4.1 Introduction

The optimized parameters are presented in this chapter in form of graphs and tables. The results displayed (parameters) include injection flow rate, surfactant and water concentration, total volume injected, soaking period, and total volume of water injected. Each of the previous parameters is iterated with other parameters fixed to obtain the best choice, which fixed in the following iterations and so on. The results are plotted against time (X axis), cumulative water and cumulative oil (Y axis). Every parameter is iterated five times. Time elapsed starts from 1/Jan/2012 to 1/Jul/2015.

4.2 Data Entered to CMG

Prior to starting the initialization of the model by using Builder, first we need to determine simulator type (STARS), type of units, and porosity type in the reservoir. This is considered as the first data entered to CMG, see table 4.1.

- **Rock Properties**

Table 4.1: Rock Properties for BB-21Well

	Grid top (m)	Grid thickness (m)	Porosity	Perm I	perm J	perm k	water saturation
layer 1	1289.49	0.54	0.256	2500	2500	1250	0.239
layer 2	1290	7	0.256	2500	2500	1250	0.239
layer 3	1297	1.3	0.256	2500	2500	1250	0.239
layer 4	1298.3	7.84	0.256	100	100	50	0.239
layer 5	1306.14	5.41	0.268	2500	2500	1250	0.549
layer 6	1314.6	3.05	0.268	100	100	50	0.549
layer 7	1319.63	5.03	0.258	2500	2500	1250	0.582
layer 8	1319.63	45.72	0.258	5	5	2.5	0.582
layer 9	1365.35	11.81	0.263	500	500	250	0.628
layer 10	1377.16	73.76	0.263	100	100	50	0.628
layer 11	1450.92	9	0.191	500	500	250	0.56
layer 12	1459.92	1.6	0.191	100	100	50	0.56

- **Fluid properties**

We have only two phases (water & oil) and their properties are illustrated below in the following two tables, see table 4.2 and table 4.3.

For water phase

Table 4.2: Property of Water Phase

Property	Water phase
FVF (bbl./STB)	1
density (g/cm^3)	1
viscosity (cp)	0.449

For oil phase

Table 4.3: Property of Oil Phase

Property	Oil phase
FVF (bbl/STB) @$10*10^6$ Pa	0.866
density (g/cm3)@$10*10^6$ Pa	0.826
viscosity (cp)	179
gas oil ratio	0

- **Initial conditions**

The initial condition of the reservoir is shown below in table 4.4.

Table 4.4: Initial Conditions of Reservoir

reference depth	1290 m
reference pressure	12911 KPa
water oil contact	1365 m

4.3 Results and Discussion

4.3.1 Concentrations of Surfactant

To start with the design process, the model is firstly loaded into the simulator and the injector well is modified with respect to every parameter. For the concentrations of surfactant and water, the injected fluid tab is used. Firstly, from CMG's Launcher window select Builder, see figure 4.1.

