TOGSE 2024

Effective transition from conventional to sustainable energy

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Integrated Production Modelling (MBAL Software) to define the Water Influx Model and Properties of an Aquifer for Libyan Undersaturated Oil Reservoir

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Outline:

- INTRODUCTION
- WATER INFLUX MODEL
- FIELD DATA
- MBAL SOFTWARE
- MBAL SOFTWARE RESULTS ANALYSIS
- CONCLUSION AND RECOMMENDATION

INTRODUCTION

Introduction

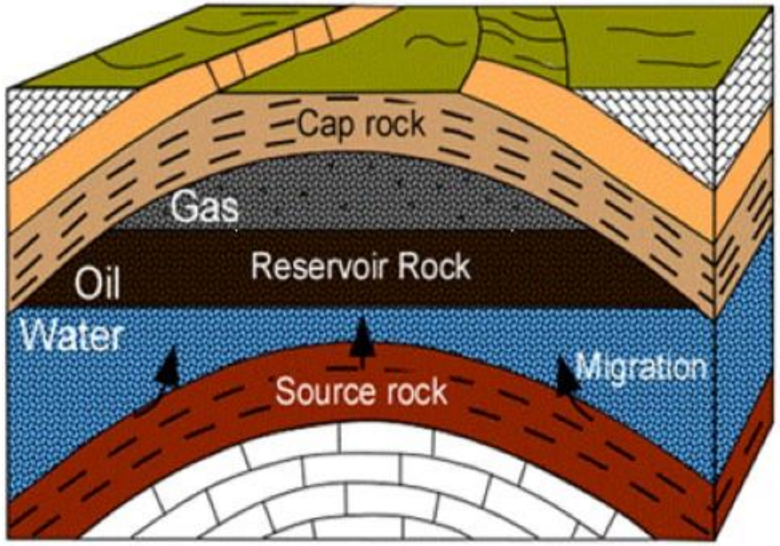
Problem Statement

Objectives

Methodology

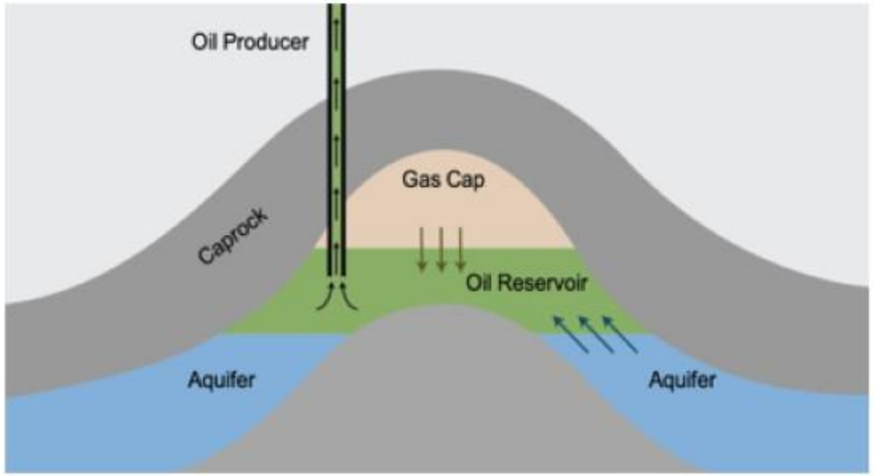
INTRODUCTION

Reservoir performance prediction is important aspect of:	the oil & gas field development planning and
	reserves estimation which depicts the behavior of the reservoir in the future.
This project is conducted in order:	to integrated production modelling (mbal software)
	to define the water influx model and
	its properties of an aquifer for libyan oil reservoir.



INTRODUCTION - Problem Statement

- As reservoir fluids are produced and reservoir pressure declines, a pressure differential develops from the surrounding aquifer into the reservoir.
- Following the basic law of fluid flow in porous media, the aquifer reacts by encroaching across the original hydrocarbon-water contact.
- In some cases, water encroachment occurs due to hydrodynamic conditions and recharge of the formation by surface waters at an outcrop.

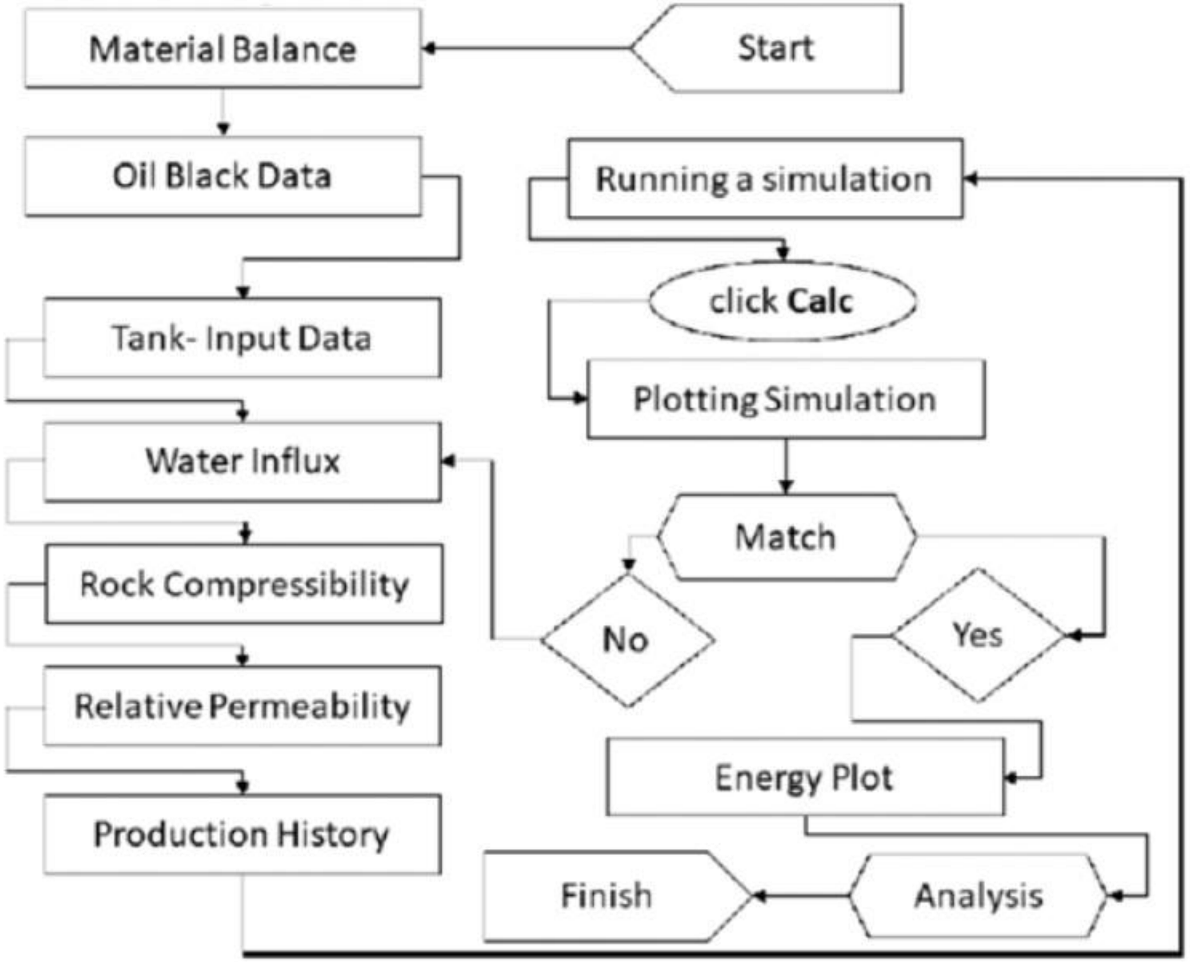


INTRODUCTION - Objectives

Our objectives are to:

- To determine the PVT of oil, gas, and water.
- To determine reservoir driving mechanism.
- To define water influx model.
- To define the properties of an aquifer.

INTRODUCTION - Methodology



Flow Chart Explains the Steps of methodology of MBAL used in this Study After Madi et al 2021

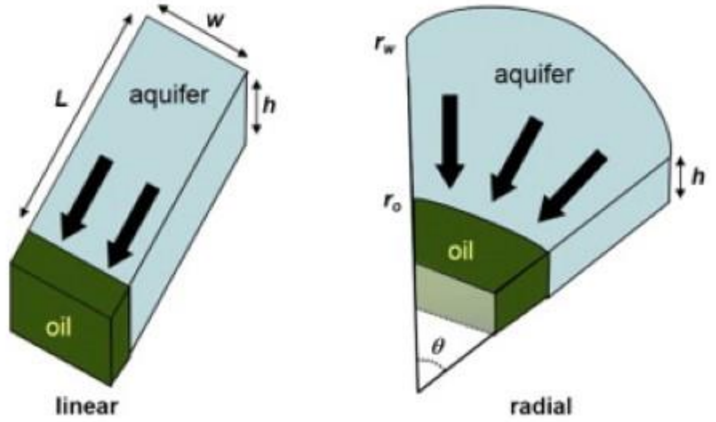
WATER INFLUX MODEL

Classification of Aquifers

Water Influx Models

Water Influx Model

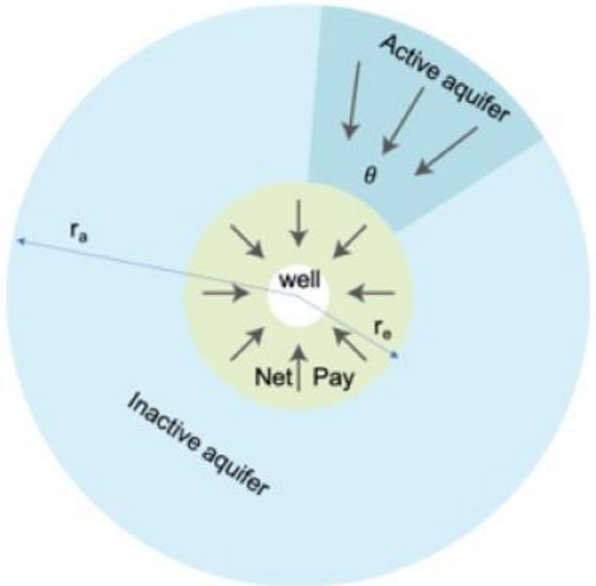
- Most petroleum reservoirs are underlain by water, and water influx into a reservoir almost always takes place at some rate when gas or oil is produced.



