UNISIM-III: Benchmark Case Proposal Based on a Fractured Karst Reservoir

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Summary

The significant world oil reserves related to fractured karst reservoirs in Brazilian pre-salt fields adds new frontiers to the (1) development of numerical methods for upscale giant fields with multiscale heterogeneities, (2) history matching and production strategy optimization under critical uncertainties and (3) forecast of the future reservoir performance. However, there is a lack of benchmark models with a heterogeneous dynamic behavior typical from fractured karst reservoirs, to develop and validate novel numerical methods. This work presents a simulation benchmark model, available as public domain data, which represents a fractured carbonate karst reservoir and add a great opportunity to test new methodologies for reservoir development and management using numerical simulation.

The work structure is divided in three steps: (1) development of a reference model, a fine grid model with high level of geologic details, treated as the real field, (2) development of a simulation model under uncertainties considering an initial stage of the field development phase, and, (3) elaboration of a benchmark proposal for studies related to the oil field development and production strategy selection. Based on the available information from well logs, several uncertainty attributes were considered in structural framework, facies and petrophysical properties. Dynamic, economic and technical uncertainties were also considered. The reference model is a giant field divided by two stratigraphic zones - the upper zone characterized by stromatolites and the lower one by coquinas. Moreover, the model is characterized by two regions with karst features near the horizons surfaces and a cluster of fractures near faults. Volcanic rocks and high permeable trends near faults are included as non-mapped uncertainties in the simulation model, as the information from well logs at the initial stage of field development does not intercept this geologic attribute. This approach will lead to several challenges on reservoir development and management.

As this benchmark is representative of a giant field, it is divided in four sectors. Sector 1 has already a production strategy defined, aiming studies regarding field management. The strategy considers WAG (water alternate gas/CO2) as recovery mechanism and the presence of 13 wells in a first wave (6 producers and 7 injectors), and other 4 wells can be added in a second wave. Field development studies can be applied in the other sectors.

This Benchmark provides a great opportunity for develop and test novel numerical methods in giant reservoirs with geologic and dynamic pre-salt trends.

1. Introduction

Some of the giant fields from Brazilian pre-salt and are associated with a carbonate-depositional environment, with evidence of natural fractures and karst-development features (Cazarin et al., 2016). These fields present a new frontier for research and development of automated methodologies regarding the field development stages. The time consumption, uncertainties representation, and multiscale heterogeneities in reservoir simulation play a critical challenge for geologists and reservoir engineers. The introduction of a giant field with multiscale heterogeneities in reservoir simulation leads to specific challenges: (1) upscaling and numerical simulation representation of multiscale heterogeneities; (2) proper modeling of the WAG flooding as an enhance the recovery; (3) CPU management regarding the optimization of computational time; (4) automated methodologies for probabilistic approaches and development strategies within an acceptable time consumption; (5) development of methodologies for field management, manly seeking the management of gas production (e.g., use of interval control valves, optimization of WAG cycles, etc.).

The generation of a benchmark model that reproduces these challenges is crucial for comparative project studies regarding the Brazilian pre-salt reservoirs. An example of benchmark models includes UNISIM-I (Avansi and Schiozer, 2015), which represents a siliciclastic reservoir model, and UNISIM- II (Correia et al., 2015), which represents a naturally fractured carbonate reservoir. However, there is a lack of synthetic models that represent the geological trends from Brazilian pre-salt reservoirs, essentially the karst-development trends and a close structural model that has similar characteristics of a real giant field from the pre-salt area.

The purpose of this work is to develop a benchmark case (UNISIM-III) that involves a compositional simulation model with geological trends and rock/fluid data with characteristics of the some fields from Brazilian pre-salt for reservoir management purposes. The static and dynamic data are a combination of a karstic reservoir and synthetic data. The work structure is divided into four steps: (1) development of a refined grid model with known characteristics called UNISIM-III-R, representing the true answer and providing an opportunity to test methodologies for reservoir development; (2) build of a simulation model under uncertainties for studies related the initial stage of field development, called UNISIM-III-2019; (3) build of a simulation model for studies related to the field development and management, called UNISIM-III-2022, (4) benchmark case proposal considering each stage of field development.

2. Model Data

The geologic and rock/fluid data combine Pre-salt data and synthetic data. The field information considered to develop UNISIM-III-R are:

- Map images of the depth of formation surfaces
- Images of interpreted seismic profiles
- Facies distribution from two wells
- Continuous logs of porosity and permeability from two wells
- Synthetic rock-fluid data based on public data from Brazilian pre-salt reservoirs

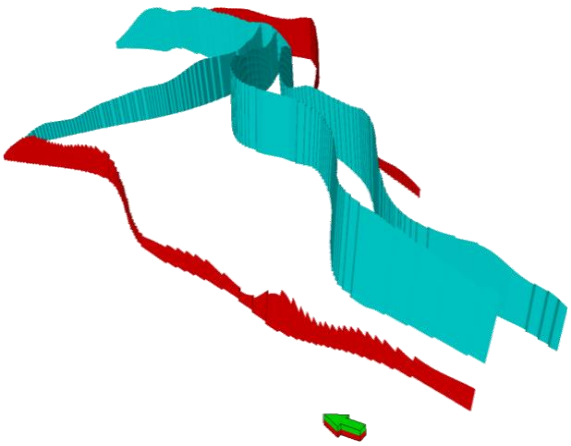
A part of the information used for the construction of the static model is supplied by the national oil and gas biofuels agency - ANP, and another part is public access.

