Appendix-I: Additional Information about Production System Integration

B1. Production System Integration

UNISIM-II-D main proposal provides information regarding just the reservoir conditions. For those users who want to consider production systems in their studies, the fixed operational constraints for wells and groups in UNISIM-II-D project should be included in the production system. Users interested in working and contributing to the production system integration project are welcome and should send their contacts to unisim-benchmark@cepetro.unicamp.br. We require the information about boundary conditions of constraints and their costs compatible with UNISIM-II-D in order to set up the same problem for all the research groups.

Table B1 presents reservoir data to be used as reference in the production system integration project. The location conditions as well as water depth are based on the Pre-salt oil fields [1-3].

Table B1: Reservoir Data

Type	Value	Unit
Reservoir depth	4,850	(m)
Sea level	1,000	(m)
Oil gravity	0.86	-
Gas gravity	1.06	-
Water density	1.01	-
Reservoir temperature	58	(°C)
Christmas tree temperature	38	(°C)
Riser bottom temperature	30	(°C)
Separator temperature	20	(°C)
Relative roughness	0.0006	-
Production water salinity	250,000	(ppm)

Table B2 presents the well operating conditions for the production forecast period.

Table B2: Well operation conditions

Operate conditions type	Value		Unit	Simulation model
	Producer	Injector		
Minimum oil rate	20	-	(std m^3/day)	BO and CO
Maximum water rate	-	5,000	(std m^3/day)	BO and CO
Maximum gas rate	-	2,000	(10^3 std m^3/day)	BO and CO
Maximum BHP	-	480	(kgf/cm^2)	BO
Maximum BHP	-	47,072	(kPa)	CO
Minimum WHP	15	-	(kgf/cm^2)	BO
Minimum WHP	1,471	-	(kPa)	CO
Maximum gas lift rate	200	-	(10^3 std m^3/day)	BO and CO

Table B3 presents preliminary and complementary information of economic parameters to be used in the production system integration.

Table B3: Additional Economic Parameters for Production System

Economic parameter	Technical parameter / decision variable	Value	Most likely	Optim.	Pessim.	Unit
Investment on connection (well-platform) of vertical / horizontal well	Production / injection flowline	4” 6” 8”	411 768 1976	514 960 2470	360 672 1729	(USD/m)
	Riser	4” 6” 8”	879 1513 2597	1098 1892 3247	769 1324 2273	(USD/m)
	Riser and flowline installation	-	11.70	14.63	10.24	USD millions
Investment on drilling and completion of vertical well	Production column	2 7/8” 3 1/2" 4 1/2"	221 234 250	276 292 313	193 205 219	(USD/m)
	Drilling and completion	-	20.90	26.38	18.28	USD millions
Investment on drilling and completion of horizontal well	Production column	2 7/8” 3 1/2" 4 1/2"	221 234 250	276 292 313	193 205 219	(USD/m)
	Drilling and completion	-	21185	26481	18537	(USD/m horiz)
		-	25.66	32.07	22.77	USD millions
Investment on recompletion of vertical well	Production column	2 7/8” 3 1/2" 4 1/2"	16 29 45	20 36 56	14 25 40	(USD/m)
	Workover	-	7.86	9.83	6.88	USD millions
Investment on recompletion of horizontal well	Production column	2 7/8” 3 1/2" 4 1/2"	16 29 45	20 36 56	14 25 40	(USD/m)
	Workover	-	9.83	12.29	8.65	USD millions
Investment on well conversion	Production column	2 7/8” 3 1/2" 4 1/2"	16 29 45	20 36 56	14 25 40	(USD/m)
	Workover	-	9.83	12.29	8.65	USD millions
Additional investment on connection for Artificial-Lift	Injection flowline 4”	-	411	514	360	(USD/m)
	Riser 4”	-	879	1098	769	(USD/m)

Note:

- The platform costs provided in UNISIM-II-D file considers water depth of 1,000m. This is considered in the first term (fixed cost) of the equation.
- User should sum vertical and horizontal lengths to obtain the total length to evaluate the economic parameters above.
- The “Drilling and Completion variable cost for horizontal well” considers only horizontal length.

Examples:

1) Drilling, completion and connection of a new vertical well measuring vertically 3,850m, 1,800m distant from the platform, with production column of 4 1/2", production flowline of 6", and riser of 6":

Investment on drilling and completion of vertical well: 0.000250 * 3850 + 20.899 = 21.86 MMUSD.

