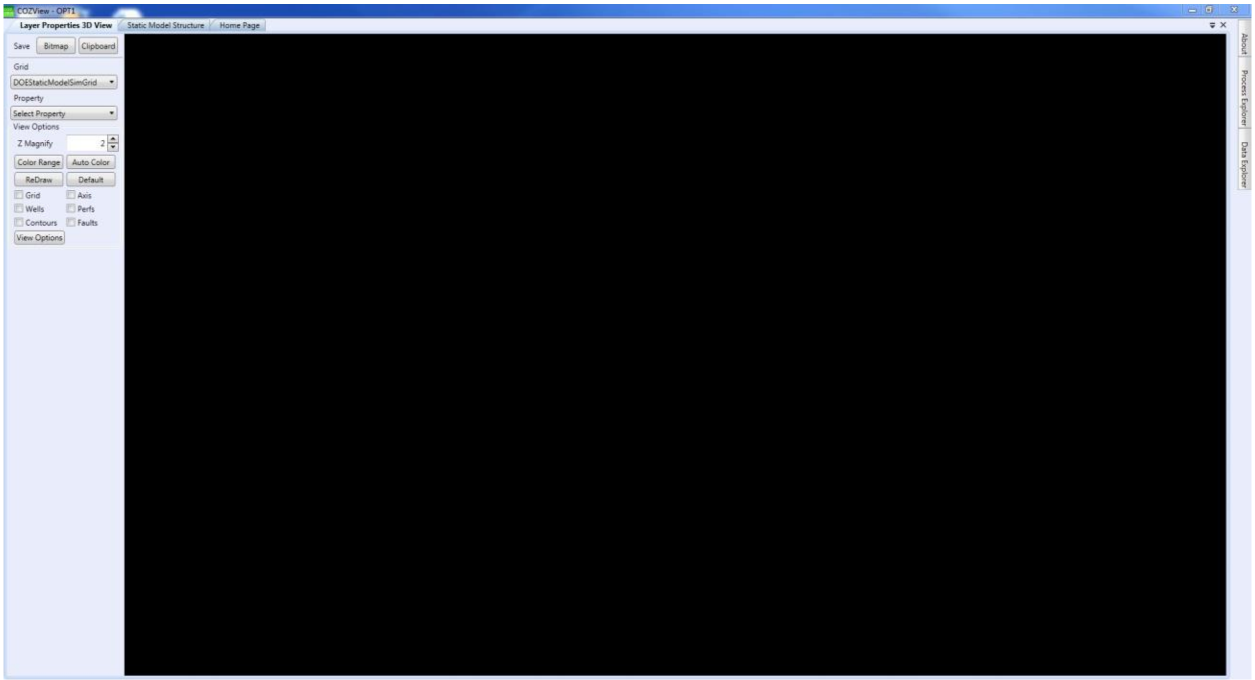
Individual layers (all properties) or individual properties (all layers) can be displayed with a left-click on the *Layer Name* or *Property Name*. Selection of the triangle at the far right of each title will cause the order of the list to be inverted.



Layer Name	Property Name	Property Value	Property Unit
B	KX MATRIX	200	mDarcy
A	KX MATRIX	100	mDarcy
C	KX MATRIX	500	mDarcy
A	KY MATRIX	100	mDarcy
C	KY MATRIX	500	mDarcy
B	KY MATRIX	200	mDarcy
B	KZ MATRIX	20	mDarcy
A	KZ MATRIX	10	mDarcy
C	KZ MATRIX	50	mDarcy
C	NET-TO-GROSS	1	
A	NET-TO-GROSS	1	
B	NET-TO-GROSS	1	
C	PHI MATRIX	0.3	fraction
A	PHI MATRIX	0.2	fraction
B	PHI MATRIX	0.25	fraction
C	ROCK COMPRESSIBILITY	5	E-6/psi
B	ROCK COMPRESSIBILITY	5	E-6/psi
A	ROCK COMPRESSIBILITY	5	E-6/psi
B	TVT GROSS	10	feet
A	TVT GROSS	10	feet
C	TVT GROSS	100	feet
B	TVT NET	10	feet
A	TVT NET	10	feet
C	TVT NET	100	feet

3.1.3 View Layer Properties

Selection of *View Layer Properties* displays a 3D viewer window. It is initially blank.



The menu in the **Select Property** box allows the user to select any of the formation properties previously input and saved. These reservoir properties are TVT NET (Net True Vertical Thickness), PHI Matrix (Matrix Porosity), Rock Compressibility, KX,KY and KZ (Permeability of matrix in X,Y and Z directions).

As these formation properties are constant within a layer, the 3D view may not be particularly interesting. If multiple layers have been input and properties are different between the layers, color variations will be noted on the edges of the model display subject to the color range settings.

The **Color Range** button can be used to set the Minimum and Maximum value for color bar. Please note that COZView will not save the user set minimum and maximum value. Switching to a different property or closing the tab will reset the default minimum and maximum values.

The **Auto Color** sets the color range to the default Minimum and Maximum values.

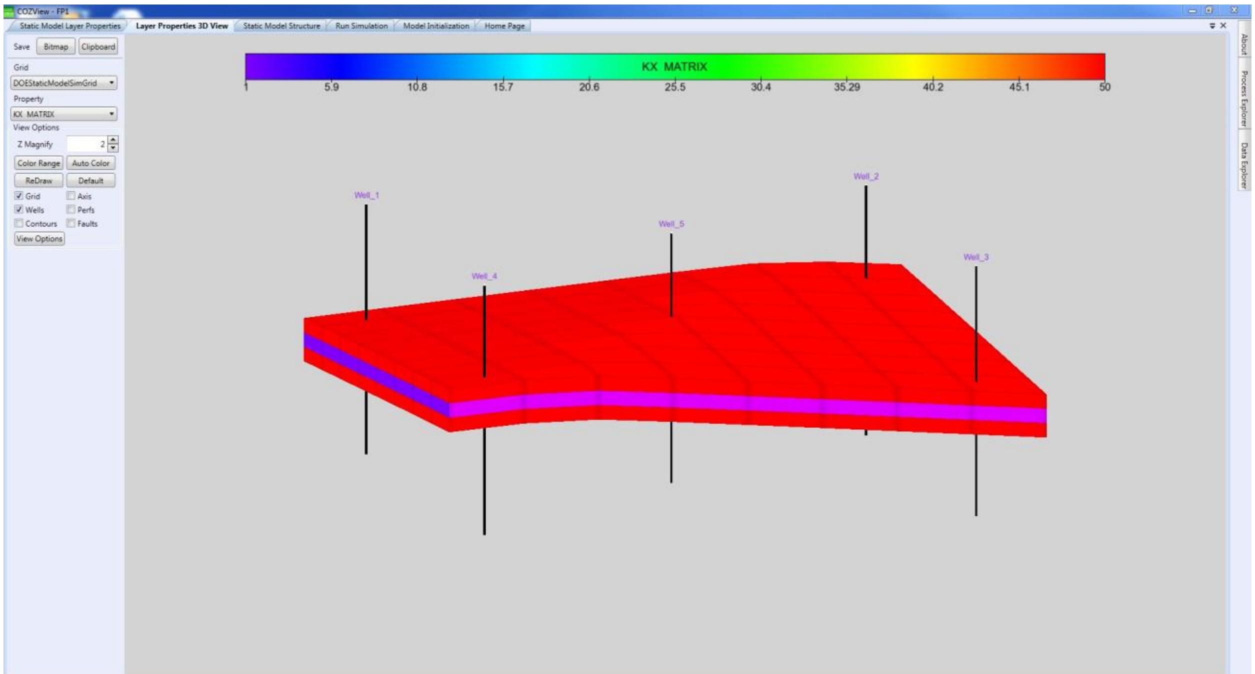
The **ReDraw** button refreshes the 3-D window to the original view. This is useful when the 3D view has been changed while using mouse operations (Zoom, Pan and Rotate).

The display of **Grid**, **Axis**, **Wells**, **Perfs** (Perforations), **Contours**, and **Faults** can be activated with selection of the appropriate check boxes.

The **View Options** button allows the user to select the background display color, size and font of well names, and color of the well bore.

COZView saves the *View Options* information. Selecting a different property will not reset the *View Options* information to the default values. However, closing the tab will reset the Color Range and View Options to the default values.

As in all 3D views in **COZView**, the view can be panned, zoomed and rotated with appropriate mouse operations.



The user can leave the *View Formation Properties* window by selecting a new menu item in the *Process Explorer* area on the right or the active *Menu Tabs* at the top

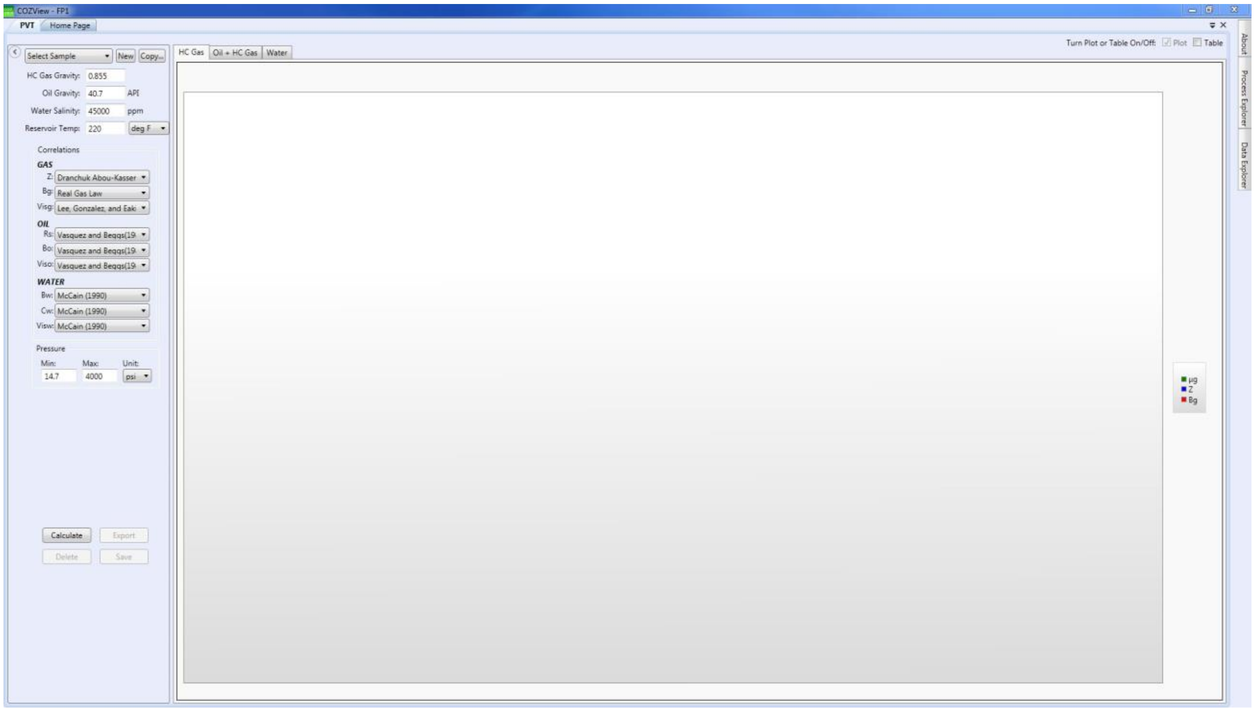
3.2 Fluid and Saturation Properties

The fluid properties (PVT) define the expansion and solubility characteristics of the reservoir fluids. Typically a reservoir will have one set of PVT properties unless areas of the reservoir are isolated from others due to barriers. Multiple PVT “tables” can be created in **COZView**; however, only one may be used in the simulation model.

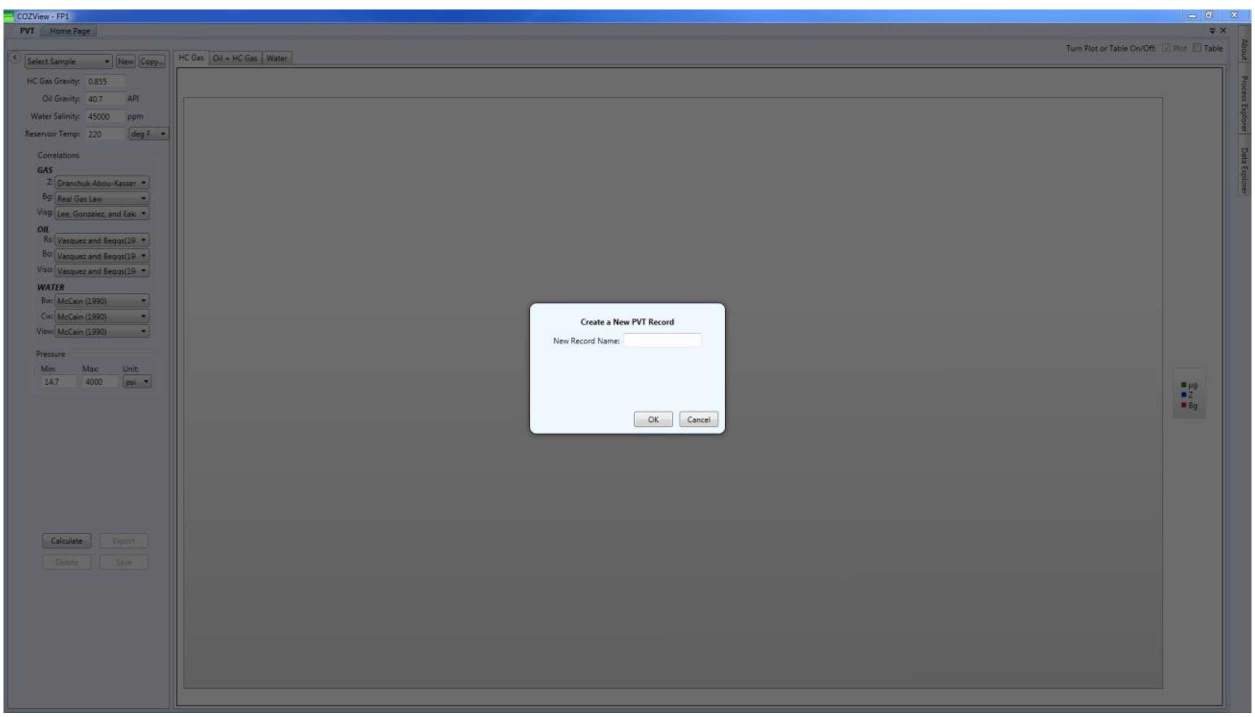
Saturation functions define the relative permeability and capillary pressure relationships (rock tables) for the reservoir. Typically, different rock types (sandstone, dolomite, limestone etc.) will have different rock tables. Multiple rock tables can be created in **COZView**; however, only one may be used in the simulation model.

3.2.1 PVT

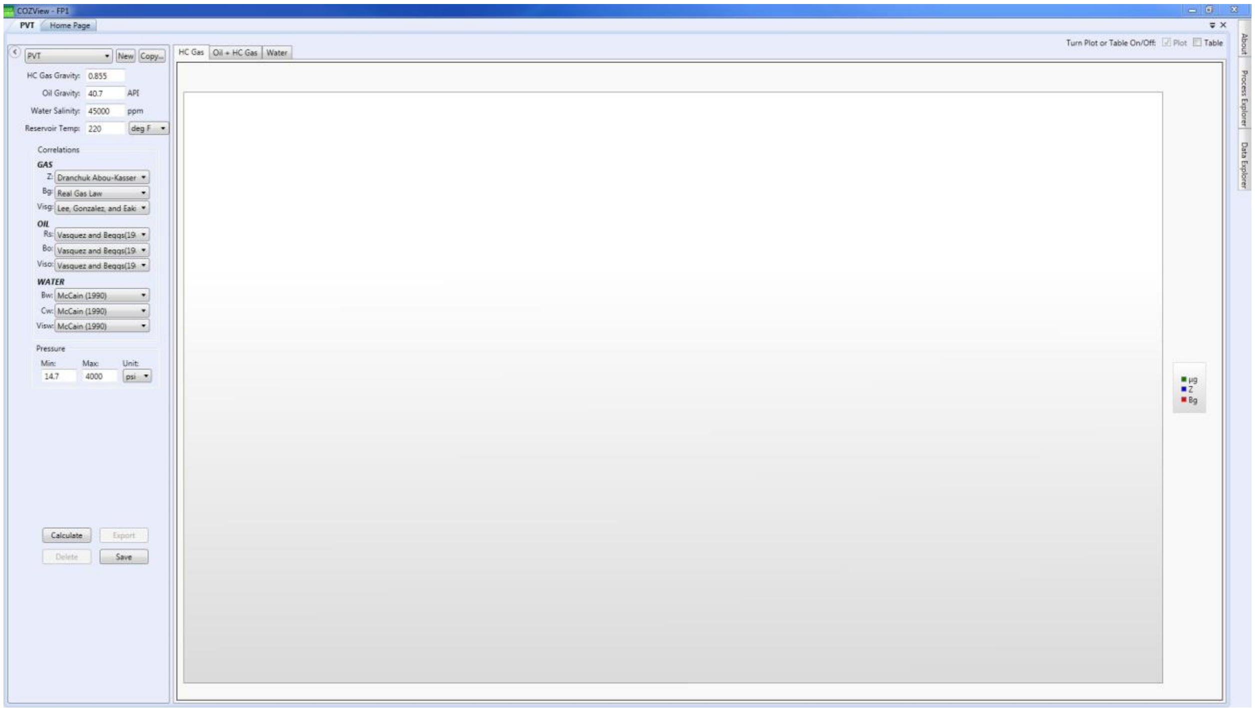
The *PVT* section allows the user to identify the PVT data and to generate appropriate PVT tables (oil, gas and water) for use in the simulator. Selection of *PVT* in the Process Explorer menu displays the *PVT* tab.



Initially this table is blank. Selection of the New button allows the user to define a PVT table by name.

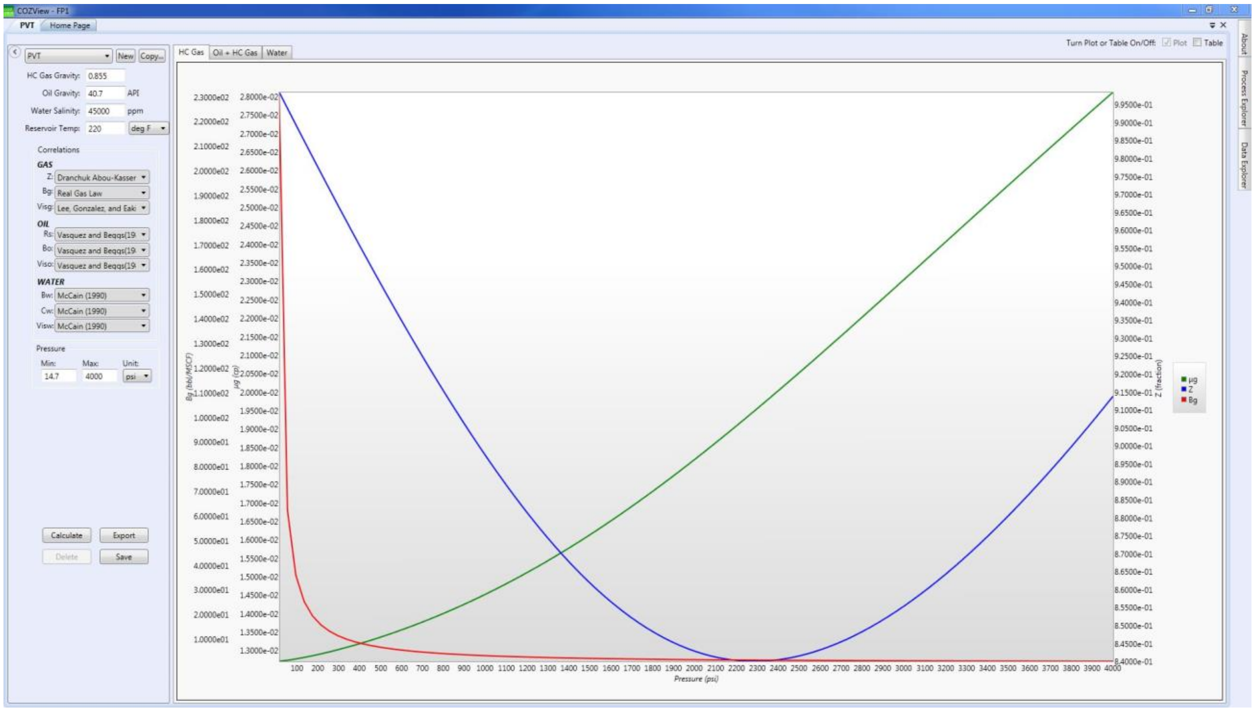


The parameter panel is on the left and a plot window is on the right. Tabs at the top of the plot window identify the phase (oil, gas, water) which is displayed in the plot window. The plot window is initially blank and default values are shown in the parameter panel. (*It is important to note that these default* *values are not intended to be representative of the user's reservoir per se.)* The New PVT sample name appears in the Sample box.



The user must then input appropriate values for the hydrocarbon gas (HC) *Gas Gravity*, *Oil Gravity*, *Water Salinity*, *Reservoir Temperature* and *Temperature Units*. At the bottom of the parameter panel, the minimum and maximum pressure range for the PVT values to be calculated must also be specified. The maximum pressure should be greater than any static or dynamic pressure the user expects to occur in the model during the simulation runs.

Selection of the **Calculate** button will result in calculation and plotting of the PVT properties based on the input parameters. Selection of the appropriate tab at the top of the plot window will display the desired phase. Tables of the calculated values can be viewed by selecting the Table box in the upper right of the window.



The correlations used to calculate the various parameters are noted in the Correlation portion of the parameter panel. A specific correlation can be selected from the associated drop down menu.

Multiple groups of PVT properties can be generated by selecting New Sample name for each group.

Once the required PVT parameters have been generated, selection of the **Save** button will save the properties. Previously calculated and saved PVT properties can be changed and the new curves can be saved without defining a new *PVT Sample Name*.

The **Export** button will save the oil, water and gas PVT property tables as text files in a location of the user's selection.

The correlations used are noted below.

Gas:

- *Z factor: Dranchuk*, P. and *Abou-Kassem*, J. (*1975*), "Calculation of Z-factors for Natural Gases Using Equations-of-State", JCPT, July-September *1975*, p. 34-36.
- Bg: *Real gas law*
- µg: *Lee, A. L. Gonzales, M.H. and Eakin, B. E. : "The Viscosity of Natural Gases",* Journal of Petroleum Technology *(Aug. 1966) p. 997-1000, Trans., AIME, 37.*

Oil:

- Rs, Bo, µo: Vasquez, M. and H. D. Beggs. "Correlations for Fluid Physical Property Prediction" Journal of Petroleum Technology (June 1980) p. 968-970.

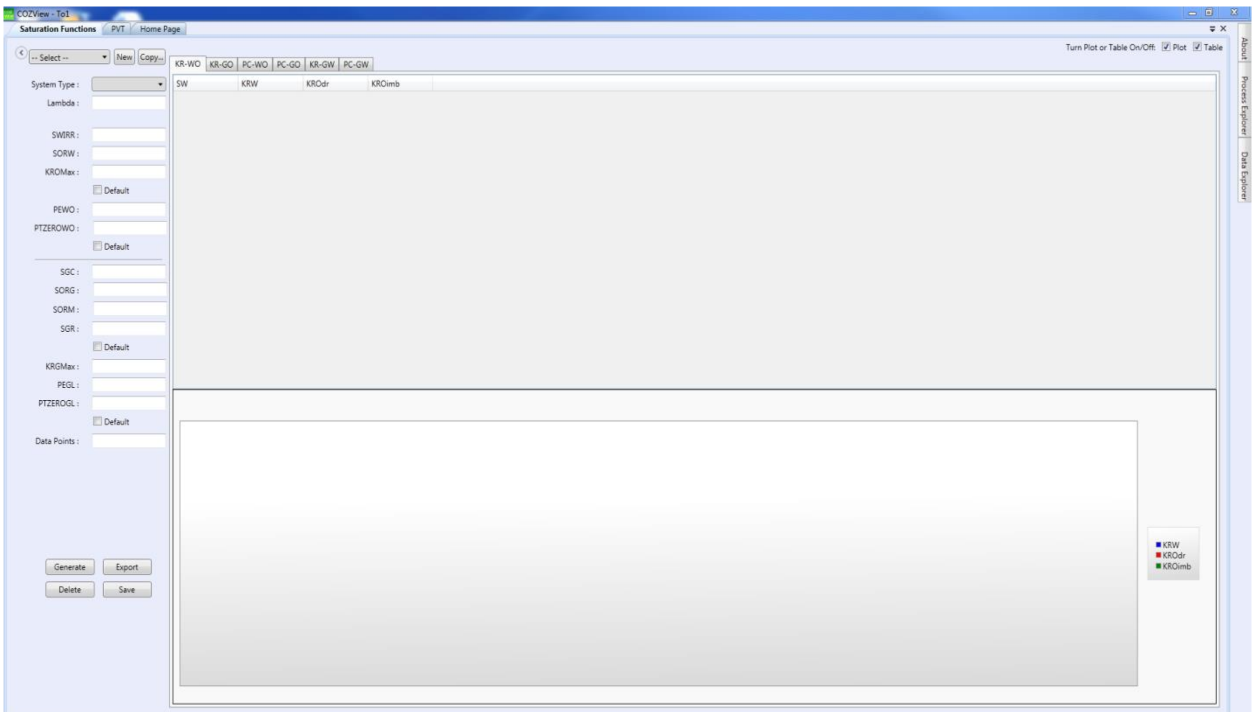
Water:

- Bw, cw, μw: McCain, W.D. *"The Properties of Petroleum Fluids."* Tulsa: PennWell Publishing Company, 1989.

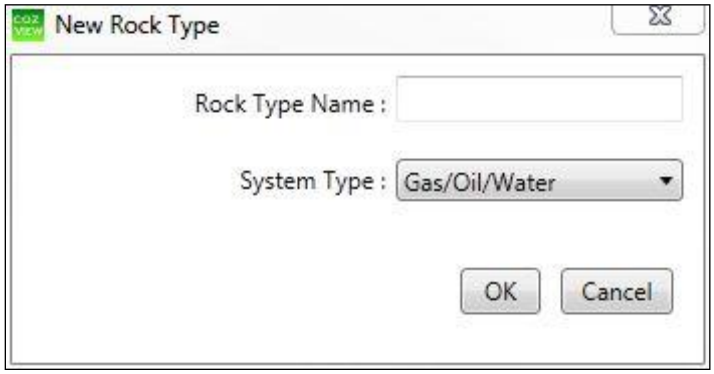
The default maximum pressure for the PVT data is 4000 psia. This default value can be overridden by the user. However, it must be noted that the CO2 property correlations' that are used in COZSim are based on actual laboratory measurements up to approximately 4000 psia. The correlations have been extended for higher pressures, but are not validated by actual data.

3.2.2 Saturation Functions

The *Saturation Functions* section allows the user to define the relative permeability and capillary pressure relationships for use in the simulation model. Multiple sets of functions can be defined. These are often referred to as rock tables. The user can define data for a gas-liquid or oil-water-gas system.



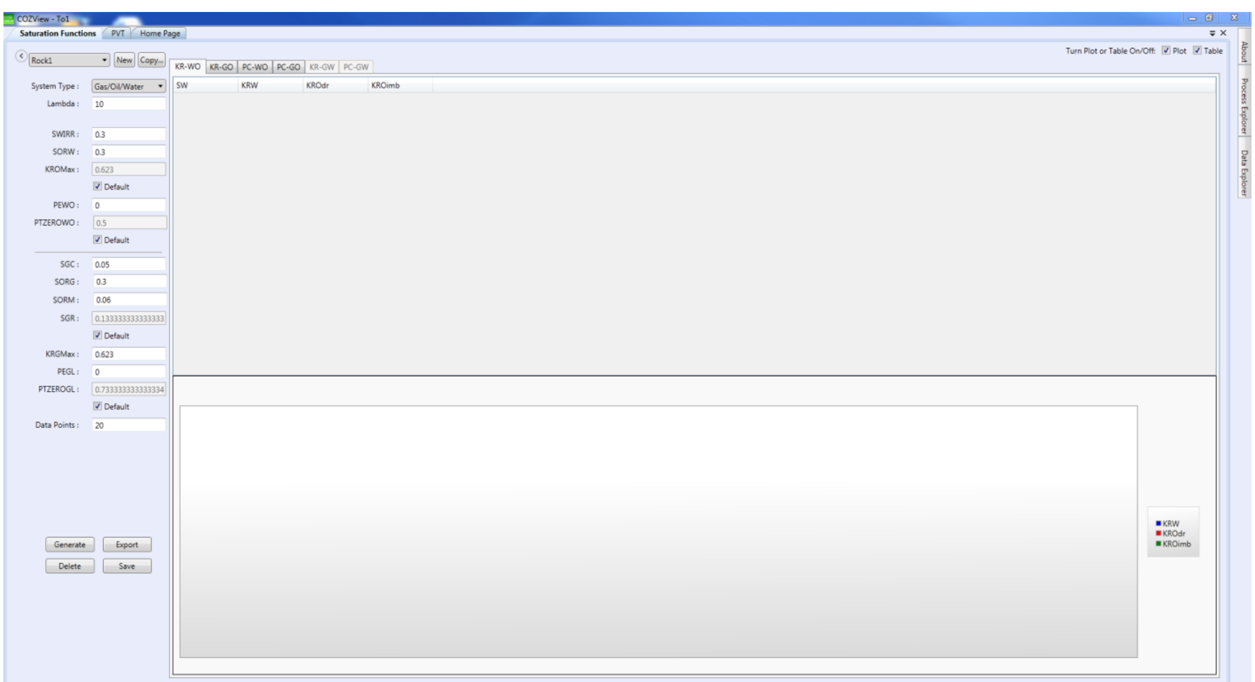
The first time the user enters this screen, a new Rock Type (table) must be identified by selecting the **New** button. This prompts the user to provide a rock type name and identify the relevant fluid system. The rock type will associate the generated curves to proper rock tables in the simulator.



The saturation functions are calculated based on the set of parameters which are shown in the left panel. Most of these parameter values will be available if laboratory data are available. A definition of each parameter is shown below. The correlations used by **COZView** are based on M.B. Standing's *Notes on Relative Permeability Relationships*, *The University of Trondheim, August 1974.*

The panel includes the default values which can be used directly or modified by the user. The default selections that are available for the KROMax, PTZEROWO, SGR and PTZEROGL use the endpoints SWIRR and SORW to calculate the proper values using the correlations. If the Default is unselected for any of these four parameters, the user can enter their own values.

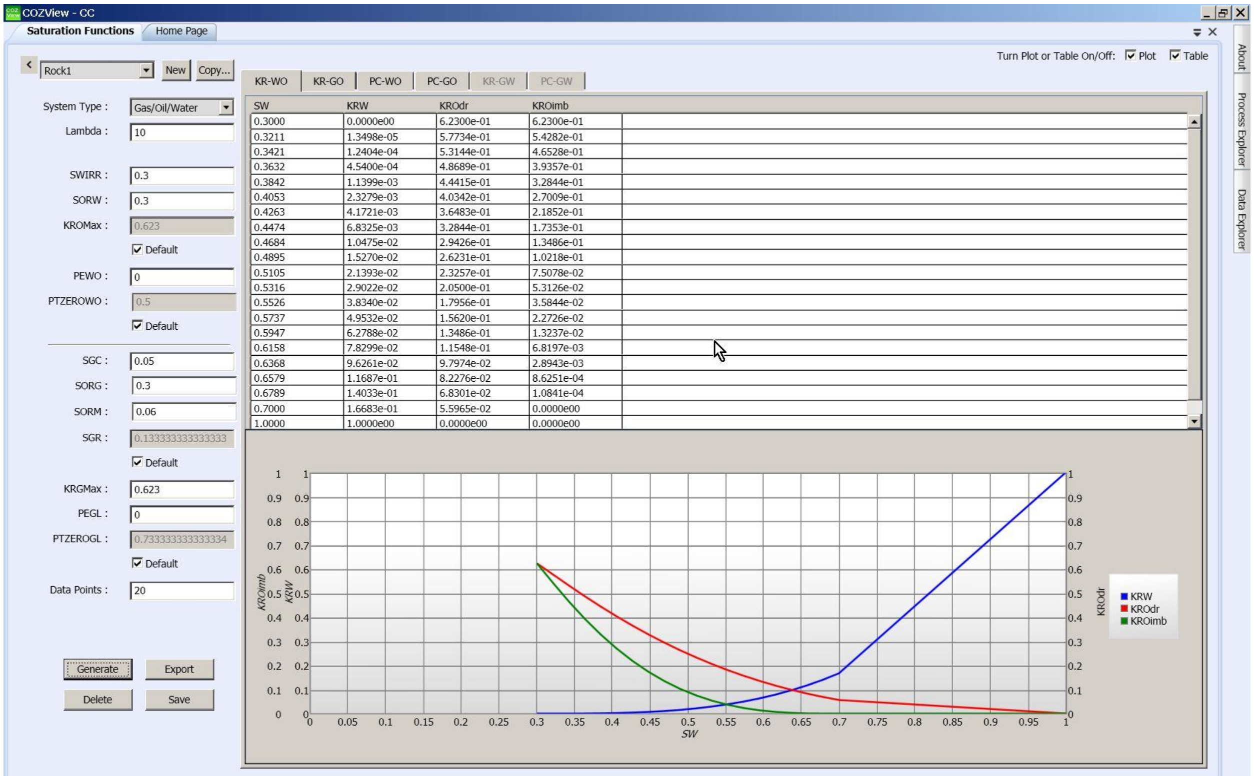
A default value is also provided for the residual oil saturation, Sorm, to the miscible fluid (CO2) displacement. The default is calculated as 0.20 times the Sorg. The user can override the default by inputting a new value.



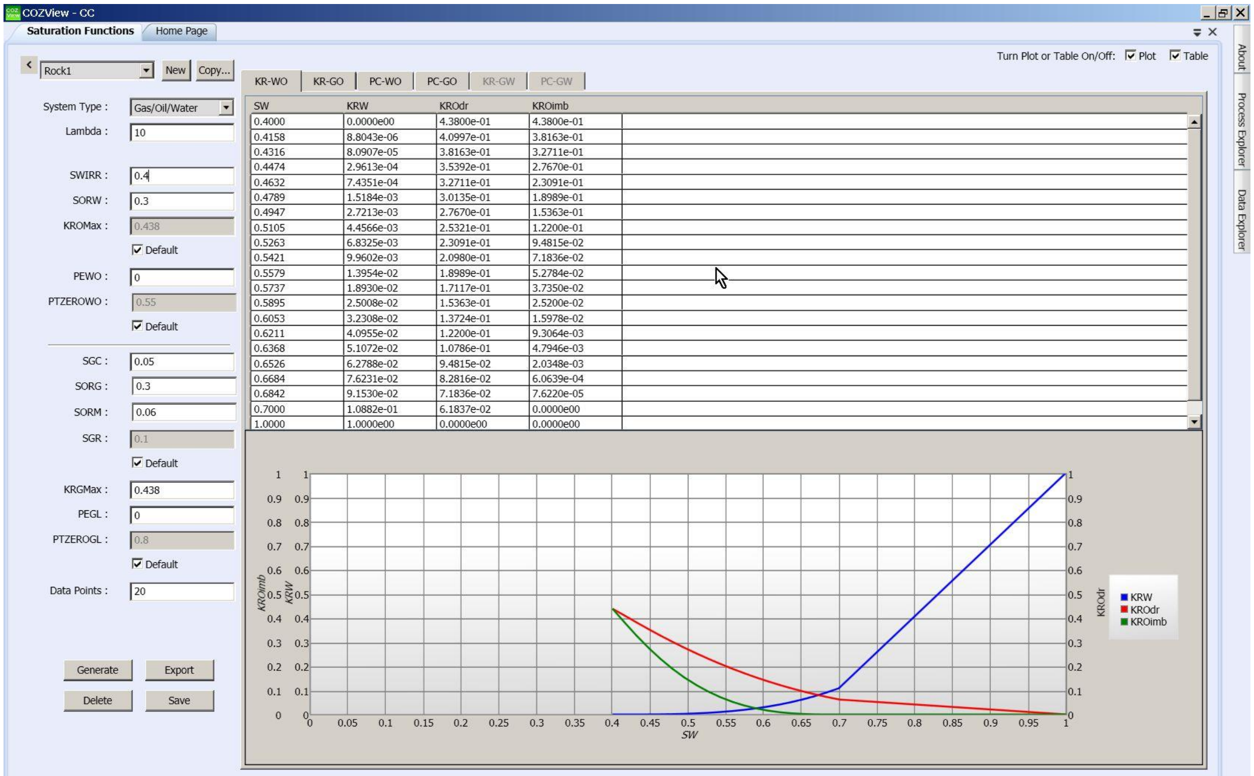
The default values associated with capillary pressure will result in a capillary pressure with no saturation transition from one phase to the other (no capillary pressure). This will have an impact on any phase volumetric calculations at the time of model initialization.

Parameter	Description	Default Value
Lambda	Pore size distribution index	10
SWIRR	Irreducible water saturation; connate water saturation	0.3
SORW	Residual oil saturation to water	0.3
KROMax	Maximum relative permeability to oil at SO=(1-SWIRR)	Default correlation
PEWO	Entry pressure on oil-water capillary pressure curve	0.0
PTZEROWO	The zero point where forced imbibition starts for the water-oil capillary pressure curve (the saturation value that capillary pressure is zero; used to rescale the curve for imbibition)	Default relationship
SGC	Critical gas saturation; SG at which gas begins to flow	0.05
SORG	Residual oil saturation to gas	0.3
SGR	Residual gas saturation; trapped gas saturation	Default relationship
KRGMax	Maximum relative permeability to gas at SG= (1-SOR-SWIRR)	Equal to KROMax
PEGL	Entry pressure on gas-liquid capillary pressure curve	0.0
PTZEROGL	The zero point where forced imbibition starts for the gas-oil capillary pressure curve(the saturation value that capillary pressure is zero; used to rescale the curve for imbibition)	Default relationship
Data points	Number of saturation values that will be used in the tables (curves). This will determine the saturation increments in the generated tables (curves).	20
SORM	Residual oil saturation to miscible CO2 displacement	Equals 0.20 times SORG

Select the **Generate** button to calculate the individual relative permeability and capillary pressure curves. The curves are generated for both drainage and imbibition process automatically. Both the curves and the tables associated with the curves are ready to view once they are generated. Different curves can be reviewed by clicking the proper tab in the window.



The screen above has generated the saturation function using the default values for all parameters. The screen below is the result of changing only the SWIRR value from 0.3 to 0.4 and generating new curves.

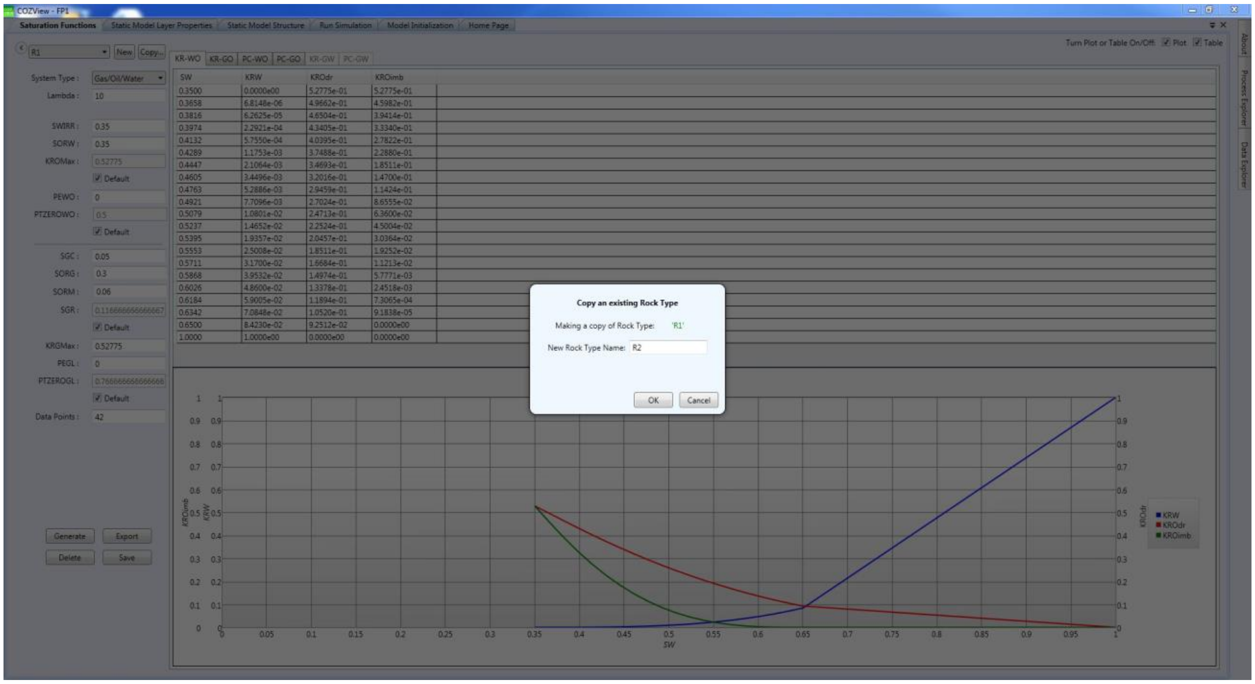


As noted above, the user can modify the shape of the individual saturation function curves with appropriate changes to endpoint parameters.