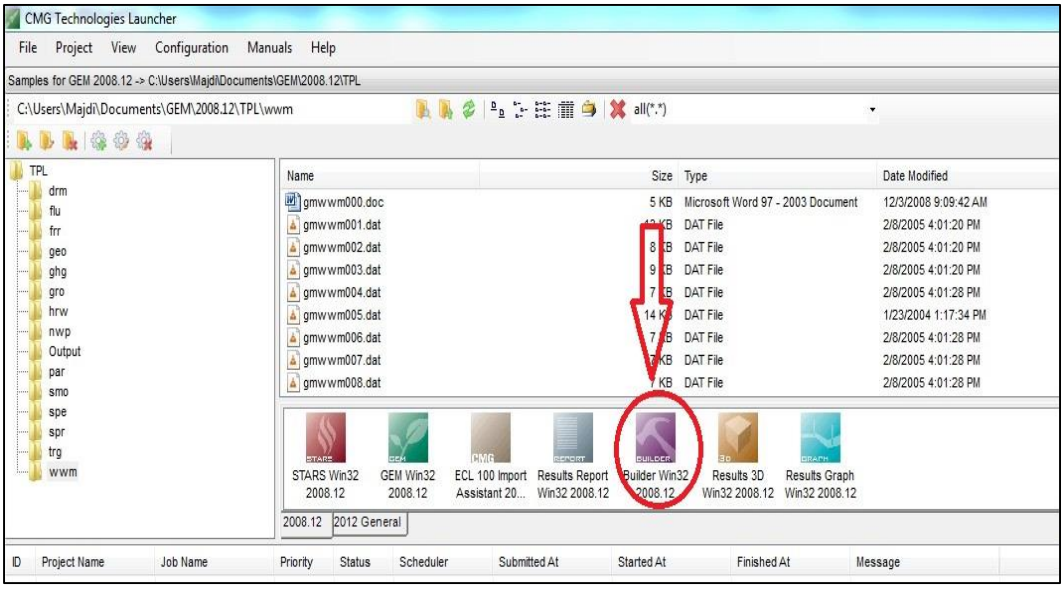

Fig.4.1: Launcher Main Window

After opening "Builder - Reservoir Simulator Settings" window close it and press the browse button in the upper left of the screen and navigate to the folder where you store your model, you can see that in figure 4.2.

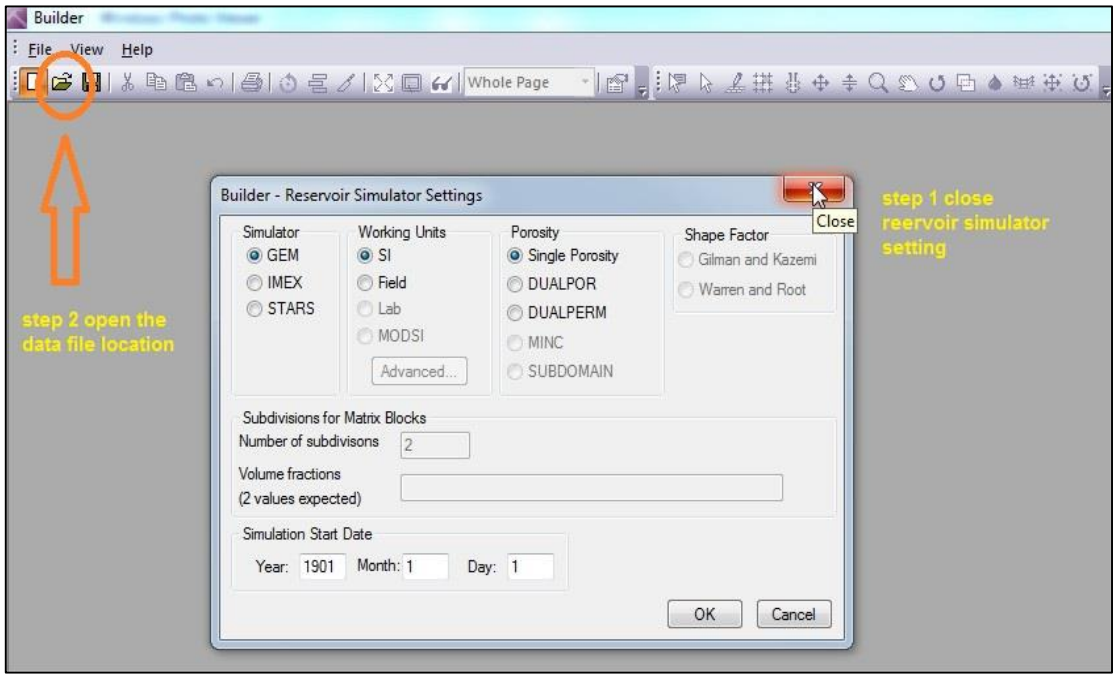

Fig.4.2: Builder – Reservoir Simulator Setting Window

Now, to start optimizing the concentration of surfactant and water, on the left hand side, from the Model Tree View> Wells & Recurrent, double click on the injector well (here, BB-23_inj), see figure 4.3.