Water Influx from the Aquifer

- The mathematical water influx models that are commonly used in the petroleum industry include:

1. Pot aquifer
2. Schilthuis' steady-state
3. Hurst's modified steady-state
4. The Van Everdingen-Hurst unsteady-state
5. The Carter-Tracy unsteady-state
6. Fetkovich's method



FIELD DATA

Libyan Undersaturated Oil Reservoir Properties

Reservoir Fluid Properties

Reservoir Rock Properties

Production History

FIELD DATA - Libyan Undersaturated Oil Reservoir Properties

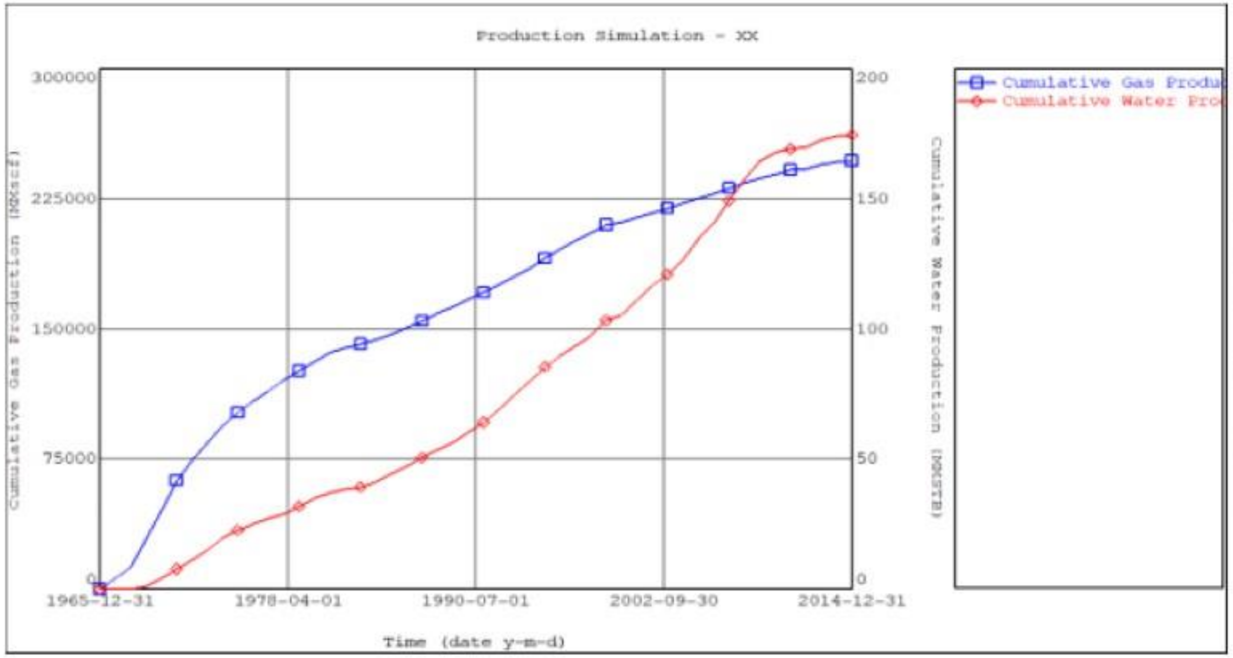
Reservoir Fluid Properties

solution gas–oil ratio GOR	580	SCF/STB
Oil Gravity	36	API
Gas gravity	0.8	API
Water Salinity	190000	
Mole % of CO_2, N_2 and H_2S	0	Percentage

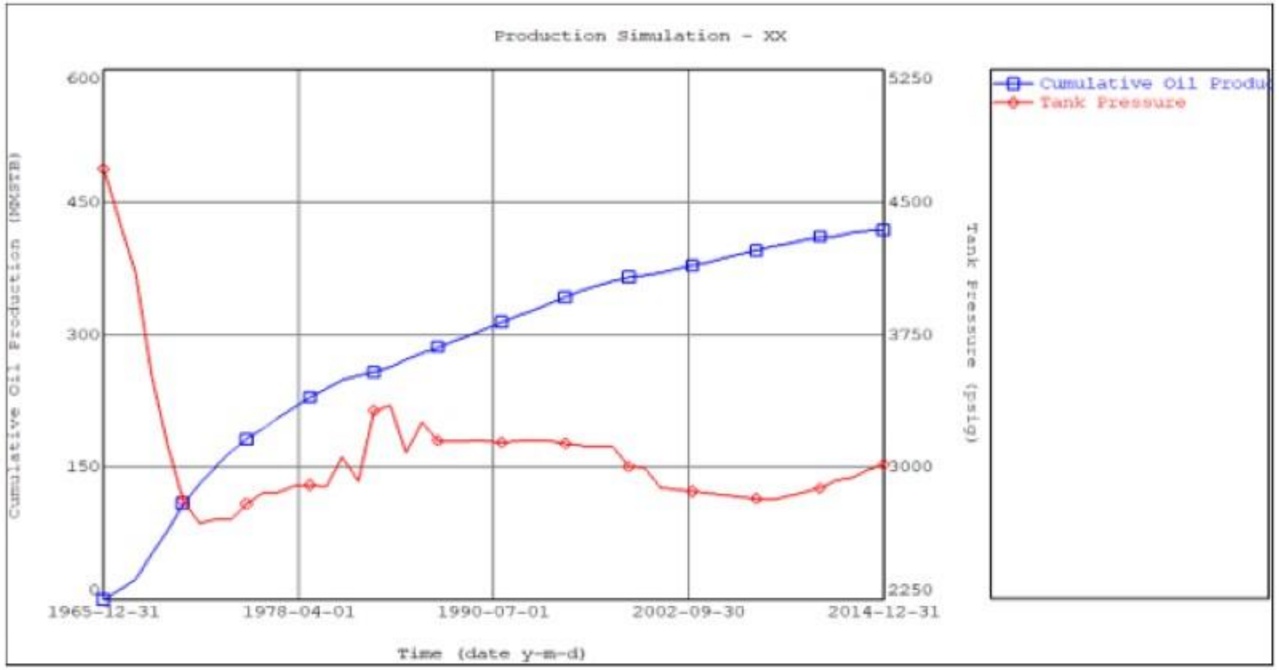
Reservoir Rock Properties

Temperature	240	F°
Porosity	0.2	Fraction
Connate Water Saturation	0.29	Fraction
Water Compressibility	0.000003435	Psi^{-1}

FIELD DATA - Production History



Gas and Water Cumulative vs. time



Oil Cumulative and Pressure vs. time

MBAL SOFTWARE

Tool Options - Material Balance Screen

PVT Oil - Single Stage Separator Screen

PVT Oil Match Input Screen

PVT Fluid Properties Calculation Input Screen

PVT Calculation Results Screen

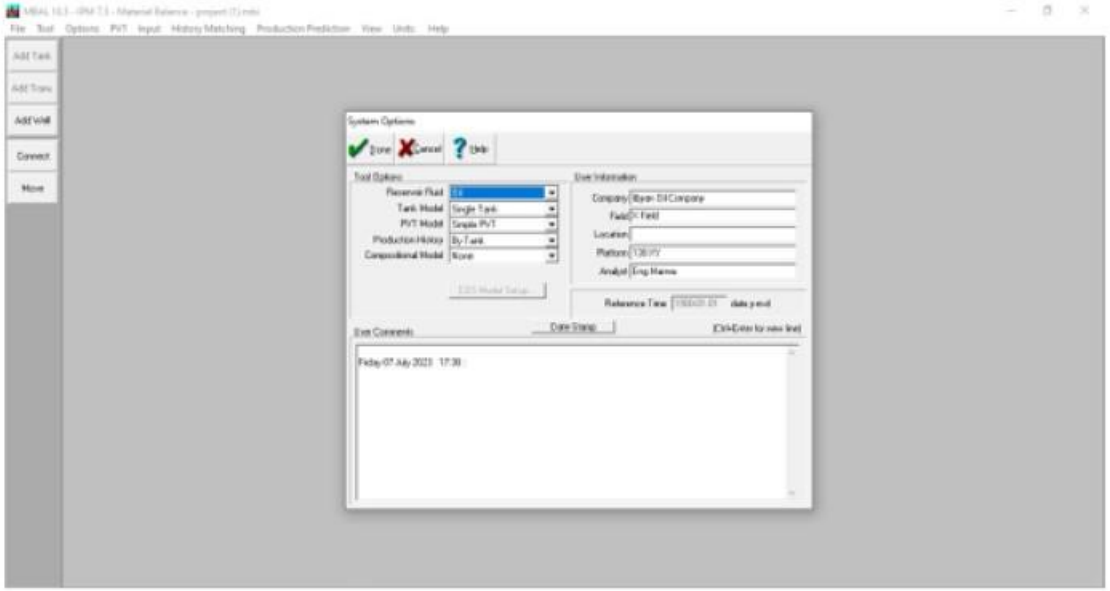
Tank Parameters

Water Influx Modeling Screen

MBAL SOFTWARE - Tool Options - Material Balance

Reservoir Fluid	Oil
Tank Model	Single Tank
PVT Model	Simple PVT
Production History	By Tank
Compositional Model	None
Company	Harouge Oil Company
Field	Amal Field
Platform	130XY
Analyst	Eng. Marwa

Tool Options - Material Balance Screen



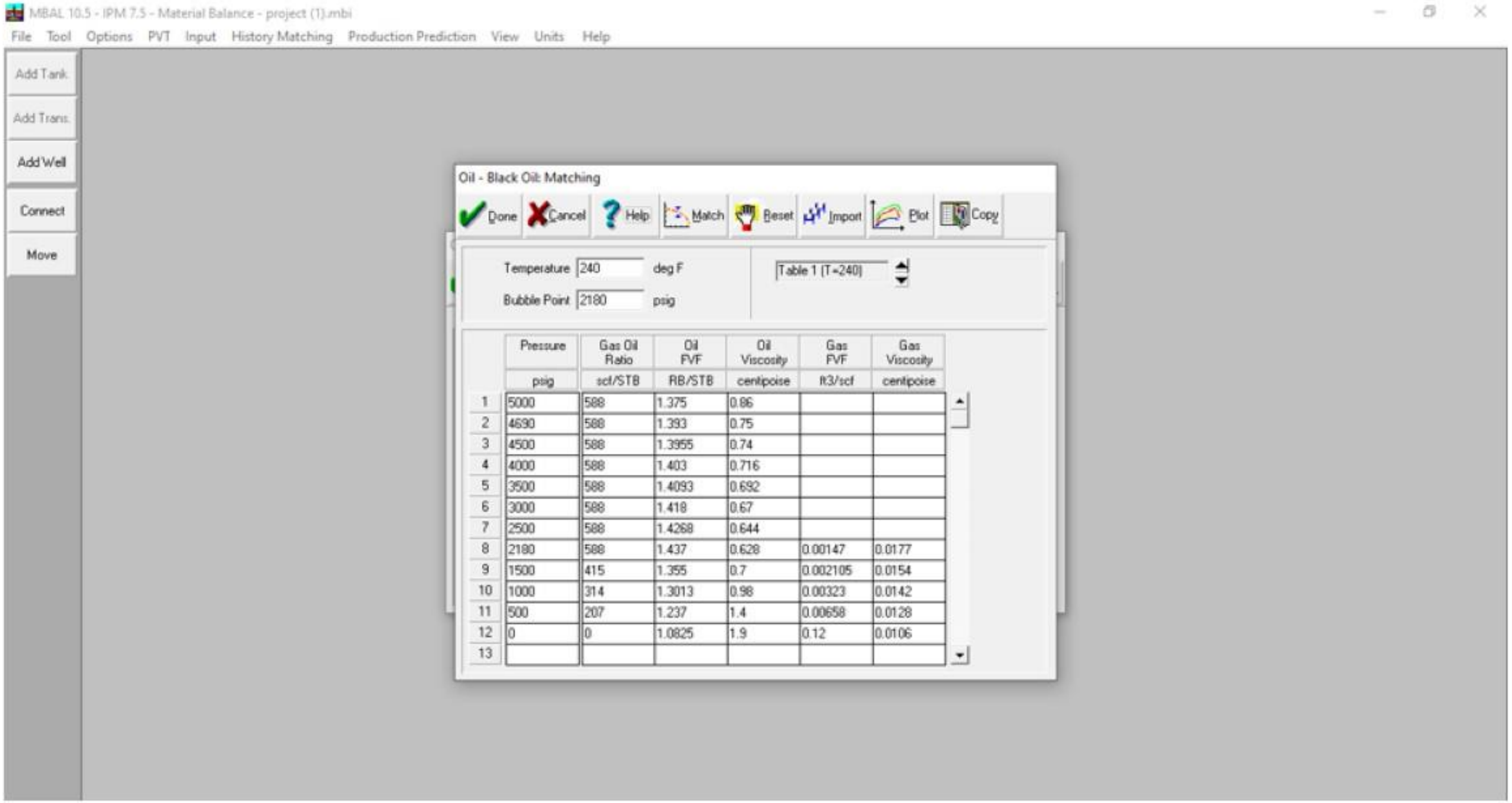
MBAL SOFTWARE - PVT Oil - Single Stage Separator Screen