If the user selects the **Generate** button and an input parameter box changes color to red, this denotes that a previous user parameter change has created an invalid parameter value. Passing the cursor over the "red" parameter box will provide information on how to correct the problem. The **Generate** button will not create the required curves and tables until the "red" parameter box problem is resolved.

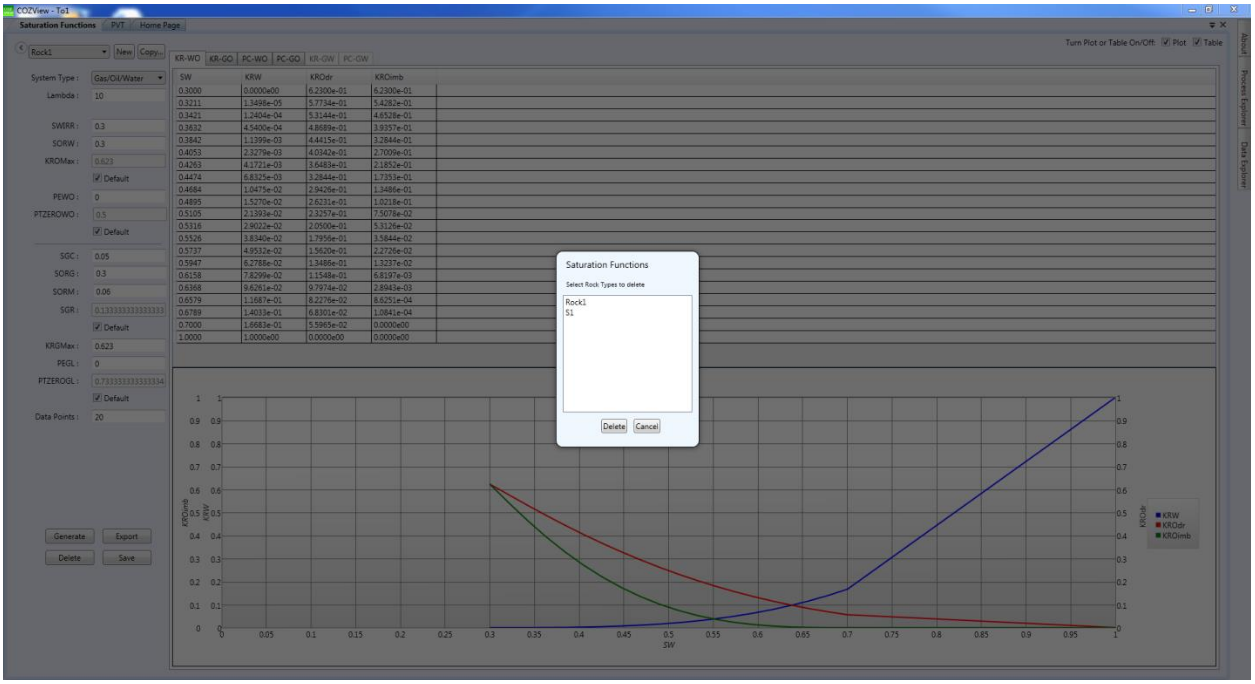
Once the required Saturation Function parameters have been generated or modified, selection of the **Save** button will save the properties. Previously calculated and saved Saturation function properties can be changed and the new curves can be saved without defining a new *Rock Type Name*.

The user can copy an existing Rock Type (table) using the **Copy** button. Please note that the **Copy** button will only copy values of endpoint saturations. The user must click Generate to create the full Saturation function property table.



The **Export** button will save the saturation function property tables as text files in a location of the user's selection.

A **Delete** button is available to remove previously saved Rock tables from the project database. The user is asked to identify the appropriate Rock table to be deleted and select *Delete.*

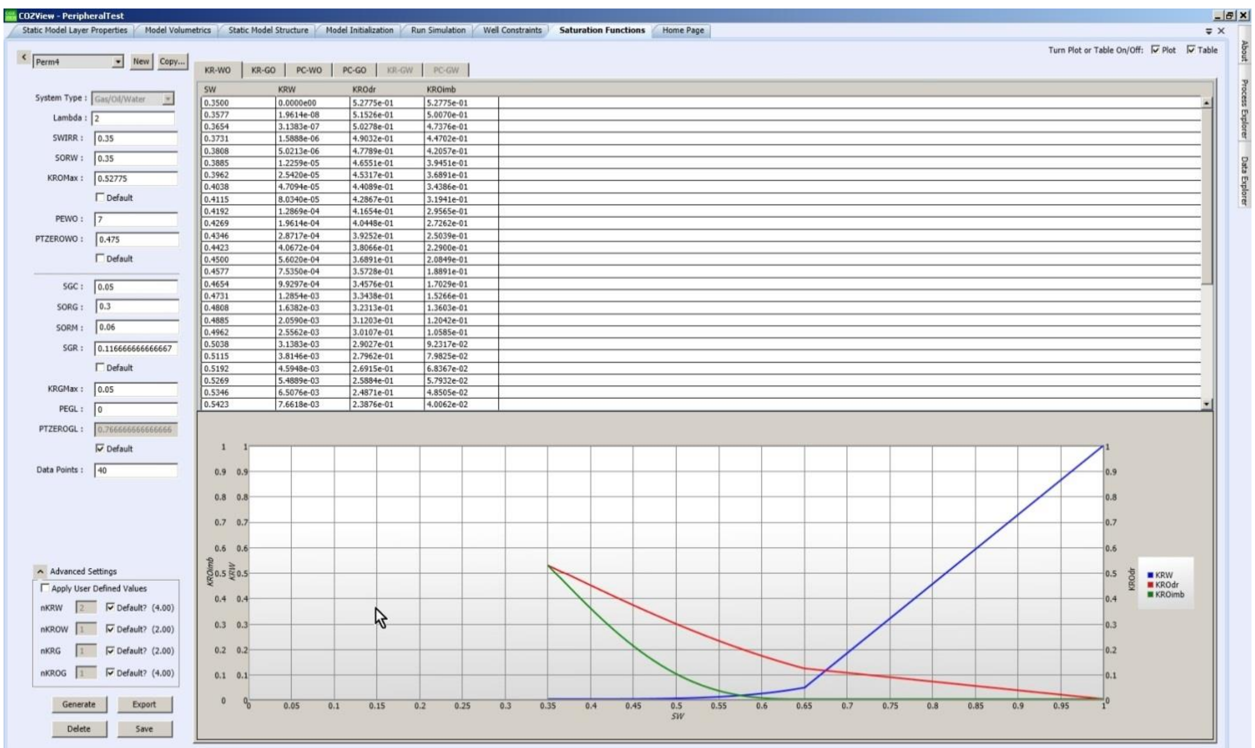


3.2.2.1 *Advanced Settings*

The Advanced Saturation Function Settings should only be used after the model OOIP and OIP (if appropriate) have been verified in the ***Verify Model*** section. These options are used to modify the shape of the relative permeability curves generated by **COZView**. The end point saturations (Sorw, Swirr, Sgc, Sorg, Sorm) are not changed. This is normally done to adjust water cuts and/or gas-oil ratios at the individual well or field level at the start of a prediction run. (This is a common practice in conventional history matching of a model to historical performance.)

Warning: Other parameters associate with generation of the relative permeability and capillary pressure curves are available to the user on this screen. These parameters were likely used/modified during calibration of the model to the OOIP and OIP. Changes to any of the parameters that are not in the Advanced Options section may change the OOIP and OIP.

Selection of **Advanced Settings** in the lower left portion of the screen will display the options shown below.



The parameters nKRW, nKROW, nKRG, nKROG are the exponents in the following equations. These are the same M.B. Standing correlations referenced earlier.

$KRW = Sw^{*nKRW}$

where $Sw^* = (Sw-Swirr)/(1-Swirr)$ and $nKRW = (3*Lambda+2)/Lambda$

nKRW can be overwritten directly to modify the relative permeability curves using the advanced settings.

$KROW_{drainage}$ = KROMax (1-Sw*)^2 * (1-(Sw*)^{nKROW})

where Sw* = (Sw-Swirr)/(1-Swirr) and nKROW = (2+Lambda)/Lambda

nKROW can be overwritten directly to modify the relative permeability curves using the advanced settings.

$KROW_{imbibition}$ = KROMax *(Snf*)^2 * (1-(1-Snf*)^{nKROW})

where Sw* = (1-Sw-Sorw)/(1-Swirr-Sorw) and nKROW = (2+Lambda)/Lambda

nKROW can be overwritten directly to modify the relative permeability curves using the advanced settings.

KROG = (SL*)^{nKROG}

where SL* = (SL-Swirr-Sorg)/(1-Swirr-Sorg) and nKROG = (3*Lambda+2)/2

SL= (Sw+So)

nKROG can be overwritten directly to modify the relative permeability curves using the advanced settings.

$KRG_{drainage}$ = KRGMax*(Sn*)^2 * (1-(1-Sn*)$^{n\ KRG}$)

where Sn* = (1-SL-Sgc)/(1-Swirr-Sorg-Sgc) and nKRG = (2+Lambda)/Lambda

$KRG_{imbibition}$ = KRGMax*(Snf*)^2 * (1-(1-Snf*)^{nKRG})

where Snf* = (1-SL-Sgr)/1-Swirr-Sorg-Sgr and nKRG = (2+Lambda)/Lambda

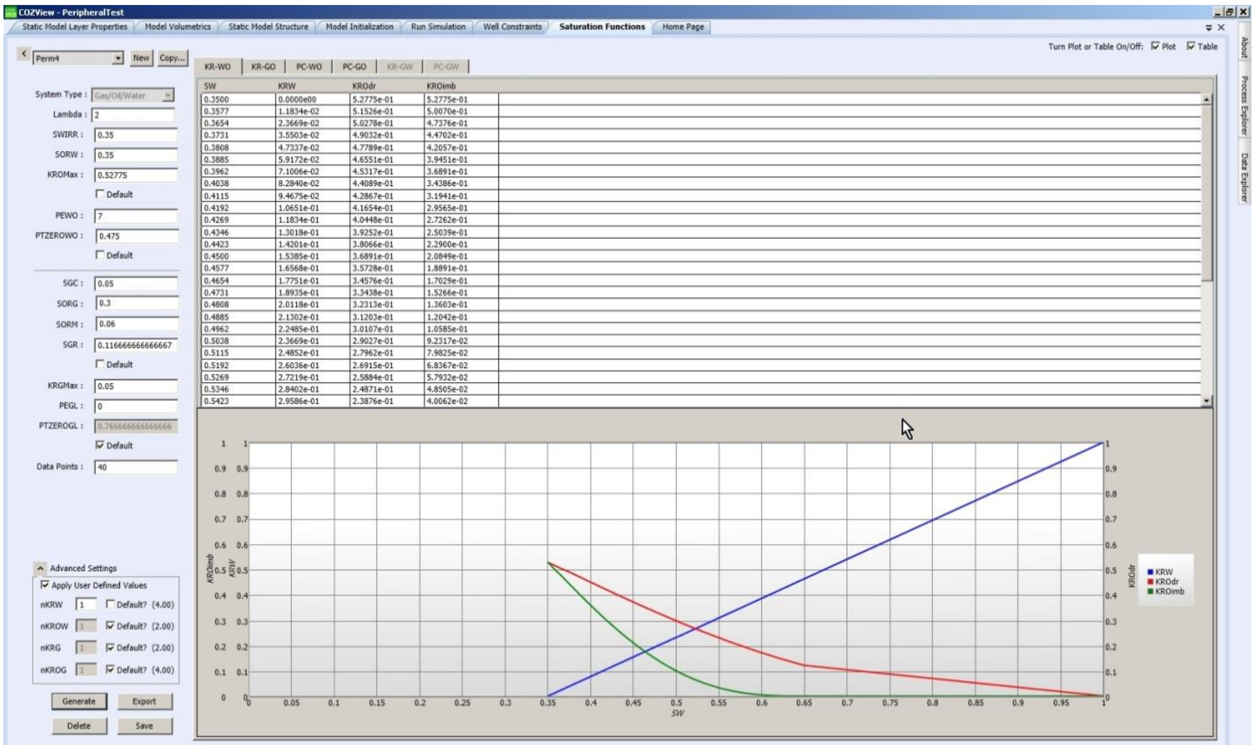
Please note that the exponent values nKROW and nKROG impact both drainage and imbibition curves.

The default “n” values are based on the Lambda value in the upper left portion of the screen. Changing the “n” exponent alters the shape of the relative permeability curve. Lowering or raising the “n” value impacts the curve shape as noted below. Imbibition and drainage curves are impacted in the same manner.

Curve	**Larger n**	**Smaller n**
KRW	Lowers	Raises
KROW	Raises	Lowers
KROG	Lowers	Raises

KRG	Raises	Lowers

To see the impact of changing the exponent on a specific relative permeability curve, the user must first Check the box *Apply User Defined Values*. Next the **Default** box should be unchecked for the relative permeability curve to be changed. (KRW in this example.) The user is then able to input a value for the new “n”. A higher value of 1.0 is input. Selection of **Generate** displays a modified relative permeability curve (KRW in this example) shown below.



The user can toggle between the Default value and the user defined value by checking and unchecking the *Apply User Defined Values* check box. When the appropriate relative permeability curves have been generated, select **Save**.

If none of the non-Advanced Setting parameters have been changed, there should be no impact on the OOIP and/or OIP. The user can run ***Verify Model*** with the new **Advanced Settings** to confirm that this is the case.

This functionality is new and earlier pictures of this screen may not show the Advanced Settings panel.

3.3 Verify Model

The *Verify Model* area allows the user to define field initialization parameters and verify the model volumetrics before launching a simulation run.

3.3.1 Model Initialization and View Model Volumetrics

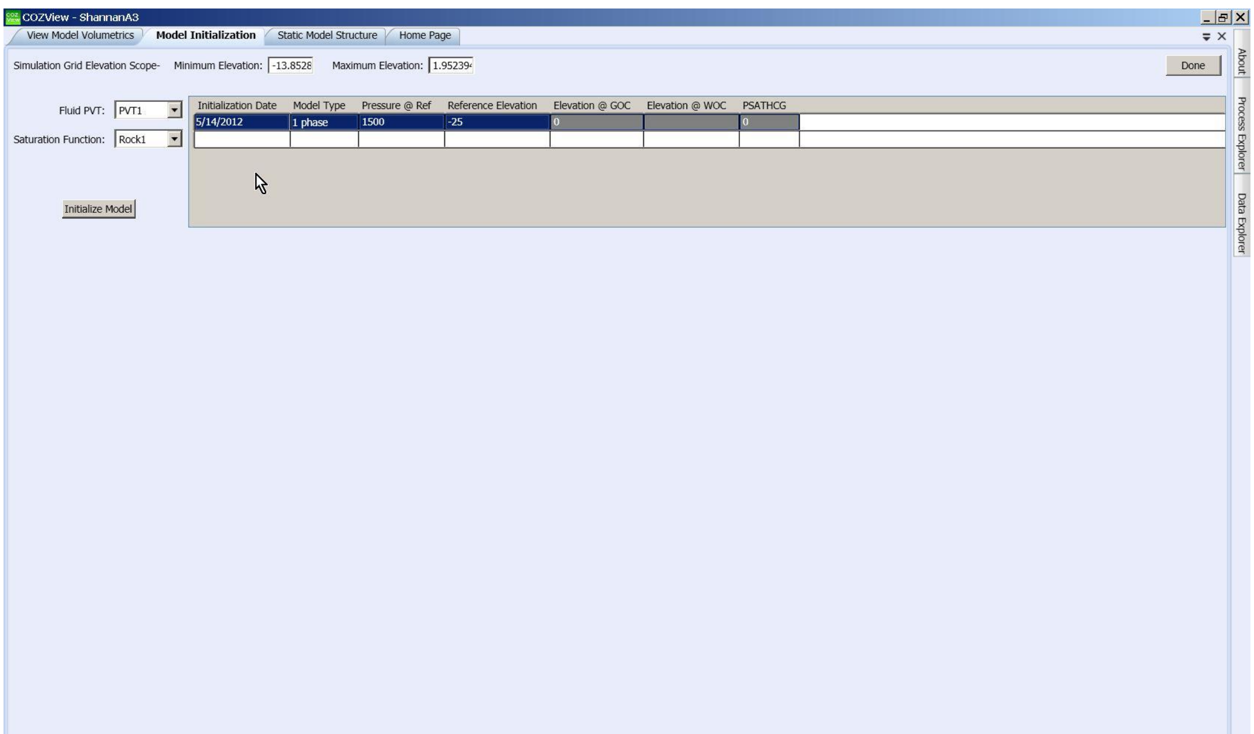
Initialization of the simulation model requires all or some of the information below

- date of the initialization,
- pressure at the reference elevation,
- reference elevation,
- GOC elevation,
- WOC elevation, and
- saturation pressure.

With this information and the data provided in the Static Model, Fluid and Saturation Properties, the volumes of oil, water and gas in the model can be calculated.

COZView allows the user to specify multiple initialization times and the associated data. The last initialization time will be the starting time for the prediction simulation run.

Selection of *Model Initialization* will display the screen below.



The model initialization is based on the premise that **one of three** possible reservoir conditions exist

- The reservoir has three phases present – free gas, oil and water. The water can be in the oil zone, as well as an aquifer. Solution gas will be present in the oil. There will be a Sorg in the free gas zone.

- The reservoir has two phases present – an oil zone and water. The water can be in the oil zone, as well as an aquifer. Solution gas will be present in the oil. **COZSim** does not currently support a gas-water two phase system.

- The reservoir has one phase present – an aquifer. **COZSim** only supports a water only, one phase system.

Examples:

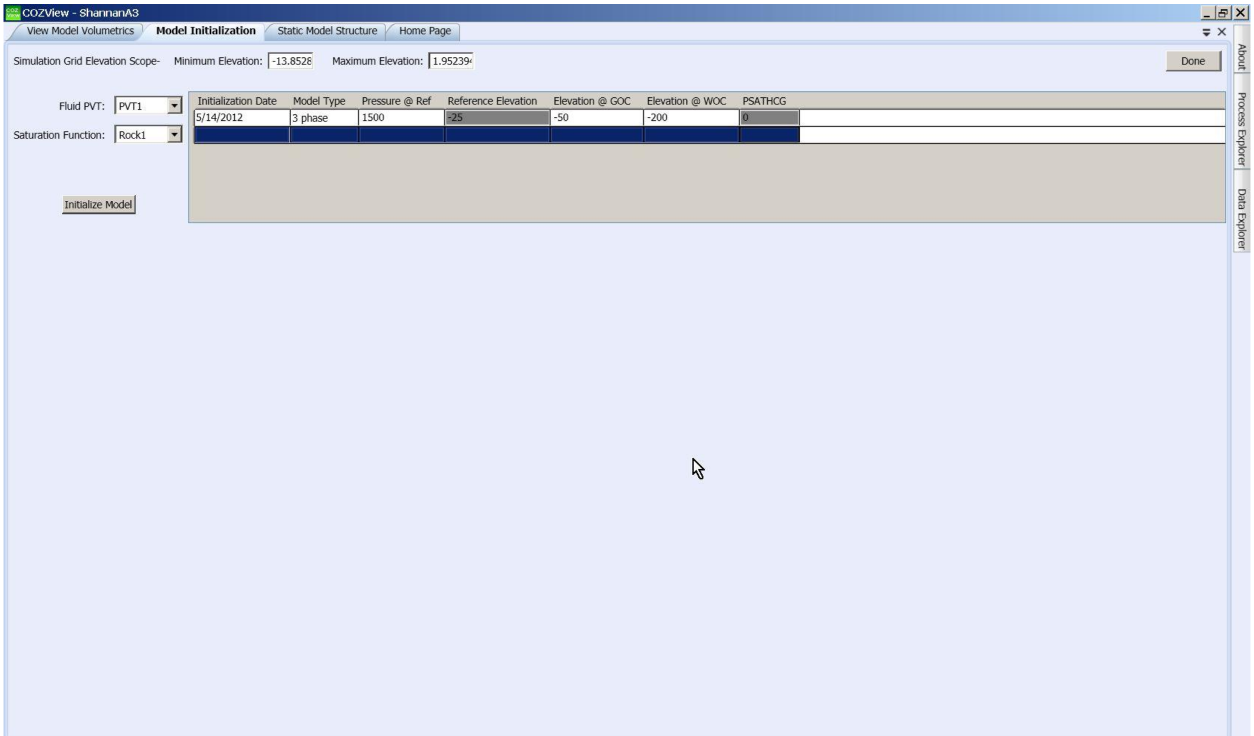
1. Oil zone with no gas cap or water leg. – 2 phase
2. Oil zone with a gas cap and no water leg. – 3 phase
3. Oil zone with water leg and no gas cap. – 2 phase
4. Oil zone with water leg and gas cap gas cap. – 3 phase

Selection of a particular *Model Type* in the Model Initialization window will alter the data required to the right. Some data will be greyed-out and not available to the user based on the Model Type selected. It is recommended to select the appropriate *Model Type* first.

It is important to note that this selection is only related to establishing initial saturation and pressure conditions at the start of the simulation run. A 2-phase model type may well become a 3-phase model type during the simulation period.

The *Model Initialization* window reports the Minimum and Maximum elevations found in the model. This can be used as a guide when inputting GOC and WOC elevations. The model defaults to the first PVT and Saturation function tables created by the user. These can be changed if appropriate, but only one PVT and one Saturation function can be used.

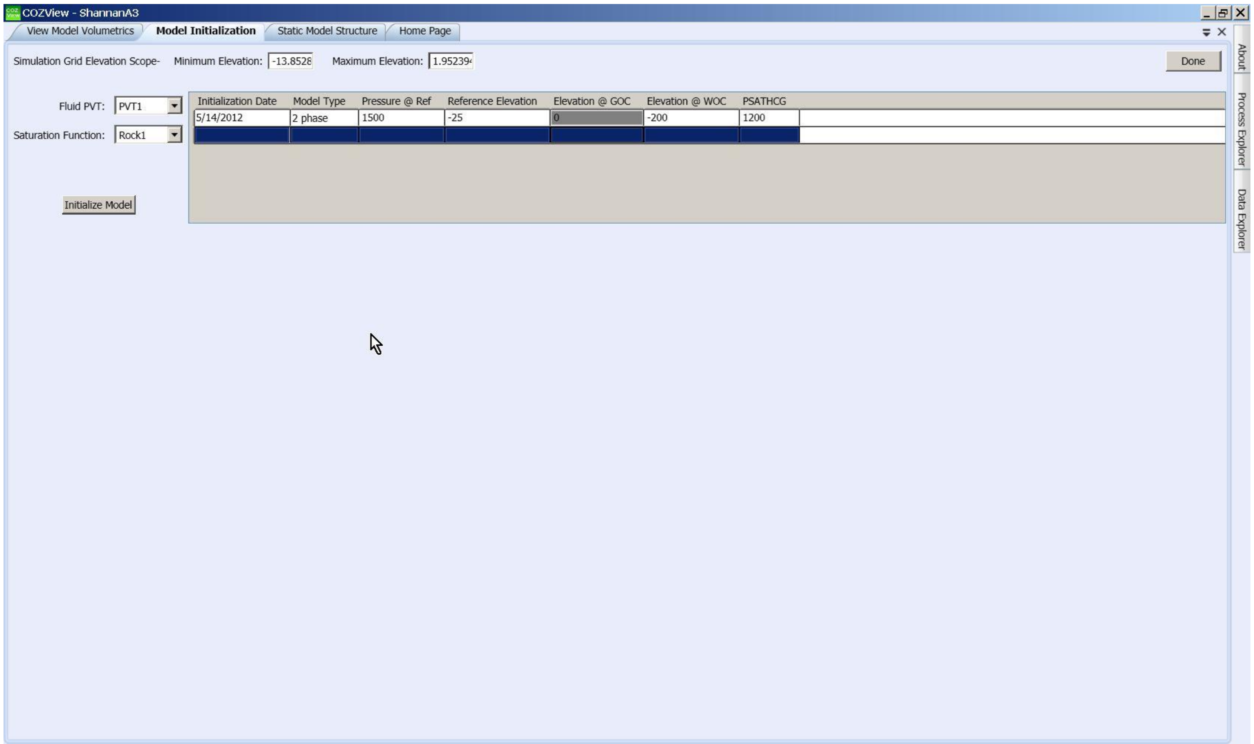
Model Type – 3-phase



If the GOC is specified above the shallowest elevation in the model, the model type is not 3-phase; it is 2-phase. If the WOC is specified below the deepest elevation in the model there will not be a water leg (aquifer) in the model, but the model type is still 3-phase as long as the GOC is deeper than the shallowest elevation in the model.

In the 3-phase model type, the reference elevation is not required, as it is assumed to be the GOC elevation. The saturation pressure is also not required. It is assumed to be the pressure at the GOC.

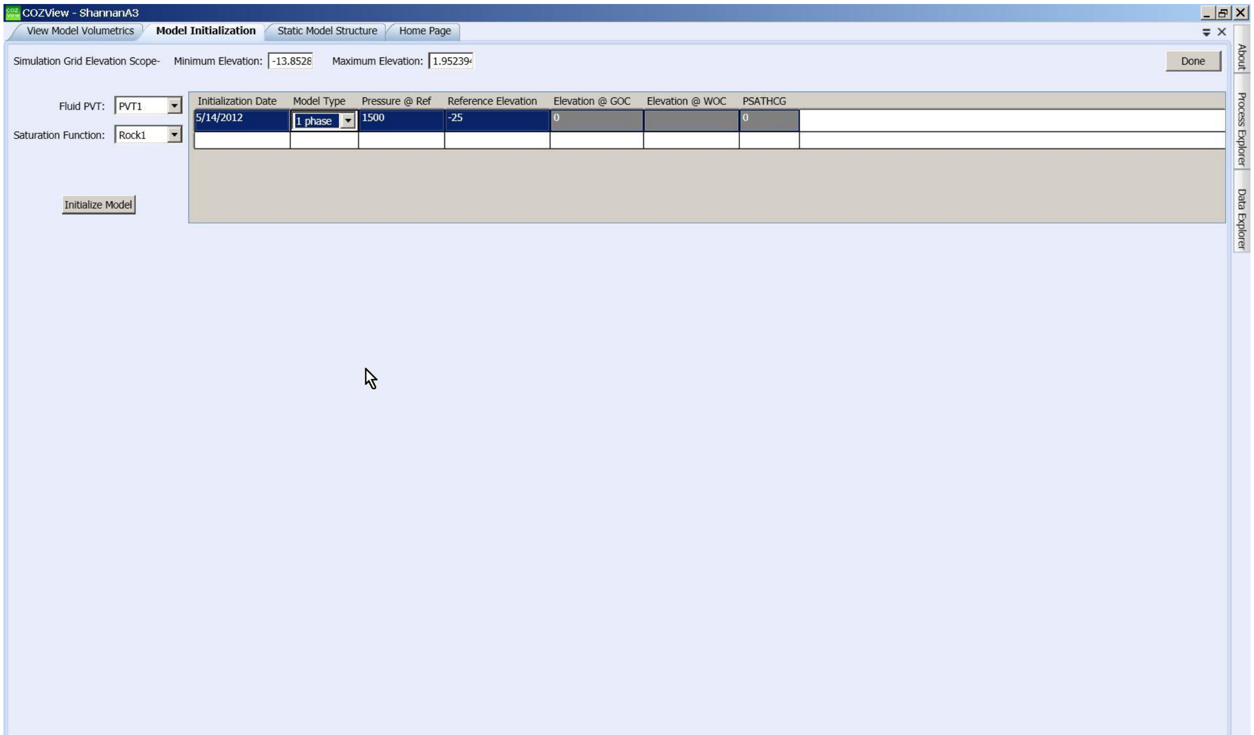
Model Type – 2-phase



If the WOC is specified below the deepest elevation in the model there will not be a water leg (aquifer) in the model, but the model type is still 2-phase.

In the 2-phase model type, the reference elevation is required. In addition the saturation pressure must also be provided. Depending on the production history of the reservoir, the saturation pressure may be the original bubble point pressure.

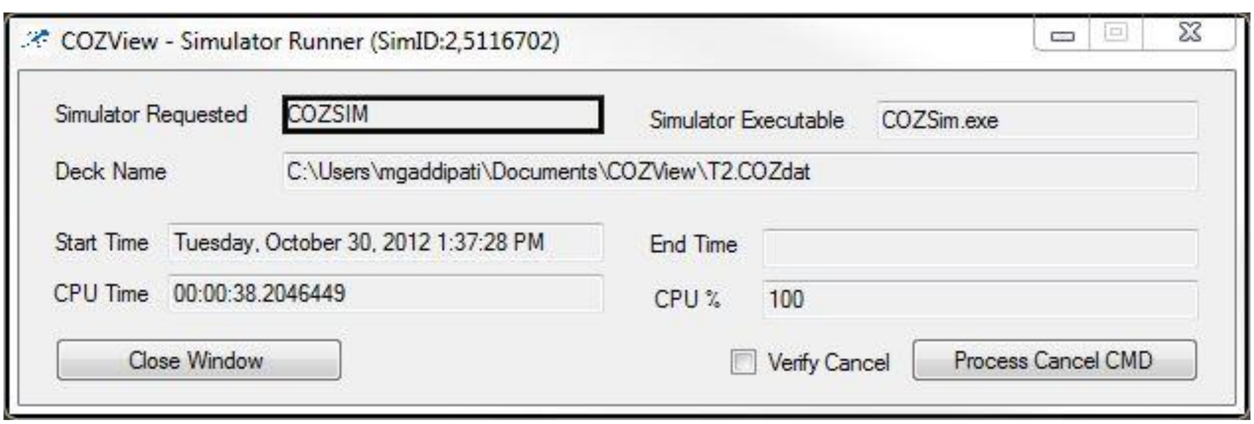
Model Type – 1-phase



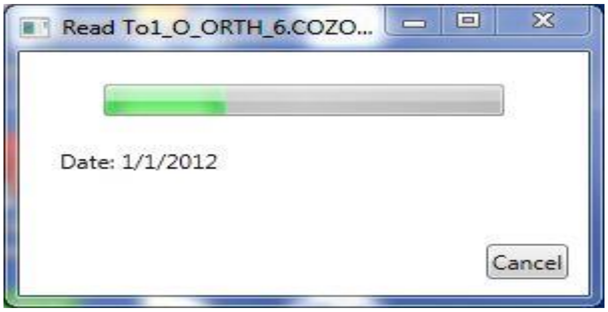
Only the reference pressure and elevation are required for the 1-phase model.

Selection of the **Initialize Model** button allows the user to make a volumetric calculation of the fluids in place in the model at each initialization time with the associated reservoir equilibrium conditions.

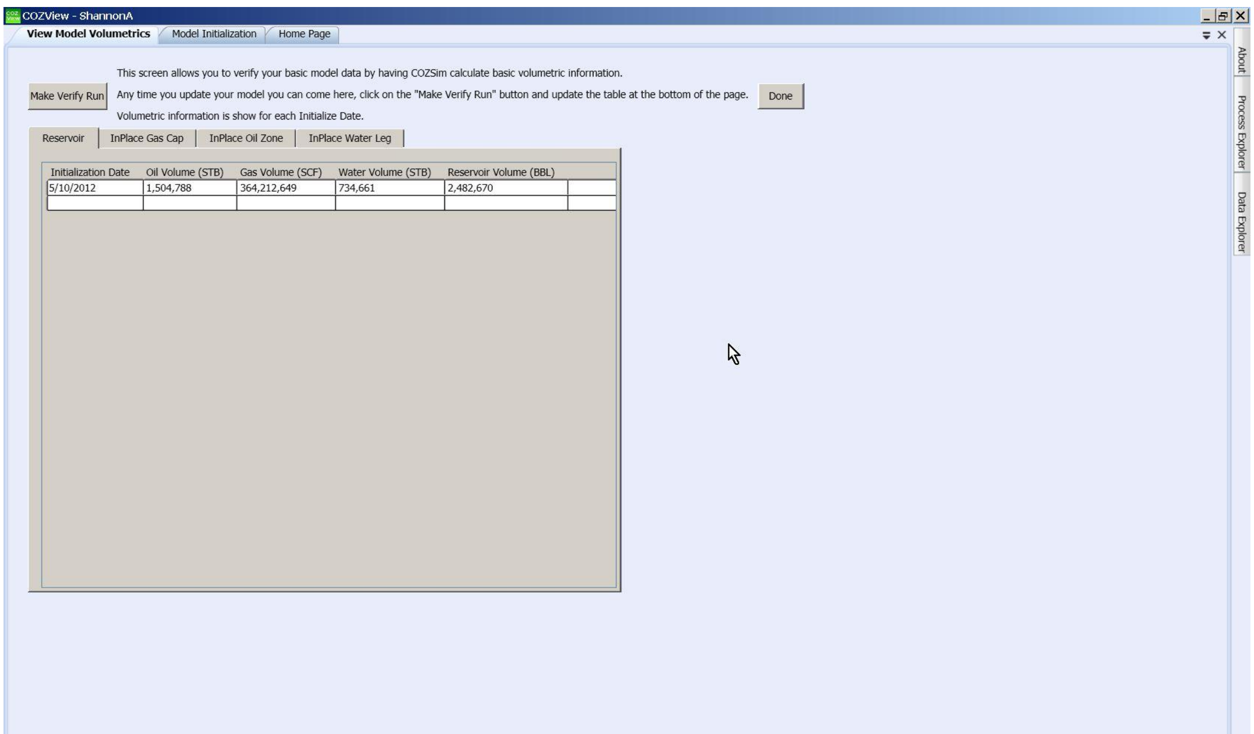
A zero timestep run is launched for the simulator and the Simulator Runner screen (below) will appear. Typically the simulator only requires a short time to initialize the model and compute the phase volumetrics.



Notification that COZView is reading the volumetric results form the binary PLTOUT file created by the simulator will also appear briefly.

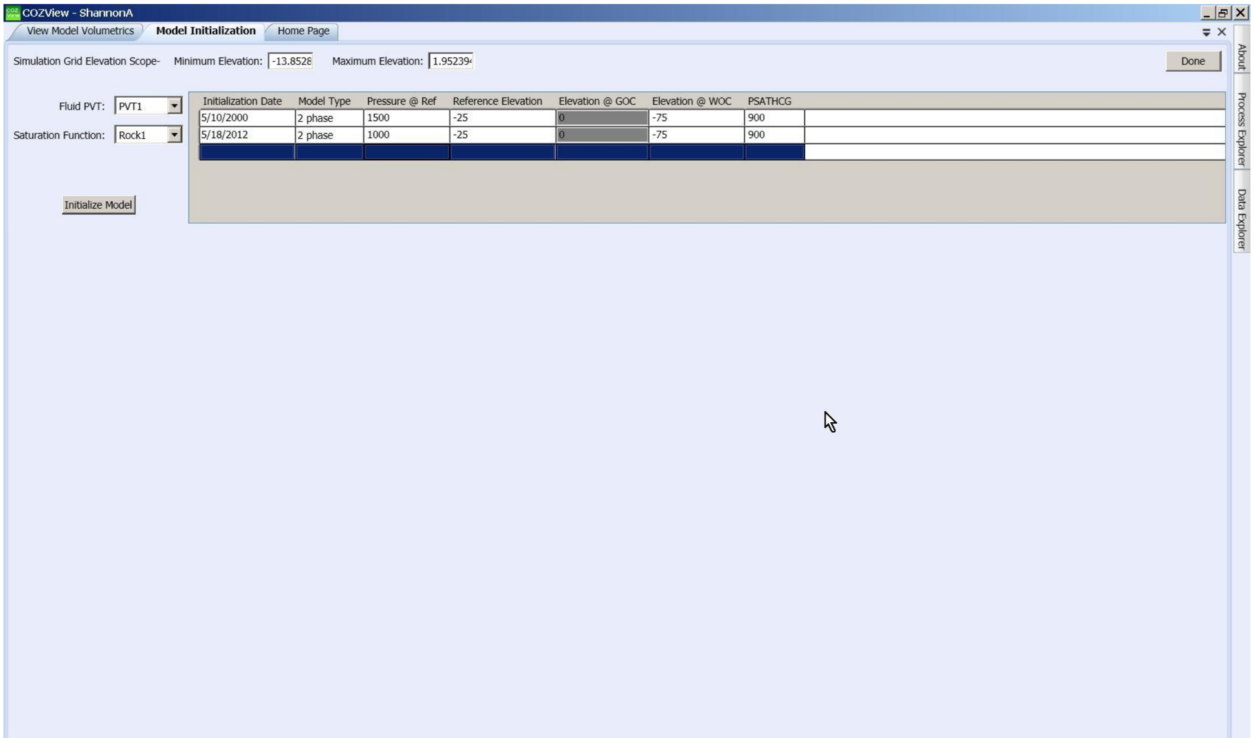


The calculated volumes are provided for the total reservoir, gas cap, oil zone and water leg. The volumes are all in stock tank units except the reservoir pore volume which is in reservoir barrels.



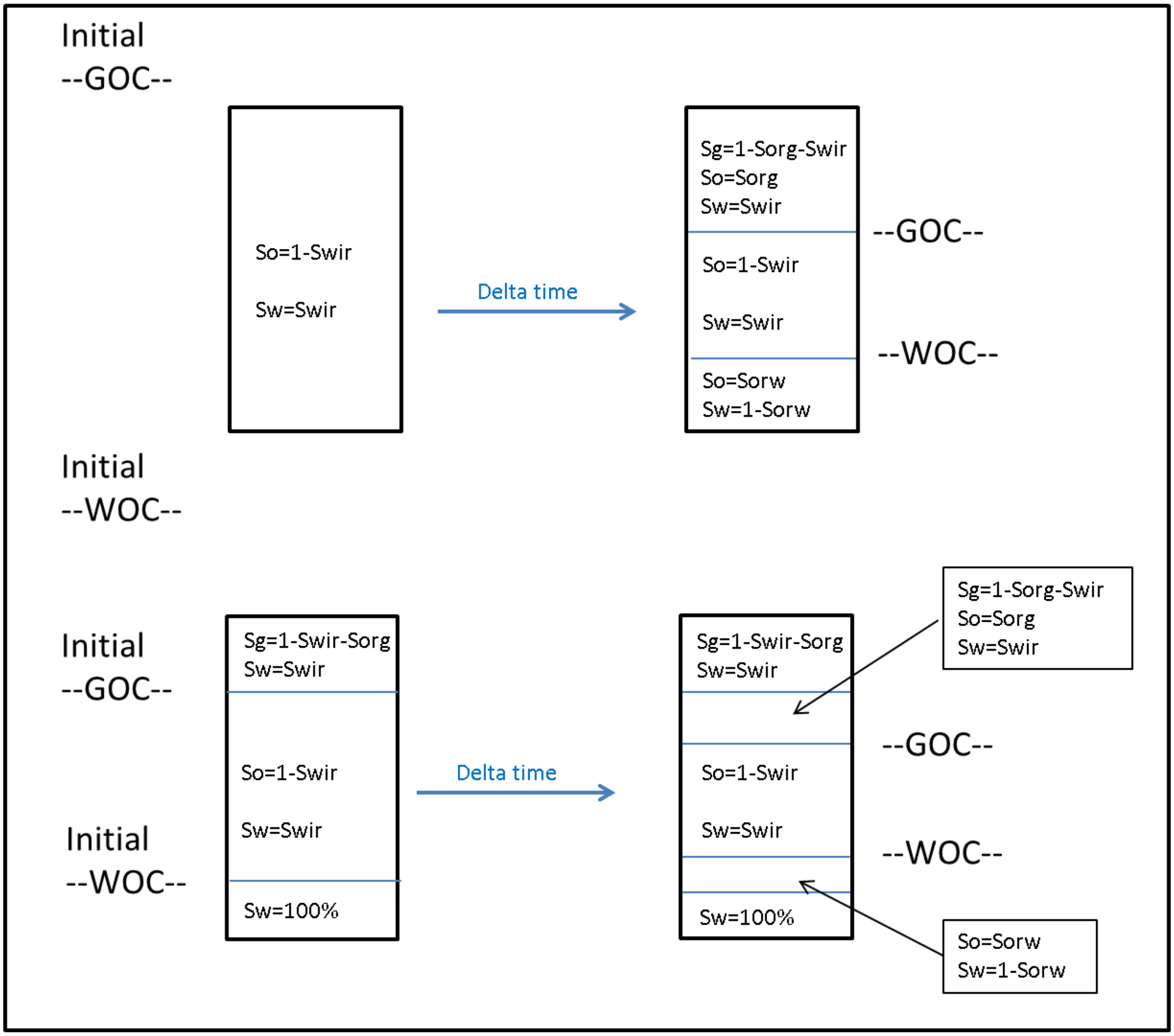
This functionality can be used to conduct a pseudo history match of the actual performance of the field in order to establish appropriate average reservoir conditions for the start of the prediction run.

