

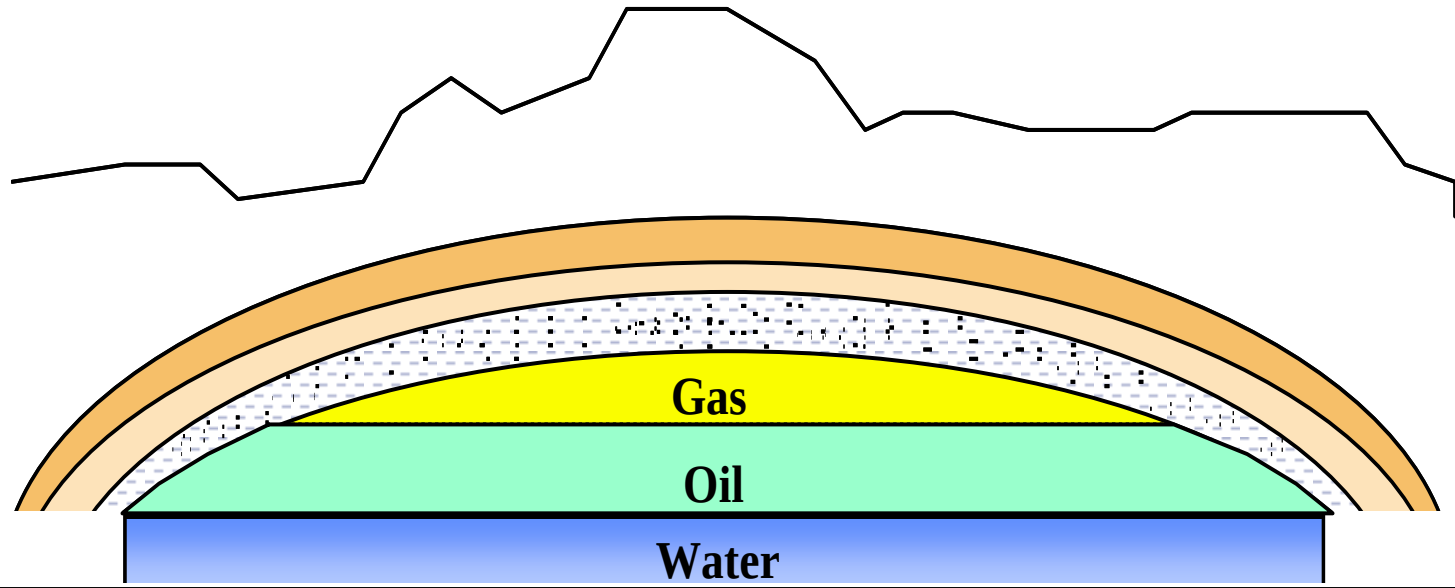
01 Jan 2000 (1 of 78)

CMG (IMEX) COURSE

Instructor:

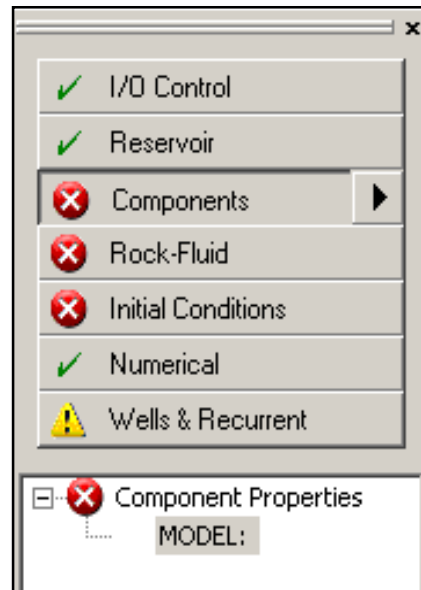
Mohammad Amin Gholamzadeh

Creating PVT Data



Creating PVT Data

1. Click the **Components** tab in the tree view. Double click the **MODEL** keyword.



2. Select **Launch dialog to create a quick BLACKOIL model using correlations** then press the **OK** button.



Creating PVT Data

3. Enter **70** (deg C implied) in the **Reservoir Temperature** box.

♦ Generate Pressure data up to **34474 kPa**. For **Bubble Point Pressure**, select the “**Value Provided**” option and enter a value of **6502 kPa**.

♦ For the **Oil Density** option, select “**Stock tank oil gravity (API)**” as the type of gravity value you want to use and enter a value of **35** in data entry window.

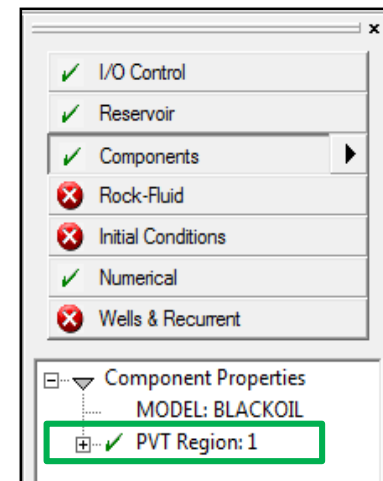
♦ Change the **Gas Density box** to display **Gas Gravity (Air=1)** and type **0.65** in the data entry window.

4. In the **Reference Pressure for Water properties** box, enter a value **27580 kPa** and **leave the rest of the options** at their default values and Click **OK**.



Creating PVT Data

5. Double click on “**PVT Region: 1**” in the tree view and select the **PVT Table** tab to view the BLACKOIL PVT data. For this example, the data shown in this table was generated using the information entered in the “**Quick black oil model**” window. However, it is also possible to directly enter or edit values in the PVT Table. These values can also be updated by using your mouse to select points on the plots associated with the PVT Region, and dragging the points to the desired location. Please note that the “**IMEX PVT Regions**” window has to be open while using your mouse to change the points on the plot.



Creating PVT Data

6. Close the PVT Table window.

7. The Component section should have a green check mark now.

Imex PVT Regions

PVT Region: 1

PVT Table: General Undersaturated Data

PVT Table Type: Oil and gas (PVT) Table Uses: Gas expansion factor (EG)

☒ Include Oil Compressibility in PVT Table
☐ Include Gas-oil Interfacial Tension in PVT Table

Tools

Differential liberation table parameters:
Bubble point pressure:
Oil formation vol. factor:
Solution gas-oil ratio:

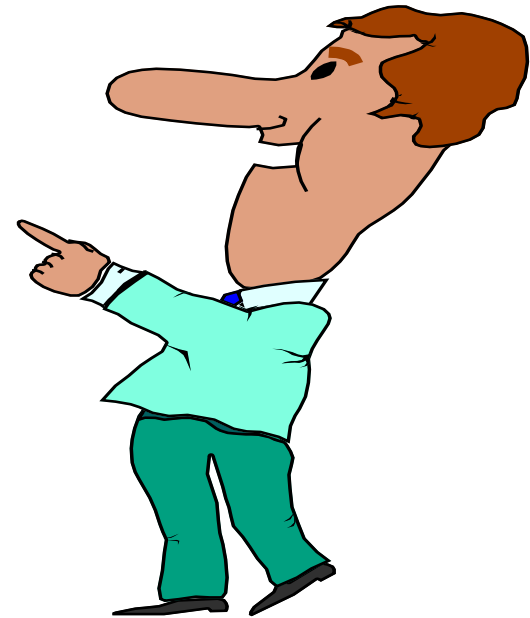
#	p kPa	Rs m3/m3	Bo	Eg m3/m3	viso cp	visg cp	co 1/kPa
1	101.325	0.678902	1.0455	0.84551	2.54115	0.0124995	4.35113
2	528.037	2.08762	1.04838	4.43609	2.40802	0.0125406	4.35113
3	954.749	3.69538	1.0517	8.07523	2.27451	0.0125947	4.35113
4	1381.46	5.43539	1.0532	11.7632	2.14808	0.0126575	4.35113
5	1808.17	7.27705	1.05918	15.5002	2.03093	0.0127276	4.35113
6	2234.88	9.20226	1.06324	19.2862	1.92339	0.0128042	4.35113
7	2661.6	11.1989	1.0675	23.1213	1.82509	0.0128867	4.35113
8	3088.31	13.2582	1.07191	27.0052	1.73533	0.0129749	4.35113
9	3515.02	15.3735	1.07649	30.9376	1.65334	0.0130686	4.35113
10	3941.73	17.5397	1.08121	34.9179	1.57836	0.0131676	4.35113

OK Cancel Apply Help

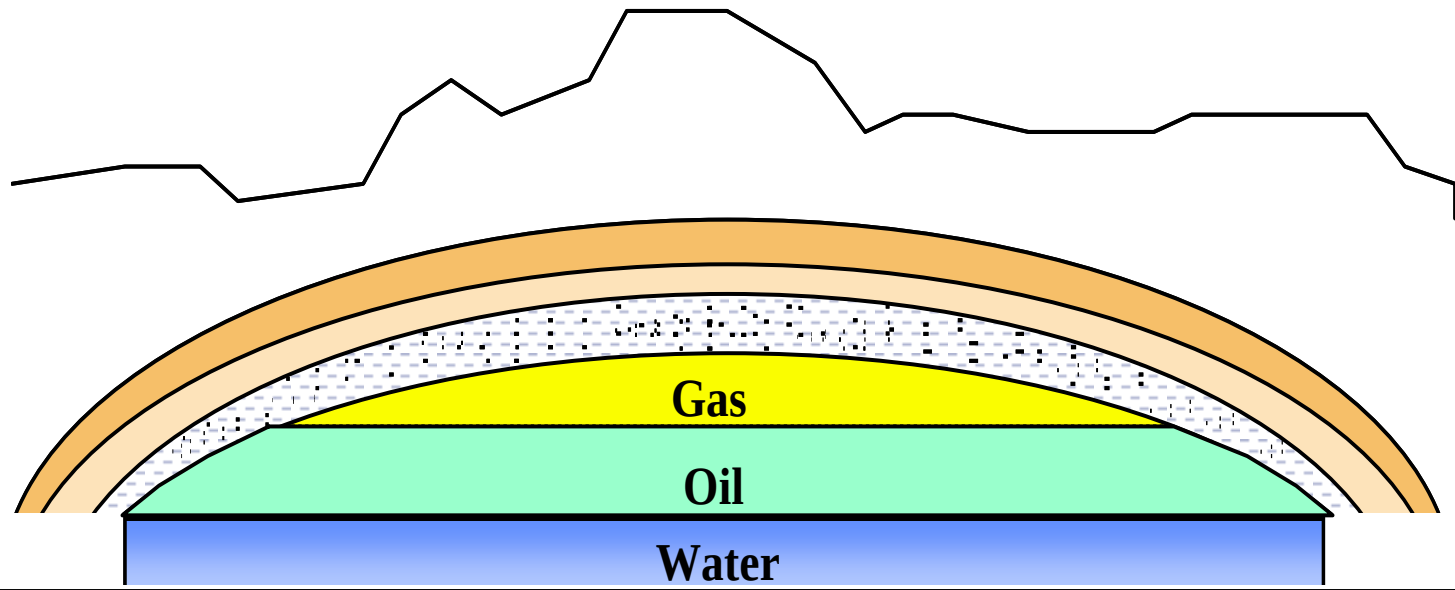


Creating PVT Data

8. At this point it is advisable to save the data again by selecting **File** from the top menu and **Save**.

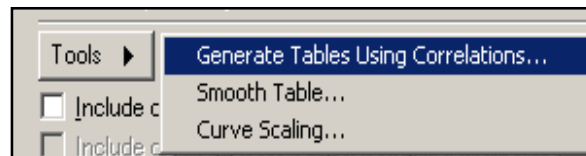


Creating Relative Permeability Data

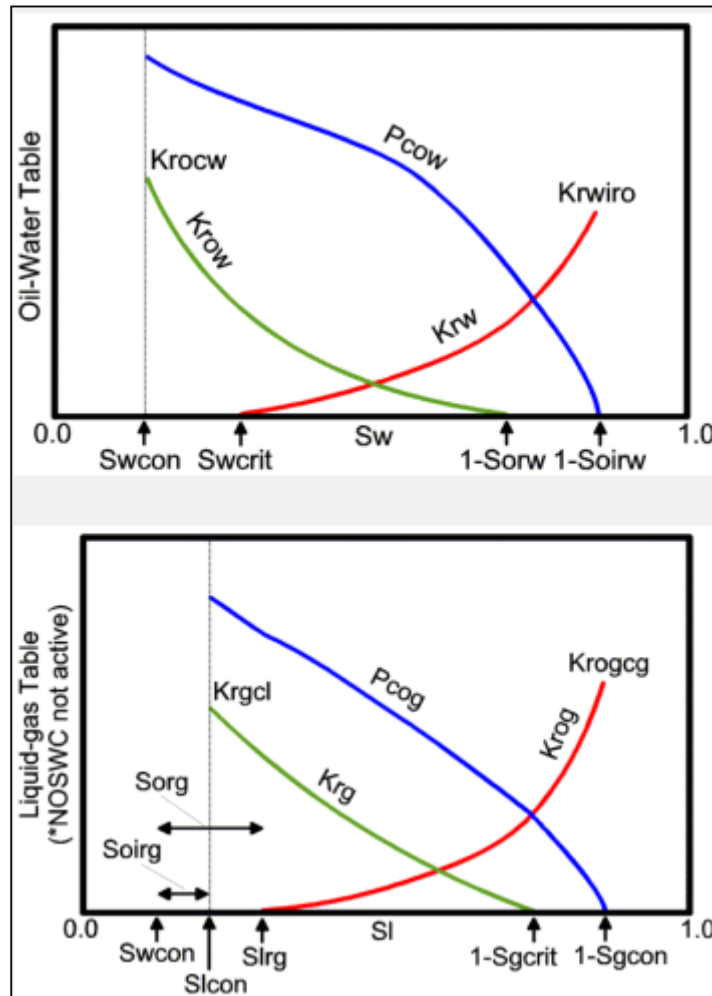


Creating Relative Permeability Data

1. Click the **Rock-Fluid tab** in the tree view.
2. Double click on **Rock Fluid Types** in the tree view. A window will open. Click on the button and select **New Rock Type**.
3. Press the **Tools** button (on the “Relative Permeability Tables” tab) and select **Generate Tables using Correlations**.



Creating Relative Permeability Data



Creating Relative Permeability Data

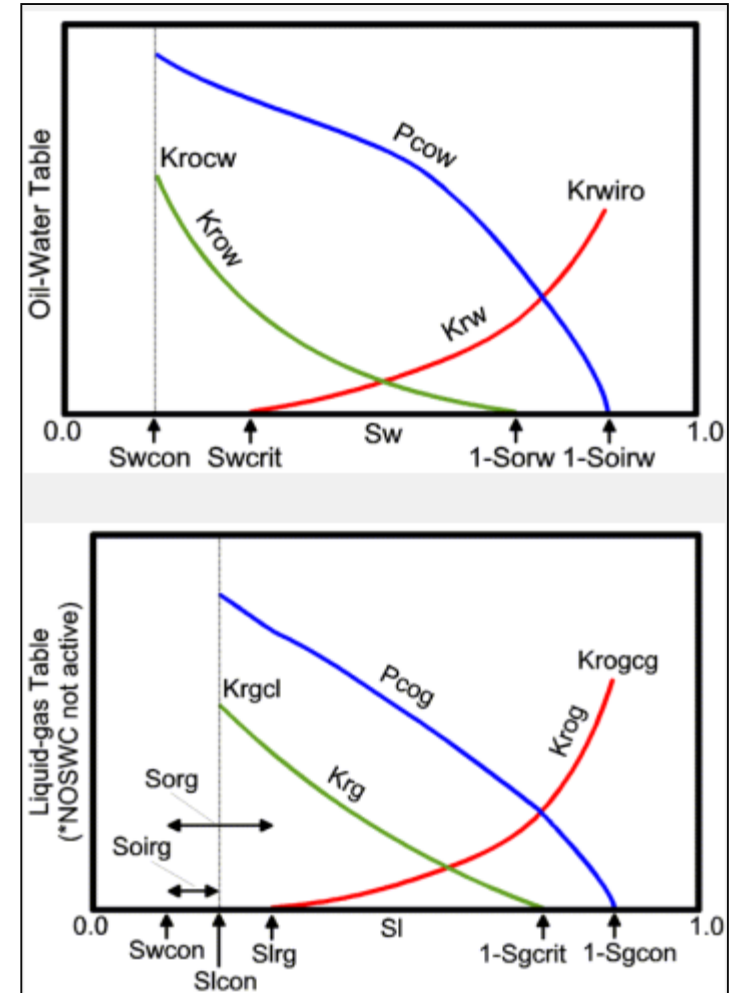
#	Description	مفهوم
1	SWCON - Endpoint Saturation: Connate Water	کمترین میزان اشباع آب که می تواند در حفره ها باقی بماند.
2	SWCRIT - Endpoint Saturation: Critical Water	کمترین میزان اشباع آب در جریان دو فاز آب- نفت که در آن فاز آب شروع به حرکت کند.
3	SOIRW - Endpoint Saturation: Irreducible Oil for Water-Oil Table	اشباع کاهش نیافتنی نفت که می تواند در سیستم آب - نفت درون حفره ها باقی بماند.
4	SORW - Endpoint Saturation: Residual Oil for Water-Oil Table	اشباع باقی مانده نفت در جریان دو فاز آب - نفت
5	SOIRG - Endpoint Saturation: Irreducible Oil for Gas-Liquid Table	اشباع کاهش نیافتنی نفت که می تواند در سیستم گاز- مایع درون حفره ها باقی بماند.
6	SORG - Endpoint Saturation: Residual Oil for Gas-Liquid Table	اشباع باقی مانده نفت در جریان دو فاز گاز- مایع
7	SGCON - Endpoint Saturation: Connate Gas	کمترین میزان اشباع گاز که می تواند در حفره ها باقی بماند.
8	SGCRIT - Endpoint Saturation: Critical Gas	کمترین میزان اشباع گاز در جریان دو فاز گاز - مایع که در آن فاز گاز شروع به حرکت کند.
9	KROCW - Kro at Connate Water	تراوایی نسبی برای فاز نفت در کمترین میزان اشباع آب در یک سیستم دو فاز آب - نفت
10	KRWIRO - Krw at Irreducible Oil	تراوایی نسبی برای فاز آب در کمترین میزان اشباع نفت در یک سیستم دو فاز آب - نفت
11	KRGCL - Krg at Connate Liquid	تراوایی نسبی برای فاز گاز در کمترین میزان اشباع مایع در جریان دو فاز گاز - مایع
12	KROGCG - Krog at Connate Gas	تراوایی نسبی برای فاز نفت در کمترین میزان اشباع گاز در دو فاز گاز - مایع.