Formation GOR	580	SCF/STB
Oil Gravity	36	API°
Gas gravity	0.8	API°
Water Salinity	190000	ppt
Mole % of CO2, N2 and H2S	0	percentage

PVT Oil - Single Stage Separator Screen

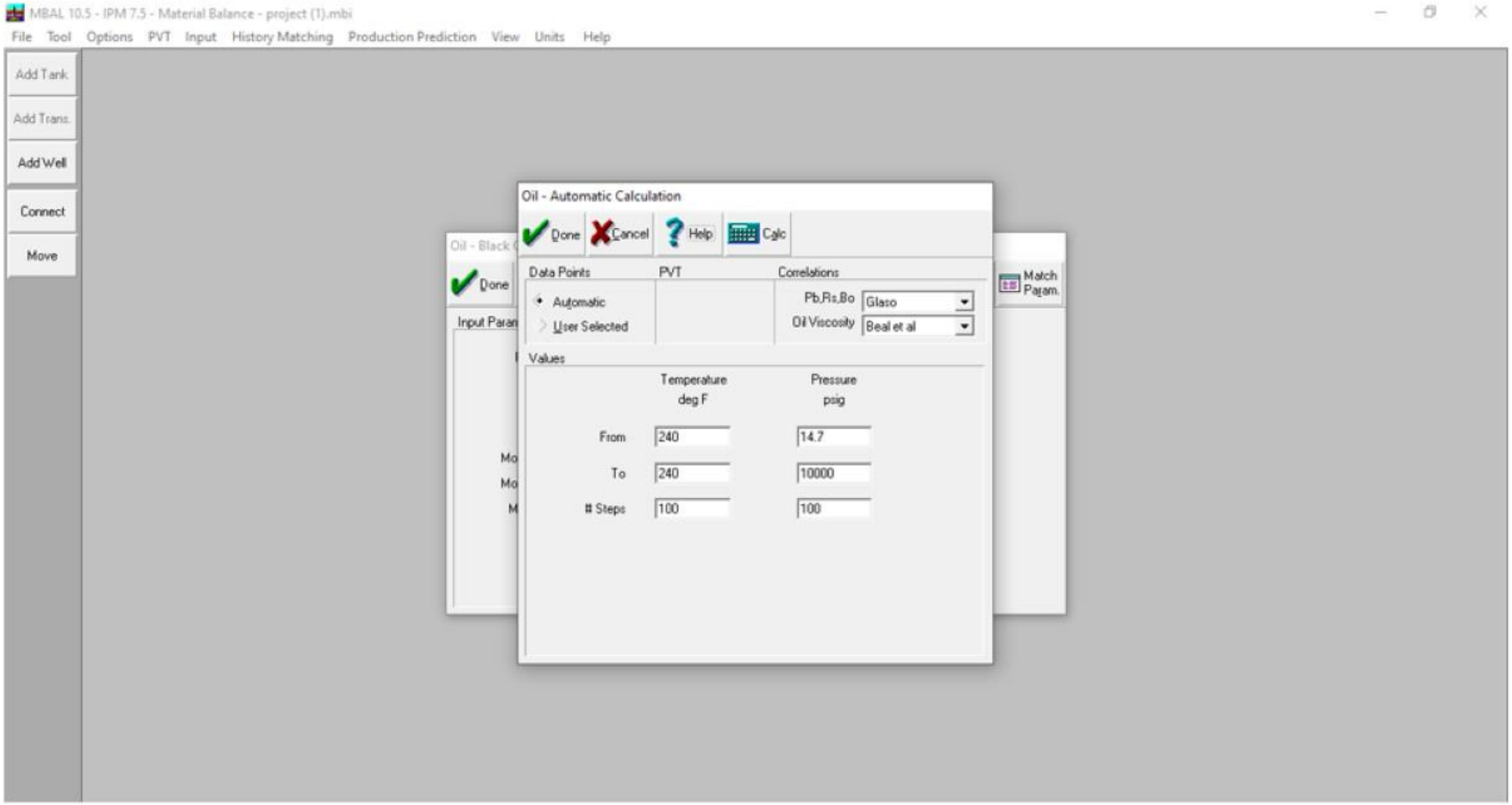
MBAL SOFTWARE - PVT Oil Match Input Screen

PVT Oil Match Input Screen



	Pressure (psig)	Gas Oil Ratio (scf/STB)	Oil FVF (RB/STB)	Oil Viscosity (centipoise)	Gas FVF (ft3/scf)	Gas Viscosity (centipoise)
1	5000	588	1.375	0.86		
2	4690	588	1.393	0.75		
3	4500	588	1.3955	0.74		
4	4000	588	1.403	0.716		
5	3500	588	1.4093	0.692		
6	3000	588	1.418	0.67		
7	2500	588	1.4268	0.644		
8	2180	588	1.437	0.628	0.00147	0.0177
9	1500	415	1.355	0.7	0.002105	0.0154
10	1000	314	1.3013	0.98	0.00323	0.0142
11	500	207	1.237	1.4	0.00658	0.0128
12	0	0	1.0825	1.9	0.12	0.0106
13						

MBAL SOFTWARE - PVT Fluid Properties Calculation Input Screen



MBAL SOFTWARE -PVT Calculation Results Screen

MBAL 10.5 - IPM 7.5 - Material Balance - project (1).mbi

File Tool Options PVT Input History Matching Production Prediction View Units Help

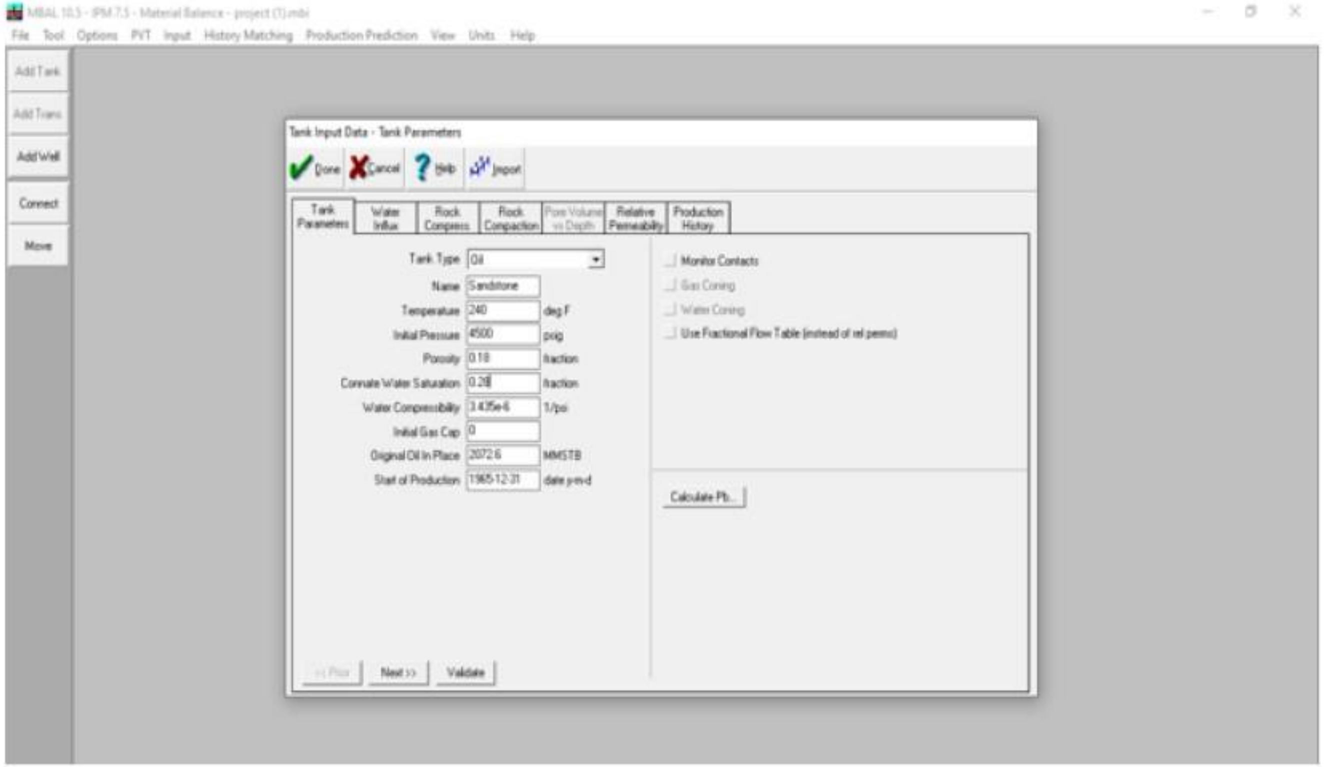
Add Tank | Add Trans. | Add Well | Connect | Move

PVT Calculations

Done | Cancel | Help | Report | Layout | Plot | Calc

Temperature	Pressure	Bubble Point	Gas Oil Ratio	Oil FVF	Oil Viscosity	Z Factor	Gas FVF	Gas Viscosity	Oil Density	Gas Density	Water FVF	Water Viscosity
deg F	psig	psig	scf/STB	RB/STB	centipoise		ft3/scf	centipoise	lb/ft3	lb/ft3	RB/STB	centipoise
240	14.7	2180	6.0858	1.08704	1.8853	0.173195	0.116665	0.0106647	48.5774	0.0910228	1.05475	0.339589
240	114.553	2180	47.4249	1.1179	1.78545	0.613661	0.0940148	0.011104	47.6394	0.40449	1.0544	0.339589
240	214.406	2180	88.7641	1.14875	1.68559	0.825684	0.0713641	0.0115434	46.7518	0.724601	1.05405	0.339589
240	314.259	2180	130.103	1.17961	1.58574	0.809265	0.0487135	0.0119827	45.9107	1.05137	1.0537	0.339589
240	414.112	2180	171.442	1.21046	1.48589	0.564403	0.0260628	0.0124221	45.1124	1.38477	1.05335	0.339589
240	513.965	2180	209.989	1.2388	1.38827	0.173176	0.00648643	0.0128391	44.4194	1.72471	1.053	0.339589
240	613.818	2180	231.357	1.25164	1.30439	0.18465	0.00581742	0.0131187	44.1497	2.07105	1.05265	0.339589
240	713.671	2180	252.726	1.26448	1.22052	0.189377	0.0051484	0.0133983	43.8854	2.42358	1.0523	0.339589
240	813.524	2180	274.094	1.27732	1.13664	0.187357	0.00447939	0.0136779	43.6264	2.78202	1.05195	0.339589
240	913.377	2180	295.463	1.29016	1.05276	0.178589	0.00381037	0.0139575	43.3726	3.14601	1.0516	0.339589
240	1013.23	2180	316.672	1.30272	0.972591	0.16613	0.00320023	0.0142318	43.1318	3.51508	1.05125	0.339589
240	1113.08	2180	336.843	1.31345	0.916674	0.169472	0.00297556	0.0144714	42.9469	3.8887	1.05089	0.339589
240	1212.94	2180	357.013	1.32417	0.860756	0.170548	0.00275089	0.014711	42.765	4.26625	1.05054	0.339589
240	1312.79	2180	377.183	1.33489	0.804838	0.169358	0.00252622	0.0149507	42.586	4.64702	1.05019	0.339589
240	1412.64	2180	397.354	1.34562	0.74892	0.165903	0.00230156	0.0151903	42.4099	5.03022	1.04984	0.339589
240	1512.5	2180	418.179	1.35651	0.698677	0.161449	0.00209333	0.0154423	42.2367	5.41501	1.04949	0.339589
240	1612.35	2180	443.583	1.36855	0.688104	0.164344	0.00200009	0.01578	42.0672	5.80049	1.04914	0.339589
240	1712.2	2180	468.986	1.38059	0.677532	0.166298	0.00190684	0.0161177	41.9008	6.18574	1.04879	0.339589
240	1812.05	2180	494.39	1.39263	0.666959	0.167311	0.0018136	0.0164555	41.7372	6.56984	1.04844	0.339589
240	1911.91	2180	519.794	1.40467	0.656386	0.167384	0.00172035	0.0167932	41.5764	6.95186	1.04809	0.339589
240	2011.76	2180	545.198	1.41671	0.645814	0.166517	0.00162711	0.017131	41.4183	7.33093	1.04774	0.339589
240	2111.61	2180	570.602	1.42875	0.635241	0.164709	0.00153386	0.0174687	41.2629	7.70623	1.04739	0.339589
240	2211.47	2180	588	1.436	0.629573	0.161961	0.00144062	0.0178064	41.1867	8.07697	1.04704	0.339589
240	2311.32	2180	588	1.43281	0.634566	0.158272	0.00134737	0.0181442	41.2782	8.44249	1.04669	0.339589
240	2411.17	2180	588	1.42963	0.639559	0.153643	0.00125413	0.0184819	41.3701	8.80219	1.04634	0.339589