Use of multiple initialization times and the associated adjustments in the reference pressure and the GOC and WOC elevations in the *Model Initialization* section will result in different in place volumes. The volume differences between the two times will reflect the net hydrocarbon production. The user will likely have a reasonable idea of the past cumulative production volumes and the current average reservoir pressure to compare to these calculated values.

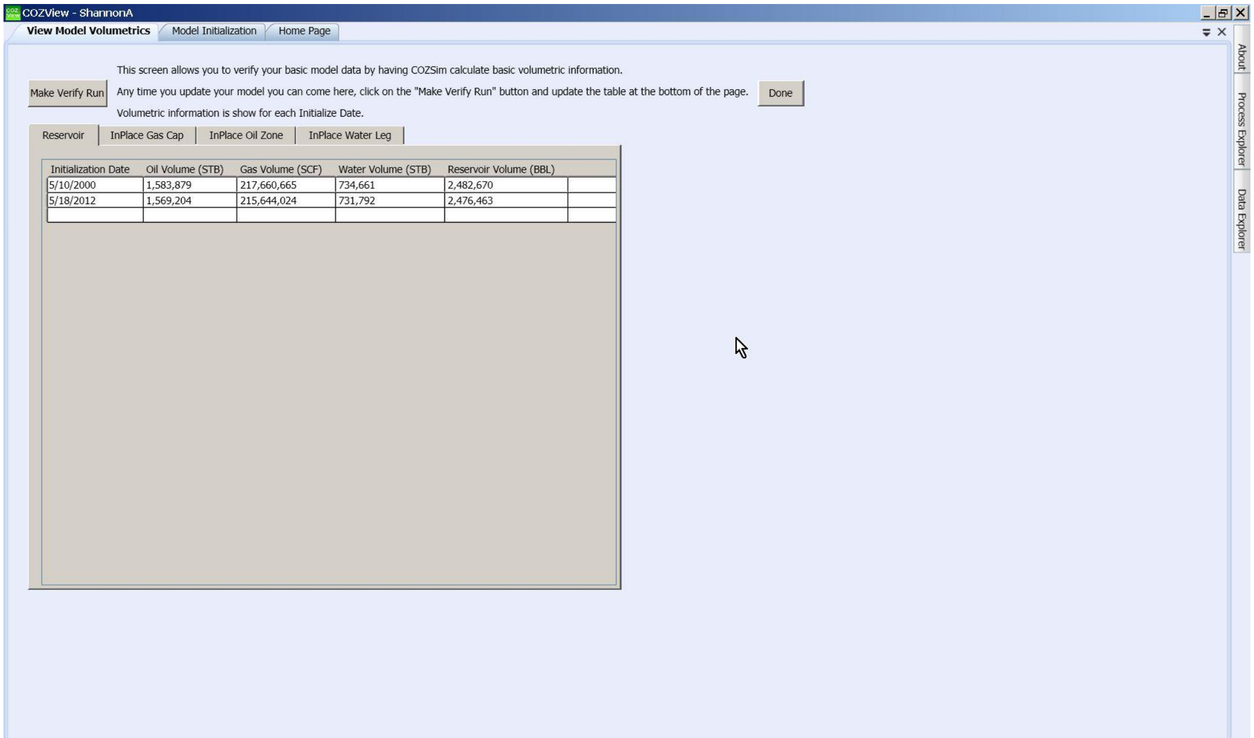


In this example, the difference in Pressure@Ref between the two initialization dates results in different in place volumes.

In the volumetric calculations the following assumptions are made about the saturations in the original oil, water and gas zones and in the zones invaded by the GOC or WOC.



Initial
--GOC--
So=1-Swir
Sw=Swir
Delta time
Sg=1-Sorg-Swir
So=Sorg
Sw=Swir
--GOC--
So=1-Swir
Sw=Swir
--WOC--
So=Sorw
Sw=1-Sorw
Initial
--WOC--
Initial
--GOC--
Sg=1-Swir-Sorg
Sw=Swir
So=1-Swir
Sw=Swir
Initial
--WOC--
Sw=100%
Delta time
Sg=1-Swir-Sorg
Sw=Swir
Sg=1-Sorg-Swir
So=Sorg
Sw=Swir
--GOC--
So=1-Swir
Sw=Swir
--WOC--
Sw=100%
So=Sorw
Sw=1-Sorw



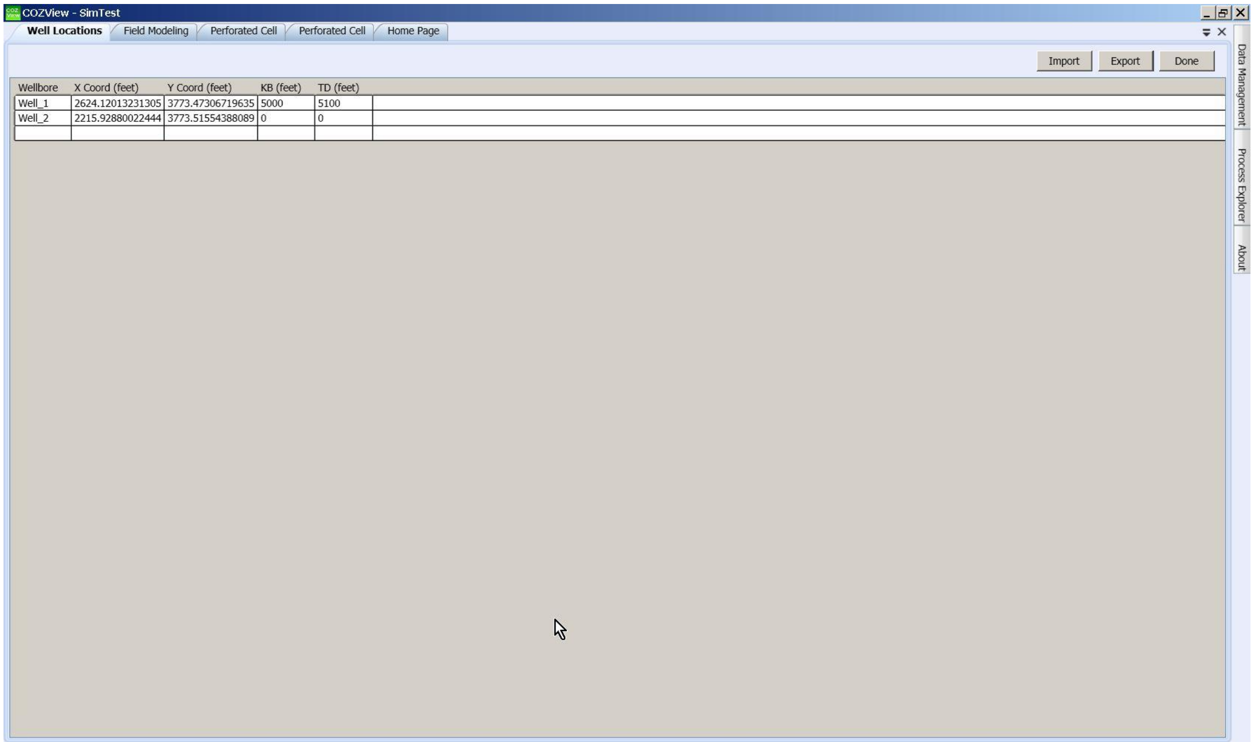
The user may also choose to make adjustments to the static model/formation properties in order to alter the calculated initial in place volumes. If formation properties are changed, but the model initialization parameters are not changed, the user can return to the *View Model Volumetrics* window and select Make Verify Run to recalculate the initial volumetrics.

3.4 Well Data

The *Well Data* section in the Process Explorer area provides the user tabular information concerning a well's location, KB, TD, completion layers and completion dates. This information is based on the definition of well locations in the *Static Model* section. If the data were not provided in the *Static Model* section, it can be input in these tables.

3.4.1 Well Location Data

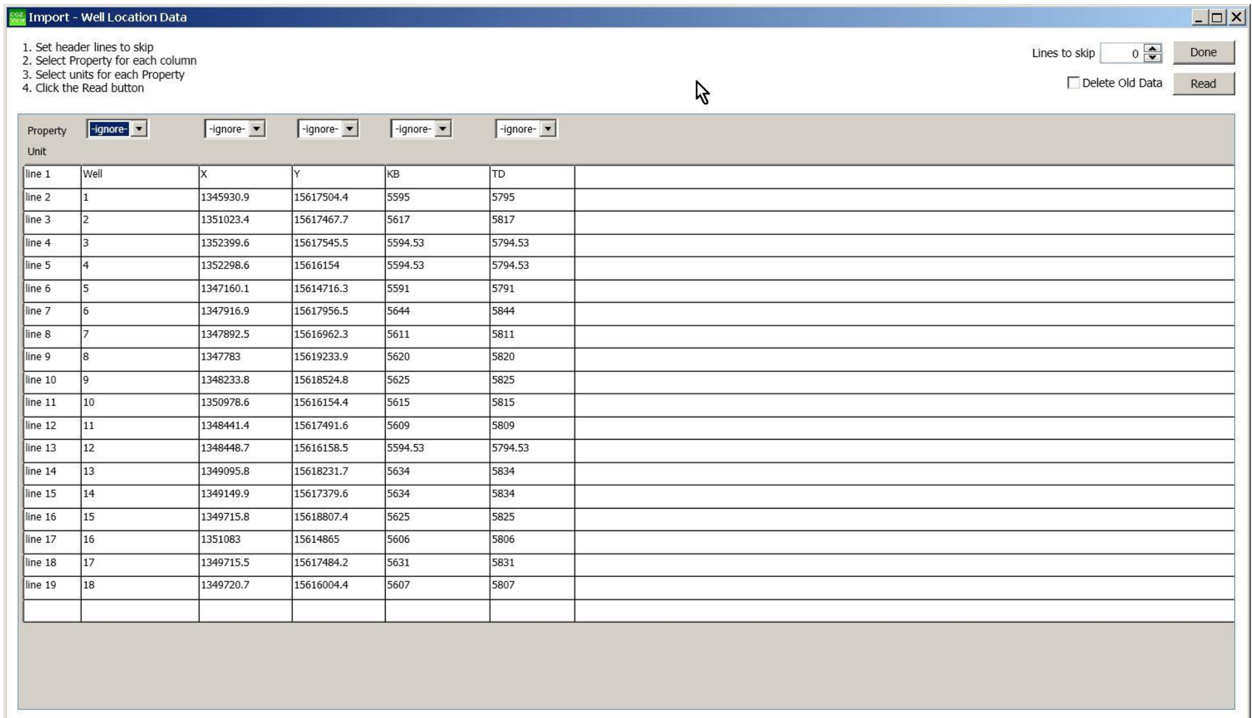
Selection of *Well Location* displays a table for the wells previously created in the *Static Model*. The X and Y coordinates in the table are based on the map well location. If the user input the KB and TD for the well in the Static Model, it will be shown in the table.



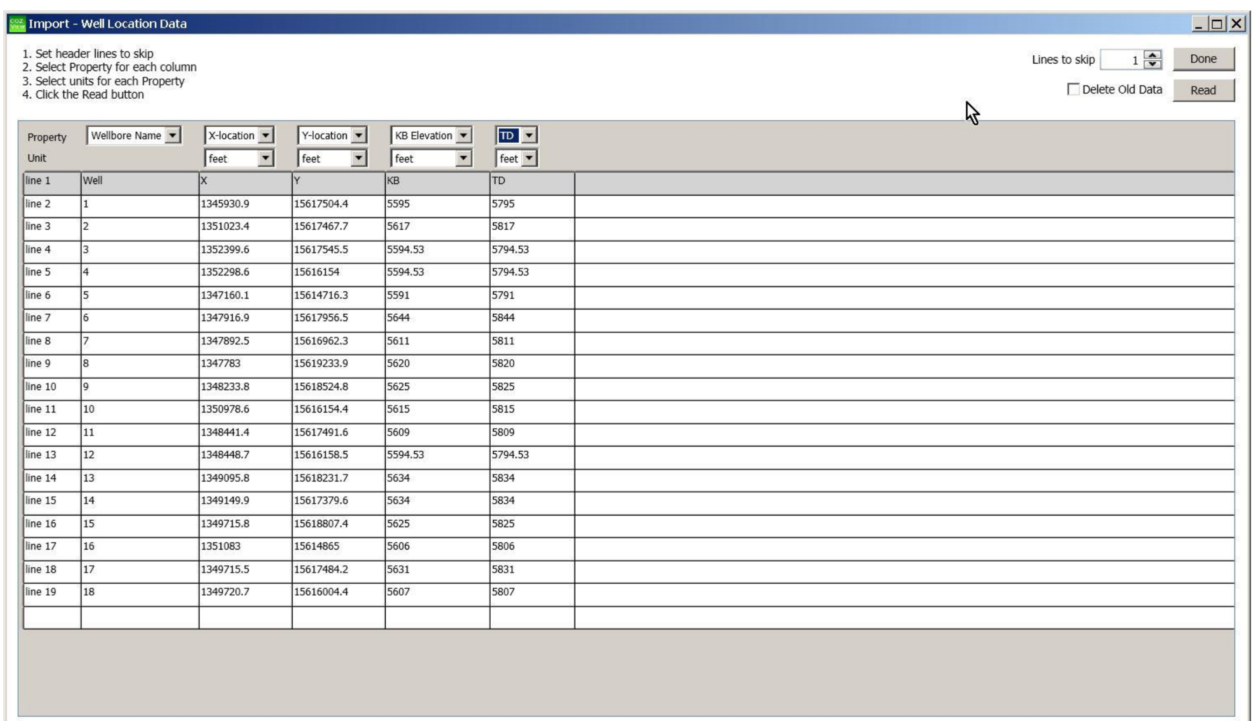
The user can input any missing data and change any data already provided by clicking on the appropriate *Well Name*. The entire well line will be highlighted in blue. The user can then double-click the data field to be input or changed.

New wells cannot be added to the model using this screen except with data *Import*. It is suggested that the user returns to the Static Model section to add any new wells.

The user may choose to input well locations using the *Import* facility rather than identifying well locations in the *Static Model*. Selection of the **Import** button generates a request for a *.csv* file location. The format of the *.csv* file should be consistent with the columns in the Well completion table.



Each of the columns has a drop down menu from which the user must select a parameter in order to identify the column content. If the .csv file contains a header row(s), the user must skip those rows when loading the data. This can be done by selecting the appropriate Lines to Skip in the upper right corner of the window. The lines (rows) to skip will be highlighted grey.



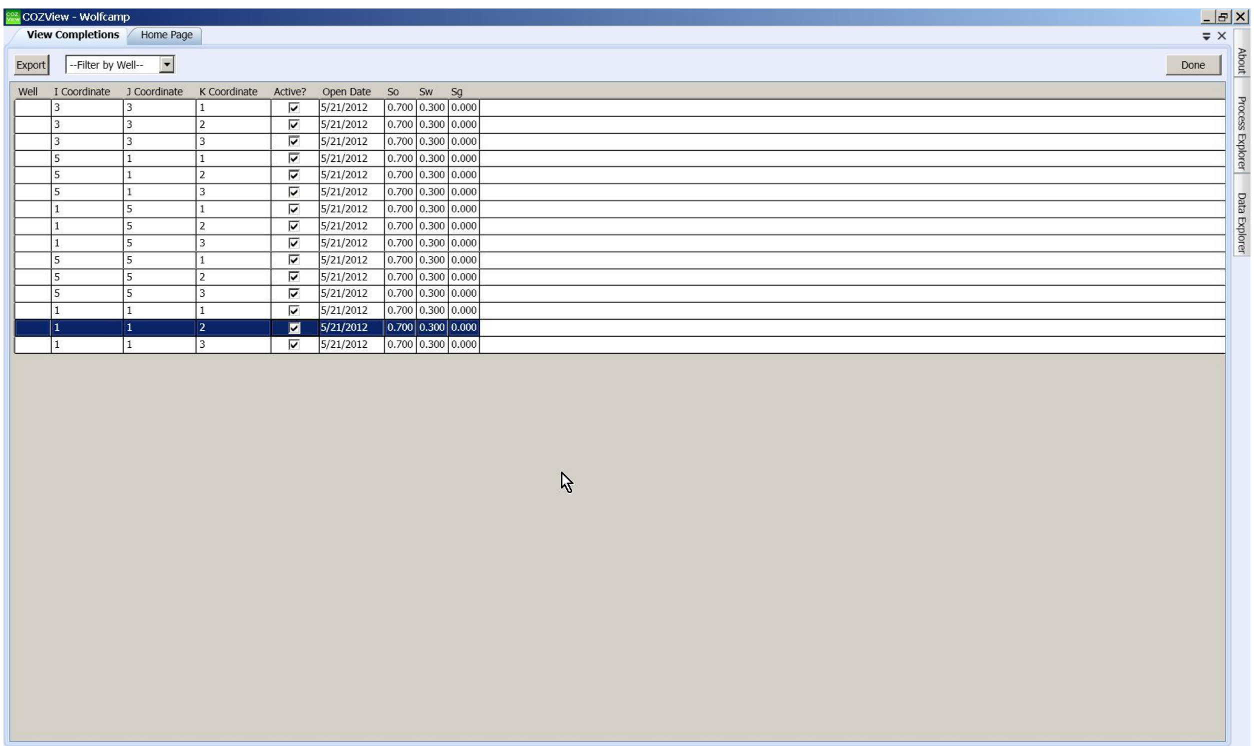
Select **Read** to load the data. A message notifying the user that the load has Completed will appear upon successful loading of the data. Select **Done** to save the data.

After the well locations have been loaded and saved, they can be viewed in the *Static Model* section in *View 3D Model* or in the *Scaled Model* area in *Assign Wells*. (*The user is reminded of rules on screen refreshing noted in section 2.4.)*

When loading well locations from a .csv file, it is important to be sure that the X,Y locations are within the boundaries of the coordinates assigned in the Static Model section.

3.4.2 Well Completions

Selection of *Well Completions* provides the user tabular information concerning each well's I,J,K location in the simulation grid, whether the well's status is active or not, the *Open Date* for the completions and the phase saturations in the well cells at the initialization time.



The user can change the well's active status and the Open Date already provided by clicking on the appropriate *Well Name*. The entire well line will be highlighted in blue. The user can then uncheck the Active box or double-click Open Date data field to be changed. The Open Date for each well is generated based on the date when the well completions were created in the model. The user should be sure that Open Dates for individual wells are consistent with the simulation run **Initialization Date** and the requirements of the simulation run to be made.

Each well is initially assumed to be completed in all layers of the model.

The I, J, K location and the reported fluid saturations for each well are based on the default grid used in COZSim and the *Model Initialization* previously carried out. If fluid saturations are not consistent with the user's expectations, changes to the layer completions and the *Model Initialization* parameters may be required.

After making any changes or entering new data, click the **Done** button to save the changes.

Changes to the *Model Initialization* may change the saturations in the well completion simulation cells. However, the *View Completions* screen will not reflect these changes unless the screen is refreshed. The screen can be refreshed by closing the *View Completions* menu tab at the top of the window (right-click) and reopening the screen from the *Process Explorer* menu area.

3.5 Prediction Period

The *Prediction* section is used to forecast future performance based on well and field constraints and limits provided by the user. Prediction simulation runs can be launched from reservoir conditions based on the static model.

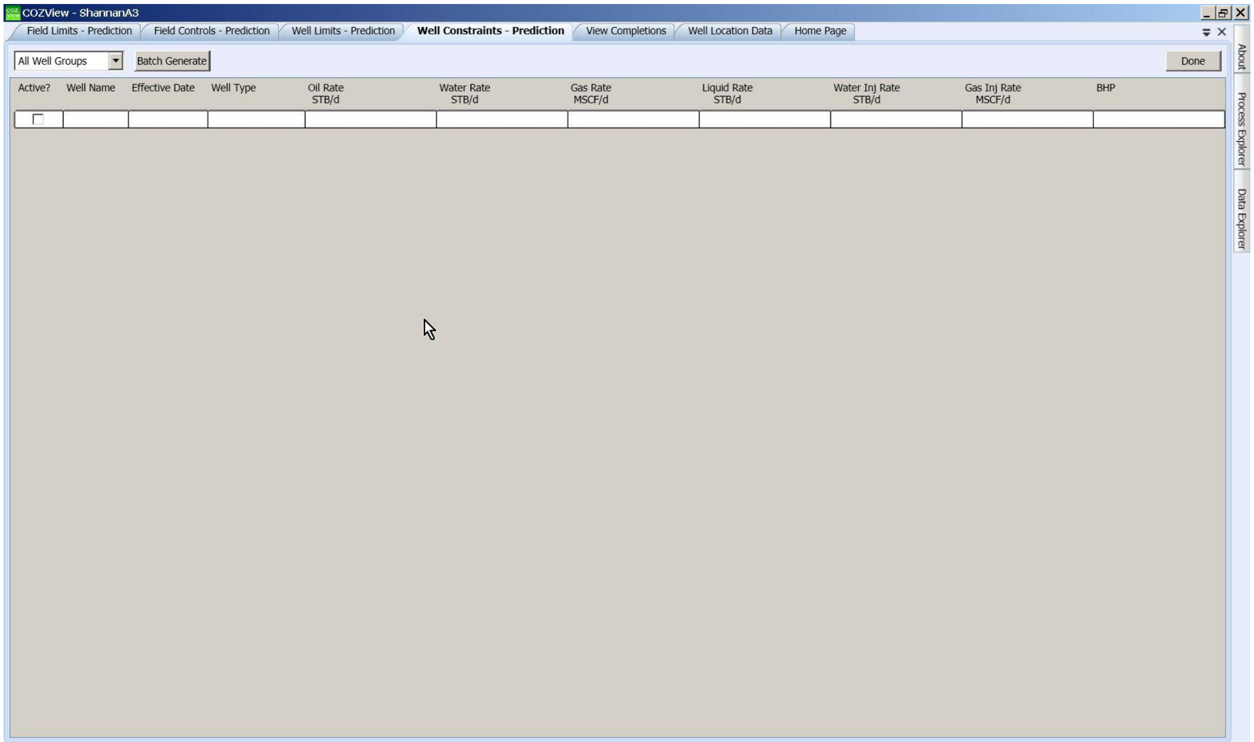
It is noted that there are a number of menu tabs that are related to well information throughout COZView. Changes in one well related menu tab should be reflected in other well related menu tabs; however, for reasons associated with **COZView'**s database it is recommended that the user close the active Menu Tab after saving any changes to the well data. This will assure that that menu tab is refreshed the next time it is accessed. A menu tab can be closed with a right-click mouse operation on the appropriate Menu Tab at the top of the **COZView** window.

3.5.1 Well Parameters

The *Well Parameters* section allows the user to specify well constraints and limits which force the simulation run to emulate actual or desired field operating practices.

3.5.1.1 Well Constraints

Selection of the *Well Constraints* menu displays the screen below.



The *Well Constraints* menu identifies the Well type, desired production and injection rates and bottom hole flowing pressure for each well. A left-click on the blank row followed by a left-click in a data field provides either a drop down menu or the ability to input a value.

The user must check the Active box to activate the control for a given well. The well must be selected from the drop down menu; the activation date must be specified; and a well type

- Oil producer
- Gas producer
- Water producer
- Liquid producer
- Water injector
- Gas/CO2 injector

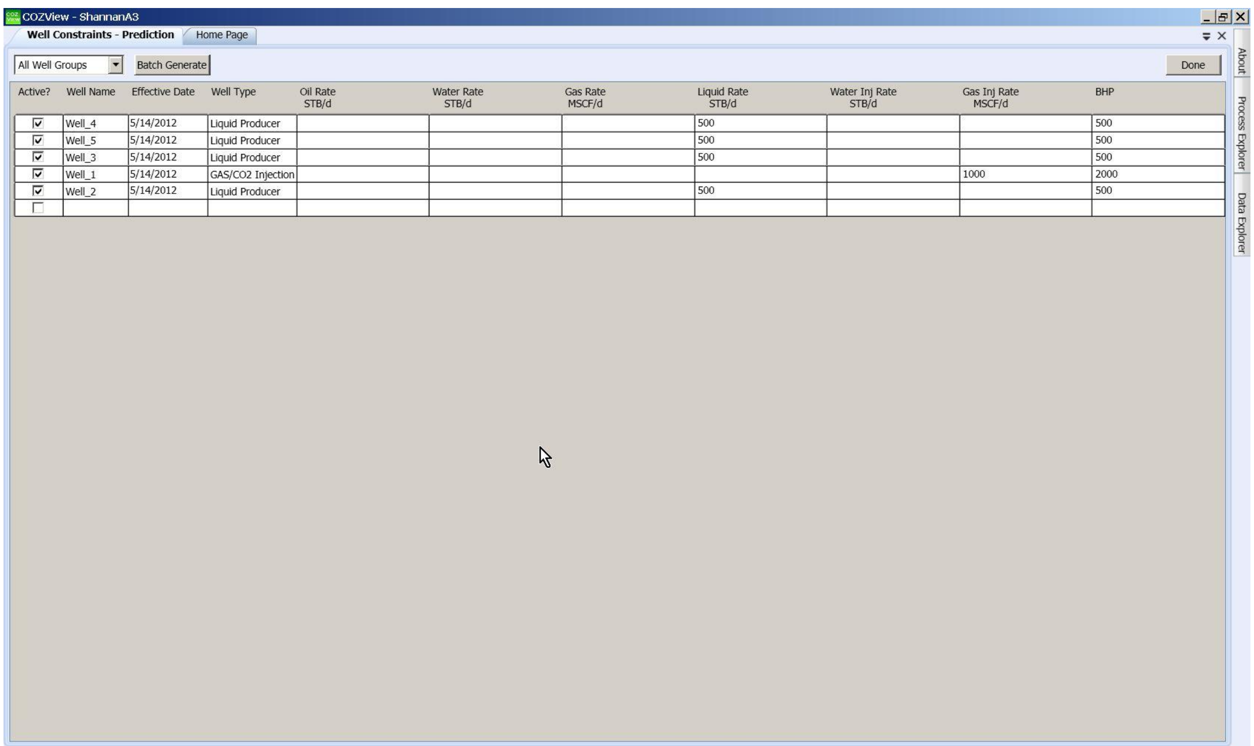
must be selected. Only one well type can be specified per well at any given time.

These well types must be specified if a well is to produce or inject in the simulation model.

The available well rates are

- Oil production rate (STB/D)
- Water production rate (STB/D)
- Gas production rate (MSCF/D)
- Liquid production rate (STB/D)
- Water injection rate (STB/D)
- Gas injection rate (MSCF/D)

In general, the user may specify a liquid, oil and water rate based on the maximum lift capacity or a desired rate for the production wells. Injection rates may be specified based on a user desired rate. These rates may or may not be achieved by the simulation model. These rates will not be exceeded in the simulation model. At least one rate should be specified for each production and injection well.

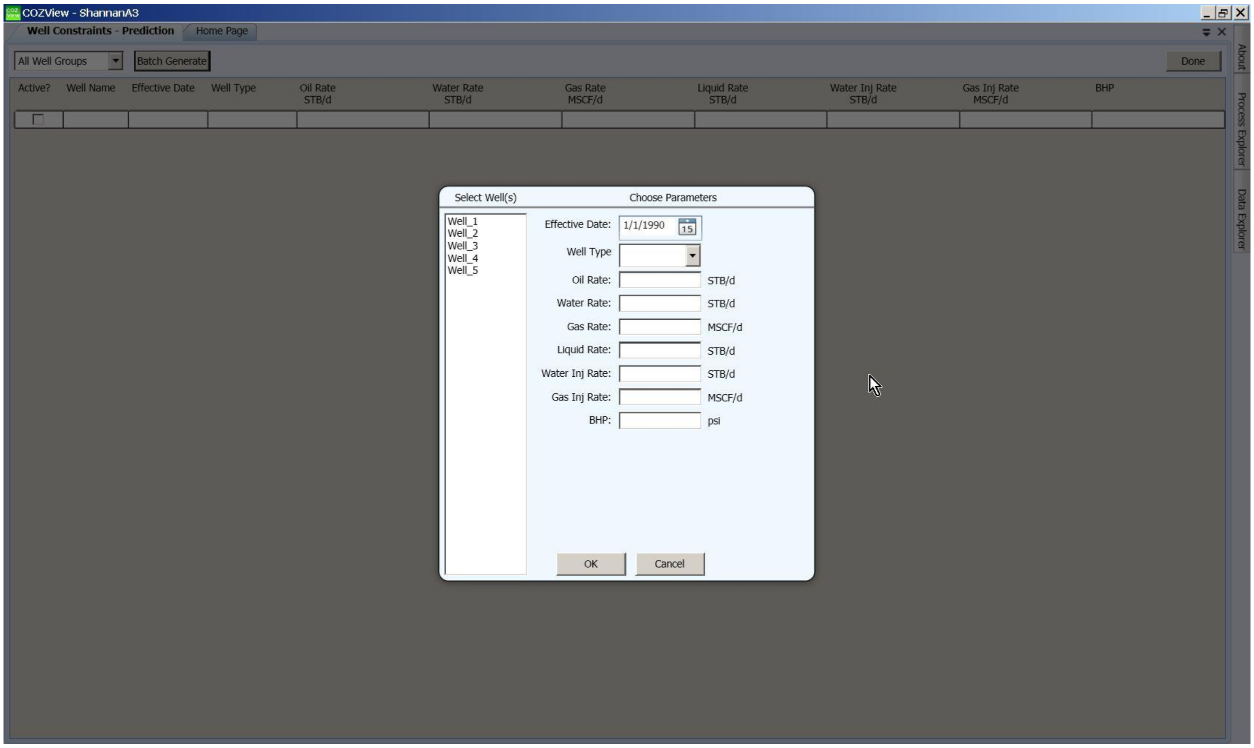


The simulator will initiate individual well production based on the greater of an assumed bottom hole flowing pressure of 14.7 psia or the user specified BHP. The well's production rate will be constrained by the well rates specified above.

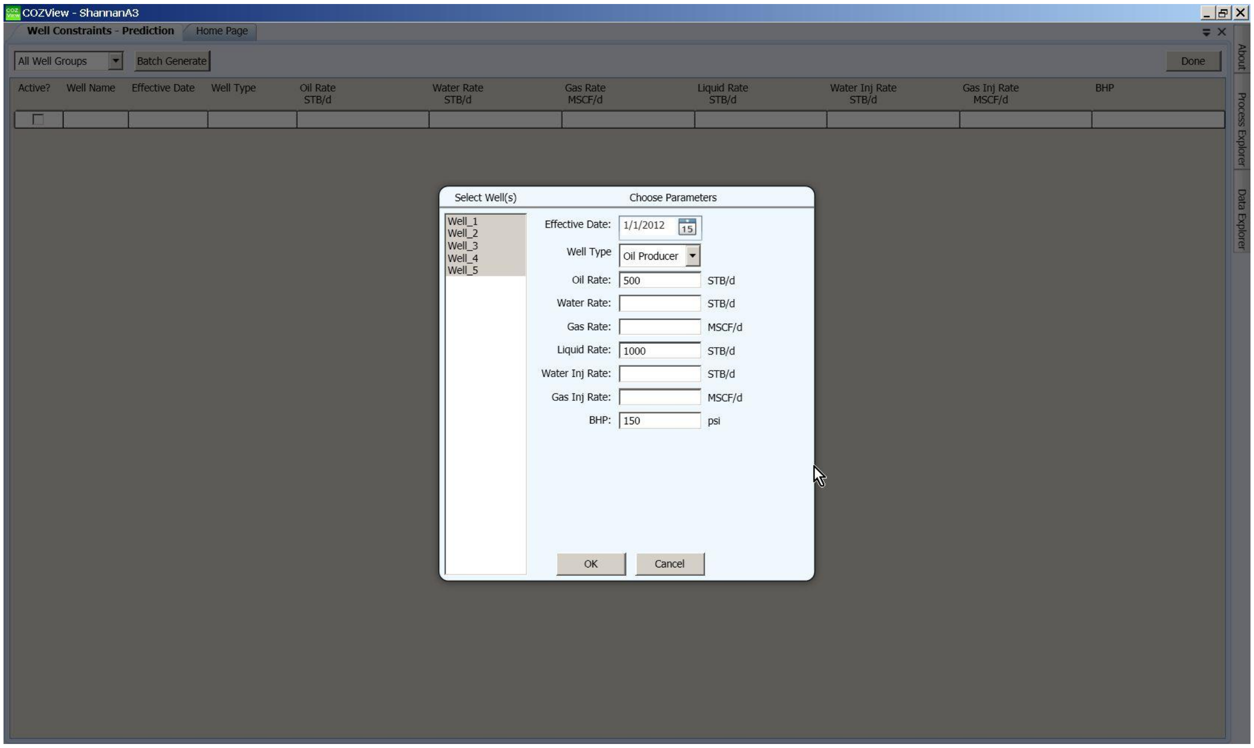
The simulator will initiate individual well injection based on the lesser of an assumed bottom hole flowing pressure equal to the maximum pressure in the PVT property tables or the user specified BHP. The well's injection rate will be constrained by the well rates specified above.

Selection of the **Done** button will save and exit the screen.

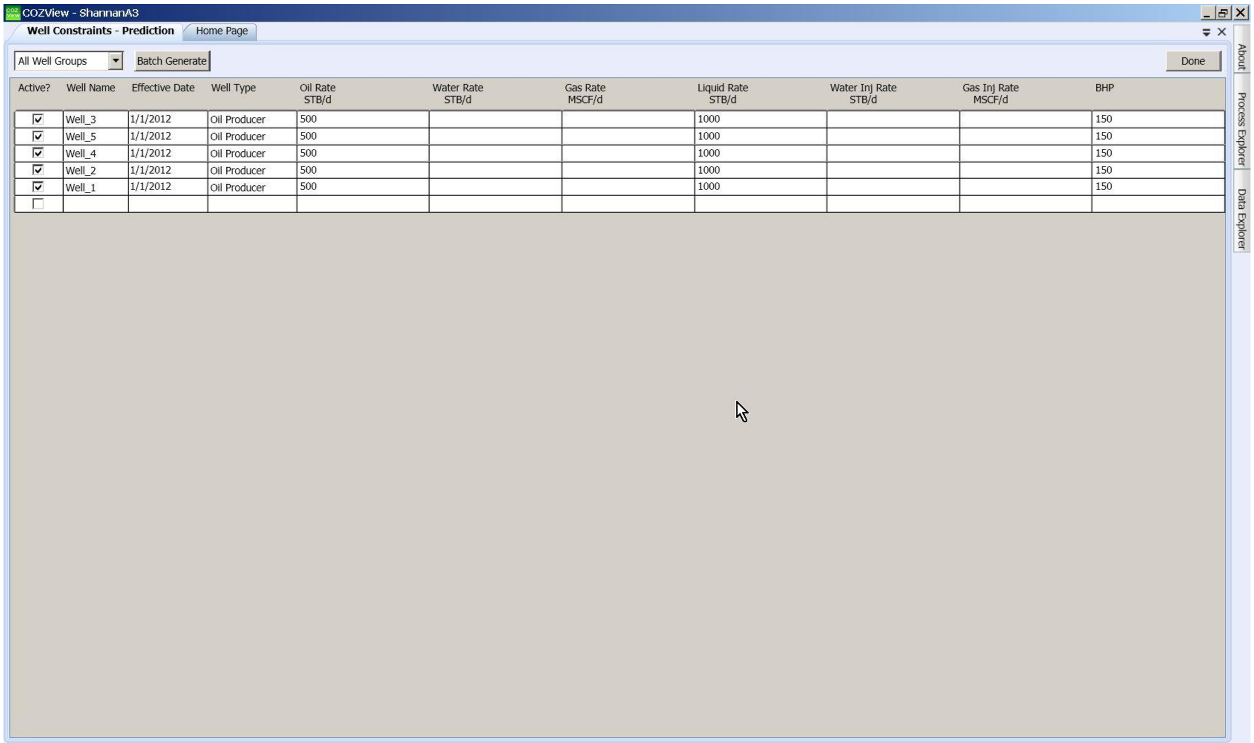
When a large number of wells are involved, the user may choose to use the **Batch Generate** button. The Batch Generate functionality allows quick assignment of parameter values to multiple wells.



The user must select the appropriate wells, define the activation date, and define the well type.



Selection of **OK** will generate a table for all wells selected. Parameter values for any given well can be changed by selecting the appropriate data field and inputting the new value. (A left-click on the data row and a left-click on the data field to be changed.)



The user may change the well constraints with time by repeating the process at a different date for the affected wells.

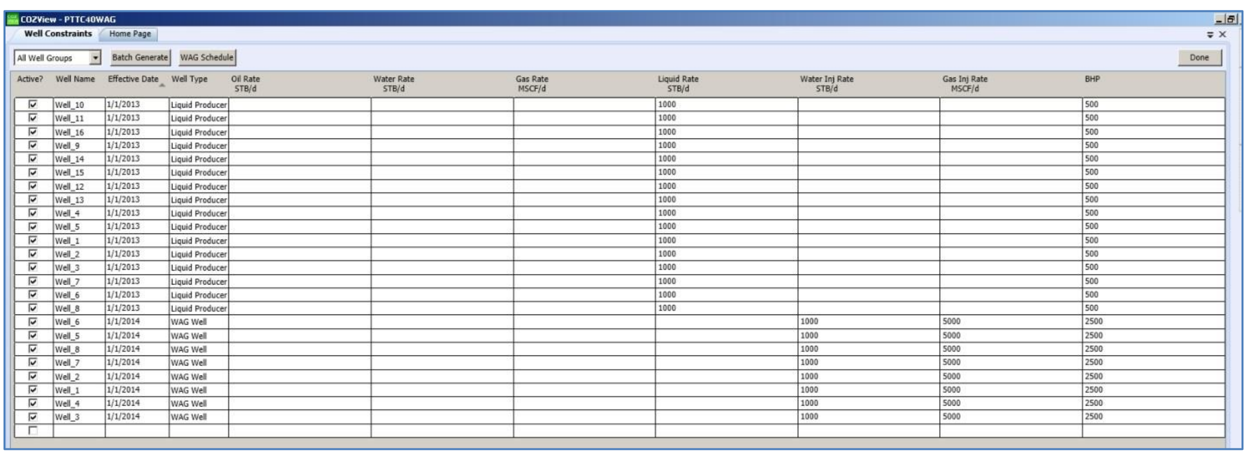
Select **Done** to save the data before leaving this screen.

3.5.1.2 WAG Schedule

Many CO2 injection projects utilize a process referred to as WAG (water-alternating-gas). Injection into designated wells is varied between CO2 and water on a defined schedule. In theory this maximizes use of the scarce CO2 resource and provides mobility control for the advancing CO2 front. A new functionality has been added to COZView to make scheduling of the WAG process easier. Prior to this, WAG scheduling had to be manually specified. COZSim has been able to handle this process from the beginning.

Establishing WAG Injection Wells

In the **Well Constraints** section each well used in the simulation must be identified with a specific *Well Type*. A new Well Type has been added, ***WAG Well***. The user must identify the injection wells that will be used in the WAG process, when they will start the WAG, the maximum individual well water and gas injection rates and the maximum individual bottom hole injection pressure. The gas injected during a WAG cycle can be hydrocarbon gas (HCG) or CO2. This will be identified in the **Field/Facility Parameters/Controls section**. Select **Done** to save.

