Optimization of A Water Alternating Gas Injection

Compositional fluid flow simulation with Water Alternating Gas Injection optimization on the up-scaled synthetic reservoir CERENA-1

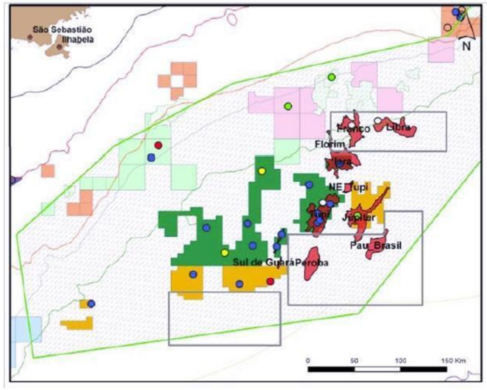
Fabusuyi Oluwatosin John
PhD. Candidate
Instituto Superior de Tecnico

Contents

Introduction

Motivation

- The synthetic reservoir modelled to replicate the reservoir in the Brazilian Pre-salt geological play, the Jupiter field to be precise, a reservoir with considerable amount of oil, and huge amount of gas that contains large CO_2 concentrations.
- Continuation on the work done by Pedro Pinto on CERENA-I.



Main Objectives

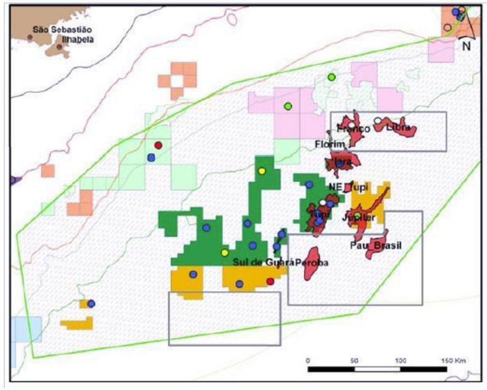
- Find a production strategy to improve oil production, and reduce the quantity of CO_2.
- Further optimization of the selected production strategy to maximize oil recovery and minimize gas production.

Introduction

Motivation

- The synthetic reservoir modelled to replicate the reservoir in the Brazilian Pre-salt geological play, the Jupiter field to be precise, a reservoir with considerable amount of oil, and huge amount of gas that contains large CO_2 concentrations.

- Continuation on the work done by Pedro Pinto on CERENA-I.



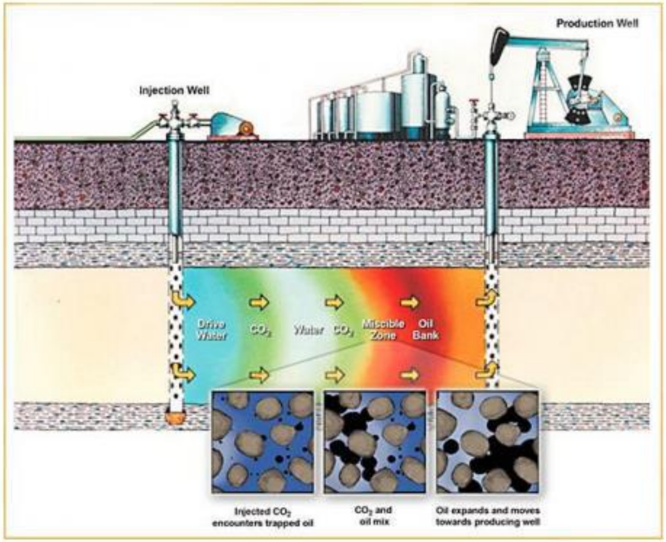
Main Objectives

- Find a production strategy to improve oil production, and reduce the quantity of CO_2.

- Further optimization of the selected production strategy to maximize oil recovery and minimize gas production.

State of the art and theoretical background

- **Water Alternating Gas Injection Scheme:** is one of the numerous enhanced recovery process. WAG injection involves drainage (D) and imbibition (I) taking place simultaneously or in cyclic alternation in the reservoir.



- **SWAG –** Simultaneous Water Alternating Gas Injection

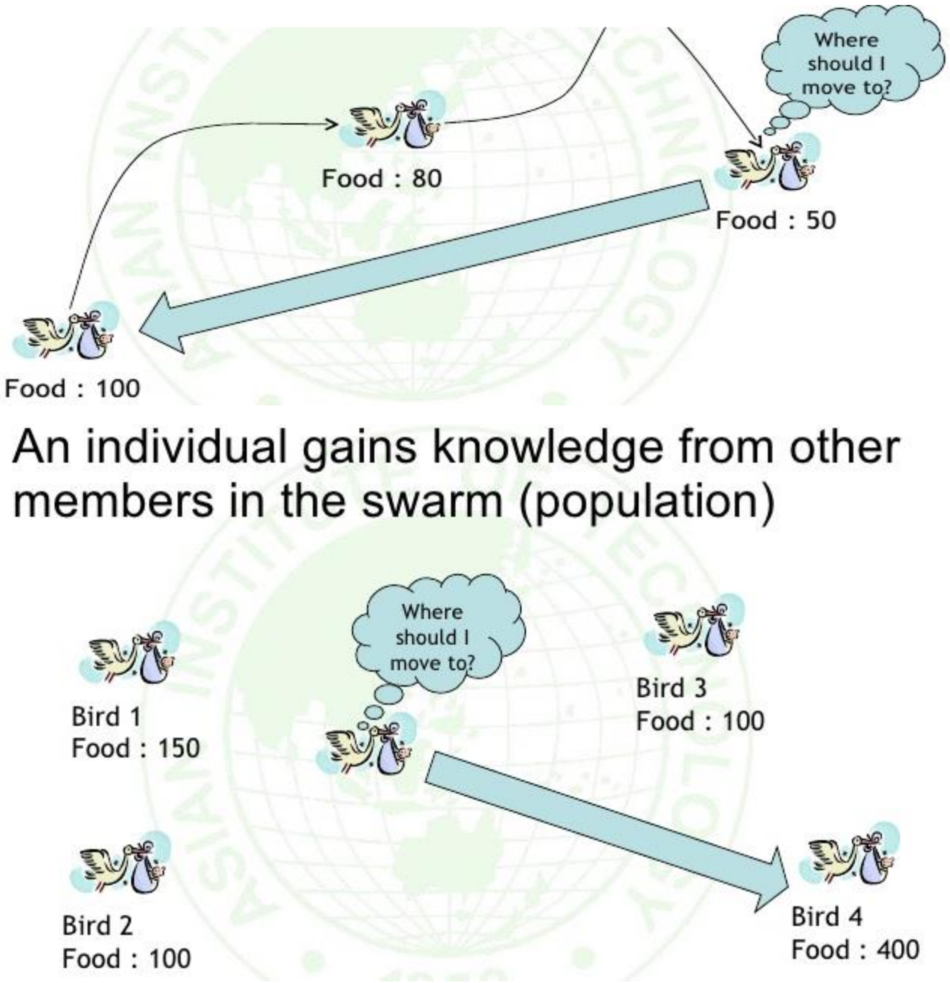
State of the art and theoretical background

Particle Swarm Optimization

- The selected optimization technique chosen for this study is the Particle Swarm Optimization technique.

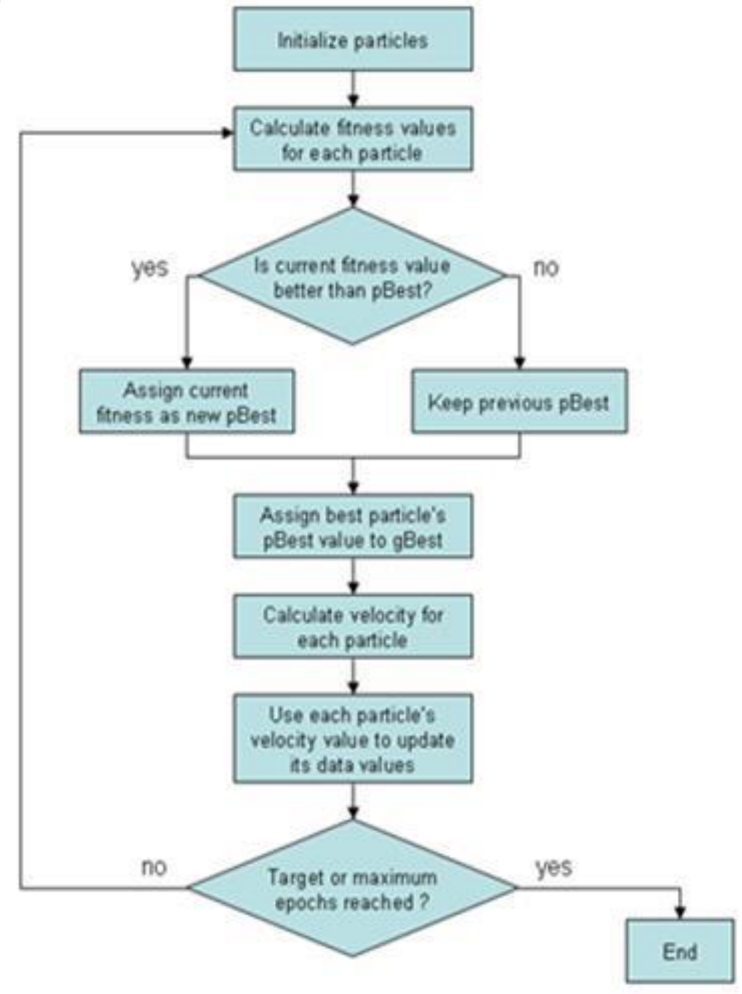
- It's a co-operative, population-based global search swarm intelligence metaheuristics.