Creating Relative Permeability Data

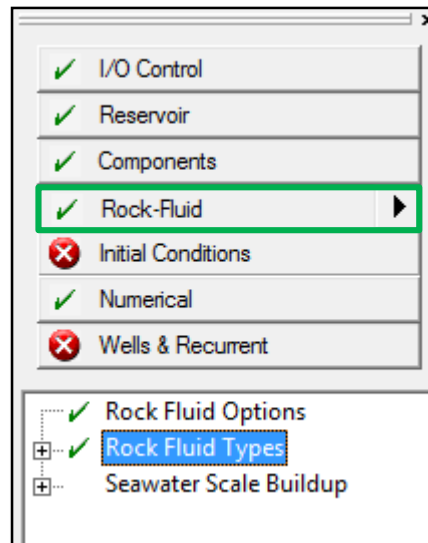
Enter the following parameters for the analytical
relative permeability curves generation.

#	Description	Value
1	SWCON - Endpoint Saturation: Connate Water	0.2
2	SWCRIT - Endpoint Saturation: Critical Water	0.2
3	SOIRW - Endpoint Saturation: Irreducible Oil for Water-Oil Table	0.4
4	SORW - Endpoint Saturation: Residual Oil for Water-Oil Table	0.4
5	SOIRG - Endpoint Saturation: Irreducible Oil for Gas-Liquid Table	0.2
6	SORG - Endpoint Saturation: Residual Oil for Gas-Liquid Table	0.2
7	SGCON - Endpoint Saturation: Connate Gas	0.05
8	SGCRIT - Endpoint Saturation: Critical Gas	0.05
9	KROCW - Kro at Connate Water	0.8
10	KRWIRO - Krw at Irreducible Oil	0.3
11	KRGCL - Krg at Connate Liquid	0.3
12	KROGCG - Krog at Connate Gas	0.8
13	All Exponents	2.0

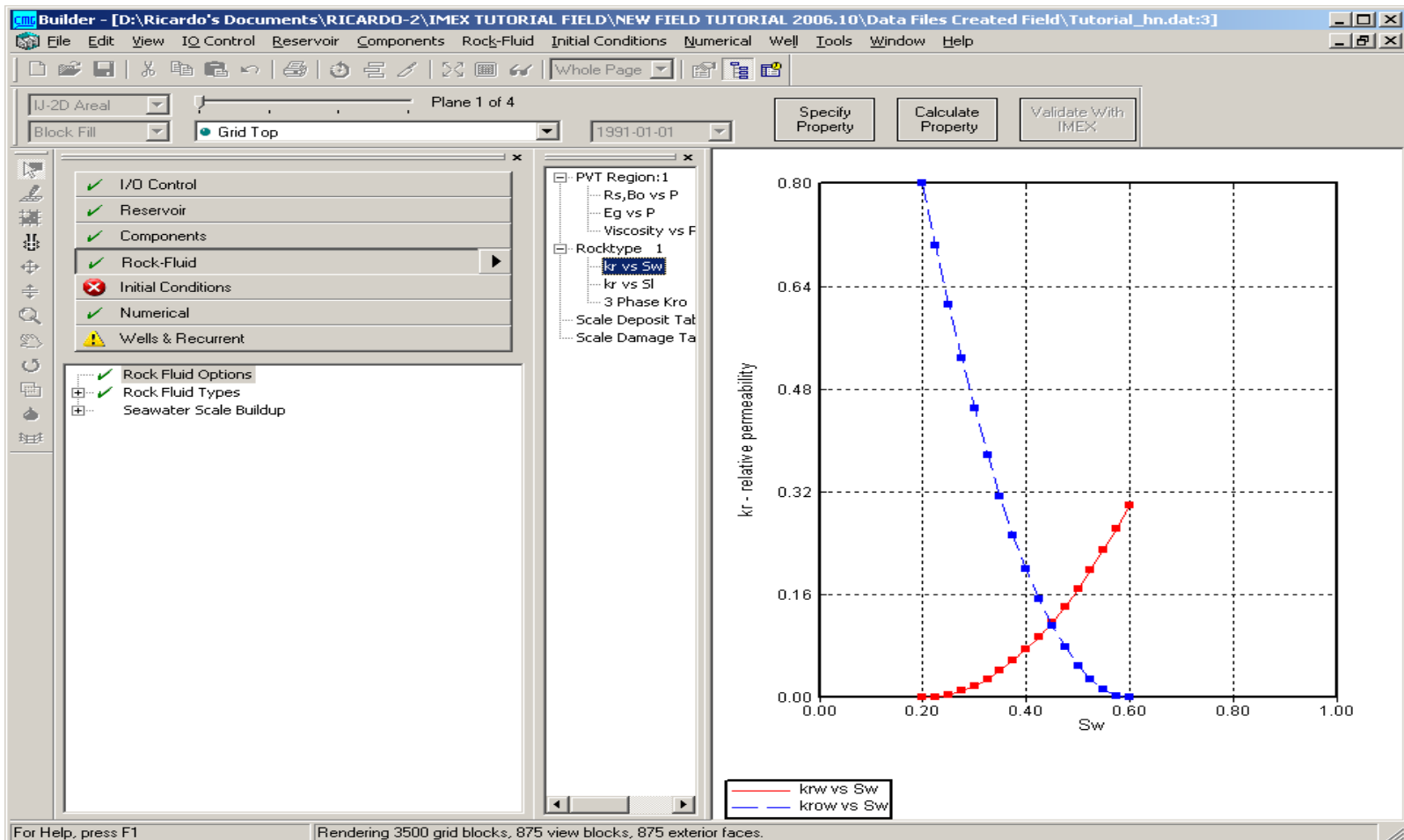


Creating Relative Permeability Data

4. Press **Apply** and then **OK**. Press **OK** again to get out of the **Rock Types** window. A graph containing the relative permeability curves will appear.
5. The **Rock Fluid** section should have a **green** check mark. Save the file at this time.

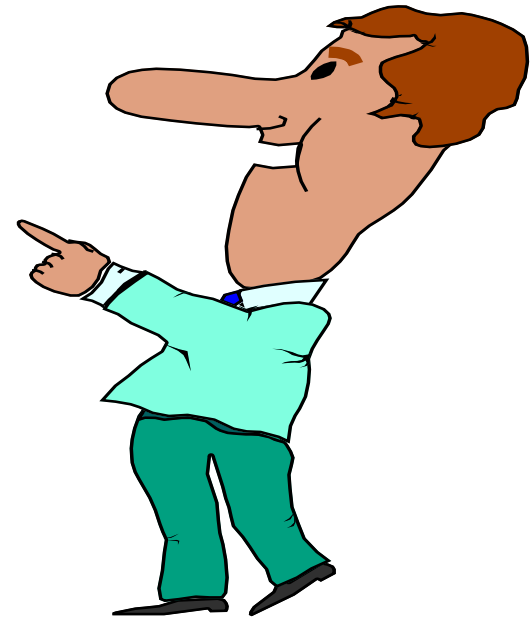


Creating Relative Permeability Data

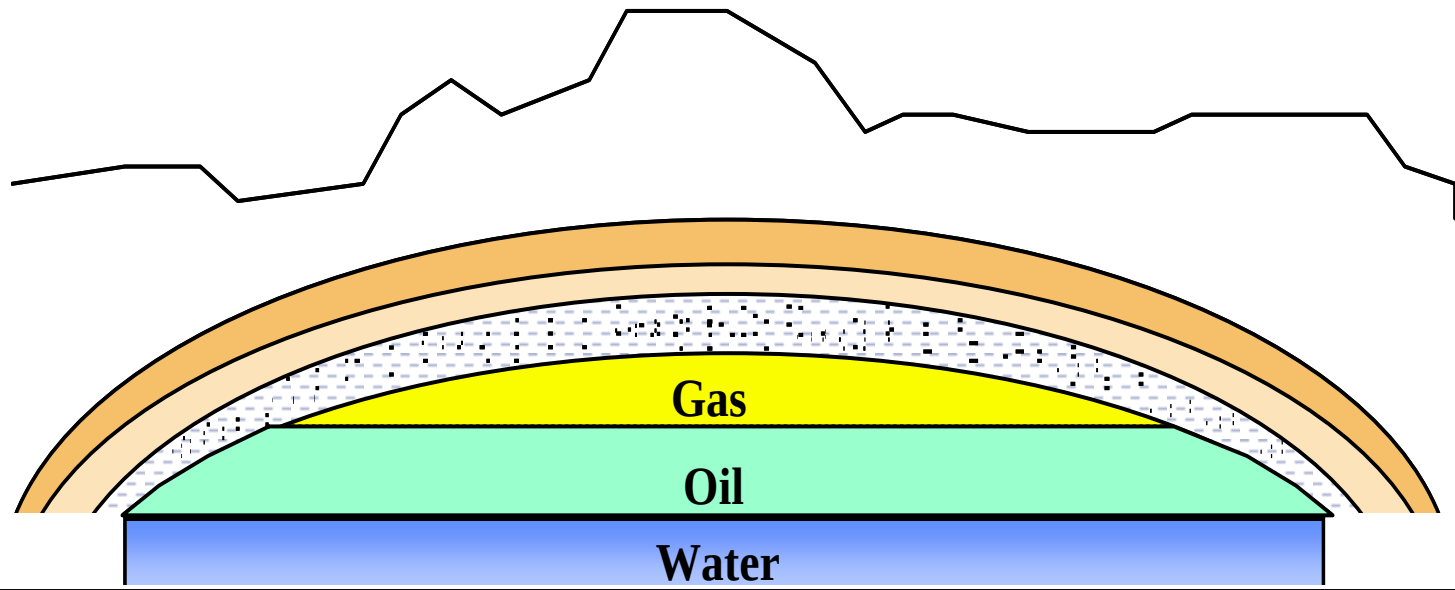


Creating Relative Permeability Data

8. At this point it is advisable to save the data again by selecting **File** from the top menu and **Save**.

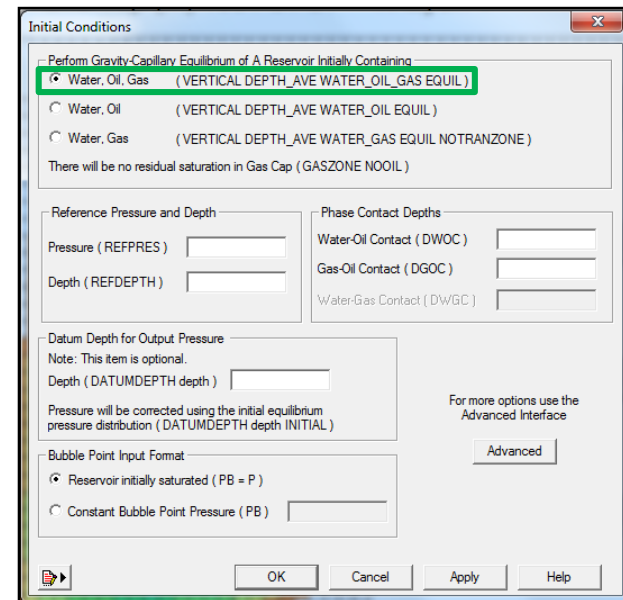
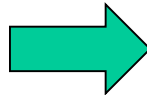
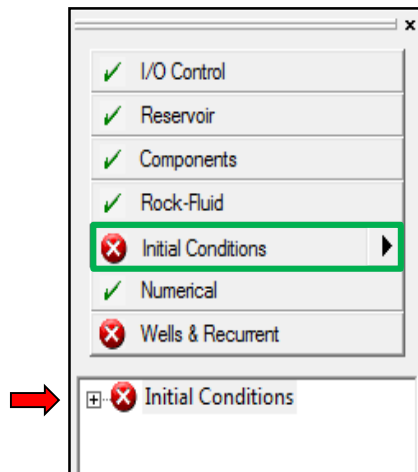


Creating Initial Conditions



Creating Initial Conditions

1. Click the **Initial Conditions** tab on the **tree view of Builder**.
2. Double click on **Initial Conditions**.
3. Select **Water**, **Oil**, **Gas** as the initial fluid in the reservoir to perform a Gravity-Capillary Equilibrium Calculation.



Creating Initial Conditions

4. Type the following values in the available fields:

27580 (kPa implied) in the Reference Pressure window

3050 (m implied) in the Reference Depth window

3080 (m implied) in the Water-Oil Contact window

1980 (m implied) in the Gas-Oil Contact window

5. Leave the other boxes blank.

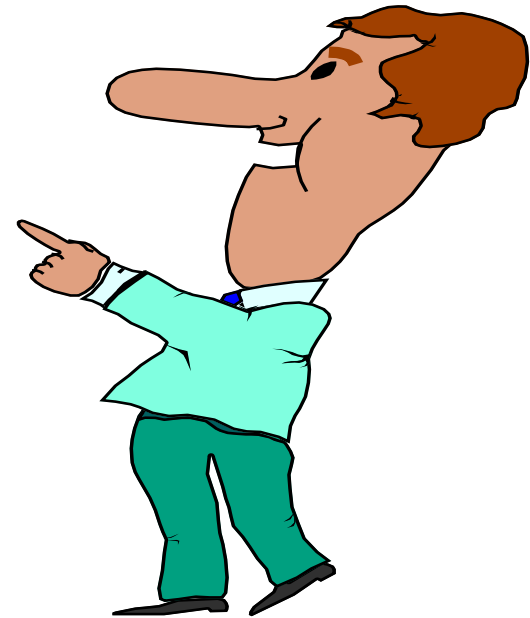
6. Click on Apply; then OK.

7. You should now be back in the main Builder window with all tabs showing a green checkmark in the tree view, except for the “Wells & Recurrent” tab.

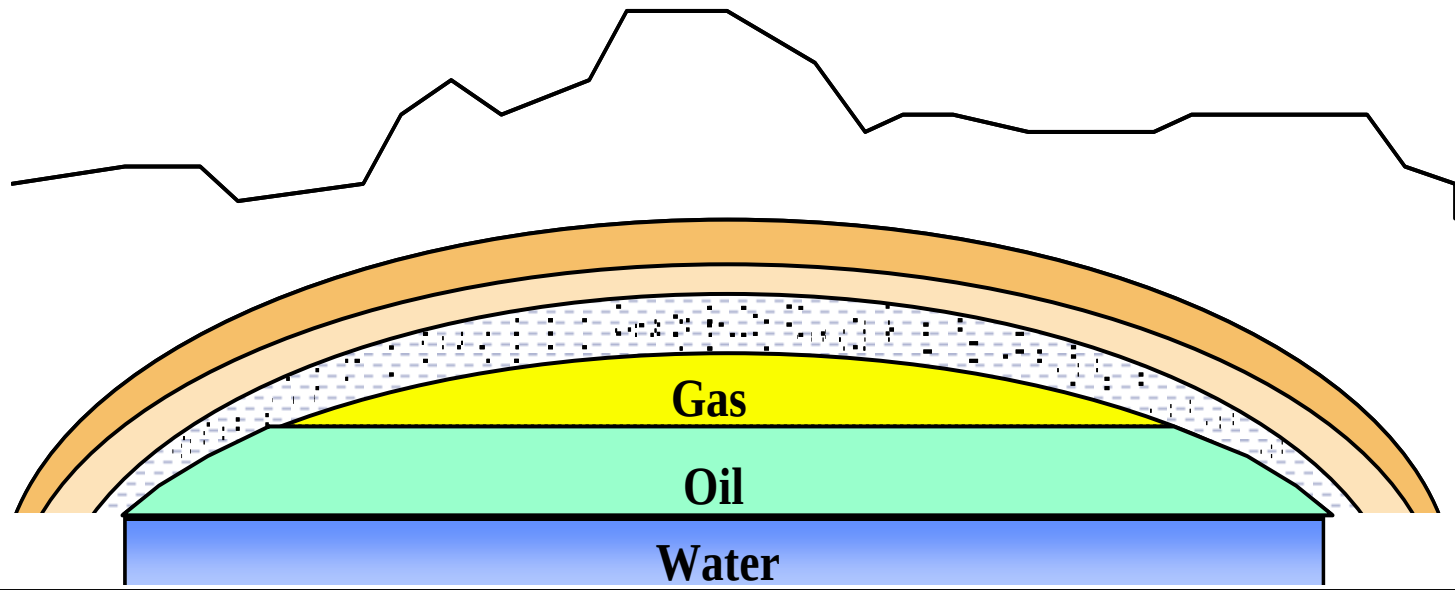


Creating Initial Conditions

8. At this point it is advisable to save the data again by selecting **File** from the top menu and **Save**.



Incorporating **Well Trajectories** And **Perforations**



*Incorporating Well Trajectories and Perforations

Once we have created the static model, we will now incorporate the trajectory and perforation information into the model.

1. Go to the main Builder menu and select **Well / Well Trajectories / Open Well Trajectory File....**

The following window will pop up.