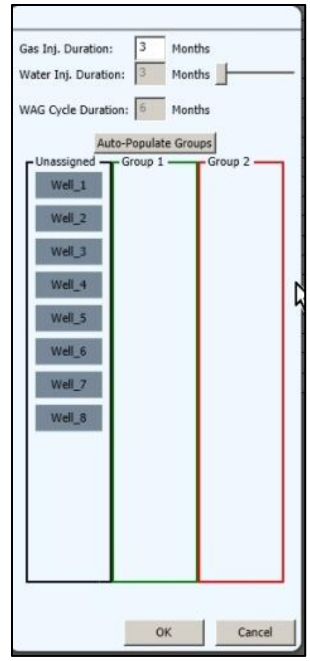


Active?	Well Name	Effective Date	Well Type	Oil Rate STB/d	Water Rate STB/d	Gas Rate MSCF/d	Liquid Rate STB/d	Water Inj Rate STB/d	Gas Inj Rate MSCF/d	BHP
☑	Well_10	1/1/2013	Liquid Producer				1000			500
☑	Well_11	1/1/2013	Liquid Producer				1000			500
☑	Well_16	1/1/2013	Liquid Producer				1000			500
☑	Well_9	1/1/2013	Liquid Producer				1000			500
☑	Well_14	1/1/2013	Liquid Producer				1000			500
☑	Well_15	1/1/2013	Liquid Producer				1000			500
☑	Well_12	1/1/2013	Liquid Producer				1000			500
☑	Well_13	1/1/2013	Liquid Producer				1000			500
☑	Well_4	1/1/2013	Liquid Producer				1000			500
☑	Well_5	1/1/2013	Liquid Producer				1000			500
☑	Well_1	1/1/2013	Liquid Producer				1000			500
☑	Well_2	1/1/2013	Liquid Producer				1000			500
☑	Well_3	1/1/2013	Liquid Producer				1000			500
☑	Well_7	1/1/2013	Liquid Producer				1000			500
☑	Well_6	1/1/2013	Liquid Producer				1000			500
☑	Well_8	1/1/2013	Liquid Producer				1000			500
☑	Well_6	1/1/2014	WAG Well					1000	5000	2500
☑	Well_5	1/1/2014	WAG Well					1000	5000	2500
☑	Well_8	1/1/2014	WAG Well					1000	5000	2500
☑	Well_7	1/1/2014	WAG Well					1000	5000	2500
☑	Well_2	1/1/2014	WAG Well					1000	5000	2500
☑	Well_1	1/1/2014	WAG Well					1000	5000	2500
☑	Well_4	1/1/2014	WAG Well					1000	5000	2500
☑	Well_3	1/1/2014	WAG Well					1000	5000	2500
☐										

Setting WAG Cycle Schedule

The user must then select the **WAG Schedule** button. Select **Yes** to the save query. The first time this screen is entered all wells previously identified as WAG wells will be shown in the left *Unassigned* column.

Each of these wells must be “assigned” to a Group. The number of possible Groups is based on the duration of the gas and water injection per WAG cycle. The concept is that all WAG wells will be active once the WAG schedule is initiated. A full cycle requires that all wells have injected water and gas for the defined durations once.



In the WAG screen above, the gas injection duration has been set to 3 months by the user (the default value is 1). Based on the gas injection duration, the water injection duration is initially set to the same value; 3 months in this case. This establishes the total WAG cycle duration at 6 months – 3 months of water injection and three months of gas injection. As the injected gas is typically purchased from an outside source and must be used on a near constant volume basis; gas injection must occur in at least some wells throughout the WAG cycle; hence, the need for two groups in this example – one of the groups always injecting gas. (The number of wells in each group is up to the user.)

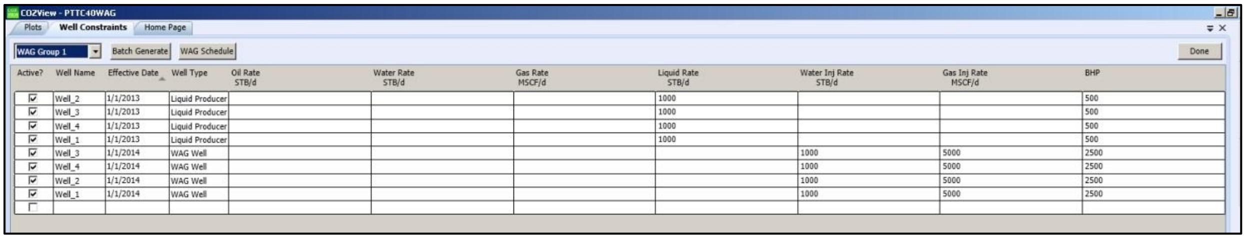
The user can assign the wells to groups by dragging each well from the *Unassigned* column to one of the *Group* columns. Typically, wells are grouped based on surface facilities and/or pattern requirements.

Select **OK** to save.

Note that the WAG schedule will be repeated in the simulation run until the run completes or the well types are changed for the WAG wells by the user in the **Well Constraint** section. The gas and water volumes used in each well in the WAG cycle can be changed later in the simulation run period in the **Well Constraints** screen, but the injection duration times during the WAG cycle cannot be changed.

The number of months of water injection relative to the number of months of gas injection can be changed with the slide bar. The duration of water injection can be changed to multiples of the gas injection duration – in this case 3 months of gas, 3, 6, 9, etc. months of water. Changing the water injection duration will change the total WAG cycle duration. This in turn changes the number of possible groups.

Once the WAG groups have been established the user can view the well constraints for all wells in a given group by selecting a group from the dropdown menu in the top left corner of the **Well Constraints** screen.



Active?	Well Name	Effective Date	Well Type	Oil Rate STB/d	Water Rate STB/d	Gas Rate MSCF/d	Liquid Rate STB/d	Water Inj Rate STB/d	Gas Inj Rate MSCF/d	BHP
☑	Well_2	1/1/2013	Liquid Producer				1000			500
☑	Well_3	1/1/2013	Liquid Producer				1000			500
☑	Well_4	1/1/2013	Liquid Producer				1000			500
☑	Well_1	1/1/2013	Liquid Producer				1000			500
☑	Well_3	1/1/2014	WAG Well					1000	5000	2500
☑	Well_4	1/1/2014	WAG Well					1000	5000	2500
☑	Well_2	1/1/2014	WAG Well					1000	5000	2500
☑	Well_1	1/1/2014	WAG Well					1000	5000	2500
☐										

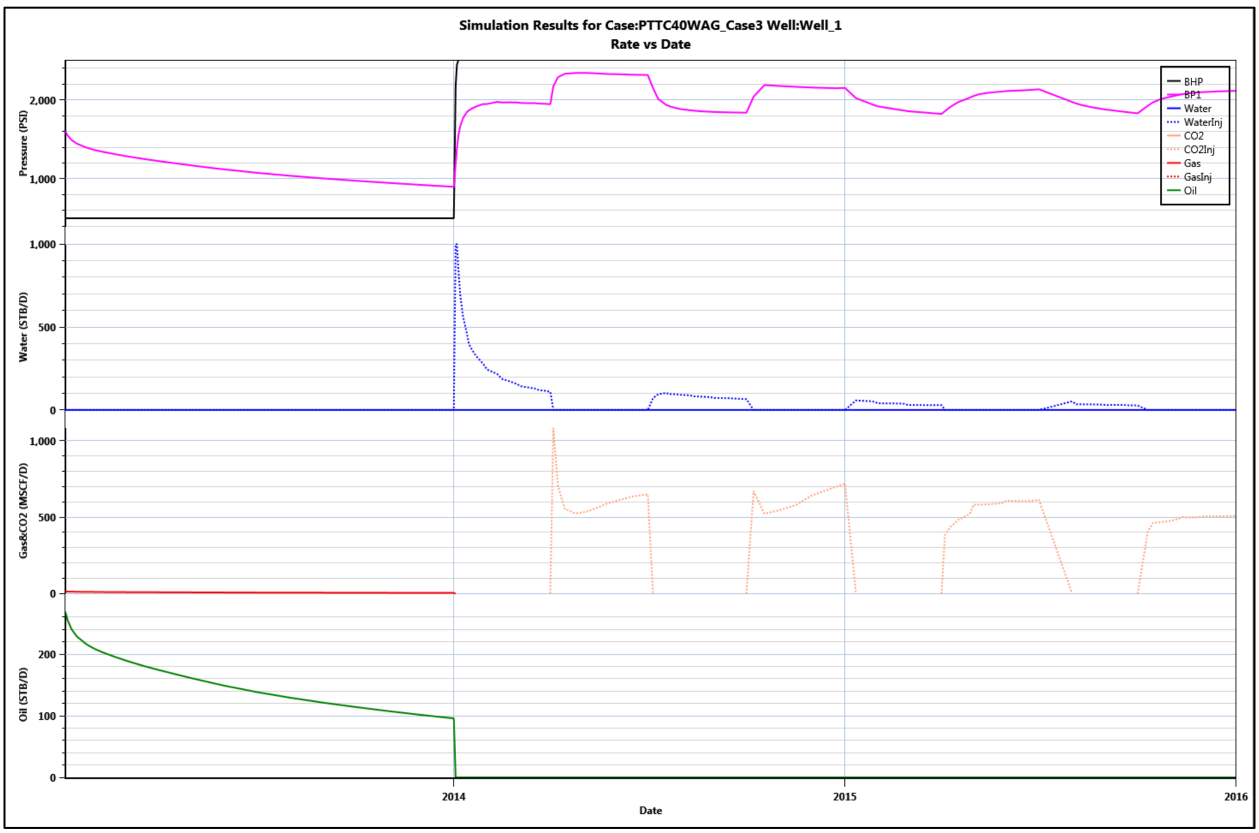
Group WAG Implementation

As described above, the number of Groups is dependent on the duration of injection for water and gas. The user does not need to place wells in all of the Groups. However, not doing so will result in some portion of the total WAG cycle duration being carried out with no gas injection.

If multiple Groups (say 3) are required, the cycle sequence is as follows for a total WAG cycle through all wells:

Group	First Gas Injection Period	Second Gas Injection Period	Third Gas Injection Period
1	Gas	Water	Water
2	Water	Gas	Water
3	Water	Water	Gas

The well plot below is an example of a 1 month CO2 injection/1 month water injection WAG cycle starting in 1/1/2014 after one year of production.

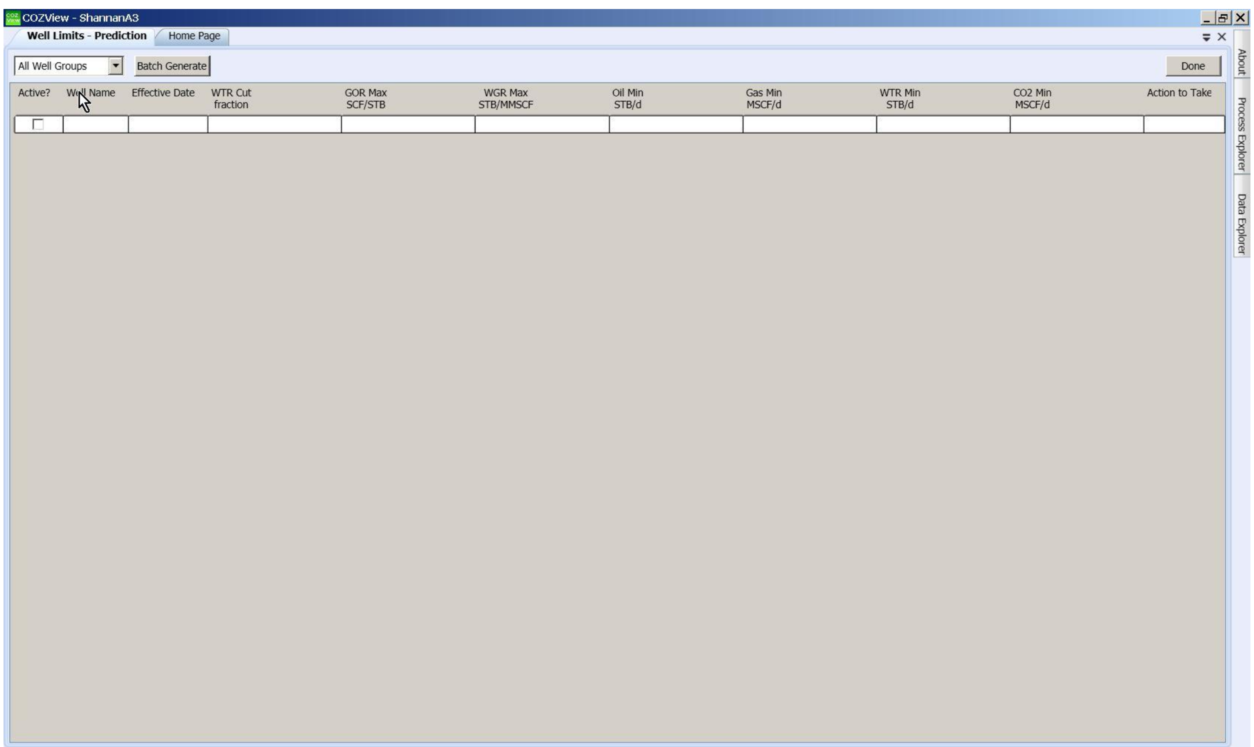


3.5.1.3 Well Limits

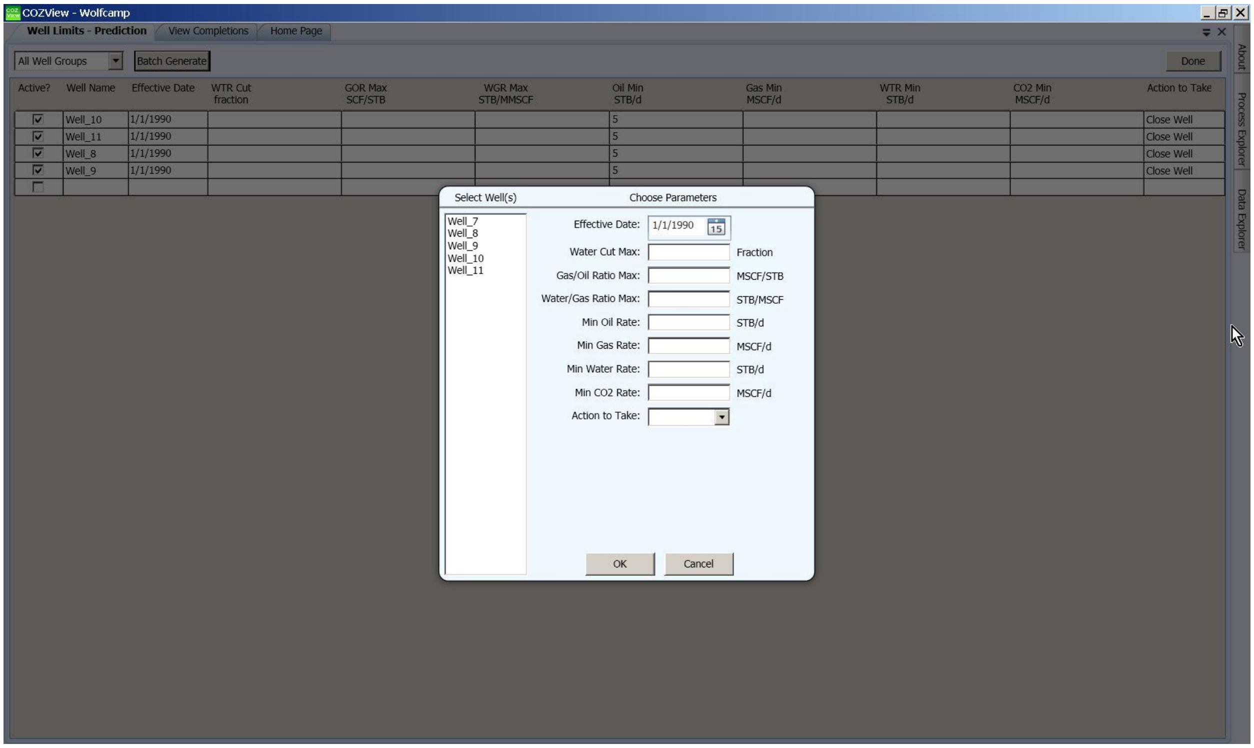
The *Well Limits* menu establishes the manner in which the wells will be constrained or limited in the simulation run - maximum water cut, maximum GOR, minimum oil rate, etc.). When a *Well Limit* is exceeded during the simulation, there are two user directed actions that will result (shut-in well or shut-in a perforation). The well limits that can be specified are

- Maximum water cut (fraction)
- Maximum producing gas-oil ratio (MSCF/STB)
- Maximum producing water-gas ratio (STB/MSCF)
- Minimum oil production rate (STB/D)
- Minimum water production rate (STB/D)
- Minimum gas production rate (MSCF/D)
- Minimum CO2 production rate (MSCF/D)

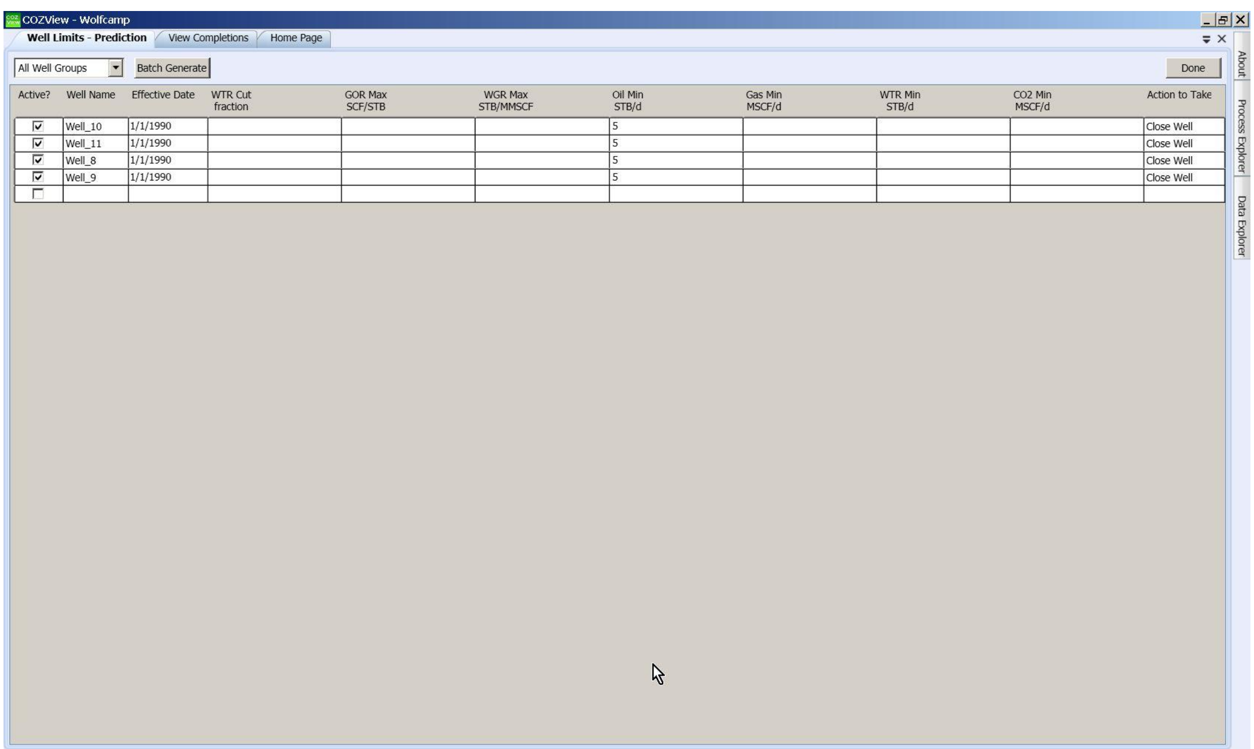
The Active box must be checked and the Effective Date specified if appropriate for each well.



When a large number of wells are involved, the user may choose to use the **Batch Generate** button. The Batch Generate functionality allows quick assignment of parameter values to multiple wells.



The user must select the appropriate wells, define the activation date, and specify the appropriate limits. Selection of **OK** will generate a table of the well limits for all selected wells. Parameter values for any given well can be changed by selecting the appropriate data field and inputting the new value.



The user may change the well limits with time by repeating the process at a different date for the affected wells.

Select **Done** to save the data before leaving this screen.

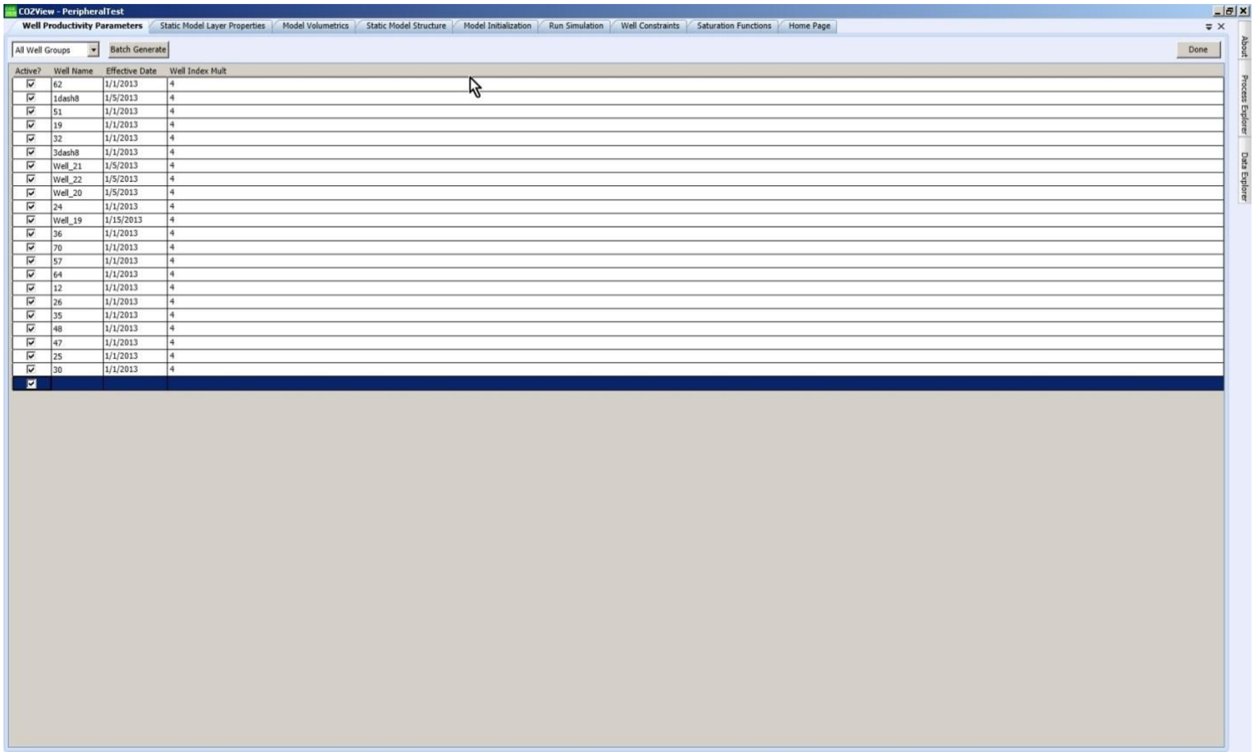
3.5.1.4 Well Productivity Parameters

The Well Productivity Parameter screen is found in the *Prediction Period/Well Parameters* section. This functionality allows the user to modify the well index (PI) calculated by the **COZSim** based on the well's location, permeability and thickness in the model. These calculated PI's are not displayed by **COZView**. It may be appropriate to adjust these values in the simulator at the start of a prediction run to better reflect actual well performance in the field. This is a common adjustment made at the end of conventional history matching before proceeding to prediction cases.

The Well Productivity Parameters screen allows the user to input a **Well Index (PI) multiplier** which is applied to the well index calculated by the simulator. A multiplier greater than 1.0 will generally increase the production capacity of a well at the start of the prediction run. A multiplier less than 1.0 will generally decrease the production capacity of a well at the start of the prediction run.

These multipliers should only be applied after the model has been successfully calibrated to the OOIP and/or OIP and a short prediction run made to determine how the simulated well rates compare to actual well rates in the field.

The user can input the parameter values on a well by well basis or the **Batch Generate** feature can be user to address multiple wells at the same time. Typically, all wells will be given the same multiplier, but this need not be the case.



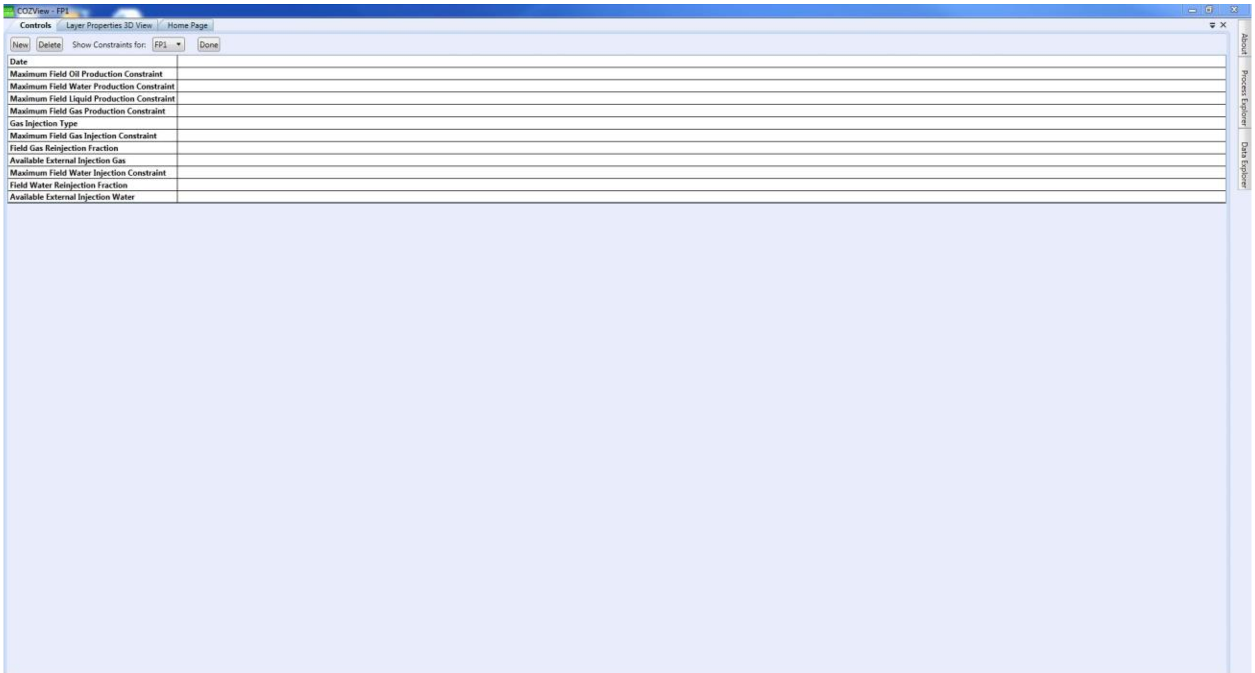
This functionality is new and earlier pictures of the Process Explorer menus may not show the Well Productivity Parameters option.

3.5.2 Field Parameters

The *Field Parameters* section allows the user to specify field controls and constraints which force the simulation run to emulate actual or desired facility capacity and operating constraints.

3.5.2.1 Field Controls

Selection of the *Field Controls* displays the screen below.



This screen provides the user with a number of field control options

Maximum Field Oil Production Constraint (STB/D)

Maximum Field Water Production Constraint (STB/D)

Maximum Field Liquid Production Constraint (STB/D)

Maximum Field Gas Production Constraint (MSCF/D)

Gas Injection Type (HC or CO2)

Maximum Field Gas Injection Constraint (MSCF/D)

Field Gas Re-Injection Fraction

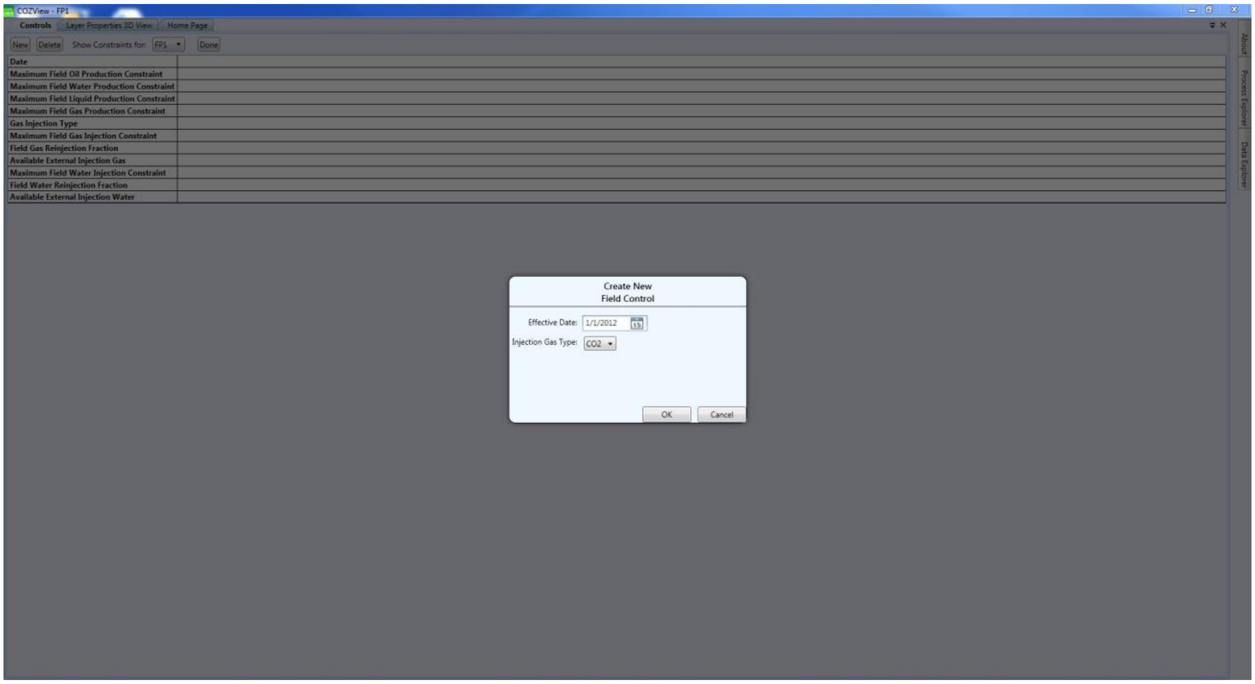
Available External Injection Gas (MSCF/D)

Maximum Field Water Injection Constraint (STB/D)

Field Water Re-Injection Fraction

Available External Injection Water (STB/D)

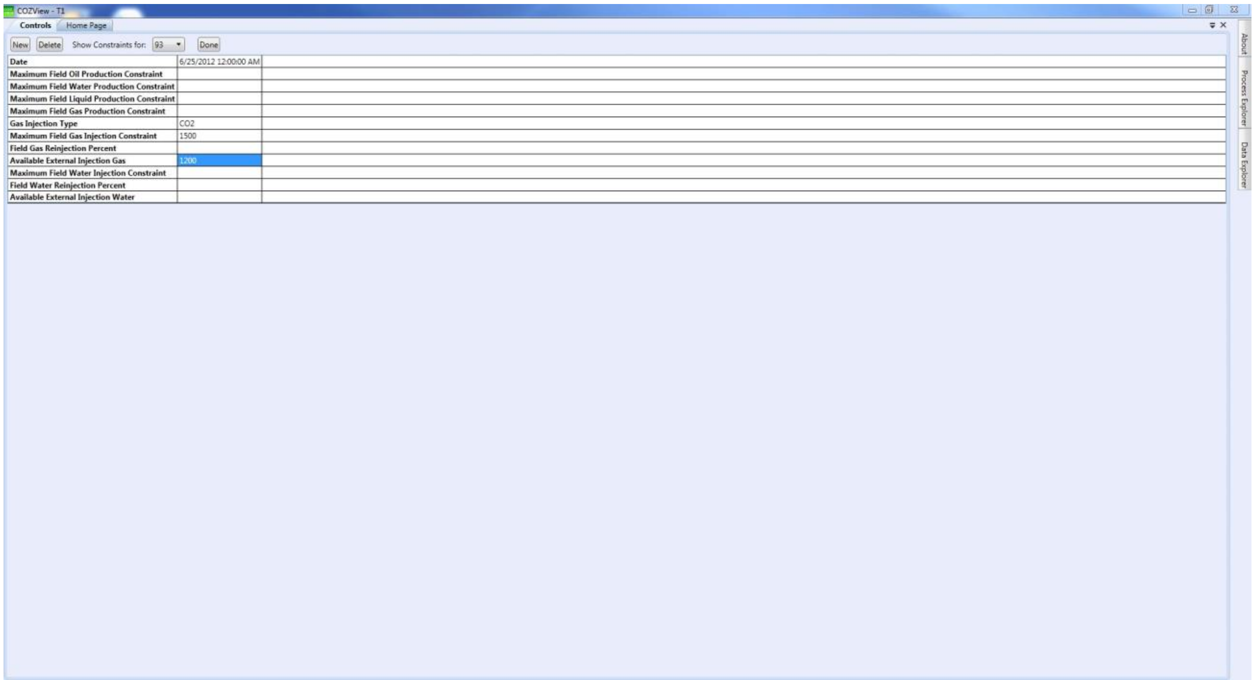
The user must first select the date at which the assigned field controls are to become effective. This is done by selecting the **New** box and assigning the appropriate activation date and Injection Gas Type from the drop down menu. Multiple dates can be provided allowing field controls to change over time during the simulation.



Select Effective date and Injection Gas Type. There are two options available for injection gas type 1) CO2 and 2) HC gas. Click Ok to Continue.

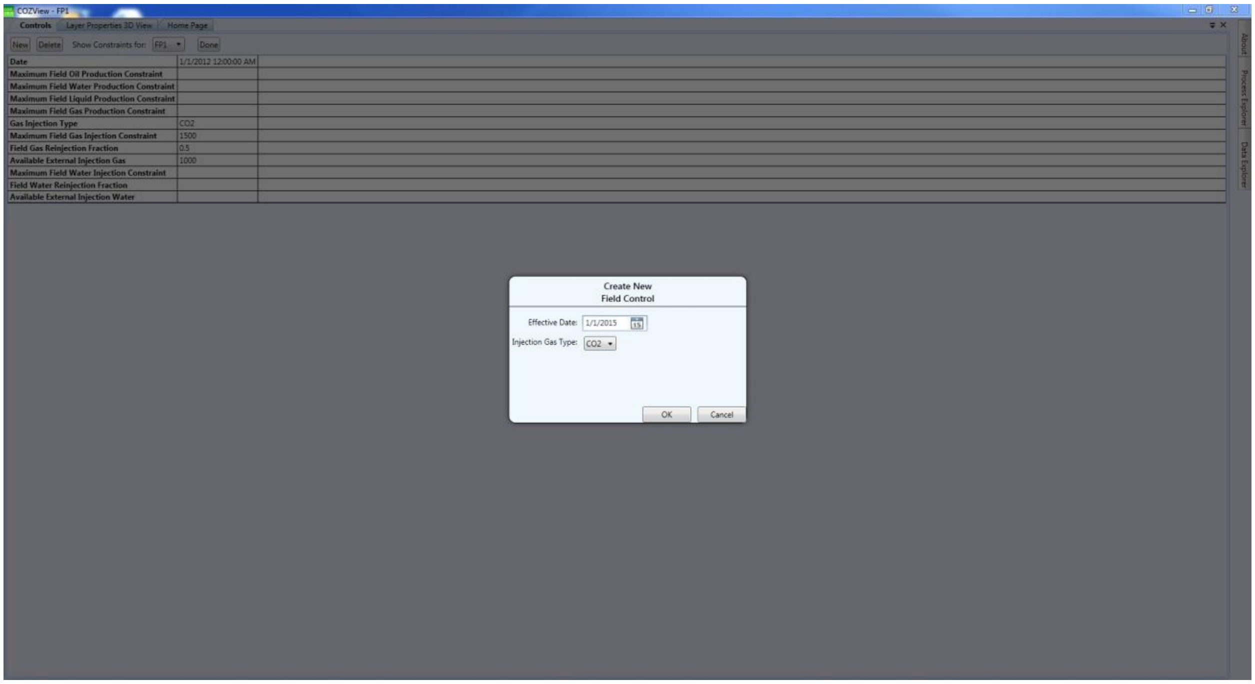
<u>It is important to note that this is the only place where the injection gas type is identified. Even if the user does not input values for the various field controls, the injection gas type must be identified. The default is CO2 gas.</u>

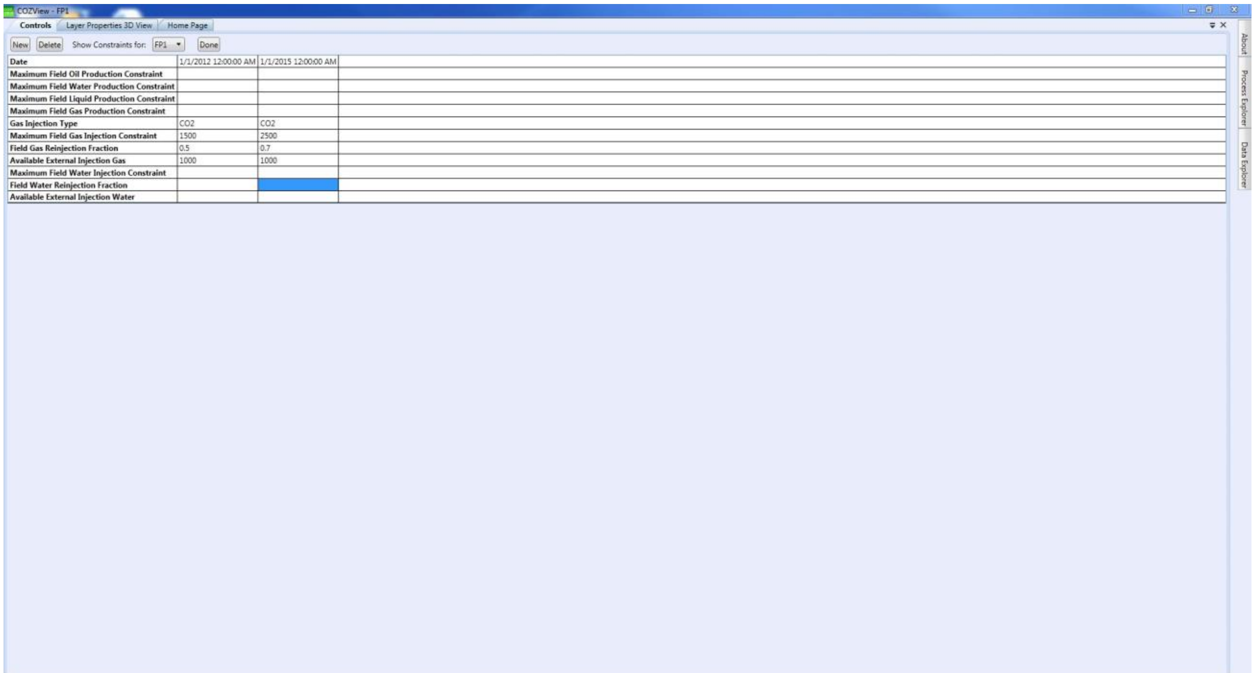
When any of these field control options are selected, the simulation run's priority is to meet these field target rates subject to individual well operational controls which may have been selected.



Please note that the Maximum Field injection constraint should always be greater than or equal to Available External Injection.

