

**GAS-OVER-BITUMEN
RESERVOIR SIMULATION
STUDY
Cold Lake Oil Sands Deposit
(Clearwater Formation)
2006 study**

Prepared for:

Scott Obrigewitsch, P.Eng

EnCana Oil & Gas Partnership
EnCana on 9th
150 – 9th Avenue S.W
CALGARY, ALBERTA. T2P 2S5

Kenny O. Adegbesan, P.Eng., Ph.D.
KADE TECHNOLOGIES INC.
300, 400 FIFTH AVENUE SW
CALGARY, ALBERTA. T2P 0L6

September 5, 2006



EnCana Oil & Gas Partnership.
EnCana on 8th
1800, 855 2nd Street SW
Calgary, Alberta

Attention: Mr. Scott Obrigewitsch, P.Eng.

September 5, 2006

Dear Scott,

Clearwater Gas-Over-Bitumen Reservoir Simulation Study

Please find attached a brief report of the reservoir simulation study to investigate the impact of gas cap gas production in the Clearwater formation.

A key finding of this study is that production of gas cap gas, even to abandonment pressure, in the Clearwater reservoir has no adverse impact on Cyclic Steam Stimulation using horizontal wells.

This conclusion is consistent for various model configurations of the Clearwater reservoir environment including those in which the gas cap gas and the underlying bitumen are in direct pressure and fluid communication (no barrier present).

Please advise if you have any questions with regards to material presented in this report and if we can be of further assistance.

Yours sincerely,

Original signed by:

Kenny O. Adegbesan, Ph.D, P.Eng.

President and Chief Reservoir Engineer.

Email address kade@kadeinc.com

TABLE OF CONTENTS

| | |
|----------|--------------------------|
| 1 | EXECUTIVE SUMMARY |
| 2 | MODELLING ASPECTS |
| 3 | SUMMARY RESULTS |

TABLES

FIGURES

1. EXECUTIVE SUMMARY

The key objective of this study is to investigate whether production of gas cap gas overlying the Clearwater bitumen, in the Cold Lake Oil Sands Area, will adversely impact bitumen recovery factor in production of the bitumen by Cyclic Steam Stimulation (CSS) techniques using horizontal wells.

Numerical reservoir simulation techniques were applied to conduct the investigation. Computer Modeling Group's (CMG) thermal reservoir simulator STARS was applied in this study.

CNRL has provided a schematic cross section¹ (Figure E.1) highlighting the clastic depositional setting. In order to model CSS effectively, the hydrocarbon system within a structural framework is required. Figure E.2 is a schematic diagram outlining the structural position of the hydrocarbons and barrier relative to the position of the model runs (Non edge, Flank and Edge). Bitumen intervals are approximately correlative to the Blue valley sands (FAE and FAB) and in the east the Yellow valley sands. The barrier is correlative with the FAC and FAD muds.

Pattern models were constructed to represent the following key geological features/configurations of the pool:

1. Non Edge areas of the pool which contains an extensive shale barrier below the gas cap and directly overlies the Clearwater bitumen (Figure E.3)
2. Non Edge areas of the pool in which there is no shale barrier separating the gas cap and the underlying bitumen. In this case the bitumen is in direct contact with the gas cap above it (Figure E.4)
3. Edge pool areas in which the bitumen extends many kilometers from the edge of a gas cap and there is no barrier separating the bitumen and the gas cap at the edge (Figure E.5)
4. Flank pool areas. The following two major types of reservoirs are identified and models were constructed to represent these reservoir types:
 - a. Flank areas containing extensive shale barriers but not overlying the bitumen zone completely (Figure E.6)
 - b. Flank areas containing no shale barriers between the gas cap and the bitumen zone (Figure E.7).

Reservoir description, thermal rock and fluid properties, geomechanical, and CSS cycle operations data used in the models were taken from the CNRL submission where available. In cases in which data could not be found in the CNRL submissions to the EUB, the technical literature were searched and relevant data for the Clearwater formation were extracted to develop the models. Most of the data input into the model, where not provided or published by CNRL, were based on published data used

¹ Evidence of Canadian Natural Resources Limited to Alberta Energy and Utilities Board. Application Numbers 1394112 and 1409180 Cold Lake Oil Sands Area: Clearwater Deposit. Figure 2.2, Page 11.

successfully to model the Clearwater CSS operations in the Imperial Oil Limited's Cold Lake and the BP Canada's Wolf Lake Projects.

Currently, the average reservoir pressure in the gas caps overlying the Clearwater bitumen formation is in the range of 700 to 1200 kPaa. The overall strategy with regards to investigating the impact of pressure depletion of the gas cap on horizontal well (HW) CSS bitumen recovery in the model involved the following procedure:

1. Produce gas cap gas from an initial average reservoir pressure of 2585 kPaa to approximately one of the following pressure levels:
 - a) A current upper average reservoir pressure level 1000 kPaa
 - b) A current lower average reservoir pressure level of 850 kPaa, and
 - c) An estimated average abandonment reservoir pressure of 200 kPaa
2. Commence CSS operations in the bitumen zone using a 1200 m horizontal well once the gas cap has been depleted to the required pressure levels. The CSS operations were conducted in a total of 26 injection and production cycles covering a total of 26 years.

In the model, steam injection into the bitumen zone and fluid movement in the reservoir during injection and production cycles were implemented by using the deformation model and imbibition and drainage relative permeability hysteresis techniques². These techniques applied in this study are similar to those successfully applied to model CSS well operations in the Clearwater formation in Cold Lake by Imperial Oil Limited.

There were limited data presented in the public domain relating to horizontal well CSS operations in the Clearwater formation in the Cold Lake Oil sands area. Although, there were no adequate relevant data available to conduct history match or to calibrate the model, sensitivity studies were carried out in the models by making changes to key performance drivers of the CSS process. The sensitivity studies cover possible scenarios of reservoir configurations and operations parameters and include changes to the following:

- Shale barrier and its extent
- Net pay of gas cap
- Net pay of bitumen zone
- Gas cap gas production
- Pressure depletion level in the gas cap
- Pressure depletion levels in the bitumen zone by production of gas cap gas
- Steam injection rate into the horizontal CSS well and
- Changes in the fluid flow physics in the bitumen zone

² SPE 18752, Beattie C.I., Boberg, T.C., and McNab, G.S., "Reservoir Simulation of Cyclic Steam Stimulation in the Cold Lake Oil Sands."SPE Reservoir Engineering, May 1991, page 200.

- Ratio of Original gas in place to Original Bitumen in Place (OGIP/OBIP ratio) in the pattern models

Calculated total hydraulic diffusivity of the formation based on data input into the model was approximately $0.86\text{E-}04 \text{ m}^2/\text{s}$. However, sensitivity runs were conducted by increasing the hydraulic diffusivity to $1.5 \text{ E-}03$ to agree with formation hydraulic diffusivity value reported by CNRL.

In all, 42 key cases were carried out to cover all the different reservoir configurations and operations scenarios. Summary results of these cases are presented in this study.

Table E.1a, E.1b and E.1c shows a summary of cases investigated for Non Edge, Edge and Flank Pool respectively. A summary of results for all the cases covering the Non Edge, Flank and Edge reservoirs are presented in Tables E.2, E.3 and E.4 respectively.

Due to limited information on CSS horizontal well length and interwell spacing in the Clearwater formation, and time limitation for this study, no sensitivity cases were conducted with regards to well pattern area or well spacing and horizontal well length. An arbitrary interwell spacing of 240 m was assumed for a 1200 m horizontal well used to construct the models investigated in this study.

Therefore, bitumen recovery factors reported on the Summary Tables are only for the purpose of comparing relative performance of relevant cases. They are not to be construed as expected field values for CSS projects. In each instance, bitumen recovery factors will be higher for smaller drainage areas and so the conclusions based on the relative values will remain valid.

Therefore, a change in the drainage pattern area from those applied in this study is not expected to change the key conclusions derived from this study.

The following are the key findings and observations of this study:

Summary of Key Results of all Models Investigated

1. In model cases involving reservoir configurations with no barriers, or incomplete barrier coverage in which there is pressure and fluid communication between the gas cap and the underlying bitumen,
 - a) *Results indicate that solution gas in the bitumen phase is evolved as the gas cap is pressure depleted due to production of gas cap gas*
 - b) *Results suggests that there is definitely no reduction in bitumen recovery from HW CSS operations in the bitumen zone whether the*

gas cap is produced or not produced prior to commencing HW CSS operations.

For example, in the case of the Non Edge pool with no barrier present and HW CSS operations utilizing a steam injection rate 400 m³/d, the bitumen recovery factor is 14.4 for the case of gas cap gas depletion to approximately 1000 kPaa and 14.5% of OBIP with no gas cap depletion.

Similarly, for the Flank reservoir (Max) having no barrier and HW CSS operations utilizing a steam injection rate of 400 m³/d, a bitumen recovery factor of 25.6% of OBIP is achieved for the case of gas cap depletion to an abandonment pressure of 201 kPaa and 25.2 % for the case of no gas cap depletion (gas cap pressure at the initial value of 2585 kPaa).

2. In model cases involving reservoir configurations with barriers present and with complete barrier coverage in which there is no pressure and fluid communication between the gas cap and the underlying bitumen,
 - a) *There is no impact of gas cap depletion on the underlying bitumen and no solution gas is evolved since there no fluid and pressure communication between the gas cap and the bitumen zone*
 - b) *HW CSS bitumen recovery is in the order of 3-4% OBIP higher in the Non Edge reservoir type with complete isolation of the bitumen zone from the gas cap, than for reservoir cases containing no barrier (communication between the gas cap and the underlying bitumen) and no gas cap production*
3. Results of sensitivity to formation diffusivity conducted using a flank pool reservoir configuration in which no barrier is present between the gas cap and the bitumen zone suggests that there is no impact of gas production on HW CSS bitumen recovery when the formation diffusivity is increased from 8.6E-04 m²/s to 1.5E-03 m²/s
 - a) *HW CSS bitumen recovery factor increased from approximately 35% to 44% of OBIP when the formation diffusivity is increased from 8.6E-04 m²/s to 1.5E-03 m²/s respectively for the cases involving gas cap depletion to an abandonment pressure of 201 kPaa and the case with no depletion of the gas cap.*
 - b) *A similar HW CSS bitumen recovery of approximately 43.7% of OBIP was achieved using a formation diffusivity of 1.5E-03 when gas cap gas was produced to an abandonment pressure of 201 kPaa and*

44.5 % when the gas cap remained at the initial pressure of 2585 (no gas cap production).

4. In all the model cases investigated, significant increase in the steam injection rate resulted in a significant increases in bitumen recovery factor. However, increase in steam injection rate into the CSS horizontal well has no effect on the significant key finding that depletion of the gas cap gas does not adversely impact HW CSS bitumen recovery.
5. Changes in the location of the dilation grid blocks and fracture permeability have no significant effect on the significant key finding that depletion of the gas cap gas does not adversely impact HW CSS bitumen recovery.
6. In general, key results of the reservoir simulation model studies suggest that there is no adverse effect of gas cap gas production on HW CSS bitumen recovery even in those cases in which there is no isolation between the gas cap and the underlying bitumen zone.

Reasons for achieving a relatively similar HW CSS bitumen recovery factors in cases involving depletion of the gas cap gas when compared to similar reservoirs cases without gas cap production are currently being investigated. However, early analysis results indicates that lower bitumen reservoir pressure below the gas cap, resulting from gas cap gas depletion, allows the steam vapors to rise higher and have better penetration into the upper regions of the reservoir. This process allows the injected steam to achieve better contact with the upper regions of the reservoir resulting in enhanced gravity drainage of the bitumen to the horizontal producer during the intermediate and late periods of the HW CSS operations. This enhanced bitumen gravity drainage likely compensated for reduced solution gas and pressure drive during the early to intermediate stages of the CSS process for depleted gas cap HW CSS bitumen case.

Figure E.8 compares the model temperature of two cases FL 13 and FL 14. In FL 13, the gas cap was depleted to an abandonment pressure of 201 kPaa prior to commencement of HW bitumen CSS. In case FL 14, there was no depletion of the gas cap and the gas cap pressure was 2585 kPaa at the start of the HW bitumen CSS process. The temperature and pressure observation point is at a location in the upper regions of the reservoir shown in Figure E.9 for the Flank reservoir configuration containing an incomplete barrier between the gas cap and the bitumen zone. Reservoir pressure in the bitumen phase at the observation point and bitumen recovery factors (over an assigned drainage area, Figures E.10) are also compared in Figure E.8.

In both cases a steam injection rate of 1000 m³/d was applied. Results demonstrate the following:

- a) *A HW CSS bitumen recovery factor of approximately 36 and 33% of OBIP was achieved for FL 13 (gas cap at 201 kPaa) and FL 14 (gas cap at 2585 kPaa) respectively. This suggests that there is absolutely no impact of gas cap gas depletion on HW CSS bitumen recovery. In fact, an incremental bitumen recovery of 3% of OBIP was achieved for the low pressure gas cap HW bitumen CSS case over the high pressure gas cap case.*

- b) *During the initial to intermediate HW CSS bitumen operation phase there is a significant temperature and pressure difference higher up in the reservoir between these cases. The case with gas cap depletion to an abandonment pressure of 201 kPaa achieved lower average pressure and significantly higher reservoir temperature than the case without gas cap gas depletion*

- c) *We suspect for the depleted gas cap situation, that lower reservoir pressure higher up in the reservoir, during the early to intermediate phase allowed heat to penetrate the upper portions of the reservoir thereby resulting in better heating and enhanced gravity drainage of the bitumen compensating for reduced pressure and solution gas drive.*

2 MODELING ASPECTS

Introduction

There is very limited data available in the public domain relating to reservoir description, thermal rock and fluid properties data, and CSS cycle operations with regards to HW CSS operations in the CNRL Primrose area. However, there is available a wealth of information in the public domain relating to numerical modeling of the CSS operations by Imperial Oil in the Cold Lake area and by BP Canada in the Wolf Lake area. We believe these are very close analogues of CNRL's operating environment.

Our first option when inputting data into the models in this study was to use available reservoir and operations data (in the public domain) of the CNRL's Primrose CSS operations. Otherwise, model reservoir data input were largely based on those available in the public domain for the Imperial Oil's Cold Lake and BP Canada's Wolf Lake CSS operations.

Model Grids

The reservoir model is compositional, multiphase and comprises three components: oil, water and gas. The reservoir grid system is three-dimensional and comprises up to 59 x 15 x 14 grid blocks in the x, y and z directions respectively. Grid refinements were carried out around the horizontal well location in both the areal and vertical directions. The minimum grid size around the horizontal wells is approximately 1 m parallel to the well and 1 m in the vertical place. Grid sizes become coarser away from the horizontal well. The model width (horizontal well spacing) is 240 m.