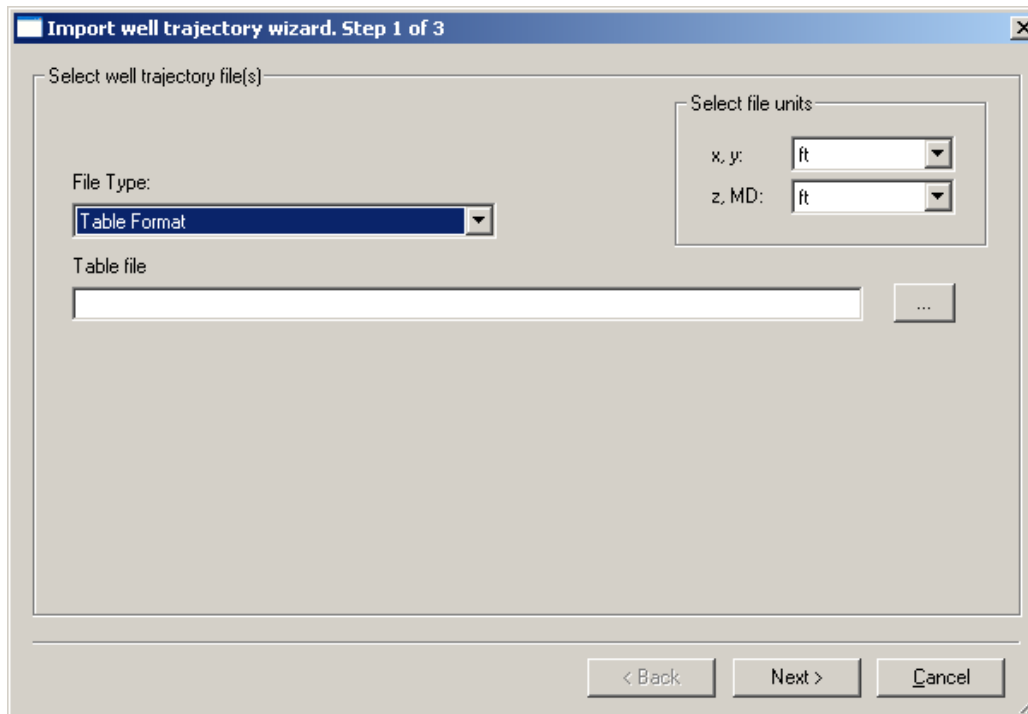
2. You need to choose Trajectory File Type and appropriate Units for it (3 Steps Wizard).



*Incorporating Well Trajectories and Perforations

3. Choose **Table Format** and **ft** for X, Y and Z,MD then browse for the file “**TRAJ_Feet.wdb**”,

Open, and press **Next >** **(Step 1 of 3)**



*Incorporating Well Trajectories and Perforations

4. Check the box **Clear all existing trajectories** then press **Next>** (Step 2 of 3).

Import well trajectory wizard. Step 2 of 3

Select trajectory names to import (existing trajectory names colored in gray).

#	Trajectory Name	Selection
1	Well 1	☒
2	Well 10	☒
3	Well 2	☒
4	Well 3	☒
5	Well 4	☒
6	Well 5	☒
7	Well 6	☒
8	Well 7	☒
9	Well 8	☒
10	Well 9	☒

Select All

Deselect All

☒ Clear all existing trajectories

☐ Automatic data point reduction
(eliminate surplus trajectory nodes while preserving deviation data)

< Back Next > Cancel

5. Click **Finish** to complete **Step 3 of 3**.

6. This screen will create a vertical trajectory for each well that exists in the main contour map.



Incorporating Well Trajectories and Perforations

Or 1. Go to the main Builder menu and select **Well / Well Trajectories / Create trajectory ...** The following window will pop up.

Create well trajectories from model wells (PERFs)

Create well trajectories from location and direction of existing model well completions.
The following conditions apply to selected wells:
- only the 1st of model well completions (PERF) will be used
- existing trajectories will be deleted.

Select well names: Wells (10 of 10) ...

Set KB elevation above datum:
☒ One for all wells 0 m
☐ Individual values

#	Well	KB elevation abo...
1	Well 1	0
2	Well 10	0
3	Well 2	0
4	Well 3	0
5	Well 4	0
6	Well 5	0
7	Well 6	0
8	Well 7	0
9	Well 8	0

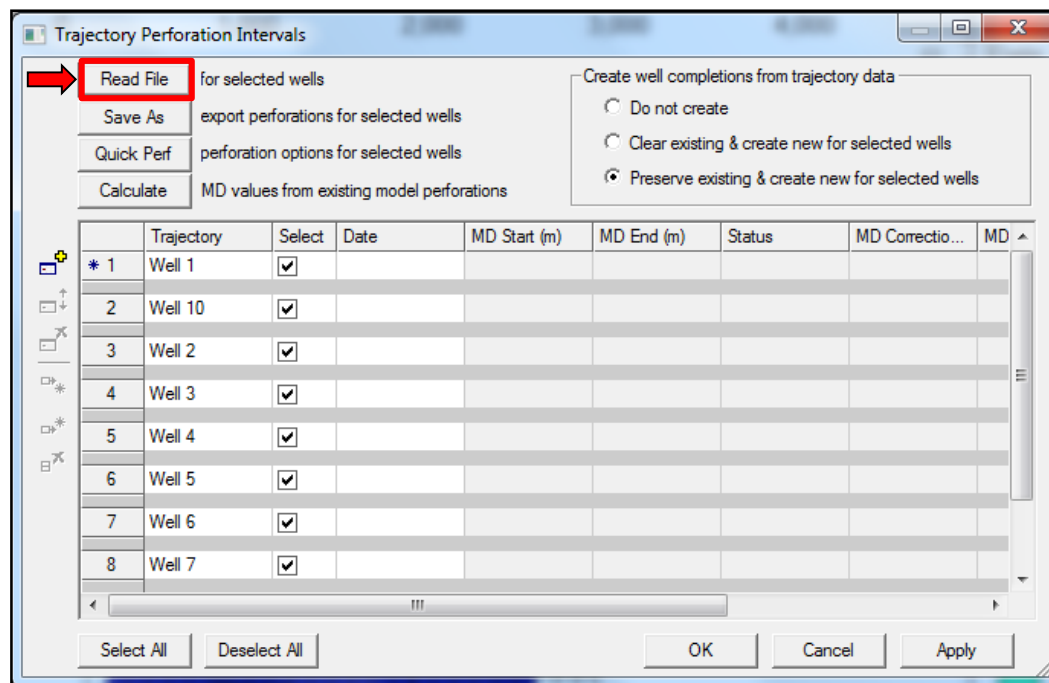
OK
Cancel

2. Click **Ok**.



Incorporating Well Trajectories and Perforations

7. Now go back to top menu and select **Well / Well Trajectories**, click on **Trajectory Perforation Intervals...** a window will open.



8. Click on **Read File** and choose **File unit selection** option as **SI** then browse **Perforations.perf** Press **Open**.



Incorporating Well Trajectories and Perforations

9. If this is done correctly, the window will be like below Figure.

Trajectory Perforation Intervals

Read File: for selected wells
Save As: export perforations for selected wells
Quick Perf: perforation options for selected wells
Calculate: MD values from existing model perforations

Create well completions from trajectory data
☐ Do not create
☐ Clear existing & create new for selected wells
☒ Preserve existing & create new for selected wells

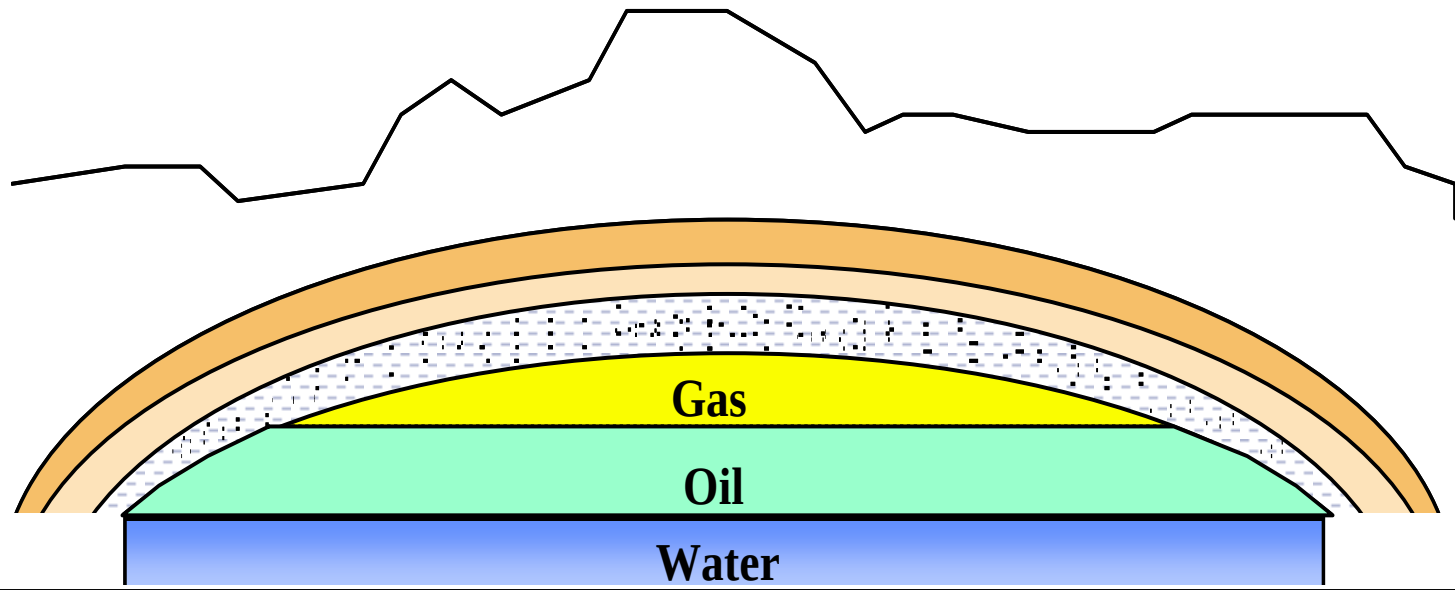
	Trajectory	Select	Date	MD Start (m)	MD End (m)	Status	MD Correctio...	MD
* 1	Well 1	☒	1991-01-01	2999.042	3024.34	Perforated	0.0	25.1
				3024.476	3050.03	Perforated	0.0	25.1
				3050.548	3075.08	Perforated	0.0	24.1
			1991-07-01	3045.248	3075.08	Cement Sque...	0.0	29.1
3	Well 10	☒	1991-01-01	2995.08	3020.89	Perforated	0.0	25.1
				3028.158	3047.49	Perforated	0.0	19.1
4	Well 2	☒	1991-01-01	2989.059	3016.06	Perforated	0.0	27.1
				3016.48	3044.31	Perforated	0.0	27.1
				3045.154	3071.32	Perforated	0.0	26.1
			1991-07-01	3045.154	3071.32	Cement Sque...	0.0	26.1

Select All Deselect All OK Cancel Apply

10. Press **Apply** and then **OK**. This completes the trajectories and Perforation of the wells in the model.



Adding Historical Production Data to the Model



Adding Historical Production Data to the Model

The last item we want to do is add historical rate data so that we can set up a history match run.

1. Go to the main Builder menu and select **Well / Import Production / Injection Data** (this is the wizard to import production/injection data into the well & recurrent data for the simulator and it also defines the status of each well).

2. STEP 1: First step of this wizard is to provide the type and name of the production file. In our case, we will use **General** and choose a file in the tutorial directory named **Production-history.prp**. Press the **Next** button.

[Use the **Next/Back** buttons on the panels to move forward/backward between each Step].



Adding Historical Production Data to the Model

3. STEP 2: Follow the instructions and highlight the first line containing the production data (top window) and well name (lower window) (as shown in the following figure). Press **Next**.

Import Production/Injection Data

Step 2: Choose the file options

Please Select(Highlight) the start line of actual data, having valid Date

Date M/D/Y	Oil Rate m3/day	Water Rate m3/day	Gas Rate m3/d
1/31/1991	3062.378418	154.99324	581851.8994
2/28/1991	2678.308594	452.269501	508878.6329
3/31/1991	747.128113	230.886734	141954.3415
4/30/1991	237.164459	90.25058	45061.24721
5/31/1991	95.735519	36.859093	18189.74861
6/30/1991	537.921143	244.09053	102205.0172
7/31/1991	402.530579	165.956543	76480.81001
8/31/1991	277.282867	396.644012	52683.74473

WELL: 'Well 1'

Please Select(Highlight) the line containing first well name

Date M/D/Y	Oil Rate m3/day	Water Rate m3/day	Gas Rate m3/d
1/31/1991	3062.378418	154.99324	581851.8994
2/28/1991	2678.308594	452.269501	508878.6329
3/31/1991	747.128113	230.886734	141954.3415
4/30/1991	237.164459	90.25058	45061.24721
5/31/1991	95.735519	36.859093	18189.74861
6/30/1991	537.921143	244.09053	102205.0172
7/31/1991	402.530579	165.956543	76480.81001
8/31/1991	277.282867	396.644012	52683.74473

WELL: 'Well 1'

Well or group names are in rows

Help View Original File Cancel < Back Next > Finish



Adding Historical Production Data to the Model

4. STEP 3: If the delimiters look good and the columns are separated correctly, click **Next** to go to **STEP 4**.

Import Production/Injection Data

Step 3: Choose delimiters

☒ Tab ☒ Space ☒ Comma ☒ Semicolon Others:

☒ Treat Consecutive Separators as one

1	2	3	4	5	6	7	8	9
	Date	Oil	Rate	Water	Rate	Gas	Rate	
	M/D/Y	m3/day	m3/day	m3/d				
WELL:	Well	1'						
	1/31/1991	3062.378418	154.99324	581851.8994				
	2/28/1991	2678.308594	452.269501	508878.6329				
	3/31/1991	747.128113	230.886734	141954.3415				
	4/30/1991	237.164459	90.25058	45061.24721				
	5/31/1991	95.735519	36.859093	18189.74861				
	6/30/1991	537.921143	244.09053	102205.0172				
	7/31/1991	402.530579	165.956543	76480.81001				
	8/31/1991	277.282867	396.644012	52683.74473				
WELL:	Well	10'						
	1/31/1991	1319.655151	5.268271	250734.4787				
	2/28/1991	1122.472168	72.494965	213269.7119				
	3/31/1991	301.006134	39.7542	57191.16546				
	4/30/1991	106.609772	8.880283	20255.85668				
	5/31/1991	41.248257	1.5032	7837.16883				



Adding Historical Production Data to the Model

5. STEP 4: Go to Columns 3 to 5 and in the identifier row, choose **Oil Produced**, **Water Produced** and **Gas Produced** for each column. Leave others as they pop up then click **Next** to go to the next step.

Import Production/Injection Data

Step 4: Choose column details

Note: For date formats that span multiple columns (eg. 26 02 1998), please do selection for each column.

	1	2	3	4	5	6	7
Identifier	Ignore Column	Date/ Time	Oil Produced	Water Produced	Gas Produced	Ignore Column	Ignore
Related info		M D Y (eg. ...)	Producing d...	Producing dail...	Producing d...		
Units			m3/day	m3/day	m3/day		
Expected period			Monthly	Monthly	Monthly		
Missing dates			zero/take ze...	zero/take zero...	zero/take ze...		

	Date	Oil	Rate	Water	Rate	Gas
	M/D/Y	m3/day	m3/day	m3/d		
1						
2						
3						
4	WELL:	Well	1'			
5						
6	1/31/1991	3062.378418	154.99324	581851.8994		
7	2/28/1991	2678.308594	452.269501	508878.6329		
8	3/31/1991	747.128113	230.886734	141954.3415		
9	4/30/1991	237.164459	90.25058	45061.24721		
10	5/31/1991	95.735519	36.859093	18189.74861		
11	6/30/1991	537.921143	244.09053	102205.0172		
12	7/31/1991	402.530579	165.956543	76480.81001		
13	8/31/1991	277.282867	396.644012	52683.74473		
14						

☒ Ignore a column for a well if all data are zero or blanks

Help View Original File Cancel < Back Next > Finish



Adding Historical Production Data to the Model

6. STEP 5: This is the place showing you which well's production data has been picked up and which well is not. For example, the program could not find any production data from well **5**, **7** and **9**. Since wells 5, 7 and 9 have no production history, the easiest action is to delete them from the model. We will do this later. Other than that, click **Finish**. The **Simulation Dates** window will appear. Press **Close**.

Import Production/Injection Data

Step 5: Check well/group names and primary constraints

Injector name suffix: Water injectors: [lw] Gas injectors: [g] Solvent injectors: [s]

Add All
Add Only Producers
Add Only Injectors
Add None
Add Only Matched

For changing primary constraints, please right click on the selected cell(s).

#	Import Name	Group	Matched	New Name	Add	Primary Constraint	Fraction
1	Well 1		☒		☒	Oil Produced	1.0
2	Well 10		☒		☒	Oil Produced	1.0
3	Well 2		☒		☒	Oil Produced	1.0
4	Well 3		☒		☒	Oil Produced	1.0
5	Well 4		☒		☒	Oil Produced	1.0
6	Well 6		☒		☒	Oil Produced	1.0
7	Well 8		☒		☒	Oil Produced	1.0

Unmatched Names

- 1 Well 5
- 2 Well 7
- 3 Well 9

Import Data Options

Group adjacent periods with rates within 0 % of each (will result in less ALTER keywords)

Import data after this date: 1901-01-01

For each well/group, apply data after last date of old data (new data append to the end of old data)

For each well/group, apply data after first date of new data (new data overwrite the old data)

Help View Original File Cancel < Back Next > **Finish**



Simulation Dates

* - no keyword data exists on this date (it can be deleted)

#	Date & Time (day)	set STOP	Comments
1	1901-01-01 (0.00)	☐	
2	1991-01-01 (32872.00)	☐	
3	1991-02-01 (32903.00)	☐	
4	1991-03-01 (32931.00)	☐	
5	1991-04-01 (32962.00)	☐	
6	1991-05-01 (32992.00)	☐	
7	1991-06-01 (33023.00)	☐	
8	1991-07-01 (33053.00)	☐	
9	1991-08-01 (33084.00)	☐	
10	* 1991-09-01 (33115.00)	☐	

Add a new date: [icon]

Add a range of dates: [icon]

Delete selected empty dates: [X icon]

Delete all empty dates: [X icon]

Close



Creating Average Monthly Production / Injection Recurrent Well Data

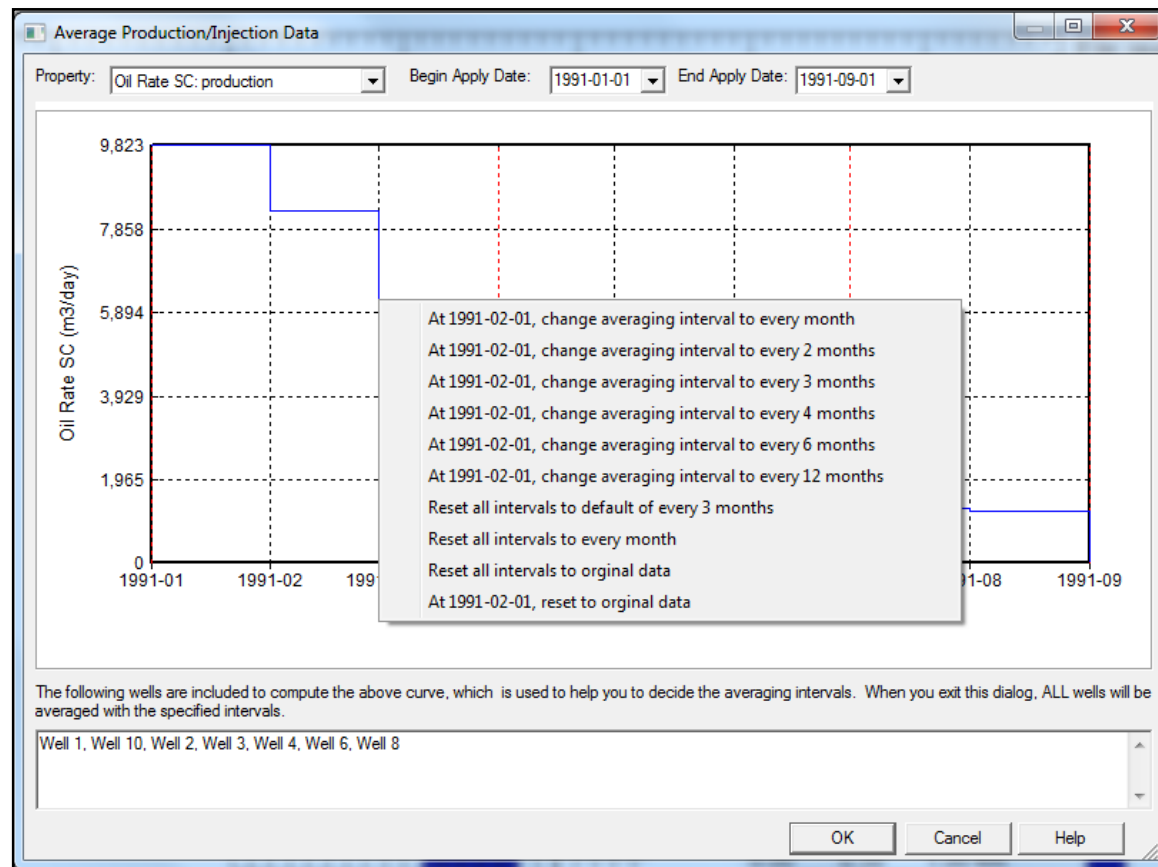
Next thing we want to do is to generate the well recurrent data for every month.