3. Reference Grid Model (UNISIM-III-R)

The reference model is a refined model for use as the true answer for test and compare methodologies. Chaves (2018) partially developed the reference model. However, after Chaves (2018), new trends were included in the geological model, which are described in the next sections. The geological modeling of the reference model is divided into structural modeling, flow unit modeling, and petrophysical modeling. The reference model was generated by combining two models - Lira-M and Lira-K. Lira-M has the same cell dimensions as the reference model and represents the output of stochastic simulation using well log data. Lira-K has a more refined cell resolution and was developed for modeling small scale heterogeneities – karsts, which are beyond the Lira-M cell. Then, the Lira-K was upscaled and integrated with Lira-M. Therefore, the reference model was developed based on a hierarchical upscaling procedure. Chaves (2018) presents details regarding the hierarchical upscaling procedure and Lira-K.

3.1 Structural Modeling

The reference model has a grid resolution of 50 x 50 x 2 meters, which results in 10,339,395 active cells with a bulk volume of roughly 50 billion m^3. The structural model consists of four surfaces and seven faults (Figure 1). The four surfaces (Figure 2) are elaborated from the depth maps over three formations, and the seven faults (Figure 1) are constructed using the image of interpreted seismic profiles (Petersohn et al., 2013) along with the generated surfaces. Three faults are the field boundaries, and four faults are internal. The structural model was developed based on public information. More details are present by Chaves, 2018.



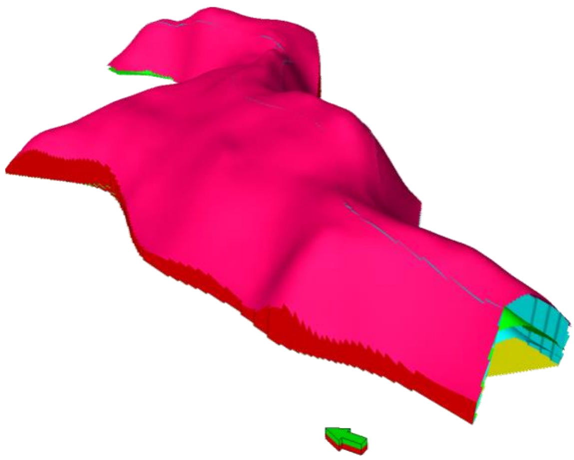


Figure 1. Faults used for the structural model Figure 2. Surfaces used for the structural model

3.2 Facies Modeling

The truncated Gaussian simulation (TGS) is applied for modeling faces, as the technique considers the depositional transition through a sequence of facies. The order of facies transition is assumed from proximal to distal. Three zones are considered. In zones 1 and 2, the facies vary from microbial laminar and stromatolitic carbonates to wackestone, mudstone, and shale. For Zone 3, the transition varies from grainstone (coquinas) to wackestone, mudstone, and shale. Figure 3 shows the zonation.

3.3 Petrophysical Modeling

Porosity and horizontal permeability were populated using Gaussian simulation biasing by facies. The continuous density-porosity (DPHI) and nuclear resonance magnetic permeability (Ktim) were used for the modeling approach. The vertical permeability was defined by applying an average multiplier on horizontal permeability for each zone, calculating the relationship between the harmonic average and the arithmetic average. The net to gross (NTG) is calculated based on a cut-off approach. If the porosity is equal to zero or permeability smaller than 0.1 mD, then NTG is equal to 0. Otherwise, NTG is 1. Figure 4 shows a cross-section near a karst region in the reference model. The distribution of karsts is delimited by two regions. Therefore, it is not expected the presence of karst features in all zones.

3.4 Fluid Model

One of the main characteristics of this benchmark is the high CO_2 content. Thus, it is considered a compositional approach for reservoir simulation. The representation of the fluid model considers 5 pseudo-components. Table 1 shows the main data used for the compositional fluid modeling, obtained from a public report (Petrobras Report, 2015).

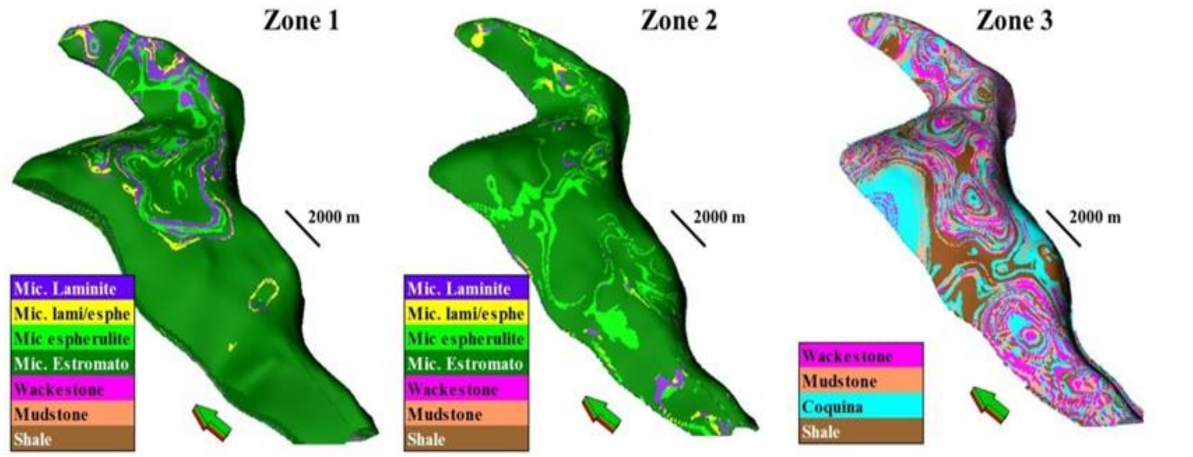


Figure 3. Facies model showing the facies for each zone (from Chaves, 2018).