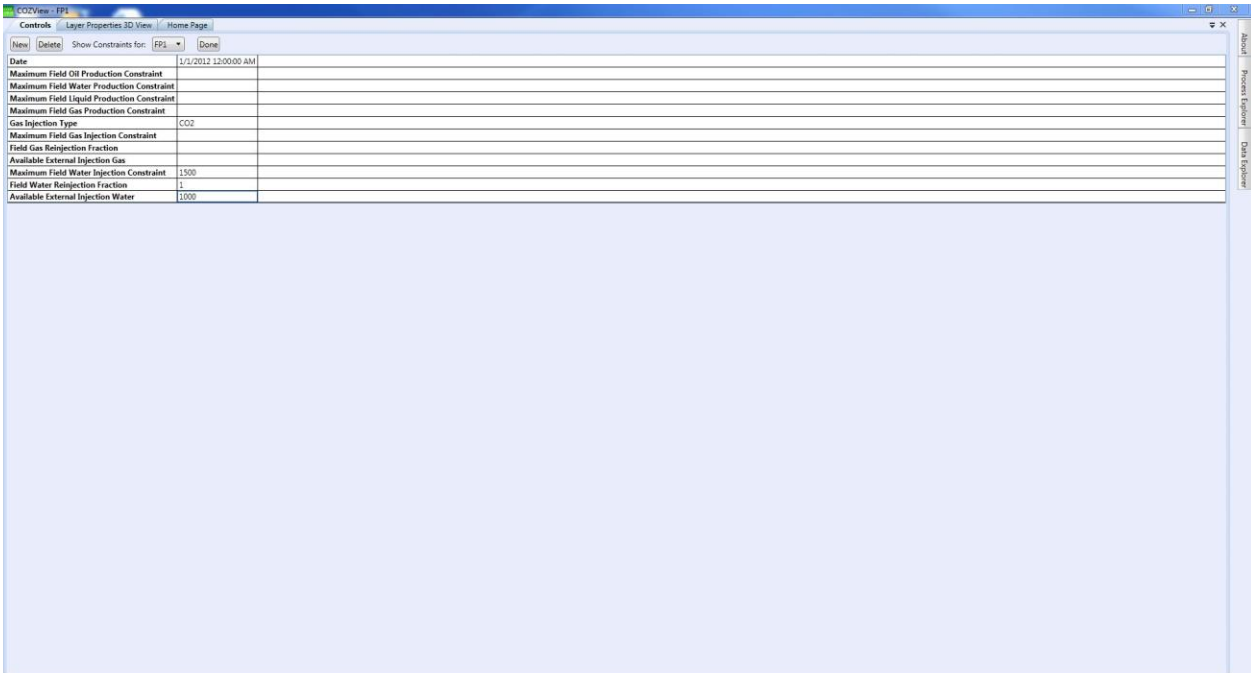
Selection of **Done** will save and exit the screen. Multiple dates can be provided allowing field controls to change over time during the simulation. Click Field Controls again under Process Explorer to input multiple Field Controls. Click New to add the new Field Controls





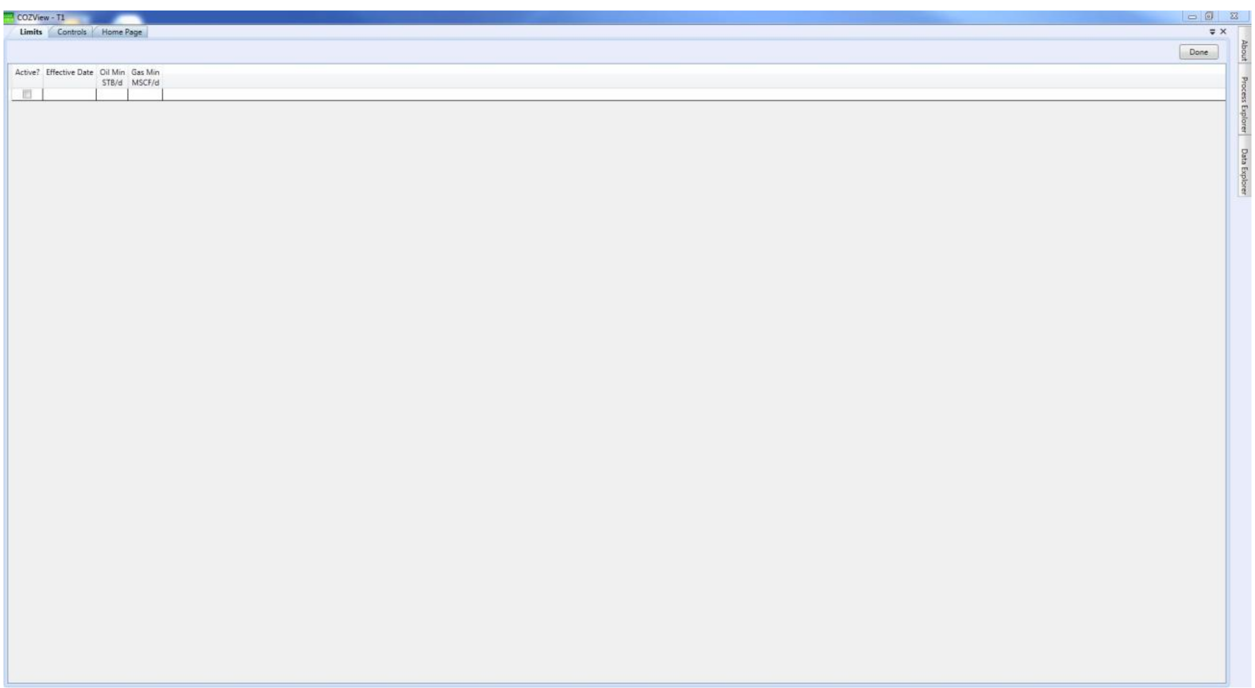
Date	1/1/2012 12:00:00 AM	1/1/2015 12:00:00 AM
Maximum Field Oil Production Constraint		
Maximum Field Water Production Constraint		
Maximum Field Liquid Production Constraint		
Maximum Field Gas Production Constraint		
Gas Injection Type	CO2	CO2
Maximum Field Gas Injection Constraint	1500	2500
Field Gas Reinjection Fraction	0.5	0.7
Available External Injection Gas	1000	1000
Maximum Field Water Injection Constraint		
Field Water Reinjection Fraction		
Available External Injection Water		

COZSim is primarily designed for CO2 injection studies. However, the user can also study a water injection scenario. Click *Field Controls* under Process Explorer. Click New to create a set of Field Controls parameters. Select CO2 as Gas Injection Type (The user must select either CO2 or HC). The user can now specify values for *Maximum Field Water Injection Constraint*, *Field Water Reinjection Fraction* and *Available External Injection Water.* Please note that assuming no well controls are set for gas injection, the Gas Injection Type "CO2" or "HC" will not inject CO2 or HC and will not affect simulation results as there are no Field Control values specified for Gas injection (Please see figure below).



3.5.2.2 Field Limits

Selection of *Field Limits* displays the screen below.



A left-click on the blank row followed by a left-click in a data field provides the ability to input a value.

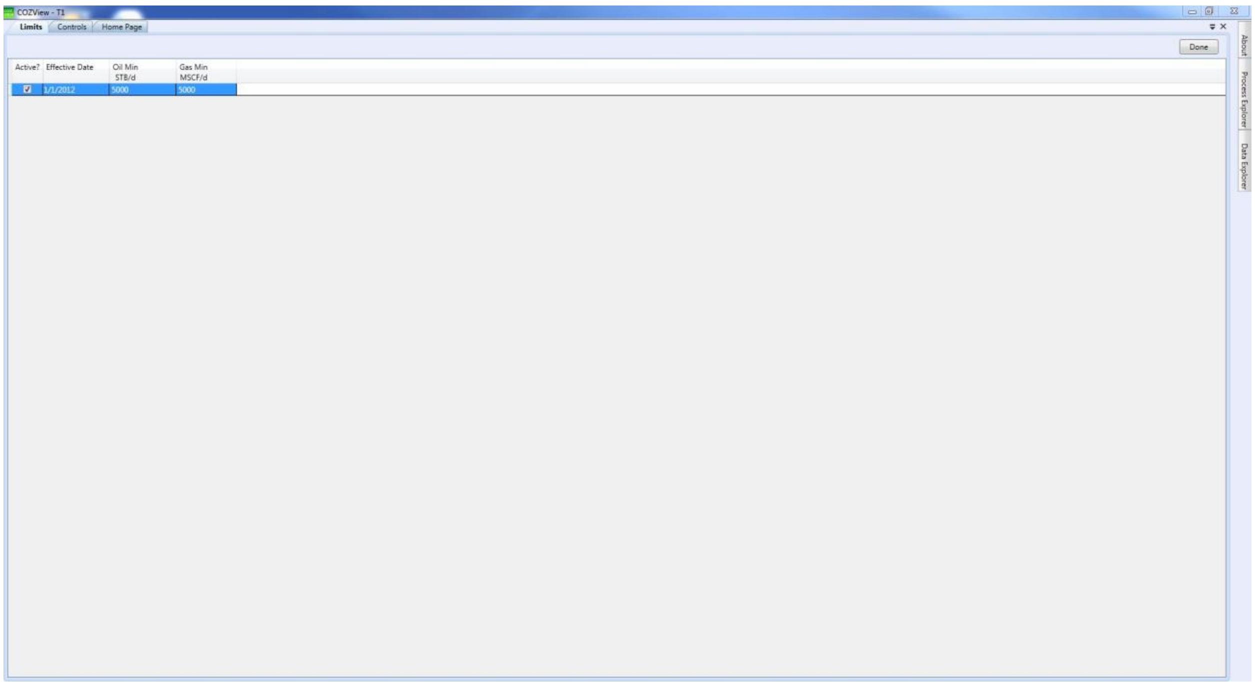
The user must check the Active box to activate the control. The available field limits are

Minimum oil production rate (STB/D)

Minimum gas production rate (MSCF/D)

If minimum field limits are reached in the simulation run, the simulator will shut-in the entire field and the simulation run will be stopped.

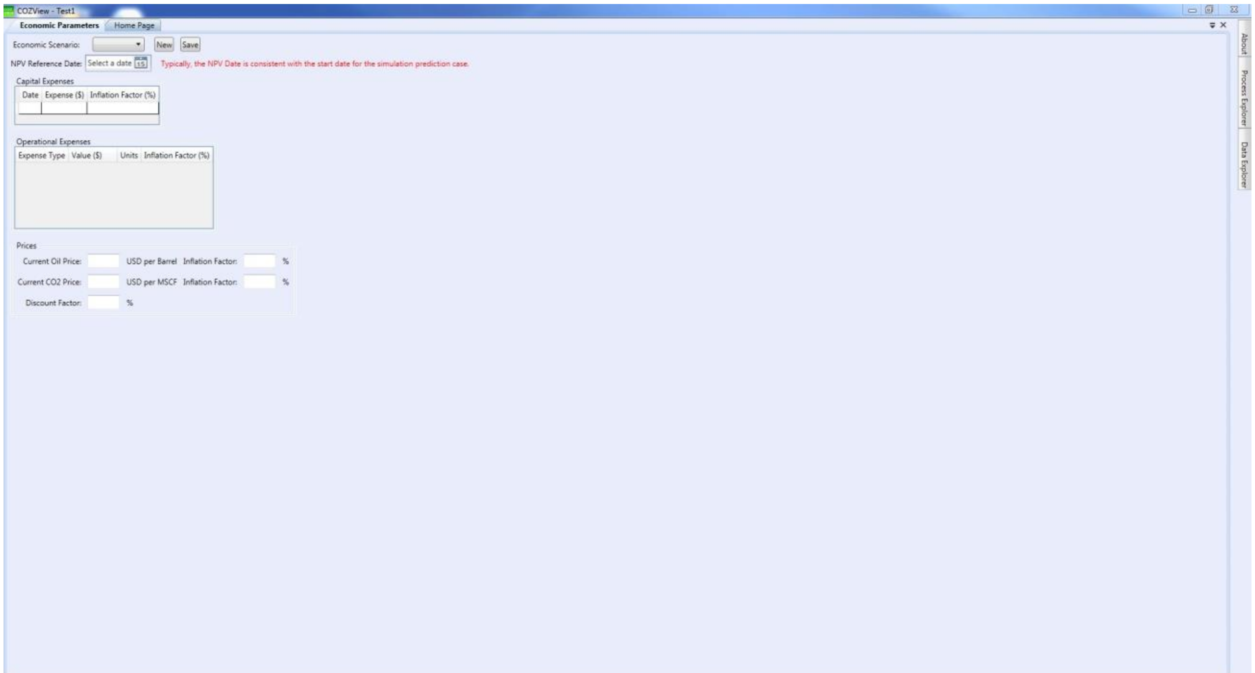
Selection of **Done** will save and exit the screen.



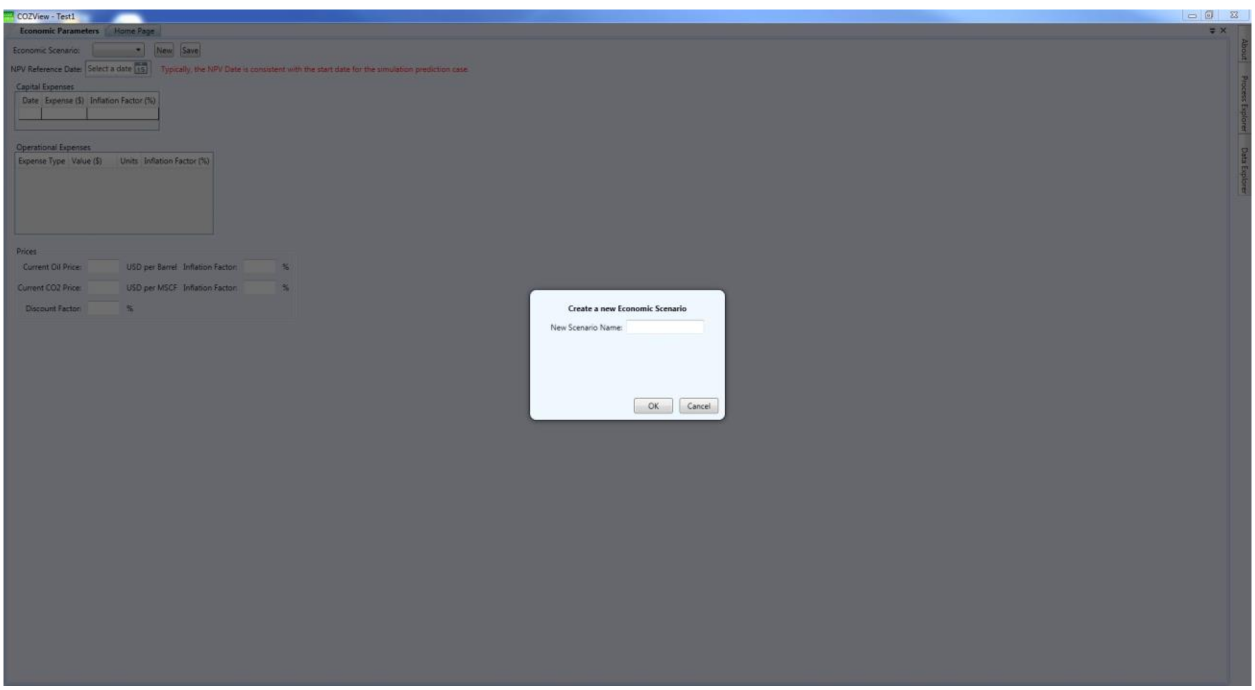
Changes to the field limits with time can be made by repeating the input process on the next row of the initial *Field Limits* screen. (A blank row is now available under the original row.)

3.5.3 Economic Parameters

The *Economic Parameters* section allows the user to specify Capital and Operational expenses for the field. The economic parameters can be tied to the optimization module for maximizing Net Present Value (See section 3.7 for details about Optimization of Net Present Value) or individual case Net Present Value calculations (section 3.6.5).



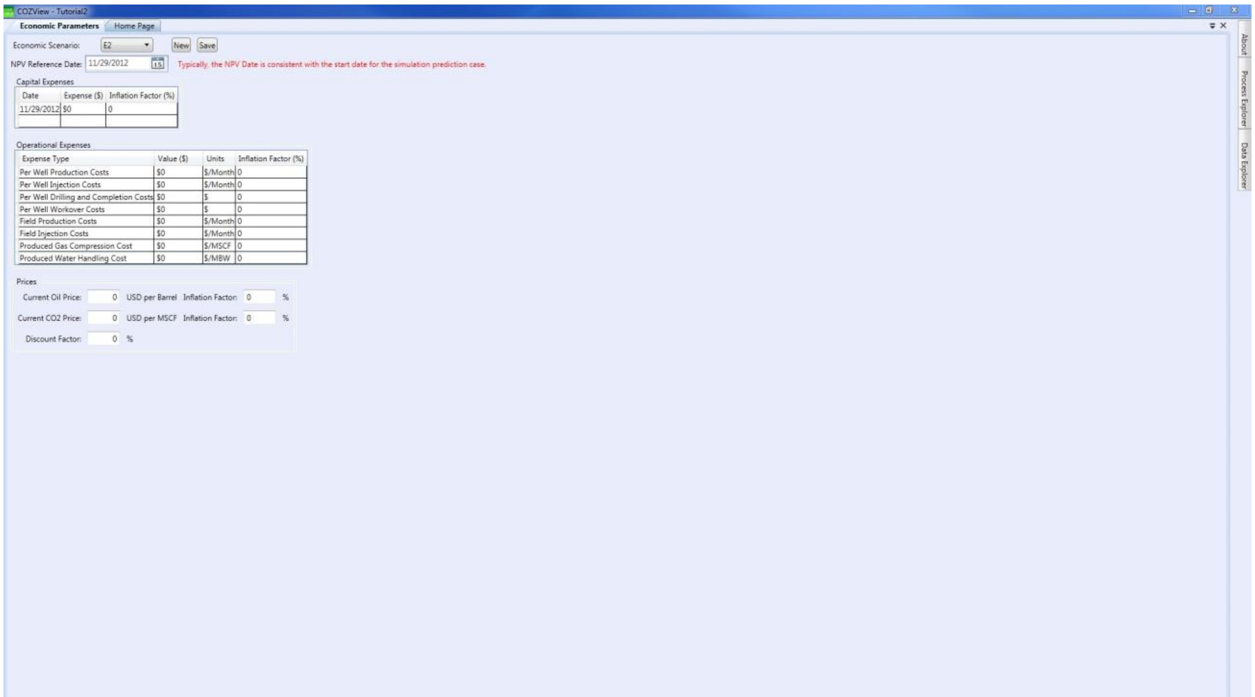
The first time the user enters this screen, a new Economic scenario must be defined by selecting the **New** button.



The Economic scenario allows the user to specify a set of economics parameters (Capital expenses, Operation expenses, Oil price, CO2 price, etc.).

Multiple Economic scenarios can be defined by clicking the **New** button and providing a new scenario name.

The NPV Reference Date typically is set to the start date of the project. All discounting and inflation of the project revenues and expenses using the specified Discount Factor and Inflation Factors will be referenced to this date.



3.5.3.1 *Capital Expenses*

The user can specify appropriate capital expenses associated with the field. Capital expenses are generally initial investment and equipment installation costs or costs at a specific time during the project.

3.5.3.2 *Operational Expenses*

The user can specify operational expenses in this section. The available options are

Per Well Production Costs ($/Month)

Per Well Injection Costs ($/Month)

Per Well Drilling and Completion Costs ($)

Per Well Workover Costs ($)

Field Production Costs ($/Month)

Field Injection Costs ($/Month)

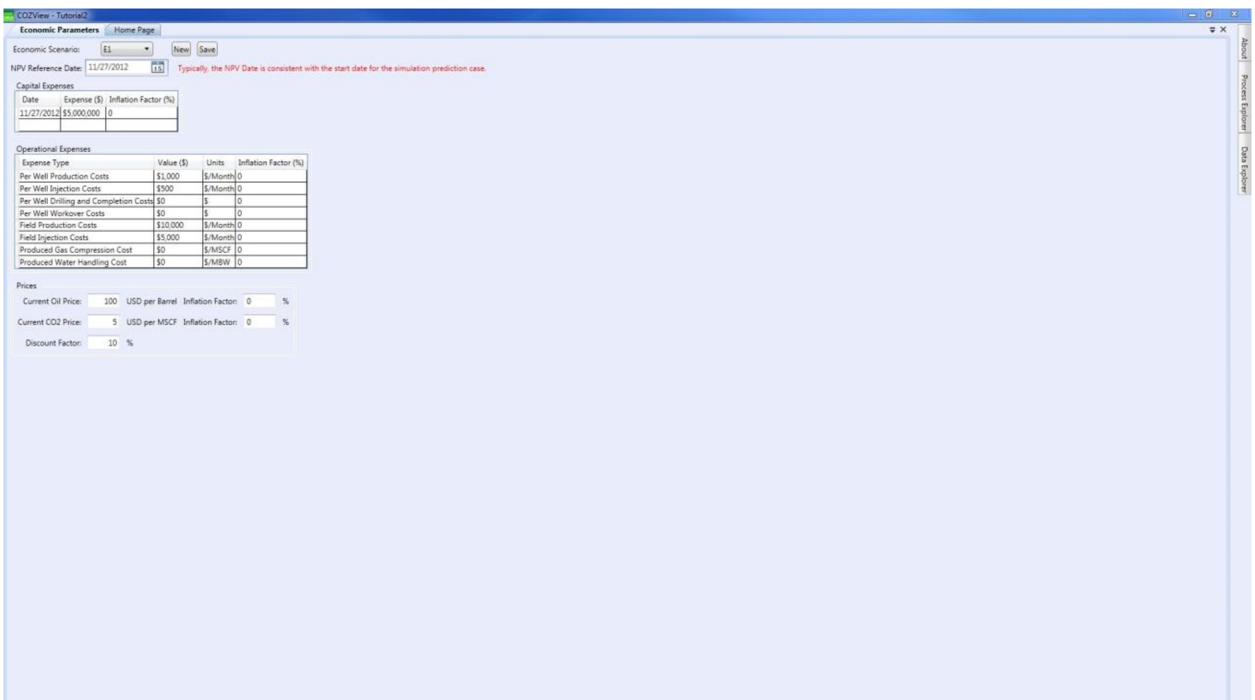
Produced Gas Compression Cost ($/MSCF)

Water Handling Costs ($/MBW)

Current oil and CO2 prices, as well as an Inflation factor for each must be specified. The Discount Factor must be provided for Net Present Value calculations.

The **New** button must be selected to provide an Economic Scenario name. Then the individual parameters can be input. Multiple Economic Scenarios can be created, but only one will be used in the NPV calculations for a prediction case or optimization runs.

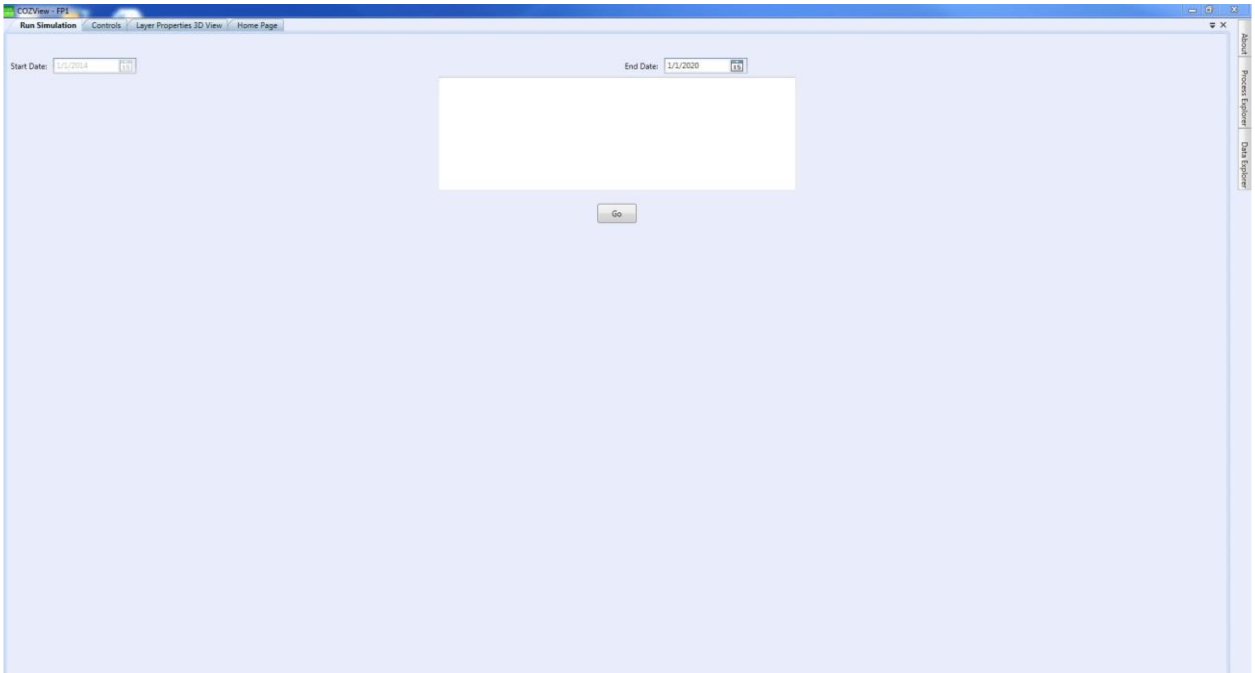
Be sure to select **Save** before exiting the screen.



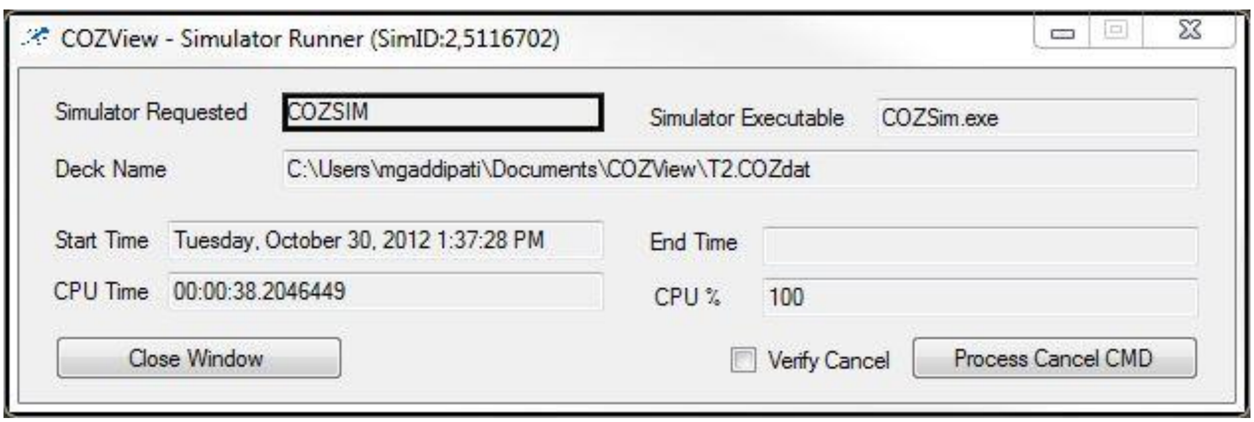
3.5.4 Run Simulation

Selection of *Run Simulation* displays the screen below. The user is only required to input the *End Date* for the simulation run. The *Start Date* is provided for reference. The Start Date is based on the last *Initialization Date* provided in the *Model Initialization* section**. The End Date must be at least one month after the Start Date.**

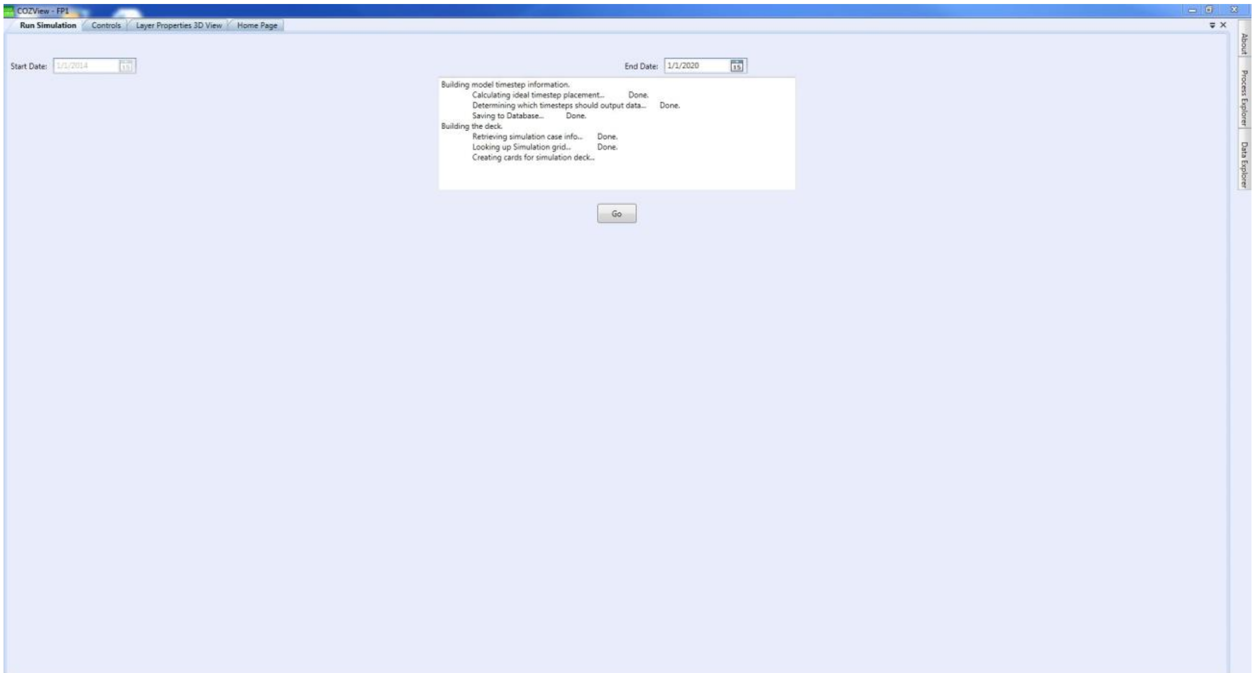
`



When the **GO** button is selected the simulation run is launched. A Simulator Runner window will appear and the CPU Time and CPU% utilization will be continuously updated.



The Run Simulation screen will be updated as the simulation model is prepared for processing.



Once the simulation run completes the Simulator Runner window will close and the simulation run results will be automatically loaded into **COZView** for display in the *Simulation Results* section.

The **COZVIEW** window can be minimized while the simulation run is in progress. <u>**DO NOT** close</u> **COZView** while the simulation run is in progress, as the simulation results will not be loaded if **COZView** and the active project are not open. *The user can view various windows within the project that is processing in COZView while the simulation run is in progress.*

The Simulator Runner window can be minimized while the simulation run is processing. While closing the Simulator Runner window will not cancel the simulation run, it is not recommended.

If the user wishes to cancel a simulation run that is in progress, select the *Verify Cancel* check box on the Simulator Runner window and click the **Process Cancel CMD** button. *The simulation results to the point of the run cancelation will be loaded subject to the frequency of reporting of the well and map results.*

The user can do other work on their computer while the simulator is running.

Depending on the duration and complexity of the simulation run, the run can take a long time to process. **COZView** does not provide any dynamic information on the progress of the run. However, two files created by **COZSim** can be accessed by the user to get an indication of run progress and to view the dynamic results. These files are ***Project name*.COZdat** and ***Project name*.COZOUT**. The .COZdat file is the input data to the simulator. The .COZOUT file contains dynamic run information including timestep size, material balance errors, individual well rates and pressures. These files can be opened with a Text editor such as TextPad or WordPad. <u>DO NOT</u> delete or edit these files during the progress of the simulation run. These files will be overwritten by **COZView** and **COZSim** when a new Verify or Simulation run is submitted for the same Project Name.

These files reside in the COZView directory created at the time COZView/COZSim was installed on the user's computer. This directory is typically in the users My Documents area.

3.5.4.1 Simulation Run Times

It is difficult to assess how long a particular simulation run will take prior to its submission. Once the simulation run is submitted there is little information available to the user relative to progress of the run. (Note the *Project name*.COZOUT file comments above.) Some general guides to what impacts simulation run time are offered here. These are not necessarily things that the user can control as most are reservoir dependent.

Parameter	**Variation**	**Impact on Total Run time**
Permeability	Larger	Slower
Areal size	Larger	Slower
Porosity	Smaller	Slower
Thickness	Smaller	Slower
Production rate	Higher	Slower
Injection rate	Higher	Slower
Duration	Longer	Slower
# of layers	Higher	Slower

3.6 View Simulation Results

When the simulation run is completed, arrays of the time dependent results and well and field plots will be automatically loaded into COZView. The arrays currently are pressure, oil saturation, gas saturation, water saturation, miscibility, and mole fraction of total CO2.

3.6.1 Plots

Selection of *Plots* will display the plot template with no simulation results. The **Simulation Results** area on the left contains five selection boxes. The boxes are

- Plot Format Type

    Individual Stacked

Single Combination

- Project
- Wells or Field

  (Only field plots are available for optimization cases.)

- Plot Type

  Injection Cumulative vs. Date

  Injection Rate vs. Date

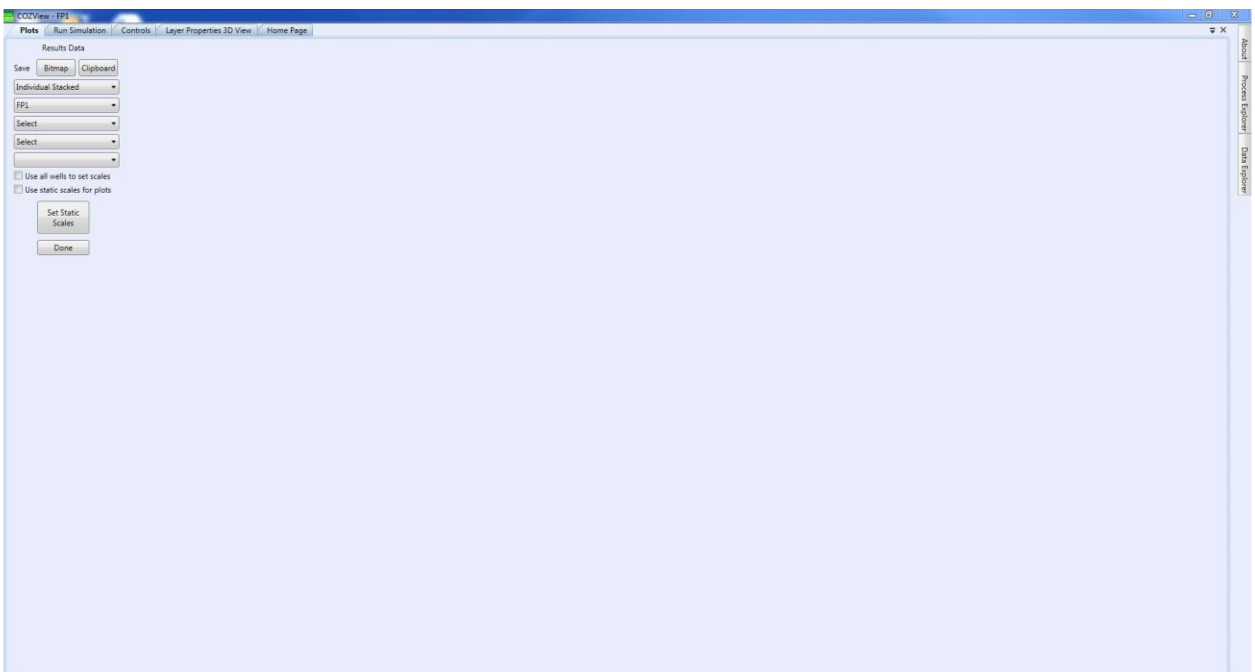
  Production Cumulative vs. Date

  Production Rate vs. date

  All Cumulative vs. Date

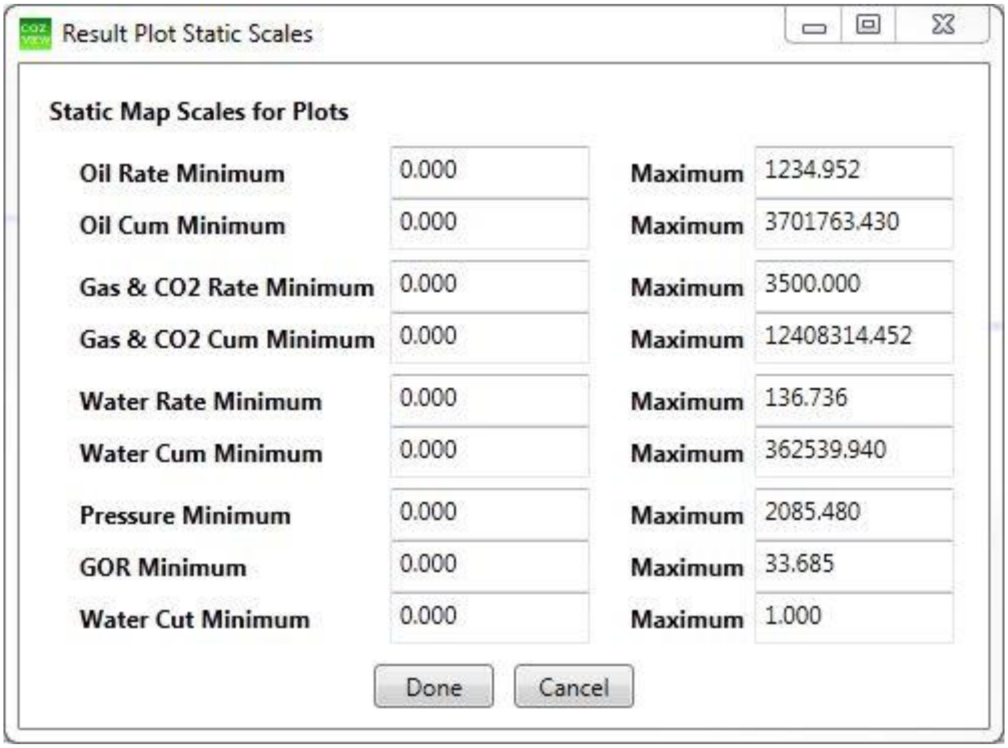
  All Rates vs. Date

  GOR and Water Cut vs. Date



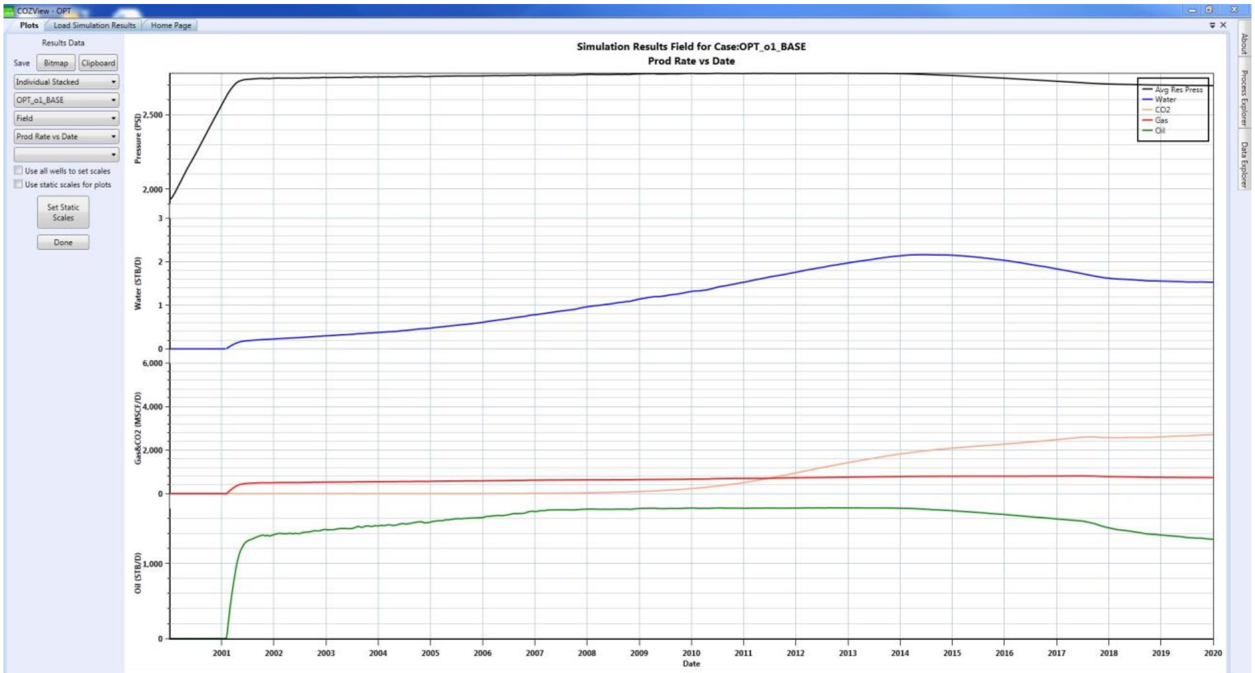
COZView has two options to set the scale for the Plots. (i) User can check the box "*Use all wells to set scales*". Selection of this box will automatically control the scales (X and Y axis) based on Property (Rates, Pressure, Cumulative, GOR and Water Cut) values for all wells. (ii) User is allowed to change the scale (X and Y axis) for each plot manually by using **Set Static Scales** button. Selection of "*Use static scales for plots"* will use the user defined scales for the X and Y axis.