1. Go back to the **main Builder menu** and select **Well / Average Production / Injection Data...**
2. Now, move your mouse and right click on the y-axis. A menu will show up to allow you to change the average interval from this point on to **monthly, bi-annually, yearly**, etc.



Creating Average Monthly Production / Injection Recurrent Well Data

3. Select “Reset all intervals to every month” and press the OK button.



Creating Field Production History (*.fhf) for History Match

- 1.** Next thing we want to do is to create a field history file so that we can make a comparison between the simulation run and the actual field history file.
- 2.** Go to the top menu again and select **Well** / “**Create Field History File...**” then provide a filename (or you can just use the default). Press **OK**.



Well Definition and Constraints

1. For those wells that **have no production history**, we can either delete them or define them as a producer or injector and shut-in the wells so that they will not affect the history match.

2. In this tutorial, we will **delete Well 5** and **change Wells 7 & 9 so that they are injectors**.

3. To do that, open the tree view and press the **Wells & Recurrent tab**. Expand the Wells list.

Right mouse click on **Well 5**, select **Delete** and press **Yes** to the message that pops up.



Well Definition and Constraints

4. Go to **Well 7**, right mouse click and select **Properties**. A new window will show up as follows:

5. Select **Well 7**.

The screenshot shows the 'Well Events' window with the 'Properties' tab selected for 'Well 7'. The window displays a list of events on the left and configuration options on the right.

Well Events List:

Name / Date	Event
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
1991-08-01	ALTER
1991-09-01	ALTER
Well 7	
1901-01-01	WELL
	INJECTOR
	constraints
	injected fluid
	SHUTIN
Well 8	
1901-01-01	WELL
	PRODUCER
	constraints
	SHUTIN
1991-01-01	PRODUCER
	constraints
1991-02-01	ALTER
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
Well 9	
1901-01-01	WELL

Configuration Options:

- ID & Type:** ☒ Well definition Previous date: <none>
- Name:** Well 7 ☐ Edit
- Type:** INJECTOR MOBWEIGHT
- Group:** <None> 3rd or 2nd level group with no other groups attached to it
- Constraints:**
- Multipliers:**
- Wellbore:**
- Injected Fluid:**
- Workover:**
- Options:**
- Layer Gradient:**
- Gas Lift:**
- Guide Rates:**
- Comments:**

Sort by: Name Date **Tools** ☒ Auto-apply



Well Definition and Constraints

6. Click on **ID & Type**, and select **INJECTOR MOBWEIGHT** for the type. Check the “**Auto-apply**” check box. Press **Apply**.

The screenshot shows the 'Well Events' dialog box. The left pane lists events for three wells. 'Well 7' is selected, showing a 'WELL' event on 1901-01-01. The right pane shows the 'ID & Type' tab with the 'Type' dropdown set to 'INJECTOR MOBWEIGHT'. The 'Auto-apply' checkbox is checked. The 'Apply' button is highlighted.

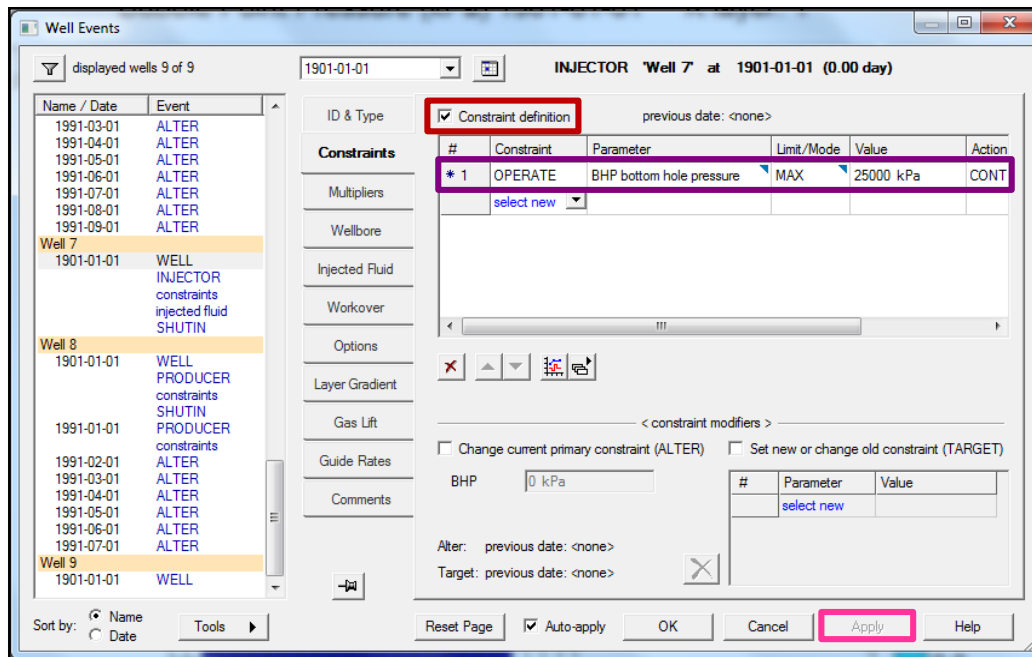
Name / Date	Event
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
1991-08-01	ALTER
1991-09-01	ALTER
Well 7	
1901-01-01	WELL
	INJECTOR constraints
	injected fluid
	SHUTIN
Well 8	
1901-01-01	WELL
	PRODUCER constraints
	SHUTIN
1991-01-01	PRODUCER constraints
1991-02-01	ALTER
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
Well 9	
1901-01-01	WELL



Well Definition and Constraints

7. Go to **Constraints** tab (say YES to apply changes if asked!!), and **check** the **Constraint definition** box.

8. Under **select new** (in the Constraint column of the table), select **OPERATE**. Then select **BHP** bottom hole pressure, **MAX**, **25000 kPa**, **CONT REPEAT**. Press **Apply**.



Well Definition and Constraints

9. Go to the **Injected Fluid** tab and choose **Water** as injection fluid. Press **Apply**.

The screenshot shows the 'Well Events' window. On the left, a list of wells is displayed with columns 'Name / Date' and 'Event'. Well 7 is selected, showing events from 1991-03-01 to 1991-09-01, all labeled 'ALTER'. Below this, Well 7 is detailed with events on 1901-01-01: 'WELL', 'INJECTOR', 'constraints', 'injected fluid', and 'SHUTIN'. Well 8 and Well 9 are also listed. The main panel on the right is titled 'INJECTOR 'Well 7' at 1901-01-01 (0.00 day)'. It contains a tabbed interface with 'Injected Fluid' selected. The 'Injected fluid' dropdown menu is set to 'WATER'. At the bottom, the 'Apply' button is highlighted with a pink box.

Name / Date	Event
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
1991-08-01	ALTER
1991-09-01	ALTER
Well 7	
1901-01-01	WELL
	INJECTOR
	constraints
	injected fluid
	SHUTIN
Well 8	
1901-01-01	WELL
	PRODUCER
	constraints
	SHUTIN
1991-01-01	PRODUCER
	constraints
1991-02-01	ALTER
1991-03-01	ALTER
1991-04-01	ALTER
1991-05-01	ALTER
1991-06-01	ALTER
1991-07-01	ALTER
Well 9	
1901-01-01	WELL

Sort by: ☐ Name ☐ Date Tools ▶

Reset Page ☒ Auto-apply OK Cancel Apply Help



Well Definition and Constraints

10. Go to the **Options** tab. Check the **Status** box and choose to **SHUTIN** the well at this time.

Press **Apply**.

The screenshot shows the 'Well Events' window with the 'Options' tab selected. The window title is 'Well Events'. The top bar shows 'displayed wells 9 of 9', a date selector set to '1901-01-01', and the well name 'INJECTOR Well 7 at 1901-01-01 (0.00 day)'. The left pane lists wells 7, 8, and 9. Well 7 is selected, showing its history: '1901-01-01 WELL INJECTOR constraints injected fluid SHUTIN'. The 'Options' tab is active, showing a table of controls. The 'Status' checkbox is checked, and the dropdown menu is set to 'SHUTIN'. The 'Apply' button is highlighted in pink.

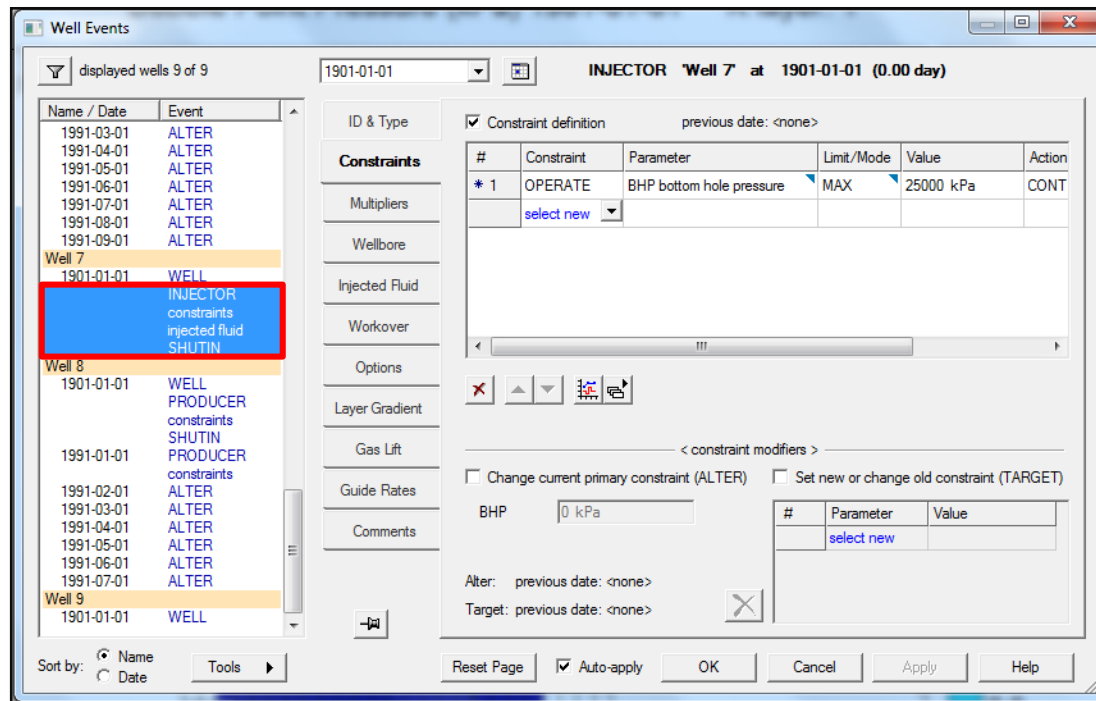
Controls	Add / Remove	Type / Value	Pre
Operating			
Status	☒	Status	SHUTIN
Fraction of time the well is on line	☐	ON-TIME	1
Alter polymer concentration	☐	ALTERCP	0 kg/m3
Alter seawater fraction	☐	ALTERFS	0
Set well's phase productivity	☐	SETPI	Oil
pi value/multiplier			0 m3/(day*kPa)
Numerical			
Initialization frequency of bottom-hole p...	☐	WELLINIT	ITER
Reset operating constraint after value ...	☐	MRC-RESET	RESET
Perforations in inactive blocks	☐	NULL-PERF	CLOSED
Number of points for WHP root search	☐	NWHYFS	9
Simultaneous BHP and well head iterat...	☐	BHPHEADINIT	SEPARATE
Well head iteration	☐	HEADITER	ONE-STEP
Well artificial lift quantity	☐	WELLALQ	0



Well Definition and Constraints

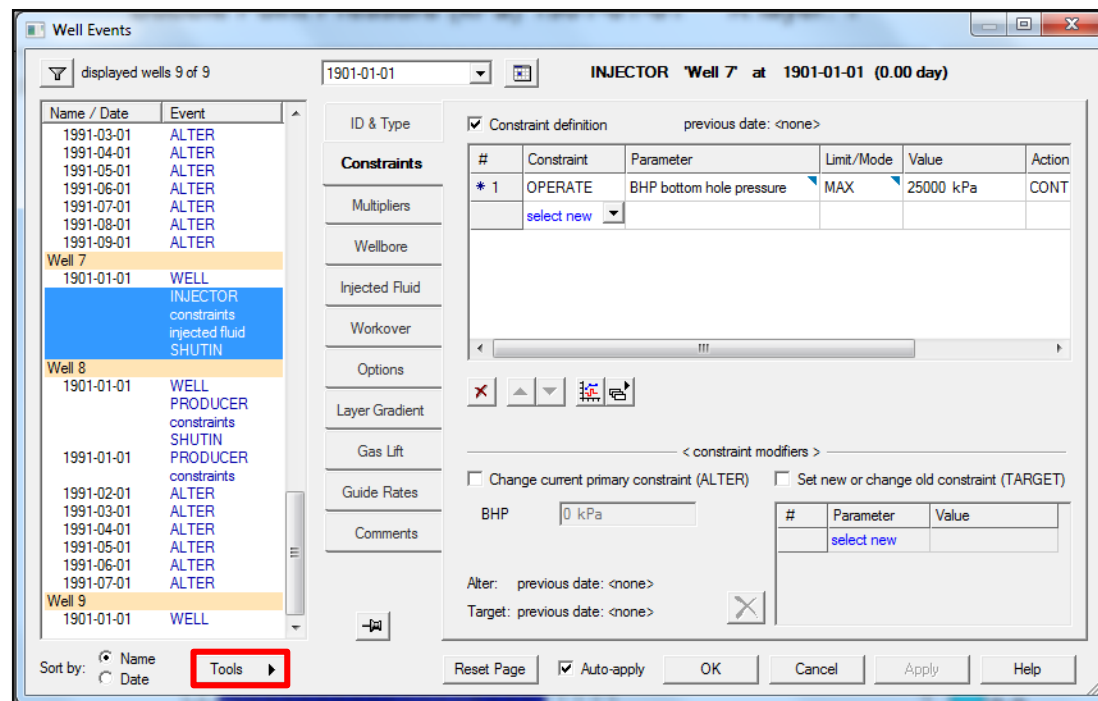
11. Now, we can copy all the above specifications to Well 9.

To do that, make sure you are looking at “**Well 7**” in the Name/Date list. Then **highlight** the following Events (for Well 7) by clicking on them with your mouse and pressing down the **Ctrl** key to select multiple items: **INJECTOR**, **constraints**, **injected fluid** and **SHUTIN** (all of them!!!).



Well Definition and Constraints

12. Press the **Tools** button at the bottom of the screen, and select **Copy events using filter**. This will open a new window.



Well Definition and Constraints

13. In the **Select Wells** tab, check on **Well 9** and then go to the **Select Dates** tab. Check the date **1991-01-01** and press the **Search & Add** button. The window should look like this:

Select well-date pairs to copy event(s): INJECTOR, SHUTIN

1.- Select Wells

#	Well	Date
1	Well 9	1991-01-01

2.- Select Dates

Auto select dates

☒ All
☐ Highlighted
☐ By step

from: 1991-01-01
to: 1991-09-01
step: 1
Days

Select Deselect

☐ Do you want to create new dates?

Add a new date:
Add a range of dates:

4.- Search Results

bold - new item
blue - repeated item

#	Well	Date
1	Well 9	1991-01-01

Search & Add Search & Remove Delete Item Clear List

OK Cancel



Well Definition and Constraints

14. Click **OK** and the same constraint information created for **Well 7** will now be copied to **Well 9**. If a message pops up requesting to change the well type for Well 9, say **Yes**. Press **OK** to close the window.

Select well-date pairs to copy event(s): INJECTOR, SHUTIN

1.- Select Wells 2.- Select Dates 3.- Set Search Conditions 4.- Search Results

bold - new item blue - repeated item

#	Well	Date
1	Well 9	1901-01-01

Auto select dates

☒ All
☐ Highlighted
☐ By step

from: 1901-01-01
to: 1991-09-01
step: 1
Days

Select Deselect

☐ Do you want to create new dates?