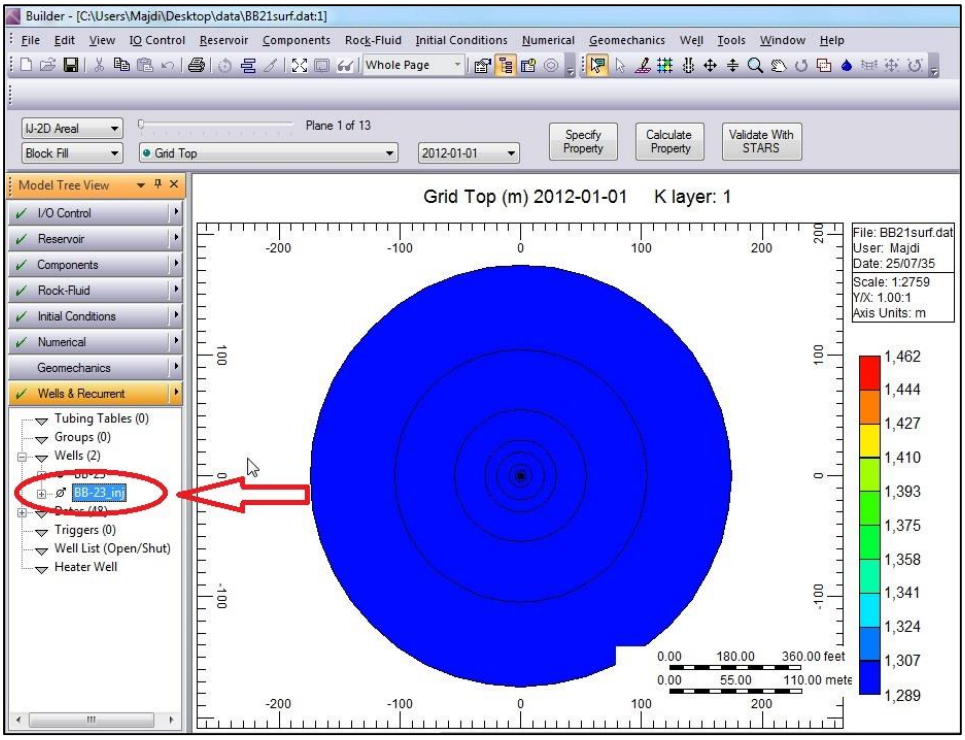

Fig.4.3. BB-23_Inj in Well & Recurrent

Secondly, after builder is opened click on Well & Recurrent / Wells / BB-21_inj / event and the following window will show up, click on "Injected Fluid" and change the concentration of the surfactant, see figure 4.4.

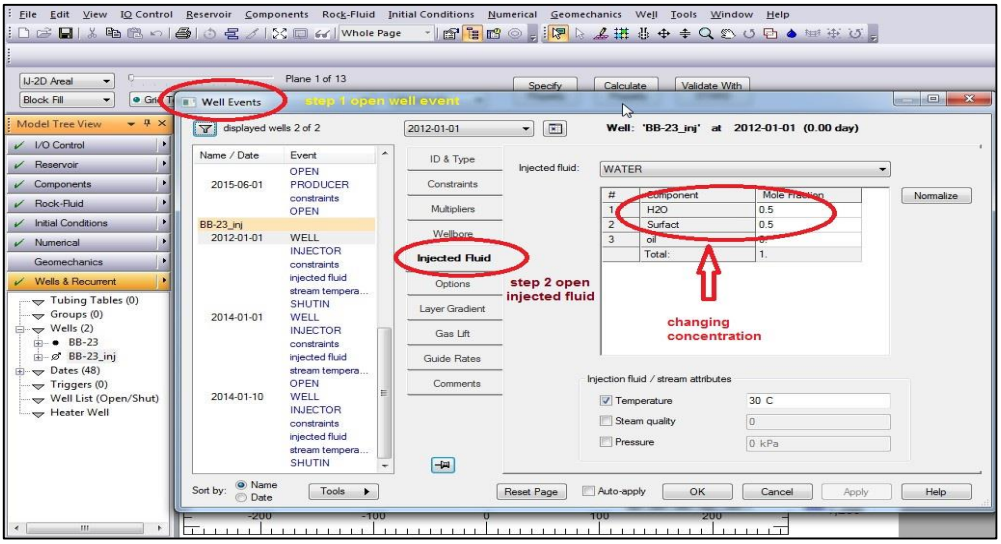

Fig.4.4: Well Events Window

From the pop-up window (Well Events), select Injected Fluid tab, then start changing surfactant concentration as in table 4.5. The optimum choice is bolded.

Table 4.5: Iterations of Surfactant Concentration

Iteration	1	2	3	4	**5**
Water concentration	0.5	0.3	0.6	0.7	**0.9**
Surfactant concentration	0.5	0.7	0.4	0.3	**0.1**

To start the simulation, and after entering the required data and changing surfactant concentration from Builder main window, click on "Validate With STARS" For each time you change concentration, see figure 4.5.