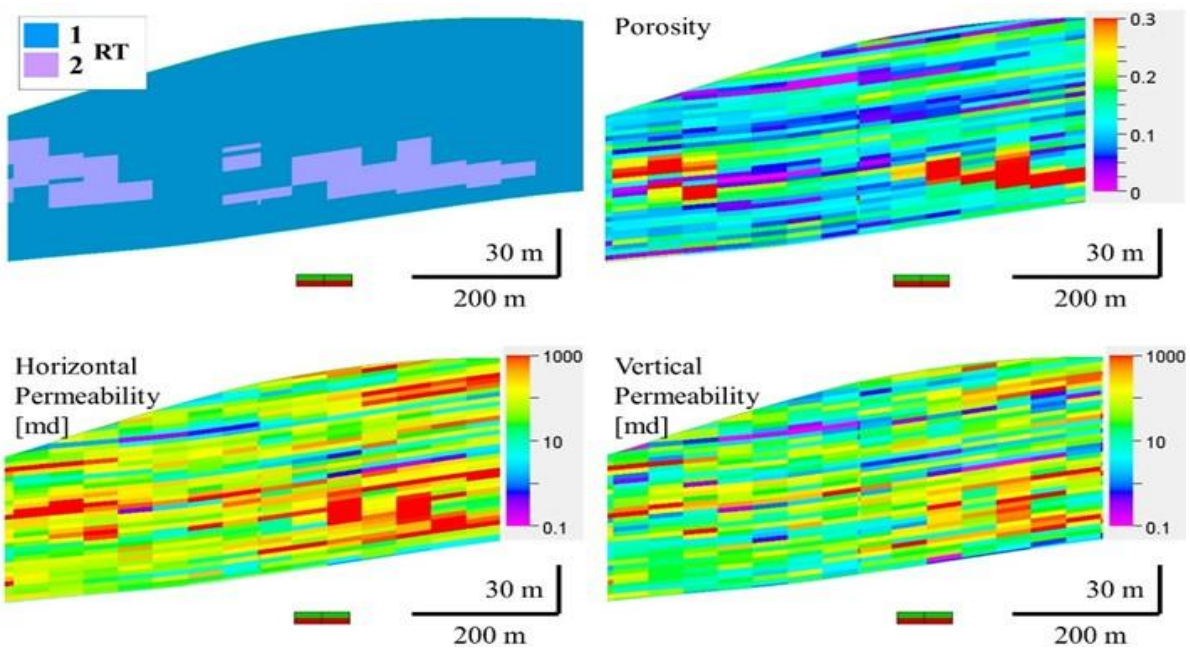


Figure 4. Cross section showing porosity and permeability near a karst region, in the reference model (from Chaves, 2018).

Table 1. Main data for compositional fluid modeling (Petrobras Report, 2015)

CO_2 - Gas (%)	44
CO_2 – Res. Fluid (%)	37
Reservoir Temperature (ºC)	90
Psat (kgf/cm²)	500
Initial Oil Visc. (cP)	0.39
RGO flash (sm³/m³)	442
RGO dif. Lib. (sm³/m³)	604
RGO sep (sm³/m³)	415
Bo sep (sm³/m³)	2

4. Simulation Model

The simulation model is created based on the stage of field development and available information. The geological model used to build the simulation model has the same high resolution of UNISIM-III-R. However, the geological model is constrained to the information of well logs and, therefore, a full set of uncertainties should be considered. Thus, it is central to generate a significant number of

equiprobable geostatistical models. This approach enables the characterization of the full range of uncertainty. After that, considering the computation effort for flow simulation purposes, it is necessary to make an upscaling procedure to a coarser model. The next sub-sections describe the production strategy for reservoir development, uncertainty variables considered to generate the simulation model, the geologic model, and the upscaling procedure for flow simulation purposes. The sections are presented according to the stage of field development: UNISIM-III-2019 and UNISIM-III-2022.
The dates presented in the benchmark's names (2019 or 2022) refer to the division into production history and forecast periods, aiming different types of studies. The reference date for UNISIM-III-2019 is 10/02/2019 (on this date, the forecast period begins), while the reference date for UNISIM-III-2022 is 02/02/2022. Details about the production strategy with the production history periods are showed in the next sections.

4.1 Simulation Model - UNISIM-III-2019

4.1.1 Production Strategy for Reservoir Development

The simulation model (UNISIM-III-2019) is created for a project at an initial stage of the field development plan under uncertainties, including 1 year of an Extended Well Test (EWT) production data, consisting of one producer and one gas injector (for reinjection of the produced gas). Besides those two wells, it is also considered the information of more two producers for geostatistical purposes. Figure 5 shows the wells' location used for geostatistical purposes: three producers and one injector.