Add a new date:
Add a range of dates:

Search & Add Delete Item
Search & Remove Clear List

OK Cancel



Well Definition and Constraints

15. Make sure that the View Type is set to **IK-2D X-Sec** (located in the upper left hand corner of the main Builder window).

16. Even though we defined Well 7 as an injector, provided constraint information and defined the trajectory path, well completions (or perforations) might need to be defined along the trajectory path. If the well completions are not defined, then the simulator will not be able to properly recognize the well.



Well Definition and Constraints

17. To define some well completions, go to the **Well** menu and select **Well Completions (PERF)**.

The following window will open:

Note: by default, Builder will provide one completion in Layer K=1. To use the following approach to **Add** a new completion, this single completion should first be deleted. Alternatively we can add to the existing completions as also described below.

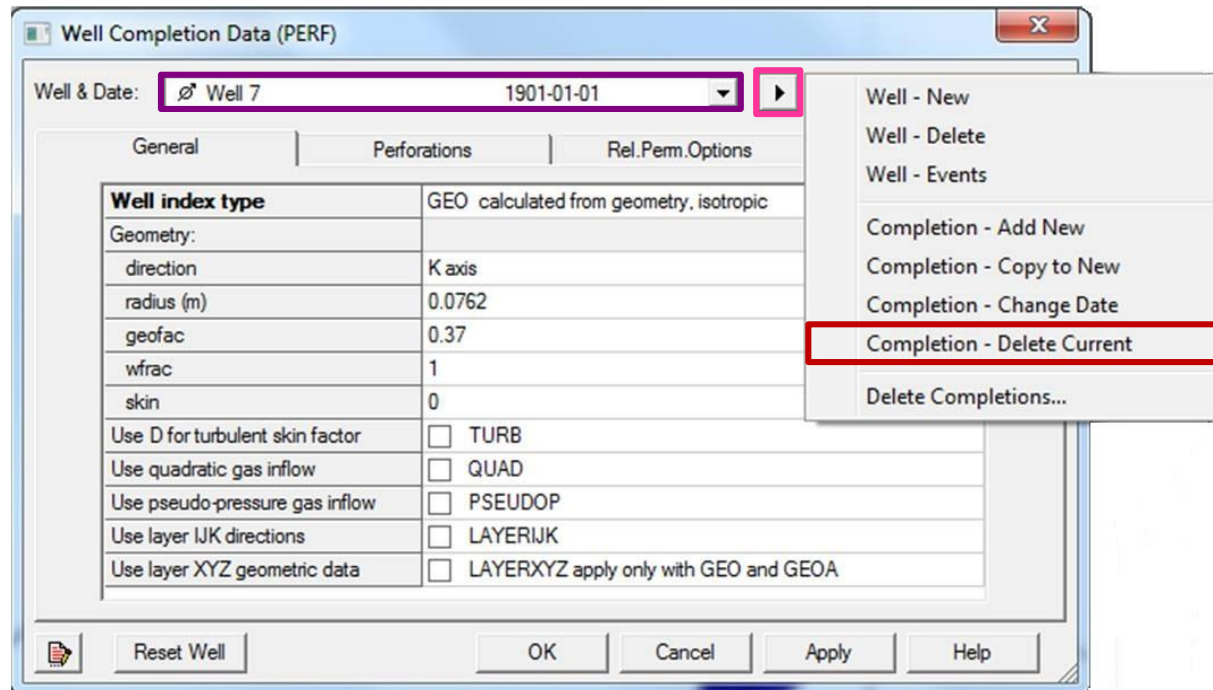
Well Completion Data (PERF)	
Well & Date: Well 1 1901-01-01 PRODUCER	
General Perforations Rel.Perm.Options	
Well index type	GEO calculated from geometry, isotropic
Geometry:	
direction	K axis
radius (m)	0.0762
geofac	0.37
wfrac	1
skin	0
Use D for turbulent skin factor	☐ TURB
Use quadratic gas inflow	☐ QUAD
Use pseudo-pressure gas inflow	☐ PSEUDOP
Use layer IJK directions	☐ LAYERIJK
Use layer XYZ geometric data	☐ LAYERXYZ apply only with GEO and GEOA



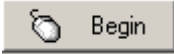
Well Definition and Constraints

18. Expand the **Well & Date** list and select “**Well 7**”.

- To delete the existing perforation date **Press** the  button and select **Completion – Delete Current**. Answer “**Yes**” to delete the model well. All related information for this completion is also deleted and must be re-entered by reference to one of the other wells.

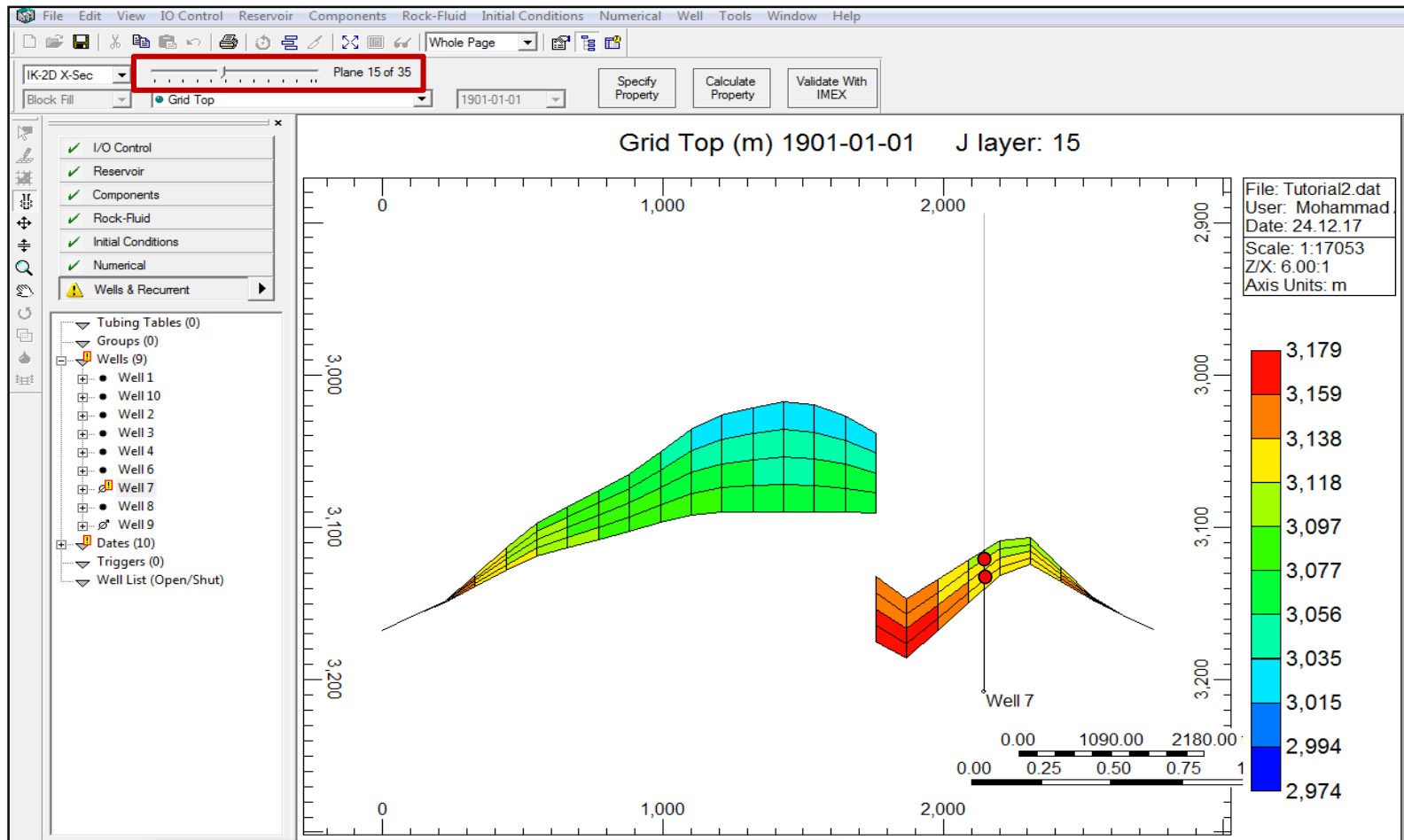


Well Definition and Constraints

- Press the  button and select **Completion – Add New**. Press the **OK** button in the window that pops up regarding the “New Well Completion Date”.
- Select the **Perforations tab** and press the  button. This will allow you to use your mouse to select the grid blocks where you want the well completions to be.
- Since the well will be **SHUTIN** right away anyway, the location where you click in the grid does not have to be exact.
- Change the Plane Slider to **15** so that you can see the trajectory for **Well 7**.
- Use your mouse to click **two** or **three** times somewhere along the **Well 7 trajectory** in the main Builder window.
- Press  when you are done. Press **Apply** and then **OK**.



Well Definition and Constraints



Well Definition and Constraints

- **Alternatively**, we can simply add to the existing completion, or change it, by going to the Perforations tab and **Delete** the existing completion with the **[X] button** and **Add new completions** with the **mouse**.

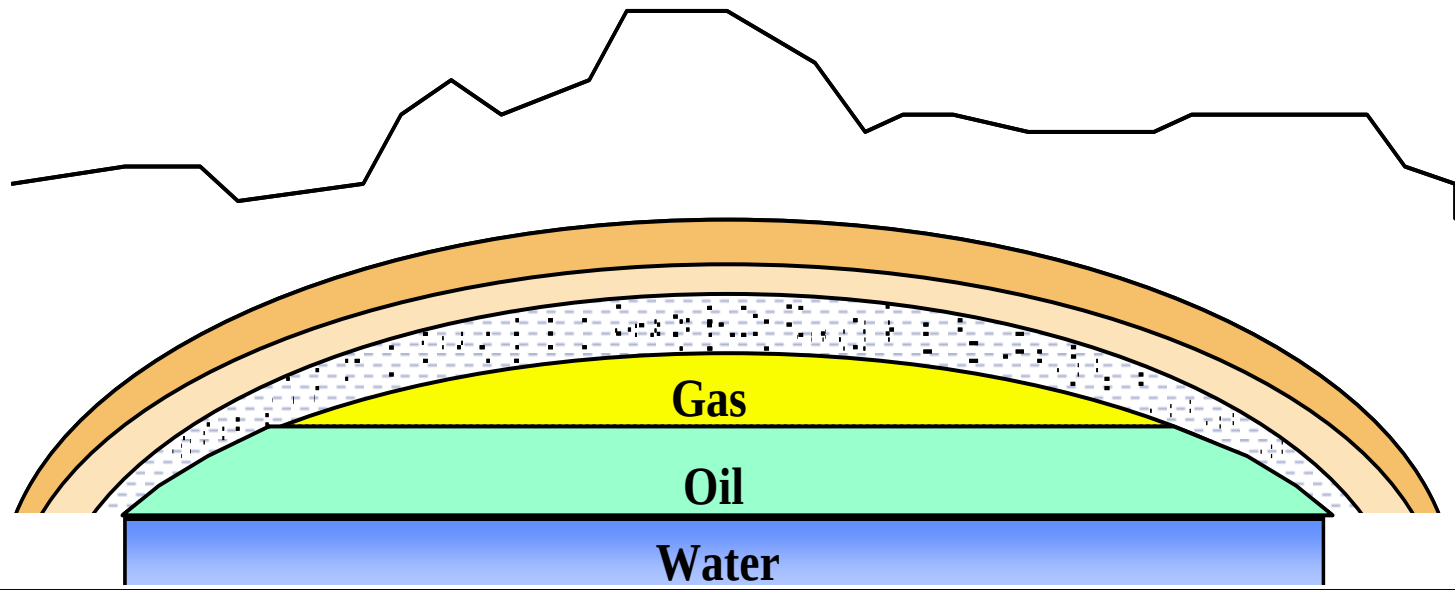
19. Repeat the steps in Section **18** for **wells 9**.

20. If everything is **OK**, all of the tabs in the tree view should have a **green** checkmark. **Although** a **warning** will be shown for the **Wells & Recurrent** tab.

21. Please **save** the file one more time!

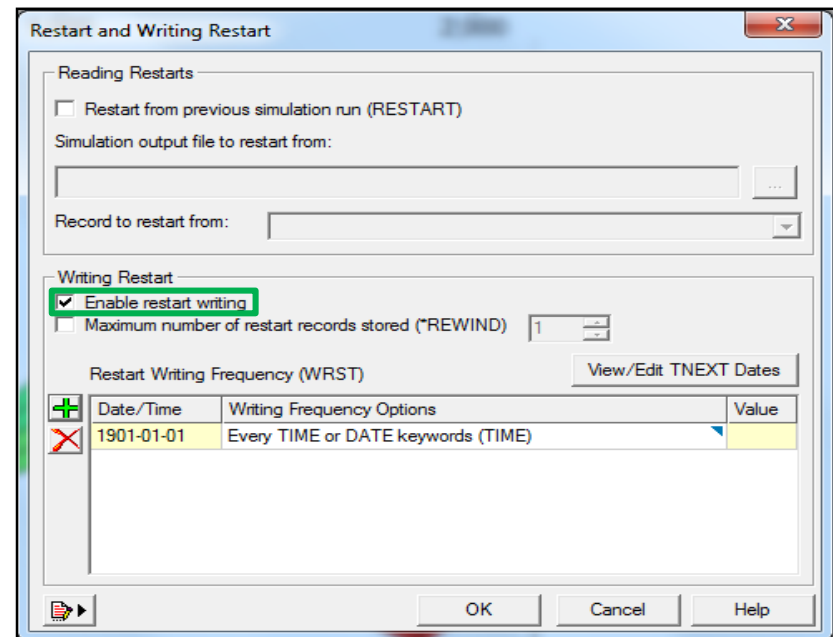
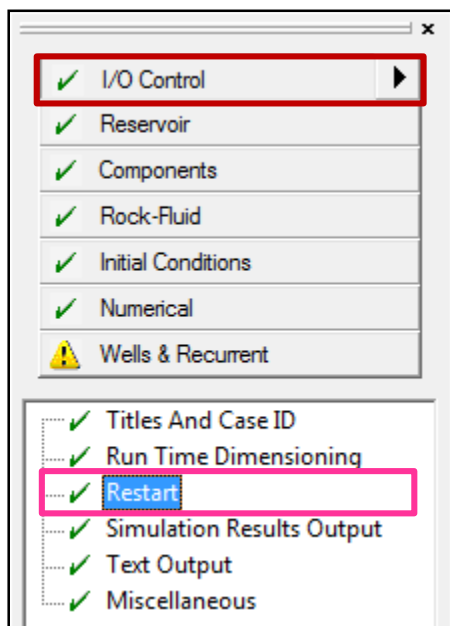


Write Out Restart information to a Restart File



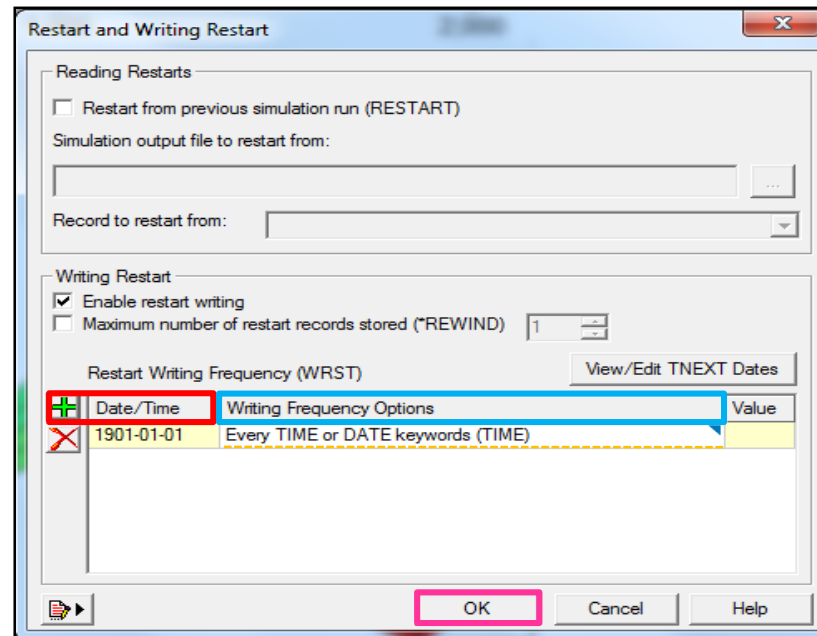
Write Out Restart information to a Restart File

1. Click on the **I/O Control** tab in the tree view.
2. Double click on **Restart**.
3. Check on **Enable Restart Writing**.



Write Out Restart information to a Restart File

4. Press the **+** button and select the first simulation date which is 1991-01-01. Press **OK**.
5. Set the “**Writing Frequency Option**” to **Every TIME or DATE Keywords**.
6. Click **OK** to close the window.



