SmartFlood 2.0 Demonstration

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November 2nd , 2012

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Model Calibration and Efficient Reservoir Imaging: MCERI

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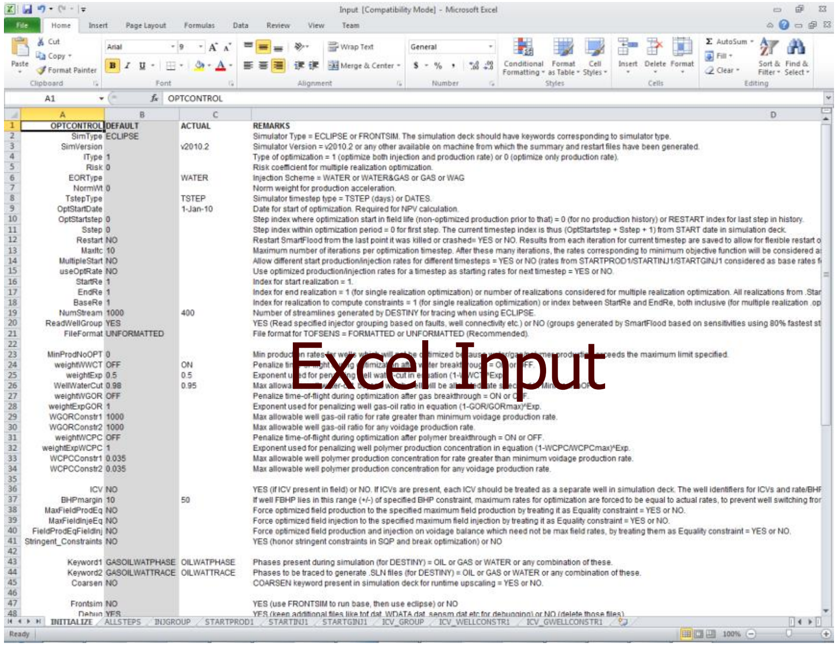
What is SmartFlood?

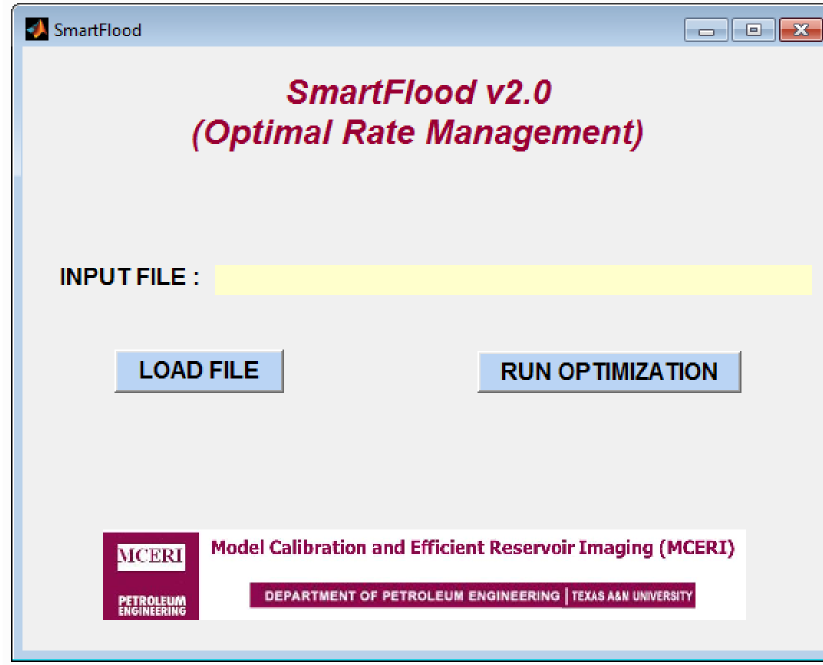
- Smartflood can optimize production/injection rates by equalizing the arrival time of the waterfront at all producers within selected sub-regions of a waterflood project under operational and facility related constraints.

- Software designed based on streamline-based approach proposed by Ahmed Alhuthali (SPE 102478) to maximize waterflood sweep efficiency.