- **Bird** = a particle, **Food** = a solution
- **pbest** = the best solution(fitness) a particle has achieved so far.
- **gbest** = the global best solution of all particles within the swarm



Particle Swarm Optimization

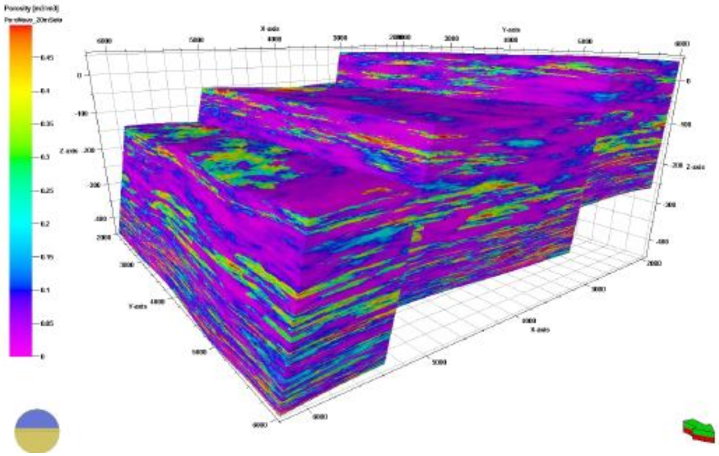
```
For each particle
    initialize particle
End For

Do
    For each particle
        calculate fitness value
        if the fitness value is better than the best fitness value (pBest) in history
            set current value as the new pBest
    End

    choose the particle with the best fitness value of all the particles as the gBest

    For each particle
        calculate particle velocity according to previous equations
        update particle position according to previous equations
    End
While maximum iterations or minimum error criteria is not attained
```

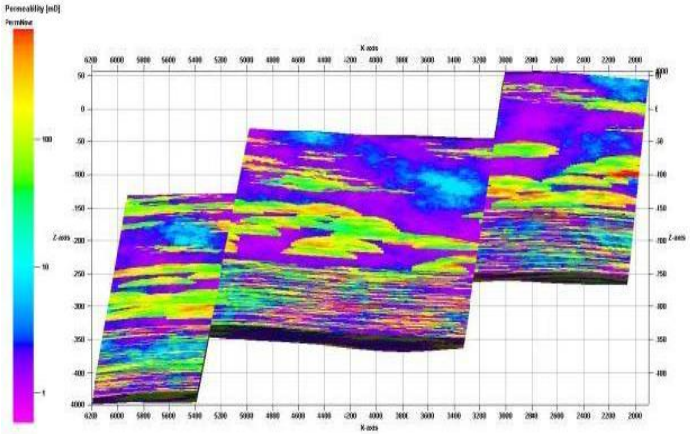


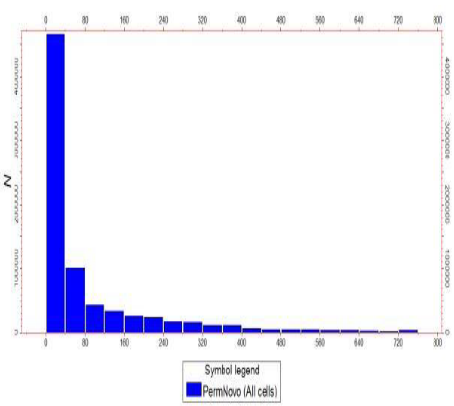
Introduction to CERENA-I

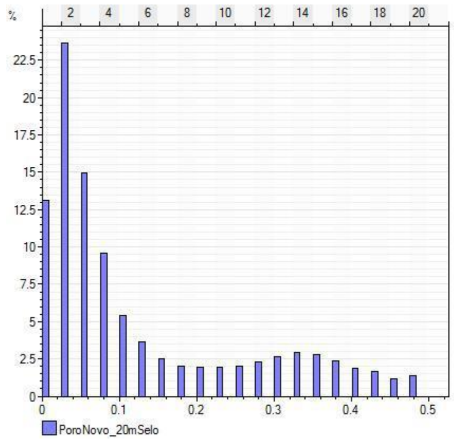
Dataset Description

- A Model based on the Jupiter field in Brazil
- Top at 5000m
- GOC at 5370m, OWC at 5435m
- 90m thick oil zone with 18ºAPI
- Oil with 55% CO_2 (molar)
- Reservoir rocks: Stromatolites and Microbiolites
- 16km^2
- 7 million cells









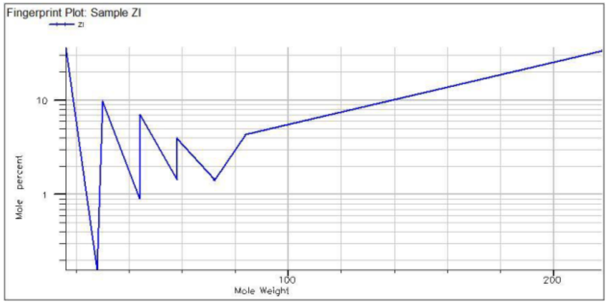
Introduction to CERENA-I

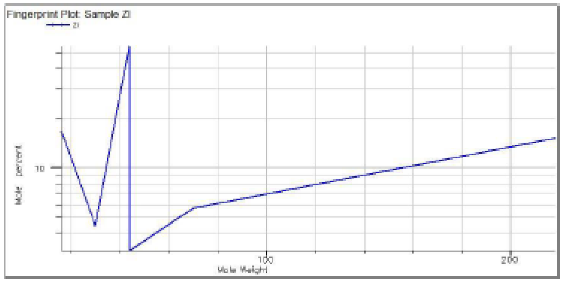
Fluid System

Component	Molar %	Mol. weight
N_2	0.16	28.013
CO_2	0.91	44.01
C_1	36.47	16.043
C_2	9.67	30.07
C_3	6.95	44.097
NC_4	3.93	58.124
IC_4	1.44	58.124
NC_5	1.41	72.151
IC_5	1.44	72.151
C_6	4.33	84
C_{7+}	33.29	218

Estimated observations

Bubble point (bar)	Dew point (bar)
493	400





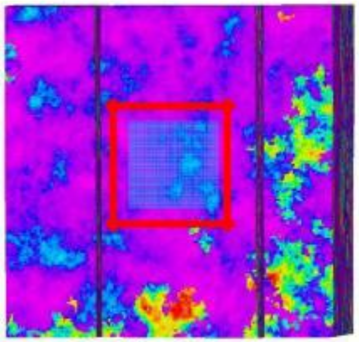
Component	Molar %	Mol. weight
CO_2	55.00	44.01
C_1	16.56	16.043
C_2	4.46	30.037
C_3	3.15	44.097
C_{4-6}	5.69	70.237
C_{7+}	15.11	218

Calculated observations

Bubble point (bar)	Dew point (bar)
492.9964	399.9967

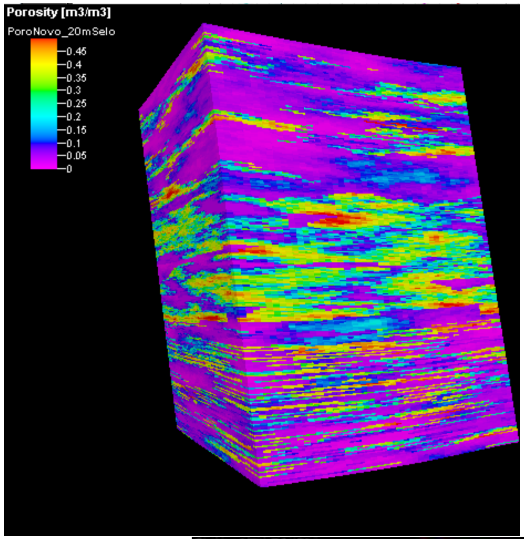
Dynamic Simulation of CERENA-I

Sectorial Model

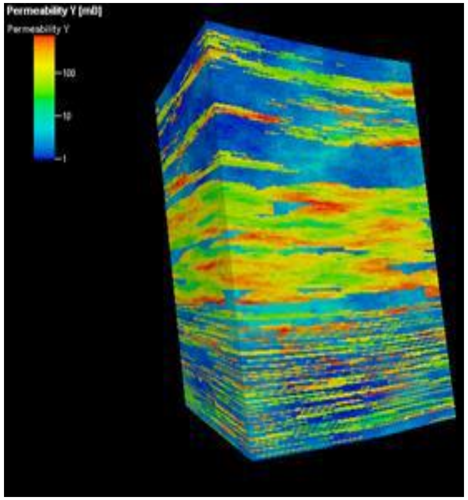


Sectorial model area

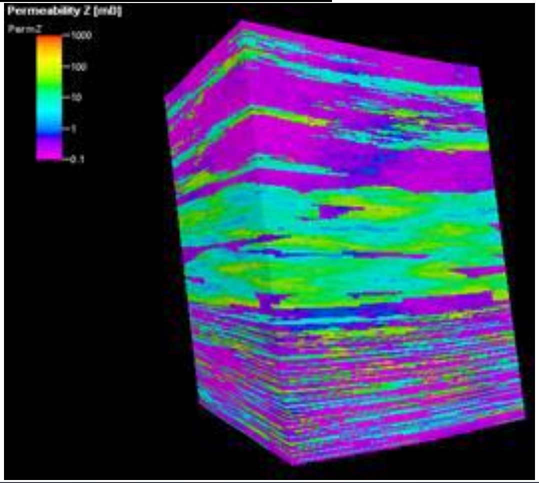
- $1km^2$
- 280,000 active cells
- Use of sectorial model,due to computational constraints