MBAL SOFTWARE - Tank Parameters



Tank Parameters Screen

Tank type	Oil	
Name	Sandstone	
Temperature	240	F°
Initial Pressure	4500	psig
Porosity	0.18	Percentage
Connate Water Saturation	0.28	Percentage
Water Compressibility	0.000003435	Psig
Initial Gas Cap	0	MMscf
Original Oil/Gas in Place	2134	MMstb
Start of Production	1965-12-31	Y-M-D

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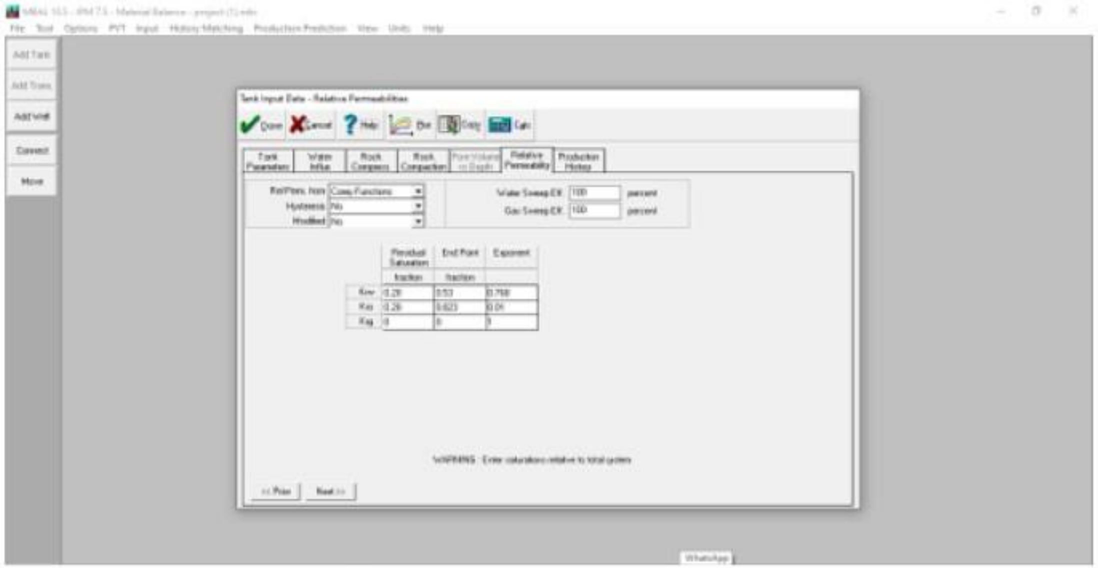
MBAL SOFTWARE -Relative Permeability Values

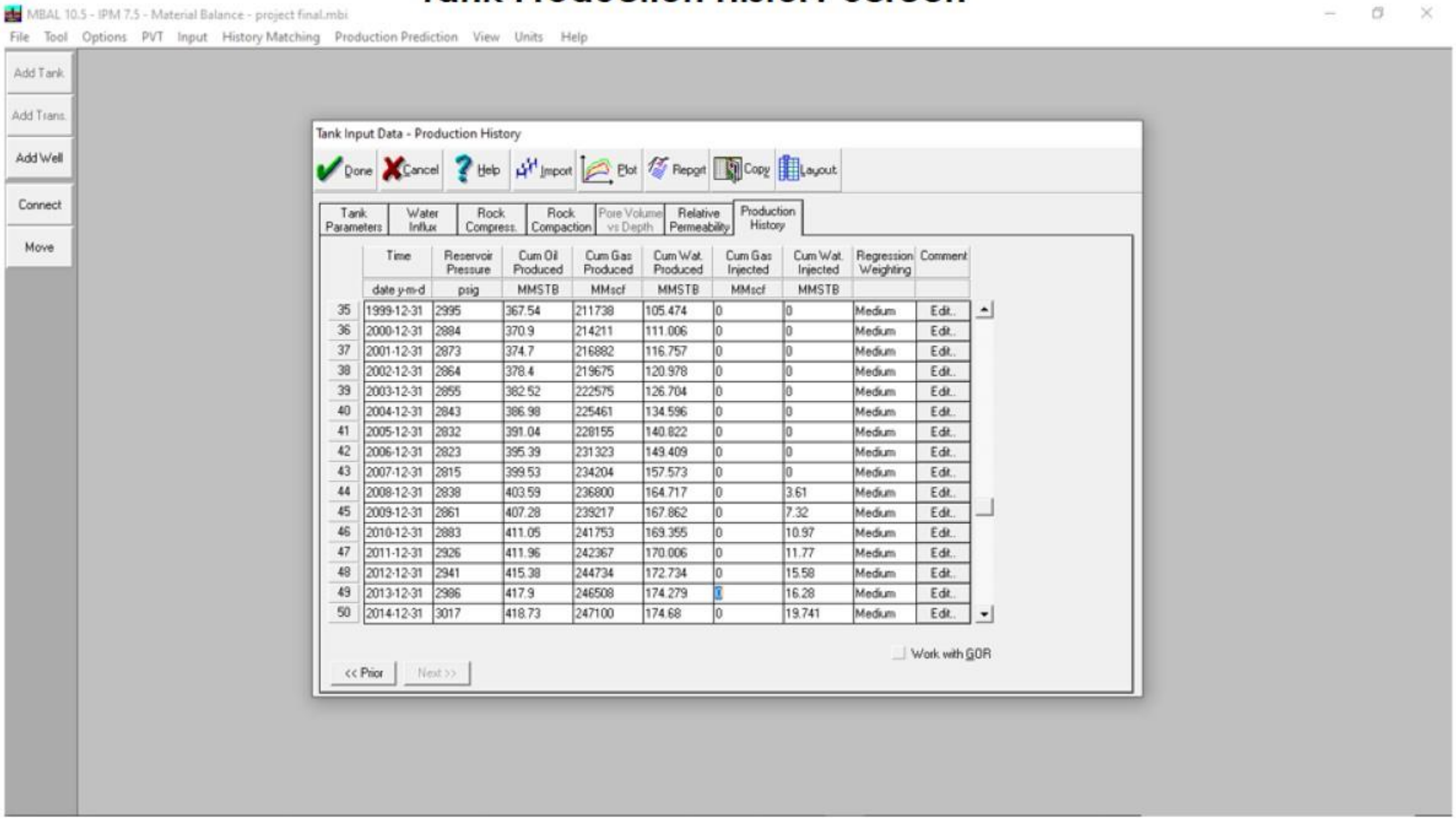
	Residual Saturations	End Points	Corey Exponents	
Krw	0.280	0.530	0.768	md
Kro	0.280	0.823	0.010	md
Krg	0.000	0.000	1.000	md