- Major advantage of this approach is the analytical computation of sensitivities of the front arrival times and gradient and Hessian of the objective function

SmartFlood 2.0





Software requirement

- MCRinstaller
- EXCEL input sheet
- ECLIPSE – modified data deck

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- Introduction
- Workflow
- Result: maximize flood efficiency
- Result: production acceleration
- Other applications
- Creating workspace

SmartFlood Workflow

Read EXCEL INPUT file

↓

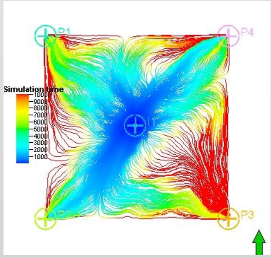
Run Simulator

ECLIPSE

ECLIPSE* reservoir simulation software

↓

Run DESTINY for streamline tracing



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Calculate sensitivities

$$\frac{\delta \tau_i}{\delta q_i}$$

↓

Update production/injection rate (loop back to Run Simulator)

$$\mathrm{q_i} = \mathrm{q_i} + \Delta q$$

↓

Output optimized rate files

Objective Function Formulation

Average arrival time | Arrival time of producer i | Norm weight

Min

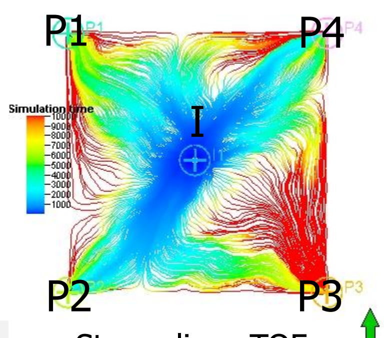
$$p(\mathbf{q}) = \sum_{i=1}^{Nprod} \left(t_d(\mathbf{q}) - t_i(\mathbf{q})\right)^2 + \eta \sum_{i=1}^{Nprod} \left(t_i(\mathbf{q})\right)^2$$

Maximize flood efficiency

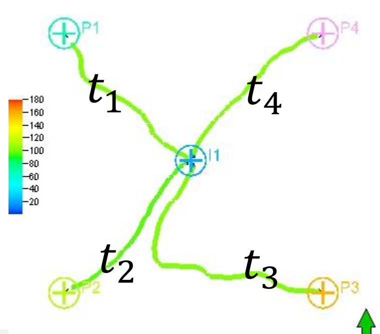
To minimize this term, variation of arrival time should be reduced which comes from rate allocation

Acceleration

To minimize this term, arrival time should be reduced which comes from produce with higher rate



Streamlines TOF



Average TOF from injector to each producer, $t_{i,m}$

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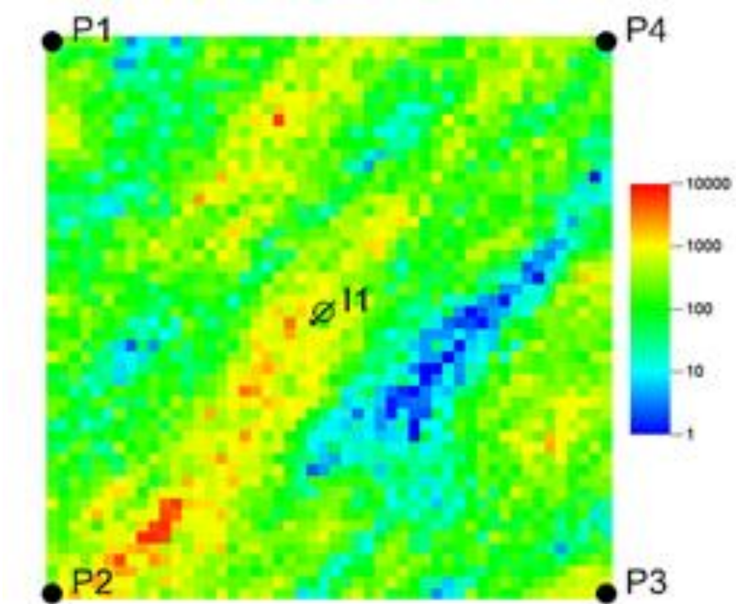
Synthetic 2D Case