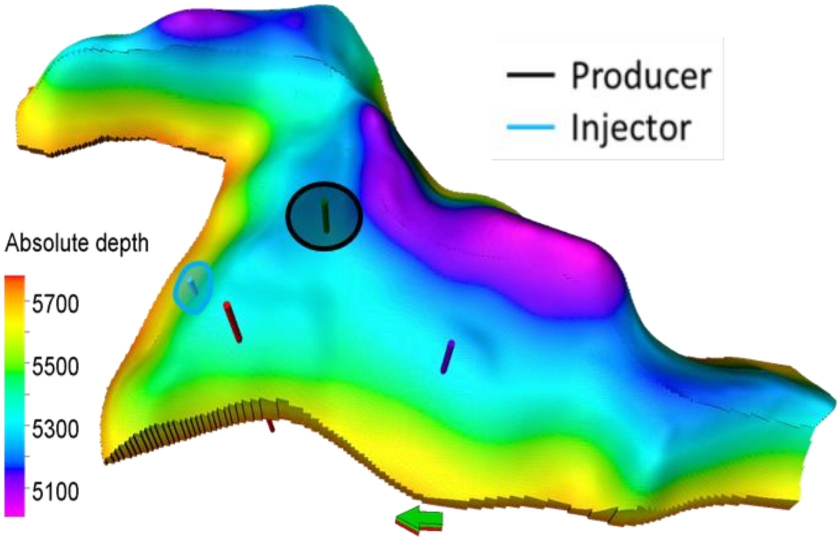
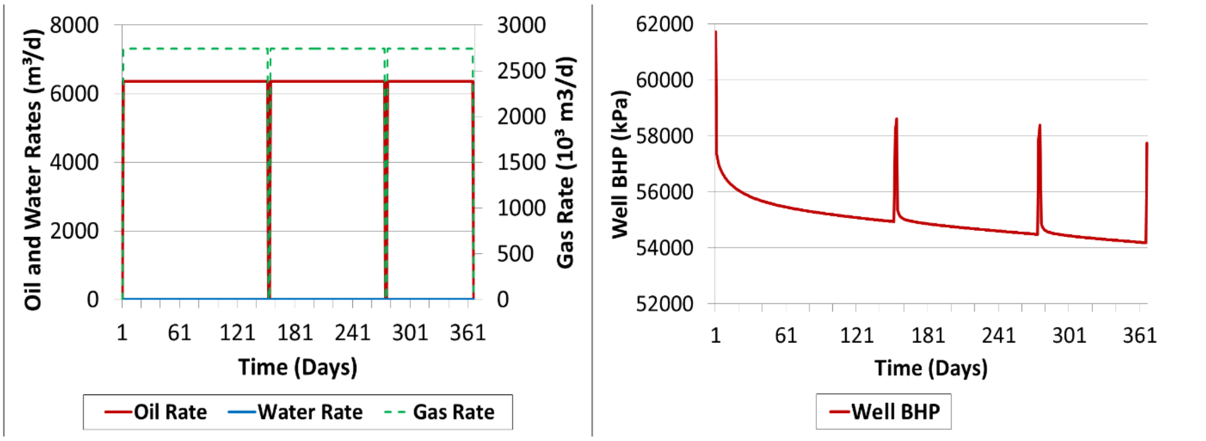


Figure 5. Production strategy for reservoir development (UNISIM-III-2019)

History data of 1 year of the EWT production was generated in UNISIM-III-R. Figure 6(a) presents the oil and gas rates, while Figure 6(b) presents the well bottom-hole pressure for the producer. Note that there are two production stops of 2 days each. The operational conditions are defined by a minimum bottom-hole pressure of 50,000 kPa and a maximum oil production of 6,359 m³/d (or 40,000 bbd).



(a) (b)

Figure 6. (a) Oil, water and gas rates and (b) well bottom-hole pressure for the producer of the EWT

4.1.2 Static Uncertainty Variables

This section describes the static and uncertainty variables, during the initial phase of the field development. One of the variables is the random seed during the modeling process for facies and petrophysical properties. Facies are used for generating the petrophysical properties (porosity, permeability, and net to gross) and for defining the different rock-types in the simulation model. The base value used as input for the facies fraction attribute is the average value from well-logs. The same assumption is applied for the uncertainty in well-log from porosity and permeability. However, as the base value is uncertain, a normal distribution is applied for facies and porosity; and a lognormal distribution is applied for permeability. Other uncertain attributes are considered and described in Table 2. The uncertainties and the respective values used as input to generate the geostatistical properties are subjective and can be changed by the participants of the benchmark proposal, for comparative approaches. Details regarding the benchmark proposal and dynamic uncertainties are present in the next sections.

Table 2. Description of uncertainty variables

Property	Attribute	Probability Distribution	Geostatistical Technique
Structural Horizons	Height	Normal	Minimum Curvature
Facies	Stochastic Seed	SEED Variable	Truncated Gaussian Simulation
	Spatial Variability	Normal	
	Well-log fraction	Normal	
Porosity	Stochastic Seed	SEED Variable	Sequential Gaussian Simulation
	Well-Log Average	Normal	
	Spatial Variability*	Normal	
Permeability	Stochastic Seed	SEED Variable	
	Correlation factor with porosity	LogNormal	
	Well-Log Average	LogNormal	

* correlated with facies

4.1.3 Non-Mapped Uncertainties

In order to increase the challenges regarding the benchmark proposal, some geological trends are not mapped in the geostatistical realizations as the information from well logs at this stage of field development is not sufficient to consider these geologic attributes. Some of the geological trends include fractures clustering near faults and volcanic rocks.