Relative Permeability Screen



MBAL SOFTWARE -Tank Production History Screen

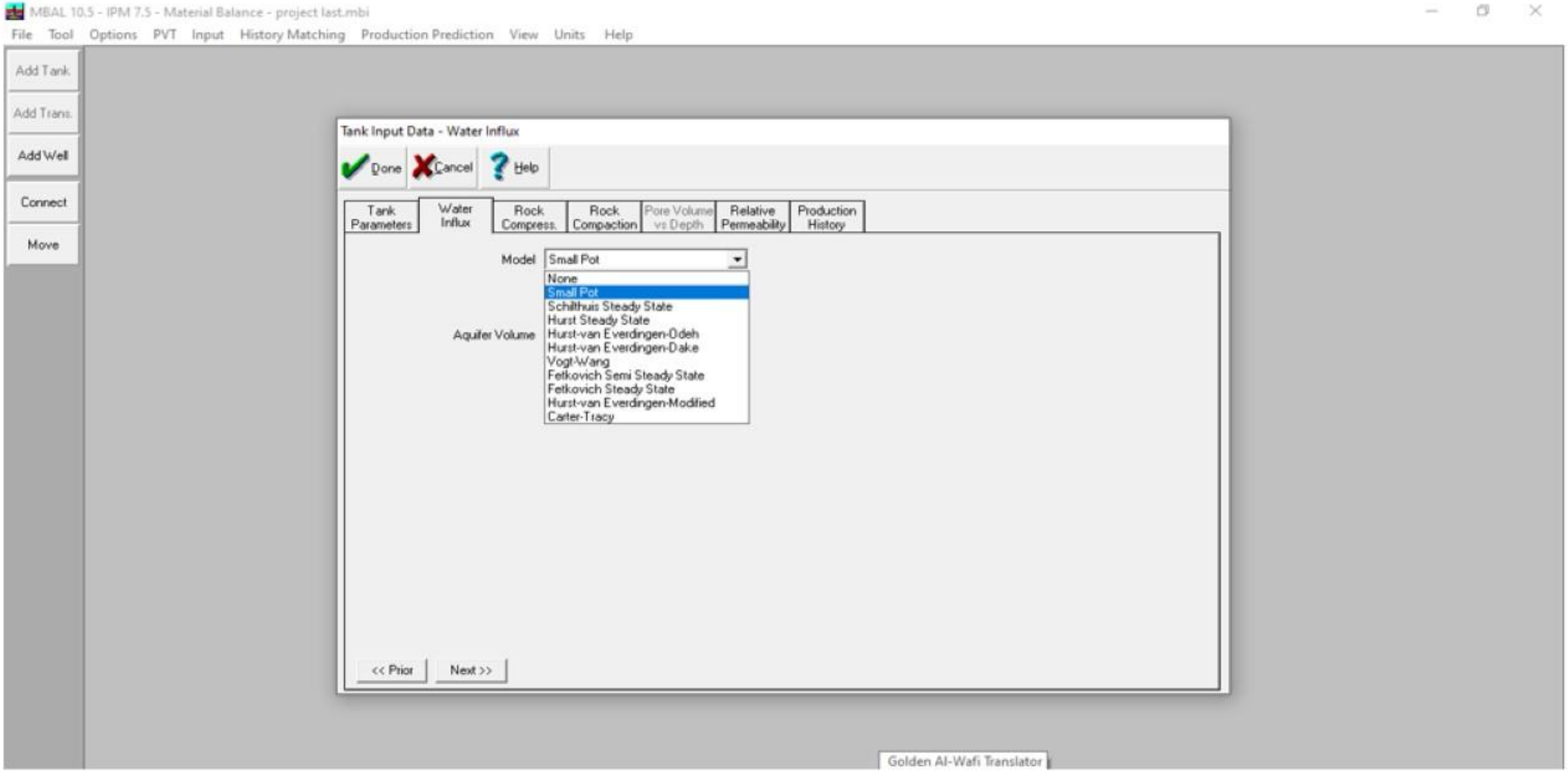
Tank Production History Screen



	Time	Reservoir Pressure	Cum Oil Produced	Cum Gas Produced	Cum Wat. Produced	Cum Gas Injected	Cum Wat. Injected	Regression Weighting	Comment
	date y-m-d	psig	MMSTB	MMscf	MMSTB	MMscf	MMSTB		
35	1999-12-31	2995	367.54	211738	105.474	0	0	Medium	Edit..
36	2000-12-31	2884	370.9	214211	111.006	0	0	Medium	Edit..
37	2001-12-31	2873	374.7	216882	116.757	0	0	Medium	Edit..
38	2002-12-31	2864	378.4	219675	120.978	0	0	Medium	Edit..
39	2003-12-31	2855	382.52	222575	126.704	0	0	Medium	Edit..
40	2004-12-31	2843	386.98	225461	134.596	0	0	Medium	Edit..
41	2005-12-31	2832	391.04	228155	140.822	0	0	Medium	Edit..
42	2006-12-31	2823	395.39	231323	149.409	0	0	Medium	Edit..
43	2007-12-31	2815	399.53	234204	157.573	0	0	Medium	Edit..
44	2008-12-31	2838	403.59	236800	164.717	0	3.61	Medium	Edit..
45	2009-12-31	2861	407.28	239217	167.862	0	7.32	Medium	Edit..
46	2010-12-31	2883	411.05	241753	169.355	0	10.97	Medium	Edit..
47	2011-12-31	2926	411.96	242367	170.006	0	11.77	Medium	Edit..
48	2012-12-31	2941	415.38	244734	172.734	0	15.58	Medium	Edit..
49	2013-12-31	2986	417.9	246508	174.279	0	16.28	Medium	Edit..
50	2014-12-31	3017	418.73	247100	174.68	0	19.741	Medium	Edit..

MBAL SOFTWARE -Water Influx Modeling Screen

Water Influx Modeling Screen



MBAL SOFTWARE RESULTS ANALYSIS

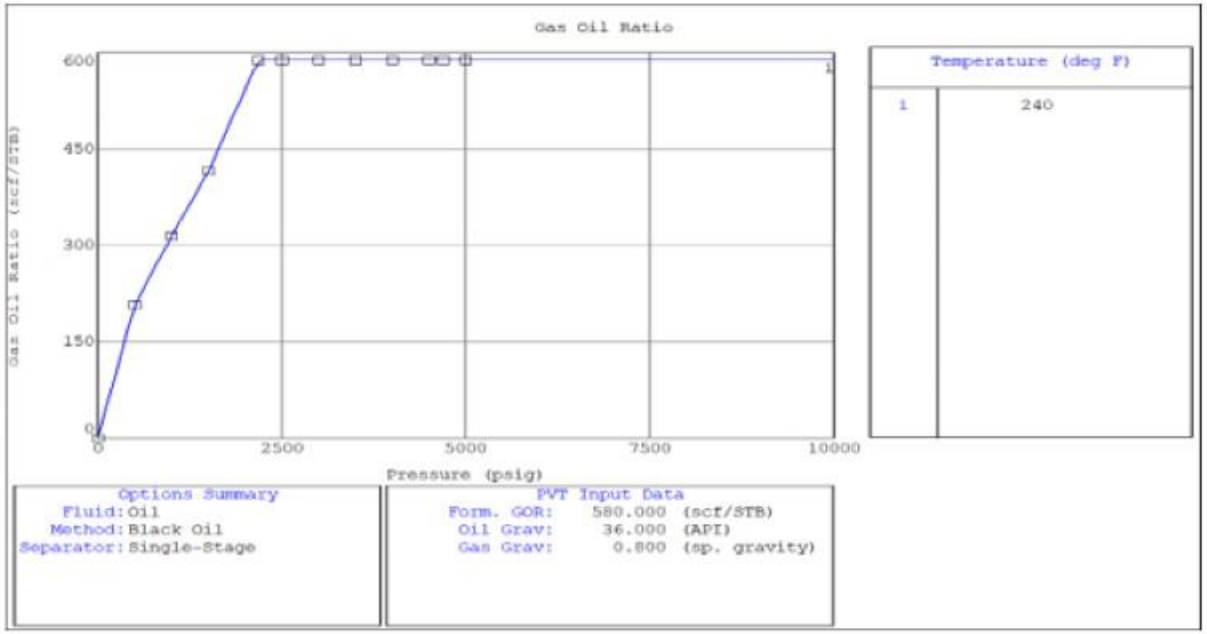
PVT Results

Tank Data History Matching

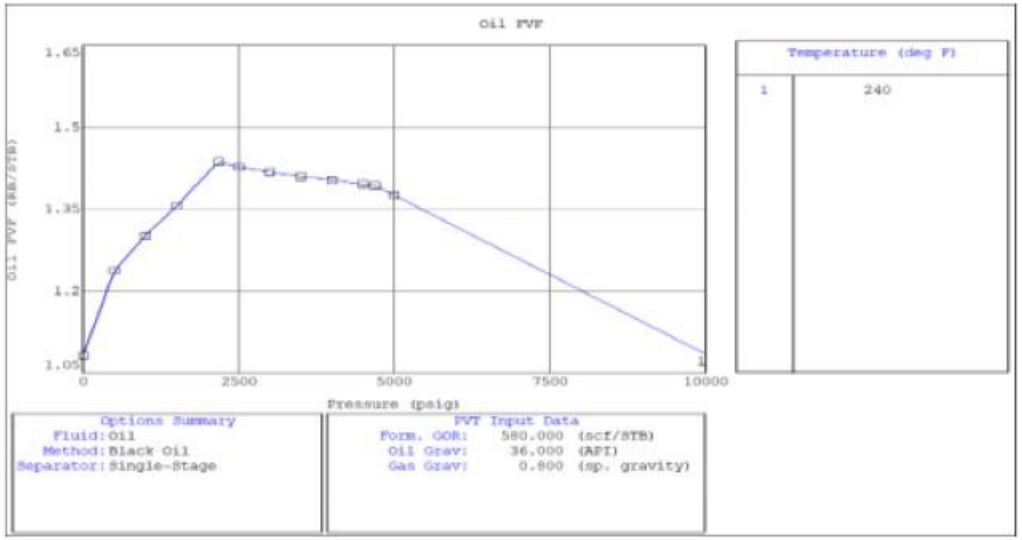
Water Influx Model

Hurst-van Everding-Odeh Model

RESULTS ANALYSIS - PVT



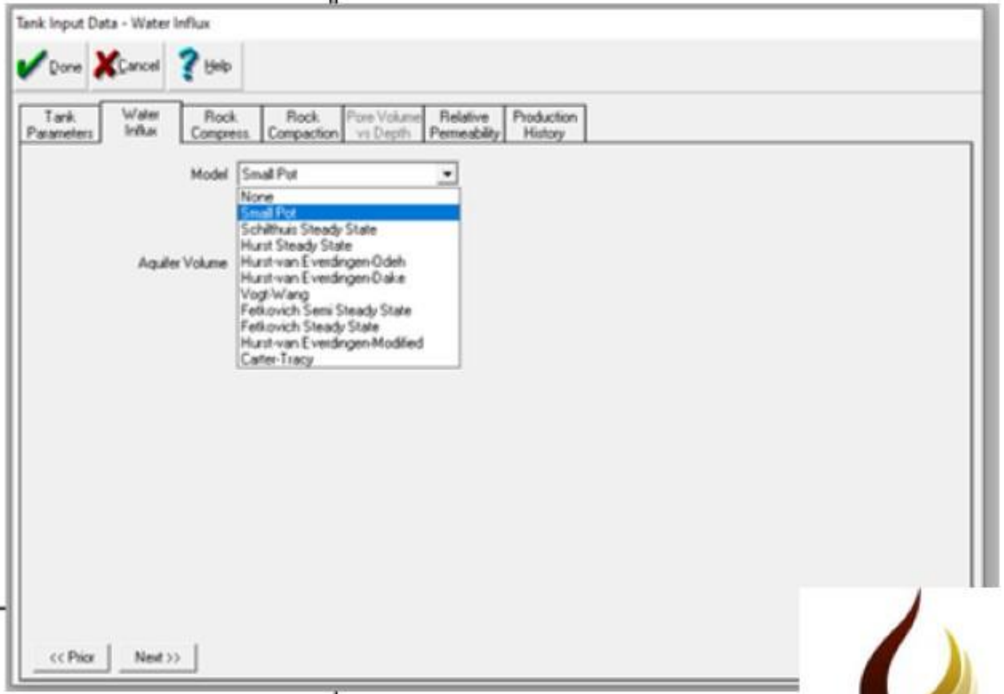
OIL FVF vs Pressure and constant Temperature



Gas Oil Ratio vs Pressure and constant Temperature

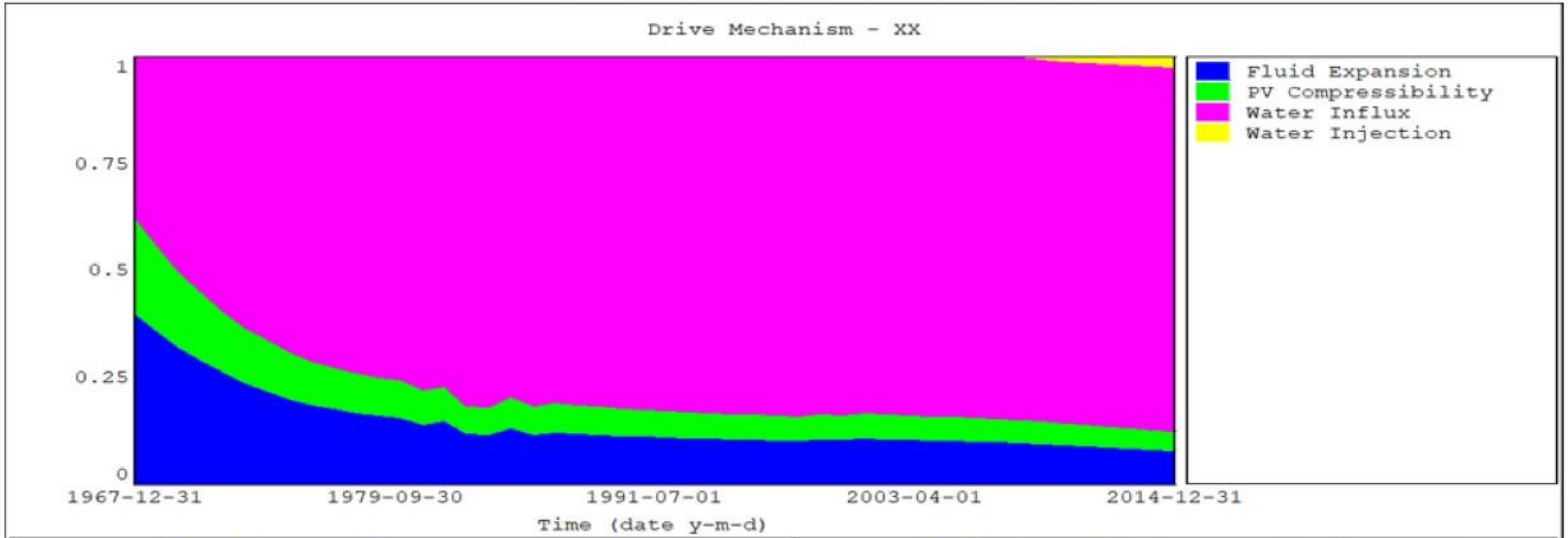
RESULTS ANALYSIS - Tank Data History Matching