Permeability

2D example case

- 50x50 grid
- Spatial Permeability

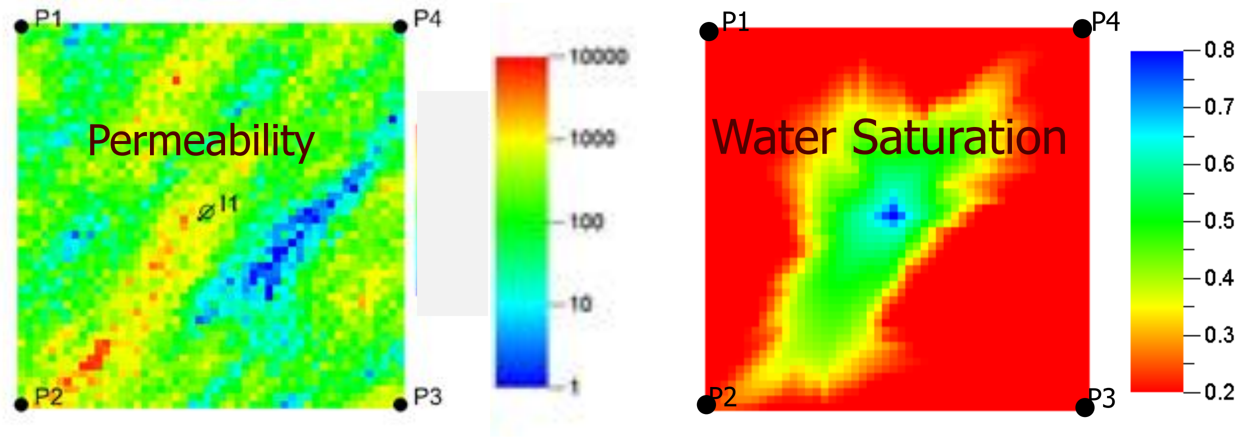
Constraints:

- Field water injection 400 RB/D
- Well production rate ≤ 300 RB/D for each well
- Production BHP ≥ 1000 psi
- Voidage balance

Want to optimize rate from 4 producers

Compare with base case of 100 RB/D each well

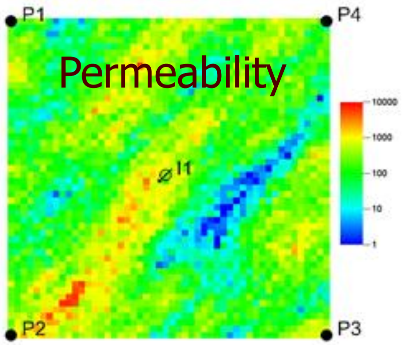
Result from Base Case (without rate optimization)