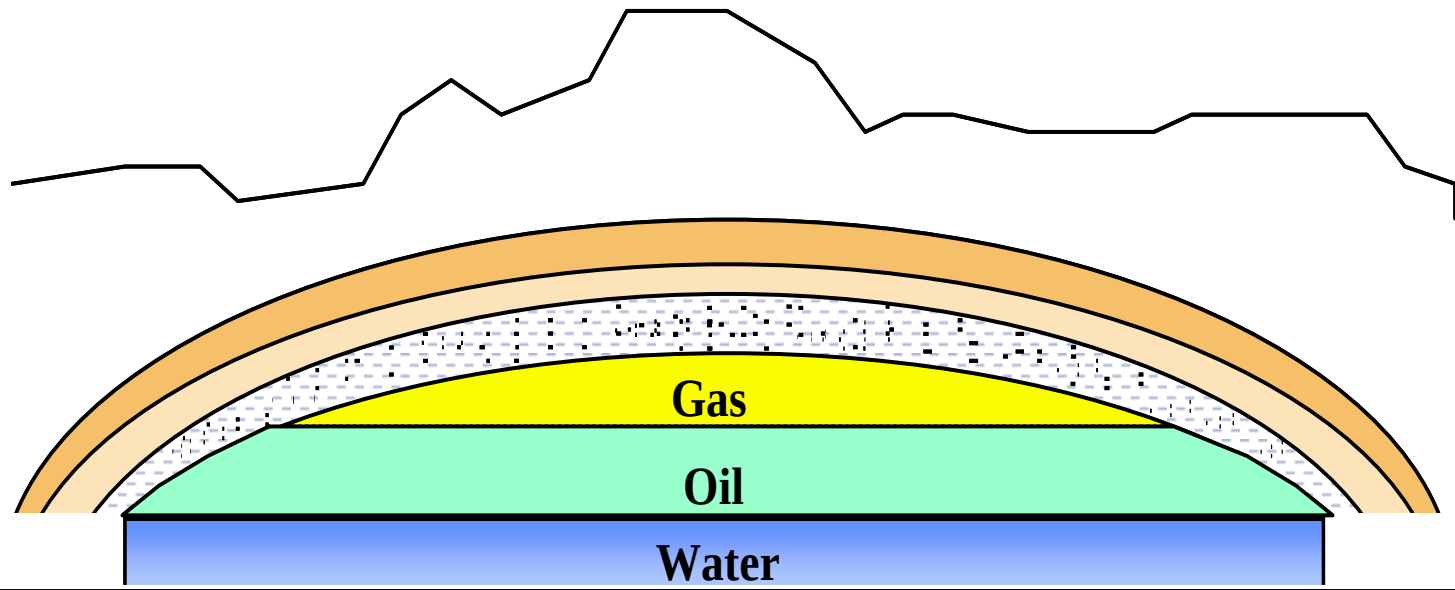
Write Out Restart information to a Restart File

7. Click **File** in the main Builder menu and select **Save As**. Name this file **Tutorial_hm.dat**.
8. We now have a completed dataset so we can exit Builder and drag and drop the **Tutorial_hm.dat** file onto the **IMEX** icon to run it. You will be able to make prediction runs without having to rerun the historical data portion as a result of using the Restart Run feature.

hm = history match

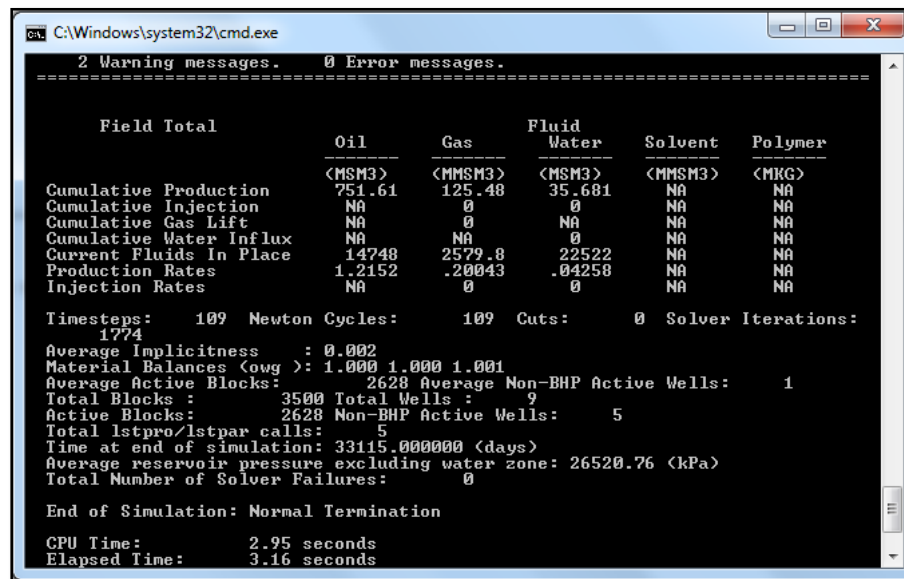


Running the IMEX Dataset



Running the IMEX Dataset

1. If everything is OK, you should be able to run the dataset using IMEX. First locate the file **Tutorial_hm.dat** in your launcher, then drag and drop it onto the **IMEX 2006.10** icon and release the mouse. A new window will show up. Press the **Run Immediately** button.
2. If there are no errors, a MS-DOS window will open up and show you the progress of the run. When finished, the MS-DOS window will be terminated and shows a brief summary of results.



```
C:\Windows\system32\cmd.exe
2 Warning messages.  0 Error messages.

=====
Field Total
Oil      Gas      Fluid Water  Solvent  Polymer
      <MSM3> <MMSM3> <MSM3> <MMSM3> <MKG>
Cumulative Production  751.61  125.48  35.681  NA      NA
Cumulative Injection   NA      0      0      NA      NA
Cumulative Gas Lift    NA      0      NA     NA      NA
Cumulative Water Influx NA      NA     0      NA      NA
Current Fluids In Place 14748   2579.8  22522  NA      NA
Production Rates       1.2152   .20043  .04258  NA      NA
Injection Rates        NA      0      0      NA      NA

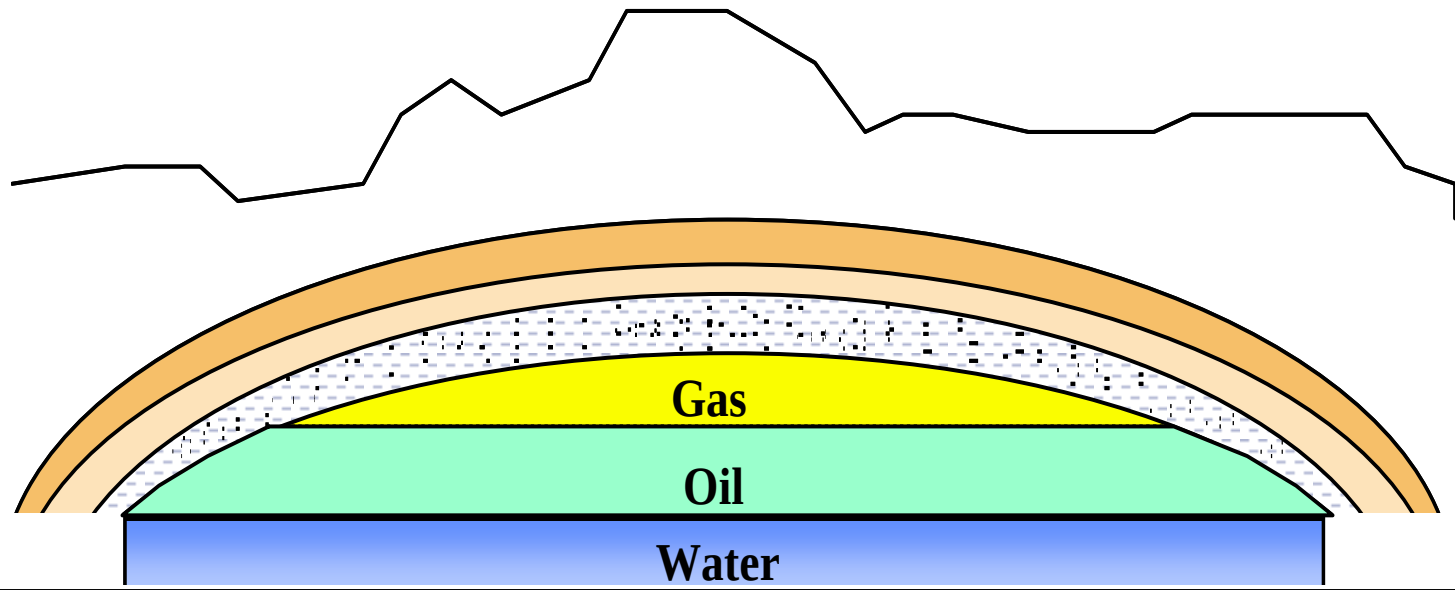
Timesteps:  109  Newton Cycles:  109  Cuts:  0  Solver Iterations:
1774
Average Implicitness : 0.002
Material Balances <owg>: 1.000 1.000 1.001
Average Active Blocks: 2628 Average Non-BHP Active Wells: 1
Total Blocks : 3500 Total Wells : 9
Active Blocks: 2628 Non-BHP Active Wells: 5
Total lstpro/lstpar calls: 5
Time at end of simulation: 33115.000000 <days>
Average reservoir pressure excluding water zone: 26520.76 <kPa>
Total Number of Solver Failures: 0

End of Simulation: Normal Termination

CPU Time: 2.95 seconds
Elapsed Time: 3.16 seconds
```



Reviewing the Simulation Results using **RESULTS GRAPH** and **RESULTS 3D**



Reviewing the Simulation Results using RESULTS GRAPH and RESULTS 3D

We can now look at the simulation run and compare it with the historical data and see how the reservoir would perform.

1. Drag and drop **Tutorial_hm.irf** onto the **Results Graph 2006.10** icon.
2. Select menu item **File**; then **Open Field History**.
3. Select the **production-history.fhf** file we created in the **Creating Field Production History** section of the tutorial.

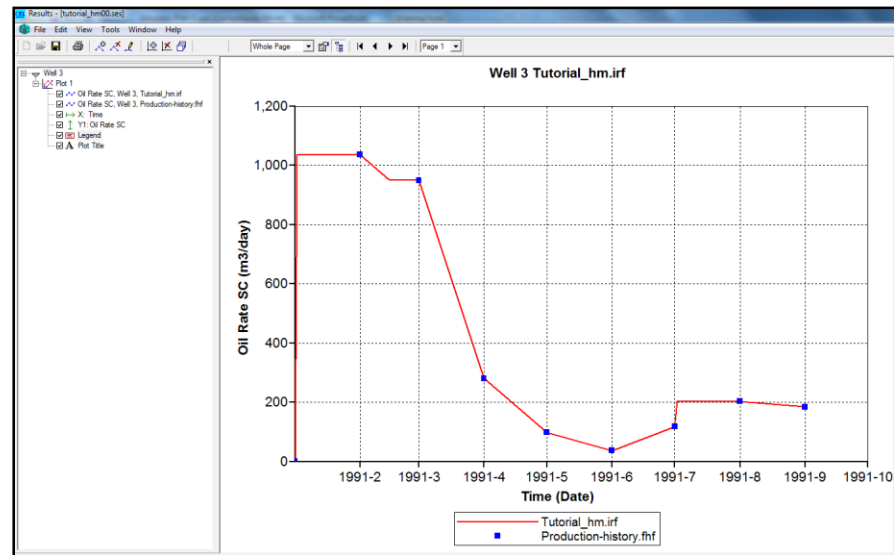
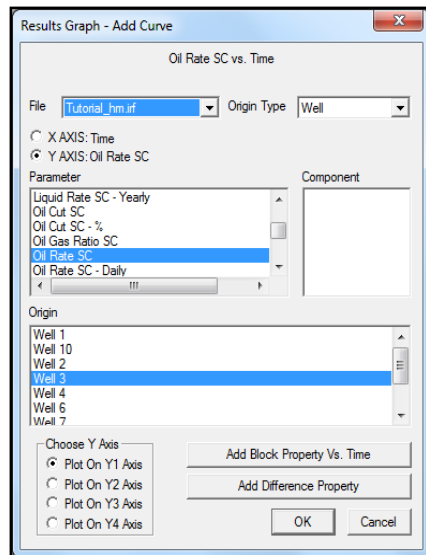


Reviewing the Simulation Results using RESULTS GRAPH and RESULTS 3D

4. Click on the **Add Curve** icon 

5. Select the file to display data from as **Tutorial_hm.irf**. Select curve parameter **Oil Rate SC**. Choose **Well 3** for the Origin and then Click **OK**.

6. Now repeat the same steps but this time select the file as **production-history.fhf**, as we want to compare the simulated data with the historical input data. You should now see a plot similar to:

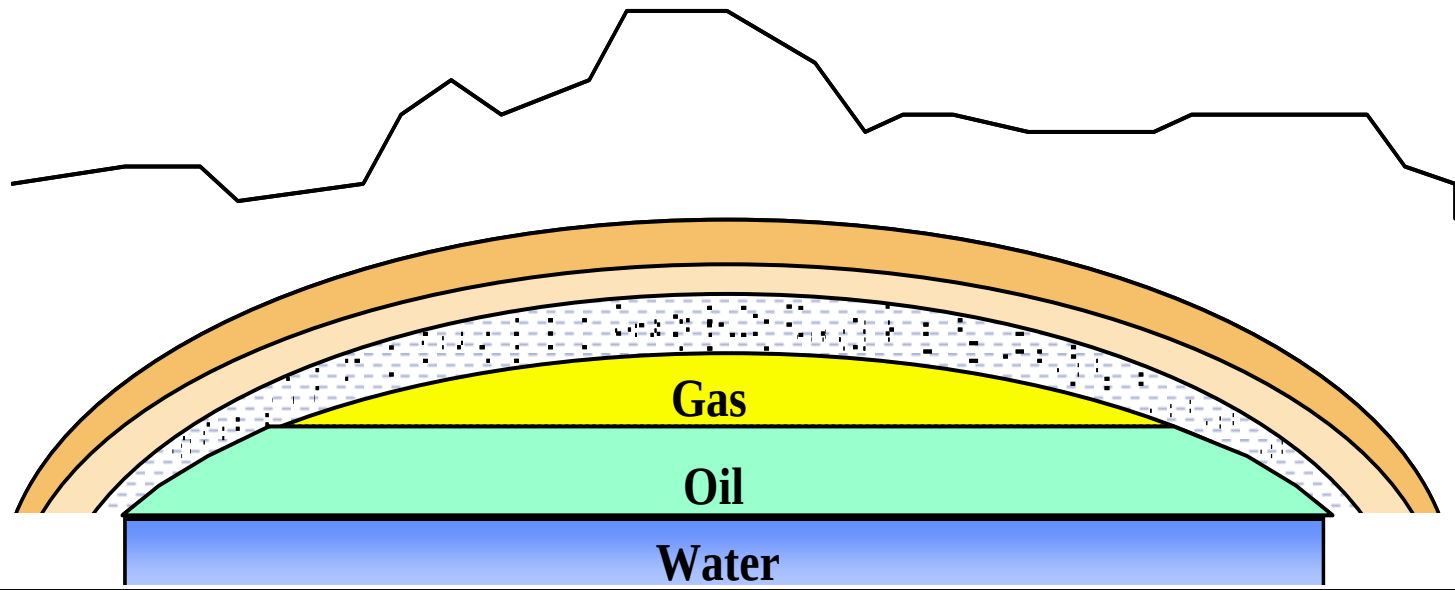


Reviewing the Simulation Results using RESULTS GRAPH and RESULTS 3D

7. Repeat the same procedure as above except this time, plot the **Water Rate SC** & **Gas Rate SC** curves either in the same plot or separately.
8. In order to view this plot for all the production wells you can use the **Repeat origins** button 
9. In the **Repeat Plots** window, select the **All Producers option** and **OK** to generate the plots.
10. You should now have a series of plots showing the historical data and simulator calculation for each of your production wells.
11. You can now continue to investigate the results from these datasets in Results Graph and Results 3D, and interactively discover the large range of features that are available to you for analyzing your data. Exit **Graph** and **save the template file**.



Using the Historical Data Restart File in a Prediction Run



Using the Historical Data Restart File in a Prediction Run

NOW

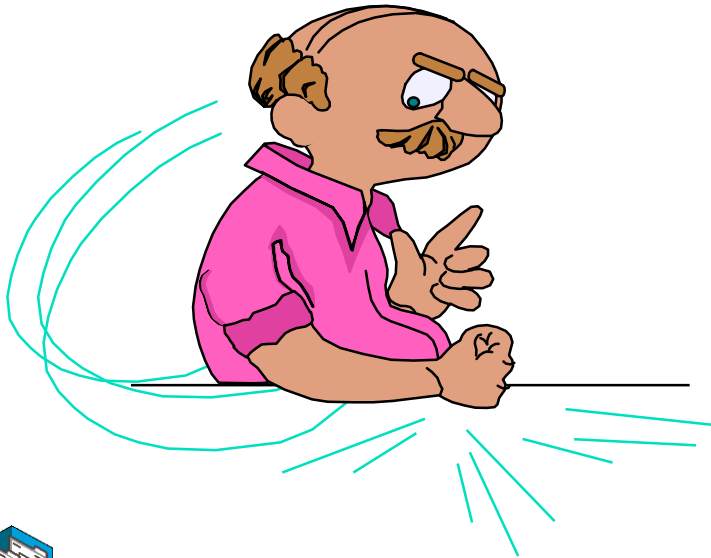
we want to

predict the reservoir performance

until 1993/01/01

if the producers are fixed to a

minimum BHP of 15000 kPa.



Using the Historical Data Restart File in a Prediction Run

1. Load the dataset **tutorial_hm.dat** back into **Builder**.
2. Click on the **I/O Control** tab in the tree view.
3. Double click on the **Restart** option.
4. Check the box for **Restart from previous simulation run (RESTART)**.
5. Browse to select **Tutorial_hm.irf**. Click “**Record to restart from**” (Note that a series of restart dates are now available).
6. In the “**Record to restart from**” field, select the date **1991/09/01** and then press **OK** to exit back to the main **Builder** window (press **OK** to the message that appears).



Using the Historical Data Restart File in a Prediction Run

7. Click on the **Well & Recurrent** section in the tree view and expand the **Dates**.

8. Double click on the date **1991-09-01**.

9. If the **set STOP** box is checked on this date, **uncheck it**. Then click the button **Add a range of dates**.

10. Change the range of dates so that the **From** date is **1991-09-01** and the **To** date is **1993-01-01**.

Press **OK**. Press **Close**.

11. If the **set STOP** box is checked on **1991-09-01**, **uncheck it** and **check 1993-01-01**. Press **Close**.

12. Click on the **Wells & Recurrent** section in the tree view again. Expand the **Well** items in the tree view and double click on **Well 1**.



Using the Historical Data Restart File in a Prediction Run

13. Change the date to **1991-09-01**, check the **Auto-apply** check box, and click on the **Constraints** tab.
14. Check the **Constraint definition** box, then change **OPERATE**, **MIN BHP** to **15000 kPa**.
15. The panel that is displayed should look similar to:
16. Click **Apply**, a new constraint will be created in the date 1991-09-01 for Well 1.

The next task will be to copy the same constraint to all the other wells to do the forecast.

Well Events

displayed wells 9 of 9

1991-09-01

PRODUCER 'Well 1' at 1991-09-01 (33115.00 day)

previous date: 1991-01-01

☒ Constraint definition

#	Constraint	Parameter	Limit/Mode	Value	Action
1	OPERATE	STO surface oil rate	MAX	3062.38 m3/day	CONT
2	OPERATE	BHP bottom hole pressure	MIN	15000 kPa	CONT

select new

< constraint modifiers >

☒ Change current primary constraint (ALTER) ☐ Set new or change old constraint (TARGET)

STO 0 m3/day

Alter: previous date: 1991-08-01

Target: previous date: <none>

Sort by: Name Date Tools

Reset Page ☒ Auto-apply OK Cancel Apply Help



Using the Historical Data Restart File in a Prediction Run

17. Highlight the **Well 1 constraints** Event for **1991-09-01** (in the Name/Date list). Click the **Tools** button at the bottom of the screen and select **Copy events using filter**.