Tank Pressure vs Time Reservoir Simulation Model History Match



RESULTS ANALYSIS - Water Influx Model

Drive Mechanism for Reservoir

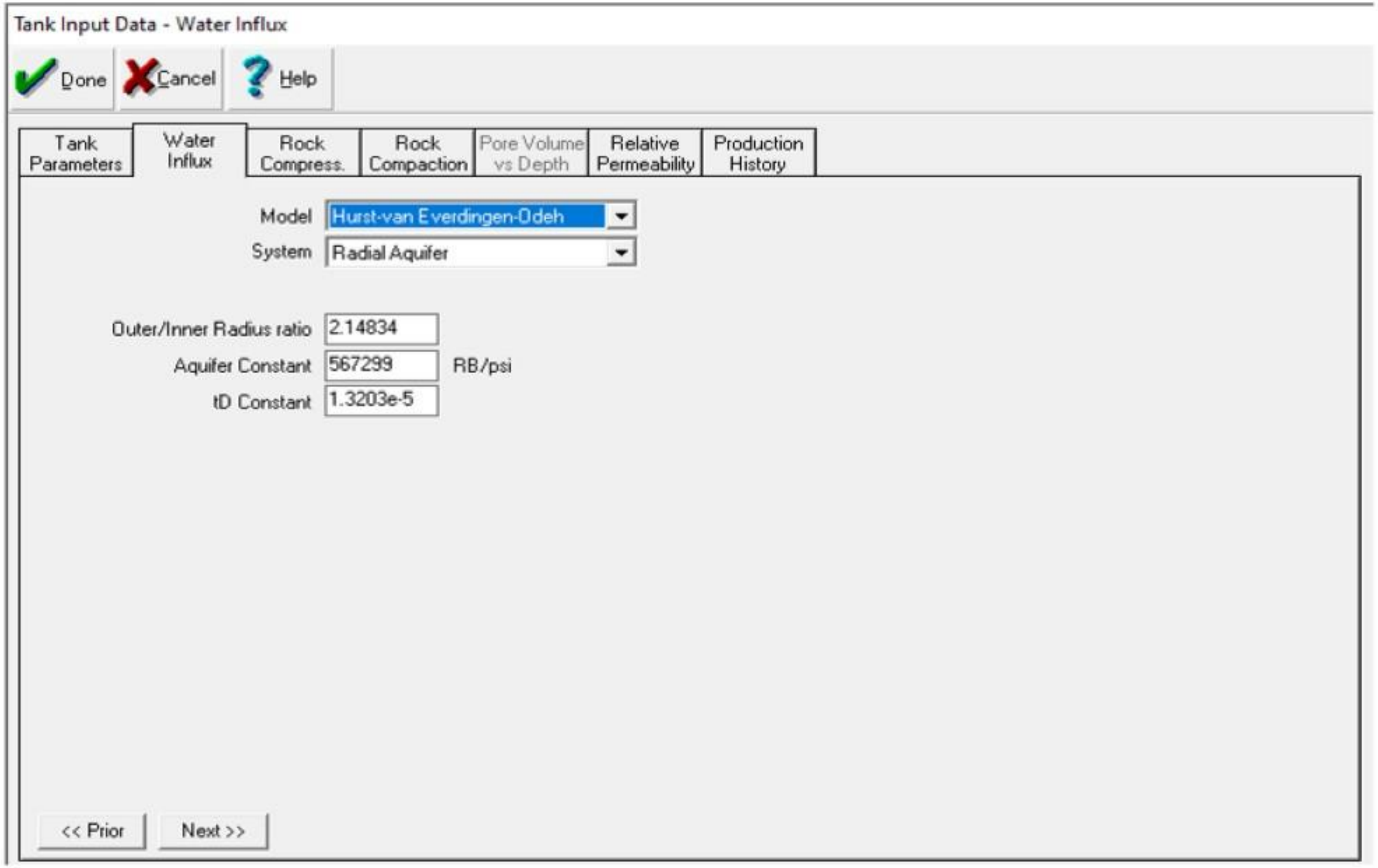


Tank Temperature	240	(deg F)
Tank Pressure	4690	(psig)
Tank Porosity	0.18	(fraction)
Connate Water Saturation	0.28	(fraction)
Water Compressibility	3.435e-6	(1/psi)
Formation Compressibility	4.43e-6	(1/psi)
Initial Gas Cap	0	
Oil in Place	2072.6	(MMSTB)
Production Start	1965-12-31	(date y-m-d)

Aquifer Model	Hurst-van Everdingen-Odeh	
Aquifer System	Radial Aquifer	
Outer/Inner Radius	9.946	
Aquifer Constant	600000	(RB/psi)
tD Constant	1.45238e-5	

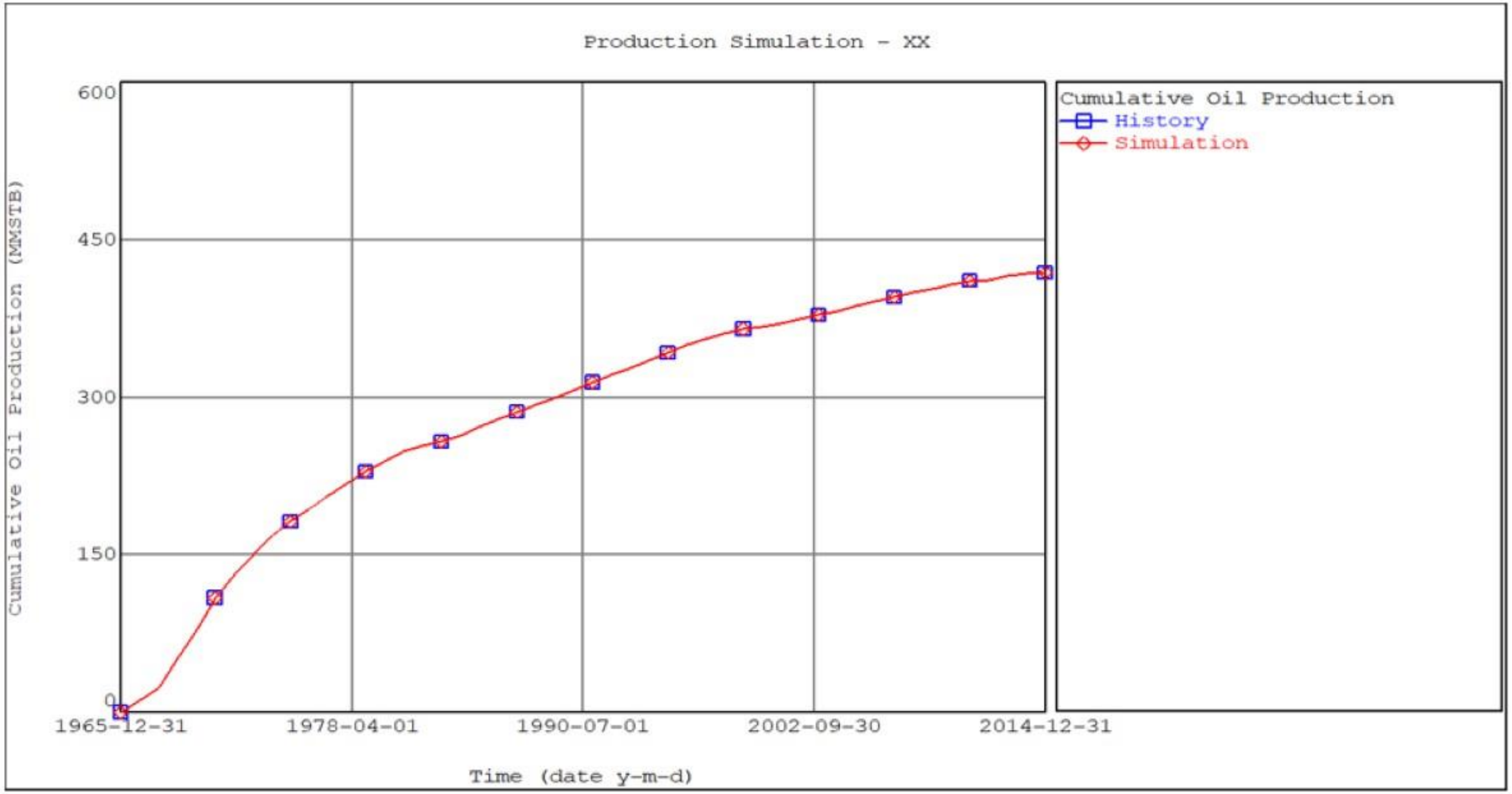
RESULTS ANALYSIS - Hurst-van Everding-Odeh Model

Hurst-van Everding-Odeh Model



RESULTS ANALYSIS - Tank Data History Matching

Cumulative Oil Production vs Time Reservoir Simulation Model History Match



CONCLUSION AND RECOMMENDATION

Conclusion

Recommendation

CONCLUSION

Results obtained from different graphs the following conclusions are drawn from this research work. Our conclusion as following:

1. In reservoir engineering material balance equation is an important investigative tool when time is limited.

2. This is very sophisticated analytical tool for evaluating water influx model and its properties through historical production.

3. In this study it has been proved that good data acquisition is required to carried out reserve water influx model and its properties evaluation with MBAL.

4. Reservoir analysis tool MBAL is used to initialize, calibrate and benchmark the history matching.

CONCLUSION

5. The main source of energy in reservoir was from Water influx, pore volume, and fluid expansion drive mechanism.

6. At the begging, the fluid expansion is from 0 to 40 % and pore volume compressibility is from 40 % to 64 % and the water influx is from 64 % to 100%, after that we has water injection.

7. The model for this reservoir is the Hurst-van Everding-Odeh with the system is radial aquifer.

8. The model properties for this model are;

   A. The Outer/Inner Radius Ratio is 2.14834.

   B. Aquifer constant is 567299 RB/psi.

   C. tD constant is 1.3203e-5.

RECOMMENDATION

Finally, central objective of this project with the help of reservoir simulation fulfilled to know the water influx model and its properties and to produce future prediction that will lead to optimize reservoir performance which meant reservoir developed in the manner that brings utmost benefit to the commercial business.