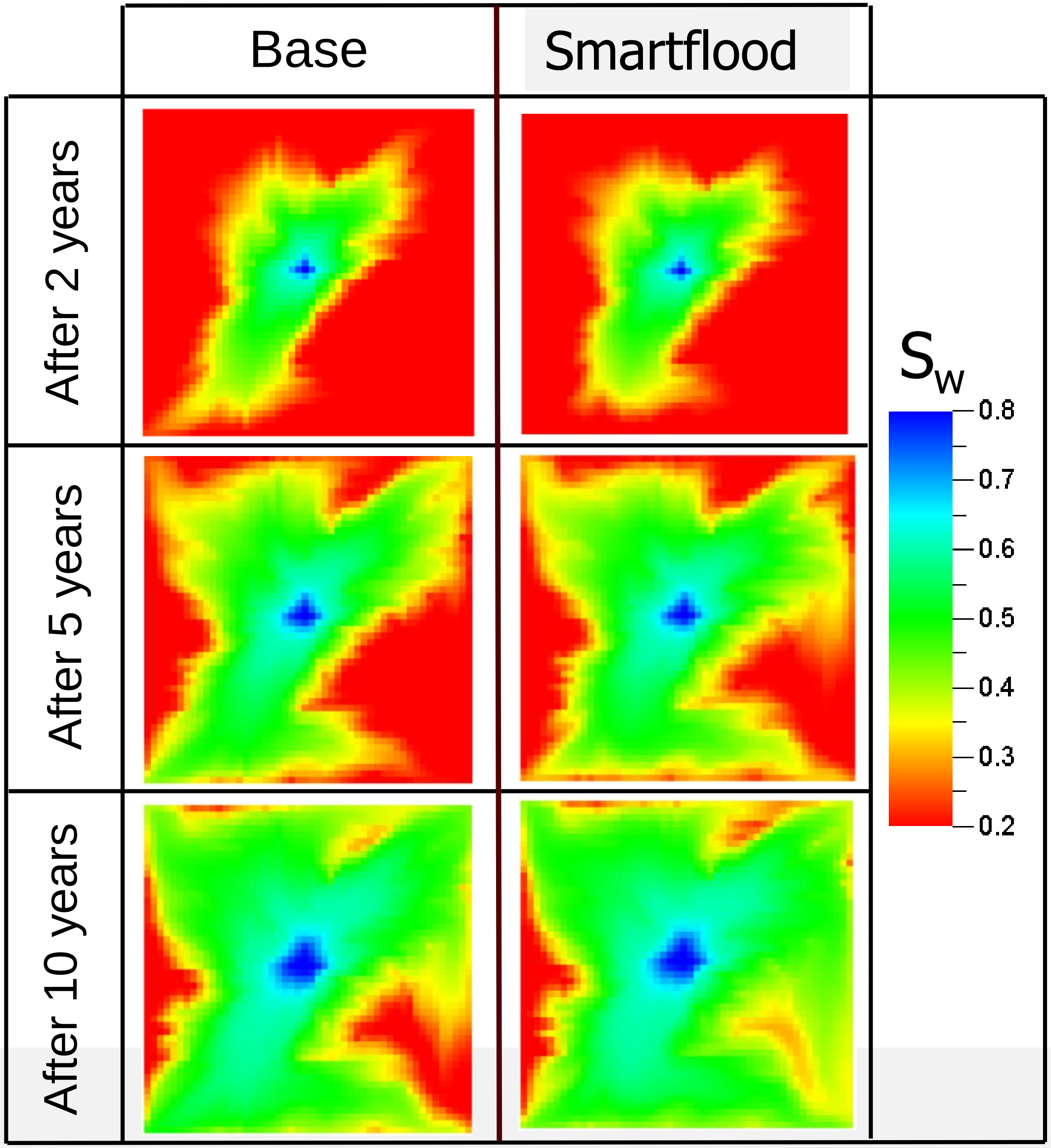


Well P2 and P4 have high permeability streak -> water breakthrough very fast

Smartflood will search for rates that equalize water breakthrough from all producers

