

## TUTORIAL #1-1

This tutorial is a minor modification of the model developed in Tutorial 1. This is an example of how to model a pattern area for CO<sub>2</sub> injection that has been previously water flood. It is assumed that the area has been uniformly swept by water down to a uniform oil saturation. In this case, the oil saturation at the end of the water flood is 50 percent. This value is higher than the SORW originally used in Tutorial 1.

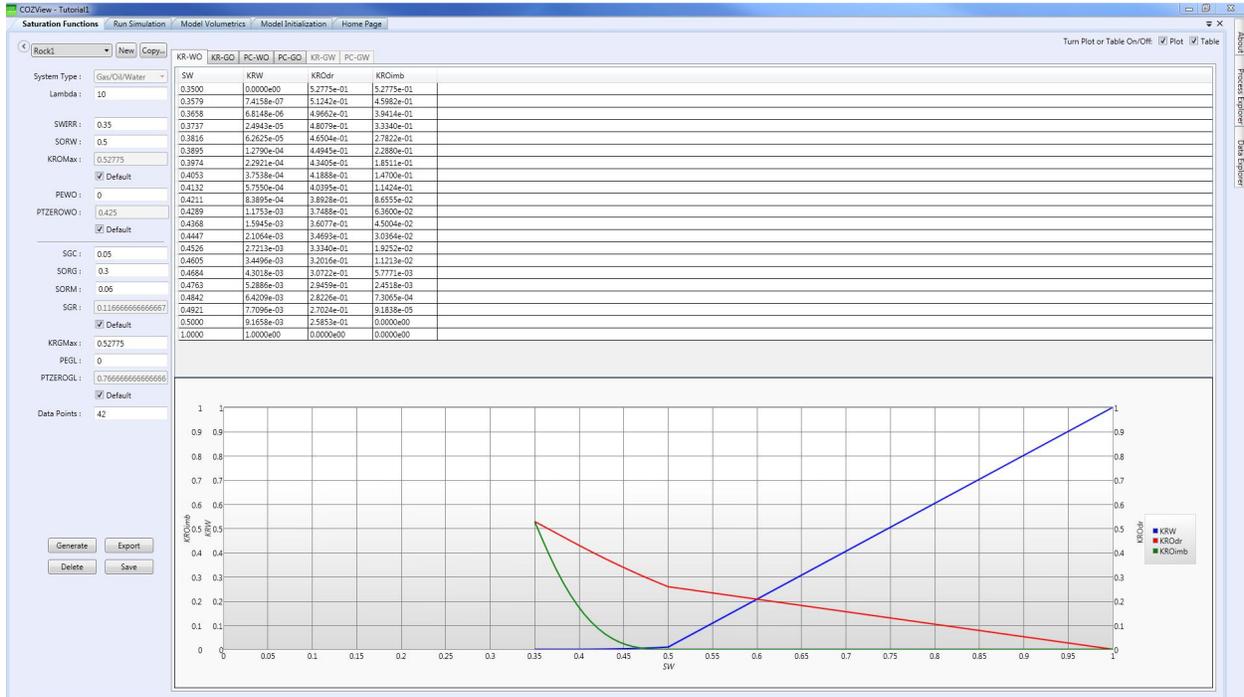
The initial OOIP was 2.79 MMSTB. The reservoir was depleted from 1/1/1990 (2500 psi @ -4500 ft ss) to 1/1/2012 (1500 psi @ -4500 ft ss) during the primary recovery and water flood operations.

This example shows how to quickly initialize the model at the end of the water flood and initiate CO<sub>2</sub> injection. Oil production results for this example are much different than for Tutorial 1 because of the oil saturation in the reservoir at the start of CO<sub>2</sub> injection.

The base case in this tutorial is Tutorial 1. From the *Recent projects* section in COZView Homepage, load the project file for Tutorial 1. It is recommended to save the project under a different name using **Save Project As** in the **Home Page** as we will make minor changes to the original project data.



Select **Saturation Functions** from the **Fluid and Saturation properties** menu area. Select **Rock1** as defined by the user in Tutorial 1. The user should change the Residual oil saturation to water (SORW) from 0.35 (default in Tutorial 1) to 0.5.