Porosity model

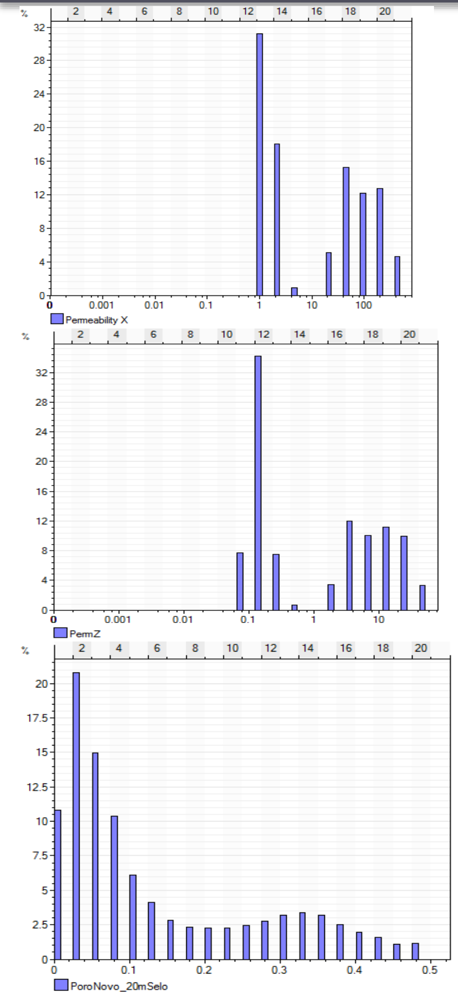


Permeability models:
- x and y to the left;
- z to the right.

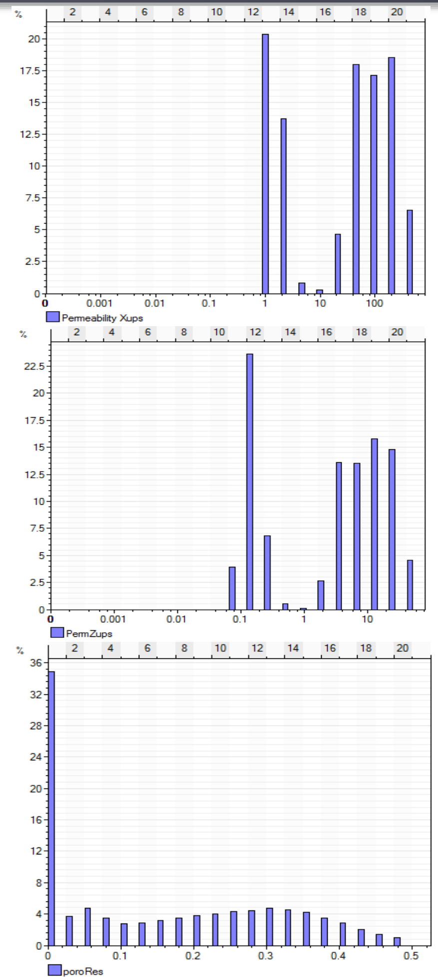


Dynamic Simulation of CERENA-I

Upscaling of CERENA-I



Real



Synthethic

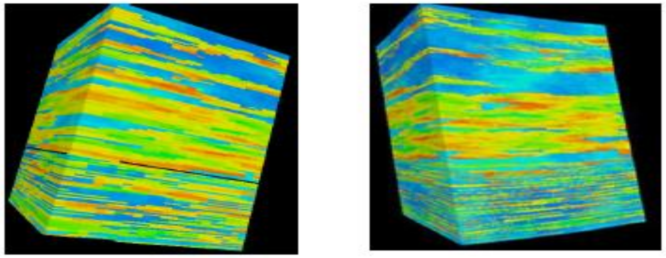


Fig 21: Upscaled perm x and y (left), original perm x and y (right)

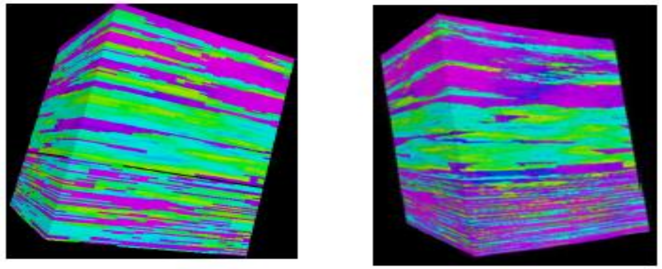


Fig 22: Upscaled perm z (left), original perm z (right)

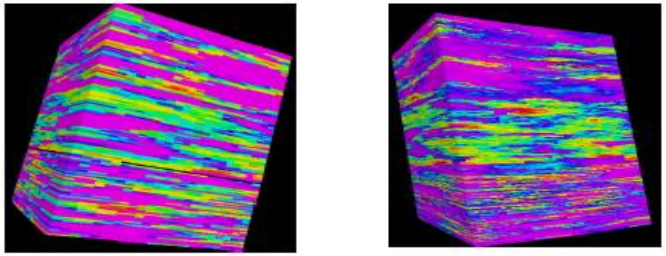
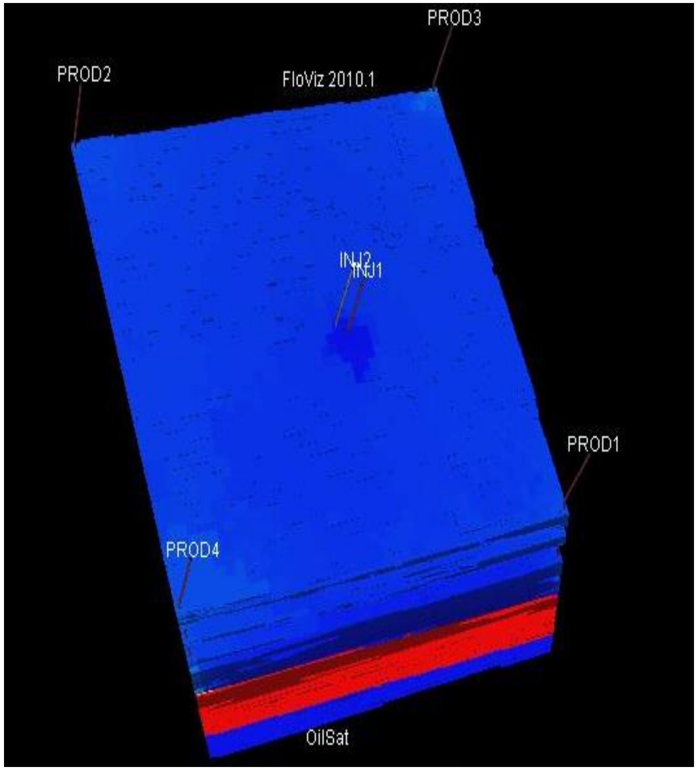


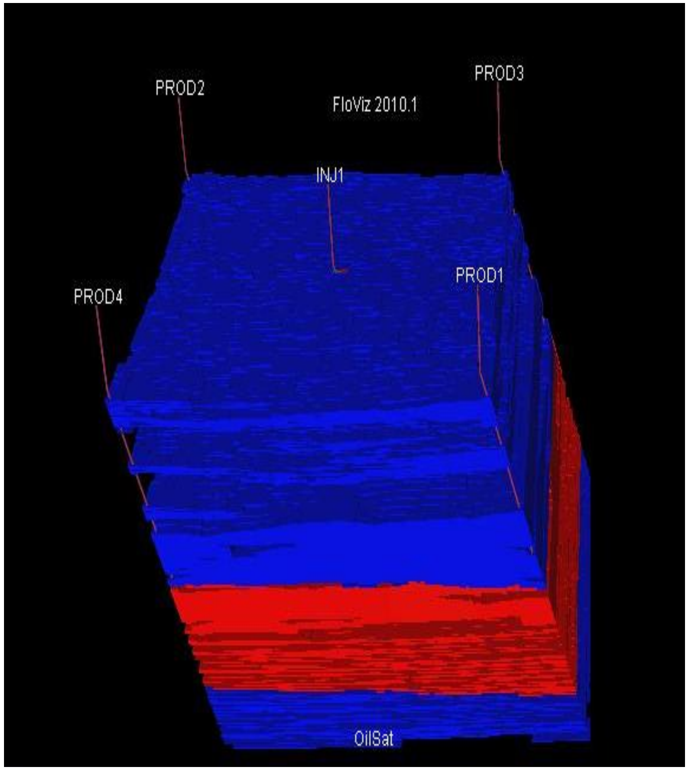
Fig 23: Upscaled porosity (left), original porosity (right)