Results after optimization

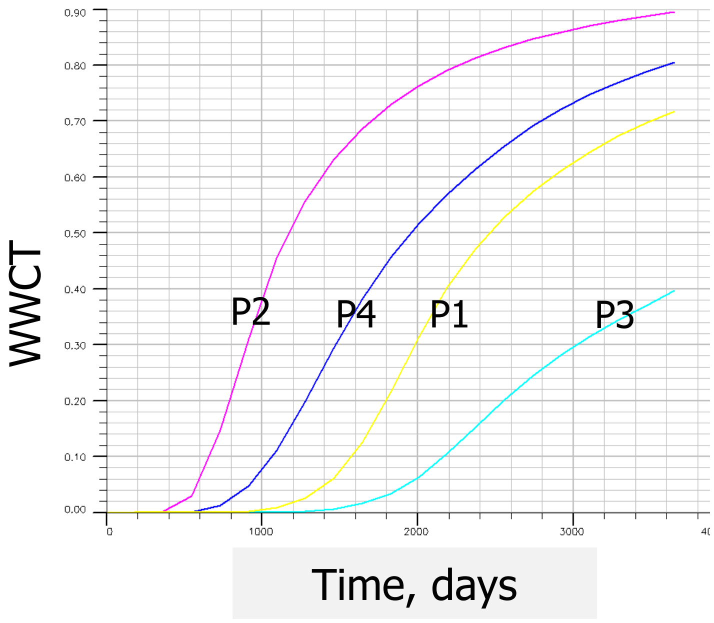




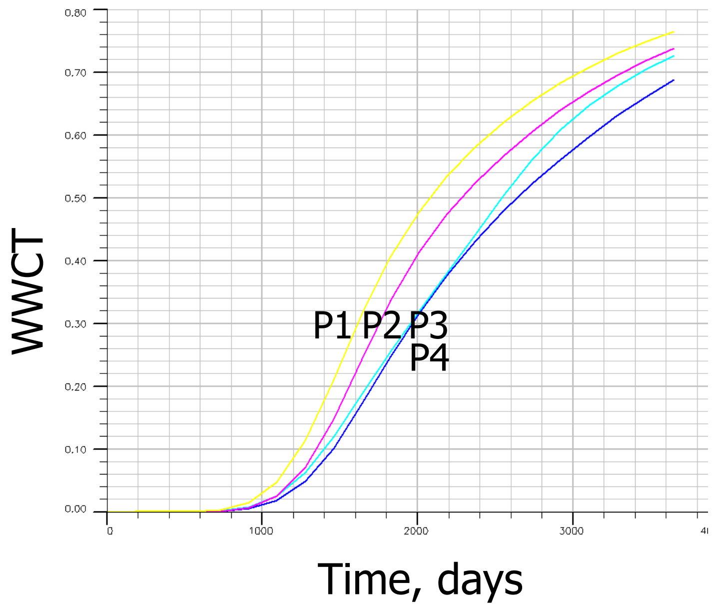
More uniform waterfront movement after optimization

Watercut Comparison

Base case



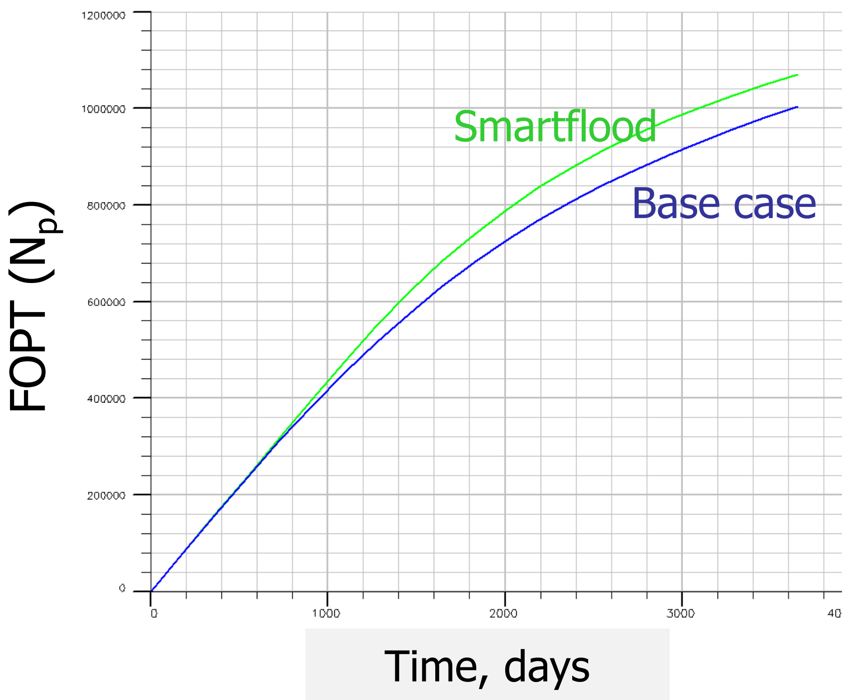
Maximum sweep efficiency



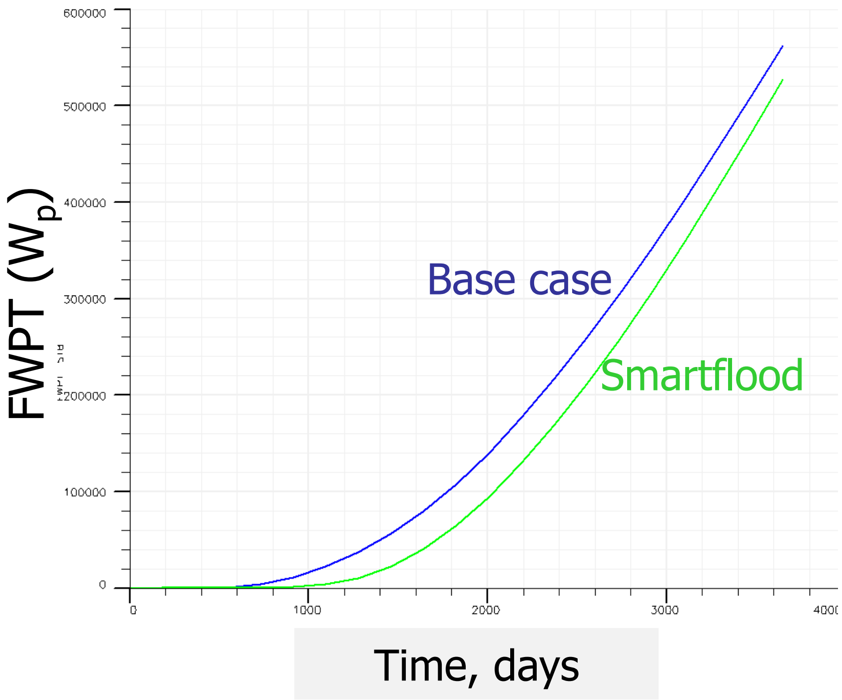
More uniform water breakthrough after optimization