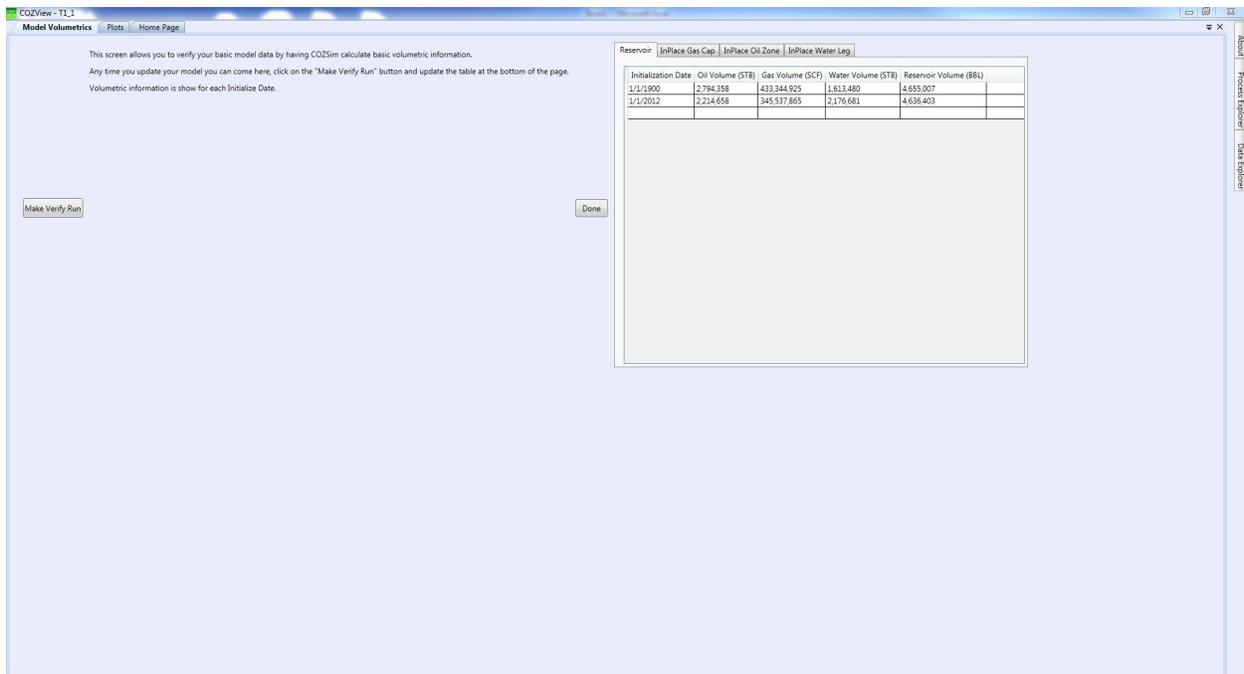
Click **Generate** to update the relative permeability tables and then **Save** the rock properties.

**Model Initialization** should be selected from the **Verify Model** menu area. The user must input two Initialization times and the associated data for 1/1/1990 (start of primary/secondary operations) and 1/1/2012 (end of water flood/start of CO2 injection). The Fluid PVT (**PVT1** is same as in Tutorial 1) and saturation functions (**Rock1**) are as just modified in this section.

- Initialization Date**      **1/1/1990**
- Model Type**                **2 phase**
- Pressure @Ref**            **2500**
- Reference Elevation**      **-4500**
- Elevation @ WOC**        **-5000 (is below the model)**
- PSATHCG**                 **800**

**Initialization Date**      **1/1/2012**  
 Model Type                    2 phase  
 Pressure @Ref                1500  
 Reference Elevation         -4500  
 Elevation @ WOC            -4550 (is below the model)  
 PSATHCG                      800

Selection of **Initialize Model** will provide the results of the volumetric calculation on the **View Model Volumetrics** screen. A brief view of the **Simulator Runner** window will appear before the volumetrics are reported. An OOIP of approximately 2.79 MMSTB should be reported subject to differences in the user defined model and this example for Initialization date 1/1/1990 and OIP of 2.21 MMSTB for 1/1/2012. The difference in oil volumes between the two dates is the “implied” oil recovery over that period. In this example, this is approximately 0.58 MMSTB of oil (21% of the OOIP).