Synthethic Real

Dynamic Simulation of CERENA-I

Production scheme for CERENA-I





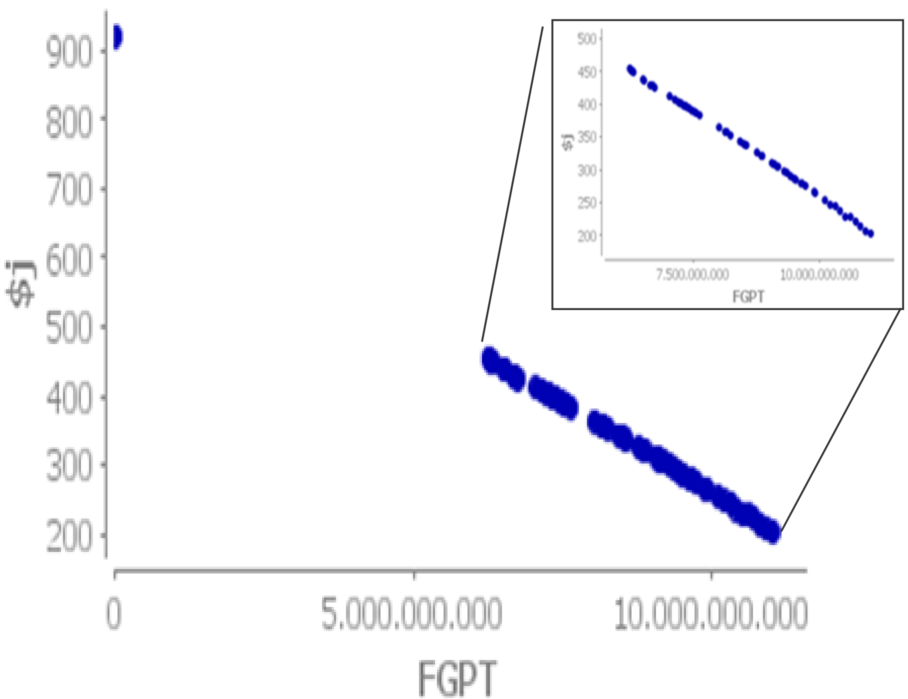
Dynamic Simulation of CERENA-I

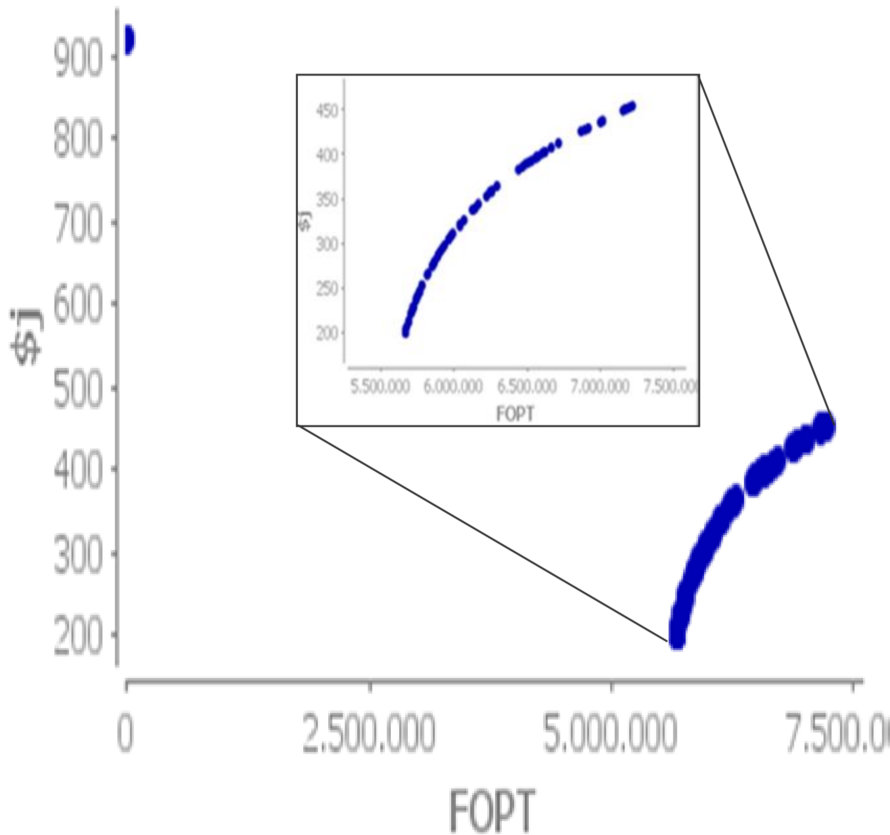
Optimization Results

Production wells Bottom-hole Pressure:

- Same BHP or Different BHP

Same Bottom-hole Pressure:

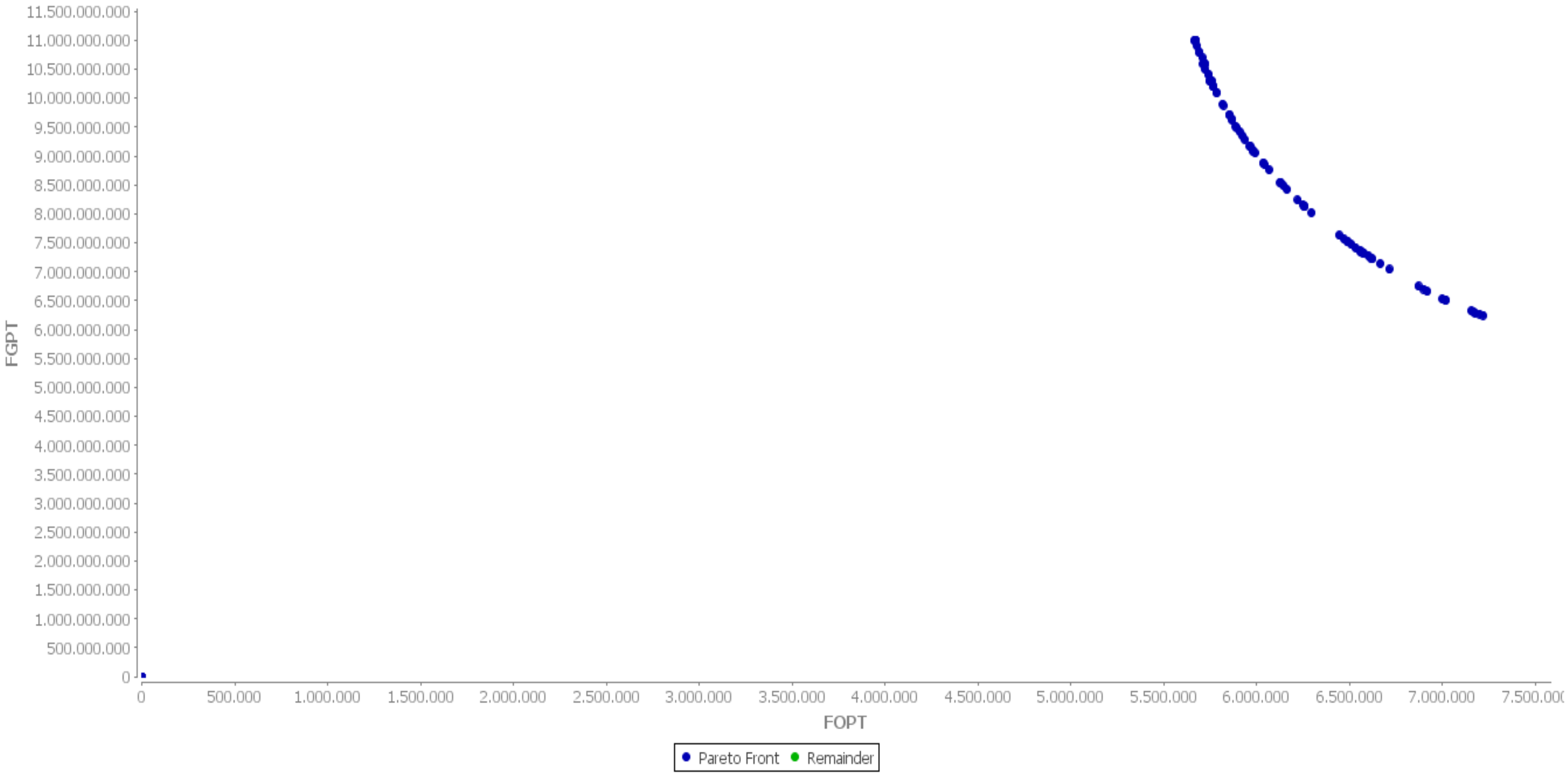




Dynamic Simulation of CERENA-I

Optimization Results

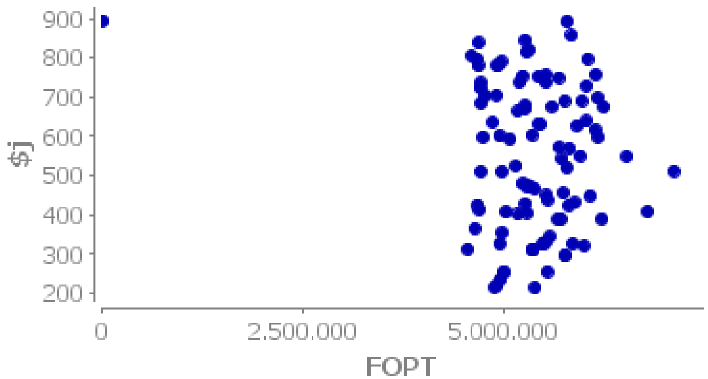
Same Bottom-hole Pressure:

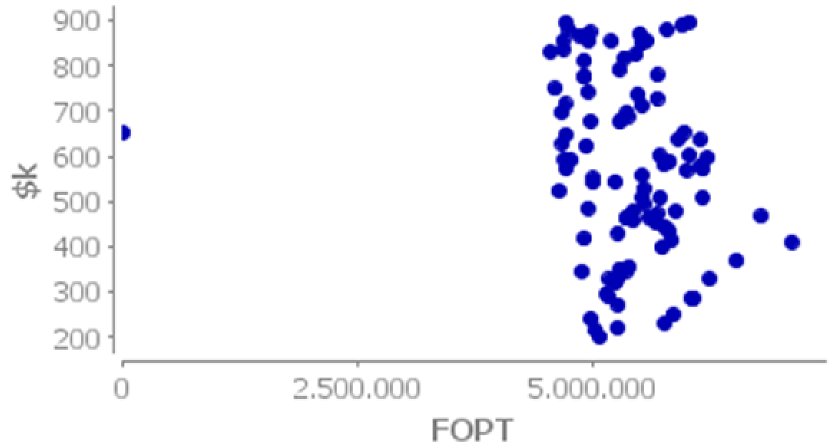


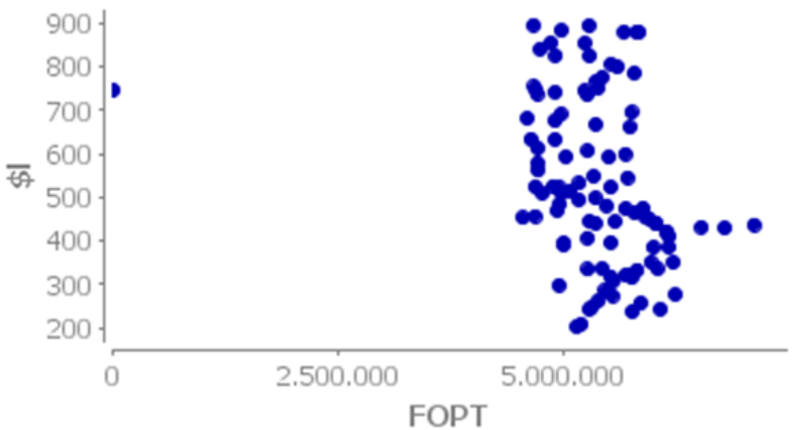
Dynamic Simulation of the CERENA-I

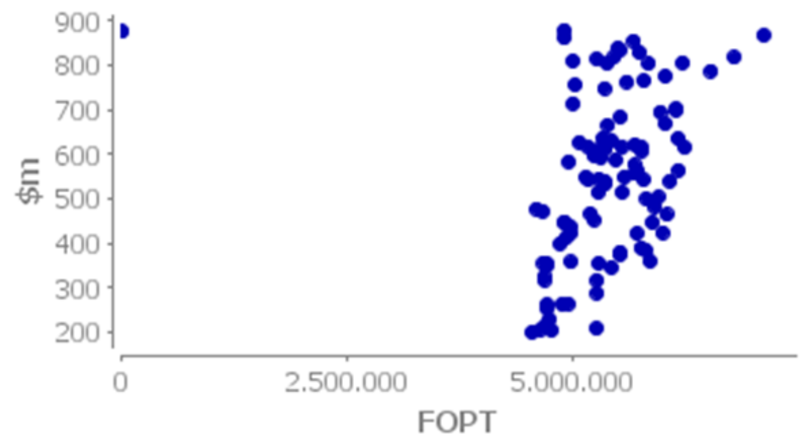
Optimization Results

Different Bottom-hole Pressure:





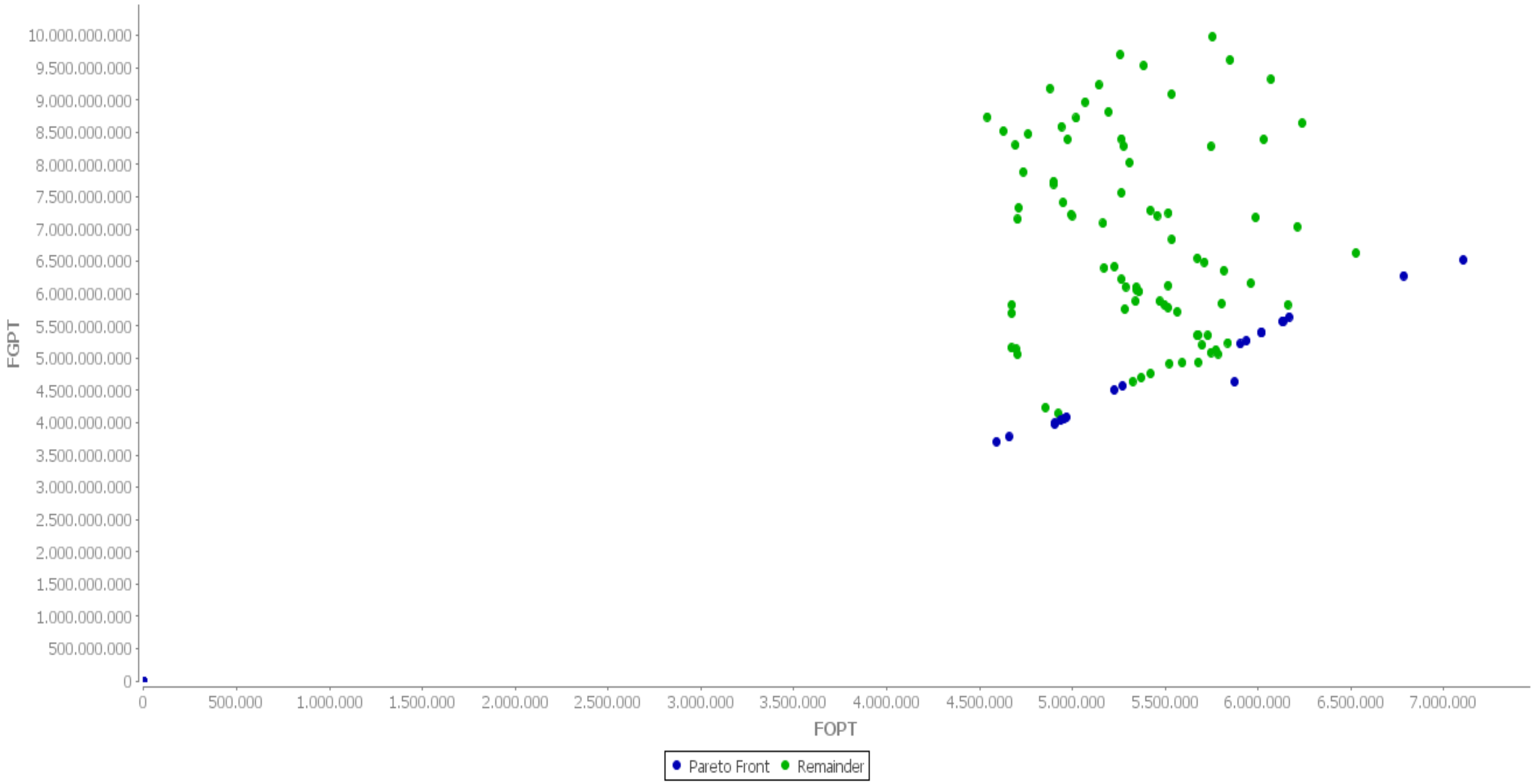




Dynamic Simulation of CERENA-I

Optimization Results

Different Bottom-hole Pressure:



Dynamic Simulation of CERENA-I

Optimization Results

Injection rate and WAG ratio: j and k are fractions for portions of water and gas injected respectively which could be from 0.01 to 0.99.