Cumulative Production Comparison

Cumulative oil production



Cumulative water production



More oil production and less water production

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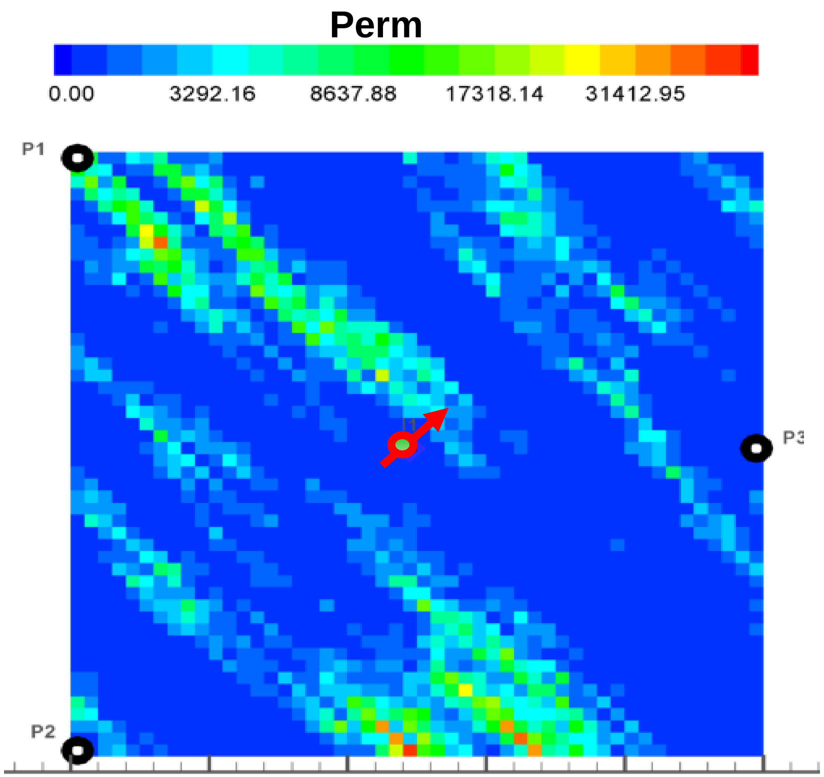
Illustration: Synthetic Field



NPV Optimization Using Sensitivities with Numerical perturbation (45 min)

Vs.

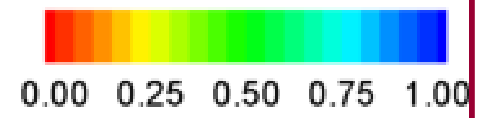
Smartflood (2-3 min)