Click **Done** to save the Model Initialization.

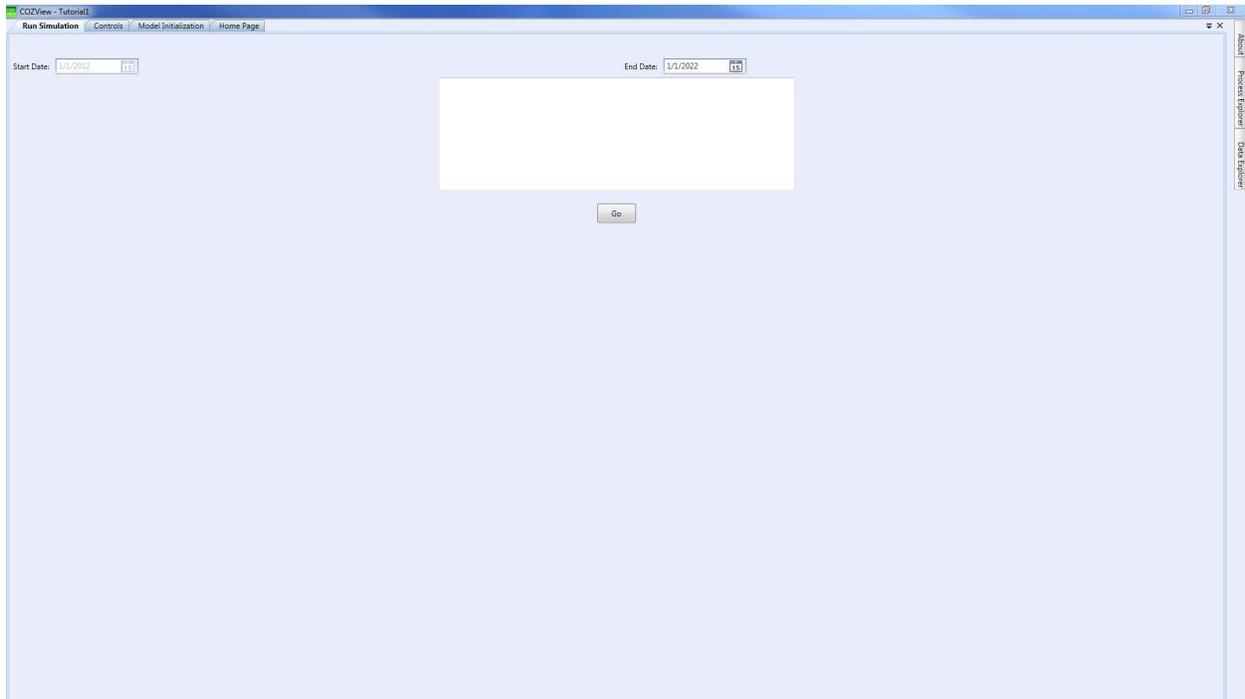
Select **Completions** from the **Well Data** area to view and alter the well completions of the CO2 Injection well (Well 5) which is perforated only in the bottom layer (Layer 3) in this example.

Well	I Coordinate	J Coordinate	K Coordinate	Active?	Open Date	So	Sw	Sg
Well_1	1	1	1	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_1	1	1	2	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_1	1	1	3	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_2	1	1	1	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_2	1	1	2	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_2	1	1	3	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_3	5	1	1	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_3	5	1	2	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_3	5	1	3	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_4	5	1	1	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_4	5	1	2	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_4	5	1	3	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000
Well_5	3	1	1	<input type="checkbox"/>	1/1/2012	0.690	0.350	0.000
Well_5	3	2	1	<input type="checkbox"/>	1/1/2012	0.571	0.429	0.000
Well_5	3	3	1	<input checked="" type="checkbox"/>	1/1/2012	0.500	0.500	0.000

CO2 injection is initiated in 1/1/2012 as in Tutorial 1. There are no field constraints in this example, but CO2 must be selected as the injection gas in the **Field Controls** section. All other data are the same as in the original project.