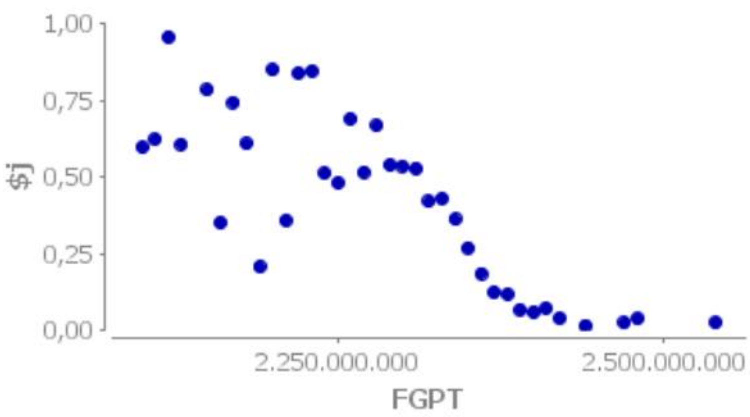
WAG ratio = Volume of water injected: Volume of Gas injected

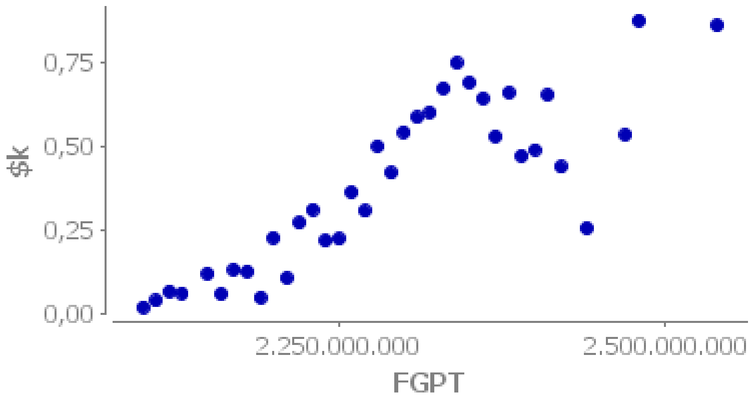
≡ Water Injection rate : Gas injection rate

≡ Water injection rate : (Water injection rate x k/j)