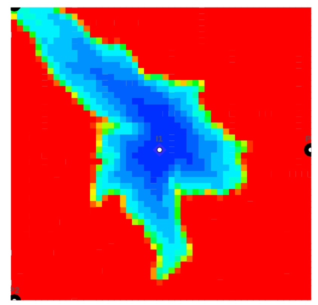
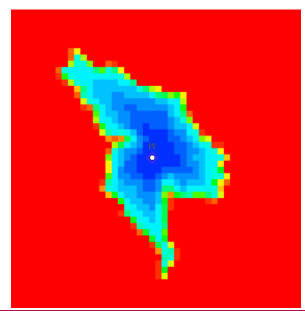
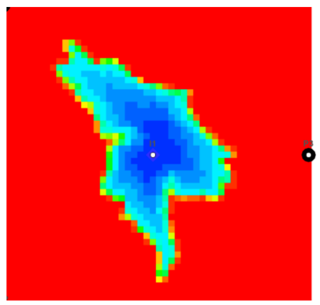
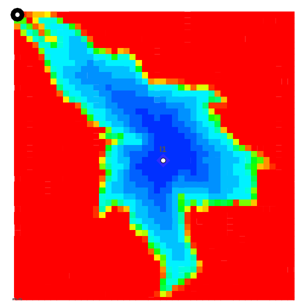
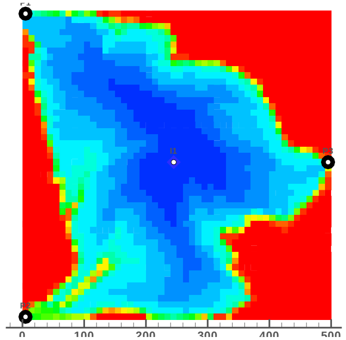
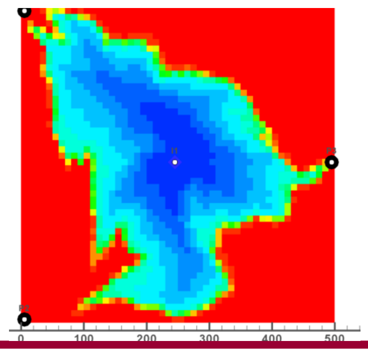
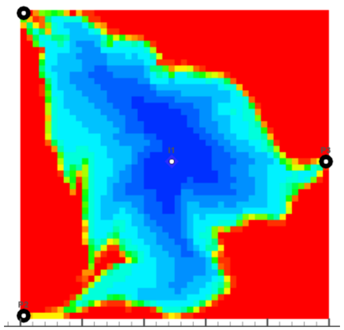
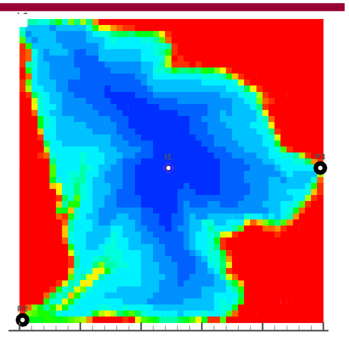
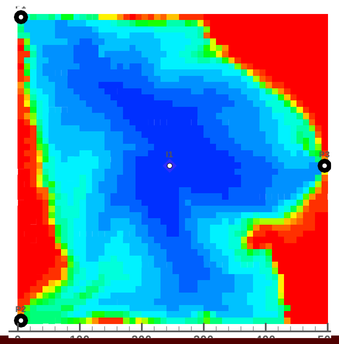
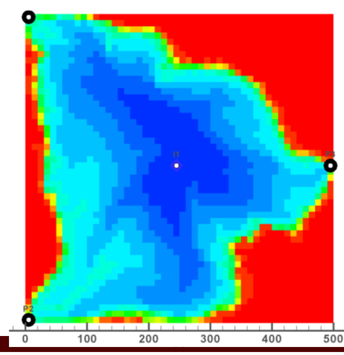
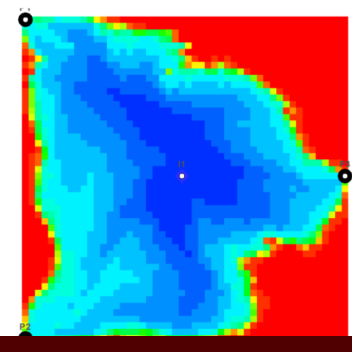
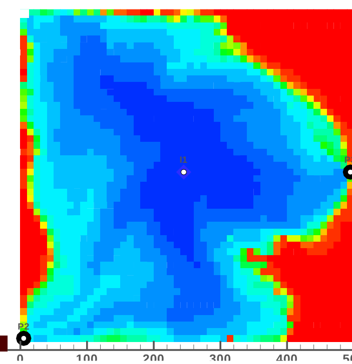
Total production time period = 5000 days. Time step for optimization = 1000 days

Specification for NPV:
Discount rate = 10%, oil price = 50$/bbl, water cost = 5$/bbl