4.1.4 Geologic Model

The geologic model has the same grid cell size of UNISIM-III-R but the geostatistical modeling is constrained to log information from four wells. Figure 7 and Figure 8 show the porosity and horizontal permeability, respectively. These properties are an example for one geostatistical realization that results from the probabilistic approach. The vertical permeability is generated as a function of horizontal permeability, through a multiplier. The NTG is calculated based on a cut-off approach.

4.1.5 Upscaling of Geologic Model

Given the high resolution of the geologic model, for reservoir simulation purposes, it is necessary to make an upscaling procedure to decrease computational efforts. It is assumed a grid cell size of 200 x 200 x 5 meters. The grid is defined by 300,000 active blocks. Porosity is upscaled applying the arithmetic average weighted by NTG. Figure 9 and Figure 10 show the upscaled porosity and permeability, respectively. Permeability is upscaled using a directional averaging technique based on the harmonic-arithmetic mean. This upscaling method has given the same response as the flow-based methods, however in a smaller time consumption. NTG is upscaled using the arithmetic average. In the end, the porosity is multiplied by NTG. Therefore, NTG is not exported for flow simulator.
Two rock-types (stromatolites and coquinas) are exported for flow simulator. As this data is uncertain, the relative-permeability curves range from mixed-wet to oil-wet.

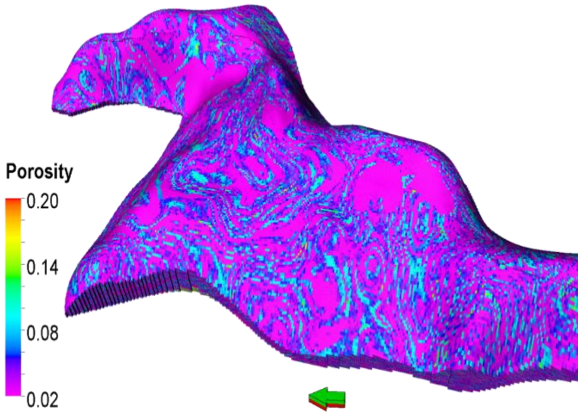


Figure 7. Porosity distribution in the geological model for UNISIM-III-2019

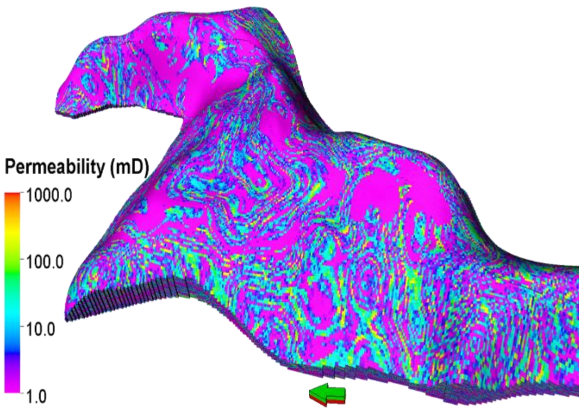


Figure 8. Horizontal Permeability distribution in the geological model for UNISIM-III-2019