Field Constraint	Date
Date	1/1/2012 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
Maximum Field Gas Injection Constraint	
Field Gas ReInjection Fraction	
Available External Injection Gas	
Maximum Field Water Injection Constraint	
Field Water ReInjection Fraction	
Available External Injection Water	

Select **Run Simulation**. The last **Model Initialization** date (1/1/2012) will be shown in the **Start Date** box. If this is not correct, return to the **Model Initialization** screen and reset the date and save. The user must provide a value in the **End Date** box. This must be at least one month after the **Start Date**.



The **End Date** for this example is 1/1/2022.

Select **Go** to initiate the simulation run.

The Simulator Runner window will appear and update the CPU activity for the simulation run. **DO NOT** close the Simulator Runner window during the simulation run. It can be minimized. Closing the Simulator runner window will stop the simulation run.

The COZOUT file at the end of this simulation run is shown below.

```

TextPad - [C:\Users\mgaddipati\Desktop\Tutorial Files\T1_2_CCOZOUT]
File Edit Search View Tools Macros Configure Window Help
Document Selector
T1_2_CCOZOUT
T1_2_CCOZOUT
DATE (YYYY MM DD) 1900 1 1
Total Grid Blocks 76
Reservoir Volume - Total 4 455 MMhbl
Reservoir Volume - Gas Cap 0 000 MMhbl
Reservoir Volume - Oil Rim 4 455 MMhbl
Reservoir Volume - Water Leg 0 000 MMhbl
In Place Volume - Total, Oil 2 794 MMSTB
In Place Volume - Total, Gas 433 210 MMSCF
In Place Volume - Total, Water 1 414 MMSTB
In Place Volume - Oil Rim, Oil 433 210 MMSCF
In Place Volume - Oil Rim, Gas 1 414 MMSTB
Mat.Bal Moles Initial Moles Current Moles Added Moles Removed Net Difference
Component: H2O 1.000000 0.3192757E+08 0.5290277E+08 0.2151002E+08 0.0000000E+00 0.0000000E+00
Component: OIL 1.000000 0.4654476E+07 0.2859328E+07 0.0000000E+00 0.1795222E+07 0.0000000E+00
Component: GAS 1.000000 0.1141851E+07 0.7112473E+06 0.0000000E+00 0.4386042E+06 0.0000000E+00
Component: CO2 1.000000 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
DATE (YYYY MM DD) 2012 1 1
Total Grid Blocks 76
Reservoir Volume - Total 4 436 MMhbl
Reservoir Volume - Gas Cap 0 000 MMhbl
Reservoir Volume - Oil Rim 4 436 MMhbl
Reservoir Volume - Water Leg 0 000 MMhbl
In Place Volume - Total, Oil 2 714 MMSTB
In Place Volume - Total, Gas 269 504 MMSCF
In Place Volume - Total, Water 719 MMSTB
In Place Volume - Oil Rim, Oil 269 504 MMSCF
In Place Volume - Oil Rim, Gas 719 MMSTB
Mat.Bal Moles Initial Moles Current Moles Added Moles Removed Net Difference
Component: H2O 1.000000 0.3192757E+08 0.5290277E+08 0.2151002E+08 0.0000000E+00 0.0000000E+00
Component: OIL 1.000000 0.4654476E+07 0.2859328E+07 0.0000000E+00 0.1795222E+07 0.0000000E+00
Component: GAS 1.000000 0.1141851E+07 0.7112473E+06 0.0000000E+00 0.4386042E+06 0.0000000E+00
Component: CO2 1.000000 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
Date: 2012 1 2 09:00:00 TSTEP: 1 SIZE: 1 0000 ITWS: 3 Elapsed time (hh:mm:ss): 0:00:00
Date: 2012 1 3 07:50:14 TSTEP: 2 SIZE: 1 3127 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:00