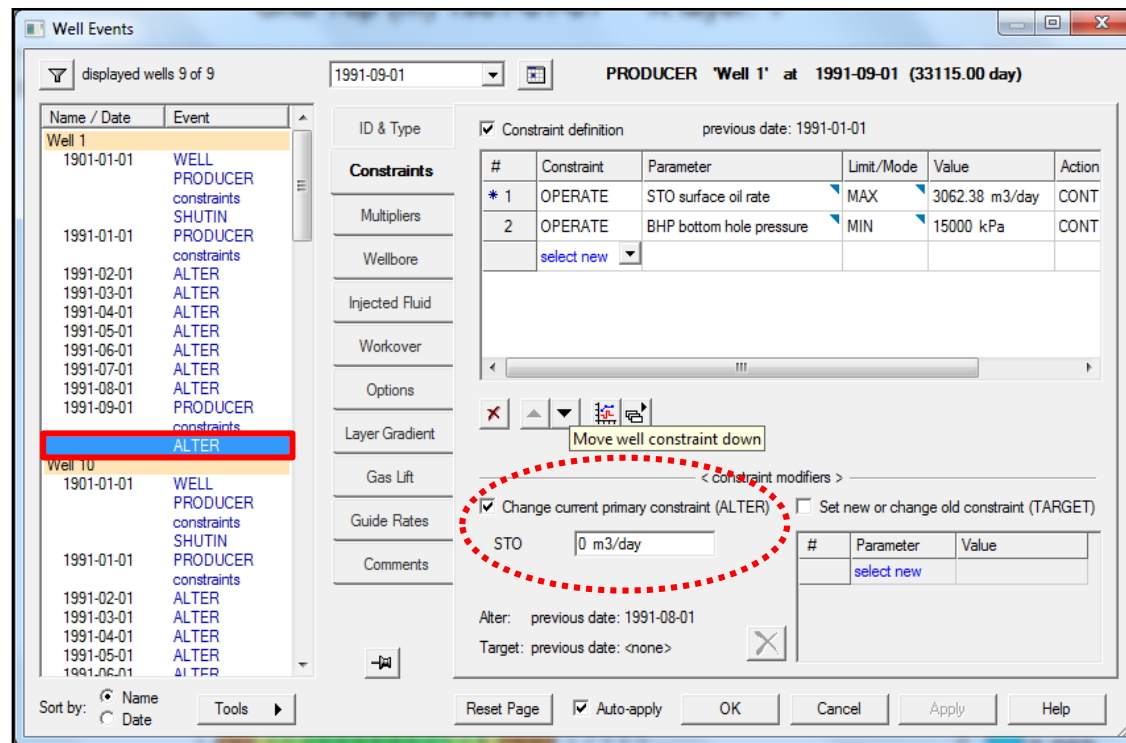
18. Follow the steps below carefully:

- On the “**Select Wells**” tab; **check Producers and Select**.
- Then on the “**Select Dates**” tab **check on 1991-09-01**.
- At this tab; make sure to **check on “Do you want to create new dates?”**. This option creates new date for wells which are already shut in because of production history event.
- **Press the Clear List** button.
- **Press the Search & Add** button, then **OK**. All the wells except wells 7 & 9 will have a new constraint starting 1991-09-01.



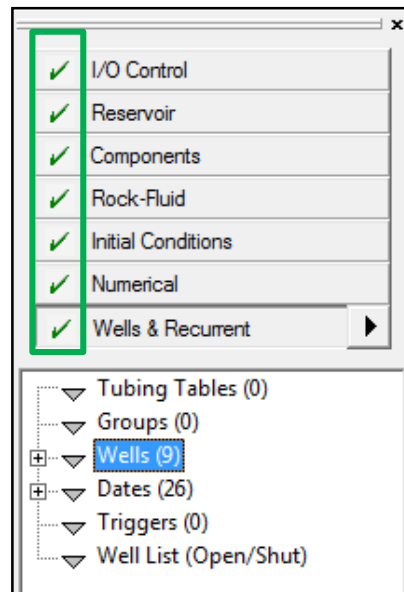
Using the Historical Data Restart File in a Prediction Run

19. On the “Well Event” window; you might see **ALTER** event equal to **0** on **1991-09-01**. This should be **deleted** from prediction data file.



Using the Historical Data Restart File in a Prediction Run

20. Right click on **highlighted ALTER** and select “Delete event using filter..” then repeat **step 17** to fix it.
21. Click **OK** and return to the main menu.
22. Save the new file as **Tutorial_pred.dat**. Now all checkmarks must be **green**.
23. We can now exit Builder and drag and drop the **Tutorial_pred.dat** file onto the **IMEX** icon to run it.



Using the Historical Data Restart File in a Prediction Run

We can now look at the simulation run and compare it with the historical data and see how the reservoir would continue to perform.

24. Drag and drop **Tutorial_pred.irf** onto the **Results Graph 2006.10** icon.

25. Select menu item **File**; then **Open Field History**.

26. Select the **production-history.fhf** file we created in the **Creating Field Production History** section of the tutorial.

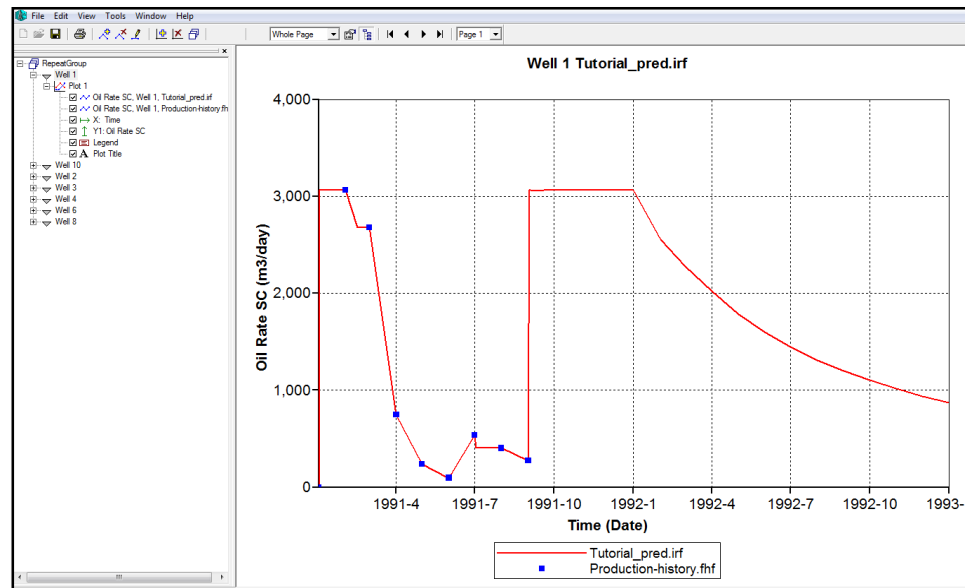


Using the Historical Data Restart File in a Prediction Run

27. Click on the **Add Curve** icon 

28. Select the file to display data from as **Tutorial_pred.irf**. Select curve parameter **Oil Rate SC** and then Click **OK**.

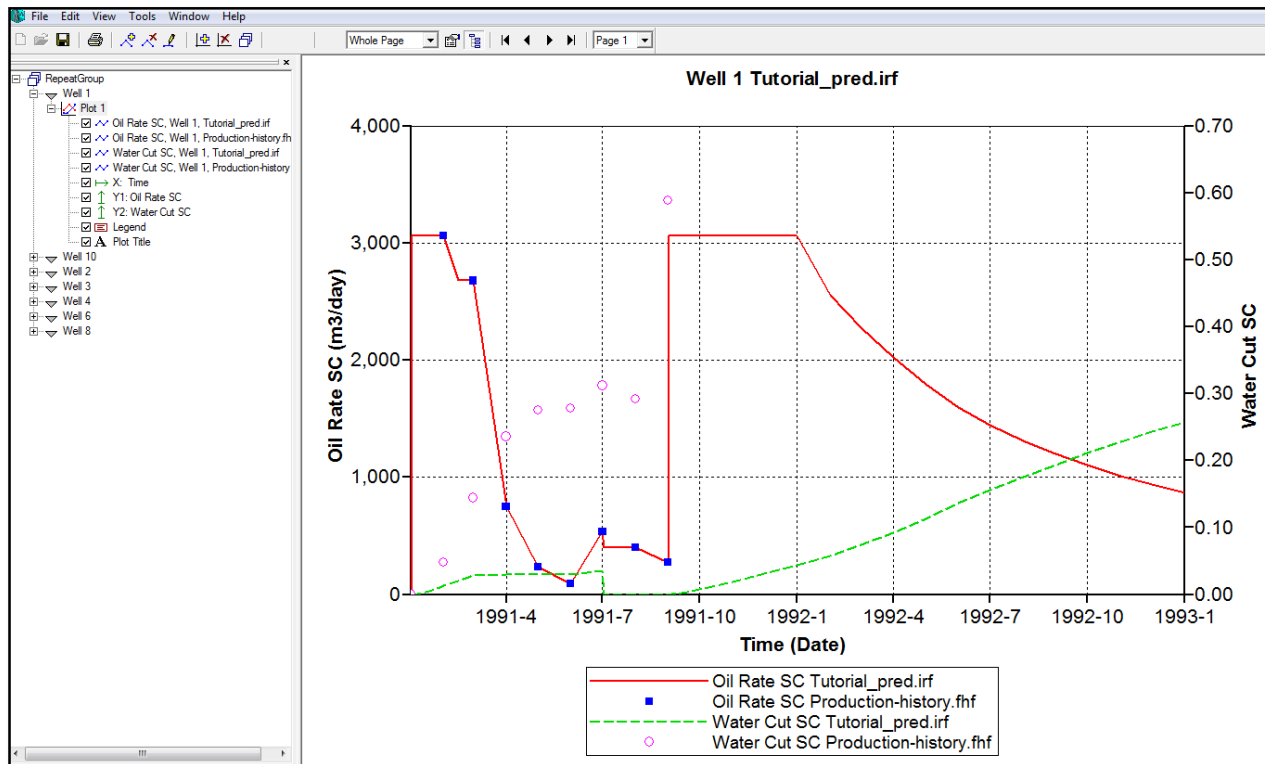
29. Now repeat the same steps but this time select the file as **production-history.fhf**, as we want to compare the prediction run and the history match run. You should now see a plot similar to:



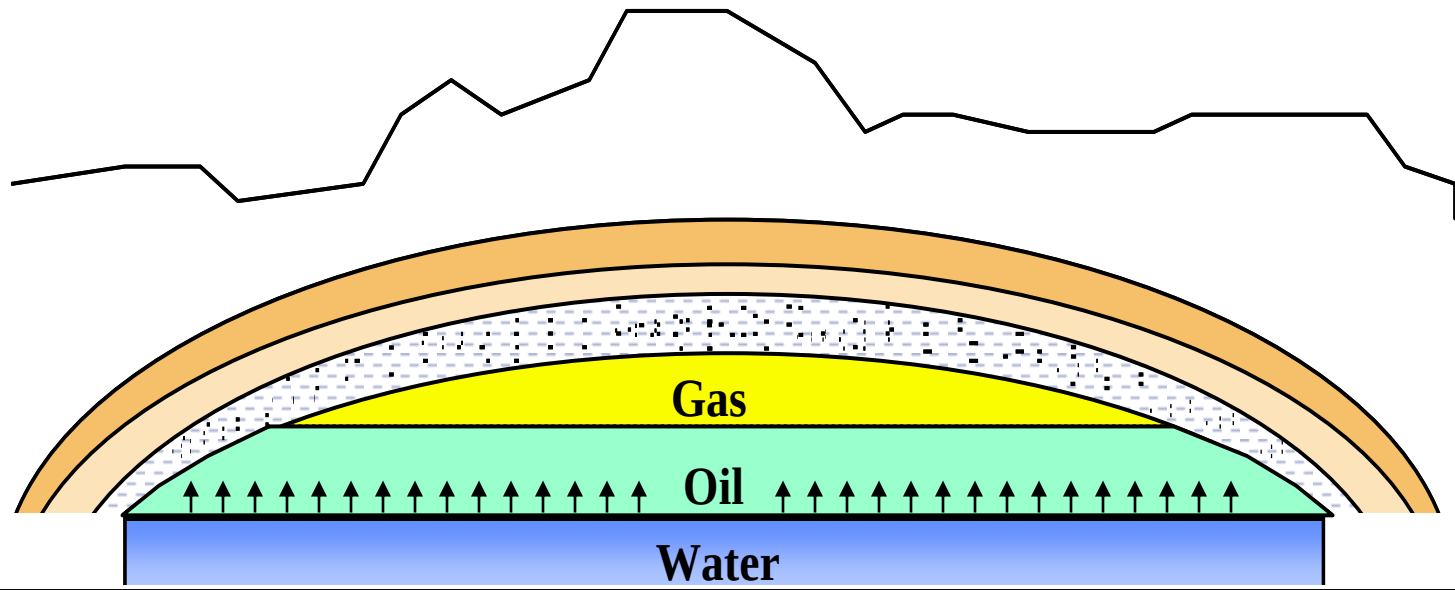
Using the Historical Data Restart File in a Prediction Run

30. You can obtain the same plot for all the producers pressing the **Repeat Plots** button.

31. **Repeat** the same procedure as above except this time plot the **Water Cut** variable.



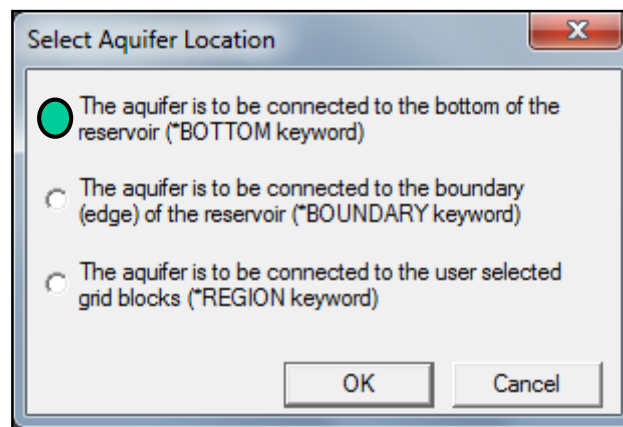
Adding an Aquifer



Adding an Aquifer

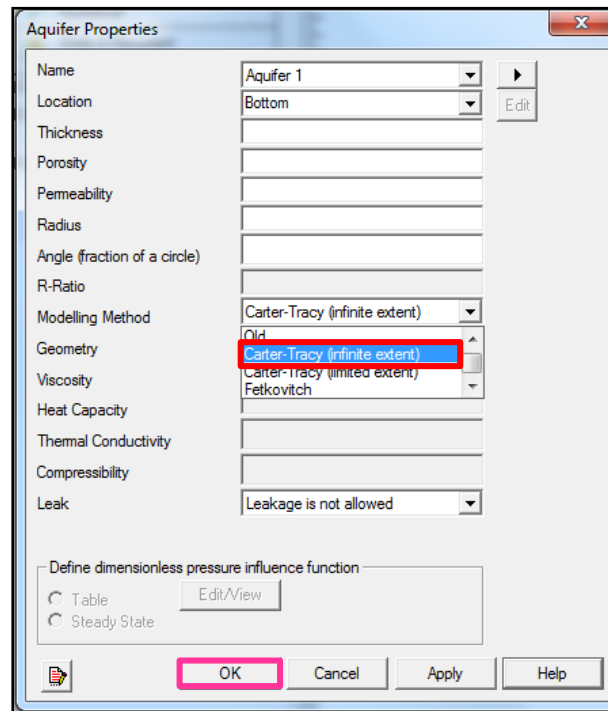
The next thing we want to do is add an aquifer, and compare the simulation runs with and without an aquifer to see the difference it makes.

1. Drag and drop **Tutorial_hm.dat** onto the Builder icon.
2. Once in Builder go to the **Reservoir** and select **Create/Edit Aquifers....**
3. Select the first listed type – **Bottom aquifer**, and **OK** the panel.



Adding an Aquifer

4. Select **Modelling Method – Carter-Tracey (infinite)**. **Leave** all other items blank.
5. **OK** to exit the panel to return to the model display area.
6. Go to **File; Save As** and change the file name to be saved to **Tutorial_hm_aq.dat**.
7. **OK** to save the new file and exit Builder.



You can now drag and drop

Tutorial_hm_aq.dat

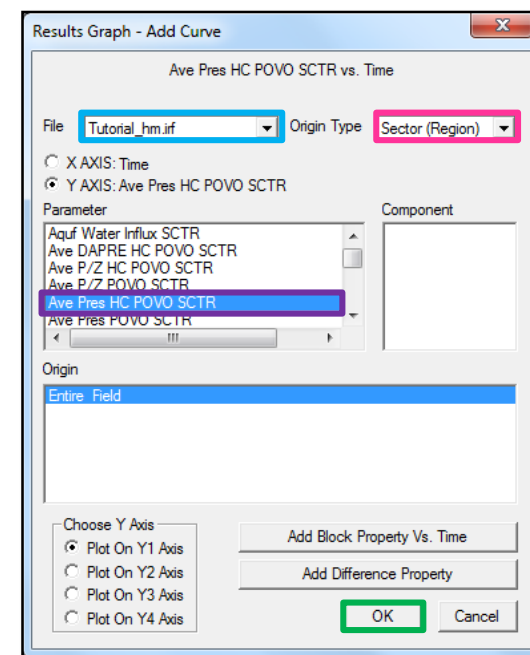
onto the IMEX icon.