Reservoir Description Parameters

Initial Reservoir pressure was set at 2585 kPaa in the gas cap. Reservoir description data input into the model for the Non Edge, Edge and Flank reservoirs are summarized in Table 2.1, 2.2 and 2.3 respectively. These data input were extracted from the CNRL submission for case in which they were provided. Otherwise, they were assumed.

Fluid properties

There were very limited data in the CNRL's submission relating to reservoir fluid characterization to allow compositional modeling of the reservoir bitumen and gas components. Published data for component properties from oil characterization for the

Wolf Lake bitumen³ was used in the model. Component properties used in the model are presented in Table 2.4.

Bitumen viscosity as a function of temperature was not available in the CNRL's submission. Viscosities versus temperature data⁴ presented for the Cold Lake Oil sands deposit by Imperial Oil were applied in the model. Viscosity-Temperature data presented for the Wolf Lake bitumen by BP Canada Inc. (SPE/DOE 17393) were applied in some of the model cases for sensitivity testing purposes. Figure 2.1 shows the bitumen viscosity data for the Cold Lake and Wolf Lake pools.

Rock Thermal Properties

Rock thermal properties applied in the model were those applied successfully to model the CSS operations in Cold Lake and published⁵ in public domain. Table 2.5 present a summary of thermal rock properties applied in the model

Deformation Model

The bitumen reservoir fracture concepts used in the model to simulate high-pressure injection are similar to those reported and applied to model Imperial Oils' Cold Lake CSS operations. Figure 2.2 present the data applied in the model

Relative Permeability Model

Relative permeability data with hysteresis (for the oil/water two phase relative permeability) used in the model were based on those reported successful in modeling the CSS operations in Cold Lake. The data used in the model are presented in Figures 2.3, 2.4 and 2.5.

CSS Cycle data

There were 26 injection and production cycles applied to model the CSS operations. Steam injection rate, injection period, soak time and production cycle periods are presented in Table 2.6. The impact of steam injection rate on the effect of gas production

³ Rubin and Bitter, "Development of Operating Strategy for a Wolf Lake Satellite Underlain by a Water Leg Using Numerical Model Studies", paper SPE/DOE 17393 presented at the SPE/DOE Symposium on EOR, Tulsa, Oklahoma, April, 1988

⁴ Denbina, E.S., Boberg, T.C., Rotter, M.B., "Evaluation of Key Reservoir Drive Mechanisms in the Early Cycles of Steam Stimulation at Cold Lake, SPE 16737, SPE Reservoir Engineering, May 1991, Page 207.

⁵ Boberg, T.C., Rotter, M.B., Stark, S.D.; "History Match of Multiwell Simulation Models of the Cyclic Steam Stimulation Process", SPE 20743, 1990, 1992

on HW CSS bitumen recovery performance were tested by sensitivity cases applying four different steam injection rate of 250, 400, 1000, and 2000 m³/d. A maximum steam injection pressure and steam quality of 12000 kPaa and 90% were applied in the model respectively.

3. SUMMARY RESULTS

Tables of summary of results are presented in Tables E.2 to Table E.4 in the Executive Summary section.

Four types of reservoirs representing different structural relationships between the gas cap and the bitumen reservoir (Figures E.1 to E.7) were evaluated to assess the impact of gas cap gas production on CSS performance in the bitumen zone. The four reservoir types were constructed based on the geological concepts contained in the CNRL's July 4, 2006 submission to the EUB.

In general, key results of the reservoir simulation model studies suggest that there is no adverse effect of gas cap gas production on CSS bitumen recovery even in those cases in which there is no isolation between the gas cap and the underlying bitumen zone.

Reasons for achieving a relatively similar HW CSS bitumen recovery factors in cases involving depletion of the gas cap gas when compared to similar reservoirs cases without gas cap production are currently being investigated. However, early analysis of the results indicates that lower bitumen reservoir pressure below the gas cap, resulting from gas cap gas depletion, allows the steam vapors to rise higher and have better penetration into the upper regions of the reservoir. This process allows the injected steam to achieve better contact with the upper regions of the reservoir resulting in enhanced gravity drainage of the bitumen to the horizontal producer during the intermediate and late periods of the HW CSS operations. This enhanced bitumen gravity drainage likely compensated for any apparent effect of reduced solution gas and pressure drive during the early to intermediate stages of the CSS process for depleted gas cap HW CSS bitumen case. It could be argued that steam rise may not occur in the presence of large scale heterogeneities. However, the reservoir fracturing and dilation during high pressure steaming has been known to break down such heterogeneous barriers.

Figure E.8 compares the model temperature of two cases FL 13 and FL 14. In FL 13, the gas cap was depleted to an abandonment pressure of 201 kPaa prior to commencement of HW bitumen CSS. In case FL 14, there was no depletion of the gas cap and the gas cap pressure was 2585 kPaa at the start of the HW bitumen CSS process. The temperature observation point is at a location in the upper regions of the reservoir shown in Figure E.9 for the Flank reservoir configuration containing an incomplete barrier between the gas cap and the bitumen zone. Average reservoir pressure in the bitumen phase and bitumen recovery factors (over an assigned drainage area) are also compared in Figure E.8.

In both cases a steam injection rate of 1000 m³/d was applied. Results demonstrate the following:

- d) A HW CSS bitumen recovery factor of approximately 36 and 33% of OBIP was achieved for FL 13 (gas cap at 201 kPaa) and FL 14 (gas cap at 2585*

kPaa) respectively. This suggests that there is absolutely no impact of gas cap gas depletion on HW CSS bitumen recovery. In fact, an incremental bitumen recovery of 3% of OBIP was achieved for the low pressure gas cap HW bitumen CSS case over the high pressure gas cap case.

- e) During the initial to intermediate HW CSS bitumen operation phase there is a significant temperature and pressure difference higher up in the reservoir between these cases. The case with gas cap depletion to an abandonment pressure of 201 kPaa achieved lower average pressure and significantly higher reservoir temperature than the case without gas cap gas depletion*
- f) We suspect for the depleted gas cap situation, that lower reservoir pressure higher up in the reservoir, during the early to intermediate phase allowed heat to penetrate the upper portions of the reservoir thereby resulting in better heating and enhanced gravity drainage of the bitumen compensating for reduced pressure and solution gas drive.*

Other performances parameters for comparison of cases FL 13 and FL 14 are presented in Figures 3.1 to 3.6.

TABLE E.1A: NON EDGE SIMULATION MODEL CASE DESCRIPTION

| | Description | | | | | | | | | | | | |
|---------------|-------------|-----------------|---------------------|---------------------|--------------------------------|--------------------------------|-----------|------------------------|------------------------------------|------------|-------------------------------|---|-------------------|
| | Run Number | Barrier pay (m) | Gas_Cap net pay (m) | Bitumen net pay (m) | Gas Cap OGIP (m ³) | Bitumen OBIP (m ³) | OGIP/OBIP | Gas Cap Gas Production | Gas Cap Pressure Before CSS (kPaa) | Well Model | Dilation Grid Block Treatment | Formation Diffusivity (m ² /s) | Steam Rate (m3/d) |
| Non Edge pool | NE 1 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 1012 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 2 | 1 | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 972 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 3 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 4 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585 | Horizontal | All Layers K x 2 | 8.60E-04 | 250 |
| | NE 5 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585 | Horizontal | Well Layer K x 10 | 8.60E-04 | 250 |
| | NE 6 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 1012 | Horizontal | All Layers K x 10 | 8.60E-04 | 400 |
| | NE 7 | 1 | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 972 | Horizontal | ... | 8.60E-04 | 400 |
| | NE 8 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585 | Horizontal | ... | 8.60E-04 | 400 |
| | NE 9 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1002 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 10 | 1 | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1033 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 11 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | No | 2586 | Horizontal | ... | 8.60E-04 | 250 |
| | NE 12 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1002 | Horizontal | ... | 8.60E-04 | 400 |
| | NE 13 | 1 | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1033 | Horizontal | ... | 8.60E-04 | 400 |
| | NE 14 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | No | 2586 | Horizontal | ... | 8.60E-04 | 400 |

TABLE E.1B: EDGE SIMULATION MODEL CASE DESCRIPTION

| | Description | | | | | | | | | | | | | |
|-----------|-------------|-------------|-------------|-------------|-------------------|-------------------|-----------|--------------------------|------------------------|------------------------------------|------------|-------------------------------|---|---------------------|
| | Run Number | Barrier (m) | Gas_Cap (m) | Bitumen (m) | Gas Cap OGIP (m3) | Bitumen OBIP (m3) | OGIP/OBIP | Initial water Saturation | Gas Cap Gas Production | Gas Cap Pressure Before CSS (kPaa) | Well Model | Dilation Grid Block Treatment | Formation Diffusivity m ² /s | Steam Rate (m3/day) |
| Edge Pool | ED 1 | No | 10 | 20 | 8.99E+06 | 1.53E+06 | 5.85 | 0.45 | Yes | 1046 | Horizontal | Well Layer K x 10 | 8.60E-04 | 250 |
| | ED 2 | No | 10 | 20 | 8.99E+06 | 1.53E+06 | 5.85 | 0.45 | No | 2586 | Horizontal | ... | 8.60E-04 | 250 |
| | ED 3 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.45 | Yes | 1010 | Horizontal | ... | 8.60E-04 | 250 |
| | ED 4 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.45 | No | 2586 | Horizontal | ... | 8.60E-04 | 250 |
| | ED 5 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.55 | Yes | 1145 | Horizontal | ... | 8.60E-04 | 250 |
| | ED 6 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.55 | No | 2585 | Horizontal | ... | 8.60E-04 | 250 |

TABLE E.1C: FLANK SIMULATION MODEL CASE DESCRIPTION

| Run Number | Description | | | | | | | | | | | |
|-----------------------------|-------------|-----------------|-----------------|------------------------|------------------------|-----------|------------------------|------------------------------------|------------|-------------------------------|---|------------------------------|
| | Barrier pay | Gas_Cap Net pay | Bitumen Net pay | Gas Cap m ³ | Bitumen m ³ | OGIP/OBIP | Gas Cap Gas Production | Gas Cap Pressure Before CSS (kPaa) | Well Model | Dilation Grid Block Treatment | Formation Diffusivity m ² /s | Steam Rate m ³ /d |
| <i>No Barrier Max Model</i> | | | | | | | | | | | | |
| FL 1 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 850 | Horizontal | Well Layer K x 10 | 8.6 E-04 | 400 |
| FL 2 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 3 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2584 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 4 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | Horizontal | All Layers K x 60 | 8.6 E-04 | 2000 |
| FL 5 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | Horizontal | Well Layer K x 10 | 8.6 E-04 | 2000 |
| FL 6 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | Horizontal | All Layers K x 60 | 8.6 E-04 | 1000 |
| FL 7 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | Horizontal | Well Layer K x 60 | 8.6 E-04 | 1000 |
| *FL 19 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | Horizontal | All Layers K x 60 | 1.5 E-03 | 1000 |
| *FL 20 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | Horizontal | ... | 1.5 E-03 | 1000 |
| <i>No Barrier Min Model</i> | | | | | | | | | | | | |
| FL 8 | No | 1 | 10 | 6.92E+06 | 2.20E+06 | 3.15 | Yes | 843 | Horizontal | Well Layer K x 10 | 8.6 E-04 | 400 |
| FL 9 | No | 1 | 10 | 6.92E+06 | 2.20E+06 | 3.15 | No | 2585 | Horizontal | ... | 8.6 E-04 | 400 |
| <i>Barrier Max Model</i> | | | | | | | | | | | | |
| FL 10 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 11 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 885 | Horizontal | Well Layer K x 10 | 8.6 E-04 | 400 |
| FL 12 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 200 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 13 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | No | 2585 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 14 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | Horizontal | All Layers K x 60 | 8.6 E-04 | 1000 |
| FL 15 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | No | 2585 | Horizontal | | 8.6 E-04 | 1000 |
| FL 16 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | Horizontal | All Layers K x 30 | 8.6 E-04 | 2000 |
| <i>Barrier Min Model</i> | | | | | | | | | | | | |
| FL 17 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | Horizontal | All Layers K x 30 | 8.6 E-04 | 2000 |
| FL 18 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1002 | Horizontal | ... | 8.6 E-04 | 400 |
| FL 19 | 5 | 1 | 2+10 | 6.92E+06 | 2.67E+06 | 2.59 | Yes | 840 | Horizontal | Well Layer K x 10 | 8.6 E-04 | 400 |
| FL 20 | 5 | 1 | 2+10 | 6.92E+06 | 2.67E+06 | 2.59 | No | 2585 | Horizontal | ... | 8.6 E-04 | 400 |

Note

Cases *FL 19 and *FL 20 were conducted with a formation diffusivity of 1.5 E-03 m²/s