Date: 2012 1 5 04:45:35 TSTEP: 3 SIZE: 1 9630 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:00
Date: 2012 1 8 05:30:37 TSTEP: 4 SIZE: 2 9535 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:01
Date: 2012 1 12 15:58:09 TSTEP: 5 SIZE: 4 4302 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:01
Date: 2012 1 19 07:27:38 TSTEP: 6 SIZE: 6 4454 ITWS: 5 Elapsed time (hh:mm:ss): 0:00:01
Date: 2012 1 29 06:41:26 TSTEP: 7 SIZE: 9 9680 ITWS: 5 Elapsed time (hh:mm:ss): 0:00:01
Date: 2012 2 1 00:00:00 TSTEP: 8 SIZE: 2 7212 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:01
Material Balance on 2012 3 1 00:00:00 Elapsed time (hh:mm:ss): 0:00:01 Updated Pressure(psi): 1594.59
Component: H2O 1.000000 0.3192757E+08 0.5290277E+08 0.2151002E+08 0.0000000E+00 0.0000000E+00
Component: OIL 1.000000 0.4654476E+07 0.2859328E+07 0.0000000E+00 0.1795222E+07 0.0000000E+00
Component: GAS 1.000000 0.1141851E+07 0.7112473E+06 0.0000000E+00 0.4386042E+06 0.0000000E+00
Component: CO2 1.000000 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
Well Name QoP(STB/D) QwP(MSCF/D) QwP(STB/D) QoP(MSCF/D) QiI(MSCF/D) QiI(STB/D) QcI(MSCF/D) GOR(CF/BB) FW(FRCT) BHP(psi)a IRL(psi)a
Well_1 0.36 0.06 2.16 0.00 0.00 0.00 0.00 167.66 0.85649 1500.00 1523.53
Well_2 0.36 0.06 2.19 0.00 0.00 0.00 0.00 167.77 0.85768 1500.00 1523.78
Well_3 0.36 0.06 2.19 0.00 0.00 0.00 0.00 167.99 0.85986 1500.00 1523.73
Well_4 0.36 0.06 2.19 0.00 0.00 0.00 0.00 167.96 0.85943 1500.00 1523.62
Well_5 1.44 0.24 9.71 0.00 0.00 0.00 0.00 323.56 167.02 0.85609 2500.00 2237.22
Total 1.44 0.24 9.71 0.00 0.00 0.00 0.00 323.56 167.02 0.85609
Well Name Wp(STB) Qo(MSCF) Wp(STB) Cp(MSCF) Cq(MSCF) Wl(STB) Cq(MSCF)
Well_1 0.9130E+01 0.1538E+03 0.5767E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Well_2 0.9170E+01 0.1644E+03 0.5839E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Well_3 0.9129E+01 0.1539E+03 0.5899E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Well_4 0.9117E+01 0.1537E+03 0.5836E+02 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Well_5 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.1131E+05
Total 0.3654E+02 0.6160E+03 0.2333E+03 0.0000E+00 0.0000E+00 0.0000E+00 0.1131E+05
Date: 2012 2 5 22:25:13 TSTEP: 9 SIZE: 4 9342 ITWS: 4 Elapsed time (hh:mm:ss): 0:00:02
Date: 2012 2 13 08:03:02 TSTEP: 10 SIZE: 7 4013 ITWS: 5 Elapsed time (hh:mm:ss): 0:00:02
Date: 2012 2 24 19:29:46 TSTEP: 11 SIZE: 11 1013 ITWS: 5 Elapsed time (hh:mm:ss): 0:00:02

```

In this example, the reservoir is depleted through primary recovery and water flooding from 1/1/1990 to 1/1/2012. The available oil for production at that time is from unswept (residual) oil in the rocks. All producers (Well 1 to Well 4) produce water only for the first three years. Producers start producing oil from 1/1/2015. The field cumulative oil produced (due to CO2 injection) by the end of 10 years (1/1/2022) is 0.57 MMSTB and the cumulative CO2 injected is 2.2 BSCF at that time.

The oil saturation maps below show the oil bank forming around the injection well and moving toward the producers.