Investment on connection (well-platform) of vertical well: 0.001513 * 1000 + 0.000768 * 1800 + 11.703 = 14.60 MMUSD.

Additional investment on connection for Artificial Lift: 0.000879 * 1000 + 0.000411 * 1800 = 1.62 MMUSD.

2) Drilling and completion of a typical horizontal well with vertical measure of 3,850m, 1,000m horizontal length, with production column of 4 1/2", injection flowline of 6", and riser of 6":

Investment on drilling and completion of horizontal well: 0.000250 * (3850 + 1000) + 0.021185 * 1000 + 25.659 = 48.06 MMUSD.

3) Recompletion of vertical well (3,850m vertical length) with production column of 4 1/2":

Investment on recompletion of vertical well: 0.000045 * 3850 + 7.860 = 8.03 MMUSD.

4) Conversion of horizontal production well (3,850m vertical plus 1,000m horizontal for total measure) into injector with production column of 4 1/2":

Investment on well conversion: 0.000045 * 4850 + 9.831 = 10.05 MMUSD.

B2. Production System Model

The production system model is based on the case of study for production units, production gathering system and well system for the UNISIM-I-D study case [2-3], and is then applied to the UNISIM-II-D benchmark case.

The production system consists of the following systems:

1) Well system, perforations to access the reservoir in various locations and pipe to christmas tree (wellhead).
2) Gathering system, composed of the pipe network that transports and controls fluid flow from wellheads to the platform.
3) Surface facilities, production units responsible for the separation, processing and storage of fluids.

The authors created the model of gathering and well systems to represent a typical satellite well with some real characteristics and information necessary for modeling. This satellite well consists of the following parts: riser, flowline (subsea production/injection line), well production/injection column and gas lift valve for producers.

The calculation of the distances of each element follows the format shown in Figure B1. The main variables for satellite well assembly are: internal diameters of the lines for riser (RI) and flowline (LM) and production/injection column diameter (CP); positioning of the gas lift valve (Zgl); injection gas flowrate for gas lift (Qgi); wellhead pressure (Pj); temperature of the lines; and correlations of multiphase and fluid flow.

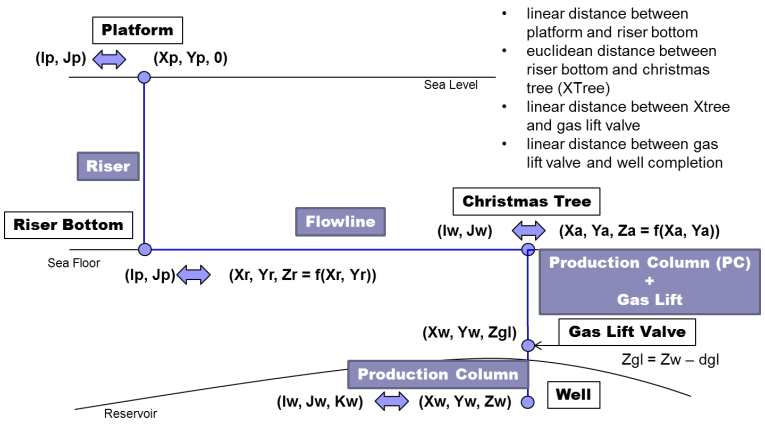

Figure B1: Satellite well layout, composed of riser, flowline, production column and gas lift valve.

The production unit (platform) in the Black-Oil and compositional versions of the benchmark is simplified, being represented by the nominal capabilities of production, separation, treatment and injection of fluids. More information can be obtained at [2-3].

B3. Reference

1. Fernandez R.O. & Santos A.J. 2017. Bacia de Santos: Sumário Geológico e Setores em oferta: https://www.gov.br/anp/pt-br/rodadas-anp/rodadas-concluidas/concessao-de-blocos-exploratorios/14a-rodada-licitacoes-blocos/arquivos/areas-oferta/sumario-santos.pdf.
2. Victorino, I. R. S.; Hohendorff Filho, J. C. V.; Castro, M. S.; Schiozer, D. J. (2019) Analysis of the Production of a Pre-Salt Based Carbonate Reservoir Through Integrated Simulation of Reservoir and Production System", International Journal of Petroleum Engineering, nº 3, October.
3. Victorino, I. R. S.; Hohendorff Filho, J. C. V.; Castro, M. S.; Schiozer, D. J. (2022) Impact of Integration of the Production Systems and Reservoir of a Benchmark Based on Carbonate Fields, Journal of Energy Resources Technology, v. 144, nº 1-15, pp. 9, September.