TABLE E.2: NON EDGE MODEL CASES -SUMMARY OF RESULTS

| | Description | | | | | | | | | | | | | | | | | | | |
|---------------|-------------|-------------|-------------|-------------|-------------------|-------------------|-----------|--------------------|-----------------------------------|------------|-------------------------------|---------------------|---------------------------------|--------------------------------|----------------------------------|----------------------|---|---|--------------------------|--|
| | Run Number | Barrier (m) | Gas_Cap (m) | Bitumen (m) | Gas Cap OGIP (m3) | Bitumen OBIP (m3) | OGIP/OBIP | Gas_Cap_Production | Gas_Cap_Pressure Before CSS (Kpa) | Well Model | Dilation Grid Block Treatment | Steam Rate (m3/day) | Cumulative steam injection (m3) | Cumulative Oil Production (m3) | Cumulative Water Production (m3) | Cumulative O/S Ratio | Cumulative Gas Evolved from Bitumen Before CSS (m3) | Cumulative Gas Produced from GasCap in CSS (m3) | Recovery Factor (% OOIP) | |
| Non Edge pool | NE 1 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 1011.60 | Horizontal | ... | 250 | 5.852E+05 | 6.893E+04 | 5.734E+05 | 0.12 | 5.540E+05 | 2.220E+05 | 11.17 | |
| | NE 2 | 1 | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 972.00 | Horizontal | ... | 250 | 5.853E+05 | 9.191E+04 | 5.797E+05 | 0.16 | 0.000E+00 | 0.000E+00 | 14.90 | |
| | NE 3 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585.09 | Horizontal | ... | 250 | 5.852E+05 | 6.974E+04 | 5.705E+05 | 0.12 | 0.000E+00 | 2.170E+06 | 11.30 | |
| | NE 4 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585.09 | Horizontal | All Layers K x 2 | 250 | 5.852E+05 | 6.744E+04 | 5.680E+05 | 0.12 | 0.000E+00 | 2.180E+06 | 10.93 | |
| | NE 5 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585.09 | Horizontal | Well Layer K x 10 | 250 | 5.852E+05 | 6.993E+04 | 5.696E+05 | 0.12 | 0.000E+00 | 2.180E+06 | 11.3 | |
| | NE 6 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 1011.60 | Horizontal | All Layers K x 10 | 400 | 9.356E+05 | 8.875E+04 | 9.142E+05 | 0.10 | 5.560E+05 | 2.280E+05 | 14.38 | |
| | NE 7 | 1 | 1 | 10 | 2.32E+06 | 617208 | 3.75 | Yes | 972.00 | Horizontal | ... | 400 | 9.357E+05 | 1.125E+05 | 9.338E+05 | 0.12 | 0.000E+00 | 0.000E+00 | 18.23 | |
| | NE 8 | No | 1 | 10 | 2.32E+06 | 617208 | 3.75 | No | 2585.09 | Horizontal | ... | 400 | 9.356E+05 | 8.946E+04 | 9.178E+05 | 0.10 | 0.000E+00 | 2.170E+06 | 14.49 | |
| | NE 12 | | | | | | | | | | | | | | | | | | | |
| | NE 9 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1001.76 | Horizontal | ... | 250 | 5.852E+05 | 1.156E+05 | 5.589E+05 | 0.20 | 1.520E+05 | 6.750E+06 | 9.36 | |
| | NE 10 | 1 | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1033.27 | Horizontal | ... | 250 | 5.852E+05 | 1.655E+05 | 5.914E+05 | 0.28 | 0.000E+00 | 0.000E+00 | 13.40 | |
| | NE 11 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | No | 2585.80 | Horizontal | ... | 250 | 5.852E+05 | 1.206E+05 | 5.375E+05 | 0.21 | 0.000E+00 | 2.160E+07 | 9.76 | |
| | NE 12 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1001.76 | Horizontal | ... | 400 | 9.357E+05 | 1.790E+05 | 9.235E+05 | 0.19 | 1.52E+05 | 6.950E+06 | 14.49 | |
| | NE 13 | 1 | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | Yes | 1033.27 | Horizontal | ... | 400 | 9.357E+05 | 2.209E+05 | 9.203E+05 | 0.24 | 0.000E+00 | 0.000E+00 | 17.89 | |
| NE 14 | No | 10 | 20 | 2.32E+07 | 1.23E+06 | 18.76 | No | 2585.80 | Horizontal | ... | 400 | 9.356E+05 | 1.788E+05 | 8.876E+05 | 0.19 | 0.000E+00 | 2.170E+07 | 14.48 | | |

TABLE E.3: EDGE MODEL CASES -SUMMARY OF RESULTS

| | Description | | | | | | | | | | | | | | Recovery Factor (% OOIP) | | | | | | | |
|-----------|-------------|-------------|-------------|-------------|-------------------|-------------------|-----------|--------------------------|------------------------|---------------------------|----------|------------|-------------------------------|---------------------|---------------------------------|--------------------------------|----------------------------------|----------------------|---|---|--------------------|---------------|
| | Run Number | Barrier (m) | Gas_Cap (m) | Bitumen (m) | Gas Cap OGIP (m3) | Bitumen OBIP (m3) | OGIP/OBIP | Initial water Saturation | Gas Cap Gas Production | Gas Cap Before CSS (kPaa) | Pressure | Well Model | Dilation Grid Block Treatment | Steam Rate (m3/day) | Cumulative steam injection (m3) | Cumulative Oil Production (m3) | Cumulative Water Production (m3) | Cumulative O/S Ratio | Cumulative Gas Evolved from Bitumen Before CSS (m3) | Cumulative Gas Produced from GasCap in CSS (m3) | TotalBitumen Model | Drainage Area |
| Edge Pool | ED 1 | No | 10 | 20 | 8.99E+06 | 1.53E+06 | 5.85 | 0.45 | Yes | 1046.00 | | Horizontal | Well Layer K x 10 | 250 | 5.868E+05 | 1.542E+05 | 5.864E+05 | 0.26 | 6.000E+04 | -1.500E+05 | 10.02 | 22.4 |
| | ED 2 | No | 10 | 20 | 8.99E+06 | 1.53E+06 | 5.85 | 0.45 | No | 2585.80 | | Horizontal | ... | 250 | 5.852E+05 | 1.538E+05 | 5.855E+05 | 0.26 | 0.000E+00 | 0.000E+00 | 10.02 | 22.3 |
| | ED 3 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.45 | Yes | 1010.10 | | Horizontal | ... | 250 | 5.852E+05 | 1.549E+05 | 5.875E+05 | 0.26 | 5.980E+04 | -2.000E+05 | 10.09 | 22.5 |
| | ED 4 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.45 | No | 2585.80 | | Horizontal | ... | 250 | 5.852E+05 | 1.539E+05 | 5.856E+05 | 0.26 | 0.000E+00 | 0.000E+00 | 10.02 | 22.3 |
| | Ed 5 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.55 | Yes | 1145.00 | | Horizontal | ... | 250 | 5.852E+05 | 8.421E+04 | 6.740E+05 | 0.14 | 5.870E+05 | -1.740E+05 | 6.70 | 14.3 |
| | Ed 6 | No | 10 | 20 | 2.87E+07 | 1.53E+06 | 18.7 | 0.55 | No | 2585.00 | | Horizontal | ... | 250 | 5.852E+05 | 7.661E+04 | 7.171E+05 | 0.13 | 0.000E+00 | 7.62E+06 | 6.10 | 13.0 |

TABLE E.4: FLANK MODEL CASES -SUMMARY OF RESULTS

| Run Number | Description | | | | | | | | | | | | Cumulative steam injection (m3) | Cumulative Oil Production (m3) | Cumulative Water Production (m3) | Cumulative O/S Ratio | Cumulative Gas Evolved from Bitumen Before CSS (m3) | Cumulative Gas Produced from GasCap in CSS (m3) | Recovery Factor (% OBIP) | |
|-----------------------------|-----------------|-----------------|-----------------|-------------------|-------------------|-----------|--------------------|------------------------------------|------------|-------------------------------|---------------------|---------------------|---------------------------------|--------------------------------|----------------------------------|----------------------|---|---|-------------------------------|--|
| | Barrier pay (m) | Gas Cap pay (m) | Bitumen pay (m) | Gas Cap OGIP (m3) | Bitumen OBIP (m3) | OGIP/OBIP | Gas Cap Production | Gas Cap Pressure Before CSS (kPaa) | Well Model | Dilation Grid Block Treatment | Steam Rate (m3/day) | Total Bitumen Model | | | | | | | per an assigned Drainage Area | |
| <i>No Barrier Max Model</i> | | | | | | | | | | | | | | | | | | | | |
| FL 1 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 850 | HW | Well Layer K x 10 | 400 | 935806 | 227596 | 918803 | 0.24 | 3.80E+06 | 5.58E+06 | 6.00 | 25.6 | |
| FL 2 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | HW | ... | 400 | 935799 | 228097 | 870888 | 0.24 | 1.56E+07 | -4.15E+05 | 6.02 | 25.6 | |
| FL 3 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2584 | HW | ... | 400 | 935827 | 209460 | 941317 | 0.22 | 0.00E+00 | 1.81E+07 | 5.52 | 23.5 | |
| FL 4 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | HW | All Layers K x 60 | 2000 | 3.68E+06 | 423782 | 2.73E+06 | 0.12 | 1.57E+07 | -3.39E+05 | 11.17 | 47.6 | |
| FL 5 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | HW | Well Layer K x 10 | 2000 | | | | | | | | | |
| FL 6 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | HW | All Layers K x 60 | 1000 | 2.34E+06 | 323558 | 2.23E+06 | 0.14 | 1.57E+07 | -6.31E+04 | 8.53 | 34.8 | |
| FL 7 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | HW | ... | 1000 | 2.34E+06 | 327064 | 2.36E+06 | 0.14 | 0.00E+00 | 2.95E+07 | 8.60 | 35.1 | |
| *FL 19 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | Yes | 201 | HW | ... | 1000 | 2.34E+06 | 390544 | 2.30E+06 | 0.17 | 1.57E+07 | -6.01E+04 | 10.25 | 43.7 | |
| *FL 20 | No | 5 | 17 | 3.46E+07 | 3.79E+06 | 9.13 | No | 2585 | HW | ... | 1000 | 2.34E+06 | 398569 | 2.35E+06 | 0.17 | 0.00E+00 | 3.04E+07 | 10.46 | 44.5 | |
| <i>No Barrier Min Model</i> | | | | | | | | | | | | | | | | | | | | |
| FL 8 | No | 1 | 10 | 6.92E+06 | 2.20E+06 | 3.15 | Yes | 843 | HW | Well Layer K x 10 | 400 | 935741 | 124709 | 930550 | 0.13 | 5.780E+06 | -166529 | 5.67 | 25.2 | |
| FL 9 | No | 1 | 10 | 6.92E+06 | 2.20E+06 | 3.15 | No | 2585 | HW | ... | 400 | 935378 | 123096 | 933712 | 0.13 | 0.000E+00 | 5.43E+06 | 5.59 | 24.9 | |
| <i>Barrier Max Model</i> | | | | | | | | | | | | | | | | | | | | |
| FL 10 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 885 | HW | Well Layer K x 10 | 400 | 935808 | 258864 | 957993 | 0.28 | 2.750E+06 | -3.74E+04 | 5.20 | 21.2 | |
| FL 11 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 200 | HW | ... | 400 | 935859 | 258765 | 952704 | 0.28 | 4.650E+06 | -3.65E+04 | 5.20 | 21.2 | |
| FL 12 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | No | 2585 | HW | ... | 400 | 935877 | 247881 | 982027 | 0.26 | 0.000E+00 | 5.13E+06 | 4.98 | 20.3 | |
| FL 13 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | HW | All Layers K x 60 | 1000 | 2.34E+06 | 435199 | 2.31E+06 | 0.19 | 4.65E+06 | -6.06E+05 | 8.75 | 35.7 | |
| FL 14 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | No | 2585 | HW | Well Layer K x 10 | 1000 | 2.34E+06 | 401693 | 2.37E+06 | 0.17 | 0.00E+00 | 3.02E+07 | 8.07 | 32.9 | |
| FL 15 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | HW | All Layers K x 60 | 2000 | 4.68E+06 | 596993 | 4.75E+06 | 0.13 | 4.64E+06 | -1.08E+05 | 12.00 | 48.9 | |
| FL 16 | 20 | 5 | 5+17 | 3.46E+07 | 4.97E+06 | 6.96 | Yes | 201 | HW | All Layers K x 30 | 2000 | 4.68E+06 | 602358 | 4.75E+06 | 0.13 | 4.64E+06 | -8.82E+04 | 12.10 | 49.3 | |
| <i>Barrier Min Model</i> | | | | | | | | | | | | | | | | | | | | |
| FL 17 | 5 | 1 | 2+10 | 6.92E+06 | 2.67E+06 | 2.59 | Yes | 840 | HW | Well Layer K x 10 | 400 | 935800 | 176235 | 942562 | 0.19 | 1.180E+06 | 9.90E+05 | 6.60 | 28.3 | |
| FL 18 | 5 | 1 | 2+10 | 6.92E+06 | 2.67E+06 | 2.59 | No | 2585 | HW | ... | 400 | 935745 | 170673 | 954220 | 0.18 | 0.000E+00 | 5.670E+06 | 6.40 | 27.4 | |

TABLE 2.1: RESERVOIR DESCRIPTION PARAMETERS -NON EDGE MODEL

| Zone Name | Porosity | Horizontal Permeability (md) | Kv/KH | Initial Gas Saturation | Initial Oil Saturation | Initial Water Saturation | Critical Water Saturation |
|---------------|----------|------------------------------|-------|------------------------|------------------------|--------------------------|---------------------------|
| gas Cap | 0.33 | 1500 | 0.2 | 0.75 | 0 | 0.25 | 0.2 |
| Shale Barrier | 0.1 | 0.01 | 0.2 | 0 | 0 | 1 | 0.45 |
| Bitumen | 0.33 | 3000 | 0.2 | 0 | 0.55 | 0.45 | 0.45 |

TABLE 2.2: RESERVOIR DESCRIPTION PARAMETERS -EDGE MODEL

| Zone Name | Porosity | Horizontal Permeability (md) | Kv/KH | Initial Gas Saturation | Initial Oil Saturation | Initial Water Saturation | Critical Water Saturation |
|---------------|----------|------------------------------|-------|------------------------|------------------------|--------------------------|---------------------------|
| gas Cap | 0.33 | 1500 | 0.2 | 0.75 | 0 | 0.25 | 0.2 |
| Shale Barrier | 0.1 | 0.01 | 0.2 | 0 | 0 | 1 | 0.45 |
| Bitumen | 0.33 | 3000 | 0.2 | 0 | 0.55 | 0.45 | 0.45 |

TABLE 2.3: RESERVOIR DESCRIPTION PARAMETERS -FLANK MODEL

| Zone Name | Porosity | Horizontal Permeability (md) | Kv/KH | Initial Gas Saturation | Initial Oil Saturation | Initial Water Saturation | Critical Water Saturation |
|---------------|----------|------------------------------|-------|------------------------|------------------------|--------------------------|---------------------------|
| gas Cap | 0.33 | 1500 | 0.2 | 0.75 | 0 | 0.25 | 0.2 |
| Shale Barrier | 0.1 | 0.01 | 0.2 | 0 | 0 | 1 | 0.45 |
| Bitumen | 0.33 | 3000 | 0.2 | 0 | 0.53875 | 0.46125 | 0.45 |

TABLE 2.4 COMPONENT PROPERTIES

```
** ===== COMPONENT PROPERTIES
*MODEL  3 3 3 1
*COMPNAME 'Water' 'Bitumen' 'CH4'
*CMM      0.01802  0.508  0.016
*PCRIT    21977.0  861.0  4585.0
*TCRIT     374.3   659.   -82.0
*KV1       0.      0.    545468.3
*KV2       0.      0.      0.0
*KV3       0.      0.      0.0
*KV4       0.      0.    -879.84
*KV5       0.      0.    -265.00
*MOLDEN    0.    1960.  59199.7
*CP        0.    1.E-06  1.E-06
*CT1       0.    848.E-06  848.E-06
```

TABLE 2.5 THERMAL ROCK PROPERTIES

| | |
|---|---------------------------|
| Rock volumetric heat capacity | 2350 KJ/m ³ -C |
| Thermal conductivity | 600.0 KJ/d-m-C |
| Over/underburden Volimetric heat capacity | 2350 KJ/m ³ -C |
| Over/underburden thermal conductivity | 149.6 KJ/d-m-C |
| Formation compressibility | 3.0e-6 1/kPa |