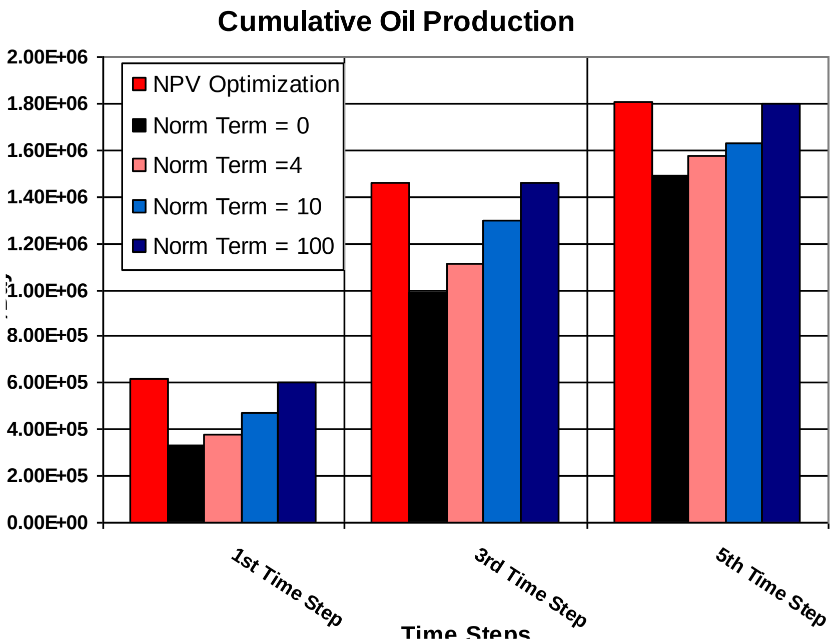
Total field rate <= 800 rb /day, Ind. Well rate <= 300 rb/day, voidage balance

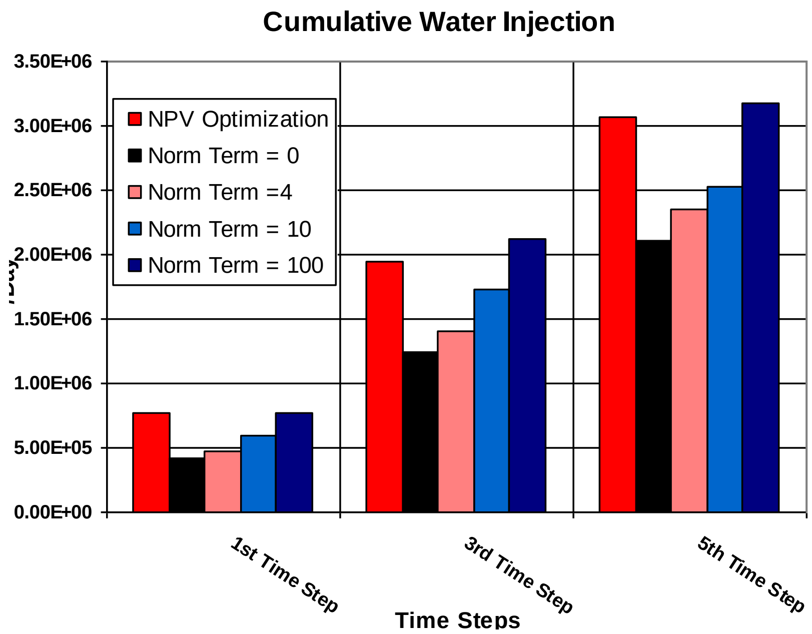
Water Saturation Maps



	NPV Opt	Norm Term = 0	Norm Term = 4	Norm Term = 100
After 1000 days				
After 3000 days				
After 5000 days				

Result of norm weight





More oil production can be produced by higher norm weight. The effect of increasing norm weight is similar to NPV optimization.

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Applications

Applications	SPE#
Optimal Waterflood Management Using Rate Control (Maximize sweep efficiency)	102478
Optimal Water Flood Management Under Geological Uncertainty Using Accelerated Production Strategy (Production acceleration by norm weight)	133882
Optimal Rate Control Under Geologic Uncertainty (Multiple realization)	113628
Field Applications of Waterflood Optimization via Optimal Rate Control With Smart Wells (ICV)	118948
Optimizing Polymerflood via Rate Control (EOR)	144833

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Thank you!

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