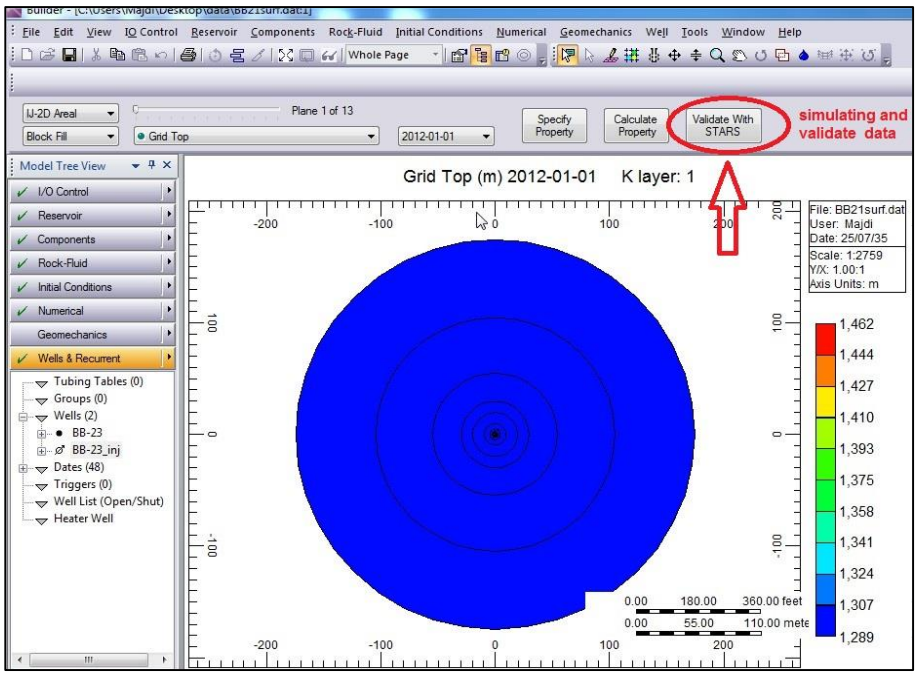

Fig.4.5: Validate With STARS Button to Start the Simulation

For each simulation run, the concentration of surfactant is changed and the cumulative oil and water production is calculated and the optimum concentration is bolded below and found to be 0.9 water – 0.1 surfactant, although it will not yields the highest cumulative oil, but the difference is very small comparing to 0.7 water-0.3 surfactant concentration which gives the highest cumulative oil (15.8 m^3), but considering the relatively high cost of the surfactant, the minimum concentration (0.1 surfactant), with that small difference, is chosen, see table 4.6 and figure 4.6. The optimum choice is bolded.

Table 4.6: Different Surfactant Concentrations and their Corresponding Cumulative Oil and Water Production

Concentration		Cumulative Oil Produced, m^3	Cumulative water Produced, m^3
Water	Surfactant		
0.5	0.5	54681.2	104119
0.3	0.7	54679.4	104115
0.6	0.4	54679.9	104136
0.7	0.3	54681.8	103852
0.9	**0.1**	**54666**	**104042**