TABLE 2.6 INJECTION AND PRODUCTION WELL SCHEDULES

| Injector Cycle | Open | Shut In | Injection Period (days) | Soak (days) | Maximum | Maximum | Cycle Size (m3) | Cum. Steam (m3) | Producer | | |
|-------------------|------------|------------|----------------------------|----------------|------------------------|-----------------------------|--------------------|--------------------|------------|------------|---------------------------|
| | | | | | Steam Rate (m3/day) | Injection Pressure (Kpa) | | | Open | Shut In | Production Time (days) |
| 1 | 2007-01-01 | 2007-01-16 | 15 | 4 | 1000 | 10800 | 15000 | 3750 | 2007-01-21 | 2007-03-22 | 60 |
| 2 | 2007-03-23 | 2007-04-12 | 20 | 4 | 1000 | 10800 | 20000 | 23750 | 2007-04-17 | 2007-07-06 | 80 |
| 3 | 2007-07-07 | 2007-08-01 | 25 | 4 | 1000 | 10800 | 25000 | 48750 | 2007-08-06 | 2007-11-14 | 100 |
| 4 | 2007-11-15 | 2007-12-15 | 30 | 4 | 1000 | 10800 | 30000 | 78750 | 2007-12-20 | 2008-04-18 | 120 |
| 5 | 2008-04-19 | 2008-05-24 | 35 | 4 | 1000 | 10800 | 35000 | 113750 | 2008-05-29 | 2008-10-16 | 140 |
| 6 | 2008-10-17 | 2008-11-26 | 40 | 4 | 1000 | 10800 | 40000 | 153750 | 2008-12-01 | 2009-05-10 | 160 |
| 7 | 2009-05-11 | 2009-06-25 | 45 | 4 | 1000 | 10800 | 45000 | 198750 | 2009-06-30 | 2009-12-27 | 180 |
| 8 | 2009-12-28 | 2010-02-16 | 50 | 4 | 1000 | 10800 | 50000 | 248750 | 2010-02-21 | 2010-09-09 | 200 |
| 9 | 2010-09-10 | 2010-11-04 | 55 | 4 | 1000 | 10800 | 55000 | 303750 | 2010-11-09 | 2011-06-17 | 220 |
| 10 | 2011-06-18 | 2011-08-17 | 60 | 4 | 1000 | 10800 | 60000 | 363750 | 2011-08-22 | 2012-04-18 | 240 |
| 11 | 2012-04-19 | 2012-06-23 | 65 | 4 | 1000 | 10800 | 65000 | 428750 | 2012-06-28 | 2013-03-15 | 260 |
| 12 | 2013-03-16 | 2013-05-25 | 70 | 4 | 1000 | 10800 | 70000 | 498750 | 2013-05-30 | 2014-03-06 | 280 |
| 13 | 2014-03-07 | 2014-05-21 | 75 | 4 | 1000 | 10800 | 75000 | 573750 | 2014-05-26 | 2015-03-22 | 300 |
| 14 | 2015-03-23 | 2015-06-11 | 80 | 4 | 1000 | 10800 | 80000 | 653750 | 2015-06-16 | 2016-05-01 | 320 |
| 15 | 2016-05-02 | 2016-07-26 | 85 | 4 | 1000 | 10800 | 85000 | 738750 | 2016-07-31 | 2017-07-06 | 340 |
| 16 | 2017-07-07 | 2017-11-04 | 120 | 4 | 1000 | 10800 | 120000 | 858750 | 2017-11-09 | 2019-02-02 | 450 |
| 17 | 2019-02-03 | 2019-06-08 | 125 | 4 | 1000 | 10800 | 125000 | 983750 | 2019-06-13 | 2020-09-15 | 460 |
| 18 | 2020-09-16 | 2021-01-24 | 130 | 4 | 1000 | 10800 | 130000 | 1113750 | 2021-01-29 | 2022-05-14 | 470 |
| 19 | 2022-05-15 | 2022-09-27 | 135 | 4 | 1000 | 10800 | 135000 | 1248750 | 2022-10-02 | 2024-01-25 | 480 |
| 20 | 2024-01-26 | 2024-06-14 | 140 | 4 | 1000 | 10800 | 140000 | 1388750 | 2024-06-19 | 2025-10-22 | 490 |
| 21 | 2025-10-23 | 2026-03-17 | 145 | 4 | 1000 | 10800 | 145000 | 1533750 | 2026-03-22 | 2027-08-04 | 500 |
| 22 | 2027-08-05 | 2028-01-02 | 150 | 4 | 1000 | 10800 | 150000 | 1683750 | 2028-01-07 | 2029-05-31 | 510 |
| 23 | 2029-06-01 | 2029-11-03 | 155 | 4 | 1000 | 10800 | 155000 | 1838750 | 2029-11-08 | 2031-04-12 | 520 |
| 24 | 2031-04-13 | 2031-09-20 | 160 | 4 | 1000 | 10800 | 160000 | 1998750 | 2031-09-25 | 2033-03-08 | 530 |
| 25 | 2033-03-09 | 2033-08-21 | 165 | 4 | 1000 | 10800 | 165000 | 2163750 | 2033-08-26 | 2035-02-17 | 540 |
| 26 | 2035-02-18 | 2035-08-07 | 170 | 4 | 1000 | 10800 | 170000 | 2333750 | 2035-08-12 | 2037-02-12 | 550 |

FIGURE E.1 CNRL'S PRIMROSE SCHEMATIC CROSS SECTION

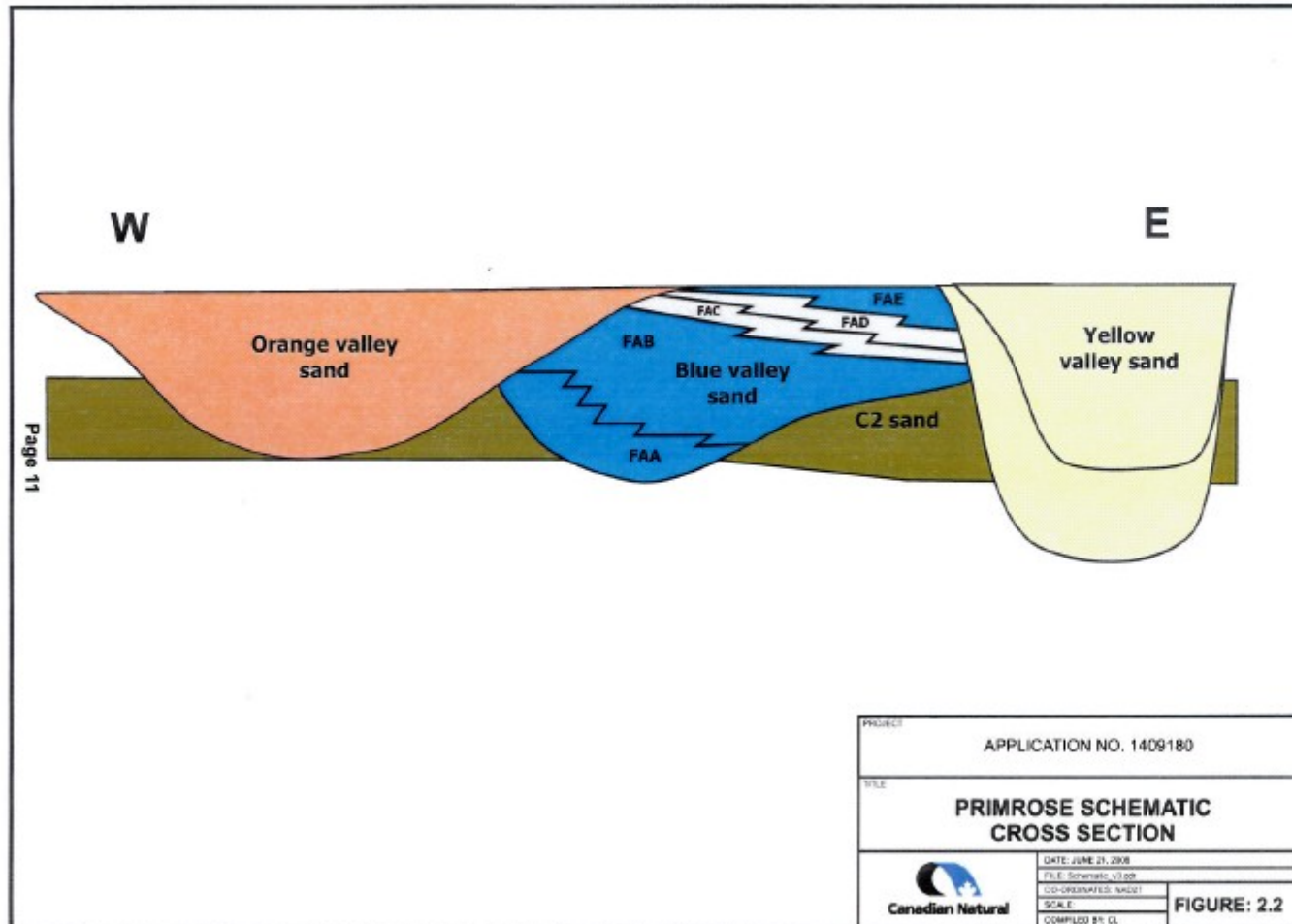
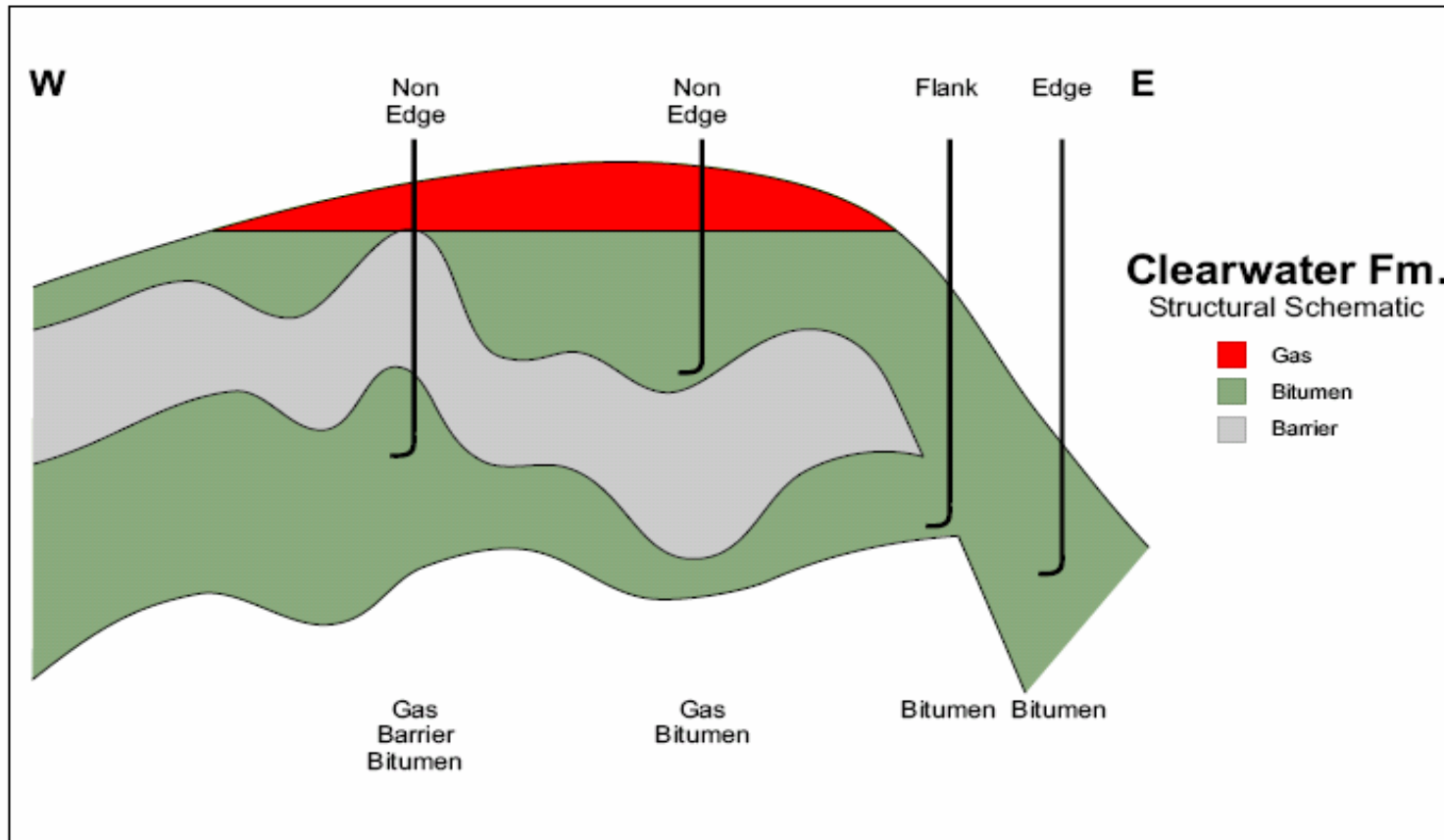