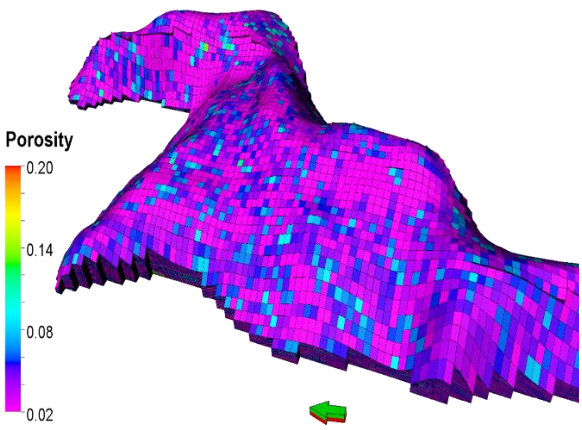


Figure 9. Porosity for the simulation model

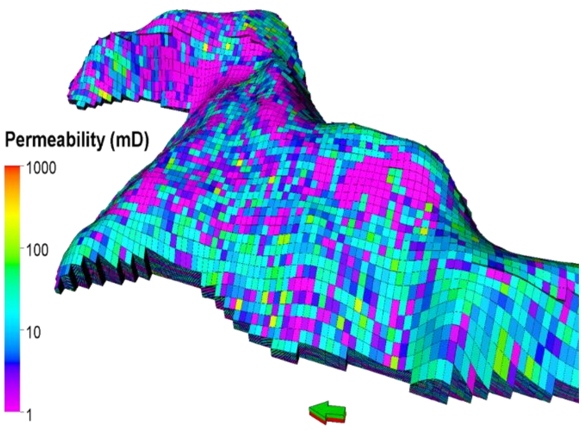
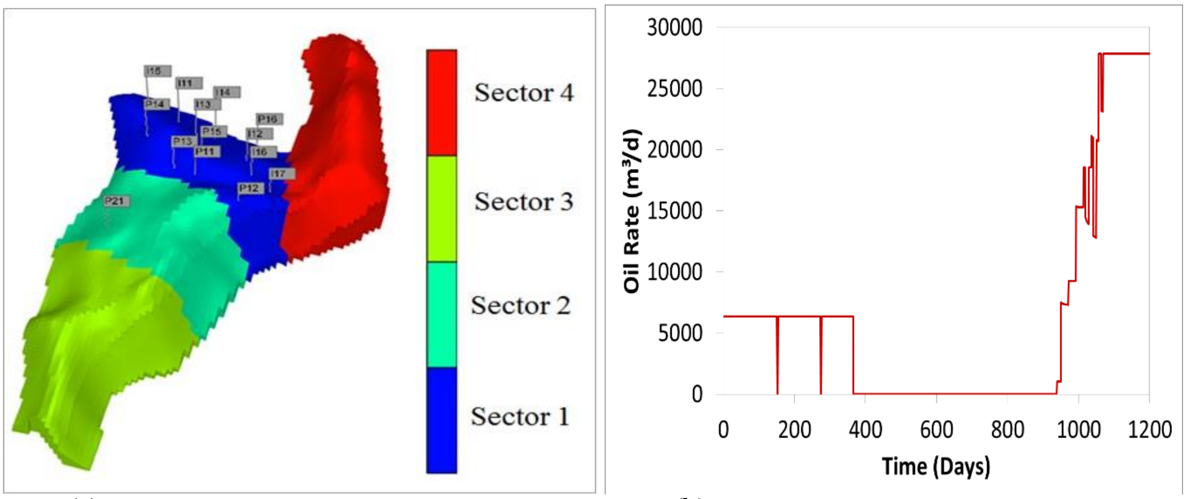


Figure 10. Permeability for the simulation model

4.2 Simulation Model – UNISIM-III-2022

The simulation model (UNISIM-III-2022) is created for project studies related to field development and management. UNISIM-III-2022 consists of four sectors. The sectors have communication among each

other, and this division intends to separate the field production in four production systems (platforms). In Sector 1, there is a strategy already defined with 6 vertical producers and 7 vertical injectors (including the wells of the EWT). Sector 2 has only one exploration well, used for geostatistical purposes. History data consists of 1 year of EWT (same as UNISIM-III-2019), then there is no production for seven months, followed by 8 months of production for 13 wells. Figure 11 (a) shows the division of the four sectors of the field, while Figure 11 (b) illustrates the oil production of the field in the history period.
Figure 12 shows the well location used for geostatistical purposes: seven producers and seven injectors. One exploration well was used only for geostatistical purposes. The same uncertainty variables, as described in Table 2, were applied in UNISIM-III-2022. However, the range of uncertainty (variability around the mean value for each attribute) decreases, comparing to UNISIM-III-2019, as the probabilistic approach is attached to more well logs. As described in the previous section for UNISIM-III-2019, the uncertainties and the respective values used as input to generate the geostatistical properties can be changed by the participants of the benchmark proposal, for comparative approaches.



(a) (b)
Figure 11. (a) 3D view of UNISIM-III-2022 with the four sectors; (b) oil field production history

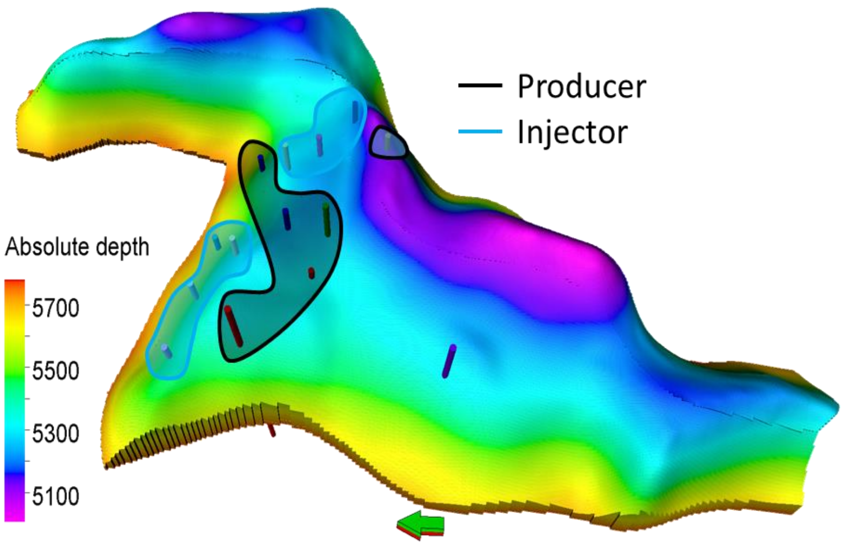


Figure 12. Production strategy for reservoir development (UNISIM-III-2022)

5. UNISIM-III Benchmark Proposal

5.1 UNISIM-III-2019 Benchmark Proposal

Participants of the benchmark study are required to present methodologies to define an oil exploitation strategy for the field development plan, including all four sectors. Each sector needs at least one separate platform. The platform of Sector 1 comprises 17 wells in total (8 producers and 9 injectors), while the platform of the other sectors comprises 16 wells each. Sector one has already 3 wells drilled (two producers and one injector), while Sector 2 has one exploration well drilled. These wells cannot have their position changed, and can be included in the strategy definition.
The forecast period starts 1 year after the beginning of the project. They should present the methods for each problem of the forecast period for the early stage of development of the field.
Deterministic and probabilistic approaches for decision analysis are proposed.
We provide the following data set:

- UNISIM-III-2019 reservoir simulation model in GEM-CMG format;
- 1 year of production history for UNISIM-III-2019 and 1219 days for UNISIM-III-2022;
- Geological, economic and operational deterministic and probabilistic data;
- Proposal description available at UNISIM-III webpage (*http://www.unisim.cepetro.unicamp.br/unisim-iii/*).