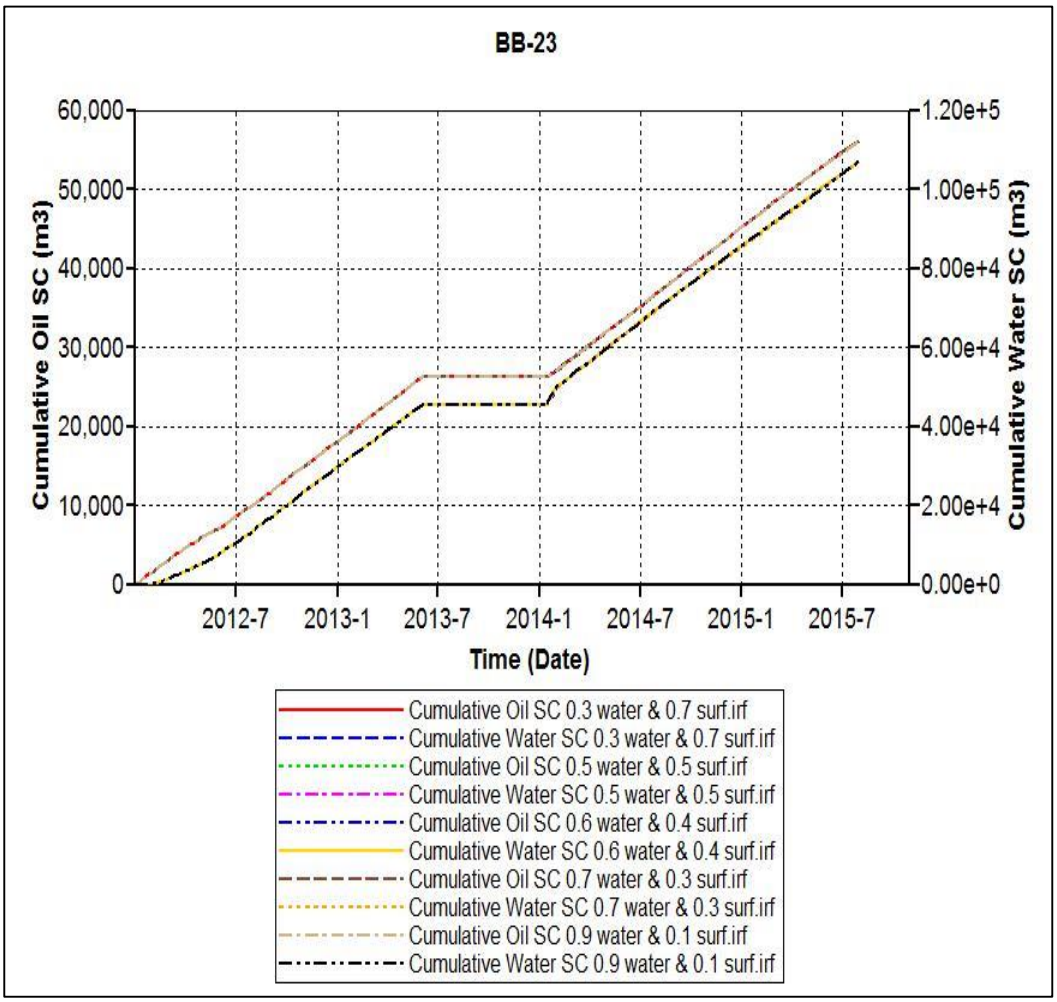

Fig.4.6: Effect of Changing Concentration on Cumulative Oil and Water

4.3.2 Fluid Injection Rate

Choosing the (0.9 surfactant- 0.1 water) concentration as optimum choice, the fluid injection rate of the (water-surfactant) system is to be optimized. Figure 4.7 shows an example for how we select different fluid injection rate. The iteration runs is tabulated in table 4.7. The optimum choice is bolded.