FIGURE E.2 CLEARWATER FORMATION STRUCTURE SCHEMATIC USED TO DEVELOP RESERVOIR SIMULATION MODELS



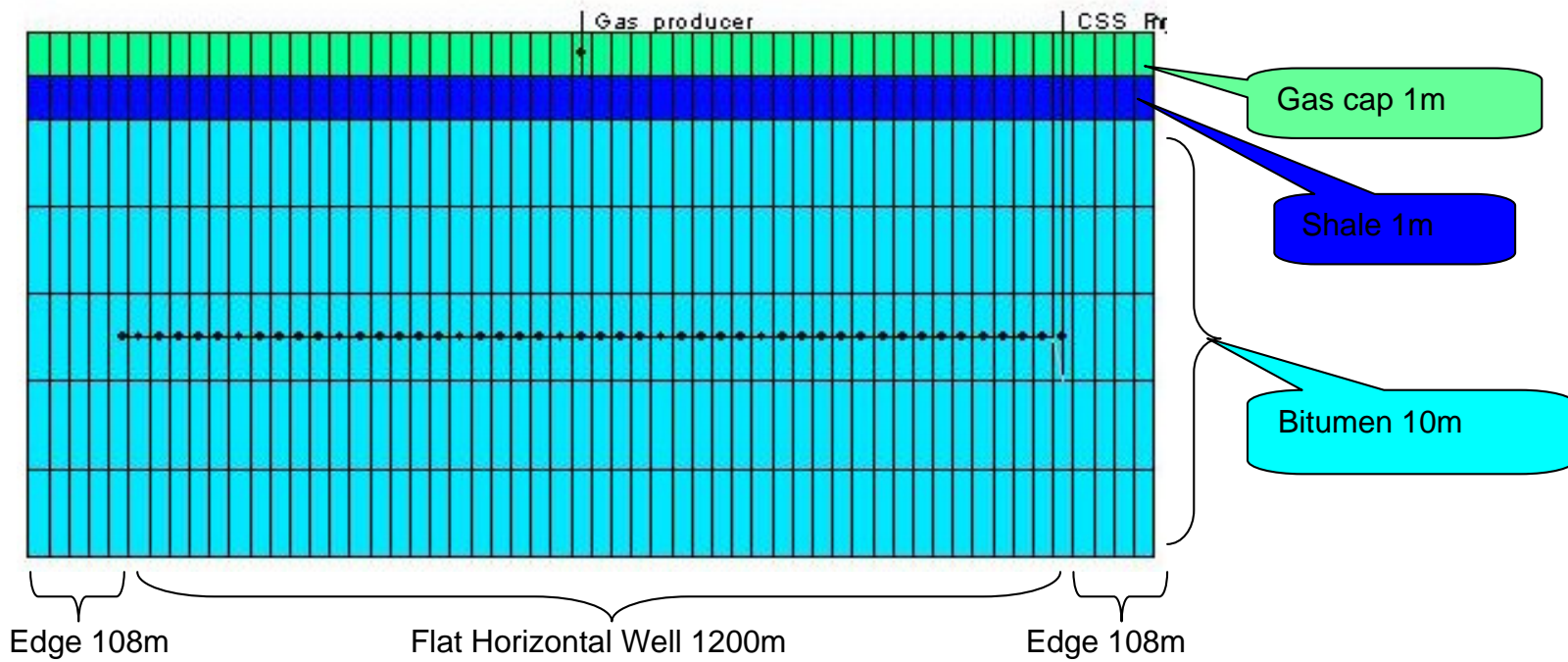


FIGURE E.3: RESERVOIR SECTION OF THE NON EDGE MODEL CONTAINING A SHALE BARRIER

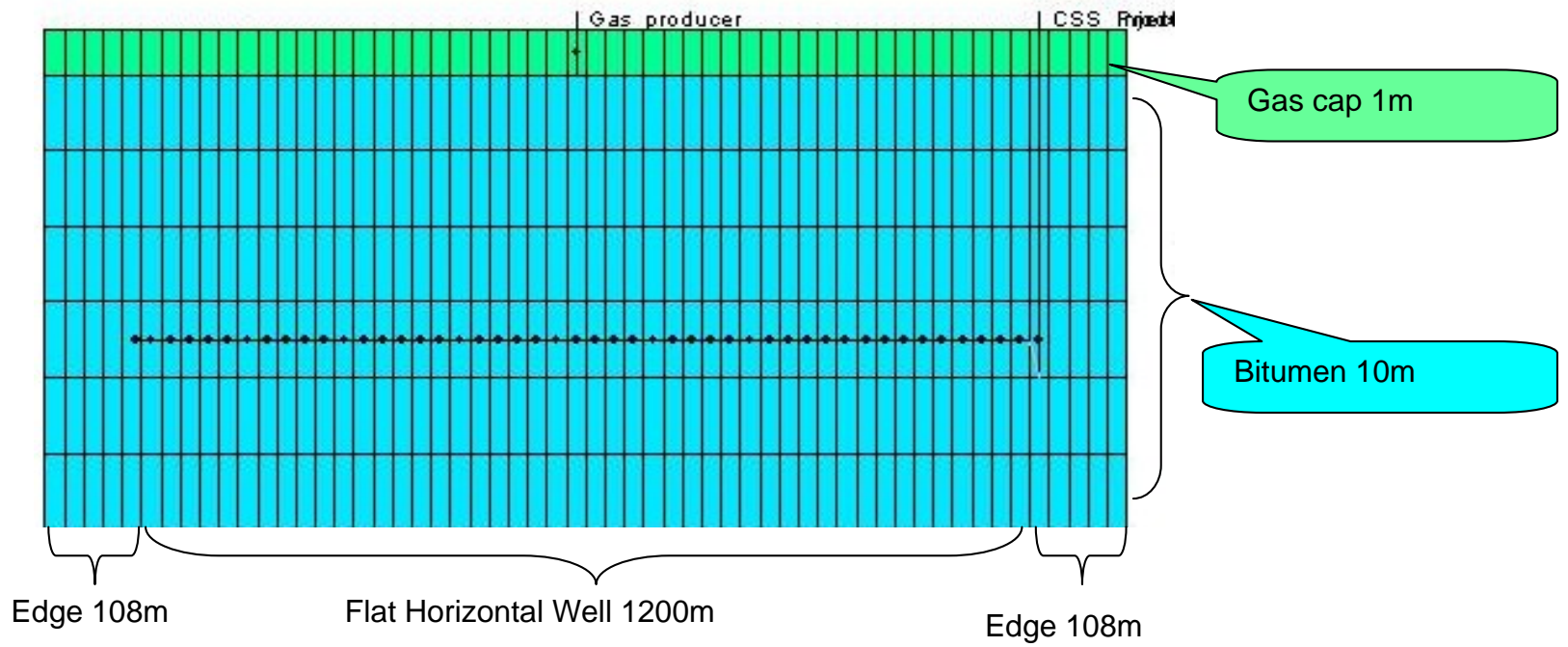


FIGURE E.4: RESERVOIR SECTION OF THE NON EDGE MODEL CONTAINING NO SHALE BARRIER

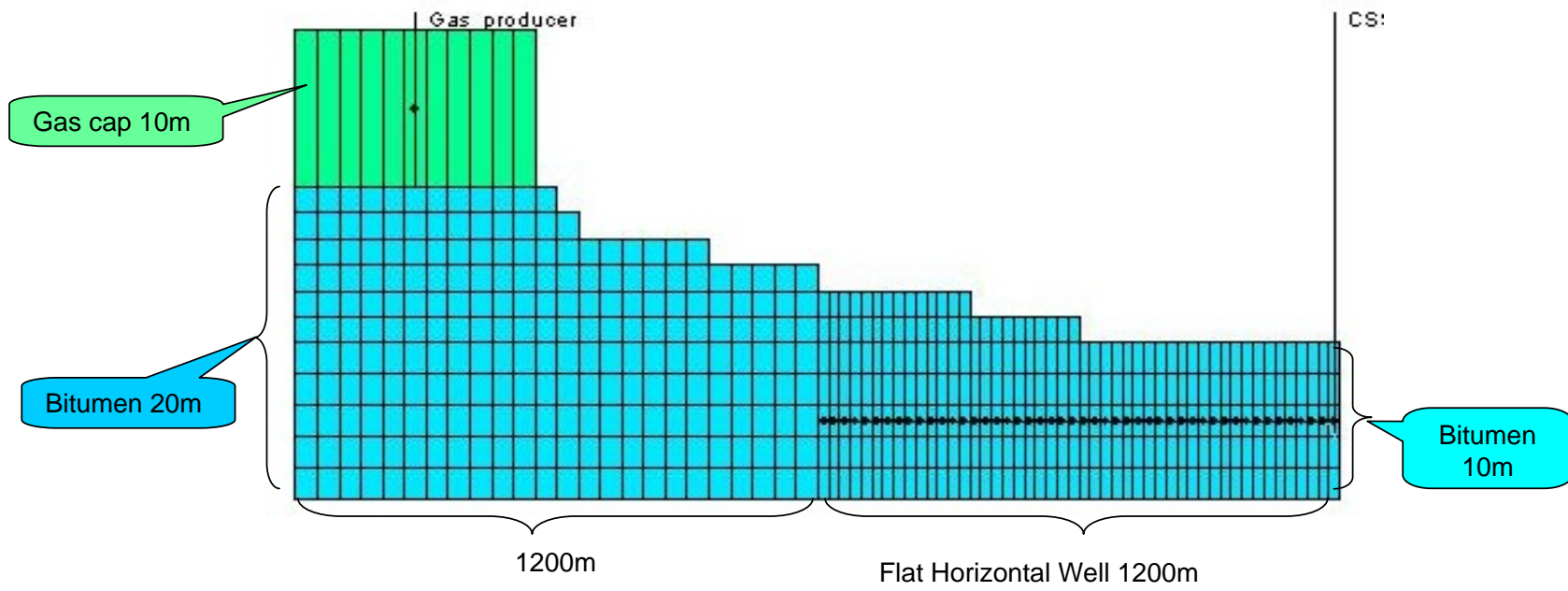
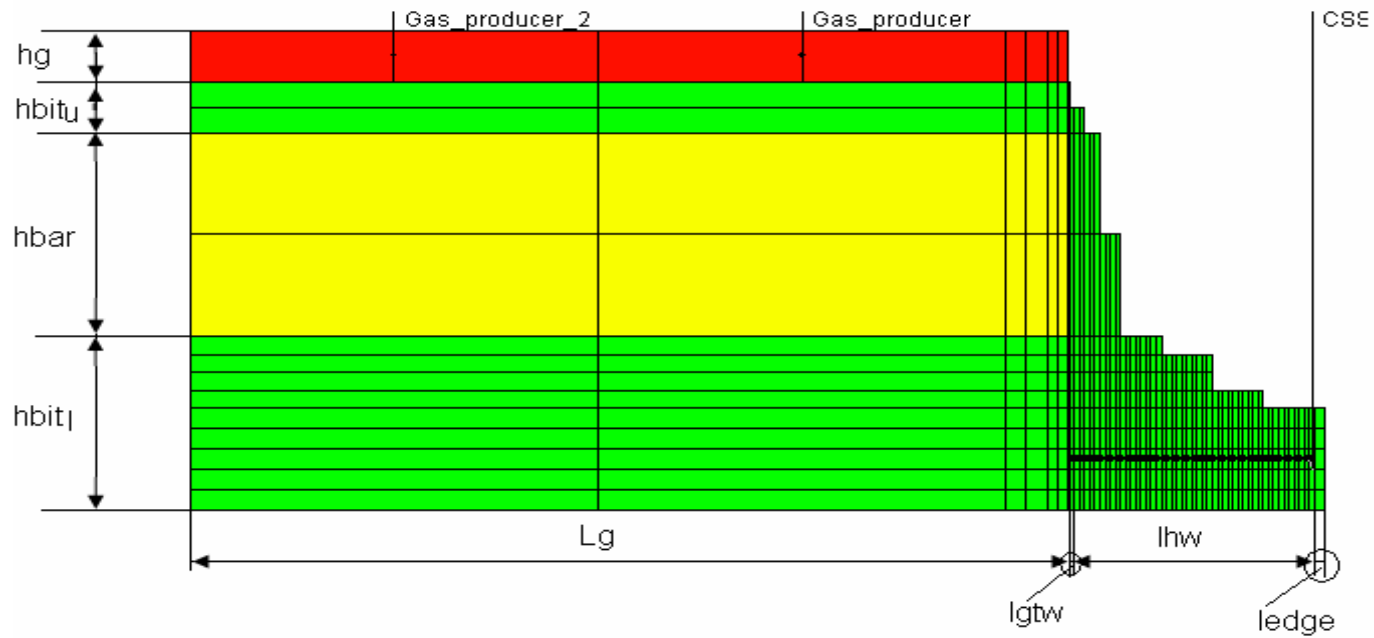
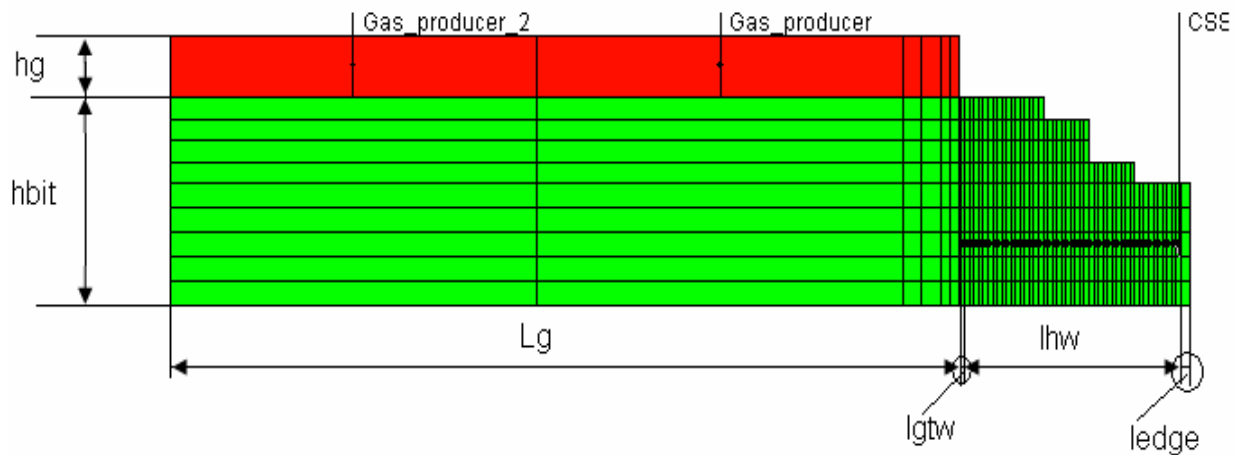


FIGURE E.5: RESERVOIR SECTION OF THE EDGE MODEL (NO SHALE BARRIER)



| Parameter Symbol | Description | Max Model | Min Model |
|------------------|--|-----------|-----------|
| | | MAX (m) | MIN (m) |
| hg | Thickness -Gas Cap | 5 | 1 |
| hbitu | Thickness -Upper Bitumen Zone | 5 | 2 |
| hbar | Thickness -Barrier | 20 | 5 |
| hbitl | Thickness -Lower Bitumen Zone | 17 | 10 |
| lg | Gas Cap & Barrier Extent | 4300 | 4300 |
| lgtw | Distance of Horizontal Well from Gas Cap | 10 | 10 |
| lhw | Length of Horizontal Well | 1200 | 1200 |
| ledge | Distance of Horizontal Well from Pool Boundary | 50 | 50 |
| reservoir width | Drainage Pattern Width | 240 | 240 |

FIGURE E.6: RESERVOIR SECTION OF THE FLANK MODEL CONTAINING A SHALE BARRIER



| Parameter Symbol | Description | Max Model | Min Model |
|------------------|--|-----------|-----------|
| | | MAX (m) | MIN (m) |
| hg | Thickness -Gas Cap | 5 | 1 |
| hbit | Thickness -Bitumen Zone | 17 | 10 |
| Lg | Gas Cap Extent | 4300 | 4300 |
| lgtw | Distance of Horizontal Well from Gas Cap | 10 | 10 |
| lhw | Length of Horizontal Well | 1200 | 1200 |
| ledge | Distance of Horizontal Well from Pool Boundary | 50 | 50 |
| reservoir width | Drainage Pattern Width | 240 | 240 |

FIGURE E.7: RESERVOIR SECTION OF THE FLANK MODEL CONTAINING NO SHALE BARRIER

FIGURE E.8 COMPARISON OF TEMPERATURE AND PRESSURE FOR CASES FL13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006.