Required Times – UNISIM-III-2019

The following date must be considered in this proposal:

- 10/02/2018 (t_0) – 0 day:
  - Simulation initial time;
  - Production starting time (EWT).
- 10/02/2019 (t_{2019}) – 365 days:
  - End of production history of EWT;
  - Starting date analysis (for updating cash flow)
- 12/02/2048 (t_f) – 11019 days:
  - Simulation final time (simulation may be ended before but not after this time);
  - Maximum date of field abandonment.

5.2 UNISIM-III-2022 Benchmark Proposal

The proposal of UNISIM-III-2022 is similar to UNISIM-III-2019, but in this case Sector 1 has already a base production strategy defined. The strategy is divided in two phases: the first phase comprises 6 producers and 7 injectors, which cannot have their positions changed. This strategy has production history until 02/02/2022 (on this date, the production forecast period starts). The second phase comprises 4 more vertical wells and the users are allowed to choose the best positions to allocate them. Thus, in UNISIM-III-2022, Sector 1 is recommended for field management studies (optimization of well control, WAG cycles, ICV control, infill drilling, among others), while the other sectors can be used for field development studies.
Sector 2 has one well used to get information, and can be used in the development strategy of Sector 2. It is important to highlight that each sector needs at least one platform, with a capacity of 16 wells each one.
For this benchmark, we provide the following data set:

- UNISIM-III-2022 reservoir simulation model in GEM-CMG format;
- 1219 days of production history;
- Geological, economic and operational deterministic and probabilistic data;
- Proposal description available at UNISIM-III webpage (*http://www.unisim.cepetro.unicamp.br/unisim-iii/*).

Required Times – UNISIM-III-2022

The following date must be considered in this proposal:

- 10/02/2018 (t_0) – 0 day:
  - Simulation initial time;

- Production starting time (EWT).
- 10/02/2019 (t_{2019}) – 365 days:
  - End of production history of EWT;
- 04/27/2021 - 938 days:
  - Production of the definitive production system begins;
- 12/26/2021 - 1181 days:
  - 13th well of the definitive production system (first phase) opens;
- 02/02/2022 (t_{2022}) – 1219 days:
  - End of production history
  - Starting date analysis (for updating cash flow)
- 12/02/2048 (t_f) – 11019 days:
  - Simulation final time (simulation may be ended before but not after this time);
  - Maximum date of field abandonment.

6. Decision variables, approaches and scenarios

The information presented in this are applied for both UNISIM-III-2019 and UNISIM-III-2022.

6.1 Decision Variables

The decision variables considered in the decision analysis process regarding the development strategy selection are: number, position and opening sequence of wells (except for the wells already drilled and with production history), well control (e. g. economic limit for well shutdown), ICV control and WAG cycles. It is highlighted that each sector must have its own platform.

Since the field presents large thickness and good vertical communication, it is recommended the use of vertical wells. Table 3 presents the operational constraints of the wells in a non-integrated approach with production system, while Table 4 presents the platform constraints related to the forecast period.

Table 3. Well data and operational conditions

Type	Vertical Producer	Vertical Injector (gas)	Vertical Injector (water)
Maximum water rate (m^3/day)	-	-	10,000
Maximum liquid rate (m^3/day)	8,000	-	-
Maximum gas rate (m^3/day)	-	4,000,000	-
BHP (kPa)	Min 50,000	Max 75,000	Max 75,000

Table 4. Platform constraints

Type	Definitive Production system	
	m^3/d	bbd
Maximum oil rate (m3/day)	28,617	180,000
Maximum liquid rate (m3/day)	28,617	180,000
Maximum water production rate (m3/day)	23,848	150,000
Maximum gas production rate (m3/day)	12,000,000	-
Maximum water injection rate (m3/day)	35,771	225,000

6.2 Deterministic approach

6.2.1 Objective-functions

Possible objective-functions of the deterministic case are:

- Net present value (NPV);
- Cumulative oil production (Np);
- Cumulative water production (Wp);
- Recovery factor (RF);
- Combination of the aforementioned indicators.

6.2.2 Geological scenario

The deterministic case was chosen by ranking 100 equiprobable images (geostatistical realizations) using the volume of oil in place (VOIP) as objective-function. The image with VOIP of 50% of cumulative probability (P50) was chosen as the deterministic case.

6.2.3 Economic scenario

Table 5 presents the deterministic economic scenario consisting of economic variables and parameters and fiscal assumptions.

Table 5. Deterministic economic scenario

Variable/Parameter	Value	Unit
Revenues		
Oil price	314.5	USD/m³
Costs		
Oil production	35.73	USD/m³
Water production	3.58	
Water injection	3.58	
Gas production	0.0096	
Gas injection	0.0103	
Abandonment (% of investments - CAPEX)	20.0	%
Investments		
Drilling and completion of vertical well	125.0	10^6 USD
Connection (vertical well-platform)	100.0	
Interval Control Valve (ICV)	1	
Platform	2	10^9 USD
Fiscal Assumptions		
Corporate tax rate	34.0	%
Social taxes rates charged over gross revenue	9.25	
Royalties rate	15.0	
Other Parameters		
Annual discount rate	9.0	%

6.3 Probabilistic approach

6.3.1 Objective-functions

Besides all the objective-functions of the deterministic approach, the probabilistic approach also includes the expected monetary value (EMV), presented in Equation (1). Risk indicators may also be considered.

$$EMV = \sum_{i=1}^{n} p_i \times NPV_i \qquad \text{Eq. 1}$$

given that:
p_i: probability of occurrence of scenario I and NPV_i: Net Present Value of scenario i.