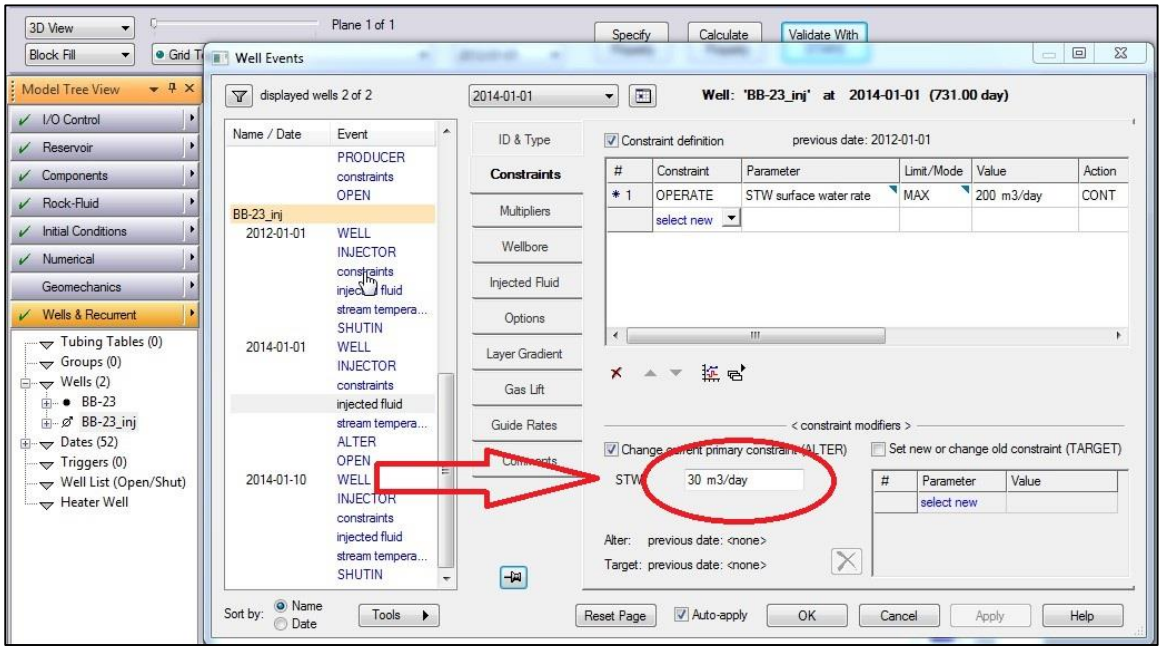

Fig.4.7: Changing Fluid Injection Rate in Well Event Window

After changing injection rate five times we found that the optimum injection rate that yields maximum cumulative oil production is 120 m^3/day, but it also yields high cumulative water production. We made our selection based on technical aspect not on economic aspect, another economic evaluation may come and change the optimum parameter according to oil price in market and cost of treating water, see figure 4.8.

Table 4.7: Cumulative Oil and Cumulative Water Produced for Each Injection Rate

Run	Injection rate, m^3/day	Cumulative Oil Produced, m^3	Cumulative water Produced, m^3
1	30	54589.5	103129
2	60	54627.1	26281.6
3	90	54613.7	103534
4	**120**	**56661.4**	**103658**
5	150	54589.5	103129

