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"Different indicators used in the selection of a production strategy can yield different decisions."

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EFFECTS OF THE OBJECTIVE FUNCTION IN PRODUCTION STRATEGY SELECTION FOR POLYMER FLOODING

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Introduction

The selection of a production strategy, seeking maximization of field performance according to some indicators, is a complex and important task. The objective function must reflect the objective of each company. Different indicators can yield different decisions.

This text summarizes the paper of Botechia and Schiozer (2017), which compares the use of production and economic indicators (objective functions - OF) in production strategy optimization process for polymer flooding. The production indicator used is the oil recovery factor (RF) and the economic indicator is the Net Present Value (NPV). The main objectives are (1) to verify the influence of the indicator used as OF in the optimization process and (2) to show the importance of including an economic indicator to test the viability of using recovery mechanisms that generate extra costs and, consequently, change the cash flow, such as polymer flooding, in which chemicals and logistics expenses must be taken into account.

Methodology

The methodology to select the production strategy considers polymer flooding as the recovery mechanism and it is based on Botechia *et al.* (2016) following the steps listed below:

- Step 1: Defining the number and location of wells
  - Step 1.1: Definition of a base scheme
  - Step 1.2: Removal of wells with poor performance
  - Step 1.3: Addition of new wells in the model
  - Step 1.4: Optimization of well location
- Step 2: Setting the production system capacities
- Step 3: Defining the schedule of well drilling
- Step 4: Setting the production/injection well rates and BHP
- Step 5: Defining the economic limit of water cut for well shutdown
- Step 6: Polymer solution concentration
- Step 7: Slug size

For comparison purposes, we performed the optimization process considering three approaches:

A. Using NPV as objective-function;
B. Using RF as objective-function;
C. Using NPV as OF until Step 1.3 (steps related to higher investments) and RF from Step 1.4 onwards (steps not related to big investments since the number of wells is already fixed).

Another assumption of this work is that there are no initial budget restrictions, so the best solution can be evaluated, without limitations. Thus, when using the recovery factor as the objective function, we consider that there is no limitation on the number of wells or platform capacity. The objective, in this case, is to find the best recovery.

Alternative C was created to emulate a situation where RF is used as an OF for a previously selected production capacity and number of wells.

Results

- Influence of OF in the optimization process

Table 1 summarizes the results (best alternative) considering the three approaches, for the polymer flooding strategies optimization. The highest economic return was achieved when considering NPV as objective-function. Using only the RF as objective-function in the optimization process, when there are no budget or platform limits, leads to negative NPV. As expected, the investments are very high, because of the high number of wells. Thus, despite the much higher oil production in this case, this extra oil production is not enough to cover additional investments necessary to produce this incremental oil. In addition, the water production is also much higher, which generates additional costs. Approach C leads to similar results as Approach A, since the steps that most influence the economic return are performed using NPV as OF. However, this alternative presents lower NPV than Approach A, since the recovery factor is used as OF in some steps of the optimization and thus, the process prioritizes the production instead of the economic return for these steps.

***Table 1**: Comparison of different approaches*

Ap.	OF	NPV (10^6 USD)	RF	Wp (10^6 m³)	Investment (10^6 USD)
A	NPV	1456	0.19	59	2457
B	RF	-607	0.27	337	5322
C	NPV+RF	1275	0.20	97	2491

Figure 1 shows the relationship between RF and NPV for Step 1.3 (addition of wells), considering NPV as objective-function for all alternatives tested in this step (each point represents a simulation run with a different strategy). In this step, the investments vary in each production strategy, since they are dependent on the number of wells. Note that there is no clear correlation between NPV and RF indicating that higher oil production does not necessarily imply a higher economic gain since there are more costs to produce this additional oil.

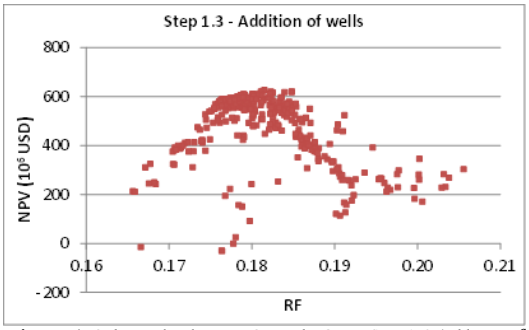

***Figure 1:** Relationship between RF and NPV in Step 1.3 (addition of wells) for Approach A (NPV as objective-function).*

Figure 2 shows the same relationship for Step 1.4 (wells localization). In this case, since the number of wells is fixed and, hence, the investments do not vary significantly in each strategy, there is a strong correlation between RF and NPV. Nevertheless, note that the NPV can take negative and positive values for similar values of recovery factor.