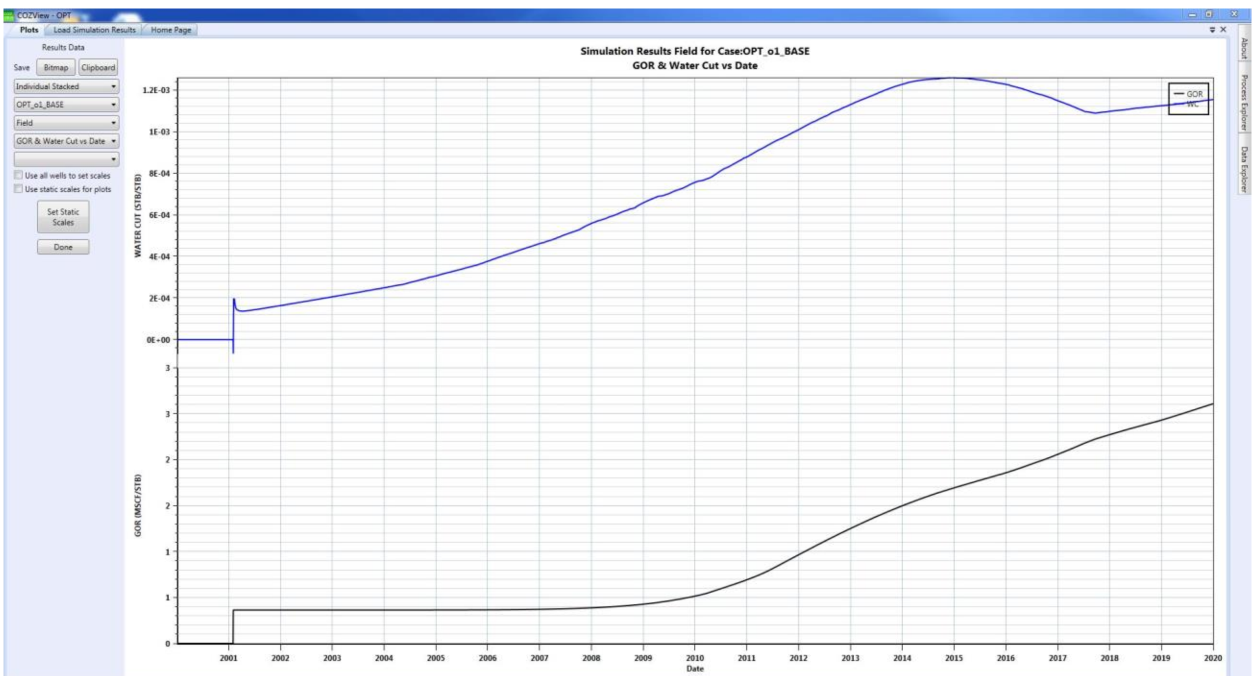
Selection of *Set Static Scales* will open a new window as shown below. The user can change the Minimum and Maximum values for each property as necessary.

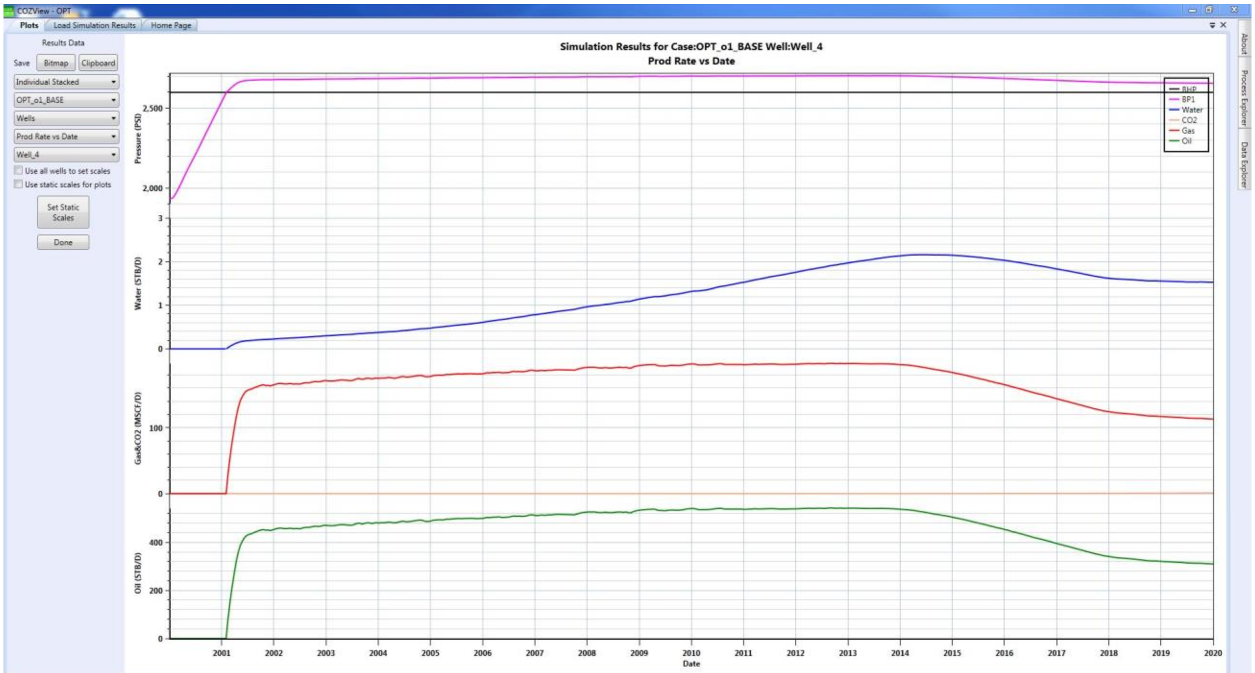


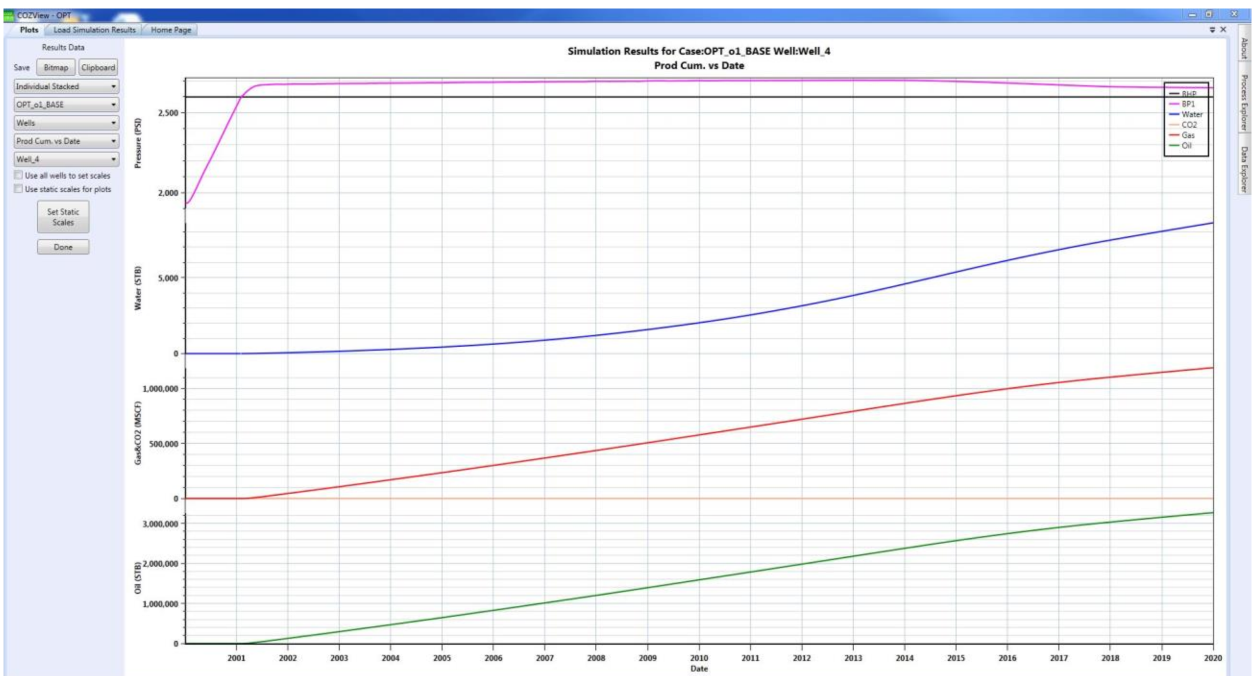
Selection of **Done** will save and close the *Plot Static Scales* window.

Some typical plots are shown below.

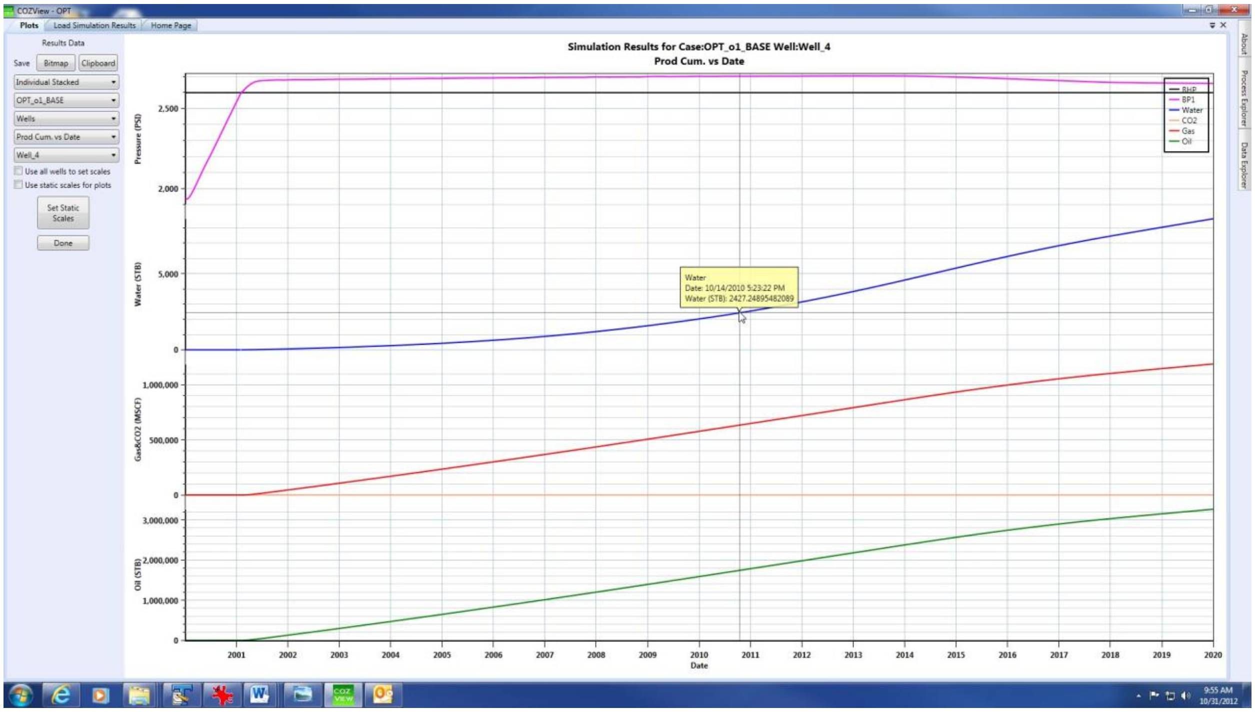

COZView - OPT
Plots
Load Simulation Results
Home Page
Results Data
Save
Bitmap
Clipboard
Individual Stacked
OPT_o1_BASE
Field
Prod Rate vs Date
Use all wells to set scales
Use static scales for plots
Set Static Scales
Done
Simulation Results Field for Case:OPT_o1_BASE
Prod Rate vs Date
Avg Res Press
Water
CO2
Gas
Oil
Pressure (PSI)
Water (STB/D)
Gas&CO2 (MSCF/D)
Oil (STB/D)
Date
About
Process Explorer
Data Explorer


COZView - OPT
Plots
Load Simulation Results
Home Page
Results Data
Save
Bitmap
Clipboard
Individual Stacked
OPT_o1_BASE
Field
GOR & Water Cut vs Date
Use all wells to set scales
Use static scales for plots
Set Static Scales
Done
Simulation Results Field for Case:OPT_o1_BASE
GOR & Water Cut vs Date
GOR
WC
WATER CUT (STB/STB)
GOR (MSCF/STB)
Date
About
Process Explorer
Data Explorer





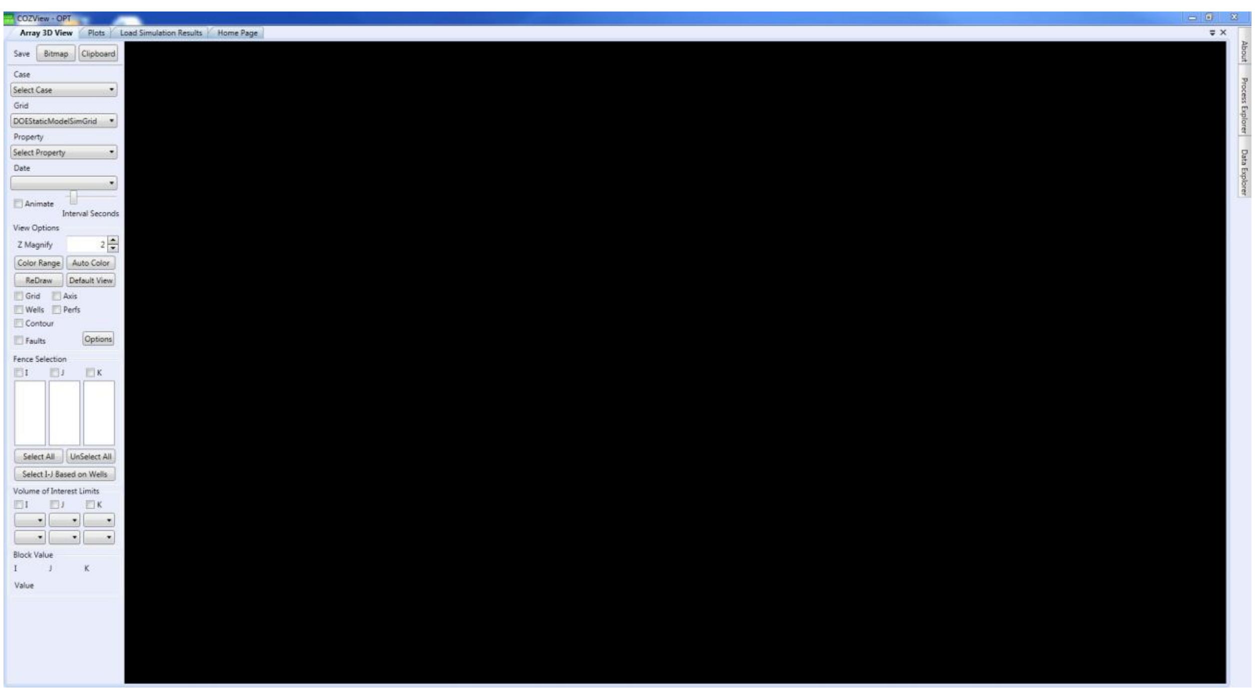
A unique functionality in COZView is the ability to assess a specific plot parameter value using the mouse. Placing the cursor on a specific plot trace and holding down the left button will display the value and date of the selected point. Continue holding down on the left mouse button and move the cursor to view other points on the same plot trace. The process can be repeated on other plot traces.



Any selected plot can be exported to a bitmap file for archiving by selecting the **Bitmap** button. Selection of the **Clipboard** button will place the plot image on the clipboard for pasting into a user selected document.

3.6.2 Array 3D View

Selection of *Array 3D View* displays a blank screen.



There are numerous simulation result map display controls in the panel on the left. The **Select Property** box will display a drop down menu of properties that are available for display.

The list of available arrays is shown below. The letter in front of each array name stands for D-data, I-initialization, and S-simulation result.

D-STRUCTURE: Structure of the reservoir

I-KRGMATRIX: Maximum relative permeability to gas in the Matrix

I-KROMATRIX: Maximum relative permeability to oil

I-KX MATRIX, I-KY MATRIX, I-KZ MATRIX: Absolute permeability's in X, Y and Z directions

I-NET-TO-GROSS: Net to Gross ratio of the reservoir

I-PHI MATRIX: Porosity

I-PORE VOL MATRIX: Pore volume (Cubic feet)

I-SORG MATRIX: Residual Oil Saturation to gas

I-SORW MATRIX: Residual Oil Saturation to water

I TRAN X MATRIX, I TRAN Y MATRIX, I TRAN Z MATRIX: Matrix transmissibility's in X, Y and Z directions

S-Miscibility: Oil Miscibility factor (0 to 1)

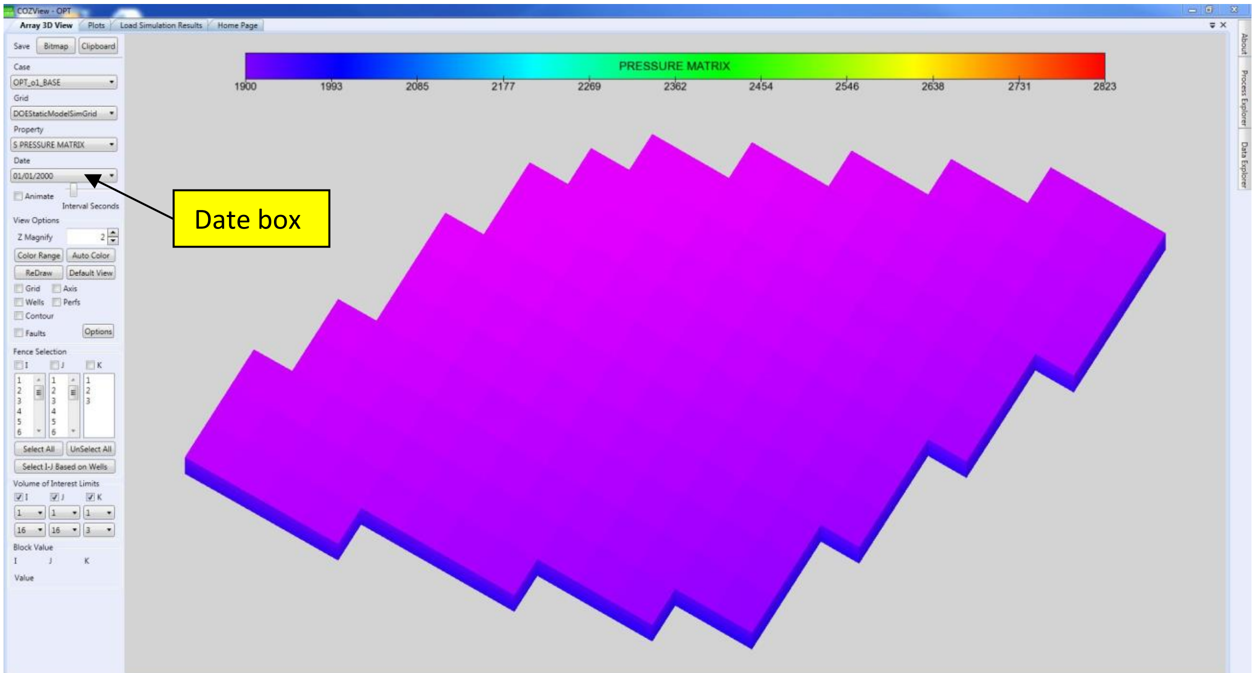
S-PRESSURE MATRIX: Reservoir Pressure

S-SATN-GAS MATRIX: Gas saturation

S-SATN-OIL MATRIX: Oil saturation

S-SATN-WAT MATRIX: Water saturation

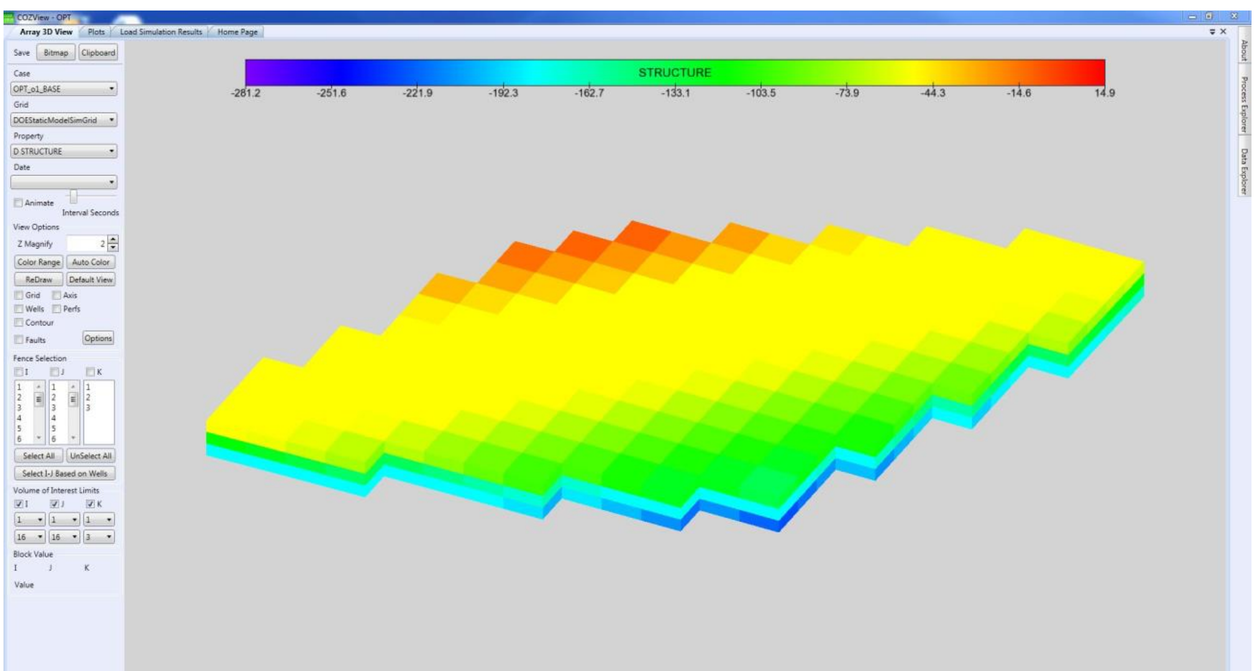
All properties when first selected will display in a high angle view. A color bar with a range scale is at the top of each property display. If the model has multiple layers, all layers will be displayed. The date of the property being displayed is shown in the date box. If multiple dates are available from the simulation run, the user may select the appropriate date.



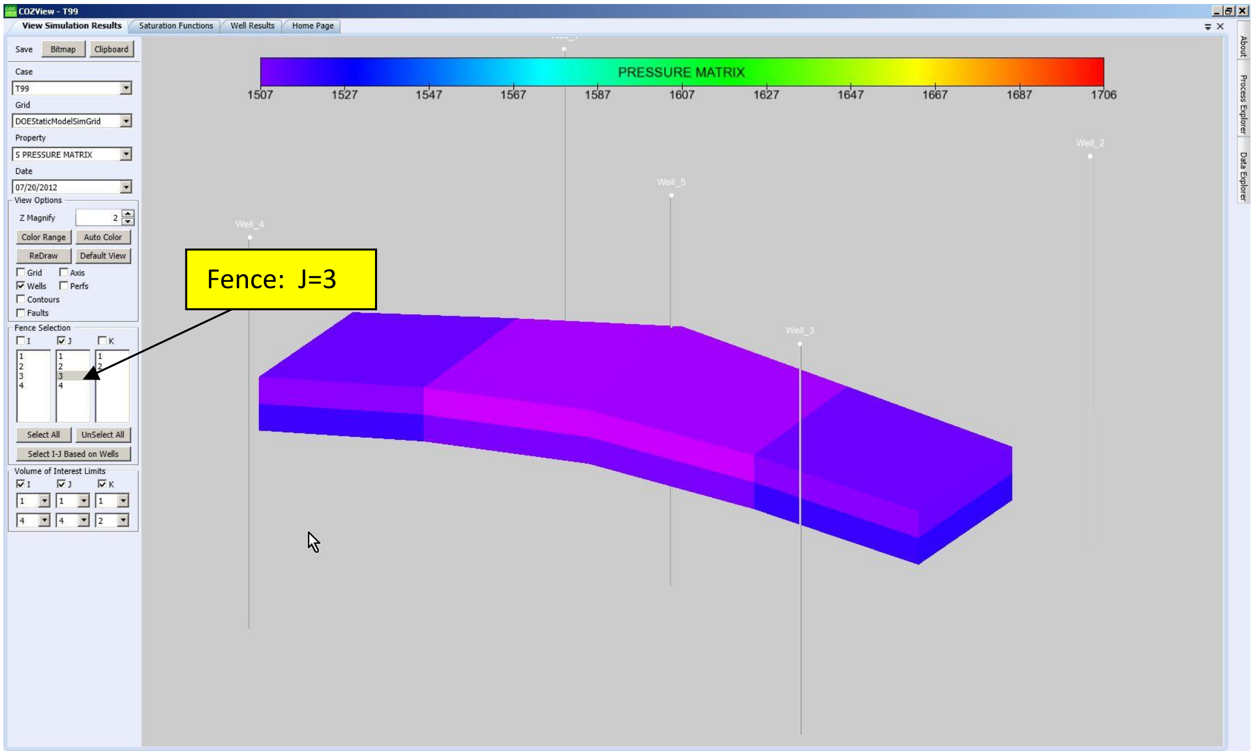
The pan, rotate and zoom operations with the mouse are functional in *Array 3D View*. Check boxes are available to display

Wells	Grid	Axis	Perfs	Faults	Contours

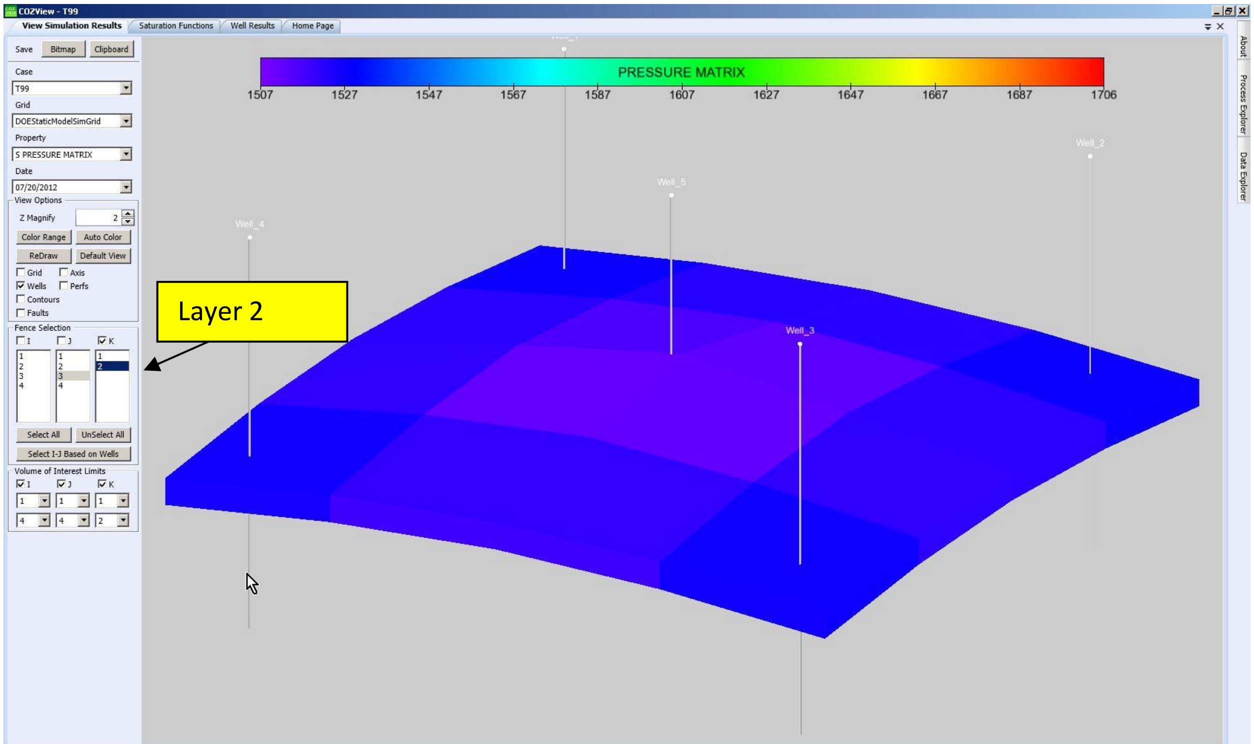
The contours will always be the structure top of the model.



Fence diagrams of any of the property displays can be created in the Fence Selection area. Checking the J box and picking row 3 will provide the display below

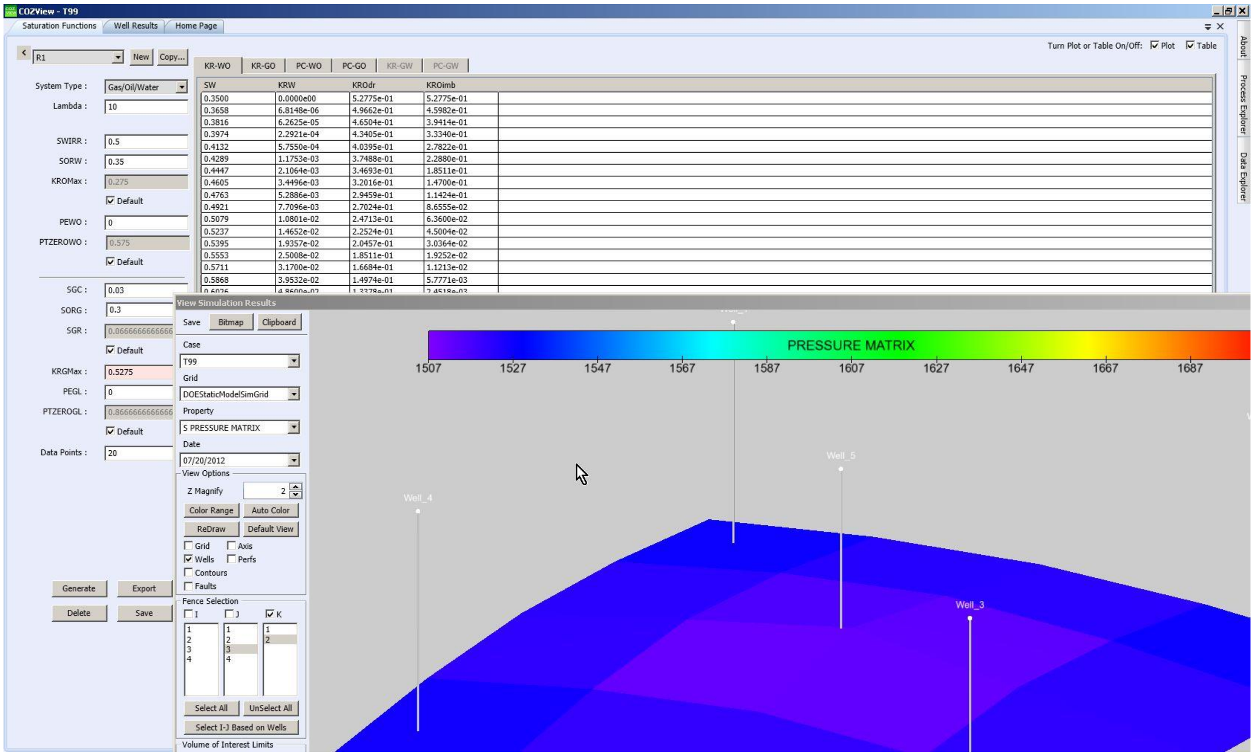


Picking the K box and 2 will display the layer 2 property below.



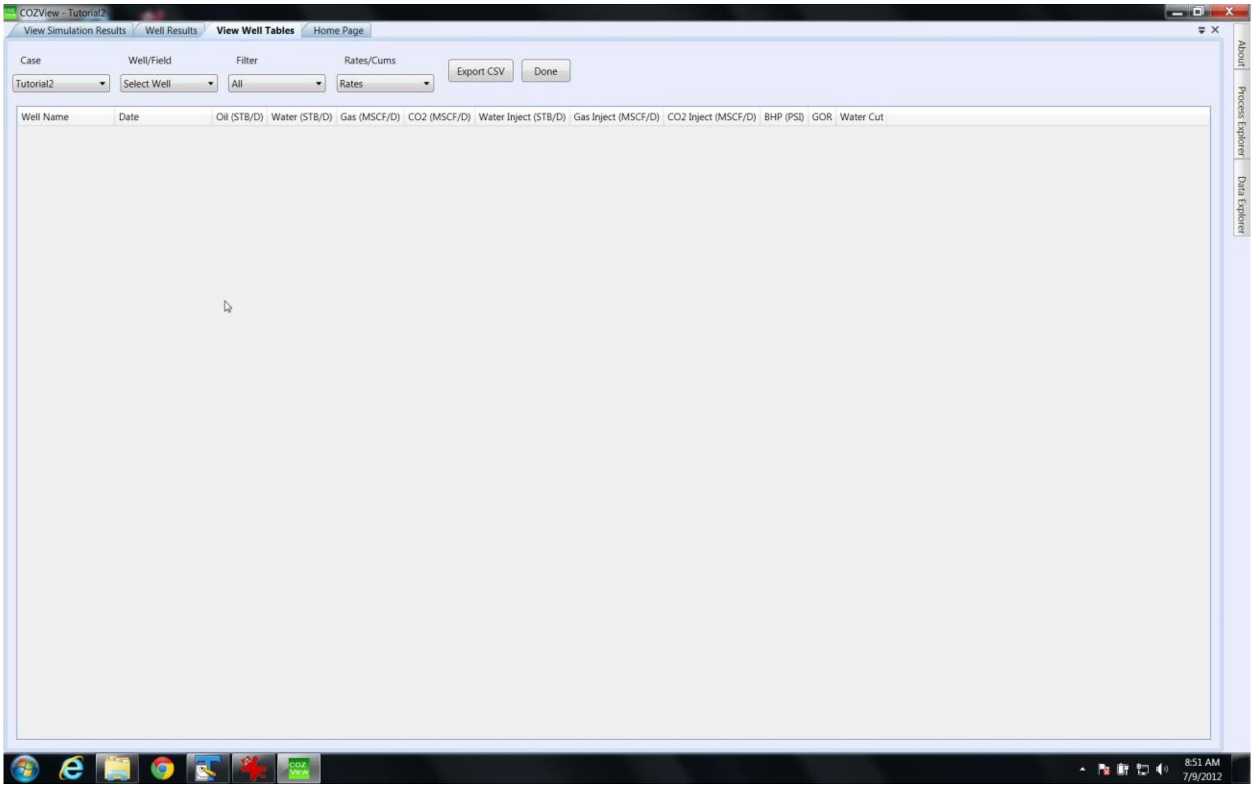
The range for the color scale can be changed by selecting the **Color Range** button. The maximum and minimum range values can be changed. This change will be applied to the current property only. It will not be saved upon selection of a different property.

The ability to view separate windows by selecting and dragging a tab to another area of the screen can be very useful when reviewing simulation results. Below the *View Maps* window has been dragged to a separate area; the *Saturation Function* window is also show as it was the last window opened prior to the *Array 3D View* window. If multiple monitors are available these views can be placed on separate monitors.



3.6.3 Tables

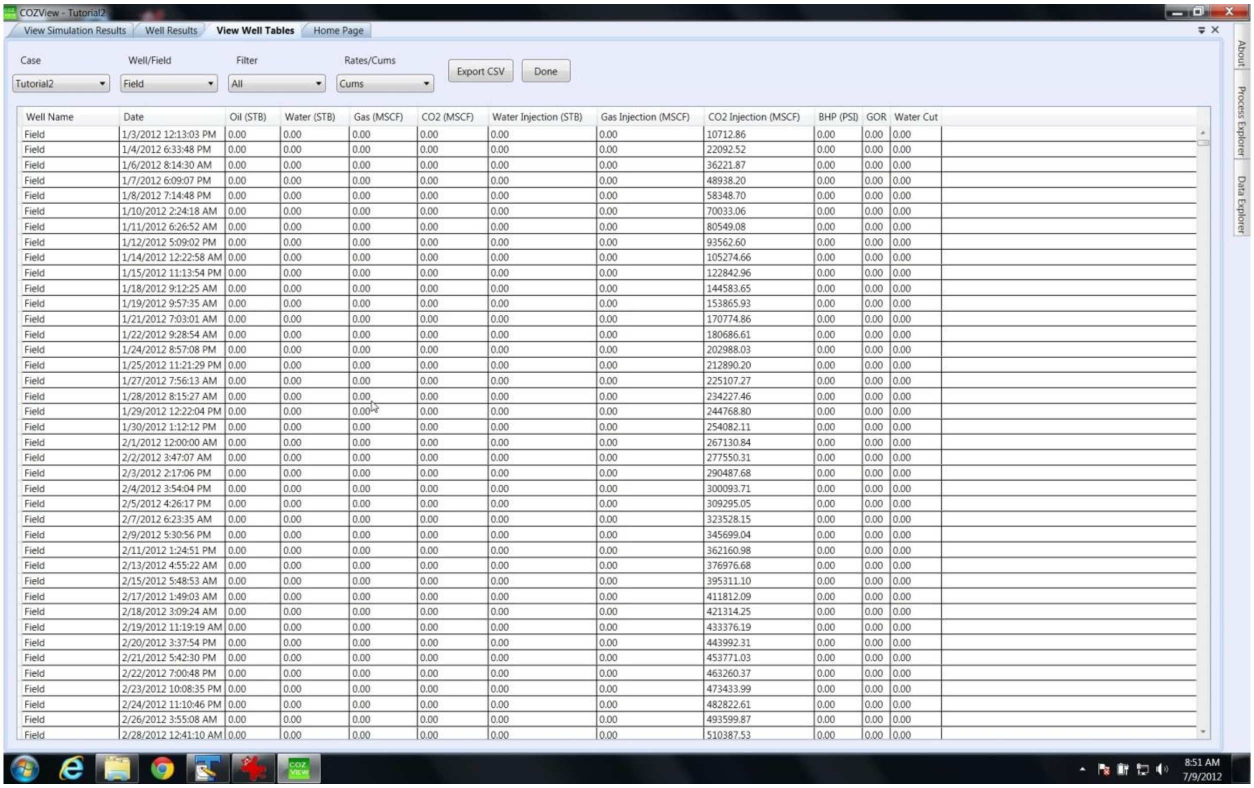
The production/injection (rate and cumulative) and bottom hole pressure simulation results at the well and field levels can be displayed in the *Tables* menu. Upon selection the initial screen is blank.



The user can select the relevant Project (Case) and the well or field data required from drop down menus. Field results can be displayed independent of the well results or with the well results. Individual well results can also be displayed. Any selected table of results can be exported to a .CSV file by selecting the **Export CSV** button. Field results are shown below.

Only field results are available for optimization cases.