≡ j: k

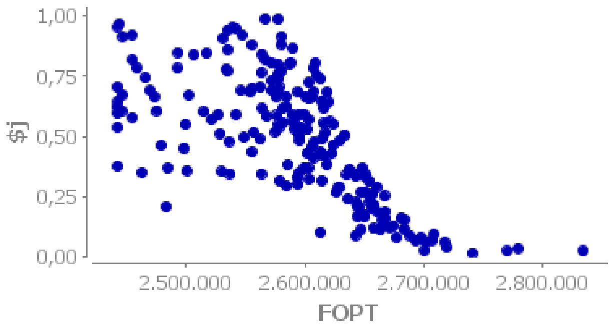
$1570 sm^3/day$

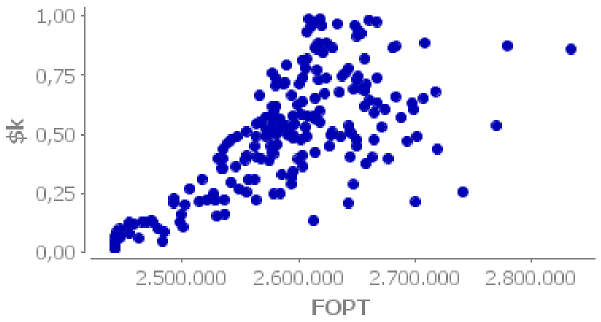


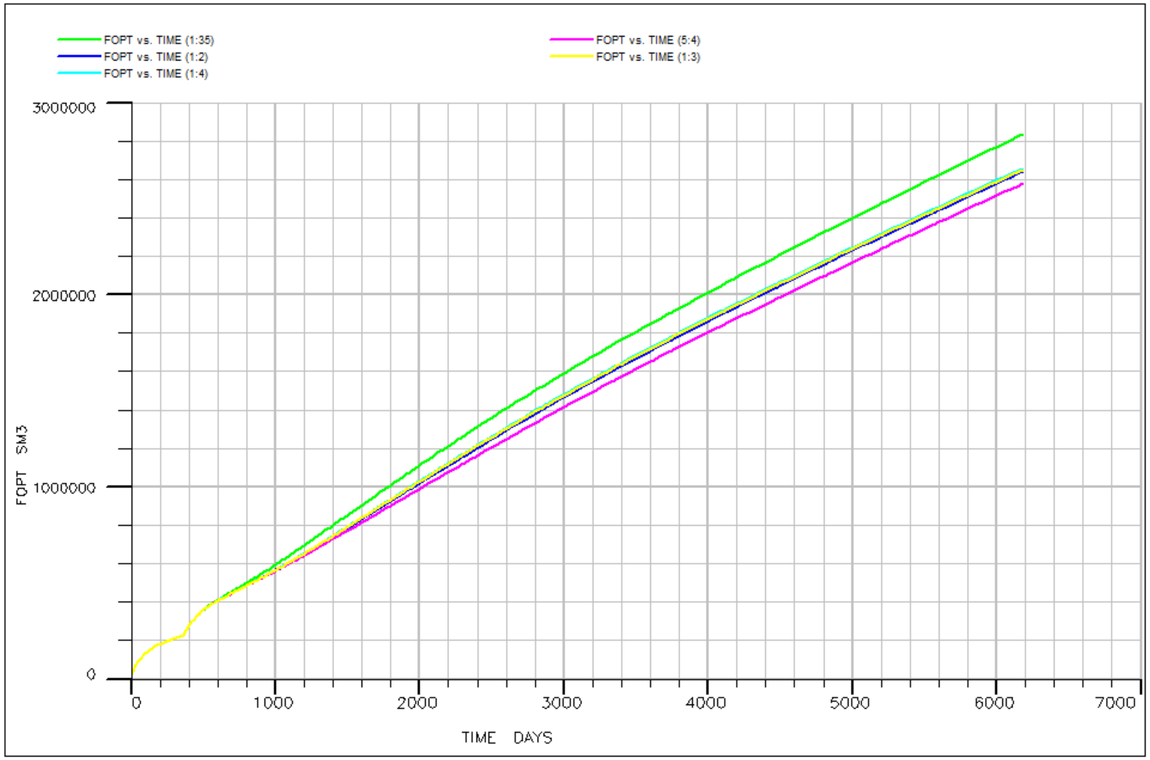


Dynamic Simulation of CERENA-I

Optimization Results





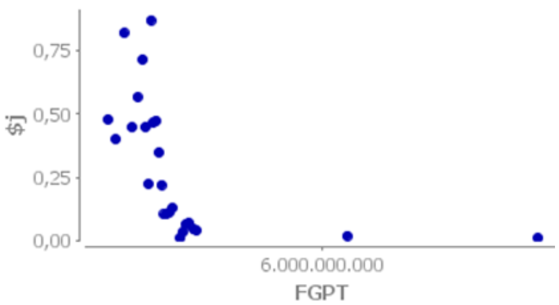


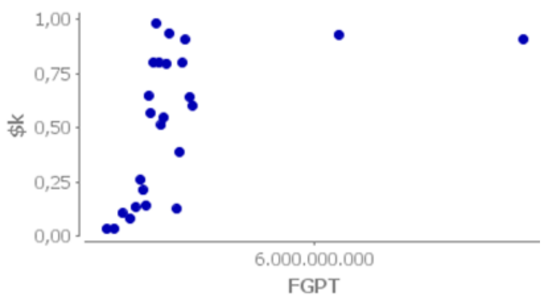
1570sm^3/day

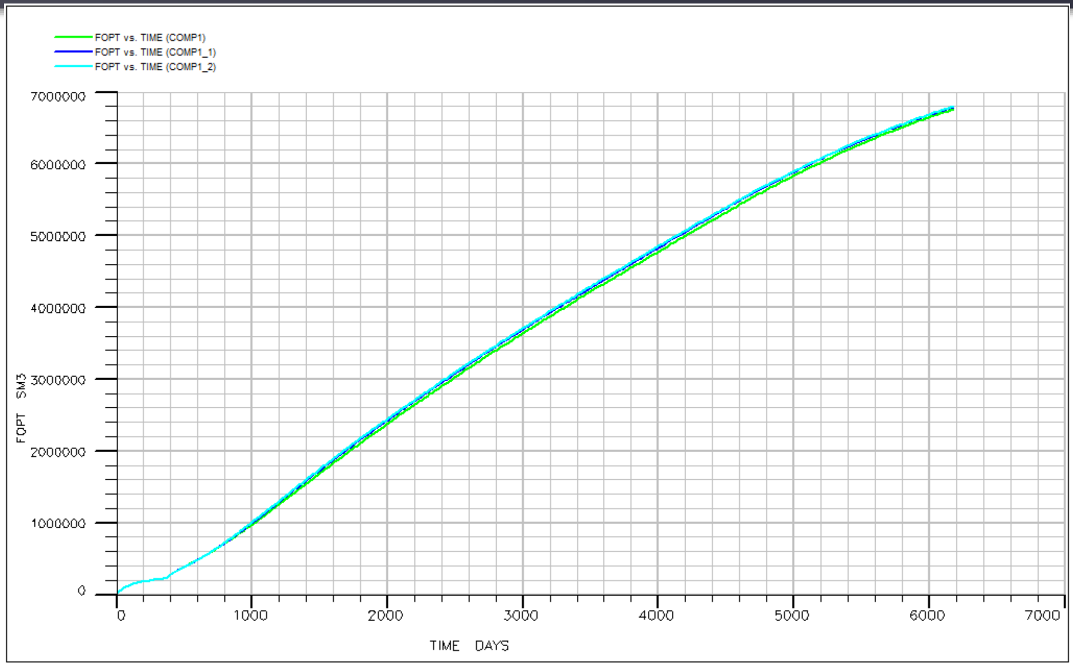
- Some selected WAG ratio

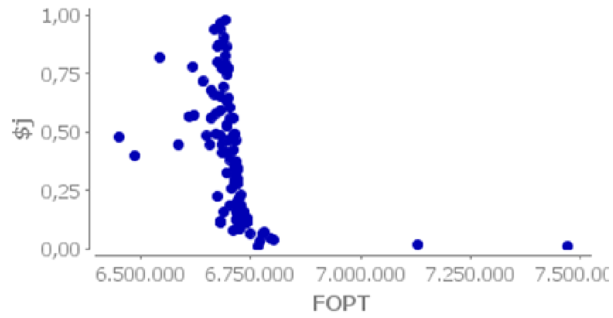
Dynamic Simulation of CERENA-I

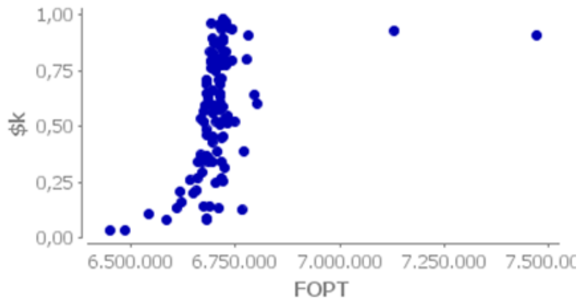
Optimization Results







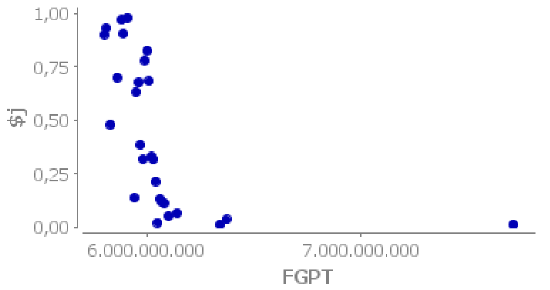


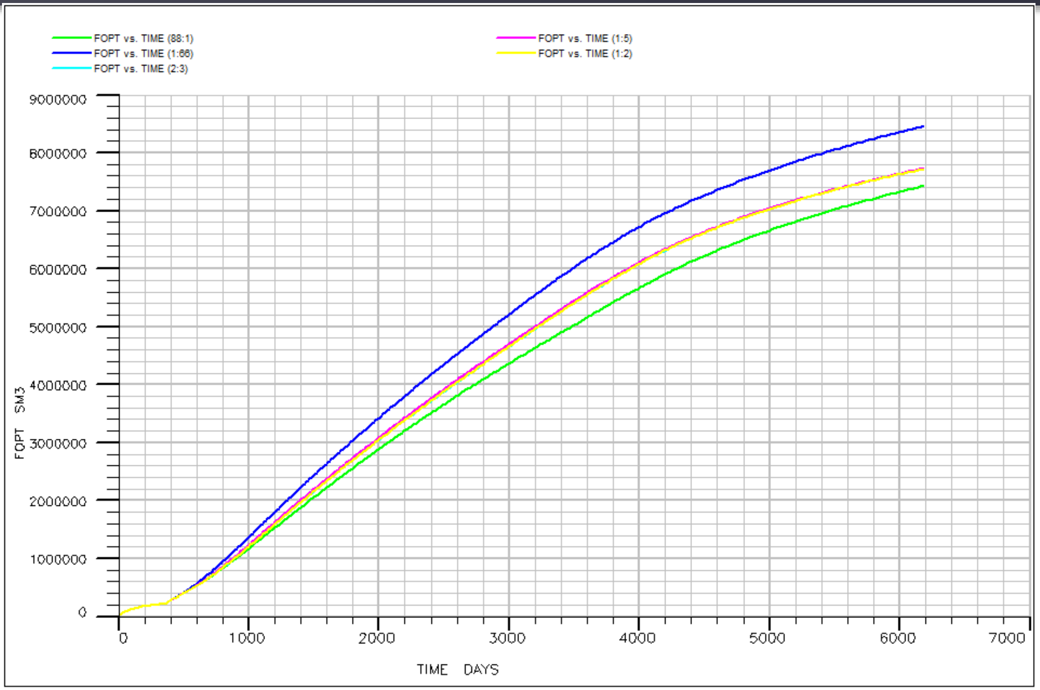


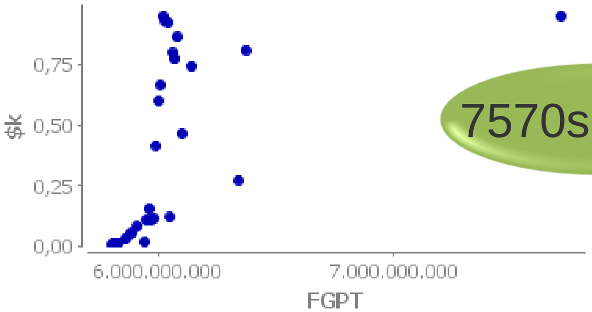
5570sm^3/day

Dynamic Simulation of CERENA-I

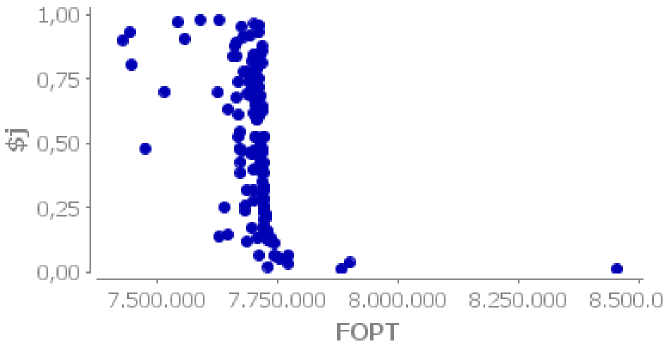
Optimization Results

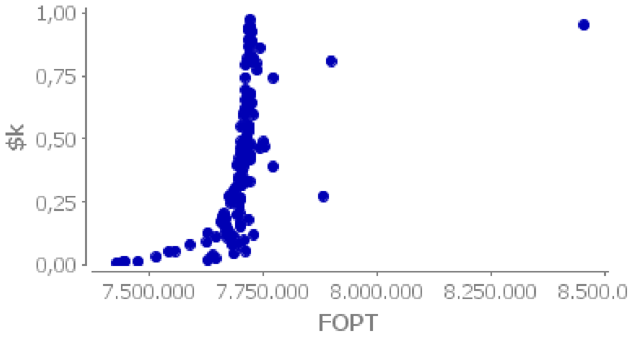






7570sm^3/day



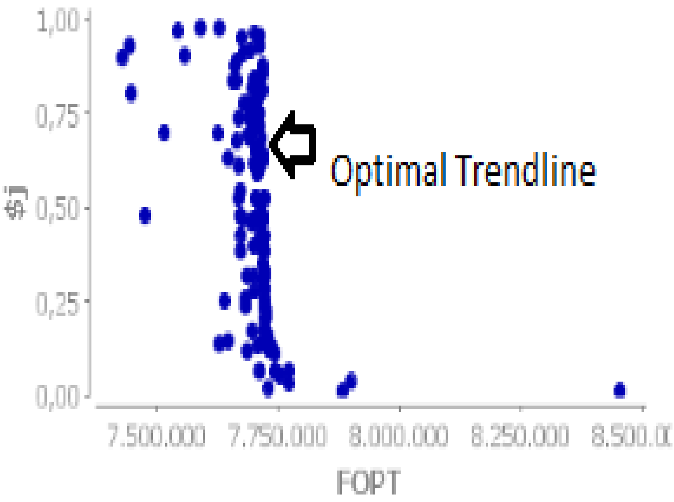


Dynamic Simulation of CERENA-I

Optimization Results

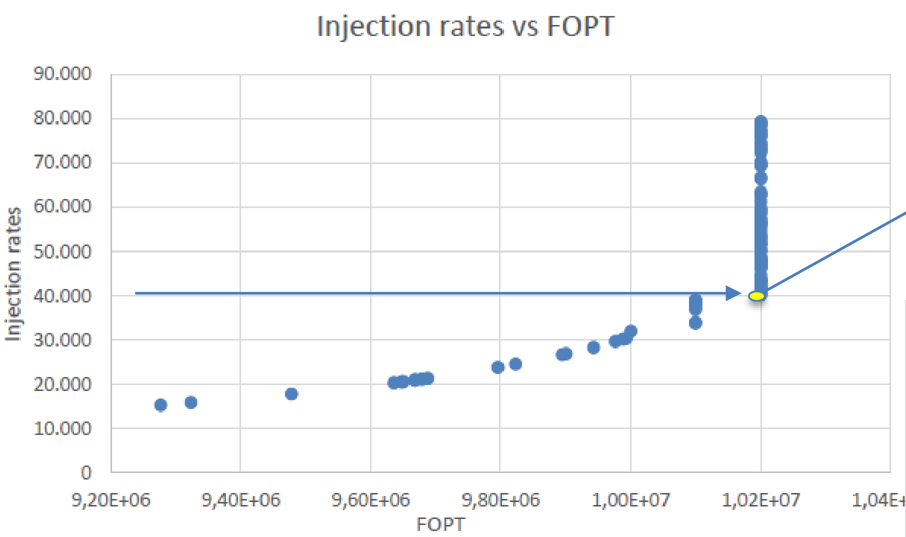
From the results obtained, we observed the following:

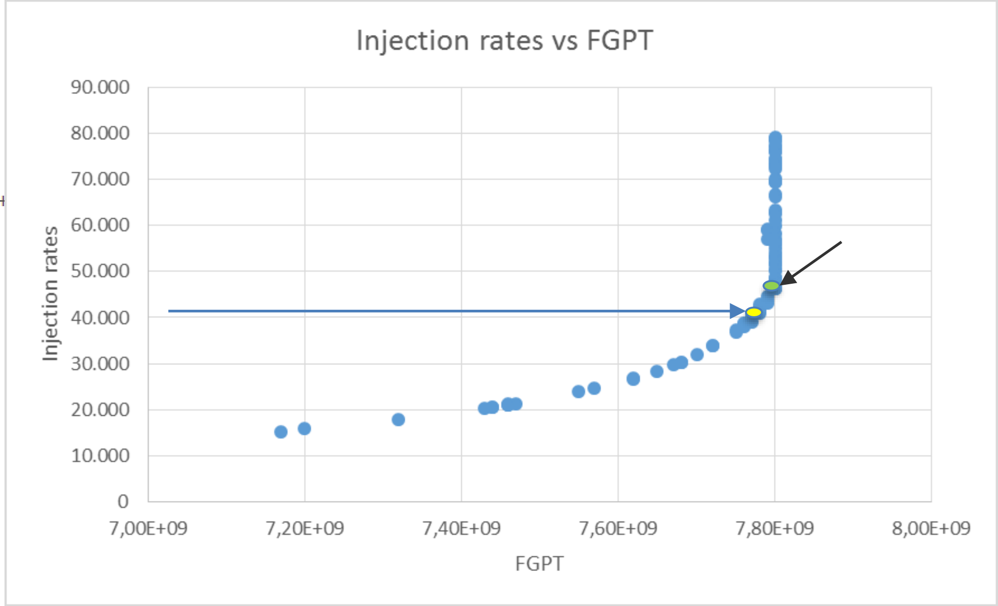
- Inverse relation between the injection fluids
- An optimal trend line is observable
- As we increased the injection rates, the optimal trend line becomes visibile.
- The optimal trend line is between the same range in the 3 injection rates tested.



Dynamic Simulation of CERENA-I

Optimization Results



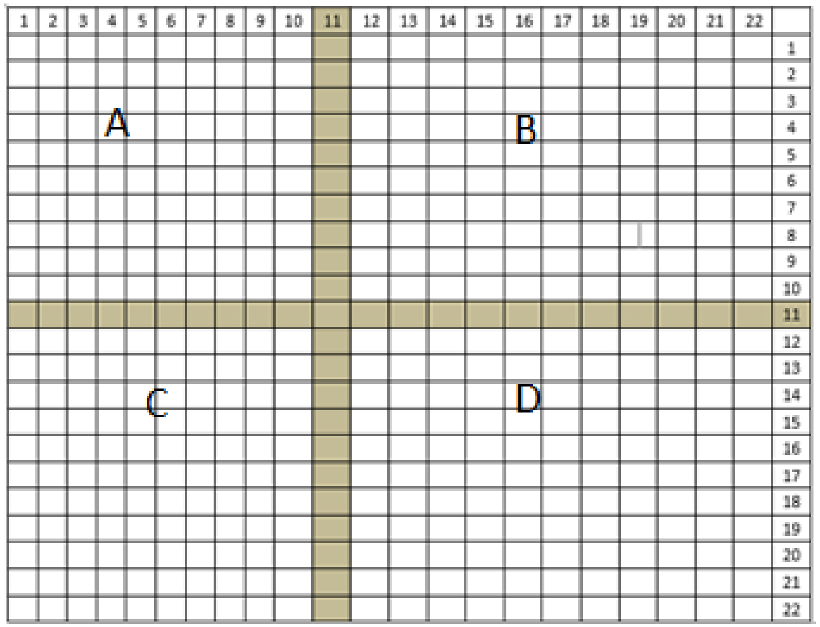


The selected WAG ratio in this work was the ratio 2:3, and the results obtained are shown below.

Dynamic Simulation of CERENA-I

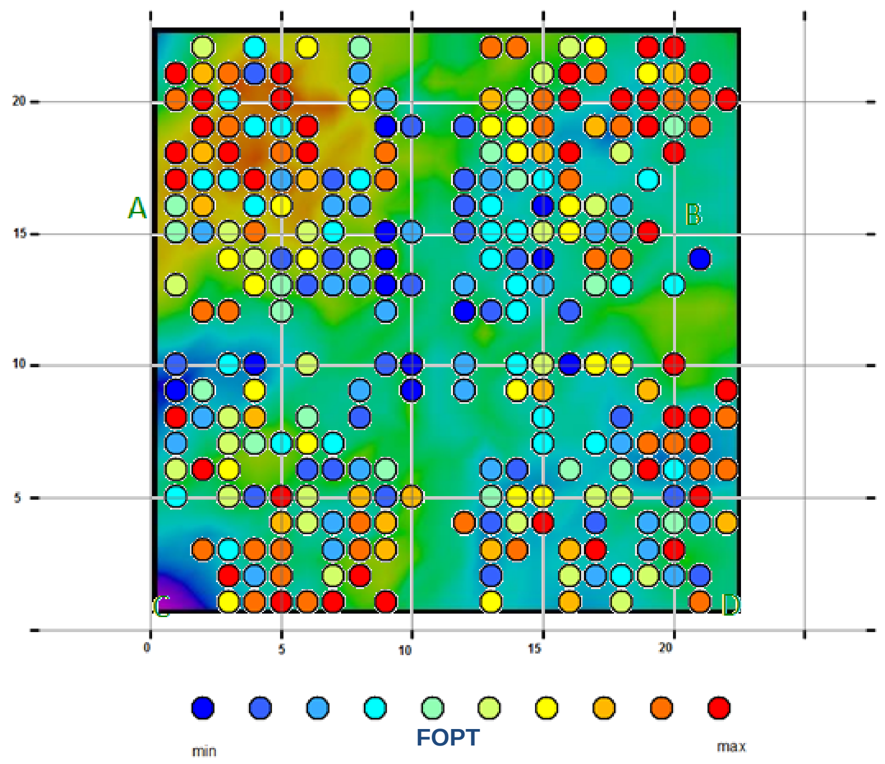
Optimization Results

Well Position: The reservoir was divided into 4 parts, with one well in each compartment. Each well is supposed to move just within its own compartment and the total oil and gas produced observed together.



Dynamic Simulation of CERENA-I

Optimization Results



Average vertical reservoir Porosity map of the reservoir overlapped over the production results

Conclusion and Future works

- This shows the importance of the parameters we discussed in improving oil recovery.
- We can also the effect of teritary recovery mechanisms on our reservoir.
- Recreating this work on the original reservoir would be of great interest.
- Plans have started to study the WAG system both microscopically and macroscopically for improved optimization.
- Plans to use other possible production schemes and compare the results are in the pipeline.

TÉCNICO LISBOA

CERENA

References

- **Archer, J. S., & Wall, C. G.** (1986). Petroleum engineering: principles and practice. London: Graham and Trotman Ltd.
- **Christensen, J. R.; Stenby, E. H., Skauge,** (2001) A. Review of WAG field experience. SPE Reservoir Evaluation & Engineering.
- **Doghaish, N. M.** (2008). Analysis of Enhanced Oil Recovery-A Literature Review. Dalhousie University. Halifax: unpublished work.
- **Horta, A., & Soares, A.** (2010). Direct Sequential Co-Simulation with Joint Probability Distributions. *Mathematical Geosciences*.
- **Kansas Geological Survey** (2004). *Sedimentologic and Diagenetic Characteristics of the Arbuckle Group.*
- **Meshal, A., G. Rida and M. Adel, (**2007). A parametric Investigations of SWAG injection technique. SPE paper # 105071 prepared to be presented in 15th SPE Oil and Gas Show, Bahrain 11-14th March
- **Nezhad, S., Mojarad, M., Paitakhti, S., Moghadas, J., & Farahmand, D.** (2006). Experimental Study on Applicability of Water.Alternating-CO2 injection in the Secondary and Tertiary Recovery. First International Oil Conference and Exhibition in Mexico (pp. 1-4). Cancun: Society of Petroleum engineers
- **Nocedal, J. and Wright, S.J**.: “Numerical Optimization”, Second Edition, Springer press, 2006.
- **Onwunalu, J., Durlofsky, L., (**2011). A new well-pattern-optimization procedure for large-scale field development. SPE Journal 16 (3), 594–607.
- **Pedro Pinto** (2013). Dynamic simulation on the synthetic reservoir CERENA I; Compositional fluid flow simulation with 4D seismic mitoring on a reservoir with a large content of CO_2.
- **Salako Abiodun Ebenezer**, (2005) Removal of Carbondioxide from Natural gas for LNG production. Semester Project Work, Institute of Petroleum Technology, Norwegian University of Science and Technology, Norway.
- **Saleem Qadir Tunio, Tariq Ali Chandio and Muhammad Khan Memon, (**2012). Comparative Study of FAWAG and SWAG as an Effective EOR Technique for a Malaysian Field. Research Journal of Applied Sciences, Engineering and Technology 4(6): 645-648, 2012.