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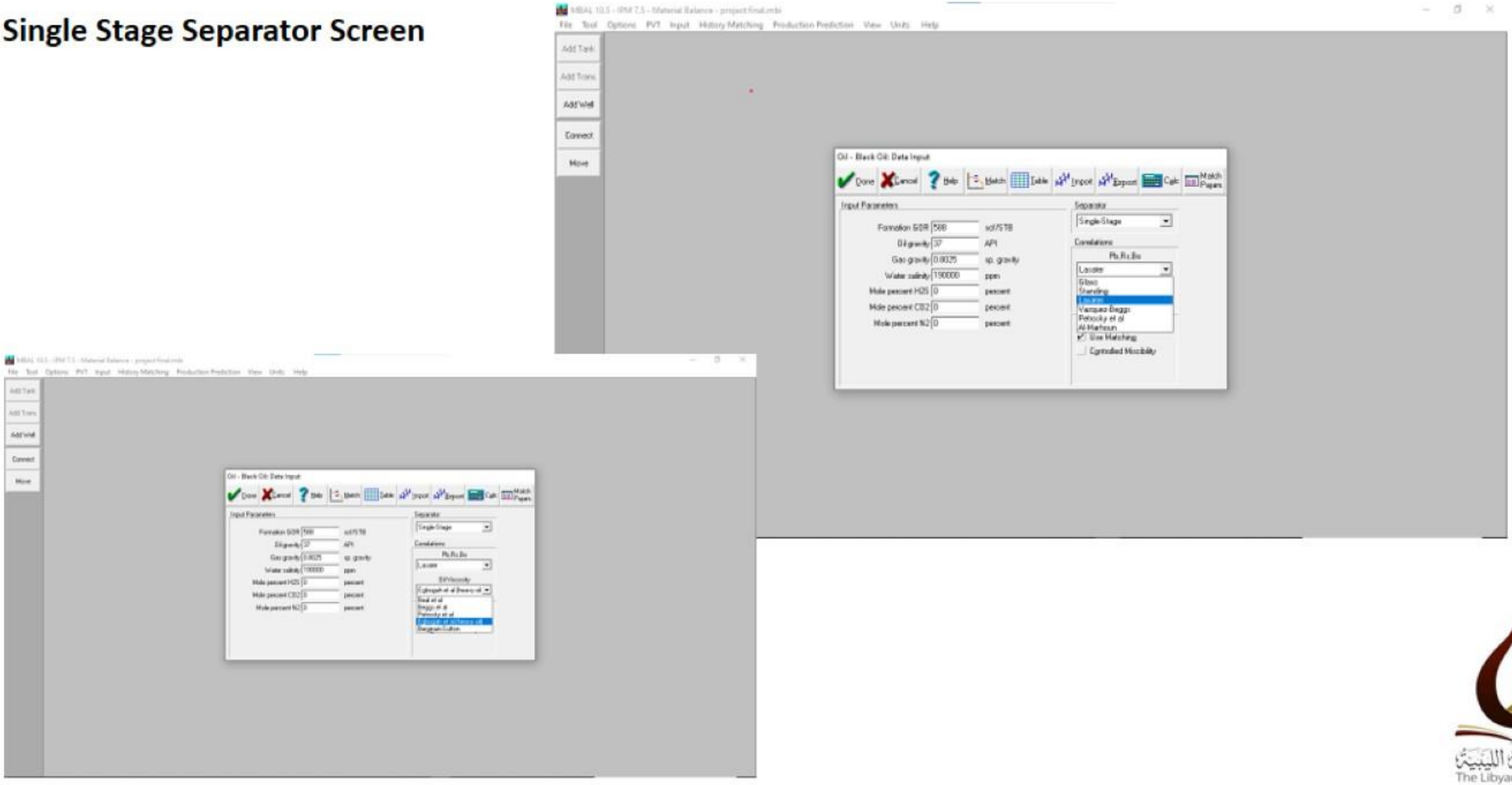
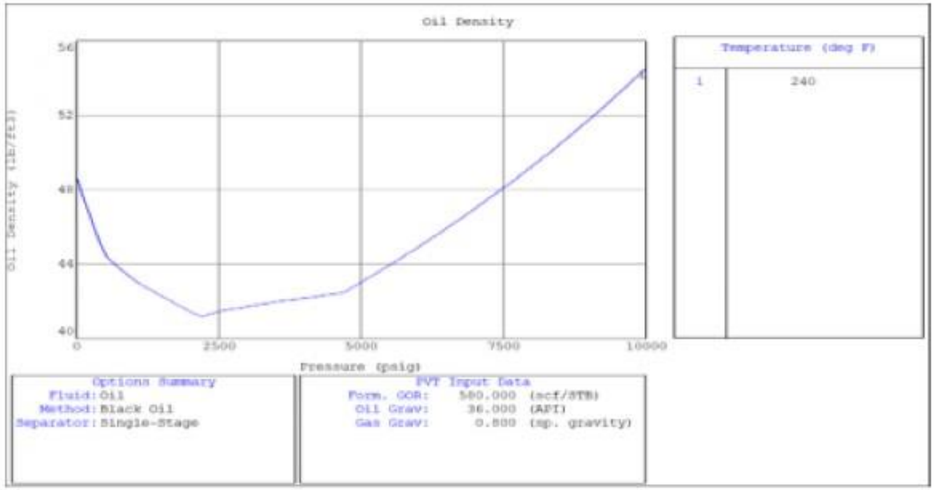
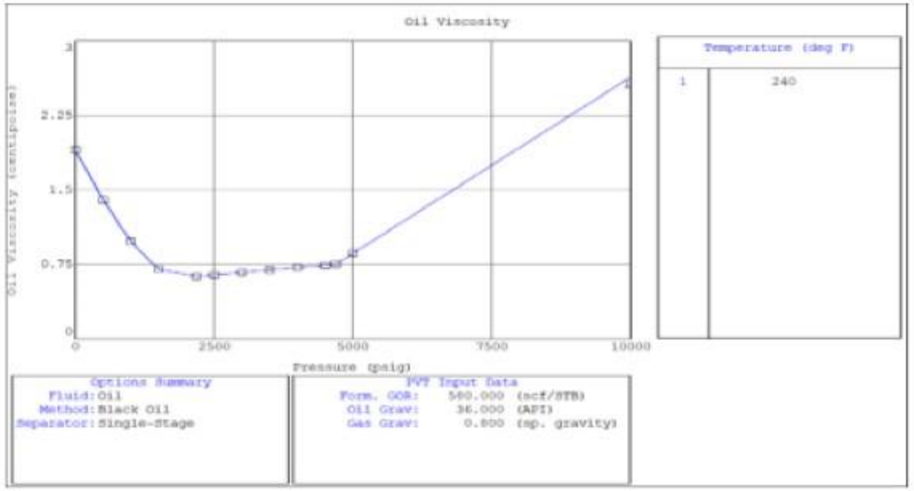
PVT Oil - Single Stage Separator Screen

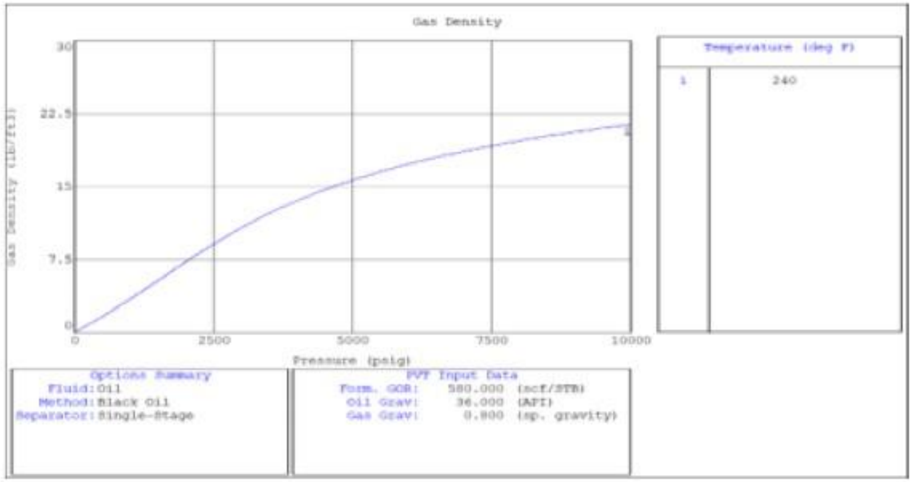


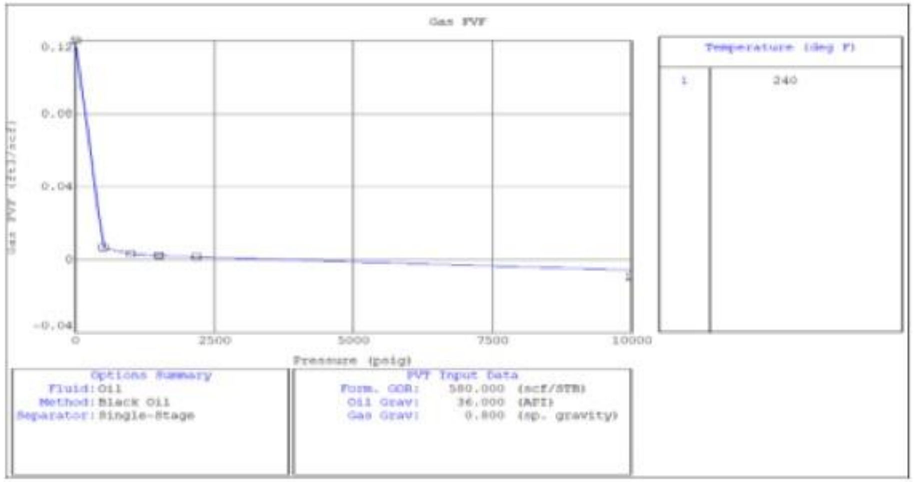


Results of Oil Density vs Pressure and constant Temperature



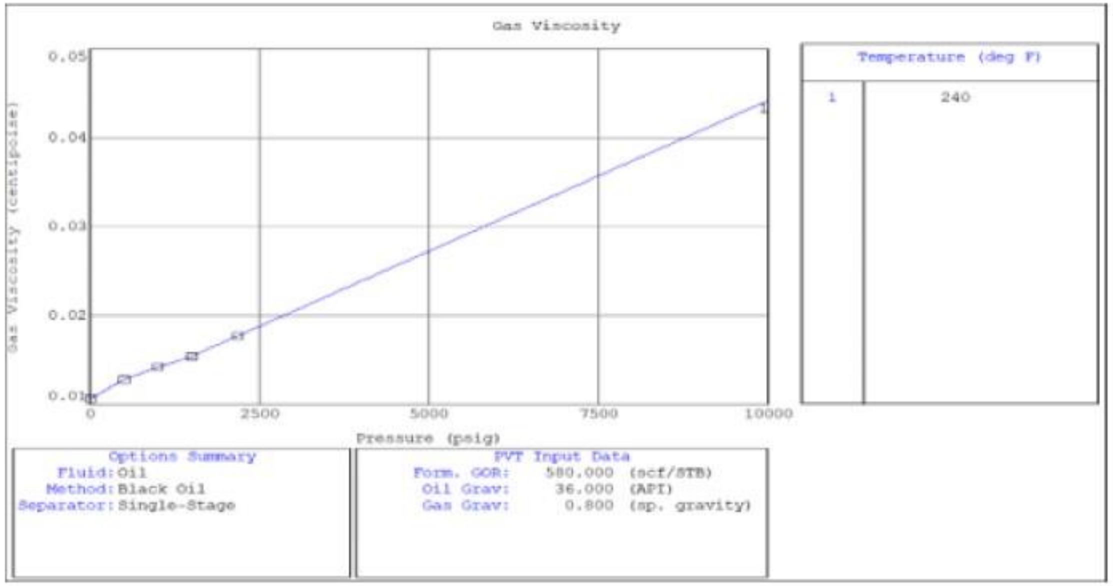
Results of Oil Viscosity vs Pressure and constant Temperature