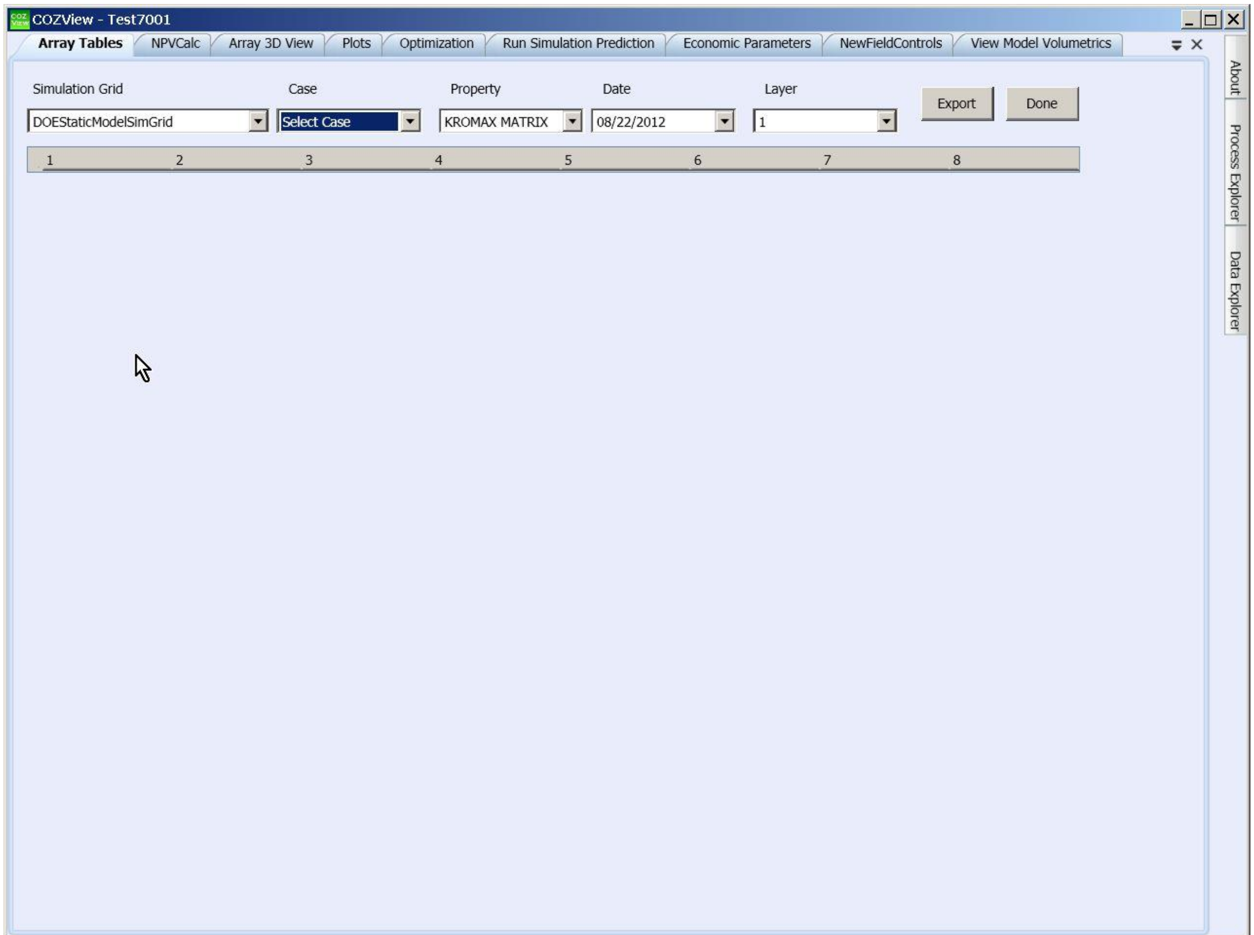
Selection of **Done** closes the screen.



Well Name	Date	Oil (STB)	Water (STB)	Gas (MSCF)	CO2 (MSCF)	Water Injection (STB)	Gas Injection (MSCF)	CO2 Injection (MSCF)	BHP (PSI)	GOR	Water Cut
Field	1/3/2012 12:13:03 PM	0.00	0.00	0.00	0.00	0.00	0.00	10712.86	0.00	0.00	0.00
Field	1/4/2012 6:33:48 PM	0.00	0.00	0.00	0.00	0.00	0.00	22092.52	0.00	0.00	0.00
Field	1/6/2012 8:14:30 AM	0.00	0.00	0.00	0.00	0.00	0.00	36221.87	0.00	0.00	0.00
Field	1/7/2012 6:09:07 PM	0.00	0.00	0.00	0.00	0.00	0.00	48938.20	0.00	0.00	0.00
Field	1/8/2012 7:14:48 PM	0.00	0.00	0.00	0.00	0.00	0.00	58348.70	0.00	0.00	0.00
Field	1/10/2012 2:24:18 AM	0.00	0.00	0.00	0.00	0.00	0.00	70033.06	0.00	0.00	0.00
Field	1/11/2012 6:26:52 AM	0.00	0.00	0.00	0.00	0.00	0.00	80549.08	0.00	0.00	0.00
Field	1/12/2012 5:09:02 PM	0.00	0.00	0.00	0.00	0.00	0.00	93562.60	0.00	0.00	0.00
Field	1/14/2012 12:22:58 AM	0.00	0.00	0.00	0.00	0.00	0.00	105274.66	0.00	0.00	0.00
Field	1/15/2012 11:13:54 PM	0.00	0.00	0.00	0.00	0.00	0.00	122842.96	0.00	0.00	0.00
Field	1/18/2012 9:12:25 AM	0.00	0.00	0.00	0.00	0.00	0.00	144583.65	0.00	0.00	0.00
Field	1/19/2012 9:57:35 AM	0.00	0.00	0.00	0.00	0.00	0.00	153865.93	0.00	0.00	0.00
Field	1/21/2012 7:03:01 AM	0.00	0.00	0.00	0.00	0.00	0.00	170774.86	0.00	0.00	0.00
Field	1/22/2012 9:28:54 AM	0.00	0.00	0.00	0.00	0.00	0.00	180686.61	0.00	0.00	0.00
Field	1/24/2012 8:57:08 PM	0.00	0.00	0.00	0.00	0.00	0.00	202988.03	0.00	0.00	0.00
Field	1/25/2012 11:21:29 PM	0.00	0.00	0.00	0.00	0.00	0.00	212890.20	0.00	0.00	0.00
Field	1/27/2012 7:56:13 AM	0.00	0.00	0.00	0.00	0.00	0.00	225107.27	0.00	0.00	0.00
Field	1/28/2012 8:15:27 AM	0.00	0.00	0.00	0.00	0.00	0.00	234227.46	0.00	0.00	0.00
Field	1/29/2012 12:22:04 PM	0.00	0.00	0.00	0.00	0.00	0.00	244768.80	0.00	0.00	0.00
Field	1/30/2012 1:12:12 PM	0.00	0.00	0.00	0.00	0.00	0.00	254082.11	0.00	0.00	0.00
Field	2/1/2012 12:00:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	267130.84	0.00	0.00	0.00
Field	2/2/2012 3:47:07 AM	0.00	0.00	0.00	0.00	0.00	0.00	277550.31	0.00	0.00	0.00
Field	2/3/2012 2:17:06 PM	0.00	0.00	0.00	0.00	0.00	0.00	290487.68	0.00	0.00	0.00
Field	2/4/2012 3:54:04 PM	0.00	0.00	0.00	0.00	0.00	0.00	300093.71	0.00	0.00	0.00
Field	2/5/2012 4:26:17 PM	0.00	0.00	0.00	0.00	0.00	0.00	309295.05	0.00	0.00	0.00
Field	2/7/2012 6:23:35 AM	0.00	0.00	0.00	0.00	0.00	0.00	323528.15	0.00	0.00	0.00
Field	2/9/2012 5:30:56 PM	0.00	0.00	0.00	0.00	0.00	0.00	345699.04	0.00	0.00	0.00
Field	2/11/2012 1:24:51 PM	0.00	0.00	0.00	0.00	0.00	0.00	362160.98	0.00	0.00	0.00
Field	2/13/2012 4:55:22 AM	0.00	0.00	0.00	0.00	0.00	0.00	376976.68	0.00	0.00	0.00
Field	2/15/2012 5:48:53 AM	0.00	0.00	0.00	0.00	0.00	0.00	395311.10	0.00	0.00	0.00
Field	2/17/2012 1:49:03 AM	0.00	0.00	0.00	0.00	0.00	0.00	411812.09	0.00	0.00	0.00
Field	2/18/2012 3:09:24 AM	0.00	0.00	0.00	0.00	0.00	0.00	421314.25	0.00	0.00	0.00
Field	2/19/2012 11:19:19 AM	0.00	0.00	0.00	0.00	0.00	0.00	433376.19	0.00	0.00	0.00
Field	2/20/2012 3:37:54 PM	0.00	0.00	0.00	0.00	0.00	0.00	443992.31	0.00	0.00	0.00
Field	2/21/2012 5:42:30 PM	0.00	0.00	0.00	0.00	0.00	0.00	453771.03	0.00	0.00	0.00
Field	2/22/2012 7:00:48 PM	0.00	0.00	0.00	0.00	0.00	0.00	463260.37	0.00	0.00	0.00
Field	2/23/2012 10:08:35 PM	0.00	0.00	0.00	0.00	0.00	0.00	473433.99	0.00	0.00	0.00
Field	2/24/2012 11:10:46 PM	0.00	0.00	0.00	0.00	0.00	0.00	482822.61	0.00	0.00	0.00
Field	2/26/2012 3:55:08 AM	0.00	0.00	0.00	0.00	0.00	0.00	493599.87	0.00	0.00	0.00
Field	2/28/2012 12:41:10 AM	0.00	0.00	0.00	0.00	0.00	0.00	510387.53	0.00	0.00	0.00

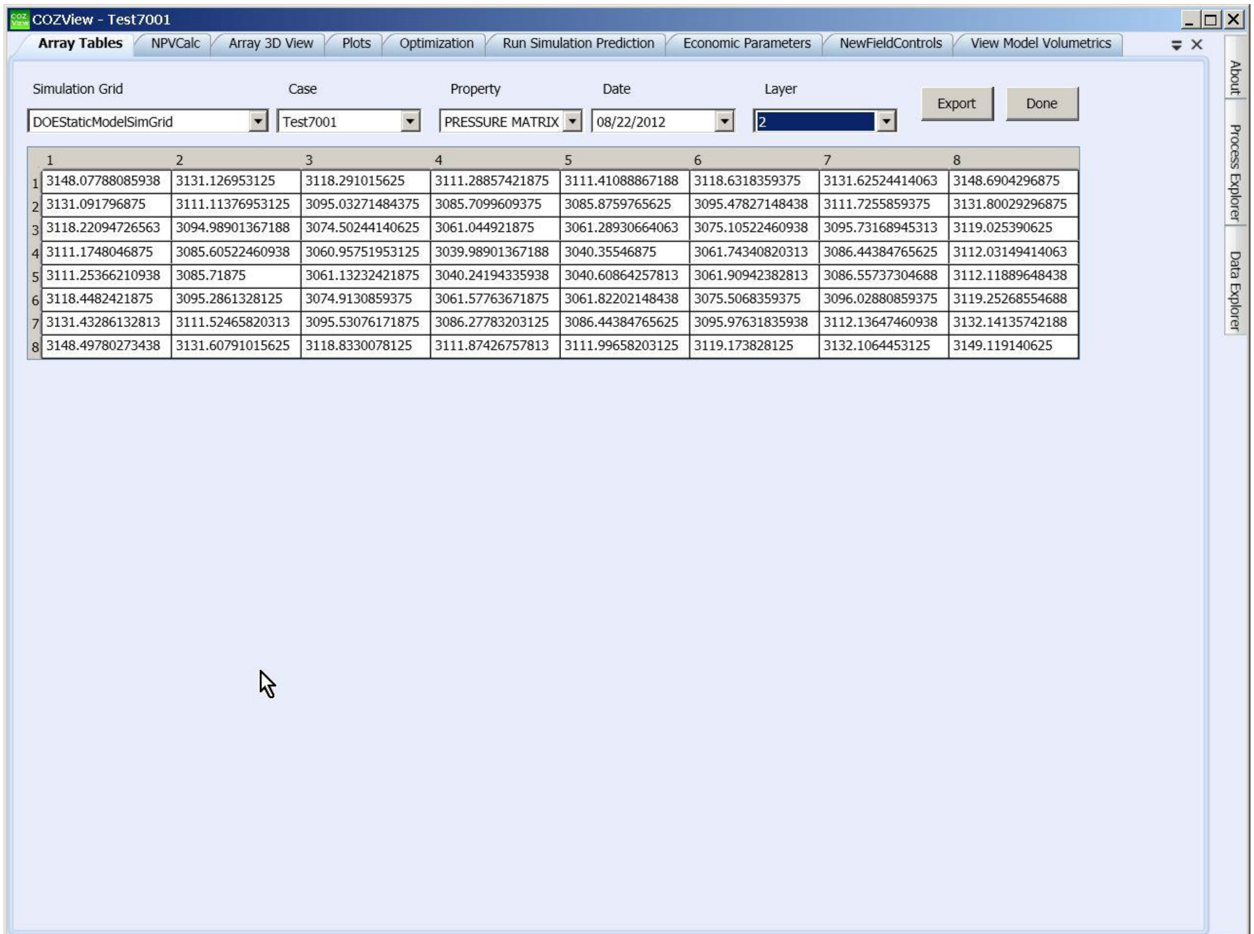
3.6.4 Array Tables

Selection of *Array Tables* in the **Simulation Results** area allows the user to display the array values at selected time steps during the simulation run. The initial screen is shown below.



The user can select the simulation case, the array property, the date and the layer to display. The display below shows the pressure in each grid cell in layer 2 at 08/22/1012 of the case Test7001 simulation run.

This information is not available for optimization cases.



The selected array results can be exported to a .CSV file if desired.

3.6.5 Calculate NPV

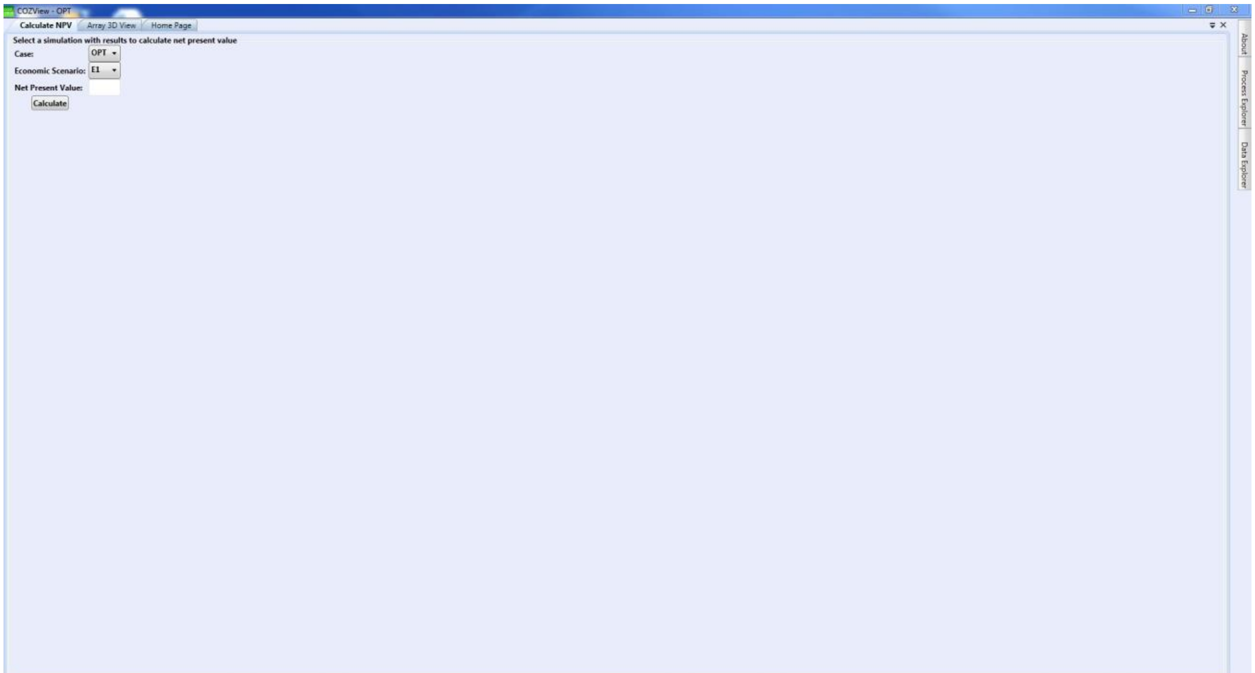
The net present value (NPV) criterion is considered as a standard measure of investment. It is the total present worth of future cash flows. The NPV method is used extensively for decision making regarding investments. It is used to realize the time value of money for approval of long term projects.

$$NPV(i) = \sum_{n=0}^{N} \frac{F_n}{(1+i)^n} - Capital\,, OperationalExpenses$$

F_n is the net cash flow, i is the rate of interest or the discount rate, n is the time period and N is total time. Each cash flow is discounted to the present value and sum of all discounted cash inflows gives the Net Present Value.

To calculate NPV in **COZView**, the user is required to define an Economic Scenario. Please see Section 3.5.3 for defining Economic Scenarios.

As soon as the simulation run is completed, the user can calculate NPV under *Process Explorer, Simulation Results*, *Calculate NPV.* Select the case and the Economic Scenario.



The user can also define a New Economic Scenario and use the simulation result to calculate a new NPV without rerunning the simulation case.

3.7 Optimization

The optimization functionality allows the user to determine the maximum net present value (NPV) for a specified prediction case, range of Field *(Facility)* Controls and set of economic parameters.

The optimization process attempts to establish the best combination of the Field Control parameters to maximize the NPV. A minimum of 1 and a maximum of 7 Field Control parameters can be varied in the optimization process. During the optimization process artificial neural network and genetic algorithm technologies are used to vary the appropriate Field Control parameters within a range of values defined by the user and simulation runs are made with those values. The optimization process designs runs with the objective of maximizing the NPV for the prediction case.

The economic parameters assigned to a specific Scenario name in the Economic Parameters section are used in the optimization process.

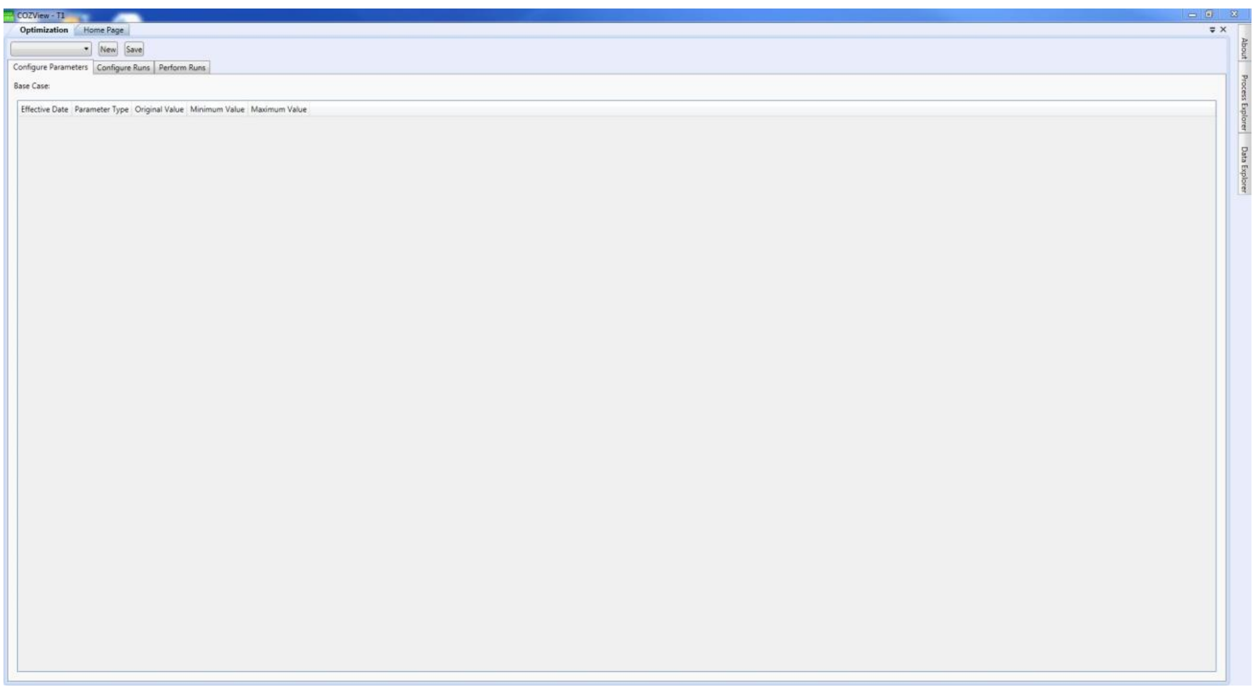
It is recommended that the user submit the Base Case simulation run as a normal prediction case before utilizing the optimization process. This will assure that the various simulation inputs are consistent with the user’s wishes and the run progresses properly. This will also give the user information on how long a single simulation run requires to process.

The user can move between tabs in COZView during the optimization process. **However, the user should not close the Optimization tab, cancel any simulation run or close COZView while the optimization process is in progress. It is also recommended that the user does NOT make changes to any of the data used by the optimization process while it is in progress.** This will result in a loss of data and/or an incomplete optimization process.

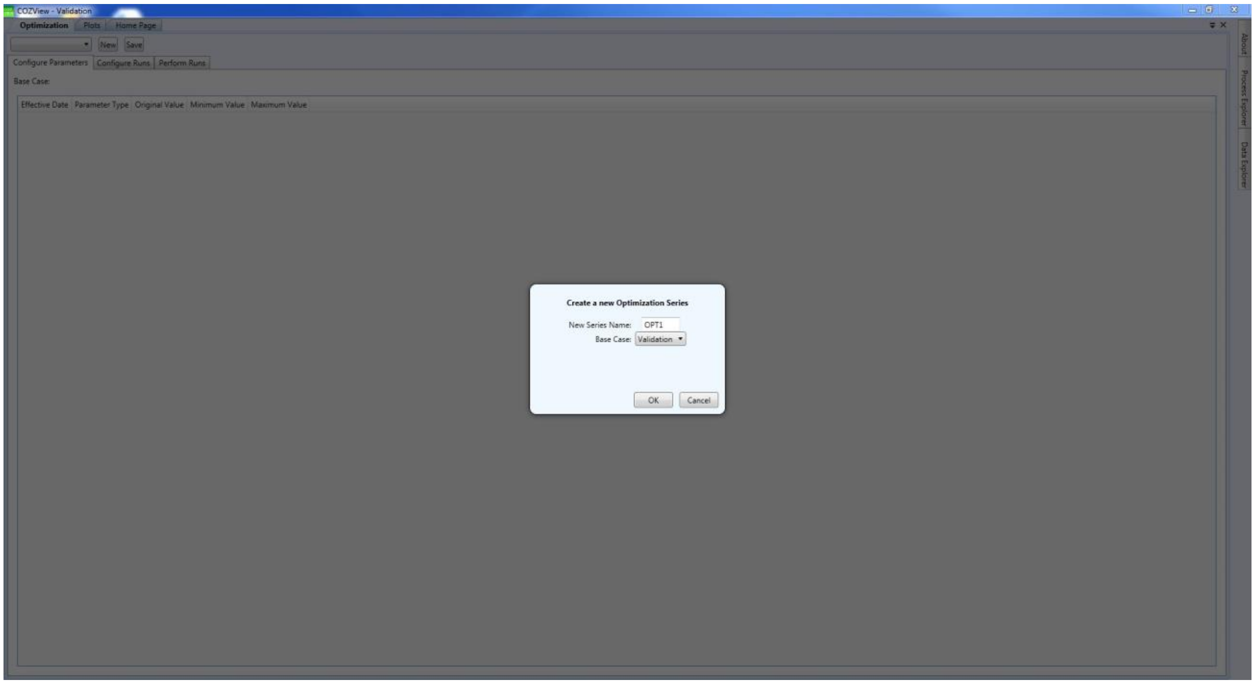
Only field results calculated by **COZSim** are loaded into **COZView** for optimization cases. **No well results or simulation result arrays are loaded for optimization cases.**

Select **Optimization** from the **Process Explorer** section. Three internal tabs are shown in this section – *Configure Parameters*, *Configure Runs*, and *Perform Runs.* The user will be in *Configure Parameters* upon initial entry to the **Optimization** section.

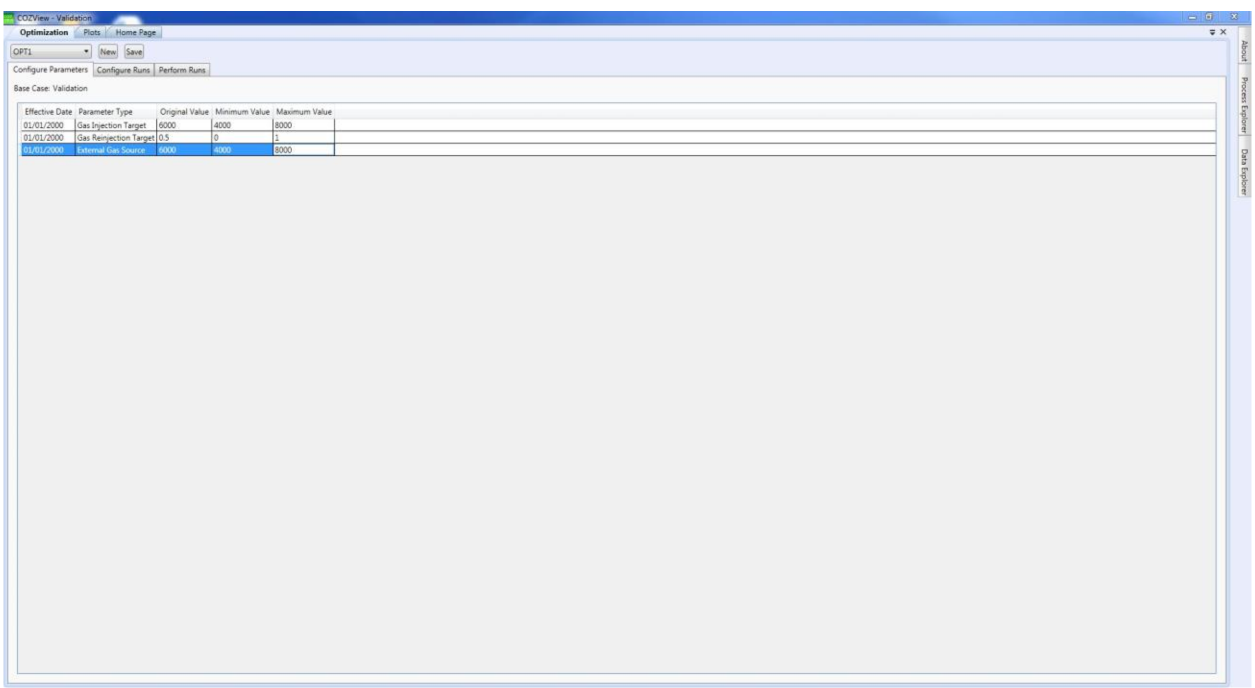
3.7.1 Configure Parameters



Select **New** to assign a *Series Name* to the optimization cases to be run. Select the *Base Case* that is the starting point for the optimization process from the drop down menu.



A table of the previously specified Field/Facility parameters and their original values will be displayed. These are the parameters available for investigation in the optimization process. The user can specify a range (minimum and maximum) over which each parameter's value can be varied during the optimization process. The user can choose to not vary a particular parameter by not providing minimum and maximum values.



The optimization process has a predefined sequence of simulation runs that will be made as it attempts to maximize the NPV. The default number of runs and the minimum and maximum number of runs in the optimization process are based on the number of Field Control parameters being varied. **COZSim** uses the default number of simulation runs for the optimization process, unless the user overrides the defaults values.

Parameters Varied	Default Number of Simulation Runs	Minimum Number of Runs	Maximum Number of Runs
1	26	23	40
2	26	23	54
3	26	23	70
4	32	29	86
5	38	35	102
6	44	41	118
7	50	47	134

The optimization process generates three types of simulation runs which are identified as Orthogonal runs (ORTH), Cluster runs (CLST), and Optimization runs (OPT).

3.7.2 Configure Runs

Select *Configure Runs* upon completion of the *Configure Parameters* section. This section allows the user to define

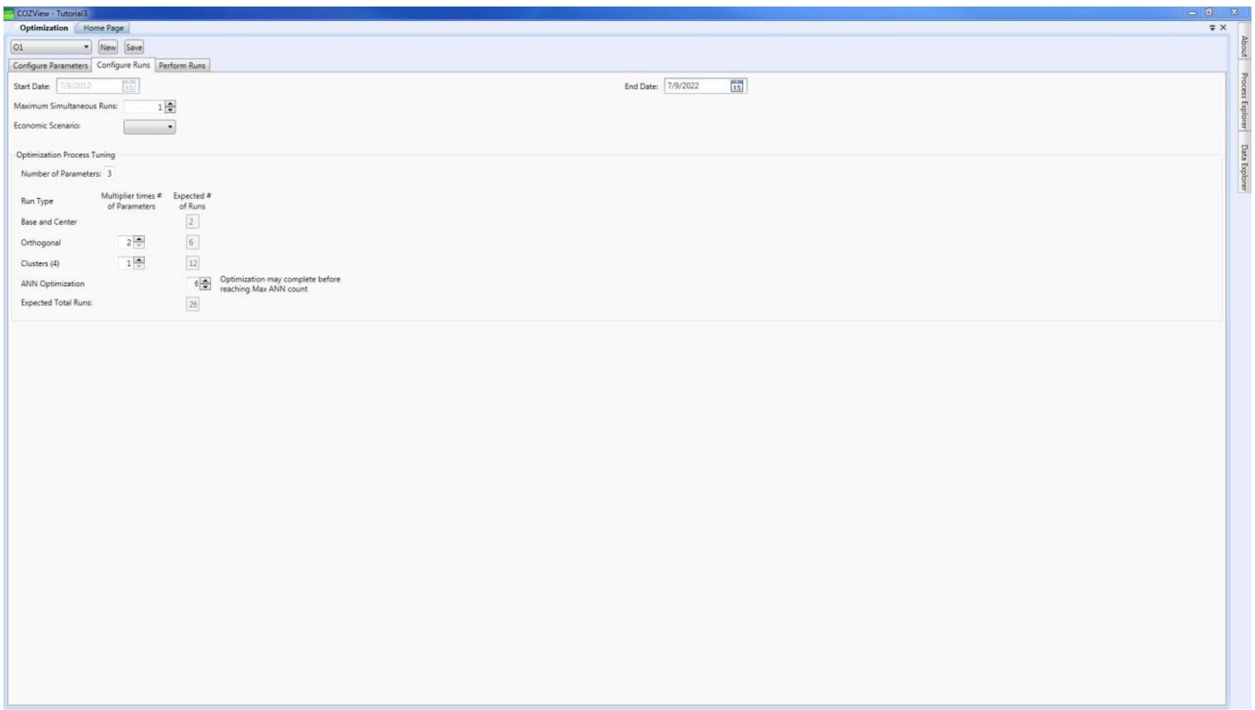
- the prediction case duration or End Date,
- the maximum number of simultaneous runs to allow during the optimization process, and
- the Economic Scenario (previously defined) to be used.

This section also identifies the default number (multipliers times # parameters) of each type of simulation run to be made (ORTH, CLST, OPT). The user may change these default values. **However, doing so may adversely impact the optimization process results.**

The ORTH simulation runs are independent of each other and can run simultaneously. The number of ORTH simulation runs is generally 2 x # of varied parameters (minimum of 6). The number of CLST simulation runs is generally four groups of 1 x # of varied parameters (minimum of 12); each group can run simultaneously, but each group must complete before the next group can start. The number of OPT simulation runs is 6. The OPT simulation runs are dependent on all prior runs. Each OPT run must complete before a new OPT run can start. In addition to these optimization process designed simulation runs, there are two additional runs in the process.

The Optimization process also runs the Base and the Center case. The user is allowed to change the number of ORTH, CLST and OPT runs in the boxes.

Run Type	Multiplier times # of Parameters	Expected # of runs
Base and Center		2
Orthogonal	2	6 (for 3 parameters)
Cluster (4)	1	12 (for 3 parameters)
ANN Optimization		6



Specify the *End Date* for the simulation runs.

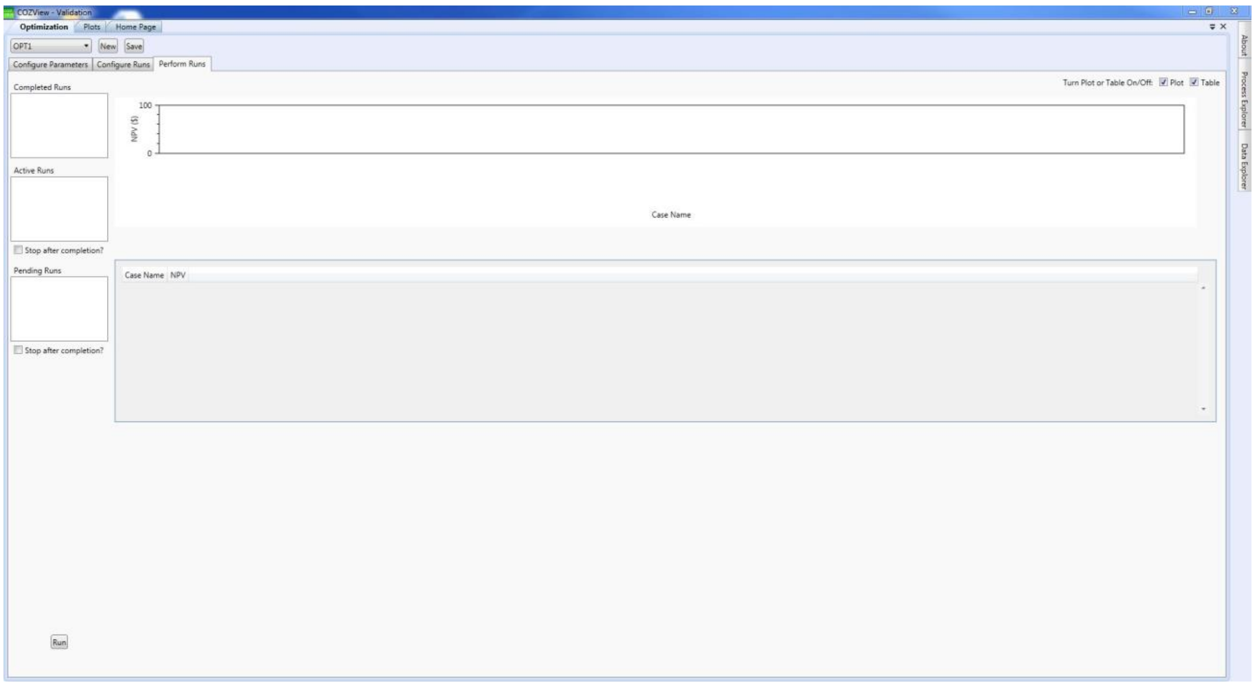
The optimization process is capable of processing multiple simulation runs simultaneously depending on where in the predefined run process the runs are being made. If the user has a multi-core CPU, simultaneous runs can be made with little processer time degradation. Use of this feature can greatly speed up the overall optimization process as many simulation runs may be required. Typically this number can be between 2 and 4.

Specify the *Economic Scenario* from the drop down menu to use in the process. Select **Save** before leaving this section.

3.7.3 Perform Runs

Select *Perform Runs* upon completion of the *Configure Runs* section. This section is used to launch the optimization process simulation runs. This is done by selecting **RUN**.

The screen will provide information about the simulation runs that have been *Completed*, are *Active* (in progress) and *Pending* (waiting to run) on the left side of the screen. Pending Runs are only those that have been designed at that point in time. New runs may be designed as the process progresses. The Simrunner window will appear for each active simulation run.

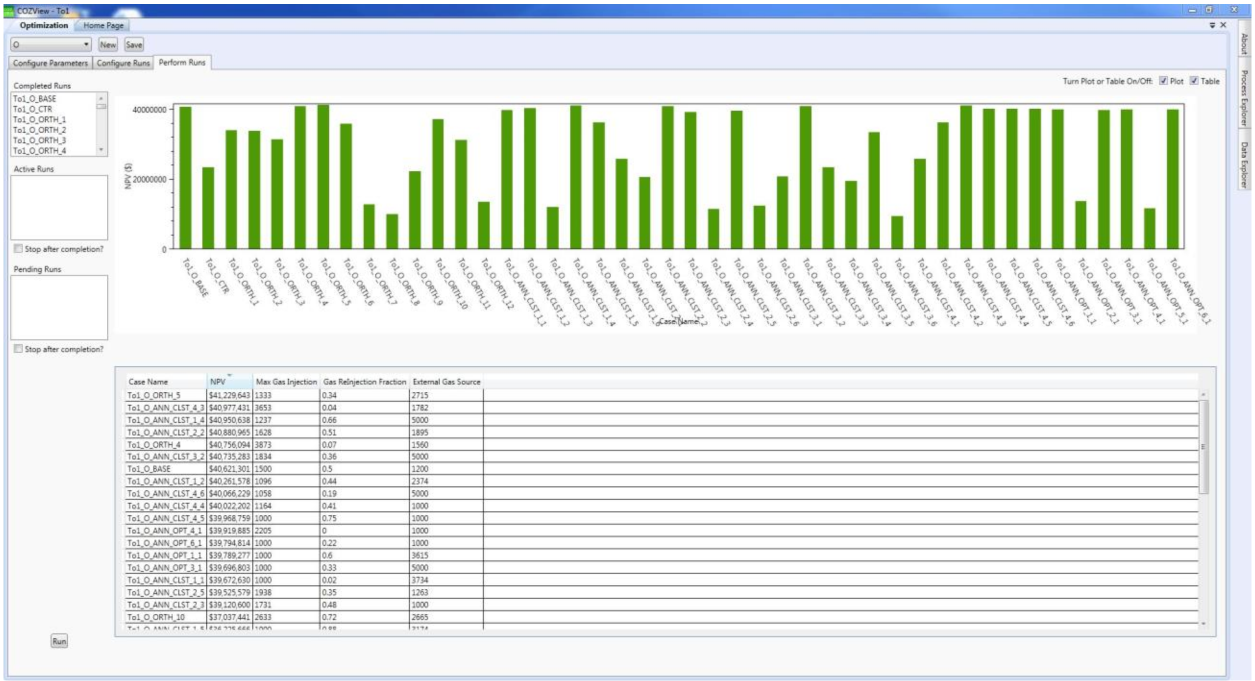


As a simulation run completes, a small window will appear notifying the user that the results of the completed simulation run are being loaded. Once the results are loaded a bar chart will display the calculated NPV for the case. The NPV is also displayed in the table. It should be noted that the optimization process does not necessarily find the maximum NPV case in a sequential process; rather multiple simulation runs designed by the process ensure that a maximum NPV is realized by the end of the process. A left click on any of the bars in the chart will display the calculated NPV value for that case.

Plots and Tables of the simulation results at the Field level <u>only</u> are available in the Simulation Results section once a run is completed.

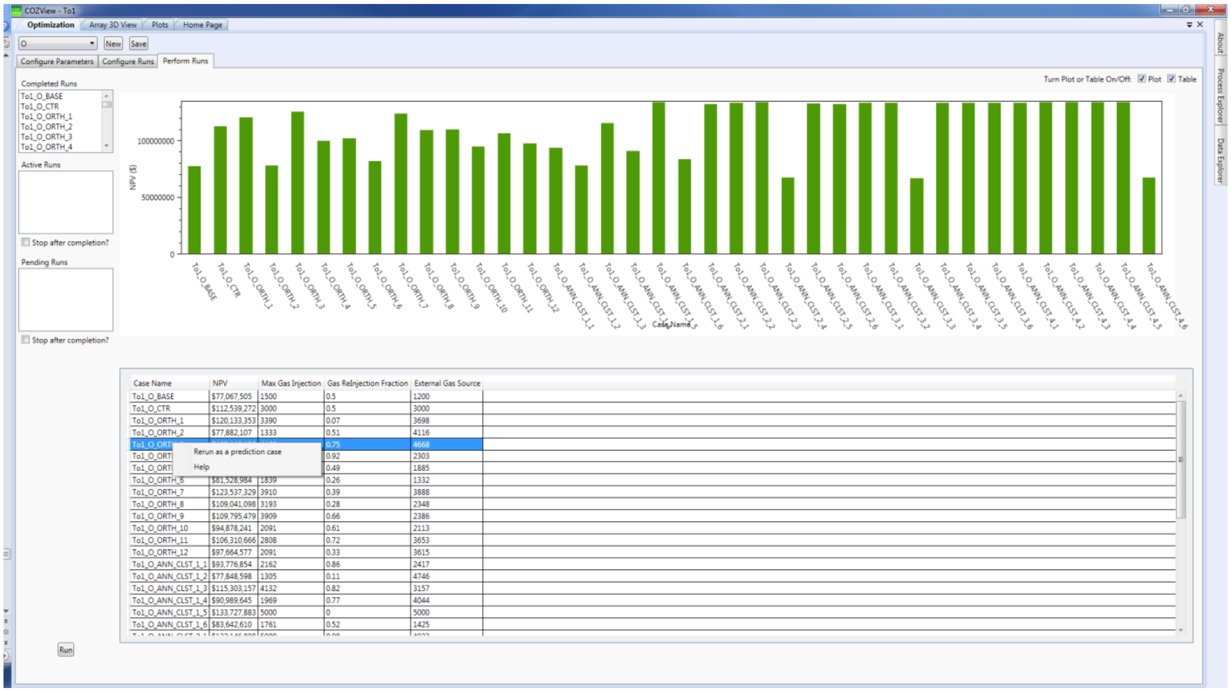
When the Optimization process is completed, the *Perform Runs* window should be similar to the figure below.