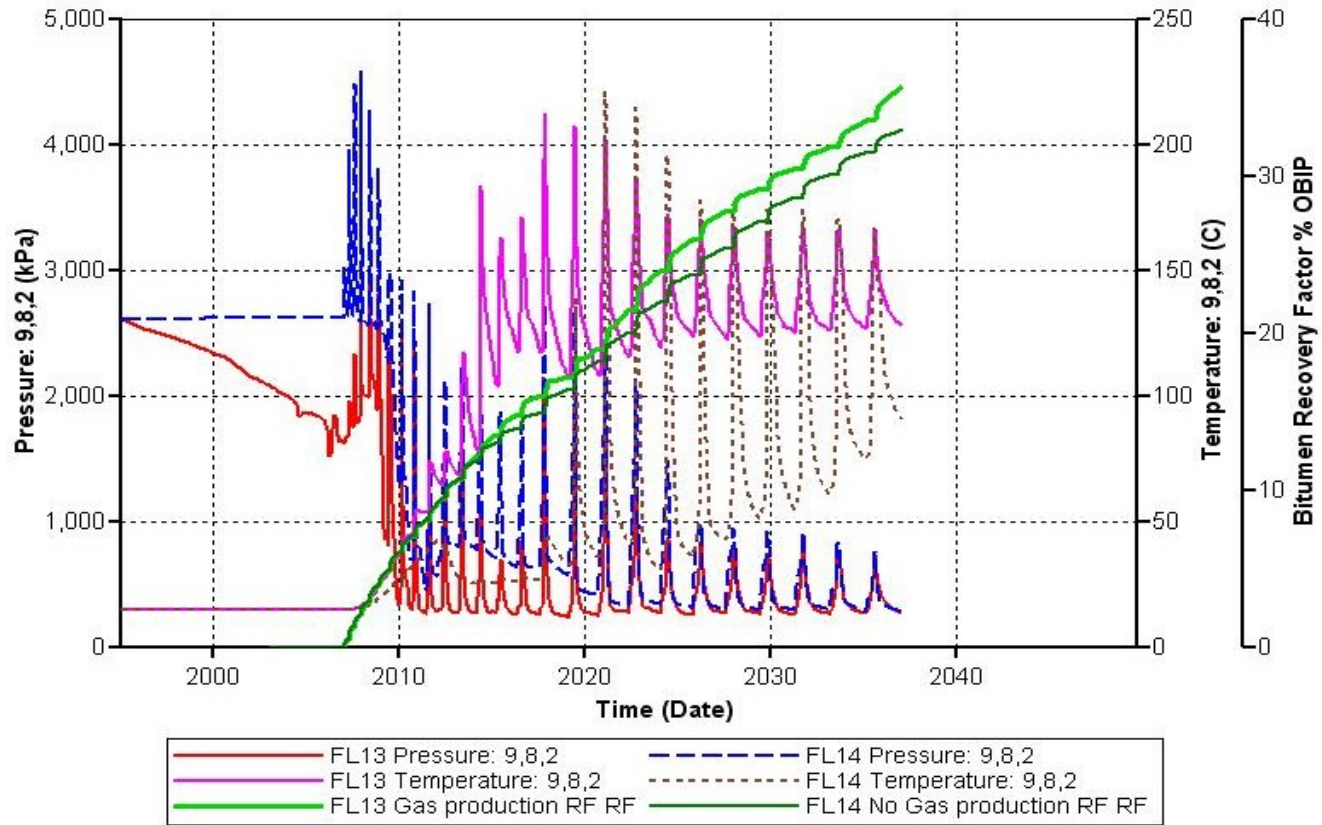


FIGURE E.9 TEMPERATURE AND PRESSURE OBSERVATION POINT FOR CASES FL13 AND FL14

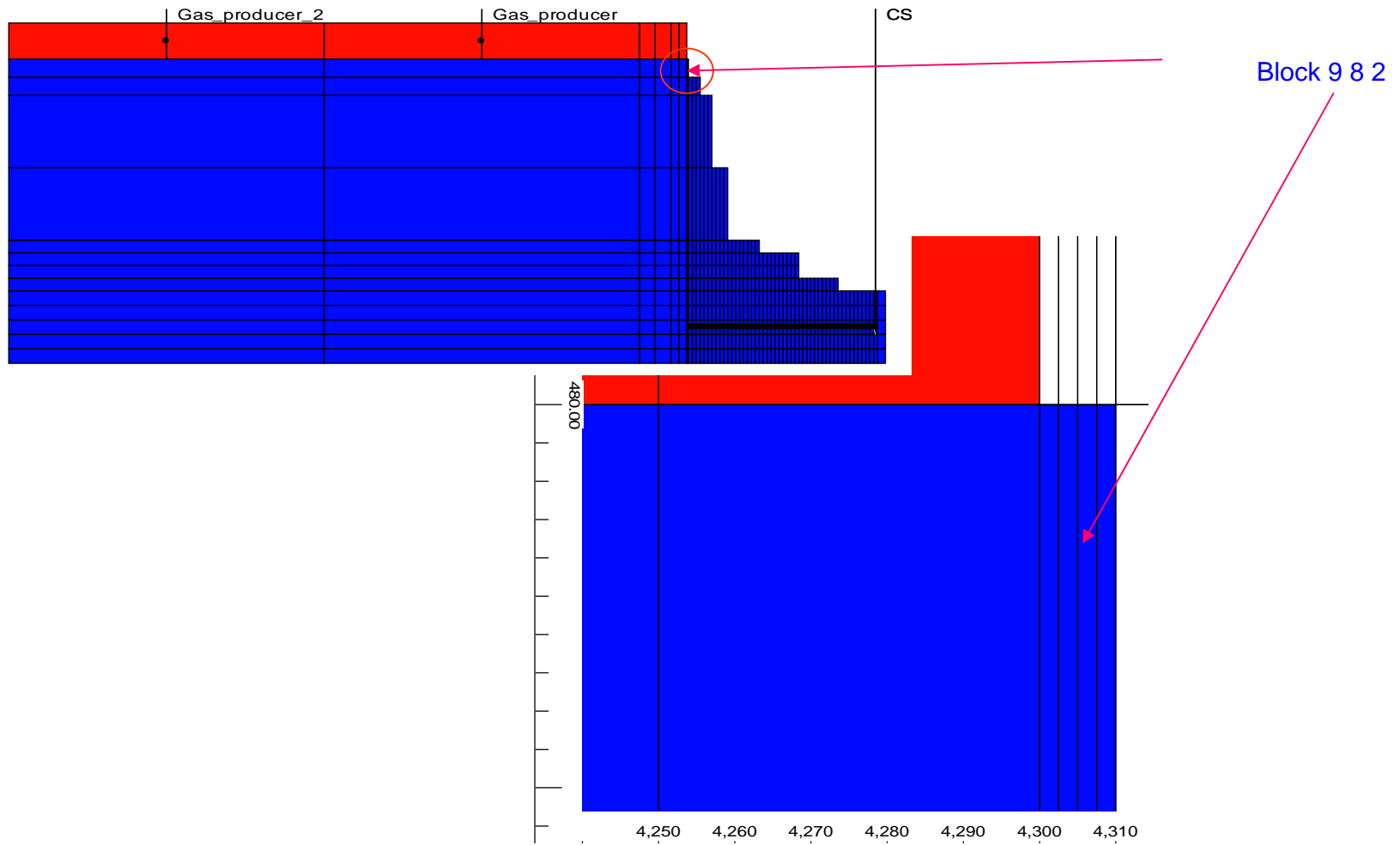


FIGURE E.10: FLANK RESERVOIR ASSIGNED DRAINAGE AREA

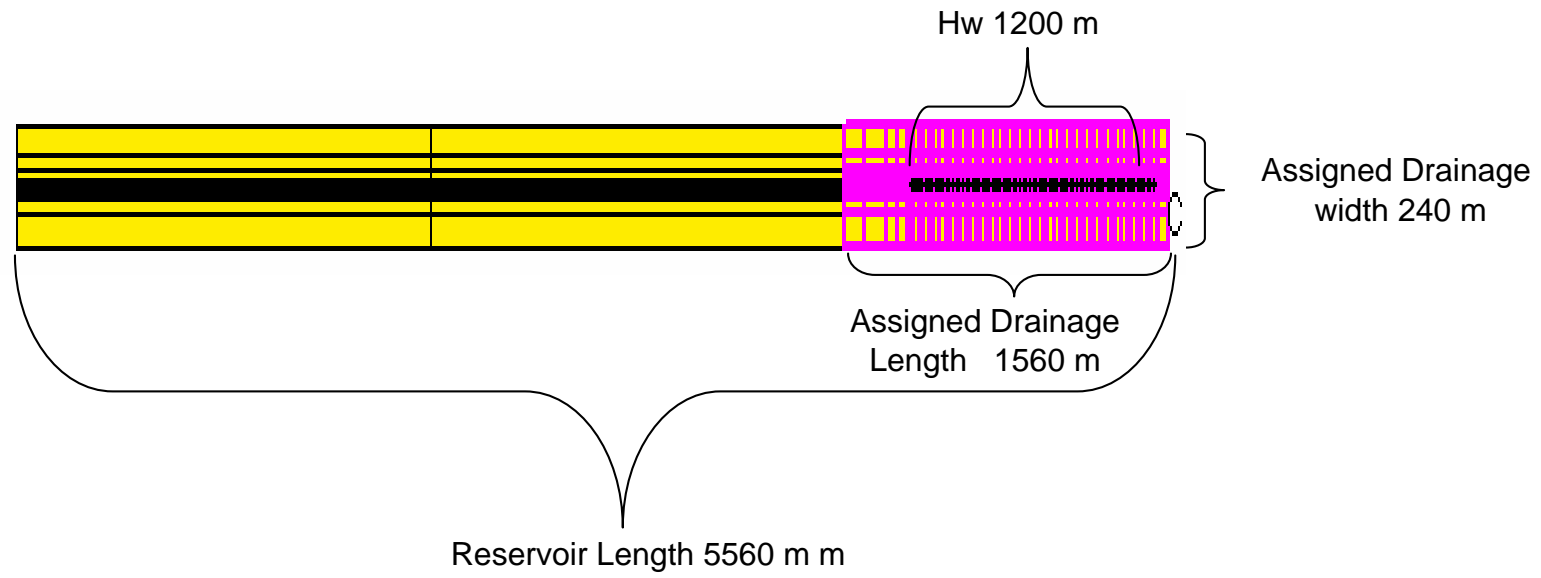


FIGURE 2.1 BITUMEN VISCOSITY DATA

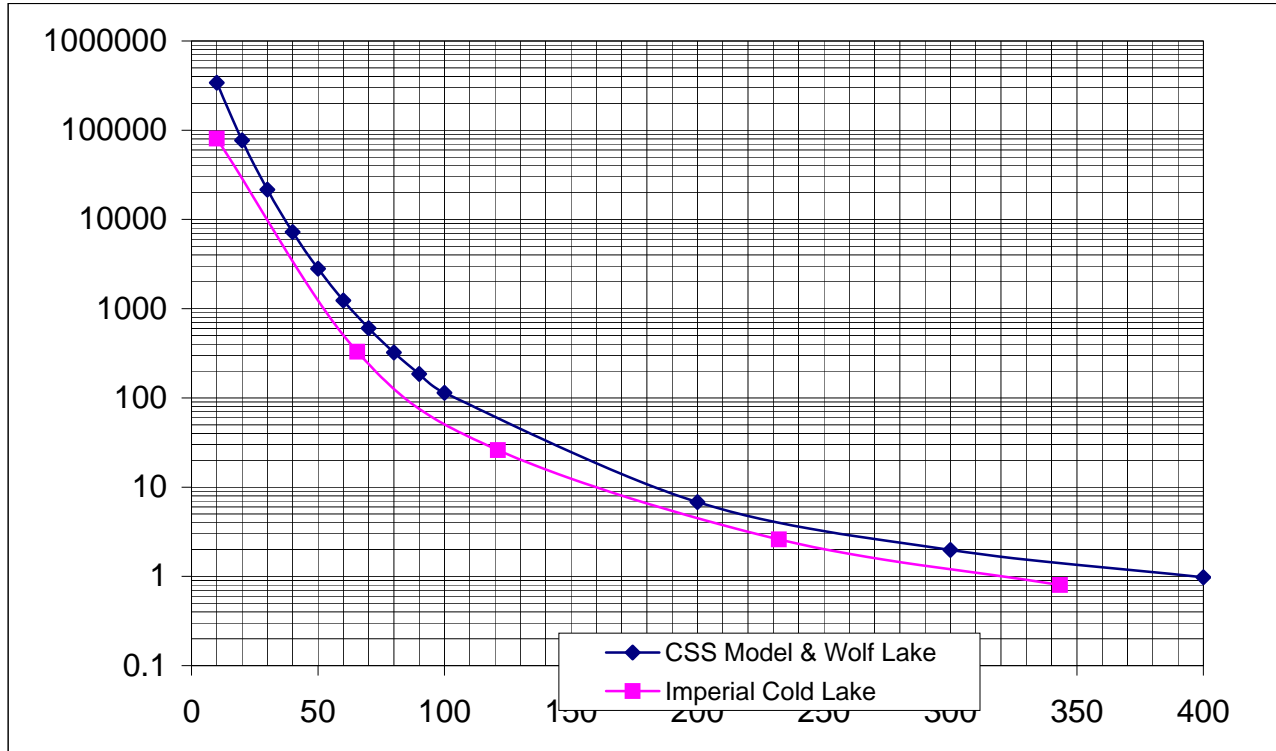
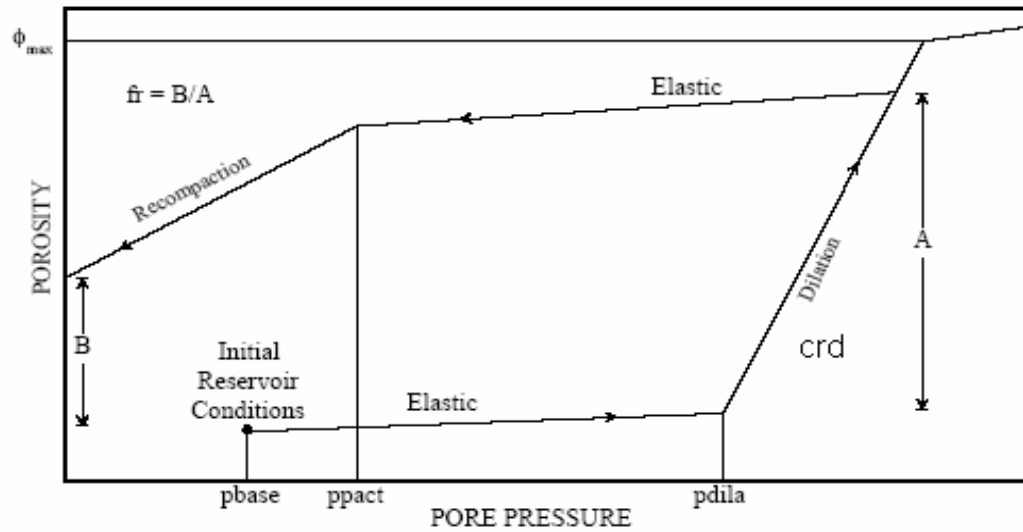