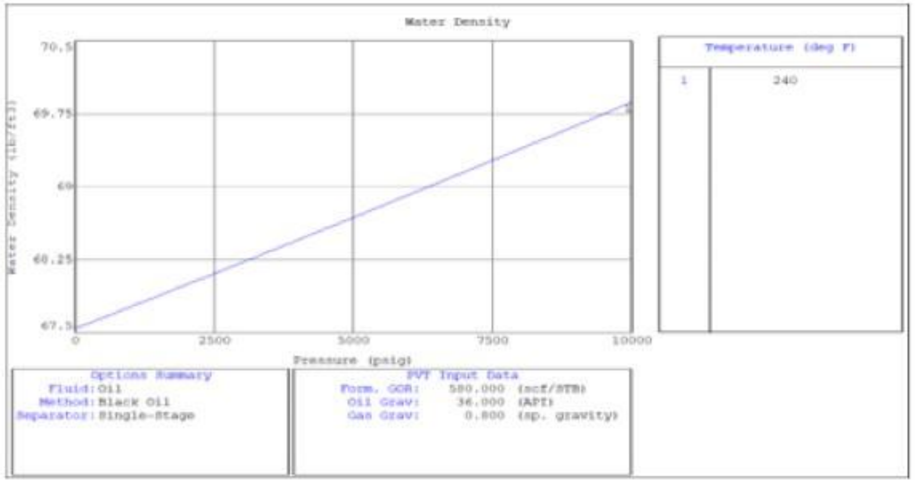


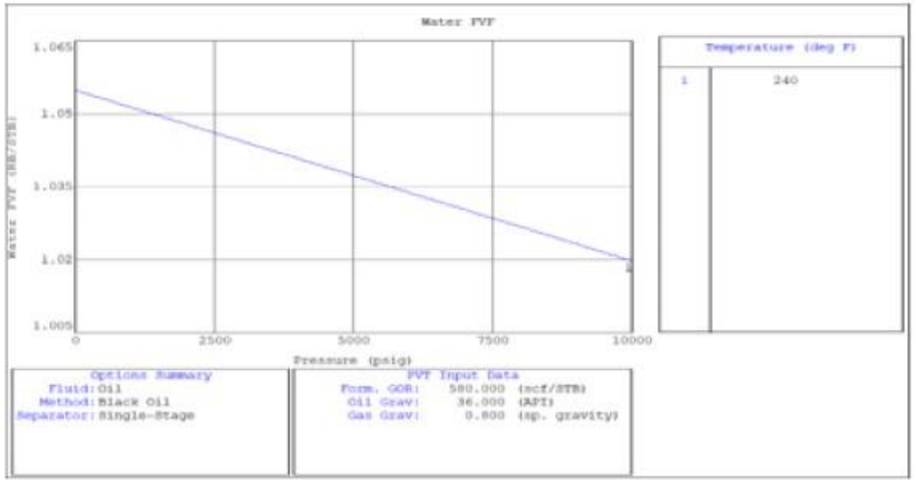
Results of Gas Density vs Pressure and constant Temperature

Results of Gas FVF vs Pressure and constant Temperature



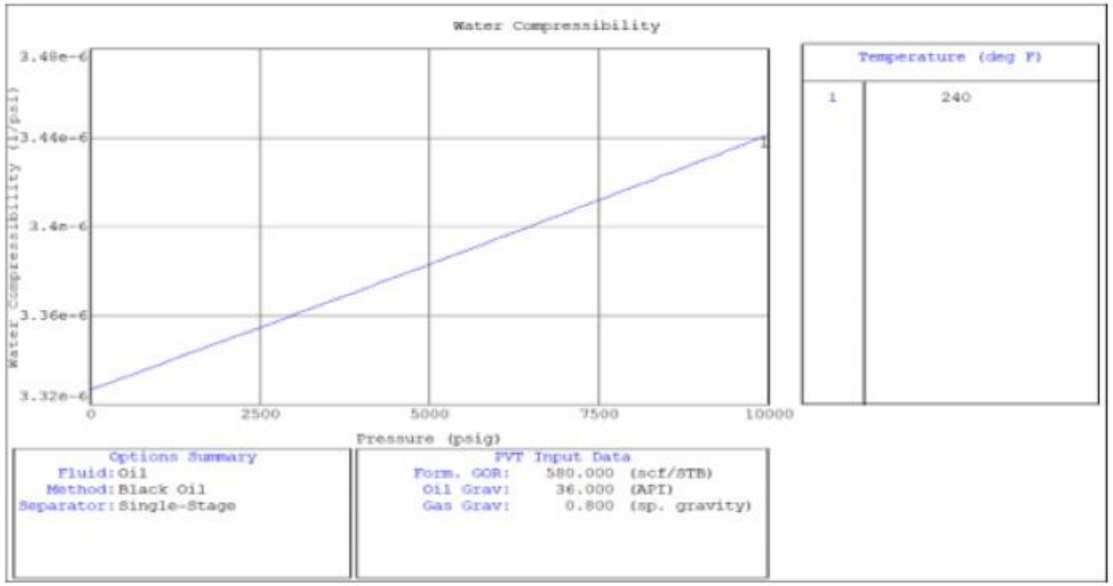
Results of Gas Viscosity vs Pressure and constant Temperature





Results of Water Density vs Pressure and constant Temperature

Results of Water FVF vs Pressure and constant Temperature



Results of Water Compressibility vs Pressure and constant Temperature

WATER INFLUX MODEL - Classification of Aquifers

Reservoir aquifer systems are commonly classified on the basis of:

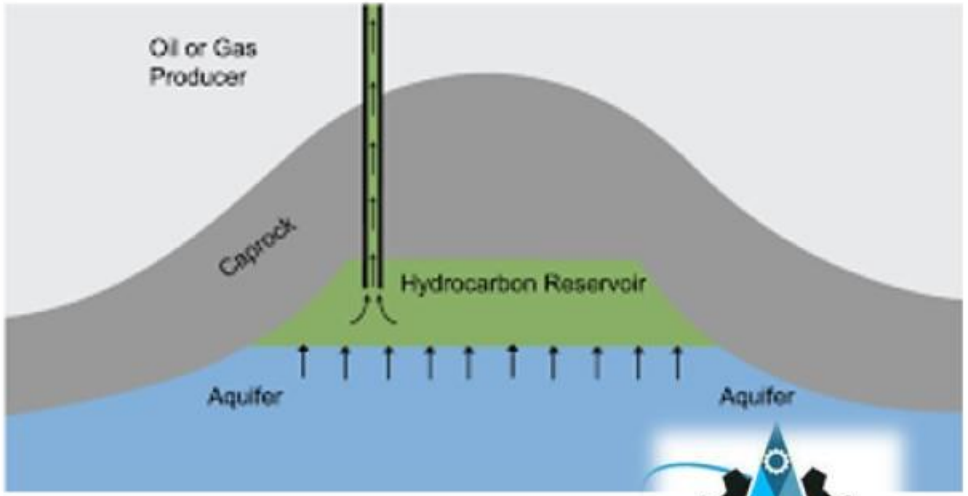
1. **Degree of pressure maintenance:**

Based on the degree of the reservoir pressure maintenance provided by the aquifer, the natural water drive is often qualitatively described as:

A. Active water drive

B. Partial water drive

C. Limited water drive



WATER INFLUX MODEL - Classification of Aquifers

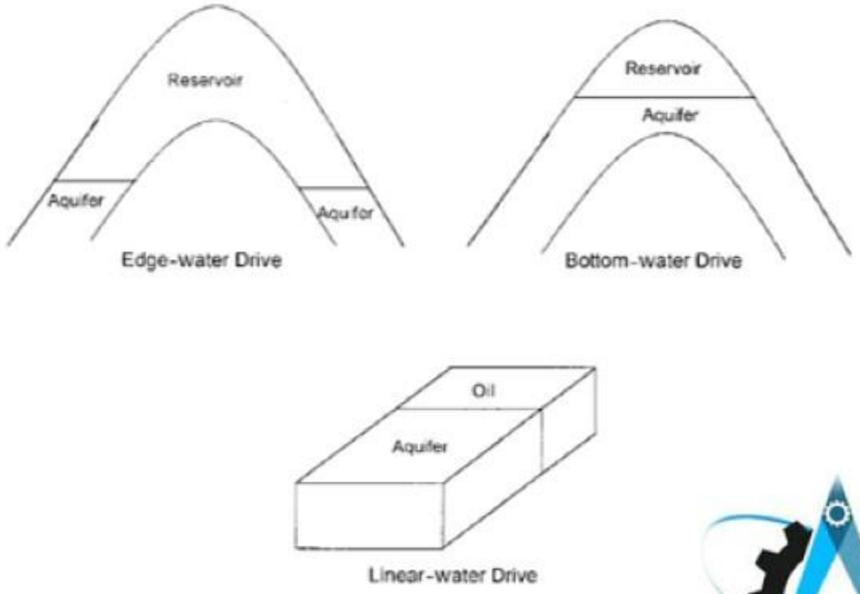
2. Flow geometry:

Reservoir-aquifer systems can be classified on the basis of flow geometry as:

A. Edge-water drive

B. Bottom-water drive

C. Linear-water drive



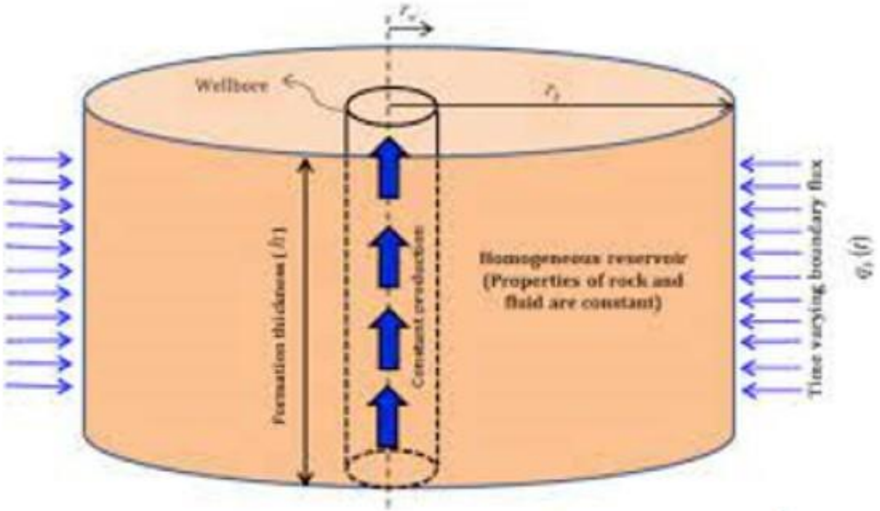
WATER INFLUX MODEL - Classification of Aquifers

3. Outer boundary conditions:

The aquifer can be classified as:

A. Infinite system

B. Finite system



WATER INFLUX MODEL - Water Influx Models

The mathematical water influx models that are commonly used in the petroleum industry include:

1. Pot aquifer
2. Schilthuis' steady-state
3. Hurst's modified steady-state
4. The Van Everdingen-Hurst unsteady-state
5. The Carter-Tracy unsteady-state
6. Fetkovich's method