(To run simulation)



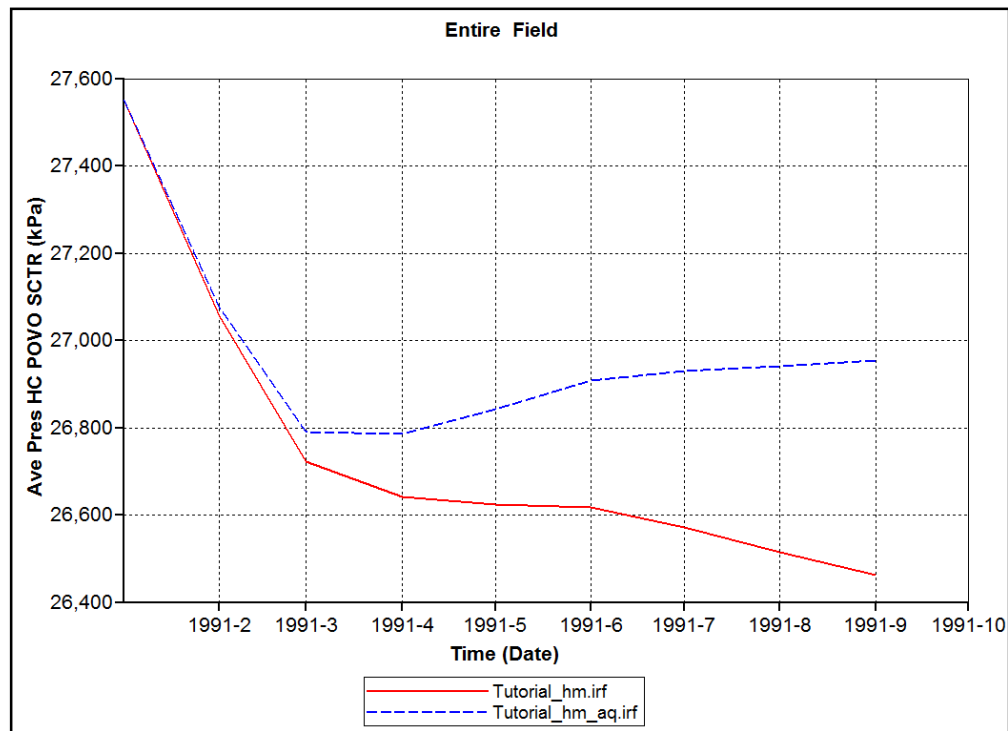
Adding an Aquifer / Analyzing the Data

1. The file **Tutorial_hm_aq.irf** file can be dragged and dropped onto the Results Graph icon.
2. Select **File; Open CMG Simulation Results** from the menu bar and select **Tutorial_hm.irf**.
3. We now have both simulation results loaded so that we can compare them.
4. Click on the **Add Curve** icon 
5. Select File – **Tutorial_hm.irf**.
6. Select Origin Type – **Sector (Region)**.
7. Parameter – **Ave Pres HC POVO SCTR**.
8. Click on **OK** to display the line.
9. Repeat the above except select the filename as **Tutorial_hm_aq.irf**.



Adding an Aquifer / Analyzing the Data

10. We now have a comparison plot that should look similar to:



Adding an Aquifer / Analyzing the Data

11. You can also enter the 3D display area from here (Results 3D) and both types of display are linked together. When you exit Results 3D or Graph, the **.ses** (line plot) or **.3tp** (3D image) file referred to is a template that you can use to re-create the images that you have generated using the same or other input files.

12. Results 3D and Graph are very intuitive and most things can be accessed by the menus or by right mouse clicking on the display areas.



Adding an Aquifer / Further Analysis

When you view the ternary plot for

***Tutorial_pred.irf** in Results 3D it seems that there*

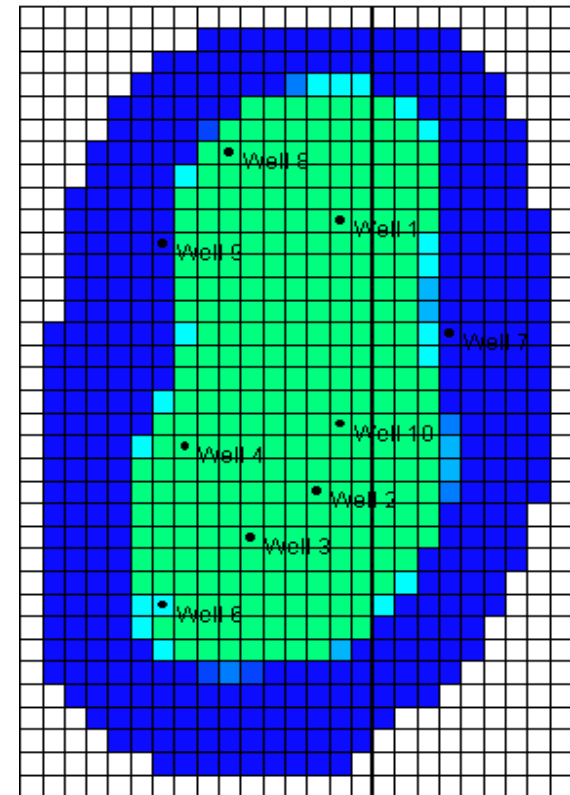
is quite a bit of oil left in the southern anticline at

*the end of this simulation, especially in **layer K = 2**.*

As part of our reservoir plan we would like to put in

*a horizontal well on **1992/1/1** to access this*

‘remaining’ oil.



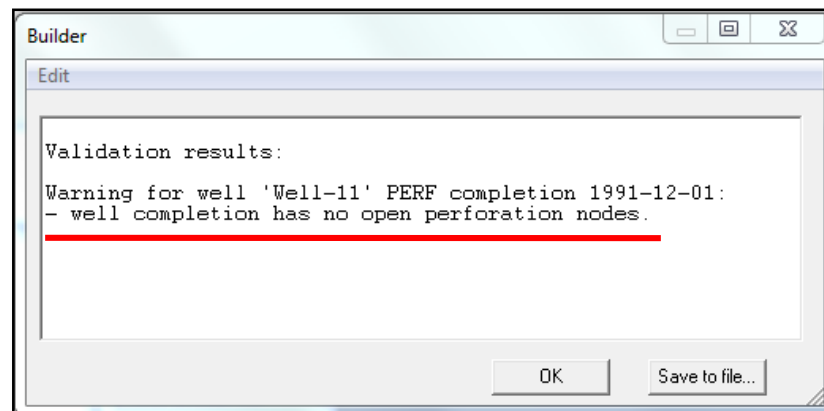
Adding an Aquifer / Further Analysis

1. Load the dataset **Tutorial_pred.dat** into Builder.
2. Make sure you have the **IJ-2D** areal view showing so that we can easily locate the well we are about to add.
3. Click on the **Wells & Recurrent** tab, then right click on **Wells** in the tree view. From the popup menu that appears, select **New...**
4. Name the new well **W11** and change the date to be **1991-12-01**.
5. Select the **Constraints** tab and check the **Constraint definition** check box.
6. Enter the constraint **OPERATE**; **BHP bottom hole pressure**; **MIN**; **10000 kPa**; **CONT REPEAT**.
7. Click **OK** to exit from the Create New Well panel.



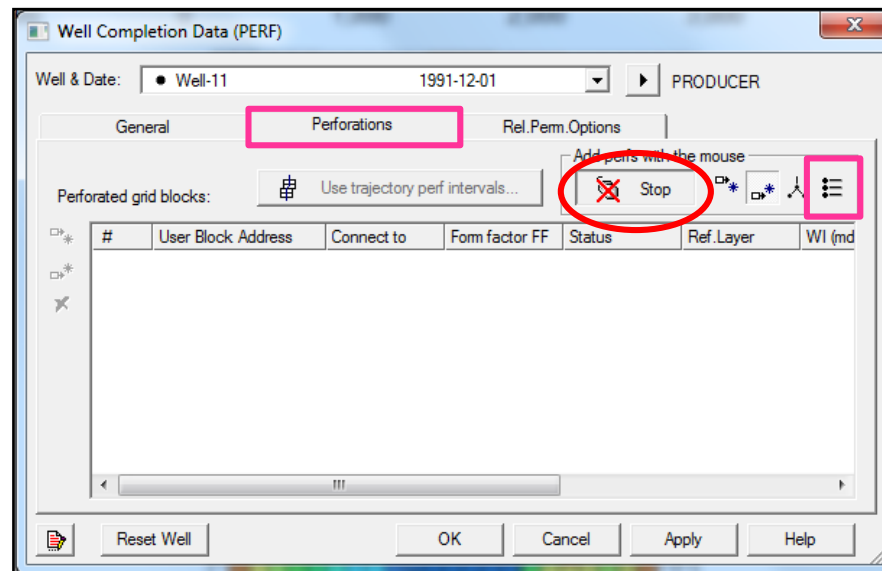
Adding an Aquifer / Further Analysis

8. Well W11 should have appeared on the **Well & Recurrent** tree view. There should be an exclamation mark next to this well indicating that there is a data problem.
9. Right click on this well and select Validate to display any error or warning messages. The message should indicate that there are no valid perforations.



Adding an Aquifer / Further Analysis

10. Click the + sign next to **W11** and double click on **1991-12-01 PERF**.
11. In the Well Completion Data (PERF) panel that appears, select the **Perforations** tab.
12. Click the **Begin** button to Add perfs with the mouse.
13. Then click on the tool button for **Advanced options for perforating intermediate blocks** between mouse clicks.



Adding an Aquifer / Further Analysis

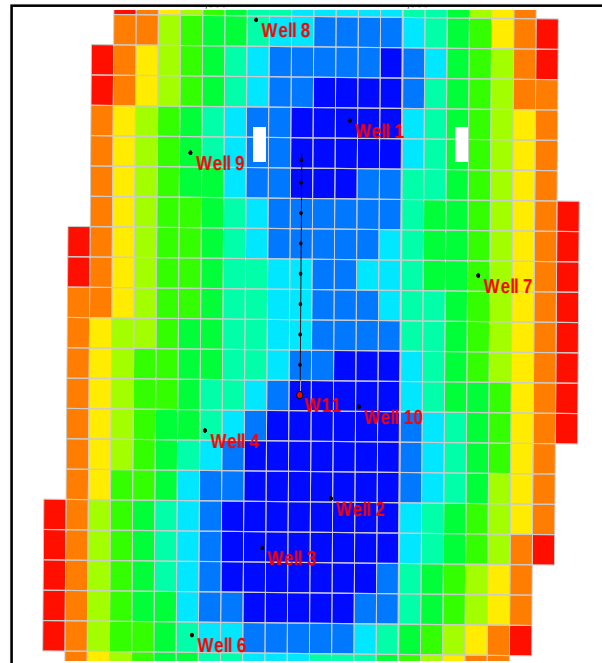
14. Check the **Perforate all intermediate blocks** box, and check the box to **Set constant well length** and change the well length to **1000 m**. Then click OK.

15. Now, move the Well Completion Data (PERF) panel to the side so that the model grid can be viewed. Using the knowledge gained from the previously displayed oil saturation plot from RESULTS 3D, select an area in the model that has both high oil saturation, and low well density. Once the area for the new horizontal has been selected, click once to add the first perforation. Move the mouse to a position approximately near the end of the 1000 m horizontal well and click a second time. Click **OK** to exit.



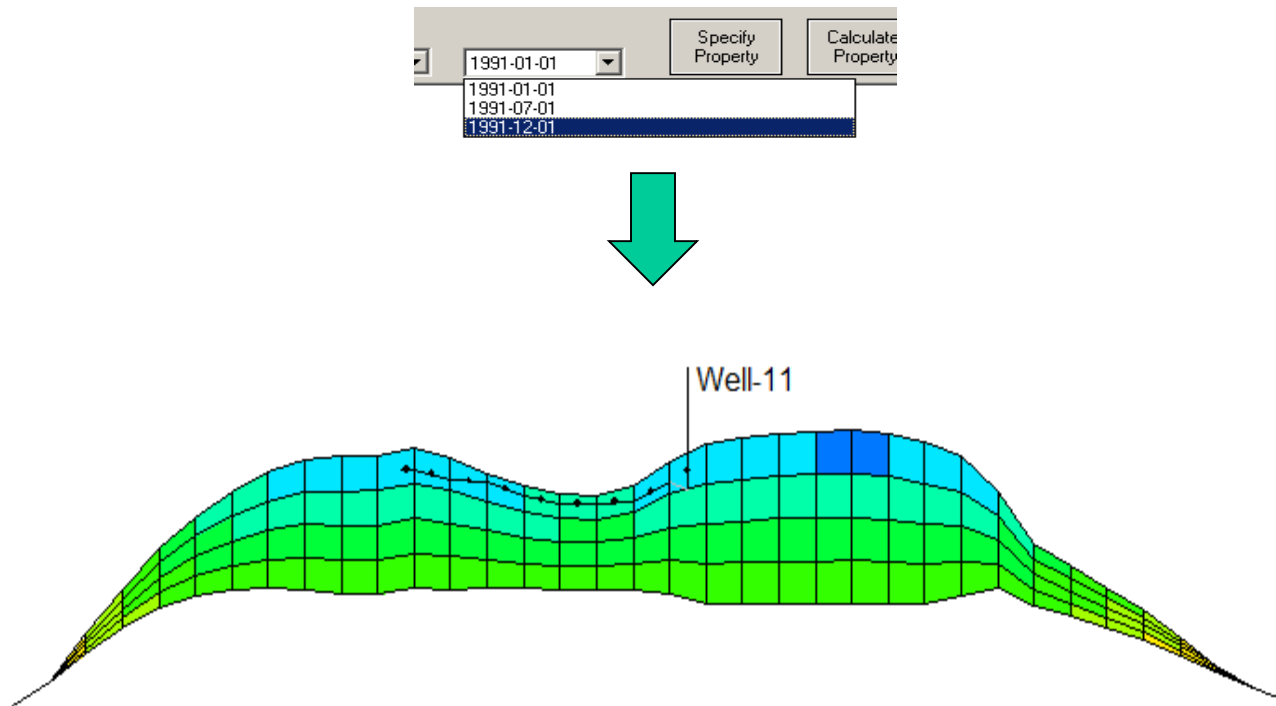
Adding an Aquifer / Further Analysis

16. Well W11 should have appeared on your display. You can also view it in **JK cross section** around **plane 12**. Note, the exact grid block position may vary slightly from that displayed below:



Adding an Aquifer / Further Analysis

17. Note that the perforation will appear and disappear depending on the date you have displayed in Builder.



Adding an Aquifer / Further Analysis

18. Double click on well **W11** to see that there is one date associated with it **1991-12-01**. If there is also the simulation start date **1991-01-01** then select this date in the tree view, right mouse click and select "**Delete**". This will remove this unwanted date.

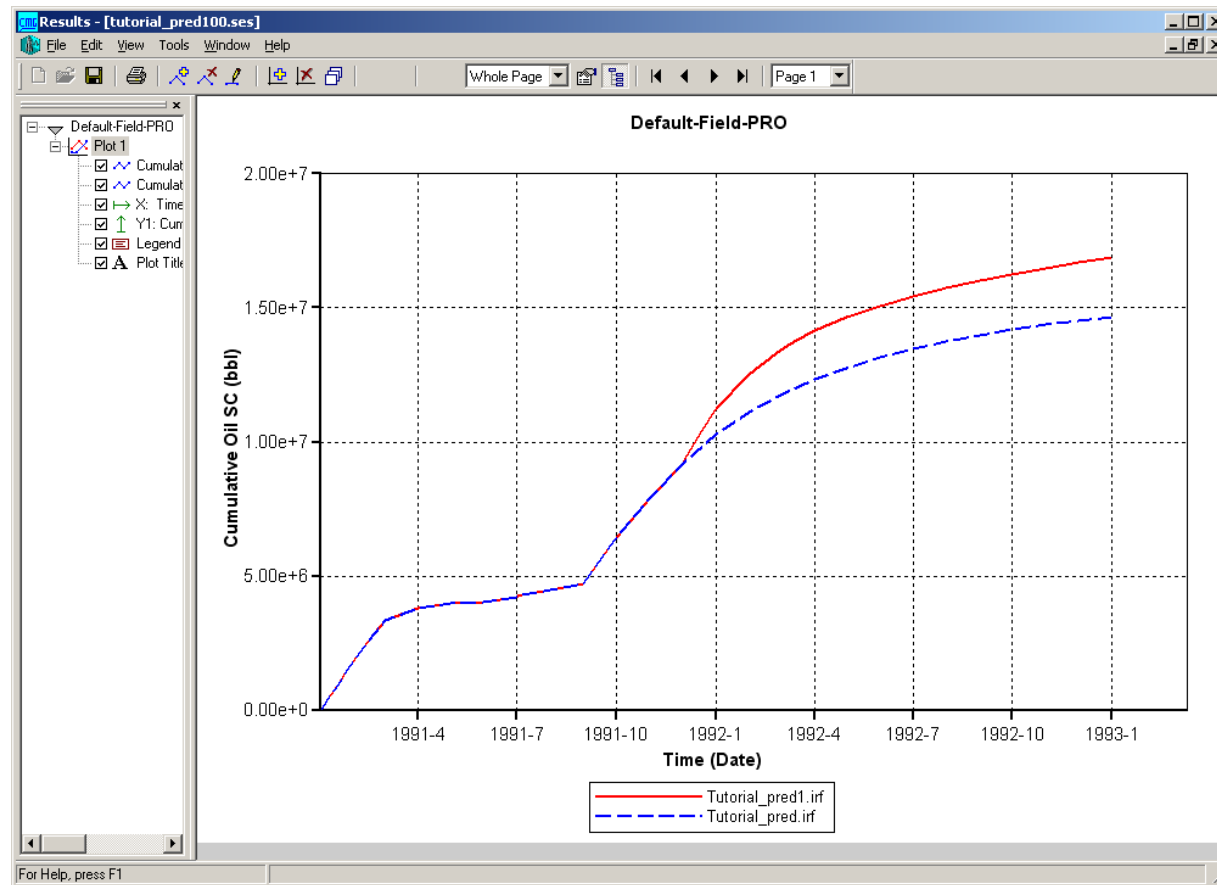
11. "Well 11" is now fully defined. **Save** the dataset as **Tutorial_Pred1.dat**, and exit.

12. Now **run** the dataset in **IMEX** and compare it with **tutorial_pred.irf**. Look at the oil saturation at the end of the simulation in Results 3D and the **Field oil production rate** in Results Graph.

Note the increased production when the horizontal well opens.



Adding an Aquifer / Further Analysis



Good luck

“Mohammad Amin Gholamzadeh”