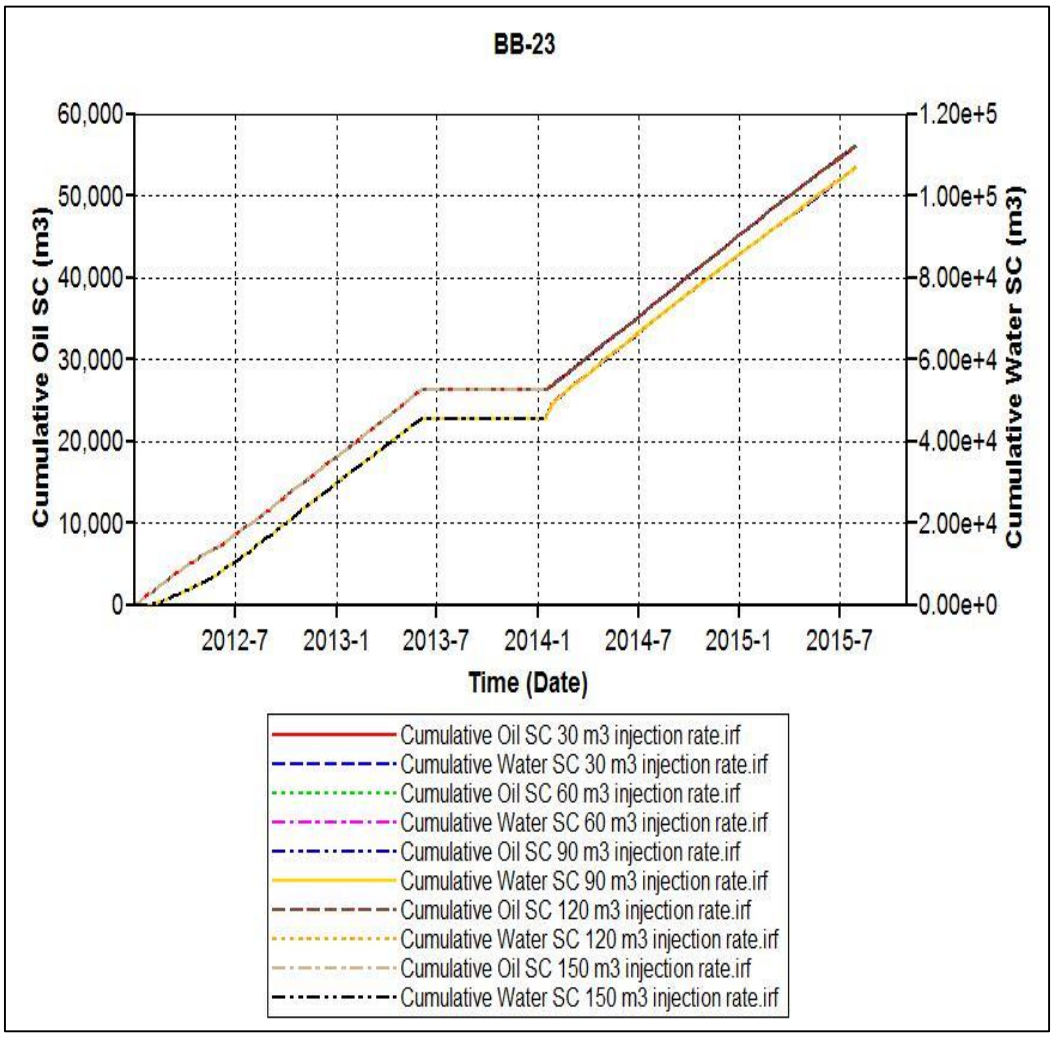

Fig.4.8: Different Injection Rates and Their Effect on Cumulative Water and Oil Production

4.3.3 Fluid Injection Period

After we select 0.9 water and 0.1 surfactant concentration as optimum one and we did the same for injection rate and we found the optimum one is 120 m^3/day we are going to use the above two parameters to simulate injection period, see figure 4.9 and table 4.8. The optimum choice is bolded.

Table 4.8: Iterations for Injected Period

Run	Injection period, day	Cumulative Oil Produced, m^3	Cumulative water Produced, m^3
1	**10**	**54589.5**	**103129**
2	15	54404.5	104011
3	20	54170.2	103909
4	25	53961.9	104077
5	30	53686.1	104328

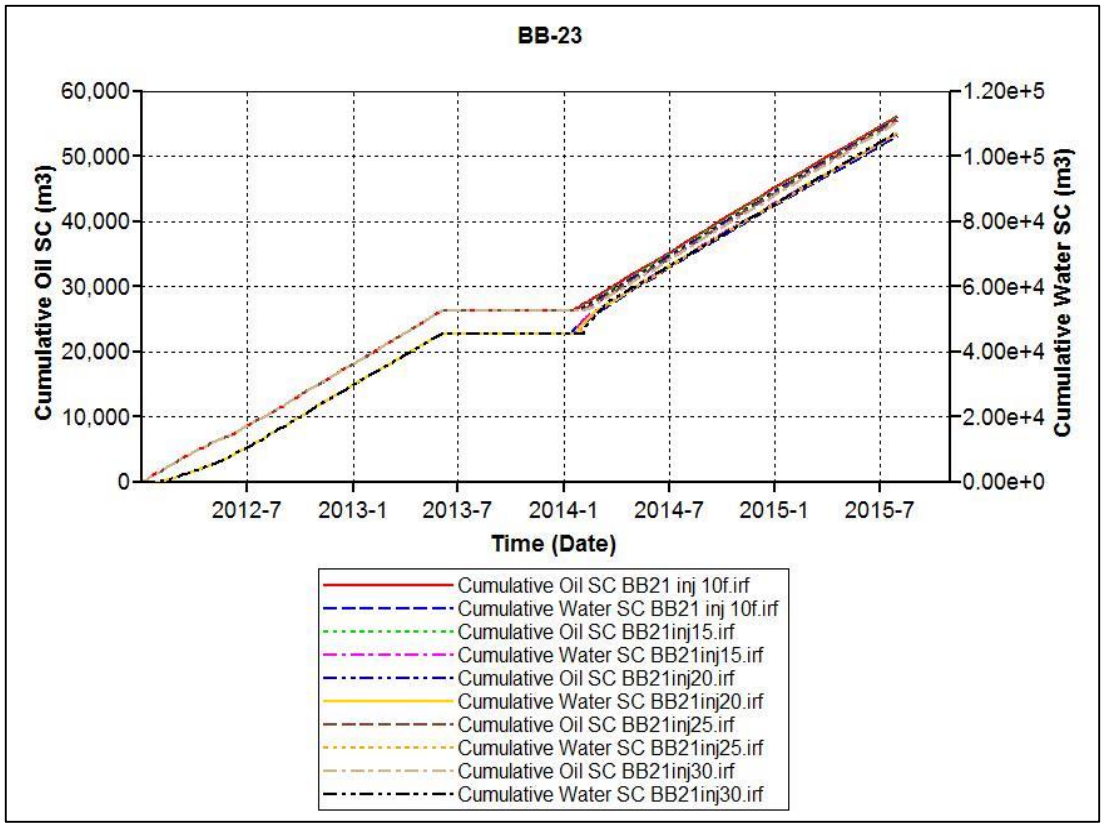

Fig.4.9: Different Injection Periods and Their Effect on Cumulative Water and Oil Production

4.3.4 Soaking Period

After optimizing the above parameter concentration, injection rate and injection period we are using them to optimize soaking period see figure 4.10 and table 4.9. The optimum choice is bolded.