FIGURE 2.2 DEFORMATION MODEL



- pbase: Reference pressure 2.585 Mpa
- pdila: Pressure at which dilation begins 9.8 MPa
- ppact: Pressure at which recompaction begins 6.0 MPa
- crd: Dilation rock compressibility 1.016E-4 1/kPa
- fr: The fraction of total dilation not recovered on recompaction. 0.45
- rat: Maximum allowed proportional increase in porosity. 1.25

FIGURE 2.3 RELATIVE PERMEABILITY MODEL -IMBIBITION (OIL-WATER)

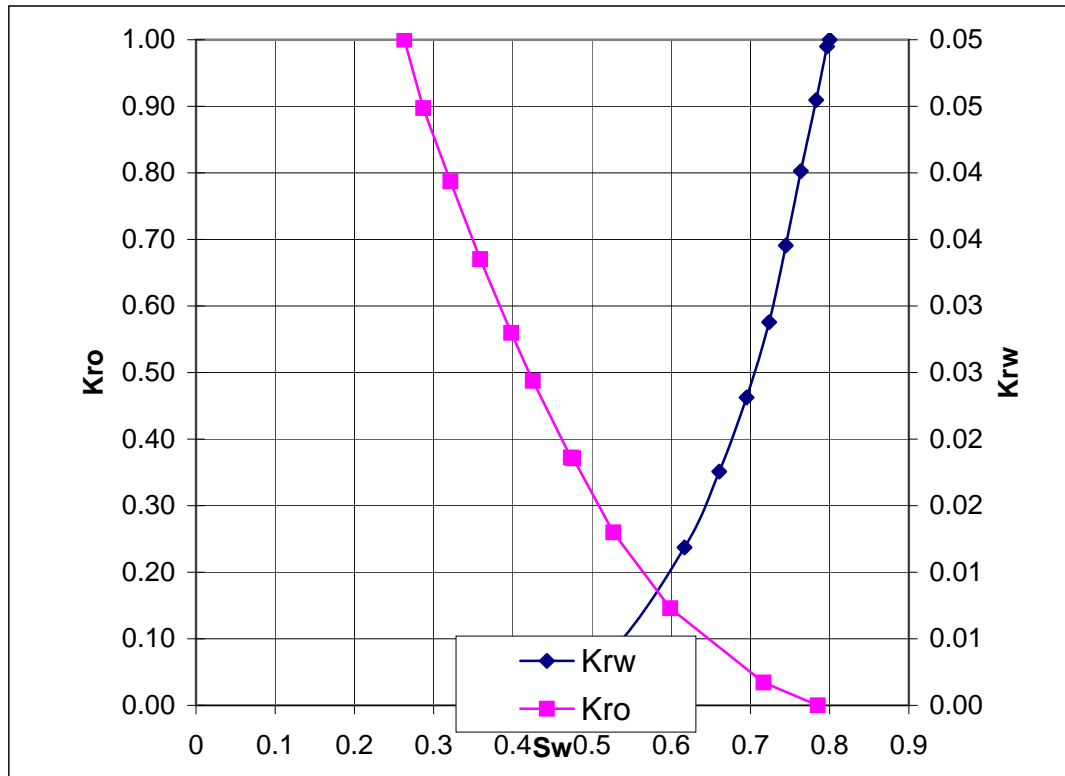


FIGURE 2.4 RELATIVE PERMEABILITY MODEL -DRAINAGE (OIL-WATER)

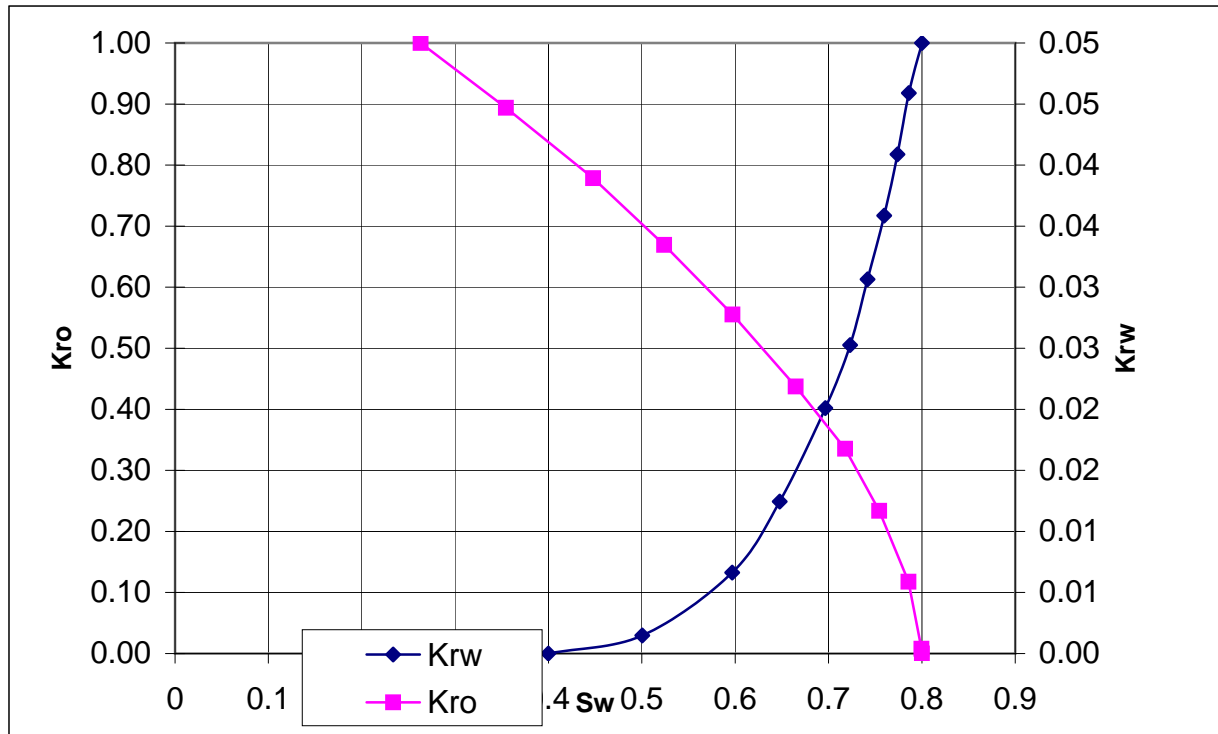


FIGURE 2.5 RELATIVE PERMEABILITY MODEL -IMBIBITION & DRAINAGE (GAS)

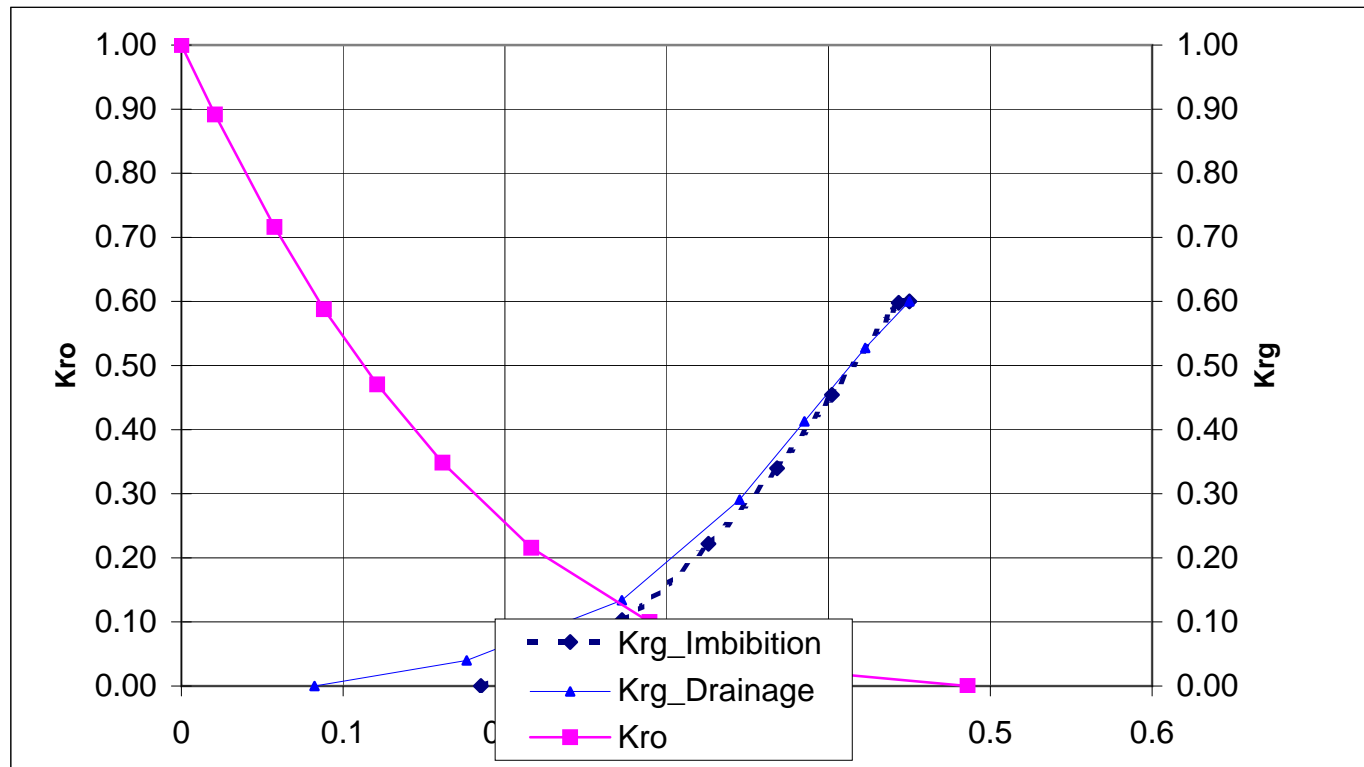


FIGURE 3.1: GAS PRODUCTION, GAS CAP PRESSURE & RECOVERY FACTORS FOR CASES FL13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006

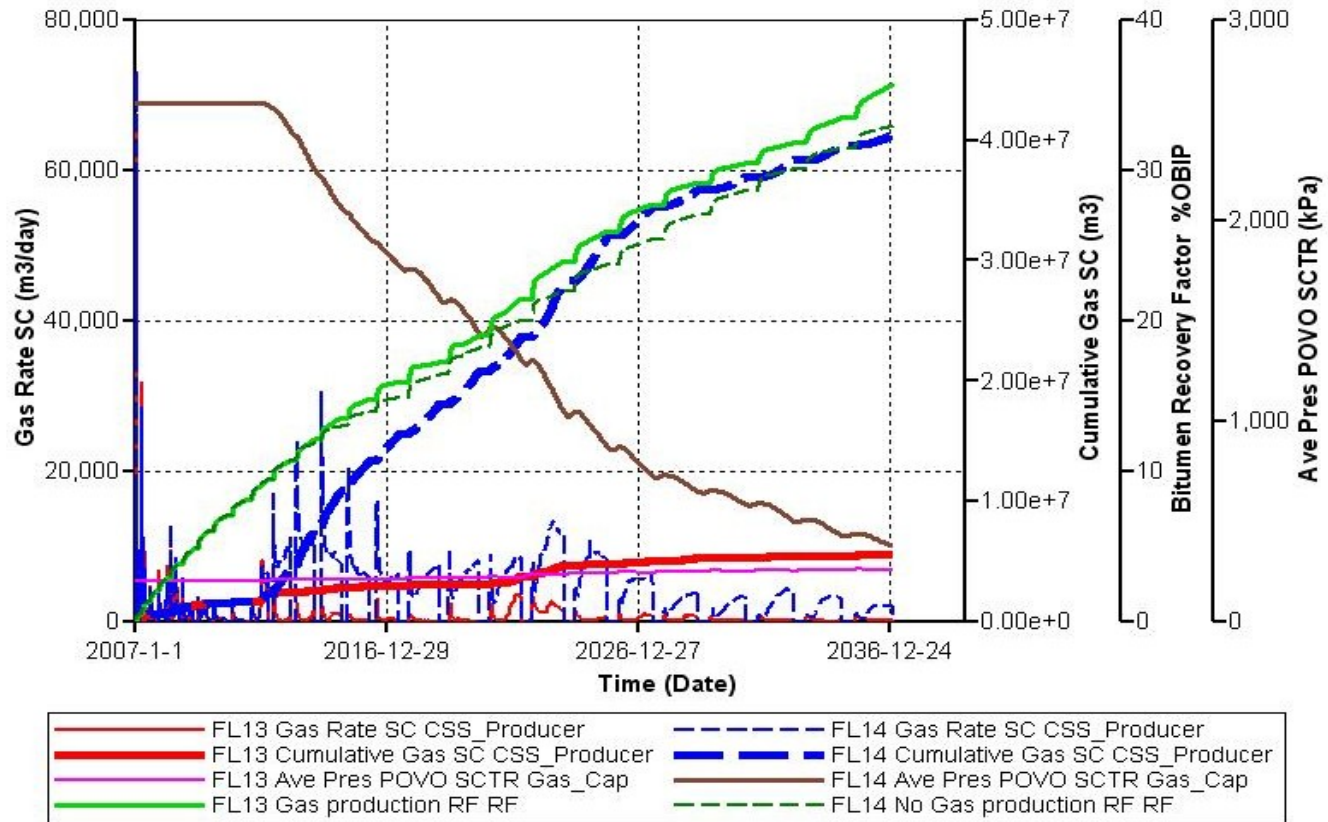


FIGURE 3.2: GAS VOLUME IN GAS CAP & BITUMEN AND AVERAGE PRESSURE IN THE BITUMEN PHASE FOR CASES FL 13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006.