"It is important to use an economic indicator to test the viability of recovery mechanisms that generate extra costs and change the cash flow."

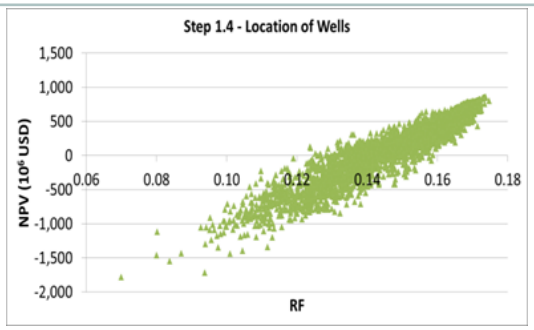

Figure 2: *Relationship between RF and NPV in Step 1.4 (wells positioning) for Approach A (NPV as objective-function).*

- Testing the viability of polymer flooding through economic indicators

Previous work (Botechia *et al.*, 2016) showed that it is important to take into account the recovery mechanism in field development to achieve the best economic efficiency for the project. Thus, if different techniques are being taken into account in the development of the field, the best way to compare them is optimizing the field considering each mechanism separately. Simplified comparisons, such as only changing the injection fluid and not changing the production strategy can lead to suboptimal decisions. Thus, for comparison purposes, the optimization process was performed one more time, for the three approaches, considering water flooding. Figure 3 shows the NPV for the three approaches for the following situations: strategy optimized for polymer flooding (red column); strategy optimized for water flooding (blue column); and strategy optimized for water flooding but injecting polymer and considering its costs (green column). Figure 4 shows the cumulative oil production (Np for the same situations).

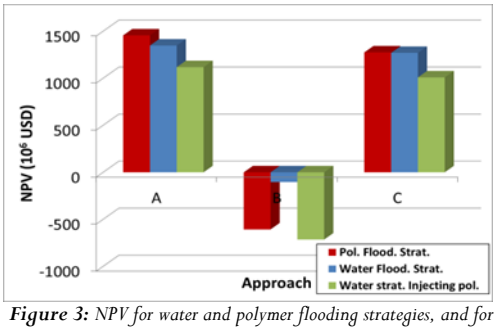

Figure 3: *NPV for water and polymer flooding strategies, and for water strategy injecting polymers.*

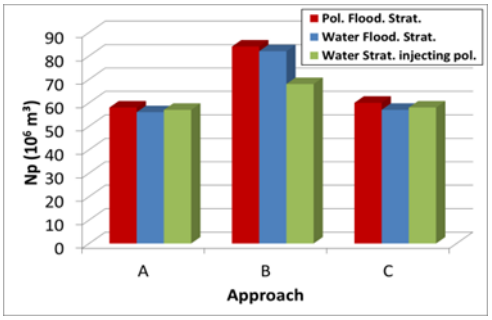

Figure 4: *Np for water and polymer flooding strategies, and for water strategy injecting polymers.*

Note that injecting polymer in a strategy designed for water flooding can lead to higher oil production in this situation (Approaches A and C – Figure 4), but with lower economic performance. See in Figure 3 that the NPV for the strategy optimized for water flooding, but injecting polymers, is the worst option in economic terms.

Conclusions

The results show that using the recovery factor as a single indicator in the conditions presented in this work (no budget restrictions, meaning high flexibility) leads to an overestimated number of wells, resulting in the worst economic performance due to elevated costs, despite the highest oil production. The use of recovery factor is a good parameter in specific cases, such as when there are a predetermined platform capacity and number of wells. In this case, when the platform size and the number of wells are already fixed, and hence, the investments do not vary significantly, there is a strong correlation between NPV and RF, and both indicators can lead to similar results. Thus, it is important to take into account the economic calculations in simulation steps, to achieve the best economic performance of the project.

The advantage of using NPV is that it considers several parameters like revenues from oil production, costs from oil and water production, costs from water injection, the speed of recovery, and in the case of this work, the cost for polymer injection, which may affect the selection of the strategy, mainly when comparing with other recovery mechanisms. However, even choosing only one indicator as objective-function for optimization processes, it is advisable to analyze other parameters together to have a better understanding of the behavior of the field. This also indicates that the objective-function must be carefully chosen by the company since the use of a non-priority objective-function can significantly affect the field's performance.

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