6.3.2 Uncertainties

The case study has a set of reservoir (Table 6) and operational (Table 7) uncertainties, as follows. In these tables, the values inside the brackets refer to the absolute value or to the multiplier of the uncertainty, while the values inside the parentheses refer to the probability of occurrence.

Reservoir uncertainties

- **GEO:** geostatistical realizations, that include: variations in the distribution of horizontal and vertical permeability and porosity; rock types; uncertainty in the transition from stromatolites to coquinas. In the case of UNISIM-III-2022, it also considers the distribution and amount of karsts (the karsts were considered non-mapped uncertainty in UNISIM-III-2019, thus they only appear in the reference model)
- **KR_est:** Relative permeability for the stromatolites region (curves)
- **KR_coq:** Relative permeability for the coquinas region (curves)
- **TRANSF:** Faults transmissibility (scalar)
- **PVT:** Gas viscosity (scalar)

Operational uncertainties

- **SA**: System availability for platform, groups of wells, producers and injectors (multiplier)
- **WI:** Well productivity (well index multiplier) (multiplier)

Table 6. Reservoir Uncertainties

Attribute	**Level [value] (probability)**				
	0	**1**	**2**	**3**	**4**
GEO	100 geostatistical realizations (0.01)				
KR_est	KR0 [strongly oil-wet] (34%)	KR1 [oil-wet] (33%)	KR2 [mixed-wet] (33%)	-	-
KR_coq	KR0 [strongly oil-wet] (34%)	KR1 [oil-wet] (33%)	KR2 [mixed-wet] (33%)		
TRANSF	TRANSF0 [0.0] (20%)	TRANSF1 [0.003] (20%)	TRANSF2 [0.008] (20%)	TRASNF3 [0.100] (20%)	TRANSF4 [1.000] (20%)
PVT	PVT0 [0.06 cp] (50%)	PVT1 [0.035 cp] (25%)	PVT2 [0.085 cp] (25%)	-	-

Table 7. Operational Uncertainties

Attribute	**Level [value] (probability)**		
	0	**1**	**2**
SA - Platform	SA0 [0.95] (34%)	SA1 [1.00] (34%)	SA2 [0.90] (34%)
SA - Group	SA0 [0.96] (34%)	SA1 [1.00] (34%)	SA2 [0.91] (34%)
SA - Producers	SA0 [0.96] (34%)	SA1 [1.00] (34%)	SA2 [0.91] (34%)
SA - Injectors	SA0 [0.98] (34%)	SA1 [1.00] (34%)	SA2 [0.92] (34%)
WI	WI0 [1.00] (34%)	WI1 [1.40] (34%)	WI2 [0.70] (34%)

6.3.3 Economic scenarios

The economic uncertainties include oil price, operational costs, and investments as can be seen in Table 8 for optimistic and pessimistic scenarios.

Table 8. Optimistic and pessimistic economic scenarios

Variable/Parameter	Optimistic	Pessimistic	Unit
Revenues			
Oil price	440.3	251.6	USD/m³
Costs			
Oil production	46.4	28.6	USD/m³
Water production	4.65	2.86	
Water injection	4.65	2.86	
Gas production	0.0124	0.00768	
Gas injection	0.0134	0.00824	
Abandonment (% of investments - CAPEX)	20.0	20.0	%
Investments			
Drilling and completion of vertical well	156.0	100.0	10^6 USD
Connection (vertical well-platform)	125.0	80.0	
Interval Control Valve (ICV)	1.3	0.7	
Platform	2.25	1.6	10^9 USD
Fiscal Assumptions			
Corporate tax rate	34.0		%
Social taxes rates charged over gross revenue	9.25		
Royalties rate	15.0		
Other Parameters			
Annual discount rate	9.0		%

6.4 Expected Results

The methodologies developed and the results achieved using this benchmark must be published with output data containing the assumptions made, the selected strategy configuration and indicators of the process, such as: methods, number of simulation runs, execution time and evolution of the objective-function. Besides, indicators of the strategy and of the wells must be presented: NPV, EMV, measures of risk, N_p, RF, W_p, W_{inj}, average pressures and well rates.

7. Conclusions

The main contribution of this work is achieved: develop UNISIM-III, a benchmark case based on a giant field with Brazilian pre-salt reservoir trends, considering (1) a simulation model under uncertainties for studies related to the initial stage of field development, called UNISIM-III-2019, and (2) a simulation model for studies related to the field development and management, called UNISIM-III-2022. In order to test and compare methodologies, it was developed a refined grid model with known characteristics called UNISIM-III-R.

We present benchmarks proposal, suitable for studies in (1) data assimilation to uncertainties reduction, (2) production forecast, and (3) decision analysis for selection of a production strategy considering the combination of geological, economic, and technical uncertainties. Some of the management studies that can be achieved with this benchmark include WAG cycles optimization, ICV control optimization, well control management, among others.

This benchmark adds an opportunity for future research on field development and management regarding a complex and giant reservoir with static and dynamic trends close to Brazilian pre-salt fields.

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