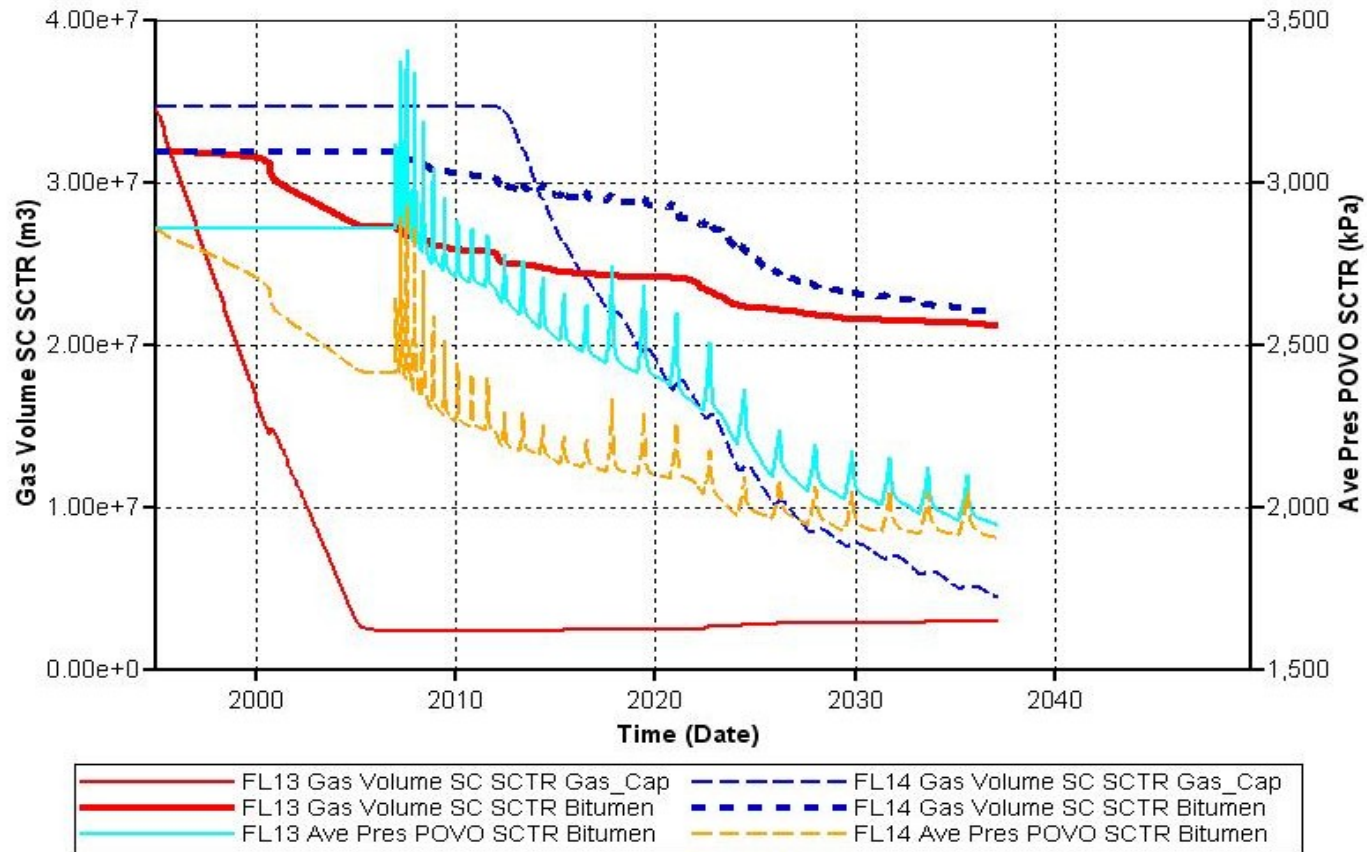


FIGURE 3.3: INJECTION AND PRODUCTION FOR CASES FL 13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006.

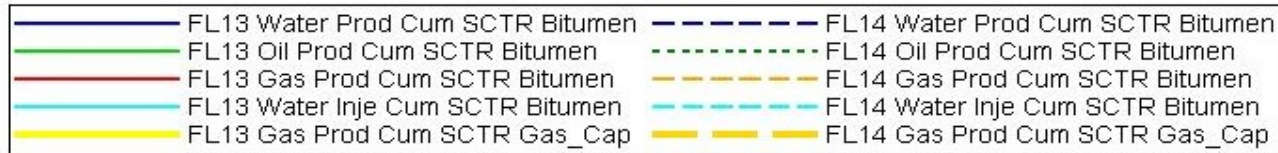
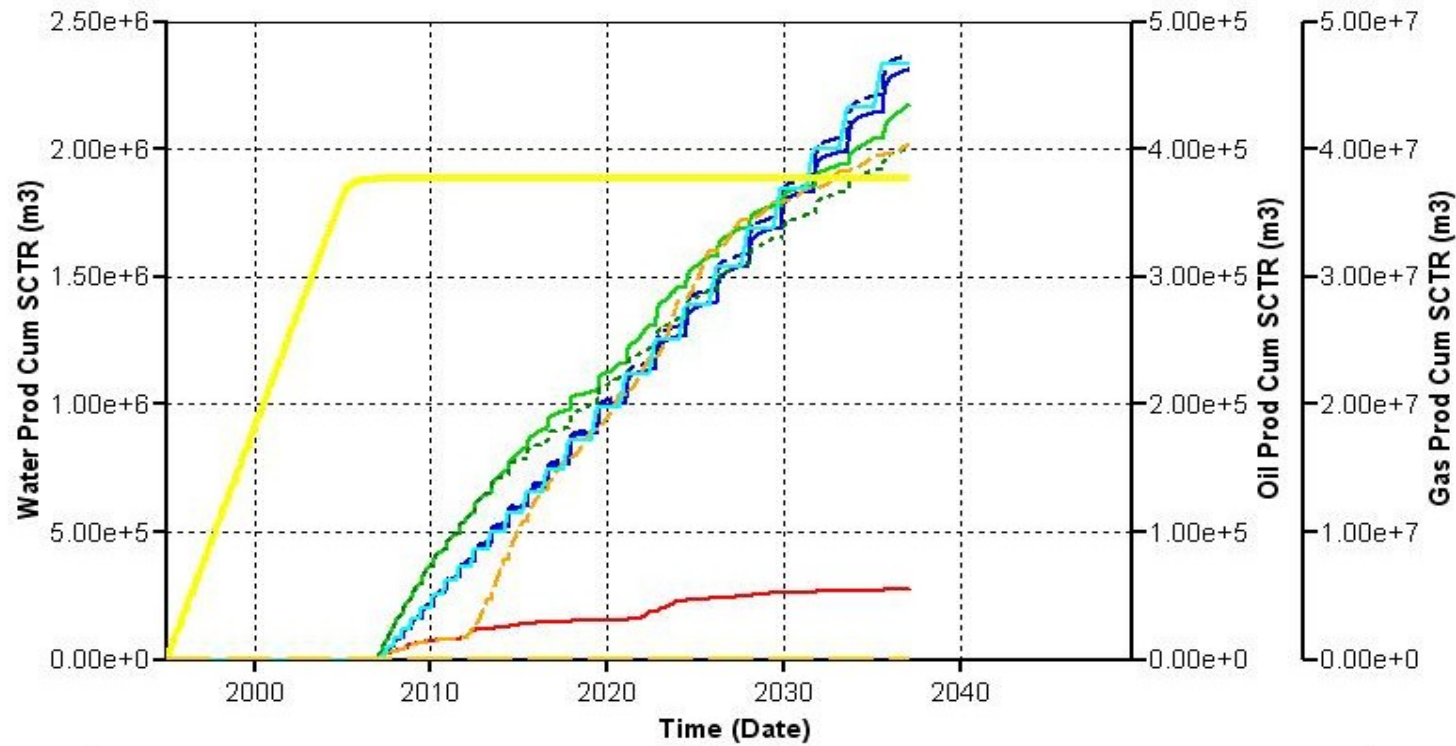


FIGURE 3.4 TEMPERATURE AND PRESSURE FOR CASES FL13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006.

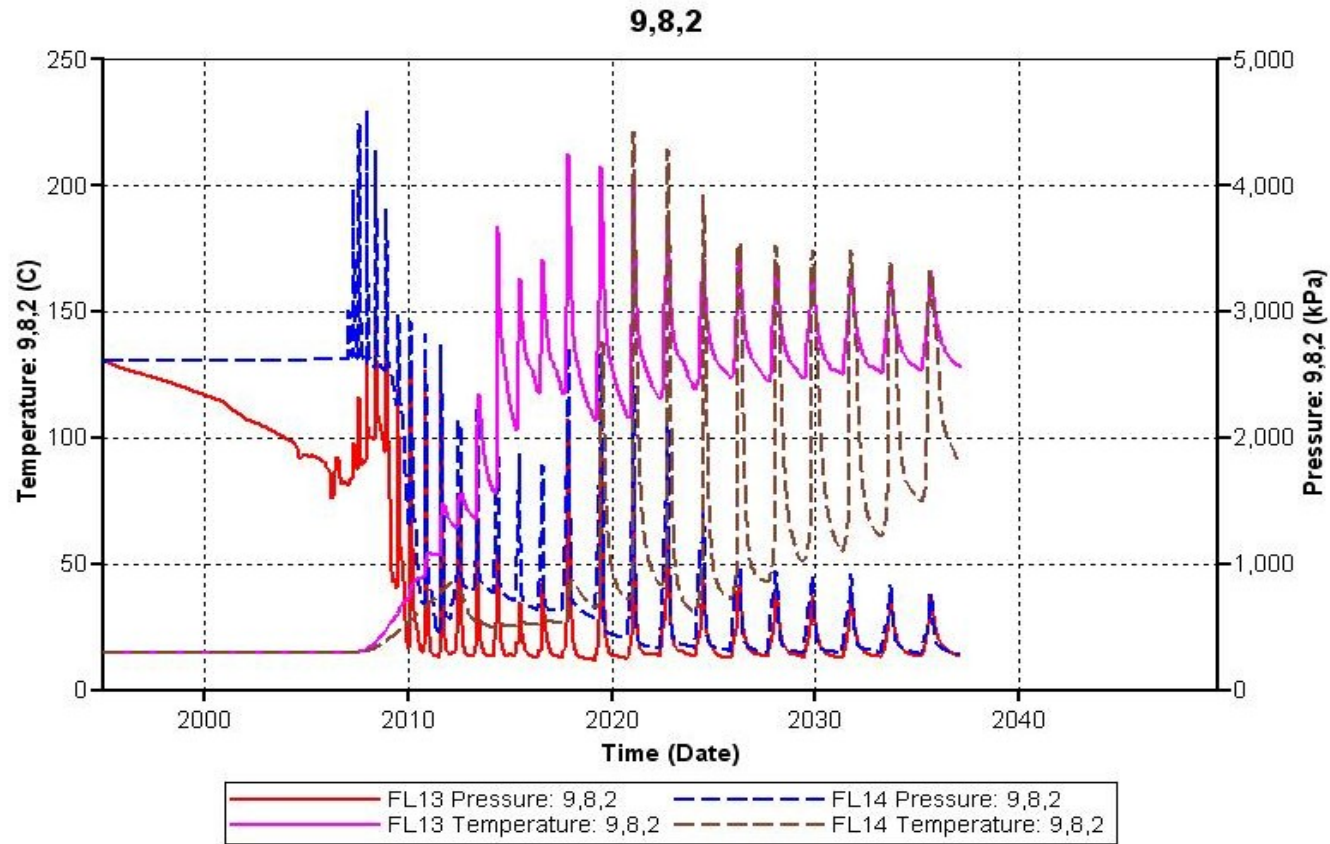


FIGURE 3.5: INJECTION AND PRODUCTION RATE FOR CASES FL 13 AND FL14

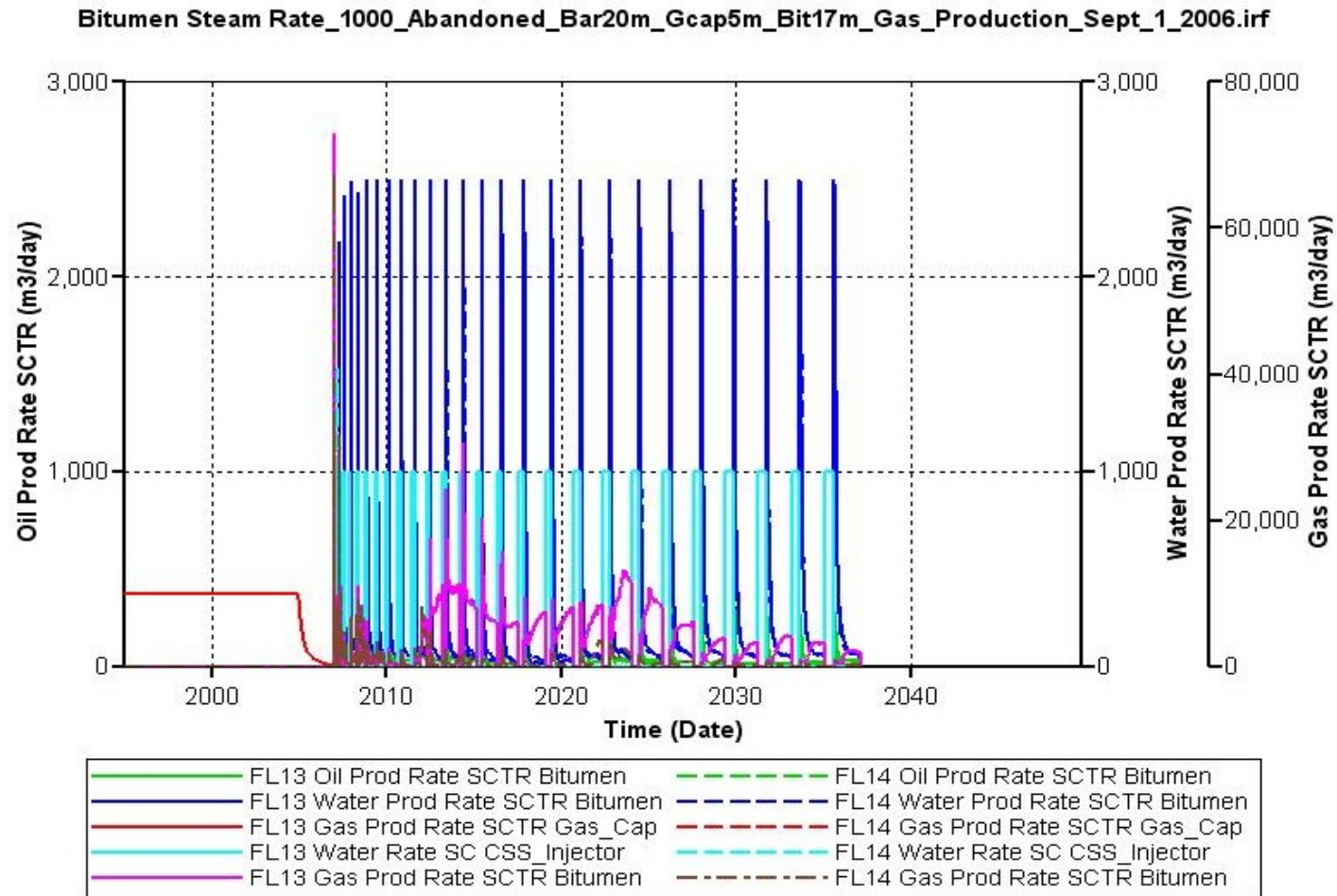


FIGURE 3.6 INJECTION & PRODUCTION, AND OIL-STEAM RATIO FOR CASES FL13 AND FL14

eam Rate_1000_Abandoned_Bar20m_Gcap5m_Bit17m_Gas_Production_Sept_1_2006.