The initial order of cases in the table is based on when the case is completed. A left-click on any of the column headers in the table will sort the cases in ascending or descending order of the selected column.



Since the Optimization runs will only have saved field plots and not individual well plots or arrays, the user can select a Case and rerun it as prediction case. The prediction run will provided individual well plots and result arrays.

The user can right click on any case in the optimization table and select *Rerun as Prediction Case*. A new simulation run with the name *Old Case Name_Rerun* will be added to the database. All result plots (field and well) and result arrays will be available for viewing from the *Simulation Results* area.



3.7.4 Case Comparison Plots

The results of different optimization cases can be compared using *Case Comparison Plots* under the *Optimization* tab in the Process Explorer.

Selection of *Case Comparison Plots* provides a plot template and no simulation results

The **Optimization Case Results Data** area on the left contains five selection boxes. The boxes are:

- Base Case
- Optimization Series

  (Note that the user is allowed to run multiple optimization series with the same base case.)
- Child Cases (Ordered by NPV)

  (These are cases run in the optimization process – ORTH, CLST, OPT.)
- Rates/Cumulative
- Data to show

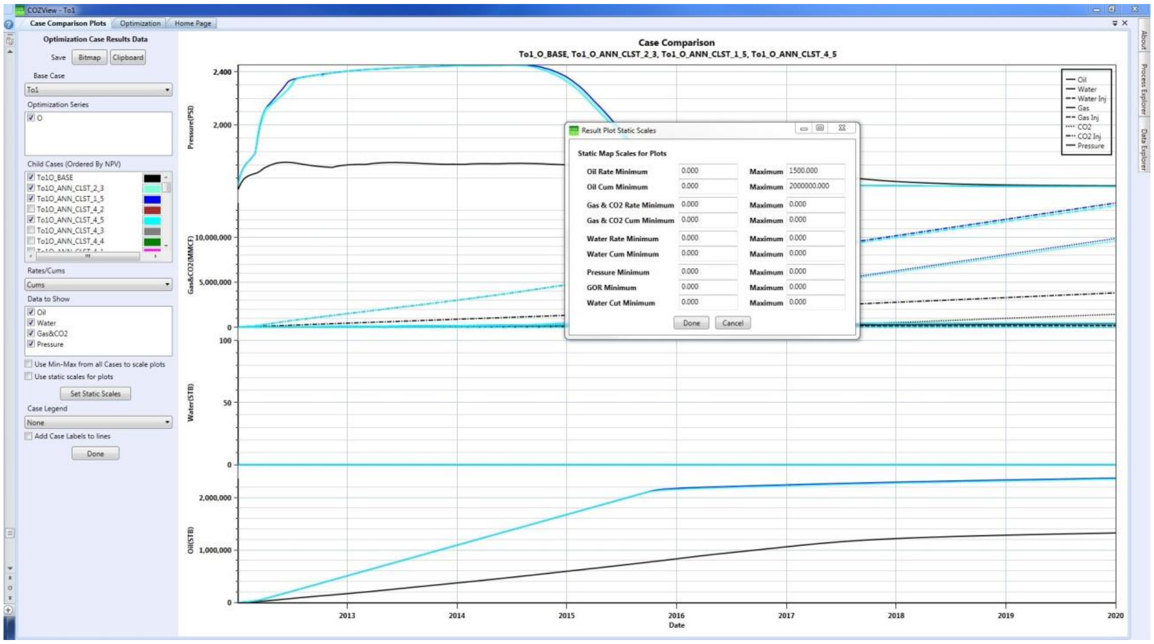
  Oil

  Water

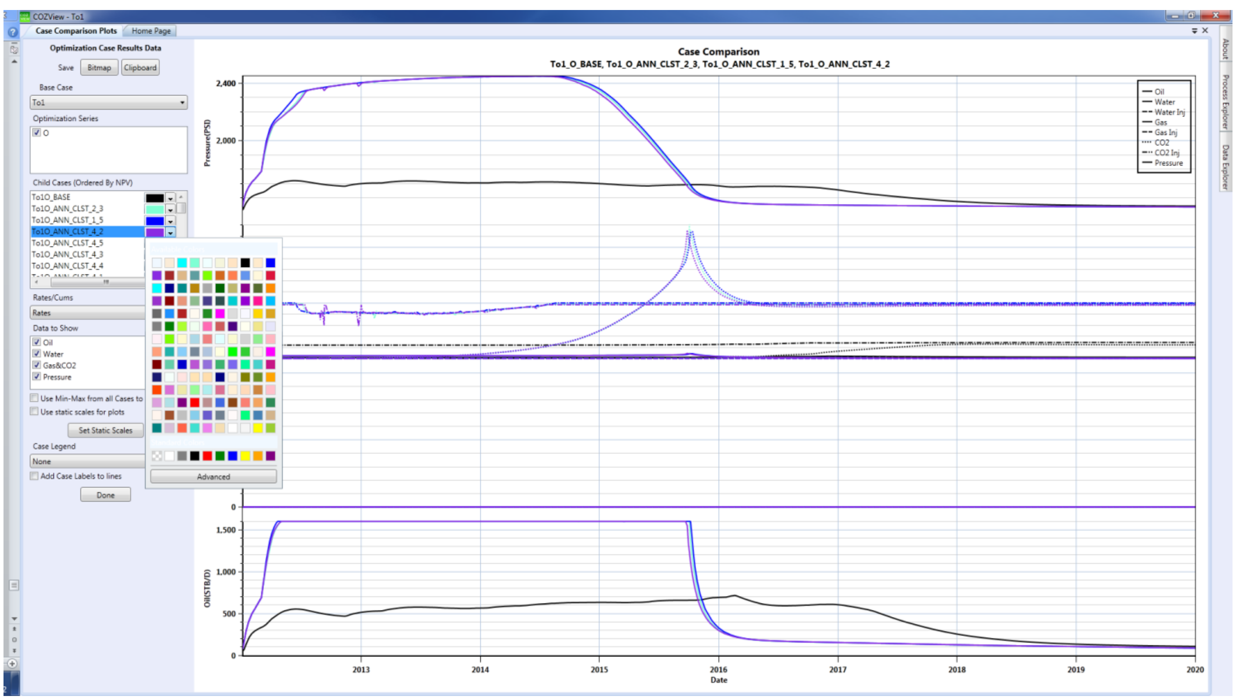
  Gas & CO2

  Pressure (Field Average Reservoir Pressure)

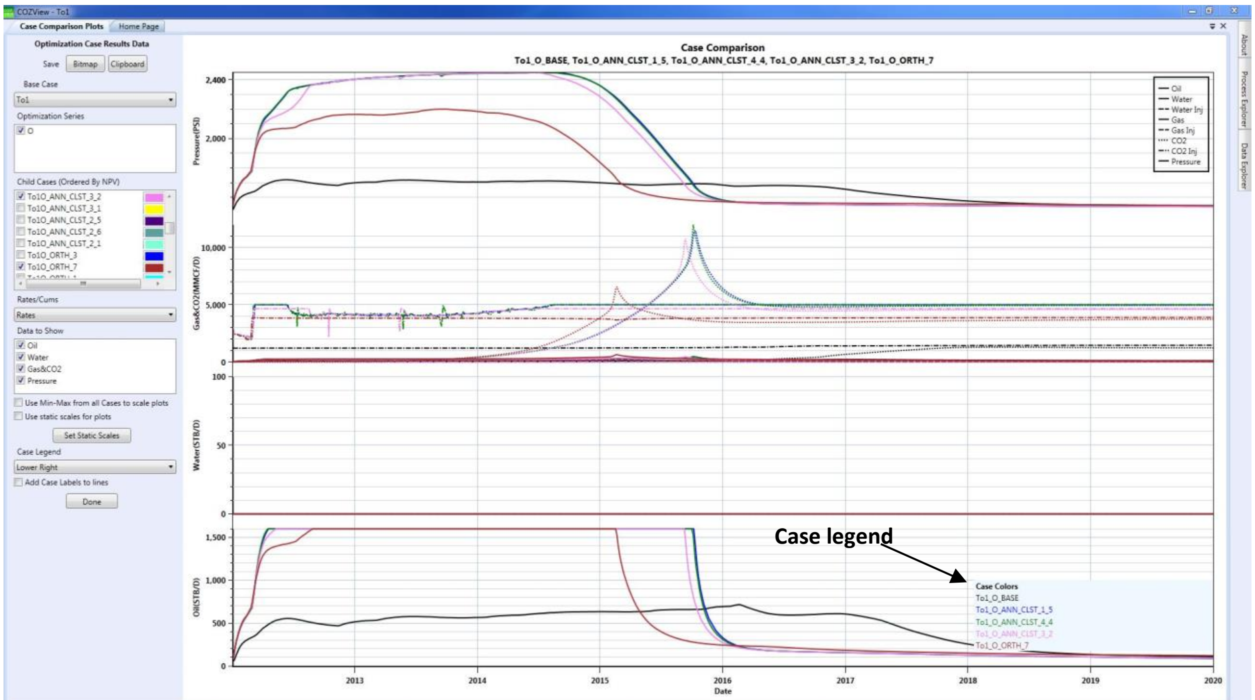
The Plot Setup in the *Case Comparison Plots* is very similar to the Plot set up in the *Simulation Results* under *Process Explorer* (Section 3.6.1). The Plot Setup has two options (i) User can check the box "*Use Min-Max from all Cases to scale plots".* (Selection of this box will automatically control the scales X and Y axis using minimum and maximum values of the property from all cases.) (ii) User is allowed to change the scale (X and Y axis) for each plot manually by using *Set Static Scales* button and selecting *"Use static scales for plots".*



COZView automatically assigns colors for each child case. However the user is allowed to change the color for each case. The color bar for each case is on the right side of the Child Cases Box.



The *Case Legend* can be selected to be at four different places on the plot (i) Lower right, (ii) Upper right, (iii) Lower Left and (IV) Upper left. Selection of the box "*Add Case Labels to lines*" will add case names to each plot curve.



The **Done** button for the *Plots* closes the *Case Comparison Plots* window.

4 Data Explorer

Data Explorer is designed to aid the user with some functionalities not typically required in the use of **COZView**. These are associated with submitting simulation runs and loading simulation results “outside” of the normal **COZView** user interface.

This has the benefit of allowing an advanced user to manually edit the **COZSim** input data file and run the simulation without going through the necessary steps in the Process Explorer.

In addition, past simulation results or simulation results that did not successfully load into **COZView** at the conclusion of the simulation run can be loaded into **COZView** for display from the *Data Explorer* area.

The available options in *Data Explorer* are

- Manage grids
- Run simulation
- Load simulation results

4.1 Manage Grids

This is an undocumented functionality generally used only by the software developers and testers.

4.2 Case Management

It is often useful in conducting a study to modify a single or a few parameters in the data and make a new simulation run. Once the simulation run is complete the user will want to compare the results (plots and 3D views) of the two (or more) case. In the case of plots, the user may wish to show multiple case results on the same plot. For 3D views the user will want to easily view the same array (e.g. oil saturation) for two different simulation cases. The goal is to ease the analysis process as the user attempts to improve or compare simulated performance of alternative cases.

Cases are defined as a set of input data within a COZ project that have different property values for user selected properties.

Examples of properties that may change between cases:

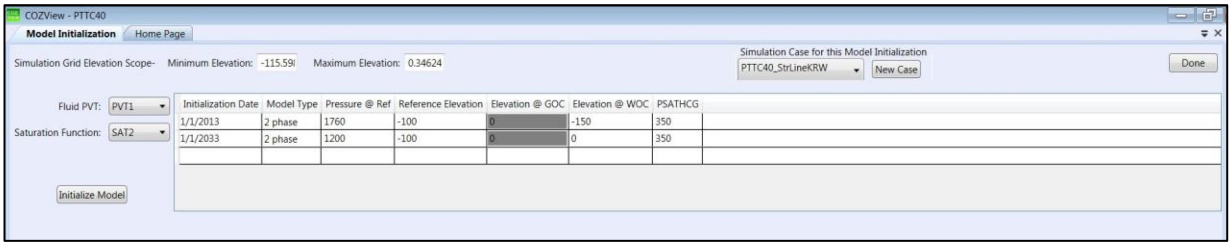
1. relative permeability curves
2. well completions
3. well constraints
4. depletion strategies
5. layer properties *
6. initialization properties*

*The user is cautioned relative to creation of multiple cases with different volumetrics. While this is allowed, comparison of simulation results may not be appropriate.

WARNING: The user should not change the structure, well locations, or grid dimensions between cases. The user is cautioned to keep a record of parameter changes between cases. While COZView allows many parameters to be changed between cases, only a few can be identified or retrieved by the case name in COZView.

New Case – Initialization Changes

Case management may start at the **Model Initialization**. A selection box has been added to create a New Case or utilize the existing case. A New Case name is suggested, but the user can change this name as they wish. A comments field is also provided to aid the user in distinguishing between cases. This should be filled in by the user. The user **cannot** return to a previous case.



This allows the user to change formation properties, PVT table, Saturation function table and/or initialization parameters for the new case. All other data from the prior case will be retained in the new case subject to changes in the ***Prediction Period Section***.

When the user selects the **Initialize Model** button the **Model Volumetrics** screen will appear along with the Simulation status window. Once the simulator has completed the initialization, the volumetric values by phase will appear in the table. The table now has a Case Name associated with each volumetric calculation; otherwise there is no change from the previous version.

If the user has only changed pre-Model Initialization data to this point and does not wish to change any well or field constraints or limits, they can proceed directly to **Run Simulation**. The use should select the new Case Name created in ***Model Initialization Section*** from the dropdown menu and set the End Date to the appropriate value. The simulation run will be launched accordingly. Note that all well and field constraints and limits will be the same as the prior case.

If the user wishes to change well or field constraints or limits in addition to the Initialization parameters, they may do so in the appropriate screens. Be sure to **Save** when changes are made. When the user is ready to submit the new simulation run (**Run Simulation**), they should select the new Case Name created in ***Model Initialization Section*** from the dropdown menu and set the End Date to the appropriate value. Select GO to launch the simulation run.

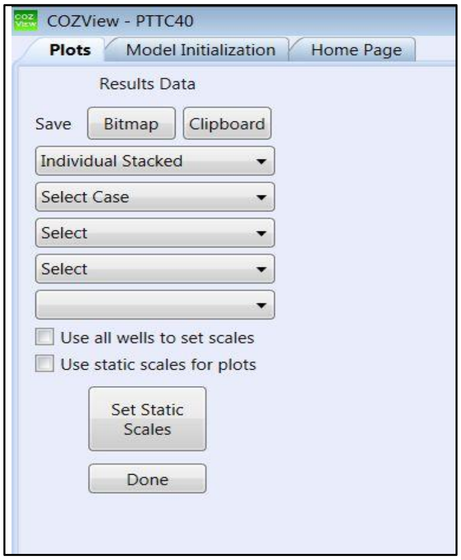
New Case – Prediction Period Changes Only

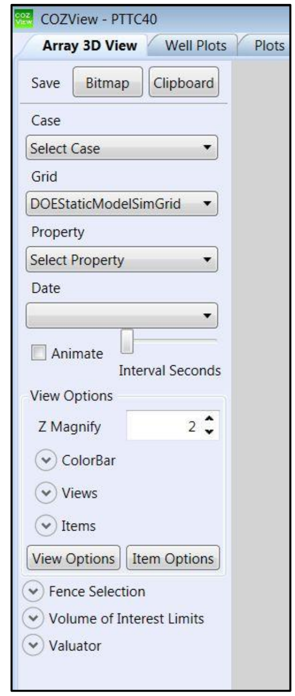
If the user wishes to create a new Case that is based on changes to well and field constraints and limits, but does not require changes to Model Initialization data, they can change the data in the appropriate screens. Be sure to Save when changes are made.

When the user is ready to submit the new simulation run, a New Case can be created at the **Run Simulation** screen. Be sure the new case name is selected after creating the New Case. Select GO to launch the simulation run. All well and field data changes will be associated with the new case name.

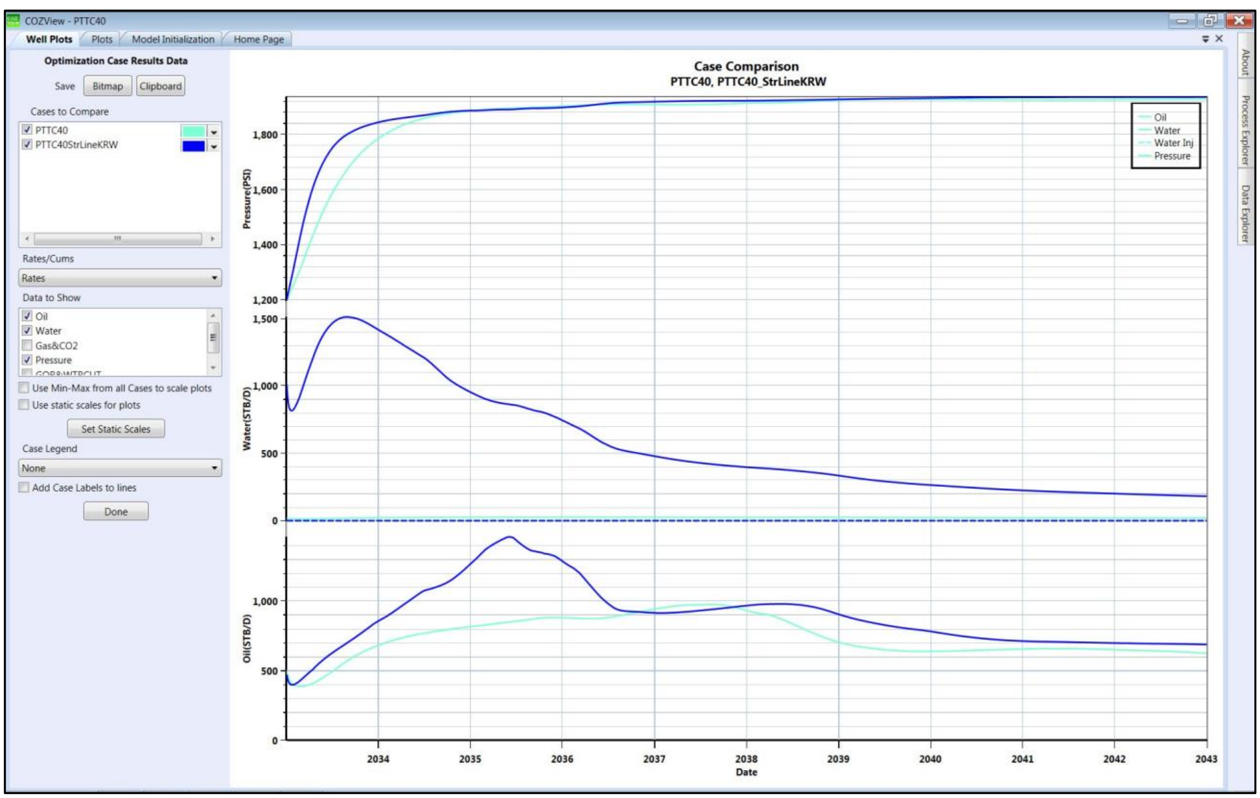
Simulation Results

All plots, tables and 3D Views contain a selection box for the Case. All prior cases run in the project will be available for viewing in the appropriate display.



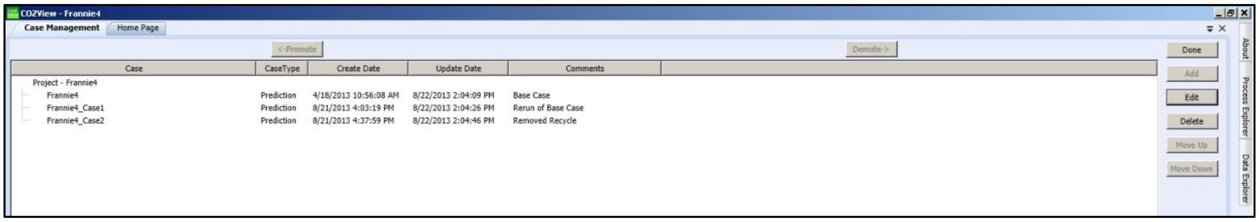


Case Comparison Plots in the **Simulation Results** menu allows the user to compare selected field level results on any of the cases run in a project on the same display plot.



Case Summary

The user can view a table of all cases run in the project under **Case Management** in the ***Data Explorer*** section. The comments field can be altered by selecting a case and the **Edit** button. Cases can also be deleted by selecting the case and the **Delete** button.



File Naming Convention

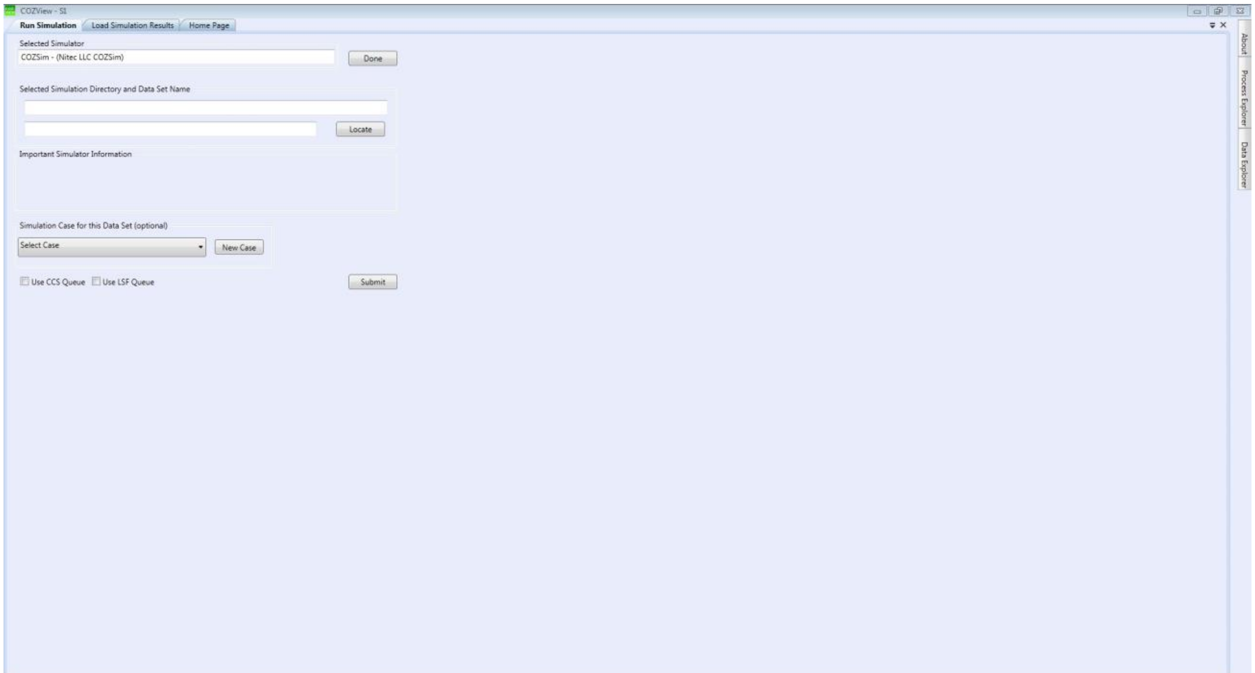
The file naming convention has been changed to include the case name in addition to the project name. A typical file name is now *Projectname_Casename*.COZOUT or *Projectname_Casename*.COZdat.

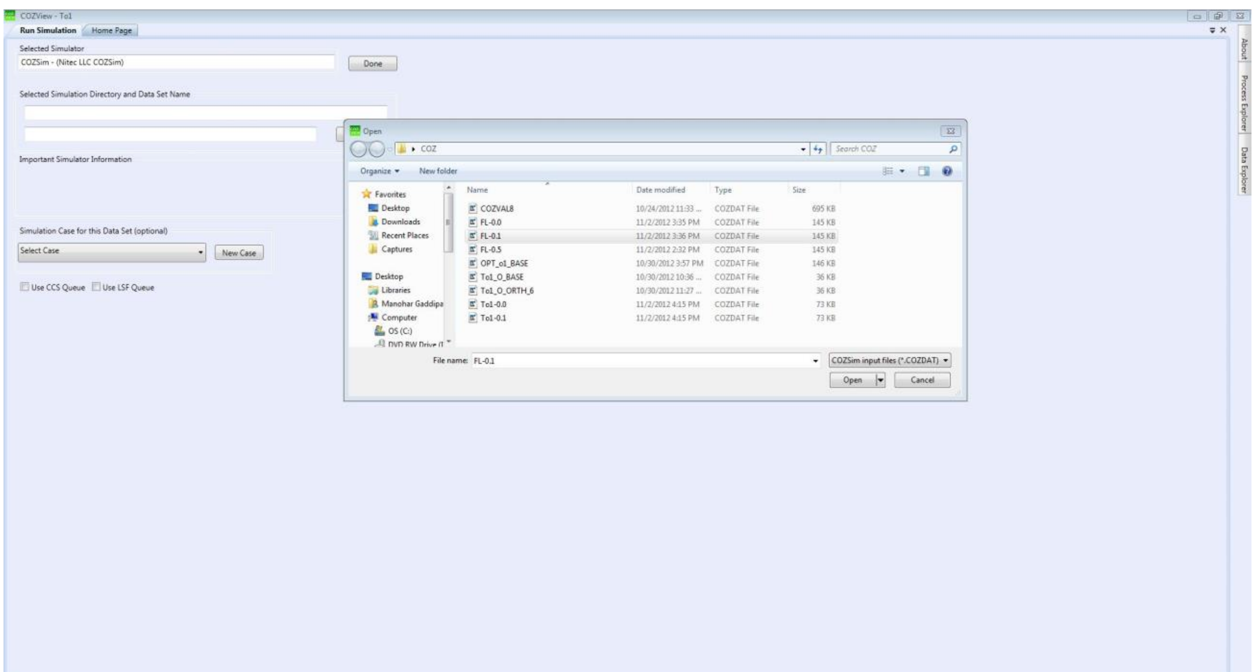
Be sure to keep in mind the rules concerning screen refreshing. A new case will not appear in a Case box if the particular screen has not been refreshed since the creation of the new case.

4.3 Manual Run Simulation

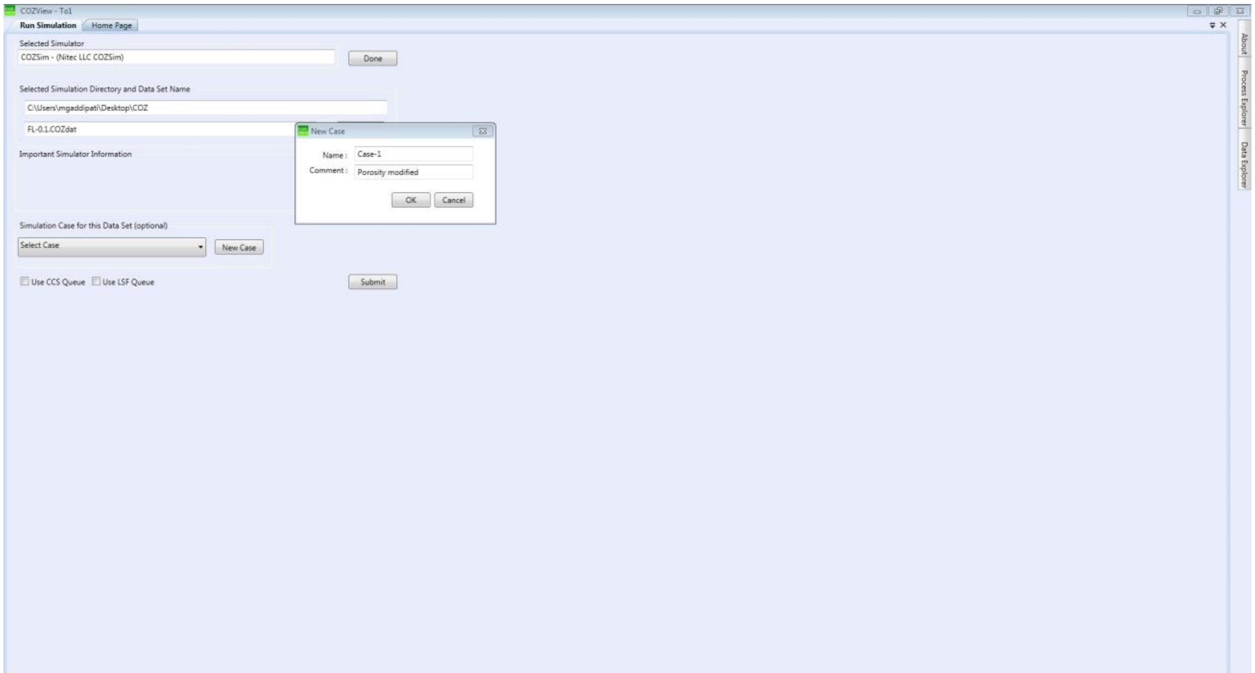
If the user is familiar with the keyword structure of the simulation run data file (ProjectName.COZDAT), this file can be edited directly by the user with a text editing program. Once the desired changes are made the data file can be loaded into **COZView** for submission to COZSim.

Selection of Run Simulation in the Data Explorer area displays the screen below. The selected simulator is always **COZSim**. The **COZSim** input data file (ProjectName.COZDAT) has to be located using the Locate button.





The simulation case name for the simulation run to be made must be selected from existing case names (dropdown menu) or a new name must be provided. If an existing case name is used, any prior simulation results for that case will be overwritten by the new simulation run.



Select *Submit* to run the simulation case. A Simulator Runner window will appear and the CPU Time and CPU% utilization will be continuously updated. Simulation results (plots and arrays) should be loaded automatically at the end of this simulation run.

4.4 Load Simulation Results

Past **COZSim** simulation run results or **COZSim** simulation results that did not successfully load into **COZView** at the conclusion of the simulation run can be loaded into **COZView** for display from the Data Explorer area.

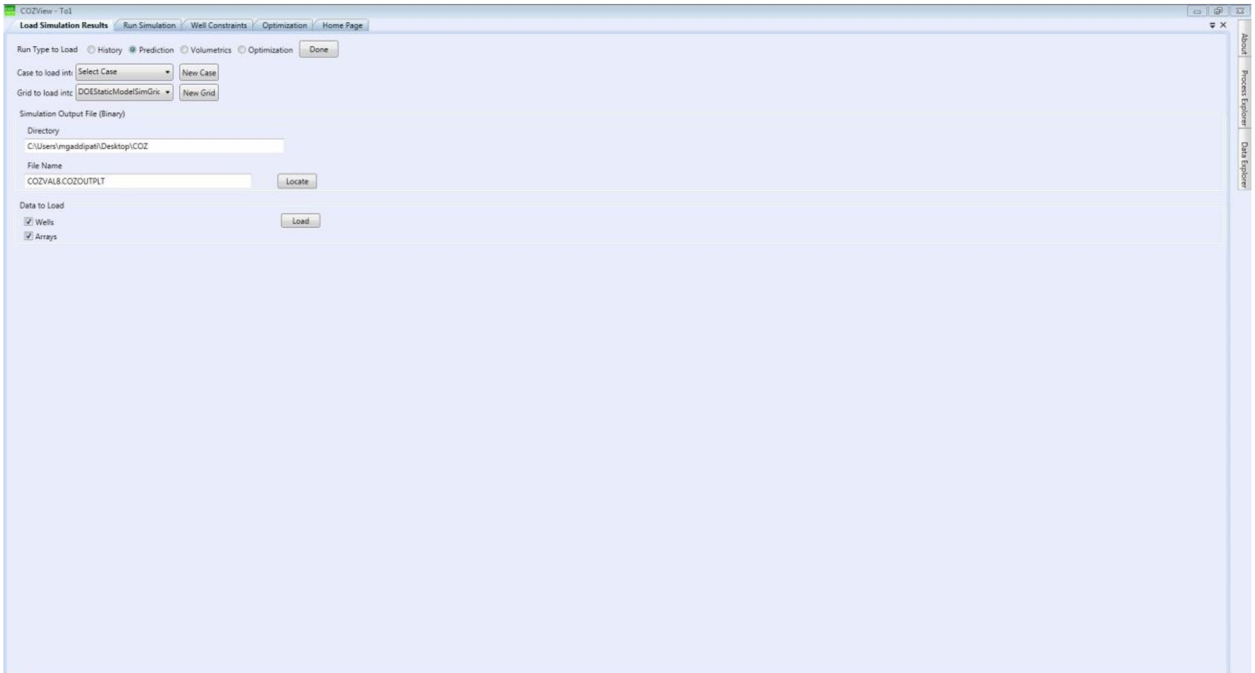
The user can load four Run types (i) History, (ii) Prediction, (iii) Volumetrics and (iv) Optimization. The results can be loaded as a New Case or can be loaded into a previously defined case. The Grid information is required to load results Arrays.

The **COZSim** Output file has to be located using the **Locate** button. There are two different binary output files that **COZSim** writes. These should be located in the **COZView** directory set up at the time of installation for all COZ project files.

ProjectName.COZOUTMAP : 3D arrays results

ProjectName.COZOUTPLT : Field and well production and injection results

Select *Locate* and browse to find the *ProjectName*.COZOUTPLT file. Then select the data to load (Wells, Arrays).



Select *Load* to load results into **COZView** for display from the *Simulation Results* area in Process Explorer.

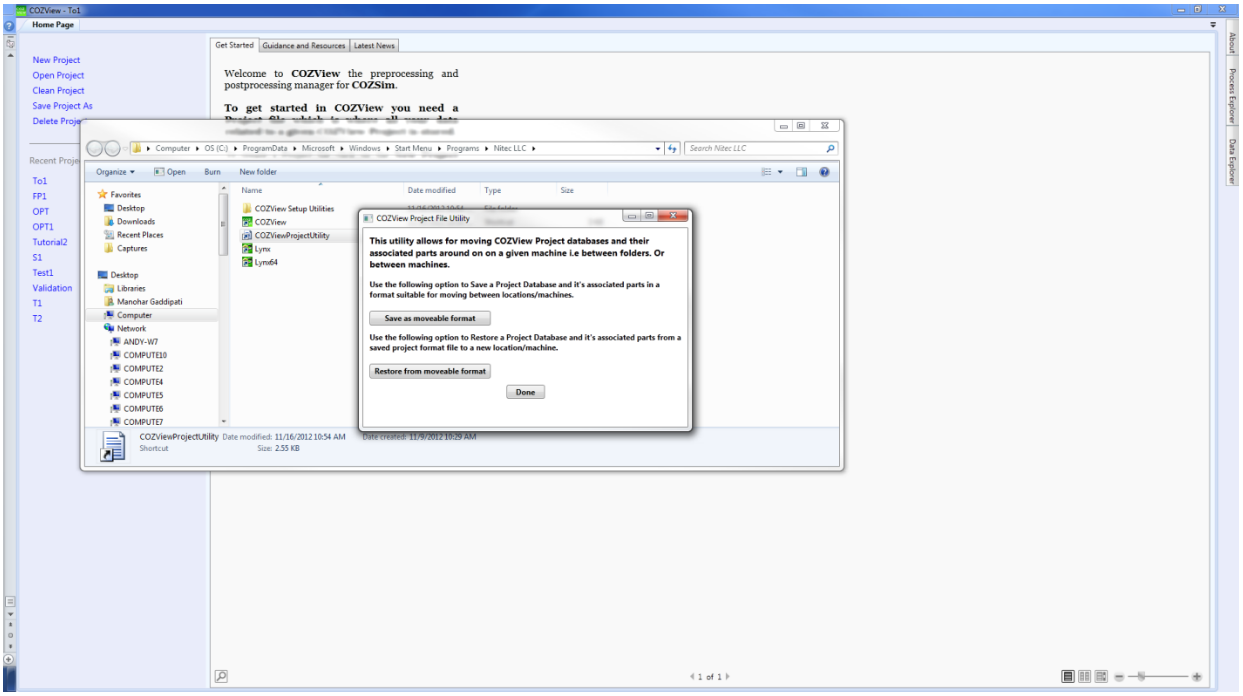
5 Sharing a Project Database

Users are also allowed to share project databases using *COZView Project Utility tool*. The project utility tool is located in the following address C:\ProgramFiles \NITEC LLC\COZView. The user can also search for *COZView Project Utility* tool in the Windows Start Menu.

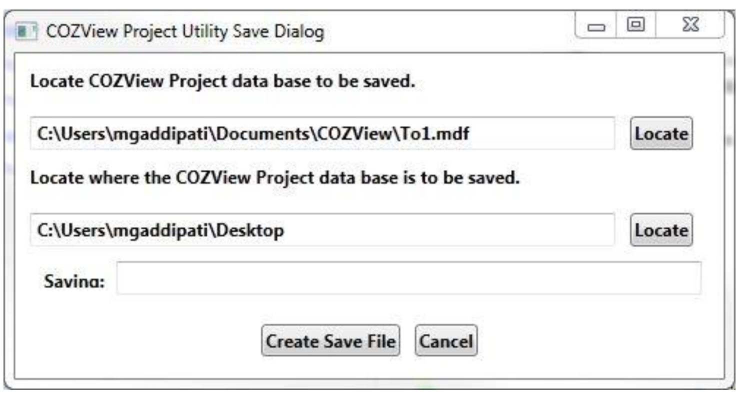
The project utility tool allows the user to move **COZView** project databases and their associated parts between different computers. The project database must be saved as a *moveable* format. The saved file (ProjectName.cvsf) can be copied or saved into a different folder or a different computer. The saved file will have all the information required to restore (load) the project database. The project database can be restored using *Restore from moveable format* button.

5.1 Saving a Project database

Click on *COZView Project Utility*, a new window pops up as shown below. The user should first save the project database as moveable format. This can be done by selecting *Save as moveable format*.



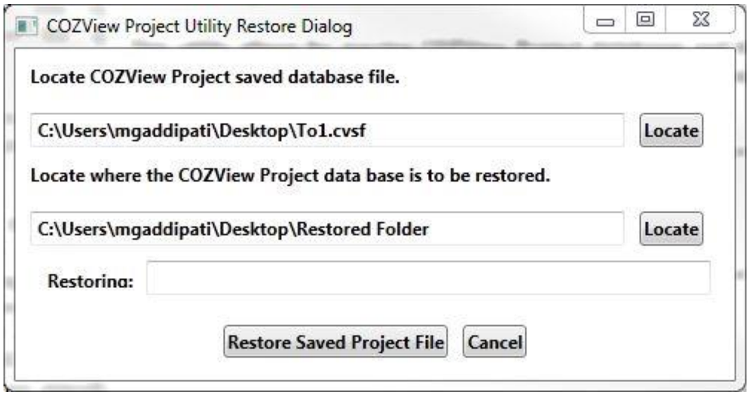
The user has to locate the Project database (.mdf file) to be saved.



The user must then select the location for the saved file. Select **Create Save** file. A completion window pops up when the process is completed.

5.2 Restoring the project database

The Project database can be restored using **COZView** project Utility tool. Click on *Restore from moveable format.* User need to locate the saved file obtained in Section 5.1 and the directory where the project database is to be restored.



Select *Restore Saved Project File.* A window pops up when the process is completed.

6 Appendices

6.1 Appendix A – Data Input Requirements

COZView Data Input Requirements List

		Units	User Value	Defaults	Comments
	PROJECT NAME	Alphanumeric(no spaces)			
Field Structural Model					
	Layer Name	Alphanumeric			
	Structural Surface	feet or meters			
	Area of Interest Coordinates - X,Y	feet or meters			
	No. Layers			1	
	Gross Thickness for each layer	feet or meters			
	Fault location(s)				
	Well Locations - X,Y	feet or meters			
Formation/Layer Properties					
	Layers	integer		1	
	Net Thickness equals Gross thickness	feet or meters			
	Net to Gross Thickness Ratio	fraction		1	
	Average Porosity	fraction or percent		0.2	
	Average Horizontal Permeability Y-direction	md or D		50	
	Average Horizontal Permeability X-direction	md or D		50	
	Average Verical Permeability, md or D	md or D		5	
	Rock compressibility	E-06/psi		4	
PVT					
	PVT Table Name	Alphanumeric			
	Gas Specific Gravity	fraction or percent		0.855	
	Oil API	degrees		40.7	
	Water Salinity	ppm		45000	
	Reservoir Temperature	degrees F		220	
	Table Minimum Pressure	psia		14.7	
	Table Maximum Pressure	psia		4000	