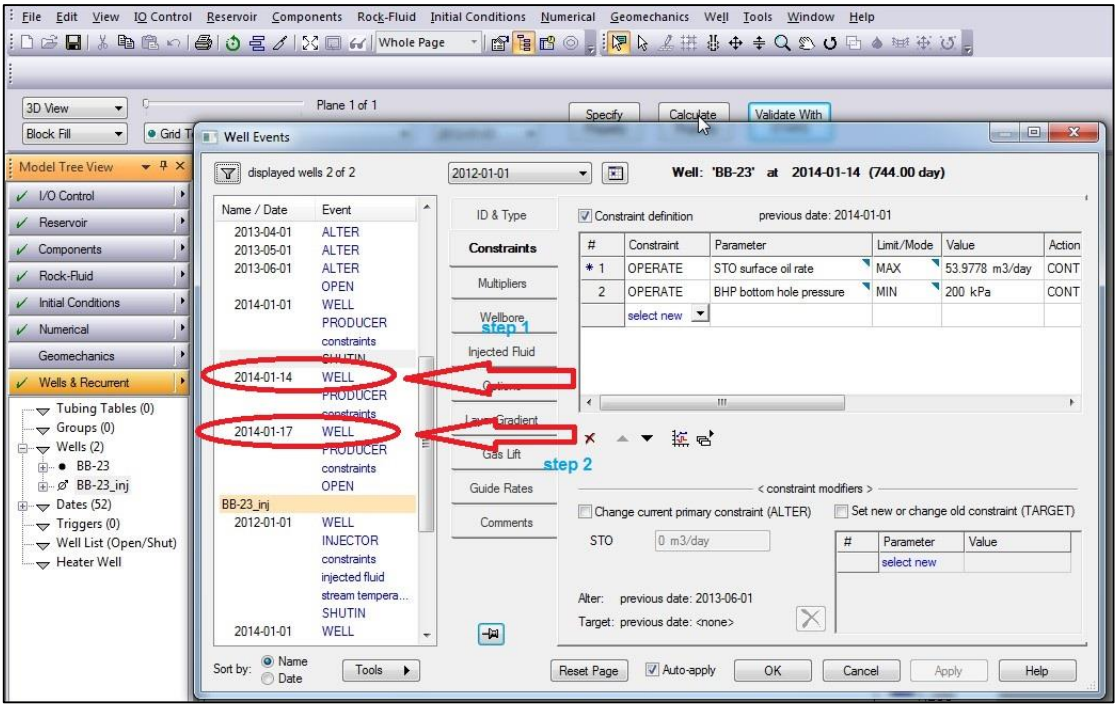

Fig.4.10: Changing Soaking Period in Well Event Window

Table 4.9: Iterations for Soaking Period

Run	Soaking Period, day	Cumulative Oil Produced, m^3	Cumulative water Produced, m^3
1	3	54639.5	103462
2	4	54642.6	103325
3	**5**	**54693.5**	**103462**
4	6	54541	103024
5	7	54492.6	103045

4.3.5 Total volume injected

It is the volume of cumulative water injected during injection period and can be obtained from the following equation:

Total volume of water injected (optimum) = optimum injection rate * optimum injection period

Total volume of water injected (optimum) = 120 * 10 = 1200 m^3

The optimum design parameters for surfactant Huff and Puff are as follow:

Table 4.10: Optimum Parameters

Injection Rate	120 m^3/day
Soaking period	5 day
injection duration	10 day
Surfactant concentration	10 day
Total volume of fluid injected	1200 m^3

- Increment in oil as a result of using this design is given by:

$$\text{Increment in oil} = \frac{\text{Optimum cumulative oil} - \text{Average cumulative oil}}{\text{Optimum cumulative oil}} * 100$$

……Eq. (4.1)

Table 4.11: Increment in Cumulative Oil Production

Type of parameter	Average cumulative oil production	Optimum cumulative oil production	Increment in oil %
Surf. Concentration	54678	54666	-0.022
Injection rate	55016	56661	2.9
Injection period	54162	54589.5	0.78
Soaking period	54601	54694	0.17